4.2 WATERSHEDS AND THE INTERTIDAL

Watersheds include the area of land that collects water flowing in a common direction, like from the mountains to the sea,. Coastal environments, such as the intertidal, are affected by everything that happens upstream.

MS-LS1-5. Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.

MS-ESS3-3. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

HS-LS2-2. Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales**.**

HS-ESS2-5. Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.

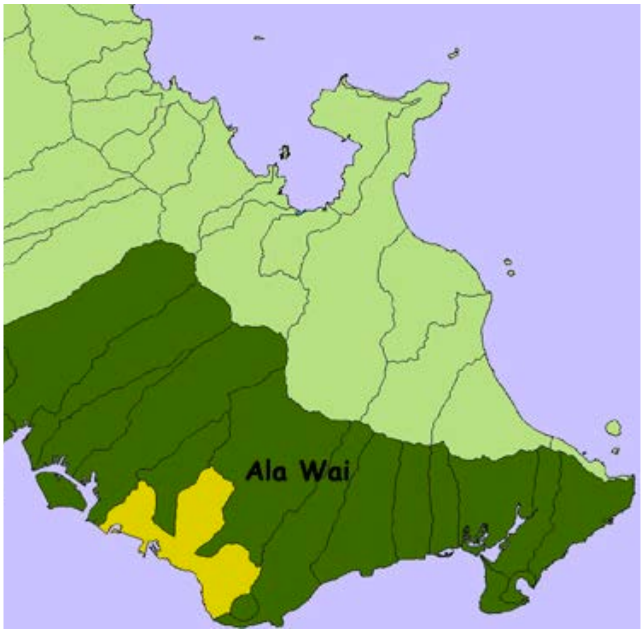
The content and activities in this topic will work towards building an understanding of communities of organisms and how they are affected by the physical and biological properties of the environment.

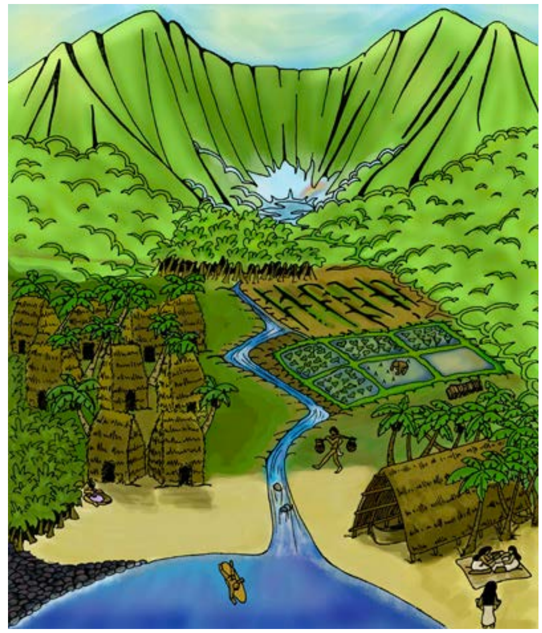
Watershed

A **watershed** is an area of land that collects rainwater into a common outlet. As rain falls, some is absorbed by plants, some is absorbed underground, and the rest is surface water that flows to a common outlet. The outlet of a watershed varies by location and may be a river, lake, or the ocean.

Forests are critically important for a watershed because they help rain to form. Water condenses on trees high up in the watershed, increasing rainfall and absorption. Forests and plants are also critically important because they help hold soil and nutrients on land, preventing sediments from flowing to the ocean.

The Hawaiian equivalent of a watershed is the ahupuaʻa. An **ahupuaʻa** is a land division with mountains, hills, valleys, or streams serving as boundaries. Ahupuaʻa include the land from the mountains to the coast. Where appropriate, ahupuaʻa also included the coastal ocean, including nearby coral reefs. The size of an ahupuaʻa varies from as little as 100 acres to more than 100,000 acres (see watershed designations for southern Oʻahu, Hawaiʻi in Fig. 4.1A).





(A) **(B)**

(A) http://cramp.wcc.hawaii.edu/Watershed_Files/Oahu/WS_Oahu_honolulu_alawai.htm
Image courtesy of Hawai‘i Coral Reef Assessment & Monitoring Program

(B) http://ethnomusicologyreview.ucla.edu/journal/volume/18/piece/698
Illustration by Mele McPherson. Image courtesy of Hale Kuamo‘o, The Hawaiian Language Center, University of Hawai‘i at Hilo.

Fig. 4.1. (A) Watersheds (ahupua‘a) of southern O‘ahu, Hawai‘i with the Ala Wai watershed highlighted in yellow. **(B)** “Ke Ahupua‘a” showing the flow of water from mountains (mauka) to ocean (makai) through a watershed

Native Hawaiians recognized the importance of forests in water production, as described in this ‘ōlelo (proverb):

“Hahai nō ka ua i ka ulu lā’au”
Rains always follows the forest.

> The rains are attracted to forest trees. Knowing this, Hawaiians hewed only the trees that were needed. ‘Ōlelo 405, Pukui, Mary Kawena. 1983. ‘Ōlelo No‘eau: Hawaiian Proverbs and Poetical Sayings. Honolulu, HI. Bishop Museum Press.

Traditionally, people living within ahupua’a boundaries had resource management practices determining when it was okay to gather resources, like food, and when resources needed to rest. The upland forests were recognized as important for supplying water. The plains were used for growing food. The coastal areas were also for used for growing food, including fish in coastal ponds (see various ahupua‘a land uses represented in Fig. 4.1B).

The Intertidal

The **intertidal** is a marine ecosystem that is covered with water during high tide and exposed to air during low tide. The organisms that live in the intertidal are adapted for the challenging conditions that come from being alternatively submerged and exposed. The intertidal zone of tropical islands has been poorly studied, particularly in comparison to the intertidal zone of temperate regions (like California). In Hawai‘i, this may be due in part to smaller organisms in the intertidal compared to temperate intertidal regions and a small tidal range that can make the zone hard to see (Fig. 4.2).

The intertidal is impacted by everything that happens both on land and in the ocean because it is at the base of the watershed. The intertidal is affected by everything that happens upstream including erosion, runoff, pollution, and development. The intertidal is vulnerable to being invaded by alien species, species that are not native to an area, and climate change impacts, like sea level rise and increasing land and ocean temperatures. In addition, the intertidal is easy to get to, which means it is easy for humans to trample and overharvest resources.

Image courtesy of K. Seraphin

Fig. 4.2. Researchers prepare to survey an intertidal bench on during low tide on O‘ahu, Hawai‘i, using transect measuring tapes.

Temperature

Temperature is a measure of the average kinetic energy of molecules. Water temperature is impacted by physical, chemical, and biological processes. The temperature in large bodies of water is generally controlled by climate and currents. In small pools or shallow lakes, temperature is affected by shading from rocks or plants, water flow rate, and water depth. Additionally, industrial discharge or sewage outflow can decrease or increase water temperature, an effect called thermal pollution. Changes in water temperature can change density. Temperature is measured with traditional thermometers as well as with digital data loggers (Fig. 4.3).

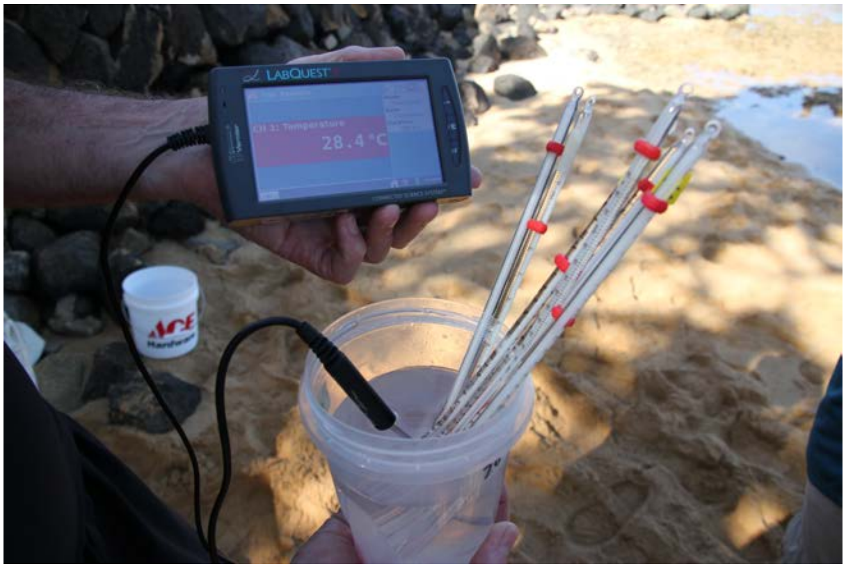


Image courtesy of K. Seraphin

Fig. 4.3. A researcher compares readings from a digital probe with traditional thermometers.

Temperature influences a wide variety of biological processes, like metabolism. Some organisms are able to withstand a wide range of temperatures. Other organisms can be adversely affected by even a small change in temperature. For example, an increase in only a few degrees above normal conditions in shallow marine waters results in coral bleaching.

Temperature in the intertidal depends on a number of factors including wave action, tidal height, air and water temperature, and rainfall. The ground also affects temperature. Intertidal areas with darker substrate will have a higher temperature than lighter substrate. **Rugosity**, or how uneven the substrate is, can affect temperature by providing shade. Tidepool temperature is affected by the rugosity, volume, and depth of the pools. Invertebrates living in intertidal areas have evolved to deal with the stress of high temperatures. Animals in the intertidal also have cooling behaviors, like moving to shaded areas.

Salinity

Salinity is a measure of the amount of dissolved salt in water. Salinity can be affected by evaporation and freshwater input from rain, rivers, and glacial melting. Most marine and freshwater organisms have a narrow range of salt tolerance. However, some organisms that live in environments like the intertidal and estuaries have a wide range of salt tolerance.

Salinity in the intertidal is affected by rain and other freshwater sources, like nearby streams. All of the things that affect evaporation rates affect salinity, like temperature, wind, wave action, and location in the intertidal (high vs. low). In intertidal areas with tidepools that are cut off from the ocean during low tide, these pools can experience high evaporation rates and become very salty.

A hydrometer is a simple device that can be used to measure salinity (Fig. 4.4). Hydrometers measure the relative density of water. Water that has more salt is more dense than fresh water. Salinity can also be measured with a refractometer. A refractometer measures how much light bends when it enters the liquid. The more salt dissolved in the water, the more the light will bend. A conductivity meter measures how well the liquid conducts electricity. The more salt dissolved in the water, the better it will conduct electricity.

(A) Image courtesy of K. Seraphin **(B)** Image courtesy of NASA

Fig. 4.4. (A) A hydrometer showing salinity of about 38 ppt. **(B)** A NASA researcher uses a different type of hydrometer to measure the level of salinity at a salt evaporation pond in San Francisco Bay, California.

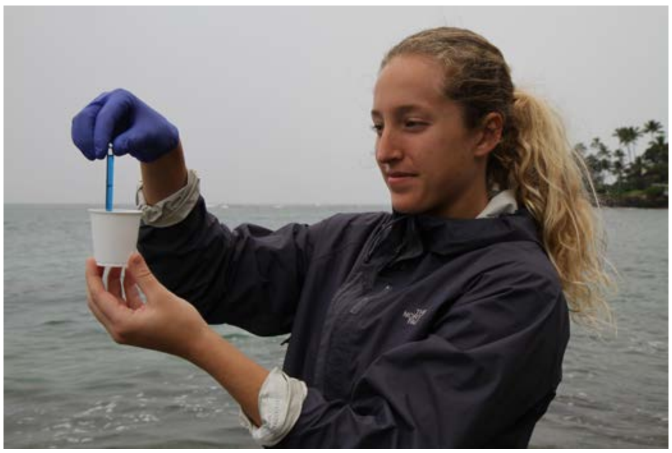
Dissolved Oxygen

Dissolved oxygen is the oxygen gas dissolved in water. Dissolved oxygen is a free oxygen molecule (O_2), rather than the oxygen atom bound to hydrogen in a water molecule (H_2O). Oxygen gas enters the water from the atmosphere and from photosynthesis by algae and aquatic plants. Oxygen gas leaves the water through respiration by algae, plants, animals, bacteria, and other microorganisms. Other chemical reactions, like decomposition of organic wastes, also remove oxygen.

The amount of oxygen that water can hold is determined by pressure, salinity, and temperature. **Solubility**, or the amount of gas that can dissolve in water, increases with pressure. At low elevations (more pressure), water holds more oxygen than at high elevations (less pressure). Gas solubility also increases as salinity decreases. This means freshwater holds more oxygen than saltwater. Seawater holds about 20 percent less oxygen than fresh water at the same temperature. Gas solubility increases as temperature decreases. This means cold water holds more oxygen than warm water.

Dissolved oxygen is essential to aquatic life. The amount of dissolved oxygen needed to sustain life depends on the location (e.g., stream vs. ocean) and the type of life. For example, fish have higher metabolic rates than crabs. Fish need more oxygen to survive than crabs. But, crabs have higher metabolic rates than mussels. Organisms in the intertidal tend to be highly resistant to oxygen deficiency.

Dissolved oxygen is lower in the early morning because no organisms can photosynthesize at night, but they all need to respire. Dissolved oxygen can be measured by chemical reaction in a lab or with a field test kit (Fig. 4.5A). Dissolved oxygen can also be measured with a digital probe (Fig. 4.5B).



(A)

(B)

Images courtesy of K. Seraphin

Fig. 4.5. (A) A researcher uses a field test kit to measure dissolved oxygen. **(B)** Researchers use a digital probe to measure dissolved oxygen on the edge of an intertidal bench.

Turbidity

Turbidity is a measure of how clear or cloudy the water is. Turbidity can be caused by biological particles in the water, such as plankton, microscopic organisms, and organic debris. Turbidity can also be caused by non-biological particles in the water, such as sand, mud, or silt.

Turbidity naturally varies by location. Cooler waters, like those off the coast of Washington and Oregon, tend to be more turbid and also more productive in terms of biomass. Warmer waters, like those off the coast of Hawaii and Tahiti, tend to be more clear and also less productive in terms of biomass.

On a regular basis, algal blooms and organisms stir up sand and sediment, increasing turbidity. Scientists are interested in these small-scale changes. Scientists are also interested in larger changes in turbidity, like those caused by storm waves, runoff, or flooding. Wastewater in particular carries many types of suspended solids that can increase turbidity. These solids provide a surface for bacteria and pollutants to attach.

Turbidity is measured by looking at water clarity, with a secchi disc or tube (Fig. 4.6). Turbidity can also be measured by looking at light reflected off particles in the water.

Image courtesy of K. Seraphin

(A) **(B)**

Fig. 4.6. (A) Researchers use a turbidity tube to measure water clarity. **(B)** A turbidity tube is composed of a clear tube, a stopper/cap to seal one end, a viewing disc, and a measuring device.

Intertidal Organisms

Most intertidal organisms have marine ancestors. The tide brings food, nutrients, and dissolved oxygen. Ocean water cools organisms down and may increase or decrease salinity. During low tide, organisms in the high intertidal are either exposed or in pools cut off from the ocean. These organisms are adapted to considerable temperature increases (because of heating effects), salinity increases (because of evaporation), and decreases in oxygen (because of demand from respiration). (Fig. 4.7).

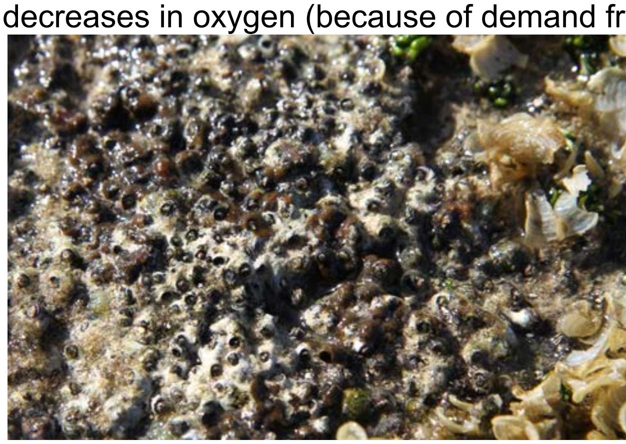


Image courtesy of K. Seraphin

Fig. 4.7. Vermitid snails (*D. gregaria*) live in colonies and are among the mollusks adapted to tropical, intertidal environments.

Activity: Predicting Water Quality Parameters in a Watershed
Water quality measurements provide information about the health of an environment. Make predications about relative water quality conditions in an area and plan a how you will sample for temperature, salinity, dissolved oxygen, and turbidity.

Practice(s): Constructing Explanations and Designing Solutions
Crosscutting Concept(s): Scale, Proportion, and Quantity
Disciplinary Core Idea: PS2.B: Types of Interactions

Materials
- Colored pens/pencils
- Blank paper for drawing a watershed (or a picture/drawing of a watershed)

Procedure
1. Make or obtain a drawing of a watershed, from the land to the ocean (mauka to makai) that includes a rocky intertidal area. If you draw an imaginary watershed, include
    a. a stream that
        i. passes near some agricultural land
        ii. passes near a residential area, and
        iii. flows into the ocean
    b. an intertidal area with
        i. a gently sloping rock bench where algae, invertebrates, and small fishes live
        ii. pools of water that are separated from the ocean at high tide
    c. residential buildings and roads where there are storm drains that collect runoff and drain into the ocean
    d. a commercial production plant that directly drains into the ocean

2. Make a legend on your drawing to indicate two color schemes for two days with very low tides:
    a. 1st color = a hot, sunny summer day
    b. 2nd color = a cool, rainy, winter day

3. Use your 1st color to indicate two areas on your watershed drawing where you predict high measures and two areas where you predict low measures for each of the following water parameters on a hot, sunny summer day with a very low tide:
    a. Temperature
    b. Salinity
    c. Dissolved Oxygen
    d. Turbidity

4. Use your 2nd color to indicate two areas on your watershed drawing where you predict high measures and two areas where you predict low measures for each of the following water parameters on a cool, rainy, wintery day with a very low tide:
    a. Temperature
    b. Salinity
    c. Dissolved Oxygen
    d. Turbidity

Activity Questions

1. How do you think the stream's water quality measures will be different than the intertidal area or the open ocean?

2. How do you think each of the following will affect the salinity of water pools that form in the high intertidal area when the tide is low?
    a. Rain
    b. Bright, hot, sunny day

3. How do you think rain affects the runoff from residential storm drains?
    a. How might this runoff affect organisms in the intertidal?

4. How would rain affect the runoff from a commercial production plant?
    a. How might this runoff affect organisms in the stream?
    b. How might this runoff affect organisms in the intertidal?

5. Describe a day where the combination of conditions would make the intertidal environment very stressful for the algae, invertebrates, and fishes that live there.

6. Describe a sampling plan that would help you to detect the largest possible differences between two locations in your watershed along the following parameters:
    a. Temperature
    b. Salinity
    c. Dissolved Oxygen
    d. Turbidity

Activity: Measuring Water Quality Parameters in a Watershed
Water quality measurements provide information about the health of an environment. In this activity, you will take measurements and compare relative water quality conditions and plan a sampling scheme for four different parameters: temperature, salinity, dissolved oxygen, and turbidity.

Practice(s): Constructing Explanations and Designing Solutions **Crosscutting Concept(s):** Scale, Proportion, and Quantity **Disciplinary Core Idea:** PS2.B: Types of Interactions

Materials
- Water quality testing equipment, for example:
    - Thermometer
    - Hydrometer
    - Dissolved oxygen test kit
    - Turbidity tube
- Water resistant paper and pencil
- Safety gear as necessary for your environment and tests you are using

Procedure
1. Make a drawing of your watershed.

2. Predict areas of high and low measures for each of the following water quality parameters:
    a. Temperature
    b. Salinity
    c. Dissolved Oxygen
    d. Turbidity

3. Discuss with your group to come up with a sampling plan. Indicate on your drawing where you will sample for each of the water parameters.

4. Conduct water quality tests in each of your pre-determined locations and record your results.

Activity Questions
1. What was the reasoning for your sampling plan?

2. How did your actual measurements compare with your predictions for high and low measures:
    a. Temperature
    b. Salinity
    c. Dissolved Oxygen
    d. Turbidity

3. How do you think your measurements were effected by the weather on the day you sampled?

4. How do you think your water quality measurements were effected by the type of test(s) you used?

5. How confident are you in your findings about water quality at this location?

6. What additional information would you like in order to draw more accurate conclusions about the water quality in this watershed?

7. What recommendations would you make to environmental resource managers and the people living in the community of your watershed in order to help improve the water quality in your watershed?