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CENTER FOR TROPICAL AND SUBTROPICAL AQUACULTURE

Abalone Culture in Hawaii

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Haliotis fulgens and *Haliotis diversicolor supertexta*

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Abalone are herbivorous marine gastropods represented throughout the world's oceans by almost 90 species comprising the family Haliotidae. Abalone have traditionally been a highly prized seafood item and were collected more than 7,000 years ago by native American Indians along the Pacific coast for food, and for the manufacture of shell implements and mother-of-pearl decorations. Early Japanese references to abalone divers date back to 30 A.D. From 1865 to 1912, dried abalone comprised about 80% of Japan's marine exports from its only foreign trading port in Nagasaki. Japan currently harvests close to 13 million pounds of abalone per year and imports an additional four million pounds per year.

This strong demand in Japan and elsewhere has resulted in extensive exploitation, and many abalone populations throughout the world have been depleted. For example, in California the annual abalone harvest has decreased from 4-5 million pounds to less than 1 million pounds per year in less than two decades. Most commercial abalone fisheries are either stable or declining, and substantial increases are not anticipated. This provides an opportunity for abalone aquaculture to increase future supplies. Abalone aquaculture has increased dramatically in recent years and currently represents about 5% of California production. Today, abalone is cultured primarily in Japan, Korea, Taiwan, and China, and there is increasing interest in Australia, Britain, Canada, Chile, France, Mexico, New Zealand, South Africa, Thailand, and the United States.

The success of abalone aquaculture depends on selecting the best species for a given culture environment. The primary selection criteria are good growth and survival, locally available feed, proven culture technology, and established markets. Most importantly, production costs must allow for a reasonable profit margin at a price that is competitive with abalone from other sources. Of the almost 90 species and subspecies, only about 15 are of commercial significance in the fishery, and only about half of these are cultured commercially.

Interest in culturing abalone in Hawaii is strong due to the abundance of clear, clean seawater that is ideal for the culture of some tropical and temperate abalone species. Seaweed producers in Hawaii regularly discard excess or offgrade products that could potentially be used as feed for abalone. Given this interest and the availability of resources, a review of the literature was undertaken and two abalone species were selected for culture trials. The green abalone, *Haliotis fulgens*, and the colorful small abalone, *Haliotis diversicolor supertexta*, were selected based on established culture technology and reports of optimum growth and survival in ambient Hawaii water temperatures from 23° to 27° C.

To assess the feasibility of culturing these species, these questions were raised:

1. Will the locally cultured seaweed, *Gracilaria tikvaheae*, provide adequate nutrition?
2. Will the two abalone species exhibit good growth and survival in Hawaii culture conditions?
3. Can *Gracilaria* be grown economically as a feed for the abalone?

Environmental Requirements

Abalone thrive in clean ocean waters with dissolved oxygen levels close to saturation, stable salinities between 32 and 35 ppt, and a pH value around 8. These conditions approximate that of seawater. Optimum temperatures for growth vary between species and life stages, but *H.d. supertexta* grow rapidly in temperatures between 22° and 30° C. The optimum temperatures for larvae and seed are at the cool end of the range, while juveniles thrive in mid range, and the most rapid growth in adults is at the warmest temperatures. Different life stages in the green abalone exhibit a similar trend within a temperature range between 18° and 28° C.

Abalone are very sensitive to hydrogen sulfide, which is produced by the anaerobic breakdown of dead animals, feed, and feces. Reduced growth has been observed at levels as low as 0.05 ppm (Chen 1989). Ammonia is produced as a metabolite by many aquatic organisms and is toxic to most at levels above 1.0 ppm. Abalone are especially sensitive to ammonia, showing reduced oxygen consumption at levels as low as 10 ug/l, and feeding inhibition at 70 ug/l (Sanno and Maniwa 1962).

Culture System

The pilot systems used for growout of *H.d. supertexta* and *H. fulgens* in Hawaii were 3.0 x 1.5 x 1.0 meter concrete raceways. Aeration was provided to the tanks via small holes in a 1-inch pvc pipe extending the length of each raceway. Water was pumped from seawater wells with a temperature range between 23° and 27° C and a salinity between 32 and 35 ppt. Tanks were covered with 80% blocking shade cloth, and water flow rates provided approximately 10 turnovers per day.

Animals were fed weekly with *Gracilaria tikvaheae* and were also able to graze on a natural growth of algal turf consisting primarily of benthic diatoms and *Ulva*. Stocking density for the green abalone and the *H.d. supertexta* was 250/m^2.

Abalone Growth and Survival

Demonstration growout trials were conducted at two locations in the Hawaiian Islands: one on the island of Oahu at Kahuku Point, and another on the Big Island of Hawaii at Keahole Point. Both locations draw seawater from inland wells and discharge water into dispersion pits. Green abalone seed, 12 mm in length, were obtained from California growers, and *H.d. supertexta* seed were obtained from Taiwanese sources at 23 mm.

Average growth for the green abalone was 41.5 mm/yr at the Kahuku location, compared to 32 mm/yr at Keahole Point. Growth of *H.d. supertexta* averaged 34.9 mm/yr at Kahuku Point and 24.0 mm/yr at Keahole Point. Those differences in growth most probably result from cooler water temperatures at the Keahole facility.

Significant unexplained mortalities in green abalone populations at both locations resulted in a survival rate in two raceways of approximately 5%. These mortalities may have resulted from loss of aeration, supersaturation of incoming water, or localized production of hydrogen sulfide from seaweed decomposition. The survival rate of green abalone in a separate raceway at the Keahole Point location was 40% over the course of the year. Survival of *H.d. supertexta* at the Kahuku location averaged 61% compared to 48% at the Keahole Point site.

Prospects for Commercial Abalone Growout

The abalone grown in these trials using *Gracilaria tikvaheae* as the principal food source exhibited good growth rates. *Gracilaria*

provided adequate nutrition in conjunction with the mixed algal turf that was available for grazing. Improved growth was observed when water temperatures were higher during the summer months and could be maintained throughout the year by incorporating a solar heated reservoir. Variable survival could be improved through closer monitoring of the culture system and water quality.

The greatest constraint to commercial culture of abalone in Hawaii is the cost of producing the *Gracilaria* used as feed. Other regions in the world producing abalone incur feed costs ranging from $0.10 to $0.30/kg of wet seaweed. Production costs of *Gracilaria* in Hawaii are far higher and represent a serious competitive disadvantage. There is, however, a good opportunity to integrate abalone culture at existing *Gracilaria* farms, utilizing excess production and off grade product as feed for cultured abalone. In this case, only handling costs are incurred as this material is currently discarded. This would provide an additional high value crop to *Gracilaria* farmers, which would increase revenues and diversify production.

There are reports that dried kelp has been successfully used when rehydrated as feed for *H.d. supertexta*. This warrants investigation as this product could be imported to Hawaii at a landed rehydrated cost in the neighborhood of $0.15/kg. If this feed supports good growth and survival in these species, the major constraint to abalone culture in Hawaii will be removed. This would allow Hawaii's abundant clean seawater to be used as a resource supporting the further development of an abalone culture industry.

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