

21 Culture of Oysters



The native oyster, *Ostrea conchaphila*, growing in a rocky intertidal area of San Francisco Bay. Photo credit: Thomas O. Moore.

History

California's oyster fishery and oyster aquaculture industry have had a rich and colorful tradition. Native Americans harvested the oyster resource for thousands of years before Spanish, Tsarist Russian and European settlers occupied the west coast. A substantial commercial oyster fishery began in the 1850s, when settlers from the east coast attracted to California by the prospect of gold and new opportunities created larger markets for oysters. The increased population and market pressure for oysters had an immediate impact on the state's shellfish resources. The only available oyster was the native oyster (*Ostrea conchaphila*; previously *O. lurida*; also called Olympia oyster in the Pacific northwest), which was intensively fished, causing a rapid decline in the natural population. In response, native oysters were transported from Shoalwater Bay, Washington (Willapa Bay) and later from other bays in the Pacific northwest and Mexico, representing the initial attempts at oyster culture on the west coast. Oysters were transplanted into San Francisco Bay, where they were maintained on oyster beds and then marketed throughout central California. The Shoalwater Bay trade of native oysters dominated the California market from 1850 through 1869. Market demand for a larger, half shell product stimulated experiments in transporting the eastern oyster, *Crassostrea virginica*, from the Atlantic states to the west coast. Several failed attempts were made to establish transport of the eastern oyster to California by sailing ships. Successful transport of oysters was achieved only after the completion of the transcontinental railroad. Shipments of juvenile and market sized oysters were transported by rail in barrels of sawdust and ice and transplanted into San Francisco Bay. Cool summer water temperatures, however, prevented successful natural reproduction of the eastern oyster.

Transcontinental trade for eastern oyster seed was established in 1875. Small, 1 inch seed was transplanted in San Francisco Bay for further growth. The Shoalwater Bay trade for native oysters was gradually terminated, and from 1872 until the early 1900s California's San Francisco Bay eastern oyster industry was the largest oyster industry on the west coast. Maximum production was reached in 1899 with an estimated 2.5 million pounds (1135 metric tons) of oyster meat.

With California's population and industrial growth came a degradation of water quality in San Francisco Bay. By 1908 eastern oyster production had fallen by 50 percent. By 1921 oyster meat quality declined to the extent that shipments of seed from the east coast were terminated, and by 1939 the last of the San Francisco Bay oysters were commercially harvested. Oysters were still transported and held in Tomales Bay until they could be marketed in San Francisco, but the industry based on the eastern oyster did not recover. The industry and state began reexamining earlier experimental plantings using the Pacific oyster, *Crassostrea gigas*, which originated in Japan. The California Department of Fish and Game (Department) and commercial growers conducted experimental plantings of Pacific oysters in Tomales Bay and Elkhorn Slough in 1929. Experimental plantings continued in a number of bays, including Drakes Estero, Bodega Lagoon, and Morro, Newport and San Francisco bays throughout the 1930s. Humboldt Bay was excluded from plantings while the Department tried to reestablish natural populations of native oysters. Several Pacific oyster plantings proved successful, demonstrating that imported Pacific oyster seed could be grown commercially in California. Shipments of seed from Japan were made through the 1930s, suspended from 1940 through 1946, and increased significantly in 1947. The imported seed was inspected in Japan by both Department personnel and commercial producers prior to shipment. Department personnel examined the shell for organisms considered harmful if introduced into state waters.

Boxes containing oyster shell with attached young oysters (spat or seed) were transported by ship in wooden crates kept moist with seawater. With the influx of seed oysters, the industry began its recovery in California and on the west coast. The Department lifted its restriction on Pacific oyster seed in Humboldt Bay in 1953, and in the next thirty years the California industry showed rapid growth with production centered in Humboldt Bay, Drakes Estero, Tomales Bay, Elkhorn Slough and Morro Bay.

The west coast oyster industry initiated other significant changes in the early 1980s which have had a significant impact on the industry nationally. These changes include the development of U.S.-based shellfish hatcheries for the domestic production of Pacific oyster seed, and the ability to ship advanced hatchery produced oyster larvae (swimming stage) to grow out sites where the larvae are placed in tanks containing cleaned shell and heated seawater for spat production. In this process called remote setting, the larvae settle on clean oyster or scallop shell, called mother shell or cultch, attach and metamorphose into the more familiar flat young oyster called spat. Spatted cultch ultimately results in about 9 to 13 market-sized oysters clustered on remnants of the old mother shell.

Another hatchery product is cultchless oyster seed that are grown out as individual oysters exclusively for the half shell market. Cultchless seed are produced by setting the larvae on sand or finely crushed oyster shell resulting in unattached, individual oysters. Many California growers purchase cultchless seed from California based advanced seed producers. These producers receive small cultchless seed from a hatchery, and then use floating upweller systems (FLUPSY) to hold the seed in flow through containers receiving bay water containing algae. FLUPSYs are raft-type structures that house a series of trays or containers that hold the oyster larvae. Water is forced upwards through the trays with the tides or through mechanical methods. The oyster seed increases in size and is more easily handled in the larger mesh bags used by the end producer. Individual growers are also adopting and expanding their own land based FLUPSYs and downwellers to cut the cost of seed and assume the responsibility of early seed growth. All oysters grown in California currently are produced from seed obtained from hatcheries located in Washington, Oregon and Hawaii.

The hatchery systems primarily produce two species of Pacific oysters: the Pacific oyster and the Kumamoto oyster, *Crassostrea sikamea*, which also originated in Japan and does not reproduce in California's cooler summertime water. Other less prominent species produced by hatcheries have included the European oyster, *Ostrea edulis*, and some eastern oyster. The ability to ship oyster larvae long distances and set the spat at the grow out areas has significantly reduced the cost of seed. The last shipment of Japanese seed to California was in 1989.

The level of oyster production within the various bays has fluctuated throughout the years, primarily because of water quality, each bay's ability to produce good standing crops of algae on which oysters feed, the adequacy of selected sites, summer mortality events and the financial viability of the various oyster operations. All growing areas are classified and certified by the California Department of Public Health (DPH), based on health related water quality standards established and regulated by the Interstate Shellfish Sanitation Conference and the National Shellfish Sanitation Program. Water bottom and offshore grow out areas are leased from the State through the California Fish and Game Commission, local Harbor and Recreation Districts, or belong to private corporations.

The industry uses a variety of oyster culture methods depending on the targeted market, the physical characteristics of the production bay and the need to protect the younger oysters from predators such as bat rays, rock crabs and drills (predatory snails). Culture methods are also influenced by factors such as substrate type, current velocity, tidal range and phytoplankton productivity. California oysters are grown from spat to market size in about 13 to 18 months, depending on the bay and the culture method used.

California oyster production is currently centered in six areas: Arcata Bay located in the North Humboldt Bay complex, Tomales Bay, Drakes Estero, Morro Bay, Santa Barbara offshore waters and Agua Hedionda Lagoon in Carlsbad. Morro Bay oyster production had declined in recent years; however a new grower has once again increased production to near former levels. Grow out techniques used in Morro Bay

include bottom, rack and bag, floating bag and stake culture. Former shellfish producers in the Santa Barbara Channel used a system of long lines with attached bags of European oysters suspended from offshore rafts in the deep waters but have discontinued production in recent years. Current production by a new grower in Santa Barbara offshore waters uses Pacific oysters and Mediterranean mussels on submerged long lines. Shellfish producers also culture cultchless oysters in Agua Hedionda Lagoon using long lines with suspended trays.

Humboldt Bay growers have used a variety of oyster culture methods, with bottom culture of Pacific oysters being the most common until the mid 1990s when they began moving to off-bottom culture. For bottom culture, cultch with attached spat was spread over leased areas in the bay, the oysters were grown to about 4 inches and are then harvested by hand picking and hydraulic dredge. Because of environmental concerns and the impact of hydraulic dredging on eelgrass, growers transitioned to off-bottom, long line and rack and bag culture of the Pacific oyster and also the Kumamoto oyster. The Kumamoto oyster derives a higher market price as non-shucked shellstock, and Pacific oysters are primarily used for the shucked oyster market with a small amount sold as single non-shucked oysters.

Long line culture primarily consists of a series of notched PVC pipes set in the substrate with twisted line stretched over the apex of the pipes (Figure 21-1). Spatted cultch is inserted at intervals between the strands of the line which hold the growing oysters above the substrate. The lines containing the clustered oysters are harvested on a flood tide, thereby reducing disturbance to the substrate or associated eelgrass. Other forms of off-bottom culture include bags of cultchless oysters supported by low racks and floating oyster bags attached to long lines.



Figure 21-1. Oyster cultch on long lines in Humboldt Bay (Humboldt County). Photo credit: Thomas O. Moore.

Drakes Estero has one of the largest off-bottom, rack culture systems along the west coast. Like all off-bottom culture, the method is used to avoid predators, use more of the water column, and avoid siltation that occurs when the oysters rest on the substrate. The rack culture system uses spatted mother shells strung on short lines with a tube spacer separating each mother shell. The short lines are hung in an inverted U shape over the horizontal rails of wooden racks set in the bay. Two other growing methods using cultchless single oysters are used in Drakes Estero.

Tomales Bay growers also use a variety of off-bottom techniques including rack and bag, stick and bag, and bag and long line culture. Rack and bag culture uses cultchless seed that is first grown in trays, upwellers and downwellers, or floating, rotating, mesh cylinders (Figure 21-2). After initial growth, the small oysters are transferred to a series of different sized mesh bags positioned on low racks in the bay.



Figure 21-2. Oysters in bags on racks in Tomales Bay (Marin County). Photo credit: Thomas O. Moore.

Bag and long line culture use cultchless seed in mesh bags attached to an anchored line which can be floated to suspend the bags vertically in the water or can be used to secure the bags on a stable, hard bottom, intertidal area (Figure 21-3). Bags can also be maintained horizontally at the surface using floats. To maintain the prime oyster shape for the half shell market, the bags must be moved frequently to prevent the individual oysters from growing together and resulting in an irregular shape.

Total annual oyster production for California has fluctuated throughout the industry's history, reflecting cyclic shellfish mortalities caused by summer mortality syndrome (SMS), availability of seed oysters, economic conditions, and the financial stability of individual companies. With the advent of hatchery technology and remote setting of oyster seed, the industry demonstrated significant growth from the mid 1980s to a second post 1960s peak in the mid 1990s (Figure 21-4). Reduced production after 1994 directly reflects several industry setbacks, which include financial restructuring after the 1990s recession, extended bay harvest closures due to sanitary degradation and oil spills, recurrence of cyclic SMS and most recently a shortage of hatchery produced seed. Several of these factors have been resolved but oyster seed supply remains a major issue due to consolidation of commercial hatchery businesses and shortages of seed due to disease issues in those hatcheries. Production increases are expected as the industry works around these challenges.



Figure 21-3. Workers placing oyster bags on ground lines in Drakes Estero (Marin County). Photo credit: Thomas O. Moore.

The overall statewide value of cultured oysters is calculated by converting all types of oyster products to a common denominator of shucked pounds of oysters expressed as packed weight. Packed weight is estimated to be 15.5 percent of live weight for Pacific oyster and 10.9 percent for eastern oyster. Shucked gallons are calculated as 8.6 pounds/gallon (1.03 kilograms/liter) for Pacific oyster and 8.5 pounds/gallon (1.04 kilograms/liter) for eastern oyster. Cultchless oysters, Kumamoto oyster and a large portion of Pacific oyster are sold as shellstock. The majority of total production in recent years is primarily Pacific oysters and to a much lesser extent, Kumamoto oysters. Annual eastern oyster production peaked in 2005 with production over 7500 pounds (3400 kilograms). However, seed availability has limited plantings since then and production in 2008 was estimated to be just over 2000 pounds (900 kilograms).

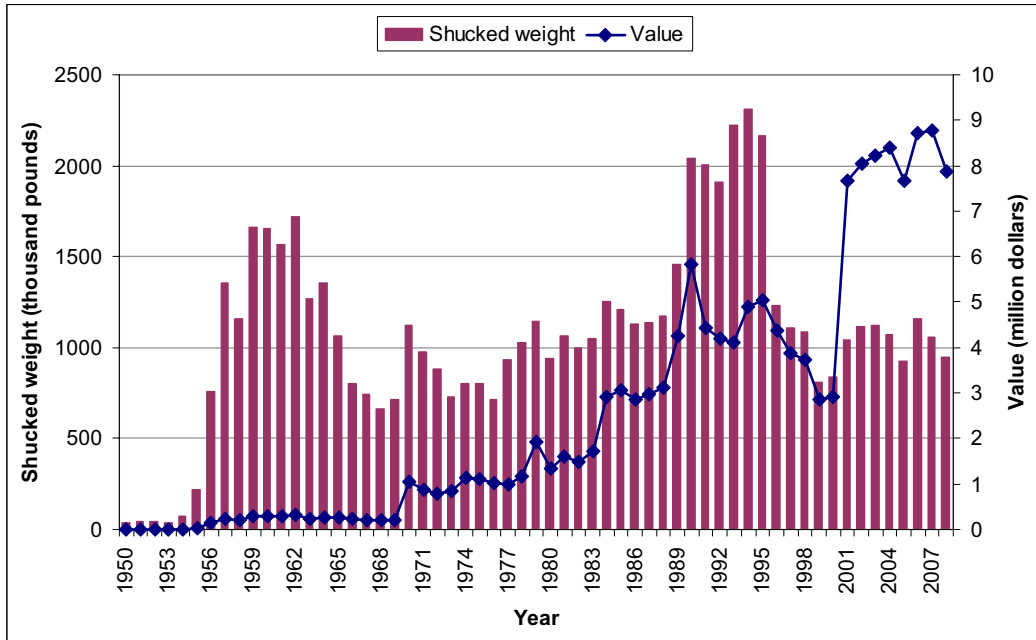


Figure 21-4. Oyster production and value, all species combined, 1950-2008. Data Source: California State Tax records (royalty reports) and Department Aquaculture Harvest Survey Database.

It is difficult to place a good estimate on the value of the California oyster industry. Market demand and price have increased over time with a change in products, such as the trend in California from shucked and jarred oysters to single oysters for the half shell trade. The Department contacts growers to obtain an estimate of the retail and/or wholesale price for that business's products. Confidentiality issues can prevent the release of production information. The large increase in the value of the oyster production seen in 2001 and following years was the result of permission to release previously confidential information (Figure 21-4).

Oyster products are marketed as shucked meat in gallons and 10 ounce jars, and as shellstock for the half shell and barbecue markets. The shucked product is marketed as small (200/gallon; 53/liter), medium (140/gallon; 37/liter), and large (100/gallon; 26/liter). Shellstock is marketed as small (2.5-3.5 inches; 6.4-8.6 centimeters), medium (3.5-4.5 inches; 8.6-11.4 centimeters), large (4.5+ inches; 11.4+ centimeters) sold by the dozen, and clusters (attached, mixed). The demand for oyster products far exceeds the state's production level, and the majority of shellfish products consumed in the state are imported from the Pacific northwest and the Atlantic and Gulf states. California's product is considered prime, and its production areas are among the best in the country.

The DPH has regulatory responsibility over shellfish product safety and periodically conducts sanitary surveys with the U.S. Food and Drug Administration under worst case scenarios to determine growing area sanitation conditions. Two essential programs are the monitoring of the bays for indications of contamination, including human sewage, and for the occurrence of natural biotoxins such as paralytic shellfish poison produced by toxic phytoplankton. The programs are designed to

provide a safe product for the consumer and an early warning system for people recreationally harvesting shellfish in noncommercial areas. The water and meat quality monitoring programs conducted by the DPH also provide an assessment of the biological condition of the bays, which is essential information used by all agencies to prevent a reoccurrence of events which led to the contamination of San Francisco Bay.

Status of Biological Knowledge

Oysters are bivalve mollusks that exhibit a variety of sizes, shapes, shell textures and colors, and vary in their mode of reproduction. These biological and physical features influence where they grow and how they reproduce, which in turn influence commercial aspects such as culture practices and marketing strategy. The depth of the shell cup and the shape of the oyster influence market price of shellstock. Individual oysters conform to the shape of the substrate to which they are attached and are therefore highly variable in shape. In addition, shell shape, texture, and color are all influenced by the oyster's genetics and physical environment such as salinity, attachment substrate, crowding by other oysters and food. They feed on phytoplankton and nutrient-bearing detritus by pumping water over their gills, filtering the food material and passing it into the mouth.

All oysters have a typical molluscan trochophore larva that develops into a veliger larva capable of filtering food, swimming and selecting a suitable substrate for attachment. The microscopic veliger settles, cements its left valve to the substrate and undergoes metamorphosis into an oyster spat. For the rest of its life the attached spat will compete for space and nutrients and, if it survives, will grow into the adult form. The five oysters now found in California belong to the family Ostreidae. They represent two groups characterized by biological variations, including different modes of reproduction and dispersal of young. The temperature at which the oysters will spawn and the rate of larval development and growth depend on a variety of factors, including species, genetics and latitude of the breeding population. Natural spawning is also influenced by lunar periodicity and tides.

The native and European oysters are rhythmical consecutive hermaphrodites; they can change sex either annually or at closer intervals. In their first year they are strongly protandric; the first expression of sex at maturity is male. They may become female in the same year or in the following year if environmental conditions are good and food is plentiful. They are also larviparous (brooders); fertilization of eggs is internal, and the larvae are held for a period of time before release. Mature, egg-carrying females spawn at about 59-63°F (15-17°C). The eggs are released into the female's own mantle cavity and are fertilized as she takes in water containing the male's sperm. When the eggs hatch, the veliger larvae are held by the gill blades and incubated for about 10 days before release. Once expelled, the advanced larvae swim freely and feed on phytoplankton before settlement and metamorphosis (native 14-18 days; European 10-14 days).

The Pacific, Kumamoto and eastern oysters are alternative hermaphrodites; sex change occurs, but its timing is erratic. They have a tendency for protandry in their first

year, but the tendency is not as strong as that of native and European oysters. They are oviparous (broadcast spawners); the eggs are immediately released and fertilization takes place in the environment. Mature, egg carrying females spawn at about 63-77°F (17-25°C) depending on the species, variety and latitude. Water temperatures required to establish a natural population are higher than those consistently found in California. Since spawning and successful reproduction rarely take place in California, the oysters are spawned and reared in shellfish hatcheries at about 77°F (25°C). The eggs hatch into free swimming trochophores, then become veliger larvae. Within 3 to 5 days these larvae settle, attach to a substrate and metamorphose to spat.

The native oyster is California's only indigenous oyster species and occurs along the Pacific coast from Sitka, Alaska to Cape San Lucas, Baja California, Mexico. The largest concentrations occur in the Pacific northwest along the coast of Washington's Puget Sound and in Willapa Bay. Although still grown commercially in Washington in specially constructed beds, natural concentrations are not abundant enough to support commercial endeavors. Populations of the native oyster are still relatively low in California. Some protection of existing populations is provided by recreational fishing regulations, which allow a daily harvest of 35 native oysters under the general invertebrate bag limit. The adult is about 2-3 inches (5-7 centimeters) in length and more often irregular in shape (Figure 21-5). Shell textures vary from smooth to rough with concentric growth lines, and the exterior has purple-brown to brown axial bands. The two shell valves are symmetrical; their interior is shades of olive green and can have a metallic sheen. The internal shell's muscle scar in adults is usually centrally located and unpigmented.



Figure 21-5. Species of oysters grown in California. Left, Pacific oyster; center, eastern oyster; upper right, Kumamoto oyster; lower right, native oyster. Credit: Department.

The native oyster is found in many of California's coastal inlets and bays, especially on hard substrate located on mud flats and gravel bars near the mouths of

small rivers and streams. It cannot withstand high temperatures or frost when exposed, and does not survive low salinity or turbid water. The natural beds are located in the subtidal zone of bays, where the oyster is better protected from both prolonged hot summer surface water temperatures and extreme cold winter water conditions. The oysters are often found attached to rocky outcroppings or other structures that offer protection from rays and other predatory fish.

Adult European oysters are about 3-4 inches (8-10 centimeters) in length, with a poorly developed beak that gives the valves an oval to round shape. The left or attachment valve is larger and more deeply cupped than the right valve, with 20 to 30 ribs and irregular, concentric lamellae. The upper, smaller valve is flat, with numerous concentric lamellae but no ribs. The hinge ligament consists of three parts: a middle, flat part on the left valve and two projections on the right. The internal valves are white, and the muscle scar is eccentrically positioned and unpigmented.

Adult eastern oysters may vary in length from 2-6 inches (5-15 centimeters) (Figure 21-5). The shells are asymmetrical, highly variable in texture and shape, and greatly influenced by environmental conditions. The external shell is usually a shade of gray, and the internal valves white with a variable colored muscle scar, usually deep purple. The left valve is longer than the right, not deeply cupped, and the beak is usually elongated and strongly curved. The shell margins are usually straight or only slightly undulating, and the inner margins of the valves are smooth.

The adult Pacific oyster ranges from about 4-6 inches (10-15 centimeters) in length (Figure 21-5). The shell is coarse, with widely spaced concentric lamella and ridges. The shell is thinner than that of eastern oysters, yet more deeply cupped. The Miyagi is the principal variety of Pacific oyster grown on the west coast. The Pacific oyster's shape may be highly variable and greatly influenced by environmental conditions. The upper, flat right valve is smaller than the left, and the inner surface of the valves is white with a faint purple hue over the muscle scar. The Kumamoto oyster is smaller, but is prized for its deeper cup (Figure 21-5). It spawns in the fall in nature and grows more slowly than the Pacific oyster.

Oyster disease and shellfish pests are a major concern to the state resource agencies and the oyster industry. Because the west coast industry depends on the movement of animals across state lines, the industry is subject to regulations established through cooperative agreements between resource agencies. All oyster seed and shellstock not destined for a terminal market that cross state lines are examined for the presence of disease and exotic "hitchhikers" (pests) which could be harmful to the natural resources and commercial interests. Seed and shellstock that do not pass certification are destroyed through cooperative agreements with the State and the industry. The various state natural resource agencies have a cooperative program which regulates the interstate movement of shellfish seed and seedstock.

Oyster diseases on the west coast occur both in hatcheries and during grow out in the natural environment. Hatcheries are artificial environments which can stress oysters and render them susceptible to an array of infections. When disease outbreaks occur in hatcheries, the stocks are destroyed and systems disinfected. This is a

protective measure for the natural resource and considered the most economically practical approach by the industry.

Natural environment associated oyster diseases on the west coast are not as widespread and devastating as those of Atlantic oysters on the east and gulf coasts, but they do occur. The most significant, in terms of reduced production, is the SMS of Pacific oysters. Summer mortality of Pacific oysters was first reported in California in the 1960s with mortality levels as high as 65 percent of adult Pacific oysters. Similar conditions occur in Pacific oysters cultured in Korea, France and Washington state. California oyster losses attributed to SMS have fluctuated over the years, and studies have addressed the initiating agent as possible pathogens, environmental factors and impacts, and stressors such as the combination of depleted energy reserves and attempted gonadal maturation. For decades, SMS was researched without resolving the cause. In 1993 and 1994, summer mortalities of Pacific oyster seed in Tomales Bay reached 52 and 63 percent, respectively, and were associated with elevated water temperatures above 68°F (20°C) and a bloom of the dinoflagellate, *Gymnodinium sanguineum* (= splendens). The etiology of this syndrome is complex with numerous environmental factors influencing disease outbreaks, but recent studies clearly implicate the role of a herpes virus specific to oysters. Warm water events resulted in expression of the virus, followed by mortalities. Growers are attempting to circumvent the problem by not planting Pacific oyster seed during the warmer months from May to October. However, seed availability during the cooler months has been a problem. A promising approach, which is being explored currently, is the use of survivors of multiple summer mortality episodes for broodstock.

Bonamiasis of the European oyster is caused by the protozoan parasite *Bonamia ostreae*. It has been detected in European oysters cultured in at least two bays in California. The parasite infects the oyster's blood cells, destroys its immune system, and impacts other physiological processes.

During the 1980s it was discovered that the protozoan parasite *Haplosporidium nelsoni*, which causes MSX or Delaware Bay Disease in Atlantic oysters on the east coast, is present in Pacific oysters in one bay in California. It is present in low numbers and appears to have little effect on the Pacific oyster host. It is now generally accepted that *H. nelsoni* was imported to California from Japan along with Pacific oyster stock. From there, it was introduced to the east coast of the U.S. along with Pacific oyster stock imported from California. The ultimate result has been catastrophic for the eastern oyster and the east and gulf coast industries. The results of these studies demonstrate the first molecular confirmation of the introduction of an exotic marine pathogen and emphasizes the need to adhere to strict importation guidelines as established by the International Council for the Exploration of the Seas (ICES).

Shellfish and the Environment

One of the more significant challenges to aquaculture in the next decade will be the industry's ability to position itself within the environmental framework and philosophy of natural resource management. Environmental issues are a concern nationally and are paramount in California. The two sets of laws and mandated course of action can

be found in the National Environmental Protection Act (NEPA) and the California Environmental Quality Act (CEQA). CEQA processes are initiated to evaluate and measure visible and potential ecological and social impacts resulting from existing and proposed human activity in the environment and to mitigate significant impacts.

Immediate environmental concerns relative to shellfish culture are the potential biological and physical impacts of culture technology on sensitive components of the marine ecosystem. These sensitive components include eelgrass as essential habitat for salmonids and other sensitive finfish, and the invertebrate assemblage present on and within the substrate that is essential to the food web of birds and other marine species. Also included are the impacts on the life habits of birds and marine mammals and on the physical structure of the bay. A key element of the CEQA process is the concept of significance of impact. Any activity in the bay environment has some level of impact on that environment. Correction, change, or outright abandonment of an activity is mandated if the level of impact exceeds the threshold of significance deemed sufficient to be detrimental to the biological or ecological parameter in question. It will be essential that shellfish technology not have significant adverse impact upon the health of the ecosystem on which it also depends. Shellfish culture and our living marine resources depend upon excellent water quality and a healthy environment and, therefore, these concepts are not mutually exclusive.

In response to these concerns, long term federal and state supported regional research has been initiated to study shellfish culture impacts. This research, which focuses on the industry in California, Washington and Oregon, is being conducted by university and state research agency personnel, and is monitored annually to identify areas that may need immediate alteration. In addition, federal and state funding, coupled with industry resources, is being directed toward the development of industry Best Management Practices to guide the industry in its present and future development.

Future Trends

Oyster hatchery and seed technology rapidly expanded in the 1980s and 1990s, including application of remote setting of oyster seed as an industry standard and the production and use of triploid (3 sets of chromosomes) oysters. The triploid condition prevents the onset of maturation and results in oysters characterized by year round production of high quality meat. Although triploid production was a positive technical breakthrough, oysters are sterile, resulting in a genetic "dead-end". To overcome this, the industry now applies high pressure following fertilization to retard both polar bodies. The resultant tetraploids (4 sets of chromosomes) are then artificially crossed with diploids (2 sets of chromosomes; normal condition), thereby producing sterile triploids that are used as production oysters while maintaining a viable genetic line in the diploid broodstock. This technology, coupled with the more recent establishment of broodstock genetic programs, will be a major industry thrust. Oyster genomic research is an industry priority and a regional cooperative effort involving university and industry geneticists and oyster hatchery managers.

The establishment of a national Molluscan Broodstock Program (MBP) and the Molluscan Broodstock Center on the west coast mark the true beginning of an oyster genetics program which fosters cutting edge genetics research. Using a mix of regional and national grants, geneticists are utilizing cooperative regional research to develop genetically marked family lines that are tested and selected for high yield and survival. Scientists are exploring the alternative strategy of crossbreeding and have demonstrated at the larval and market sizes that hybrid Pacific oysters have dramatically higher yield and superior metabolic performance than their inbred parents. This striking hybrid vigor or heterosis suggests that crossbreeding, in addition to traditional selection as practiced by the MBP, could improve oyster yield dramatically and quickly. Technology is also being developed to measure and more readily define “future performance” at the larval stage, thereby avoiding costly grow out trials and stock maintenance.

Current and future trends of the oyster industry are reflected throughout the west coast and the Pacific Rim because of the industry’s regional infrastructure and markets. Industry shellfish hatcheries which were once concentrated in the Pacific northwest have opened in Hawaii, thereby taking advantage of stable water quality and consistent solar radiance used in energy efficient algal culture. The primary markets for seed are west coast producers who will expand into more international markets. The industry is rapidly expanding Kumamoto oyster production because of its higher value and half shell market demand, and greater market attention will be given to value added shellfish products such as flash frozen half shell products for both domestic and international Pacific Rim markets.

The oyster industry will concentrate on developing more efficient methods of off-bottom culture techniques that are less intrusive and result in fewer environmental impacts. The greater adaptation of off-bottom culture, coupled with the higher valued half shell Kumamoto oyster, is a potential that may offset the loss of shucked product produced in bottom culture. The development and adaptation of more environmentally sound practices will remain an industry priority.

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Oyster production and value, 1950-2008.								
Year	Shucked pounds	Value	Year	Shucked pounds	Value	Year	Shucked pounds	Value
1950	38,600	\$6,716	1970	1,119,484	\$1,041,695	1990	2,040,015	\$5,832,404
1951	43,300	\$7,534	1971	978,826	\$880,251	1991	2,002,257	\$4,430,003
1952	45,100	\$7,847	1972	885,001	\$788,639	1992	1,910,328	\$4,194,444
1953	37,600	\$6,542	1973	726,875	\$831,604	1993	2,224,526	\$4,112,746
1954	73,500	\$12,789	1974	799,742	\$1,124,646	1994	2,310,286	\$4,884,678
1955	218,300	\$37,984	1975	799,885	\$1,105,468	1995	2,166,037	\$5,040,488
1956	755,600	\$131,474	1976	716,356	\$1,019,209	1996	1,235,351	\$4,373,748
1957	1,359,200	\$236,501	1977	929,544	\$994,137	1997	1,107,357	\$3,874,488
1958	1,158,600	\$201,596	1978	1,025,127	\$1,174,996	1998	1,085,185	\$3,719,820
1959	1,659,699	\$288,788	1979	1,144,623	\$1,921,872	1999	805,976	\$2,862,814
1960	1,656,689	\$288,765	1980	939,455	\$1,352,968	2000	835,986	\$2,907,294
1961	1,568,894	\$296,614	1981	1,061,983	\$1,593,076	2001	1,040,893	\$7,681,312
1962	1,722,139	\$306,418	1982	999,865	\$1,499,684	2002	1,116,932	\$8,046,357

Oyster production and value, 1950-2008.								
Year	Shucked pounds	Value	Year	Shucked pounds	Value	Year	Shucked pounds	Value
1963	1,269,017	\$230,719	1983	1,047,075	\$1,719,544	2003	1,125,777	\$8,227,316
1964	1,354,294	\$253,163	1984	1,252,680	\$2,920,799	2004	1,074,007	\$8,406,471
1965	1,062,792	\$263,440	1985	1,209,091	\$3,064,296	2005	927,234	\$7,675,168
1966	800,427	\$221,710	1986	1,130,540	\$2,862,643	2006	1,156,907	\$8,705,567
1967	742,141	\$207,274	1987	1,138,237	\$2,983,353	2007	1,060,000	\$8,775,887
1968	661,254	\$197,911	1988	1,172,024	\$3,129,851	2008	950,000	\$7,866,000
1969	713,045	\$212,099	1989	1,457,781	\$4,259,097			

Data Source: California State Tax records (royalty reports) and Department Aquaculture Harvest Survey Database.