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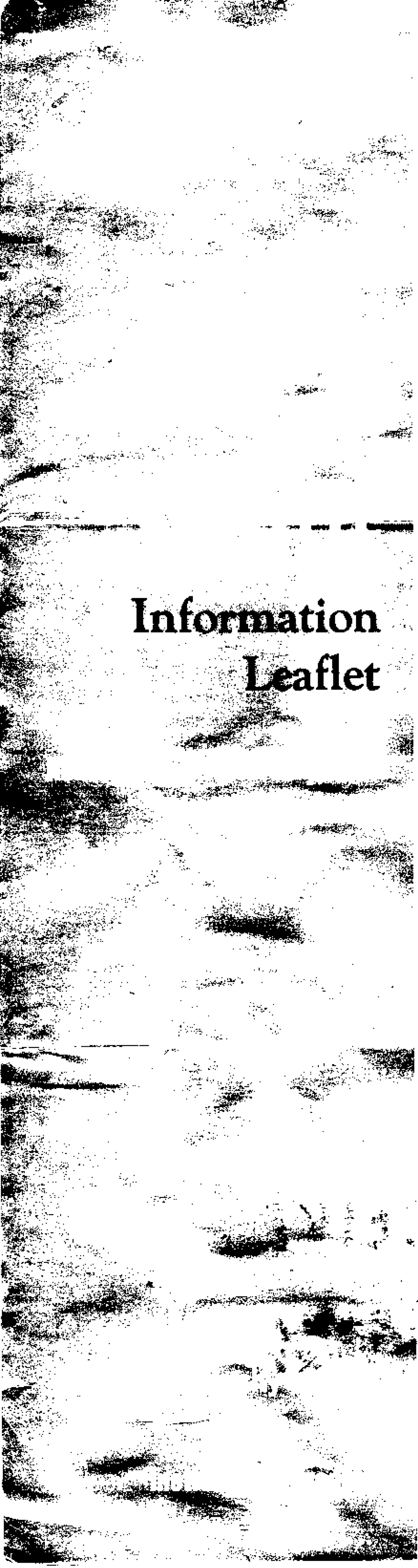


AQUACULTURE: The New Shrimp Crop

Recently there has been an upsurge of interest in commercial culture of marine and estuarine animals. This interest has been stimulated both by the growing need for more protein food and by increased knowledge of the life histories of some of the animals which appear capable of being cultured. Many biologists as well as business organizations are encouraged to believe that we are now in a position to begin a program of commercial marine aquaculture — a program which would improve our often primitive methods of harvesting the sea.

However, some of the schemes for producing marine resources by culture are impractical, and the limitations of marine aquaculture should be indicated to suggest what can be realistically expected from such activity. It is very unlikely, for example, that aquatic farms will be set up in North America to grow marine plants for food. Some popular conceptions of extensive acreages of plants being grown in shallow waters adjacent to the United States may be unrealistic. Although some seaweeds are edible, they are relatively nonnutritious. More importantly, there is currently no food market, nor is one likely to be easily established, for the products of such farms. Secondly, it seems unlikely that we can establish extensive marine fish farms in deep water because of the great practical and legal difficulties of creating and controlling large enclosures in these areas. Sea farms will, therefore, only be feasible in shallow water regions. Furthermore, these farms probably will be limited for the most part to warmer regions of our coastline, although colder areas may prove feasible if supplied with heated water from power plant effluents. Thirdly, at least in the beginning stages of marine aquaculture, only animals of high market value can be raised profitably. Later, when techniques and skills have been improved, it may be possible to reduce production costs sufficiently to justify experiments with medium and low-priced fishes and invertebrates.

There is more enthusiasm for the possibilities of commercial culture of crustaceans than of any other kind of seafood. The market demand for shrimp in the United States, for example, seems insatiable. In 1968 the United States imported 209.5 million pounds of shrimp, almost 30 million more pounds than it produced. In Japan there is a high and growing demand for shrimp, and the Japanese are buying large quantities from many parts of the world.

This strong demand has raised the price of shrimp to high levels. In 1968 the retail price in the United States ranged from about

These curious technicians are inspecting female shrimp ready to spawn in a hatchery at Takamatsu, Japan. In the heated waters of these wooden, tile-lined tanks, eggs hatch into larvae. Here the young spend the first three weeks of their lives.

Photo credit: C. P. Idyll

$1.30 to $1.50 per pound. In Japan shrimp farmers are able to get as much as $4.40 per pound in times of shrimp scarcity. Consistently high market value encourages the hope that profitable culture operations may be possible.

There have been attempts all over the world, some of them with a long history, to raise several species of shrimp.

In India, Malaysia, Pakistan, Singapore, Viet Nam and Cambodia the method is basically similar. In this old-style Asian method, postlarval or juvenile shrimp are either captured in shallow areas near shore or are allowed to be swept into artificial ponds by tidal action. In these ponds, or bunds, they feed on natural food found there. Five to six weeks later they are harvested by placing filter nets on the pond outlets during receding tides or when the ponds are drained. In India three major kinds of pond culture are practiced: 1) rotation with rice; 2) together with rice; and 3) in units along the river banks in areas of poor agricultural value. In Thailand both rice fields and converted salt fields are used.

The species involved in shrimp culture are nearly all members of the family Penaeidae, and most are in the genus *Penaeus*. In this genus spawning usually occurs when the adult is from nine to thirteen months old in the sea in depths to about 30 fathoms. A female may lay as many as 1 million eggs which are fertilized from sperm receptacles attached to the underside of her body during mating. The eggs are free floating at first and then gradually sink as development progresses. Hatching occurs within 24 hours and is followed by a series of larval stages. In the pink shrimp of South Florida, *Penaeus duorarum*, there are five nauplius stages during which the animal exists on yolk material, three protozoeal stages when feeding on phytoplankton begins, and three mysis stages when the diet begins to change to zooplankton. Larval stages and some subsequent post-larval stages are passed in a period of a few weeks during which time the young shrimp are transported by tidal currents to enclosed estuarine areas where they spend postlarval and juvenile stages. After a period of a few months in the estuarine habitat they return to the ocean for spawning.

A successful shrimp culture operation in the Philippines centers around *Penaeus monodon*, commonly called "sugpo." In the early history of this industry, sugpo were raised only incidentally with milkfish, *Chanos chanos*. While these animals continue to be cultivated together in some places, most culturists find it more economical to raise a pure culture of sugpo.

The ponds used for the cultivation of sugpo are typically 25 acres in area, divided into five sections by internal dikes. Two compartments serve as nursery ponds, two are rearing ponds, and one is a headpond where marketable shrimp are herded for capture. In preparation for stocking with the sugpo fry, the ponds are cleaned and dried, and the bottoms levelled. After this, tidal waters are let in to induce the growth of "lab-lab," a complex mat of fungi, bacteria, diatoms, algae, and small animals which serve as rich organic food for the young shrimp. The growth of filamentous algae is discouraged since it was found that the shrimp became entangled in it. Small bundles of dry twigs are included in the ponds to give the juveniles something to cling to.

When the young shrimp enter their natural estuarine habitat as postlarvae and juveniles, they are caught by the shrimp culturist and placed in the artificial nursery ponds. Often the shrimp fry are caught by commercial shrimpers and transported live to the shrimp culturist in plastic bags. After spending an initial one or two months in the nursery ponds, the juvenile shrimp are transferred to the rearing ponds where the stocking rate is about 4,000 per acre. In these larger ponds "lab-lab" is supplemented with ground fish, small crabs, boiled fish or rice bran. About 5-10 months after capture, the sugpo are about 6 inches long, 6-8 grams in weight and ready for market. Harvesting is accomplished either with a series of bamboo screen traps or with net traps called "lumpots."

Some problems have arisen with this method of culture. Often there is a critical lack of fry. Because there is no attempt to raise shrimp from the eggs to fry size, shrimp pond owners must depend on natural seasonal fluctuations in fry availability. In addition, there is often a low rate of survival among the fry. A scarcity of food, attack by predators which inadvertently get through the control gates, and loss because of deep burrowing all contribute to this low survival rate.

A much more sophisticated kind of shrimp culture has been developed in Japan involving the raising of shrimp from eggs through larval stages to saleable size. This method was pioneered by a Japanese scientist, Dr. Motosaku Fujinaga, using *Penaeus japonicus*.

Using this method, ripe females are bought from a commercial fishery and transported to tanks at the hatchery. Each female lays about 200,000-300,000 eggs which are kept floating in the tanks by circulating compressed air which keeps the water in motion. Heaters in the spawning tanks keep the water temperature at about 80°F. Hatching occurs in 13-14 hours and is followed by nauplius stages when yolk material serves as food. After this, the protozoeal and later stages must be provided with suitable live food. Nauplii are fed with diatoms which have been simultaneously cultured. At the

Fully grown shrimp are here being harvested from ponds at Aio in Japan. They will now be taken to the packing house where they will be placed in cold sawdust for shipment to distant Tokyo and other markets.

Photo credit: C. P. Idyll

later mysis stages, the diet is changed to brine shrimp, *Artemia salina*, and later to ground clams, oyster eggs and larvae or other animal food. As postlarvae the shrimp are transferred to outdoor growing ponds. *Artemia* nauplii or similar food must be abundant at this stage to reduce cannibalism.

Survival from the nauplii to protozoeal stages can be as high as 90%; from protozoeal to mysis stages, to 70%; and from mysis to postlarvae, to 90%. Therefore, under favorable conditions, survival from the egg to the last mysis stage has been recorded as high as 57%, which is much higher than in nature.

Japanese techniques have reached a point where large numbers of juveniles or "fry" can be produced routinely. Production of 1 million or more juveniles per tank can be achieved and exceeds the requirements of culturists. From this point forward, however, techniques have not yet been fully successful. Relatively small quantities of shrimp are being raised from fry size to marketable size in Japan. In 1967 only

404 metric tons were sold, compared to 2,031 tons caught by vessels. One major problem is in securing sufficient quantities of satisfactory, cheap shrimp food. Furthermore, Japanese face the problem of relatively cold waters which limits them to one crop of shrimp per year. Finallly, additional areas suitable for shrimp culture are scarce in Japan, which already employs almost all its coastal water for some purpose. As a consequence, Japanese shrimp farmers have looked elsewhere for areas in which to set up their operations. This search has included Korea, France, Mexico, and the United States.

Artificial culture has also been attempted with the fresh water shrimp, *Macrobrachium rosenbergii*, in Malaysia and elsewhere. The culture of *M. rosenbergii* has now reached a stage where large scale production of juveniles can be accomplished by private culturists. Governmental hatcheries supply juveniles free of charge to encourage private operations. The most important problems which remain are of food and feeding and controlling mortality due to disease and cannibalism.

In Great Britain and elsewhere in Europe trials have been conducted in the commercial culture of several species of shellfish including the Dublin prawn, *Nephrops*, the deep water prawn, *Pandalus borealis*, and the prawn, *Palaemon serratus*. The experimental work by some commercial firms has ceased in Britain, and perhaps elsewhere, despite good success in growing larvae. Heavy cannibalism and the long growing periods of older stages make commercial success for these species unlikely at the moment.

In the United States several organizations have embarked on programs of shrimp culture and a large number of others have expressed interest in doing so. Among agencies engaged in this kind of work are the Galveston Laboratory of the Bureau of Commercial Fisheries; Marifarms, Inc. in Panama City, Florida; Sea Farms, Inc. in Florida Bay of South Florida; and several others. By the end of 1969 none of these had yet sold any cultured shrimp, although several had reared stockable fry.

At the University of Miami marine aquaculture experiments, sponsored jointly by the Florida Power and Light Company, the National Science Foundation (through a Sea Grant award), Armour and Company and the United Fruit Company, have been launched with the pink shrimp, *Penaeus duorarum*. Under the direction of Dr. Durbin C. Tabb and

Mass cultures of microscopic plants grown at the University of Miami's experimental shrimp culture site must be carefully synchronized with shrimp growth so that they reach the proper density just as the shrimp transform to the first protozoeal stage when they begin to feed.

Photo Credit: C. P. Idyll

Dr. W. T. Yang, this project has succeeded in developing techniques for large scale production of postlarval shrimp. The procedures at the University of Miami and elsewhere in the United States are similar to those of the Japanese and attempt to control the whole life history.

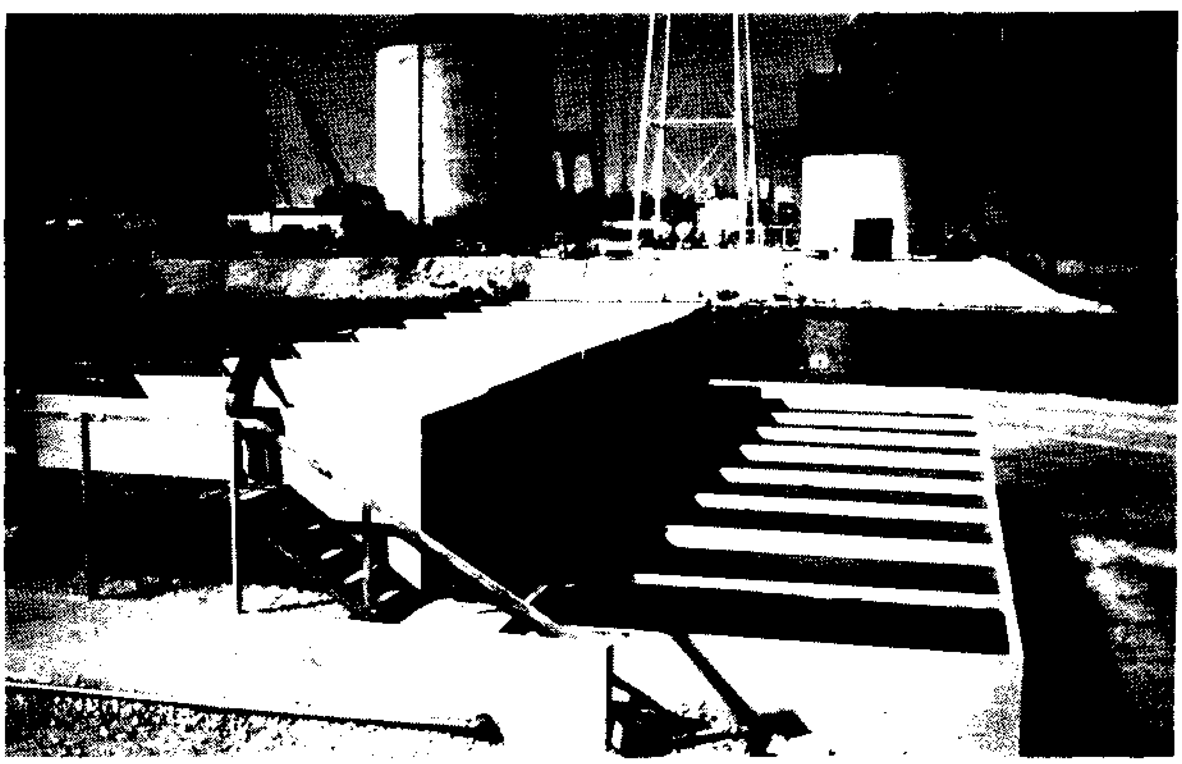
Until the culturist can produce his own brood stock, and not be obligated to catch young from wild populations, he has not accomplished true farming. Intensive mariculture for any species will be fully successful only when complete control of the life history from beginning to end is possible. No major industry can hope to be permanently established where the procedures involve continual capturing of young in nature. However, an intermediate step involving the ability to induce wild female shrimp to spawn in captivity and to raise them from the egg through to the "fry" stage, overcomes some of the serious deficiencies of methods which depend on the vagaries of nature.

In the University's hatchery-laboratory building, egg-bearing females are placed in tanks of filtered sea water which is continually aerated and kept at temperatures between 81°-84°F. Mass culture of diatoms is carried on stimultaneously in an adjacent room which is kept at temperatures ranging from 72° - 75°F. Three hatching experiments have been completed with excellent success, producing far more postlarvae than needed for experiments. In May, 1969, about 250,000 advanced postlarvae were transferred to outdoor growing ponds, and by August, 1969, a total of about 600,000 small shrimp were in outdoor growing facilities.

Several problems remain to be solved in the raising of postlarval shrimp. The first is the difficulty in obtaining shrimp eggs when needed. Even though the goal is eventually to raise brood animals, it is at present still necessary to collect wild gravid females from the fishing grounds. There is another difficulty involved with bringing diatom cultures needed to feed the shrimp larvae to the proper density at the time the shrimp transform to the first protozoeal stage. Because the cultures must be started before the gravid females are collected, synchronizing the collection of females with diatom growth is sometimes impossible.

While refinements are required in the techniques of producing postlarvae, these problems are minor compared to the larger problems of carrying the shrimp from the postlarval size to saleable size. At this stage there are several variables yet to be balanced: the kinds and quantities of food and their cost in relation to growth and survival, labor requirements, stocking densities which can be achieved without sustaining mortalities from oxygen deficiencies or disease, and the growth rate necessary to keep the cost of food and labor below the selling price of the shrimp.

These are the problems receiving attention from biologists and experimental shrimp culturists, and it is hoped that commercial catches of shrimp can be supplemented by shrimp produced on the farm.



These outdoor 20-ton rearing tanks provide a habitat for postlarval shrimp. The tanks are seen here prior to the construction of a weather-proof roof which now covers them. The large towers in the background are part of the Florida Power and Light Company's Turkey Point Power Station.

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These outdoor growing ponds at Turkey Point are partially filled for stocking. Three acres of ponds are divided into one 1-acre pond, two ½-acre ponds, and four ¼-acre ponds. Across the ponds can be seen the University of Miami's small hatchery-laboratory building.

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