The Seafood Review

CHILL OUT!

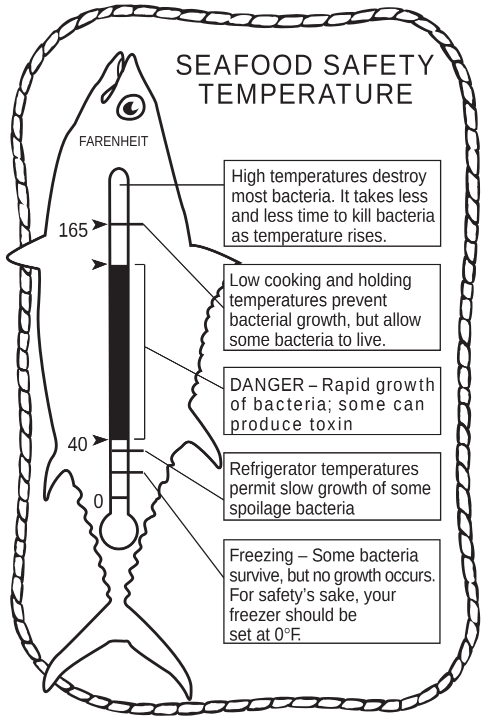
The temperture is rising and the seafood is becoming unsafe.

Keep seafood, including smoked seafood, chilled to maintain safety and quality.

Treat fish like ice cream. Buy it last, come straight home and refrigerate it first. Store seafood below 40 degrees F, as close to 32 degrees as possible. Freeze fish for at least seven days at 0 degrees F before making sashimi, sushi, ceviche, or cold-smoked fish. This kills any parasites that might be in the raw fish.

For safety, best flavor, and best results with frozen fish, remove from freezer and place in the refrigerator to thaw about 24 hours before preparation.

Sometimes you do not need to thaw fish before you cook it. As a general rule, allow 10 minutes per inch of thickness for fresh fish to cook and 20 minutes per inch for frozen fish. Fish is done when it turns opaque.



ALIVE AND WELL

Know your seafood seller. Keep live shellfish alive.

Refrigerate live shellfish properly by placing it in a well ventilated container covered with a damp cloth or towel.

Do not store shellfish in airtight bags or containers. Storing live seafood such as clams, oysters, mussels, crabs, lobsters and crayfish in salt water shortens their life. Do not store them in fresh water either, because that also will kill them.

Dead shellfish spoil rapidly and develop bad smells and flavors.

WHEN IN DOUBT THROW IT OUT!

WISE WAYS CHECKOFF

To avoid cross-contamination, these steps should be followed when preparing any food:

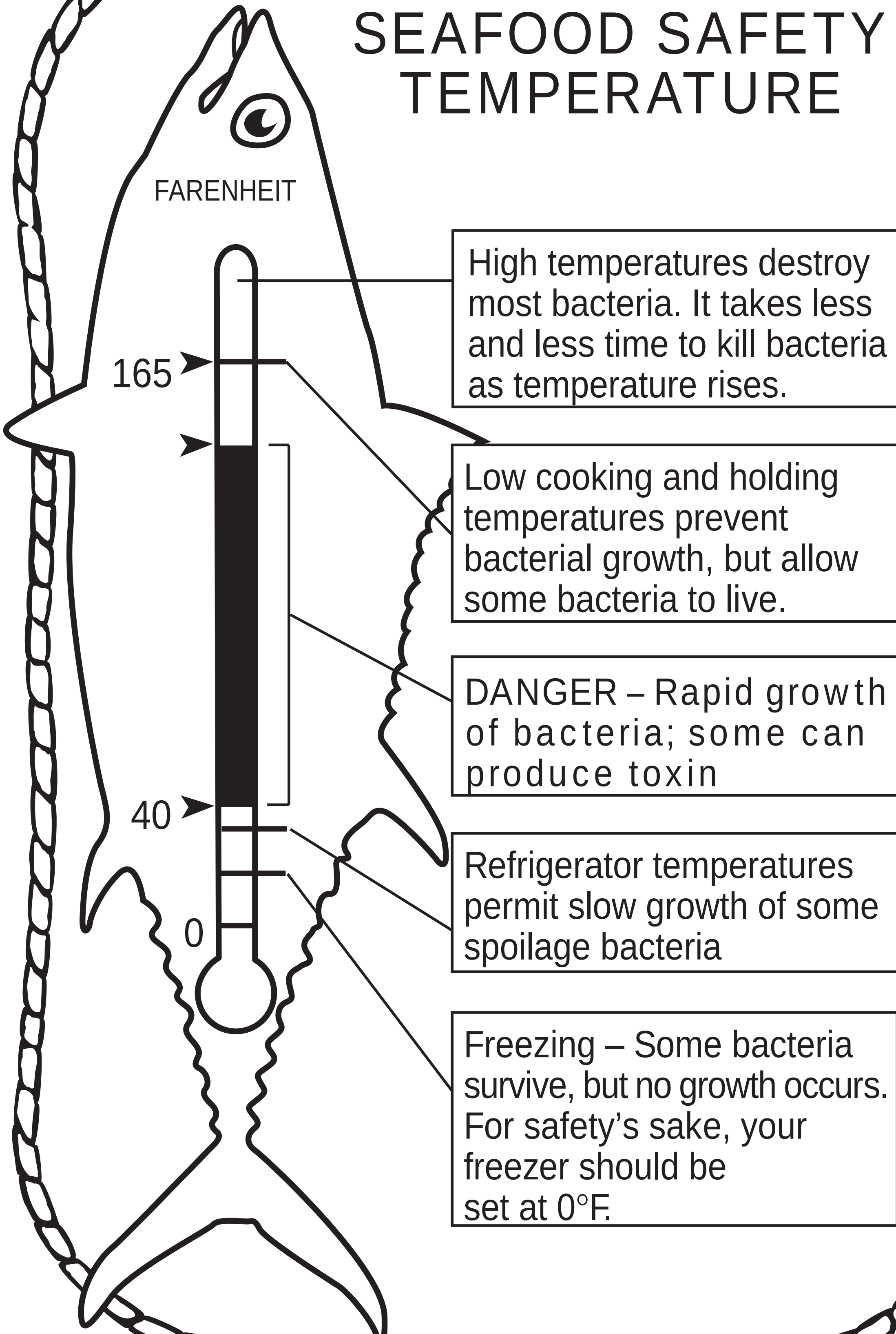
Keep raw and cooked seafood separate from each other. This prevents bacteria from spoiling the cooked food.

Wash hands thoroughly before and after cooking seafood.

After preparing and cooking seafood, wash cooking, cutting and serving utensils. Wash cutting boards and containers.

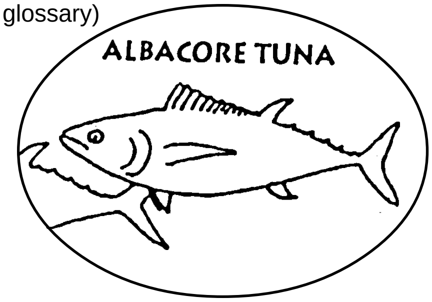
If you use a sponge to clean an area where raw seafood has been, wash and sanitize it thoroughly after use.

SEAFOOD SAFETY TEMPERATURE



CALIFORNIA'S GOLDEN SEAS BOOKLET

(Words in **bold** type–**colored** on screen–are found in the glossary)



ALBACORE TUNA

Anatomy - What does an albacore look like?

Albacore is the only tuna with white meat (the meat of other tunas is red). Albacore are sleek, fast-swimming fish with long pectoral (side) fins. They have very dark blue backs and silvery white bellies. They grow up to 4 1/2 feet in length and live to be about 10 years old.
Albacore caught in California's fishery weigh up to 76 pounds.

Habitat - Where and how do albacore live?

Albacore are found in **subtropical** and **temperate oceans** around the world. These highly migratory fish travel farther than most other fish. Young albacore migrate very long distances. Two or three-year-old albacore caught off California may have hatched anywhere from the Philippines to Hawaii, where the fish live for about two years before traveling to North America. Fisher folk look for albacore from Alaska to Baja California during summer and fall. Albacore are open water fish that do not come near shore very often. They prefer water temperatures of 50 to 64 degrees. Acoustic tracking studies have shown that these fish like to live within the depths of the **thermocline**, rather than in the upper layers of the ocean. They often travel in tight schools that may number thousands of fish.

Albacore grow quickly; a fish two feet long is only two years old. Albacore mature at about six years old and spawn during summer. Females each can produce 800,000 to more than 2 million eggs. Albacore, like swordfish, like to stay on the warm side of **upwelling fronts**, in clear blue waters. Upwelling fronts are areas where deep water full of nutrients comes to the surface. These may be areas where warm- and cold-water currents meet. Albacore eat any small creature that travels by but mainly feed on **krill** (tiny planktonic crustaceans), squids and fish. Sharks and large billfish, such as swordfish, eat albacore.

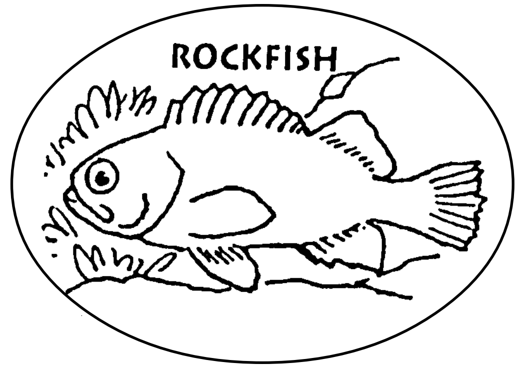
Fishery - How are albacore harvested or caught?

Albacore have been an important fishery for many years. In 1903, some albacore were canned in an experiment. People liked the canned tuna, and this was the beginning of the tuna canning industry. California's tuna industry grew to become the largest in the world. Later, other kinds of tuna were also canned, but albacore is still considered the best because of its mild flavor.

Other kinds of tuna are caught with purse seine nets, but most albacore are caught by **trolling**. Fisher folk tow hooks with feathers attached, called jigs, near the water surface behind the boat to catch albacore. This is a different kind of trolling from salmon fishing, which is also called trolling. Fishing albacore, the boat travels about 4 to 5 miles per hour. It does not stop moving as fish are caught. To find albacore, fisher folk must travel far out to sea, looking for albacore water — warm water around 59 to 62 degrees F.
Fisher folk also catch albacore by throwing live bait, such as anchovies, into the water to attract albacore, then hooking the fish with jigs attached to heavy poles and pulling them aboard. In the early 1900's, these "bait boats" caught nearly 50 percent of the albacore canned in California. Today about 12 bait boats still fish for albacore, but trollers catch more fish.

Track Questions (Optional)

Locate an area on the map where albacore live.
What is the most common way to catch albacore in California?
On a world map, follow the route that albacore take to get to California.



BOCACCIO ROCKFISH (Pacific Snapper)

Anatomy - What do bocaccio look like?

Bocaccio rockfish are one of more than 60 species of rockfish found in California's Golden Seas. Rockfish are one of the most important fish families in California waters, and bocaccio are one of the most important species in the commercial catch. Bocaccio are round-bodied fish with lower jaws that jut out and very large mouths. Their backs are brown or reddish brown, their sides are mottled pink or brown, and their bellies are silvery white. Large bocaccio also often have large black spots on their sides.

Habitat - Where and how do bocaccio live?

Bocaccio are found in the Pacific Ocean from Alaska to Mexico, but few range north of northern California. California fisher folk catch these fish in both northern and southern California. Most bocaccio live in waters 50 to 1,000 feet deep. Very young bocaccio live in shallow waters in kelp beds. They will even drift with kelp that has broken loose from the ocean bottom. Adult bocaccio live in deep water over a hard, rocky bottom. That is why they are called rockfish.

Bocaccio grow up to 3 feet in length and can live for about 50 years. Adult bocaccio are about 18 inches long and 6 years old. Most bocaccio spawn or reproduce in winter or spring. One female may produce more than 2 million eggs.

Bocaccio eat other rockfish, sablefish, anchovies, squid and krill. Marine mammals, such as harbor seals and elephant seals, eat bocaccio. King salmon and other fish also eat baby bocaccio.

Fisheries - How are bocaccio rockfish harvested or caught?

For more than 100 years, bocaccio have been the leading rockfish caught by California's commercial fishing fleet. In the early 1900's fisher folk caught rockfish with **hook and line**. Today rockfish are caught with **gillnets** and **trawl nets** as well as hook and line. In northern California, the biggest volume of rockfish is caught with trawl nets. Bocaccio is one of 13 rockfish species that are sometimes called Pacific snapper. Bocaccio is usually sold in **fillet** form to markets and restaurants.

Track questions (optional)

Locate on the map where bocaccio rockfish may be found.
Where do adult bocaccio live?
How do fisher folk catch bocaccio?

CALIFORNIA HALIBUT

Anatomy - What do halibut look like?

California halibut grow up to five feet long and can weigh as much as 72 pounds. The average halibut caught weighs about 10 pounds. California halibut is a flatfish, with both eyes on the same side of its head. The upper side, where the eyes are, is usually brown and black with sandy colored blotches. The underside has no eyes and is white. The different colors help the halibut blend into its surroundings so other creatures don't see it. Halibut sometimes lie on the bottom, half buried in the sand. When a halibut swims in the water, its white belly blends into the light coming from the surface.

Habitat - Where do halibut live?

Halibut live at the bottom of the ocean on sandy bottom near rocky reefs and kelp. They live near the shore in water from a few inches to 600 feet deep. Fisher folk can find California halibut from Bodega Bay south to Baja California. During **El Niño** cycles, halibut move northward, following warm-water **currents**. This movement causes the California halibut catch in southern California waters to decline and catches to the north of Point Conception to increase.

Destruction and filling in of **estuaries** in southern California during the past 100 years is an important reason for the decrease of many kinds of fish found near shore in California's Golden Seas. This includes California halibut. Estuaries are the nursery grounds for young halibut as well as many other types of fish. Many of the estuaries have been destroyed by filling and dredging for building sites.

Fishery - How are California halibut harvested or caught?

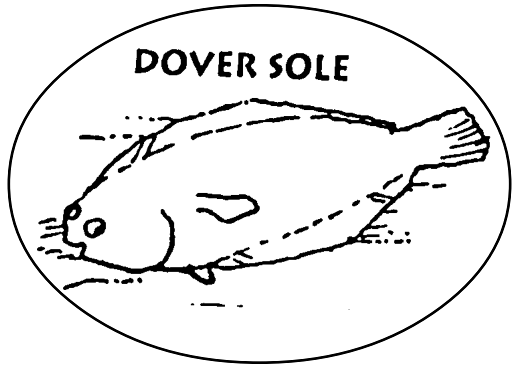
Fisher folk use trawls, gillnets, or hook and line gear to catch California halibut. They look for halibut in stirred up water or areas near the mouths of streams. This is where halibut seek food, such as anchovies, white croakers, or squid. The cloudy water provides protection for these small prey fish, making it harder for their predators, the halibut, to see them.

When halibut chase after food, they are less likely to be caught by a fisherman towing a trawl net across the ocean floor. Trawlers more often catch fish that are resting on the bottom. Active fish are more apt to be caught by swimming into a stationary gillnet, which fisher folk set across a path that halibut are likely to swim. The halibut must be hungry and bite a fishing lure to be caught with hook-and-line gear. When halibut are not feeding, the hook-and-line method is unlikely to catch this flatfish. The hook-and-line halibut fishery is most active in summertime, when California halibut move into shallow water.

Halibut catches seem to peak in 20-year cycles. There were peak catches in 1945, 1965, and 1985. In the 1980's, fisher folk caught more than one million pounds of California halibut each year; gillnets provided nearly 75 percent of the catch. California halibut are one of the most valuable fish per pound in nearshore fisheries.

Track Questions (optional)

Locate on the map where halibut are found.
Name two coastal communities that might be affected by El Niño and its effect on California halibut.
When do you think the next peak catch of California halibut will be?



DOVER SOLE

Anatomy - What do Dover sole look like?

Dover sole is a flatfish that looks something like an elongated pancake with fins and tail and small eyes. It can grow up to 2 1/2 feet long. Like halibut and other flatfish, Dover sole begins life looking like other fish, with an eye on each side of its head. When it settles on the bottom to live, one of its eyes migrates to the other side, the fish turns over on that side and takes up life as a flatfish. Dover sole is brown on the top side and off-white on its belly. Dover sole is covered with a thick layer of slime, which protects the skin surface. Another name for Dover is slime sole.

Habitat - Where and how do Dover sole live?

Dover sole range from the Bering Sea in Alaska to Baja California. They live on muddy ocean bottom in water from 180 feet to 4,800 feet deep. While Dover sole do not school, they do tend to be found together, lying half buried in the mud 5 or 10 feet apart. Dover sole live a long time — 50 years or more. Females produce 50,000 to 250,000 eggs when they spawn, or reproduce. Spawning occurs between September and April. Dover sole eat small clams and worms.

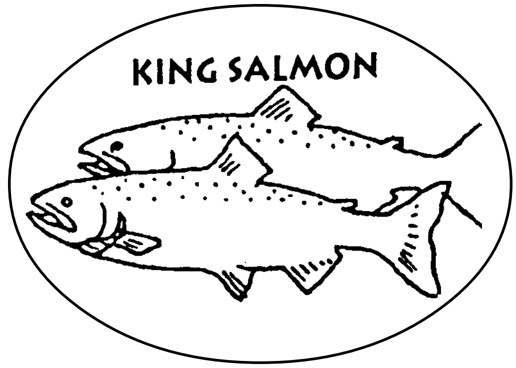
Fishery - How is Dover sole harvested or caught?

When Dover sole was first caught in the late 1800's, fisher folk threw it back in the ocean or used it for animal food because it was too soft to handle. The discovery in the 1940's that freezing the meat firms it up when thawed opened up the fishery for this mild-flavored fish. Today Dover sole is an important fishery in California. Dover sole is commonly found in supermarkets and restaurants.

Most Dover sole is caught with trawl nets. Trawl vessels tow a funnel-shaped net along the seafloor. Heavy steel doors, called "**otter boards**", are attached on each side of the mouth of the net to hold it open as it skims the ocean floor. Little rubber disks (called **mud gear**) attached to the **footrope** of the net stir up the bottom and herd flatfish into the catching bag, or **codend**. Dover sole are caught in deep water, from about 1,000 to 4,500 feet deep. Once caught, they are quickly processed. Most fishing for Dover sole takes place in northern and central California. Crescent City, Eureka, San Francisco, Monterey, Morro Bay, and Port San Luis are the main ports where Dover sole are landed.

Track Questions (optional)

Locate on the map where you would find Dover sole off California's coast.
What kind of bottom do fisher folk look for to find Dover sole?
What new invention enabled fisher folk to market Dover sole?



KING SALMON

Anatomy - What do king salmon look like?

In the ocean, king salmon are bluish or greenish blue in color, with black on their backs, silver and white on their bellies. They have dark spots on their backs and tail fins. When king salmon enter coastal streams to spawn, they change to a color that ranges from olive brown to dark red. They develop a hooked nose as they swim upriver to spawn.

King salmon are the largest of five different species of Pacific salmon, reaching 58 inches in length and weighing up to 126 pounds.

Habitat - Where and how do king salmon live?

King salmon are born, reproduce and die in freshwater coastal streams but spend most of their lives in the ocean. Fish that behave this way are called **anadromous fish**. King salmon are usually 3 to 5 years old when they return to their birth stream to spawn. Two of the major river systems where salmon spawn in California are the Klamath and the Sacramento Rivers.

To spawn, king salmon seek out gravel beds and carve out large depressions, called **redds**. Each female can produce between 2,000 and 14,000 bright red eggs. After the male fertilizes the eggs, the fish cover the eggs with gravel. With the exception of a few young males, called jacks, salmon die after they spawn.

Newly hatched larvae, called **alevins**, mature into **fry**, also called **parrs.** In California streams, most fry begin their migration to the ocean within a few weeks. Out migrating juvenile salmon are called **smolts**. In the ocean, king salmon eat krill or smaller fish such as anchovies, herring, sardines, or baby bocaccio rockfish.

Fishery - How are king salmon harvested or caught?

Native Americans caught king salmon along the lower Klamath River for hundreds of years. By 1850, commercial salmon fisheries developed in the Sacramento and San Joaquin Rivers, as well as in San Francisco Bay. In the early days, gillnets were used to catch the salmon and workers canned the meat. Today only Native Americans on the Klamath River use gillnets to catch salmon.

Fisher folk now catch salmon in the ocean by "**trolling**." They as well as their boats are called "trollers." Trollers tow up to 6 wire lines with weights attached. Colorful lures (called hoochies) or baited hooks are clipped to each line and the lines are lowered underwater, sometimes nearly to the ocean floor. The boat "trolls" through the water at a speed of around 2 miles per hour, towing the fishing gear until fish bite the hooks. Fisher folk pull the hooked fish onboard while the boat keeps moving. Salmon trollers hunt for king salmon in shallow water near shore and out to depths of 400 feet or more.

KING SALMON continued

Fisher folk look for cloudy, green-colored water to find salmon. The water appears green because it is full of microscopic plant and animal life that bait fish such as anchovies eat. The abundance of small bait fish attracts the salmon. This is how the food chain operates: plankton provide food for bait fish, small fish provide food for salmon, and salmon provide food for larger animals, including people.

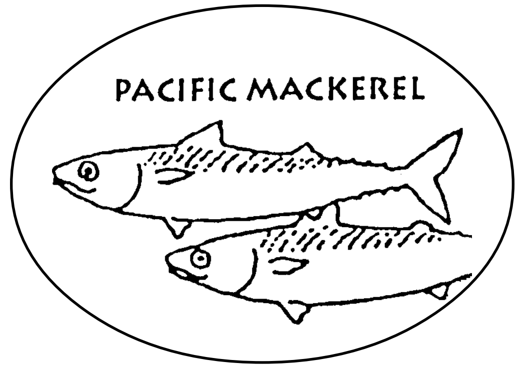
Since the 1950's, the number of salmon returning to California's rivers has drastically declined, in large part due to water management and timber harvesting practices that dammed up rivers and cut down trees right to the edge of streams. The decline of salmon has led to shorter fishing seasons and limits on the number of salmon caught. Still, king salmon are prized by seafood consumers all over the country.

Track Questions (optional)

Where in the ocean would you look for king salmon if you were a salmon troller?

Name two of the most important river systems in California for king salmon.

Discuss why salmon need adequate water and shade trees near the streams where they live and spawn.



PACIFIC MACKEREL

Anatomy - What do Pacific mackerel look like?

Pacific mackerel are long and sleek; they are small tunas and, like other tunas, they grow quickly. They are most easily identified by dark, slightly wavy bars on their green or blue backs. Sometimes these fish are also called "blue mackerel." They grow to about 25 inches long and live for about 11 years. A 2-year old fish will be about 12 inches long. Pacific mackerel are mature adults by the time they are 3 years old.

Habitat - Where and how do Pacific mackerel live?

Pacific mackerel are found in coastal waters throughout the world. Mackerel are schooling fish; they like to swim in groups. They like to live at or near the surface of the water but will swim as deep as 300 feet. They usually stay within 20 miles of shore but can range offshore as far as 250 miles. The nursery grounds for young mackerel are in kelp beds, open bays and sandy areas close to the shore. These nursery grounds are found from Point Conception south to Mexico.

Pacific mackerel like warm, northward flowing currents. The abundance of mackerel depends on these warm waters. A warm current, called **El Niño**, increased the supply of mackerel in the late 1950's and early 1960's. Cooler currents in the late 1960's and early 1970's caused the mackerel population to decrease. When the El Niño warm-water current returned in the late 1970's, the abundance of mackerel again increased.

Mackerel eat small fishes, squids, and krill. Marine mammals such as porpoises, sea lions, and elephant seals eat the mackerel. Tunas also eat Pacific mackerel. Mackerel, like sardines, anchovies, and squid, are an important part of the food chain because they are eaten by many different creatures. For that reason they are often called "bait fish."

Fisheries - How are Pacific mackerel harvested or caught?

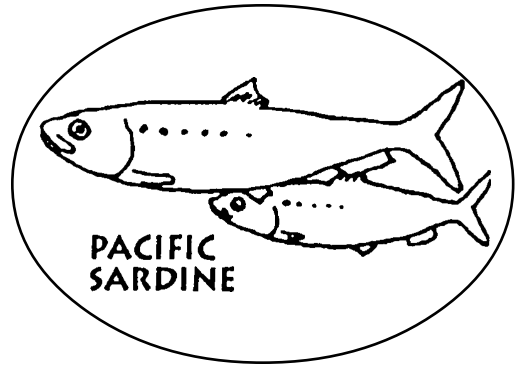
Because of their abundance and the development of efficient canning techniques, Pacific mackerel became a major fishery in the 1930's and 1940's. Many canneries were built in Monterey and on Terminal Island, in southern California, to provide food and fish meal during those years. Today canneries still operate in Monterey and Terminal Island. Most Pacific mackerel are harvested off the shores of southern California. Fisher folk use round-haul nets such as the **purse seine** to catch schools of mackerel that are swimming together. Immigrant Sicilian fishermen brought this fishing method to California in the early 1900's to catch schooling fish like mackerel, sardines, and squid.

In the daytime, Pacific mackerel are usually scattered, chasing bait. These fish are harder to catch during daytime for several reasons: [1] Fish are scattered. [2] They are harder to see in daytime if they aren't right on the surface. [3] Fish can see the net and avoid it.

At night Pacific mackerel school up. Airplanes can see the schools from the air because the fish swimming through the water cause an effect called "**bioluminescence**." Spotter pilots and fisher folk say the fish "flare" — they light up in the water. Pacific mackerel are easier to find and catch at night. Today fisher folk locate mackerel with electronic fish finders and with airplanes that can spot fish schools from the air.

Track Questions (optional)

Locate the area of the Pacific Ocean where you would find Pacific mackerel.
What is El Niño and why is it important to mackerel?
When is the best time to catch Pacific mackerel and why?



PACIFIC SARDINE

Anatomy - What do Pacific sardines look like?

Pacific sardines are elongated, sleek fish with blue or green backs and silvery white bellies. They have dark spots on their upper sides. Sardines can grow to 16 inches in length and live for 10 years. A sardine 9 1/2 inches long is considered an adult.

Habitat - Where and how do sardines live?

Sardines are found not only in the Pacific Ocean but also in waters off West Africa, Japan, Peru, New Zealand, and Australia. Along the North American coast, Pacific sardines can be found from Baja California northward to Alaska when the ocean is in a warm-water cycle. Warm-water ocean cycles favor the abundance of sardines. When the ocean enters a cold-water cycle, sardines decline and anchovies increase in number. Over the last 1,850 years, sardines have had 12 major periods of abundance. We know this because studies in a deep ocean trench off the Santa Barbara coast measured layers of sardines and layers of anchovies in core samples of the ocean bottom.

Like mackerel and anchovies, sardines are schooling fish. They are often found in groups numbering in the hundreds of thousands. Also like mackerel, sardines usually live in the upper 150 feet of the ocean. For this reason sardines, mackerel and anchovies are all called **pelagic fish**: they live in the open sea. Most sardines stay within about 100 miles of the coast, but some sardines have been found as far as 350 miles offshore.

Sardines may spawn throughout the year, but spawning peaks in summer. Sardines feed on **plankton**. Many other fish, birds, and marine mammals eat sardines.

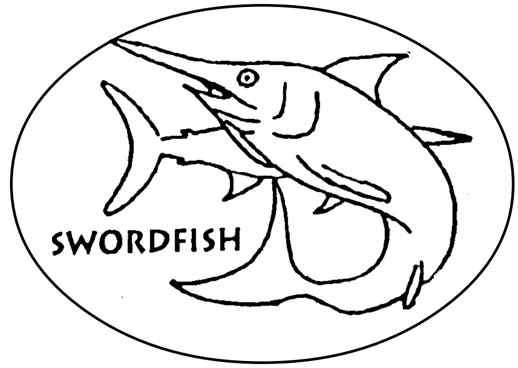
Fishery - How are sardines harvested or caught?

California's sardine fishing industry began in the early 1900's and grew as the demand for food increased during and after World War I. Sardine catches peaked in 1936. During this time the sardine fishery was the largest fishery in North America. Sardines were canned for people to eat, and they were also used for pet food and fertilizer. More than 100 canneries and reduction plants sprang up in California, including famous Cannery Row in Monterey. Many canneries also were built in Los Angeles, San Diego, and San Francisco.

Sardines are fished much like mackerel and squid, with round-haul nets such as **purse seines** and **lamparas**. Like mackerel, sardine schools are easier to see and to catch at night or just before dawn. Sardines rise to the surface at night. Fisher folk can identify a sardine school at night by the crescent moon shape it forms when it glows, or flares, in the water. Remember that the glow is caused by bioluminescence. The glow from a school of anchovies looks like long silvery stringers in the water. Sardines appear to light up and move straight ahead. Mackerel tend to flare and scatter, moving in all directions. Fisher folk sometimes use airplanes to spot schools of sardines. The pilot tells the skipper of the boat where to place his net.

Track Questions (optional)

Locate on the map where sardines are found off the California coast.
How does the present warm-water cycle affect the abundance of sardines?
How do fisher folk find schools of sardines?
How do spotter pilots tell the difference between a school of sardines, a school of anchovies, and a school of mackerel?



SWORDFISH

Anatomy - What does a swordfish look like?

The swordfish is a strange looking fish. Its upper jaw stretches into a long, flat sword. That's how this fish got its name. Swordfish are black or brown-black in color. They may grow to 15 feet in length, including the sword.

Habitat - Where and how do swordfish live?

Swordfish live all over the world in **tropical**, **subtropical**, and **temperate** ocean waters. That means that the waters tend to be warm. In the Pacific Ocean, swordfish can be found from Vancouver Island in Canada to Chile, but they seem to be most common from Oregon southward. Swordfish travel north in summer and fall, and they probably return to southern waters in winter. These sleek fish usually travel alone or sometimes in pairs. They can range from the surface to depths of 2,000 feet, and they may be found in both places in one day. In California waters, swordfish sometimes bask at the surface of the ocean during the day. Perhaps they are resting in the warm surface water to digest the fish they ate the previous night.

Swordfish grow to be at least nine years old, or maybe older, but no one knows for sure. Like some fish, females grow larger than males. A female swordfish can produce up to 6 million eggs in one season. Swordfish reproduce in tropical waters during spring and summer.

Why do swordfish have swords? Sometimes they use their swords to catch food. Swordfish eat nearly anything. They especially like sardines, anchovies and squid. Small swordfish are eaten by tunas, other billfish, blue sharks and mako sharks.

Fishery - How are swordfish harvested or caught?

In a Native American legend from southern California, swordfish were called the men of the sea. Hundreds of years ago Native Americans hunted swordfish in canoes and sometimes caught them with harpoons. California's commercial swordfish fishery began in 1927, and until the 1970's, fisher folk still caught swordfish with harpoons when the big fish came to the surface. Harpoon boats were usually small, only 30 to 50 feet long. A 20- to 30-foot plank extended beyond the bow of the boat for the harpooner to stand on to harpoon the fish. Fisher folk still catch swordfish with harpoons today.

Since the late 1970's, fisher folk also have used gillnets to catch swordfish. Swordfish nets are made of very wide mesh about 20-22 inches across, similar to the nets used for thresher shark. The large openings are designed to catch big fish and allow small fish to pass through the net. Fisher folk set the net at dusk and drift most of the night, with the net attached to the boat. They pull in the net and retrieve the catch at dawn.

Fisher folk look for temperature fronts where currents meet in the ocean to find swordfish. They look for swordfish on the warmer, blue-water side of these water breaks. Swordfish seem to prefer clear warm water, perhaps because it is easier for them to see and catch their food.

Track Questions (optional)

Locate on the map where you might catch swordfish.
Name two ways that swordfish are caught.
What ocean conditions do fisher folk look for to find swordfish?
How do these conditions differ from conditions that thresher shark prefer?

THRESHER SHARK

Anatomy - What does a thresher shark look like?
Thresher sharks get their name from their extremely long tail fin, which looks like an old fashioned grain thresher, an old-style farming tool. The tail of a thresher shark may be longer than the rest of its body. Ancient Greeks referred to these sharks as fox-like. They have small jaws compared to white sharks. Thresher sharks come in many colors: their backs may be purple, gray, brown, bluish, or almost black. Their sides are blue, golden or silver, and their bellies are white.

Habitat - Where and how do thresher sharks live?
Thresher sharks are found throughout the world in warm oceans, but not in tropical waters. Along the Pacific coast they are common from Oregon to South America. Threshers are rarely seen or caught more than 70 miles from shore. Both adults and young sharks congregate in inshore waters (25 miles or less from the coast) during spring and summer. Some thresher sharks may travel far across the ocean.

Threshers reach 20 feet in length and some probably live more than 30 years. Male sharks mature at age 3 to 7, when they are about 11 feet long. Female sharks become adults when they are 9 to 14 years old. Females give birth to live young, usually four at a time. The baby sharks, called pups, are 4 to 5 feet long at birth.

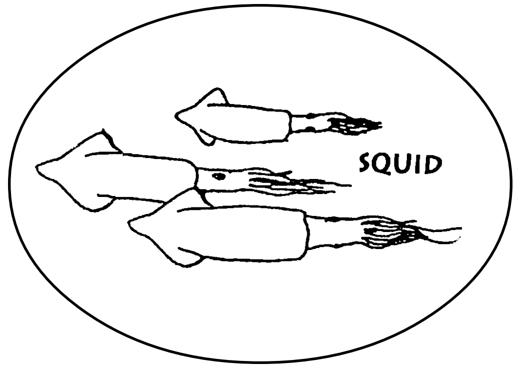
Threshers are fussy about what they eat. They like to eat squid and small fish, especially anchovies. They are often found feeding in cloudy, green-colored water because that is where plankton and small bait fish are. Thresher sharks often catch their prey by stunning it with their huge tail fins. Young thresher sharks sometimes leap completely out of the water. No one knows why they do this. Perhaps they are playing.

Fishery - How are thresher sharks harvested or caught?
Fisher folk most often catch thresher sharks with gillnets sunk under the ocean surface, the same net and fishing method used for swordfish. They look for thresher sharks on the colder, green-water side of temperature fronts in the ocean—places where warm and cold-water currents meet and bait fish like anchovy are abundant. When fisher folk find a good spot, they reel out the net at dusk and attach it to the back end, or stern, of the boat. Then the boat, the net, and the fishing crew drift in the ocean, usually all night. At dawn the crew pulls in the net and quickly stores the catch in ice in a refrigerated fish hold to keep the fish fresh. Sometimes these boats stay out in the ocean for several days at a time.

The thresher shark fishery became important in the late 1970's and 1980's when people discovered that shark is a good-tasting seafood. California's thresher shark fishery is strictly regulated. It is closed for 6 months each year to protect sharks during their breeding season.

Track Questions (optional)

Locate an area off the California coast where you might catch a thresher shark.
How do thresher sharks catch their food?
What ocean conditions do fisher folk look for to find thresher shark?



CALIFORNIA MARKET SQUID

Anatomy - What do market squids look like?

Squid are shellfish related to the octopus, in the class of **cephalopods** (head-footed ones). California market squid are one of more than 300 species of squid found in all the oceans of the world. California squid are smaller than most other squid species. They grow up to 12 inches long, and have large eyes and a slim, tube-shaped body
with ten tentacles on one end. Squid do not have bones like fish or an exterior shell like other shellfish. Instead, they have an internal quill inside that looks like an old-fashioned quill pen. Squid can change color rapidly, a defense they can use to blend into their environment. Frightened squid become dark brown, the same color as the rocks around them. Another defense squid use is squirting out a dark, inky fluid to confuse the attacker and to screen their escape. This ink is called sepia. In Europe several hundred years ago people used squid ink to write. Normally squid are a pale cream color.

Habitat - Where and how do market squid live?

Market squid range from southeastern Alaska to Baja California. They can be found near the bottom and in midwater from near shore to depths of 800 feet or more. Market squid usually travel in schools, sometimes with thousands of other squids. Squid can swim very fast by sucking in water and squirting it out, like a jet. They can move both forward and backward this way.

In central California, squid spawn in summer and fall in protected sandy areas such as Monterey Bay. Female squid each produce 20 to 30 sticky elongated egg capsules, and each capsule contains hundreds of eggs. In southern California, squid spawn in winter and early spring. Market squid live for about two years and die after spawning. Squid eat mostly plankton, such as krill, along with some small fish, small squid and other small animals. Many kinds of fish, seabirds and marine mammals feed on squid.

Fishery - How are market squid harvested or caught?

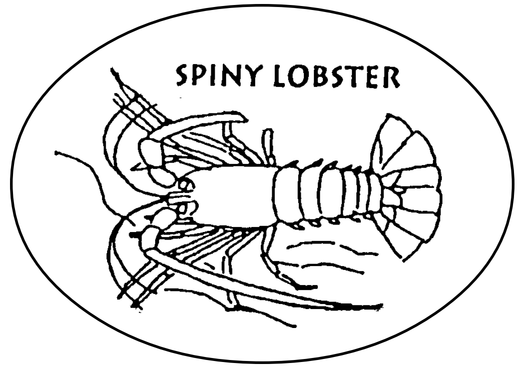
California's squid fishery began in 1863 in Monterey Bay, when Chinese fisher folk attached torches to the bows of skiffs and rowed into the Bay at night to attract squid. When squid rose to the surface, the fisher folk encircled the school with a small **purse seine net** and hauled in the catch by hand. The squid were then dried and exported to China.

Beginning in the early 1900's, Italian and Sicilian fisher folk moved to California and brought round-haul nets, called **lamparas**, from their homeland to catch squid and other fish. In the 1970's squid became known as "calamari" in restaurants. When people learned that it tastes like abalone, which they liked very much, squid became very popular.

Today fisher folk catch squid with **purse seine** and **lampara** nets from April to October off Monterey and the central coast. In southern California they catch squid from about November to March. California's squid fishery is the largest of its kind in the U.S.
Fisher folk still use bright lights to attract the squid to the surface, as the Chinese did more than 100 years ago. Squid schools are encircled with round-haul nets, then the catch is scooped up, stored in the boat holds and quickly delivered to processors on land. Squid are packed and sold fresh and frozen. Much of California's squid catch is exported to Europe, where it is highly valued.

Track Questions (optional)

Locate on a map where squid are found in California.
When do squid spawn in Monterey? In southern California?
When and where do fisher folk catch California squid?



CALIFORNIA SPINY LOBSTER

Anatomy - What does the California spiny lobster look like?

The California spiny lobster has a dark red, elongated body with a tail and 10 legs but no claws. This lobster can grow up to 3 feet in length and weigh 26 pounds. A lobster fisherman once caught a 15-pound spiny lobster that scientists found to be about 75 years old.

Habitat - Where and how do California spiny lobsters live?

California spiny lobsters are found off the California coast from Monterey Bay to Manzanillo, Mexico, in the Gulf of California. Most of the population lives between Point Conception and Baja California. Lobsters live among rocks from the intertidal zone to depths of 240 feet or more. They usually hide in caves and crevices by day and come out to feed at night to avoid their predators, creatures that would eat them. They search for food in sandy areas, and they like to feed in muddy water, for example, places where streams run into the ocean. This is so their predators won't be able to see them.

Spiny lobsters mate during winter and spring, when the male attaches a small white packet of sperm to the underside of the female. When the female extrudes her eggs in late spring, they are fertilized by sperm from the packet. Females carry between 120,000 and 680,000 eggs. Spiny lobster larvae float in the water and go through 12 stages of development before they settle to the bottom as little lobsters. This process takes 18 months. Lobsters, like crabs, have shells, called **exoskeletons**. In order to grow they must shed their shells or **molt**. Adult lobsters molt once a year. Older lobsters molt less often.

California spiny lobsters are scavengers that will eat almost anything that does not move. They usually eat algae and invertebrates such as barnacles and mussels. Sea otters, octopi and large fish with big teeth, such as sheephead, eat lobster.

Fishery - Where and how are California spiny lobsters harvested or caught?

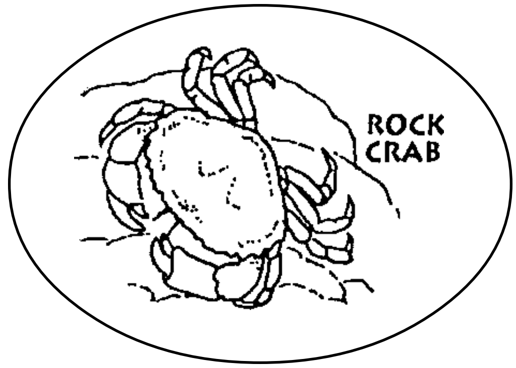
Fisher folk began trapping spiny lobsters in California more than 100 years ago. Lobster were not as popular then as they are today. After World War II, people wanted more lobsters and the fishery grew to supply more lobsters for the market.

Commercial fisher folk catch spiny lobsters in wire mesh traps that they have first baited with fish. They place the traps in the sand near rocky reefs where lobsters live. They weight the traps with cement blocks or bricks to hold them in place on the bottom. Lobsters are attracted to the bait and crawl into the trap, but adult lobsters can not get out. Attached to each trap is a line connected to a buoy that floats on the surface. Each buoy must be marked with the individual's permit number. This is how fisher folk find their traps in the ocean.

Lobster season begins in the fall and ends in early spring. Usually fisher folk place their traps in shallow water in the fall, when season opens. They move the traps to deeper water in the winter, when storms cause lobsters to move to deeper water. Traps are normally tended every day or two, except when storms and rough seas make it too dangerous to work on the ocean. Traps must be built with excape ports to allow small lobsters to escape. Many fisher folk make their own traps.

Track Questions (optional)

Locate on the map where California spiny lobsters are found.
When are spiny lobster the most active and why?
Where do fisher folk place their traps to catch lobster?



DUNGENESS AND ROCK CRABS

Note: Fisher folk harvest two main kinds of crabs in California: rock crab and Dungeness crab. Dungeness crabs are fished from central California to the Oregon border. Rock crabs are harvested from about Bodega Bay, in northern California, to southern California. Dungeness and rock crabs are cousins; they both are from the same genus - Can*cer*.

Anatomy - What do Dungeness crabs and rock crabs look like?

The Dungeness crab has a typical crab shape, with a hard shell covering its body, eight legs and two claws. Dungeness may grow as large as 9 inches wide across the back of its shell, or **carapace**. The upper edges of its claws have a saw-tooth shape. The Dungeness crab has a reddish brown back with a pattern of white spots. Sometimes the front part of its body is purplish in color.

There are actually three kinds of rock crab in California's Golden Seas: red, brown, and yellow. Rock crabs do not have white spots, and their claws do not have saw-tooth edges. Red rock crabs have dark red bodies and bumpy black-tipped pincers on their claws. Red rock crabs are the largest of the three, but these crabs grow only to 7 inches across the back, not as large as Dungeness.

Habitat - Where and how do Dungeness crabs and rock crabs live?

Dungeness crabs are found from Alaska to central California. These crabs prefer sandy or sand-mud bottom and range from the intertidal zone to about 300 feet, sometimes deeper. Dungeness move shallow and deep with the seasons, but they do not seem to migrate more than 10 miles in any direction. Dungeness crabs mate between March and July, right after molting, when their shells are still soft. A large female crab may carry 2 million eggs. Newly hatched larvae pass through 6 different stages before settling to the bottom and changing into an adult crab shape. Quiet inshore bays and estuaries are important nursery grounds for very young crabs. Dungeness crabs eat almost any food, including clams, fishes, shrimps, and other Dungeness crabs. Creatures that eat Dungeness include sea otters, octopi, larger crabs, and fishes like king salmon, lingcod, rockfishes, and flatfishes.

Red rock crabs are found from Alaska to Baja California, yellow crabs live from Humboldt Bay in northern California to Baja California, and brown crabs live from British Columbia to Baja. These crabs live in waters from the low intertidal zone down to depths of 300 feet or more. Although they are found together over most of their range, yellows are most abundant in southern California, browns in central California, and reds in northern California. Yellow rock crabs prefer sand or muddy bottoms, but browns and reds prefer rocky or hard bottom. Rock crabs behave a lot like Dungeness crabs. They also have a very wide diet, but they prefer to eat snails, clams, abalone, barnacles and oysters. Like Dungeness crabs, rock crabs are eaten by many creatures.

DUNGENESS AND ROCK CRABS continued

Fishery - How are crabs harvested or caught?

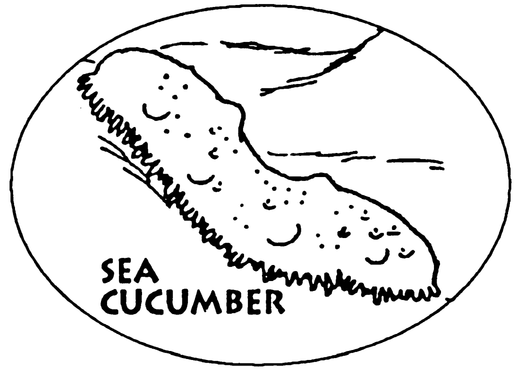
Dungeness crabs are the familiar crabs sold whole in many fish markets, especially in northern California. The Dungeness fishery is very old: the first crabs were sold during the California Gold Rush in the mid-1800's. Fisher folk catch Dungeness with circular steel traps about 3 feet in diameter. They tie a long rope and buoy to each trap, and the buoy floats on the surface to mark the trap's location. Each trap has two special openings that allow small crabs to escape. Only male crabs that measure at least 6 1/4 inches across the back, or **carapace,** may be sold at market. Smaller males and all females are returned alive to the ocean. Dungeness crab is sold whole, fresh or frozen, and the meat also is canned. Most Dungeness crabs in California are caught in the ocean off Crescent City and Eureka, near the Oregon border.

The rock crab fishery has grown in the last 30 years because more and more people like to eat rock crabs. Rock crab is the most common crab sold in southern California, and that is where most rock crabs are caught. Many fisher folk fish for lobster in fall and winter and rock crab in summer, when lobster season is closed. Fisher folk often make their own traps out of wire mesh. Sometimes traps are made of plastic.

Fisher folk bait traps with oily fish to catch crab. The scent attracts crabs into the trap. Most traps are set in 60 to 250 feet of water on sandy bottom or near rocks. These traps also have special ports for small crabs to escape. Almost all rock crabs are sold fresh.

Track Questions (optional)

Locate on the map where most Dungeness crabs and rock crabs are caught.
How are Dungeness and rock crabs the same? How are they different?
Where would you set your trap to catch crabs?



RED SEA CUCUMBER

Anatomy - What do red sea cucumbers look like?

Red sea cucumbers are shaped like the cucumber vegetable. They are sausage-shaped animals covered with small projections, called papillae, that look like warts. Red sea cucumbers are usually red in color, but some are brown, black, or white. Red sea cucumbers can grow as long as 16 inches.

Habitat - Where and how do sea cucumbers live?

Sea cucumbers are found in ocean waters from the Gulf of Alaska to Baja California. Sea cucumbers live on the bottom, over sand, mud and rock. In California, red sea cucumbers are often found in deeper water, to 300 feet deep or more. Another species, called a warty sea cucumber, lives from the intertidal zone to about 90 feet. Sea cucumbers can travel at least 300 feet in a day and they live about 12 years. Female sea cucumbers spawn millions of eggs into the water each year. When the females release their eggs, the males release sperm at the same time. This is called broadcast spawning. Sea urchins and abalone also reproduce this way.

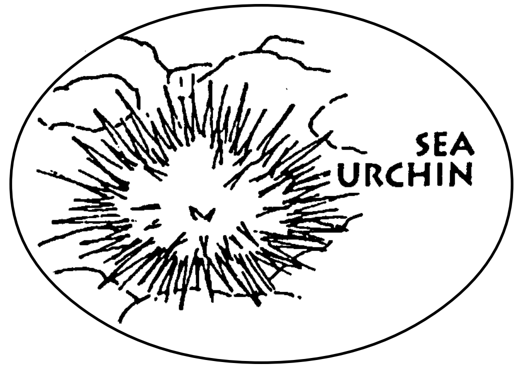
Sea cucumbers use tentacles around their mouths to eat mud and sand and the organic particles they feed on. When a cucumber is attacked, it responds by discharging or pushing out most of its internal organs. These organs are sticky and poisonous, and they often drive off the predator. Soon after, the cucumber regrows its organs. This is the way sea cucumbers protect themselves. Sea stars, crabs and sea otters prey on sea cucumbers.

Fishery - How are red sea cucumbers harvested or caught?

Sea cucumbers are among the most unusual sea creatures to be fished commercially. Fisher folk harvest most sea cucumbers with small otter trawl nets, and most of the catch comes from the Santa Barbara and Los Angeles areas. Sea cucumbers are a popular food in many parts of the world. In France they are called beche de mer and in Asia they are known as trepang. Processors in California usually dry the cucumbers and sell them to markets in California and overseas.

Track Questions (optional)

Locate on the map where most sea cucumbers are caught in California.
Who likes to eat sea cucumbers?
Are sea cucumbers a plant or an animal?



RED SEA URCHIN

Anatomy - What does a red sea urchin look like?

Red sea urchins are round, spiny animals that look something like a pin cushion. They range from dark purple to light red, and their spines can be as long as five inches. Urchins use their spines to trap drift kelp, which is mostly what they eat. Baby urchins also hide under the spine canopy of large urchins. Red sea urchins are the largest sea urchins found in North America. Their shell, called a “test,” grows as large as 7 inches in diameter. Large sea urchins may be more than 50 years old. The urchin’s mouth is at the bottom of the test. It is made up of five hard, pointy segments and is called Aristotle’s lantern.

Habitat - Where and how does a red sea urchin live?

Red sea urchins are found from Japan to the tip of Baja California. They live on the bottom of the ocean from the low intertidal zone to more than 150 feet deep. Red sea urchins prefer rocky bottom, especially ledges and crevices. They avoid sand and mud.

Sea urchins usually spawn in spring and summer in northern California. In southern California they spawn in winter. Sea urchins are broadcast spawners, like abalone and sea cucumbers. Female sea urchins produce millions of eggs, and the fertilized larvae drift on the ocean currents for up to two months before settling onto the bottom as baby urchins. Sea urchins eat mainly giant kelp, but they also eat other dead animals found on the bottom. Sea urchin predators include sea otters, crabs, starfish, spiny lobsters, and sheephead.

Fishery - How are sea urchins harvested or caught?

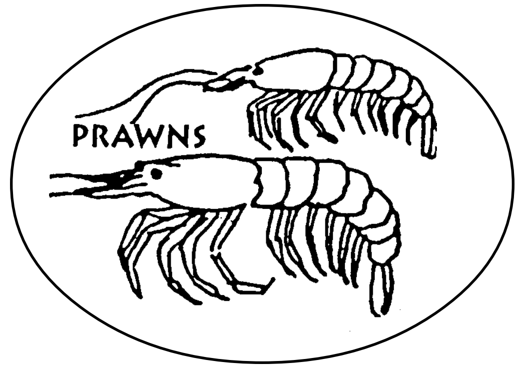
Native Americans harvested and ate sea urchins for hundreds of years. Sea urchins were not harvested commercially in California until the 1970’s. In the 1989 they became California’s most valuable seafood. Most of the catch comes from southern California’s Channel Islands. Sea urchins are also harvested in northern California.

Divers use fast boats and “**hookah” gear”** to harvest sea urchins. The boat has an air compressor mounted on deck that pumps air through a long hose to a mouthpiece, called a regulator, that the diver places in his mouth to breathe underwater. The diver’s hose may be 600 feet or longer. Divers work on the bottom in depths of 20 to more than 60 feet. They use a two-pronged rake to pluck urchins one by one from the reefs and rocks. Divers place their catch is net bags to carry them to the boat. A full bag may weigh 300 pounds, and divers can pick two or three bagfuls of urchins in a day, if they find a good spot. In the beginning of the fishery, divers could harvest 3,000 pounds or more of urchins in a day.

Sea urchins are harvested for their eggs, called roe or uni. In a processing plant on land, workers crack open the urchins and spoon out the roe. There are five pieces of roe in each urchin, and they are shaped like tangerine slices. The roe is soaked in a solution to remove some of the water, then workers hand pack it into little wooden trays. Much of the harvest is exported to Japan, where “uni” is considered a delicacy.

Track Questions (optional)

Locate on the map where sea urchins are found off California’s coast.
What part of the urchin do people eat?
What country consumes most of the sea urchin harvest?



SPOT PRAWN

Anatomy - What does a spot prawn look like?

Spot prawns are members of the shrimp family. They are related to lobsters and other **crustaceans** because they have a carapace and five pairs of walking legs. Spot prawns also have 10 leg-like appendages on their bellies that are adapted for swimming, and these are called swimmerets. Spot prawns are aptly named for the 4 bright white spots on their bodies. They live to be about 6 years old. These large shrimp may grow to measure 2 inches in carapace length, and about 5-6 inches total length. Their shell color is pale pink.

Habitat - Where and how does a spot prawn live?

Spot prawns can be found from Alaska to San Diego, California, in depths of 150 to 1,600 feet. Juveniles settle in shallow water and move to deeper water as they become adults. Major populations occur in California waters off Monterey and the Channel Islands.

Unlike many other fish and shellfish species where individuals are either male or female, spot prawns are hermaphrodites: a single animal changes from male to female over the course of its life. Spot prawns reach sexual maturity at age three, and each individual mates once as a male and once or twice as a female. Females spawn at age four and older. Spawning takes place once a year at depths of 500 to 700 feet, and spot prawns produce 1,000 to 5,000 eggs. Usually the eggs appear on the female's swimmerets in September, and the female carries the eggs for 4 to 5 months before they hatch.

Spot prawns feed on other shrimp, plankton, small mollusks, worms, sponges and fish carcasses. They usually forage on the bottom throughout the day and night. Many creatures eat spot prawns.

Fishery - How are spot prawns harvested or caught?

A small fishery for spot prawns began in Monterey in the 1930's, when these prawns were caught in octopus traps. Beginning in the 1970's, central California became the major center for the spot prawn harvest and trawl gear became the primary method of catch. In the late 1980's, traps again became popular as a way to harvest spot prawns. A market for live prawns developed, and it proved to be profitable as fisher folk could earn twice as much money for live prawns, which are sold mainly to restaurants and Asian markets.

Beginning in the 1990's, trap gear accounted for nearly 75 percent of all spot prawns landed, while trawl gear harvested about 25 percent. Trawl fishermen also began fishing for the live market. To keep the prawns alive, trawlers make short tows and keep their catch in recirculating seawater tanks on deck.

Track questions (optional)

How are spot prawns related to lobsters?
How do spot prawns differ from other fish and shellfish species?
Where and how are spot prawns fished?

GLOSSARY

alevin a young fish; esp: the newly hatched salmon when still attached to its yolk sack

anadromous fish fish that spend most of their adult life in the ocean and swim up rivers from the sea to breed

bioluminescence the light produced by living organisms
For example, when plankton in water is disturbed, such as by a fish or school of fish swimming, each plankter nearby undergoes a chemical reaction that produces light. This light, bioluminescence, can be seen at night and is one way that fisher folk locate schools of fish.

carapace a bony case or shield that covers the back of an animal (such as a turtle, crab, or lobster)

cephalopod (head-footed one) any of a class of mollusks, including the squids and octopi, that have a tubular siphon under the head, a group of muscular arms around the front of the head, highly developed eyes, and usually a bag of inky fluid that can be ejected for defense or concealment

codend a funnel-shaped mesh bag at the back end of a trawl net that catches fish

cork line the top rope of a gillnet with floats attached to hold up the net underwater

crustacean any of a large class of mostly aquatic arthropods (animals having a hard (chitinous) exoskeleton, jointed limbs with a pair of appendages on each body segment, and two pairs of antennae) Examples include lobsters, shrimps, crabs and barnacles.

current a stream of water in the ocean that flows continuously in one direction

ecosystem all populations of plants and animals interacting with their physical and biological surroundings in a defined region

El Niño off California, a mass of warm water that surges northward from the equator periodically, caused by a large-scale change in Pacific Ocean currents

estuary a water passage where the ocean tide meets a fresh water current; esp: an arm of the sea at the lower end of a river

exoskeleton an external supportive covering, or shell, of an animal
For example, a spiny lobster has an exoskeleton.

fillet a slice of fish with most bones removed, usually cut from the side of the fish

foot rope the bottom rope extending around the mouth of a trawl net, usually weighted to hold the net on the ocean bottom

fry recently hatched fishes

gillnet a rectangular section of webbing that may be anchored on the ocean bottom or suspended midwater to catch fish
Gillnets are constructed in many different sizes, each designed to catch different sizes or species of fish.

head rope the top rope extending around the mouth of a trawl net, to which floats are attached to keep the net mouth open vertically

highly migratory species fish such as swordfish or tuna that range widely over the ocean

hookah gear an air supply system used in commercial diving, consisting of an air compressor mounted on the boat, which pumps compressed air into a long rubber air hose fitted with a regulator, which the diver places in his or her mouth to breathe underwater

hook and line a fishing method that catches fish by means of a series of baited hooks, which are suspended on lines into the ocean
Examples of hook-and-line fishing systems are horizontal longline, vertical setline (also called Portuguese longline or buoy gear) trolling, and jigging

krill tiny planktonic crustaceans that form an important food source for many species, including baleen whales

lampara a type of round-haul net used to catch schooling fishes
The lampara net has a large central bag of webbing and short wings of larger mesh, hung so that when the wings are pulled in, the net forms a scoop, trapping the fish.

lead line	the bottom rope on a gillnet, which is weighted The floats on the cork line and the weights on the lead line act to hold the net open vertically underwater.
molt	the periodic act of shedding a shell or outer covering Arthropods such as crabs and lobsters must molt their shells to grow larger.
mud gear	rubber disks strung on wire rope which is attached to the foot rope of a trawl net. The purpose of mud gear is to stir up the bottom and herd the fish into the net.
otter boards (trawl doors)	curved wood or steel doors, rectangular in shape, which are attached to the lines leading to the trawl net, used to spread the net open horizontally
parr	a young salmon or trout actively feeding in fresh water; also the young of any of several other fishes
pelagic fish	a fish that lives in the open sea Coastal pelagic fishes include mackerel, sardines, and anchovy; highly migratory pelagic fishes include swordfish and albacore tuna.
plankton	tiny animal and plant life that floats or swims in a body of water, such as the ocean Minute plant life is called phytoplankton; microscopic animal life is called zooplankton. A single planktonic organism is called a plankter.
purse seine net	a type of round-haul net designed to catch schooling fishes The purse seine net consists of a straight wall of webbing with metal rings attached to the bottom. A purse line is threaded through the rings, which when pulled, closes the bottom of the net like a purse, trapping the fish inside.
redd	the spawning ground or nest of certain fishes, including salmon
smolt	a young salmon at the stage in its development when it assumes the silvery color of an adult and readies itself for life in the ocean

subtropical	relating to the regions bordering on the tropical zone
tropical zone	a region banding the equator and extending 23.5 degrees to the north and south
temperate oceans	the region between the tropic of Cancer and the arctic circle or between the tropic of Capricorn and the antarctic circle
thermocline	a layer in a thermally stratified body of water that separates an upper, warmer, lighter zone from a lower, colder, heavier zone Specifically, a thermocline is a stratum in which the temperature declines at least 1 degree centigrade with each meter increase in depth.
trolling	a form of fishing where baited hooks attached to long fishing lines are towed slowly through the water behind the boat
upwelling	water movement caused by strong northwest winds, which push away coastal surface water and allow cold, nutrient-rich water from the deep ocean to take its place In California, upwelling usually occurs in spring and fall. The nutrients in upwelled water provide food for plankton, which in turn provide food for larger fish, shellfish, and so on up the food web.
wetfish	coastal pelagic fish, such as mackerel, sardines and squid, that are typically canned "wet from the sea" with little pre-processing

A BRIEF LOOK AT THE USE AND CAPTURE OF SEA FOOD BY THE NATIVE AMERICANS OF CALIFORNIA

By Dr. Milton Love
University of California, Santa Barbara

For many thousands of years, humans have harvested aquatic organisms for food. One of the earliest known sites (dating from between 60,000 and 70,000 years ago) is located on the west coast of South Africa. As with other prehistoric peoples who foraged from the sea, hard-shelled intertidal invertebrates (such as limpets and mussels) were the first quarry; these were easily caught and required few or no tools to capture.

Initially, these foods were probably part of a larger diet, consisting of both terrestrial and aquatic organisms (for instance, the South African site contains marine invertebrates, bones and ostrich eggs). However, over time, communities arose which specialized and depended upon seafood for their survival. Perhaps the first of these fishery-based societies were the Maglemosians, who lived around the Baltic Sea beginning about 8,000 B. C. Soon after (between 6,000 and 3,000 B. C.), a number of other seafood-dependent peoples arose. Among these were societies at the mouth of the Nile, and along the coast of Japan, Peru and California.

There is some debate over when humans first came to California. While almost everyone agrees they came from Asia, via an Asian-Alaska land bridge, the exact timing of that migration is still under discussion. Certainly there is very good evidence that at least 11,000 years ago there were Native Americans along the coast of California.

How dependent were these coastal tribes on food from the sea? The overall importance of seafood for any tribe depended on its availability, and that varied along the California coast. For instance, for many Pomo (who lived along what is now the Mendocino and Sonoma coasts), sea foods were an important, but by no means total, part of their diet. Many of these peoples probably made annual movements between the coast (where they foraged in the sea) to the interior. This migration occurred for several reasons. First, much of the coast in this area was narrow and heavily wave-swept, with frequent winter storms. This meant that there was not enough easily-obtained food for many Pomos along the coast, particularly during the harsh winters. So, while their diets emphasized sea animals, terrestrial plants (such as nuts, grasses and berries) and animals (including deer, rabbits and gophers) were also important.

On the other hand, the Chumash, who lived along the coast from about San Luis Obispo to Malibu, tended to live in the same villages throughout the year. Their region had a broad, shallow coastal shelf (laden with fishes, sea mammals and shellfishes) and moderate weather throughout most of the year. Because it was generally possible to fish throughout the year, the Chumash became quite sophisticated seafarers and fishermen, and their diets reflected an overall dependency on the sea.

(However, they still ate large quantities of land organisms, particularly acorns, which formed a major source of stored foods, available when other foods were inaccessible).

How do researchers reconstruct the diets of a culture? Ideally, anthropologists conduct research in several ways. If the culture still exists (for instance the Inuits of northern Canada), the researchers observe the diets and/or interview members of that society. If the culture is extinct (as with Elizabethan England), there are often written records to pore over. But neither method is very useful in understanding the food habits of the California Native Americans who lived before the time of the Spanish missions. True, the Spanish explorers and missionaries recorded some information on diets, but these were scattered and fragmentary. And by the time anthropologists became interested in these peoples (just prior to the turn of the Twentieth Century), there were no Native Americans in California who were actually alive before the missions were established.

Thus, most of what we know about what these people ate and how they captured their prey comes from middens; the refuse piles which were created adjacent to all villages. Researchers sift through these sites (which may be tens of feet thick), separating out all of the remnants of ancient meals (primarily bones and shells). Under many circumstances, middens can be virtual gold mines for inquiring anthropologists. Not only can they tell what the peoples ate, but because the inhabitants tended to throw today's garbage on top of yesterday's, changes in food habits can be examined by starting at the top (the most recent deposit) and working down through time, layer by layer. Of course, researchers have to be careful in their analyses. For instance, for some fishes which were very important foods (such as sardines), all that is left of the skeletons may be almost microscopic earbones (otoliths), which require very time-consuming methods to find. If researchers focus on the bigger remains (the jaw bones of seals or foot-long mussels shells), they may miss an extremely important part of the diet.

Based on midden research and on the diaries of European explorers, what were the most important sea organisms for coastal Native Americans? The diets varied with location, of course, but there are certain patterns.

First, the coastal peoples depended heavily on shellfish, particularly mussels. All along the coast, mussels were the most important shellfish and often the most important food. Mussels are extremely abundant on the rocks of the intertidal zone, they grow fast and they are easy to capture. Additionally, Native Americans ate every other edible intertidal animal. Along rocky shores, this included black abalone, barnacles, sea urchins, chitons and limpets. There is some evidence that tribes would sometimes over-harvest the intertidal zone and have to turn to very small shore creatures, such as turban snails. If sandy or muddy beaches were nearby, Native Americans also captured various clams and cockles. While we eat some of these animals (for instance abalone, clams and sea urchins), some of these organisms (such as chitons, barnacles and limpets) are rarely consumed.

Fishes were also extremely important to the diets of coastal Native Americans, but what species were taken depended not only on what lived nearby, but also on the fishing and seamanship skills of the various tribes. In northern and central California, tribes situated near rivers and streams caught large quantities of salmon and steelhead. Those living on the open coast focused on such near-shore species as pile perch, grass rockfish, kelp greenling, and various eelblennies — all fishes that are popular today. In sheltered bays, such as Tomales Bay, starry flounders, Pacific herring and various sea perches (such as pile perch and walleye perch) were quite important. In southern California, the more skillful seamanship and fishing abilities of the Chumash enabled them to capture a much wider variety of important fishes. Very large quantities of small, inshore schooling fishes, such as Pacific sardines, Pacific mackerel and white croakers were netted. In the kelp beds, the California sheephead was widely taken, as were kelp bass and various sea perches and rockfishes. Sharks were important parts of their diets; mako and Pacific angel sharks bones have been found in a number of middens. The Chumash regularly took their canoes well out to sea to capture yellowtail, bonito and occasionally tuna. Even swordfish were sometimes taken; they were probably harpooned as they slowly swam along the surface. Virtually all of the fishes important to California Native Americans are still consumed today.

All along the California coast, marine mammals (particularly sea lions and harbor seals, but also sea otters) were an important food resource. Native Americans probably captured many of these by killing them while these mammals were hauled up on shore. The bones of very young seals and sea lions are common in middens; these were probably the easiest to catch. Some marine mammals were also harpooned at sea. Researchers have also found whale remains in middens It is unlikely that Native Americans killed these large animals, though they undoubtedly ate ones that had washed up on beaches.

How did Native Americans catch these organisms?

Hands

Judging from the astronomical quantities of shellfish found in the middens of California Native Americans, just walking through the intertidal zone and digging things up or prying them off rocks was the most important way to catch dinner. However, hands alone are not very efficient in capturing some of these animals and simple tools were undoubtedly used to speed the process. For instance, it is difficult to pry a large abalone off a rock with bare hands, smashing it with a stone is much more efficient.

Nets

Nets can be an extremely efficient way to catch fishes, and the coastal Native Americans produced a variety of them, each serving a different function. Native Americans used a number of plant materials to form the net mesh. Fibers from surfgrass, nettle, hemp and milkweed (to name a few) were twisted into line suitable for netting.

Dip Net – Dip nets are small nets designed to be lowered into shallow water, then scooped back towards the boat. Dip nets are circular and their openings are reinforced with some kind of inflexible framework. Native Americans probably used various wood frames, often made of willow. While salmon and steelhead were often dip netted from streams and rivers, these nets were most often used to catch small, schooling fishes. As an example, in 1769, Pedro Fages, a Spanish explorer, wrote that the Chumash caught large numbers of small fishes by throwing ground-up cactus leaves in the ocean, then scooping a dip net into the schools of fishes which had been attracted. Various fishes, particularly sardines, herrings and white croakers could be caught with this gear. Large dip nets are used by various peoples throughout the world and are still used to catch squid off California.

Drag Net – Native American drag nets were sack-shaped affairs, sometimes with an opening are much as 8 feet across. The opening was made of particularly thick, tough fibers, so it would stay rigid and not close when the net was towed through the water. The nets were taken to sea, allowed to sink to the bottom, then towed from the stern of the canoe. Drawings of these nets closely resemble the modern-day otter trawl. Native Americans probably caught various bottom-dwelling species, such as white croakers, halibut and sole, species often taken today in trawl nets.

Seine Net – As used by Native Americans, seine nets may have been extremely efficient for catching shallow water, near-shore fishes. The nets were long and deep and had perforated rocks to keep the net bottom near the ocean floor and wood floats to keep the top of the net near the ocean surface. A net was dragged along the bottom by a canoe, then pulled into a circle or perhaps towed towards shore. This was undoubtedly a very effective way of catching large numbers of sardines, perches, queenfish, herring or anchovies.

Hook and Line

Hook and line was widely used by California Native Americans. Because it catches only one or a few fish at a time, hook and line is usually not as effective as nets as a way to catch large quantities of fishes. However, under certain circumstances hook and line was a popular method. For instance, for Native Americans, it was far easier to catch swift-moving open-water fishes, such as bonitos, yellowtails and tunas, with hook and line than with nets. Their nets were relatively small and fragile, while their quarry was fast and strong. Similarly, fishing in kelp beds or on rocky reefs may have been best done with hook and line, because nets were apt to tear in this difficult terrain.

Native Americans fashioned line in the same way that they fashioned netting, by twisting and perhaps braiding long strands of plant fibers. Recent experiments have shown that the line formed by this method was fairly strong, perhaps equivalent to today's 15 or 20 lb. test. This may explain why very few really large fishes are found in middens; neither line nor net was able to haul in the really big ones.

Hooks were made in various ways, using a range of materials. Most commonly, California Native Americans either used shells (most often abalone and mussels) or bone, although one explorer noted that the Chumash around San Luis Obispo used curved cactus spines. To make a shell hook, a roughly circular piece of shell was broken off with a stone and the center of the shell was then drilled out with a chert drill, using water and sand as an abrasive. The exterior was then smoothed to roundness by rubbing on a sandstone shell. At this point, the hook resembled a slim, polished donut. To make it a hook, a second drill was used to break off a small section, giving the remainder the familiar hooked shape. Additional whittling away of shell was sometimes done to produce barbs and a place to attach line. Literally thousands of these hooks have been found in Native American middens and burial sites. Twentieth Century experiments with these hooks showed that they were quite effective in capturing a wide variety of fishes. Bone hooks were made of two pieces, one piece shorter than the other, which were lashed together with twine and tar to form a "v" shape. The longer piece served as the hook shank and the smaller formed the point.

Harpoon and Spear

While similar, harpoons and spears have one major difference. In both cases, a sharp pointed object is thrown at a quarry. With harpoons, the head comes off after striking a prey and is pulled in with a rope; spears stay intact after contact. Both harpoons and spears were used to capture large, surface-dwelling fishes (such as barracuda and swordfish), salmon and steelhead in rivers and such marine mammals as sea otters, harbor seals and sea lions. Harpoon and spear points were commonly made of sharpened rock, wood or marine mammal (often whale) bone. Harpoon arrows, where the head came off the arrow and was retrieved by a line, were also used by some tribes, and may have been a major way of capturing sea otters. It is likely that Native Americans lured fish in toward their boats, where they could be harpooned. One person would hurl a shell or bone lure out from the canoe and retrieve it toward the vessel. When a pursuing fish was within striking distance, a second person would strike at the quarry.

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EFFECTS OF WATER MOVEMENT AND OTHER PARAMETERS ON FISHES AND FISHERIES

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Fishes are extremely sensitive to their environment. If you think about it, a fish's life is divided into only three parts: 1) Eating, 2) Avoiding being eaten, and 3) Reproducing. Everything else is just window dressing for these three activities. What I will do is go through various environmental factors in a fish's life and explain how it might react, and how this impacts a fisherman.

The major environmental factors in a fish's life are: 1) water temperature, 2) water clarity, 3) water motion, 4) water salinity and 5) light levels (both daily and seasonally). These water parameters are caused by six phenomena: 1)currents, 2) waves and swells, 3) time of day, 4) time of year, 5) tides and 6) rainfall. Obviously, some of these phenomena produce more than one effect. For instance, when an El Niño occurs, water temperature rises, but so does water clarity. During storms, waves cause more water motion near shore, which causes sand and mud to be kicked up, resulting in a decline in water clarity. Time of year influences rainfall, light levels, water motion, water clarity, water temperature etc. A full moon produces more light at night, but it also produces larger tides.

Currents are a major factor in a fish's life for a number of reasons. Off California, there are two major currents. First, there is the **California Current**, a cold current which sweeps down the coast as far south as Pt. Conception, then swings offshore. During winter and spring, the California Current is at its strongest and parts of it enter southern California waters. There is also the **Davidson Current**, a flow of warmer water which moves northward from Baja California and primarily bathes southern California and parts of central California during summer and fall. Periodically, there is an **El Niño**, which is a mass of warm water that moves northward from a region near the equator.

How and why do these factors influence fish behavior? Let's take them one at a time.

Water temperature - In any part of the ocean, water temperature is controlled by three major factors: 1) water depth, 2) energy from the sun, and 3) currents. In the case of water depth, the deeper the water, generally the colder it is. Energy from the sun warms the water; during summer there is more energy available than during the winter. Currents also tend to be seasonal in nature. The cold California Current is strongest in winter and spring, and the warmer Davidson Current is strongest in summer and fall.

In addition, the ocean waters near the coast of California are sometimes subject to *upwelling*, a special kind of current. In upwelling, winds help blow surface ocean water away from the coast and cold deep water replaces it. This occurs primarily during winter and spring and may cause a very rapid decrease in temperature. Tides also influence water temperature, because they influence current speed and direction. For instance, as the tide goes out, warm inshore water may be transported offshore. By the same token, incoming tides may bring in cold water. Surprisingly, tides can influence water miles offshore and many hundreds of feet down.

Most fishes are cold-blooded. That is, their body temperature is the same as their environment. This means that the chemical processes in their bodies are greatly influenced by water temperature. When the water is warm, their internal processes tend to speed up. This means they tend to be more active and require more food. On the other hand, when temperatures decrease fishes often slow down and become torpid, they require less energy and they feed less. *Fishes often seek out the temperatures they prefer*.

Changes in water temperature are also often cues for reproduction. Many fishes start to develop eggs and sperm during either spring or fall, when there tend to be either rapid increases or decreases in water temperature. In turn, fishes often change their behavior when they are breeding. For instance, they may migrate to spawning grounds, change their position in the water column or form large schools.

Fishes may also be attracted to particular water temperatures because food may be more available there. For instance, areas where two water masses meet (these are called *oceanic fronts*) are characterized by places where surface water temperature changes very rapidly. During the summer and fall off California, a typical oceanic front may exist perhaps 100 miles from the coast, where the California Current and Davidson Current brush against each other. These areas tend to have large amounts of plankton, which in turn attract small fishes, such as anchovies and sardines, and these attract large fishes, such as tunas and swordfishes.

How might a fisherman use a knowledge of water temperature to increase catches? Many fishermen, particularly those chasing pelagic fishes such as tunas and swordfish, now use satellite images of the California coast which show sea surface temperatures. They look for regions where warm and cold oceanic fronts meet and they fish there. Mako shark and swordfish fishermen know that these species tend to stay on the warmer side of the temperature break, while blue sharks often remain on the cooler edge. This knowledge helps them target makos or swordfish but avoid blues, which are largely unmarketed.

During the 1983 El Nino, California halibut moved northward from southern California into central California following the warm current. Catches of California halibut in central California were higher than they had ever been before, while those in southern California decreased dramatically. In a future El Niño, halibut fishermen who recognized this movement might increase their effort off central California.

Effects of Water Movement – 3

Fishermen from the beginnings of time have recognized spawning aggregations and many have used an increase (or decrease) in water temperature to begin searching for these schools. Herring fishermen in San Francisco Bay harvest fish which come into the Bay to spawn, and their spawning is partially a response to changes in water temperature. Hook and line fishermen, who depend on fishes being hungry, are particularly sensitive to temperature fluctuations. Fishes such as barracuda, will virtually stop feeding when temperatures suddenly drop. In the past, large numbers of barracuda were taken by trolling lures and troll fishermen were acutely aware of temperature changes. Often they did not even try trolling when cold water set in. On the other hand, as temperatures rose, their effort increased.

Fish behavior may also vary with temperature. Swordfish harpooners capture swordfish as they lay on the surface. However swordfish may not come to the surface if water temperatures stay high. Rather, they will stay underwater, where temperatures are cooler. Harpooners may look for cooler water, avoiding too warm conditions.

Water clarity - Water clarity, which is basically how far a fish can see, is dependent on the amount of suspended material in the water. This material may be sediment (sand, mud etc.) or it may be plankton. There are a number of factors which influence water clarity. Tidal action is a major factor. For instance, a patch of clear water offshore can quickly become turbid as a receding tide brings out sand or mud. Similarly, an incoming tide may bring clear offshore water into cloudy nearshore areas. Currents are a major determinant of water clarity. For instance, the waters of El Niños tend to be clear. Upwelled water (water brought up from deep depths to the surface by winds) starts off very clear. However, this water contains huge amounts of nutrients and, within a few days, plankton starts to grow, which makes the water cloudy. Particularly in shallow water, winds and waves stir up the bottom, making the water cloudy. Similarly, periods of calm help the sand and mud to settle out, and water visibility increases. Sediment-carrying river water may cloud the ocean for miles.

Some fishes are attracted to cloudy water, while others tend to avoid it. Small species, such as white croakers, northern anchovies and sardines, often seek out turbid water because it helps protect them from predators. Lobsters are another species that defend themselves against predation by hiding in crevices by day and foraging by night; lobsters prefer to feed in muddy water. For the same reason, some predators, such as salmon and California halibut, may congregate in this water, attracted there by fishes on which they feed. However some species, particularly oceanic ones such as tunas and swordfishes, are usually found in clear waters. These are animals that depend heavily on vision for survival, and they are rarely found in cloudy nearshore waters.

Effects of Water Movement – 4

Fisher folk are keenly aware of water clarity. A good example is salmon trollers. Fishermen know that salmon may be found in turbid water, called “coffee water” or “salmon water.” Trollers will actively seek out these conditions to find fish. It is likely that salmon are attracted to “coffee water” because their foods, anchovies, sardines and other small fish, are hiding in this habitat. Tuna fishermen tend to avoid cloudy water and search for “tuna water”, very clear, deep blue water. Gillnetters have found that turbid water is best for capturing their quarry (white seabass, California halibut, angels sharks, thresher sharks etc.). This may be because the nets are less visible in cloudy water. Also, small prey species are usually found in the turbid water, and their presence attracts the larger fish.

Water Motion - Water motion may be seen in a number of phenomena. Currents are large-scale horizontal movements of water caused by prevailing winds. Most currents are relatively slow and most are somewhat predictable. Swells and waves may move water about, usually more in a vertical dimension than in a horizontal one. If you observe a sea gull sitting on the water before, during and after a swell passes, you will see that while it goes up and down a number of feet, it really doesn’t move along the water very much. Tides move great amounts of water inshore and offshore and, as mentioned before, the effects of tides can be seen in water many hundreds of feet down.

Overall, water movement may be the most important influence in a fish’s life, primarily because it controls so many other critical factors. First, fishes have to be able to control their position. If water movement is too intense (say near a beach during a massive storm), many species will move out of the area, into calmer water. This is one of the reasons that smaller or medium-sized schooling fishes (such as white croakers, northern anchovies and Pacific sardines) tend to move away from very shallow water during the winter. They are at a disadvantage in turbulent conditions. By the same token, their predators (such as California halibut or white seabass) probably could withstand the rough, winter conditions, but they too move offshore following their food supply.

During the fall, lobsters are found in shallow water, often in depths of only a few feet. But as winter storms batter the coast, the water near shore becomes rough and lobsters move offshore. Lobster fishermen often start the season in the fall by setting their traps in shallow water, but they know that as the season progresses they will likely have to set them deeper.

On the other hand, some fishes seek out rough water because their food may be exposed or at a disadvantage there. California halibut sometimes congregate at the mouths of estuaries, where currents can momentarily disorient small fishes. A number of fishes inhabit the surf zone, right in the largest waves, where they pick off those sand crabs that have been exposed by the surf.

Effects of Water Movement – 5

Currents also can bring in or take away food, particularly for those fishes (such as Pacific herring and Pacific sardines) that eat plankton. Nutrient-rich upwelled water contains high concentrations of plankton and these fishes will concentrate in areas of upwelling. When the upwelling stops, this current and the plankton dissipate, and the fishes move on. An even more striking example is an El Niño current, which contains very little plankton and may bathe hundreds of miles of California coast. When this occurs, fishes may not find enough to eat, causing their growth to slow and their reproduction to be impaired. If plankton-eating fishes move out of an area or do not reproduce well due to lack of food, this in turn has a negative effect on larger predatory fishes.

Currents have a profound effect on reproduction. Many fishes spawn near the surface to take advantage of currents. First, the currents take the eggs or larvae away from the immediate vicinity, which is often a place where there are many organisms waiting to eat the newly-spawned animals. Second, the currents may carry the young to nursery areas, where more food is available. What happens is that currents vary between years, in speed and direction, and in some years the young are carried where they should be and in others they are not. Thus, some years produce lots of young fishes and other years do not.

Reef fishes often station themselves at the up-current side of the reef, in order to be the first predators to get a crack at whatever food is carried onto the reef by the current. Thus, often there will be a school of fishes on one end of the reef, but few on the other. In turn, the species which prey on these fishes may concentrate on the up-current end.

Water motion also influences both temperature and water clarity. Currents bring with them warmer or colder water and water of different clarity.

Tides – An incoming tide may bring in clear offshore water, while an outgoing one may carry sand or mud and cause increased turbidity. Salmon trollers sometimes find that the salmon bite changes with the change of tide. Perhaps this is due to sudden changes in water clarity.

Fishermen pay close attention to water movement and often take advantage of the way that fishes respond to it. For instance, California scorpionfish are a popular food fish in southern California. Some fishermen have noted that, while this species normally lives on the bottom, during the night from June to September it predictably comes to the surface to spawn, probably to take advantage of the currents. These fishermen know the scorpionfish spawning grounds and fish for them at night, at the surface.

Effects of Water Movement – 6

Fishermen are often keenly aware of the inshore-offshore movements of fishes and invertebrates and these movements are often associated with increased swells and turbidity inshore during winter. As mentioned before, winter storms seem to drive lobsters into deeper water, as well as small schooling fishes and their predators. Halibut fishermen may quit fishing in shallow water as soon as storm-driven heavy swells hit a beach. Not all fishes seem to be influenced by intense water motion, however. Fishermen report that swordfish will often stay right at the surface and catches will remain good even in very heavy seas and high winds.

Water salinity – In most of the ocean, salinity is fairly constant. For this reason, most fishes have very little tolerance for changes in salinity. Only at the mouths of rivers and streams does salinity vary, and it varies with the time of year and distance from the mouth. The high water period, usually in winter and spring, brings with it increased runoff and increased water flow. In these circumstances, the freshwater plume is greater and extends to sea farther. In many circumstances, marine fishes are driven away from low salinity environments and fishermen may avoid them. However, there are some instances when the opposite is true. California halibut are often more abundant around river and stream mouths, and fishermen will often seek out these sites when pursuing halibut. The halibut are probably there because ocean waters around river mouths are typically cloudy from river sediment and stirred up bottoms. As mentioned before, cloudy water attracts white croakers, northern anchovies etc. and the halibut are attracted to these prey.

Light levels – Light varies greatly in the ocean. First, light only penetrates a relatively short distance into the water. Below about thirty feet, red light does not penetrate and by about 400 feet all that remains of the color spectrum is green and blue. By 1,000 feet, even that light from the sun is gone. Second, the amount of light available to organisms is dependent on the turbidity of the water. Water clarity is discussed above, but basically the more material in the water (sand, mud, plankton etc.), the more light will be scattered or absorbed, and the darker the water will be. Third, moon phase is a major factor in influencing light levels; full moons produce considerable light, while new moons produce relatively dark nights. Light levels also change with time of day and with time of year.

Fishes are very sensitive to light and often link their behavior to light levels. Many fishes are most active during the *crepuscular* periods, that is at dawn and dusk. That is when they tend to feed most readily and often school most tightly. However, some species are *diurnal* (most active during the day) and some are *nocturnal* (active at night). Seasonal light level changes (lengthening light periods during spring and shortening periods during fall) are also one of the cues marine organisms use to begin migrations and to reproduce.

Effects of Water Movement – 7

A knowledge of fish behavior as it is influenced by light levels is often crucial to successful fishing. For instance, during the night anchovies often swim about individually or in small groups. During this time they are not easy to catch in quantity by purse seine or lampara nets. However, just as light levels begin to increase with dawn, the fish school up and are most susceptible to capture. Fishermen know that this period may be quite limited, because when the sun comes up the anchovy schools may travel into the kelp beds or swim downward, both activities making them virtually impossible to catch.

Gillnetters have found that white seabass can often see a gillnet in the daylight and on very dark nights. On dark nights the bioluminescence in the water (produced by certain planktonic organisms) causes the net to glow and the seabass avoid it. However, when the moon is full, the moonlight counteracts the glow and helps decrease the net's visibility. Seabass also tend to be caught in gillnets more readily at dawn and dusk, probably because the fish are actively feeding then and do not notice the net. The periods around the new and, particularly, full moons seem to produce the best fishing in many fisheries. Fishermen may set more nets or spend more time fishing during these periods.

Opposite from seabass, swordfish catches are often lower during the full moon, peaking when nights are darkest. Salmon trollers sometimes catch fewer salmon during the days following full or nearly full moons, perhaps because the fish are feeding at night and are not hungry during the day.

Sometimes feeding fish are actually less susceptible to capture. For instance, California halibut draggers have found that, in general they catch more fish during the day, because halibut often feed at night. However, on those occasions when the fish feed during the day, night catches increase. Observant fishermen note these occurrences and alter their fishing efforts accordingly.

INDUSTRY CHALLENGES

Recently, all aspects of the food production industry, including agriculture, aquaculture and commercial fishing, have come under increased scrutiny. Various agricultural practices, such as pesticide use and irrigation techniques, have raised concerns. Some observers have suggested that aquaculture (fish and shellfish farming) may lead to increased water pollution, the spread of aquatic diseases and products high in antibiotics or other contaminants.

Commercial fishing has not been exempt from its share of the debate and here are some of the issues that have been raised.

Fisheries Management

The commercial fishing industry of California has changed greatly in the past 100 years and no more so than in the regulations governing its practices. At the beginning, all fishermen needed were vessels and a net (or trap or hook and line) and they were ready to fish in California waters. Over time, with the development of modern, more efficient fishing tools, both fishermen and fishery managers realized that some restrictions had to be placed on fisheries in order to insure their survival. Today, myriad laws govern commercial fisheries. These regulations cover who can participate in the harvest, how the resource can be captured, when and where the fishery should occur, and how many and what size the harvested species must be. California's commercial fishermen must be familiar with more than 75 pages of commercial fishing laws, in addition to those that govern any specific "limited entry" fisheries in which they fish.

Below, we present examples of fishery management techniques.

Gear restrictions and ***gear prohibitions*** are commonly placed on the use of fishing gear to decrease its efficiency — in other words, to reduce its effective catch rate to conserve the resource and protect against overharvesting. One example of a gear restriction is limiting the amount or length of gillnet that can be deployed by one vessel in a specific fishery (e.g. not more than 1,000 fathoms, or 6,000 feet, of gill or trammel net may be fished in combination each day for California halibut in southern California). Minimum mesh size is another form of gear restriction mandated to select the size of fish caught, thus minimize the harvest of undersize or immature fish (e.g. minimum mesh size for halibut is 8.5" measured between knots, which selects for mature halibut measuring more than 22 inches total length, the minimum size for this fish). One example of a gear prohibition: the California Fish and Game Code prohibits the capture of white seabass and barracuda with purse seine nets.

Closed seasons and ***closed areas*** are often, though not always, combined. The goal of limiting fishing periods or fishing areas is often to limit the catch or to allow mature fishes to spawn. If certain species have well-defined nursery grounds, where young fish are particularly common, closures may also be implemented to protect juveniles. In California, many species are managed via closed seasons, primarily to protect spawning individuals. For example, the harvest of spiny lobster is prohibited from mid-March through early October. The swordfish/shark driftnet fishery is closed within 25 miles of the coast from mid-December to January 31 and is closed completely from February 1 to mid-August to protect thresher shark.

In some fisheries, *quotas* (catch limits) may be set, either throughout the species' range, within a particular population, or even in a specific area. When the quota is met, the season closes. Fishery managers try to set quotas that allow fishermen a reasonable catch while preserving the fishery resource. Because most fish populations undergo

large, natural (and often somewhat unpredictable) swings, setting a quota can be a maddening task for managers and a frustrating experience for fishermen. For instance, there have been numerous cases in salmon fisheries where managers predicted low numbers of fish for a coming year and set small quotas, only to see large numbers of fish return to their spawning grounds. In California, the Pacific herring fishery is governed by a quota, which is set annually by the Department of Fish and Game.

Trip limits, catch quotas per individual fishing trip, may also be instituted. As an example, the groundfish (rockfish, lingcod, flatfish etc.) trawl fisheries off the Pacific Northwest and California have overall poundage quotas for various species; when any one of these is filled, the fishery for that species ceases for the year. Within this fishery, vessels are only allowed to harvest a certain amount of fish per trip, and the number of trips per week or month also is regulated. The main purpose of trip limits is to extend the season over a longer portion of the year.

Minimum size limits are often established and there are several reasons for creating these restrictions. Sometimes they are instituted to ensure a reservoir of mature individuals to help stabilize or increase the resource biomass. Creating minimum size limits insures that a viable portion of the resource survives to reproduce at least once. In other instances, a species only becomes marketable when it reaches a certain size, and minimum size requirements foster a more marketable resource. There are a number of ways to prevent small individuals from being taken in a fishery. In the dive fisheries for sea urchins and abalone, fishermen can see their quarry before harvest and can measure their catch directly. Allowing escapement of undersized organisms is a common technique and this is often based on gear restrictions, most commonly by setting minimum mesh sizes for nets and mandating escape ports in traps. About 35 commercial species fished in California waters are regulated by size restrictions.

Restricting access to a fishery through ***limited entry*** is a relatively recent management technique. In limited-entry fisheries, either the right to fish, or the quantities of resource available to an individual fisherman, are restricted. License limitation is a common limited-entry technique. Under this program, the number of vessels allowed to participate in a fishery may be limited (e.g. salmon) or the number of fishermen may be restricted (e.g. urchin divers). In California, most commercial fisheries are regulated through the Legislature, although a few fisheries are regulated by the Fish and Game Commission. A new fisherman may enter a limited-entry fishery through a lottery (sea urchin fishery), by buying a permit (gillnet), or by buying a vessel with a permit (salmon troller).

Another limited entry method receiving attention worldwide is ***catch rights.*** The most common version is called an ***individual transferable quota*** (ITQ) or ***individual fisherman's quota*** (IFQ). Under this method, fishermen receive certificates, representing the right to catch and sell a share of the total allowable catch (TAC). The TAC for each year is set by fishery managers and may vary with fluctuations in the resource. Usually ITQ's are transferable (can be sold, bought, or leased) and they can be assigned to fishermen for a specific time period (annually, for instance) or in perpetuity. Currently ITQ's are not utilized in California fisheries, although federal resource managers are considering adopting ITQ's for specific groundfish species. (References: Gulland and Carroz 1968, Waters 1991, Boyd and Dewees 1992)

Incidental Catch vs. Bycatch and Discards

Most fisheries catch a complex of species in a typical trip (e.g. groundfish). Fishermen targeting a single species (e.g. salmon) often catch other species incidentally (rockfish, for example). Many times this "incidental catch" is marketable and forms an important part of the fisherman's catch, providing additional revenue to offset the cost of the fishing trip. Many new and delicious seafoods have been discovered by experimental marketing of "incidental" species. For example, angel shark, popular fish and chips fare, are sometimes caught when gillnetting for California halibut. Before markets were developed, fishermen returned these fish to the sea alive as a "bycatch."

In commercial fisheries, bycatch is defined as that part of the catch that cannot be marketed. This may because these organisms are inedible, too small, currently have no market, or are illegal to possess. Bycatch may be returned to the sea alive; utilized for personal use to feed crew and family; or used as bait to catch other seafood species. Bycatch that is dead may also be returned to the ocean as a discard, where it becomes "free lunch" for opportunistic sea creatures. All fisheries have some bycatch: this varies between fisheries, and even varies within a fishery, changing with season, location and slight differences in fishing gear. Fishermen try to reduce bycatch by changing fishing locations or times, or altering their fishing practices.

Probably the best-known example of a fishery bycatch is that involving yellowfin tuna *(Thunnus albacares)* and various dolphin species. This bycatch occurs largely in the eastern tropical Pacific Ocean (ETP), an 8,000 square mile area roughly bounded by southern Baja California on the north, Peru on the south and out to sea several thousand miles. In these waters, adult yellowfin tunas aggregate under herds of dolphins, swimming juxtaposed in the warm tropical waters. A similar relationship between yellowfin and certain mammal species has been observed worldwide but is particularly notable in the ETP, which provides about 25 percent of the world's canned tuna supply as it is the site of the world's largest yellowfin tuna fishery Why this symbiotic relationship exists is not precisely known, although recent research suggests that the tuna follow the dolphins because the mammals are better able to find the fishes and squids that both species feed on.

In the ETP, the commercial fishery began close to shore about 1919 with pole and line vessels from California. These small boats were called bait boats because they relied on bait found near shore to attract tuna. Fishermen chummed the water, then individually poled the attracted tuna aboard with jigs attached to poles. With improvements in nets, vessels, and net retrieval technology, purse seining (encircling a fish school with a round-haul net) became a far more efficient technique for harvesting these fast-moving, schooling fish. Fishermen recognized that large yellowfin schooled with dolphins farther offshore and, because these mammals leap out of the water, that dolphins were easier to find than the tuna. The purse seine net allowed fishermen to follow the large fish further out to sea, which was impossible when the fishery relied on bait. Scientists also discovered that the dolphins associated with mature tuna stocks; thus by concentrating on dolphin-associated fish, fishermen could increase fishery production without impacting inshore stocks of juvenile tuna.

The purse seine net was introduced in 1957, but the technology had a drawback: unfortunately, when the dolphin-tuna aggregations were enclosed, some of the mammals became trapped in the nets and died. Fishermen, who relied on dolphins to locate fish, realized that these dolphin mortalities were unacceptable (both for humanitarian and ecological reasons) and began experimenting with ways to reduce the problem.

Two of the major advances in reducing dolphin mortality were developed by tuna fishermen. The first was a procedure created in 1957 by Anton Misetich, called the "backdown." In this procedure, the top of the deployed purse seine is intentionally pulled underwater, allowing dolphins to swim over the top of the net and escape. The second advance was the placement in the nets of "Medina panels," developed by Harold Medina. Constructed of fine mesh webbing, Medina panels sewn into the upper part of the purse seine net protected dolphins from becoming tangled.

Over the years, teams of fishermen and scientists have further developed techniques to minimize dolphin mortality in the tuna fishery. Backdowns, Medina panels, advanced skipper training and numerous other techniques springing from research and workshops have been adopted as regulations in the Marine Mammal Protection Act, which was first passed by Congress in 1972 and has since governed U.S. tuna fleet operations in the ETP. (The international tuna fleet fishing in the ETP is supervised by the Inter-American Tropical Tuna Commission, a scientific group which has been very successful at introducing U.S. techniques to foreign fishermen.) These measures have dramatically reduced dolphin mortality in the ETP. For many years, the U.S. tuna fleet has achieved a notable dolphin safety record: more than 99 percent of dolphins encircled are released alive.

In 1990 U.S. canners adopted a "dolphin-safe" policy, refusing to buy tuna caught in association with dolphins. In 1992 Congress also passed the Dolphin Protection Consumer Information Act; canneries may now label their tuna "dolphin safe" if it is not caught by driftnets on the high seas or by encirclement of dolphins in the ETP. However, an extensive study on dolphins and the tuna industry sponsored by the National Research Council concluded: "the committee was unable to identify any currently available alternative to setting nets on dolphins that is as efficient as dolphin seining for catching large yellowfin tuna…"

Indeed, some environmentalists and researchers, in addition to fishermen, have begun questioning the wisdom of the current "dolphin-safe" policy. This policy prohibits a catch from being labeled dolphin safe if only one dolphin is encircled, even if it is released unharmed. The prohibition on setting on dolphin has forced fishermen to shift to setting on tuna aggregated under logs or other floating objects. "Log fishing" has produced a 30 percent bycatch rate of juvenile tuna, other fish, and even marine turtles. Scientists estimate that if the entire fleet in the ETP were to fish this way, yellowfin production would be reduced by 30 to 60 percent. Most likely there would be an equally significant impact on bycatch species. Many observers now believe that the most balanced approach is to permit setting on mature tuna associated with dolphin, but to require the use of the best technology and training available, thus minimizing dolphin mortality. Fishermen have suggested that "dolphin safe" be redefined to mean any catch where 100 percent of the involved marine mammals are released unharmed.
(References: Pleschner 1990; Edwards 1992; National Research Council 1992; Kronman 1992; Freeman 1993)

Gillnets

There is a tremendous amount of confusion and misunderstanding concerning gillnets. These are nylon or monofilament nets of many different dimensions and characteristics, which are hung much like a curtain. Gillnets may either drift in the water column, usually attached to the boat, or they may be set, anchored on the ocean bottom. Fish in the area swim into the nets and are caught, usually around their midsection (the term "gillnet" is actually a misnomer). The advantage of gillnets is that they can be regulated to control the size of fish caught, thus targeting mature fish. In fact, gillnets are among the most size-selective of fishing gears. Moreover, they catch fish consistently, even when the fish aren't hungry. In hook-and-line fishing, the fish must be lured into biting a hook, and oftentimes for reasons of their own, the fish don't bite. Used properly, gillnets are a relatively inexpensive and efficient way to provide a consistent seafood supply yearlong. In California waters, there are as many as nine different gillnet fisheries, each of which targets a specific species complex. Eight of these fisheries operate near shore and the ninth, the swordfish/shark driftnet fishery, ranges up to 200 miles or more out to sea.

Many of the problems associated with gillnets are linked to observations and reports of excessive bycatch and unregulated fishing by foreign high-seas driftnet fleets. In contrast, California's gillnet fisheries are among the most strictly regulated fisheries in the world.

The gillnet controversy began several years ago when foreign high-seas drift gillnet fleets from Japan, Taiwan, and Korea escalated operations in the North and South Pacific, fishing for squid and albacore tuna. These fleets deployed small-mesh nets up to 15-20 miles in length, typically set right at the ocean surface, and incurred a large bycatch of seabirds, marine mammals and turtles, as well as salmon returning to spawn in the Pacific Northwest and Alaska. Large-scale driftnetting in international waters has since been prohibited by the United Nations.

Driftnetting off California is a very different endeavor from foreign high-seas practices; it has developed in ways to minimize bycatch. For example, swordfish/shark driftnets are hung suspended so the top of the net is 12 to 60 feet below the ocean surface, depending on water temperature. Most interactions with marine mammals and birds occur at the surface. Similarly, to protect migrating gray whales, California fishermen lobbied successfully for a law prohibiting the use of swordfish/shark driftnets within 25 miles of the coast during the whales' peak migration period. (Bottom-set gillnets deployed near shore are prohibited within one mile of headlands during this time, and the nets must be constructed with breakaway panels.) To minimize the bycatch of smaller fish and blue sharks (a species largely unmarketed), fishermen increased the mesh size of swordfish/shark drift nets to 22 inches — nearly as wide as an open car window.

The California Department of Fish and Game (DFG) closely regulates all of California's gillnet fisheries. Besides the driftnet fishery for shark and swordfish, there are seasonal driftnet fisheries for white seabass, yellowtail and barracuda, and set-net fisheries for rockfish, white seabass, white croaker, flying fish, and an inshore complex that includes California halibut, angel shark, and several other shark species. A six-year study by the DFG on California's gillnet fisheries documented that 83 percent of the catch in the inshore set net fishery was either marketed or released alive. Many inshore gillnetters utilize their entire catch, reserving their unmarketable species for crab bait, which otherwise costs $.15 per pound or more. (Crab fishermen typically use 10 pounds of bait per trap per week, and many fishermen deploy 100 to 200 traps.)

Regarding ***marine mammals in gillnets*****,** some marine mammals and seabirds do get caught in California's gillnet fisheries, despite precautions. Commercial fishermen make concerted efforts to avoid marine mammals whenever possible, but the mammals have learned to fish the nets (and hooks), and sometimes get caught in the process.

Over the years, gillnet fishermen have cooperated with DFG and the Legislature to implement closures and gear restrictions (such as breakaway panels, for instance) to protect sensitive areas and creatures. Nearshore closures on the central coast and in the San Francisco area to protect sea otters, harbor porpoise and seabirds resulted in the elimination of the halibut fishery in those areas. Coastal gillnets in southern California have virtually no interactions with otters, harbor porpoise or seabirds. Of the eight types of nets utilized near shore, only one, used in the halibut fishery, has had periodic interactions with marine mammals, primarily California sea lions and harbor seals.
In 1990, California voters passed Proposition 132, which phased out all coastal gillnets in state waters of southern California (within three miles of the mainland and one mile of offshore islands) by 1994. This action curtailed local supplies of several popular fish, including California halibut and white seabass.

In addition to DFG regulations, the federal National Marine Fisheries Service (NMFS) has placed observers on California's inshore halibut set net fishery and the offshore swordfish/shark driftnet fishery to monitor the interactions with marine mammals and other marine life, and has required all other fishermen to report any mammals killed accidentally in the course of fishing. (Federal laws exact a $10,000 fine per incident for deliberate harassment or killing of a marine mammal.) The effectiveness of these laws, among other measures, can be seen in the fact that many marine mammal populations in California are approaching or have exceeded historic population levels in the presence of gillnets. This is especially true for gray whales, elephant seals, California sea lions, and harbor seals. Harbor porpoise and sea otter populations also are healthy and increasing. According to marine mammal scientists, there is no evidence that the relatively small number of marine mammals taken in California's gillnet fisheries is having a detrimental effect on their populations.
(References: Pleschner 1990, 1991; Vojkovich et al. 1990; Hanan et al. 1992; Jameson 1993)

Ghost Nets

Ghost nets usually refer to gillnets which have been lost and, in theory, keep fishing. Netting may be lost due to extreme sea conditions. However, these are expensive pieces of equipment (gillnets cost several thousand dollars apiece) and fishermen take pains to ensure that their equipment does not get lost. More to the point, there is no scientific evidence that ghost nets continue fishing.

Gillnets must be anchored at both ends to stay open and effectively catch fish. This is why set nets are deployed with heavy anchors at each end. Driftnets are deployed with a buoy at one end and the other end is usually attached to the vessel (or to another buoy). This tension holds the net open. When gillnets are no longer held in place by anchors or vessels, they tend to deform quickly, balling up into heaps of webbing. Few fish can be trapped by these masses of material.

Marine mammal interactions with fisheries

Marine mammal populations in California are healthy and expanding in part as a result of protection from hunting and the cooperation of fishermen in developing low-impact fishing techniques. However, increasing populations of marine mammals, specifically California sea lions, harbor seals, and increasingly, sea otters, have created many problems for fishermen.

At heart, commercial fishermen, recreational fishermen, and marine mammals are competitors for many of the same resources. But whereas fishermen are regulated, marine mammals are not — in fact, they are fully protected under the MMPA. Federal law does not allow management by resource managers who are mandated to conserve a balance of resources. Accidental entrapment is only one of the interactions that occurs between marine mammals and fishermen. Seals and sea lions are intelligent animals that quickly learn to associate fishing vessels with "free lunch." Sea lions have been documented following a fishing boat for hours, waiting for the fisherman to pull his catch. Gillnetters often retrieve their gear to find only fish heads. This problem is particularly acute in southern California, where marine mammal rookeries and haul-outs now extend throughout all the northern Channel Islands and increasingly along the mainland coast. Rookeries and haul-outs also are expanding at Año Nuevo and the Farallon Islands, in northern California. Gillnet and hook-and-line fishermen report that their only relief from seal and sea lion predation is in early springtime, during breeding season.

A classic example of the resource conflict between marine mammals and man involves the sea otter, *Enhydra lutris*. Hunted to near extinction during the 1800's, small remnant populations survived in Alaska and along the central California coast. Protection from hunting under international treaty, state law, and finally the federal Endangered Species Act, where California sea otters were listed as "threatened" in 1977, allowed this species to grow and, in Alaska, to reoccupy much of its historic range. Today there are more than 150,000 sea otters in Alaska and the Aleutians, growing colonies in British Columbia and Washington State, and more than 2,000 off the central California coast extending from Pt. Año Nuevo in the north beyond Pismo Beach in the south.

Sea otters are extremely efficient predators, feeding primarily on large shellfishes such as sea urchins, abalones, crabs, and clams. Lacking a fatty layer of blubber, otters rely on dense fur and a high metabolism to stay warm. California sea otters spend most of their time in the chill Pacific Ocean, rarely coming ashore, and they consume 25 percent or more of their body weight daily: a typical adult male consumes more than two tons of shellfish per year (this is muscle material, not counting shell weight).

Among few tool-using animals, sea otters are quite flexible in their feeding behavior, capable of smashing abalone open with a rock or digging three feet down in the mud to capture clams. Otters are able to forage in waters from the intertidal zone down to depths of 300 feet. Numerous studies have documented the impact of sea otters on shellfish resources: otters quickly reduce exposed shellfish numbers to very low levels. In Alaska, overpopulation of sea otters at Amchitka Island in the 1960's resulted in starvation and a die-off, prompting biologists to "translocate" animals to other areas with abundant shellfish reserves.

In California, the near absence of sea otters in the early 1900's enabled shellfish resources to rebound. California sea otters were "officially" rediscovered in Monterey in 1938, coinciding with the decline of Monterey's abalone fishery. By the 1960's sea otters had expanded into rich abalone beds north of Morro Bay: Morro Bay's abalone fishery collapsed in the early 1970's. As the sea otter population has grown, subdominant and juvenile male otters, pushed to the edges of their established range, form"migrant fronts" and colonize new areas where food is abundant. In this wave like fashion California sea otters have increased their range.

Sea otters have been documented as a primary cause for the collapse of several fisheries, including a Dungeness crab fishery in Prince William Sound, Alaska; the red abalone fishery off central California; and the recreational Pismo clam fishery at Pismo Beach. In the Pismo Beach area alone, sea otters were estimated to eat 80 clams per otter per day, consuming an estimated 700,000 clams in one year. Sea urchins also are one of the otter's preferred foods, and continued sea otter expansion jeopardizes the future of a major sea urchin fishery both north and south of the current sea otter range. In fact, sea urchins are now California's top valued fishery.

The controversy over sea otters and shellfisheries has continued since the early 1950's. In 1986, in an effort to achieve a balance between sea otter protection and important shellfisheries, Congress passed an amendment to the Endangered Species Act, enacted as Public Law 99-625, that authorized a "zonal management" system in southern California as part of a translocation of otters to San Nicolas Island, the outermost island in the Channel Island chain. Sea otters were protected at the island and in their central coast range, and a management zone was established throughout the rest of southern California south of Point Conception. PL 99-625 mandated that any otters found in the management zone were to be relocated by federal and state biologists, employing all feasible nonlethal means. The continuation of PL 99-625 now is uncertain, as federal biologists seek to abandon the management zone (state biologists disagree). Biologists and others now acknowledge that continued sea otter expansion into northern and southern California will eliminate fisheries for abalones, sea urchins and clams, and will adversely affect, if not eliminate, fisheries for crab and spiny lobster.
(References: Miller 1974; Calkins 1978; Pleschner 1984; Wendell et al. 1986; Booth 1988)

Seafood Safety

Americans are increasingly asking questions about the safety of our food, and the rising popularity of "organically" grown produce attests to this growing awareness. Concerns have also risen regarding seafood. In particular, consumers want to be assured that the seafood they eat is wholesome, of good quality, and does not contain hazardous levels of chemical contaminants.

Chemical contaminants may be of two types, natural and man-made. The major natural toxins (biotoxins) are produced by microscopic marine algae, which may be assimilated by filter-feeding bivalve shellfish (oysters, clams and mussels). Concentrated levels of these biotoxins do not harm the shellfish but in humans they can cause paralytic shellfish poisoning (PSP) or amnesiac shellfish poisoning (ASP). PSP in humans is uncommon in California waters and there is no record of any person contracting ASP in this state. The California Department of Health Services tests all of California's shellfish growing areas every week for marine biotoxins, and all harvesters and growers must obtain a certificate from the CDHS prior to harvest.

Pollutants such as various pesticides (e.g.. DDT), industrial chemicals (e.g. PCBs) and such heavy metals as mercury also have caused concerns. These contaminants may enter fishes and shellfishes in several ways. Small amounts are absorbed by these organisms directly from the water through their gills and other tissues. However, most of the pollutants found in aquatic organisms arrive there through the food chain. First, these materials are absorbed by phytoplankton, bacteria, fungi and other small organisms. In turn, these are eaten by larger animals, eventually ending up in the organisms we eat.

California has a wide range of agencies that monitor the marine environment, both the water and the organisms. At the state and federal level, the agencies responsible for this oversight include the California Department of Health Services, Department of Fish and Game, California Environmental Protection Agency, Water Quality Control Board and the National Marine Fisheries Service. At the local level, some sanitation districts also monitor fishes.

How serious a problem is pollutant contamination in California marine seafood? In general, pollution is not considered a significant problem in California's commercially-harvested seafood. One exception came to light in a major study of fishes from southern California (Office of Environmental Health Hazard Assessments, 1991). This research showed that, of important commercial fishes, white croakers from a limited area off southern California (around Santa Monica Bay) should not be consumed. Commercial fishing in Santa Monica Bay is now prohibited. The fishing industry works closely with health agencies to safeguard the ocean and California's seafood supply.

Habitat Degradation

One of the most difficult problems a commercial fisherman faces is the loss of marine resources due to environmental degradation. Water pollution (from pesticides, oil spills, heavy metals, etc.) and the outright destruction of habitat have had a profound effect on the animal life in our ocean. Often this effect is subtle. Rarely, for instance, are there massive kills of fishes or shellfishes off California. More often, environmental alteration acts to reduce the number of larval or juvenile organisms that survive to adulthood. A good example is the California halibut (Paralichthys californicus). After hatching from eggs, larval halibut spend about one month drifting in the nearshore surface waters along our coast. When they are ready to settle out and take up a bottom-dwelling existence, these little fish search for quiet, calm back bays and estuaries, where they live for one or more years. Very few young halibut live on the open coast. Unfortunately, over the last 100 years, most of these coastal embayments have been destroyed, either filled in for housing and businesses or dredged for marinas. Undoubtedly this has decreased the number of California halibut which survive to become adults.

However, in at least one case, commercial fishermen are taking the lead in reversing decades of environmental abuse. California's salmon populations have declined drastically and this has occurred from a variety of causes. Among the leading abuses are poor logging practices which cause erosion and burying salmon spawning grounds, gravel mining which removes spawning gravel beds, and water diversion which lowers water levels and raises water temperatures. Beginning in 1978, commercial salmon fishermen began to tax themselves, creating the Salmon Stamp Program. All of this money, now totaling millions of dollars, goes to restoring salmon populations.

Some of the money has gone into capturing salmon that have entered the once-productive San Joaquin River. This was once a major salmon river, but dams, water diversion and other environmental alterations have created a system with almost no spawning habitat. Salmon which do enter this system usually die without reproducing. Eggs and sperm from these fish are removed, the eggs hatched and the larvae raised in hatcheries. To improve survival rates, the young salmon are often trucked downstream. Research has shown that an estimated 500,000 additional salmon have been added to the fishery through these efforts, and some 250,000 have returned to spawn either at hatcheries or into several Central Valley streams.

But salmon fishermen do more than just donate money towards salmon enhancement; they also donate their time. A good example is the Eel River Salmon Restoration Project, formed by salmon trollers in 1983. This volunteer group focused on improving the habitat of a number of salmon streams in northern California by repairing years of damage done to them. Erosion caused by logging and other activities, is a major problem because it promotes sediment runoff that covers the gravel in which salmon spawn. Trollers planted trees on stream-side hills and removed piles of dirt and tree debris left in abandoned logging areas. Metal culverts, used as bridges in some streams, are also a problem because they impede fish movement. Fishermen removed those that were not needed and, in one case, even built a new bridge to replace a pipe that was still necessary. Many streams have few pools for fish to rest in, and fishermen spent considerable time narrowing stretches of streams, which increased water flow and scoured out new pools. In some cases, fishermen even put new gravel into old spawning areas which had lost this material.
(References: Hashagen 1987, Pleschner 1990b)

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