Molluscan Mariculture in the Greater Caribbean: An Overview

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ABSTRACT—Marine mollusks suitable for mariculture in the Caribbean area have received increased attention in recent years in an effort to produce more seafood for inhabitants of the area. However, molluscan mariculture in the Caribbean is still, with a few exceptions, in its infancy when compared with these activities elsewhere. Pilot and commercial culture operations for American oysters, Crassostrea virginica, *and mangrove oysters,* C. rhyzophorae, *exist in Jamaica, Cuba, Venezuela, and Mexico, and for rock mussels,* Perna perna, *in Venezuela. Extensive research has been carried out on the mariculture potential of the queen conch,* Strombus gigas, *with experimental hatcheries in some countries (more are under construction or planned), and a commercial hatchery is already operating in Turks and Caicos. The culture potential of several mollusks in the Caribbean, including native and exotic species, and several problems impeding increase in molluscan culture in the Caribbean are discussed.*

Introduction

This paper reviews the history and current status of both experimental and commercial molluscan mariculture in the greater Caribbean area (Fig. 1). Seafood is and has been a staple for Caribbean people since pre-Columbian times. In many areas, however, seafood demand exceeds both the current catch and potentially available resources. A recent review of eastern Caribbean fisheries by Olsen et al. (1984) incorporated land area, human population, shelf area, number of tourists, and fish landings by island/nation. These figures, together with total seafood consumption rates (local residents and tourists), permitted a comparison between island-shelf potential yield and demand for marine protein in the Caribbean which revealed that:

1) Only a few of the eastern island nations are currently supplying their own seafood demand,
2) The current demand for seafood in the area is about 775,000 metric tons (t), which greatly exceeds both current landings of about 87,000 t and the 200,000 t potential yield, and
3) The shelf area of many islands is

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Figure 1.—Map of greater Caribbean region.

Figure 2.—Mangrove oyster culture system in coastal region.

generally too small to support additional fishing effort, and although there are some areas that can support additional exploitation, increased seafood production must come from resources not already exploited.

Although almost all island nations presently have this serious seafood production deficit, some nations are in more trouble than others. For example, the Dominican Republic, which currently lands about 6,435 t of finfish and shellfish, has a seafood demand of 137,000 t and a potential yield from its shelf of only 864 t.

Mollusk culture could increase seafood production in many Caribbean island nations and reduce the difference between present production and demand. Another reason for culturing mollusks in the Caribbean is that as export products (for food or the aquarium or ornamental shell trade) they generate hard currency to help alleviate serious trade deficits that characterize many Caribbean nations, as well as provide needed employment. Finally, cultured mollusks, in particular cephalopods (Hanlon, In press) and the sea hare, *Aplysia* spp. (Fay, 1971), can and have been used extensively in neuroscience and behavioral research.

However, despite these incentives, molluscan culture in the greater Caribbean is, with few exceptions, in its infancy when compared with the status of these activities in such countries as Japan, Australia, France, Spain, the Netherlands, and others. In addition, available information on the molluscan culture in the Caribbean is limited. In contrast, the journal *Aquaculture* (Morse et al., 1984) devoted over 400 pages to "Recent innovations in cultivation of Pacific mollusks." Possibly because of the vastness of the Pacific Ocean and variety of marine habitats and molluscan species, the research effort is more extensive than in the Caribbean. Nonetheless, the importance of increasing food production in the Caribbean is every bit as important as it is in the Pacific, and perhaps even more so considering the large human population and the relative lack of other food sources in many Caribbean island nations.

Present molluscan mariculture activities in the Caribbean can be divided into three categories: Semi-intensive culture, extensive culture, and research.

Semi-intensive Culture

In the Caribbean, semi-intensive culture of mangrove oysters, *Crassostrea rhizophorae*, is presently practiced in Cuba and Jamaica, while American oysters, *C. virginica*, are raised in Mexico and Venezuela, and the South American rock mussel, *Perna perna*, is cultured only in Venezuela.

Cuba

Over a 12-year period (1963-74), biological and ecological studies and breeding experiments supervised by United Nations Development Program/Food and Agriculture Organization (UNDP/FAO) experts, were conducted on mangrove oysters in Cuba, and many locations were found suitable for culture. A mangrove oyster culture system was developed during the study period, based on known methods and the use of inexpensive and readily available local materials (Nikolic et al., 1976).

Farming facilities, generally located in estuarine areas, consist of stockades of palm posts driven into muddy or sandy bottoms, arranged in line or in a quadrangle (Fig. 2). Posts extend about 1-1.5 m above the surface of the water and are placed 2.5 m apart, supporting 6 m long, wooden traverse beams. Red mangrove terminal branches, suspended from the traverse beams with tarred ropes or monofilament nylon thread, are used as spat collectors. The collectors are checked at least once a month (Fig. 3) to make certain that the binding ropes are securely fastened, that collectors are favorably located in terms of tidal cycles, and to remove fouling organisms and predators. The oysters are harvested 5-6 months after placing the collectors. Subsequent harvests take place each month thereafter, when the largest oysters are collected during monthly cleaning operations. (Nikolic et al., 1976).

The first commercial oyster farm in Cuba, located on the northeastern shore, began operating in 1975. About 30 farms were initially planned by Cuban officials, with an estimated potential production between 6,500 and 7,500 t. However, because of industrial pollution in the culture areas, only about 20 percent of the area could be used. Presently there are 19 farms in operation, with an estimated potential production between 900 and 1,100 t of unshucked oysters. In the last 3 years, wide fluctuations in seasonality and abundance of spat settlement have adversely affected growout schemes. To optimize oyster growout, it is necessary to have an adequate, consistent source of spat. A hatchery under construction and supervision of FAO experts, combined with ongoing pilot scale research on controlled reproduction and oyster larval maintenance, is expected to produce sufficient spat consistently[1].

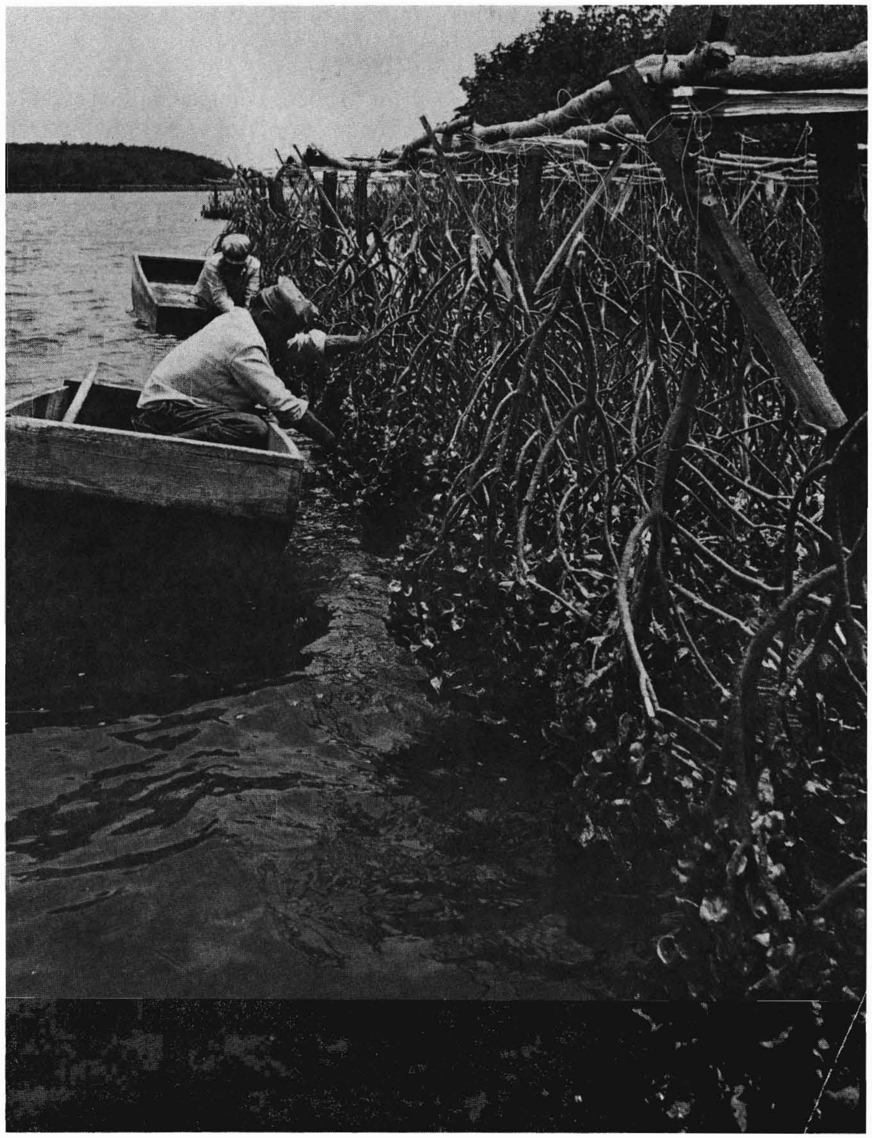

Figure 3.—Mangrove oyster culture system in Cuba.

Jamaica

In July 1977, a joint mangrove oyster culture project was set up by the International Development Research Center (IDRC) of Canada and the Government of Jamaica (through the Fisheries Division of the Ministry of Agriculture and the University of the West Indies' Department of Zoology) to determine its feasibility in arresting the loss in natural oyster populations to land reclamation, particularly in the Kingston Harbor area, and to ensure a constant or increased supply of oysters. After 4 years the culture system was considered viable so in 1980 an "Oyster Culture Unit" was set up within the Ministry of Agriculture to operate pilot farms and provide extension services[2].

[1]Frias-Lepoureau, J. A. Mariculture Section, Ministry of the Fishing Industry, Cuba. Personal commun., 1 October 1984.

[2]MooYoung, R. R. Inland Fisheries Project, Ministry of Agriculture, Jamaica. Personal commun., 8 November 1984.

The system adapted known oyster raft-culture methods to Jamaican conditions (Wade et al., 1981). Spat collectors are made of pieces of old car tires, cut into 8 × 8 cm squares and drilled in the center. These are strung together with monofilament line, (10-12 collectors per string), aged in seawater for 2 weeks before use, and then hung from bamboo and mangrove racks in the intertidal zone to collect spat. When the preferred density of about 10 oysters per collector has settled, the collectors are restrung on long monofilament plastic lines, spaced with 10 cm bamboo poles and tied to bamboo rafts. Flotation for the rafts is provided by 44-gallon oil drums painted with antirust paint, and anchored by nylon ropes tied to 80-pound concrete blocks. Market size of 7-8 cm is reached in 6 months. Only about 10 percent of production is suitable for marketing because of poaching, diseases, and fouling organisms, all major problems. In addition, some potential growout sites located near urban centers may give rise to health problems caused by pollution; therefore, the Jamaican government is considering depuration plants and strict marketing regulations (ADCP, 1983).

Oyster spat is presently collected at the pilot farm of the Oyster Culture Unit in Bowden, Port Morant. Growout is only carried out at this time in Port Antonio, where local fishermen built and have maintained growout rafts since January 1982. Growout was attempted at Falmouth, but was discontinued due to high coliform counts. Microbial studies to institute preventive measures are under way in a joint project between the University of the West Indies and the University of South Florida.

Belmont-Bluefields is a proposed growout site. There are plans to grow the oysters in baskets and trays, which produce single shells instead of clusters, and which have more appeal for tourists. There is a high demand for oysters from hotels and restaurants, and all present production is readily sold in Kingston. No reliable production figures are available but the quantities sold are reported to be small. Three Jamaican workers from the Project have recently completed overseas training at Dalhousie University in Canada through IDRC scholarships. Finally, an experimental oyster hatchery is being planned[3].

Mexico

In Mexico, commercial aquaculture activities involving oysters (and seven other groups of organisms which include shrimp and lobsters) are reserved exclusively for aquaculture cooperatives. Although the most successful oyster farming cooperatives are located along Mexico's Pacific coast (culturing a local species, *Crassostrea corteziensis*), experimental oyster culture in Mexico began in the lagoon of Tamiahua in 1957 (Conrad, 1985). American oysters are also raised, and its most important culture grounds are on Mexico's Gulf coast, in the lagoons of Pueblo Viejo, Tamiahua, Tampamochoc, Machona-Carmen, Macoacan and others in the States of Veracruz and Tabasco (Lizarraga, 1974).

Seed is commonly collected on collars of oyster shell cultch, although roof tiles and wire-mesh or plastic bags are also used. Spat collectors are placed in stockades, hung from traverse beams, and after 2-3 months (when the seed is 2-3 cm) they are moved for growout. Two basic systems are used. In one the collectors are placed on the bottom in areas consolidated with old oyster shells, and in the other, a suspension system is used with collectors strung on galvanized wire strings, separated by plastic tubing, and hung in stockades. Growout time to commercial size (about 8-10 cm) is between 8 and 14 months, and the reported yield from these areas averages 25 tons/ha (Haro et al., 1983; Lizarraga, 1974).

The potential for increased oyster production in the Gulf of Mexico is considerable, with over 100,000 ha having potential for utilizing intensive culture techniques (Haro et al., 1983). Current production is about 40,000 t/year, but a decline is predicted due to pollution in lagoons such as Tamiahua and others[4], where oil exploitation activities have resulted in destruction of natural beds (Conrad, 1985).

Venezuela

Experimental culture of the American oyster began in 1974 in the canals of Guariquen, in the Gulf of Paria. The Center for Fisheries Research of Cumana, under the Ministry of Agriculture and Livestock, beginning in 1974, carried out several studies on the biology and culture potential of the American oyster (unpubl.) which stimulated the creation of two commercial ventures in 1980. For spat collection and growout these operations used old tires cut in strips and hung from floating wooden rafts. In November 1980, there were 120 rafts: 100 rafts were 15 × 6 m with 420 strips each and 20 rafts were 15 × 14 m with 800 strips each. Commercial size, 8-12 cm, is reached in 1 year.

The marketed production in 1980, 1981, and 1982 was 170, 176 and 132 tons, respectively. The estimated production of a single operation in 1980 was about 1,000 t, most of which could not be marketed because the marketing channels were inadequate to handle production. Studies of the economic feasibility of smoking and canning oyster meats, possibly for export, have been made (Cervigon, 1983). However, in a recent visit to Venezuela, the senior author was informed that marketing difficulties had apparently proved insurmountable and that both commercial ventures would cease operations.

The mangrove oyster was also the subject of experimental and commercial culture in Venezuela. Experimental culture began in the early 1960's, and there were two commercial attempts, both using wild spat and floating rafts: One, in 1969, in the Gulf of Cariaco and the other in 1971 in la Restinga lagoon, Margarita Island. Both faced problems of spat settling, competition, and shell brittleness, and both failed due to marketing difficulties (Mandelli and Acuna, 1975; Cervigon, 1983).

Culture of rock mussels, *Perna perna*, began in 1960 in the Gulf of Cariaco in northeastern Venezuela (Fig. 4) using slightly modified Spanish raft-culture techniques (Iversen, 1966). Presently, there are two private ventures with 20 rafts and seven smaller ventures with a

[3]Sessing, J. Jamaican aquaculturist, P.O. Box 642, Kingston 8, Jamaica. Personal commun., April 1985.

[4]Orbe, A. Centro de Investigacion y Estudios Avanzados IPN, Unidad Merida, Merida, Yucatan, Mexico. Personal commun., 6 November 1984.

Figure 4.—Rock mussel rafts in Venezuela.

total of 45 rafts operated by fishermen's cooperatives. The latter have not produced any mussels in the last few years because of red tide problems in the area which, in August 1977, killed nine people who ate contaminated mussels.

Annual market production since 1972 has ranged from 42 to 650 t. In 1980, production was estimated at 650 to 920 t, but only 30 t were marketed due to red tide. In 1983, production was estimated at 182 t. This decrease is attributed to the replacing of wooden spat collectors by tire strips to which mussel spat reportedly cannot attach securely. Besides red-tide-related problems, commercially successful mussel culture in Venezuela faces marketing problems similar to that of oysters (Salaya et al., 1973; Mandelli and Acuna, 1975; Cervigon, 1983). Extensive research on the rearing of mussel larvae has been recently carried out at the Instituto Oceanografico of Universidad de Oriente in Cumana[5]. A project to set up a mussel depuration plant is being planned, and another project for a large-scale mussel farming operation was recently presented to the National Council for Scientific Research of Venezuela (CONICIT) and is presently being evaluated[6].

[5]Cervigon, F. Fundacion Cientifica Los Roques, Caracas, Venezuela. Personal commun., May 1985.

[6]Robaina, G. Universidad de Oriente, Boca de Rio, Isla de Margarita, Venezuela. Personal commun., December 1985.

Extensive Culture

The queen conch, *Strombus gigas*, is the only marine mollusk considered to be cultured extensively in the Caribbean. Increased demand for its meat, especially in U.S. markets, has resulted in overfishing and the decline of stocks, and has threatened its critical role as one of the most important subsistence-level fisheries of the area (Brownell and Stevely, 1981).

Concern over the decline of stocks led to extensive research on the mass-rearing of juveniles in hatcheries and using these juveniles to reestablish or replenish depleted natural populations. Such research was carried on since about 1980 in Bonaire, Puerto Rico, Los Roques Archipelago in Venezuela, Quintana Roo in Mexico, Turks and Caicos, Miami, and the Berry Islands in the Bahamas (Iversen and Jory, 1985).

Preliminary results of many of these research programs were presented in a Conch Mariculture Session at the 35th Annual Gulf and Caribbean Fisheries Institute in Nassau, Bahamas, in November 1982. What has happened since then? The projects at the University of Miami, Los Roques and the Berry Islands have ended due to lack of financial support. The project in Puerto Rico might not receive further funding[7]. However, there is also encouraging news. The Bonaire hatchery reported rearing and releasing 750,000 juveniles off Bonaire in 1984 in deep waters where they will not be easily accessible to fishermen[8]. This may be an example of technological success, but does not imply economic feasibility. A hatchery is being set up at the Hydrolab site at Salt River on St. Croix, U.S. Virgin Islands, mainly to obtain animals for further research[9]. And construction of a hatchery is about to begin on the island of Martinique, French West Indies[10].

The senior author recently visited the Puerto Morelos hatchery in Quintana Roo, Mexico, and was informed that it is preparing for its first field release of hatchery-reared juveniles. Finally, in 1984 Trade Wind Industries, Inc.[11], constructed and started operating the first commercial queen conch hatchery on the island of Providenciales, Turks and Caicos. During the 1984 spawning season, 20 larviculture tanks were in operation, and the juvenile conchs produced were stocked in protective cages near the hatchery. The company reportedly has also acquired sea-bottom leases to grow conch to commercial size[12].

The release size for hatchery-reared conch discussed, and recommended and/or used so far varies from 2 cm (Siddall, 1983), to 5 cm (Creswell, 1984) to 12-15 cm (Jory and Iversen, 1983; Woon, 1983). The release size can have important consequences on the rate of survival to market size. There is good scientific evidence that natural mortality is greater for smaller individuals, and hatchery-reared mollusks are no exception (Jory et al., 1984), including queen conch (Appeldoorn and Ballantine, 1983; Jory and Iversen, 1983) as well as other mollusks such as abalone[13]. Recent large-scale releases of small (2-5 cm) hatchery-reared conchs in Bonaire, Mexico, Venezuela, and St. Croix should provide an indication of the optimum release size.

Pilot Projects and Research Activities

Bahamas

Molluscan mariculture has been attempted at three locations in the Bahamas. In the middle 1970's a private company conducted a pilot experiment with imported American oysters. In a pond dredged out for a dock project in Rudder Cut Cay, Exuma, the water was fertilized and imported oyster spat was placed in rafts. The project was promptly abandoned due to very slow growth rates.

The second study, growing oysters and clams in rafts by the Wallace Groves Aquaculture Foundation of Freeport, produced discouraging results. The third study is by Worldwide Protein Bahamas Ltd., using imported spat of American and European oysters and hard clams, *Mercenaria mercenaria*, grown in discharge canals from company shrimp ponds on Long Island. Preliminary results indicate that fouling by algae and particulate matter hinder production. Water temperatures were too high for European oysters and the species may be abandoned, but growout of American oysters and hard clams continues. In addition, the company recently obtained permission from Bahamian authorities to import Manila clams, *Tapes japonicus*, from the Philippines, for growout trials[14].

Turks and Caicos

The Smithsonian Institution's Marine Systems Laboratory has recently sought to determine the culture potential of the topshell or magpie shell, *Cittarium pica*. Its life cycle has been closed (Heslinga and Hillmann, 1981), and preliminary results indicate that juveniles placed in floating cages can reach market size in 12-18 months. Similar research has also been carried out in the Dominican Republic, Antigua, and St. Vincent[15]. The Mariculture Team of the Marine Systems Laboratory visited the island of St. Lucia where they demonstrated topshell culture methods; these appeared to be easily adapted to local conditions, and the feasibility of establishing a pilot project was indicated[16].

Topshells are widely consumed in the Caribbean; the species has been overfished in many areas and several nations are contemplating plans to regulate its fisheries. Mariculture may be a viable option to increase production since topshells appear to fulfill many of the criteria for commercial culture.

St. Lucia

In 1983 a joint "Experimental Oyster Project" was started on St. Lucia between a local yacht charter company and the Fisheries Management Unit of the Ministry of Agriculture, Lands, Fisheries, and Cooperatives. Imported Japanese oyster, *Crassostrea gigas*, spat were placed in bamboo and plastic mesh rafts at two sites. Unfortunately, the rafts at one site were destroyed but there are

[7]Appeldorn, R. Department of Marine Sciences, University of Puerto Rico, Puerto Rico. Personal commun., October 1984.
[8]Hensen, R. Department of Agriculture and Fisheries, Bonaire. Personal commun., October 1984.
[9]Coulston, M. L. Hydrolab Project West Indies Laboratory, Fairleigh Dickinson University, St. Croix. Personal commun., 22 October 1984.
[10]Bazin, P. Association pour le Development de l'Aquaculture a la Martinique, Martinique. Personal commun., September 1984.
[11]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.
[12]Creswell, L. Center for Marine Biotechnology, Harbor Branch Institution, Inc., Florida. Personal commun., November 1984.
[13]Haaker, P. California Department of Fish and Game. Personal commun., October 1983.
[14]Higgs, C. Ministry of Agriculture, Fisheries and Local Government, Nassau, Bahamas. Personal commun., October 1984.
[15]Bernard, W. L. Marine Systems Laboratory, Smithsonian Institution, Washington, D.C. Personal commun., October 1985.
[16]Walters, H. D. Ministry of Agriculture, Lands, Fisheries, and Cooperatives, Castries, St. Lucia. Personal commun., 5 October 1984.

plans for a second attempt. In addition, several local private concerns have contacted the Fisheries Management Unit for advice regarding oyster culture[16].

Panama

Between January and December 1979, two pilot studies were conducted to determine culture potential of the mangrove oyster. Two experimental farms were located in the Archipelago de Bocas del Toro, using the Cuban culture system described earlier in this paper. Preliminary results were encouraging but the project was not scaled-up to a commercial level[17]. University of Panama and University of Delaware scientists are jointly experimenting with commercially important bivalves with encouraging results at the University of Panama's Centro de Ciencias del Mar y Limnologia laboratory on Panama's Pacific coast[18].

Colombia

Studies on mangrove oyster biology, preparatory to culture, have been carried out at the Cienaga Grande de Santa Marta and in the Gulf of Uraba on the Caribbean coast of Colombia. Research has concentrated on basic biological aspects of the oysters and testing for the best methods of spat collection and growout. Results are very encouraging; it may be possible to raise oysters in closed suspended baskets to commercial size (6-8 cm) in about 7 months. Bottom culturing methods are not suitable in the Gulf of Uraba due to the heavy sedimentation coming from the Rio Atrato (Wedler, 1980; Aguilera, 1984). No plans for commercial scale-up were mentioned.

St. Kitts and Nevis

In 1981 the Government of St. Kitts and Nevis and the IDRC tried unsuccessfully to establish a pilot project to culture mussels. The project failed because no suitable local species of mussel could be found. In 1983 the project was redesigned into a Conch Management Program with a "red algae, *Gracilaria* spp., Research Project" as a subcomponent, which continues[19].

Nicaragua

In 1976, an oyster culture pilot study was carried out with assistance from Japanese scientists, using strung scallop shells separated by PVC spacers and hung from mangrove structures. Spat was successfully collected and grown during the dry season (May-December) but failed during the rainy season due to depressed salinities and high sedimentation in the estuarine site. Oysters grew well up to 81 mm, but mortalities were more than 80 percent. Because most of the Nicaraguan coastline where oysters can be raised has similar estuarine conditions, government officials are not inclined to conduct further oyster culture experiments[20].

Puerto Rico

Experiments to determine the commercial feasibility of mangrove oyster culture started in December 1972, with the joint support of the Puerto Rico Department of Agriculture and the U.S. National Marine Fisheries Service. These experiments consisted of monitoring growth of collected spat in bags, with frames made of concrete-coated plywood and plastic sheeting suspended from 3 × 4 m rafts. Oysters reportedly reached market size in 2 months (Watters and Prinslow, 1975). No commercial oyster culture presently exists in Puerto Rico. The Commonwealth Government encourages such nondestructive uses of its coastal lagoons which are coming under increasing development pressure[21].

U.S. Virgin Islands

Since May 1972, the St. Croix Artificial Upwelling Project on the north shore of the island produced phytoplankton by pumping nutrient-rich seawater from 870 m depth into 100 m^2 ponds. This was used to feed oysters, clams, and scallops which grew adequately. A pilot-scale operation was carried out between October 1976 and October 1978 in which Manila clams produced in the Project Hatchery were successfully grown to determine yields and production costs. Very encouraging results were also obtained culturing brine shrimp (Roels et al., 1979). The Project apparently developed into The Maritek Corporation in 1980 (Seafood Business Report, 1984), and is presently engaged in penaeid shrimp culture in the Bahamas[22].

Other Candidates

Caribbean Species

Milk Conch

The milk conch, *Strombus costatus*, although considerably smaller than the queen conch, is nevertheless of commercial value. Its biology has been studied and it has been reared for possible use in the marine aquarium trade and for extensive mariculture. Hatchery techniques, predation problems, and outlook are very similar to those for the queen conch (Appeldoorn and Ballantine, 1983).

Great White Lucine and Gaudy Asaphis

In many Caribbean areas, low primary productivity generally precludes culturing suspension-feeding mollusks. Recent research has shown two clam species, the great white lucine, *Codakia orbicularis*, and the gaudy asaphis, *Asaphis deflorata*, to have possible chemoautotrophic capabilities through a symbiotic relationship with sulphur-fixing bacteria within their gill tissues; hence, they have been suggested as viable mariculture candidates. Both species have been reared in the laboratory, and chemical analyses have shown that the

[17]Arosemena, D. H. Departamento de Direccion de Recursos Marinos, Panama. Personal commun., 28 September 1984.

[18]D'Croz, L., and J. R. Villalaz. Centro de Ciencias del Mar y Limnologia, Facultad de Ciencias Naturales y Farmacia, Universidad de Panama. Personal commun., 29 October 1984.

[19]Wilkins, R. Department of Agriculture, St. Kitts and Nevis. Personal commun., 25 September 1984.

[20]Martinez Casco, S. Centro de Investigaciones Pesqueras, Instituto Nicaraguense de la Pesca. Personal commun., 4 October 1984.

[21]Torres, F. Corporation for the Development and Administration of the Marine Resources, Puerto Rico. Personal commun., 7 November 1984.

[22]Higgs, C. Ministry of Agriculture, Fisheries and Local Government, Nassau, Bahamas. Personal commun., July 1984.

great white lucine is relatively high in protein, carbohydrates, and calories but low in cholesterol compared with other clam species (Berg and Alatalo, 1982). It has also been speculated that industrial sulfide wastes may be adapted to a mariculture system involving these clams (Berg and Alatalo, 1984). No pilot or commercial projects to rear these clams are planned[23].

Cephalopods

Many cephalopod species are important research subjects in neuroscience, environmental toxicology, learning behavior, and other areas. The highly developed giant axon of squids, for example, is used in numerous models of visual experimentation (Hanlon and Forsythe, In press). In addition, fisheries biologists have recently begun using cultured cephalopods for life-cycle analyses (Hanlon, In press). The advantages of laboratory-cultured cephalopods to the researcher include the consistent availability of experimental animals of known species, age, sex, and environmental background (Hanlon and Forsythe, In press). In the Western Atlantic, cephalopods are presently being cultured on an experimental scale at the Marine Biomedical Institute of the University of Texas Medical Branch, Galveston, Tex.[24], and at the Centro de Investigaciones Cientificas de la Universidad de Oriente, on Margarita Island off northeastern Venezuela (Robaina, 1983).

Roger Hanlon of the Texas Marine Biomedical Institute reports[24] that the life cycles of several *Octopus* and *Loligo* species have been closed, and extensive information pertinent to their potential commercial mariculture has been accumulated. He further reports receiving requests from people interested in culturing cephalopods commercially in the southern Caribbean.

The only known commercial culture operation of cephalopods is in Japan, where *Octopus vulgaris* is reared; production in recent years was about 50 t annually (Boletzky and Hanlon, 1983). However, "the outlook for future commercial culture of cephalopods is unpredictable, because it is predominantly an economic consideration. When and if the capture fishery cannot meet the market demand, culture will receive emphasis" (Hanlon, In press). Finally, cephalopods may have much potential in the aquarium trade, because of the spectacular color changes of many species and because they can be easily maintained in aquariums (Hanlon, In press).

Scallops

Scallops of the family Pectinidae are the basis of several important commercial fisheries around the world. Commercial scallop farming in Japan has been very successful, and scientists elsewhere are trying to adapt Japanese techniques to their own countries (Wood, 1978). Pilot research continues worldwide, and in Latin America, Peru (Wolff, 1984), and Mexico (Kimbrough, 1983) have recently reported commercial culture operations. Those, however, are on the Pacific coast; no pilot- or commercial-scale scallop culture project is known in the Caribbean. Research on induced reproduction and larval rearing is being carried on in Venezuela[25]. Berg (1984) recently suggested scallop culture as having potential in Bermuda.

Pearl Oysters

Pearl oysters have been successfully cultured for many years in Japan, Republic of Korea, China, Australia, Indonesia, the Philippines, and other countries, and the techniques are well known. Berg (1984), in reviewing the culture potential of Bermudian bivalves, mentioned that there appears to be no reason why these techniques could not be successfully applied to Atlantic pearl oysters, *Pinctada* spp. On Mexico's Pacific coast the pearl oyster, *P. mazatlanica*, has been experimentally cultured[26]. No information is available on present or recent research on pearl oyster culture in the Caribbean, although in Venezuela aspects of its biology have been studied to some extent (Martinez, 1971), and a research proposal is currently being evaluated[27].

Pen Shells

The culture potential of pen shells, *Pinna carnea* and *Atrina rigida*, was also reviewed by Berg (1984), who concluded that they seem to have poor potential because of the possibly long planktonic development which would make larval rearing difficult. He also mentioned that they may be suitable as an additional species in a polyculture system, since they seem to invest little energy developing viscera and shell and therefore might grow very fast. Pen shells are very valuable in several Caribbean countries, and in Mexico, where they command higher prices than shrimp and as high as abalone (about U.S.$10.00/kg as of early 1985)[28]. A shellfish hatchery to produce larvae of commercially important bivalves, including several species of oysters, clams, scallops, and pen shells, recently started operating in Bahia Kino, in the Gulf of California (O'Sullivan, 1984). No commercial or research projects are known in the Caribbean.

Exotic Species

Green Mussels

A species from the Indo-Pacific, the green mussel, *Perna viridis*, is considered to be a good candidate for introduction into the Caribbean. Presently there are over 5,000 ha under its culture in Thailand and the Philippines. Research at the Harbor Branch Institution in Florida has shown considerable potential for this species' culture in localized Caribbean areas where primary productivity is sufficient to support filter-feeding bivalves[29].

Giant Clams

Species of giant clams, *Tridacna* spp., are being intensively studied at various institutions in the Philippines, Australia, Micronesia, and California for possible commercial culture. These

[23]Berg, C. J. Woods Hole Oceanographic Institution. Personal commun., 7 November 1984.
[24]R. Hanlon, Marine Biomedical Institute, Texas. Personal commun., 5 November 1984.

[25]Padron, M. Universidad de Oriente, Boca de Rio, Isla de Margarita, Venezuela. Personal commun., 5 December 1985.
[26]Diaz, G. J. J. 1969. Cultivo experimental de madreperla, *Pinctada mazatlanica*, en la Bahia de La Paz, Baja Calif., Mex., (mimeogr.) 12 p.

[27]Robaina, G. Universidad de Oriente, Boca de Rio, Isla de Margarita, Venezuela. Personal commun., 4 December 1985.
[28]Reyes, C. Instituto Tecnologico y de Estudios Superiores de Monterrey, Guaymas, Sonora, Mex. Personal commun., March 1985.
[29]Creswell, L. Center for Marine Biotechnology, Harbor Branch Institution, Fl. Personal commun., November 1984.

clams have a thin layer of tissue in their mantle where zooxanthellae live and provide food (Munro and Heslinga, 1983). This aspect of their biology is unique and actually is a strong plus for the species' introduction to the Caribbean, particularly in areas of low productivity that cannot support filter-feeding bivalves such as oysters or mussels. Cultured tridacnids from Palau may soon be introduced to the island of Guadaloupe, pending approval of import permits[30]. However, as with any other exotic species, the possible ecological consequences of introducing any new species into a new environment must first be carefully considered, as is strongly urged by Munro and Heslinga (1983).

Discussion and Conclusions

Molluscan mariculture is nonexistent in several Caribbean countries; in a few it is at an experimental or incipient stage of development while only a handful of commercial molluscan culture operations presently exist anywhere in the area. Three species of bivalves (American and mangrove oysters and rock mussels) are raised in semi-intensive facilities; one gastropod, the queen conch, is raised in extensive culture (mass-reared in hatcheries and released to augment natural populations).

Techniques for oyster and mussel culture are very similar, involving wild spat collection on different substrates (i.e., from mangrove branches to synthetic ropes) and growout with the collectors suspended from floating rafts or wooden stockades. These techniques have proven successful in some Caribbean countries and have potential in several others. Queen conch culture involves mass-rearing juveniles in hatcheries and field growout to commercial size; the first has had limited success so far while the second remains unproven.

Introduction of exotic molluscan species into the Caribbean must be carefully considered. Several native species, particularly filter-feeding bivalves, appear suitable and should be exhaustively studied before considering any introduction. An exception may be that of exotic species with phototrophic capabilities, such as giant clams, which may be suitable for introduction in those areas where the naturally low primary productivity precludes the culture of filter-feeding species. However, much care should be exercised if these or any other exotic species is introduced into the Caribbean, and guidelines such as those recommended by the International Council for the Exploration of the Sea should be followed (ICES, 1972).

Several problems still hamper Caribbean molluscan culture. These include insufficient biological information on potential candidate species, dependency on wild spat, lack of economic information, few trained technicians, inadequate marketing channels, low primary productivity in many areas, and pollution and public health considerations.

The FAO Species Identification Sheets for Fishery Purposes of the Western Central Atlantic (Fischer, 1978) list 37 bivalves and 24 gastropods which are large, edible, and common enough to serve as human food. Several of these species of oysters, clams, scallops, arks, mussels, and pen shells, as well as others not included in the FAO sheets, may meet the criteria for culture candidates proposed by Bardach et al. (1972) and Webber and Riordan (1975).

However, adequate biological information on which to judge the feasibility of culture projects for many species is lacking, particularly concerning reproductive aspects (spawning season, larval stage requirements) and growth rates and factors which affect it. Research in progress at several Caribbean institutions will help alleviate this. However, economic support for research sometimes may end prematurely, as in the case of the queen conch, whose biology and culture potential (including hatchery techniques) was intensively investigated at several institutions for a few years, until funding was discontinued. UNDP/FAO has advocated establishment of a Caribbean Regional Aquaculture Center, which has also been strongly supported by countries in the region and may be approved and implemented in the near future[31].

To depend on natural spat settlement as a source of seed for commercial growout is generally not advisable because of the wide fluctuations in spat abundance and settlement due to biotic and abiotic factors. Cuba, for example, has reported such problems for their oyster culture operations, and is investigating controlled reproduction and oyster larval maintenance as well as construction of a hatchery. Other countries such as Mexico, Jamaica, Panama, and Venezuela are operating or planning hatcheries and/or are involved in active research for this purpose.

Economic problems also hamper development of Caribbean molluscan culture (as well as culture of most other marine species), particularly the distribution channels and availability of the products. Acceptability of seafood is not a problem: Most Caribbean islands and countries bordering the Caribbean have high rates of seafood consumption (>20 g/person per day), and in some of these countries fish constitutes almost 20 percent of the total protein source (Olsen et al., 1984). Adequate distribution channels and product availability problems must be viewed in terms of the added technological and economic burden involved in processing and marketing highly perishable products in places where refrigeration may be unavailable or inadequate (May, 1978). That inadequate marketing channels are a problem today is exemplified by the Venezuelan oyster culture operations discussed previously.

Another problem is pollution and related public health considerations. Since the Caribbean is generally a developing region with relatively modest industrialization and urbanization, water pollution from land-produced wastes has not reached the alarming levels of more industrialized regions. However, there are localized areas where marine pollution from industrial, domestic, and agricultural wastes, and from oil production and transport, is a problem (Rodriguez, 1981), and this is likely to become a problem in other areas as industrialization and urbanization occur.

Estuarine areas are particularly affected by pollution and urban development. Besides being highly productive nursery grounds for many commercially important animals, clean estuaries are

[30]Heslinga, G. Micronesian Mariculture Demonstration Center, Palau. Personal commun., February 1985.

[31]Choudhury, P. C. Fishery Resources and Environment Division, FAO, Rome. Personal commun., 28 September 1984.

also needed for molluscan culture. Public health aspects of pollution must be especially considered because the occurrence of human viruses in mollusks from waters lightly to moderately polluted is well documented (Vaughn and Landry, 1984) and because information on the extent of pollution in the Caribbean (i.e., from sewage) is very limited (Rodriguez, 1981).

Finally, the harvesting of cultured mollusks may often have to be restricted owing either to periodic red tide outbreaks, as in the case of the Venezuelan mussel culture operations discussed, or to ciguatera poisoning, which may occur in populations of topshells of certain areas (Olsen et al., 1984).

In conclusion, molluscan mariculture in the Caribbean has a long way to go to partially augment catches from traditional capture fisheries. It is doubtful that it can soon achieve the production per unit area obtained in other parts of the world because it is still in its infancy and many of the problems remain unresolved. However, current and planned research are encouraging.

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