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AN EVALUATION OF METHODS FOR DETERMINING MOVEMENT OF SHRIMP

PHASE II: SHRIMP HOLDING STUDIES

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INTRODUCTION

As a prelude to tagging studies on pink shrimp (*Pandalus jordani*) or other laboratory studies, basic information was needed to establish criteria necessary to hold shrimp in aquariums with minimum mortality. A one-year study was conducted at the Fish Commission Laboratory in Newport to obtain data on these requirements. The objective was to design aquariums suitable for holding shrimp, determine the optimum levels of shrimp density, water temperature and salinity needed to maintain minimum mortalities, and describe other factors related to maintaining shrimp in an artificial environment. The results of these findings would not only benefit laboratory work but would be of value in field work.

MATERIALS AND METHODS

Aquarium Design

The study was conducted in a controlled-temperature room at the Newport laboratory. Shrimp were held in fiberglass aquariums with inside dimensions of 23 inches wide, 23 inches long and 12 inches high. The water depth in each aquarium was 10 inches giving each a capacity of approximately 23 gallons. To efficiently utilize available space, stands were constructed to hold the aquariums in stacks of three. Each had a common filter, reservoir and headbox (Figure 1).

A Teel 0.1 HP submersible pump was used to circulate the water through the system. Polyethylene and polyvinyl chloride plastic pipe and fittings were used for the salt water lines. A small plastic dishpan served as a headbox for distribution of the water to the aquariums. An adjustable clamp was placed on a short piece of Tygon tubing at the end of each inflow line to the aquariums.

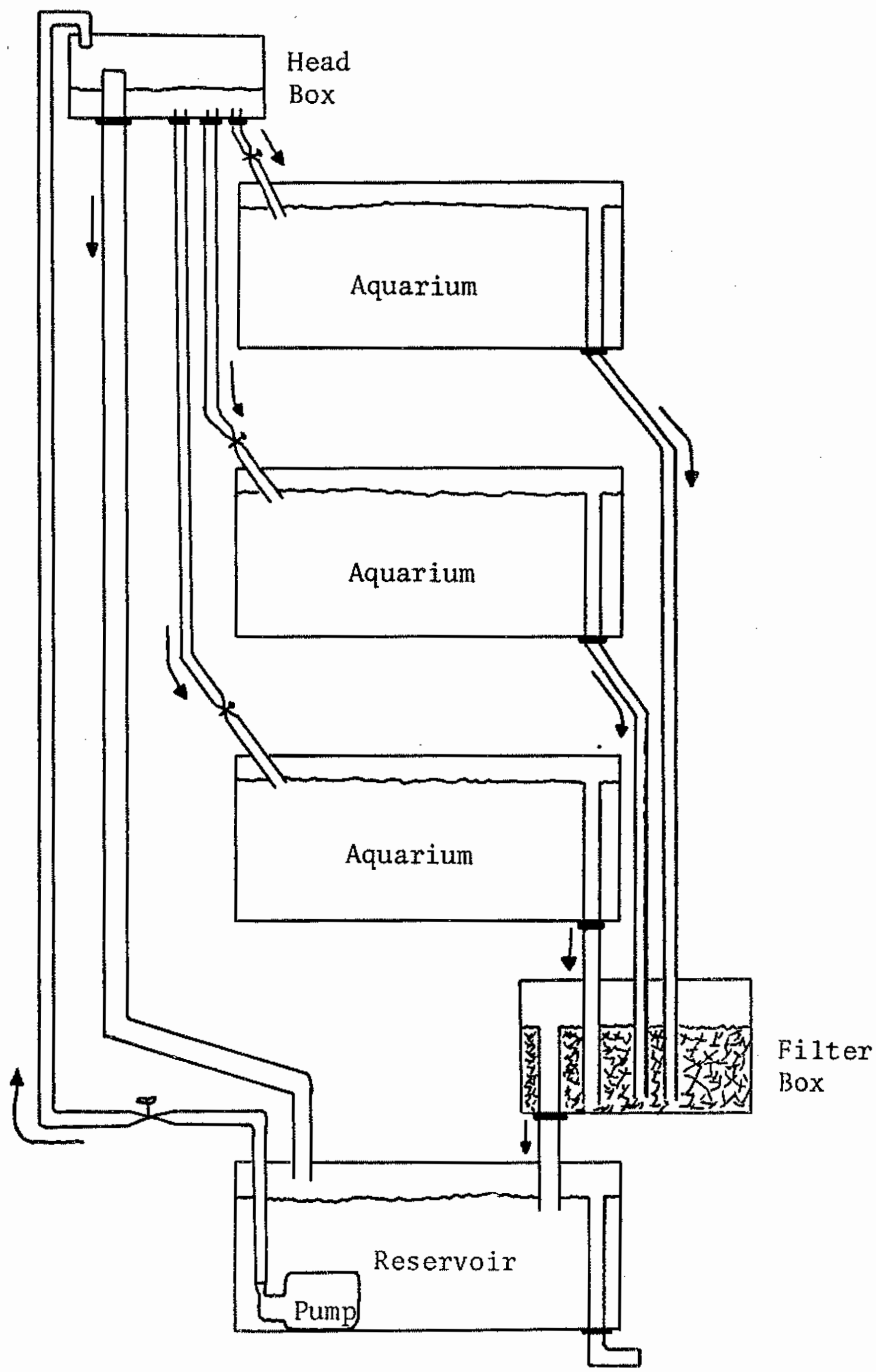

Figure 1. Diagram of Closed-circulating System for Shrimp Aquariums (supporting stand not illustrated).

These clamps were adjusted to allow a flow of 1.5 gallons per minute to each aquarium. The filter box, 19-inches long, 12-inches wide, and 8-inches high, contained crushed oyster shell as a filtering and buffering medium. Two-inch diameter perforated styrene plastic pipes, 11-inches long, were placed, as a sleeve, over each standpipe in the aquariums. They prevented shrimp from being drawn through the standpipe by the outflowing water.

Fluorescent lights in the room were controlled by a 24-hour time switch and were adjusted weekly to simulate the change in hours of daylight and darkness.

Air temperature in the room was maintained at 2-3 F below the water temperature desired for the experiments. The water temperature was then regulated by placing in each reservoir a 500-watt water immersion heater controlled by a thermoregulator with a sensitivity of ± 0.5 F.

Salinity readings were taken daily and distilled water was added when needed to maintain salinities at prescribed levels.

A one-half inch layer of fine beach sand was placed in the bottom of each aquarium.

Test Animals

The pink shrimp used for the studies were obtained from trawl catches of commercial fishermen, fishing off the Oregon coast. From 40-60 viable shrimp were placed in 20-30 gallon plastic waste containers. Dead or dying shrimp were culled frequently and the water was changed at least twice a day while at sea. In most cases shrimp were in the containers 12-16 hours before being placed in the aquariums. One group was held 36 hours before being brought to the laboratory. Before the shrimp were placed in the aquariums, the aquarium water temperatures and salinities were adjusted to match the conditions of the water in the containers.

The shrimp were fed a diet of freshly minced cockle (*Clinocardium nuttalli*) or gaper clams (*Tresus capax*). Several species of flatfish and the Oregon moist pellet were also tried as food. To prevent cannibalism the shrimp were fed daily. The molted exoskeletons of shrimp were left in the aquariums for the shrimp as a source of lime salts needed for calcification of new exoskeleton.

The shrimp used in the study were adults of various ages. No attempt was made to test a particular age group or sex.

Experimental Design

Two types of tests were conducted; density and temperature-salinity.

The density test was conducted to determine the effects of crowding on shrimp and the optimum number of shrimp per square foot of aquarium bottom for maximum survival. Shrimp held at four different densities were tested with three replicates of each density. The test was run for 30 days at a temperature and salinity matching natural conditions (45 F, 34 $^{o}/oo$).

The temperature-salinity series tested the survival of shrimp at three different salinities (25, 30 and 35 $^{o}/oo$) and three different temperatures (44, 54 and 64 F). These levels were chosen because they approximated the ranges of temperature and salinity which the shrimp could be subjected to if they were being held aboard a research vessel during field work. The temperature-salinity tests were run for 15 days. The results were tabulated for two periods; 1-5 days to show what proportion of animals are initially affected by the temperature and salinity and 6-15 days to show the mortality of the surviving animals which are subjected to prolonged exposure to the test conditions.

RESULTS

Test Animals

The test shrimp readily adapted to aquarium conditions. An initial test demonstrated that aquariums with no sand on the bottom caused nearly one-half of the shrimp to swim continually in the water column. After a layer of sand was added to the bottom the shrimp quickly settled to the bottom and swimming activity decreased greatly.

Minced clam meat was a preferred food. The shrimp did not readily accept flatfish or the Oregon moist pellet as food.

Well fed shrimp did not exhibit any cannibalism. Even in tanks which had a high density of animals, shrimp were able to molt and were not attacked by their companions. However, on some occasions, because of a shortage of food, shrimp mortalities not removed from the tanks were eaten. Whenever a female, with an egg mass, died, the eggs would be quickly eaten.

Density Test

The mean survival rates of the four density levels tested ranged from 66.7 to 88.0 per cent (Table 1). An analysis of variance indicated no significant differences in survival attributable to numbers of shrimp initially placed in the aquariums.

The water temperatures during most of the test ranged from 45 to 47 F, but did reach 54 F for short periods because of operating difficulties with the cooling system. Salinities ranged from 34 to 36.6 $^{o}/oo$. The pH varied from 7.98 to 8.07.

Table 1. Proportion of Shrimp Surviving after 30 Days at Four Density Levels.

Initial Density	No. Shrimp Per ft^2	Per cent Survival Replicate 1	Replicate 2	Replicate 3	Mean Survival (per cent)
11	3.0	64	100	100	88.0
24	6.5	75	62	71	69.3
37	10.0	70	70	76	72.0
50	13.7	72	66	62	66.7

Temperature-Salinity Tests

The temperature-salinity tests were run with 15 or fewer animals per tank. The results in Table 2 show mortality for two periods at three different temperatures and salinities.

Table 2. Per Cent Mortality of Shrimp Held at Three Different Temperatures and Salinities

Period (days)	Temperature - 44 F, Salinity 25 °/oo Total No. Animals	25 °/oo Mortality (%)	30 °/oo Total No. Animals	30 °/oo Mortality (%)	35 °/oo Total No. Animals	35 °/oo Mortality (%)
1-5	42	19.0	64	1.6	72	1.4
6-15	34	5.9	63	1.6	71	0
1-15	42	23.8	64	3.1	72	1.4

Period (days)	Temperature - 54 F, Salinity 25 °/oo Total No. Animals	25 °/oo Mortality (%)	30 °/oo Total No. Animals	30 °/oo Mortality (%)	35 °/oo Total No. Animals	35 °/oo Mortality (%)
1-5	26	3.8	33	3.0	33	0
6-15	25	0	32	3.1	33	3.0
1-15	26	3.8	33	6.1	33	3.0

Period (days)	Temperature - 64 F, Salinity 25 °/oo Total No. Animals	25 °/oo Mortality (%)	30 °/oo Total No. Animals	30 °/oo Mortality (%)	35 °/oo Total No. Animals	35 °/oo Mortality (%)
1-5	39	100	45	48.9	45	68.9
6-15	0	--	23	95.0	14	42.0
1-15	39	100	45	97.0	45	82.0

The mortality at 25 $^{o}/oo$ salinity and at a temperature of 44 F was significantly higher than mortalities at 30 and 35 $^{o}/oo$ salinity during the first 5 days. There were no significant differences in mortalities during days 6 through 15 at the 3 salinities at a temperature of 44 F.

At 54 F, the percentages of mortalities were low and the differences were insignificant.

The test at 64 F inflicted heavy mortalities on the shrimp, especially at 25 $^{o}/oo$ salinity during the first 5 days. The shrimp held at 30 and 35 $^{o}/oo$ salinity also experienced heavy mortality during the first 5 days and by day 15 they had total mortalities approaching 100%.

DISCUSSION

The results of these tests show that shrimp can be successfully held in laboratory aquariums within reasonable limits of water temperature and salinity.

The over-all mortality rate in the density test was 30.9%. There were no significant differences in mortalities at the 4 levels tested or in molting rate but, density did have an effect on the mortality following molting (Table 3). Over-all 31.9% of the mortalities were shrimp that died while trying to molt or if they completed the molt they did not survive more than one day. A progressively greater percentage of shrimp died during or after molting in direct relation to the increased densities.

Table 3. Comparison of Holding Density on Shrimp-Molting Rate and Mortality following Molting

Total Number Shrimp Tested	Number Shrimp per ft^2	Percentage of Shrimp that Molted	Percentage of Molted Shrimp that Died
33	3.0	48.5	6.2
72	6.5	52.8	15.8
111	10.0	56.7	17.5
150	13.6	54.0	22.2

The other obvious cause of death resulted from injuries to the rostrums of the shrimp and accounted for 6.2% of the mortalities. When shrimp swam in the water column they appeared to be blind and would often swim directly into the sides of the aquarium. This behavior resulted in injuries to the rostrum and subsequent death. These shrimp had no other obvious injury.

No causes could be attributed to the remaining 61.9% of the mortalities.

The low mortalities that occurred in certain temperature-salinity tests indicate that the shrimp are relatively hardy animals; but these results were obtained in stable conditions. Rapid changes in salinity resulted in high mortalities. This was demonstrated when I was preparing for the first temperature-salinity tests. Two stacks of aquariums had salinities of 36.6 $^{o}/oo$ and 34.8 $^{o}/oo$. Distilled water was added to decrease the salinities to 30.0 and 27.5 $^{o}/oo$, respectively. Eighteen hours later 90% of the shrimp in both aquariums were dead or mortally stressed. This clearly indicated the need for more gradual salinity changes. A second attempt was made on two stacks of aquariums having salinities of 34.6 and 36.2 $^{o}/oo$. The salinity of both stacks was reduced to 25 $^{o}/oo$, but it was done in 7 steps taking 3 days. The first stack had an average reduction of 1.4 $^{o}/oo$ per step and the salinity of the second stack was reduced in steps of 1.6 $^{o}/oo$. The proportion of dead or dying shrimp in the two stacks were 28 and 55%, respectively. Shrimp mortalities during salinity changes could be reduced by making the changes more gradual. In subsequent tests when the salinity levels had to be decreased, reduction was made in stages of 1.5 $^{o}/oo$ or less every 6-8 hours.

The adverse reactions of the shrimp to these rapid changes were demonstrated in the field when live shrimp were brought back to the laboratory. Anytime there were low salinities in the upper layer of ocean water, it was impossible to keep shrimp alive (Table 4). Difficulties occurred when the salinity difference from top to bottom was 5 $^{o}/oo$ or more. Water temperatures of 59-61 F on the surface of the ocean in September 1971 was the suspected cause of heavy shrimp mortality since salinities did not differ enough from top to bottom to cause mortalities. In October 1971, shrimp collecting was successful when salinity conditions were similar to the September period but surface temperatures were 5-8 F lower.

Table 4. Summary of Salinities and Water Temperatures during Shrimp Collecting Trips off the Oregon Coast.

Date	Salinity ($^{o}/oo$)		Water Temperature(F)		Area	Remarks
	Surface	Bottom	Surface	Bottom		
10-69	32	33.8	57-58	45.3-46.0	Tillamook Head	Successfully kept shrimp alive
11-69	31-32	33.6-33.8	52	46.3-47.2	" "	" "
2-70	-	-	51-52	46.3-48.2	" "	" "
3-70	25	33-34	51-52	46-48	" "	All shrimp died
10-70	33	33-34	51-53	46-48	Newport	Successfully kept shrimp alive
3-71	33	33-34	46-48	-	Coos Bay	" "
6-71	27-29	33-34	53-55	-	" "	All shrimp died
9-71	31	33-34	59-61	-	Newport	Most shrimp died
10-71	31	33-34	53-54	-	Coos Bay	Successfully kept shrimp alive

If a tagging or marking study is initiated off the Oregon coast, consideration must be given to the time of year the operation will take place because shrimp cannot survive rapid changes in salinities. During the winter, surface salinities and temperatures are not much different from bottom conditions. There would be little difficulty in keeping adequate numbers of shrimp alive. During the spring, surface temperatures are still relatively cool, but surface salinities as far south as Coos Bay are lowered by heavy discharges of fresh water from the Columbia River. These salinities are too low to keep shrimp alive. Through the summer, strong northwest winds cause upwelling along the coast which results in slight differences in salinity from the surface to the bottom. Solar heating of the surface waters during this period results in temperature differences of 5-10 F compared with bottom temperatures. Differences of water temperature approaching 10 F probably are marginal for good shrimp survival. During some years, the northwest winds are not as strong and there are intrusions of warm water from offshore. The temperature of this water can reach 64 F which is definitely too warm for shrimp as demonstrated in the temperature-salinity tests.

It was mentioned previously in the discussion about salinity changes that some shrimp were stressed and would eventually die. A stressed shrimp was characterized by the appearance of a white area in the muscle tissue of the abdomen which indicated a necrosis of the tissue. These shrimp could function normally except for the affected tissue and adjacent appendages (pleopods) which were immobile. When a shrimp was badly affected death was inevitable.

Rigdon and Baxter (1971) described the occurrence of necrosis in brown shrimp (*Penaeus aztecus*) held in laboratory tanks. Their description of muscle discoloration and the extent of this affliction was similar to that which occurred in the pink shrimp. They made a histological examination of the affected tissue and concluded that it was not pathological. The condition was related to high water temperatures, anoxia, stress, or a combination of these factors. Necrosis occurred in pink shrimp during all phases of handling. There was a high occurrence of it when the shrimp were held in the containers on ship board during the collecting trips. When the shrimp were in the aquariums in the laboratory, any sudden change in salinity or temperature would result in some of the shrimp being affected by this condition. The extent of the necrosis varied from only a minor affliction to 100% of the abdomen being discolored. Typically, the posterior 3-4 segments of the abdomen would become affected. Shrimp affected to this extent could survive up to two weeks, but they could not regenerate new tissue to replace that which was destroyed. In one instance, two shrimp, in which the last two segments and the telson were affected, survived for several months. These segments eventually sloughed off. The shrimp were able to successfully molt, but no new tissue was regenerated.

If the shrimp was only slightly affected, it could regenerate new tissue to replace that which was destroyed. In one test, 30 shrimp which had a slight amount of necrosis were held for 32 days. Fifty-three percent of the shrimp survived and showed complete recovery from the condition. However, if a tagging or marking study is undertaken, all shrimp which display necrosis should be discarded.

CONCLUSION

I found the best conditions for holding shrimp were a temperature of 44 F, a salinity of 35 $^{o}/oo$ and a density of 3 shrimp per square foot. The pink shrimp is not an easily-handled laboratory animal. It requires a stable environment and any sudden change in this environment can cause mortality. If proper precautions are taken to maintain a stable environment, the pink shrimp can be successfully held in the laboratory and experimented on for extended periods.

LITERATURE CITED

Rigdon, R.H. and K.N. Baxter. Spontaneous necrosis in muscles of brown shrimp, *Penaeus aztecus*, Trans. Am. Fish. Soc. 99(3):583-587.