Culture of Abalone

History

Pioneering efforts to mass cultivate abalone in California began about 35 years ago. Three abalone species, the red (*Haliotis rufescens*), the green (*H. fulgens*), and the pink (*H. corrugata*) have been farmed, and research into cultivation techniques has been conducted on the black (*H. cracherodii*) and white abalone (*H. sorenseni*). The red abalone, however, is the mainstay of the industry and comprises more than 95 percent of total production. Abalone are grown in either land-based tanks or in cages suspended in the water column. The cages are typically tethered from a raft but have also been suspended beneath a wharf. Aquaculturists that operate these in-water systems typically obtain small seed abalone from land-based hatcheries for grow-out.

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 through-flowing 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.

The number of participants in this industry and their total production have increased through time, peaking in 1996. In 1991, 15 registered abalone aquaculturists in California produced an estimated 175,000 pounds of abalone in the shell. By 1996, 27 registered abalone aquaculturists produced over 292,000 pounds of product. Participation and production then declined slightly through 1998 when 22 aquaculturists produced 162,000 pounds of product valued at $2.4 million. Only 13 of the 22 abalone aquaculturists registered in 1998 were actively producing abalone and most of the production came from four or five growers.

Red abalone being grown out on plastic substrate.

The decline in participation and production since 1996 is attributable, at least in part, to disease impacts exacerbated to some extent by a significant El Niño event. Until recently, cultivated abalone had been considered relatively disease-free. The bacterium *Vibrio sp.* infected larval cultures, but it was typically suppressed by using filtered, ultraviolet treated seawater. That perspective changed with the introduction of a parasitic sabellid polychaete worm from South Africa. By the mid-1990s, the parasite had spread to virtually every abalone aquaculture facility in the state. The worm induces the infested abalone to form a tube for it out of nacreous material. With heavy infestations, the abalone shell is brittle and very deformed and abalone growth is stunted. Impacts to the industry included loss from voluntary stock destruction and reduced income from marketing deformed product. Cooperative efforts by the industry, the Department of Fish and Game (DFG), and Sea Grant sponsored university researchers have almost completely eradicated the worm from California.

Unfortunately, the industry also started experiencing elevated losses of cultured product from withering syndrome (WS) during this same time frame. This disease, caused by a rickettsia-like prokaryote, is characterized by a drastic shrinkage of the abalones' foot and is always fatal. However, red abalone can be infected by the bacterium without showing clinical signs of disease. Research suggests that a stress trigger is necessary to induce clinical signs of the disease in this specie. The only recognized stress trigger is elevated water temperature. With the El Niño event, many facilities experienced elevated water temperatures that triggered WS, resulting in elevated mortality in their cultured stock.

The dedicated entrepreneurs at the core of this industry have achieved their successes despite these challenges and interest in abalone aquaculture remains high, prompted in part by the closure of the commercial abalone fishery in 1997. Presently, abalone are available to meet market demands only through importation or the purchase of cultured abalone. Consequently, there is a high market demand and a good price to growers for the farmed product.

A more recent positive development in abalone aquaculture is the production of cultured abalone pearls. The product is produced by inserting a nucleus into the abalone. Given time, nacre is laid over the nucleus to form a semi-spherical pearl that has all the lustrous hues of the shell interior. Once extracted, these pearls are set in

jewelry and the meat is processed for sale to restaurant trade as either a fresh or frozen product.

Status of Biological Knowledge

A considerable amount of research on abalone aquaculture has been accomplished by the private sector, particularly with respect to systems design and overall technology. University and DFG scientists have also made major contributions. Sea Grant-funded research has greatly increased our understanding of abalone developmental biology. Spawning induction procedures, larval settlement inducers, and larval rearing systems were developed by researchers funded through this program. Sea Grant-funded research has also contributed significantly to our understanding of abalone diseases.

The DFG began abalone culture investigations in 1971 at its Granite Canyon Laboratory near Monterey. That effort led to the development of a through-flowing larval rearing system and the development of a flush-fill tank system that have been adopted by the industry. The DFG subsequently developed a pilot production hatchery at Granite Canyon that provided training opportunities and resulted in the production of seed abalone for enhancement research.

The DFG's Marine Region shellfish pathology laboratory in Bodega Bay has expanded our knowledge of the biology of the parasitic sabellid worm that has contributed significantly to the success that has been achieved in the cooperative eradication efforts. That laboratory also identified the causative agent for WS and has conducted extensive research into questions related to transmission and control of this pathogen.

Two principle areas for research, nutrition and genetics, may provide significant benefits to the industry in the future. Prepared diets have been developed and are being used widely for juvenile stages. However, most prepared feeds are expensive and not readily accepted by adult abalone in comparison to giant kelp. Less progress has been made in genetics research. Most growers use a selection process where brood stock is selected based on growth rates. Wild broodstock is also used to maintain genetic diversity in cultured stocks. Some research has been done with triploidy as a means of enhancing abalone growth rates. While encouraging, the results have not been applied broadly within the industry.

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