

Student Workbook

California Education and the Environment Initiative

E

Earth Science
Standard
E.5.d.



Ocean Currents and Natural Systems

California Education and the Environment Initiative

Approved by the California State Board of Education, 2010

The Education and the Environment Curriculum is a cooperative endeavor of the following entities:

California Environmental Protection Agency
California Natural Resources Agency
Office of the Secretary of Education
California State Board of Education
California Department of Education
California Integrated Waste Management Board

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Key Partners:

Special thanks to **Heal the Bay**, sponsor of the EEI law, for their partnership and participation in reviewing portions of the EEI curriculum.

Valuable assistance with maps, photos, videos and design was provided by the **National Geographic Society** under a contract with the State of California.

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Key Unit Vocabulary

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Alginate: A carbohydrate found in certain brown algae, such as kelp, that is used commercially as a stabilizer for many products including ice cream.

Biomass: The total mass of living matter in a given area; or, plant material (wood, grains, agricultural waste, vegetation) sometimes used as an energy source.

Breakwater: A structure built by humans to protect a bay or harbor from wave action.

California Current: A cold, slow current that flows southward from Alaska along the California coast to northern Baja California.

California Department of Fish and Game: The agency responsible for the management of California's diverse natural resources and natural communities, as well as the diversified use of fish and wildlife for recreation, commerce, science, and education.

Cyclic temperature fluctuation: Long-term patterns of temperature change that are repeated.

Distribution: The geographic area inhabited by a species.

Dredging: The use of heavy equipment and machinery to remove sediments from one location and transport them to another.

Filter feeder: An organism that feeds on particles of suspended matter by straining them from water.

Fishery: An ocean region where humans harvest or raise marine animals, such as fish and invertebrates. It is also used to refer to the processes of harvesting and raising marine animals.

Gyre: A global circular motion of ocean currents that flow clockwise in the Northern Hemisphere and counterclockwise in the Southern Hemisphere.

Habitat destruction: Damaging a habitat by removing plants, disturbing the soil, or substantially changing other parts of the natural system.

Jetty: A coastal structure that runs perpendicular to the shoreline, built by humans to influence currents, and protect harbors and coastal areas.

Kelp: Large brown algae that grow primarily in shallow ocean water in temperate and arctic regions.

Latitude: An angular measurement of the distance north or south from the Equator.

Longshore current: A current that runs parallel to the shore and carries sediments along the coastline.

Natural system: The interacting components, processes, and cycles within an environment, as well as the interactions among organisms and their environment.

Overfishing: Harvesting a fish species faster than its population is replenished by reproduction.

Pacific sardine (*Sardinops sagax*): A species of fish found in coastal areas of the eastern Pacific Ocean that filter feeds on phytoplankton and small zooplankton.

Phytoplankton: Plankton, such as diatoms and dinoflagellates, that are capable of producing food energy through photosynthesis.

Plankton: Any organism in fresh or sea water that passively drifts with currents. Plankton range in size from microscopic bacteria to large jellies.

Key Unit Vocabulary

Lesson 1 | page 2 of 2

Population: The number of individuals of one or more species living in a place at a given time.

Primary productivity: The conversion of solar energy to organic material that is synthesized through photosynthesis and chemosynthesis and is available to organisms in an ecosystem.

Resource management: The management or restoration of natural resources, such as ecosystems, to maintain or improve the condition of the natural system or a particular resource.

Salinity: The total amount of salts dissolved in water; sea water averages 35 parts per thousand.

Scientific research: Investigations conducted according to the principles and methods of science, including the empirical testing of hypotheses.

Seasonal thermocline: The seasonal change in water temperature caused by increased solar radiation in the spring and summer, that results in the presence of a thermocline.

Sustainable population: A population of organisms that is large enough to maintain itself for a long time.

Thermocline: A vertical gradient in the ocean or a lake characterized by a rapid change of temperature with depth.

Upwelling: The wind-driven movement of cold, usually nutrient-rich water from ocean depths to the surface.

Variable: A factor or function that changes in response to varying conditions or over time.

Vertical current: The movement of water from deeper depths to the surface, as in upwelling or convection.

Vertical layering: The layers of water in a lake or the ocean that result from differences in temperature and density.

Zooplankton: Animals, such as copepods, jellies, and fish larvae, that are part of the plankton that drift with currents.

California Sardine Industry Timeline

Lesson 1 | page 1 of 2

Name: _____

Instructions: Complete the timeline of events in the history of the sardine industry based on your reading of *California Connections: Packed Like a Can of Sardines* (Student Edition, pages 2–5). Use the **California Sardine Industry Timeline Scoring Tool** on the next page to guide your responses.

The diagram is a timeline structure. It features a central vertical line. Six horizontal lines branch out from this central line, three to the left and three to the right. Each of these six horizontal lines is connected to a large, empty rectangular box. The boxes are arranged in a vertical column on each side, corresponding to the horizontal branches. The boxes are intended for students to write historical events related to the sardine industry.

California Sardine Industry Timeline

Lesson 1 | page 2 of 2

Name: _____

California Sardine Industry Timeline Scoring Tool

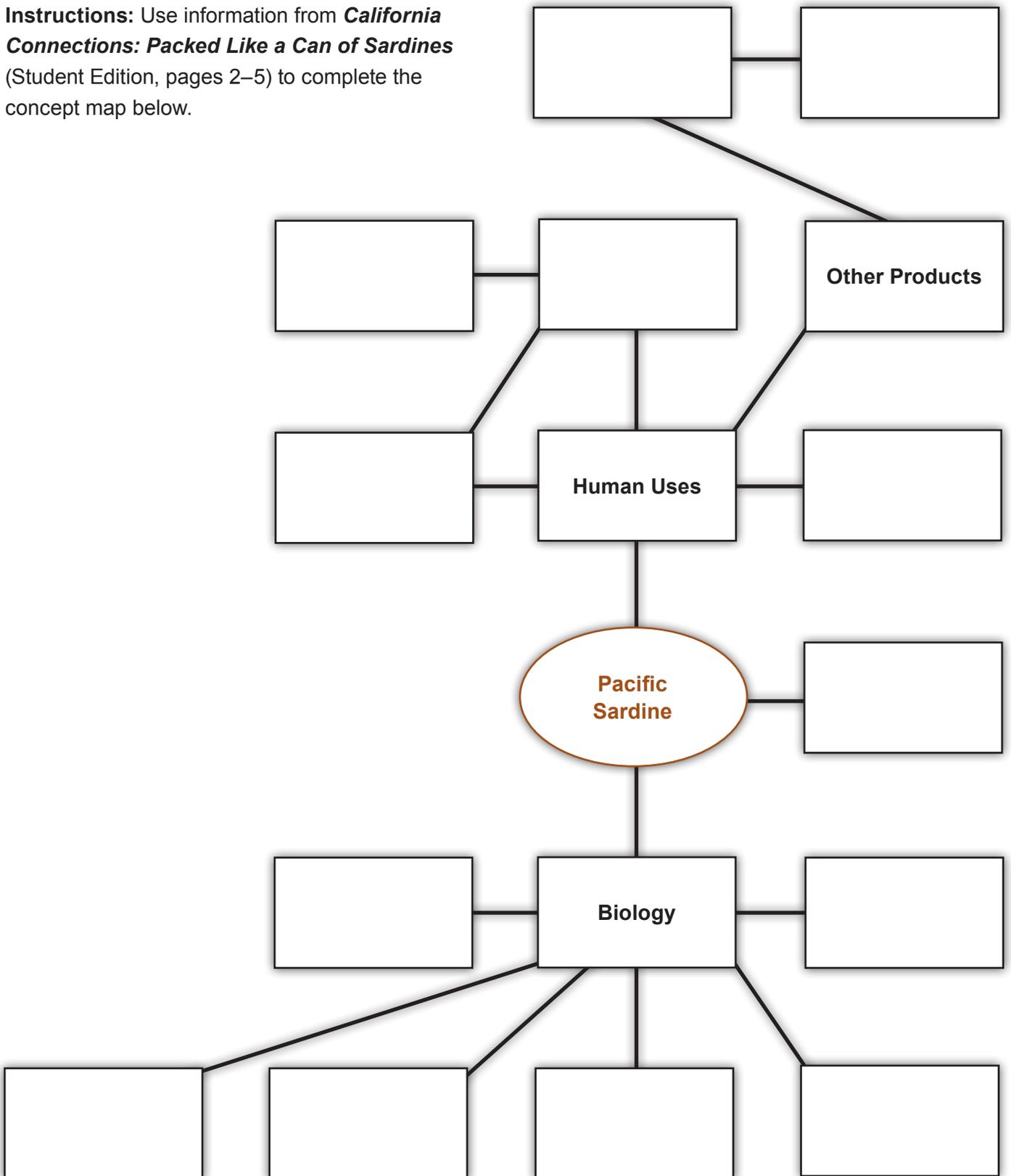
Component	5 Points	3 Points	1 Point
The sequence is correct, starting in the 1800s and ending in present day.			
The information presented in <i>California Connections: Packed Like a Can of Sardines</i> is represented on the timeline.			
The interactions with humans are represented through the presentation of historical facts.			

Physical Environment and Sardine Fisheries Concept Map

Lesson 1

Name: _____

Instructions: Use information from *California Connections: Packed Like a Can of Sardines* (Student Edition, pages 2–5) to complete the concept map below.



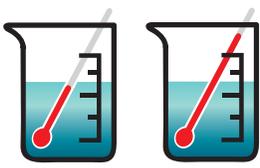
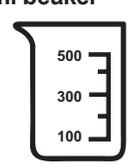
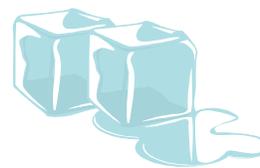
Ocean Layering Data Sheet

Name: _____

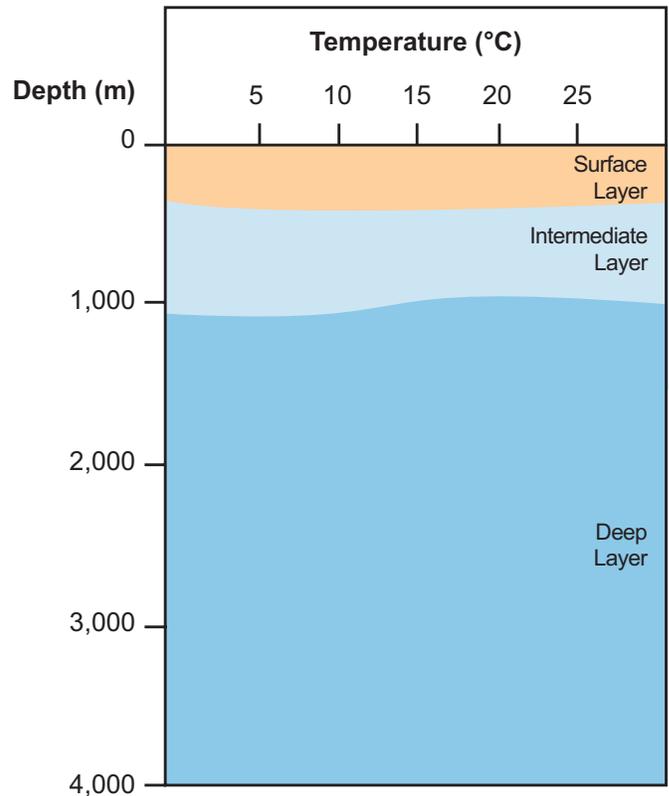
Instructions: Read the following prompt while looking at the **Structured Ocean Layering Diagram** and participate in a class discussion about the causes of differences in ocean water temperatures, density, and mixing.

The ocean primarily forms layers because water with a higher density sinks below water with a lower density. In the ocean, two important variables govern water density: temperature and salinity. In this demonstration you will observe how one of these variables, temperature, affects the layering of a body of water.

Materials Needed

<p>Two thermometers</p> 	<p>One 500 and one 100 ml beaker</p> 
<p>Ice cubes</p> 	<p>Bottle of food coloring</p> 
<p>Three glass containers</p> 	<p>Plastic wrap</p> 

Structured Ocean Layering Diagram



Ocean Layering Data Sheet

Name: _____

Instructions: You will investigate what happens when waters of different temperatures meet. Write a hypothesis about whether water at different temperatures will mix or form layers, and if it forms layers, what will happen to warm water in comparison to cool water. Use information from the class discussion and what you already know about the density of water at different temperatures to help you form your hypothesis.

My hypothesis about how what will happen when water at two different temperatures comes in contact is:

Trial Number	Water Temp. (°F)	Water Temp. (°F)	Water Temp. (°F)	Observations
1	Water on bottom layer _____	Water on top layer _____	Water after mixing _____	_____ _____ _____
2	Water on bottom layer _____	Water on top layer _____	Water after mixing _____	_____ _____ _____
3	Water on bottom layer _____	Water on top layer _____	Water after mixing _____	_____ _____ _____

Ocean Layering Data Sheet

Name: _____

Instructions: Use the data from the chart on the previous page to complete the following tasks in the spaces provided.

1. What happened to the water when you removed the plastic wrap?

2. Describe the mixed layer.

3. What happened to the mixed layer as the temperature of the water masses began to equalize?

Ocean Layers

Lesson 2

Name: _____

Instructions: Answer the following questions in the spaces provided. (5 points each)

1. Why does warmer water float on colder water?

2. Did you observe any mixing of the layers? Explain.

3. Does mixing occur in the ocean? Explain.

4. How could the properties of the ocean water you observed in this demonstration affect the geographic distribution of coastal and marine organisms?

Ocean Layers, Currents, and Distribution of Marine Organisms

Lesson 3 | page 1 of 2

Name: _____

Instructions: Select the best answer and circle the correct letter.

1. Off California's coast, a thermocline _____.
 - a. disappears during the summer
 - b. forms during the summer, as the California Current brings cold water to form an upper layer
 - c. forms during the summer, as increased sunlight heats the upper layers of the water
 - d. remains constant all year round
2. In polar regions, phytoplankton _____.
 - a. thrive all year round, because nutrients are always plentiful
 - b. thrive during the summer, when sunlight increases
 - c. cannot survive, because the waters are too cold
 - d. cannot survive, because a permanent thermocline traps nutrients deep below the surface
3. In tropical regions, _____.
 - a. a permanent thermocline traps nutrients in the deep water
 - b. primary productivity is high all year round, because there is a constant supply of solar energy for photosynthesis
 - c. the thermocline disappears in the winter
 - d. the upper and lower layers of water mix all year round

Instructions: Complete the following tasks in the spaces provided.

4. Explain how a seasonal thermocline creates vertical layering off California's coast.

Ocean Layers, Currents, and Distribution of Marine Organisms

Lesson 3 | page 2 of 2

Name: _____

5. Why is ocean layering seasonal off California's coast?

6. How does seasonal vertical layering influence distribution of primary producers and other organisms?

7. How does the movement of currents off California's coast affect the distribution of marine organisms?

Jetties, Breakwaters, and Currents

Name: _____

Instructions: Complete the following tasks in the spaces provided. (5 points each)

1. Describe a breakwater, its function, and how it works.

2. Describe a jetty, its function, and how it works.

3. What are three reasons to build jetties or breakwaters?

4. Identify and describe two effects on the natural environment resulting from construction of a jetty or breakwater.

Kelp Harvest Ban Discussion Questions

Lesson 5 | page 1 of 2

Name: _____

Instructions: Complete the following paragraphs using the words from the Word Bank. (1 point each)

Word Bank

alginate	nutrients	primary producer
increases	solar energy	sunlight
reduces	temperate	
food source	habitat	

Kelp is a _____, since it converts _____ to organic energy by photosynthesis. Several physical properties of the ocean promote its growth: kelp requires _____ and _____; and it lives in _____ regions where waters are cool throughout the year. Kelp plays an important role in the ocean. It provides a _____ for many species, such as sea otters that forage and raise babies in the kelp beds. It also acts as a _____ for many organisms, such as the sea urchin.

Kelp harvesting has many effects on both ecosystems and humans. Extensive harvesting _____ populations of fish and other organisms that live in kelp forests. However, harvesting _____ profits for companies that use kelp, such as those that produce _____, an additive used in food and cosmetics.

Scientific Knowledge, Policy, and Management Decisions

Lesson 6 | page 1 of 3

Name: _____

Instructions: Take turns reading the events on the timeline below. Categorize each event as an example of scientific knowledge, management policy, or a management decision in the right-hand column.

Date	Event	Scientific Knowledge, Policy, or Management Decision
1945	An estimated 550,000 metric tons of sardines caught off the California coast. Catch greater than any other fish catch in North America. Twenty-four canneries operate along Cannery Row.	
1947	Sardine fishery falls to 100,000 metric tons; and a tax imposed on fishermen to help support scientific research.	
1949	Research collaborative established to investigate the sardine fishery's collapse. Participants include: Scripps Institution of Oceanography, the NOAA/NMFS Southwest Fisheries Science Center, and the California Department of Fish and Game. This group is later named the California Cooperative Oceanic Fisheries Investigations (CalCOFI).	
1957	Ocean off California warms by 3.6° F (2° C), causing anomalies in precipitation, plankton abundance, and fisheries.	
1958	Oceanographers, fishery personnel, and meteorologists conclude that understanding and forecasting fluctuations in coastal fisheries are best achieved by studying the entire ocean and ocean-atmosphere relationships.	
1960	Approach to sardine question becomes more interdisciplinary and ecosystem based.	

Scientific Knowledge, Policy, and Management Decisions

Lesson 6 | page 2 of 3

Name: _____

Date	Event	Scientific Knowledge, Policy, or Management Decision
1963	First volume of CalCOFI atlas series describes temperature and salinity in the California Current.	
1964	Sardine spawning biomass in this year (at 30,000 metric tons) is 1% of the spawning biomass of 1938. (Spawning biomass is an estimate of the total weight of the fish population. The sardine biomass estimate is based on a sample of fish eggs and plankton eggs.) State legislature enacts fishery moratorium.	
1969	By counting fish scales taken from sediment off the Santa Barbara coast, CalCOFI scientists reconstruct an 1,800-year record that shows sardines follow a cycle of decline and recovery approximately every 30 to 60 years.	
1972	Sardine spawning biomass minimum at less than 10,000 metric tons.	
1977	Researchers observe long-term changes in sea-surface temperature, ocean circulation, and climate.	
1979	Egg-production method, a new technique for measuring the size of the fishery, is introduced.	
1982	Large anomalies in temperature and zooplankton biomass in the CalCOFI data first linked to tropical ocean warming phenomena.	

Scientific Knowledge, Policy, and Management Decisions

Lesson 6 | page 3 of 3

Name: _____

Date	Event	Scientific Knowledge, Policy, or Management Decision
1983	Quick-response study of 1983–1984 El Niño makes it one of the most thoroughly documented El Niño events to date.	
1985	Sardine spawning biomass reaches 30,000 metric tons; the highest since 1964.	
1986	California lifts its moratorium on sardine fishing in response to measured increases in spawning biomass.	
1995	Sardine spawning biomass reaches 300,000 metric tons; the highest since 1954.	
1998	Significant data compiled on consequences of El Niño to nutrient, chlorophyll, and zooplankton patterns in the California Current, providing a close look at links between ocean physics and biology.	
1999	Spawning biomass of sardines exceeds 1 million metric tons for the first time since the CalCOFI surveys began in 1951.	

Management of a Natural Resource

Lesson 6 | page 1 of 2

Name: _____

Instructions: Read the prompt and complete the task on the chart below. (10 points)

1. Consider the ways that scientific evidence has been used to make decisions about the sardine industry. Record your ideas in the chart below. On the left, list examples of the kinds of scientific evidence that scientists have collected about sardines and their ecosystems. On the right, list examples of management policies and decisions that have been made about the sardine industry.

Examples of Scientific Evidence	Examples of Policies and Management Decisions

Instructions: Answer the following questions and complete the tasks in the spaces provided. (5 points each)

2. How have sardine populations and their ecosystems changed over time? Use scientific evidence to explain your answer.

Management of a Natural Resource

Lesson 6 | page 2 of 2

Name: _____

3. How do scientists explain the decline in sardines that occurred in the 1940s?

4. Give an example of how scientists' understanding of sardine populations influenced a management policy decision.



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