Ocean Farming Systems, Inc.

P. O. BOX 164 TAVERNIER, FLORIDA 33070 305-852-3624 305-852-9284

INTENSIVE MARINE FISH FARMING

A PILOT PROJECT

WITH THE FLORIDA POMPANO (T. Carolinus)

Prepared by:

Michael F. McMaster

Thomas C. Kloth

July, 1977

PREFACE

ABOUT THE COMPANY:

Ocean Farming Systems, Inc. was formed in the summer of 1975. The founder, principal owner, and primary technologist for the company is Michael F. McMaster. Additional technical staff include Dr. Paul Taskes, Farm Manager; Robert Cermak, Zoologist.

Currently, the company is engaged in the intensive cultivation of the Brine Shrimp (*Artemia salina*) on a 10 acre, ocean front farm on Plantation Key in the Florida Keys. The farm consists of 2.5 million gallons of tankage, a fish hatchery, and laboratory. The company markets the Brine Shrimp under the name "Caribbean Brand". Other products produced at the farm are live foods such as live unicellular green algae's, the Marine Rotifer (*Brachionus plicatilis*), and live marine specimens.

Current users of the tank grown live Brine Shrimp include the Pet Industry, Government and University Laboratories dealing in the marine sciences.

Two new programs for the coming year include a pilot scale program, testing the sea cage culturing methods for Florida pompano. The company has produced pompano eggs, fry, juveniles, and marketable fish under artificial and intensive conditions and now believes that in the U.S.A. the economically viable farming method for this fish will be via sea cage farming. Secondly, the marketing of a new sprayed dry algae (Spirulina) used as a fish and poultry food additive.

TEXT - INTENSIVE FISH FARMING

The word "intensive" with regards to fish farming has a very broad connotation. Instensive fish farming is generally defined as raising fish in densities exceeding the natural carrying capacity of a body of water through artificial techniques such as supplemental feeding, artificial aeration, manipulation of water exchange, etc. We prefer to divide intensive fish farming into semi-intensive and highly intensive based upon fish density and the degree of control of the reproductive cycle. Our view of intensive fish farming encompasses two basic points:

1. Fish are raised in high densities (exceeding one pound of fish per cubic foot of water at harvest).
2. The reproductive cycle of the fish is completely controlled which allows the farm to operate continuously.

An example of the semi-intensive system is the pond culture of catfish in the United States. This pond culture will yield 2,000 to 5,000 pounds of catfish/acre/year. For the highly intensive system, an example is the pompano, (_Trachinotus carolinus_), a marine fish which has been raised in densities exceeding 3 lbs./cu. ft. water (120,000-200,000 lbs./acre/yr.).

Although the semi-intensive pond culture of marine fish has been tried numerous times in the United States, there are no large-scale, commercial marine fish farms in the United States currently using this technique. It must be noted that there are no intensive marine fish farms either. However, the commercial feasibility of intensive marine fish farming has been demonstrated with the yellowtail (Seriola quinqueradiata) and the pompano. Commerical feasibility has yet to be demonstrated with the semi-intensive pond culture.

The decision to use either the semi-intensive pond culture or intensive tank/cage culture must be based on a number of economic, engineering and biological factors. Obviously, marine fish farming is limited to coastal regions. Factors such as land prices, pollution, zoning restrictions, environmental conditions, regulatory agencies, etc. further restrict areas available for marine fish farming. These restrictions are especially important in highly industrialized nations such as the United States. Thus the concept of intensive farming is very attractive to marine organisms since the yield/volume of water increases tremendously.

As stated previously, our view of intensive fish farming includes raising fish in high densities with complete control of their reproductive cycle. The actual containers used to raise the fish are varied and include raceways, tanks, and floating cages. The size and shape of the container may vary considerably, but fish density is always high. Therefore, a floating cage in a bay can be an intensive system just as a land-based tank or raceway. Complete control of the reproductive cycle of a fish allows continuous harvesting throughout the year. The total amount of product, and therefore profits, increase if there is no "down time" with regards to harvest. Recently, it was shown with salmon that a continuous supply of fry increased net cash revenue by 25% when compared to having fry available in only one quarter of the year (Gates and Mueller, 1975).

A major problem for intensive marine fish farming has been the production of fry. Most, if not all, commercial marine fish farms obtain fry from wild populations. Obviously, this puts the fish farmer at the mercy of nature, not to mention various state and federal conservation agencies. Additionally, the fish production is limited because stocking can occur only when the wild fry are available. An improved method is to have a continuous supply of fry available from a marine fish hatchery. However, establishing such a hatchery for marine fish has many inherrent difficulties. The eggs and larvae of most commercially important marine fish are small and extremely delicate and the hatchery technology available from the trout, catfish and salmon industries is not applicable to marine fish eggs and larvae. Although many academic and private institutions have investigated the problems associated with raising marine larvae, none, to the authors' knowledge, has successfully solved the problems to the point of establishing a large-scale, commercial venture except for the staff of Ocean Farming Systems, Inc. (O.F.S).

Basically the concept of O.F.S. is farm marine fish, specifically the pompano, on a continuous, intensive system much like that of the poultry industry. To achieve this objective, complete control of the biological processes of the pompano is necessary. A program has been developed involving broodstock, hatchery and grow-out phases to supply eggs, fry, and marketable fish on a continuous basis throughout the year.

The broodstock phase involves the production of eggs and is divided into two parts. First is the production of gravid females on a predictable schedule throughout the year, not just during the natural spawning season. Next is the actual production of eggs from the gravid females with the injection of hormones. By combining these two phases, pompano eggs are continuously produced throughout the year.

An adult pompano will produce approximately 100,000 eggs per pound of body weight. This compares with 4,000 eggs per pound for catfish and 2,500 eggs per pound for trout. So although the eggs and subsequent larvae from pelagic spawners are small and fragile, nature compensates by greatly increasing the fecundity. The O.F.S.

staff has produced in excess of 1,000,000 eggs per month annually.

Another notable achievement of our broodstock program was the successful closing of the pompano's life cycle. The original broodstock fish were caught by commercial fisherman. The first generation fry produced by the wild fish were successfully raised and spawned to produce second generation fish.

The pompano eggs were sent to a unique hatchery designed and developed specifically for the pompano. The hatchery stage was completely controlled to maximize survival and growth of the larvae. Although our first hatchery was designed to produce 35,000 fry/month, it actually produced an average of 45,000 fry/month with a maximum of 80,000 fry in one month.

The preceding statements show that a major problem, i.e., the production of marine fry, has been solved. Furthermore, the production of marine fish fry has been accomplished not merely at a bench scale level, but in a large-scale, commercial venture.

After the fry are produced, the grow-out to marketable fish more closely parallels fish farming practice employed with trout, yellowtail, and catfish. The fry are sent to the farm and placed in concrete tanks or cages. The progress of the fish must be closely monitored and managed throughout the grow-out phase. Strict management of an intensive fish farm is a vital necessity. Feeding, hygiene, disease incidence and other factors are continuously monitored to maximize production yields. Marketable pompano have been produced via these methods.

The decision to use an intensive system is based upon both biological and economic factors. From the biological viewpoint the fish to be cultured must be adaptable to an intensive system, i.e. to crowding, handling, artificial food, etc. These restrictions are not insurmountable. The most notable successes in marine fish farming involve the pompano and Japanese yellowtail, both of which are fast-swimming fish. Additionally, the yellowtail is piscivorous and the pompano can be cannabalistic under certain conditions. Despite these disadvantages, both have been successfully cultured at a commercial level. With a true intensive system, a fish's adaptability to handling is critical since the fish are sorted, counted, weighed, and moved on a regular basis. From a handling aspect, fish such as the pompano are ideal. The fish also should readily accept an artificial diet. Food acceptance has not been a major problem, although providing a nutritionally adequate diet for marine fish can be difficult. Inventory control,a potentially serious problem, is simplified with an intensive system. When fish are confined in tanks or cages, assessment of numbers, growth, feeding, disease occurance, and general behavior is relatively easy. Harvesting is simplified since the fish are in a small, confined area.

From a biological viewpoint, the crowding of fish has several advantages. The expenditure of nervous energy (spontaneous activity and swimming activity are reduced. Swimming is made easier because of the hydrodynamical effect of increased turbulance in the water due to the high fish density. The overall result is that less energy is needed for the maintenance of the fish and more energy is available for growth. This leads to an improvement in feed conversion efficiency and a subsequent decrease in feed costs per pound of fish.

There are two basic types of intensive systems. One is a land-based tank farm and the other is a floating cage farm. The basic difference is whether to bring the water to the fish or take the fish to the water. In either case, the water quality must be good for successful, intensive farming. The two major considerations for water quality, assuming the water is relatively free of man-made pollutants, are the oxygen level and the amount of metabolic wastes (ammonia, etc.) in the water. If oxygen levels are not adequate or metabolic wastes accumulate to harmful levels, or both, adverse results will occur due to stress on the fish. This stress can manifest itself in many ways including reduced growth, increase in disease incidence, and an increase in mortality. With a tank system, optimal levels of dissolved oxygen and metabolic wastes can be maintained by regulating the amount of water pumped through the tanks, or adding supplemental aeration. With cages, the fish are in a body of water with theoretically infinite dilution capacities, the ocean. Of course, the cages will have to be carefully located in an area that provides water movement that will continuously circulate new, clean water.

The selection of the system to use depends more on economic considerations than biological factors. Theoretically, a fish that survives and grows well in a tank that is 10 feet in diameter should also do well in a 10 foot diameter cage. This hypothisis will be tested in the coming months.

The tank system involves a much larger initial expenditure of capital to construct than the farm with cages. These funds are needed for the purchase of land, and the construction of buildings, tanks and the water delivery system. Redundancy of systems must be provided to prevent expensive stock loss in case of a system failure. Operating expenses are greater because of the machinery and systems involved. The maintenance staff must be both sufficiently large and technically qualified to handle any problems that may arise. This is especially important in developing countries such as in Central and South America where technically qualified people are not as plentiful as in the United States. Although tank culture is a capital intensive method, it has a very good profit potential. Examples of commercial applications can be found with trout, catfish, and marine fish.

With marine fish, the only large scale commercial venture with tanks was the OMI Dominicana pompano farm in the Dominican Republic. Reasons for selecting this area in the early 1970's were many, but included a readily available, but inexpensive, labor pool and and good quality sea water with a minimum of fluctuation in such environmental parameters as temperature, salinity and dissolved sediments. The farm itself was divided into two areas. First was the broodstock-hatchery complex and the other was the farm grow-out area. All egg and fry production was done in the broodstock-hatchery section. Additionally, all support facilities for the entire farm were located there. These included offices, laboratories, feed mill, machine shop and fish processing area.

Cage culture does not involve as much initial capital expenditure as with tanks since the grow-out section of the farm is not land-based. However, there will still be land-based, support facilities for the broodstock and hatchery. Eventually the technique used by some members of the catfish and trout industries of buying eggs or fingerlings may be employed in marine fish farming. Central hatcheries could provide eggs and/or fry to many fish farms. This would then decrease initial capital costs plus lower operating costs.

There are problems involved with cage culture but none is prohibitive. A major drawback has been the lack of economical cage material that could withstand the corrosive effects of sea water. There are now available several types of cage material plus prefabricated cages that should withstand the rigors of the marine environment quite well. Another problem is that the cages must be located in protected waters to minimize damage from storms. Also, the selected area must have clean, well oxygenated water. Sites that satisfy these criteria are available. For example, the Florida Keys, Bahama Islands, and other countries offer many areas that could satisfy these criteria.

In addition to initial capital costs being lower, operating expenses for cages are also lower. The necessity of pumping large amounts of water has been eliminated. Besides drastically reducing the energy bill, the requirement of a large and technically qualified maintenance staff is eliminated. Cage cleaning is simpler than tank cleaning, since excess food, etc., fall through the floor and are washed away. Cage fouling by barnacles, etc. can be minimized by site location and by polyculture methods.

Application of cage culture seems to be limited mainly to freshwater. In the marine environment, cage culture has been used mainly for small, experimental projects. The Japanese, however, use cage culture extensively for the yellowtail, a pelagic marine fish. Bardach et. al. (1972) have described the yellowtail system. Basically, the Japanese collect fry from the wild and then raise them in large floating cages. The fry are raised in cages ranging from 2 to 50 m^2 in area and 1-3m deep. After the fry are 8-50 q in size, they are placed in larger, grow-out cages. These cages are 35-100 m^2 in area and 3-6 m deep. The fish are harvested when they weigh 1-1.5 kg. In 1968, approximately 30,000 metric tons of yellowtail were produced by cage culture.

Currently, we are projecting a pilot test for culturing the pompano in an Oceanic cage starting in the second quarter of 1978. The cage is eight feet in diameter (circular), three feet deep and will enclose approximately twelve hundred gallons of water. Assuming the cage methods will yield approximately the same poundage of fish per gallon that tank culture did, we will expect to grow six hundred pounds of pompano per cage. In warm sub tropical to tropical water such as the Florida Keys the grow-out period should be six months to market ready fish. One surface acre of Ocean is adequate for 100 cages assuming there is sufficient water circulation in the plot area. The annual yield per acre could approach 120,000 pounds of marketable pompano.

The future potential for the commercial mariculture of fish in tanks or cages is great. The major biological problems for marine fish (reproductive control, fry production, etc.) have been solved. Furthermore, marine fish (pompano) have been grown to market size with artificial diets in intensive systems. The problems of intensive marine fish farming now shift from biology to economics. Specifically, the economics of energy, labor, land and food.

A brief comparion between the land or water acreage utilized for fish protein production compared to other agricultural products (Table 1) lends a great deal of merit to the idea of marine fish farming. It is obvious that on an acreage basis, intensive fish farming is superior to most other agricultural products. It is important to realize that the cost of production, yield, and sale price is specific to every species of fish. Because the cost of raising marine fish in an intensive system is high, the sale price of the fish must also be high. The species to be raised are then limited to those fish which command a high sale price such as pompano or red snapper. If the objective of the farm is not profit but rather protein production, then many other fish could be used. This concept could be used in developing countries with a food problem where the government or private organizations would be willing to subsidize the venture.

The decision to use either floating cages or land tanks is based upon the economics involved with regards to land, energy, labor, etc. The actual profit potential for either intensive, system is nearly the same assuming the economics of site location match the system being used. For example, tank farming in Saudi Arabia or Venezuela, where energy is inexpensive, could produce the same profit per ton of pompano as a sea cage farm in the Florida Keys where energy is very expensive. Although tank farming has a higher yield/acre for the pompano, this apparent superiority is offset by higher operating costs.

TABLE 1. A comparison of the production of various types of agricultural products.

PRODUCT	AREA	YIELD (lbs/arce/yr)
Beef	U.S.A.	2.434
Corn/Wheat	U.S.A.	24,344
Bananas/Sugar Cane	Tropics	304,000
Tomatoes	U.S.A.	60,000
Freshwater Shrimp	Asia	4,000
Proposed Marine Shrimp Farm	Central America	4,000
Pompano Sea Cage Farm	Florida Keys 1978	120,000 (est.)
Pompano Land Tank Farm	Dominican Republic	200,000 (est.)

LITERATURE CITED

Bardach, J.E., J. H. Ryther and W.D. McLarney (1972) Aquaculture: The Farming and Hushbandry of Freshwater and Marine Organisms, Wiley Inter Science, New York.

Gates, J.M. and J.J. Mueler (1975): Optimizing the Growth and Marketing of Fish in a Controlled Environment. Mar. Tech. Soc. J. 9(5) : 13-16.