The Growth Rate of Marked Juvenile Brown Shrimp, *Penaeus aztecus,* in a Semi-impounded Louisiana Coastal Marsh

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ABSTRACT

Several tests were conducted in May through July 1975 to determine the growth rate of juvenile brown shrimp, and to assess effects of an injected fluorescent pigment mark on growth and mortality rates. Three mark-recapture tests resulted in growth rate estimates of 0.87, 0.81 and 0.52 mm/day. Other tests indicated no significant differences in survival or growth rates of marked and unmarked shrimp. Length frequencies and abundances of shrimp trapped at the study area outlet were also determined. The length frequencies exhibited a major mode, interpreted as the result of shrimp emigration from the study area, and a secondary mode of larger shrimp, interpreted as the result of (1) immigration from the east, or (2) emigration of larger shrimp from the far side of the study area. Length frequencies could not be used to estimate growth rates. Knowledge of shrimp growth rate is important to management; at present, no growth rate estimates can be considered conclusive. With refinement, the methods of this study show promise of helping to obtain reliable estimates.

INTRODUCTION

The brown shrimp, *Penaeus aztecus,* contributes about 50% to the total shrimp catch in the Gulf of Mexico; the 1974 Louisiana catch was 27.4 million pounds, heads on, valued at 18 million dollars (U.S. Dept. of Commerce 1975).

Knowledge of shrimp population dynamics is essential to proper use of this valuable resource. Effective management by the regulating agencies to optimize the shrimp catch should be based on the best scientific information. For example, accurate knowledge of shrimp growth rates is necessary before optimal size for initial harvest can be determined.

Until recently most shrimp growth rate estimates were made using length frequencies. Results of these studies varied widely. Weymouth et al. (1933), McCoy and Brown (1967), and Herke (1971) attributed at least part of the variation in growth rate estimates to assorted factors which may confound length frequency interpretations. One way to avoid this confounding is to use a mark-recapture technique instead of the length frequency method.

The principal objectives of this study were to determine for juvenile brown shrimp 45 mm TL (total length) and longer (l) the growth rate in a semi-impounded marsh nursery and (2) the effects of an injected fluorescent pigment on growth and mortality rates. A secondary objective was to determine the number and length frequency of brown shrimp caught in a trap at the outlet of the study area.

Study Area

The study area was approximately 3,000 ha of semi-impounded marsh at Rockefeller Wildlife Refuge, Grand Chenier, Louisiana; it was bounded on all sides by man-made levees (Fig. 1). The entire study area was typical brackish marsh as classified by Chabreck et al. (1968); the dominant plant was *Spartina patens.*

The only permanent access provided for water flow in and out of the area was over two weirs (low dams) located about 4 km, by water, from the Gulf of Mexico (Fig. 1). Chabreck and Hoffpauir (1965), Chabreck (1968), and Herke (1968, 1971) discussed weir construction and function. A primary function of weirs is to partially stabilize water levels, which enhances waterfowl food plant production, provides favorable conditions for fur bearers, alligators and other forms of wildlife, improves trapper access, and other benefits. The weir crests were approximately 15 cm below average marsh soil surface, thus water flowed in on most high tides and out when the tide level fell. If water level on both sides of the weir fell below crest level the water behind the weir was impounded; hence the term "semi-impounded." However, impounded conditions rarely occurred during the study. There may have been some exchange of water over levees at high water, or through levee breaks, but this was never witnessed. Just inland from the two weirs the respective channels converged to form a single channel which led to the many ponds and smaller channels of the study area. Salinity in the area was influenced by tidal exchange over the weirs and by rainfall and evaporation.

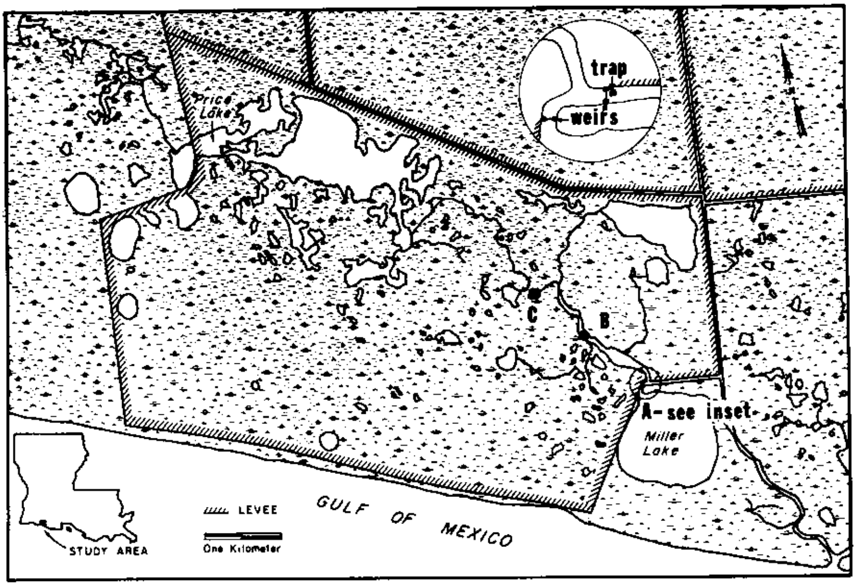

Fig. 1. Diagrammatic map of the study area at Rockefeller Wildlife Refuge, Grand Chenier, Louisiana. Numerous small ponds and channels are not shown.

MATERIALS AND METHODS

A recording salinometer near B (Fig. 1), and a recording thermometer just upstream of the trap weir, provided salinity and temperature information during the study.

Marking Technique

Shrimp were marked by injection of a small amount of fluorescent pigment (Day-Glo Corp., Cleveland, Ohio) mixed with petroleum jelly in a manner similar to that first described by Klima (1965). This mixture was drawn into a 3-cc disposable syringe with a locking tip and a 25-gauge needle was placed on the syringe. The pigment mixture was injected into the musculature between the first and second abdominal segments. During marking, a shrimp was held in one hand and the syringe was held in the other.

The marking method was initially tested in the laboratory at Louisiana State University. Equal numbers of marked and unmarked shrimp were held in large aquaria; marked shrimp exhibited better survival than unmarked shrimp in these limited tests.

Semi-impoundment Mark-Recapture

Shrimp were collected in May 1975, as soon as they became sufficiently abundant, with either a 4.8-m otter trawl or the push trawl described by Herke (1969); collection was most successful in ponds near the weir that were so shallow an airboat was required. Since it caused less mortality than the otter trawl, the push trawl was used whenever possible; the lower bar of the trawl mouth was set to lightly touch the pond bottom.

Shrimp were marked during four separate marking periods; a different color pigment was used for each period. Trawled shrimp were held in a 1-m^3 hardware cloth live cage secured to the small barge used as the platform for marking work. A 3.2-mm mesh net liner was suspended inside the cage to reduce abrasion of shrimp and predation through the hardware cloth by crabs.

Shrimp for marking were sorted a few at a time by hand. Only those 45-55 mm TL were retained in plastic dishpans containing about 3 cm of water; these were then marked and released immediately. To reduce mortality due to high daytime water temperatures, we usually marked from about 2 to 10 AM. Those marked with yellow, red, and blue pigment were released in the main channel about 1 km inland from the weirs (B, Fig. 1). Green-marked shrimp were released in a large, shallow pond about 2 km inland from the weirs (C, Fig. 1).

Recapture was by one of three methods: in the surface trawl while collecting shrimp for marking; in the otter trawl, which was used when no marking was being done; and in a stationary trap at one weir. The trap, described by Yakupzack (1976), was designed to fish continuously for organisms passing seaward over the weir. All shrimp taken in recapture attempts were examined under an ultraviolet light although most marks were seen without the aid of the light. Recapture efforts were continued through mid-October 1975.

The growth rate for recaptured shrimp marked with each color was calculated by the regression of length on time since the last day of the respective marking period. The slopes of the regression lines were compared to determine whether growth was statistically different between groups marked at different times.

Survival Tests and Pond Stocking

Three field tests were conducted to determine whether there was significant short-term marking mortality. In each test two small live boxes, about 60 cm on a side, were floated near the barge. Each box was stocked with 15 marked and 15 unmarked individuals, all between 45 and 55 mm. The boxes were checked for surviving shrimp after 72 hours.

Two 0.04 ha, slightly brackish ponds, designated as Ponds A and B, were each stocked with 170 marked and 170 unmarked shrimp to assess the effect of marking on growth rates and delayed mortality. These shrimp were 45-55 mm TL and were collected from various Refuge canals by otter trawl. The ponds were drained and refilled prior to stocking to reduce predation and interspecific competition, and to be sure no other shrimp were in the ponds. Water pumped into the ponds was strained through a 1-mm mesh saran screen.

Each pond was sampled occasionally for recaptures by 10 casts of a 1.2-m cast net. Growth and survival of both marked and unmarked shrimp were again calculated and compared statistically.

Length Frequencies and Abundance of Shrimp

A random sample of trap catch, containing about 75-100 brown shrimp, was taken each day. To determine the length frequency distribution these shrimp were measured by 5-mm groupings designated by the shortest length included (e.g. 40=40-44; 45=45-49, etc.).

Every brown shrimp in the day's catch was counted if there were fewer than about 200. Otherwise the length frequency sample was weighed; the remainder of the day's brown shrimp catch was weighed; and the number in the catch was estimated based on the proportionate weights of the sample and the day's catch. The total number was then subdivided among the length categories in the same proportion as in the length frequency sample. Weekly length frequencies were derived by summing the number in each length category of the daily length frequencies obtained for that week (it was not possible to operate the trap every day—see "trap days," Fig. 5).

RESULTS AND DISCUSSION

Semi-impoundment Mark-Recapture

Pigment colors, dates of release, and the number of shrimp marked are shown in Table 1. Of the total 16,523 shrimp marked, 82 (0.5%) were recaptured after marking with their color was terminated.

Growth rates, and r^2 values, from the regression analyses were: yellow, 0.01 mm/day, $r^2 = 0.00004$; red, 0.87 mm/day, $r^2 = 0.66$; blue, 0.81 mm/day, $r^2 = 0.61$; and green, 0.52 mm/day, $r^2 = 0.53$.

Table 1. Shrimp marking periods and numbers marked

Color	Dates (1975)	Number marked
Yellow	5/13-5/17	2,160
Red	5/22-5/30	5,897
Blue	6/5-6/13	6,136
Green	6/19-6/26	2,330

So few returns were obtained, over so short a time, from shrimp marked with yellow that the regression of length on time was useless. Therefore, there will be no further discussion of the yellow test.

The regressions of length on time since the last day of the respective marking period for shrimp marked with red, blue, and green pigments are presented in Figure 2. The t-value derived from the comparison of the slopes of the "red" and "green" shrimp indicated a significant difference in growth at the 95% level. There was no significant difference in the estimated growth rates between "red" and "blue" or "blue" and "green" shrimp, although the latter approached significance at the 90% level.

Data from most previous studies of brown shrimp growth rates are presented in Table 2. The growth rate estimates listed vary widely, and most are higher than ours. The average of all studies which employed length frequency techniques on brown shrimp of a size similar to those of our study is about 1.4 mm/day. Interpretation of the length frequencies in some of these studies may have been confounded by the inclusion of transients in the samples and/or other factors.

Other brown shrimp mark-recapture experiments cannot be directly compared to this study because they were performed on much larger shrimp. Both McCoy (1968) and Welker et al. (1975) found a growth rate of about 1.0 mm/day for subadult brown shrimp, whereas the estimate of Rose et al. (1975) was only 0.27 mm/day.

Four general factors (discussed in more detail in Knudsen 1976) may have influenced the results obtained in our study. The first two were of an experimental artifact nature. Handling of shrimp may have affected growth rate. For example, in a similar study Welker et al. (1975) found that shrimp did not grow as fast immediately after marking and handling as they did after 10 days had elapsed. Secondly, relatively few marked individuals were recaptured over a short time period; more recaptures over a longer time might have produced more reliable results. The other two factors were of a biological nature. First, temperature and salinity conditions during the study (Fig. 3) are regarded as relatively harsh and thus may have affected shrimp growth. Second, emigration of larger and faster growing shrimp from the study area was thought to occur early after release, thereby leaving slower growing individuals to be recaptured later in each test period. This seemed to be especially noticeable halfway through the period when "green" shrimp were at liberty; the salinity dropped from 7.8 to 3.3 ppt in one day and remained low (Fig. 3). Modal length of shrimp caught in the trap dropped from 105 mm on that day to 80 mm on the next.

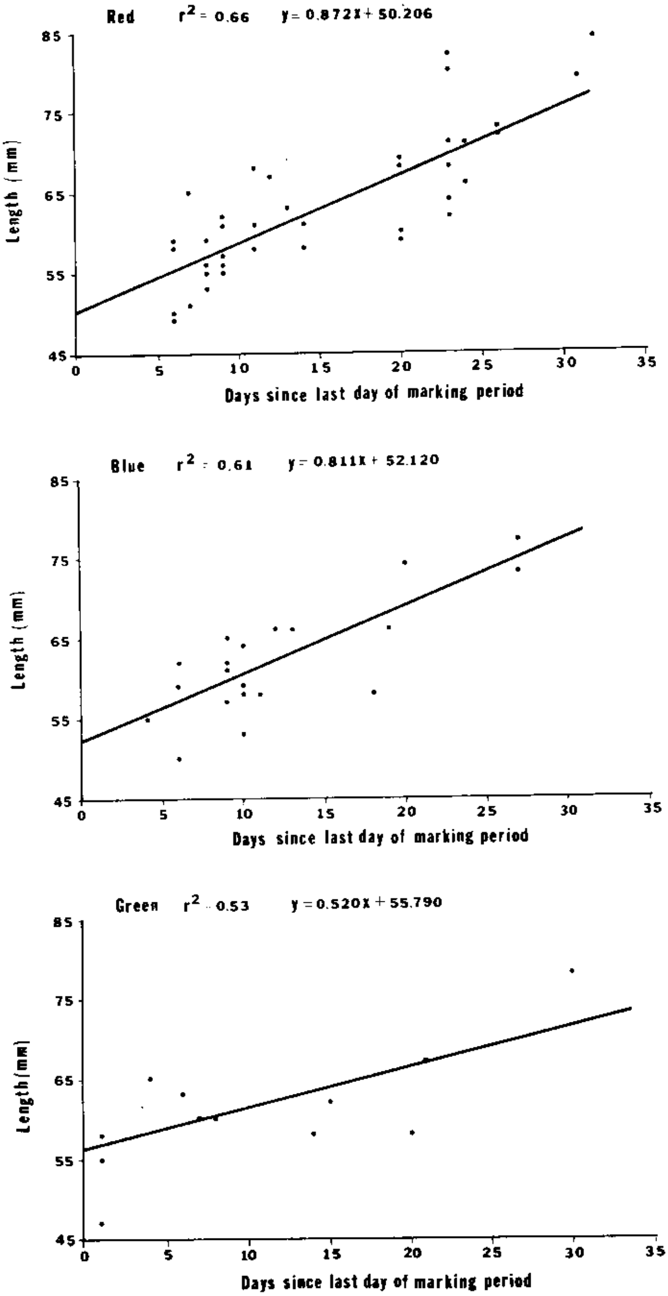

Fig. 2. Regression of length on time since the last day of the marking period calculated for shrimp bearing red, blue, and green pigments in the semi-impounded area.

Table 2. Previous studies of brown shrimp growth rates. Growth rates have been converted to mm/day if originally reported in other units

Author	Situation	Months	Method	Size range	Growth rate
Williams (1955)	Natural estuary, No. Car.	April-June 1951-53	Length frequency (largest)	20-120 mm	0.8-1.54 mm/day
George (1962)	Natural estuary, Grand Terre, La.	April-June 1961	Length frequency (modal)	45-105 mm	1.4 mm/day
St. Amant et al. (1963)	Barataria Bay, La.	March-May 1962	Length frequency (largest and modal)	23-125	0.7-1.7 mm/day
Loesch (1965)	Mobile Bay, Ala.	Spring, 1954-55	Length frequency	Juvenile-subadult	1.0-1.2 mm/day
Ringo (1965)	Galveston Bay, Tex.	March-May 1964	Length frequency (largest)	16-90 mm	1.7-3.3 mm/day
St. Amant et al. (1966)	Barataria Bay, La.	April-May, 1962-64, 3 year avg.	Length frequency	20-90 mm	1.0 mm/day
		April-May, 1965			1.06 mm/day
McCoy (1968)	Natural estuary, No. Car.	July-Sept. 1967	Mark-recapture	115 mm+	1.0 mm/day
Jacob (1971)	Natural estuary, southern La.	March-June, 1969-70 2 year avg.	Length frequency (largest)	12-145	1.32 mm/day
Wengert (1972)	Semi-impounded	March-May, 1971	Length frequency (largest)	10-127 mm (all in marsh at Marsh Island, La.).	1.31-1.78 mm/day
	Natural marsh	March-May, 1971			1.46 mm/day
	Semi-impounded	May-August, 1971			0.98 mm/day
	Natural marsh	May-August, 1971			1.34 mm/day
Gaidry and White (1973)	Barataria Bay, La.	Spring, 1970-72 3 year avg.	Length frequency (modal)	15-120 mm	1.05 mm/day
	Southwest La.	Spring, 1971-72 2 year avg.			1.43 mm/day

Table 2. CONTINUED

Author	Situation	Months	Method	Size range	Growth rate
Rose et al. (1975)	Louisiana, Semi-impoundments	March-June, 1968	Length frequency	12-160 mm	1.3 mm/day
	with predator and	June-Oct., 1968	Mark-recapture	Subadults	0.27 mm/day
	competitor control	April-May, 1969	Length frequency	Juveniles	1.9 mm/day
Welker et al. (1975)	Biloxi Bay, Miss.	May-June, 1968	Mark-recapture	90-150 mm	0.87-1.0 mm/day
This study	Grand Chenier, La.	May-June, 1975	Mark-recapture	45-84 mm	0.53-0.87 mm/day

Total trap catch was relatively high on both days, probably indicating an emigration to avoid unfavorable conditions, with the larger individuals being the first to leave.

Results derived from this type of study can have direct management application. For example, the Louisiana Wildlife and Fisheries Commission uses growth rate in setting the brown shrimp inshore season. Biologists monitor juvenile size and abundance and assume a growth rate of 1.5 mm/day to predict when 50% of the first major group of shrimp will attain a size useful to the market (letter dated 28 June 1976, W.S. Perret, Louisiana Wildlife and Fisheries Commission). We suggest brown shrimp growth rate may be considerably different than 1.5 mm/day; if so, calculations based on this estimate may result in less than optimum harvest. Our own estimates are very tentative, but there is also much disagreement among estimates made by others. Most of the latter estimates were made from length frequency analysis and range from 0.7 to 3.3 mm/day (Table 2). Such variability seems likely to be due more to unreliability of the length frequency method than to variability of natural growth rates among the numerous studies. To date, no study of brown shrimp growth rates, including ours, can be considered conclusive. The subject of shrimp growth rate, from postlarval to adult stages, deserves further study, preferably by methods other than length frequency analysis.

Possible Technique Improvements

The marking procedures used in this study proved to be relatively successful; almost all marking was done by two workers. When shrimp of the desired size were plentiful, two workers could collect and mark approximately 1000 shrimp in 8-10 hours. Other marking techniques were attempted, but none were as successful as simply working with individual shrimp by hand. The procedure used in this study could be improved and expanded to become very useful in future studies of juvenile shrimp dynamics.

One way to improve most mark-recapture experiments is to increase the number of marked individuals, and ultimately the number of returns. Increased

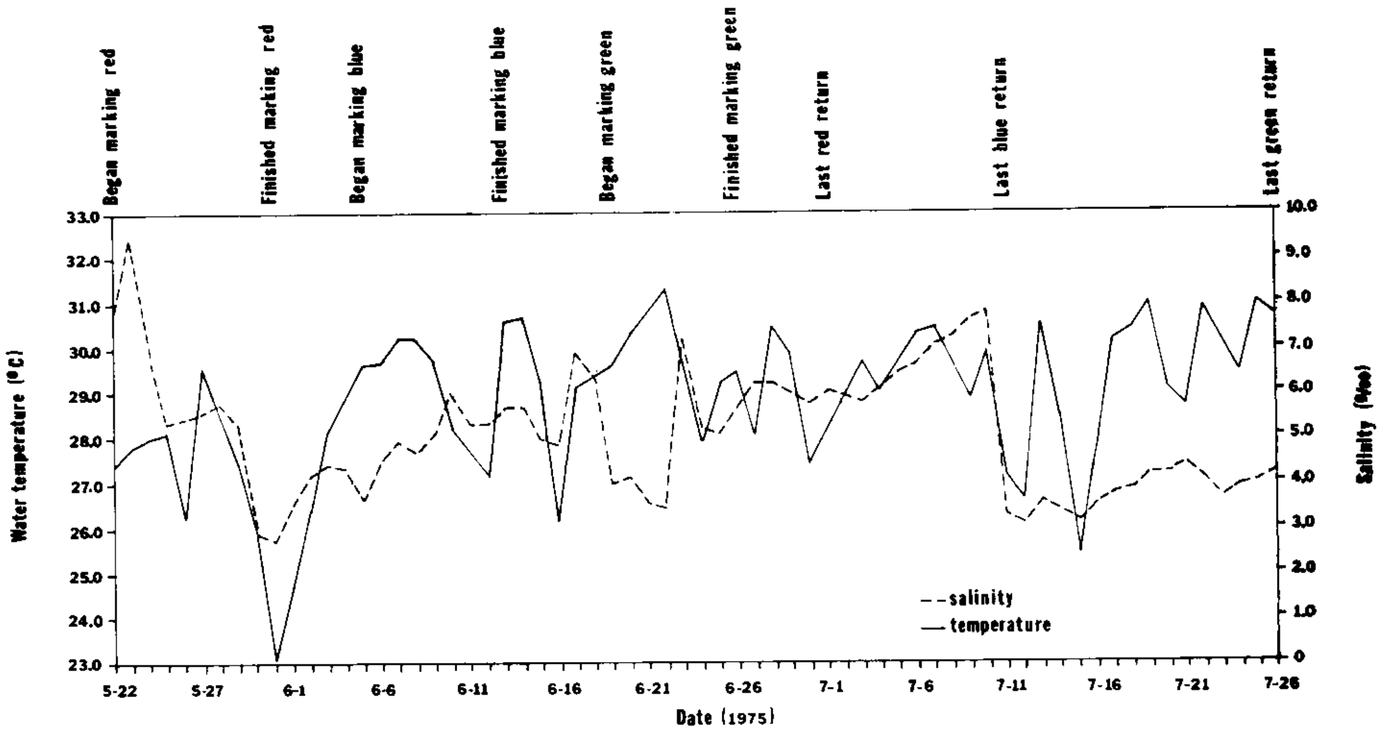

Fig. 3. Daily average water temperatures and salinities during the study period.

recapture efforts with the trawls, resulting in more trawl-caught recaptures, would have improved this study significantly. The desirability of increased recaptures at the trap, under our marking conditions, is less clear. The trap was intended to capture approximately 7% of the organisms passing seaward over the two weirs. However, there is doubt that the trap was capturing even this small proportion; only 15 of the 16,523 marked shrimp were recaptured in the trap. Even if there were 90% mortality, thus only 1,652 marked shrimp left to emigrate, the trap theoretically should have captured 116 marked individuals if it were operating as intended. Trap system modifications that forced all emigrating shrimp into the trap would have greatly increased our recaptures; however, such an increase might actually have been undesirable.

As already indicated, a number of things can affect the slope of the regression line and thus the estimate of growth rate. Some studies have indicated shrimp tend to emigrate upon attainment of a specific size. (See the discussion following under "Length Frequencies and Abundance of Shrimp.") If shrimp always left the nursery upon attainment of an exact size, say 75 mm, then all recaptures at the trap would have been 75 mm long and a regression line based on only trap recaptures would have had zero slope. Obviously, shrimp do not all emigrate upon reaching a precise size, but if there is even such a tendency this will reduce the slope of the regression line. Thus there could have been a downward bias in our estimation, although it may have been minor; the 15 trap-caught recaptures were fairly evenly dispersed throughout the total 82 recaptures.

Growth during the marking period would produce a bias similar to the one just discussed. With sufficient manpower, both of these biases could be reduced by marking at least as many shrimp over a more restricted size range and over a shorter time span.

Using biological stains, as described by Klima (1965) and others, rather than fluorescent pigments, might have been an improvement because returns could have been made by persons in addition to those directly involved in the study.

Another improvement could have been made by releasing progressively larger shrimp. This, together with returns over a longer time period, would allow a fit of data to a von Bertalanffy growth curve which describes growth better than a simple linear regression (Fabens 1965). Data from this study was applied to a computer program designed to generate the von Bertalanffy function. However, recaptures were too few and over a size range too small to provide meaningful results.

Survival Tests and Pond Stocking

The colors and dates of the survival tests were as follows: red, 26-29 May; blue, 5-8 June; and green, 24-27 June. The number of live shrimp remaining in each box, in each test, after 72 hours and the resulting "t" values (binomial) were:

					Survival Rate		
Color	*Marked*	*Unmarked*	*Marked*	*Unmarked*	*Marked*	*Unmarked*	*"t" value*
red	6	9	6	9	0.4	0.6	1.587
blue	15	15	12	12	0.9	0.9	0
green	15	14	15	13	1.0	0.9	1.825

The "t" values are not significant (P > .05).

Ponds A and B were stocked on 31 May and 18 June 1975 respectively. The results of the regression analyses for growth rates in the ponds were:

Pond A	*b-value (mm/day)*	*r*
marked	0.39	0.58
unmarked	0.37	0.65
Pond B		
marked	0.38	0.60
unmarked	0.29	0.52

There was no significant difference between the four estimated growth rates from the pond tests (P >.05). The regressions of length on time since stocking are presented in Figure 4.

The number of marked and unmarked shrimp recovered from each pond in each cast net sample is presented in Table 3. When these data were subjected to a 2 x 6 contingency Chi-square test the difference in survival was not significant (P > .05).

The results of the 72-hour and the long term pond survival tests indicated that the marking procedure can be useful for future mark-recapture experiments on juvenile shrimp. Mortality was not exceptionally high and probably was due primarily to confinement. In any event, mortality due to marking is not important in growth rate estimates except that it reduces the number of returns and a high mortality might indicate a slowed growth of survivors.

Although the results of growth rate estimates of marked and unmarked shrimp in the two ponds were abnormally low, they were still valid for comparison with each other; the low growth rates were common to all shrimp in the ponds. Comparisons of growth between marked and unmarked shrimp in the ponds showed no significant differences, thus the results from the semi-impounded area could have been a true reflection of the actual growth rate. However, since both the marked and unmarked shrimp were handled, the pond stocking experiments gave no indication of the effects on growth caused by handling alone.

Inspection of the plots of recaptures from the ponds (Fig. 4) revealed that growth rate slowed progressively to no growth in both ponds. In addition, when the ponds were drained, only 14 of the original 340 shrimp were found in Pond B after 2 months, and none of the 340 shrimp were found in Pond A after 3 months. Also, no shrimp recovered was larger than 100 mm and most were approximately 85 mm in later samples. This apparent cessation of growth and high mortality could have been the result of low oxygen concentrations, high temperature, low salinity, or any combination of these or other unknown factors. Oxygen levels were monitored occasionally and found to be adequate, but could have gone to zero under certain conditions during the study. Water temperature occasionally exceeded 30°C, which could have stressed the shrimp. Salinity was static in both ponds at 1.5-2.0 ppt throughout the study. We suspect that inability to emigrate upon attainment of a given size, in response to the

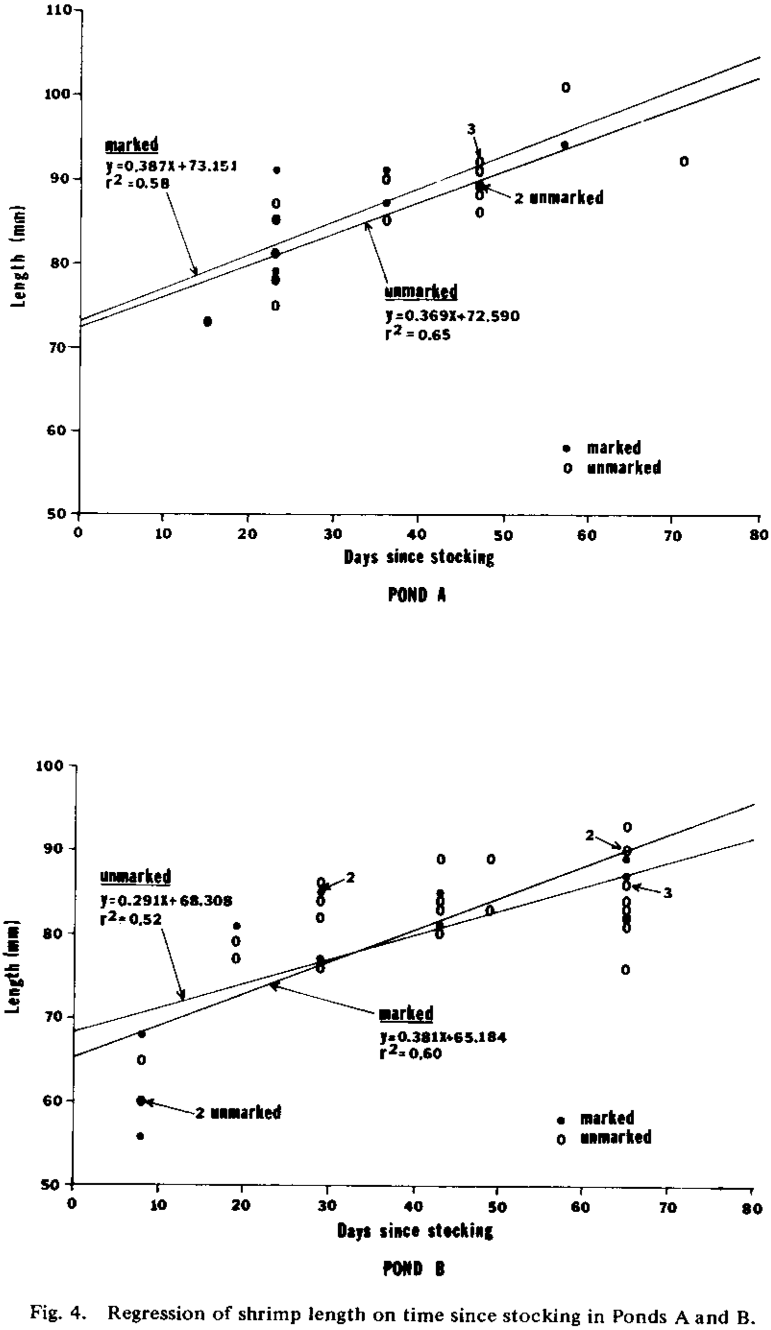

Fig. 4. Regression of shrimp length on time since stocking in Ponds A and B.

Table 3. Recaptures from ponds, and Chi-square values for survival differences

Pond A*			Pond B†		
Days since stocking	Number marked, recaptured	Number unmarked, recaptured	Days since stocking	Number marked, recaptured	Number unmarked, recaptured
15	1	1	8	3	3
23	6	4	19	1	2
36	2	2	29	3	4
47	1	8	43	3	4
57	1	1	49	0	2
71	0	1	65	3	11

*Chi-square = 5.84 (P > .05) †Chi-square = 3.23 (P > .05)

conditions just noted, was the primary cause for the apparent slowing of growth and eventual mortality. Wheeler (1967) found that shrimp growth ceased at 80 mm TL in very similar conditions but gave no indication of probable cause.

Length Frequencies and Abundance of Shrimp

Approximately 31,000 brown shrimp were trapped, in 107 trapping days, between 2 May and 25 September 1975 (Fig. 5).

Various authors have indicated most shrimp emigrated from their study area when they reached some relatively restricted size range. For example, Gaidry and White (1973) found movement of the larger shrimp from Rockefeller Refuge at approximately 70 mm TL. About two-thirds of the shrimp we trapped were taken between 2 May and 27 June; over half of these were less than 60 mm TL. However, the trap caught only organisms that had already passed over the weir in a seaward direction. Since it could not catch shrimp moving in the opposite direction,. it is impossible to state with certainty that trapped shrimp were emigrating to the Gulf rather than moving in and out over the weir. The obvious modal trend in the weekly length frequencies, at 60-75 mm, from 27 June through 25 September appears to be evidence of migration toward the Gulf upon attainment of a given size during this period. However, the daily length frequencies (Knudsen 1976:44-49) indicated that this size range was not clearcut. The daily length mode fluctuated often and rather widely. In other words, the modal size at emigration during this period was 60-75 mm but actual emigration seemed to depend more on daily local conditions than on a specific size.

A secondary modal trend occurred at 100-120 mm and may have resulted from an ingress (and subsequent outward movement) of older shrimp in their westward coastal migration as noted by Farfante (1969) and Gaidry and White (1973). These larger shrimp could also have come from the far western portion of the study area. Although their relative numbers are unknown, some large shrimp were taken in sporadic trawling in this area.

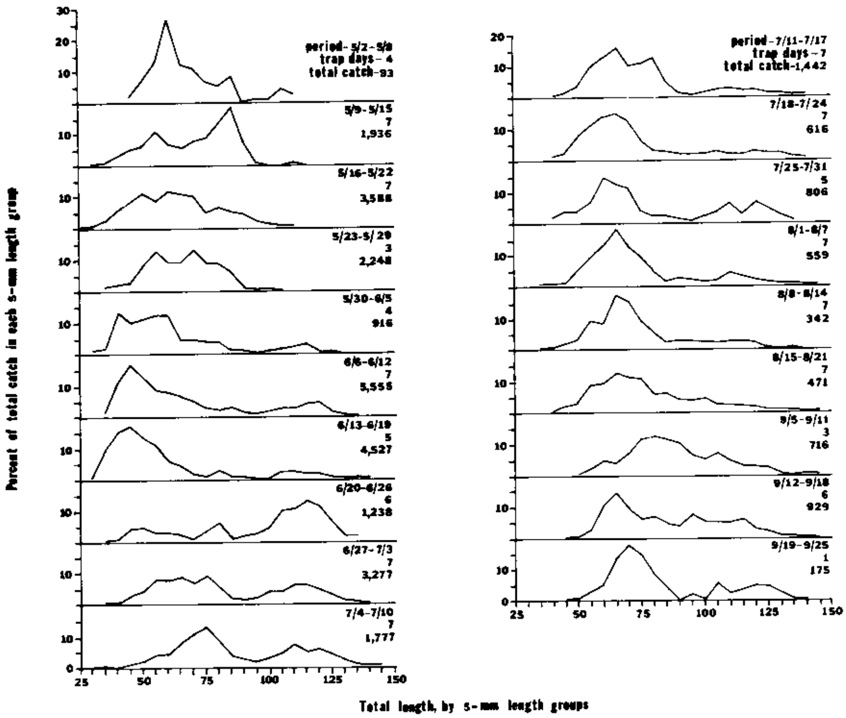

Fig. 5. Weekly length frequencies, abundances, and number of trap-days for brown shrimp caught in the trap at the weir.

The trap length frequencies served as an example of how sampling transient organisms can confound interpretation of length frequencies for growth estimates. All attempts to determine growth rate from the weekly length frequencies, or the daily length frequencies, led to confusion. The trends in modes, or in largest or smallest individuals could have, in some instances, reflected growth rates, but they were probably also a reflection of emigration and immigration patterns. This re-emphasizes the point that further study of shrimp growth rates should be by methods other than length frequency analysis.

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