ADVANCES IN MARINE AQUACULTURE IN THE RED SEA

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"The work in the field of mariculture in the Red Sea started in Israel in 1970. Three years later an intensive research and development program was initiated on *Sparus aurata* as a candidate organism for mariculture. This paper discusses the considerations for selecting this species. The work at present in the Eilat Mariculture Laboratory concentrates on the following subjects: nutrition, controlled reproduction, larval rearing, fish disease, and fish farming. The state-of-the-art of the *Sparus aurata* culture is described."

Introduction

Mariculture seems to have the potential of providing seafood in larger quantities than it does at present. Demand for seafood, fish, invertebrates, and algae is growing, whereas the worldwide fisheries harvests seem to have reached a plateau (Gordin, 1980). The annual catch of the last few years has fluctuated around 70 million metric tons (see Figure 1). Pollution, overfishing, fishing effort, and cost have helped to counteract the human desire to increase fisheries yields. And, of course, fish populations, wherever they exist, are finite; we can tax them only to the degree that will allow their continued survival. Otherwise, the many sad examples like the heavy depletion of the California sardine and the South American anchovy will repeat themselves elsewhere.

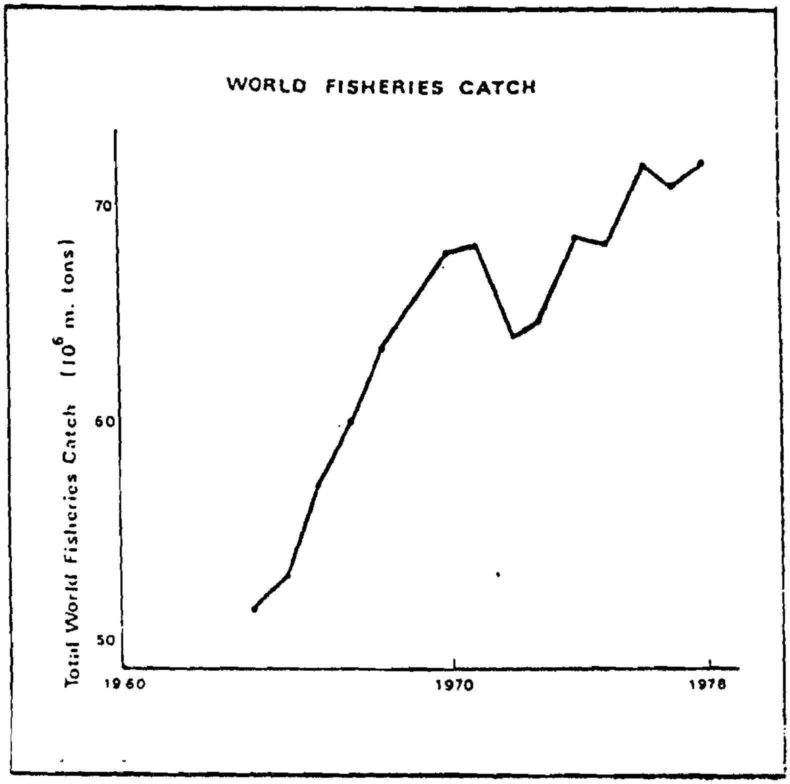

FIGURE 1. World fisheries catch from mid-1960s to 1978. (Data from FAO, 1979, and U.S. National Marine Fisheries Service, 1980)

Efforts should, therefore, be directed toward developing technologies that will utilize the world's oceans and their waters for seafood production to ease the pressure on the wild fish populations, on the one hand, and to provide means for new avenues of food production on the other. Mariculture should be considered as one of the solutions. However, its potential, though partially recognized, is not a simple matter to realize. It needs a very coordinated, long-term program, which will include basic and applied research, pilot plants, and -- whenever the technology is ready -- intensive commercial efforts. This approach was advocated during the last decade (Nagel, 1979; Ryther, 1975), when the need for a concentrated drive of research and development in the field of aquaculture was recognized.

The contribution of aquaculture to world fisheries production in the middle 1970s was around 8.5 percent of the total fisheries landing. Table 1 shows the following trends: (a) most of the world aquaculture production comes from one geographic region -- Asia (81 percent); (b) an inference from the first trend is that most of the production results from extensive farming; (c) most of the finfish production is practiced in freshwater (above 60 percent of total aquaculture production); and (d) most of the marine production yields molluscs and macroalgae (first or second trophic level). Significant expansion of the freshwater aquaculture is questionable due to the worldwide shortage of this commodity. However, sea and brackish waters are available almost everywhere along the shores of the world's oceans. Employing existing, traditional, highly extensive technology, but expanding the farmed area to available lagoons and lowlands in southeast Asia alone, will double and triple the world aquaculture production. There are 30 million hectares suitable for mariculture and brackish water aquaculture in that region; a few hundred kg per hectare per year will triple the world aquaculture production. However, not everywhere is such an approach appropriate due to lack of land, social problems, and available technologies. Nagel (1979) has called for a 2.5×10^9 U.S. dollars/yr^{-1}

TABLE 1. Aquaculture production (in thousands of tons) in 1975. (Modified from Pillay, 1976)

Area	Finfish	Molluscs	Seaweeds	Crustaceans	Total	Percent
Asia	1202	460.3	754.8	14.76	2431.8	39.8
China	2200	-	300	-	2500	41
Europe	422	399.5	-	-	821.5	13.5
N. America	23.4	134.1	-	-	157.5	2.6
L. America	26	47.1	-	0.9	74	1.2
Africa	107.1	0.25	-	-	107.35	1.7
Australia	-	10.05	-	-	10.05	0.2
TOTAL	3980.5	1051.3	1054.8	15.66	6102.2	
Percent	(65.2)	(17.2)	(17.3)	(0.3)		(100)

investment in aquaculture to achieve a significant increase in production; this is one-fifth of what is invested in agriculture development in the less-developed countries alone. The development of mariculture is very important in countries that have limited freshwater resources, such as in the Middle East. Therefore, in 1970 the Israel Oceanographic and Limnological Research Institute (IOLR) started work on mariculture in Eilat, where it seemed most needed.

Selecting Species For Cultivation

One of the most critical stages in the development of mariculture is deciding what species to domesticate for farming. The domestication of a wild animal so that humans can make wise manipulation of it is a long process, which requires sophisticated and intensive research and development. It is, therefore, essential that this effort be spent on a species that can be used later for farming. Two examples -- both negative -- will illustrate the critical problem of species selection for mariculture:

1. The edible oyster (*Saccostrea cuculatta*) was selected because it was growing naturally in the Gulf of Aqaba, and its zoogeographic distribution extended throughout the Indo-Pacific region. It seemed, at the time, the most available and simple species to use. However, a few, very crucial considerations were neglected: (a) Red Sea water is oligotrophic; it has a very low nutrient level and, therefore, very low primary productivity. Oysters are known to feed on phytoplankton. (b) *S. cuculatta* inhabits the upper belt of intertidal zone; thus, it is exposed to the atmosphere for more than 60 percent of the time and, therefore, not feeding but 40 percent of the time. (c) However, this habitat serves as a refuge, eliminating all its natural enemies and predators. When artificially forced to be submerged, it is soon attacked and killed by predators, parasites, and the growth of sessile organisms such as bryozoans and soft corals. (d) If one can eliminate the predators and other adversaries and provide plenty of food, its inherent growth rate is still very slow. And, (e) there is no known market for this species in our region or in Europe. So even if the biological problems did not exist, one would have a very severe problem marketing the end product. After three years of investigation, the project was discontinued.

2. Rabbitfish *Siganus* (three species: *S. rivulatus, S. luridus,* and *S. argentus*) was chosen in 1970 because: (a) high prices existed on the local (Eilat) market due to the excellent taste the fish has when it is very fresh; (b) the rabbitfish is a hardy fish, enduring handling and diseases; and (c) the siganids' fry appear in midsummer in Eilat in very large numbers. However, there were some neglected considerations: (a) The Eilat market paid high prices at the time, because people there knew the fish. But Eilat is a very small town, and its market is extremely limited. Nobody studied the markets in the north of Israel, where it was a rejected species. (Two siganid species have migrated to the Mediterranean through the Suez Canal and established viable populations in the Levant Sea. Some years they composed up to 20 percent of the total landings in Israel. However, the Israeli housewives shy away from it, considering it a trash fish.) (b) The fish has a short shelf-life. And, (c) some of the basic assumptions were questionable. In captivity, the fish was sensitive and susceptible to handling and diseases. Fry were abundant some years but almost absent in others. Thus, the research and devel-

opment effort on domesticating the siganids was also abandoned. It is of extreme importance to evaluate the species before selecting it as a candidate for research and development in mariculture.

Establishing Proper Selection Criteria

After these two negative experiences, IOLR developed a list of criteria before choosing the next organism: It had to have high prices and good, established markets (local and export); it had to have a high tolerance for temperature and salinity fluctuations; and its fry should be available in significant numbers to allow a large experimental program.

Two species of fish fulfilled these criteria -- *Sparus aurata* (the gilt-head bream) and *Dicentrarchus labrax* -- but availability of the latter's fry to the *Sparus* was about 1:100, which was not sufficient to establish a reliable experimental program. As a result, *Sparus aurata* was selected in 1973. At that time the mariculture team at Eilat had five members, and the first order of business was to maintain the fish fry alive once transferred from nature. Therefore, nutrition and fish diseases were the first research categories developed. This year (1982) ten scientists, ten biology and chemistry technicians, maintenance and administrative staff make up the team.

Developing the Mariculture Laboratory in Eilat

A few principles directed the development of the Mariculture Laboratory in Eilat. First, the investigators decided to concentrate all available means to develop one species for aquaculture. When this species matures to the stage where some of the developed technology can be implemented, another species will be considered -- a crucial point since each species is a world in itself, very complicated but very specific. Therefore, it is essential not to dilute the effort by adding another species before the time is right. Second, the investigators believed that all disciplines of mariculture should be developed in the Eilat laboratory, i.e., fish nutrition, diseases, reproduction, larval rearing, food chain, pond and cage fish culture and, recently, oysters and shrimps. The interaction between scientists and technicians of different disciplines should enhance the whole project and accelerate its realization. Third, problems that could not be dealt with in Eilat due to lack of expertise or equipment were delegated to universities throughout the country, thus enlarging the scientific basis of the project.

The fourth consideration involved identifying problems and areas in the project that were inhibiting the whole effort. For example, the major bottleneck during the period 1975-1977 in becoming independent of nature for fry supply was successful spawning. The major effort (means and manpower) was directed toward solving this problem. A similar thrust is now being carried out with larval growth and survival. The fifth factor involved periodic analysis of economics and the state-of-the-art to assist the decision-making process. Finally, whenever another organism or system was to be examined, "backyard" experiments were carried out for a few years first, with minimal effort.

As a result of this scheme and the government's recognition of the importance of the project, the IOLR Eilat Mariculture Laboratory developed in the pace shown in Table 2. Over the nine years since the first *Sparus aurata* fry

TABLE 2. Pace of IOLR Mariculture Laboratory in Eilat.[a]

Category	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
Fish nutrition	---	---	---	---	---	---	---	---	---	---
Fish diseases		---	---	---	---	---	---	---	---	---
Fish reproduction			===	===	===	---	---	---	---	---
Larval rearing				---	---	---	---	===	===	===
Cage culture			---	---	---	---	---	---	---	---
Int. fish pond			---	---	---	---	---	---	===	===
Oyster culture				...	...	---	---	---	---	---
Shrimp culture						...	...	...	---	---
Macroalgae									...	...

[a]Key: == intensive effort, ...backyard experiment.

TABLE 3. Summary of state-of-the-art at the IOLR Eilat Mariculture Laboratory.[a]

Pond Culture Species	Density fish · ha^{-1}	Growth Period (months)	Fish Weight at Harvest (g)	Yield (kg · ha^{-1})
Sparus aurata[b]	35,000	14	200-300	6,500-12,000
Mugil cephalus	6,000	14	300-400	1,800- 2,400
Cassostrea gigas	220,000	12	70-100	14,000-20,000
Phytoplankton	-	12	-	(33,000 D.W.)[c]

[a]No data available for shrimp and macroalgae. Additional statistics include *S. aurata* spawning time of 6 months (rather than 6 weeks in nature), larval rearing survival rate of 3-5 percent (best result 8 percent), nutrition was based on a satisfactory diet, and basic and veterinary research was conducted on diseases.

[b]The food conversion coefficient was 1:2.5. In contrast, cage-cultured *S. aurata* had a density of 240 fish · m^{-3}, a growth period of 16 months, a harvest weight of 250-300 g, a yield of 60-72 kg · m^{-3}, and a food conversion coefficient of 1:3.

[c]D.W. = dry weight.

were brought to Eilat, the basic research and development work was conducted in an ever-increasing effort. At present all the mariculture categories listed in Table 2 are functioning toward the realization of fish and oyster farming in the Israeli desert near the Red Sea and in cages in the gulf water itself. Table 3 summarizes the state-of-the-art at the Eilat laboratory.

The main effort at present is spent on the problem of larval survival rates, and a parallel one is devoted to the intensive seawater fish pond. The latter is a new field, and very little could be learned elsewhere. The dominating factor acting upon the ponds is evaporation, which in Eilat occurs at the rate of 1 cm per day (Assaf and Kessler, 1976). This fact forced us to compensate the salinity increase by pumping continuously "fresh" seawater, thus maintaining salinity at a physiological level. Such continuous pumping is energy demanding, and thus very expensive. Therefore, we decided at the very beginning of our work to concentrate the effort on development of an intensive culture system, which will be able to pay for the pumping cost (economic consideration).

Intensive culture means artificial feeding, i.e., fertilizing the ponds with nutrients, thus causing very intensive phytoplankton blooms. These blooms produce some 33 tons of dry organic matter $\cdot$ yr^{-1} $\cdot$ ha^{-1} (Gordin et al., 1980), which cause severe ecological problems in the pond, mainly in the sediments. However, we use the algae to feed the oyster beds, thus deriving another edible and salable crop from the same system. We anticipate that the system will go semicommercial around 1985 and fully commercial around 1987.

Concluding Remarks

First, the reasons for choosing *Sparus aurata* arose in the following order: economical, biological, and availability of fry at the beginning. Second, the importance of developing all disciplines of research and development under one roof was recognized at an early stage. Its application enhanced the rate of development and assisted in budget problems. Third, universities should be recruited to assist in basic research whenever needed. Fourth, economic analysis should accompany the research and development effort. Fifth, the research and development effort should concentrate on one species at a time and not indulge in superficial work on many species simultaneously. Finally, for the Israeli desert, mariculture must be intensive and integrated.

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