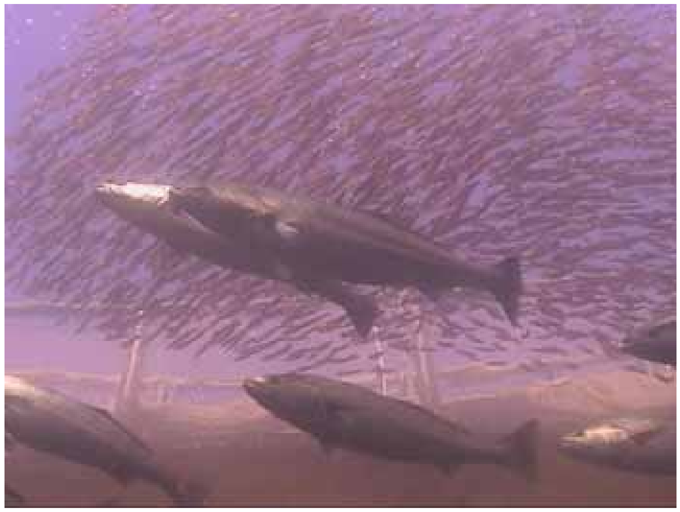
22 Culture of Marine Finfish



White seabass, *Atractscion nobilis*, in net pen. Photo credit: Hubbs-SeaWorld Research Institute.

Introduction

The impetus to develop marine aquaculture globally is strong and development is occurring in many regions. Wild fishery landings peaked in the 1980s, and current statistics of the United Nation's Food and Agriculture Organization (FAO) indicate that 80 percent of world fisheries are fully or over exploited. World population continues to increase as does the per capita consumption of seafood. Within the U.S., marine aquaculture has not advanced but the need to do so is clear. The U.S. currently imports 80 percent of its seafood of which 50 percent is farmed. The economic imbalance caused by these imports contributes $9 billion each year to the U.S. trade deficit, which is second only to oil. Recent concerns regarding food safety have also placed focus on the value of expanding a domestic supply. This notion has been further bolstered by the economic and environmental considerations related to "food miles" as seafood products are transported over great distances for packaging and final marketing.

Marine finfish farming in California and the U.S. is in its infancy. Although progress has been made in developing hatchery technologies for several species over the last 10 years, regulatory issues have stymied investment in outlets for growing these fish out in sea cages. In the U.S., commercial scale fingerling production has been demonstrated for cobia, red drum, and striped bass in the southeast; Atlantic cod and summer flounder in the northeast; and Pacific threadfin and Almaco jack in Hawaii. Offshore rearing trials have been conducted on some level for all these species, but the only commercial U.S. production of market size fish are the species being grown in Hawaii.

In California, commercial scale fingerling production of striped bass and white seabass (*Atractoscion nobilis*) has been demonstrated. The hatchery technologies for both species were developed for stock enhancement; however, white seabass enhancement has continued through the Ocean Resources Enhancement and Hatchery Program (OREHP) while striped bass has been curtailed. Growout to market has not been commercialized for either species, but two federally funded research projects have been conducted to evaluate the commercial potential for both. In addition to these two species, extensive research has been conducted in recent years on spawning and rearing of California halibut (*Paralichthys californicus*), yellowtail (*Seriola lalandi*), California sheephead (*Semicossyphus pulcher*) and cabezon (*Scorpaenichthys marmoratus*). Most of this research has been conducted by Hubbs-SeaWorld Research Institute (HSWRI) in San Diego, where spawning populations of all of these species have been maintained. In addition, several commercial abalone farms seeking opportunities to diversify have been evaluating the feasibility of raising California halibut and cabezon as a secondary species. Southern California is considered an ideal region for rearing marine fish in the U.S. because of its mild climate and ocean conditions, and high value species that are native or established. This list of species above does not represent all of the California species with aquaculture potential. Other species of interest would include tunas, lingcod and sablefish, to name a few.

A description of the rearing methods and typical results for each of these species is beyond the scope of this chapter. General methods are provided below that work well for a variety of marine species. These methods and results are based almost exclusively on the work at HSWRI; however, operational and regional differences can be expected. Specific examples are given for white seabass, California halibut, yellowtail and cabezon because most of the current interest lies with those species. California sheephead were found to grow far too slowly to be considered economical for food fish production, although production of juvenile sheephead for stock enhancement or the ornamental trade are possibilities. There is also great interest in the commercial potential for striped bass grown in sea cages. Striped bass are covered cursorily in this chapter because the culture methods for striped bass are very well documented.

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

The OREHP began in 1982 as a result of legislation (Assembly Bill 1414) authored by California Assemblyman Larry Stirling. The legislation was adopted to fund research into the artificial propagation of marine finfish species whose populations had become depleted. The ultimate goal of the legislation is to enhance populations of marine finfish species important to California for their recreational and commercial fishing value. Initially, research was focused on California halibut and white seabass; however, white seabass were eventually chosen as the primary species to focus on because of the depressed condition of the stock and its higher value to recreational and commercial fishers.

The California Department of Fish and Game (Department) 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. Members of the panel provide policy direction, review research proposals and recommend allocation of funds for the

OREHP. The program is funded through the sale of recreational and commercial marine enhancement stamps for all saltwater anglers south of Point Arguello.

Since 1995, the OREHP has supported the operation of the Leon Raymond Hubbard, Jr. Marine Fish Hatchery in Carlsbad, California. HSWRI operates this hatchery, which raises white seabass. As part of their OREHP contract, HSWRI has developed the culture protocols required for the program and the assessment techniques that will help evaluate the impact of the hatchery reared fish on the population. A Department Fish Pathologist works in conjunction with HSWRI staff to investigate and manage disease issues. In addition, HSWRI and the Department have obtained research grants to support collaborative projects in fish health, physiology, systems design, post release acoustic tracking, environmental monitoring and genetics.

Species Descriptions

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 in previously published Status of the Fisheries Reports.

Culture Facilities and Systems

In California, land based facilities are used for broodstock holding, maturation and larval rearing of marine finfish. Juvenile ongrowing has been conducted on a limited scale for some species in ocean cages but primarily in land based pools and raceways. Seawater is pumped into land based facilities from nearshore areas where water quality is often naturally variable with respect to parameters such as temperature and salinity. In heavily populated areas, water quality is often impaired by anthropogenic sources, which can be exacerbated by runoff during the rainy seasons.

Broodstock maturation systems are typically recirculated for biosecurity purposes and to control water temperature to induce spawning. Pool volumes range widely from 5000 to 42,000 gallons (19 to 160 kiloliters) depending on the species and number of fish used in the breeding population. Minimum tank size for spawning fish is not typically evaluated because maximum egg production is always desirable. Egg hatching and early larval rearing systems require fine control over water quality parameters because most of these species have pelagic ocean larvae that are physiologically adapted to stable ocean conditions. Low flow requirements make flow through systems practical, but recirculating systems are generally preferred for maximum control and biosecurity. Pool volumes for egg hatching and early larval rearing typically range from 80 to 450 gallons (0.3 to 1.7 kiloliters), although larger 1320 gallon (5.0 kiloliters) pools are currently being evaluated for large pelagic species. Juvenile grow out has been conducted in flow through systems (pools and raceways) up to 8000 gallons (30 kiloliters) in volume and nearshore cages up to 790,000 gallons (3000 kiloliters).

Reproduction

Spawning of marine finfish is typically allowed to occur naturally or is induced seminaturally using photo-thermal manipulation, where 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 for most species in California because it has not been deemed necessary. Multi-generational selective breeding programs have not been developed for any of these species.

White seabass, California halibut and yellowtail are all “batch” spawners that release pelagic eggs. Egg sizes average approximately 0.0488, 0.0323, and 0.0531 inches (1.24, 0.82, and 1.35 millimeters) in diameter for each species, respectfully. In group spawning situations, females will release hundreds of thousands of eggs to several million eggs per batch. White seabass and yellowtail are spring and early summer spawners. California halibut have an extended spawning period from late winter to late fall.

Unlike the other species mentioned, female cabezon produce an adhesive egg mass that attaches to hard substrate. A captive broodstock at HSWRI has yielded egg clusters estimated (gravimetrically) to contain tens of thousands to several hundred thousand eggs. Cabezon spawn in the winter and spring.

Age and Growth

Growth of each of these species is highly dependent on water temperature. The growth of marine fish reared in recirculating systems benefits from temperature control that can be maintained year round. Not only is growth faster when temperature is optimized, but it is stable and predictable. Rearing fish in flow through systems, including cages, is done at the mercy of ambient water temperatures and growth fluctuates accordingly. Optimum rearing temperatures for the different culture species and life stages described here have not been empirically defined. Life history patterns are often used to help guide culture methods, but even then information may be lacking. Ocean surface temperatures in southern California typically range from 53 to 72°F (12 to 22°C), which will support culture of all the species described herein. However, growth and performance of most species is maximized when water temperatures are on the upper end of this range-64 to 72°F (18 to 22°C). This is especially true for striped bass and California halibut. Yellowtail and white seabass are expected to benefit from warmer temperatures of 72 to 77°F (22 to 25°C) that would be more typical off Mexico. Cabezon are coastal groundfish that perform best in cooler waters of 53 to 58°F (12 to 14°C). It is important to note that white seabass, California halibut, and striped bass are found in brackish water as juveniles and, therefore, are generally tolerant of changing temperature and salinity. Yellowtail and cabezon are coastal species that are expected to be less tolerant, although this has not been empirically demonstrated.

Growth to market size for these species has been evaluated on a limited basis. A typical market size for farm raised fish is approximately 2 pounds (1 kilogram) for fresh or live product. The species described here can be expected to reach market size in 1 to 3 years. When ranked from fastest to slowest growing based on preliminary research, the following order results: yellowtail, striped bass, and white seabass, with California halibut and cabezon roughly tied for last.

Food and Feeding

The larvae of the pelagic species described in this chapter begin feeding several days after they hatch. Egg hatching occurs in just a couple of days for all species except cabezon eggs, which hatch in a couple of weeks. With the exception of white seabass, which are large enough to consume newly hatched brine shrimp (*Artemia spp.*) as a first feed, the other species require smaller prey items such as rotifers for the first week of feeding before transitioning to brine shrimp nauplii. Beginning at approximately 3 weeks of age, dry feed is offered to the fish in addition to the brine shrimp in a “weaning” process. The amount of brine shrimp nauplii 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.

Parasites and Disease

The disease organisms observed among cultured species described here are listed in Table 22-1. This list includes only those diseases observed among fish cultured at HSWRI, and a review of the literature would likely include additional pathogens. The number of disease organisms can be related directly to the culture history for each species, as well as the scale of production. This is balanced against the relative hardiness of each. Species cultured over a longer time period and on a larger scale tend to be associated with a greater number of disease organisms. Striped bass is an exception because it is extremely hardy and very well suited to the culture environment.

Table 22-1. List of observed disease organisms among several cultured species.				
	Protozoans	**Bacterial**	**Invertebrate Parasites**	**Others (Fungal, Virus, Etc)**
White Seabass	*Uronema* *Myxosporidean* *Trichodina* *Ichthyobodo* *Cryptobia* *Hexamita* Sporozoan	*Flexibacter* *Vibrio spp*. Epitheliocystis Spirochete *Piscirickettsia salmonis* Mycobacterium	Monogenean trematodes (*Anchoromicrotyle guayamensis* (gill fluke) and *Gyrodactylus* (skin fluke) Copepods (*Caligus* and *Lepeophtheirus*)	Fungus (unidentified) Herpesvirus Viral Nervous Necrosis Virus
California Halibut	*Trichodina* *Ichthyobodo* (formally *Costia*)	Epitheliocystis *Flexibacter*	Monogenean trematodes	Fungal pseudoneoplasm
Yellowtail	Myxosporidian *Trichodina*	*Flexibacter* Epitheliocystis	*Anisakis* Monogenean trematodes (*Zeuxapta seriolae* (gill fluke) and *Benedenia seriolae* (skin fluke)	
Striped Bass	*Trichodina*	*Vibrio spp.*		
Cabezon	*Uronema* *Ichthyobodo*		Monogenean trematode (*Gyrodactylus*) (skin fluke)	

Among the noninfectious 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 prevalent among cultured marine fish, although the cause and effects are not well understood.

Predators and Competitors

Cannibalism can be a significant problem among younger life stages of marine fish before size 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. Bird predators can effectively be excluded using inexpensive netting. In cages, marine mammals such as California sea lions and harbor seals can be a problem for cage operators if given the opportunity. Birds, both diving and non-diving, can also prey on caged fish. To prevent predation on caged fish, extra netting is typically employed over the cage and below the water line around the fish containment net. Removing dead or dying fish from the cages promptly will reduce the attraction to predators.

Aquaculture Potential

The aquaculture potential for these species has yet to be demonstrated on a commercial basis but is considered to be very good because there are known markets for fresh and live products. Because the current regional supply of these species is from the wild, the availability is often inconsistent and limited by natural abundance and fishing regulation. In other regions, species similar to all but cabezon are being successfully cultured commercially. Among the croaker species, red drum and seatrout are being cultured in the U.S., while totoaba, corvina and maigre are being evaluated for culture in Mexico, Argentina and the Mediterranean.

A number of flatfish species are also being cultured. On the U.S. east coast, the summer flounder and southern flounder are being evaluated for culture. In Japan, flounders have been cultured on a commercial scale for many years. The speckled flounder and fine flounder are also being cultured in South America. The commercial culture of several species of jacks is also well established worldwide with increasing interest in expansion. The four most highly valued jack species are the yellowtail “hamachi”, the kingfish yellowtail, goldstriped amberjack or yellowtail, and the greater amberjack. Commercial culture of one or more of these species has been taking place in Japan, Australia and New Zealand for many years, while new operations are currently being established in Europe and South America. Striped bass and its hybrids are cultured in many parts of the world on commercial basis.

Conclusions

Aquaculture of marine finfish is in its infancy in the U.S. and California has done little to improve this condition. With 1100 miles (1800 kilometers) of coastline in California, opportunities to farm the ocean should be readily available. Unlike the agriculture industry in California, which consistently ranks number one in the nation (about $33.8 billion in 2007), mariculture opportunities in California are impeded by competing uses for coastal resources and a restrictive regulatory environment. Recent legislation (California Sustainable Oceans Act of 2006) was passed that should provide greater definition to the regulatory requirements involved in permitting coastal sites for farming marine finfish.

One of the top priorities for the National Oceanic and Atmospheric Administration’s aquaculture program is to produce a sound and effective regulatory framework for marine aquaculture in the U.S., including federal waters. The focus is on sustainable aquaculture (finfish and shellfish) on land and in the ocean to meet the growing demand for seafood.

There is a clear need for aquaculture development worldwide. California has access to the coastal resources and high value marine species necessary to compete in the world seafood market; however, until recently regulations effectively deterred development of marine finfish culture. The new regulations should provide the framework to develop sustainable finfish culture in California.

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Further Reading

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