Advances in Pacific Shrimp Culture

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INTRODUCTION

The culture of shrimp in the Pacific has been practiced for many years especially in the Indo-Pacific region. The method of semi-culture consists of allowing shrimp fry to enter artificial ponds during incoming tides and then grow utilizing natural foods produced in the ponds. The natural production of foods may be enhanced by the addition of fertilizers and tilling of the bottom when the ponds are completely drained. In the Philippines, shrimp fry are collected and transported to the ponds. These methods have been amply described by Kesteven (1958), Simpson and Hancock (1968), Tham Ah Kow (1968), Caces et al (1968), George et al (1968), and Pannikar (1968).

In the states of Sinaloa and Nayarit, on the Pacific coast of Mexico, shrimp are produced and captured in coastal lagoons and estuaries through the use of fixed structures "Tapos and Sierra". Shrimp postlarvae and juveniles enter protected waters during the first part of the year with incoming tides; later the Tapos retain the shrimp while they feed on natural food and reach market size. Traditionally the Tapos were constructed by driving wooden piles into the bottom across channels communicating coastal lagoons and estuaries with the sea. A woven mat of branches and palm fronds between the piles forms a wall permitting water flow but retaining the shrimp. At the center of the Tapo, a gate opens into the "Chiquero" a heart or kidney shaped enclosure. The shrimp are attracted into the enclosure at night by lights behind the gate. After capture they are removed with dipnets. This method has been described by Mercado (1959), Núñez and Chapa (1950, 1951 and 1952), and Chapa (1963).

More recently, the artificial culture of shrimp has flourished in the Pacific, especially in Japan. In 1933, Dr. Fujinaga succeeded in the artificial spawning and hatching of *Penaeus japonicus* but it was in 1959 that he established the first commercial scale shrimp farm in Takamatsu (Fujinaga, 1969). The artificial culture of shrimp as developed in Japan by Fujinaga, consisted of placing female shrimp in aquaria measuring 2 m x 1 m x 1 m filled with filtered seawater. The females were removed after spawning and when the larvae reached the protozoeal stage they were fed pure cultures of diatoms, mainly *Skeletonema costatum*. After the mysis stage, nauplii of *Artemia salina* were fed to the larvae; and after the postlarval stage, the shrimp were fed on crushed clam meat (Idyll, 1965; Fujinaga, 1969). When the small shrimp reached 15 mm in length they were placed in outdoor ponds where they grew to market size. At Fujinaga's Takamatsu farm, there are several types of ponds: small concrete ponds with a false bottom about 6 inches above the concrete slab, large concrete ponds without the false bottom and two large tidal ponds. The tidal ponds cover an area of 40,000 m^2. At his Aio farm, the ponds have an area of about 40,000 m^2 each (Idyll, 1965).

The artificial culture methods developed for *Penaeus japonicus* from the egg to the juvenile stage have been applied to *P. semisulcatus* and *Metapenaeus monoceros* (Simpson and Hancock, 1968). Since 1964, Fujinaga (1969) has modified the methods of rearing shrimp postlarvae from eggs. The new method utilizes large outdoor concrete tanks, 2 m deep and 10 m per side. Bay water is introduced through 80- to 100-mesh screens directly into the tanks. The mature female shrimp are placed in the tanks, allowed to spawn overnight and removed the next day. The number of females per tank during a series of experiments conducted in 1963 varied from 18 to 198. No direct correlation between the number of females per tank and the number of young shrimp produced was evident, but Fujinaga recommends the use of more than 30 females per tank. The production of diatoms is stimulated by adding potassium nitrate and dibasic potassium phosphate at the rate of 200 g and 20 g per day per tank from the day after hatching. *Artemia* and crushed baby clam meat were fed to the shrimp, but the larvae were apparently feeding on natural zooplankton also. Fujinaga cites the following advantages for the new method over the old: average production of young shrimp per tank 1000×10^3 over 10×10^3 and on the same number of shrimp fry basis, the use of one-fifth to one-tenth the number of gravid females, a survival rate from nauplii to young shrimp of 24% as compared to from 2.5 to 5%, a reduction of 72% in the amount of *Artemia* eggs and of 56% in the amount of baby clam meat needed in raising postlarvae, the elimination of separate diatom cultures, and a reduction in labor costs.

RECENT DEVELOPMENTS

Mexico

In Mexico, new Tapos are being constructed of concrete and net panels. The new type consists of concrete pilings driven into the bottom, the pilings are held together by cross members of reinforced concrete and a concrete walk on top. On the sides of the piles there are double grooves into which the net panels can be inserted. This permits inserting new net panels while others are removed for repairs or cleaning. By law the Tapos must be open during part of the year to permit migrations of shrimp. In this case the net panels in the concrete Tapos are removed, but the main structure is permanent.

In 1964, the shrimp fishermen's cooperative association, La Sinaloense, constructed a primitive canal from the Presidio River to the Huizache lagoon, did some dredging on the Ostial estuary and opened a new mouth connecting this estuary with the ocean. According to Chapa (1966), shrimp catches in Huizache lagoon increased by a factor of seven. In view of these results, he recommended the construction of a freshwater canal from the Baluarte River to the Caimanero lagoon and dredging the Agua Dulce estuary communicating this lagoon with the Chametla mouth at the ocean. This lagoon is joined to Huizache lagoon by a narrow chanel at Pozo de la Hacienda.

In 1966, the Federal Department of Hydraulic Resources received a formal request from two cooperative associations exploiting these lagoons, the Alvaro Obregón and the Sinaloense, to construct more efficient canals. The canals were in operation from 1966 to September 1968 when they were destroyed by hurricane Noemi which hit the mainland close to Mazatlán.

At the end of 1968, the Department of Hydraulic Resources initiated the Fisheries Development Pilot Plans for Escuinapa and Yavaros. The plans include constructing canals to bring fresh water to coastal lagoons, improving the access of seawater and postlarvae from the sea to the lagoons, building flow control structures to regulate amounts of water and water levels in lagoons, constructing and improving roads. In connection with these developments, the National University of Mexico and our Institution, the Monterrey Institute of Technology, agreed to undertake research programs which include: rearing commercial shrimp from the eggs to postlarvae; description of larval stages; production of postlarvae in quantities to stock ponds and enclosures in coastal lagoons; studying the effect of temperature and salinity on shrimp larvae, postlarvae and juveniles, to determine the best conditions for growth and development; studies of migrations of postlarvae and juveniles into coastal lagoons; determining hydrographic conditions in coastal lagoons; an evaluation of phytoplankton, zooplankton and benthic communities in coastal lagoons; recording climatic conditions with particular emphasis on winds, rainfall, solar energy, evaporation, temperatures, relative humidity and barometric changes; and determining the amounts and kinds of pesticides introduced into lagoons by drainage water from adjacent agricultural areas.

At the School of Marine and Food Sciences of the Monterrey Institute of Technology located in Guaymas, state of Sonora, we have succeeded in rearing postlarvae of *Penaeus californiensis*, our brown shrimp, and of a rock shrimp of the genus *Eusicyonia*. The rearing of shrimp postlarvae at our school has two main goals, one is the description of larval stages of the commercial species of our Pacific coast and the other is the mass production of postlarvae for shrimp farming.

Our present facilities include small and large aquaria, and rearing tanks. Our source of sea water is the Bay of Bacochibampo which is relatively unpolluted and has a wide open connection with the Sea of Cortez. Water temperatures vary from 17C in winter to 32C in summer and salinities remain fairly constant, from 34.70 °/oo to 37.09 °/oo. The water is pumped through PVC piping to two storage tanks with a total capacity of 12 m^3 located on the hillside above our main building. The water is filtered through diatomaceous earth filters. The pumping and filtering systems are duplicated to prevent interruptions in the seawater supply. The water is distributed to the building by gravity through PVC piping.

Our aquaria room occupies an area of 110 m^2 with small aquaria placed in upper and lower rows in three sections. We have eighty 70-liter aquaria, eight 90-liter aquaria, and six large rearing tanks with a capacity of 2 m^3 each constructed of marine plywood reinforced with fiberglass at the joints.

A separate insulated room measuring 3.5 m by 1.5 m occupies the south corner of the aquaria room and is used for the culture of diatoms. One 25,000 BTU/hr. reverse cycle airconditioner maintains temperatures constant in this room. Illumination is provided by twenty-three 74-watt slim-line daylight lamps. The diatoms are cultured in 5 gallon carboys.

One section of small aquaria receives water directly from the main pipe, but the other two sections and the rearing tanks receive water filtered by 4 double batteries of Cuno filters with 50- and 5- micron pores respectively. The filtered water flows through two Karbate heat exchangers, one to warm it the other to cool it. The heat exchangers have automatic temperature controls regulating the flow of hot or cold freshwater through the shells.

Each row of small aquaria is fed through a separate pipe and the amounts of warm and cool seawater can be varied to provide different temperatures to each row of aquaria and to the rearing tanks. Freshwater or brine can be added in varying proportions to change salinities. The same type of Cuno filter is used for the freshwater and the brine solution.

Compressed air is supplied to the aquaria room by a Quincy model FC-325 air compressor, a DeVilbiss type UAN-50-40 model 230 air compressor serves as a stand by. In case of power failure, air from high pressure steel cylinders may be used to provide aeration.

Two 25,000 BTU/hr. reverse cycle air conditioners provide temperature control for the aquaria room.

A research laboratory with 30 m^2 of floor space connects with the aquaria room.

The larval stages of *Penaeus californiensis* have been described by one of our staff members and will be published in the near future. We detected five naupliar stages, three protozoeal stages and three mysis stages.

The eggs hatched 15 hours after spawning at 28C, and 54 hours after spawning the first protozoea appeared; the first mysis developed 190 hours after spawning and the first postlarva at 295 hours. Forty-seven days after spawning the postlarvae had reached a total length of 20 mm. At 23C it took the shrimp five days longer to reach the postlarval stage.

We found the survival rate between stages greatly reduced between first nauplius and first protozoea. Overall survival rates, between first nauplius and postlarvae, averaged 4% with a maximum survival rate of 8.1% which is lower than that reported at present for *P. japonicus* using 200 ton tanks. The experiments were conducted in aquaria at 30C.

The rock shrimp *(Eusicyonia sp.)* is being captured in increasing amounts by our commercial fishermen. We were able to obtain adults from eggs in aquaria and rearing tanks and samples of all larval stages were obtained for study purposes.

Small scale feeding experiments with brown shrimp using artificial foods produced from fishmeal, shrimp heads and commercial feeds were conducted. Apparently a mixture developed from shrimp heads shows some promise. These experiments will be continued on a larger scale on the same species and other commercial shrimps.

We have completed construction of six new concrete outdoor rearing tanks with a capacity of 20 m^3 each. The tanks can be filled with filtered or unfiltered sea water. A roof protects the tanks from direct sunlight and rainfall, but the roofing sheets may be removed if necessary for plankton production.

Japan

During May 1970, we visited the Seto Inland Sea shrimp farming area of Japan. Dr. Tomotoshi Okaichi of Kagawa University accompanied us to the Saibai Gyogyo Center in Yashima and to the Shrimp and Yellowtail Farming Company, Ltd., in Takamatsu where we visited with Dr. Uto Kobayashi, Director of the Center, and later with Dr. Ichiro Sugiura, Director and Treasurer of the Farming Company.

Research is being conducted at this center on the culture of shrimp, crabs, clams and fishes. They have several new shrimp rearing tanks measuring 10 m per side and over 2 m in depth. These tanks will have means for raising the temperature of the sea water. The water supply is pumped from the bay into the tanks through plankton nets that retain most zooplankton.

The tanks are filled with water to one-third their depth before introducing gravid females. After spawning the females are removed and commercial agricultural fertilizers are added to promote phytoplankton growth. Soybean residues are added to the tanks 4 days after spawning. Water is introduced daily to the tanks so that when the first postlarval stage is reached the water depth is 2 m. The optimum concentration of diatoms is regulated by the amounts of fertilizer and seawater added. To reduce the concentration only water is added, and to increase it water and fertilizers are added.

It takes about 2 weeks for the shrimp to reach postlarval stage and the postlarvae are kept in the tanks for an additional week before releasing into net enclosed areas in the Inland Sea. After they reach a length of 25 mm to 30 mm the nets are removed and the fry are released. In one confined area, the survival rate from 13 mm to 30 mm was 63%. While the shrimp were kept confined, they were fed a supplemental diet of non-commercial ground shrimp. There are 14 stations on the Inland Sea conducting similar experiments, but only 4 were successful in increasing production. These were stations located in confined areas where shrimp migrations are restricted.

At the commercial shrimp farm in Takamatsu, production of shrimp postlarvae is still carried out in several 2-ton tanks as originally built by Dr. Fujinaga. The small and large concrete ponds are no longer in use since shrimp farming is conducted mainly in a large tidal pond with an area of 4 hectares. Some concrete ponds are used to hold shrimp for market during winter months

Live shrimp for "Tempura" continues to carry a high price in Japan, offsetting to a certain extent the high cost of feeding shrimp on ground clams and non-commercial shrimp. The cost of producing 1,000 postlarvae, excluding investments, is $0.80 U.S.

We asked our hosts, and later Drs. Ohta and Kirata at the Naikai Regional Fisheries Research Laboratory south of Hiroshima, what they thought the main advances in shrimp culture in Japan had been during the past 5 years. The consensus was that the main advance was an increased efficiency in production of postlarvae brought about by several factors. One is the use of large rearing tanks (200 tons) that permit the production of larval food directly from naturally occurring mixed cultures of phytoplankton. Another factor is that survival rates from the egg to the postlarval stage have increased from 0.8% in 1960 and 4.8% in 1964, to from 30 to 50% in 1970. This increase in survival is due not only to the new rearing techniques, but also to improvements in training and experience of the personnel involved in shrimp culture.

We were told that there are plans in Japan to construct floating plants to rear shrimp postlarvae with a capacity of 1,000 tons of water. The main advantage of this plant is that it could be moved into an area where shrimp fry are needed, eliminating transportation of fry.

The rearing of postlarvae of *P. japonicus* in Japan is now a repeatable process which has been fairly well established and allows production to meet market demands. Since this operation still depends on obtaining gravid females from the natural environment, production of postlarvae is seasonal. Feeding costs from postlarvae to adults are relatively high, but the price commanded by live shrimp for Tempura makes shrimp farming selfsustaining.

In Mexico, we are gaining experience in producing shrimp postlarvae. If we succeed in managing large areas of water and in reducing or eliminating the cost of supplementary feeding, shrimp farming would have a great future since the Pacific coast of Mexico has over 800,000 hectares of coastal lagoons and the Gulf of Mexico and Caribbean coasts over 640,000 hectares. Even if only part of the total area can be properly managed, the potential is promising.

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