THE BIOLOGY OF THE BROWN SHRIMP, "PENAEUS AZTECUS", IN IMPOUNDMENTS

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INTRODUCTION

The recent interest in pond culture of shrimp by the Louisiana Wild Life and Fisheries Commission led to further experiments pertaining to this phase of shrimp production. Experiments pertaining to growth and mortality of shrimp in impoundments were maintained on Rockefeller Wild Life Refuge, Cameron Parish, Louisiana during the summers of 1962 and 1963.

The practice of raising shrimp in ponds may prove to be an important development in the near future. The harvest of shrimp is a very unstable enterprise that results from a variation in natural production from year to year (Viosca, 1958). Because of this instability and the constantly rising human population, there will be years of low natural production when the supply available will not be able to meet the demand. It is at this time of low production that pond culture of shrimp may play the important role that it has the potential of achieving.

It is hoped that the present study together with other studies will contribute to the biological information available on pond culture of brown shrimp, *Penaeus aztecus.* More complete biological data should furnish a basis for successful pond culture of shrimp in the near future.

DESCRIPTION OF THE AREA

The study area is located on Rockefeller Wild Life Refuge, Cameron Parish, Louisiana. Rockefeller Refuge is typically salt marsh, which is transversed by many natural bayous and artificial canals ,one of which, the Headquarter's Canal, is the most important in this study. The canal is man made and leads into the Gulf of Mexico. It has a general north-south flow and is 6 miles long, 50 feet wide with an average depth of 6 feet. Salinities in the canal range from 10,000-20,000 ppm. The Headquarter's Canal served as both a source of water for the ponds and the collecting area for juvenile shrimp.

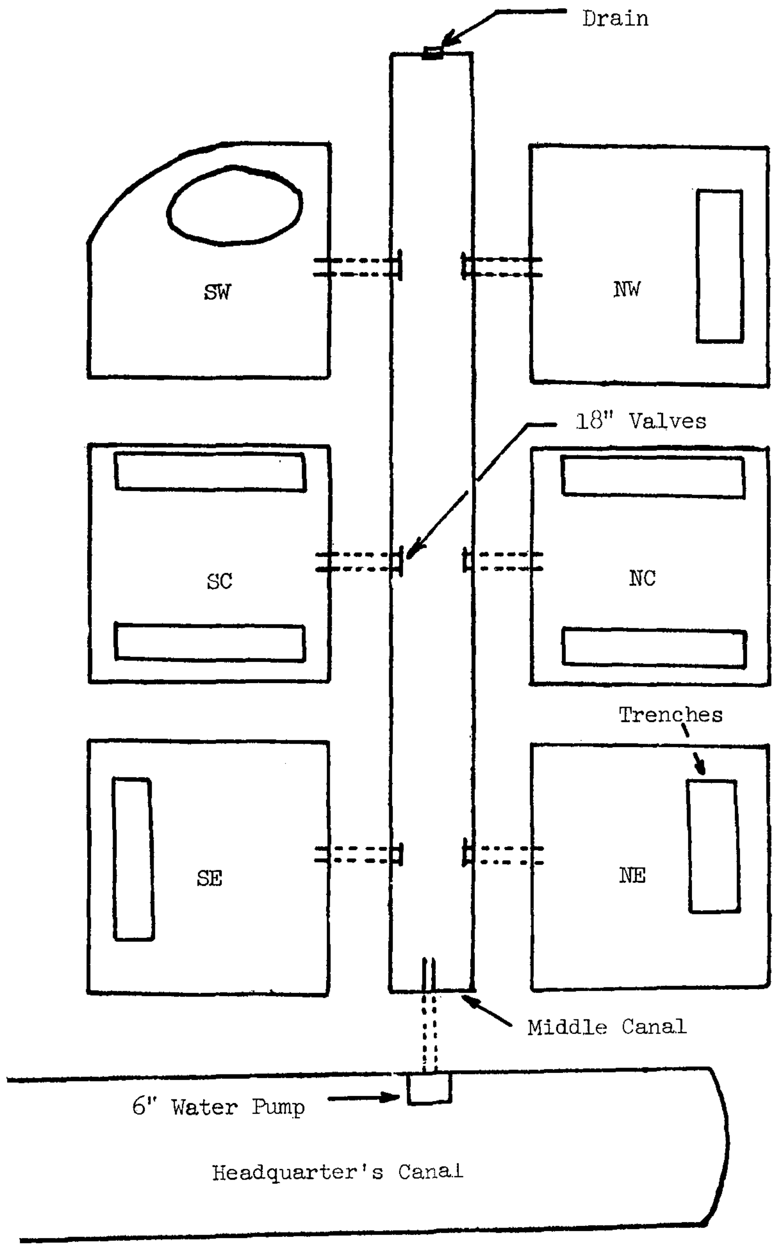
The ponds are located at the headwaters of the Headquarter's Canal. There are six ponds that were used in the study, all of which have a surface area of 1/3 acre. Water depth averaged 3 feet with one or two 6-foot trenches in each pond. Rooted vegetation in the impoundments is primarily widgeon grass, *Ruppia maritima,* which at times covered as much as 85 per cent of the pond surface. Salinities in the ponds ranged from 7,000-20,000 ppm. Figure I shows how the ponds are arranged in relation to each other and to the Headquarter's Canal.

The climatic condition of the study area is typical of similar areas lying along the northern coast of the Gulf of Mexico. Normally this segment of the state is quite humid with an average yearly rainfall of 57.2 inches; however, during this study, conditions were unusually dry with the average rainfall dropping to 39.6 inches in 1962 and 41.7 inches in 1963 (U. S. Department of Commerce, 1962, 1963).

METHODS AND PROCEDURES

All of the six ponds were filled to capacity early in April before the juvenile shrimp had reached the collecting area. The ponds were

FIGURE 1. Arrangement of the shrimp ponds, location of valves, water pump, and trenches within each pond.



filled by pumping water from the Headquarter's Canal into the middle canal shown in Figure I. This middle canal was used to hold water to fill the ponds, thereby easily controlling the water levels within the ponds.

When the ponds were filled to capacity the valves were closed and the inlets screened so that fish could not enter nor shrimp escape from any of the ponds. On completion of the screening process the ponds were treated with rotenone at 2 ppm to remove all the fish present in the ponds. This was done in all ponds except the NC in 1962 and the NC and SW in 1963. The natural fish populations were allowed to remain throughout the study period.

After the rotenone had dissipated, the ponds were then ready for stocking. The juvenile shrimp were caught in the Headquarter's Canal with the use of a beam trawl that was pulled behind a 20-foot scow that contained 2 live wells (Figure II).

The beam trawl was dragged for only a short period of time (5-8 minutes). This insured better survival of young shrimp that would otherwise be injured in long hauls. All of the live juvenile shrimp were taken from the net and placed in the live wells. Best survival rates occurred when the shrimp were stocked within 2-3 hours after capture. They were taken from the live wells, individually counted and gently placed in the ponds.

Stocking rates for the first summer period were determined after conference with other biologists to establish the most useful basis for study. In 1963 the stocking rates were based on the past season's results. Only two stocking rates were used in 1963. All of the south ponds were stocked at 400 pounds per acre and the north ponds at 600 pounds per acre. Each stocking rate was tested, using three different methods. The methods used are as follows: (1) stocking of shrimp alone plus feeding Purina Fish Chow at .1% body weight, (2) stocking of shrimp plus a mixed fish population, and (3) stocking of shrimp plus 100 striped mullet *(Mugil cephelus)*. These mullet were used to control algae and to stir up the bottom materials. thereby increasing the turbidity and possibly controlling the widgeon grass. These rates are expressed as pounds per acre at maturity. Maturity was designated as 25 count shrimp or 25 shrimp per pound. The average size at stocking was 400 mm. or 150-200 count. Table I gives the stocking rates for each pond in 1962 and 1963.

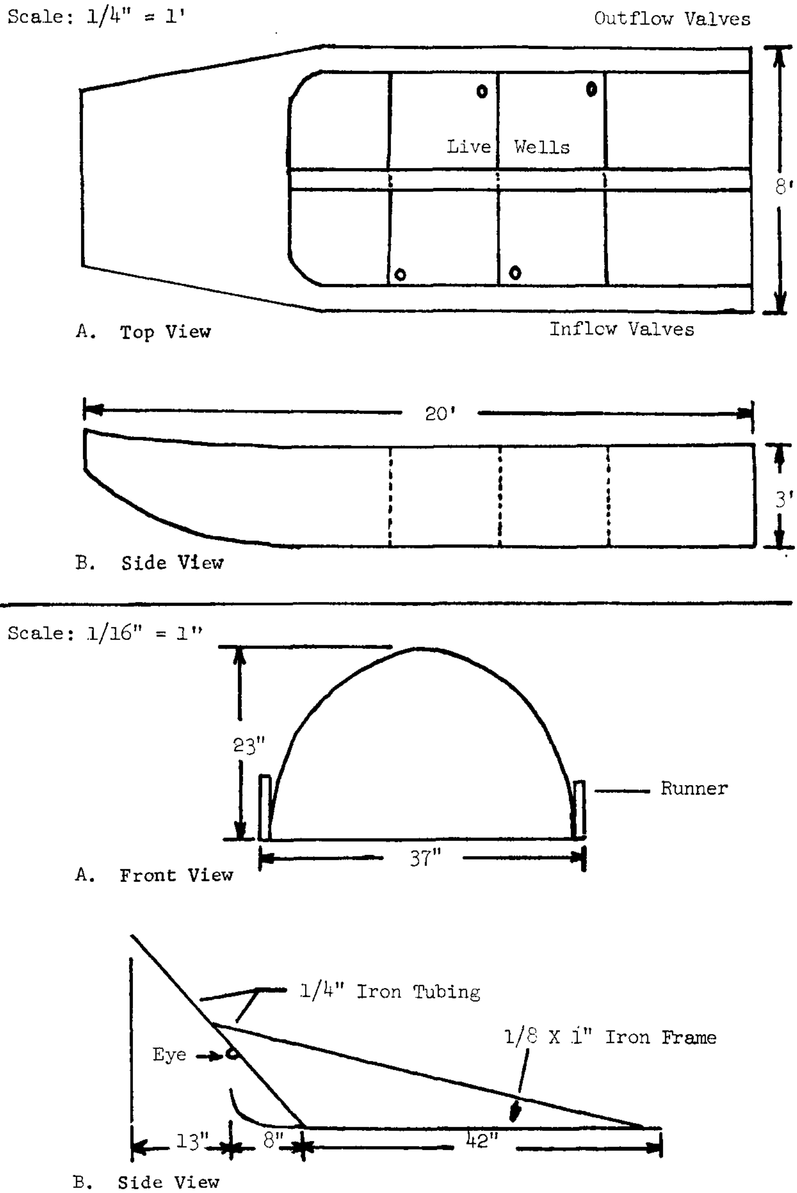
The ponds were sampled once every two weeks by dragging the beam trawl by hand across three corners of each pond. All shrimp sampled were counted and measured in millimeters to get the average growth in length from one sample to the next. Numbers of shrimp in each sample served as an indicator of mortality. The shrimp were not weighed.

During the sampling ,shrimp from each pond were preserved and later used for stomach analysis. The stomachs were taken and the content microscopically examined. Food contents were broken into the following five major groups: vegetation, invertebrates, diatoms, algae and bottom or organic debris.

Shrimp were allowed to live and grow in the ponds for 6 months in 1962 and 5 months in 1963. After this period the ponds were drained and the shrimp harvested. Before draining most of the widgeon grass was raked out so that shrimp would not be trapped beneath the vegetation during the drainage process.

One pond was drained at a time by opening the screened 18-inch valve only slightly. Slow draining allowed the shrimp to move to the deeper parts of the pond where they would become concentrated. Shrimp were removed from the shallow areas with a minnow seine and out of the deep trenches by dragging a 15-foot otter trawl through them until all of the shrimp were removed.

FIGURE II. Diagram of the 20-foot scow and the beam trawl used to capture shrimp for stocking.



The harvested shrimp were counted, measured, and weighed from each pond and tabulated. This information gives the total production, rate of growth from the last sample, and mortality for the entire period for each pond.

Table I. The numbers and pounds per acre (25 count at maturity) of brown shrimp stocked in each of the six ponds at Rockefeller Refuge in 1962 and 1963. Presence of fish in ponds indicated.

Pond	Number of Shrimp stocked 1962	1963	Pounds per acre at maturity 1962	1963	Fish Present or absent 1962	1963
Northeast	9000	5000	1080	600	—	—
Northcenter	6000	5000	720	600	+	+
Northwest	946	5000	113	600	—	+
Southwest	9558	3333	1270	400	—	+
Southcenter	6000	3333	720	400	—	—
Southeast	3000	3333	360	400	—	+

DISCUSSION OF RESULTS

Growth

The growth rate of shrimp for these experiments was concerned only with length. The growth patterns were very similar in 1962 and 1963. Growth was very rapid immediately after stocking but gradually decreased toward the end of the experiment. Rapid early growth in impoundments and tanks was pointed out by Johnson and Fielding (1956) in Florida for the white shrimp, *Penaeus setiferus* and Hudinago (1942) noted the same growth pattern for the Japanese shrimp, *Penaeus japonicus*. After this period the growth rate declined considerably and seemed to have reached a standstill as the time of harvest approached.

The growth increments, which were the increase in size from one sample to the next for the same pond were generally smaller with each subsequent sample (Table II). This showed that there was a general decline in growth during the late periods of the experiments and tends to support the above observation.

An analysis of variance was used to test the effect of the different stocking rates for 1962 (Table III). The results of the test at the 5 per cent level showed that there was no significant difference between the stocking rates. It was assumed by the author that the effect of the stocking rates was not significant over the entire summer period because of an indication of high mortality obtained from the later samples. Mortality tended to bring the total population in most of the ponds to approximately the same density.

In 1963 a paired "t-test" was used to test the effects of feeding, wild fish population and stocked mullet on shrimp growth. The 5 per cent level of significance was used. They were paired off in the following manner: feeding against wild fish populations; feeding against stocked mullet as well as wild fish population against stocked mullet to determine the effects of each on growth of shrimp. In all conditions examined there was no significant difference in growth. The paired "t-test" was also used to test the effects of the two stocking rates. There was no significant difference at the 5 per cent level. Growth followed the same pattern as in 1962.

Growth rates were also analyzed by examining the standard deviation for 1962 (Table IV) and 1963 (Table V). Generally the standard deviation became smaller with each successive sample. The extremes

Table II. Average total length (mm.) of brown shrimp for each sampling period and the growth increments (mm.) between samples for each pond in 1962 and 1963. Growth increments in parenthesis.

Pond Designation and Year	Stocking Rates (lbs./acre)	Sampling Period I	II	III	IV	V	VI	Harvest
Northeast								
1962	1080	86	91	95	98	106	128	135
			(5)	(4)	(3)	(8)	(22)	(8)
1963	600	92	96	100	103	110	113	119
			(4)	(4)	(3)	(7)	(3)	(6)
Northcenter								
1962	720	98	104	105	108	107	111	118
			(6)	(1)	(3)	(-1)	(4)	(7)
1963	600	101	97	97	97	92	93	102
			(-4)	(0)	(0)	(-5)	(1)	(9)
Northwest								
1962	113	Samples were too few to get an average rate or growth increment.						
1963	600	102	104	106	111	112	109	110
			(2)	(2)	(5)	(1)	(-3)	(1)
Southwest								
1962	1270	83	84	85	83	93	103	110
			(1)	(1)	(-2)	(10)	(10)	(7)
1963	400	76	83	88	91	95	94	103
			(7)	(5)	(3)	(4)	(-1)	(9)
Southcenter								
1962	720	86	89	97	97	105	112	115
			(3)	(8)	(0)	(8)	(7)	(3)
1963	400	83	91	—	97	97	100	104
			(8)		(6)	(0)	(3)	(4)
Southeast								
1962	360	103	107	107	110	109	124	126
			(4)	(0)	(3)	(-1)	(15)	(2)
1963	400	100	113	102	107	115	111	116
			(13	(-11)	(5)	(8)	(-4)	(5)

Table III. Analysis of variance of the average total length growth increment of brown shrimp between sampling periods within six ponds stocked at different densities at Rockefeller Refuge, 1962.

Source of Variation	d.f.	s.s.	m.s.	"F" value
Sampling periods	5	311.07	62.2	3.70
Ponds	4	152.80	38.2	2.27
Ponds X Periods	20	323.60	16.8	
	29			

"F" value 5 and 20 d.f. at 5 per cent level = 3.2891
"F" value 4 and 20 d.f. at 5 per cent level = 3.5147

Table IV. The mean total length, standard deviation, high and low extremes and the number of shrimp observed at each sampling period for the indicated pond in 1962.

Pond	I 7/5	II 7/19	III 8/2	IV 8/16	V 8/29	VI 10/5	Harvest 11/9
	Samples and date, 1962						
Northeast							
Mean	86	91	95	98	106	128	135
Standard deviation	8	8	8	7	10	0	7
Extremes							
Low	63	73	80	80	95	128	112
High	100	113	110	120	122	128	146
Observations	97	108	84	101	24	1	13
Northcenter							
Mean	98	104	105	108	107	111	118
Standard deviation	7	8	7	5	4	3	14
Extremes							
Low	85	93	92	102	103	107	103
High	108	115	118	117	115	117	170
Observations	30	30	29	11	15	15	1200
Southwest							
Mean	83	84	85	83	93	103	110
Standard deviation	10	8	6	4	2	5	8
Extremes							
Low	70	70	70	76	80	95	98
High	113	110	100	100	100	114	143
Observations	83	79	47	39	11	20	1377
Southcenter							
Mean	86	89	92	92	105	112	115
Standard deviation	7	6	6	4	6	2	5
Extremes							
Low	73	70	70	90	95	110	103
High	98	98	118	111	123	115	127
Observations	33	39	53	28	20	7	1290
Southeast							
Mean	103	107	107	110	114	124	126
Standard deviation	6	6	6	5	7	7	7
Extremes							
Low	90	98	95	96	103	117	111
High	114	117	121	116	124	140	133
Observations	29	30	29	20	19	8	149

showed a tendency to come closer to the average size with time. Smaller variances became evident in later samples because of smaller standard deviations and narrow extremes. This is an indication that the majority of the shrimp were approaching uniform size.

A recent study (Anonymous, 1963) reported stocking 8,000 white shrimp averaging 75 millimeters in length in a one-acre pond. They were fed chopped crabs and fish. A production of 240 pounds of 35-count white shrimp was obtained from the period between May and November. This production was very high when compared with the

Table V. The mean total length, standard deviation, high and low extremes and the number of shrimp observed at each sampling period for the indicated pond in 1963.

Pond	I 6/26	II 7/10	III 7/24	IV 8/7	V 8/21	VI 9/4	Harvest 10/15
	Samples and dates, 1963						
Northeast							
Mean	92	96	100	103	110	113	119
Standard deviation	8	7	6	8	6	5	8
Extremes							
Low	70	85	89	93	102	105	110
High	104	106	114	111	125	126	133
Observations	30	30	62	17	49	10	456
Northcenter							
Mean	101	97	97	97	92	93	102
Standard deviation	10	12	9	6	10	6	6
Extremes							
Low	83	65	86	85	72	85	93
High	115	125	116	111	105	100	120
Observations	24	41	36	21	3	4	670
Northwest							
Mean	102	104	106	111	112	109	110
Standard deviation	9	6	1	4	6	4	4
Extremes							
Low	85	95	98	104	100	103	100
High	114	115	115	116	122	115	123
Observations	14	19	25	14	43	11	385
Southwest							
Mean	76	83	88	91	95	94	103
Standard deviation	6	8	5	6	7	6	5
Extremes							
Low	65	65	82	81	85	83	90
High	85	100	98	105	110	106	107
Observations	13	30	21	29	49	25	540
Southcenter							
Mean	83	91	—	97	97	100	104
Standard deviation	12	8	—	8	—	—	5
Extremes							
Low	71	83	—	87	97	100	99
High	102	103	—	112	97	100	125
Observations	6	9	0	10	1	1	158
Southeast							
Mean	100	113	102	107	115	111	116
Standard deviation	8	8	5	3	2	3	4
Extremes							
Low	83	98	97	103	112	107	111
High	112	121	112	112	122	115	123
Observations	10	7	3	5	4	5	892

Table VI. The numbers of brown shrimp stocked and the numbers and weight harvested, for the indicated ponds in 1962 and 1963. Percentage mortality is computed from numbers stocked and later harvested.

Pond Year	Number Stocked	Number Harvested	Pounds Harvested	Per Cent Mortality
Northeast				
1962	9000	13	.44	99.8%
1963	5000	456	11.40	91.0%
Northcenter				
1962	6000	1200	25.00	80.0%
1963	5000	670	10.80	87.0%
Northwest				
1962	946	0	0.00	100.0%
1963	5000	385	7.70	92.0%
Southwest				
1962	9558	1377	25.50	85.6%
1963	3333	540	7.30	84.0%
Southcenter				
1962	6000	1290	30.00	78.5%
1963	3333	158	3.30	96.0%
Southeast				
1962	3000	149	4.20	95.0%
1963	3333	892	22.30	73.0%

results obtained from a one-third acre pond at Rockefeller Refuge that was stocked with 3,333 brown shrimp which were fed a commercial fish food. Shrimp in this pond were 43-count and 10 pounds per acre were harvested. Table VI shows the results of the experiments for the two years.

Mortality

As with growth, mortality followed the same pattern in 1962 and 1963. Tables IV and V give the number of shrimp obtained in each sample from the indicated pond. It can be seen from the tables that there is a rapid decrease in the number of shrimp sampled after the third week in August.

Exosekeletons were taken in the beam trawl samples after this period, where as none were collected prior to this period. Dead shrimp were also observed on the bottom of the ponds. No definite reasons can be given for this occurrence, however, some generalizations are needed. It was observed that mortality occurred among the larger shrimp. This may have been due to the physiological condition of the shrimp before migration (Kutkuhn, 1962). This coupled with the fact that food conversion is lower in low salinities (Johnson and Fielding, 1956) may be combined reasons for the mortalities and slow growth that occurred.

Stomach Analysis

Stomachs of 317 shrimp were examined for food contents in 1962 and 1963. The results of the analysis are presented by shrimp size classes and by the month in which the shrimp were sampled (Table

Table VII. Percentages of food groups by size classes of brown shrimp and by months sampled in 1962 and 1963.

Food Group	Total Length (mm.) of Shrimp						
	70-79	80-89	90-99	100-109	110-119	120-129	130
Invertebrates	3	1	8	8	6	13	10
Vegetation	2	0.5	3	4	4	2	3
Diatoms	14	44.5	11	25	9	17	6
Algae	22	3	3	6	14	4	3
Organic Debris	59	51	75	57	67	64	78
Empty Stomachs	11	42	43	62	56	59	63

Food Group	Months Sampled					
	June	July	Aug.	Sept.	Oct.	Nov.
Invertebrates	1	4	6	4	18	20
Vegetation	1	5	1	1	4	3
Diatoms	29	23	11	2	3	20
Algae	6	6	9	1	6	3
Organic Debris	63	62	73	92	69	54
Empty Stomachs	38	33	50	75	74	56

VII). The percentage of food content was obtained by the occurrence of each food group present in the stomachs and was not a volumetric examination. The results show that as shrimp increased in length more invertebrates were included in their diets. This trend occurred in both total length and time groupings. There was a tendency for larger shrimp to have little or no food present in their stomachs. This led the author to believe that brown shrimp may have a change in food habits and/or the food desired was not present. This change is believed to occur late in their life cycle and may be another possible reason for the high mortalities which occurred during the latter parts of the experiments.

Water Chemistry

Table VIII shows the ranges in water chemical data that existed for both years. At all times during the experiment dissolved oxygen content seemed to have been appropriate enough to sustain the life of shrimp in ponds. Test jars to determine the lower dissolved oxygen tolerance indicated that the lower limits was slightly less than 1 ppm. Dissolved oxygen was also taken from daybreak to noon and increased from 1 ppm to 14 ppm by noon.

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Table VIII. Water Chemistry for six one-third acre ponds on Rockefeller Refuge during 1962 and 1963.

Chemical Test	Ranges
Dissolved Oxygen	1-14 ppm
Dissolved Carbon Dioxide	0-9 ppm
Phenolthphalein Alkalinity	0-17.5 ppm
Methyl-Orange Alkalinity	10-145 ppm
pH	7-9.6
Temperature	30-36° C.
Salinity	6,500-20,000 ppm
Sulfides	Negative

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