A STUDY OF THE BEHAVIOR OF PENAEID SHRIMP UNDER CONTROLLED LABORATORY CONDITIONS

A Thesis

by

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ABSTRACT

A Study of the Behavior of Penaeid Shrimp Under
Controlled Laboratory Conditions. (April, 1978)

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One of the major objectives of this research project was to fully describe the types of behavior exhibited by the Gulf shrimp, Penaeus setiferus and Penaeus aztecus, under controlled laboratory conditions. An experiment dealing with the effects of crowding on short-term behavior showed that the major source of variance in behavior was the social density of the shrimp, rather than the spacial density. The second series of experiments attempted to answer the question of whether or not the shrimp shows inherent aggregation, or if aggregation under natural conditions is a factor of the environment. The results of this experiment, carried out under controlled laboratory conditions, showed that under this limited series of experiments the shrimp showed no tendency to aggregate.

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A STUDY OF THE BEHAVIOR OF PENAEID SHRIMP UNDER CONTROLLED LABORATORY CONDITIONS

Introduction

There is a large amount of literature dealing with decapod crustacean behavior, but a relatively small amount of research has dealt specifically with the behavior of the Gulf commercial species of penaeid shrimp, *Penaeus setiferus* (white shrimp) and *Penaeus aztecus* (brown shrimp). The U.S. Bureau of Commercial Fisheries has funded applied research dealing with the behavior of shrimp, specifically the burrowing behavior of the pink shrimp, *Penaeus duorarum* Burkenroad (Fuss, 1964; Fuss and Ogren, 1966). This is the only behavior that is fully described in recent literature, undoubtedly because investigations into this behavior can result in improved trawling methods and possible economic gain.

One of the major objectives of this research project is to fully describe the types of behavior exhibited by the Gulf shrimp, *Penaeus setiferus* and *Penaeus aztecus*. Since many uncontrollable factors may influence the shrimp's behavior in its natural habitat, a thorough behavioral study was conducted under controlled laboratory conditions.

The first series of experiments dealt with the effects of crowding on penaeid shrimp behavior. In general, the long-term effects of crowding are decreased growth and survival. This series of experiments concentrated on the effects of crowding on the shrimp's short-term behavior. Variations in behavior under crowded conditions were explored initially, in an attempt to determine whether these variations were influenced by the social density or spacial density of the shrimp.

The second series of experiments dealt with the aggregation tendency of penaeid shrimp. Shrimpers in the Gulf area claim that after a front has moved through the area, the shrimp are caught in pockets or large aggregations. In this series of experiments, aggregation of penaeid shrimp was investigated in the absence of natural environmental factors, such as current or food concentration, in an attempt to determine whether aggregation was inherent or influenced by environmental factors.

Methods

The shrimp, *Penaeus setiferus* and *Penaeus aztecus*, used in this study were obtained from a local bait camp. The initial behavior observations were made using 20-30 shrimp in an 120 gallon tank. The aerator was in the tank constantly, and the observations were made in bright light.

The shrimp were observed under laboratory conditions so that most of the variables affacting the shrimp's behavior could be controlled. For this reason, it was decided that sediment for the shrimp to burrow into should be left out of all of the tanks. There was no way readily available to screen the sediment and remove all of the microorganisms. Also, a concentration of a certain ion in the sediment could have ultimately been responsible for changes in the shrimp's behavior. By leaving out the sediment, burrowing behavior, which has been described by Fuss (1964), was automatically excluded from the observed behavior categories. It was necessary to watch the shrimp for signs of molting, since the shrimp may go into abnormal behavior patterns during this time. Since the molting cycle has a two week period, a fresh batch of shrimp was obtained every two weeks. Thus the behaviors observed should have been normal, or at least common, behaviors for the shrimp.

The series of experiments dealing with crowding was conducted in three different sized tanks: 15.0 liters, 67.3 liters, and 80.4 liters. These tanks had the following dimensions respectively: 19.5cm x 25.3cm x 30.5cm; 60cm x 33.5cm x 33.5cm; 60cm x 33.5cm x 40cm. These tanks were constantly aerated until the time of the experiment so that the current caused by the aerator would not influence the shrimp's behavior. The salinity of the seawater was kept constant at 26-28‰ and the temperature was 18°C. The light intensity was kept at a dim level. Four different densities of shrimp (5, 10, 15, and 20) were tested in all combinations in three different spacial densities (15.0, 67.3, and 80.4 liters) and their behavior was recorded 10 times at three minute intervals for a total of 30 minutes. A certain density of shrimp was tested in the series of tanks, small to medium to large, at 5:00 pm. each day with a 15 minute initial adjustment period in each tank. The behavior was then expressed as a percentage of total activity and analyzed through an analysis of variance.

The experiments testing inherent aggregation were conducted in a tank measuring 60cm x 33.5cm x 33.5cm, with a salinity of 27‰ and temperature of 18°C. The aeration of the tank was constant up to the time of the experiment and the light intensity was constantly dim. Two kinds of shrimp boxes (perforated with large holes) were used to house the shrimp: 1) a clear plastic box measuring 22.2cm x 14.0cm x 8.2cm and 2) the same box covered with a black plastic sheet.

Inherent aggregation was tested through the shrimp's movements when placed in the following situations: 1) in an empty aquarium, to see if it had a natural preference for one side of the tank over another; 2) in an aquarium with two empty clear shrimp boxes, arranged as shown in Fig. 1; 3) in an aquarium with the shrimp boxes filled with shrimp in the following numbers: (first run) 9 shrimp in Area 1 and 3 shrimp in Area 2;

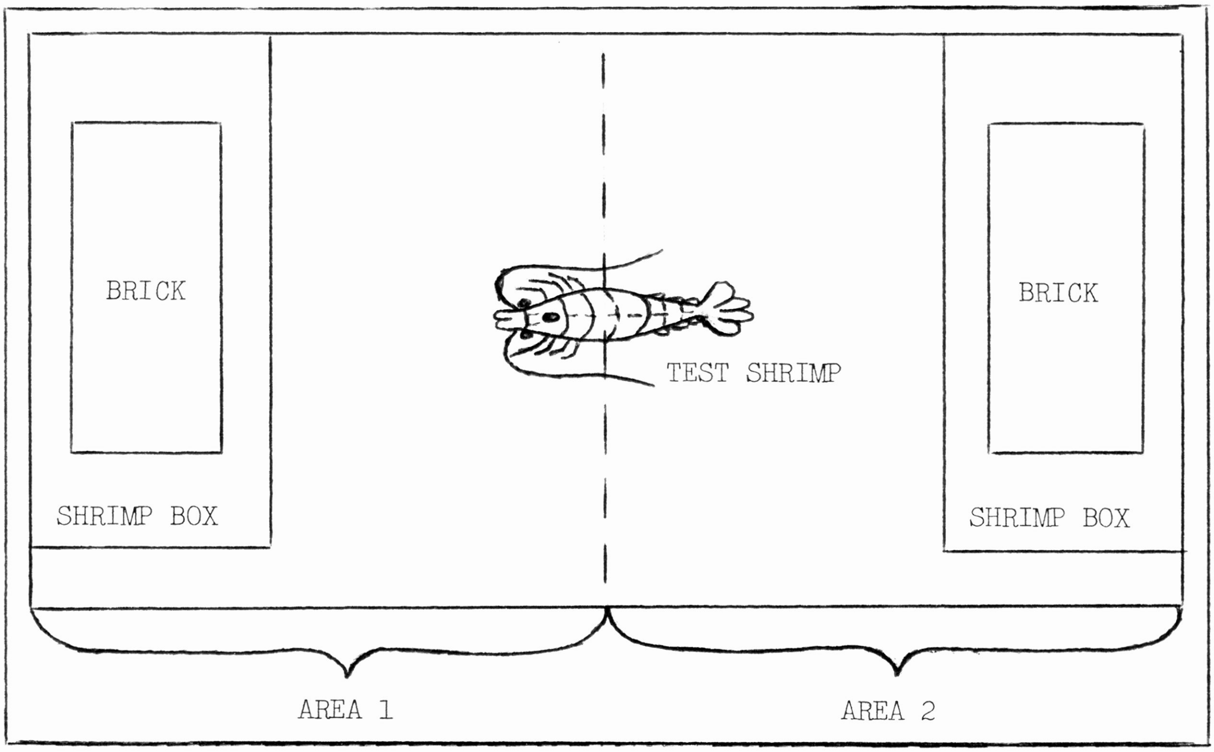

Figure 1. Aquarium Arrangement for Aggregation Experiments

(second run) 9 shrimp in Area 1 and none in Area 2; 4) in an aquarium with the shrimp boxes switched in position; 5) in an aquarium with the blackened shrimp boxes filled with shrimp in the following numbers: (first run) 3 shrimp in Area 1 and 9 shrimp in Area 2; (second run) no shrimp in Area 1 and 9 shrimp in Area 2; 6) in an aquarium with the blackened shrimp boxes switched in position.

The clear boxes were used so that visual information regarding the enclosed shrimp could reach the test shrimp. The blackened boxes were used so that chemical information only regarding the enclosed shrimp could reach the test shrimp. In this way, possible effects of chemical or visual stimulation could be separated and identified.

The test shrimp was released into the center of the tank, in such a way that it wasn't directed into either end of the tank. The number of minutes spent in each area was recorded as well as the number of moves made to a new area. Every type of behavior made by the test shrimp was classified (into one of the behavior categories) and the time that each new behavior began was recorded.

Results

General Behavior

It was possible to classify the behavior of penaeid shrimp into 20 different categories. Using these behavior categories, I was able to describe every position assumed by the shrimp under observation in a shorthand fashion. A brief description of each of these categories follows.

Stationary with antenna up. The shrimp is completely stationary on the bottom with its antenna raised and approximately parallel to the bottom.

Stationary with antenna down. The shrimp is completely stationary on the bottom with its antenna resting of the bottom surface.

Pereiopods only. The shrimp is resting on the tips of its pleopods and the pereiopods are moved in a random manner . . . no particles are being carried from the pereiopods to the mouth, yet the pereiopods are extended and withdrawn in a rapid fashion.

Pleopods only. The shrimp is resting on the tips of its pereiopods with the posterior part of its body raised so that the pleopods are clear of the bottom surface. The pleopods are moving in a rhythmic fashion, usually slowly.

Movement of appendages. This is a bottom-associated activity that consists of flurries of appendage movements which look like short hops off of the bottom. The pereiopods are typically rapidly extended and withdrawn in a random-looking manner. The pleopods move rapidly for a short time, then rest, causing the tail to hump occasionally. The uropod is typically fanned out and then contracted when the tail begins to hump. This action is repeated in rapid sequence which results in the "hopping" motion.

Crawling. The pleopods of the shrimp are moving slowly and the shrimp is "walking" using its pereiopods. This is usually a fairly rapid movement across the floor of the tank.

Picking. This behavior is similar to the crawling behavior with the following exceptions: 1) the pereiopods methodically pick up particles from the bottom and bring them to the mouth parts; 2) this movement is typically slow and "searching."

Twitching compound eyes. This is a relatively rare behavior usually performed in conjunction with one of the bottom associated behaviors. The compound eyes of the shrimp are simply "twitched" or brought together in a rapid movement.

Rocking. The shrimp is stationary except for the slight waving of the most anterior set of pleopods. This movement results in a rocking motion.

Swimming vertically. The shrimp is swimming with its body line perpindicular to the bottom, the head region up. The pereiopods are withdrawn and held in close to the body and the pleopods are moving in a rapid and continuous manner. This activity is typically performed with the dorsal side of the shrimp adjacent to the tank wall, with the shrimp essentially stationary in the water column.

Swimming horizontally. This behavior is similar to the swimming vertically behavior with the following exceptions: 1) the body line is parallel to the bottom surface and perpindicular to the aquarium wall; 2) the rostrum is touching the wall of the tank.

Swimming at an angle. This behavior is nearly the same as the swimming horizontally behavior but the shrimp's body line is approximately at a 45 angle to the bottom surface and perpindicular to the aquarium wall. Again, the shrimp is relatively stationary in the water column.

Swimming with pereiopods in. The shrimp is moving through the water column by swimming with its pereiopods totally withdrawn or folded in closely to its body.

Swimming with pereiopods out. The shrimp is moving through the water column by swimming with its pereiopods partially withdrawn so that some pereiopods are still extended. This behavior is typical before the shrimp lands on the bottom after swimming.

Swimming and feeding. The shrimp is in a position where its ventral surface is parallel to the aquarium wall. The pereiopods are fully extended and picking along the wall of the aquarium, while the pleopods are moving constantly in a rhythmical fashion. The shrimp moves slowly across the aquarium wall.

Escape reaction. The uropods are snapped quickly up to the abdomen, causing the shrimp to be propelled quickly in any desired direction. The pereiopods are completely withdrawn.

Picking on shrimp. In this behavior, one shrimp treats another shrimp as a food item and begins to pick over it with its pereiopods. This behavior typically elicits an escape reaction from the shrimp that is being treated as a food item.

Grooming behavior. The uropods of the shrimp are drawn up towards the head region and the pereiopods methodically pick over the tail fan.

On top. One shrimp rests in some fashion on top of another shrimp. Both will usually remain stationary for a short time, and then the bottom shrimp will use the escape reaction.

On tail. The shrimp usually performs this activity in the corner of the aquarium. The shrimp descends from swimming at a 45 degree angle to the bottom and comes to rest on its tail with its pereiopods flexed against the aquarium wall. The body line is at a 45 degree angle to the bottom and it is completely stationary while in this position

Crowding Experimental Series

Only seven of the previously mentioned behaviors occurred frequently during the course of these experiments. Thus, an analysis of variance was limited to these seven behaviors. Figures 2 through 8 show the results of these analyses. These analyses show that the primary source of variance in the behavior of the shrimp is the social density of the shrimp. There were only four of the seven behaviors that showed any variance when tested for the three different tank sizes and four different social densities.

The antenna up behavior variance was found to be related to the social density of the shrimp. In Figure 2, this behavior is shown to be most prominent for the densities of 5 and 20 shrimp. There is a notable decrease in this activity for the densities of 10 and 15 shrimp, with the means of these two behavior readings remarkedly similar. There was no notable variance between the tank sizes.

The movement of appendages behavior was found to be related to both social density and spacial density of the shrimp. Figure 5 shows that this behavior is similar for the densities of 10, 15, and 20, while it markedly decreases for the density of 5 shrimp. There is also a large difference in behavior between tank sizes for the densities of 5 and 15 shrimp. Statistically, the variance due to social density was significant in the medium tank and was marginal in the small tank, while only the density of

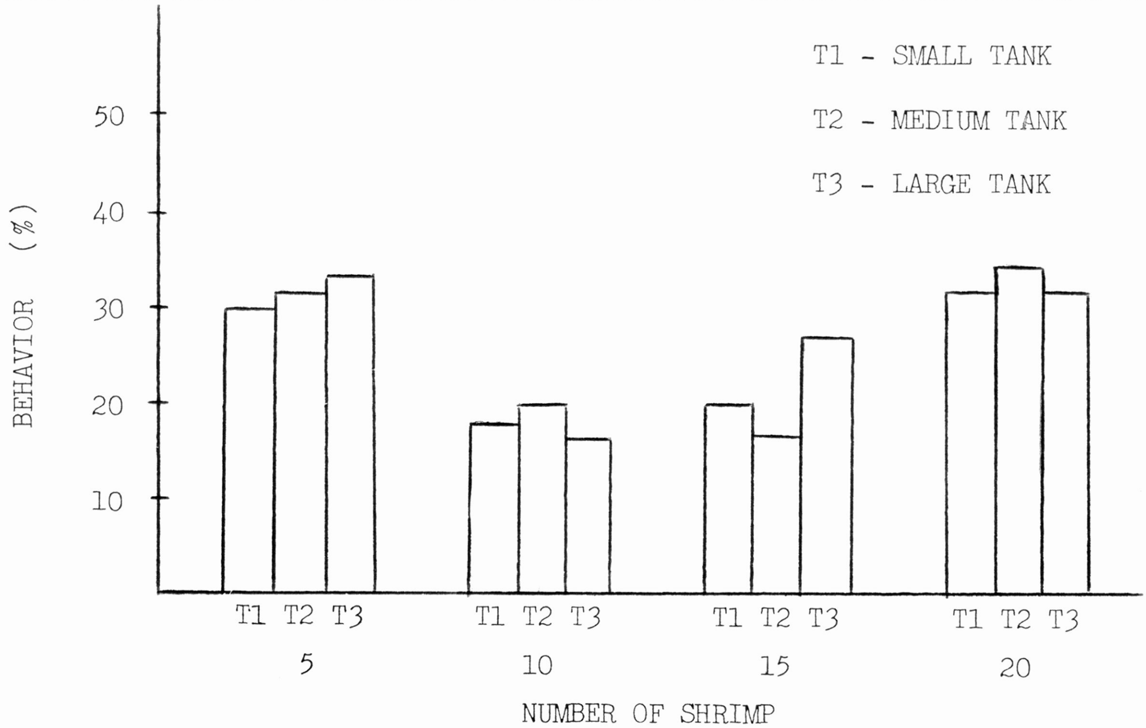

FIGURE 2. ANTENNA UP BEHAVIOR

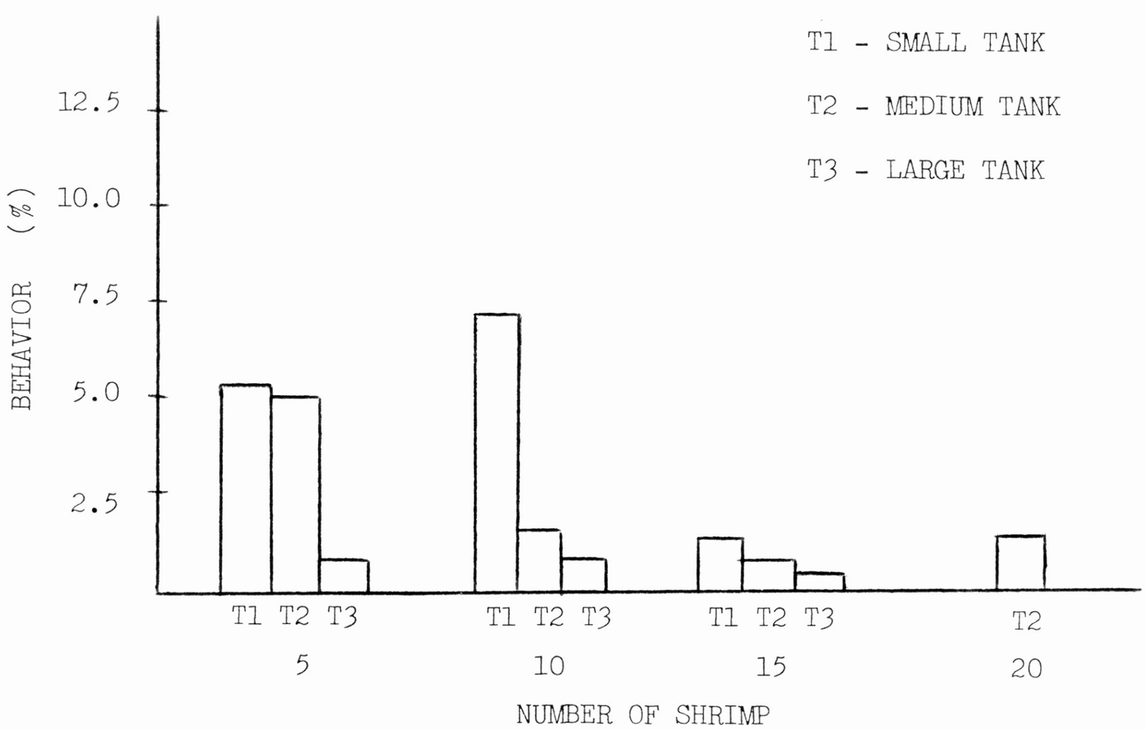

FIGURE 3. ANTENNA DOWN BEHAVIOR

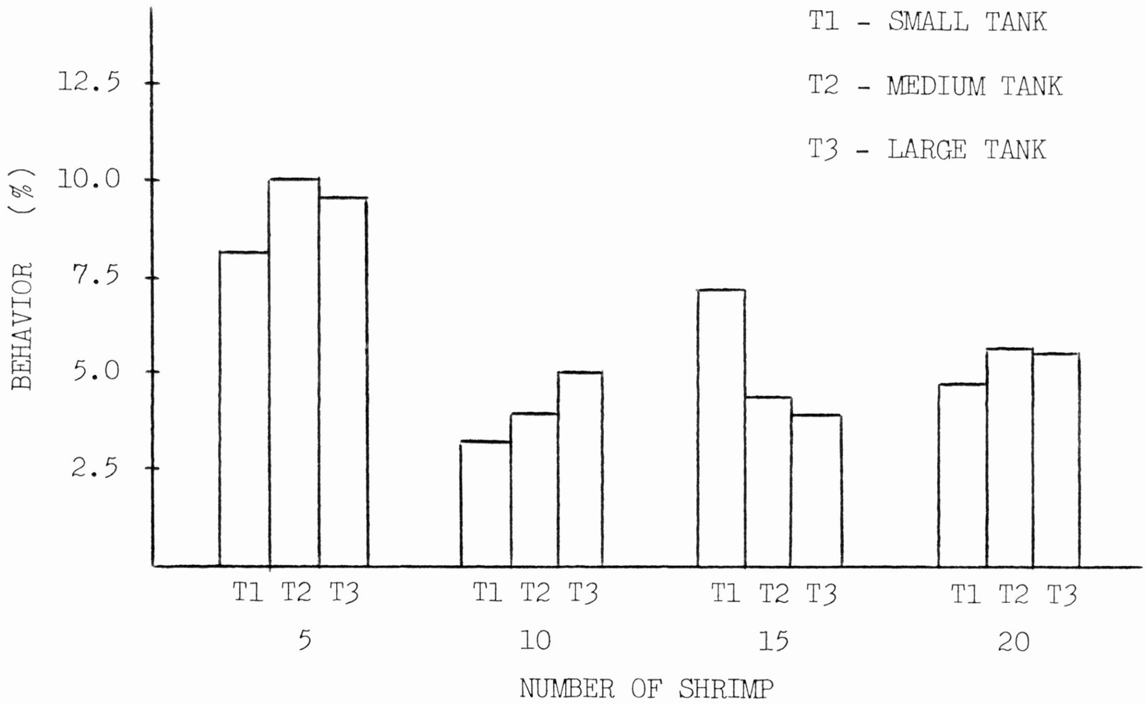

FIGURE 4. CRAWLING BEHAVIOR

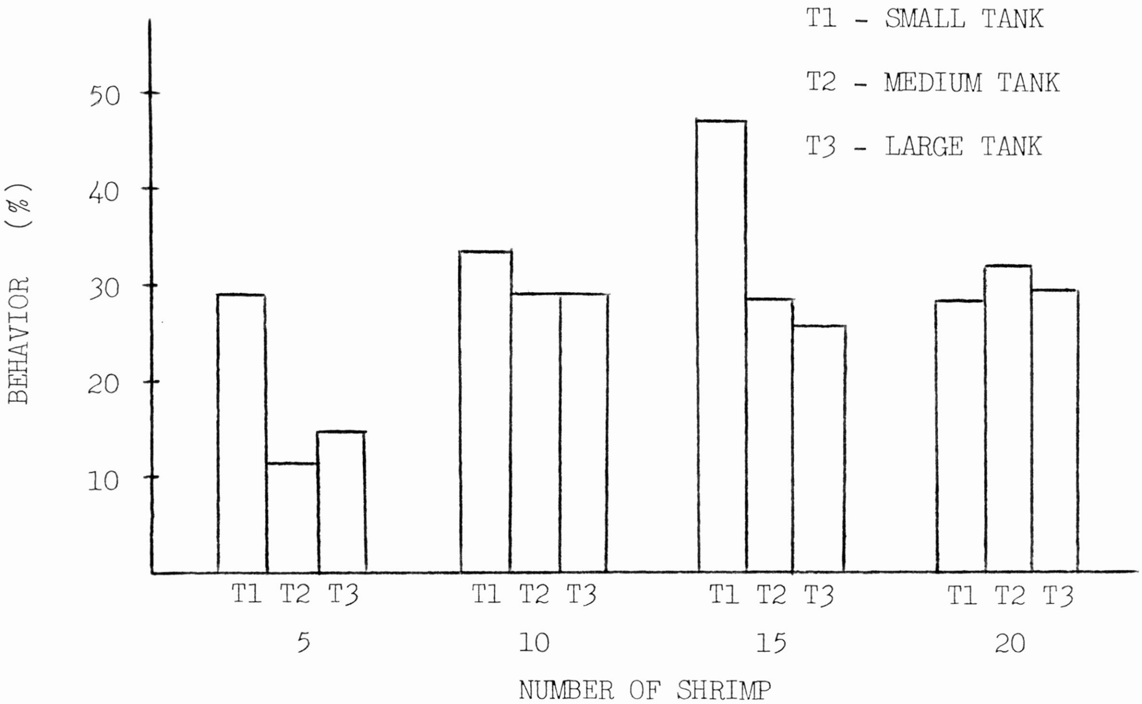

FIGURE 5. MOVEMENT OF APPENDAGES BEHAVIOR

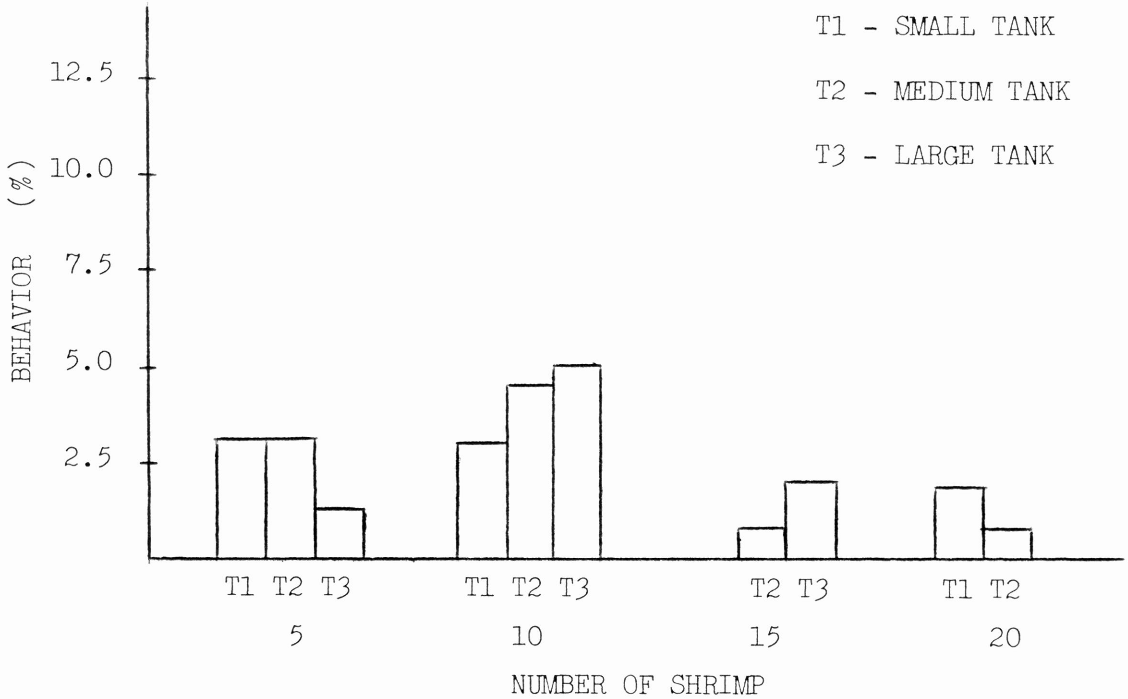

FIGURE 6. SWIMMING WITH PEREIOPODS IN BEHAVIOR

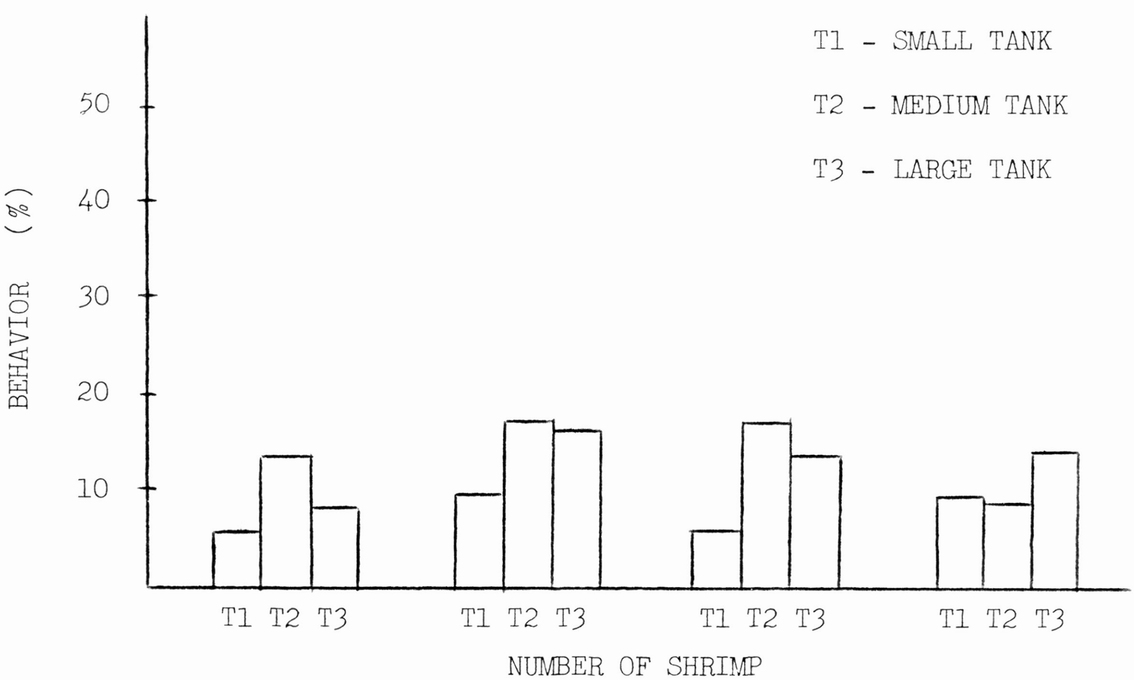

FIGURE 7. SWIMMING WITH PEREIOPODS OUT BEHAVIOR

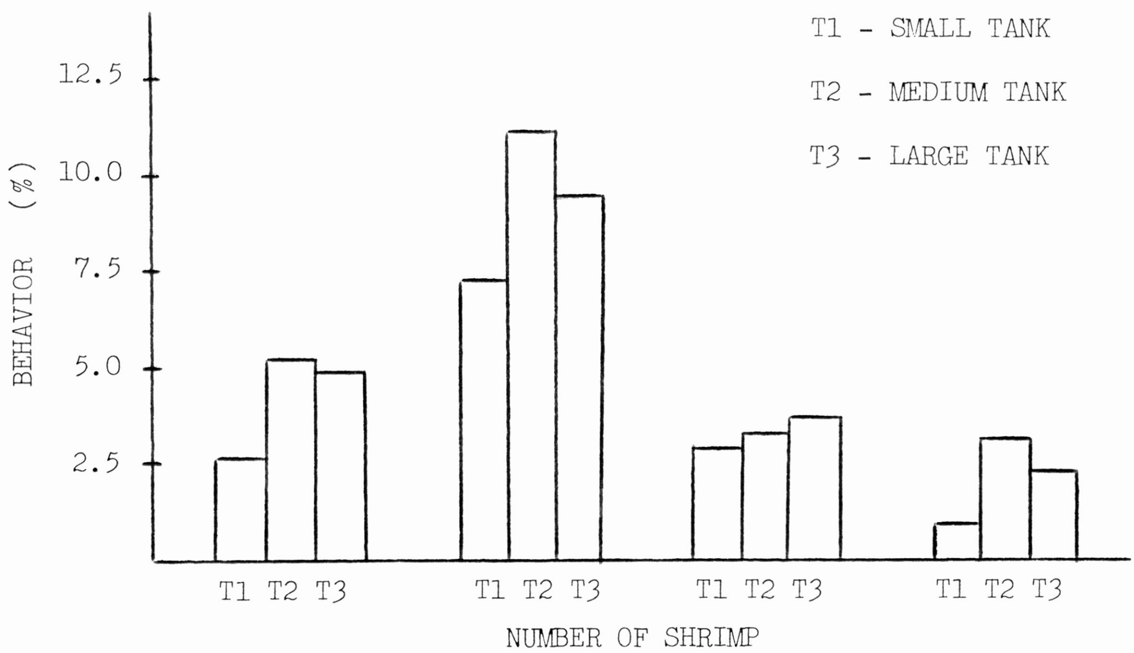

FIGURE 8. SWIMMING AND FEEDING BEHAVIOR

15 shows a statistically valid variance between tank sizes.

It was found that the variance in the swimming with pereiopods out behavior can be attributed to changes in spatial density for the social density of 15. The density of 5 also shows variance in the amount of this activity between tank sizes, although statistics showed it to be only marginly significant. The densities of 5 and 20 showed less overall activity than the densities of 10 and 15 and the amount of activity in the small tank is shown to be less the the other two tank sizes for all but the density of 20, as is shown in Figure 7.

In Figure 8, the swimming and feeding behavior is most prominent for the social density of 10, while it is found in a similar amount for the other three densities. There is no appreciable variance found between tank sizes for any of the social densities.

Aggregation Experiments

These experiments were first run in an attempt to see if a lone shrimp would aggregate with a large number of shrimp over a small number. The results of four replicates of this experimental series are shown in Tables 1 through 4. As the number of moves to a new area increases, the probability that the movement of the test shrimp is random also increases. An analysis of this data shows that there is no statistical similarity between the various times spent with the large number of shrimp. In fact, there was no definite preference shown for one side of the tank over another, or even in the time spent with the small amount of shrimp. The movement of the shrimp appeared to be essentially random throughout the first run of this experiment.

The second run of this experiment was undertaken in an attempt to account for any tendency to aggregate. If there was any inherent tendency to aggregate in the test shrimp, it would spend most of its time with the box containing the shrimp, wherever that box may be positioned. Tables 5 through 7 show the results from three replicates of this run. There is, again, no evidence from this data that the shrimp tends to aggregate with other shrimp. A clear preference for one side of the tank over another is not even obvious. Again, it appears that the shrimp was just randomly moving from side to side, without much regard for the prescence of the enclosed shrimp.

Discussion

In these rather limited series of experiments, the primary source of variation in behavior under crowded conditions was shown to be the changing

TABLE 1

DATA FROM AGGREGATION SERIES: PART 1 (REP. 1)

SITUATION	CONTROL		CLEAR BOXES		BLACKENED BOXES	
CONDITION	A	B	C	D	D	C
9 SHRIMP	15.0	10.3	.8	2.8	3.5	5.8
3 SHRIMP	0.0	4.7	14.2	12.2	11.5	9.2
# OF MOVES	0	5	1	2	2	4

CONDITION CATEGORIES: A - SHRIMP ALONE IN TANK

B - SHRIMP WITH TWO EMPTY BOXES

C - LARGE # OF SHRIMP IN AREA 1

D - LARGE # OF SHRIMP IN AREA 2

TABLE 2

DATA FROM AGGREGATION SERIES: PART 1 (REP. 2)

SITUATION	CONTROL		CLEAR BOXES		BLACKENED BOXES	
CONDITION	A	B	C	D	D	C
9 SHRIMP	15.0	7.7	8.3	3.6	7.8	4.9
3 SHRIMP	0.0	7.3	6.7	11.4	7.2	9.1
# OF MOVES	0	26	5	16	8	31

TABLE 3

DATA FROM AGGREGATION SERIES: PART 1 (REP. 3)

SITUATION	CONTROL		CLEAR BOXES		BLACKENED BOXES	
CONDITION	A	B	C	D	D	C
9 SHRIMP	6.5	8.5	0.0	9.6	8.2	8.0
3 SHRIMP	8.5	6.5	15.0	5.4	6.8	7.0
# OF MOVES	37	18	0	1	4	5

CONDITION CATEGORIES: A - SHRIMP ALONE IN TANK

B - SHRIMP WITH TWO EMPTY BOXES

C - LARGE # OF SHRIMP IN AREA 1

D - LARGE # OF SHRIMP IN AREA 2

TABLE 4

DATA FROM AGGREGATION SERIES: PART 1 (REP. 4)

SITUATION	CONTROL		CLEAR BOXES		BLACKENED BOXES	
CONDITION	A	B	C	D	D	C
9 SHRIMP	7.6	7.0	5.8	8.3	8.4	4.3
3 SHRIMP	7.4	8.0	9.2	6.7	6.6	10.7
# OF MOVES	12	28	24	21	33	38

TABLE 5

DATA FROM AGGREGATION SERIES: PART 2 (REP. 1)

SITUATION	CONTROL		CLEAR BOXES		BLACKENED BOXES	
CONDITION	A	B	C	D	D	C
9 SHRIMP	8.0	7.6	5.0	4.1	5.7	9.4
0 SHRIMP	7.0	7.4	10.0	10.9	9.3	5.6
# OF MOVES	23	31	16	11	23	6

CONDITION CATEGORIES: A - SHRIMP ALONE IN TANK

B - SHRIMP WITH TWO EMPTY BOXES

C - LARGE # OF SHRIMP IN AREA 1

D - LARGE # OF SHRIMP IN AREA 2

TABLE 6

DATA FROM AGGREGATION SERIES: PART 2 (REP. 2)

SITUATION	CONTROL		CLEAR BOXES		BLACKENED BOXES	
CONDITION	A	B	C	D	D	C
9 SHRIMP	1.6	9.4	7.1	14.1	15.0	.7
0 SHRIMP	13.4	5.6	7.9	.9	0.0	14.3
# OF MOVES	1	17	4	2	0	6

TABLE 7

DATA FROM AGGREGATION SERIES: PART 2 (REP. 3)

SITUATION	CONTROL		CLEAR BOXES		BLACKENED BOXES	
CONDITION	A	B	C	D	D	C
9 SHRIMP	6.1	9.5	2.8	9.6	3.8	8.2
0 SHRIMP	8.9	5.5	12.2	5.4	11.2	6.8
# OF MOVES	2	18	9	15	3	11

CONDITION CATEGORIES: A - SHRIMP ALONE IN TANK

B - SHRIMP WITH TWO EMPTY BOXES

C - LARGE # OF SHRIMP IN AREA 1

D - LARGE # OF SHRIMP IN AREA 2

social density of the shrimp. Also, the shrimp showed no tendency to aggregate under laboratory conditions in the two series of experiments run.

I'm not satisfied with the analysis of results obtained from the crowding series of experiments. Further analysis is planned to determine: 1) if there is any natural correlation between two or more behaviors; 2) if there is a linear regression or a systematic increase in activity as the volume per shrimp decreases, or the number of shrimp per tank increases. In the analysis of data for this paper I worked only with seven of twenty behaviors due to a lack of time, and because the other 13 behaviors didn't occur as often as the seven chosen. It would be interesting to go back and analyse each of the less common behaviors and determine if their occurrence is associated with a certain spacial or social density in any way.

There were several limitations found in the experimental design of this experiment. The major drawback is apparent in the fact that both the medium and large tanks had the same bottom area. Since the shrimp is a bottom associated animal, this area may be a critical factor when determining the cause for variance in behavior. This may be why there wasn't much variance in behavior caused by spacial density changes.

There are several variations of the crowding experiments which could have provided a good deal of additional information about the source of variance in behavior. For example, due to a shortage of live shrimp during the winter months, it was necessary to use whatever shrimp could be obtained without reference to whether they were brown or white shrimp, male or female. A majority of the shrimp used was Penaeus setiferus, or white shrimp, but during the month of March brown shrimp were also used. This series of experiments could be rerun for the following types of shrimp: 1) all white shrimp in each of the following combinations: a) male; b) female; and c) mixture of males and females; 2) all brown shrimp in the same combinations; 3) a mixture of equal amounts of brown and white shrimp in the afore-mentioned combinations. Since the different combinations of shrimp could have had an effect on the behavior of these shrimp, these additional series of experiments could further isolate the source of variance in the shrimp's behavior. It would also be interesting to determine if the behavior of different combinations of shrimp varied significantly.

It has been suggested that the test shrimp in the aggregation series of experiments couldn't locate the other shrimp by chemical sensing due to lack of currents in the tank. However, if currents were added, it would be difficult to be sure whether the shrimp was aggregating just because that is the way the current is moving, or because it is responding to the chemical or visual stimulation from the enclosed shrimp.

While running this series of experiments, I accounted for all of the test shrimp's movements by recording the behavior form and the time that each behavior began. There wasn't sufficient time left to analyse the behaviors exhibited by the test shrimp, but this data could give us a clue as to why the shrimp didn't aggregate under laboratory conditions.

This experiment could be improved by: 1) running more replicates of the experiment; 2) adding the aerator, so that a small current is set up in the tank . . . then compare the results of this run with those not using an aerator; 3) using the same types and combinations of shrimp suggested for the improvement of the crowding series of experiments; 4) test for time of day effects on aggregation.

I intend to improve my data analysis this summer and will hopefully be better able to account for behavioral variations as well as the random movements of shrimp in the aggregation experiments. It would take at least a year or two to incorporate in all of the improvements suggested, and thus this research could possibly expand into a graduate research project. However, I believe that this project could turn into some informative basic research that could be utilized by mariculturists if it is expanded upon.

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