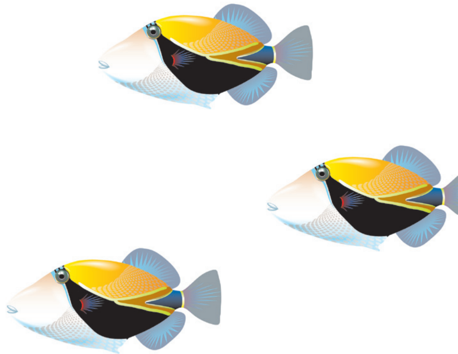
GRADE 5 UNIT 6 OVERVIEW

Life in the Open Ocean



Introduction

Open ocean ecosystems are complex, self-sustaining, and interdependent communities of marine plants, bacteria, and animals. Commercial and recreational fishing and tourism are prime beneficiaries of open ocean ecosystems. Because this unit addresses complex interrelationships in open ocean ecosystems, students are initially made aware of the global importance of open oceans.

Unlike the continents, which are surrounded by submerged continental shelves, the Hawaiian Islands were formed by volcanic lava flows that rose directly from the bottom of the ocean. Due to this, the nearshore shallow water areas surrounding the islands are very narrow and the deeper open ocean waters are much closer to land than their continental counterparts. Students study these nearshore and open ocean areas by exploring marine maps of the Hawaiian Islands.

Students gain a better understanding of ecosystems by identifying plankton and its role in these ecosystems. They discover that phytoplankton are at the base of food chains and food webs in marine ecosystems. Students understand that phytoplankton are eaten by zooplankton (herbivores and first-level consumers), which are eaten by small organisms, which, are in turn, eaten by larger organisms, such as sharks further up the food chain. Using Internet resources, students identify and list the islands' most common types of sharks, recording relevant statistics prior to developing nearshore and open ocean energy pyramids. Students also note which animals are producers, consumers, or decomposers.

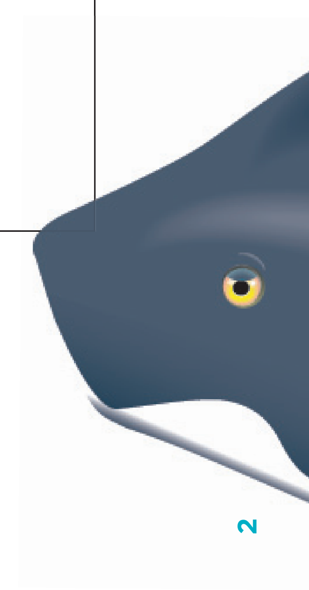
Not much goes to waste in open ocean ecosystems. Students find that *marine snow* (excess organic materials, including dead animals, plants, sediments, and fecal matter) aggregate and sink toward the dark ocean bottom where food is scarce. They learn that some deep-water animals depend on marine snow for subsistence, and that some species migrate upward in search of food.

In culminating activities, students review the previous lessons and assess their understanding of the matter and energy cycle in open ocean ecosystems.

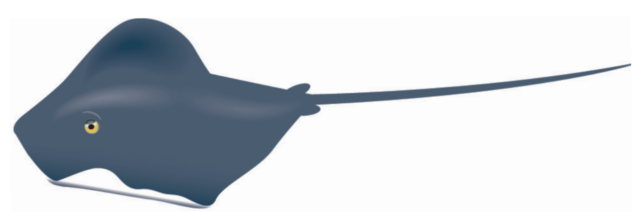
At A Glance

Each Lesson addresses HCPS III Benchmarks. The Lessons provide an opportunity for students to move toward mastery of the indicated benchmarks.

ESSENTIAL QUESTIONS	HCPS III BENCHMARKS	**LESSON**, *Brief Summary,* Duration
What are the zones of the open ocean? How much of the Earth does the ocean cover? How do we describe the open ocean around Hawai'i?	Science Standard 1: The Scientific Process: Scientific Investigation: SC.5.1.2 Formulate and defend conclusions based on evidence. Science Standard 2: Scientific Process: Nature of Science SC.5.2.1 Use models and/or simulations to represent and investigate features of objects, events, and processes in the real world. Math Standard 1: Numbers and Operations: Number Sense: MA 5.1.1 Represent percent and ratio using pictures or objects. Math Standard 10: Patterns, Functions and Algebra: Symbolic Representation: MA 5.10.2: Model problem situations with objects or manipulatives and use representations (e.g., graphs, tables, equations) to draw conclusions	**Lesson 1: Where in the World is the Open Ocean?** The lesson begins with a hands-on activity where students discover that the Earth is 70% water and 30% land. After the realization that the ocean is vast, the class will view a presentation that will introduce them to the parts or zones of the Open Ocean and discuss why the Hawaiian Islands have no continental shelf. Next, the class will be introduced to bathymetry and how it relates to the zones of the Open Ocean. To wrap the lesson up, students will use a bathymetric map of the Hawaiian Islands to locate and describe inshore and offshore or open ocean areas. Two 45-minute periods



ESSENTIAL QUESTIONS	HCPS III BENCHMARKS	**LESSON**, *Brief Summary,* Duration
Where do sharks live? What is the role of sharks in the marine food chain? How does energy flow in a marine ecosystem?	Science Standard 3: Life and Environmental Sciences: 5.3.1 Describe the flow of energy among producers, consumers, and decomposers.	**Lesson 2: Sharks – The Top Predators of the Open Ocean** Sharks live in both inshore and offshore or open ocean waters. They are found in all the oceans of the world. Sharks are feared and often misunderstood. In this lesson, students investigate and research common Hawaiian inshore and open ocean sharks. They investigate shark size, where they hunt for food, and what they eat; in doing so, students are able to describe where sharks fit in the marine food chain as well as how energy flows through that ecosystem.
What is plankton? How does plankton support food webs in terms of the flow of energy?	Science Standard 3: Life and Environmental Sciences: SC.5.3.1 Describe the flow of energy among producers, consumers, and decomposers. SC.5.3.2 Describe the interdependent relationships among producers, consumers, and decomposers in an ecosystem in terms of cycles of matter.	**Lesson 3: What's Missing from this Picture?** In this lesson, students view underwater images showing fish and squid in the open ocean, and compare these images with images of animals on land. They discover that visible plants are conspicuously absent from the open ocean images. This discovery provides the opportunity to introduce and explore the role of plankton. Students add zooplankton and phytoplankton to their food chains and explore the role of a decomposer in a marine food web. One 45-minute period



ESSENTIAL QUESTIONS	HCPS III BENCHMARKS	LESSON, *Brief Summary,* Duration
How does marine snow play a role in the Open Ocean ecosystem? How does matter cycle through producers, consumers, decomposers in the open ocean?	Science Standard 3: Life and Environmental Sciences: 5.3.1 Describe the flow of energy among producers, consumers, and decomposers. SC.5.3.2 Describe the interdependent relationships among producers, consumers, and decomposers in an ecosystem in terms of cycles of matter.	**Lesson 4: Marine Snow** In this lesson, students review the parts of the ocean water column, which consists of the photic and aphotic zones. These two zones play an important role in the formation and distribution of marine snow. Through a PowerPoint presentation, the students gain a better understanding how marine snow forms, how it is distributed, and what role it plays in the Open Ocean food chain. The lesson ends with students completing a zonation exercise that will show that they can explain how marine snow forms and the role it plays in the marine ecosystem in terms of the cycles of matter. One 45-minute period
How does matter cycle and energy flow in the open ocean?	Science Standard 2: The Scientific Process: Nature of Science SC.5.2.1 Use models and/or simulations to represent and investigate features of objects, events, and processes in the real world. Science Standard 3: Life and Environmental Sciences: SC.5.3.1 Describe the flow of energy among producers, consumers, and decomposers. SC.5.3.2 Describe the interdependent relationships among producers, consumers, and decomposers in an ecosystem in terms of cycles of matter.	**Culminating Lesson: Matter Cycles and Energy Flow in the Open Ocean** To refresh the information students learned throughout this unit, the class will participate in a short review game. Students will then demonstrate what they have learned in this unit about the zones of the Open Ocean, the organisms in the Open Ocean and how matter cycles and energy flows through a matching activity. One 45-minute period

"Hawaii Content & Performance Standards III Database." Hawaii Department of Education. June 2007. Department of Education. 17 Dec. 2007.

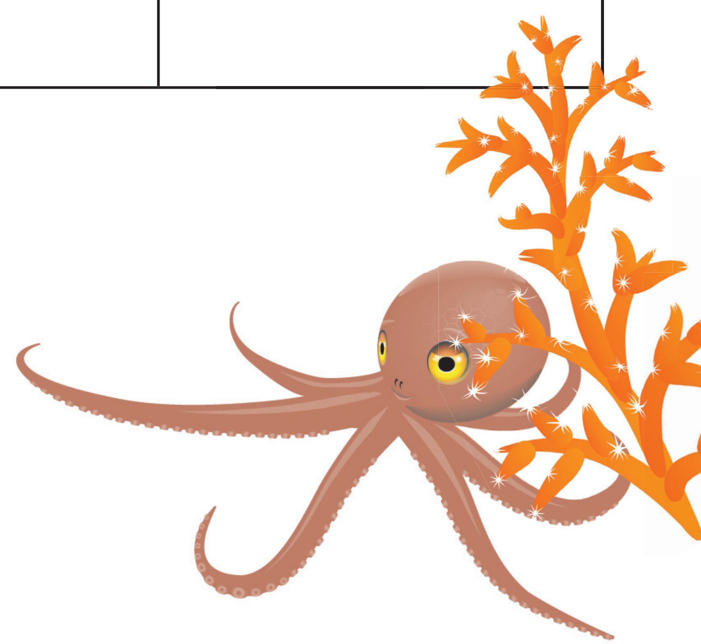
Benchmark Rubric

I. HCPS III Benchmarks*

Below is a general Benchmark Rubric. Within each lesson, there are other assessment tools and additional rubrics specific to the performance tasks within each lesson.

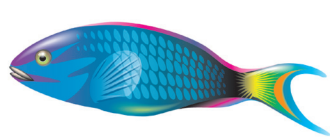
Topic		**Scientific Inquiry**	
Benchmark SC.5.1.2		Formulate and defend conclusions based on evidence	
Rubric			
Advanced	**Proficient**	**Partially Proficient**	**Novice**
Formulate and defend conclusions that are supported by detailed evidence and make connections to the real world	Formulate and defend conclusions that are supported by evidence	Make conclusions that are partially supported by evidence	Make conclusions without evidence

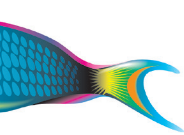
Topic		**Unifying Concepts and Themes**	
Benchmark SC.5.2.1		Use models and/or simulations to represent and investigate features of objects, events, and processes in the real world	
Rubric			
Advanced	**Proficient**	**Partially Proficient**	**Novice**
Consistently select and use models and simulations to effectively represent and investigate features of objects, events, and processes in the real world	Use models and/or simulations to represent and investigate features of objects, events, and processes in the real world	With assistance, use models or simulations to represent features of objects, events, or processes in the real world	Recognize examples of models or simulations that can be used to represent features of objects, events, or processes

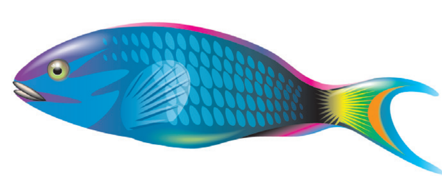


Topic		**Cycles of Matter and Energy**	
Benchmark SC.5.3.1		Describe the cycle of energy among producers, consumers, and decomposers	
Rubric			
Advanced	**Proficient**	**Partially Proficient**	**Novice**
Explain and give detailed examples of the cycle of energy among producers, consumers, and decomposers	Describe the cycle of energy among producers, consumers, and decomposers	Describe a part of the energy cycle with an example (e.g., describe one or two parts of a food chain)	Recognize an example of part of an energy cycle
Topic		**Interdependence**	
Benchmark SC.5.3.2		Describe the interdependent relationships among producers, consumers, and decomposers in an ecosystem in terms of the cycles of matter	
Rubric			
Advanced	**Proficient**	**Partially Proficient**	**Novice**
Explain and give examples of how specific relationships among producers, consumers, and decomposers in an ecosystem affect the cycling of matter	Describe the interdependent relationships among producers, consumers, and decomposers in an ecosystem in terms of the cycling of matter	Identify a few relationships between producers, consumers, or decomposers in an ecosystem in terms of the cycling of matter	Recall, with assistance, that matter cycles in an ecosystem among producers, consumers, and decomposers

Topic		**Numbers and Number Systems**	
Benchmark MA.5.1.1		Represent percent and ratio using pictures or objects	
Rubric			
Advanced	**Proficient**	**Partially Proficient**	**Novice**
Represent percent and ratio using pictures or objects, with accuracy	Represent percent and ratio using pictures or objects, with no significant errors	Represent percent and ratio using pictures or objects, with a few significant errors	Represent percent and ratio using pictures or objects, with many significant errors







Topic		Numeric and Algebraic Representations	
Benchmark MA.5.10.2		Model problem situations with objects or manipulatives and use representations (e.g., graphs, tables, equations) to draw conclusions	
Rubric			
Advanced	**Proficient**	**Partially Proficient**	**Novice**
Model problem situations with objects or manipulatives and use representations to draw conclusions, with accuracy	Model problem situations with objects or manipulatives and use representations to draw conclusions, with no significant errors	Model problem situations with objects or manipulatives and use representations to draw conclusions, with a few significant errors	Model problem situations with objects or manipulatives and use representations to draw conclusions, with many significant errors

II. General Learner Outcomes*

A list of the Hawai‘i Department of Education's General Learner Outcomes (GLOs) follows. Each Unit of the Lessons from the Sea Curriculum addresses the GLOs. Within some lessons, there is more specific mention of individual GLOs with specific pertinence.

I. Self-directed Learner (The ability to be responsible for one's own learning.).
II. Community Contributor (The understanding that it is essential for human beings to work together.).
III. Complex Thinker (The ability to demonstrate critical thinking and problem solving.).
IV. Quality Producer (The ability to recognize and produce quality performance and quality products.).
V. Effective Communicator (The ability to communicate effectively.).
VI. Effective and Ethical User of Technology (The ability to use a variety of technologies effectively and ethically.).

** "Hawai'i Content & Performance Standards III Database." Hawai'i Department of Education. June 2007. Department of Education. 17 Dec. 2007.*

Science Background for the Teacher

Note: Bolded words within this section are defined in the Science Background for the Teacher Glossary. The footnotes refer to the references found in the Science Background for the Teacher Bibliography at the end of this section.

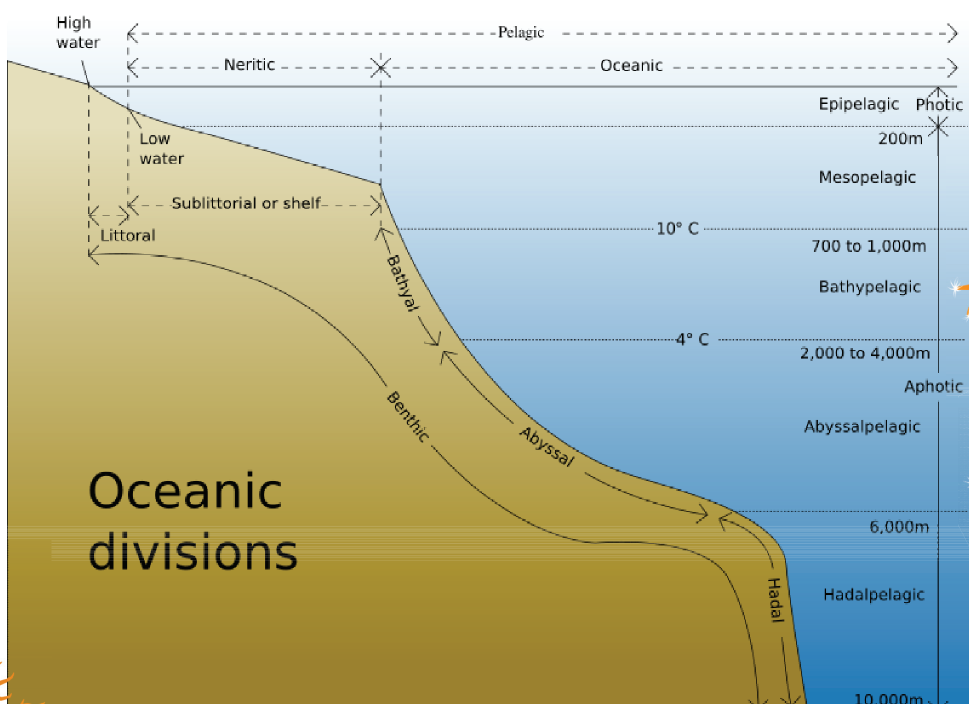
How can we describe the habitat of the open ocean (oceanic zone)?[1] (Lessons 1 and 4)

To discuss the habitat of the open ocean, we must first understand what this area is, and how we distinguish it from the coastal oceans. The land masses that make up the world's continents consist of more than what we can see on the surface. Each continent also has a **continental shelf**, which lies under the sea surface and gradually slopes down to the ocean's greater depths. The part of the ocean that overlaps this continental shelf is called the **neritic zone**, and is generally less than 200 m (650 ft.) deep.

Outside of the neritic zone lies the **oceanic zone**, or open ocean habitat, extending from the surface down to the deepest depths of the ocean. Oceans, in general, cover approximately 71% of the Earth's surface and 90% of the oceans' area is made up of oceanic zone habitat, with the other 10% being the neritic zone, or coastal oceans.

Another way of describing the ocean's habitat is to use divisions called the **benthic division** and the **pelagic division**. The benthic division simply refers to the ocean bottom, including all plants, animals, and structures (such as reefs) that live there. The pelagic division is the water above the sea floor and away from bottom-based structure.

Note the difference between these *divisions* and the *zones* described above. Since the benthic division consists of everything associated with the sea floor, it extends from the neritic zone throughout the entire oceanic zone. Likewise, the pelagic division represents everything in the water column and off the bottom, so it is not limited to the oceanic zone, but extends into the neritic zone and nearly all the way to shore. This lesson will, therefore, involve both benthic and pelagic divisions, but will focus only on the oceanic zone, not the neritic zone.



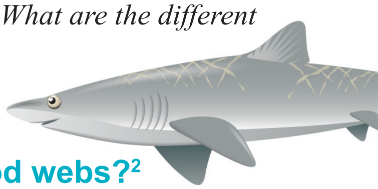
Subdivisions in the Oceanic Zones

The oceanic zone is subdivided into the **epipelagic**, **mesopelagic**, **bathypelagic**, and **abyssalpelagic zones**. Each of these zones is delineated by both depth and the relative penetration of sunlight through the water.

In the epipelagic zone, at ocean depths between 0–200 m (0–650 ft.), penetrating sunlight allows for relatively high photosynthetic activity of **phytoplankton** (generally, microscopic algae), providing energy and food sources for other organisms. This *lighted* region is, therefore, also referred to as the **photic zone**. Below the epipelagic zone (and photic zone), deeper water organisms must rely primarily on energy sources generated from the above photic zone. It is at this depth that begins the mesopelagic zone (200m- 700m), followed by the bathypelagic zone (700m-1,000m), and finally the abyssalpelagic zone (2,000m-4,000m). In these regions, little to no light penetrates and, therefore, all of these deeper and darker depths fall into the region known as the **aphotic zone**. For additional information concerning the aphotic zone, refer to http://oceanexplorer.noaa.gov/edu/curriculum/section5.pdf.

Imagining what it would be like to live in the open ocean is difficult, because the environment is so radically different than what we are used to on land. Organisms in the photic zone are able to differentiate between day and night and can see prey and predators once they are close enough, but the density of water and the presence of particulates (such as plankton) does not allow for long-distance vision like we are accustomed to on land. Without the presence of kelp, a reef, or even the seafloor (hundreds of meters deep), living in the open ocean would feel like swimming in a blue cloud, with no visual landmarks to get your bearings (unless you are at the surface). Pelagic organisms appear to take advantage of the few visual landmarks that are available. The most obvious example of this visual landmark phenomenon is the aggregation of fish around fish aggregation devices.

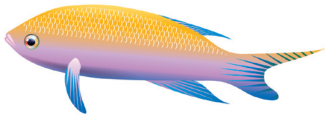
Animals living in the aphotic zone of the open ocean experience constant darkness, with no visible difference between day and night. A number of different organisms living at these depths exhibit bioluminescence of some kind, and swimming through the aphotic zone is probably like swimming through infinite blackness with occasional flashes of light and glowing organisms drifting past. This part of the ocean is also completely isolated from sea-surface disturbances like storms or waves, which makes it a very quiet and still environment as well. You can imagine how organisms in this habitat would need a variety of senses to survive, and many of these are discussed below (see Question 3, *What are the different organisms that live in the open ocean?*).



How do ocean currents near Hawai‘i impact open ocean food chains and food webs?[2]

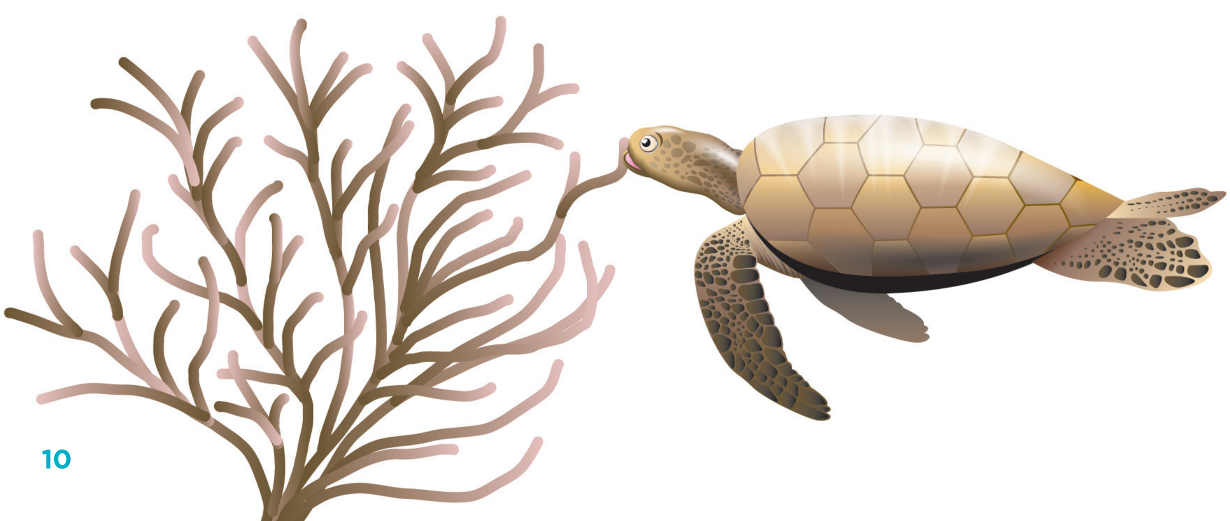
(Lessons 1 and 4)

Places like the Hawaiian archipelago are volcanic islands formed by lava flows that rose directly from the bottom of the sea. Although our islands are bordered by areas of shallow water, it is more appropriate to refer to these as *nearshore* waters here, rather than using the term *neritic*, which implies the presence of an underlying continental shelf, although some scientists still use *neritic*. Hawai‘i's nearshore, shallow (< 200 m) waters are much smaller in area than those found around continents, and the deeper waters of the oceanic zone are, therefore, much closer to us than most other parts of the terrestrial world. Because open ocean waters are closer to land, this makes Hawai‘i one of the best places in the world to utilize open ocean resources. Commercial and recreational fishing are the main beneficiaries of our oceanic environment, but whale-watching tours, blue-water diving, and sea-bird tours are also popular, in part, because of the deep waters surrounding the islands.



Currents also play an important role in Hawai‘i’s oceanic habitat. **Surface currents** are horizontally flowing masses of water (like rivers flowing through the ocean) that are usually caused by wind patterns. Global wind patterns form within latitudinal bands in both hemispheres, with a majority of the surface wind energy concentrated in easterly trade winds and westerly winds. As surface winds move over the water, some of the energy in the winds is transferred to the water through friction. The pull of the wind on the water creates a mass movement of water, forming a surface current. However, due to the **Coriolis effect**, surface currents do not flow in a straight line in the direction the winds are pulling them. Instead, they flow to the left or right (depending on hemisphere) of the prevailing wind direction at approximately 30–45°. In the Northern Hemisphere, surface currents flow to the right of the wind direction, and in the Southern Hemisphere, to the left of the wind direction. As the surface currents flow, they are blocked by continents and ocean basin **topography**, which deflects the surface currents into a circular pattern. The roughly circular flow around the periphery of an ocean basin is called a **gyre**. For additional information concerning the formation of currents and ocean gyres, refer to www.learningdemo.com/noaa/lesson08.html

Ocean currents play an important role in food chains of the open ocean. The open ocean is characterized by patchy distribution of biological resources that vary over time. Therefore, meals in the open ocean can be few and far between. However, reliable sources of abundant food can often be found in areas of **upwelling**. Upwelling generally occurs on the eastern side of ocean basins, along the west coasts of continents. In these areas, the prevailing winds blow parallel to the coast, causing surface currents in that area to flow towards the open ocean. As the surface water moves towards the open ocean, deep, nutrient-rich water flows up to replace the surface water. The influx of nutrient-rich water increases the abundance of phytoplankton which require nutrients to photosynthesize. Increased phytoplankton growth means more food for animals higher up in the food chain. Areas of upwelling support a large biomass of organisms and some of the most productive fisheries in the world. Upwelling can also occur in areas where currents meet underwater structures such as **seamounts** and **plateaus**. For example, Penguin Banks, a shallow plateau off the west coast of Moloka‘i, is a productive shallow marine benthic habitat for many species of pelagic and bottom fish. The upwelling that occurs here provides nutrients for plankton, which in turn provide the foundation for an entire food chain all the way up to some of Hawai`i’s largest fish predators. This has made Penguin Banks a popular location for commercial and recreational fishing, as well as for the local tiger shark population. During a tracking study on tiger sharks in the early 1990s, researchers found that six out of eight sharks that were tagged off the island of O‘ahu swam to Penguin Banks within the first 24 hours. This suggested that Penguin Banks was an important feeding ground for tiger sharks, and also showed that tiger sharks were not territorial animals that patrolled a single stretch of coastline, as many people had previously thought.
For additional information concerning upwelling and its ecological implications, refer to http://oceanexplorer.noaa.gov/explorations/02quest/background/upwelling/upwelling.html



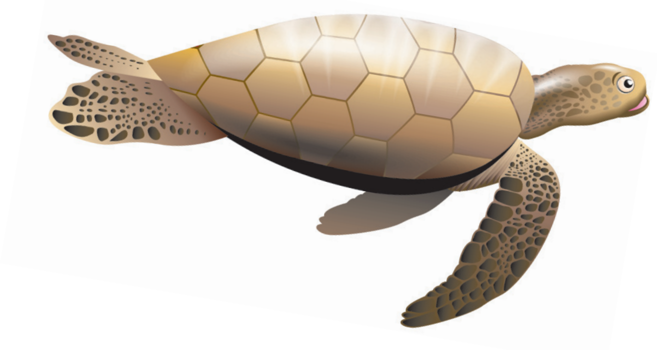
What types of organisms can be found in the open ocean? What types of features do they possess that help them survive in the open ocean?[3] (Lesson 3)

Plankton (fish eggs, larvae, microscopic crustaceans) are a diverse group of organisms at the base of the food chain in aquatic environments. Plankton are primarily found in the epipelagic or photic zone, the area in the open ocean from the surface down to 200 m (650 ft). The epipelagic zone of the open ocean lacks the typical primary producers found in coastal shallow water ecosystems; such as large seaweeds, seagrasses, and coral reefs, due to a lack of substrates on which to attach and grow. Although floating seaweeds are important in a few places, such as the Sargasso Sea, in most of the epipelagic zone, the only primary producers are the phytoplankton, or the photosynthetic plankton consisting primarily of single-celled algae and bacteria. Phytoplankton perform more than 95% of the photosynthesis in the ocean, producing nearly half the oxygen in our atmosphere. The most abundant phytoplankton are the photosynthetic picoplankton and nanoplankton (the prefixes pico and nano are used to categorize plankton by size, with pico the smallest, followed by nano, micro, meso, macro, and megaplankton), and they contribute 90% or more of the epipelagic's photosynthesis in many places. **Cyanobacteria** are the most abundant members of the picoplankton and contribute at least half of the ocean's total **primary production**. Larger phytoplankton, such as **diatoms** and **dinoflagellates**, are also important components of the phytoplankton. Diatoms are especially common in the nutrient-rich waters of the temperate and Polar Regions. In the tropics, dinoflagellates may replace diatoms as the most abundant members of the larger phytoplankton. When occurring in nutrient-rich waters, dinoflagellates are known to bloom or grow explosively into huge numbers, sometimes called **red tides**, wherein the sea appears red due to red pigment in the algae's tissues. For more information on phytoplankton, see http://seagrant.gso.uri.edu/factsheets/phytoplankton.html.

Many familiar fishes are also found in the open ocean, including groups such as jacks (*ulua*), dolphinfish (*mahimahi*), opah, tunas and skipjacks (*'ahi* and *aku*), flying fishes, mackerels (*'opelu*), marlin, sailfish, swordfishes, billfishes (*a'u*), and others. Sharks (*mano*) and manta rays (*hahalua*) are also found in these regions. The epipelagic zone is, by far, the most important in terms of fisheries and human consumption, comprising approximately half of the 70–80 million tons of fish captured worldwide annually. Generally, fishes in this region have evolved similar features of open ocean swimmers, including characteristics, such as silvery coloring, counter-shading, and body streamlining (see question below). Many fish occurring in the epipelagic zone are also schooling, migratory, and endothermic (able to internally maintain body temperature).

Mesopelagic zone communities are typified by fish groups, such as lanternfishes, hatchetfishes, and lightfishes, and invertebrates, such as shrimp and squids. Many of these deeper water organisms tend to feed on the small animals found in the plankton, as well as food matter falling from the photic zone above. Mesopelagic zone fish (generally laternfish) tend to be small and silvery in color and commonly migrate upward during nighttime hours for feeding, and then back down to greater depths during daytime hours.

In the deeper bathypelagic and benthopelagic zones (just above the bottom, or **benthic division**), less commonly known organisms are found, including anglerfishes, rattails, seadevils, and brotulas. Because the conditions of the environment in the mesopelagic, bathypelagic, and benthopelagic zones (low levels of light and low abundance of prey compared to that of the nearshore or epipelagic habitats), many organisms in this region have evolved features such as light emitting



bioluminescent organs (hence descriptive names like lanternfish and lightfish), large dagger-like teeth (e.g., viperfishes), and modified dorsal fins or other appendages that act as *lures* for attracting prey (e.g., anglerfishes, hatchetfishes). Very large eyes and/or stalked eyes have evolved for detecting low levels of light (usually in the mesopelagic zone), and the total absence of eyes has evolved in many organisms in the deepest depths (usually the bathypelagic and benthopelagic zones) where complete darkness provides no selective advantage for sight.

In addition to adaptating to the scarcity of light, animals of the deeper waters have evolved to cope with the increased pressure from the weight of the water column. Particularly in the bathypelagic and benthopelagic zones, **evolution** has resulted in the loss of the gas bladder, which functions to control buoyancy in shallow water fishes. The mesopelagic zone laternfish; however, maintain their gas bladders, which function in their nightly vertical migration behavior.

Organisms of the bathypelagic zone have given way to some of the most bizarre sexual dimorphisms known in order to surmount difficulties in finding mates in very dark and vast habitats. Male anglerfishes can be extremely tiny, with females up to 10 times greater in size. Once a male and female encounter each other, the male attaches himself to the body of the female and, in essence, becomes parasitic and totally dependent on her for nutrition. For a short descriptive video of adaptations of deep water organisms, go to http://www.pbs.org/wgbh/nova/abyss/life/bestiary.html and http://www.learningdemo.com/noaa/ (Select Lesson 6 – Deep Sea Benthos.).

How are sharks different from bony fish? Which sharks are considered the top predators of the open ocean, and why?[4] (Lesson 2)

Sharks are fish, but they are very different from most of the other ocean animals. When we think about a typical fish, we usually think of fish like tunas, jacks, or reef fishes like parrotfish, surgeonfish, and goatfish. These fishes have bony skeletons and a single gill opening on each side of their heads, and are collectively known as **teleosts**, or *bony fishes*. Sharks (and their very close relatives – the stingrays) are called **elasmobranchs**, and differ from teleosts in that they have a cartilaginous skeleton (generally softer and more flexible than bone), and have multiple gill openings (5–7) on each side of the head.

Sharks are often considered large, **apex predators** at the top of the food chain. However, there are more than 400 species of sharks, many of which are small, harmless, and nowhere near the top of the food chain. Some sharks that are considered apex predators of the open ocean include great white sharks, mako sharks, oceanic whitetip sharks, and others. However, even these species can be preyed upon when they are young, and may occasionally be killed and/or eaten by orcas (killer whales) and larger individuals of their own species.

Tiger sharks are the most well-known apex predator in Hawaiian waters, but are generally not considered to be an *oceanic* species because they are usually not found in the open ocean environment. However, several tagging and tracking studies have shown that tiger sharks will readily swim across large stretches of open water, and frequently swim between islands within the Hawaiian archipelago. There is also some evidence that tiger sharks may occasionally cross ocean basins, but they spend most of their time closer to coastal areas. People used to think that tiger sharks were highly territorial and commonly patrolled a single stretch of coastline for long periods. However, that myth has been dispelled by various tracking studies (see Question 2, *Which sharks are considered the top predators of the open ocean, and why?* above for additional information). Tiger sharks are at the top of the food chain throughout Hawaiian coastal waters, but probably have less of an impact on prey species in the open ocean environment.

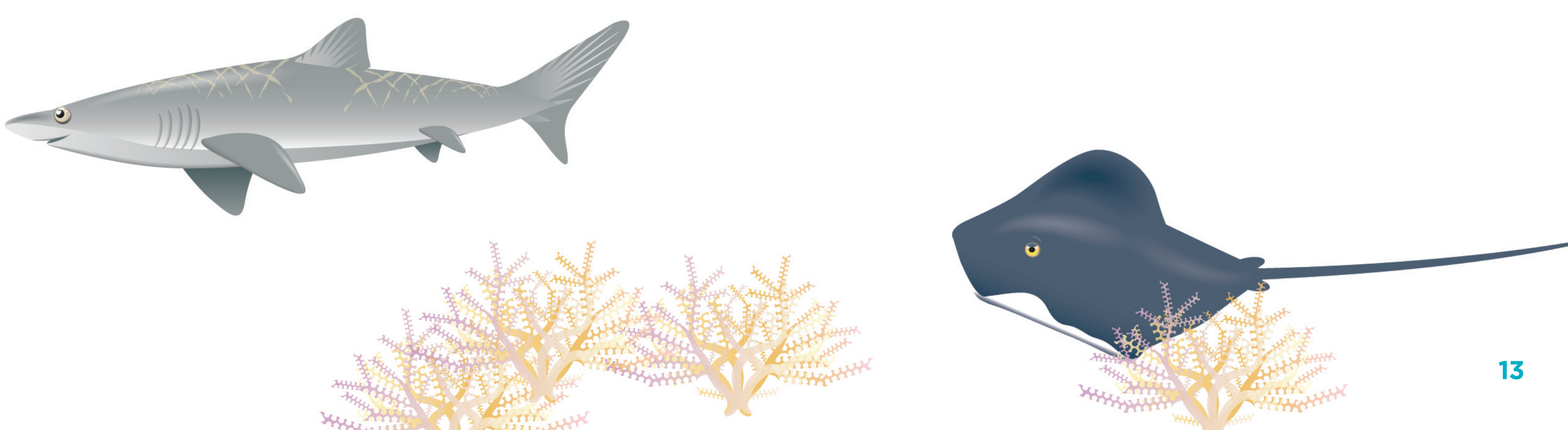
Although great white sharks are extremely large and responsible for more attacks on humans than any other species, oceanic whitetips may be equally aggressive. This disparity may be related to the prey density of the open ocean habitat versus prey density in coastal habitats. For instance, great white sharks often aggregate around coastal areas of high prey density – such as seal or sea lion colonies along the Western U.S. or South Africa. Oceanic whitetips, however, are found only in the oceanic zone where prey can sometimes be very scarce and hard to find. Some researchers think that oceanic whitetips may have to be aggressive to catch enough prey to survive.

Apex predators may sometimes be important in maintaining the balance of their entire ecosystem, but this is not always the case. Sharks are often presented as being crucial to the natural balance of the oceans, but so far, there is little scientific evidence supporting this belief and the overall effect is probably overstated. Sharks are long-lived, slow-growing, and produce relatively few offspring compared to most species. This makes sharks extremely vulnerable to fishing pressure, because once the adults of a population have been killed, it can take decades for younger animals to reach an age at which they can reproduce. But, these life history characteristics also coincide with relatively low metabolic rates of sharks, compared with many bony fishes, especially oceanic fishes like tunas, mahimahi, and billfishes. This slow metabolism means that sharks can probably go long periods without feeding and likely consume less prey per pound than bony fishes in the open ocean. Therefore, bony fishes may actually have a larger effect on the rest of the ecosystem than sharks.

How does matter cycle and energy flow in an open ocean ecosystem?[5] (Lessons 2 and 4)

Energy in the form of sunlight supports almost all life on Earth through **photosynthesis**, a process that uses the sun's energy to convert water and nutrients into organic matter, or food. Organisms, such as micro- (phytoplankton) and macro- (seaweeds) algae, green plants, and photosynthetic blue-green or purple bacteria are considered **autotrophs,** because they create their own food resource through photosynthesis. In the open ocean, light only penetrates to approximately 200 m (650 ft.). It is in this zone, known as the photic zone, where photosynthesis occurs.

Photosynthetic organisms form the base of the food chain in ecosystems, where sunlight is the primary energy source. When autotrophs produce more organic matter than is used in respiration, there is a net increase in the biomass of organic matter called primary production. The extra organic matter is used by these organisms to grow and reproduce, creating more food for the heterotrophs. Because autotrophs produce food for other animals, they are often called **primary producers**. Oxygen is also produced by photosynthetic organisms through photosynthesis. All of the oxygen on Earth, both in air and in the oceans, is produced by photosynthetic organisms, and is constantly replenished by these organisms. Therefore, photosynthetic organisms, through photosynthesis, produce not only food for other organisms, but also the oxygen that organisms need to live. For additional information concerning photosynthesis, refer to http://photoscience.la.asu.edu/photosyn/education/photointro.html or http://www.pbs.org/wgbh/nova/methuselah/photosynthesis.html.



The organic matter produced by phytoplankton through photosynthesis is passed up the food chain in the epipelagic zone in the open ocean when **heterotrophic**, **herbivorous zooplankton** eat the phytoplankton. Because phytoplankton are too small for large animals to feed on, herbivorous zooplankton provide the link between the primary producers and the rest of the epipelagic community. The herbivores are consumed by carnivores, which are then fed upon by successively larger animals. As such, the energy captured by the primary producers is passed up the food web. **Protozoan** zooplankton are particularly important, because they can catch the tiny pico- and nano-plankton, which are too small for most larger multicellular organisms to catch and eat. Without protozoans, much of the primary production in the epipelagic zone would go unutilized. Copepods, which are small crustaceans, are the most abundant of the zooplankton, typically accounting for more than 70% of zooplankton consumption. Most copepods are **omnivorous**, consuming both phytoplankton and zooplankton. Other crustaceans, for example krill, are also important members of the plankton. Krill are commonly found in colder water, especially in the Polar Regions. Due to their large size (up to 6 cm or 2.36 in.), krill are an important prey resource for many fishes, seabirds, and large filter-feeding whales.

Many zooplankton spend their entire lives in the plankton, and are called **holoplankton**. In contrast, **meroplankton** comprise the larval stages of many fish and invertebrate species, spending only the early stages of their life history in the plankton. For additional information concerning zooplankton, refer to http://seagrant.gso.uri.edu/factsheets/zooplankton.html.

The flow of energy through an ecosystem is almost always more complex and indirect than can be shown in a simple food chain. Energy can spread through multiple levels of a food chain, or skip several levels all at once. An individual krill may be eaten by an *opelu*, which is eaten by a *mahimahi*, which is eaten by a blue shark, which is eaten by a great white shark; or that krill may be eaten by a humpback whale and removed from the food chain in an instant. Still, food chains are easy to visualize and understand, and are an effective illustrative tool as long as one realizes that food chains are simple examples of complex patterns.

Three examples of food chains are listed in the table below, with the category or *level* of the food chain provided in the far left-hand column. Note that not all levels are represented in each chain, and that energy in the food chain flows from the bottom (sunlight) to the top.

<table>
<tr><th>Level</th><th>Food Chain 1</th><th>Food Chain 2</th><th>Food Chain 3</th></tr>
<tr><td>Apex Level Predator</td><td>Oceanic whitetip shark</td><td>great white shark</td><td>orca
(killer whale)</td></tr>
<tr><td>Large Fish/Mammal/ Shark Carnivore</td><td>yellowfin tuna (ahi)</td><td>blue shark</td><td rowspan="3">humpback whale

Note: Humpbacks eat krill. No Fish Level in this chain.</td></tr>
<tr><td>Fish Carnivore</td><td>mackerel</td><td>dolphinfish (mahimahi)</td></tr>
<tr><td>Fish Carnivore</td><td>sardine</td><td>opelu</td></tr>
</table>

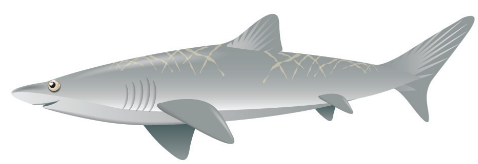
Herbivorous Zooplankton	copepods	protozoans	krill
Primary Producers/ Autotrophs/ Phytoplankton	diatoms	blue-green bacteria	macro-algae
Sun	sunlight	sunlight	sunlight

Science Background for the Teacher Glossary

apex predator: a predator at the top of the food chain that, as an adult, is not preyed upon by any other predator.
aphotic zone: the deeper regions of the water environment in which no light penetrates; generally, the bathypelagic and benthopelagic zones.
autotroph: an organism capable of synthesizing its own food from (sun) energy and inorganic substances.
bathypelagic zone: below the mesopelagic zone; generally 1,000–4,000 meters (3,280-13,123 ft.) in depth, low to no light penetration; together with the benthopelagic zone falls into the aphotic or *midnight* zone.
benthopelagic zone: below the bathypelagic zone; generally 4,000–6,000 meters (13,123-19,685 ft.) in depth, no light penetration, and falls into the aphotic or *midnight* zone; sometimes referred to as the *abyssal* zone.
benthic zone: the bottom or lowest level of a body of water, including the sand, mud, silt, and organisms that live there; also benthic community.
bioluminescence: the production of light by a living organism, usually through a symbiotic association with light producing bacteria.
continental shelf: the shallow, gradually sloping seabed around a continental margin, not usually deeper than 200 meters (650 feet).
Coriolis effect: the apparent deflection of a moving object from its initial course when its speed and direction are measured in reference to the surface of the rotating Earth.
cyanobacteria: a group of generally photosynthetic bacteria, also referred to as blue-green algae.
diatoms: unicellular algae with hard silica present in their cell walls.
dinoflagellates: unicellular protists characterized by two flagella of unequal sizes.
elasmobranches: vertebrates that have skeletons made of cartilage and 5–7 gill openings on each side of the head; includes all sharks and rays; distinct from the teleosts or *bony fishes.*
epipelagic zone: the lighted, open ocean layer from the surface to approximately 200 meters (650 feet) deep.
evolution: the process through which a population of organisms accumulates genetic changes over generations that can lead to adaptations to environmental conditions.
FAD: Fish Aggregation Device; any structure in the open ocean that aggregates fish and other marine organisms; may consist of natural debris or a man-made structure.
gyre: a circular flow of mid-latitude ocean currents around the periphery of an ocean basin.
herbivores: animals that eat only plants.
heterotrophic: organisms that obtain nourishment from the ingestion and breakdown of organic matter such as plants and animals.
holoplankton: organisms that are planktonic for their entire life cycle.
meroplankton: temporary zooplankton, such as the larval stages of some organisms (e.g., fishes and crabs).
mesopelagic zone: below the epipelagic zone; generally 200–1,000 meters (650-3,280 ft.) in depth, with low light penetration; commonly referred to as the *twilight zone.*
neritic zone: the water that overlies the continental shelves. Generally, less than 200 m (650 ft.) deep.

oceanic zone: the open ocean, away from the influence of land, generally beginning at the outer edge of the continental shelf.
omnivorous: heterotrophs that feed on both plants and animals.
pelagic division: consists of the water above the sea floor and its organisms.
photic zone: the surface zone of the sea having sufficient light penetration for photosynthesis.
photosynthesis: the process by which plants convert water and carbon dioxide into carbohydrates, using sunlight as the source of energy.
phytoplankton: the type of plankton, consisting of microscopic photosynthetic algae and bacteria.
plankton: a diverse group of minute animals (zooplankton) and plants (phytoplankton) that freely drift in the water.
plateau: a large region that is higher than the surrounding area and relatively flat.
primary consumer: this is an organism which is found near the very bottom of the food pyramid, which consumes plant material.
primary producers: plants, algae and bacteria that are able to manufacture food from simple inorganic substances; form the base of the food chain.
primary production: the biomass produced through photosynthesis and/or chemosynthesis in a community or group of communities.
protozoans: single-celled organisms that are animal-like in that they ingest food and usually move around.
red tides: phenomenon associated with population explosions (blooms) of certain types of dinoflagellates; red pigments inside the dinoflagellates cause the water to have a red to brown color.
seamounts: isolated, extinct volcanic peak that rises at least 1000 m (3,280 ft.) from the sea floor.
secondary consumer: an organism that feeds on primary consumers; a carnivore.
surface current: a mass of moving water, like a river flowing through the ocean, usually due to winds blowing over the surface of the water.
teleosts: *bony fishes,* such as *ahi, mahimahi*, jacks, and reef fishes that have a bony skeleton and a single gill opening on each side of the head.
tertiary consumer: high-level consumer, which is usually the top predator in an ecosystem and/or food chain.
topography: the shapes, patterns, and physical configuration of the surface of the land or ocean floor, including its relief (local differences in elevation) and the positions of natural and man-made features.
upwelling: the movement of nutrient rich waters from the bottom of the ocean to the surface.
zooplankton: the heterotrophic animal and protozoan plankton.

Science Background for the Teacher- Bibliography



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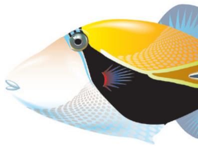

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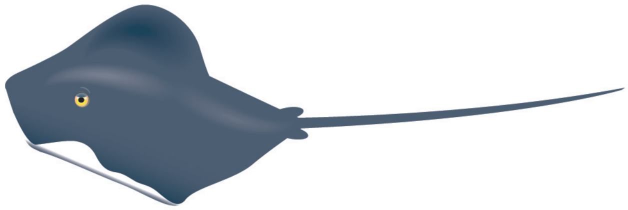
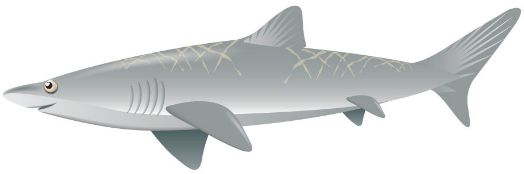
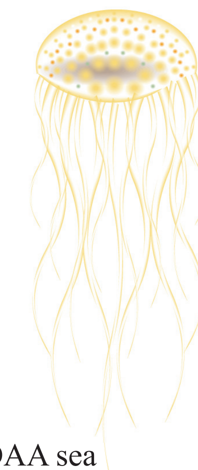




NOAA Resources

Below is a list of resources compiled by the Outreach Education Office of the National Oceanic and Atmospheric Administration. The science standards and the ocean literacy principles addressed in this unit were used as a guideline in selecting the following resources. To access the print resources listed below, contact NOAA's Outreach Education Office directly:

Outreach Unit
NOAA Office of Public and Constituent Affairs
1305 East West Highway #1W514
Silver Spring, MD 20910
Phone: (301) 713-1208
Email: NOAA-OUTREACH@noaa.gov
http://www.education.noaa.gov/



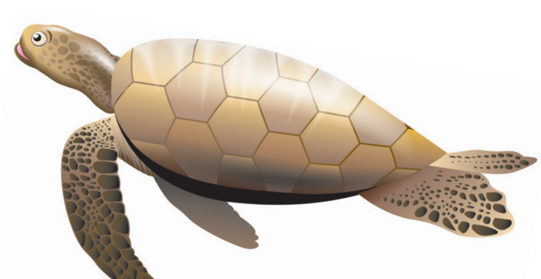
Resources:

- Gray's Reef sea turtle tracking
  http://graysreef.noaa.gov/turtletag.html

- Animals in Curriculum Education aka ACES developed by U.S Satellite Laboratories brings Black-Footed Albatross tracking and other related data into the classroom. It also includes NOAA sea surface temperature data and tracking an Albatross lesson plan (uses Geography, Biology, Investigation and Experimentation, Data Analysis skills) found at http://signalsofspring.net/aces/

- NOAA Coral Reef Watch Grades 4–6 student curriculum found at
  http://coralreefwatch.noaa.gov/satellite/education/reef_remote_sensing.html,
  which incorporates satellite data and remote sensing. Lesson 3 focuses on phytoplankton.

- For more activities that may enhance this unit review the activities on this document:
  http://www.coralreef.noaa.gov/outreach/resourcecd08/resources/activities/elementary_sa.pdf

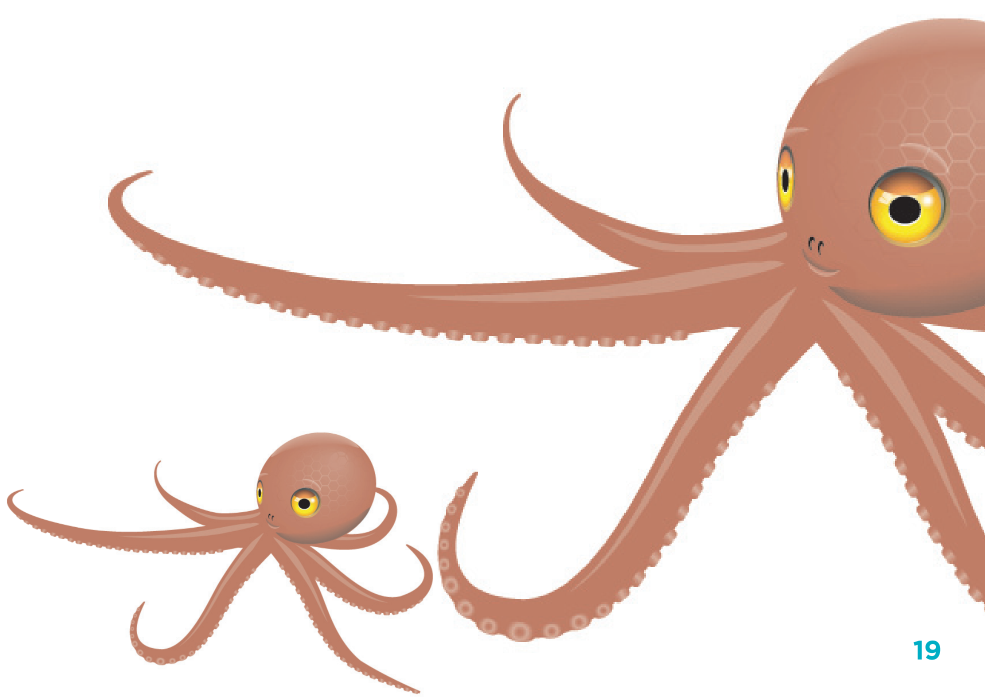


OCEAN LITERACY ESSENTIAL PRINCIPLES

1. The Earth has one big ocean with many features.
   - 1a. The ocean is the dominant physical feature on our planet Earth- covering approximately 70% of the planet's surface. There is one ocean with many ocean basins, such as the North Pacific, South Pacific, North Atlantic, South Atlantic, Indian and Arctic.

5. The ocean supports a great diversity of life and ecosystems.
   - 5a. Ocean life ranges in size from the smallest virus to the largest animal that has lived on Earth, the blue whale.
   - 5b. Most life in the ocean exists as microbes. Microbes are the most important primary producers in the ocean. Not only are they the most abundant life form in the ocean, they have extremely fast growth rates and life cycles.
   - 5d. Ocean biology provides many unique examples of life cycles, adaptations and important relationships among organisms (symbiosis, predator-prey dynamics and energy transfer) that do not occur on land.
   - 5e. The ocean is three-dimensional, offering vast living space and diverse habitats from the surface through the water column to the seafloor. Most of the living space on Earth is in the ocean.
   - 5f. Ocean habitats are defined by environmental factors. Due to interactions of abiotic factors, such as salinity, temperature, oxygen, pH, light, nutrients, pressure, substrate and circulation, ocean life is not evenly distributed temporally or spatially, i.e., it is "patchy." Some regions of the ocean support more diverse and abundant life than anywhere on Earth, while much of the ocean is considered a desert.
   - 5g. There are deep ocean ecosystems that are independent of energy from sunlight and photosynthetic organisms. Hydrothermal vents, submarine hot springs, methane cold seeps and whale falls rely only on chemical energy and chemosynthetic organisms to support life.
   - 5h. Tides, waves and predation cause vertical zonation patterns along the shore, influencing the distribution and diversity of organisms.

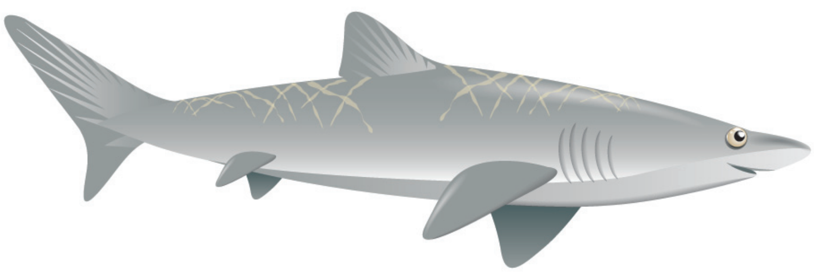
Lesson 1: 1a. 5e.
Lesson 2: 1a. 5a. 5d. 5e. 5h.
Lesson 3: 1a. 5a. 5d. 5e.
Lesson 4: 1a. 5a. 5b. 5d. 5e. 5f. 5h.
Lesson 5: 5a. 5b. 5d. 5e. 5f. 5g.
Culminating: 5a. 5b. 5d. 5e. 5f. 5g.

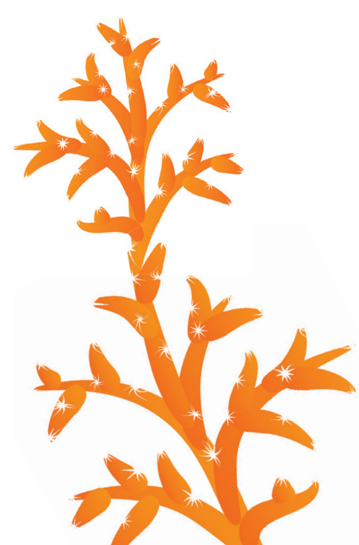


CLIMATE LITERACY ESSENTIAL PRINCIPLES

3. Life on Earth depends on, is shaped by, and affects climate.
   - 3a. Individual organisms survive within specific ranges of temperature, precipitation, humidity, and sunlight. Organisms exposed to climate conditions outside their normal range must adapt or migrate, or they will perish.
   - 3e. Life-including microbes, plants, and animals and humans—is a major driver of the global carbon cycle and can influence global climate by modifying the chemical makeup of the atmosphere. The geologic record shows that life has significantly altered the atmosphere during Earth's history.

Lesson 1: 3a.
Lesson 5: 3e.
Culminating: 3a. 3e.





NOAA Marine Science Career - Case Studies

Jeff Drazen - PhD

Associate Professor
University of Hawaii - Department of Oceanography

Our friend, Dr. Jeff Drazen, is an Associate Professor at the University of Hawai'i and he leads the Deep-Sea Fish Ecology Lab. In their lab, Jeff studies how deep sea fish find food and survive. This research is important, because there is relatively little information about deep-sea species.

Jeff's interest in marine life began at the age of three in the Pacific Northwest. His grandparents used to take him to the beach to explore tidepools and go fishing. When Jeff was very young, he decided he was going to be a marine biologist. Jeff went to college at the University of San Diego and received a degree in biology and marine science. During college, Jeff had professors who taught marine science and brought in a five-gallon bucket with vent worms, which are three-foot long animals that live thousands of feet deep in the ocean. Jeff was fascinated with this unexplored ecosystem and, following graduation, he went to Scripps Institution of Oceanography. While Jeff was at Scripps, he worked with a deep-sea ecologist, who studied the abyssal plain, which is a flat muddy sea plain ranging in depths from 3,000 to 5,000 meters. Jeff earned a doctorate degree, as a deep-sea ecologist, so now he gets to research the creatures that live on our ocean floor.

Jeff shared with us the coolest thing he had ever seen during one of his expeditions under the sea. Jeff's story began on a submarine that dove 1,000 meters deep (3,000 feet) on the north side of Molokai. He told us, "The submarine we were in could only fit three people and was only a little bigger than a minivan. For this study, we were interested in scavengers on the seafloor. Bait was placed in front of the submarine and the lights were turned off so that we would not scare away the scavengers we were trying to attract. While we were sitting there, the whole submarine moved! I asked the submarine pilot if we had floated off the seafloor. He told me we hadn't; the instruments still told us that we were on the seafloor. We decided to turn the light on for a quick second. When we did, we saw a 16-foot long 6-gill shark! The shark was searching for the fish the submarine was using as bait. The cool part of this is that scientists have known that they live offshore, but didn't know how common or abundant they are. During the rest of the dives off Molokai, we kept seeing more 6-gill sharks ranging from 10-16 feet long. "

There are new discoveries, like their experiences with the 6-gilled sharks, quite often. So, Dr. Jeff Drazen spends a lot of his time reading to learn about what other scientists are learning and discovering. Jeff's research is helping people all over the world understand what lives deep beneath the surface of our ocean.

His advice to budding scientists is to read and learn about the animals, get a guide book and go to the beach, go fishing, or even go to museums and aquariums. Places like the Waikiki Aquarium and the Bishop Museum can have great sources of information, activities and people who can teach you.

Watch their video of the 6-gilled shark on You-tube at: http://www.youtube.com/watch?v=pHuvs9Qqa5o.

Glossary of Cooperative Learning Techniques

In an effort to maximize student engagement and learning, the NOAA Sea Earth and Atmosphere curricular resources were designed using cooperative learning techniques. This guide defines the expectations for implementation of each technique.

What is Cooperative Learning?

Cooperative learning may be broadly defined as any classroom learning situation in which students of all levels of performance work together in structured groups toward a shared or common goal. According to Johnson, Johnson and Holubc, (1994): "Cooperative learning is the instructional use of small groups through which students work together to maximize their own and each other's learning." In classrooms where collaboration is practiced, students pursue learning in groups of varying size: negotiating, initiating, planning and evaluating together. Rather than working as individuals in competition with every other individual in the classroom, students are given the responsibility of creating a learning community where all students participate in significant and meaningful ways. Cooperative learning requires that students work together to achieve goals which they could not achieve individually.

Jigsaw

To Jigsaw materials refers to the use of a strategy in which each student on a team receives only a piece of the material that is to be learned in which that student becomes the "expert." Once the material is learned each member of the team takes a turn teaching the other members their assigned content. This type of dynamic makes the students rely on the other members of their team to learn all of the material.

Think-Pair-Share

This four-step discussion strategy incorporates wait time and aspects of cooperative learning. Students (and teachers) learn to LISTEN while a question is posed, THINK (without raising hands) of a response, PAIR with a neighbor to discuss responses, and SHARE their responses with the whole class. Time limits and transition cues help the discussion move smoothly. Students are able to rehearse responses mentally and verbally, and all students have an opportunity to talk.

Numbered Heads

This structure is useful for quickly reviewing objective material in a fun way. The students in each team are numbered (each team might have 4 students numbered 1, 2, 3, 4). Students coach each other on material to be mastered. Teachers pose a question and call a number. Only the students with that number are eligible to answer and earn points for their team, building both individual accountability and positive interdependence.

KWL Chart

A pre-assessment tool consisting of three vertical columns. Students list what they "**K**now" about a topic. What they "**W**ant" to know about a topic. The last column students share what they have "**L**earned" about a topic.

KWL CHART

Be sure to bullet your list.

Use content words only (nouns, verbs, names of people and places, dates, numbers, etc.).

WHAT DO I KNOW?	WHAT DO I WANT TO KNOW? *or* WHAT DO I WANT TO SOLVE?	WHAT HAVE I LEARNED?
•		•

Role Cards

Assign students to cooperative learning groups. Once students are in their groups the teacher will hand out premade role cards that will help each member of the group contribute to the completion of the given task. Before roles are assigned, the teacher should explain and model the task as well as the individual roles for students so that they know and understand how his/her individual role will contribute to the success of the group completing the task. When this technique is used, taking on a different role will aid in student proficiency.

Example of role cards:

Role Card #1

Facilitator:

Makes certain that everyone contributes and keeps the group on task.

Role Card #2

Recorder:

Keeps notes on important thoughts expressed in the group. Writes final summary.

Role Card #3

Reporter:

Shares summary of group with large group. Speaks for the group, not just a personal view.

Role Card #4

Materials Manager:

Picks up, distributes, collects, turns in, or puts away materials. Manages materials in the group during work.

Role Card #5

Time Keeper:

Keeps track of time and reminds groups how much time is left.

Role Card #6

Checker:

Checks for accuracy and clarity of thinking during discussions. May also check written work and keeps track of group point scores.

Round Table

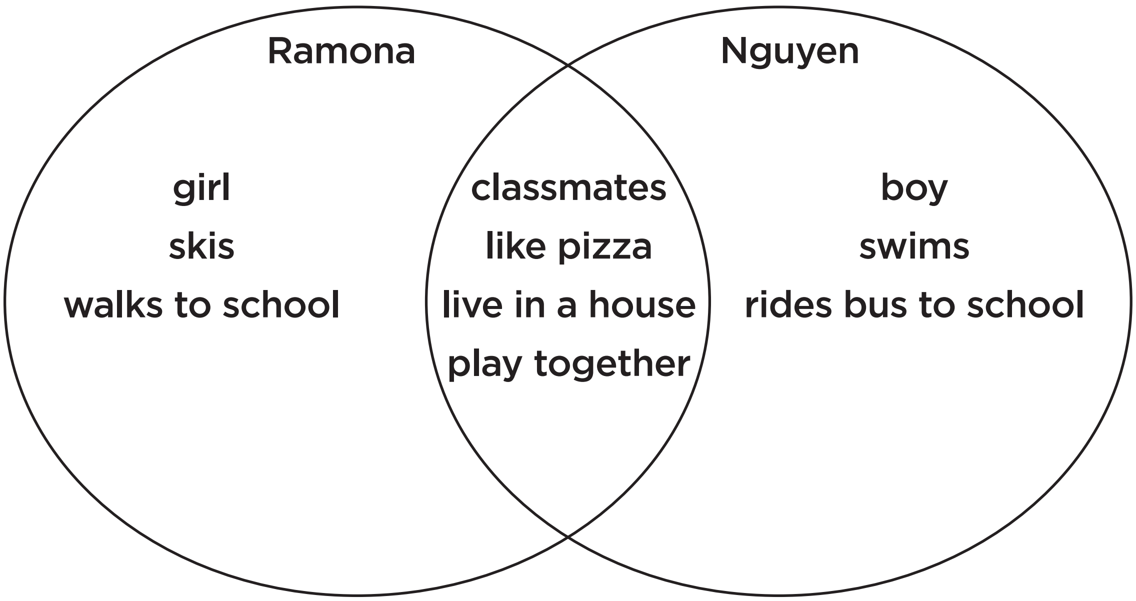
Round table can be used for brainstorming, reviewing, or practicing while also serving as a team builder. Students sit in teams of 3 or more, with one piece of paper and one pencil. The teacher asks a question which has multiple answers. Students take turns writing one answer on the paper, then passing the paper and pencil clockwise to the next person. When time is called, teams with the most correct answers are recognized. Teams reflect on their strategies and consider ways they could improve.

Three-Step Interview

This involves structured group activity with students. Using interviews/listening techniques that have been modeled; one student interviews another about an announced topic. Once time is up, students switch roles as interviewer and interviewee. Pairs then join to form groups of four. Students take turns introducing their pair partners and sharing what the pair partners had to say. This structure can be used as a team builder, and also for opinion questions, predicting, evaluation, sharing book reports, etc.

Venn Diagram

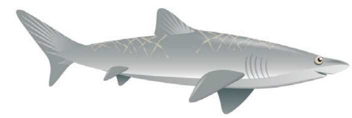
A diagram using circles to represent sets, with the position and overlap of the circles comparing and contrasting the relationships between two given pieces of information.



References and Credits

Hawaiian Names for Fishes (NOAA):
www.st.nmfs.noaa.gov/st1/recreational/documents/local%20fish%20names/local%20names%20hawaii.txt

DLNR Div Aquatic Resources:
http://client.nextlevelsw.com/dar/education.cfm?showSection



A long list of books about sharks can be obtained at
http://hawaii.gov/dlnr/dar/sharks/otherrefs.html

Photos and illustrations of plankton can be seen at
http://usasearch.gov/search?v%3aproject=firstgov-noaa-images&v%3afile=viv_924%4028%3aOQS6xK&v:state=root%7Croot-0-20%7C0