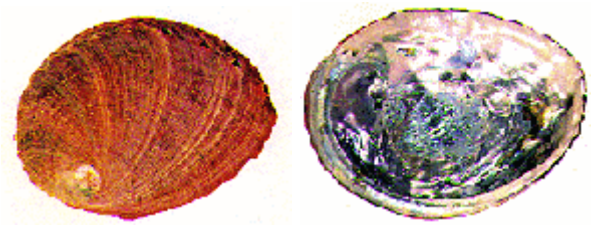
Seafood Watch
Seafood Report

MONTEREY BAY AQUARIUM®

Cultured Abalone
(*Haliotis* spp.)



Red Abalone, *Haliotis rufescens*, courtesy of FISHTECH INC.

Final Report
March, 26 2003

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About Seafood Watch® and the Seafood Reports

Monterey Bay Aquarium's Seafood Watch® program evaluates the ecological sustainability of wild-caught and farmed seafood commonly found in the United States marketplace. Seafood Watch® defines sustainable seafood as originating from sources, whether wild-caught or farmed, which can maintain or increase production in the long-term without jeopardizing the structure or function of affected ecosystems. Seafood Watch® makes its science-based recommendations available to the public in the form of regional pocket guides that can be downloaded from the Internet (seafoodwatch.org) or obtained from the Seafood Watch® program by emailing seafoodwatch@mbayaq.org. The program's goals are to raise awareness of important ocean conservation issues and empower seafood consumers and businesses to make choices for healthy oceans.

Each sustainability recommendation on the regional pocket guides is supported by a Seafood Report. Each report synthesizes and analyzes the most current ecological, fisheries and ecosystem science on a species, then evaluates this information against the program's conservation ethic to arrive at a recommendation of "Best Choices", "Good Alternatives" or "Avoid." The detailed evaluation methodology is available upon request. In producing the Seafood Reports, Seafood Watch® seeks out research published in academic, peer-reviewed journals whenever possible. Other sources of information include government technical publications, fishery management plans and supporting documents, and other scientific reviews of ecological sustainability. Seafood Watch® Fisheries Research Analysts also communicate regularly with ecologists, fisheries and aquaculture scientists, and members of industry and conservation organizations when evaluating fisheries and aquaculture practices. Capture fisheries and aquaculture practices are highly dynamic; as the scientific information on each species changes, Seafood Watch's sustainability recommendations and the underlying Seafood Reports will be updated to reflect these changes.

Parties interested in capture fisheries, aquaculture practices and the sustainability of ocean ecosystems are welcome to use Seafood Reports in any way they find useful. For more information about Seafood Watch® and Seafood Reports, please contact the Seafood Watch® program at Monterey Bay Aquarium by calling 1-877-229-9990.

Disclaimer

Seafood Watch® strives to have all Seafood Reports reviewed for accuracy and completeness by external scientists with expertise in ecology, fisheries science and aquaculture. Scientific review, however, does not constitute an endorsement of the Seafood Watch® program or its recommendations on the part of the reviewing scientists. Seafood Watch® is solely responsible for the conclusions reached in this report.

Seafood Watch® and Seafood Reports are made possible through a grant from the David and Lucile Packard Foundation.

Executive Summary

Abalone is one of the most prized sea delicacies worldwide. Entirely comprised in the genus *Haliotis*, these herbivorous marine gastropods have long been utilized as a food source by humans (Leighton 1989). As a result of over 50 years of heavy fishing (both sport and commercial), poaching, predation by an increasing population of sea otters, pollution of mainland habitat, disease, and inadequate wild stock management, all five major abalone species inhabiting the central and southern Pacific coast of California are now depleted. In an effort to rebuild stocks, the commercial fishery for abalone was closed in 1997. A sport fishery remains open north of San Francisco, California.

Wild and farmed abalone from Mexico, Australia, New Zealand, Taiwan, Japan, and China fulfill most of the demand for abalone throughout the world. In addition, a U.S. abalone aquaculture industry in central and northern California has been in production since the mid-1980s. Current production is minimal, with most of the product exported to Asia. Abalone farmers in California have faced significant regulations, disease and pest problems (sabellid worm and withering foot syndrome), and conflicts with interest groups such as kelp habitat conservationists and local fishermen who share harbor space with abalone farmers. Research with state and federal governments has lead to improved disease control and harvesting efficiency to produce a sustainable, highly regarded product.

Seafood Recommendation:

Abalone farming is a highly regulated, well-managed industry. Although wild abalone populations remain in a state of recovery, abalone farming allows public consumption of this ocean delicacy. Disease is a factor requiring continuous monitoring, which is conducted by state and federal agencies such as CDFG and the Regional Water Quality Board. Poaching caused by high demand (and high prices) is an ongoing issue, however, government agencies are doing their best to enforce bag limits in the sport fishery. Because of low environmental impacts, farmed abalone ranks as a BEST CHOICE on the Seafood Watch West Coast pocket guide.

Sustainability Criteria	Conservation Concern			
	Low	Moderate	High	Critical
Use of Marine Resources	√			
Escapement	√			
Disease Transfer	√			
Habitat/Ecosystem Effects	√			
Pollution	√			
Chemical Use	√			
Management Effectiveness	√			

Overall Seafood Rank: US Cultured Abalone

Best Choices **Good Alternative** **Avoid**

Species Biology

Scientific name:

Commercially harvested abalone are primarily of the genus *Haliotis*. There are over 70 species of extant haliotid species, all of which are marine (Table 1). Eight of those are native to the northeastern Pacific Ocean (Leighton 2000). The greatest variety comes from the southwestern Pacific and Indian Oceans (Leighton 2000). The most important species with regard to aquaculture in North America is the red abalone, *Haliotis rufescens,* while in Asia, *H. discuss hannai* and *H. diversicolor supertexta* are predominantly cultured (McBride 1998; Leighton 2000).

Table 1: Commercially important abalone species, location, and fishery status

Species name:	Common name	Location	Fishery?
Haliotis rufescens	red abalone	North America	farmed, recreational
Haliotis rufescens	red abalone	Chile	farmed
Haliotis cracherodii	Black abalone	North America	no
Haliotis fulgens	Green abalone	North America	wild/farmed (Mexico)
Haliotis corrugata	Pink abalone	North America	wild/farmed (Mexico)
Haliotis kamtschatkana	Pinto abalone	North America	yes, AK, B.C.
Haliotis midae	Perlemoen	South Africa	wild/farmed
Haliotis laevigata	Greenlip abalone	S. Australia	wild
Haliotis rubra	Blacklip abalone	S. Australia	wild/ farmed
Haliotis roei	Roe's abalone	Australia	wild
Haliotis iris	black-footed paua	New Zealand	wild
Haliotis diversicolor supertexta	Small abalone?	Taiwan	wild/ farmed
Haliotis discus hannai	Disk abalone	Japan, China	wild/ farmed

Distribution and Habitat:

Abalones are found throughout a majority of the world's temperate oceans, living on nearshore rocky substrates, reefs and crevices (Leighton 2000). Except for a rare species occurring off the Florida Keys (*H. pourtaliesii*), North American abalones are endemic to the Pacific coast (Leighton 1989). The largest members of the genus occur near the coasts of Japan, southeast Asia, Australia, New Zealand, Africa and western North America (Leighton 2000). Species can live in water temperatures ranging from 2°C to 30°C (Leighton 2000).

Depth distribution of several CA abalone species(Cox 1962; Leighton 2000; Ebert 2001).

Black abalone: 0-20 feet, Oregon to southern Baja, Mexico
Green abalone: 1-20 feet, Point Conception to Baja, Channel Islands
Pink abalone: 10-70 feet, same as green
Red abalone: 0-80 feet, Oregon to northern Baja (shallow living in southerly regions)
Flat, pinto, threaded abalones: 20-100 feet, north of Pt. Conception
White abalone: 80-450 feet, Pt. Conception to central Baja California

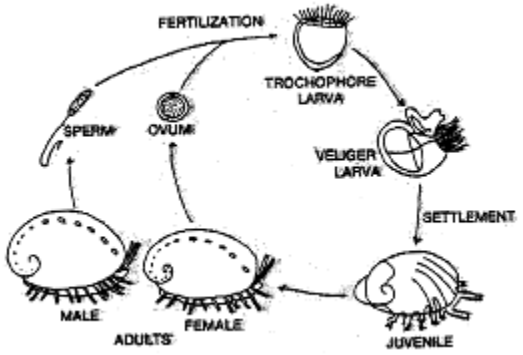
Biological Characteristics/ Life History:

Abalone are broadcast spawners, releasing their gametes into the water column for fertilization (Leighton 2000). Most temperate species have an annual reproductive cycle; the periodicity and duration of spawning varies both intra- and interspecifically (McShane 1992). For example, some tropical species spawn monthly following lunar cycles (Jarayabhand and Paphavasit 1996). While spawning is induced artificially in aquaculture facilities, few mechanisms (except for temperature-related events) leading to synchronized spawning in nature have been identified (Leighton 2000). Abalone eggs are negatively buoyant and usually hatch within 24 hours of fertilization (Mottet 1978). Trochophore larvae (Fig. 1) are active swimmers for a few days (*H. fulgens*) to a few weeks, and may be dispersed over large distances (Leighton 2000).

Fecundity is great for these animals; a female can produce as many as 10 million eggs (Mottet 1978). Mortality, however, is also thought to be high (McShane 1992). Estimated mortality rates for certain species range from 35% to 90% (Tetschulte 1976). Some researchers believe larval viability, predation, and export to unsuitable environments by ocean currents may cause high mortality of wild abalone larvae.

Abalone growth and longevity studies reveal large variation in growth rates between species (Day and Fleming 1992). Longevity varies between a decade for smaller species to almost 40 years for white abalone (Leet et al. 2001). Generalizations are made regarding abalone growth, such as: 1) abalone growth rates are highly variable between areas, seasons, and temperature regimes, 2) growth rates may differ widely even among individuals occupying the same area, 3) generally speaking, most California species increase in shell length by about an inch per year under optimal conditions (Leighton 2000). Red abalone are the largest members of the genus, with a maximum shell length of 31.3 cm (Leighton 2000). Most market-sized, cultured red abalone are 80-90 mm (McBride 1998).

Figure 1: Life cycle of Abalone, from Cox (1962)



Food Habits:

Juveniles feed on benthic microflora, larger adults feed on larger marine algae such as drifting *Macrocystis* and *Nereocystis* spp. (Leighton 2000) and understory red algae. Researchers are working to develop artificial feeds in abalone culture to reduce dependence on harvested kelp (Fleming 1995).

Statement on Availability of Science:

Much research on abalone has been conducted in countries with fishery interests. There were four symposia dedicated to the biology, culture and fisheries of abalone. The first was held in La Paz Mexico in 1989, a second in Hobart, Tasmania in 1994, the third was in Monterey

California in 1997 and the fourth in Cape Town, South Africa in 2000. Scientists, government workers, commercial and recreational fishermen, and aquaculturists work diligently to advance knowledge of natural history, fishery management and abalone culture.

Fishery Information

Abalone are highly prized in many cultures and are fished throughout their natural range. Because of this, they have been depleted in many locations, including the coast of California. For the commercial fishery off California, a harvesting moratorium was enacted in August 1993 for the black abalone (*H. cracherodii*); the take of green (*H. fulgens*), pink (*H. corregata*), and white (*H. sorenseni*) abalone ceased in January of 1996 (Daniels and Floren 1998). Currently, no commercial harvesting of any species is allowed in the state, and recreational take is limited to one species, red abalone, north of San Francisco only (Daniels and Floren 1998). Wild abalone are still taken by other countries (Fig. 2).

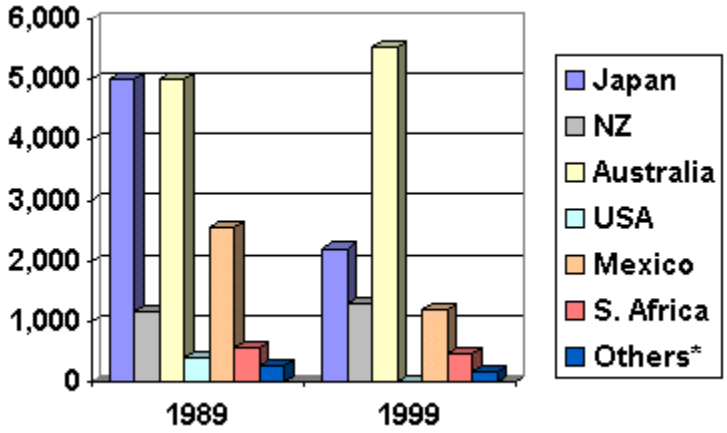


Figure 2: Wild Abalone World Fishery (metric tons): 1989, 1999 (Courtesy FISHTECH, Inc.)

Aquaculture Information

As a result of wild stock depletion, abalone farming began in the late 1950s and early 1960s in Japan and China and was followed by a small contingent in California in the late 1960s. During the 1960s, several government and private researchers began studies to advance knowledge of hatchery systems, leading to successful production of juvenile abalone for release in the wild (Ebert 1992; Leighton 2000).

As the depletion of wild stocks closed many fisheries, development of abalone cultivation has grown rapidly and it is now widespread in many countries including USA, Mexico, South Africa, Australia, Japan, China, Taiwan, Ireland, Iceland and others (Fig. 3). From 1989 to 1999, wild abalone fisheries have declined by approximately 30%, while the global production of farmed abalone has increased over 600% (Gordon and Cook 2001). The largest cultured abalone producer in the world is China with over 300 farms and a total production of approximately 3500 tons, mostly *H. diversicolor supertexta* (Gordon and Cook 2001).

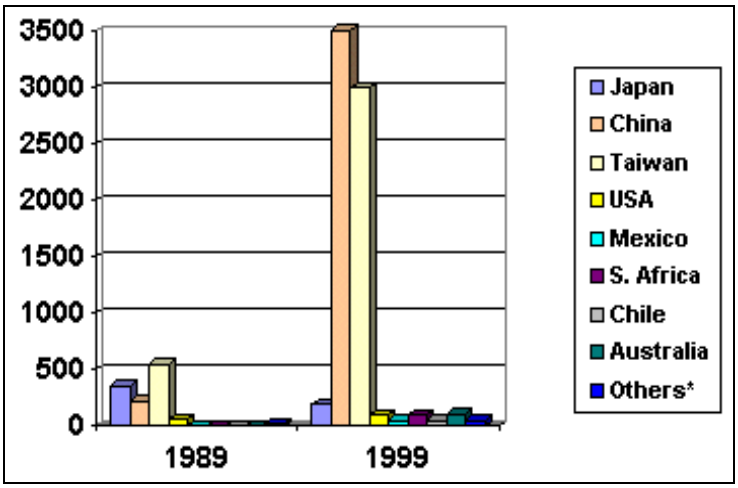


Figure 3: World Farmed Abalone Production (mt): 1989, 1999
(Gordon and Cook 2001)

Market Information

Common/Market names: Abalone is known as abulón or aulone in Mexico (Leighton 2000). When used for sushi or sashimi, abalone is commonly sold as *awabi*.

Seasonal Availability: Due to the advent of abalone farming, the product may be found year round, though at varied cost.

Product Forms: Abalone is sold fresh, frozen, dried, salted, and canned.

Import/Export Statistics: The largest importers of abalone into the U.S. West Coast region are: Mexico, Peru, Australia, and New Zealand. Imports have declined throughout the 1990s (Fig. 4), presumably to an increase in domestic product or a shift in demand due to cost.

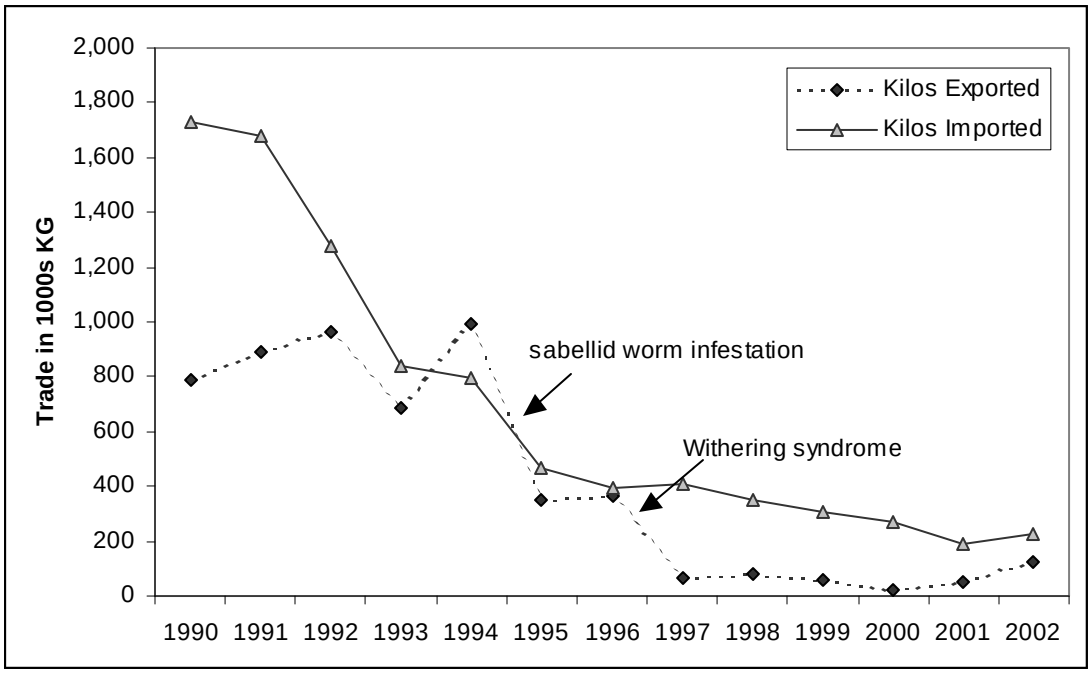


Figure 4: Import/Exports of abalone (live/shell weight) through U.S. Ports, 1990-2002 (Source: NMFS Trade Statistics)

Management/Monitoring/Enforcement:

Because of their coastal distribution, abalone in the U.S. are managed by individual states. In California, management consists of setting limits for recreational divers, constructing the Abalone Recovery Management Plan (ARMP), due on January 1, 2003, and enforcing regulations. Recreational divers (breath-hold only) north of San Francisco are allowed a daily possession limit of three and a yearly limit of 24.

Aquaculture Operation Types:

Abalone can be cultured on land in seawater tanks or in the sea, suspended in barrels or cages in the water column of sheltered bays or coastline. Aquaculturists that operate in-water systems usually obtain seed abalone from land-based hatcheries (Ebert 2001). Abalone are induced to spawn using hydrogen peroxide or ultraviolet light treated seawater (Ebert 2001). In California's Living Marine Resources status report, Earl Ebert of U.S. Abalone in Davenport, California, explains the typical abalone culture system:

> "In a typical hatchery operation, ripe brood stock abalone are induced to spawn using hydrogen peroxide or ultraviolet light treated seawater. Fertilized eggs that successfully develop to the veliger swimming stage are transferred to larval rearing tanks. In about six days at 59° F, larvae are ready to settle from the planktonic to the benthic stage. They are transferred to nursery tanks, and commence to feed on diatoms. After six months of growth, half-inch abalone are then transferred to plastic mesh baskets suspended in larger tanks. At this point, the abalone begin feeding on macroalgae. An additional six to eight months are required before they reach the size where they are transferred to grow-out tanks or in-water systems. After growing in these tanks or in-water systems for 20 months or longer, they attain the typical three- to four-inch shell length preferred by the market." (p. 494; Ebert 2001)

Level of Operation/Type of Feed:

- **California, USA:**
  There are currently 21 registered marine aquaculturists along the coast of California (Tom Moore, CDFG, Bodega Bay, California, pers. comm.). Approximately five to seven are productive abalone farms. The largest is currently selling about one million abalone per year and the smaller farms 50,000 or less (Gordon and Cook 2001). The farmed size is normally three and a half to four inches (Leighton 1989). In 1998 the total amount of abalone produced was approximately 73 metric tons (mt; in-shell weight) of product valued at US$2.4 million (Ebert 2001). The red abalone comprises 95% of total production, followed by green and pink abalones (Haaker et al. 2001).
- **Japan:**
  Japan has many major farming operations, most of which are involved in ocean enhancement. Almost all Japanese farming consists of ocean bottom growing from farmed seeds (Gordon and Cook 2001). Japan produces 25 to 30 million seeds per year.
- **China:**
  China has over 300 abalone farms producing over 3,500 mt in 1998 (Gordon and Cook 2001).
- **Taiwan:**
  Taiwan currently has over 400 farms (many are small family run operations). Total production is over 2,500 mt, most of which is consumed in Taiwan. The 1999 production is expected to exceed 1,500 mt (Gordon and Cook 2001).

- **Australia/Tasmania:**
  Farmed production has been increasing and was estimated at 150 mt for 1999 (Gordon and Cook 2001).
- **Chile:** Red abalone was introduced to Chile in 1977, but culture has only recently begun to increase, mainly with the in-water barrel system (Godoy and Jerez 1998).
- **South Africa:**
  Abalone farming is a recent activity in South Africa, beginning with the cultivation of *H. midae*, a native species which is also fished in the wild (Cook 1998). Most farms utilize a "pump-ashore, land-based, on-growing system" and other technologies adapted from the U.S. or Japan (Cook 1998). Kelp is generally used as feed although alternative items are under research in areas without access to fresh kelp (Cook 1998).

Operation Management:

The process of obtaining permits for an abalone farm is long and arduous (Dave Ebert, US Abalone, pers. comm.). Several permits are required from various agencies, such as the State Water Resources Board, Regional Water Quality Board, Coastal Development Commission (as most abalone farms are near the coast), County management authorities, and the state Fish and Game Department (Tom Moore, pers. comm.). Once a facility is in business, it is monitored by the Regional Water Quality Board and CDFG officials (Dave Ebert, pers. comm.). Any changes or expansions from the original design must be approved by these agencies.

Status of stocks/trends:

As a result of over 50 years of heavy fishing (both sport and commercial), poaching, predation by an increasing population of sea otters, pollution of mainland habitat (discharge), disease, and inadequate wild stock management, all five major abalone species inhabiting the central and southern Pacific coast of California are now depleted (Haaker et al. 2001). A potentially sustainable abalone aquaculture industry, however, is emerging to meet market demand. An introduced pest (sabellid worm) and a native disease (Withering Syndrome) have resulted in setbacks for the industry, but have mostly been eradicated through research and regulation.

The introduction of a parasitic sabellid polychaete worm from South Africa in the early 1990's wreaked havoc on nearly every abalone aquaculture facility in the state (Ebert 2001). The worm stunts growth of the abalone and causes the shell to become brittle and deformed, causing an unmarketable product and significant economic loss (Culver et al. 1997). Fortunately, research on the part of government and industry has almost eradicated this problem. The California DFG supports an inspection program, whereby farms may be spot tested and certified to be "sabellid free" (Carolyn Friedman, University of Washington, pers. comm.). To prevent outbreaks, abalone seed may be transferred only from certified sabellid-free farms.

The industry experienced an even deadlier disease known as Withering Syndrome (WS), caused by a naturally occurring prokaryote, that has also been detrimental to wild populations (Haaker et al. 1992). The condition is caused mainly by thermal stress, and is characterized by a severe shrinkage of the abalones' foot, ultimately leading to death (Ebert 2001). Opponents to abalone farming fear propagation of these and other diseases will lead to even further decline in wild populations, as abalone are farmed either in the ocean or via sea-water circulating systems. However, because the bacteria which causes WS is already present in natural systems, stress

caused by environmental changes (such as El Nino) seems a more likely cause for outbreaks in wild stocks.

Poaching continues to weaken already sensitive wild populations, and there is speculation that increased demand for abalone will only lead to more poaching, regardless of the penalties. Law enforcement officials close to the situation estimate at least 4,800 abalone per diveable day are being poached from northern California waters (Daniels and Floren 1998). In an effort to halt illegal poaching, CDFG officials often set up road checkpoints leading away from popular abalone fishing areas. Also, the presence of more than sport quantities of abalone found aboard any boat now constitutes *prima facie* evidence of commercial poaching and can result in confiscation of boat and equipment (Daniels and Floren 1998). While these regulations have turned many would-be poachers away, the lucrative market continues to present motivation for many. Abalone can fetch up to $20 per pound or more (Dave Ebert, pers. comm.).

Local attention in the Monterey Bay has been directed to the issue of the abalones' main food source: kelp. Some recreational dive interests and conservation groups oppose kelp harvesting for abalone aquaculture because they fear too much kelp removal will weaken kelp forest ecosystems. Kelp has been harvested in California since 1911, and is used for numerous products as well as abalone aquaculture (King 2001). Currently, between 100,000 and 170,000 mt are harvested from California waters each year (Foster and Schiel 1985). McBride (1998) reported abalone aquaculturists in California and Baja California Sur harvested about 10% of the total industrial and aquaculture kelp harvest in California (McBride 1998). Additionally, recent report by the Monterey Bay National Marine Sanctuary states, "no significant negative impacts on the kelp forest community have been attributed to kelp harvesting" (King 2001).

Seafood Recommendation:

Abalone farming is a highly regulated, well-managed industry. Although wild abalone populations remain in a state of recovery, abalone farming allows public consumption of this ocean delicacy. Disease is a factor requiring continuous monitoring, which is conducted by state and federal agencies such as CDFG and the Regional Water Quality Board. Poaching caused by high demand (and high prices) is an ongoing issue, however, government agencies are doing their best to enforce bag limits. Because of minimal environmental impact, farmed abalone ranks as a BEST CHOICE on the Seafood Watch West Coast regional pocket guide.

Sustainability Criteria	Conservation Concern			
	Low	Moderate	High	Critical
Fishmeal Use	√			
Escapement	√			
Disease Transfer	√			
Habitat/Ecosystem Effects	√			
Pollution	√			
Chemical Use	√			
Management Effectiveness	√			

Overall Seafood Rank: US Cultured Abalone

Best Choices **Good Alternative** **Avoid**

Acknowledgements

Seafood Watch is indebted to Dr. Susan McBride (University of California, Davis), Dr. Dave Ebert (formerly of US Abalone), and Ms. Kelly O'Reilly (California Department of Fish & Game) for reviewing this report for scientific accuracy and clarity. Roy Gordon of Fishtech, Inc. provided many of the figures displayed in this report, as well as information on abalone farming and market. Dr. Carolyn Friedman (University of Washington) provided insight into diseases affecting abalone stocks, and Tom Moore (CDF&G) and Justin Malan (Executive Director, California Aquaculture Association) provided insight into farmed abalone regulation and monitoring processes. Thanks to Randy Kochevar and Michelle Mackenzie for internal review.

NOTE: Scientific review does not constitute endorsement of Seafood Watch recommendations on the part of the reviewing scientists; the Seafood Watch staff is solely responsible for the conclusions reached in this report.

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