

Abalone

Description

Abalones are members of a large class (Gastropoda) of molluscs having one-piece shells. They belong to the family Haliotidae and the genus *Haliotis*, which means sea ear, referring to the flattened shape of the shell.

Abalone shells are rounded or oval with a large dome towards one end. The shell has a row of respiratory pores. The muscular foot has strong suction power permitting the abalone to clamp tightly to rocky surfaces. An epipodium, a sensory structure and extension of the foot that bears tentacles, circles the foot and projects beyond the shell edge in the living abalone. Nine species of abalone occur in North America: black (*H. cracherodii*), flat (*H. walallensis*), green (*H. fulgens*), pink (*H. corrugata*), pinto (*H. kamtschatkana*), red (*H. rufescens*), threaded (*H. assimilis*), Western Atlantic (*H. pourtalesii*), and white (*H. sorenseni*) abalone.

Black abalone (*H. cracherodii*) have black and smooth epipodium and tentacles. The shell surface is black or dark blue, and smooth. There are 5 to 9 open pores, and the pores are flush with the shell surface. Black abalone range from Mendocino County, California to southern Baja California. They are found in intertidal and shallow subtidal zones down to a depth of about 20 feet. Black abalone reach 7.75 inches in length, but are commonly 5 to 6 inches long.

Flat abalone (*H. walallensis*) have a mottled yellowish and brown epipodium, with a pebbly appearing surface and lacy edge. The tentacles are greenish and slender. The shell is flattened, narrow, and marked with low ribs. There are 5 to 6 open pores, and the pore edges are moderately elevated above the shell surface. Flat abalone range from British Columbia, Canada to San Diego, California. They are found in the subtidal zone from 20 feet down to at least 70 feet. Flat abalone reach 7 inches in length, but are commonly under 5 inches.

Green abalone (*H. fulgens*) have a mottled cream and brown epipodium, with tubercles scattered on the surface and a frilly edge. The tentacles are olive green. The shell is usually brown, and its surface marked with many low, flat-topped ribs that run parallel to the pores. There are 5 to 7 open pores, and the pore edges are elevated above the shell surface. A groove often parallels the outer edge of the line of pores. Green abalone range from Point Conception, California to Bahia Magdalena, Baja California. They are found in the intertidal and subtidal zones down to at least 30 feet. Green abalone are often found in crevices where surfgrass and algal cover is dense. They reach 10 inches in length, but are generally smaller.

Pink abalone (*H. corrugata*) have a mottled black and white epipodium with many tubercles on the surface and a lacy edge. The foot is yellow to light orange. The tentacles are black. The shell is thick and its surface is marked with wavy corrugations. There are 2 to 4 open pores, and pore edges are strongly elevated above the surface. Pink abalone range from Point Conception, California to Santa Maria Bay, Baja California. They are found in the subtidal zone from 20 feet down to at least 120 feet, commonly in beds of giant kelp. Pink abalone reach 10 inches in length, but individuals over 7 inches long are now rare.

Pinto abalone (*H. kamtschatkana*) have a mottled pale yellow to dark brown epipodium, with a pebbly appearing surface and lacy edge. Tentacles are yellowish brown, or occasionally green, and thin. The shell is irregularly mottled and narrow. There are 3 to 6 open pores, and the pore edges are elevated above the shell surface. A groove often parallels the line of pores. Pinto abalone range from Sitka, Alaska to Monterey, California. They are found in the intertidal and subtidal zones down to at least 70 feet. Pinto

abalone reach 6.49 inches in length, but are commonly 4 inches long. Pinto abalone are also known regionally as northern abalone.

Red abalone (*H. rufescens*) usually have a black epipodium, but some specimens have a barred black and cream pattern on their epipodium. The surface of the epipodium is smooth and broadly scalloped along the edge. The area around the foot is black and the sole is tan to grey. The tentacles are black. The shell surface is generally brick red and the inside edge is often red. There are 3 to 4 open pores, and the pores are moderately elevated above the shell surface. Red abalone range from Sunset Bay, Oregon to Tortugas, Baja California. North of Point Conception, they are found in the intertidal and subtidal zones down to at least 60 feet. South of Point Conception, they are found in the subtidal zone down to over 100 feet. Red abalone reach 12.3 inches in length, but are commonly 7 to 9 inches long.

Threaded abalone (*H. assimilis*) have a mottled pale yellow to dark brown epipodium with a pebbly appearing surface and frilly edge. The tentacles are yellowish brown, short and thin. The shell is oval and the surface is marked with prominent ribs interspersed with narrow ones. There are 4 to 6 open pores, and the pores are moderately elevated above the shell surface. Threaded abalone range from San Luis Obispo County, California to Bahia Tortugas, Baja California. They are found in the subtidal zone from 20 feet down to at least 80 feet, commonly on rock surfaces. Threaded abalone reach 6 inches in length, but are commonly smaller. Threaded abalone are considered a subspecies of the pinto abalone by some scientists.

Western Atlantic abalone (*H. pourtalesii*) have a yellowish epipodium with large and small sensory tentacles. The sole of the foot is tan. The shell is reddish-orange. Western Atlantic abalone range from North Carolina through the Gulf of Mexico to Brazil. They are found from 187 feet down to at least 1,200 feet on hard substrates. The largest recorded shell had a length of about 1.2 inches.

White abalone (*H. sorenseni*) have a tan and pebbly epipodium. The sole of the foot is orange. The shell is deep, thin and oval. There are 3 to 5 open pores, and the edges of the pores are elevated above the shell surface. White abalone range from Point Conception to Bahia Tortugas, Baja California. Most white abalone are found in the Channel Islands in California. White abalone are found in the subtidal zone down to at least 200 feet. They are commonly found in open, exposed areas. White abalone reach 10 inches in length, but are commonly 5 to 8 inches long.

Natural History

Abalones reach sexual maturity at a small size, and fertility is high and increases exponentially with size. Sexes are separate and fertilization is external. The eggs and sperm broadcast into the water through the pores with the respiratory current. A 1.5 inch abalone may spawn 10,000 eggs or more at a time, while an 8 inch abalone may spawn 11 million or more eggs. The spawning season varies among species with black, green and pink abalone spawning between spring and fall, and pinto abalone spawning during the summer. Red abalone in some locations spawn throughout the year. The fertilized eggs hatch into floating larvae that feed on plankton until their shells begin to form. Once the shell forms, the juvenile abalone sinks to the bottom where it clings to rocks and crevices with its single powerful foot. Settling rates appear to be variable. After settling, abalones change their diet and feed on macroalgae.

Except for black abalone, hybridization for abalone species is not uncommon in areas where several species occur together. There are 12 recognized hybrids in southern California and northern Baja California.

Limited growth information is available for abalones. Commercial sizes of 6.25 inches for pinks, seven inches for greens and 7.75 inches for reds are reached after a minimum of 10 to 15 years in southern California. Pinto abalone reach about 2.5 inches in a minimum of 6 years.

Juvenile abalones feed on rock-encrusting coralline algae and on diatom and bacterial films. Adult abalones feed primarily on loose pieces of marine algae drifting with the surge or current. Large brown algae such as giant kelp, bull kelp, feather boa kelp and elk kelp are preferred, although other species of algae may be eaten at various times.

Abalone eggs and larvae are consumed by filter-feeding fish and shellfish. Predators of juvenile abalones include crabs, lobsters, gastropods, octopuses, seastars, and fishes. The bat ray in southern California and the sea otter in central California prey selectively on larger abalones.

Production

In decreasing order of total catch between 1950 and 1995, red (46.6%), pink (41.2%), black (8.7%), green (3.5%), and white (>1%) abalones have all been harvested in California. Since 1993, only red abalone have been taken commercially, and the Fish and Game Commission closed all red abalone harvest south of San Francisco in May 1997. Pinto abalone are commercially harvested in Alaska and British Columbia. Flat and threaded abalones have limited distributions and neither is common. The western Atlantic abalone is rare and is not fished commercially.

Aquaculture of red, pink, and green abalones occurs in California. There is limited aquaculture of green and *H. diversicolor supertexta* abalones in Hawaii.

California. The commercial fishery for abalones in California began in the 1850's. Chinese Americans initially harvested intertidal green and black abalones with skiffs using long, hooked poles. This fishery was eliminated in California in 1900 by closure of shallow waters to commercial harvest. Japanese American divers followed the Chinese Americans as the fishery moved to the subtidal zone. Initially, free divers working from barrel floats harvested abalones. Later, hard-hat divers harvested abalones from deeper waters. In the late 1950's, "hooka" gear, which supplied air from the surface to divers using light masks, fins and wet suits, began replacing hard-hat gear. Since the 1970's, multi-hose hooka gear and specialized, high-speed, seaworthy boats have become common in the fishery.

In California, abalone divers must use underwater diving gear consisting of an above-surface air pump operated from a boat and at least 100 feet of air hose, and must be fully submerged while taking abalone. Abalones may be taken only by hand or with abalone irons. An abalone iron is a flat device not more than 36" long and not less than 1/16 inch thick, with rounded smooth edges and a curve with a radius of less than 18 inches. The commercial abalone fishery in California is managed through size limits, limits on the number of permits for commercial abalone divers, and restrictions on harvesting areas. Minimum commercial size limits in California are: 7-3/4 inches for red abalone, 7 inches for green abalone, 6-1/4 inches for pink or white abalone, 5-3/4 inches for black abalone, and 4 inches for pinto, threaded, and flat abalone. Commercial harvesting is prohibited during January, February and August. A moratorium on commercial harvesting of black abalone began in July, 1993, and extends through January 1, 1997. It is unlikely that stocks of black abalone will recover enough for the fishery to reopen. In June, 1994, the California Department of Fish and Game proposed and the Fish and Game Commission adopted effective January 1, 1995 a two-year closure on sport and commercial harvesting of pink, green and white abalone. Prices to fishermen for red abalone were around \$500 to \$600 per dozen in 1993-94.

The California commercial abalone harvest reached a record 5.4 million pounds in 1957. Since then, commercial harvests have declined dramatically to about 461,376 pounds in 1993 (Table 1.). Current stocks of most abalone species in central and southern California are over utilized. This is the combined result of commercial harvest efficiency, increased market demand, sport fishery expansion, an expanding population of sea otters, pollution of mainland habitat, unexplained mortalities of black abalone due to a condition known as "withering syndrome," and loss of kelp populations associated with El Niño events. Management efforts through size limits and limits on commercial harvesting permits have been ineffective. Reseeding experiments have not been successful. Commercial abalone harvesting in California may be eliminated if the sea otter range is not contained. Studies in a California fishery reserve

have shown that even protected populations cannot support a fishery within the sea otter range in central California. New laws pending in the 1997 Legislature would establish a multi-year moratorium on the commercial and recreational harvest of all species of abalone south of the entrance to San Francisco Bay until stocks have demonstrated some level of recovery and a new management plan is in effect.

Alaska. The southeast Alaska commercial abalone fishery was sporadic and local prior to 1971. Shore picking was the primary harvesting method, but after 1960 some scuba gear was used. The fishery increased dramatically during the 1970's due to improved scuba gear, increased product demand, and the use of larger vessels. The Alaska abalone harvest reached a record 315,000 pounds in 1978-79, and then fell to about 36,000 pounds in 1992-93 when a minimum size limit was instituted (Table 1.). The Alaska pinto abalone fishery is managed through guideline harvest ranges, a minimum legal size of 3.75 inches, a restrictive season, and local area closures for conservation and food fisheries. The fishery opens in October to remain outside spawning and settling periods. Guideline harvests prior to 1988-89 varied 33,000 to 57,000 pounds per year. The season was shortened each year, and in 1993-94 the most productive areas were closed after 6 days and a catch of 37,000 pounds.

British Columbia. Prior to 1971, the British Columbia commercial pinto abalone fishery was sporadic and local. Shore picking was the main harvest method, but after 1960 some scuba gear was used. The fishery accelerated rapidly during the 1970's due to improved scuba gear, reduced access to herring and salmon fisheries, acceptance of the pinto abalone in the Japanese market, increased product demand, and the introduction of larger vessels with freezer capacity. Abalone landings peaked in 1977 at 474.8 metric tons (1,047,000 pounds) and then declined rapidly as management of the fishery began. Landings in 1990 totaled 110,000 pounds. The British Columbia abalone fishery was managed through a minimum size limit of 100 mm (3.9 inches), vessel license limitations, vessel and fishery quotas, seasonal restrictions, and local permanent area closures. In 1991, the commercial abalone fishery was closed to allow abalone stocks to rebuild. After a 5-year period, the commercial fishery may reopen if surveys indicate that abalone stocks have recovered.

Products

During the early years of the abalone fishery, abalones were dried and smoked, or canned for export, and sold fresh for local markets. Currently, most abalones are exported to Japan, either fresh or frozen whole. The U.S. market is primarily in California for live abalone for the sashimi market, and for some fresh and frozen steaks for restaurants.

A major change occurred in marketing U.S. abalones in 1993. Prior to 1993, black abalones were the primary export product. After the 1993 moratorium on black abalone harvesting, due to the "withering syndrome" that reduced black abalone stocks, red abalones took over the export market. Prices to the fishermen of \$500 to \$600 per dozen for red abalone made production of abalone steaks uneconomical for most markets. High prices for abalone may have also intensified illegal abalone fishing operations in closed areas.

Abalone steaks are prepared by removing the abalone from the shell, cutting off the head and viscera, and hand trimming the foot. Red and some green abalone are allowed to relax for 24 hours before the final trimming of the foot. This resting period weakens muscle contractions that can damage the flesh during tenderizing. The foot is then sliced horizontally across the grain of the meat. The steaks are tenderized by pounding, usually with wooden mallets, to break the tough fibers in the meat. The yield of steaks from a live abalone is about 15 percent.

The entire flesh of the abalone is edible. Traditional U.S. consumption has been primarily the muscle portion. The gonad, however, is considered a delicacy by the Japanese when it can be removed and eaten immediately from a live abalone. The trimmed muscles remaining after trimming for steak production were historically used for abalone burger production. As the price of abalone meat increased, these trimmings were canned. Today, they are used fresh or frozen in Asian restaurants for soups and

other dishes. The primary use for abalone shells is in making mother-of-pearl inlays on furniture, produced principally in Korea. Abalone shells are also sold to shell collectors and as souvenirs, and are used in making jewelry.

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Table 1. Abalone Landings 1977-98 (Pounds).

Year	California	Alaska	British Columbia	Total
1977	1,436,154	6,981	1,046,754	2,489,889
1978	1,295,034	164,719	890,666	2,350,419
1979	992,499	315,187	434,751	1,742,437
1980	1,238,989	272,375	233,689	1,745,053
1981	1,109,651	263,394	206,352	1,579,397
1982	1,240,579	202,463	180,999	1,624,041
1983	840,112	81,654	117,506	1,039,272
1984	826,672	109,216	126,766	1,062,654
1985	762,070	67,616	96,562	926,248
1986	615,037	40,537	100,531	756,105
1987	763,056	61,224	102,294	926,574
1988	568,826	67,615	100,310	736,751
1989	730,890	76,100	105,822	912,812
1990	520,854	52,071	110,231	683,156
1991	376,980	68,386	closed	445,366
1992	519,103	44,034	closed	563,137
1993	461,376	35,988	closed	497,364
1994	327,019	34,852	closed	361,871
1995	264,334	22,879	closed	287,213
1996	224,792	14,352	closed	239,144
1997	112,751	closed	closed	112,751
1998	closed			0

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