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STUDIES ON THE EFFECTS OF SOME ENVIRONMENTAL FACTORS ON SURVIVAL AND GROWTH OF THE POLYCHAETE, *PERINEREIS NUNTIA* VAR. *VALLATA*

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The effects of environmental factors on growth of polychaete *Perinereis nuntia* var. *vallata* which usually inhabit the pebbly shore were studied. The young worms reared for 4 months after artificial fertilization at 20°C were placed under different experimental conditions. The worms fed on the sludge actively at temperature ranging from 20 to 36°C, but hardly below 10°C and above 40°C. They survived for a long period at below 40°C and chlorinities of 10.4–19.3‰. Weight gain and food conversion efficiency in a high population density (33 worms/100 cm^2) were less than those in a low population density (9 worms/100 cm^2), indicating that the growth correlated negatively with the population density. The food intake and the weight gain in the sand-gravel substratum were more conspicuous as compared with those either in gravels or in sand, indicating suitability of the mixture of sand and gravel for the living of the worms.

INTRODUCTION

It is known that the polychaetous annelid *Perinereis nuntia* var. *vallata* inhabit the coastal area with specific gravities ranging from 10.00 to 24.00 (Cl 7.81–17.94‰) (ISHIKAWA 1938). FUKUSHIMA and ISHIDA (1966) observed them on gravels of tidelands in a bay facing the open sea. YOSHIDA (1970) reported that they inhabited substratum of sandy mud, mud or gravels which was periodically exposed by ebb tide. These facts indicate that *P. nuntia* var. *vallata* usually inhabits gravel lands that is under a relatively little influence of river water.

It is probable that the environmental factors such as chlorinity, water temperature and substratum, are subjected to seasonal fluctuations and the changes of these factors influence the growth of individuals. The present paper reports on the results of the experiments conducted to clarify the effects of environmental factors such as chlorinity, temperature and substratum on the growth and survival of adults *P. nuntia* var. *vallata*.

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METHODS

The worms used for these experiments were obtained through artificial insemination and reared in the vessels with the sea water whose chlorinity (hereafter described as Cl) was maintained at 19.3‰ for about 4 months. The rearing vessels used here were acrylic resin containers of 0.5 *l* in volume. The rearing experiment was carried out according to the sand filtration method, by covering the bottoms of the containers with glass wool, filling them with a mixture of the sea sand and gravels of in diameter 4–6 mm to make the surface area 58 cm^2 and the depth 8 cm each, which were then introduced with a continuous flow of the sea water diluted with demineralized water that flowed out from the bottom (Fig. 1). The inflow of water for each container was 12.4 *l*/day. The diet used was activated sludge composed mainly of bacteria and protozoa obtained by aerating the domestic sewage that was mainly composed of organic matters and inorganic salts. It was carefully placed on the surface of the mixture of sand and gravels in which the worms were kept. The decrease in the amount of the sludge was taken to be the food intake. The difference in the individual body weight between the beginning and the end of each experiment divided by the number of days of experimental period was taken to be the body weight gain per day, and the body weight gain divided by the food intake as the food conversion efficiency. The diet was supplied as much as worms could consume. In calculating the food conversion efficiency, the diet and the body weight gain were estimated in terms of dry weight in all cases. In the analysis of Cl was determined with MOHR's method (JAPAN SEWAGE WORKS ASSOCIATION 1967). As a rule, the experiment was conducted 7 times on each experimental group, and the estimation was made based on the average value. The experiment was conducted at a room temperature of 18–21°C, and aeration was done so as to maintain the dissolved exygen concentration (hereafter called as DO) of the surface water at 5–6 mg/*l*.

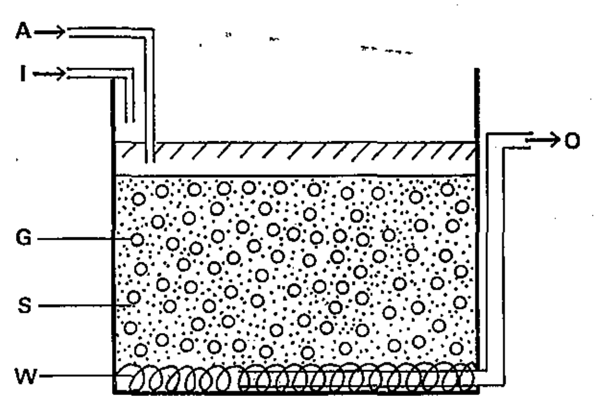

Fig. 1 Experimental apparatus. A: Air; I: Inflow; G: Gravel; S: Sand; W: Glass wool; O: Out flow

RESULTS

1. *Effect of concentration of the sea water*

To study the effect of concentration of the sea water on growth, the sea water diluted with demineralized water to a chlorinity of 2.0, 3.4, 5.7, 10.4, 15.6 or 19.3‰ was passed, and as much activated sludge as the worms could consume was placed as diet in each container. The worms of about 0.2 g wet weight were reared at a density of 5, 10 and 19 individuals per 58 cm^2 (9, 17 and 33 individuals per 100 cm^2) for 20 days. The food intake, weight gain, food conversion efficiency and survival at the respective chlorinities of the culture water are shown in Fig. 2. At any chlorinity of the sea water the effect on survival was hardly recognized, whereas the food intake and the weight gain varied greatly depending on chlorinity: in the group of 33 individuals/100 cm^2, the food intake was 200.4, 322.2 and 267.4

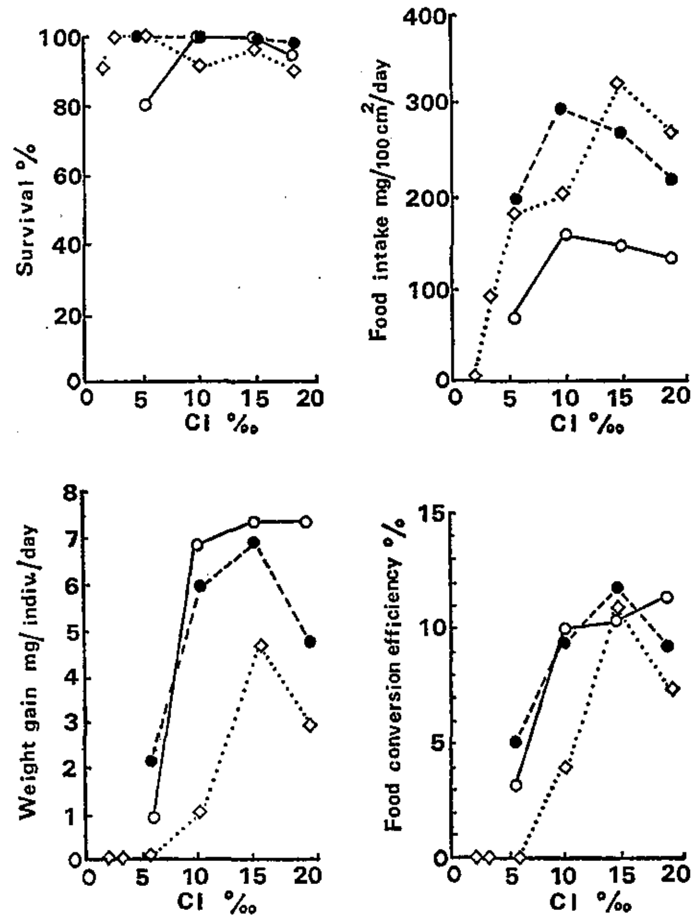

Fig. 2 Effect of concentration of the sea water (indicated by chlorinity). ○: 9 individuals/100 cm^2, ●: 17 individuals/100 cm^2, ◇: 33 individuals/100 cm^2.

mg/100 cm²/day and the weight gain was 1.0, 4.7 and 2.8 mg/individual/day at 10.4‰ Cl, 15.6 and 19.3‰ respectively. The growth was positive at chlorinities of over 10.4‰. At 5.7 and 3.4‰ Cl, however, the weight gain was zero though the corresponding food intake was 181.4, and 95.5 mg/100 cm²/day. This shows that the growth lowers at low chlorinities, though food intake is active. Additionally, the tendency that the body weight gain increased with a decrease in population density could be recognized.

The average value of the food conversion efficiency obtained at the respective densities was 2.7, 7.7, 10.9 and 9.1% at Cl 5.7, 10.4, 15.6 and 19.3‰ respectively. These data indicate that the assimilation ratio of the taken food is higher with increasing chlorinity.

2. *Effect of water temperature*

To investigate the effect of water temperature on the growth of *P. nuntia* var. *vallata*, experimental containers were placed in water baths maintained at 10, 20, 30, 34, 38 and 47°C (with a variation of ±3°C), and supplied with the sea water (Cl 19.3‰) and sludge. The individuals, each about 0.2 g in wet weight, were placed in the 58 cm² containers to give the population density of 29 worms/100 cm². The period of experiment was 17 days. The worms were weighed both in the beginning and at the end of the experiment. The results are shown in Fig. 3. The adult worms were able to survive adequately under temperatures ranging as widely as 10 to 38°C. However, at 10°C the food intake decreased extremely without weight gain, and at 34°C the weight gain was zero. This shows that the worms do not grow both at low and high temperatures. The food intake, weight gain, and food conversion efficiency were 267.4 mg/100 cm²/day, 2.8 mg/individual/day and 7.2% at 20°C and 222.4 mg, 1.9 mg and 5.1% at 30°C respectively. Both the food intake and weight gain increased largely as compared with those at 10°C and 34°C. Thus the optimum water temperature for the growth of the worm falls somewhere between 10°C and 34°C, probably in the vicinity of 20°C. Under high temperature of 46–47°C the worms died about 2 hours after thermal exposure.

3. *Effect of population density*

To study the effect of population density on the growth of the worm, three groups of worms of 0.2–0.3 g wet weight placed in experimental containers of 58 cm² at the density of 9, 17, and 33 per 100 cm², and two groups of worms of about 0.5 g wet weight placed in containers of 150 cm² at the density of 7 and 13 per 100 cm² were reared. They were reared for 17 days, at 20°C, Cl 19.3‰. The results in the groups of 0.2–0.3 g initial wet weight are shown in Fig. 4: the food intake per 100 cm² and per individual were 127.3, 211.0, and 267.4 mg/100 cm²/day, and 14.8, 12.3, and 8.3 mg/individual/day at the density of 9, 17 and 33 individuals/100 cm², respectively. The food intake per unit area increased as the

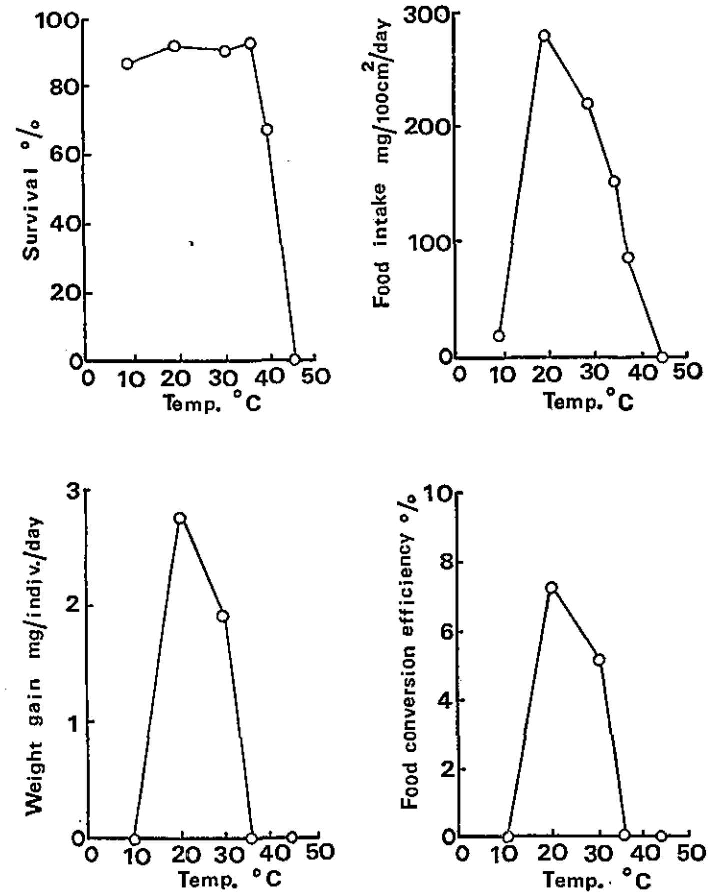

Fig. 3 Effect of water temperature.

population density increased, but the food intake per individual increased with a decrease in population density. The weight gain and the food conversion efficiency were 2.8 mg/individual/day and 7.2% at a high density (33 individuals/100 cm²), and 7.2 mg/individual/day and 11.2% at a low density (9 individuals/100 cm²). These values differed conspicuously depending on the population density. This indicates that the individual growth increases as the population density decreases. A similar tendency was observed in worms of 0.5 g initial wet weight (Table 1). These facts indicate that the population density is effective even on the growth.

4. *Effects of substrata*

It is known from studies on benthos found in tidal flat that the substratum or the particle size is as important as other environmental factors for their survival (Tsuchiya and Kurihara, 1976). In order to study the effects of substrata on

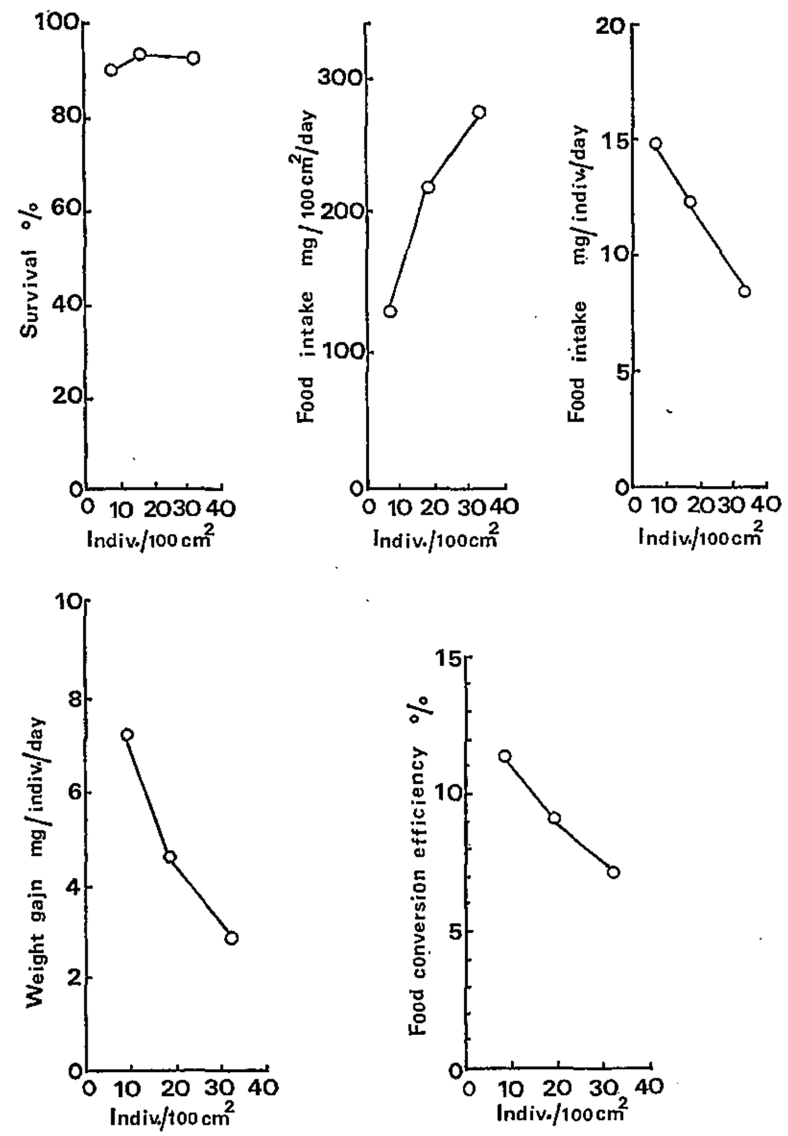

Fig. 4 Effect of population density on the growth of the small sized-worms.

Table 1.
Effect of population density on the growth of the large sized-worms

Population density worms/100cm^2	Survival (%)	Food intake mg/100cm^2/day	Food intake mg/individual/day	Weight gain mg/individual/day	Food conversion efficiency (%)
7	100	145.3	21.8	13.0	13.3
13	98	168.3	12.8	6.1	10.8

the growth of the worm, a series of experiments were conducted using substrata of three classes, i.e., fine sea sand (0.1 mm in diameter or less), gravels (4–6 mm in diameter) and a uniform mixture of the two. The survival, food intake, weight gain, and food conversion efficiency in these substrata were compared. In this experiment the population density was 29 individuals per 100 cm^2 and the experimental period was 17 days. The results are shown in Table 2. The effects of the kind of substratum on the worm's survival were not observed, but variations were detected in the food intake, weight gain, and food conversion efficiency; the food intake was 267.4 mg/100 cm^2/day in the sand-gravel group. The value dropped to 57% in the sand group and 62% in the gravel group as compared to that of the sand-gravel group. The weight gain of the sand-gravel group was obviously greater than that of the sand. Regarding the food conversion efficiency, the sand-gravel group indicated a value of 7.2%, while the gravel group attained a value of 9.2%. Thus, it seems that gravels are more appropriate for growth than sand alone.

Table 2.
Effects of substrata

Substrata	Population density worms/100 cm^2	Survival (%)	Food intake mg/100cm^2/day	Food intake mg/individual/day	Weight gain mg/individual/day	Food conversion efficiency (%)
Sea sand	29	90.0	152.3	4.9	1.5	5.6
Sea sand + Gravel	29	88.6	267.4	8.3	2.8	7.2
Gravel	29	89.2	166.2	5.4	2.5	9.2

DISCUSSION

The polychaete *P. nuntia* var. *vallata* will be unable to survive in an environment of constantly low chlorinity. Although they were able to survive for a short period of time even at Cl 2.0–5.0‰, their growth was zero. Therefore low chlorinity is not desirable for their survival and a chlorinity of 10.0‰ or more is required for their growth, differing from *Neanthes japonica* which can survive and grow positively at a low chlorinity range such as 0.5–4.5‰ (Inamori and Kurihara 1979). This may be supported by the observation that the lower survival limit of of the specific gravity of the natural habitat is 10.00 (Cl 7.81‰). In planarians organic matter is known to be lost in the form of mucus or other forms (Teal 1957). The present polychaete excreted a large amount of mucus in low chlorine medium, forming a protective coat on the body surface. The mucus secretion may affect largely the growth, lowering growth at low chlorinity.

Since *P. nuntia* var. *vallata* were observed to be inactive in ingestion at 10°C, this species is not able to grow at low water temperatures. At the water temperature of 30°C, *P. nuntia* var. *vallata* was observed to have adequately grown up though not exceeding the case at 20°C, and to ingest vigorously. At 34°C, the weight gain was not observed, but feeding behavior was observed as sufficiently as the body weight was maintained. Although at 47°C, the present worms died in about 2 hours they were able to survive long enough at 40–45°C. After being placed at a temperature of 45°C for several hours, they were able to survive by forming burrows with falling water temperature to about 30°C. Therefore, it can be said that the tolerance of *P. nuntia* var. *vallata* against high temperatures is extremely high. On the other hand, *N. japonica* died in 2 hours at 43°C, and became inactive in ingestion at 3.5°C. But at 6°C it began to ingest, and at 9.5°C the weight gain was more than that at 30°C (INAMORI and KURIHARA 1979). This indicates that, in contrast to *P. nuntia* var. *vallata*, tolerance against low temperature is rather high in *N. japonica*, although the optimum water temperature for both species is in the vicinity of 20°C. INAMORI and KURIHARA (1979) reported that the weight gain of an individual of *N. japonica* decreased as population density increased. As in the case of *N. japonica*, the present species also showed a tendency that the higher the population density, the less the food intake, and the lower the density, the more the weight gain per individual. For explaining the effect of the population density various factors can be considered. At a high density the shape of burrows becomes unsuitable for living (INAMORI and KURIHARA 1979), and the frequency of contact with other individuals during feeding increase, resulting in shortening of feeding time (YOSHIDA, 1976).

In natural field *P. nuntia* var. *vallata* inhabits substrata containing gravels, while *N. japonica* inhabits muddy-sand of tidal flats formed in estuaries. It was found in the present experiment that the growth of *P. nuntia* var. *vallata* was retarded in a substratum of sand alone as compared with that in a substratum containing gravels. Thus, the particle size of substratum seems to be importance for the growth of worm from the standpoint of food intake, growth and food conversion efficiency.

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