Culture of Marine Finfish

History of Finfish Culture

The impetus to develop marine aquaculture in the U.S. is strong. In 1998, the U.S. imported $8.2 billion in edible fishery products. During the past 15 years, production of food fish by capture fisheries reached a plateau of 66 million tons per year. Similarly, FAO statistics report that 60 percent of marine fisheries are fully or overexploited. Under these conditions, and with a growing human population, it is estimated that aquaculture production will have to increase by 140 percent from 1995 levels by the year 2025.

Marine finfish farming in California and the United States is in its infancy. In California, with the exception of anadromous species, no marine finfish are being produced on a commercial scale. In the United States, specifically Texas, only red drum are cultured in large numbers. However, the red drum fingerlings being produced are used primarily for stock enhancement and not grown out and marketed for direct human consumption. Like the Texas stocking program for red drum, California has been evaluating the efficacy of marine stock enhancement since the early 1980s. This research has been conducted largely under the auspices of the Ocean Resources Enhancement and Hatchery Program (OREHP). In recent years, the stock enhancement research has lead to projects designed to evaluate the feasibility of commercial growout in nearshore cages. The two primary species that have been investigated in California are the white seabass (*Atractoscion nobilis*) and the California halibut (*Paralichthys californicus*). Giant sea bass (*Stereolepis gigas*) have also been studied but to a much lesser extent.

History of the Ocean Resources Enhancement and Hatchery Program (OREHP)

The OREHP began in 1982 and has since been reauthorized with minor modifications. This program funds research through the sale of recreational and commercial marine enhancement stamps for all saltwater anglers south of Point Arguello. The California Department of Fish and Game manages the OREHP with the assistance of an advisory panel that consists of academic and management agency scientists, representatives of both commercial and recreational fishing groups, and the aquaculture industry. Since 1995, OREHP has supported operation of the Leon Raymond Hubbard, Jr. Marine Fish Hatchery in Carlsbad, California. This research facility is dedicated to improving our understanding of marine fish culture.

The species described in this chapter are native to California and have historically represented important fisheries to the region. Detailed descriptions of the natural history and fisheries for each are provided elsewhere in this volume.

Culture, Facilities and Systems

In California, land-based research facilities (hatcheries) are used for broodstock holding and maturation, and for larval rearing of marine finfish. Juvenile culture has been conducted on a limited scale for white seabass in cages, pools and raceways, and with California halibut in raceways. Seawater is pumped into land-based facilities from nearshore areas, (typically lagoons, harbors, or embayments) where water quality may be highly variable.

Broodstock maturation systems are typically recirculated so that water temperature can be controlled and used to induce spawning. Pool volumes range from 5,000 to 11,500 gallons. Egg hatching and early larval rearing systems require fine control over water quality parameters. Low flow requirements make flow-through systems practical, but recirculating systems are generally recommended. Pool volumes for egg hatching and early larval rearing range from 80 to 450 gallons. Juvenile growout has been conducted in flow-through systems (pools and raceways) up to 8,000 gallons in volume and nearshore cages up to 145,000 gallons.

California's OREHP maintains one of the largest breeding populations of a single species of marine finfish, white seabass, in the world. More than 250 adult fish are maintained in captivity either in breeding pools or support facilities. The need for this large number of individuals stems from the stock enhancement objectives of the program and the desire to ensure genetic diversity of released animals. However, the large broodstock population also results in a surplus of egg production that could help support a developing commercial culture industry.

Spawning of marine finfish, including white seabass and California halibut is often allowed to occur naturally or is induced semi-naturally using photo-thermal manipulation. That is, seasonal cycles are either natural (ambient water temperature and photoperiod) or controlled to promote spawning out of season. Hormone-induced spawning has not been investigated thoroughly and the few attempts to induce spawning have been largely unsuccessful. The disposition and general hardiness of California halibut and giant sea bass makes them potentially better suited to the extra handling required for hormone injections, while white seabass are not.

Female white seabass and California halibut are reported to mature in the wild at four to five years. For white

seabass, this represents a size of 27 inches and for California halibut, 18.5 inches. Eggs from each of these species are pelagic. Females are batch-spawners, with each batch typically yielding hundreds of thousands to more than a million eggs.

Growth of each of these species is highly dependent on water temperature. White seabass and California halibut are physiologically adapted to estuarine conditions as juveniles and therefore can tolerate (and may prefer) higher temperatures (71-81° F) associated with embayments. Furthermore, the southern range for these species near Magdelena Bay in Baja California, Mexico where water temperatures can be expected to be even warmer than those in California.

White seabass have been cultured in raceways to a size of 3.3 pounds in two years at temperatures of 56-79° F. A similar growout period in cages yielded only a 1.75 pound white seabass, but water temperature was considerably lower (52-72° F). California halibut cultured in raceways exhibited slow growth, reaching a maximum of 0.9 pound in two years under conditions of 55-77° F. It should be noted that these data are preliminary and that growth will likely be improved as the nutritional requirements and the potential for selective breeding are investigated more fully.

White seabass begin feeding at an age of four to five days (post hatch). Their relatively large size allows them to feed successfully on newly hatched *Artemia*. California halibut and giant sea bass both require smaller prey items such as rotifers for the first week of feeding, before transitioning to *Artemia* nauplii. Beginning at 20 days, dry feed is offered to the fish along with the *Artemia*. In order to help the fish wean from a live prey diet to dry feed, frozen zooplankton (adult *Artemia*, krill or mysids) is also fed to the fish. The amount of live food (*Artemia* nauplii) and frozen feed is slowly reduced as fish begin feeding on the dry feed. Once on dry feed, the feed size is increased as the fish grow. The feed type, characterized by the protein and fat content, may also be adjusted to reduce costs and improve fillet quality.

Among the more common infectious diseases affecting white seabass and California halibut are: 1) protozoans; 2) bacteria; and 3) invertebrate parasites. Among these pathogens, the bacterium *Flexibacter maritimus* is the most common and difficult to eradicate. Infections by this organism occur frequently after handling the fish and may result in lesions and fin rot. Among the non-infectious diseases, gas bubble disease is often severe among white seabass cultured in shallow water systems that are not adequately degassed, including floating raceways in natural water bodies. Nutritional deficiencies are also likely in cultured marine fish, although the effects are not well understood.

Cannibalism can be a significant problem among younger life stages of marine fish before grading is practical. Cannibalism can be reduced by optimizing feeding and nutrition and by grading the fish. In outdoor rearing pools, birds such as herons are known to prey on cultured fish. These predators can effectively be excluded using inexpensive netting. In cages, marine mammals such as California sea lions and harbor seals can be a problem if given the opportunity. Birds, both diving and non-diving, can also prey on caged fish. To prevent predation on caged fish, extra netting (*i.e.*, in addition to the fish containment net) should be employed above and below the water.

Aquaculture Potential

The aquaculture potential for white seabass and California halibut should be excellent. The potential for giant sea bass culture appears to be less promising, although further research is warranted for this species. White seabass and California halibut are popular, high-value species. Wild white seabass are available seasonally and at a large size of more than six to seven pounds. Wild halibut are available year-round and there is a growing market for live fish.

In other regions, species similar to white seabass and California halibut are being cultured successfully -- in some cases on a truly commercial scale. Among some of the croaker species (related to white seabass), red drum, and seatrout are being cultured in the United States. Totoaba, corvina, and maigre (all members of the croaker family) are being evaluated for culture in Mexico, Argentina, and the Mediterranean, respectively. Several species of flatfish are also being cultured. On the East Coast of the United States, the summer flounder and southern flounder are being evaluated for culture. In Japan, a flounder has been cultured on a commercial scale for many years, and two species of flounders are being cultured in South America.

Conclusions

Aquaculture of marine finfish is in its infancy in the United States, and California has not contributed significantly to its development. With 1,200 miles of coastline, opportunities to farm the ocean should be readily available. Unlike the agriculture industry in California, which consistently ranks number one in the nation (greater than $26 billion in 1997), mariculture opportunities in California are impeded by competing uses for coastal resources and a restrictive regulatory environment. In addition to the typical burdens associated with bureaucracies, California regulatory agencies often over-

lap in authority, lack a clearly defined process, and are often poorly educated about the need for aquaculture and what is involved with mariculture activities.

There is a clear need for aquaculture development worldwide and California has access to the coastal resources and high value marine species necessary to compete in the world seafood market. A proactive approach is required to make this a reality.

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