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Won Tack Yang
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University of Miami Sea Grant

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MENIPPE MERCENARIA

Won Tack Yang[1] and George E. Krantz[2]
Rosenstiel School of Marine and Atmospheric Science
University of Miami

University of Miami
Sea Grant Program
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PRESENT ADDRESSES

1– Food and Agriculture Administration,
Projekt UDANG, PO Box #1
Jepara, Indonesia

2– Center for Environmental and
Estuarine Studies, University
of Maryland, Cambridge, Md.

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Information Services
Sea Grant Program
University of Miami
P. O. Box 248106
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33124

INTRODUCTION

Economically viable mariculture of any crustacean species depends largely on successful seedling production. Only penaeid shrimp have been cultured successfully for seedling purposes. The methodology for the mass production of crab seedling is still in its early stages. Despite the lower number of larval stages of the brachyurans, the mass culture of crabs is more difficult than that of penaeid shrimp which have more stages. A major difficulty is that crab zoeae are highly susceptible to adverse environmenal changes, especially in mass culture procedures.

The Japanese blue crab, Neptunus trituberculatus, has been mass produced in a number of Japanese fish culture research centers since about 1968. Utsunomiya (1969) presented some basic information on the characteristics of culture water used for larval rearing. Still, a perfect seedling production method has not been established.

Stone crab, Menippe mercenaria Say, development up to the sixth zoeal stage was first described by Porter (1960). He noted, however, that only five stages seem to occur in nature. Reporting details of stone crab larval rearing in the laboratory using small-volume containers, Ong and Costlow (197) showed that both salinity and temperature affect the rate of larval development and larval survival up to early crab stages.

One of the present authors developed a mass-culture production method for the stone crab from egg hatching to early crab stages (Yang, 1971). Later, he successfully reared crabs through the second generation (Yang, 1972).

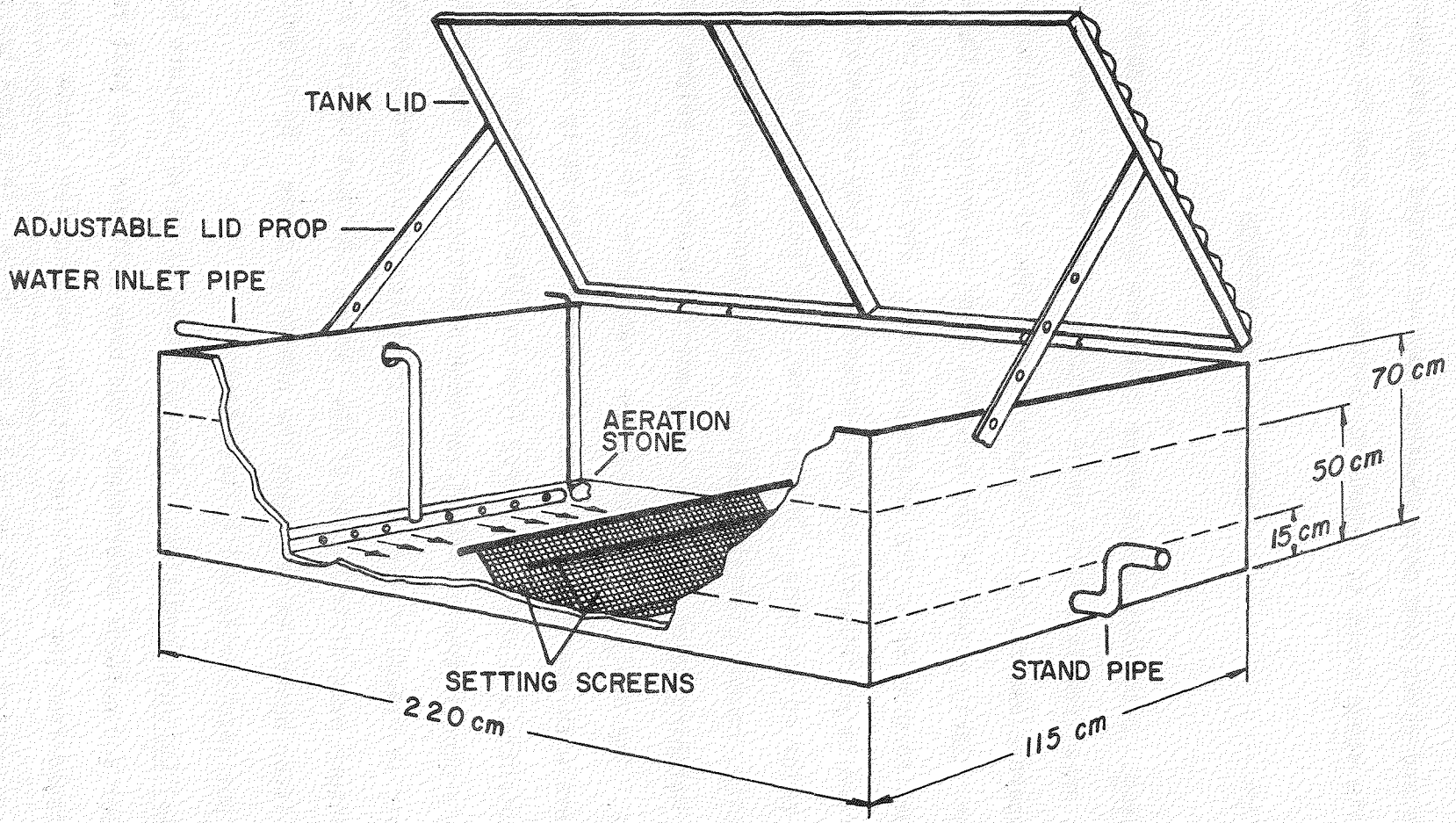
This presentation summarizes Yang's culture technique for stone crab larvae and gives some data obtained when we tested the adaptability of juvenile stone crabs to intensive culture systems used for penaeid shrimp.

MATERIALS AND METHODS

Spawning. Ovigerous female stone crabs are usually available in the Miami, Fla., area from late April until October. The females are kept individually in separate aquaria to facilitate observation of ovi-position and egg development. Early stages of the external eggs are orange and the egg color changes to grayish as the embryo develops. The heartbeat of the embryo is observed to be frequent and well-marked zoeal body pigmentation is noted just prior to hatching. At this time, the female is placed in a 1000-liter capacity, round, plastic container with dacron-wool filtered seawater.

Hatching takes place in early morning hours and seldom during daylight hours. The newly hatched zoeae are transferred to 100-liter plastic containers with dacron-wool-filtered seawater. The early zoeae are highly phototactic and are transferred from an illuminated side of the container with a dipnet made of 180-micron-mesh plankton net. The 100-liter container is placed in the shade and the water is stirred thoroughly and gently to ensure even distribution of the larvae. Aliquot samples are taken with a 1-liter beaker to determine the number of zoeae. By aliquot, the zoeae are put into the larval culture tanks.

Larval Culture Conditions. Several sizes of larval culture tanks both for indoor and outdoor experiments have been utilized, but best results were achieved from the 1800-liter outdoor, rectangular, wooden tank (Fig. 1). Its dimensions are 220 cm by 115 cm by 70 cm. This tank has a roof made from translucent corrugated fiberglas roofing material, with hinges and


TANK LID
ADJUSTABLE LID PROP
WATER INLET PIPE
AERATION STONE
70 cm
50 cm
15 cm
SETTING SCREENS
STAND PIPE
220 cm
115 cm

adjustable side arms for any desired opening. The lid is closed at night.

The inside of the tank is painted with polyester resin with white or black pigment, preferably with two or three coatings. The inside edges and corners are reinforced with fiberglas cloth tape. The tank is provided with a drain hole at one corner of the bottom and a stand-pipe at the bottom center of one side. Two PVC elbows were jointed to make this stand-pipe to maintain a water depth of 15 cm in the tank. This stand-pipe, which has an inside diameter of 3.7 cm, is used for the running-water system of culture.

At the start of larval rearing in the 1800-liter wooden tanks, the static water level was maintained at a depth of 50 cm. Chlorella was added to the larval culture-tank water until the cell density reached about 500,000 per ml turning the culture water light greenish. At the end of the zoeal stage, the water level was decreased to 15 cm and flowing filtered seawater was utilized. A screen around the intake of the stand-pipe prevented loss of larvae.

Five airstones, one at each corner and at the center, were placed in the tank. Moderate aeration was provided throughout the culture period.

All culture water came from Biscayne Bay and was pumped through the RSMAS seawater system. On many occasions, dacron-wool-filtered seawater was used. The particle filtration range of this filter was approximately 30 microns. In most cases, seawater was filtered with plankton-net material of mesh-size opening of 100 to 160 microns which removed fish eggs and larvae, Sagitta, and other predatory organisms. Culture water filtered by plankton-net material always produced better results than the dacron-wool-filtered seawater. This roughly filtered water provided food organisms for crab larvae since copepod nauplii and copepodites and other smaller invertebrate eggs and larvae were introduced into the tank.

Salinity of the culture water was usually above 30 ppt, ranging from 30 to 36 ppt.

During the early megalopal stage (when the population was about 10% megalopa), about five or six settling screens were placed in the bottom of the 1800-liter tank for the megalopae to settle upon. Each screen, made from fiberglas window screen material, measured about one meter long and 15 cm high, and was anchored to the bottom.

The crab larvae were fed initially with rotifers (Brachionus plicatilis) at a rate of 0.3 rotifer per ml. Rotifers were mass cultured in 200-liter plastic drums on a diet of marine-acclimated Chlorella, which were cultured separately in pasteurized seawater.

Three to five grams of Artemia cysts were put into each tank every day through the larval period. The cysts were placed inside floating, plastic tubing rings to prevent attachment to the tank walls. The Artemia cysts usually hatched the next day.

In the early megalopal stage, blended shrimp, scallop or squid meat, or a mixture of these was fed. These diets were prepared by blending in a household electrical blender, then sieved and washed; only the minced meat was placed on the settling screens.

In 1973, the above techniques were utilized to produce 5,840 first stage stone crabs. These animals were transported from the RSMAS laboratories to the Turkey Point Experimental Mariculture facility in an aerated seawater tank. Rolls of fiberglas screen provided substrate to reduce contact and cannibalism among individuals. At Turkey Point, the crabs were stocked in two sizes of outdoor concrete shrimp-rearing tanks (10 sq meters and 1.5 sq meters of tank bottom) at densities of 100 per sq meter. Description of these facilities may be found in Tabb et al., 1969 and Norris, 1974. The tanks were provided with filtered, flowing seawater, continuous aeration,

and a combination of river rock and fiberglas window screen substrate. Stone crabs dispersed uniformly in the substrate within the first three days. Movement and feeding was restricted to the immediate vicinity of a selected and defended habitat. Diets of chopped squid and fish, trout pellets, experimental Ralston Purina shrimp diets were utilized in various tanks. Juvenile crabs remained in the concrete tanks for 85 days when all survivors were placed in one 0.4 hectare saltwater pond with a marl substrate bottom. Juvenile crab growth was determined by measuring the carapace width and occasionally by weighing individuals.

RESULTS AND DISCUSSION

One problem in crab larval culture is accurate determination of the population of the larvae in large tanks. Due to phototactic characteristics of larvae, it is impossible to get statistically valid aliquot samples from the population. Therefore only the population at stocking and the harvested population can be used with any validity.

The proper number of zoeae to be stocked in larval rearing tanks is suggested by the data shown in Table I. In one experiment, 5,200 larvae (2.9 zoeae per liter) were stocked in each of three tanks and in three other tanks in initial population was 15,000 (8 zoeae per liter). Survival averaged 12.7% on the low initial stocking density tanks and 7.6% in the tanks with the higher stocking density. A high zoeae population at initial stocking does not seem to be desirable. For the type of culture system described herein, an initial stocking population of about 6,000 per tank (1,800 liter) is advisable. The observed survival (Table I) is much lower than reported by Ong and Costlow (1970).

Among the various salinity and temperature combinations tested, these investigators reported high larval survival (74%) to the first crab stage

TABLE 1.

Production of stone crabs in 1800-liter tanks at two stocking rates.

Experiment No. and Date	Tank Number	Initial Population	Harvested Population (2nd-3rd Crab)	Survival
Experiment A	6	5,200	777	15%
7/25/73	7	5,200	524	10%
	8	5,200	662	13%
Experiment B	6	15,000	1,384	9.2%
8/16/73	7	15,000	608	4.1%
	8	15,000	960	6.4%
	9	15,000	1,584	10.6%

at 35 ppt salinity and 25°C, and 72% survival at 30 ppt salinity and 30°C. They cultured the larvae in finger bowls, changed water every day, and fed newly hatched Artemia nauplii daily. In an 1,800-liter tank mass culture, it is almost impossible to change water every day. In fact, changing water in a mass-culture system can produce mass mortality because it tends to upset the stability of the culture water.

Most problems during the culture period occurred in later zoeal and early megalopal stages. Higher mortality takes place at this time due to adverse culture water conditions, even though Chlorella was added to stabilize the culture water. Caution had to be exercised so that the Chlorella density in the culture water would not exceed 1,000,000 cells per ml. Heavy blooms of Chlorella lead to an over-saturation of oxygen and higher pH during the late afternoon hours of clear, sunshiny days. This can cause gas disease in the larvae, as experience with the Japanese blue crab showed (Kon et al., 1968; Utsunomiya, 1969).

This initially green culture water usually turned brownish as diatoms became more dominant. When this color change occurred, the culture tended to be always successful.

The sequence of larval development of the stone crab in mass culture is represented in Figure 2. This sequence occurred at 33.7 ppt salinity and in a temperature range of 30.2°C to 32°C. The numbers at days 6,9, and 13 represent the percentage of mixed stages observed at this time.

Porter (1960) reared stone crab larvae from egg to the first crab stage in 27 days on an Artemia nauplii diet at a salinity of 30 to 35 ppt and temperature of 30°C. Ong and Costlow (1970) cultured M. mercenaria larvae to the first crab stage in 21 days also solely on Artemia diet. The faster development time in this study may be explained by the availability of a multiple diet of rotifers and Artemia nauplii; and more important, natural

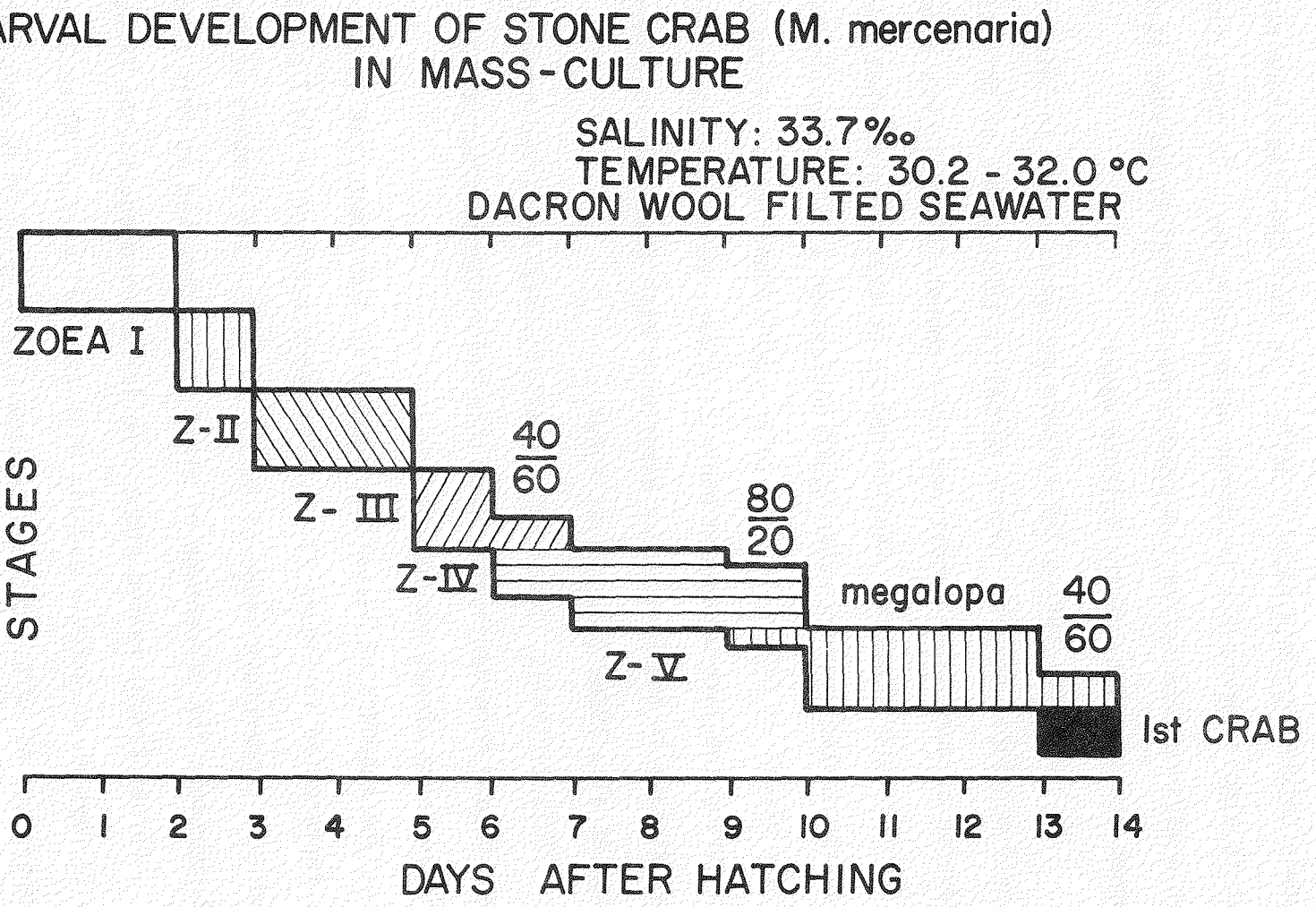


Figure 2. Larval development of stone crab (*Menippe mercenaria*) mass-cultured in outdoor 1800-liter wooden tank at a salinity of 33.7 ppt and temperature of 30.2 to 32.0°C. The numbers are the percentage ratio of the larval stages at that particular time.

food organisms present in the culture water which were introduced into the tank by the roughly filtered seawater.

In some indoor cultures produced late in the natural spawning season, the sixth zoeal stage was observed. Whenever this was noted, the cultures were not successful. Ong and Costlow (1970) found that less than 2% of fifth zoeae developed into sixth zoeae, but the majority of the sixth zoeae (nine out of 11) died and only two metamorphosed into megalopa.

In early stone crab mass-culture studies, the water in the bottom of the tanks appeared to become stagnant after 10 days despite aeration. Factors detrimental to larval culture such as the gradual dropping of pH, over 2 ppm concentration of NH_3-N, and extensive bubble formation occurred. These observations led to the practice of stirring the water mass on the tank bottom twice a day, and culturing the later fifth zoeal or very early megalopal stages in a flowing seawater system. Feeding blended molluscan or shrimp meat can be conducted without changing water quality.

Form several experiments using running-water system, it was determined that a minimum water turnover of four times a day was desirable. In early megalopal stages, higher water exchange rates are advisable.

In many of the early culture experiments, failures arose due to feeding large concentrations of Artemia. Dead Artemia appeared to produce, along with heavy aeration, protein bubbles. These bubbles impaired water quality and inhibited the growth of phytoplankton needed to stabilize the culture water. For an initial stocking density of about 6,000 crab larvae, about three grams of brine shrimp cysts appears to be an effective feeding level. Based on the Artemia population size in the tank, fewer or more cysts can be added.

Even though first crab stage stone crabs were uniform in size and reached this size in a relatively short period (Figure 2), growth of

juvenile stone crabs was extremely erratic and survival very low (Tables 2 and 3). In the 1.5 sq meter tanks, 5.7 percent survived 85 days; whereas 8.1% survived in the 100 sq meter tanks. After concentration of all of the stone crabs (439) in one 0.4 hectare saltwater pond, mortality continued and only 1.6% (91 of the original study group) lived through the 307 day observation period. Formulation of a meaningful growth rate for juvenile crabs was complicated by the high mortality but even more so by a great range in individual size.

TABLE 2

Growth and survival of first stage stone crabs in 1.5 sq meter tanks for 85 days

Number of days	Mean width	Mean wieght	Number of crabs	Survival Period	Survival Cumulative
0	4.1	-	1,440	-	-
42	7.8	-	197	13.7	13.7
67	17.2	2.35	112	56.9	7.8
85	-	-	82	-	-

TABLE 3

Growth and survival of stone crabs under mariculture conditions at Turkey Point. First stage crabs were stocked at 100/sq meter in tanks for 83 days and then placed in saltwater pond after 85 days.

Number of days	Mean width	Mean weight	Number of crabs	Survival Period	Survival Cumulative
0	4.1	-	4,400	-	-
37	8.2	-	1,283	29.2	19.2
69	20.2	3.3	490	38.2	11.1
83	-	-	357	72.9	8.1
85	-	-	439	-	7.5
184	52.2	51.0	219	49.8	3.8
307	68.5	121.5	91	41.6	1.6

As an example of size variation at day 69 on Table 3, the mean carapace width of 20.2 mm was comprised of individuals ranging from 4 mm to 40 mm. These animals ranged from 0.09 gram to 10.4 grams in weight. Predation and aggressive behavior undoubtedly eliminated the small animals and contributed to the observed high mortality. The great variation in carapace width was also evident following 97 days in a saltwater pond situation. At 184 days, male stone crabs ranged from 6.3 mm to 79.6 mm in carapace width and weighed from 9.6 to 196 grams. Female stone crabs ranged in size from 18.8 to 64.1 mm with a weight range of 11.3 to 79.5 grams. At the termination of the pond experiment (307 days), the surviving stone crabs ranged from 39 to 92 mm in carapace width.

Growth at successive molts from 1st crab has been recorded for several crabs in aquaria. Optimum conditions permitted rapid growth and survival of individual stone crabs. Some male crabs reach up to 650 grams in 19 months on a diet of chopped squid, fish, yeast, and vitamins.

The very poor survival influenced food conversion efficiencies of all test diets. The highest food conversion efficiency (5.1 to 1 and 5.6 to 1) was observed in two tanks fed an experimental Ralston Purina marine ration in round pellet form.

Data in Tables 2 and 3 indicate that poor survival due to cannibalism and aggressive behavior , and extreme variation in growth of the juvenile stone crab make it a very poor candidate for intensive mariculture in tank and pond systems like those utilized at Turkey Point. However, this was the first attempt at "intensive culture" of these animals, and many technical difficulties in determining stocking density, habitat preference, feeding techniques and handling of extremely aggressive animals were resolved. One problem of paramount importance in future mariculture attempts is the behavior of the crabs in the saltwater ponds. Stone crabs burrow into the pond bottom and can be removed only by carefully digging them out of their burrows by hand. Three man-days of labor were required to remove 91 crabs from the pond at the end of the study. The burrows usually had three surface escape tunnels and one descending tunnel often to 18" in depth. The distribution of the burrows was uniform over the pond bottom except where structures arose from the pond bottom. The structures were a water overflow gate, a water inlet baffle and an unused shrimp harvest support. The total number of holes in the bottom closely approximated the number of crabs placed in the pond. Maximum density of occupied holes was 4 per 10 sq meter in the pond bottom. Only four holes more than the original stocking number were found.

The distribution of the occupied holes to the unoccupied holes suggested that aggressive interaction and cannibalism probably accounted for the high mortality shown in Table 3.

CONCLUSIONS

Stone crabs did not adapt well to intensive culture techniques used for penaeid shrimp. Larval culture procedures, though fairly successful, suffered from the logistics of feeding large number of larvae and from difficulty in maintaining water quality in large volume culture tanks. Aggressive behavior, high mortality, and wide variation in growth of juvenile crabs suggest that the species may be better utilized in extensive culture systems--possibly using natural habitat and natural food. Perhaps the larval culture procedures have an important role in providing stone crabs for natural resource management of rehabilitation of declining natural fisheries.

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