# CONTROLLED REARING OF DUNGENESS CRAB LARVAE AND THE INFLUENCE OF ENVIRONMENTAL CONDITIONS ON THEIR SURVIVAL

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# CONTROLLED REARING OF DUNGENESS CRAB LARVAE AND THE INFLUENCE OF ENVIRONMENTAL CONDITIONS ON THEIR SURVIVAL

## INTRODUCTION

Culture methods for Dungeness crab larvae, and the effects of temperature, salinity, various laboratory diets, and diet concentrations on survival and growth were covered in previous progress reports (Reed, 1966, 1967 and 1968). Objectives during the July 1, 1968, to June 30, 1969, project period were to determine the following:

1. The effects of diet concentration on survival and growth.
2. The effects of crab larval concentration on survival.
3. The effects of diet concentration on cannibalism.
4. The effects of light intensity on the swimming behavior of crab larvae.
5. The effects of water current on the swimming behavior of crab larvae.

A change in project personnel in September 1968 necessitated a slight readjustment in the program schedule in order that the new project biologist could familiarize himself with the techniques of holding and rearing crab larvae.

## METHODS AND MATERIALS

Dungeness crab larvae were generally subjected to similar rearing conditions for each experiment. All rearing water was filtered and treated with an ultraviolet light. Water temperatures were maintained at 11 C, ±0.5 C, in a constant temperature water bath and salinities were adjusted down to 30 ‰ (±0.5 ‰) with distilled water. Rearing water was changed and larvae were fed three times a week. Flasks were cleaned about every 11 days. The larvae were subjected daily to 16 hours (5:00 a.m. to 9:00 p.m.) of fluorescent light.

## Effects of diet concentration on survival and growth

A diet concentration study, using San Francisco brine shrimp (*Artemia salina*) for food, was conducted to determine optimum concentrations of food organisms to feed Dungeness crab larvae. This work was an elaboration of efforts initiated by Paul Reed in 1968 which terminated prematurely after 38 days of rearing when the ectocommensal protozoan *Vorticella* sp. infested the zoeae.

Ovigerous Dungeness crabs were provided by commercial fishermen on January 21, 1969. Females, with eggs near hatching were isolated into individual 117.8 liter (31 gallon) tanks containing running sea water of approximately 10 C.

On January 22, 180 newly hatched zoeae from one female were collected, divided into groups of five, and placed into 36 250 ml Erlenmeyer flasks containing 200 ml of rearing water.

The zoeae were separated into units of 30 and fed a specific diet concentration of 1, 5, 10, 15 or 20 brine shrimp per ml of rearing water. An unfed group was reared as a control.

## Effects of crab larvae concentration on survival

The effect of crab larval concentration on survival was tested by rearing two groups of five crab zoeae vs. eleven zoeae per 200 ml of water. Larvae were fed at a diet concentration of five brine shrimp per ml.

## Effects of diet concentration on cannibalism

The problem of cannibalism by crab megalopae on younger crab zoeae was reported by Reed, 1967. To determine the effects of diet concentration on this cannibalism, crab zoeae reared in 250 ml flasks, containing 200 ml of water were fed brine shrimp at a diet concentration of 1, 5, 10, 15 or

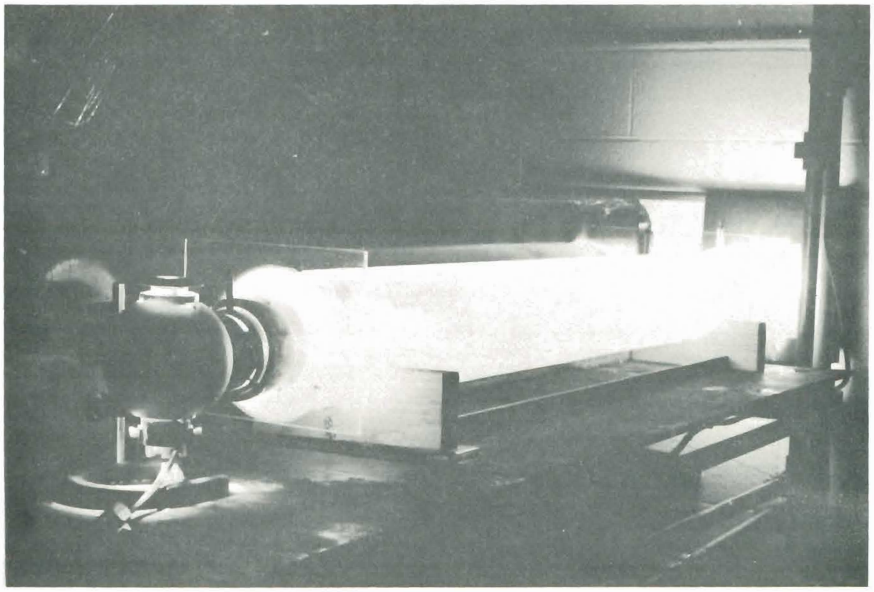
20 per ml of rearing water through the fifth zoeal stage. The flasks were then divided into two groups just before the zoeae molted into the megalops stage. One group contained 3 to 5 zoeae per flask while the other flasks held single zoeae. The crab larvae were fed at the same diet concentrations through the megalops stage.

Effects of light intensity on the swimming behavior of crab larvae

To test the effects of water current on crab larvae, a stimulus must be available that the larvae will respond to. Since crab larvae were already known to be positive phototropic, tests were designed to subject crab larvae to light.

Originally, plans were made to observe the effects of light intensity on all larval stages of the Dungeness crab, but due to delays in receiving test equipment, the larvae had already molted to the fifth zoeal stage before our experiments could be started. The small numbers of zoeae remaining after these tests precluded extending the experiments into the megalops stage.

A plexiglass cylinder, 154 cm long and 15 cm in diameter was constructed to test the effects of light intensity on crab larvae behavior (Figure 1). It was equipped at one end with an adjustable incandescent microscope light capable of producing approximately 8,100 foot candles (ft-c) of light. The chamber was filled with filtered and ultraviolet treated sea water of approximately 11 C through a half-inch fill hole at one end. Water in the chamber was changed after approximately 1 hour of use to minimize a temperature increase. The chamber was placed in a darkened, unheated aquaria room of approximately 16 C to eliminate incidental light. A portable fan, directed at the side of the chamber, reduced the problem of condensation collecting on the tube.



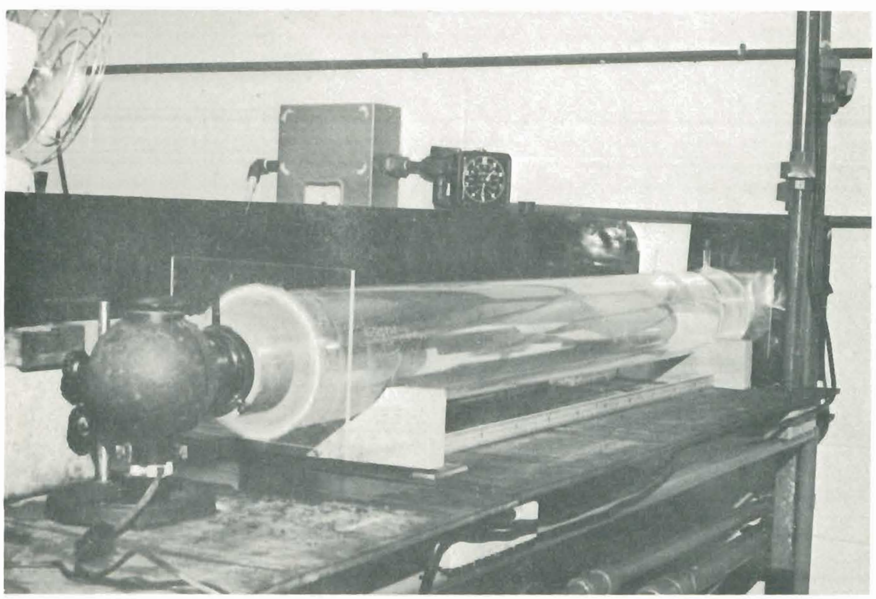


Figure 1. Plexiglass chamber used to test the effects of different light intensities on crab larval swimming behavior. Top photo shows chamber in operation

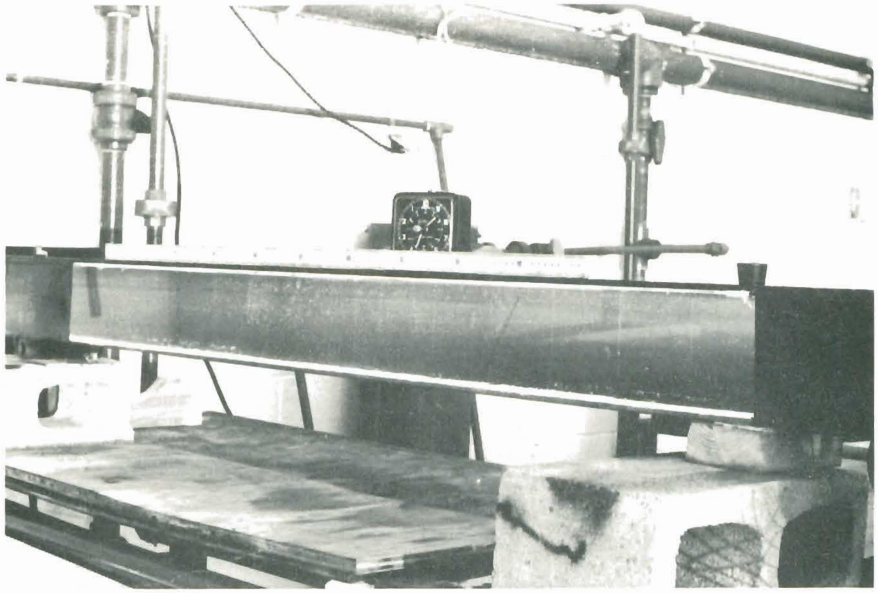
Crab zoeae were introduced at the opposite end of the chamber from the light source and subjected to one of three light intensities (25, 340 and 990 ft-c). The time the zoeae require to reach the bottom, positive or negative movement (in cm) during this period, and location after 1, 2, 3, 4 and 5 minutes were recorded. Zoeae were placed in the chamber one at a time for observation.

Effects of water current on the swimming behavior of crab larvae

A chamber, 257 cm long, 10 cm wide, 14 cm high and made of 6.35 mm thick plexiglass was constructed to make preliminary tests on the effect of water current on crab larvae (Figure 2). It was equipped at the inflow end with an adjustable incandescent microscope light capable of producing approximately 3,700 ft-c. The chamber was painted black with a 133 x 14 cm window left unpainted on one side, 92 cm back from the inflow end. Ten cm sections were marked on the back side of the viewing chamber to measure larval movement. The chamber was equipped with a pump capable of discharging 38 liters per minute at maximum capacity. Flows were measured by a calibrated flow meter and regulated by either a rheostat or a valve. Water temperature was maintained at approximately 11 C, ±2 C. A fan circulated air across the face of the viewing window to reduce condensation.

The apparatus was originally constructed as an open trough but problems with controlling water velocities and air bubbles necessitated changing the system to a closed one.

Tests were originally designed to subject all stages of crab larvae to water velocities of 2.10, 4.21 and 6.32 cm per second at light intensities of 0.75, 66.0 and 155.0 ft-c of light. Lack of test animals and problems of designing the swimming chamber reduced this experiment



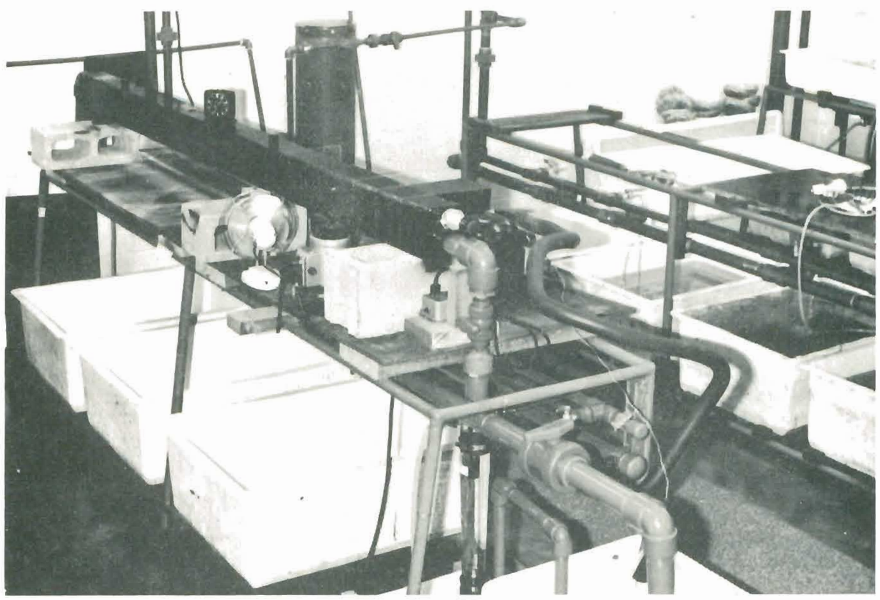


Figure 2. Plexiglass chamber used to test effects of water velocity on crab larval swimming behavior. Top photo shows viewing window

to making preliminary observations on fourth stage zoeae. These experiments were terminated prematurely due to high mortality.

## RESULTS

### Effects of diet concentrations on survival and growth

All zoeae in the unfed control group were dead by the fourteenth day (Figure 3). The best survival (46.7%) occurred when zoeae were fed at a concentration of 10 brine shrimp per ml. The poorest survival (13.3%) occurred when zoeae were fed at a concentration of 20 brine shrimp per ml. Survivals of 16.7, 33.3 and 33.3% were experienced at diet concentrations of 1, 5 and 15 per ml, respectively. This substantiated the results of previous work (Reed, 1968).

In contrast to observations made by other investigators, no significant increase in mortality was observed during the molting of the zoeae. A sharp increase in mortality was observed at all diet concentrations immediately following molting of fifth zoeae to megalopae due partially to cannibalism.

Growth or time of molting was affected at each of the diet concentrations. The time taken for all zoeae in a test group to complete each molt was shortest for zoeae reared on a diet concentration of five brine shrimp per ml and occurred predominantly on a single day especially through the first three zoeal molts. Time of molting of zoeae was delayed most significantly at diet concentrations of 1 and 15 brine shrimp per ml.

The first observed molting of zoeac from the 1st, 2nd, 3rd, 4th and 5th zoeal stages and the megalopae occurred on the 14th, 26th, 37th, 51st, 72nd and 109th day, respectively. Molting of zoeae into the megalops stage was first observed at diet concentrations of 10 and 15 brine shrimp per ml

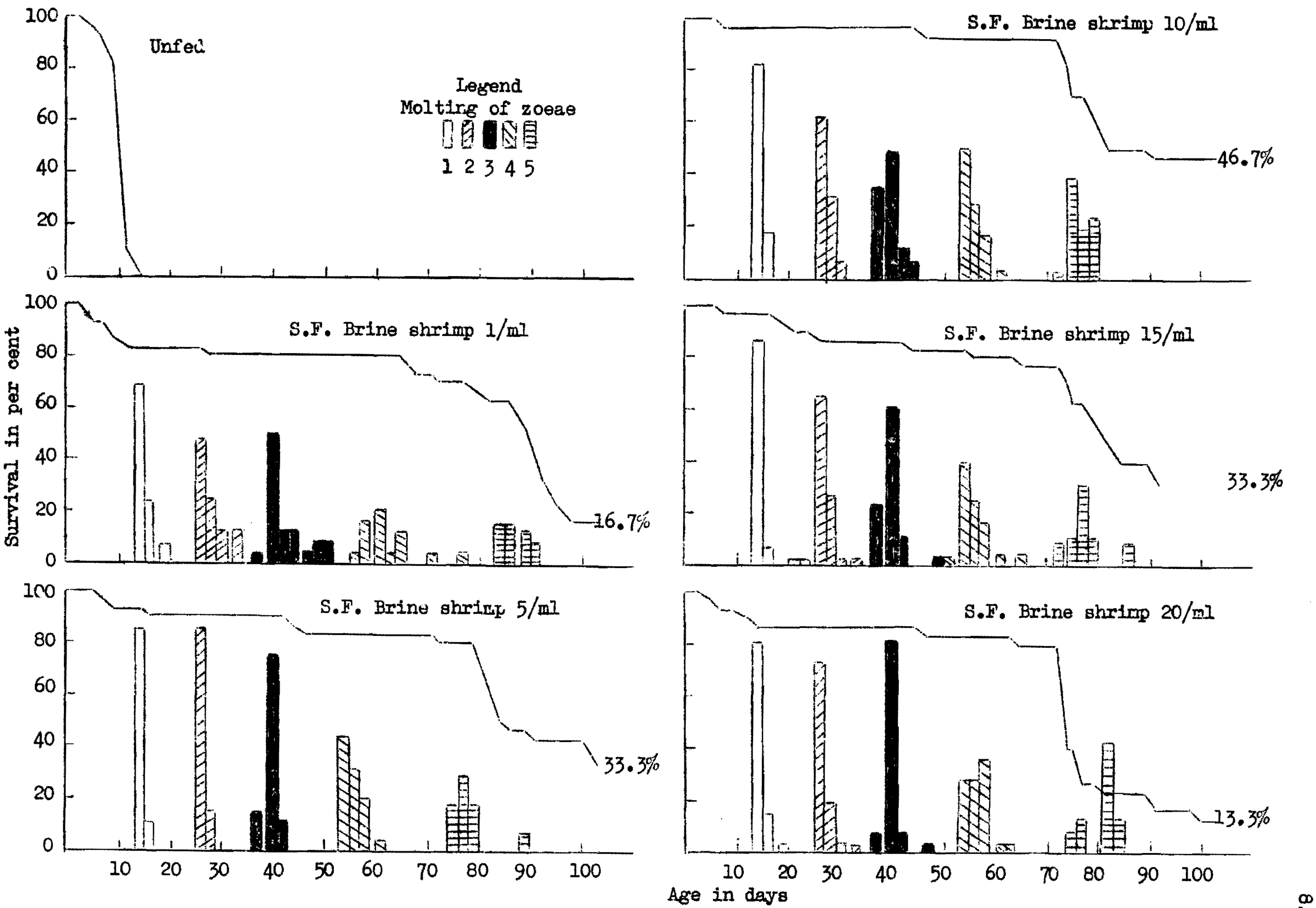



Figure 3. Survival of Dungeness crab zoeae (line) and molt of survivors (histogram) at various food concentrations

(day 72) whereas a diet of 1 per ml delayed molting until day 84. On day 109, the first of two megalopae, both fed at a diet concentration of 5 per ml, molted into post larval crabs.

Average size and range in size of the megalopae measured from tip of rostral spine to tip of telson when fully extended are shown in Table 1 by diet concentration. The average size of the megalopae fed at diet concentrations of 1, 5, 10, 15 or 20 brine shrimp per ml were 7.32, 8.25, 8.46, 8.45 and 7.82 mm in length, respectively. Megalopae collected from Yaquina Bay were about 11 mm long.

Effects of crab larval concentrations on survival

Survival of crab larvae, reared at the same diet concentration of five brine shrimp per ml of rearing water but at two larval densities (5 and 11 zoeae per flask) after 77 days of rearing, was 80.0 and 9.6%, respectively (Figure 4). Crab zoeae raised at a concentration of 11 per flask experienced a gradual but steady mortality through the second molt (day 26) followed by a significant increase in mortality through the next two molts. No zoeae in this group molted into the megalops stage. Survival of zoeae reared at 5 per flask was characterized by irregular periods of light mortality throughout the zoeal period with several coincidental with time of molting. An accelerated mortality, attributed to cannibalism, occurred for this group several days after the first occurrence of the megalopae.

Table 1. Size composition of Dungeness crab megalopae, by diet concentration, 1969

| Diet concentration | Size range (mm) | Average size (mm) |
|---|---|---|
| 1/ml | 6.65-8.25 | 7.32 |
| 5/ml | 7.85-8.65 | 8.25 |
| 10/ml | 8.25-8.91 | 8.46 |
| 15/ml | 7.98-9.04 | 8.45 |
| 20/ml | 7.45-8.25 | 7.82 |

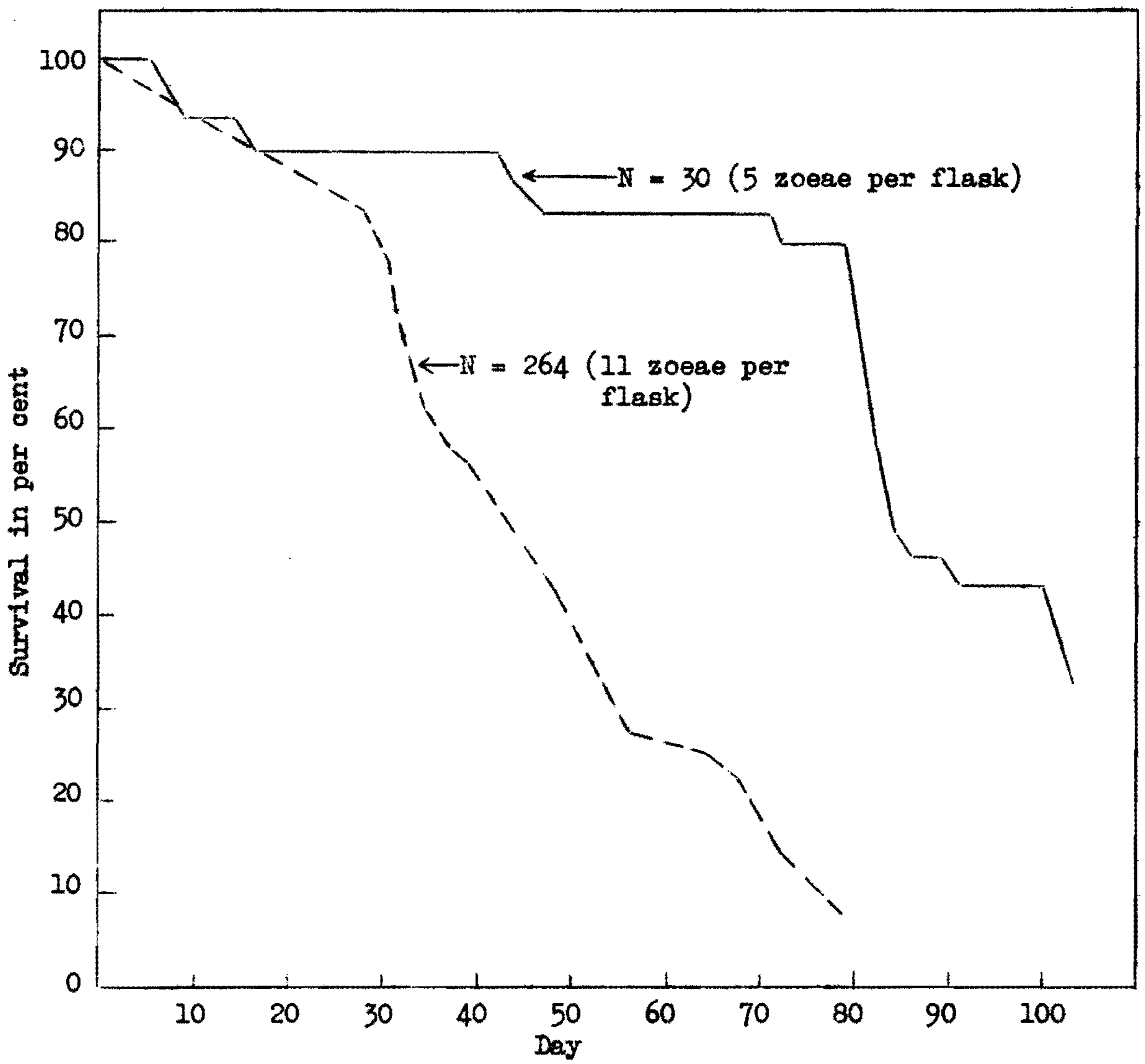



Figure 4. Survival of Dungeness crab larvae at two different larval concentrations

Effects of diet concentration on cannibalism

A decrease in survival of crab larvae following the appearance of the megalops is partially attributed to cannibalism. To determine the significance of cannibalism, survival of crab larvae reared individually and at densities of 3 to 5 per flask and fed the same diet concentration of 1, 5, 10, 15 or 20 brine shrimp per ml was compared. All mortalities observed were classified as results of cannibalism although natural mortality and cannibalism could not always be differentiated.

Survival of crab megalopae, after 32 days of observation, was higher at each diet concentration for larvae held singularly than for those reared together (Figure 5). Highest and lowest survival rates recorded for megelopae held individually was 78% (fed 5 brine shrimp per ml) and 50% (fed 1 and 20 brine shrimp per ml). Survivals of 42 and 0% (fed 10 and 20 brine shrimp per ml, respectively) were demonstrated for megalopae reared in a group. The poorest survival at the highest diet concentration indicates that the crab larvae were receiving a sufficient diet but were possibly overcrowded. This was partially substantiated by the low survival experienced with crab larvae fed 20 brine shrimp per ml in the diet concentration study (Figure 3).

Effects of light intensity on the swimming behavior of crab larvae

Results of the tests showed that fifth stage zoeae exhibited a wide range in sensitivity to the three light intensities tested. A general inverse relationship occurred between light intensity, and time and the distance swam before the zoeae reached the bottom of the light chamber. At a light intensity of 25 ft-c, the zoeae required an average of 21.0 seconds and swam towards the light (positive movement) a distance

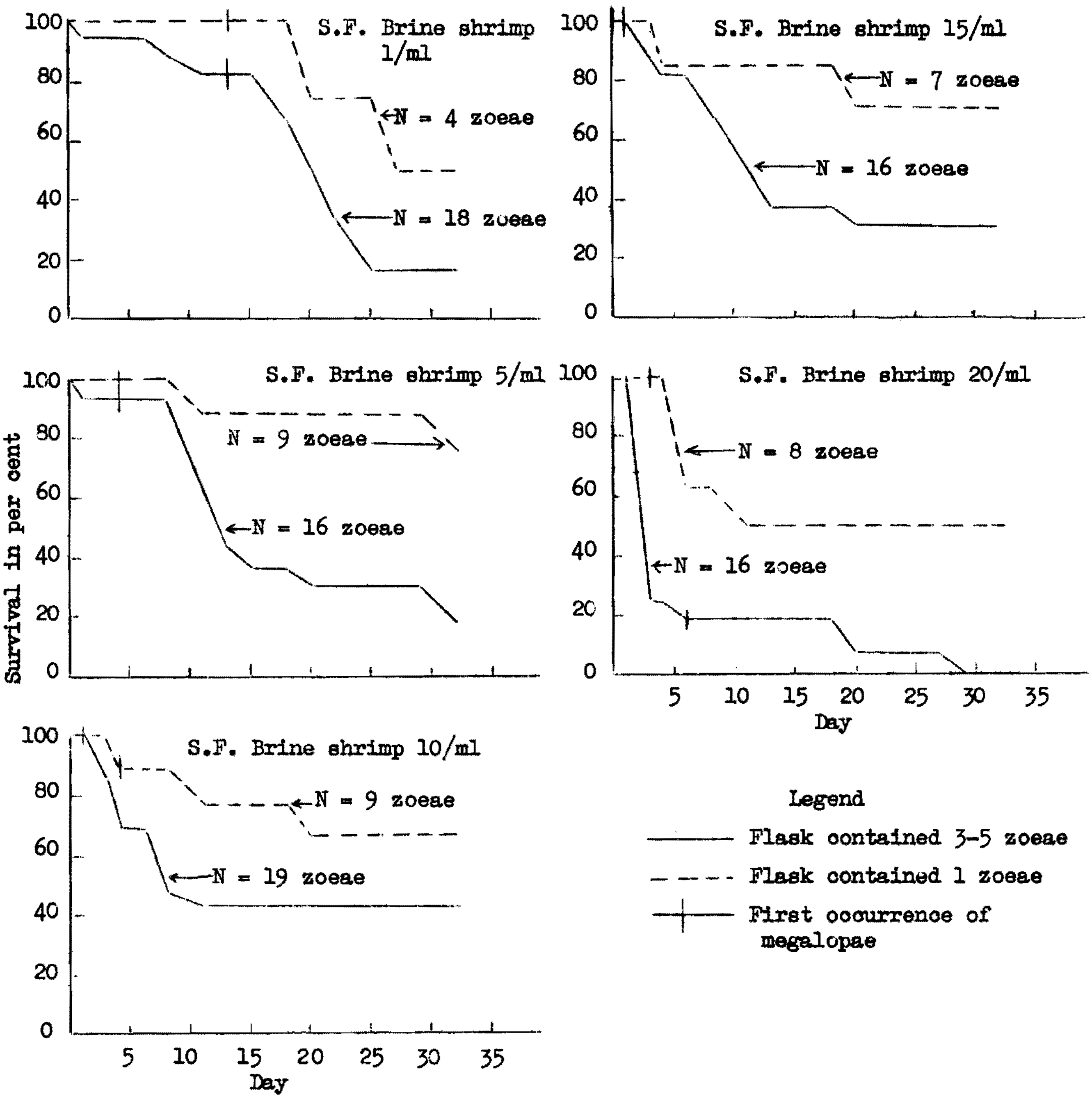



Figure 5. Effect of cannibalism on survival of Dungeness crab zoeae by diet concentration

of 7.3 cm before they reached the bottom (Table 2). Zoeae subjected to 990 ft-c took 19.6 seconds and had a positive swimming movement of 2.8 cm before reaching the bottom.

Table 2. Summary of the effects of light intensity on swimming behavior of Dungeness crab zoeae

| Light intensity (ft-candles) | Time to reach bottom (sec.) | | Distance traveled to reach bottom (cm) | | Mean distance traveled by time (cm) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Minutes | | | | | |
| | Range | Ave. | Range | Ave. | 1 | 2 | 3 | 4 | 5 | Total |
| 25 | 5-105 | 21.0 | -3-+100 | +7.3 | 14.2 | 4.3 | 10.5 | 8.2 | 6.3 | 43.5 |
| 340 | 5-88 | 20.1 | -3-+65 | +7.2 | 6.6 | 8.2 | 9.5 | 9.5 | 7.5 | 41.3 |
| 990 | 5-40 | 19.6 | -2-+10 | +2.8 | 5.1 | 8.8 | 4.5 | 10.0 | 6.6 | 35.0 |

The maximum mean distance traveled by the zoeae (14.2 cm) occurred during the first minute of observation at a light intensity of 25 ft-c (Table 2). The minimum mean distance traveled (4.3 cm) was recorded during the second minute of observation at the same light intensity. The zoeal movement for each minute of observation was generally sporadic at each light intensity.

Figure 6 shows that an inverse relationship occurred between light intensity and cumulative average distance traveled by the zoeae. The cumulative reaction to light by the zoeae was generally similar at all three light intensities. At the end of 5 minutes zoeae subjected to 25 ft-c of light had a positive movement of 43.5 cm while those at 990 ft-c had swum 35.0 cm towards the light.

Swimming speed of the zoeae at each light intensity was generally sporadic during each of the periods of observation (Figure 7). During the first minute, zoeae confronted with 25 ft-c of light exhibited the strongest attraction and swam at an average speed of 2.37 mm per second

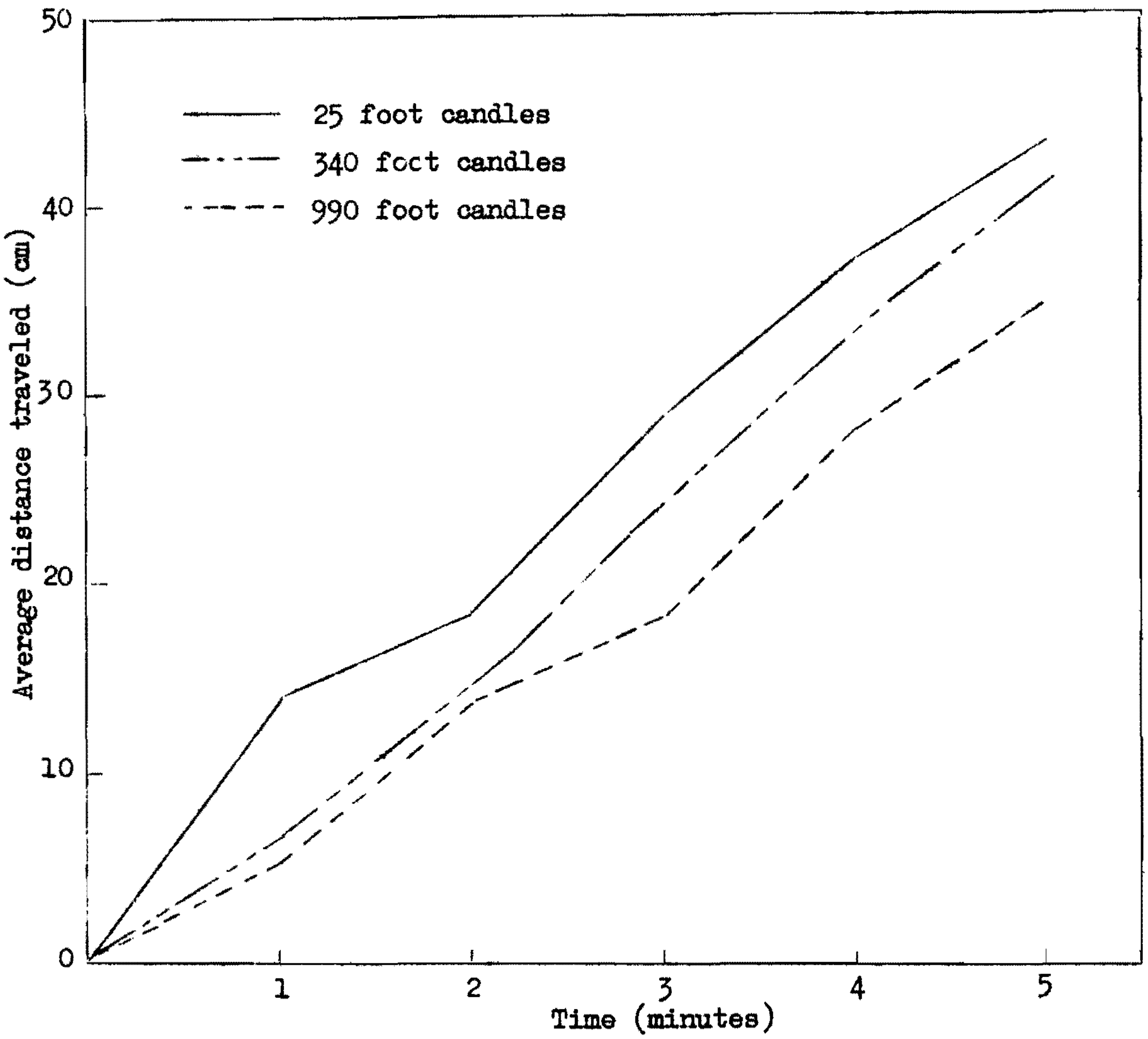



Figure 6. Average total distance traveled by fifth stage Dungeness crab zoeae at 1-minute intervals by light intensity

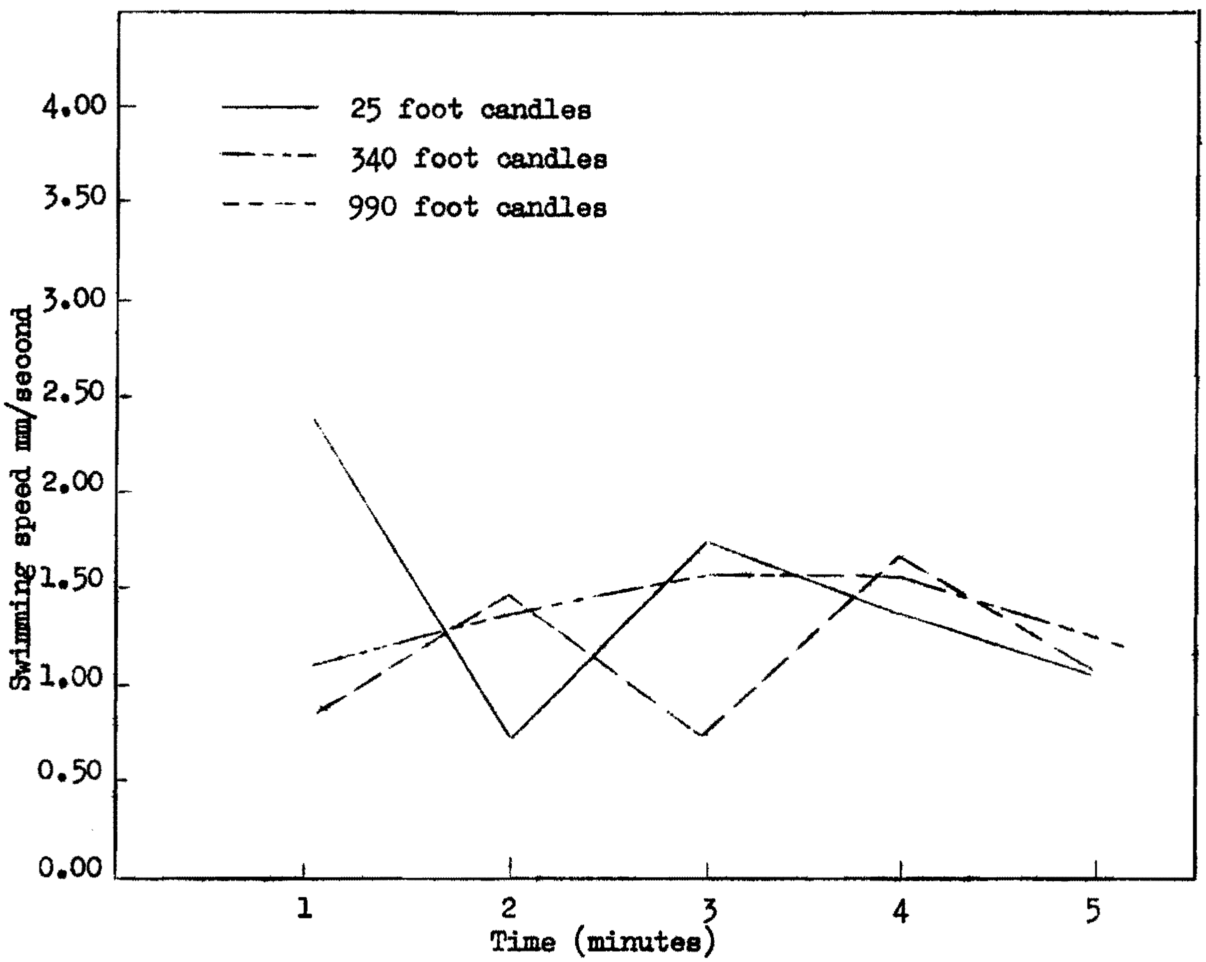



Figure 7. Average swimming speed of fifth stage Dungeness crab zoeae in each of five 1-minute periods by light intensity

while those subjected to 990 ft-c were attracted the least (0.85 mm per second). Swimming behavior progressively approached uniformity throughout the observation period until at the end of 5 minutes a reduction in swimming speed was observed at all three light intensities and the difference in speed was only 0.20 mm per second.

<u>Effects of water current on the swimming behavior of crab larvae</u>

Crab zoeae, subjected to a light intensity of 66 ft-c and a water velocity of 2.1 cm per second, generally exhibited no positive response after release into the swimming chamber but instead drifted with the current until they settled to the bottom. This generally required less than 1 minute. After settling to the bottom, most of the zoeae remained in position throughout the 5-minute observation period. One zoeae, after settling to the bottom below the point of release, started to actively swim against the current in short bursts and after 197 seconds had swum 65 cm (3.3 mm per second average speed).

Zoeae subjected to 66 and 155 ft-c of light and 4.21 cm per second current were swept out of the swimming chamber within 1 minute of release.

## SUMMARY

Dungeness crab larvae were fed San Francisco brine shrimp at concentrations of 1, 5, 10, 15 or 20 per ml. Survival after 103 days of rearing was highest and lowest when fed at diet concentrations of 10 and 20 brine shrimp per ml, respectively. Mortality was most significant during the megalops stage.

Time of molting was shortest when zoeae were fed at a concentration of five brine shrimp per ml. Molting of the first through fifth zoeal stages and megalops stage first occurred on the 14th, 26th, 37th, 51st,

72nd and 109th days, respectively. Megalopae were largest (8.46 mm) when fed at a diet concentration of 10 brine shrimp per ml.

Survival of zoeae, reared 77 days at a concentration of 5 and 11 per flask, and fed five brine shrimp per ml was 80.0 and 9.6%, respectively.

Cannibalism by the megalopae on zoeae and other megalopae was documented at all diet concentrations.

Fifth stage crab zoeae were subjected to 24, 340 and 990 ft-c of light and their behavior recorded. An inverse relationship was evident between light intensity, settling out time, and distance covered by the zoeae. Swimming speed was sporadic at each light intensity.

Crab zoeae, when subjected to water current, using light as an attractor, generally exhibited no positive response. General behavior was to settle to the bottom and remain in that position throughout the 5-minute observation period.

## LITERATURE CITED

Reed, P. H., 1966. Controlled rearing of Dungeness crab larvae and the influence of environmental conditions on their survival. Commercial Fisheries Research and Development Act Progress Report, November 16, 1965, to June 30, 1966. Fish Commission of Oregon Processed Report, 10p.

Reed, P. H., 1967. Controlled rearing of Dungeness crab larvae and the influence of environmental conditions on their survival. Commercial Fisheries Research and Development Act Progress Report, July 1, 1966, to June 30, 1967. Fish Commission of Oregon Processed Report. 12p.

Reed, P. H., 1968. Controlled rearing of Dungeness crab larvae and the influence of environmental conditions on their survival. Commercial Fisheries Research and Development Act Progress Report, July 1, 1967, to June 30, 1968. Fish Commission of Oregon Processed Report. 10p.