California - CA - Aquaculture

CALIFORNIA AQUACULTURE: GROWTH, KEYED TO DIVERSITY AND MARKETS

California aquaculture is as diverse as its lands and people. Located on the Pacific Coast of the lower continental United States, the state is typically Pacific-Rim in geology, topography, population, and outlook. It is a composite of extensive rural areas mixed with high density metropolitan centers concentrated around San Diego, the Los Angeles basin, Santa Barbara, the San Francisco Bay area, and Sacramento. With over 29 million people of mixed ethnic origin, California is the major marketplace on the West Coast, and a prime international market for aquaculture and fisheries products.

California is internationally known for its large and diverse agriculture industry. The same resources that have supported diversity in traditional agriculture also support the most diverse aquaculture industry in the United States. The state's size and north-south latitude range (43°N to 32.5°S), combined with its particular geology and topography provides a multitude of climatic and water conditions suitable for a variety of growing conditions. The configurations of six mountain ranges, large and small valleys, geothermal and other water resources, and a coastal marine influence creates unique micro-climates and a wide range of water temperatures for freshwater fish culture. The state's 3427 mile tideline coast, although primarily scenic rocky cliffs, possesses a number of bays and offshore sites and supports a substantial marine aquaculture industry. (See the primary species listed on page 2.)

SHELLFISH

Oysters: Oyster culture is the oldest aquaculture industry in California and dates back to the 1850s. With depletion of the indigenous native oyster, *Ostrea lurida*, early entrepreneurs began importing native oysters from the Pacific Northwest, then eastern oysters from the Atlantic Coast for growout in San Francisco Bay. Although mild winter conditions allowed faster growth rates in California than those experienced in many areas of the country, cooler summer water temperatures prevented significant successful reproduction of most oysters. Despite this the industry flourished, and between 1880 and 1910 California became one of the largest oyster producing states. As conditions in San Francisco Bay declined, so declined the industry, and the Bay was abandoned for shellfish culture in 1939. The industry was rebuilt in the 1950s based upon imported Japanese and Pacific oyster seed and growout in other bay systems. Japanese seed is still imported, however, today most California oysters originate from hatcheries located in the states of Washington and Oregon. They are shipped to California as eyed veliger

EXAMPLE AQUACULTURE SPECIES GROWN IN CALIFORNIA

Pacific Oyster	*Crassostrea gigas*
Kumamoto Oyster	*C. sikamea*
Eastern Oyster	*C. virginica*
European Oyster	*Ostrea edulis*
Red Abalone	*Haliotis rufescens*
Pink Abalone	*H. corrugata*
Green Abalone	*H. fulgens*
Bay Mussel	*Mytilus edulis**
Manila Clam	*Tapes japonica*
Channel Catfish	*Ictalurus punctatus*
Blue Catfish	*I. furcatus*
Rainbow Trout	*Oncorhynchus mykis*
Steelhead Rainbow Trout	*O. mykis*
Atlantic Salmon	*Salmo salar*
Golden Shiners	*Notemigonus crysoleucus*
Fathead Minnows	*Pinephales promelas*
Goldfish	*Carassius auratus*
Common Carp	*Cyprinus carpio*
Hybrid Carp	*C. carpio* x goldfish cross
Koi	*C. carpio*
Guppies and numerous tropicals	*Poecilia reticulata* & Others
Red Ear Sunfish	*Lepomis microlophis*
Bluegill	*L. macrochirus*
White Crappie	*Pomoxis annularis*
Mosquitofish	*Gambusia affinis*
Artemia	*Artemia salina*
Tubificid Worms	*Tubifix tubifix and Lumbriculus variegatus*
White Sturgeon	*Acipenser transmontanus*
Striped Bass	*Morone saxatilis*
Hybrid Bass(Striped bass x White bass)	*M. saxatilis*; *M. chrysops*
Black Bass	*Micropterus salmoides*
Redbelly Tilapia	*Tilapia zilli*
"Hornorum" Tilapia	*Oreochromis hornorum*
Mozambique Tilapia	*O. mossambicus*
Sterile Grass Carp	*Ctenopharyngodon idella*
Freshwater Shrimp	*Macrobrachium rosenbergii*
Algae (Freshwater & Marine)	*Spirulina, Chaetoceros gracilis; Nannochloropsis oculata; Isochrysis galbana, Thalassiosira pseudonana;Thalassiosira sp.; Tetraselmis sp.*

*M. galloprovincialis or M. trossulus (see Aquaculture 1989 (81):275-284)

larvae and set on cultch at the growout sites (remote setting). Maturity of the West Coast oyster hatcheries and remote setting of eyed larvae are among the more significant industry developments for California in the 1980s. The primary oyster species remains the Pacific oyster, however, other species are grown. California has several smaller shellfish hatcheries that specialize in production of cultchless seed and other specialized shellfish products including the European oyster, Pacific Kumamoto, mussels, and some triploid oyster seed.

California's oyster growing areas include Humboldt, Drake's, Tomales, Morro, and San Diego Bays, and offshore sites near Santa Barbara. Growing areas include lands leased from the state, navigation districts, municipalities, and public utilities. The industry employs a variety of growout techniques, each designed for the particular environmental conditions. Techniques include bottom culture and a variety of off-bottom techniques such as rack and line, rack and bag, stake, longline, raft, and tray culture.

Oysters are marketed primarily as a shucked product in 8 oz and 10 oz jars, 1 gal re-pack containers, and shellstock for the half-shell trade and the barbecue oyster market. Markets are diversified and include exports to the East Coast states, retail outlets, restaurants, and over-the-counter sales. A 10 oz jar of medium oysters sells for about $1.95 wholesale[1], medium shellstock sells for between $25-35 per hundred in bulk, for about $5 per dozen in small allotments, and individual oysters sell for between $.25-.38 each. Oyster production figures are reported to the resource agency where they are totaled and converted to pounds of shucked meat. The industry production for 1988 was 1,640,000 pounds of shucked meat. This does not represent the true value of the products, as nearly one-half of the oyster production is sold as singles, specialty products, and bulk shellstock.

Shellfish growers are also experimenting with a number of species including manila and pismo clams and scallops. Of special significance are abalone and mussels, two species making the transition from research and development (R&D) to commercial viability.

Abalone: California is unique in the United States as the only state with an established abalone fishery. As the natural fishery declined and market value grew, interest in culturing abalone both as a crop and to enhance the natural fishery was inevitable. In the 1960s large financial commitments were made by several privately-financed R&D companies and the state resource agency to develop abalone culture technology at hatchery sites along the central coast. These companies are now producing abalone seed for enhancement programs, for other growers internationally, and for gourmet restaurants. There are about 15 registered abalone firms in the state; three are producing significant volumes of seed

[1]Wholesale prices used in this text represent ex-farm prices to the grower, and in most cases represent estimates. There is no total reporting system for aquaculture production in the state, but estimates for all forms of aquaculture production, including cash flow from research and development product sales, place the ex-farm value in excess of $50 million annually.

and market animals, and several are in the pilot phase.

Of the species grown, about 95 percent are red abalone and 5 percent are pink or green abalone. The grow-out phase generally takes place in land-based, tank and raceway systems, or raft and barrel-habitat systems submerged in sheltered marine environments. Hatchery-set abalone are grown in tanks until they are 8-10 mm, they may then be transferred to suspended containers in tanks or raceways or sold as seed. At 20-28 months the kelp-fed, 5-8 cm "abs" are marketed in gourmet restaurants located primarily on the East and West Coasts of the U.S. and in Hawaii and Japan. In 1989 an excess of 2.6 million seed animals and 315,000 food animals were produced. Seed abalone prices range from about $.25 -.35 each, and food abalone prices are about $40 per pound.

Mussels: Another fast developing segment of the shellfish industry is mussel culture. Based on the capture of natural set and enhanced by the availability of hatchery seed, mussel farms have been established in Humboldt, Tomales, Agua Hedionda Lagoon (North of San Diego), and off the Santa Barbara coastline. Growout techniques include thinning and harvest of mussels attached to offshore oil structures and tube and bag culture in bay systems. Mussels are sold both wholesale and retail by growers, and wholesale prices range from about $1.40-1.85 per pound. Total state production increased to 1.5 million pounds in 1989 and is expanding.

CHANNEL CATFISH

Channel Catfish: California's channel catfish industry is one of the most profitable aquaculture industries in the state. It is based on traditional pond production of channel catfish with some production of the channel catfish x blue catfish cross. Most production occurs at locations throughout the Great Central Valley and in the Imperial and Coachella Valleys of southern California. Production is also expanding at geothermal sites in northeastern portions of the state. Catfish are produced on farms ranging in size from 2 to 400 acres of surface water, with production ranging from 1,500 to 12,000 pounds per acre.

The state's catfish market structure is somewhat unique. There is no processing industry, and only a few small processing units for channel catfish exist. Most of the product is sold live, primarily to recreational lakes for fee-fishing that services a billion dollar-plus recreational fishing industry, and to the live-tank, foodfish markets. The live-haul, foodfish market is considered prime. Market outlets are centered around Asian and Southeast Asian communities in and around large metropolitan centers. Fish are harvested, transported live, and sold to retail outlets with holding tanks in urban areas. They are then sold live as a fresh product to individual buyers and/or restaurants. Other markets include fry and fingerling sales to other producers, fingerling sales for farm pond stocking, and sale of fresh fish in the round to local restaurants, retail stores, and through farmers markets.

California growers get premium price for their catfish product. Fingerling sales are about $.04-.05 per inch, and sales based on bid to the recreational fishing market range from $1.40-2.00 per pound. The live, foodfish market range for California annual production is about 5 million pounds live weight. Growth is expected in the industry, and specialized processing is in the future.

SALMONIDS

Rainbow Trout and Other Salmonids: Rainbow trout production is one of the oldest viable aquaculture industries in California. Production facilities are located throughout the state, primarily in association with artesian springs or the lower discharge water of reservoirs. Production facilities include concrete and soil raceways, and production rates range from about 1,000 to 3,000 per 449 gallons/minute of water flow with the efficiency of the system dependent upon water quality, temperature, degree of fall between production units, and degree of the grower's technical skill. Most facilities average 15,000 pounds per 449 gallons per minute per year of water flow.

The rainbow trout industry, like catfish, does little processing. Most trout are marketed through the recreational fee-fishing lakes. Some trout, however, are marketed through the live-tank, retail outlets and in cooperative planting programs with the state resource agency. Bid contracts with larger recreational lakes range between $1.45-1.75 per pound live weight.

California is also a major trout egg producer with national and international sales. Industry R&D efforts have developed year-round, high quality egg production through photoperiod control and nutrition. Approximately 80 to 100 million eggs are moved annually depending on dry and wet years. Other developments that are now marketed include triploid trout and eggs and all-female eggs.

Another segment of the salmonid industry is land-based rearing of coho and chinook salmon and steelhead rainbow trout. Although in decline in recent years, salmon and steelhead eggs are hatched and reared at freshwater sites in northeastern California. Originally, before the onset of smoltification, they were transferred to coastal tank systems. Here they were transitioned to salt water. The steelhead were then grown and sold as whole fish, and the salmon are sold to the 7 to 13 oz portion market. Growers have also used innovative marketing techniques of shipping smaller salmon to the northwest and buying back larger salmon for finishing before selling to the whole fish market. Several growers have worked with Atlantic salmon at land-based facilities, including development of Atlantic salmon broodstock and egg sources.

BAITFISH, ORNAMENTAL FISH, CRUSTACEANS, AND LIVE FEED

With California's large population and love for recreational fishing and fish-related hobbies, the state's non-foodfish aquaculture industry is big business. Baitfish production consists primarily of golden shiners and fathead minnows. Goldfish are also produced for bait, but use is restricted to the Colorado River fishery. Production is accomplished in ponds with some fathead minnows produced in polyculture with channel catfish in broodstock ponds. The minnows are stocked as a nutrient supplement, then the excess is harvested for bait when the broodfish are moved or after the spawning season.

California imports a significant number of golden shiners from other states and internally produces about 18-20 million fish annually. Wholesale prices for fish run about $50, $80, and $125 per 1000 for small, medium, and large, respectively. The wholesale price for fathead minnows is about $45 per 1000.

Goldfish, koi-carp, guppies, assorted tropicals and aquarium frogs are produced for the aquarium trade and the aquarium feeder-fish industry. The culls of these fish are used to feed more valuable fish in the aquarium trade. A large segment of this industry, however, produces these same species as ornamental fish in the lucrative world of hobby fish. A single fish may sell for $2.50, or in the case of some ornamental koi, hundreds to thousands of dollars. Annual production of feeder goldfish ranges between $20-32 and $40-60 per 1000 for small and large fish, respectively. Production of these fish takes place throughout California in ponds, tanks, and closed systems.

A major aquaculture industry in the state is production, harvesting, and sale of artemia for the aquarium industry and as larval feed for fish and shellfish aquaculture. These small crustaceans are produced in managed, hypersaline evaporation salt ponds at a number of sites located the San Francisco Bay Area and desert areas in southeastern California. Both the adult and cysts of the ferry shrimp are produced, processed, and packaged for national and international markets, is a multi-million dollar commodity, and are among the most valuable aquaculture commodities in the state. Interest in larger crustacea as a human food item is has also been attempted in the state. Although California does not have a crustacean aquaculture food industry, it does have a *Macrobrachium* hatchery that produces postlarvae for R&D operations within the state and for national export.

The production of tubificid annelids also provides an important food source for the aquarium trade and fish hobbyists. While much of the worm market is obtained from sewage treatment ponds, a substantial amount of the market is supplied by the controlled production of these thread-like worms in pond systems receiving the effluent discharge from aquaculture facilities. Several species are used, most referred to as either red or black worms. The typical production system may be a series of inter-linked, shallow ponds or raceway units receiving a portion of the discharge from a trout raceway system. Clumps of worms are harvested, purged to remove gut content, and usually sold to distributors on a profit-shared basis. Distributors buy the worms from producers for about $6-7 per pound. Retail outlets sell the black worms for about $0.99-1.09 per oz in northern California, and

both red and black worms sell for about $1 per oz in the Los Angeles area.

STURGEON, STRIPED BASS AND HYBRID BASS

Among the fastest growing segments of the finfish industry are sturgeon and hybrid striped bass culture. Growers are using two approaches to develop the industry segments. The first is diversification of the farm by combining the culture of these R&D species with an economically viable species such as channel catfish. This allows shared facilities and resources and year-round activity and markets by separating activities seasonally. A working design incorporates first-use water in intensive tank culture of sturgeon and striped bass, second-use water is then settled and directed to channel catfish ponds, and final-use water is directed toward traditional terrestrial agriculture. Each aquatic crop results in profit through shared resources, whereas seasonality and technically associated obstacles preclude profitability of any one R&D species that is cultured alone. A second approach taken with these species is monoculture R&D operations, most of which depend primarily upon venture capital. These R&D facilities range from intensive tank culture using liquid oxygen to partially closed/recycle systems that also incorporate liquid oxygen. The sturgeon industry is another high-tech aquaculture industry, but has begun to produce both meat and caviar. The striped bass culture used to fill resource agency contracts is intermittent, but both the industry and the agency are interest in keeping a portion of the program alive.

Hybrid striped bass culture in California has moved from R&D to economic viability. The fish are cultured under intensive high-tech conditions in circular tanks using liquid oxygen. Culture facilities are confined to areas south of the Tehachapi Mountains or in areas of terminal drainage. This policy is maintained by the Fish & Game Commission to protect against introduction of the hybrid or the white bass used in cross-mating in north state water systems containing sensitive native species.

Production of these three fish has increased dramatically in recent years. Sturgeon fingerlings are sold to about 40 growers statewide and to markets nationally and internationally.Processed fish of about 12 to 16 pounds are marketed to white-tablecloth restaurants, with total production of foodfish in 1989 in excess of 200,000 pounds. Growers are receiving about $3.50-4.50 per pound live weight. 1990 also marked the first year for reproduction of F-1, "domestic" females by commercial growers.

TILAPIA AND OTHER R&D SPECIES

Tilapia culture facilities have the same location restrictions as those imposed upon the culture of hybrid striped bass, with additional restrictions placed on the species of tilapia allowed for culture. There is great interest in tilapia, and markets have been established in

inland and coastal cities receiving the imported product and products farmed at sites in California and farms in surrounding states. California has been knocked out of the processed tilapia markets by low priced imported products and now markets to the live-markets in major metropolitan areas. Ex-farm prices for tilapia average about $2.30 per pound current production is in excess of 500,000 pounds per year.

California farmers are growing a wide variety of R&D species and secondary species at large and small farm sites scattered throughout the state. Species include various centrachids and a variety of catfish for recreational fisheries and farm ponds. Also included are threadfin shad, aquarium frogs, mosquitofish for mosquito abatement districts, black bass and carp for Asian markets, and R&D operations producing *Macrobrachium*, *Spirulina*, sterile grass carp for the state aquatic weed projects in the south state, and crayfish. There are over 450 registered marine and freshwater aquatic farmers in the state with a healthy mix of established successful enterprises, start-up operations breaking into the established markets, and entrepreneurs providing the cutting edge with R&D efforts.

REGULATORY AGENCIES AND SUPPORT INSTITUTIONS

California's industry operates under the jurisdiction of a number of State agencies, the primary two being the California Departments of Fish & Game (CDFG) and Health Services. The CDFG is the lead agency. The California Fish & Game Commission is a Governor's appointed body which sets the CDFG regulations based upon the code of law and rules on actions or appeals that impact the industry. The CDFG operates through various departmental divisions which interact with the industry depending on jurisdiction such as marine, inland fisheries, anadromous fisheries, and enforcement, but has an aquaculture coordinator who assists the industry in departmental matters. The CDFG also uses two advisory committees consisting of industry, agency, and university personnel (Aquaculture Industry Advisory Committee and State Aquatic Disease Committee

The California Department of Health Service (CDHS) has regulatory authority over all health and sanitation aspects of the shellfish (filter feeding mollusks) industry, including growing waters, harvesting, processing, and shipping of products. The CDHS has excellent rapport with the industry and is known nationally for its innovative paralytic shellfish poison (PSP) cooperative industry/agency program and the development of PSP bay plans.

The industry association, the California Aquaculture Association (CAA), is well organized and one of the more effective state associations in the country. The CAA works with agencies and the state legislature to improve the industry's position in the state. Its members work with state and regional aquaculture funding institutions and researchers to address technical problems and insure an adequate research base for future industry growth.

California aquaculture produces no single major crop. Its strength lies in the use of abundant and diverse resources to produce one of the larger volumes of aquatic products in the country and a diversity of crops because of varied resources. The industry has undergone its greatest expansion during a period of inertia or decline for many traditional agricultural commodities. California growers are characteristically progressive and technically sound and comfortable whether in a production system, boardroom, or in the chambers of the state legislature. The state has a strong foundation for innovative R&D efforts in the commercial and investment communities. It also has strong market and population bases possessing positive attitudes about nutrition based on the consumption of aquatic products for a healthy lifestyle.

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