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Effects of High Temperature and Silt on Cardiac and Scaphognathite Activity of Pink Shrimp (*Pandalus borealis*), Coon Stripe Shrimp (*Pandalus hypsinotus*) and Side Striped Shrimp (*Pandalopsis japonica*)

TAKASHI NAKANISHI[1] AND TUNEO NISHIYAMA[2]

Abstract

In order to study the effects of the rapid increase of temperature and the silt condition in relation to the pink shrimp, coon stripe shrimp and side striped shrimp, cardiac and scaphognathite activities were monitored by the impedance pneumograph method. The increase of temperature was from 5° to 8° or 10° C for 6–12 hours. In this condition, there was no effect of the increase of temperature on the heartbeat rate. The effect of silt on cardiac and scaphognathite activities was also not so serious.

At 5.0±0.5° C, the mean heartbeat rate of pink shrimp was 56.3 (9–11.5 g wet weight)–70.4 (1.5–3 g) beats/minute, coon stripe shrimp 48.2 (25–35 g)–68.3 (40–50 g) beats/minute and side striped shrimp 57.8 (3.5–7 g) –71.6 (10—16 g) beats/minute.

I. INTRODUCTION

Pandalid supplies have decreased rapidly in Alaska since 1977. The average water temperature has dropped since this year. It is well known that temperature is one of the main environmental conditions for the shrimp. So this drop seems to be one reason behind this decrease. But there are some reports relating to the effect of temperature on pandalid shrimps. The cardiac and scaphognathite activities are affected by the change of water temperature (Cumberlidge and Uglow, 1977). We monitored the heartbeat rate and scaphognathite activity as one step to study the effect of temperature on pandalid shrimps. We studied the pink shrimp and the coon stripe shrimp.

There is a lot of silt from the glacier during the summer season in Alaska. The effects of silt on marine animals are not well known. We monitored also the effect of silt on the heartbeat rate and the scaphognathite activity of pandalid shrimps. We studied pink shrimp, coon stripe shrimp and side striped shrimp that are the main species of pandalid fishery in Alaska.

The impedance pneumograph method was used to monitor the heartbeat rate

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)
2) Institute of Marine Science, University of Alaska, Fairbanks, Alaska 99701, U. S. A

and scaphognathite activtity of crustaceans (Dyer and Uglow, 1977 and Belman, 1975). The modification of Dyer and Uglow needs only one electrode to monitor one measurment.

II. Material and Method

Experiments were carried out from December, 1979, to March, 1980, at Seward Marine Station, University of Alaska.

Shrimps were caught at Cook inlet near Homer in October 16, 1979 and at Resurrection Bay near Seward in March 1, 1980 by a trawl net gier. These shrimps were cultured in three square tanks (1.0×1.0×1.0 in height, meter) and one circular tank (1.5 in diameter and 1.0 in height, meter). They were fed on chopped herrings twice a week. The water temperature in these tanks was from 3° to 8 °C during this experiment. The light in the experimental room was continuously on. These tanks were covered by black polyethylene sheets, so the light intensity in the tanks was not changed.

The heartbeat rate and the scaphognathite activity were monitored by the method of Dyer and Uglow (1977). We made two small holes in the carapace of these shrimps. Two stainless steel electrodes were glued to the carapace with a cyanoacrylate glue. One was to measure the heartbeat rate and another was to measure the scaphognathite activity. Electrodes were connected to an impedance converter (Nihon–Kouden, Inc.) which generates a low intensity alternating field across the electrode and the common earth. Impedance between the electrode and the common earth was changed by movements of the cardiac or scaphognathite activities. This change was recorded on the CRT to monitor the heartbeat rate and the scaphognathite activity. These shrimps with two electrodes could remain alive normally more than one month, so the effect of the electrodes seemed not so serious.

These shrimps were placed in the net (20×5×15 in height, cm) and this net placed in the tank (50×50×30 in height, cm). Usually eight nets were placed in this tank to study the effect of high temperature. When we studied the effect of silt, we placed a smaller vessel (20 in diameter × 40 in height, cm) in this tank and put four nets in this smaller vessel. The water temperature in smaller vessele was maintained by the running sea water in this outer tank. The fluctuation of temperature during one experiment did not exceed 0.5° C. The elapsed time of 10 beats was measured with a stop-watch. These movements were monitored five times in each block. All rates reported were the average of these five measurements. The light intensity was 100–200 lux over the surface.

Shrimps assumed a resting condition 24 hours after from attaching the electrode and this condition continued for 3–5 days. In order to study the effects of high temperature, the heartbeat rate was monitored in the running sea water for 24 hours and this running sea water was stopped, so the temperature was increased by the room temperature that maintained at 15°–18 °C during the experiment. Heartbeat rates were monitored 6 and 12 hours later.

In order to study the effects of the silt condition, cardiac and scaphognathite activities were monitored in the normal and silt conditions for three days. Shrimps with two electrodes were placed in the nets. One day later, cardiac and scaphognathite activities were monitored for 8 hours. Next day, these activities were monitored once in a clear sea water and then mud was put in this vessel to make a silt. This mud was the deposition of silt of the glacier. The density of the silt in the vessel was maintained at 300 to 400 ppm. This density was as same as the density of the silt near Seward.

This silt water was well aerated. After monitoring for 8 hours, the clear running sea water was put in this vessel. The next day, these activities were monitored for 8 hours. The effect of silt was studied by the change of these mesurements.

III. Result

The heartbeat rate of the pink shrimp at 5.0±0.5°C was correlated with wet weight (Fig. 1–A). This relationship was estimated by the body weight (W: g wet weight/animal) and its heartbeat rate (H: beates/min.)

$Y = -1.8698X + 73.11$ ($r = 0.6080$, $n = 42$).

No relationship could be discerned between the heartbeat rate and the wet weight of the pink shrimp at 8.5±0.5 °C (Fig. 1–B), coon stripe shrimp at 5.0±0.5 °C (Fig. 2–A) and side striped shrimp at 5.0±0.5 °C (Fig. 2–B). Mean heartbeat rates of these pandalid shrimps are shown in Table 1. The heartbeat rate of pink shrimp at 8.5±0.5 °C was faster than that at 5.0±0.5 °C.

The relationship between the heartbeat rate and the scaphognathite activity of the pink shrimp is shown in Fig. 3. There was no clear correlationship. The mean of the scaphognathite activity of pink shrimp was 63.8±20.4 beats/min. (wet weight 9–14 g, n=8, at 5.0±0.5 °C) and that of the coon stripe shrimp was 59.4±

Table 1. Mean heartbeat rate of pink shrimp, coon stripe shrimp and side striped shrimp.

	W. T (°C)	wet weight (g)	heartbeat rate (beats/min.)	S. D.	n
Pandalus borealis	5.0±0.5	1.5– 3.0	70.4	9.4	14
		4.0– 7.5	61.2	7.9	19
		9.0–11.5	56.3	6.1	8
	8.5±0.5	1.5– 3.0	75.7	10.7	9
		4.5– 7.5	68.8	12.1	19
Pandalus hypsinotus	5.0±0.5	10–20	66.6	13.8	7
		25–35	48.2	18.5	5
		40–50	68.3	9.7	3
Pandalopsis japonica	5.0±0.5	3.5– 7	57.8	14.0	12
		10–16	71.6	16.3	5

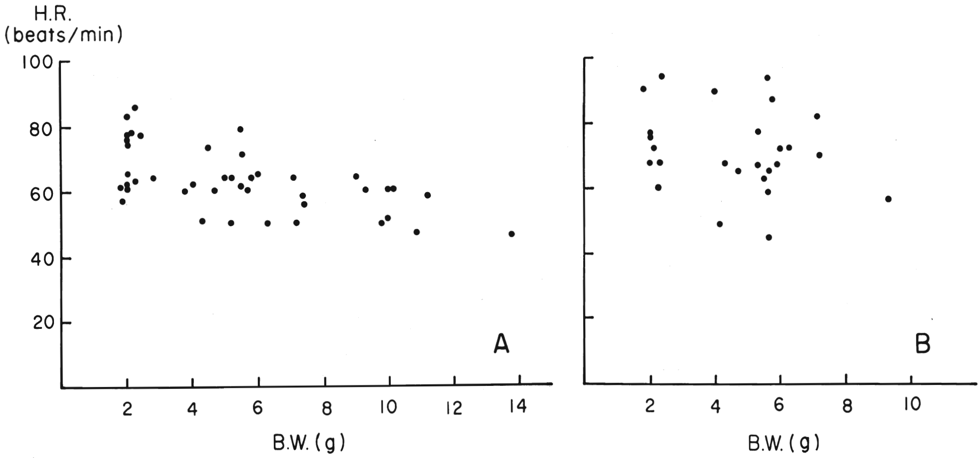

Fig. 1. Relationship between the heart rate and the body weight of pink shrimp at 5.0±0.5°C (A) and 8.5±0.5°C (B).

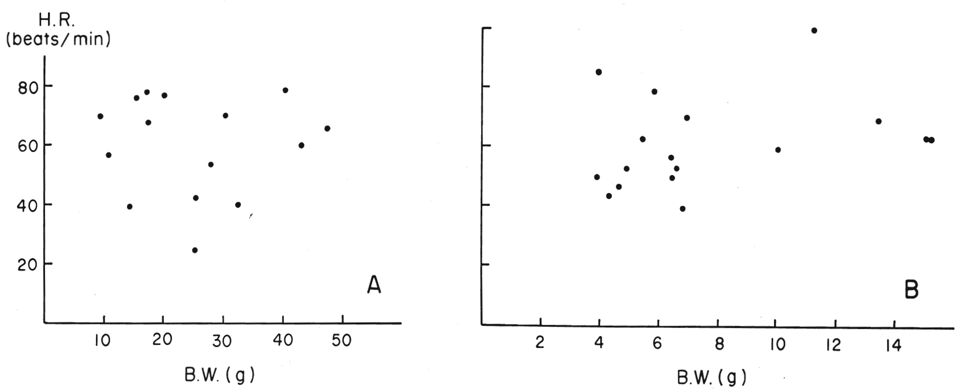

Fig. 2. Relationship between the heart rate and the body weight of coon stripe shrimp (A) and side stripe shrimp (B), at 5.0±0.5°C.

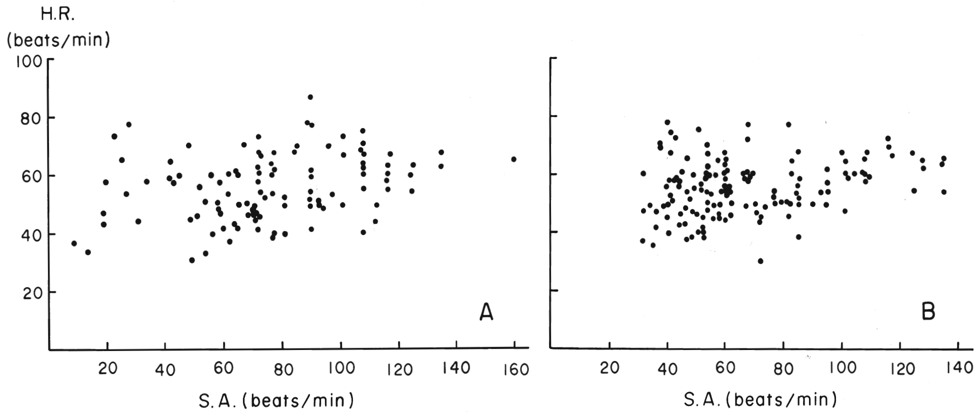

Fig. 3. Relationship between the heart rate and the scaphognathite activity of pink shrimp, at 5.0±0.5°C. Body weight 3–8g (A) and 8–12g (B).

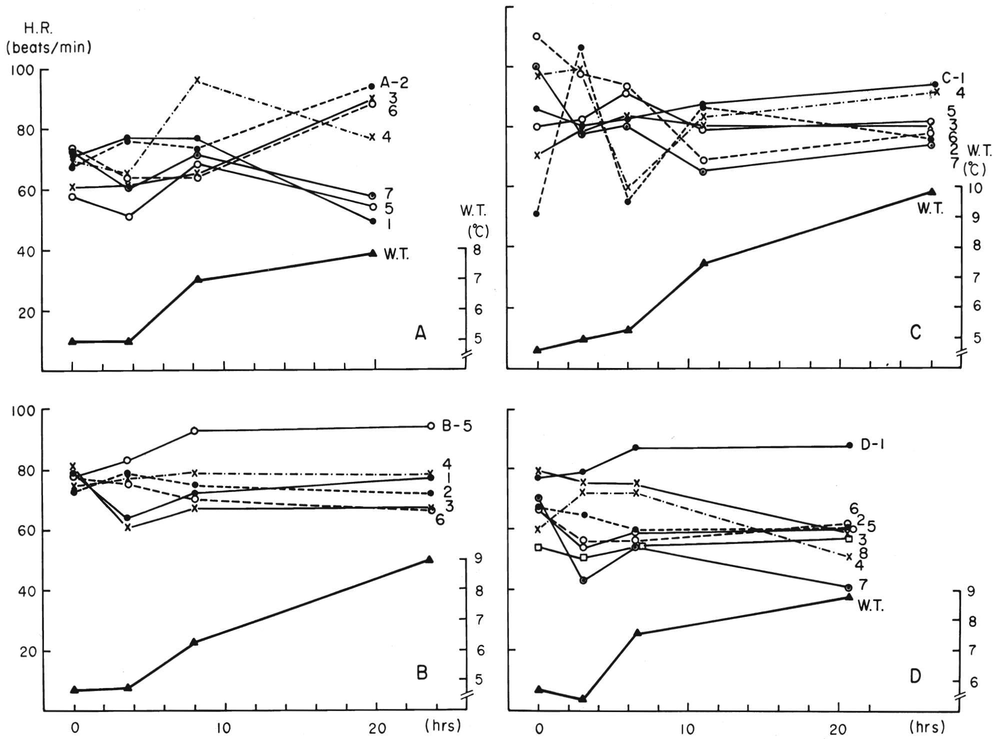

Fig. 4. Effects of rapid increase of temperature on the heart rate of pink shrimp (A–C) and coon stripe shrimp (D).

	No.	C. L. (cm)	B. W. (g)		No.	C. L. (cm)	B. W. (g)
Fig. 4–A	1	1.6	2.78	**Fig. 4–C**	1	1.6	2.18
	2	1.5	2.11		2	1.5	2.55
	3	2.0	5.35		3	1.6	2.29
	4	2.0	5.29		4	2.2	5.45
	5	2.0	5.56		5	2.1	5.56
	6	2.0	5.85		6	1.9	4.41
					7	2.0	5.71
Fig. 4–B	1	1.5	2.03	**Fig. 4–D**	1	2.7	19.50
	2	1.6	2.36		2	2.5	17.21
	3	1.5	1.83		3	2.7	17.33
	4	1.4	1.96		4	3.7	43.97
	5	1.9	4.27		5	4.0	47.18
	6	2.0	5.75		6	3.8	41.15
	7	2.0	5.52		7	3.3	30.86
					8	3.0	28.52

18.2 (wet weight 10–33 g, n=8 at 5.0±0.5 °C). That of the side striped shrimp was 61.7±2.9 beats/min. (wet weight 6–7 g, n=3) and 55.6±7.9 beats/min. (wet weight 10–15g, n=5) at 5.0±0.5 °C.

Fig.4 shows the effect of the rapid increase of water temperature on the heartbeat rate of the pink shrimp and coon stripe shrimp. In Fig. 4–A, the change of temperature was from 5.0° to 7.8 °C. Heartbeat rates of A–2, A–3 and A–6 were increased with the rise in temperature but the rates of A–1, A–5 and A–7 were de-

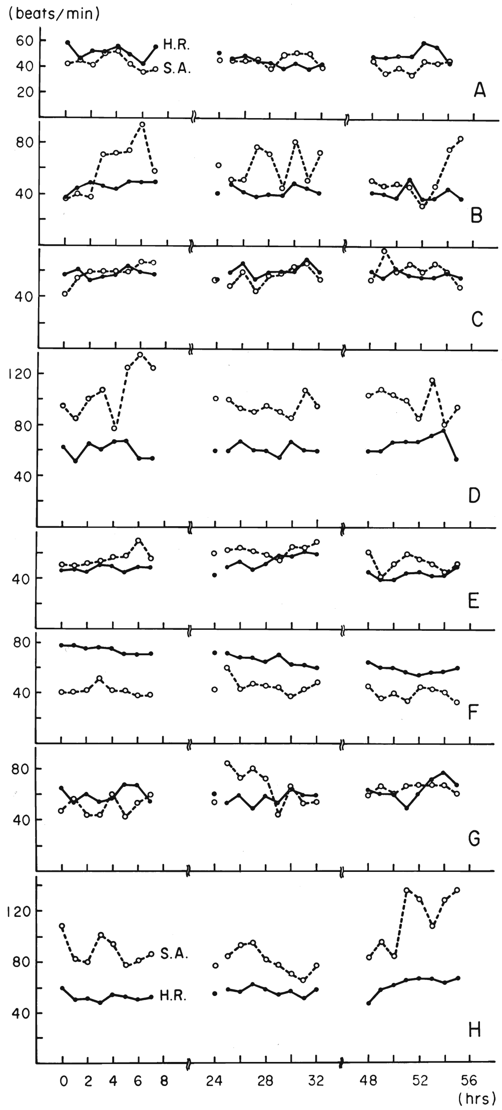

Fig. 5. Effect of silt on heart and scaphognathite activity of pink shrimp at $5 \pm 0.5°$ C. At the middle day (24 hours later), these activities were monitored in the silt condition.

	C. L. (cm)	B. W. (g)		C. L. (cm)	B. W. (g)
A	2.4	9.80	E	2.7	10.96
B	2.5	13.80	F	2.5	9.01
C	2.4	11.23	G	2.4	10.83
D	2.4	10.04	H	2.3	10.04

creased. This rate of A–4 had no tendency. The change of Fig. 4–B was from 4.6° to 9.8℃. The heartbeat rates of B–1, B–3 and B–5 were increased only slightly but these rates of B–2 and B–6 were decreased slightly. This rate of B–3 was constant. Its change of Fig. 4–C was from 4.7° to 9.0℃. Heartbeat rate of C–6 was increased. Other rates of Fig. 4–C showed a slight increase. There was no actual effect of high temperature on the heartbeat rate of pink shrimp. Fig 4–D shows the effect

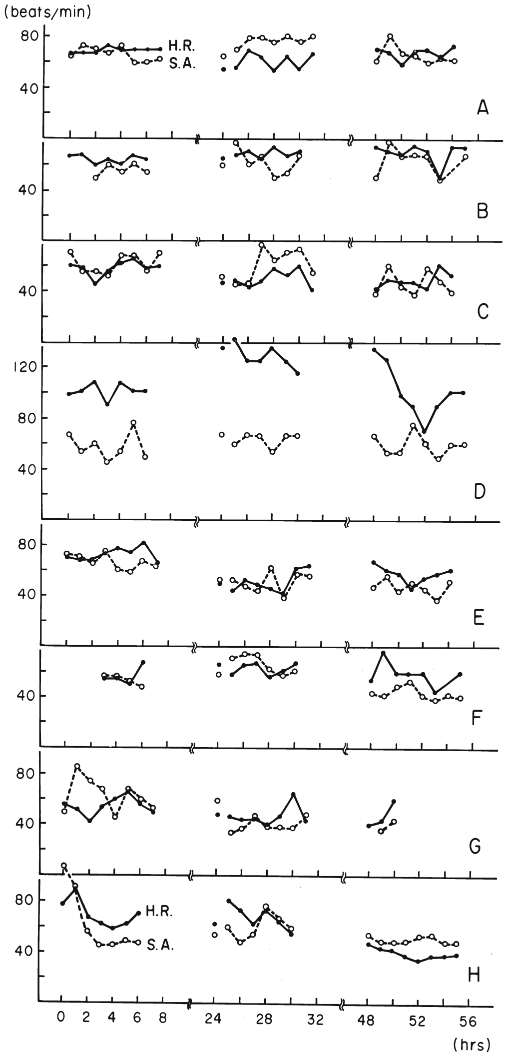

Fig. 6. Effect of silt on heart and scaphognathite activisy of side striped shrimp at 5.5°C–6.0°C. At the middle day (24 hours later). these activities were monitored in the silt condition.

	C. L. (cm)	B. W. (g)		C. L. (cm)	B. W. (g)
A	2. 9	13. 38	E	2. 2	6. 90
B	3. 0	15. 00	F	2. 6	9. 96
C	2. 2	6. 36	G	2. 2	6. 45
D	2. 8	11. 24	H	2. 8	14. 44

on the heartbeat rate of coon stripe shrimp. The change of water temperature was from 5. 3° to 8. 8° C. Heartbeat rates of D–2, D–5, D–6 and D–8 were increased slightly, but these rates of D–3, D–4 and D–7 were decreased. The rate of D–1 was constant. There was also no actual effect of high temperature on the heartbeat rate of coon stripe shrimp.

The effect of the silt on the heartbeat rate and the scaphognathite activity of pink shrimp is shown in Fig. 5. The heartbeat rate of 5–F was faster than the

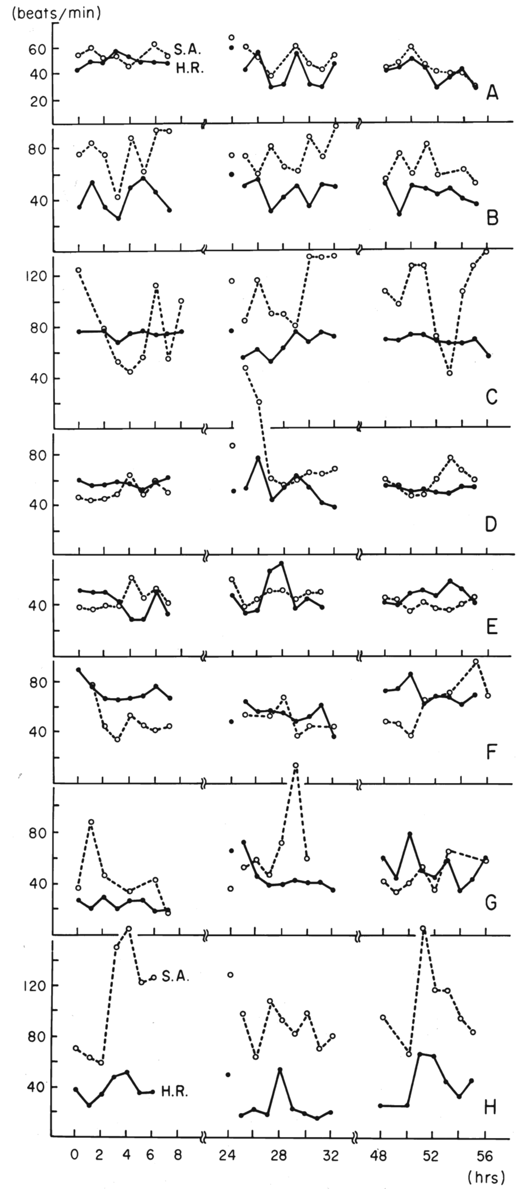

Fig. 7. Effect of silt on heart and scaphognathite activity of coon stripe shrimp at 5.5±0.5°C. At the middle day (24 hours later), these activities were monitored in the silt condition

	C. L. (cm)	B. W. (g)		C. L. (cm)	B. W. (g)
A	2.9	15.0	E	2.7	25.5
B	3.3	32.7	F	2.3	9.3
C	2.7	15.8	G	3.0	25.8
D	2.8	11.4	H	2.9	14.3

scaphognathite activity. Heartbeat rates of 5-B, 5-D, 5-E and 5-H were slower than the scaphognathite activities. There was little difference between heartbeat rates and scaphognathite activities of 5-A, 5-C and 5-G. This effect on side striped shrimp is shown in Fig. 6. The heartbeat rate of 6-D was faster than the scaphognathite activity. There were no difference between other heartbeat rates and scaphognathite activities in Fig. 6. This effect on coon stripe shrimp is shown in Fig. 7. The heartbeat rates of 7-B and 7-H were faster than scaphognathite activities. There was no change between other heartbeat rates and scaphognathite activities in Fig. 7. There was not outstanding effect of silt on the heartbeat rate and the scaphognathite activity of these pandalid shrimps. Heartbeat rates and scaphognathite activities of the pink shrimp and the side striped shrimp were more static than those of the coon stripe shrimp. In particular it was noticed that the scaphognathite activiy of coon stripe shrimp was fluctuated. The rapid movement at the escape was not observed just putting after the mud into the water, and these shrimps continued in the resting condition in the silt as in the case of the clear running sea water.

IV. Discussion

The relationship between body weight and heartbeat rate was first demonstrated by Schwartzkopff (1955): the effect of the body weight is a logarithmic relationship: Frequency (Heartbeat rate) = Constant × Weight$^{-0.12}$. The relationthips between the heartbeat rate and the body weight are usually logarithmic relationships (Schwartzkopff, 1955 and Defur and Mangum., 1979). In this experiment, a clear relationship was observed only in pink shrimp at 5.0±0.5°C and this relationship is a linear equation. The body weight range in other measurements is not so large and the heartbeat rate has a large fluctuation, so it may be difficult to study this relationship.

There is clear correlationship between the heartbeat rate and the branchial mantle movement in fish (Itazawa 1970). In this experiment, some scaphognathite activities of pink shrimp and coon stripe shrimp were faster than heartbeat rates, but there is no clear relationship. Heartbeat rates were usually more stable than scaphognathite activities in pandalid shrimps. The activies at the right scaphognathite and the left scaphognathite are different (McDonald and et al, 1977 and Dyer and Uglow, 1977). So the necessity of water movement in the gill chamber for respiration may be much less than the actual movement. This may be one reason for this large fluctuation. Heartbeat rate may be clearly correlated with the blood volum sent from the heart per unit time, so in the same cnndition heartbeat rates of pandalid shrimps were more stable than the scaphognathite activity. Heartbeat rates of pandalid shrimps were from 40 to 80 bearts/min. These are a few faster than in other crustaceans (Defur and Mangunm 1979).

The heartbeat rate usually increases with the rise in temperature. There were actually differences between heartbeat rates of pink shrimp at 5.0±0.5°C and at 8.5±0.5°C during long term acclimation. But the rapid increase of temperature had no actual effec on the heartbeat rate. Pink shrimp have a vertical migration habit. This rapid temperature change (from 5°C to 9°C or 10°C) may be familiar in relation to pink shrimp. It may be one reason for this phenomenon.

In fish, the effect of silt on the branchial mantle movement is well known as a cleaning movement. But in this experiment, there are not actual effects of silt on the heartbeat rate nor on the scaphognathite activity. The diameter of the silt in this experiment was a maximum of 20 micrometer and usually under 2 micrometer. The space of the secondary gill lamella of pandalid shrimps was 30–40 micrometer. So this fine silt does not have a serious effect on the heartbeat rate and the scaphognathite activity. The pandalid shrimps are usually living on/in the sand or mud, so this effect may be not so serious. In this silt condition, 300–400 ppm, even if just under the surface, we could not see shrimps in the net. This silt condition had to be serious for shrimps, so we have to study this effect by other means.

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Pink shrimp, Coon stripe shrimp および Side striped shrimp の心拍数と呼吸運動におよぼす高水温と泥の影響

中 西　孝・西 山 恒 夫

寒海性エビの pink shrimp, coon stripe shrimp および side striped shrimp におよぼす高水温と環境水の泥の影響を，心拍数と呼吸運動を指標にして調べた。水温を5°Cから8～10°Cへ，6～12時間かよけ上昇させた時，心拍数に変化は見られなかつた。泥の濁度が300～400ppmの時は，心拍数および呼吸運動には変化は見られなかつた。