Growth of the Sand Shrimp, *Crangon septemspinosa*, in Rhode Island[1]

ABSTRACT: Growth rate of the sand shrimp, *Crangon septemspinosa*, in Rhode Island waters is directly proportional to water temperature. For individuals 20–30 mm long, growth is less than 0.4 mm/week during the winter (average water temperature 5 C) and greater than 1.1 mm/week during the summer (20 C). Smaller shrimp (20–30 mm) grow faster than larger shrimp (40–50 mm). Linear relationships between length and weight are derived.

Introduction

The sand shrimp, *Crangon septemspinosa*, is a common estuarine decapod distributed along the northwestern Atlantic from Newfoundland to eastern Florida (Squires 1965; Williams 1955, 1965; Price 1962). Haefner (1969a, b, 1970, 1971, 1972) determined environmental tolerances and correlated these with distribution. We show here that the growth rate of *Crangon* in Rhode Island waters is directly proportional to water temperature. This finding is in contrast to the observations of Price (1962), who noted that the growth of shrimp in the Delaware Bay area was 0.4 mm/week for both winter and summer (0–27 C temperature range). We would like to discuss this difference between the populations of Rhode Island and Delaware.

Methods

COLLECTING AREA

Shrimp were seined from sand flats in the Pettaquamscutt River, Rhode Island (41° 26′ 55″N and 71° 27′ 05″W), which empties into Rhode Island Sound near the mouth of Narragansett Bay. The station was characterized by water depths of 0.5-1 m; average salinity of 27 o/oo; fine to coarse sand; and current velocities of approximately 20-30 cm/sec at full tidal flow.

LENGTH-WEIGHT RELATIONSHIPS

The shrimp were sampled over six months (Jun. 12, Jul. 13, Aug. 11, Dec. 2, 1970) with a 2 x 1 m hand seine (2 mm mesh). Lengths were measured to the nearest mm from the tip of the antennal scale to the end of the telson (total length according to Price 1962 and Lasker 1966).

For wet-weight determinations, shrimp were rolled on paper towels to absorb excess moisture and weighed to the nearest 0.1 mg; for dry-weight, the shrimp were freeze-dried and weighed. Least-squares regressions were then derived for both length-wet weight and length-dry weight. Length was the independent variable and weight was the dependent variable. All statistical tests were according to Ostle (1963) and Fryer (1966).

For the regression analyses, ovigerous shrimp were separated from the males and non-ovigerous females because the mass of the egg pads would contribute to the weight of the shrimp without affecting their length. The shrimp were sexed on the basis of external characteristics of the first pleopod (Price 1962), and only shrimp that could be sexed were included in this and the following analysis. This procedure of sexing avoided the difference in growth rates noted by Regnault (1970) between juveniles and preadults.

GROWTH

Shrimp were sampled 27 times over a 12-month period to estimate growth (Table 1). During winter and spring, the shrimp had migrated out of shallow water making it impossible to obtain sufficient numbers with a seine. As an alternative, shrimp collected in the fall were divided into size classes, and each group was placed in a laboratory tank with sand, seawater pumped directly from Naragansett Bay, and food (tissues of *Mercenaria mercenaria*) given *ad libitum*, approximating as closely as possible the conditions found in nature. The field program was resumed in May 1971, when water temperature in the river reached 10 C. Field samples were frozen and thawed at a later date for analysis. Shrimp in each sample were sexed, measured for total length to the nearest mm, and placed into the following size classes: 15–19, 20–24, 25–29, 30–34, 35–39, 40–44, 45–49, 50–54 mm.

Each size class and sex was traced throughout a season (assuming constant recruitment) by following similarities in frequency distribution, i.e. percent of total abundance on each sampling date. Mean length of each size class was calculated. Growth increment for each size class was thus the difference between mean length at the beginning and the end of a period. Each increment was divided by the length of the period in weeks to give a rate of growth in mm/week. Growth rates of the laboratory population were determined in the same way.

Results and Discussion

LENGTH-WEIGHT RELATIONSHIPS

Regressions are shown in Table 2 and Figs. 1 and 2 for shrimp 17–60 mm long. All two-way combinations, except one (dry-weight basis: males and non-ovigerous females compared with ovigerous shrimp), were found to have different slopes or intercepts ($P < 0.05$). Thus, a single equation (e.g., the pooled group) cannot describe lenght-weight relationships for the entire population; only an approximation can be derived.

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TABLE 1. Sampling schedule of a field population of *C. septemspinosa* and the number of shrimp that were used to estimate growth. The seasons were delineated on the basis of average water temperature. The shrimp during the winter and spring seasons were drawn from a stock held in the laboratory because a natural population of shrimp was not available.

Season	Sampling Date	Season's Duration in Weeks	Sample Size	Average Water Temp. C.
Fall 1970	Sep. 17		72	
	Oct. 28		104	
	Nov. 6	11	99	13
	Nov. 20		82	
	Dec. 2		118	
Winter 1970–1971	Dec. 2		118	
	Dec. 18	16	200	4
	Jan. 5		127	
	Mar. 24		82	
Spring 1971	Mar. 24		82	
	Apr. 27	6	83	6
	May 7		75	
Early Summer 1971	May 1		111	
	May 13		91	
	May 20		127	
	May 27	8	155	15
	Jun. 3		149	
	Jun. 10		129	
	Jun. 25		90	
Summer 1971	Jun. 10		129	
	Jun. 25		90	
	Jul. 2		80	
	Jul. 9	8	126	20
	Jul. 16		98	
	Jul. 22		100	
	Aug. 3		100	
Late Summer 1971	Jul. 22		100	
	Aug. 3		100	
	Aug. 13		100	
	Aug. 27	13	100	17
	Sep. 10		100	
	Sep. 24		100	
	Oct. 21		100	

Length-weight differences within the population might be due to weighing errors, but reproducibility, even with gravid females, was good (the correlation coefficients are high). Ovigerous groups have higher intercepts than the other groups because the mass of the egg pads contribute to the weight of the shrimp without affecting their length.

For vertebrate and invertebrate species, weight varies as some power of length. The relationship is (Richer 1958):

$$W = bL^a \text{ or}$$

$$\log W = a \log L + \log B$$

where a is the slope; if it is three, growth is "isometric" and follows the cube rule (weight changes as the cube of the length), a characteristic of many species. Log-weight on log-length regressions for *Crangon* in the 17–60 mm range (Table 3) are not

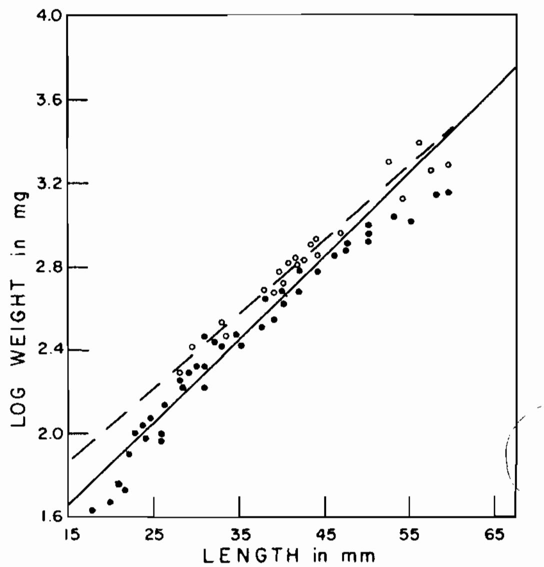

Fig. 1. Wet-weight on length regression for *C. septemspinosa*. The solid line and closed circle are for males and non-ovigerous females (n = 237), and the long-dashed line and the open circles are for ovigerous shrimp (n = 40). Representative data for both lines are plotted.

TABLE 2. Length-weight relationships for *C. septemspinosa*. The regression equations are log W = a L + log b, where log W is the log weight in mg, a is the slope of the regression line, L is the length in mm, log b is the ordinate intercept. The correlation coefficient is *r*.

	Wet-weight Basis	Dry-weight Basis
Males and non-ovigerous females	Log W = 0.039 L + 1.1	Log W = 0.039 L + 0.51
n = 237	$r = 0.97$	$r = 0.97$
Ovigerous shrimp	Log W = 0.035 L + 1.3	Log W = 0.039 L + 0.66
n = 40	$r = 0.97$	$r = 0.91$
Pooled	Log W = 0.040 L + 1.0	Log W = 0.041 L + 0.47
n = 277	$r = 0.97$	$r = 0.96$

signficantly different from 3.0 ($P < 0.05$), and the growth of *Crangon*, therefore, follows the cube rule.

GROWTH

As shown in Table 4, growth of *Crangon* is a function of water temperature and initial size. A direct relationship between growth and water temperature is shown in Fig. 3. Growth is greatest during the summer and, conversely, lowest in cooler water. Some of the variation of Table 4 is explained in Fig. 4, where growth rate is plotted against size. An inverse relationship between growth rate and size (i.e. larger shrimp have a lower growth rate than smaller shrimp) is apparent ($P < 0.05$ that $r \neq 0$). To incorporate this in a general growth equation for the field population, we must, therefore, consider both water temperature

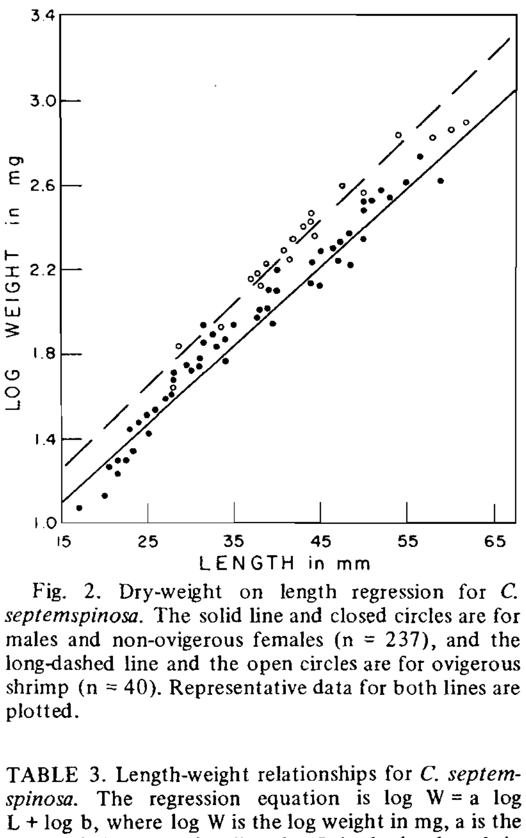

Fig. 2. Dry-weight on length regression for *C. septemspinosa*. The solid line and closed circles are for males and non-ovigerous females (n = 237), and the long-dashed line and the open circles are for ovigerous shrimp (n = 40). Representative data for both lines are plotted.

TABLE 3. Length-weight relationships for *C. septemspinosa*. The regression equation is log W = a log L + log b, where log W is the log weight in mg, a is the slope of the regression line, log L is the log length in mm, log b is the ordinate intercept. The correlation coefficient is *r*. Jun. 12 and Jul. 13, 1970 sampling dates only.

	Wet-weight Basis
Males and non-ovigerous females	log W = 2.9 log L – 2.0
n = 71	$r = 0.96$
Ovigerous shrimp	log W = 3.1 log L – 2.2
n = 39	$r = 0.98$

and size by multiple regression, obtaining for pooled data (Table 4) the following:

$$Y = 0.062\ X_1 - 0.0084\ X_2 + 0.23\ (r = 0.88)$$

where

Y = mean size increment in mm/week for a particular water temperature and for a particular size;

X_1 = water temperature C;

X_2 = size of the organism in mm.

The equation describes a family of lines (Fig. 5) and, in general, says that smaller shrimp of both sexes grow faster than larger ones at the same temperature. Rates for each size are given in Table 4; note, for example, that 30 and 38 mm shrimp at 20 C grow at 1.25 and 1.13 mm/week, respectively; the corresponding rates at 4 C are 0.38 and 0.25 mm/week.

Female *Crangon crangon* have a greater growth rate (Meixner 1968, 1969); female *Crangon* sp. attain larger sizes (Price 1962; Meixner 1968, 1969); and female *C. septemspinosa* have a greater life expectancy than males (Price 1962). Thus, the growth dynamics of a population of *C. septemspinosa* in Rhode Island, which is dominated by females (70% of the total individuals; Wilcox 1972), should be considered with these facts in mind.

The growth rate derived by Price (1962) for all sizes and sexes of shrimp in Delaware Bay is 0.4 mm/week and does not vary with the season. This value is low, one-third the maximum summer rate observed in this study. Furthermore, a constant rate over time differs from our findings, which show that growth is closely related to temperature. Winter growth in Rhode Island waters, however, is similar to Price's (1962) value.

Regional differences between growth rates and effects of temperature are not easily explained. Growth rates free from temperature influences seem to be the exception rather than the rule (Hoar 1966). Price (1962) explains the situation as follows: "This phenomenon is more easily resolved when considering that the sand shrimp is a cold water form and in this region [Delaware Bay] is near the southern extreme of its range. Expected increase in growth rates with higher temperatures may be nullified by increased energy demands of reproduction and retarded by metabolism adapted to low temperatures. Advent of cooler temperatures decreases the demand of reproduction and, for this boreal shrimp, may permit a rate of growth of the same magnitude as in warmer months." It may be that because summer water temperatures are lower in Rhode Island than in Delaware Bay and, therefore, not as demanding in a metabolic sense for a boreal species, energy is available for growth of the northern individuals. However, a growth rate in Rhode Island three times that of Delaware Bay population seems too wide a margin to be explained by temperature.

There is always some danger in extrapolating laboratory data (winter and spring growth rates) to the field and these results should be viewed with this reservation. However, experimental error in determining growth rates of the winter and spring (laboratory) population is minimal because conditions appeared to be optimal for survival and the same group was measured repeatedly. Over-estimation of growth rates

TABLE 4. Seasonal growth of *C. septemspinosa*. Growth rate: mm/week; initial size: the mean length (mm) of each size class. The seasons were delineated on the basis of average water temperature. The shrimp during the winter and spring were drawn from a stock held in the laboratory because a field population was not available.

13 C Fall 1970		4 C Winter 1970-1971		6 C Spring 1971		15 C Early Summer 1971		20 C Summer 1971		17 C Late Summer 1971	
Size	Rate	Size	Rate	Size	Rate	Size	Rate	Size	Rate	Size	Rate
18	.750	28	.063	31	.500	22	1.375	13	1.250	18	1.077
22	.833	29	.250	36	.167	26	1.375	13	1.250	18	1.077
28	.750	30	.375	36	.333	27	0.875	17	1.875	23	0.846
32	.833	33	.063	38	.333	28	1.500	18	1.125	23	0.846
38	.750	34	.250	41	.000	32	1.125	21	1.376	27	0.846
42	.677	35	.250	43	.500	34	1.250	22	1.000	28	0.692
		38	.250	45	.333	36	0.750	27	1.250	31	0.769
		40	.000	49	.333	37	1.250	30	1.250	32	0.385
		40	.063	51	.000	41	0.875	33	1.875	36	0.385
		42	.000	51	.167	42	0.875	33	1.375		
		42	.063					37	0.875		
		43	.125					38	1.125		
		46	.063								
		48	.000								
		49	.000								
		50	.063								

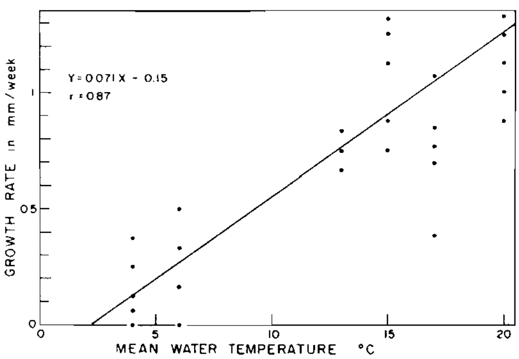

Fig. 3. Growth rate as a function of water temperature for *C. septemspinosa*.

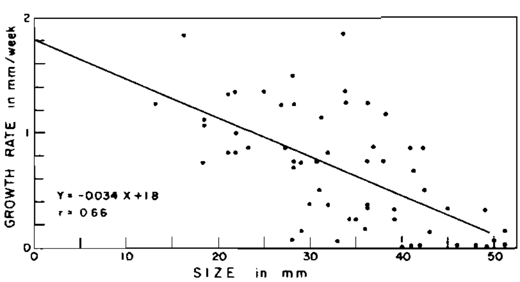

Fig. 4. Growth rate as a function of size for *C. septemspinosa*.

during the summer seems unlikely because the same rates were obtained during an independent study (Wilcox 1972). In the laboratory, shrimp 20–30 mm long molted twice a month at 20 C, and grew 3–5

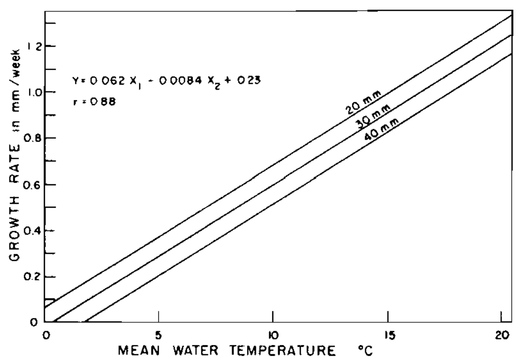

Fig. 5. Growth rate as a function of water temperature and size for *C. septemspinosa*. X_1 is water temperature (C) and X_2 is size (mm).

mm over the two intermolt periods. This rate agreed with the field data, but was several times greater than Price (1962) observed.

In conclusion, the family of lines shown in Fig. 5 is an estimate of growth for *C. septemspinosa* in Rhode Island. Growth of an "average" shrimp is less than 0.4 mm/week during the winter and greater than 1.1 mm/week during the summer.

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