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The Effect of Temperature on Growth, Survivial and Oxygen Consumption of Larvae and Post-larvae of *Paralithodes brevipes* (Decapoda: Anomura)

TAKASHI NAKANISHI[1)]

Abstract

In order to study the effects of temperature on larvae and post-larvae of *P. brevipes* two types of experiments, growth test under conrtolled laboratory conditions and metabolic rate, were designed. With the growth test, −1.8°, 3°, 8°, 13° and 18° C were used as the experimental temperature. The growth rate was similar at 8°, 13° and 18° C. At 3° C, the rate was twice that at 8°, 13° and 18° C. At −1.8° C, larvae did not develope to Z 2. The survival ratio at Z 3 was 30-50% at 8° C, and this was the highest ratio in this experiment. Temperature had less influence on the oxygen consumption at Z 1 and G that at Z 2 and Z 3.

I. Introduction

Paralithodes brevipes is distributed in cold sea from Kushiro and Nemuro, Hokkaido to Chishima and Kamchastka. The fishery of this crab is limited only near Nemuro, but it is one of important fisheries in Hokkaido. The catch of this crab in Hokkaido declined from 1,875 tons in 1973 to 448 tons in 1978 (Hokkaido 1975, 1980).

This crab is distributed in shallower and more limited areas than another one of the same genus, the king crab (*Paralithodes camtschatica*). Larvae of *P. brevipes* hatch out near Nemuro in the same season as the king crab, from late March to middle April. MARUKAWA (1933) reported on this carb and described the zoea, glaucothoe and young crab stages. KURATA (1956) reared this carb from egg to the first young crab stage in a laboratory and described the larval stages.

There have been a lot studies about the effects of temperature on larvae of crabs. However, concerning the larvae of this crab, there is still little information (KURATA 1956). In this study, the survival ratio, growth rate and oxygen consumption were measured and the effects of temperature on them are discussed. Temperature is one important factor rearing larvae and post-larvae of crabs.

I wish to express my hearty thanks to Dr. Y. ITAZAWA of Kyushu University for his kind advice and criticism on reading the manuscript. I am also indebted to the Nemuro Fisheries Co-operative Association, Hokkaido, especially to Mr. H. KAHATA and Mr. M. SUZUKI, for their providing of egg-bearing female crabs.

[1)] Japan Sea Regional Fisheries Research Laboratory, Suido-cho, Niigata 951, Japan
(〒951 新潟市水道町1丁目5939—22 日本海区水産研究所)

II. Materials and methods

In order to study the effects of temperature on larvae and post-larvae of *P. brevipes*, two types of experiments, growth test under controlled laboratory conditions and determination of metabolic rate, were designed. The experiments were carried out from March to June, 1978, at the Hokkaido Regional Fisheries Research Laboratory, Kushiro, Hokkaido.

Egg-bearing females were caught near Nemuro by crab-pots in Octorber, 1977. These females were transported to the laboratory and cultured in a tank (1×2×0.7m). They were fed on sardine, squid and shrimp. The water temperature was controlled at under 3° C. The larvae that had hatched out during a short period were used to get an equal level of growth rate.

The growth experiment was carried out in polyethylene tanks (47×30×20 cm) with 5 *l* sea water (S=32−33‰). These tank were placed in rooms of constant temperatures of −1.8°, 3°, 8°, 13° and 18° C. The daily means of temperature are shown in Fig. 1. At each temperature, four tanks were used, two with 20 zoeae and other two with 40 zoeae. Residual food and moulted shells were removed once a day. The water was not aerated but the oxygen saturation was usually over 90%. The zoeae were fed on *Artemia salina* nauplii, with about 2,000 nauplii for each tank, once a day. When 50% of the zoeae in each population developed to the next stage, the former stage was regarded as terminated.

The oxygen consumption was determined by measuring the change of oxygen concentration in the water in a closed syringe. The experiments were carried out at 3°, 8°, 13° and 18°C, with the zoeae used in the growth test at the same temperature. The zoeae were placed in 2 *ml* syringes placed in a water bath controlled at the required temperature. Two samples of water (about 0.2 *ml* each) were taken from the syringe at zero time and two more samples at 30 minutes to 2 hours later, depending on the temperature and the developmental stage. The oxygen concentration of water samples was calculated from the oxygen pressure determined with an oxygen electrode (Instrumentation Laboratory Co.). In each test, 5 syringes were used, each containing a single larva.

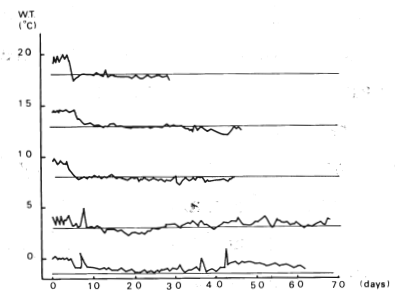

Fig. 1. The daily means of water temperature.

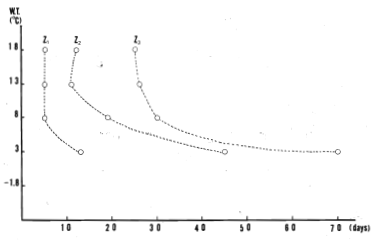

Fig. 2. The effect of water temperature on terms (days) required for each stage.

The carapace length and body weight of larvae and post-larvae were measured. For this study, the larvae were reared in a tank (1 m in diameter with 1 m depth) with running seawater at a rate of 1 *l*/minute. Glaucothoe larvae were reared in a net-cage, also being fed on *Artemia salina* nauplii. The water temperature was 5–7° C. Ten zoeae and 5 glaucothoe were sampled daily and stored in a −30° C refrigerator. The carapace length was measured with an ocular micrometer. The wet-weight of larvae was measured after removing the water from the body surface as much as possible, and dry-weight after vacuum drying at 60° C.

III. Results

The zoeal stage is abbreviated as Z and the glaucothoe stage as G. The effects of temperature on terms (days) required during each larval stage of *P. brevipes* are shown in Fig. 2. At −1.8° C, no larvae developed to Z 2. At 3° C, the term from Z 1 to G was 70 days, this was about twice those at 8°, 13° and 18° C. Terms from Z 1 to Z 2 at 8°, 13° and 18° C were similar. But the term from Z 2 to Z 3 at 8° C was about twice those at 13° and 18° C and the term from Z 3 to G at 8° C was shorter than those at 13° and 18°C. The logarithms of terms plotted against the logarithms of temperature are shown in Fig. 3. Terms are related to temperature by the following equation during zoeal stages without 18° C. $Y=146.77X^{-0.6800}$ ($r=0.9994$, $n=3$, $p<0.05\%$).

The survival ratios of larvae and post-larvae under the different temperature conditions are shown in Fig. 4. At zoeal stages, the survival ratio in tanks with 20 zoeae was almost higher than that ratio in tanks with 40 zoeae. When the zoeal numbers were decreased, the zoeae were moved to two tanks 30 days later at 3° C and to one tank 33 days later at 8° C, 22 days later at 13° C and 20 days later at 18° C. At −1.8° C, ice covered the surface of these tanks many times but there was no visible effect of ice on the zoeae. The survival ratio decreased slightly with time after 12 days. No larvae developed to Z 2 and all larvae died 62 days later. At 3° C, the survival ratio decreased slightly with time until 25 days later. There were few deaths during Z 3. The survival ratio decreased during G and all post-larvae died

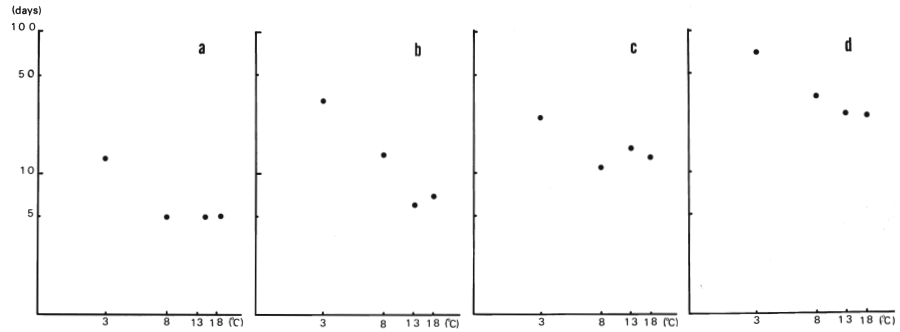

Fig. 3. Logarithms of terms (days) required for each larval stage of *P. brevipes* plotted against logarithms of temperature. a–Z 1, b–Z 2, c–Z 3, d–Z 1–3.

80 days later. At 8° C, the survival ratio decreased mainly during moulting. The survival ratio at Z 3 was 30–50% and this was the highest ratio in this study. All post-larvae were dead 44 days later. At 13° C, the survival ratio decreased gradually with time until 22 days later and all post-larvae were dead 44 days later. At 18° C, the survival ratio decreased gradually with time until 20 days later and all post-

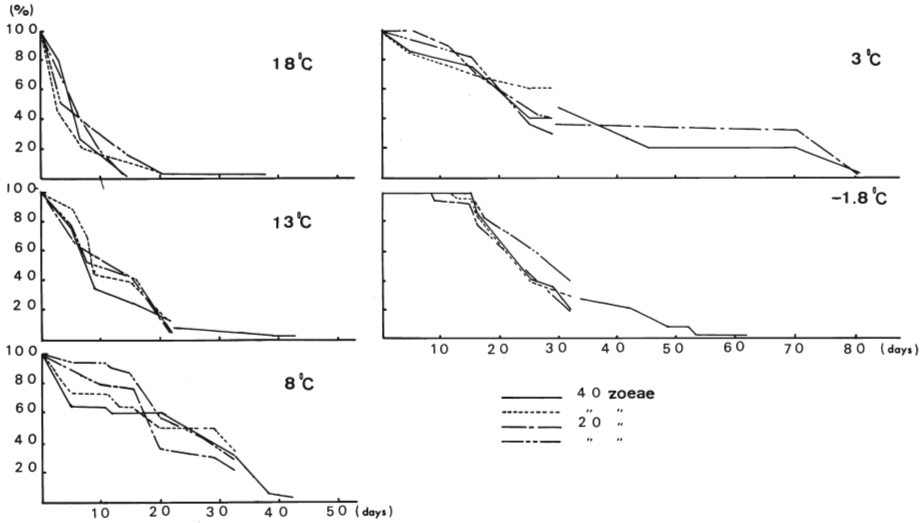

Fig. 4. Surivival ratio of larvae of *P. brevipes* at −1.8°, 3°, 8°, 13° and 18° C.

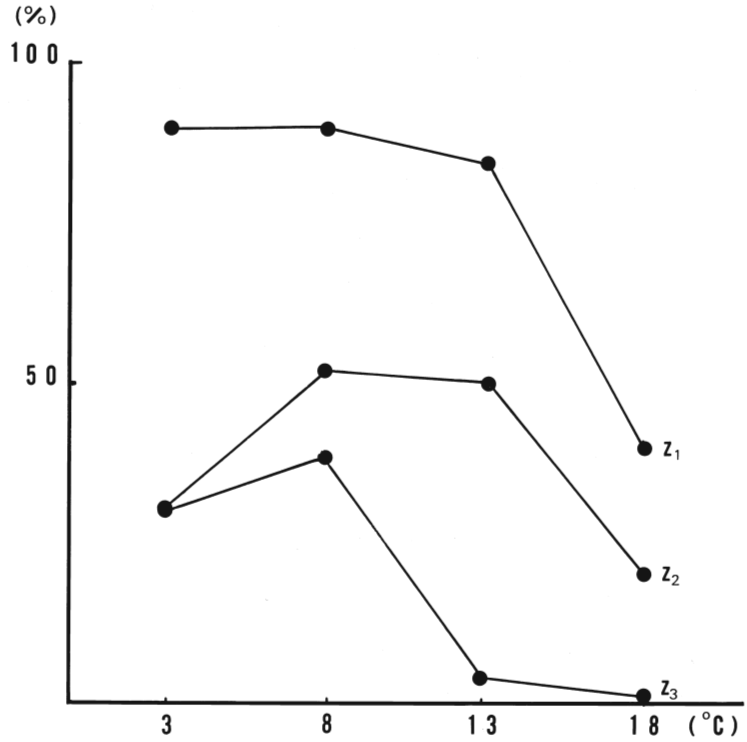

Fig. 5. The surival ratio at each stage of *P. brevipes*.

larvae were dead 30 days later. The survival ratios at each stage are shown in Fig. 5. These survival ratios at Z 1 at 3°, 8° and 13° C were 70–80% but 40% at 18° C. The ratios at Z 2 at 8° and 13° C were about 50%, but 30% at 3° C and 20% at 18° C. The ratio at Z 3 was 30% at 3° C and 38% at 8° C but was under 5% at 13° and 18° C.

The relationship between oxygen consumption and growth rate is shown in Fig. 6 and Table 1. The oxygen consumption at 8°, 13° and 18° C had peaks at 15–20 days later and decreased slightly after these periods. The maximum oxygen consumption was 3.0 μl/individual at 20 days later at 8° C. The relationship between oxygen consumption and the stages are shown in Fig. 7. The oxygen consumption at 3° and 8° C had peaks at Z 3 and those at 13° and 18° C had peaks at Z 2. The oxygen consumption at G was similar or less than that at Z 1. The relationship between oxygen cosumption and temperature is shown in Fig. 8. Temperature had less effect on oxygen consumption at Z 1 and G than at Z 2 and Z 3. Oxygen consumption at Z 2 and Z 3 peaked at 8°C.

The relationships between carapace length, wet body weight, dry body weight and water percent and the stages are shown in Fig. 9 a–d and Table 2. The carapace length and wet weight increased with growth, but did not change at G. At the middle of G, all glaucothoe were moved to the net-cage, but only two glaucothoe moulted to the first young crab stage. The relationship between carapace length and body weight from Z 1 to Z 3 was described by the equation

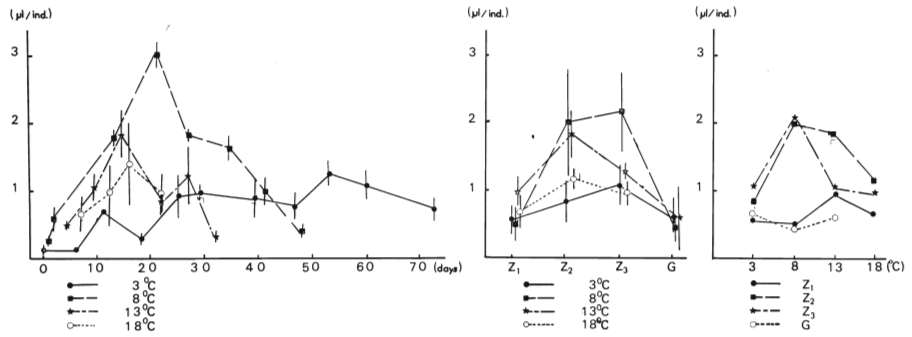

Fig. 6 **Fig. 7** **Fig. 8**

Fig. 6. The relationship between oxygen consumption and growth rate of *P. brevipes*. The vertical line is standard deviation.

Fig. 7. The relationship between oxygen consumption and stages of *P. brevipes*.

Fig. 8. The relationship between oxygen consumption and temperature of *P. brevipes*.

Table 1. The oxygen consumption of larvae and post-larvae of *p. brevipes*.

	3° C mean±s.d. n. (μl/hr., ind.)	8° C mean±s.d. n. (μl/hr., ind.)	13° C mean±s.d. n. (μl/hr., ind.)	18° C mean±s.d. n. (μl/hr., ind.)
Z 1	0.566±0.24 12	0.493±0.23 25	0.954±0.20 13	0.666±0.28 8
Z 2	0.809±0.30 25	2.006±0.86 11	1.837±0.32 8	1.157±0.55 14
Z 3	1.079±0.15 15	2.106±0.61 14	1.044±0.51 12	0.975±0.35 6
G	0.630±0.17 6	0.968±0.41 9	0.587±0.49 6	

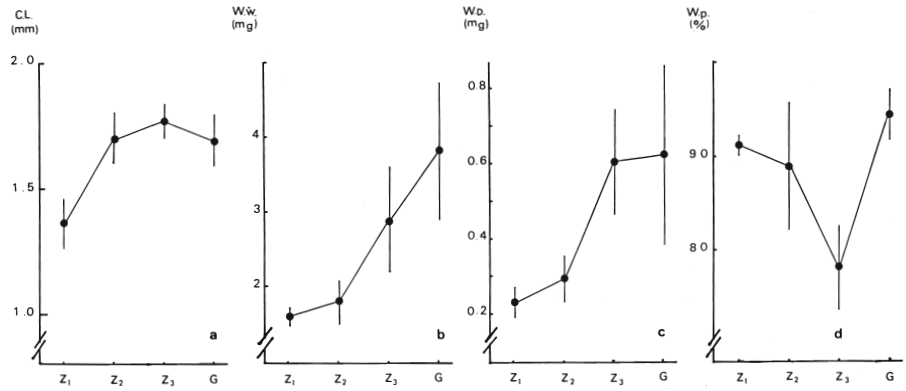

Fig. 9. The relationship between carapace length (a), wet weight (b), dry weight (c) and water percent (d) and stage of *P. bervipes*. The vertical line is standard deviation.

Table 2. The carapace length, wet weight, dry weight and water percent of larvae and post-larvae of *P. brevipes*.

	L. (mm)	n	W. w. (mg/ind.)	D. w. (mg/ind.)	Water percent (%)
Z 1	1.362±0.12	7	1.591±0.13	0.229±0.04	85.74±2.5
Z 2	1.692±0.10	10	1.819±0.29	0.288±0.06	84.18±2.7
Z 3	1.769±0.07	6	2.899±0.77	0.600±0.14	79.07±2.2
G	1.694±0.12	3	3.845±0.90	0.625±0.27	87.55±1.2

$W_w = 0.9246\ L^{1.654}$ ($r = 0.687$, $n = 23$, $p < 0.01\%$)

$W_d = 0.0945\ L^{2.567}$ ($r = 0.708$, $n = 24$, $p < 0.01\%$)

W_w = wet weight (mg), W_d = dry weight (mg), L = carapace length (mm).

IV. Discussion

The growth rate increased with temperature, but at 13° and 18° C this effect was not so great as that at 8° C. When the effect of temperature is discussed, especially on rearing larvae, a total effective temperature is useful. The relationship between total effective temperature and temperature is shown in Fig. 10. These totals during the whole zoeal life were about 220 at 3° and 8° C. These totals at each stage were similar 3° and 8° C. The totals of king crab were almost similar at each stage from 3° to 8° C. *P. brevipes* has three zoeal stages and the king crab has four zoeal stages, so the totals of king crab at each stage might be smaller than those of *P. brevipes*. This was 330 at 13°C and 440 at 18° C. This total is usually similar during the optimum temperature (KURATA 1960). The high temperature such as 13° and 18° C were not optimum temperatures for *P. brevipes*. Larvae at −1.8° C did not develope to Z 2, so there is a biological zero between −1.8° and 3° C.

KURATA (1956) reared 84 larvae to first stage young crabs but in this study only 2 first stage young crabs were reared in 500 *l* tank. There are not so many studies on *P. brevipes* as there are on the king crab, so it is difficult to study the reason for

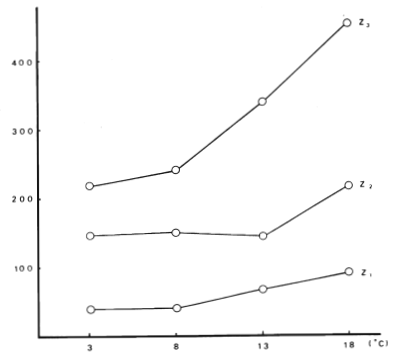

Fig. 10. The relationship between total effective temperature and temperature.

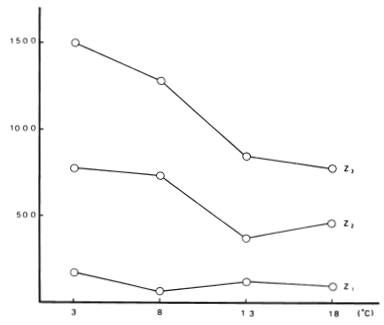

Fig. 11. The relationship between total oxygen consumption (oxygen consumption × days required for each stage) and temperature.

these deaths. The survival ratio decreased during the moulting period to the frist stage young crab, so the rearing method at G might have problems.

The survival ratio of the larvae of king crab was high at 8° and 13° C (NAKANISHI 1980) but this ratio for *P. brevipes* was high at 3° and 8° C. *P. brevipes* may not adapt to higher temperatures.

The oxygen consumption at G was lower than that at Z, because of the swimming larval forms at Z and low level of acitvity at G. This larvae and post-larvae rearing method is not so good, because the conditions at G might be bad. This may be also one of the factors for this decrease. One of the most important factors influencing metabolic rates of poikilotherms is temperature. But at Z 1 and G, their metabolic rates were maintained at an almost constant level from 3° to 18° C. At Z 2 and Z 3, these rates peaked at 8° C and decreased rapidly at 13° and 18° C. This may be due to a higher activity level at 8° C. Such water temperature as 13° and 18° C was higher than the optimum temperature for larvae, so the level of activity may have decreased. This effect may be also due to the habit of *P. brevipes* of usually living in cold water. The oxygen consumption of larvae of *P. brevipes* was about twice that of king crab.

The total oxygen consumption at each stage is shown in Fig. 11. These totals at Z 1 were similar from 3° to 18° C. But those at Z 2 and Z3 were different between those at 3° and 8° C and those at 13° and 18° C. These totals are 20–30% larger than those of the king crab (NAKANISHI 1980), especially at 8° C, where this total is twice as large.

The difference of days required during each larval stage and total oxygen consumption may show a biological changing point between 8° an 13° C. From the survival ratio and time required for a whole zoeal life, the optimum rearing temperature of larval stages seems to be 8° C.

The zoea of *P. brevipes* were larger than that of king crab, their carapace length was 20–30% larger than that of king crab and the wet weigth was three or four times heavier, the dry weight was three or five times heavier (NAKANISHI 1974).

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ハナサキガニ幼生期の生長・生残および酸素消費量におよぼす水温の影響

中西　孝

要　旨

ハナサキガニの幼生におよぼす水温の影響を調べる為に，生長・生残率および酸素消費量を，−1.8℃より5℃間隔の各水温中で測定した．生長および生残率については，−1.8°・3°・8°・13°そして18℃で実験した．8°・13・18°でのZⅠ～Gの日数は約30日でほぼ同じであったが，3℃では約2倍の日数を要した．−1.8℃では，Z－2への脱皮はなく，ふ化後66日で全数が死亡した．Z－3の生残率の最高は水温8℃の時で30～50%であった．酸素消費量については3°・8°・13°・18℃で実験した．Z－IとGではZ－2とZ－3に比べ水温の影響は少なかった．以上の結果から幼生期の至適飼育水温は8℃と推定した．