

MARICULTURE IN CALIFORNIA



by

Earl E. Ebert

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ABSTRACT

Mariculture in California is currently under development by several private concerns, universities, and by the California Department of Fish and Game. At present, most of these efforts classify as research and development with a few in the pilot production phase.

The Department of Fish and Game is presently conducting research in the culture of mortality resistant strains of Pacific oyster, *Crassostrea virginica*, the red abalone, *Haliotis rufescens*, and the spot prawn, *Pandalus platyceros*.

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INTRODUCTION

Today, man largely exploits food resources from the sea and the way he exploited terrestrial resources prior to the advent of animal husbandry: That is, hunting-type fisheries, exploiting wild, native stocks with no seeding or replenishment programs. Generally this practice works for the offshore or finned-fish fisheries provided good management practices are implemented, and adhered to. However, nearshore hunting-type shellfish fisheries are not sustaining, in some instances, due to several factors such as pollution, over-exploitation where there is easy access to the resource, and selective resource utilization. In this latter instance population imbalances arise favoring less desirable or economically unimportant species that compete with the sought-after species for forage and space. An example of this is found in our abalone fishery whereby the sea urchin, a close competitor of the abalone for forage and space, but relatively unimportant, economically, has become dominant on several fishery grounds that once supported substantial numbers of abalones.

Proponents of mariculture or sea farming contend that intensive farming of limited areas can produce yields that are now obtained from extensive fishing grounds. They also maintain that conflicts will be minimized between sport and commercial fishing interests, and other recreational pursuits. Opponents of mariculture see it as a threat to their public domain.

Opinion varies widely as to what role mariculture may have as a source of protein production in the future.

The fact is, no one really knows because the technology has not been sufficiently advanced to do more than speculate.

HISTORIC REVIEW

Mariculture began in California a century ago with the introduction of the eastern oyster, *Crassostrea virginica*, into San Francisco Bay. The industry that developed was based upon the transplantation of oyster "seed" from the Atlantic Coast, because this species does not reproduce in the Bay. The fishery persisted from 1872 to 1921, peaking in 1899 with a maximum production of 2.5 million lbs of meat. The decline of the fishery was reportedly due to inferior meat yields probably related to urban growth and pollution of Bay waters.

The year 1932 marked a new era for oyster mariculture in California with the introduction of seed of the Pacific oyster, *C. gigas*, from Japan. Commercial enterprises became established in Drakes Estero, Morro Bay and Elkhorn Slough as a result of experimental seed plantings accomplished by the California Department of Fish and Game (then Division). This fledgling Pacific oyster industry expanded into Tomales and Humboldt Bays and became the mainstay of oyster mariculture. Essentially the history of mariculture in California is that of the oyster cultivation, and even this fishery was based on two non-native species.

STATUS OF MARICULTURE

The oyster industry continues to figure prominently in mariculture today. Technological advances have been made in cultivation practices on growing beds and in the hatchery. Off-bottom cultivation practices have been implemented in some growing areas permitting optimal growth and survival. Oyster mortality due to siltation or predators is minimized. The inability to obtain a dependable supply of good

quality Pacific oyster seed impaired the industry in past years. Domestic seed now available from Washington State and a California hatchery provides more than one-half of the seed oysters to the industry. Average production of Pacific oysters for the past decade slightly exceeds one million pounds of meats. Principal growing areas are located in Humboldt Bay, Drakes Estero, Tomales Bay and Morro Bay. Off-bottom type cultivation is practiced in Humboldt Bay, Tomales Bay and Drakes Estero, in addition to bottom cultivation.

Private enterprise has shown an increasing interest in mariculture and a number of corporations are in various developmental or production stages.

Pacific Mariculture, located on the San Mateo County coast at Pigeon Point began operations in 1965. Initial emphasis was on cultivation of the red abalone, *Haliotis rufescens* and several oyster species. They were the first to develop mass cultivation techniques for the red abalone; but, because they could not obtain an open - coastal lease, exclusive from the public, in which to grow the abalone they shifted direction and concentrated upon the oyster. Pacific Mariculture has developed a successful seed oyster hatchery operation. They supply seed of the eastern oyster, Pacific oyster and European oyster, *Ostrea edulis*, to the northwest, the eastern seaboard and parts of Europe. They also cultivate seed of the Japanese littleneck clam, *Tapes semi-decussata*, and the hard shell clam, *Mercenaria mercenaria*.

Marine Associates, located along the central California coast near Cayucos, became operational in 1968. Their operations are directed towards mass cultivation of the red abalone from the egg to a harvestable size in shore-side ponds. They recently completed a new hatchery based upon information developed during their pilot-hatchery operations. At present they have constructed three ponds, the main one is of

approximately 865,000 gallon capacity and has been stocked with 80,000 juvenile red abalone spawned in their hatchery. Marine Associates expect to grow one million abalones in a pond of this size, up to 3 to 4 inches long, taking approximately three years. Abalones of this size are salable to export markets.

International Shellfish Enterprises was formed to grow shellfish, principally oysters, in heated water effluent resultant from fossil fuel, steam-electric power plant operations. They began pilot hatchery studies in a trailer at the Pacific Gas and Electric Company's power plant at Moss Landing, on Monterey Bay. Construction of a large (5,000 sq ft) hatchery was begun in 1972. However the company has not yet achieved a production-level capacity.

Limnos Corporation is situated on south San Diego Bay at the San Diego Gas and Electric power station and also uses heated water effluent in their operations. Initially, Limnos Corporation was interested in cultivation of the American lobster, *Homarus americanus*. Techniques were developed for mass cultivation of this species but problems arose over finding a suitable growing area. Because of this, Limnos shifted operations, primarily to shrimp cultivation and more specifically to the brown shrimp, *Penaeus aztecus*. Their operation might be termed pilot-production. A 100 acre pond was first stocked in June 1972 with 200,000 post-larval stage brown shrimp. Potential yield from this pond has not yet been assessed. Limnos Corporation reports that brown shrimp can be stocked in their pond at a density of 22,000 shrimp per acre, and will endeavor to accomplish this in the future.

Monterey Abalone Farms represents a recent venture, on a relatively modest scale, to cultivate the red abalone. Their pilot hatchery is located on Cannery Row in Monterey and is now in a research and development phase. They are principally interested in the nutritional aspects

of red abalone cultivation. Monterey Abalone Farms has succeeded in hatching and rearing quantities of red abalones, and they have evaluated a variety of food formulations. Unfortunately, specific information on their findings is proprietary and not available.

Pacific Ocean Farms, Inc. was established in 1972 to cultivate the red abalone. The corporation has not constructed a hatchery or developed their lease-site. Pacific Ocean Farms did succeed in obtaining a 50 acre open coastal lease off the central California coast near Point Sur. This lease is significant in that it provides for growing red abalones in the ocean exclusive from the public. This was possible because red abalones no longer support a commercial or sportsfishery in the region; and the lease site is in a remote area having poor public access.

Silverking Oceanic Farms, Inc. is located at Waddell Creek, 17 miles north of Santa Cruz on State Highway 1. Their operation consists of hatching eggs from silver salmon and steelhead trout, releasing marked fingerlings into Waddell Creek, then harvesting the adult marked fish when they return from the ocean to spawn. This operation requires close supervision by the Department. The present operation is considered pilot-production and Silverking Oceanic Farms has applied to the Fish and Game Commission to develop a similar, but full scale production operation in northern California at Elk Creek, Mendocino County. They expect to hatch 20 million eggs (silver and king salmon) annually if this site is approved.

Recent practices on leased beds of giant kelp, *Macrocystis* spp. qualify as mariculture, at least in southern California. The kelp industry has been active in restoration of kelp beds in southern California primarily by controlling the herbivorous sea urchin through physical or chemical means. Also juvenile and adult plants are being

transplanted into former kelp bed regions to promote new bed development. Mass culture techniques for giant kelp have been developed in the laboratory for re-seeding impoverished beds or establishing new beds. In addition to the above listed corporations, several other companies and individuals are involved in private mariculture enterprises often of a small-scale nature, and in a research stage of development (Table 1).

STATE MARINE CULTURE LABORATORY

In late 1970, after an extended planning period, fraught with administrative problems, a marine culture laboratory finally became a reality for the California Department of Fish and Game. The laboratory is located approximately 12 miles south of Monterey on State Highway 1 at Granite Canyon. The seawater system incorporates many of the latest ideas in design and equipment to provide for wide-ranging capabilities. The facility has a dual seawater delivery system, ultra-violet treatment, high transport water filtration, a fully automatic heated seawater system and portable seawater chiller units. The broad objectives of the Marine Culture Laboratory are: (1) to explore the feasibility for mass cultivation of selected marine shellfish species; (2) to improve existing fisheries or possibly create new fisheries; (3) to obtain life history information of shellfish and; (4) to provide information for mariculture. The program, in part, is funded under the Bartlett Commercial Fisheries Research and Development Act (P.L. 88-309).

Priority species being investigated include the Pacific oyster, red abalone, and spot prawn, *Pandalus platyceros*. Culture studies have also been accomplished on the market crab, *Cancer magister*, and to a limited extent, on the spiny lobster, *Panulirus interruptus*. However, these latter two species are of lower priority and work is accomplished seasonally, as time permits.

TABLE 1. Private Maricultural Enterprises in California

Company	Location of operations	Type of Operation	Operational stage*
Coast Oyster Company	Humboldt Bay	Pacific oyster; bottom cultivation	P
Eureka Oyster Farms	Humboldt Bay	Pacific oyster; hanging cultivation	P
Aquaculture Corp.	Tomaes Bay	Seeking shellfish having therapeutic value: emphasis on mussels	R&D
Frank Spenger Company	Tomaes Bay	Pacific oyster; bottom cultivation. Purchases and holds adult eastern oysters for restaurant trade.	P
Hamlet Oyster Beds	Tomaes Bay	Pacific oyster; bottom cultivation	P
Pacific Shellfish Co.	Tomaes Bay	Pacific oyster; bottom cultivation	PP
Tomaes Bay Oyster Co.	Tomaes Bay	Pacific oyster; hanging culture. Purchases and holds adult eastern oysters for restaurant trade	P
Johnson's Oyster Co.	Drakes Estero	Pacific oyster; 90% hanging culture; 10% bottom culture.	P
Pacific mariculture, Inc.	Pigeon Point	Hatchery operations, principally oyster, some clams. Provides oyster and clam seed stock to industry.	P
International Shellfish Enterprises	Moss Landing-Elkhorn Slough	Constructed large hatchery; principally for oysters; not yet in operation.	R
Pacific Ocean Farms	Pacific Grove	Plan to cultivate red abalone on open coastal lease	R

TABLE 1. (Continued)

Company	Location of operations	Type of operation	Operational stage*
Aquaculture Enterprises	Monterey Bay	Cultivation of American lobster	R
Monterey Abalone Farms	Monterey Bay	Cultivation of red abalone; principally nutritional studies to optimize abalone growth	R
California Marine Associates	Cayucos	Red abalone cultivation in shore-side ponds	R&D
Morro Bay Oyster Co.	Morro Bay	Pacific oyster; bottom cultivation	P
Marine Futures	Encina Lagoon	Pacific oyster cultivation in heated water effluent from power plant	PP
Limnos Corporation	San Diego Bay	Cultivation of brown shrimp in 100 acre pond receiving heated water effluent from power plant	PP

*Legend

R&D = Research and Development

R = Research

PP = Pilot Production

P = Full Production

The specific objective of the Pacific oyster study is to develop a resistant strain. This oyster frequently experiences high summer mortalities in growing areas of central and northern California. Causative factors of these mortalities are largely unknown. The study approach was to select old oyster stock known to have survived several high mortality periods, spawn these and distribute the progeny on growing beds. The assumption being that the adult stock had developed an inherent resistance to the factor(s) responsible for summer mortalities and would transmit this to their offspring.

Successful spawnings and seed (spat) sets were obtained in the spring and fall of 1972. These progeny have been distributed on oyster growing areas at Elkhorn Slough, Drakes Estero, Tomales and Humboldt Bays. A routine monitoring program indicates that these offspring of "resistant" parent stock are exhibiting good growth and survival characteristics. It is anticipated that the progeny of the spring 1972 spawning will attain maturity by the fall of 1973, be spawnable and, hopefully, produce a second generation of oysters possessing good survival characteristics.

The red abalone study has been designed to examine known culture techniques, and improve upon and develop new techniques in order to enhance the mariculture potential of this species. The use of elevated temperatures to optimize embryological, larval and post-larval development and growth is also being examined.

Research on the feasibility of culturing spot prawn has been in progress since March, 1971. This species lends itself exceedingly well to laboratory mass cultivation procedures but laboratory growth rates are somewhat less than desirable for mariculture. One year old laboratory

reared spot prawns nurtured on a mixed natural foods diet averaged 21.7 mm carapace length, having an average weight of 7.1 g.

Forage culture represents an integral and specialized element of the overall laboratory operations. Close coordination must be maintained with shellfish hatching periods to insure adequate quantities and types of forage for larval shellfish. At the Marine Culture Laboratory unicellular algae species such as *Isochrysis galbana*, *Monochrysis lutheri* and *Phaeodactylum tricornutum* are routinely cultured for oyster rearing. *Phaeodactylum* is also mass cultured in 200 gallon reservoirs in the greenhouse and extensively used for supplemental feeding and conditioning of various filter feeding organisms in the laboratory.

The brine shrimp, *Artemia salina*, is the principal zooplankter cultured, and serves as forage for certain crustacean larvae such as the spot prawn. Additional zooplankters being studied to determine suitability as forage include copepods, and larvae of the echiurid worm, *Urechis caupo*.

SEA GRANT STUDIES

The National Sea Grant Program in California provides funding to Sea Grant Colleges for a number of mariculture-oriented projects (Table 2). The Sea Grant Program was created to accelerate the development and optimum utilization of our marine resources. A requirement of the Sea Grant program is that it be so administered so as to supplement and not duplicate or overlap any existing and related Government activities.

DISCUSSION

We are in the midst of a research and development period for mariculture, and undoubtedly viable sea farming ventures will evolve. To date, the only animal proven economically feasible for mariculture in California is the oyster. The oyster is probably the most studied

TABLE 2. National Sea Grant Mariculture Programs in California.

Organization	Project
California Institute of Technology Pasadena, California 91109	Restoration, Propagation and Management of Marine Algae, <i>Macrocystis pyrifera</i> .
University of California, Davis Davis, California 95616	The Culture, Selective Breeding and Genetics of the Lobster, <i>Homarus americanus</i> . Habitats for Rearing of Lobsters, <i>Homarus americanus</i> .
University of California - San Diego, Institute of Marine Resources La Jolla, California 92037	Abalone Culture Methodology and Larval Ecology. The red, <i>H. rufescens</i> , pink, <i>H. corrugata</i> , green, <i>H. fulgens</i> , and white abalone, <i>H. sorenseni</i> .
University of California - Santa Barbara Santa Barbara, California 93106	Continued Studies of Seaweed Resource Management (Cultivation). Inclusive are <i>Gelidium</i> , <i>Gracillaria</i> and <i>Macrocystis</i> . Ecosystem Studies and Mariculture Potentialities of a Coastal Lagoon.
Humboldt State University Arcata, California 95521	Sewage Fertilization of Brackish and Saltwater Fish Ponds for Rearing, Pink Salmon, <i>Oncorhynchus kisutch</i> , and Steelhead Trout, <i>Salmo gairdneri</i> . The Utilization of Fish Wastes for Rearing of Crabs, <i>Cancer magister</i> , in Salt and Brackish Water.
San Diego State University San Diego, California 92115	Studies of Recruitment and Growth of Puerulus and Juveniles of the California Spiny Lobster, <i>Panulirus interruptus</i> . Investigation and Development of an American Lobster, <i>Homarus americanus</i> , Fishery in California.

and best known invertebrate animal. Significant technological advances have been made in oyster cultivation, but further research is necessary in the areas of nutritional requirements, diseases and selective breeding.

The potential for cultivation of such mollusks as oysters, scallops, various clams and abalones is good. They are all filter feeders or herbivorous species, and feed at the photosynthetic base of the food chain. Thus only one step is involved in the conversion of plant to animal matter.

Private enterprise in mariculture, in California, is largely represented by small companies, with limited capital attempting to do costly research and development. Either government subsidy must be provided, or preferably, government agencies must accomplish the bulk of research and development.

The Department has made recommendations to; (1) continue research in developing shellfish culture methods as well as initiating work in cultivating other marine organisms; (2) to work with industry in developing new techniques for cultivating marine organisms; and (3) encourage the development of mariculture in California on both private and state-owned lands. These recommendations closely parallel the purpose of the Sea Grant Program for mariculture.

It is imperative that programs established under Sea Grant in California, relative to Mariculture, have objectives that are compatible to the Department's recommendations, as the Department is charged with the responsibility for managing the living resources of the State. Such a working relationship is necessary if we are to expediently obtain and disseminate the information so vitally needed by the mariculture industry.