Marine Unit 3

On the Edge: Living in the Intertidal Zone

Overview

The intertidal area, that part of the shoreline that is underwater at high tide and exposed when the tide is low, offers a harsh environment for organisms. Salinity, temperature, and moisture vary widely, and wave action can displace or destroy habitat. These conditions vary within the intertidal area and create different zones or vertical banding of habitat and organisms. In this unit, students learn about the variation in environmental conditions and organisms adapted to live within the intertidal zone. This unit focuses on the intertidal zone of rocky shorelines, providing a complement to the focus on sandy beaches in Coastal Unit 1.

Length of Entire Unit

Three class periods

Unit Focus Questions

1) How do environmental conditions vary within the intertidal zone, and how does that variation affect the organisms that live in this zone?

2) How are Hawaiian marine organisms adapted to conditions within the intertidal zone?

Unit at a Glance

Activity #1

Intertidal Zonation

Students work in groups to understand environmental conditions within the five subzones represented in intertidal areas, and how Hawaiian marine organisms are adapted to survive in these conditions.

Length
One class period

Prerequisite Activity
None

Objectives
- Identify and explain environmental conditions in the intertidal zone and their effects on organisms that live in this zone.
- Identify, be able to explain, and give examples of adaptations to these conditions exhibited by Hawaiian marine species.
- Describe and explain the concept of "zonation" using the intertidal zone and its inhabitants as examples.

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.

Activity #2

A Day in the Neighborhood: Skits About the Intertidal Zone

Student groups develop and perform skits to teach the class about environmental conditions, organisms, and adaptations within an intertidal subzone.

Length
Two class periods

Prerequisite Activity
Activity #1 "Intertidal Zonation"

Objectives
- Dramatize environmental conditions within the intertidal zone and the responses of organisms to these conditions.

DOE Grades 9-12 Science Standards and Benchmarks
DOING SCIENTIFIC INQUIRY: Students demonstrate the skills necessary to engage in scientific inquiry.
- Communicate and defend scientific explanations and conclusions.

Enrichment Ideas

- Play the "Adaptation Concentration" game (see Marine Unit 2, Activity #1) using the "Life on the Edge" species cards.
- Using the "Life on the Edge" species cards, do in-class identification drills in which students, or groups of students, match photos and the information provided on the back of each card.
- Adapt the "Adaptations Game Show" (see Alpine/Aeolian Unit 3, Activity #3) using the "Life on the Edge" species cards.
- Research traditional Hawaiian uses of intertidal areas and organisms. (See "Resources for Further Reading and Research" for resources.)
- Consult a tide chart to determine a good day and time for exploring tidepools. Go to an intertidal area, such as the tidepools at Mākena, gathering evidence of zonation and making species observations.
- Research how different intertidal and marine organisms regulate salt concentrations in their body in an environment that is saline or characterized by fluctuating salinity.
- Add a lab in which students study the effects of varying salinity levels on marine animals that are osmoregulators and osmoconformers. There are many straightforward labs written up in biology textbooks and on the Internet.

Resources for Further Reading and Research

Fielding, Ann, *Hawaiian Reefs and Tidepools*, Island Explorations, Makawao, Hawai'i, 1998.

Hoover, John P., *Hawaii's Fishes: A Guide for Snorkelers, Divers and Aquarists*, Mutual Publishing, Honolulu, 1993.

Hoover, John P., *Hawai'i's Sea Creatures: A Guide to Hawai'i's Marine Invertebrates,* Honolulu: Mutual Publishing, Honolulu, 1998.

The Intertidal Zone video, Bullfrog Films, 1986. 17 minutes. Available for purchase or rental at (800) 543-3764 or <www.bullfrogfilms.com/catalog/zone.html>.

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

Randall, John E., *Shore Fishes of Hawaii*, Natural World Press, 1996.

Traditional and Hawaiian Cultural Uses of Marine Life

Abbott, Isabella, and E. H. Williamson, *Limu — An Ethnobotanical Study of Some Edible Hawaiian Seaweeds,* Pacific Tropical Botanical Garden, Lawai, Hawai'i, 1974.

Fortner, Heather J., *The Limu Eater* Sea Grant Misc. Report, UNIHI-SEAGRANT-MR-79-01, 1978.

Hobson, Edmund S. and E. H. Chave, *Hawaiian Reef Animals*, University of Hawai'i Press, Honolulu, 1990.

Kamakau, S. M., *The Works of the People of Old.* Bishop Museum Press, Honolulu, 1976.

Taylor, Leighton, *Sharks of Hawai'i, Their Biology and Cultural Significance,* University of Hawai'i Press, Honolulu, 1993.

Titcomb, Margaret, *Native Use of Fish in Hawaii*, University of Hawai‘i Press, Honolulu, 1972.

_____, “Native Use of Marine Invertebrates in Old Hawaii,” *Pacific Science*, Vol. 32, No. 4., 1979, pp. 325-386.

Wyban, Carol Araki, *Tide and Current: Fishponds of Hawai‘i,* University of Hawai‘i Press, Honolulu, 1992.

Activity #1

Intertidal Zonation

● ● ● Class Period One *Intertidal Subzones*

Materials & Setup

- "Hāmākua Poko" acetate (master, p. 13)
- "Intertidal Subzones Table" acetate (master, p. 14)
- "Intertidal Images" acetates (master, pp. 15-16)
- One copy of "Subzone Conditions Cards" (master, pp. 17-21)
- One set of "On the Edge Species Cards" (master, pp. 22-37), divided into five subzone categories using the "Subzones Species Key" (p. 38)
- Overhead projector and screen

Instructions

1) Show the photo of Hāmākua Poko (near Mama's Fish House on Maui, between Kūʻau and Hoʻokipa) on the overhead. The photograph generally illustrates the concept of zonation. Ask students to look at the photo and see if they can figure out what "zonation" means. This is the lead-in question to a brief class overview of the intertidal zone. (NOTE: You can find more background for leading this discussion in Teacher Background "Intertidal Conditions," pp. 9-12.)

2) Lead the discussion to this definition of zonation: the distribution of plants and animals according to environmental conditions. The pattern of vertical banding that is shown in the photograph is similar to that seen along rocky shorelines where there are bands of "microhabitats" or "subzones" within a relatively narrow shoreline area.

3) The part of the shore that is underwater at high tide and exposed when the tide is low is called the "intertidal zone." What factors do students think would influence the width of this zone? (Use "Intertidal Images" acetates to show variations in slope and tidal range.)

4) Ask students what the physical conditions would be like for species in the intertidal zone. As they answer, make the following points:

   - Conditions vary in the intertidal zone, changing hour to hour, day to day, season to season. This is because of the ebb and flow of the tide, different seasonal wave patterns, light and temperature changes through the course of a day or night.
   - Conditions vary within the intertidal zone itself, depending upon the beach slope, relationship to the high and low tide lines, and the terrain.
   - Much of the intertidal zone should be alternately wet and dry, exposing organisms to fluctuations in moisture, wind exposure, etc.
   - In tidepools the salt water can be concentrated by evaporation or diluted by rain water, so organisms are exposed to fluctuations in salinity.

- Wave action can displace or destroy habitat, and can also crush, break, or tear organisms. Wave action has different effects depending upon the location in the intertidal zone.
- Saltwater splash from waves can expose organisms to dessication (drying out).

5) Ask students if the intertidal zone is such a difficult place to live, why would any organisms live there at all? What are the benefits to organisms that can survive here? As students answer, make the following points:

   - One advantage is avoiding many of the predators common in the more stable environmental conditions of the deeper waters at the edge of the intertidal. So snails, for example, can graze with less risk of predation.
   - Under certain conditions (e.g., high tides at night) larger predators such as octopuses and eels can gain access to tidepools, but not consistently. Other predators include crabs, birds, and humans. Even experienced marine life observers have little specific information about predation. The intertidal zone seems to be a pretty safe place to live for organisms that can tolerate the environmental extremes.
   - Also, through much of the intertidal zone, regular inundations by ocean water bring nutrients for algae growth, new food sources, and an abundant supply of oxygen.

6) Because of the variations in conditions, there are "sub-zones" within the intertidal zone. Show the "Intertidal Subzones Table" acetate and review the zonation within the intertidal area. Leave the "Intertidal Subzones Table" up on the overhead. Divide students into five groups. Give each group the Hypothesis Card for one of the subzones, from the "Subzone Conditions Cards."

7) Have groups hypothesize about the environmental conditions in the subzone it was assigned. Students will consider three variables: fluctuations in salinity, wave action, and exposure to air. Have them write their hypotheses in the corresponding columns on the Hypothesis Card. Then, on the back of the card, have them write at least two hypotheses about how organisms that live in this subzone are adapted to live in these conditions.

8) After groups are finished recording their hypotheses, hand out the Comparison Card (from the "Subzones Conditions Cards") and "On the Edge Species Cards" that correspond to each group's subzone (see the "Subzones Species Key"). Have groups compare their hypotheses with actual conditions listed on the Comparison Card and compare their adaptations hypotheses with information available on the species cards. Students should make notes about these comparisons on the card or on a separate piece of paper.

9) Have each group share its hypotheses with the rest of the class, explaining similarities and differences between the Comparison Card and Species Cards.

10) Wrap up the class with a discussion based on the following questions:

- Which one or two of these subzones do you think would be the harshest environment for marine organisms? Why?

  Well-reasoned responses are acceptable. In general, the splash zone and upper intertidal zones are considered the harshest zones because the organisms in these zones are exposed to greater extremes than those in other zones.

- In which subzone or subzones would you expect to find the most organisms and greatest diversity of marine organisms? Explain your answer.

  Again, well-reasoned responses are acceptable. The lower intertidal and subtidal zones, being the most reliably submerged, are home to more and a greater variety of organisms than the others.

- Many of the plant and animal species in the intertidal zone were used for food and medicine in traditional Hawaiian culture. Many are still used today. Why do you think so many of these species would be used for food—other than how *ono* they are?

  Well-reasoned responses are acceptable. The primary reason is probably that these species are accessible and relatively easy to gather or hunt.

- Are there any species that seem better adapted to avoid "human predation" than others? Why?

  Well-reasoned responses are acceptable. Some possible answers include:

  - Animals that live in the subtidal zone may be more difficult for humans to gather.
  - Animals that grip tightly and are difficult to get off the rocks may be less vulnerable.
  - Animals that are spiny or have sharp shells may be more difficult for humans to gather.
  - Plants or animals that taste bad would discourage humans collecting food.
  - Animals that quickly hide (such as rock crabs or zebra blennies) may be more difficult for humans to trap.

Journal Ideas

- Have you ever collected *ʻopihi*, *limu*, or other plants or animals in the intertidal zone? Or do you know someone who does? What is your (or their) favorite part of collecting?
- Hawaiians were careful observers of their environment. What observations do (or would) you make as you enter the intertidal zone? How would these observations affect your actions?
- Describe what conditions would be like in various parts of the intertidal zone if the following traditional Hawaiian prayer for surf were successful. This prayer would be chanted while lashing at the ocean's edge with a length of *pohuehue* vine or after building a mound of sand and wrapping the *pohuehue* vine around it.

Ku mai! Ku mai!	Arise! Arise!
Ka nalu nui mai Kahiki mai.	Great surfs from Kahiki.
ʻAlo poʻi pu!	Waves break together!
Ku mai i ka pohuehue	Rise with the *pohuehue*
Hu! Kaikoʻo loa!	Well up, raging surf!

Jane Gutmanis, Na Pule Kahiko: Ancient Hawaiian Prayers, *Editions Limited, Honolulu, Hawaiʻi, 1983, p. 101.*

Assessment Tools

- Hypothesis Cards
- Participation in group work and class discussion
- Journal entries

Teacher Background

Intertidal Conditions

Conditions

The intertidal zone, also known as the "littoral zone," is the transition area between land and the ocean. This is the area between the normal limits of high and low tides.

The intertidal zone is a harsh habitat, exposed to environmental extremes of temperature, water oxygen level, salinity, moisture/water level, and wave stress. Conditions here can change dramatically over the course of a day in response to tidal ebb and flow, wind, solar exposure, and rainfall. Conditions in the intertidal zone also vary over longer time scales with tidal fluctuations (e.g., highly variable spring tides and the smaller fluctuations of neap tides) and seasonal changes in wave action.

Despite these environmental challenges, much of the intertidal zone is densely populated with living organisms. Competition within the intertidal zone is keen, and organisms are highly specialized and adapted to unique conditions within this zone.

Temperature

Normal air temperatures vary seasonally and within each 24-hour period. Lower temperatures can also be caused by wind and evaporative cooling. Temperature increases are also seen on hot, windless days. When organisms are exposed to the air, they must withstand these temperature variations.

Even when organisms are covered by water, as in a tidepool, temperature has an effect. One effect of temperature fluctuations is on dissolved oxygen. Elevated temperatures create oxygen-poor conditions. The water may become so warm that the oxygen content drops to near zero.

Salinity

The concentration of salts in the water captured in tidepools varies with factors such as exposure to sun and heavy rainfall. When a tidepool is exposed to the sun for many hours, the water evaporates and salinity increases. During periods of heavy rainfall, the water in exposed tidepools will be diluted and salinity will decrease.

Wave stress

The entire intertidal zone is subject, to one extent or another, to wave action. Waves have a variety of effects on habitat conditions in the intertidal zone, ranging from splashing water to strong forces that drag and lift at organisms and scour habitats. Tidal changes exacerbate wave action—water movement and wave pounding increase as the tide comes in. There are also seasonal variations in the size and strength of waves.

Tidal changes in water level

When the tide is out, intertidal organisms are exposed to the air. Depending upon where they are in relation to the high and low tide lines, organisms may spend periods of up to several hours in dry conditions. Parts of the intertidal zone are alternately exposed and immersed by tides twice each day.

Zonation

Zonation is the distribution of plants and animals based on environmental conditions. Natural communities found within the intertidal zone are good examples of zonation because the spatial variation in environmental conditions can be so extreme.

The rocky marine seashore is commonly divided into several subzones based on proximity to the ocean and, therefore, usual patterns of immersion and exposure.

Subzone	Alternate name	Description
Splash zone		The splash zone is a barren, rocky area frequently exposed to ocean spray but not typically immersed, even by high tides.
Upper intertidal zone	Eulittoral zone	The upper intertidal zone is covered by water only at high tide.
Lower intertidal zone	Sublittoral zone	The lower intertidal zone is underwater most of the time, except at extremely low tide. When exposed, strong waves and currents buffet this area.
Subtidal zone		The subtidal zone is always submerged. This subzone is usually considered to be the deeper water at the edge of the shoreline, the subtidal zone also includes many tidepools.
Tidepools		Tidepools are permanent and ephemeral collections of water.

Adaptations

The table below outlines a few of the environmental extremes of the intertidal zone, their potential effects on plants and animals in the zone, and ways in which organisms are adapted to live in these conditions.

Conditions	Potential Effects	Adaptations
Tidal ebb and flow; saltwater splash from wave action	Organisms exposed to the air during ebb tides, or that live in the splash zone, are subject to dessication (drying). Exposure to variable air temperatures	— Protective body structures such as shells (Snails withdraw into their shells and some secrete a mucous seal. Mollusks close their shells to retain moisture.) — "Limpets" (snails with conical, caplike shells) grind small depressions in rocks and clamp the underside of their body to the rock, leaving only their shell exposed. — Some algae have waxy coatings. — Anemones gather in large masses to reduce exposed body surface. — Seaweeds grow in dense colonies. The upper layers shelter the lower layers.
Wave action	Displacement and loss of habitat Crushing, breaking, or tearing the organism	— Streamlined or flattened shapes (e.g., *ʻopihi*) — Smooth surfaces that reduce friction and deflect wave force (e.g., *pipipi* or black nerites) — Clustering to reduce surface area exposure (e.g., barnacles) — Hiding or growing in crevices, or under sheltering rocks or plants (e.g., *nahawele* or black purse shells) — Burrowing in the sand (e.g., many types of crabs) — Strong structures to attach to a solid substrate Root-like "holdfasts" in plants and tube feet (suction cups) in animals are two examples. — Flexibility (e.g. many algae, sea palms)
Tidal ebb and flow, hot conditions that cause evaporation, rainfall that dilutes tidepools	Rapid changes in water salinity	— Retain sea water inside shell to maintain constant salinity (e.g., black purse shells) — Quickly adjust their internal salt balance (e.g., tidepool fishes) — Burrow to escape large fluctuations in salinity (e.g., worms)

Osmoconformers and Osmoregulators

Animals in the intertidal zone exhibit a range of adaptations to fluctuating salinity levels in the water that surrounds them. These adaptations can be divided into two general categories: osmoconformation and osmoregulation. “Osmoconformers” are not able to control salt concentrations in their bodily tissues. “Osmoregulators” can control internal salt concentrations.

Many marine invertebrates are osmoconformers. The result of this adaptive strategy is that these organisms do not expend energy regulating salt concentrations. Many, however, do have behavioral patterns that help them maintain relatively consistent internal salinity levels even when environmental salinity fluctuates dramatically, as it often does, particularly in the upper intertidal zone. Some, like mussels, enclose seawater in their shells; other animals, such as limpets, seal out the effects of fluctuating salinity by clamping tightly to rocks. (These strategies can be thought of as behavioral osmoregulation as opposed to physiological osmoregulation.)

Marine invertebrates are usually osmoconformers and have a fair tolerance to changes in salt concentration.These animals can generally survive in brackish water that is diluted to around 80 percent of normal salinity. Marine invertebrates that survive in fresh or more diluted brackish water are osmoregulators. These animals include crabs and other crustaceans.

Osmoregulators use a variety of strategies to maintain internal salinity levels and to quickly adjust to changing environmental salinity. All of these strategies involve transporting ions across cell membranes. The direction and mechanisms of transport depend on whether the organism’s optimal internal salinity is higher or lower than that in the environment. Aquatic vertebrates, including the marine fish found in the intertidal zone, are all osmoregulators.

Hāmākua Poko

Photo: Ann Fielding

Intertidal Subzones Table

Subzone	Alternate name	Description
Splash zone		The splash zone is a barren, rocky area frequently exposed to ocean spray but not typically immersed, even by high tides.
Upper intertidal zone	Eulittoral zone	The upper intertidal zone is covered by water only at high tide.
Lower intertidal zone	Sublittoral zone	The lower intertidal zone is underwater most of the time, except at extremely low tide. When exposed, strong waves and currents buffet this area.
Subtidal zone		The subtidal zone is always submerged. This subzone is usually considered to be the deeper water at the edge of the shoreline, the subtidal zone also includes many tidepools.
Tidepools		Tidepools are permanent and ephemeral collections of water.

Intertidal Images

Intertidal area at Hāna (Photo: Ann Fielding)

Intertidal area at Hoʻokipa (Photo: Ann Fielding)

Intertidal area at Makapu'u (Photo: Ann Fielding)

Intertidal area at La Pérouse (Photo: Ann Fielding)

Subzone Condition Cards

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Hypothesis Card: Subtidal Zone

When/how often covered by water	Fluctuations in salinity	Wave action	Exposure to air
The subtidal zone is always submerged. This subzone is usually considered to be the deeper water at the edge of the shoreline, the subtidal zone also includes many tidepools.			

Comparison Card: Subtidal Zone

When/how often covered by water	Fluctuations in salinity	Wave action	Exposure to air
The subtidal zone is always submerged. This subzone is usually considered to be the deeper water at the edge of the shoreline, the subtidal zone also includes many tidepools.	There is little or no fluctuation in salinity since the area is always covered by water.	Effects from pounding waves are minimal since the area is always covered by water. Surge or strong currents can be a factor here, however.	Exposure to air is rare.

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Hypothesis Card: Tidepools

When/how often covered by water	Fluctuations in salinity	Wave action	Exposure to air
Many tidepools are permanent, always filled with water. Others may dry up between tides.			

Comparison Card: Tidepools

When/how often covered by water	Fluctuations in salinity	Wave action	Exposure to air
Many tidepools are permanent, always filled with water. Others may dry up between tides.	Salinity may fluctuate greatly as water evaporates between tides or rainwater dilutes the salt water in a pool.	Wave action is an insignificant factor when the tide is out. But when the tide comes in, heavy surge causes significant water movement in these pools.	As water evaporates, parts of tidepools are occasionally exposed to air. Air exposure is most frequent around the edges of pools and in pools that tend to dry out between high tides.

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Hypothesis Card: Lower Intertidal Zone

When/how often covered by water	Fluctuations in salinity	Wave action	Exposure to air
The lower intertidal zone is underwater most of the time, except at extremely low tide.			

Comparison Card: Lower Intertidal Zone

When/how often covered by water	Fluctuations in salinity	Wave action	Exposure to air
The lower intertidal zone is underwater most of the time, except at extremely low tide.	There is little fluctuation in salinity because the area is almost always submerged	When this area is exposed at extremely low tide, strong waves and currents buffet it.	Exposure to air is infrequent, occuring only during unusually low tides

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Hypothesis Card: Upper Intertidal Zone

When/how often covered by water	Fluctuations in salinity	Wave action	Exposure to air
The upper intertidal zone is covered by water only at high tide.			

Comparison Card: Upper Intertidal Zone

When/how often covered by water	Fluctuations in salinity	Wave action	Exposure to air
The upper intertidal zone is covered by water only at high tide.	Fluctuations in salinity can occur when exposed organisms are rained on.	Rough waves buffet this area, which is exposed to them for longer durations than is the lower intertidal zone.	The upper intertidal zone is frequently exposed to air.

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Hypothesis Card: Splash Zone

When/how often covered by water	Fluctuations in salinity	Wave action	Exposure to air
The splash zone is a barren, rocky area frequently exposed to ocean spray but not typically immersed, even by high tides.			

Comparison Card: Splash Zone

When/how often covered by water	Fluctuations in salinity	Wave action	Exposure to air
The splash zone is a barren, rocky area frequently exposed to ocean spray but not typically immersed, even by high tides.	Salinity fluctuates as salt spray accumulates on organisms and as rainwater occasionally washes it off.	Wave action is typically not a factor in this area.	The splash zone is almost always exposed to air.

Species Cards for the Life on the Edge Activity

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Pipipi Kōlea or Dotted Periwinkle

Littoraria pintado

Where in the Intertidal Zone?

- Abundant in the splash zone on most rocky shores
- Live just above the nerites, where they are only occasionally splashed by waves

What They Eat

- Feed on algae film on wet rocks

Behaviors, Characteristics, and Adaptations

- Breathe air through wet gills
- When rocks are dry, shut shell doors to retain moisture and use mucus to glue shells to rock

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

Pipipi or Black Nerite

Nerita picea

Where in the Intertidal Zone?

- Abundant on rocky shores in the splash zone
- Live closer to the water than the *pipipi kōlea*

What They Eat

- Feed on algae film on wet rocks

Behaviors, Characteristics, and Adaptations

- Breathe air through wet gills
- When rocks are dry, shut shell doors to retain moisture

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

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ʻOpihi ʻAwa or False *ʻOpihi*

Siphonaria normalis

Where in the Intertidal Zone?
- Live on rocks above the water
- Can be abundant in the mid-intertidal zone

What They Eat
- Feed on algae film on wet rocks

Behaviors, Characteristics, and Adaptations
- Breathe with both gills and lungs
- More closely related to land snails than true *ʻopihi*
- Clamp tightly to rocks to maintain moisture

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

ʻOpihi Makaiaūli or Black-Foot *ʻOpihi*

Cellana exarata

Where in the Intertidal Zone?
- Live in the mid-intertidal zone in areas where the waves pound
- Live higher on the rocks than the other types of *ʻopihi*

What They Eat
- Graze on algae

Behaviors, Characteristics, and Adaptations
- Clamp tightly to the rock with a muscular foot
- Sometimes, on warm, sunny days, lift their shells off the rock, perhaps to cool down
- Have "home scars" to which they return after feeding

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

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Nahawele or *Pāpaua* or Black Purse Shells

Isognomon californicum

Where in the Intertidal Zone?
- Live in clusters in crevices around the high tide line
- Often live in brackish water that is trapped in these crevices

What They Eat
- Feed on organic matter suspended in water, which they filter through their gills

Behaviors, Characteristics, and Adaptations
- Attach to rocks using filaments called "byssal threads"
- Typically occur in dense clusters that help protect individual animals from the pounding of waves

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

Maka'awa or Granular Drupe

Morula granulata

Where in the Intertidal Zone?
- Found in abundance on rocky shores with good water movement
- Totally exposed during low tide

What They Eat
- Drill into and eat limpets, snails, oysters, barnacles, and possibly other organisms

Behaviors, Characteristics, and Adaptations
- Adhere to wet rocks with a muscular foot
- Make neat holes in the shells of other molluscs using the boring "drills" on their feet, then inject enzymes to digest the organism in its own shell before consuming the liquified tissues
- Taste bitter, prompting the Hawaiian name, which means "sour face"

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

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ʻOpihi ʻĀlinalina or Yellow-Foot *ʻOpihi*

Cellana sandwicensis

Where in the Intertidal Zone?
- Live at the low tide mark and just below in rocky areas where the waves pound

What They Eat
- Graze on algae

Behaviors, Characteristics, and Adaptations
- Need constant splash and do not tolerate drying out as much as the black-foot *ʻopihi*
- Clamp tightly to the rock with a muscular foot
- Often wear "caps" of seaweed

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

Hāʻukeʻuke Kaupali or Shingle or Helmet Urchin

Colobocentrotus atratus

Where in the Intertidal Zone?
- Live low in the intertidal zone where the waves pound
- Cling to exposed, rocky shores, where few other animals survive

What They Eat
- Feed on algae

Behaviors, Characteristics, and Adaptations
- Have little tolerance to drying
- Clamp onto rocks with many strong tube feet (suction cups)
- Have flat spines, allowing water to flow over them easily

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

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ʻAʻama or Thin-Shelled Rock Crab

Grapsus tenuicrustatus

Where in the Intertidal Zone?
- Live on rocky shores with strong waves
- Forage for algae in the splash zone
- Cast molted shells, which are red and found high on the rocks above the intertidal zone

What They Eat
- Feed on algae

Behaviors, Characteristics, and Adaptations
- Have long legs and spines on legs, which are used for gripping rocks
- Retreat to water or crevices when approached

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

Pāoʻo or Zebra Blenny

Istiblennius zebra

Where in the Intertidal Zone?
- Live in tidepools

What They Eat
- Feed on detritus

Behaviors, Characteristics, and Adaptations
- Can leap from pool to pool
- Are bottom dwellers

Photo: Marjorie L. Awai in John P. Hoover, Hawaii's Fishes, *Mutual Publishing*

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ʻOʻopu Ohune or Cocos Frill Goby

Bathygobius cocosensis

Where in the Intertidal Zone?
- Live in tidepools

What They Eat
- Carnivorous

Behaviors, Characteristics, and Adaptations
- Have pelvic fins that form sucking discs for holding on to rocks in surf
- Are bottom-dwellers
- Have dark mottled colorings that blend well with the black volcanic rock and can lighten to match other backgrounds

Photo: Marjorie L. Awai in John P. Hoover, Hawaii's Fishes, *Mutual Publishing*

Loli Okuhi Kuhi or Black Sea Cucumber

Holothuria atra

Where in the Intertidal Zone?
- Are found in sandy areas in tidepools
- Are bottom dwellers, found lying fully exposed on sand or rubble bottoms from the shallows to depths of at least 100 feet

What They Eat
- Swallow sand and digest organic matter in sand

Behaviors, Characteristics, and Adaptations
- Are related to sea stars
- Secrete skin toxin when handled roughly
- Have black bodies, covered with a camoflauging layer of sand

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

Cut on dashed lines, fold on solid line

Āholehole or Hawaiian Flagtail

Kuhlia sandvicensis

Where in the Intertidal Zone?
- Juveniles abundant in tidepools
- Common in brackish water

What They Eat
- Adults feed on plankton at night.

Behaviors, Characteristics, and Adaptations
- Adults found in dense schools by day, often on top of the reef in areas of heavy surge, where they are safe from predators
- Swim away and hide in crevices when approached by predators

Photo: John P. Hoover, Hawaii's Fishes, *Mutual Publishing*

Āholehole or Hawaiian Flagtail

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Photo: John P. Hoover, Hawaii's Fishes, *Mutual Publishing*

Cut on dashed lines, fold on solid line

Loli or White-Spotted Sea Cucumber

Actinopyga mauritiana

Where in the Intertidal Zone?

- Found under rocks in shallow water, their bodies almost totally buried
- Live in areas of high surge in the lower intertidal or subtidal zones

What They Eat

- Swallow sand and digest organic matter in sand

Behaviors, Characteristics, and Adaptations

- Have strong tube feet that stick to rocks where other organisms might be swept away
- Have an anus ringed with five tiny teeth that may offer protection against pearlfishes and other animals that live in the intestines of sea cucumbers
- Have mottled, camoflauging coloration

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

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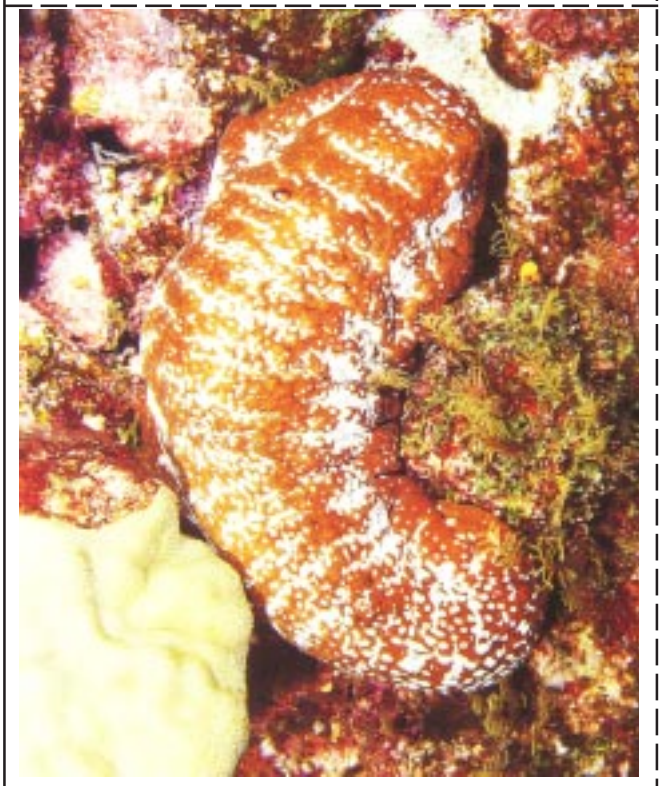

Photo: John P. Hoover, Hawai'i's Sea Creatures, *Mutual Publishing*

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'Ina or Oblong Urchin

Echinometra oblonga

Where in the Intertidal Zone?

- Found on shallow, rocky shores exposed to constant wave action, way down in the lower intertidal or upper subtidal zones
- Often the dominant urchins in these areas
- Also found on reef flats, at less than ten feet in depth

What They Eat

- Feed on algae

Behaviors, Characteristics, and Adaptations

- Use spines and teeth to bore hollows into soft rock where they live
- Protect their soft undersides from predator by burrowing and create depressions that hold water when exposed at low tide
- Have tube feet for attaching to rocks

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

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

Cut on dashed lines, fold on solid line

'Ina Kea or Rock-Boring Urchin

Echinometra mathaei

Where in the Intertidal Zone?

- Found in tidepools and deeper, often anchoring themselves under branching finger coral
- Found on shallow, rocky shores exposed to constant wave action, down low in the lower intertidal or upper subtidal zones
- Almost always submerged

What They Eat

- Feed on algae

Behaviors, Characteristics, and Adaptations

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Photo: Philip Thomas

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- Protect their soft undersides from predators by burrowing
- Have tube feet for attaching to rocks

Photo: Philip Thomas

Kaunaʻoa or Variable Worm Snail

Serpulorbis variabilis

Where in the Intertidal Zone?

- Found in environments exposed to waves and surge, such as the lower intertidal zone, including tidepools and wave-exposed reef flats

What They Eat

- Feed by trapping suspended food particles in strands or a net of mucous

Behaviors, Characteristics, and Adaptations

- Permanently cement themselves to rocks or other hard surfaces
- Have sharp shell openings that may cut feet or hands

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

Cut on dashed lines, fold on solid line

Seurat's Hermit Crab

Calcinus seurati

Where in the Intertidal Zone?
- Live in rocky tidepools in the splash zone, amongst the periwinkles and nerites
- Common in rocky areas with strong surf

What They Eat
- Scavenge and eat algae

Behaviors, Characteristics, and Adaptations
- Can tolerate warm stagnant water
- Live in discarded periwinkle and nerite shells
- Use their left claws to block openings when they withdraw into their shells

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

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Cut on dashed lines, fold on solid line

Limu Kala or *ʻAkala*

Sargassum echinocarpum

Where in the Intertidal Zone?

- Grows on rocks in the middle to lower part of the intertidal zone, usually lower down than *limu pālahalaha*

Behaviors, Characteristics, and Adaptations

- Is a brown seaweed that grows up to 50 centimeters (20 inches) high
- Produces small, inflated bladders for flotation

Photo: Jennifer Smith

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Photo: Jennifer Smith

Cut on dashed lines, fold on solid line

Limu ʻAkiʻaki

Ahnfeltia concinna

Where in the Intertidal Zone?

- Grows on *pāhoehoe* lava boulders in the upper intertidal zone, higher than the other kinds of *limu*

Behaviors, Characteristics, and Adaptations

- Grows upright to .3 meters (one foot) tall
- Has tough, rubbery branches that grow close together in dense bunches

Photo: Kim Martz and Forest Starr

Bubble Algae

Dictyosphaeria spp.

Where in the Intertidal Zone?

- Found in tidepools and on shallow reefs

Behaviors, Characteristics, and Adaptations

- Is a green seaweed composed of tiny, round cells

Photo: Ed Robinson ©1984

Cut on dashed lines, fold on solid line

Limu Pālahalaha or Sea Lettuce

Ulva fasciata

Where in the Intertidal Zone?

- Commonly grows on lava rock and old coral in the middle part of the intertidal zone
- Uncovered at low tide

Behaviors, Characteristics, and Adaptations

- Its base resembles a lettuce leaf, with ribbon-like blades that can grow longer than 75 centimeters (30 inches).

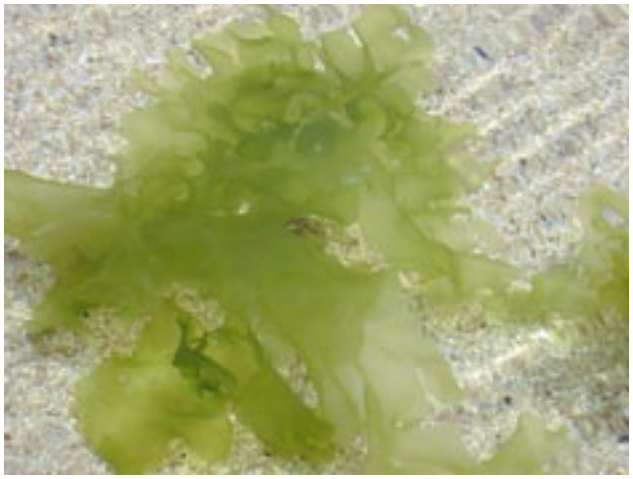

Photo: Kim Martz and Forest Starr

Spiny Brittle Star

Ophiocoma erinaceus

Where in the Intertidal Zone?

- Live under rocks in tidepools and in deeper water, too

What They Eat

- Feed on detritus

Behaviors, Characteristics, and Adaptations

- Have flexible arms, making them fast-moving
- Have tube feet but no gripping suction cups
- Can drop an arm for a quick getaway when a predator attacks

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

Cut on dashed lines, fold on solid line

Kūpīpī or Blackspot Sergeant
Abudefduf sordidus

Where in the Intertidal Zone?
- Young found in tidepools, inlets, and even in brackish water
- Adults found around boulders and rocks in the shallow surge zone

What They Eat
- Feed on algae

Behaviors, Characteristics, and Adaptations
- Young protected from larger predators in the tidepools
- Swim away and hide in crevices when approached by predators

Photo: John P. Hoover, Hawaii's Fishes, *Mutual Publishing*

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- Swim away and hide in crevices when approached by predators

Photo: John P. Hoover Hawaii's Fishes, *Mutual Publishing*

Subzones Species Key

Splash Zone

- *Pipipi Kōlea* or Dotted Periwinkle
- *Pipipi* or Black Nerite
- Seurat's Hermit Crab
- *ʻAʻama* or Thin-Shelled Rock Crab

Upper Intertidal

- *ʻOpihi ʻAwa* or False *ʻOpihi*
- *ʻOpihi Makaiaūli* or Black-Foot *ʻOpihi*
- *Nahawele* or *Pāpaua* or Black Purse Shells
- *Makaʻawa* or Granular Drupe
- *Limu ʻAkiʻaki*
- *Limu Pālahalaha* or Sea Lettuce
- *Limu Kala* or *ʻAkala*

Lower Intertidal

- *Limu Kala* or *ʻAkala*
- *Hāʻukeʻuke* or Shingle or Helmet Urchin
- *ʻOpihi ʻĀlinalina* or Yellowfoot *ʻOpihi*
- *ʻIna Kea* or Rock-Boring Urchin
- *Loli* or White-spotted Sea Cucumber
- *ʻIna* or Oblong Urchin
- *Kaunaʻoa* or Variable Worm Snail

Subtidal

- *Loli* or White-spotted Sea Cucumber
- *ʻIna* or Oblong Urchin
- *ʻIna Kea* or Rock-Boring Urchin
- *Kūpīpī* or Blackspot Sergeant
- *Āholehole* or Hawaiian Flagtail

Tidepools

- *Pāoʻo* or Zebra Blenny
- *ʻOʻopu Ohune* or Cocos Frill Goby
- Juvenile *Kūpīpī* or Blackspot Sergeant
- Juvenile *Āholehole* or Hawaiian Flagtail
- *Loli Okuhi Kuhi* or Black Sea Cucumber
- Spiny Brittle Star
- *ʻIna Kea* or Rock-Boring Urchin
- Bubble Algae
- Seurat's Hermit Crab
- *Kaunaʻoa* or Variable Worm Snail

Activity #2

A Day in the Neighborhood: Skits about the Intertidal Zone

● ● ● Class Period One *Skit Preparation*

Materials & Setup

For each student

• Student Page "A Day in the Neighborhood: Skits About the Intertidal Zone" (p. 42)

Instructions

1) Divide students into the same groups they were in during the previous activity.

2) Hand out the Student Page "A Day in the Neighborhood: Skits About the Intertidal Zone." Using this sheet as a guide, student groups will plan and perform a five-minute skit about life in a particular subzone of the intertidal zone.

3) Review the instructions and guidelines with students, and give them the rest of the class period to work in their small groups to plan the skit.

Recommendation

Give students longer than just overnight to research, write, and prepare their skits. If this is possible, schedule the performances to take place in several days (or after a weekend), and move on to another topic during the intervening periods.

● ● ● Class Period Two *Skit Performances*

Materials & Setup

• Twenty-five copies, "Skit Assessment Chart" (master, p. 41)

Instructions

1) Have students sit together in their groups. Give each group four copies of the "Skit Assessment Chart." Group members will use these charts to assess other groups' skits. Different group members should take responsibility for assessing each skit.

2) Have student groups put on their skits, beginning at either the top (splash zone) or bottom (subtidal zone) and taking the subzones in order. You may place tidepools at the beginning or the end, regardless of which zone you begin with.

3) After all skits have been performed, ask students to discuss what they learned about the intertidal zone from the skits. Begin this discussion by having students make comparisons between the subzone they studied and other subzones. Then ask students to identify commonalities and patterns among all of the subzones.

Journal Ideas

- Write a first-person narrative about a day in the life of a plant or animal in the subzone that you studied.
- Look around you and find some other examples of zonation. Describe them and the conditions that create them.

Assessment Tools

- Student skits: Use the "Skit Assessment Chart" (p. 41) to help gauge students' performance.
- Groups' assessments of other groups' skits
- Participation in the class discussion
- Journal entries

Skit Assessment Chart

Group members

Subzone

Assessment Criteria	Notes
Explains environmental conditions in the subzone	
Dramatizes at least three examples of how organisms in the subzone respond to or protect themselves from changing environmental conditions throughout the day and night	
Dramatizes at least three examples of how organisms interact with each other in the intertidal zone These organisms may include plants, animals, and humans.	
Involves everyone in the group	
Is five minutes long	
Other (e.g., originality)	

A Day in the Neighborhood: Skits About the Intertidal Zone

Work with your group to write and perform a five-minute skit about a typical day in the intertidal zone. Your skit should:

1) Explain environmental conditions in the subzone.

2) Dramatize at least three examples of how organisms in the intertidal zone respond to or protect themselves from changing environmental conditions throughout the day and night.

3) Dramatize at least three examples of how organisms interact with each other in the intertidal zone. These organisms may include plants, animals, and humans.

4) Involve everyone in your group.

Use the information on the intertidal zone species cards and what you learned from the class discussion and homework assignment as the basis for your skit. You may also do additional research to bring in information that other groups in your class may not think of or include in their skits. Your skit might include dance, songs, chants, reflections of cultural significance, and other creative elements.

Research Resources

Tide charts

Fielding, Ann, *Hawaiian Reefs and Tidepools*, Island Explorations, Makawao, Hawai'i, 1998.

Fielding, Ann and Ed Robinson, *An Underwater Guide to Hawai'i*, University of Hawai'i Press, Honolulu, 1993.

Hobson, Edmund S. and E. H. Chave, *Hawaiian Reef Animals*. University of Hawai'i Press, Honolulu, 1990.

Hoover, John P., *Hawaii's Fishes: A Guide for Snorkelers, Divers and Aquarists*, Mutual Publishing, Honolulu, 1993.

_____, *Hawai'i's Sea Creatures: A Guide to Hawaii's Marine Invertebrates*, Mutual Publishing, Honolulu, 1998.

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

Randall, John E., *Shore Fishes of Hawaii*, Natural World Press, 1996.

Suggested Internet Keywords

Algae
Intertidal
Marine invertebrate
Marine fish
Tidepool
Species name (scientific, Hawaiian, or common)

You may add "Hawaii" to any of the above search terms to narrow your findings.