**Student Edition**

California Education and the Environment Initiative

Earth Science Standard E.5.d.

# Ocean Currents and Natural Systems

**California Education and the Environment Initiative**

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

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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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# Packed Like a Can of Sardines

From the late 1800s to the mid-1900s, the sardine industry dominated the coastal town of Monterey, California. John Steinbeck described the scene in his novel *Cannery Row:* "In the morning when the sardine fleet has made a catch, the purse-seiners waddle heavily into the bay blowing their whistles. The deep-laden boats pull in against the coast where the canneries dip their tails into the bay… The whole street rumbles and groans and screams and rattles while the silver rivers of fish pour in out of the boats and the boats rise higher and higher in the water until they are empty. The canneries rumble and rattle and squeak until the last fish is cleaned and cut and cooked and canned and then the whistles scream again…"

Visit Cannery Row in Monterey today, and you no longer smell the fishy odors of industry. Instead, tourists explore shops, restaurants, and museums that now live in former canneries. Why did the sardine industry boom in this town, and what happened to it? The story of sardines in California goes back well beyond the 19th century, perhaps even further than recorded history. The roots of the sardine's initial abundance in Monterey Bay can be discovered in part by exploring the region's natural history.

Sardine fishermen

## The Natural History of Monterey Bay

On the West Coast of North America strong winds in spring and summer blow from the north

and continue south down the coast. The spinning of Earth influences the direction of these winds and causes the upper 10 to 30 meters of the ocean's surface to move offshore. This same force makes sea levels drop. The nutrient-rich waters from the ocean depths then move upward in a process called upwelling. When upwelling occurs, nutrients become available to support the growth of phytoplankton, microscopic organisms that drift in the ocean. (Although they are too small to be seen individually, when clustered, phytoplankton look like algae and give the ocean a greenish or reddish tint.) The blooms of plankton that result from upwelling support major elements of ocean food chains. Large populations of filter-feeding fish, such as sardines, benefit from the nutritious plankton.

The ocean, controlled by tides and currents, has its own rhythms and unique cycles. The size of the sardine population represents just one of these many cycles. The sardine population temporarily declines every 30 to 60 years. Researchers have identified evidence of this cycle from deposits of fish scales in sediment in the Santa Barbara Basin and on the northwest coast of the Pacific Ocean near Vancouver, British Columbia. Significant sardine populations existed but varied in size. The fish scales near Vancouver indicate that fish on the northern Pacific Coast have regularly declined and recovered for at least 1,700 years. Scientists generally agree that these fluctuations occur in periods of 30 to 60 years. Thus, sardine populations naturally go through "booms" and "busts" every so often.

Sardines in "quarter-oil" cans

## History of the Sardine Industry

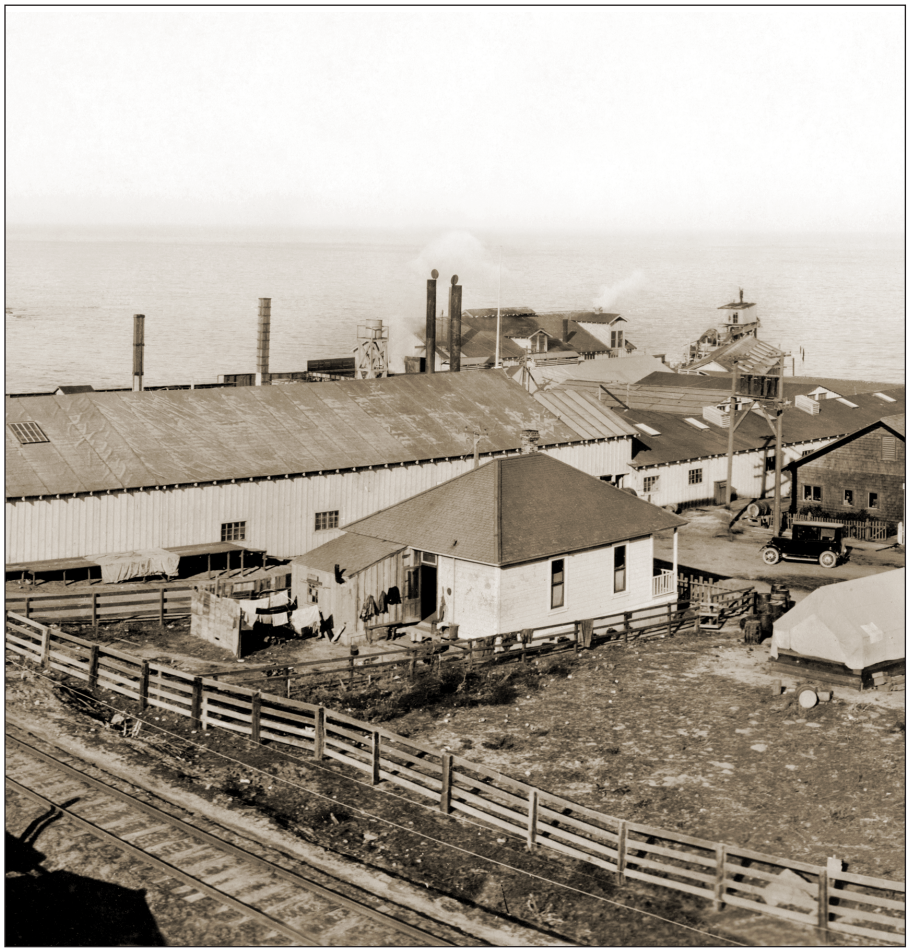
California's sardine industry, or fishery, began in the late 1800s. It grew in part due to the need to feed soldiers stationed in Europe during World War I. The small, protein-rich sardine proved ideal for shipping. Since the threat of attack by German submarines in the North Atlantic off the coast of New England prevented harvesting sardines in those waters, California became an alternate supplier to feed the troops. The war also prevented England and France from exporting sardines to the United States; prior to the start of the war Europe had been the main supplier of sardines to the United States. Even after the war ended in 1918, California's sardine fishery kept growing.

By the early 1920s, fishermen in Monterey were heavily fishing sardines. The industry learned that the fish was a profitable species. At first the industry caught sardines for

human consumption, though it had trouble selling sardines in Monterey.

Soon the industry found other ways to sell fish. Fish byproducts, including oil, fertilizer, and meal, produced excellent profits. The poultry industry, which used fish meal in chicken feed, also enjoyed huge profits as the cost of raising chickens dramatically declined and poultry reached markets in record numbers. At its peak in the 1930s, California's sardine industry was the largest fishery in the Western Hemisphere, accounting for almost 25% of all fish caught in the United States. The statewide catch in 1937 was 790,000 tons, compared with 16,000 in 1917. Of course, these numbers do not reflect the number of fish available, but rather the number that the industry could catch at the time.

In the 1940s, the fishery began to decline. The California Department of Fish and Game noticed a drop in both the size and number of sardines. Eventually the California Assembly passed laws prohibiting the use of the sardines in fish meal. This move pitted the state's regulatory power against the fishing industry. In response, the industry continually sought loopholes in the laws that they felt jeopardized their profits—California had already imposed a tax on each ton of edible fish produced. For every ton of sardines canned the state of California received $0.50. In a peak year, such as those of the 1930s, the state earned approximately $400,000 from sardines. Prohibition of fish meal and fish oil manufacturing hurt the fishing industry but not state revenue. Soon the California Department of Fish and Game set another standard, requiring that a fixed number of sardines be canned before they were made into other products, such as oil and fertilizer. Even so, the population of sardines continued to drop, and canneries began to close.



Hovden Cannery building (ca. 1918)

In February of 1973 the last California cannery closed its doors. That cannery was the Hovden Cannery, now home to the Monterey Bay Aquarium. Those employed in the sardine

Monterey Bay Aquarium

industry faced unemployment. Due to the unique geographic beauty of Monterey Bay, however, city planners sought to capitalize on yet another growing industry: tourism. Many of the unemployed cannery workers eventually found employment in tourism-related businesses, such as retail shops, restaurants, and other entertainment venues.

## What Caused the Decline?

When the sardine population in Monterey Bay began to decline in the 1940s, was it simply nature at work? Did the fish populations plummet due to natural cycles, or did overfishing, contribute to a naturally occurring cycle of decline? Scientists and industry continue to discuss the effects of fishing, especially in situations such as that of the sardine, where the industry fished so heavily. Some scientists think that if people continue to overfish, the industry could influence natural fish cycles.

Over the past 30 years California resource managers have more carefully managed fisheries. Researchers have observed dramatic increases in the Pacific sardine population, with current estimates of the biomass of sardines in U.S. waters at 3.8 billion pounds, the highest level in recent history. By 2002, the sardine catch was over 110,000 tons. Although these levels do not reach as high as in the sardine heyday of the 1930s, they represent an unsurpassed increase over the levels of the 1950s through 1970s. Scientists attribute these high numbers to the role of management changes resulting from better scientific data, assessment surveys, monitoring of fish landings (catches), and the subsequent enactment of laws to protect fish.

# Case Studies: Santa Monica Breakwater and Huntington Harbor

Engineers typically build a few types of man-made structures along the coast to redirect sediment, protect a harbor, or build beaches. These structures include jetties, breakwaters, and seawalls. Breakwaters and seawalls typically run parallel to the coastline, while jetties run perpendicular. Here are two case studies, one of a breakwater and one of a jetty.

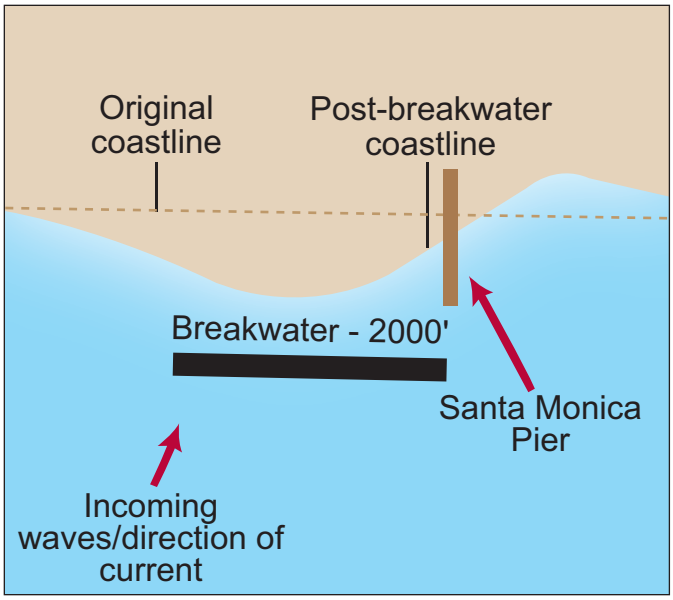
## Santa Monica Breakwater

The Santa Monica Breakwater was built in 1934 to protect boats moored in the Santa Monica Harbor near the Pier. The structure was originally built to protect approximately 45 boats. The breakwater dramatically changed the shape of the beach, which widened as sand deposited on the shore behind the structure. After the breakwater was built, the beach areas began to expand and stabilize, increasing the opportunities for more recreational activities.

The Santa Monica Breakwater was a 2,000-foot-long structure that sat approximately 1,300 feet offshore and ran parallel to the coastline. This breakwater was engineered to let sand pass through it, resulting in the deposition of sand on the beach side of the structure and erosion downstream. Although sand deposition initially takes place behind breakwaters, the systems are meant to reach an equilibrium in which no additional erosion or deposition occurs. The Santa Monica Harbor no longer exists today, and the breakwater structure has dramatically changed, looking more like scattered jagged rock piles sticking up sporadically along the horizon.

## Huntington Harbor

The land that now occupies the Huntington Harbor was once a tidal marsh and was completely covered by water during high tide. Planning and construction of the Huntington Harbor began in the early 1960s, and the harbor opened in 1969 after channel dredging, depositing more than five feet of fill, and placing jetties at the harbor's entrance.




Santa Monica breakwater

Today it is one of the most popular small-boat harbors in California.

The harbor consists of a jetty system, referred to as the Anaheim Bay jetties. These long jetties protect the entrance of the bay, which serves as the entrance to the Naval Weapons Station Seal Beach and Huntington Harbor. Today Huntington Harbor consists of five man-made islands and a network of channels that all connect to the open ocean through the Anaheim Bay jetty.

This jetty system changed the course of the longshore current, blocking sediment transport to beaches south of the jetties. This has resulted in significant erosion. Every five to six years, engineers bring in thousands of cubic yards of sand to rebuild the thinning beaches and protect coastal developments to the south. Such sand replenishment projects cost the federal and state governments millions of dollars.

Anaheim Bay jetties and Huntington Harbor

# Plan Extends Kelp Harvest Ban

By Anna Davison

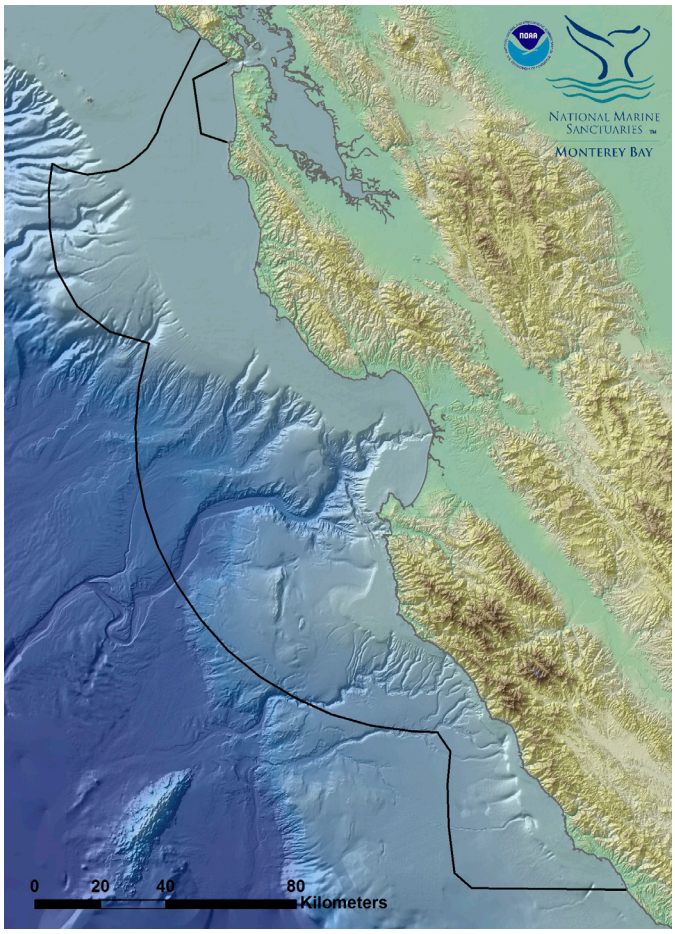
Supporters of the Edward F. Ricketts State Marine Conservation Area were celebrating Friday after the state Fish and Game Commission agreed to curtail kelp harvesting in a broad area of the underwater park. The commission adopted a final statewide kelp management plan at the meeting, but not before hearing comments from dozens of people trying to persuade the commission to ban kelp harvesting in the park altogether.

The new plan, which will be in effect for five years, prohibits harvesting in the entire Monterey Bay National Marine Sanctuary between April 1 and July 31.

Harvesting is also banned at all times in an area from the Monterey breakwater to a line extending seaward from Chart House Restaurant on Cannery Row.

The commission had been poised to adopt regulations banning harvesting from the breakwater to the vicinity of Drake Avenue, but after hearing impassioned arguments against kelp harvesting in the Cannery Row area, it extended the no-take area by 100 yards.

"It was a wonderful victory," said Ed Cooper, a recreational diver and one of the original organizers of the park, which extends from the Monterey breakwater to Hopkins Marine Station. Cooper was joined at the meeting by dozens of other members of the group Friends of the Edward F. Ricketts Marine Park–among them divers, photographers, business people, environmentalists, surfers, and marine scientists.




Monterey Bay National Marine Sanctuary

"We're not quite there yet, but it really shows the direction it's going," Cooper said as he stood surrounded by supporters waving placards that read, "Save our underwater forest" and "No kelp, no otters."

"What we've got here is a group of very committed individuals," said commission president Mike Chrisman. "We heard them; we really did."

Though some who attended the meeting were disappointed that the commission didn't declare the entire park a no-harvest area, others were pleased that the commission expanded the no-take area at the last minute. They said the change was a victory against what they see as a powerful proharvest lobby comprised of businesses—which take the kelp to extract alginate, used as a stabilizer in everything from paint to party dip—and abalone farmers, who depend on harvested kelp to feed the shellfish.

But abalone farmers said they're just earning a living.

"We're the center of the abalone industry, and we should be allowed to survive," said Joe Cavanaugh, founder of Monterey Abalone Company. He said the problem is the perception that harvesters are stripping kelp beds bare.

Sea otter

"People think the kelp forest is being clear-cut. This is a sustainable resource, and each year it's being renewed," Cavanaugh said.

Speakers at the meeting stressed the importance of kelp as a habitat for countless creatures.

Jim Curland, a spokesman for the national organization Defenders of Wildlife, said he was particularly concerned that the harvest endangers sea otters.

"They use it as nursery grounds; they use it as foraging grounds," he said.

Others talked about the economic value of the intact kelp in terms of tourism dollars.

"People come to Monterey to see the sea otters," said Berkley White, a spokesman for the Cannery Row Business Association. "If the (kelp) canopy isn't there, the otters aren't there. …Our bottom line is dependent on that area."

Opponents of the harvest also questioned the amount harvesters pay to take the kelp. At the moment, they pay $1.71 per ton along with a $100 license fee–but many say that's far too low.

"We must ensure that the public are not subsidizing the harvest," said Aaron King, a marine scientist with the Monterey Bay National Marine Sanctuary.

Later, kelp lover Joanne Garden burst into song, and others joined her for a tuneful tribute to the algae.

"Where have all the kelp plants gone? Long time passing…," they sang.

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A Knight Ridder Newspaper

# Monterey Bay National Marine Sanctuary

Article provided by NOAA's National Marine Sanctuary Program

Designated in 1992, the Monterey Bay National Marine Sanctuary is our nation's largest marine sanctuary, protecting 5,322 square miles of one of the world's most productive marine environments. The Monterey Bay National Marine Sanctuary is administered by the United States Department of Commerce's National Oceanic and Atmospheric Administration (NOAA). The sanctuary extends from Marin County to Cambria, encompassing nearly 300 miles of shoreline and 5,322 square miles of ocean extending an average distance of 25 miles from shore.

Within its boundary is a rich array of habitats, from rugged rocky shores and lush kelp forests to one of the largest underwater canyons in North America. These habitats abound with life, from tiny microscopic plants to enormous blue whales. Its northern shores are lined with pocket beaches and steep bluffs. The shoreline of Monterey Bay itself is a long crescent-shaped beach punctuated in the middle by Elkhorn Slough. Underwater, its major feature is the huge Monterey Submarine Canyon. From its head, where Elkhorn Slough meets the bay, the canyon meanders 60 miles out to sea, cutting a trench one mile deep. At its deepest point, the Monterey Bay National Marine Sanctuary reaches down 10,663 feet (more than two miles).

Garibaldi fish in kelp forest

The sanctuary contains a great diversity of habitats and marine life. It is home to numerous mammals, seabirds, fish, invertebrates, and algae. More than 450 species of algae, 33 species of marine mammals, 94 species of seabirds, 345 species of fish, 4 species of sea turtles, and

thousands of invertebrates have been recorded in this remarkably productive coastal environment. Some live here year-round. Others visit seasonally or migrate through. When the California Current runs strong, it carries cold-water animals down from the north. When it weakens in late summer, the warm water brings sea turtles, swarms of jellies, and other plants and animals up from the south.

Some 2,000 sea otters live in nearshore kelp beds protected by the sanctuary. In winter and spring, gray whales can be spotted from high bluffs. Visitors who venture offshore in boats can find blue and humpback whales, along with seabirds, orcas, and dolphins. Divers find kelp forests filled with fish and invertebrates. The sanctuary's rich waters support important commercial and sport fisheries for Dungeness crabs, spot prawns, market squid, salmon, rockfish, and other species.

There is a human dimension to the Monterey Bay National Marine Sanctuary with several urban centers and approximately three million people living within 50 miles of its shoreline, many of whom rely on sanctuary resources for pleasure or work. Humans have lived along the shores and harvested natural resources for thousands of years. Along the sanctuary's shores today are two dozen research institutions, making it a leading hub for marine science in the country. With its great diversity of habitats and life, and due to the human communities along its shoreline, the Monterey Bay sanctuary is a national focus for recreation, research, and education.

Monterey Bay National Marine Sanctuary and the other 12 sanctuaries found around the country are part of our collective riches as a nation, treasures that belong to all of us. They protect some of our most precious marine resources and serve as living classrooms. They provide for a wide range of recreational activities, from beachcombing and tide pooling to whale watching and sport fishing. They support valuable commercial industries, such as fishing and kelp harvesting. And, they help ensure, with proper management, that these activities remain a part of our country's legacy far into the future.

National Marine Sanctuaries of the West Coast

Sea otter

## Connected by the Currents

There are five national marine sanctuaries along the West Coast of the United States. Each of our five West Coast national marine sanctuaries is a jewel unto itself with its own unique character. Each has a distinct set of physical conditions, including climate, daily weather patterns, the lay of the coast, and the makeup of the seafloor. These and other factors help define the nature of each sanctuary and set each apart from the others.

But in the restless ocean, driven by wind and storms and powerful currents, no place is truly isolated from another. Each of our sanctuaries is intimately connected not only with the others, but also to the entire coast from Alaska to Baja California, and to the far reaches of the world ocean.

Our national marine sanctuaries on the West Coast are linked by the California Current—a broad, shallow "river" of ocean water meandering southward along the Pacific Coast. This slow-moving surface current carries some 10 trillion gallons of water per hour—a flow 55 times greater than the Amazon. Below it, two counter currents, the Davidson Current and a deeper undercurrent, flow north.

Carrying cold, nutrient-rich water southward from the North Pacific, the California Current shapes the nature of the entire West Coast, setting the stage for an abundance and diversity of ocean life equaled in only a few other places on Earth.

The current runs strongest in spring and summer, when northwest winds drive it southward and toward the coast. During these times, cold, nutrient-rich water wells to the sunlit surface. There, light and nutrients fuel an explosion of life with clouds of tiny, drifting plants known as phytoplankton that form the base of ocean food webs here. Closer to shore, these same forces spur the growth of towering kelp forests.

When it runs strong, the current carries drifting plants and animals southward from sub-arctic waters. When it slackens in the fall, the surface waters warm and southern species move northward. This ever-shifting mix of species adds to the great diversity of our marine communities in our West Coast national marine sanctuaries.

The current serves as a vast, open highway for whales, birds, fish and plankton, which follow it on long migrations in search of food or suitable places to nest, spawn, or give birth. For some—such as Pacific sardines, northern anchovies, gray whales, western gulls, and Brandt's cormorants—the boundaries of their lives are largely defined by the boundaries of the California Current.

Vast schools of sardines, anchovies, and hake spawn in the warmer waters around the Channel Islands, then swim north through our other sanctuaries where they find rich pastures of plankton to feed on. The small fish are joined by giant blue whales and other whales that come to feed on krill and various plankton.

Salmon spawned in streams along the Olympic Coast follow the current north to the Gulf of Alaska and south to Cordell Bank, Gulf of the Farallones, Monterey Bay, and the Channel Islands sanctuaries in search of food.

Gray whales traverse the entire coast, passing through all five marine sanctuaries twice each year as they migrate from Alaska to Baja California. Meanwhile, pods of transient orcas travel from the Olympic Coast to Monterey Bay and the Channel Islands in spring to hunt gray whale calves as they swim north with their mothers.

Elephant seals, sea lions, and fur seals roam widely along the coast and far out to sea. They then return to rookeries in the Channel Islands, Monterey Bay, and the Gulf of the Farallones National Marine Sanctuaries where they give birth to their pups.

A brown pelican or black storm-petrel appearing along the Olympic Coast may have been hatched and fledged on the Channel Islands. And some 400,000 gulls, cormorants, and murres nest in the Gulf of the Farallones then fly far and wide to our other sanctuaries and beyond. Our sanctuaries protect vital habitat for shorebirds and countless species along the important migration route known as the Pacific Flyway.

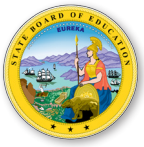
The connections extend further still as other species pass through these waters on their way to and from more distant places. Each year, albacore tuna follow currents across the Pacific Ocean and back again; sooty shearwaters travel here from as far away as New Zealand; and leatherback turtles migrate from Indonesia. Albatrosses breeding on the northwestern Hawaiian Islands regularly fly back and forth to Cordell Bank and the other West Coast national marine sanctuaries to find food for their chicks.

The great currents shaping ocean life recognize no man-made boundaries. No one sanctuary can shelter these wide-ranging ocean wanderers. The lines of our sanctuaries can only mark their passage. But taken together, the influence and protection of our sanctuaries extend far beyond their physical boundaries.

Each sanctuary is distinct from the other, but they are all part of a larger system connected by wind and water. And as part of this greater system, our national marine sanctuaries help protect not just individual places, but the entire fabric of ocean life along the West Coast of the United States.

For more information, visit **http://www.sanctuaries.noaa.gov/about/westcoast.html** and **http://montereybay.noaa.gov.**

School of sardines in kelp forest



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