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Effect of temperature on development of embryos and hatching of the eggs of deep sea prawn (Pandalus borealis KRØYER).

By

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INTRODUCTION

The deep sea prawn is off the southern part of Norwegian waters close to its southern border of distribution, and is there found on depths below 100 meter where the temperature usually is 5-8°C. In some areas the deep sea prawn is also fished where the temperature in certain periods may rise to 11°C. ALLEN (1959) asserted that off the Northumberland, the deep sea prawn is distributed and breed in areas where the temperature usually is 11°C.

RASMUSSEN (1953) has given a comprehensive description of the geographic variation of spawning time and duration of the embryonic development in Norwegian waters.

In the southern Norway, the prawns develop to sexually mature males 1 1/2 years old (September-October) and function as mature females one year later. The prawns may function as females 2-3 years. The spawning takes place mainly in October. The females bear the eggs on their pleopods until February when the eggs start hatching.

Though the data for prawns in the sea indicates a connection between development rate and sea temperature, there seems to be no quantitative data.

In connection with plans for construction of power plants using sea water in the cooling processes, experiments for studying effects of heated sea water on marine fish and shellfish were performed.

Even if the discharge of heated sea water will be at the sea surface, periodic increase in temperature also in the deep water may occur more frequently at some alternative power plant sites in the Oslo Fjord area (ANON, 1975).

In this paper will be presented some results of an investigation on temperature effects on development rate and hatching of eggs of deep sea prawns. The investigation were performed in the period November 1974 - April 1975 at Biologisk Stasjon Flødevigen.

MATERIAL AND METHODS

Eggbearing prawns were fished with a commercial trawler 5. November in Gråholmdypet (SW of Torungen, Arendal) on 150 m depth. Only prawns which were undamaged and viable were selected to the experiment. For each of 6 experimental tanks were at random selected 147-160 prawns. Measurements showed that the size distribution were uniform.

Due to high temperature in the sea water intake, the temperature in the experimental tanks had to be lowered gradually according to the intake water. At 4. January the temperature were finally set to 11, 10, 9, 8 and 7°C. There were two experimental groups (controls) at 7°C. The mean value of the three lowest temperatures for the entire experiment were 0.3-0.5°C higher than noted on the figures and in the text. The temperature in the tanks were controlled and recorded twice a day.

Every day dead prawns were removed from the tanks, the length measured and the number (amount) of eggs on the pleopods estimated: full of eggs: 1, half-full: 1/2, no eggs: 0. From February and onwards, once a week the amount of eggs on all live prawns were estimated in the same way.

Every 10-14. day were taken samples of eggs from the prawns. From 50 prawns chosen at random in each group, were taken one egg from each prawn. The eggs were measured for total length and width, length and width of the eye spot. With the intention to characterize the egg development, they were grouped in different stages.

As done by PERKINS (1972) for Homarus americanus, were calculated the eyeindex:

$$\text{eye index} = \frac{\text{length of eye} + \text{width of eye}}{2}$$

This is used as an index of embryonic development. The eye spot is convenient to measure because it is dark pigmented and is in good contrast to the other parts of the embryo.

The water outlet of the tanks were arranged so that the newly hatched larvae drifted with the current to a separate box. There they were concentrated by the use of light and collected and counted every day.

To compare the experimental data with the egg development from prawns in the sea, were taken samples of eggs from prawns in the Gråholmdypet. In this paper, only some of the results will be presented.

RESULTS

Development of the embryos

The egg size increased evenly until the hatching. However, there were no significant difference between the experimental groups. The eye index (Fig. 1) also increased evenly, though the rate decreased when the development approached the hatching. The difference between the experimental groups were statistically not significant, apart from the lowest temperature (7°C) where the eye spots were smaller, i.e. the embryos required more time to attain the same developmental stage. The development of the eggs on prawns in the sea were at the same time significant smaller.

The distribution of development stages in the different temperatures showed little effect of temperature. This may be due to improper definition of the stages.

"Day degree" is an expression for sum of heat (energy), i.e. the sum of the temperatures observed each day and then in turn an expression for mean temperature. The day degrees were calculated from 12. December when the highest temperature reached 11°C. For the mean eye index at the different observation dates, is calculated the regression lines against the day degree (Fig. 2).

Fig. 2 shows that the eye index as a function of temperature increased more at lower temperature than at higher. This support the view that the prawns (i.e. embryos) are evolutionary more adapted to the lower temperatures.

Hatching of the larvae

Every week during the hatching period were estimated the number of eggs on the surviving prawns. The data shows that the prawns in the highest temperature first "lost" their eggs. The first newly hatched larvae were recorded on the 25. January in 10 and 11°C (Fig. 3). At the other temperatures the larvae appeared from 26.-28. January. The number of larvae recorded at the different temperatures variated from day to day, especially at 7°C (O).

The data shows that there were recorded relatively few larvae in the highest temperatures. The highest numbers were found in 8°C and one of the two groups at 7°C.

Figure 3 indicates that the hatching time were accelerated with increasing temperature. The data when half of the larvae at each temperature had been hatched were:

7°C (L):	22. February
7°C (O):	22. February
8°C	18. February
9°C	16. February
10°C	14. February
11°C	6. February

So, the hatching were at an average accelerated up to 16 days. The data also shows that the duration of the hatching period to some extent decreased with increasing temperature. The period when 95% of the larvae were hatched were:

7°C (L)	1. February - 11. March	38 days
7°C (O)	5. February - 11. March	34 days
8°C	3. February - 4. March	30 days
9°C	28. January - 28. February	32 days
10°C	27. January - 28. February	33 days
11°C	25. January - 21. February	28 days

The data shows that totally there were recorded relatively few newly hatched larvae in the highest experimental temperatures. The numbers were:

7°C (L)	:	16469
7°C (O)	:	45240
8°C	:	48438
9°C	:	26959
10°C	:	5439
11°C	:	7170

This will be discussed later.

Survival of the female prawns

In Fig. 4 is shown the survival of the female prawns. The lines is calculated from statistical calculated equations. Although there is a marked mortality of the prawns also in the "normal" temperature (7°C), there is an obvious temperature effect as the survival decreases with increasing temperature. At 11°C no female prawn survived the hatching period. At 8°C only 30% of the prawns survived. The mortality to some extent increased during the hatching period, apart from the prawns in 11°C that showed a linear mortality. Data not presented here, shows that at the lowest temperatures, most of the females hatched their eggs prior to death. At 11°C died about 50% of the prawns before their eggs were hatched.

DISCUSSION

As mentioned earlier, constant water temperature and difference in temperature between the experimental groups could not be established during the entire experimental period. This may have caused that the difference in temperature effect on the developmental rate of the embryos were too small.

The size distribution of the prawns selected for the experiment indicates that the prawns consisted of 3-4 year classes of age 1.5-4.5 years.

RASMUSSEN (1953) found that a marked natural mortality takes place among the females after they had spawned the first time (usually at age 2 1/2 year). Taking into consideration also possible laboratory "stress", it is obvious that the observed mortality only partly is due to the temperature level. However, the difference in mortality is expected to be a temperature effect.

By using the day degree, is attained quantitative expression for growth efficiency at different temperature levels. The differences in the present material for eye index is small. However, there is a tendency that growth and development rate per day degree is somewhat higher at 7-8°C than at 10-11°C. From this it may be concluded that 10-11°C implies physiologically stress to the prawn embryos. This aspect would possibly have been more pronounced if the experiment with different temperatures had started earlier, i.e. just after the spawning.

From the relation between prawn size and numbers of eggs, size distribution of prawns, numbers of surviving prawns, amount of egg on live and dead prawns, has been calculated where the eggs from the spawning has gone to. Fig. 5 shows that at 11°C, about 70% of the eggs were lost due to the mortality of the ovigerous prawns. Ca. 27% of the eggs disappeared in another way and only 2.7% were hatched. At the lower temperatures, the percentage of eggs removed with died prawns decreased. On the other hand, the numbers of eggs with unknown fate was very high. Though this, the highest percentage of completed development and successfull hatching were recorded in 7 (0) and 8°C.

Though they were not counted, very few unhatched eggs were found on the bottom in the tanks. BERKELEY (1930, 1937) has mentioned that successfull hatching depends on that the female prawn keep their eggs on the pleopods and continuously provides the eggs with fresh sea water. This is confirmed by the present author.

It is concluded that continual increased temperature above the prawn ground, may accelerate the hatching period. In addition, increased temperature, say 10-11°C, may cause increased mortality on the ovigerous prawns which in turn will result in heavy loss of fertilized eggs. Whether effects on recruitment and stock of the prawns may be distinguished as effects of increased temperature, will presumeably depend on the level of the natural mortality and the fishing mortality of the stock in the area. Migration of prawns from other areas into the affected water may also diminish the temperature effect.

SUMMARY

The effect of temperature on the development rate of embryos were small. Significant difference occurred between eggs at 7 and 11°C.

The hatching period was 2 weeks shorter and 2 weeks accelerated at 11°C compared with 7°C.

The mortality of the female prawns during the ovigerous period were dependent of the temperature: 40% at 7-8°C, at 9-10°C still higher and at 11°C close to 100%.

During the experiment 20-70% of the eggs were lost from the death of the ovigerous prawns, highest percentage in 11°C, lowest in 7°C. A high portion of the eggs disappeared, presumably because they loosened from the prawns. This phenomenon were most pronounced at 7°C when the prawns had the longest survival.

Of the calculated number of eggs after the hatching, only 2% (at 11°C) to 19% (at 8°C) of the eggs were hatched.

REFERENCES

ALLEN, J.A. 1959. On the biology of Pandalus borealis KRØYER, with reference to a population off the Northumberland coast. J.mar.biol.Ass.U.K., 38: 189-220.

ANON. 1975. Termiske Kraftverk i Oslofjordområdet. Resipient-vurderinger. Fiskeridirektoratet Havforskningsinstitutt, Vassdrags og Havnelaboratoriet, Norsk Institutt for Vannforskning.

BERKELEY, A.A. 1930. The post embryonic development of the common Pandalids of British Columbia. Contr.Can.Biol. Fish. NS 6 (6): 79-163.

BERKELEY, A.A. 1937. Hatching and rearing Pandalid larvae. p. 231-232 in NEEDHAM, J.G. et al. ed. Culture methods for invertebrate animals. Dover Publications Inc.N.Y.

PERKINS, H.C. 1972. Development rates at various temperature of embryos of the northern lobster (Homarus americanus MILNE-EDWARDS). Fish.Bull.Natl.Oceanic. Atmos.Adm. (Seattle) 70 (1): 95-99.

RASMUSSEN, B. 1953. On the geographical variation in growth and sexual development of the deep sea prawn (Pandalus borealis Kr.) FiskDir.Skr.Ser.HavUnders., 10 (3): 1-160.

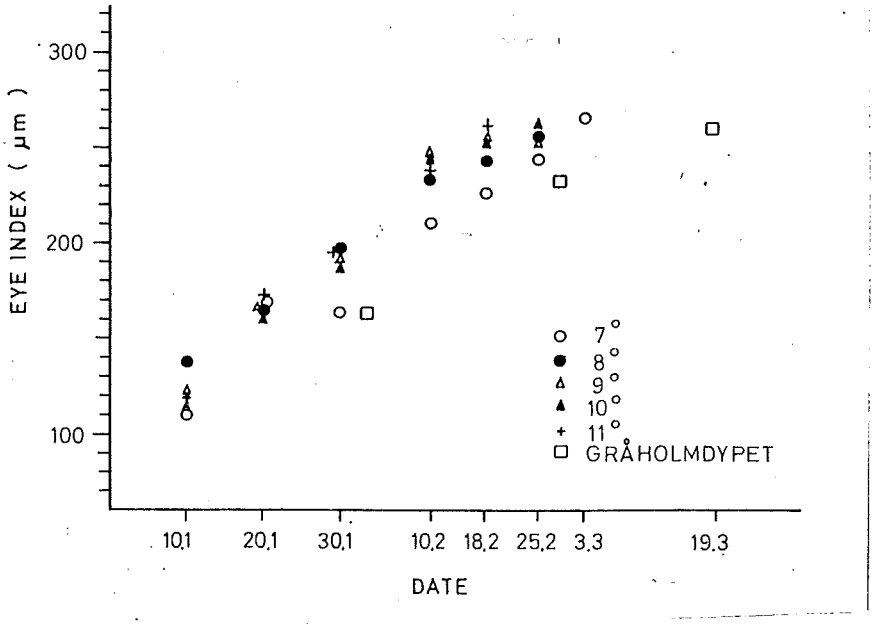

Fig. 1. Eye index of embryo at the experimental temperatures (°C).

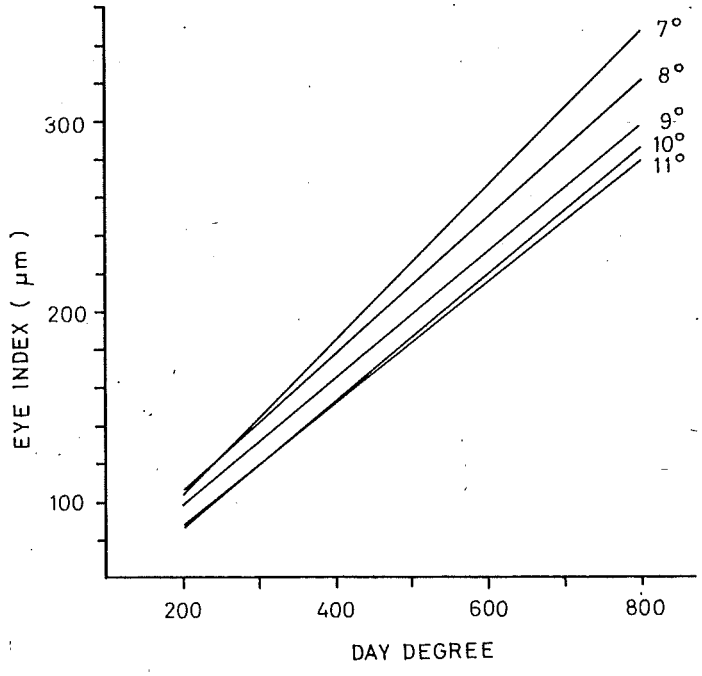

Fig. 2. Regression lines for eye index of embryo against the number of day degrees at the experimental temperatures.

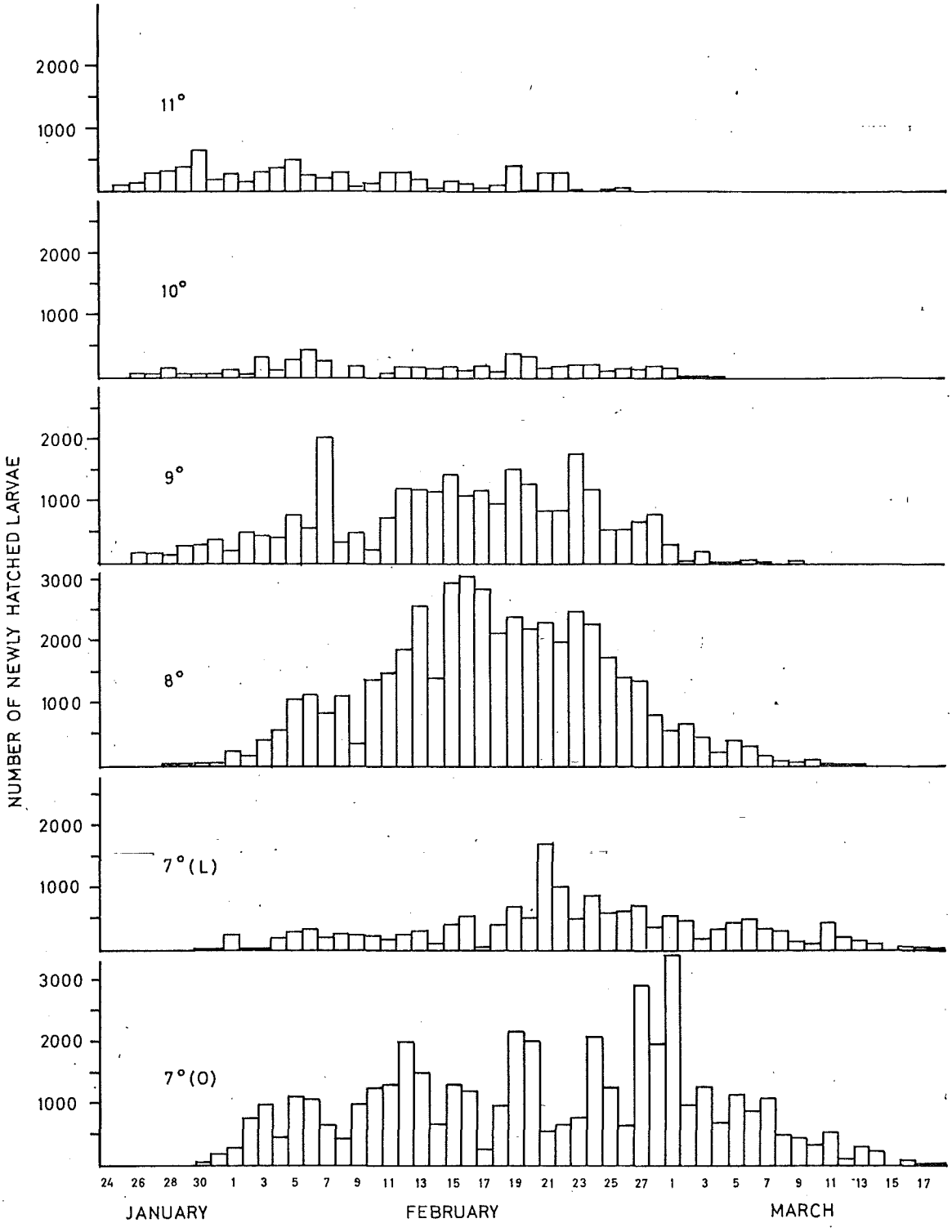

Fig. 3. The number of newly hatched larvae recorded each day at the experimental temperatures.

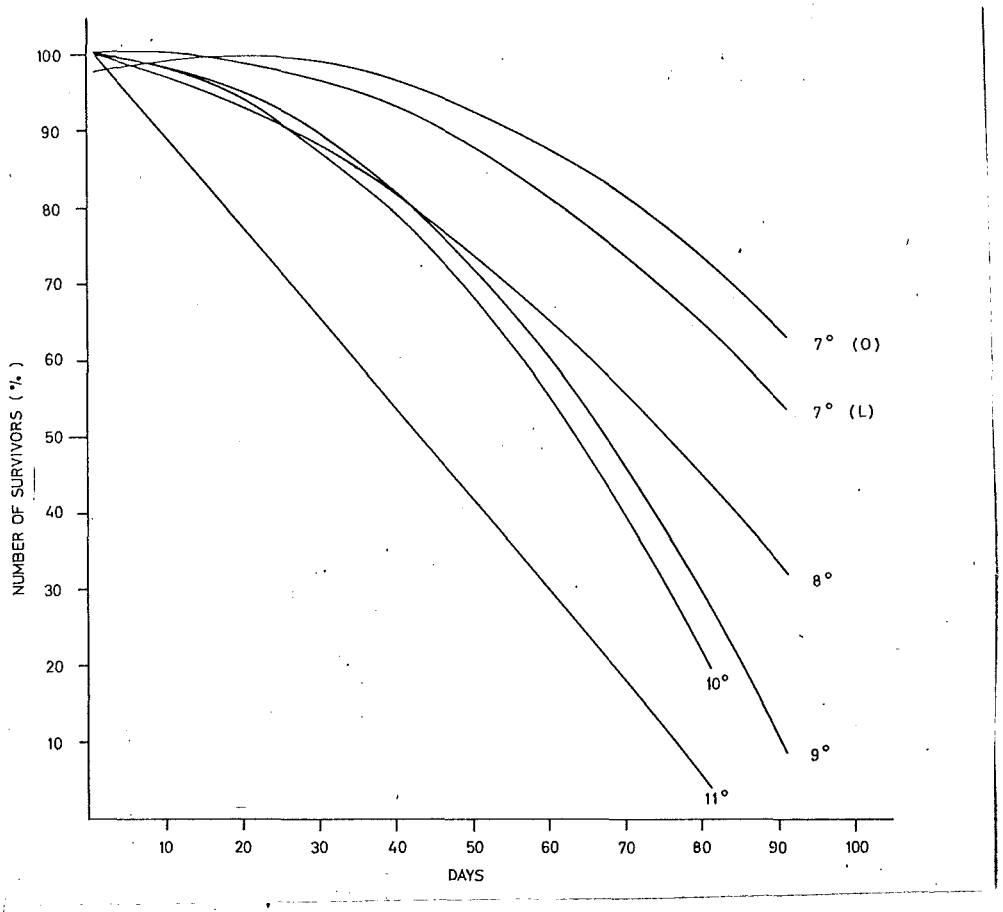

Fig. 4. Survival of female prawns at the experimental temperatures, given as percent of the number of prawns 12. December. The lines are drawn from statistical calculated equations.

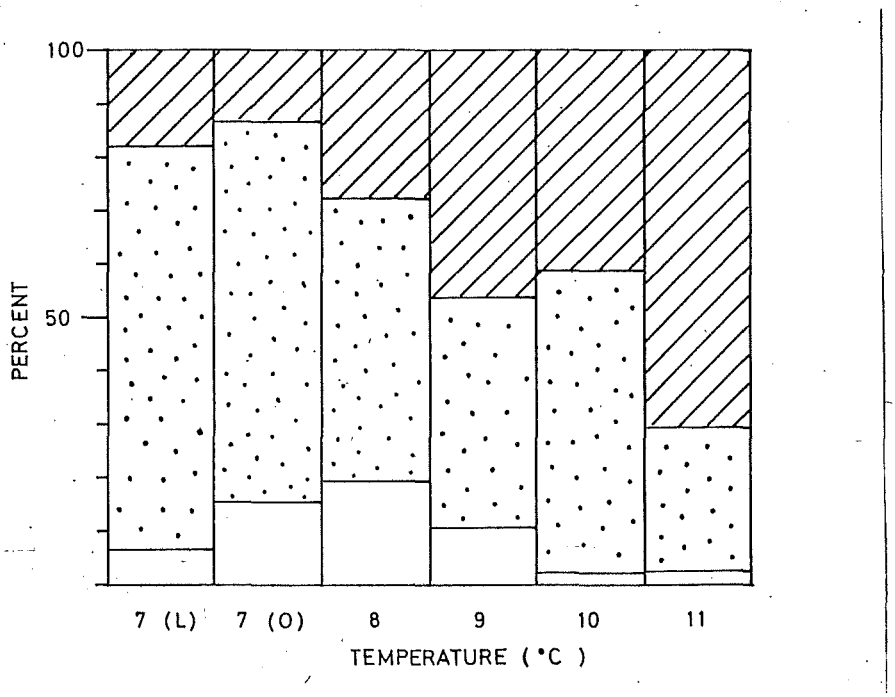

Fig. 5. The "fate" of the prawn eggs, given as percent of the calculated total number at start of the experiment (12. December): striped: lost with dead prawns, dotted: fallen off the prawns, or died on live prawns, open: successfull hatching, recorded as 1. stage larvae.