Seasonal changes of an oxygen consumption by *Crangon crangon* L. (Crustacea, Natantia) in the Gulf of Gdańsk*

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Crangon crangon L.
Oxygen consumption
Gulf of Gdańsk

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Abstract

During 1978 seasonal measurements of the oxygen consumption by *Crangon crangon* males and females were carried out. The measurements were taken at temperatures of: 4°, 9°, 12°C (spring), 15°, 18°C (summer), 10° and 9°C (autumn) and 4°C (winter) by manometric method. The oxygen consumption usually increased with ambient temperature increases, but none was noted in the 10° - 15°C range. The highest oxygen consumption was observed in summer when the temperature was at 18°C. During the spring the consumption was lower than at a similar temperature in autumn. In individuals of different sexes, but of the same body mass the oxygen consumption was higher in females. At all temperatures applied, the oxygen consumption rose with the increase in wet mass of the individuals, but the rate of metabolism of the *Crangon crangon* fell.

1. Introduction

Among the numerous factors affecting the metabolic processes in marine animals, the most important are considered to be: temperature (Winberg 1971; Kamler 1971; Prus 1976; Bass 1977; Opaliński Jażdżewski 1978), salinity (Hagerman 1970), physiological state of the organism (Khmeleva 1973), moulting period in shrimps (Hagerman 1976a), sex and size of individuals (Branch Newell 1978) and age of individuals (Khmeleva 1973).

There are several papers on the effect of the ecological factors on the metabolic processes in *Crangon crangon*. Most of the data concern shrimps from fully saline waters. Salinity has an important effect on the metabolism of the animals, hence

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most papers deal with this subject and are based on osmoregulation measurements (Hagerman 1970, 1976b, 1978; Weber, Spaargaren 1970; Spaargaren 1971; Weber, Marrsewijk 1972; Spaargaren, Kraay 1973).

The coastal waters of the southern Baltic are of the mixohaline type with a salinity of about 7‰ and with insignificant fluctuations. Due to small annual salinity fluctuations, while measurements of the oxygen consumption by *Crangon crangon* were being carried out. The temperature conditions in the Gulf of Gdańsk seem to have had the greatest influence. The water temperature ranged from 0.2°C (February) to 18.1°C (August) on average (Communique of the Institute of Meteorology and Water Management 1978).

2. Material and method

Samples of *Crangon crangon* were collected during 1978 from the coastal waters of the Gulf of Gdańsk near Gdynia 0.5 miles off shore at a depth of 3 m. A 100 × 50 cm drag and net with 1 mm mesh were used to collect the material.

The individuals were placed into crystallizers, the bottom of which was covered by a 2 cm layer of sand with a few centimetres of filtered sea water with a salinity of 7‰ over it. The crystallizers, each containing 5 individuals, were set in a water thermostat of the same temperature as the sea water at the time the samples were taken. Measurements were carried out after an adaptation period at least 24 hours. The oxygen consumption was measured by manometric method in Warburg apparatus. The lowest experimental temperature was 4°C in spring and winter, the highest was 18°C in summer (Table 1). One individual was placed in each calibrated measure of the Warburg apparatus which contained 13 cm^3 of filtered sea water; 0.5 cm^3 of 10% KOH was used for absorption of the CO_2 given off. The measurements took 4 hours. For the first 30 minutes after placing the containers into the apparatus no observations were carried out, this being the adaptation period. Manometric readings were carried out every half an hour. Not only was the quantity of the oxygen used during exposure recorded, but also whether the oxygen consumption during the process of respiration was constant. For better gas exchange between the water and the ambient air, the containers were shaken for five minutes at a speed of 45 mm/sec during each observation period. On concluding the experiment, the sex and wet mass of individuals were determined. The oxygen consumption of 265 individuals was analysed. The interdependences of the oxygen consumption and body mass were approximated by the power function: $R=aW^b$, where: R – oxygen consumption (mm^3 O_2 individuals per hour); W – wet mass (mg); a – oxygen consumption by unit of weight (mg per hour) and b – expotential which relates the two variables (Duncan, Klekowski 1975). Calculations were made by means of the least squares method and using a confidence interval at the 0.05 level.

3. Results

The most significant environmental factor influencing consumption of oxygen by *C. crangon* is temperature (Szaniawska 1980). Accordingly, when carrying out observations on the seasonal changes in oxygen consumption by the shrimp, measurements were made in spring at temperatures of 4°, 9° and 12°C, in summer at 15° and 18°C, autumn at 10° and 9°C and winter at 4°C. These temperatures are typical of the coastal waters of the Gulf of Gdańsk in consecutive seasons. A standard shrimp mass equal to 233 mg was determined for monthly samples (containing 100 individuals each) for the whole period of observations in order to note the effect of temperature on the level of oxygen consumed by *C. crangon*. By doing so, determination of the quantity of oxygen consumed by an average-sized shrimp was possible and mass could also be eliminated as a factor influencing oxygen consumption. It was possible from this, to state that the quantity of oxygen consumed by *C. crangon* increases with the rise of an ambient temperature (Fig. 1).

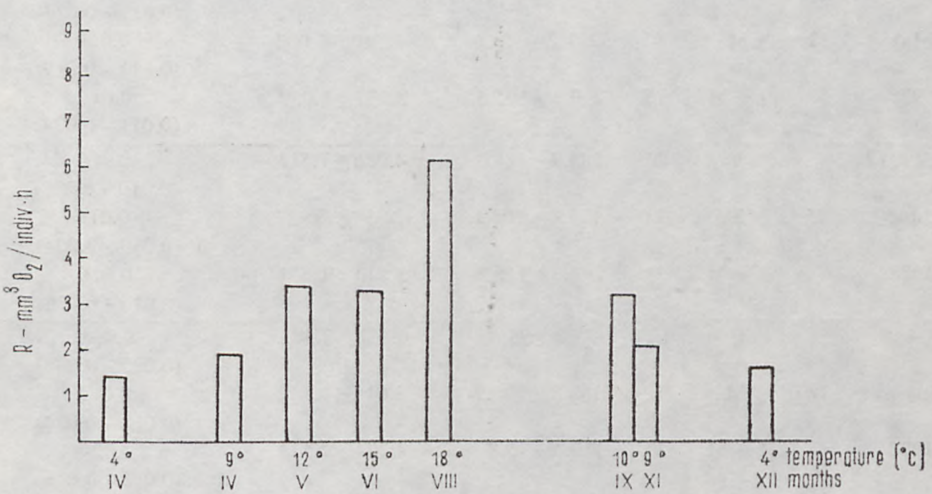

Fig. 1. Seasonal changes in the oxygen consumption by the standard mass *C. crangon*

The lowest oxygen consumption by an individual of standard mass was observed in April at a temperature of 4°C and was equal to 1.457 mm^3 O_2 per individual^{-1} hour^{-1}. At temperatures from 10° to 15°C the oxygen consumption ranged between 3.234–3.424 mm^3 O_2 per individual^{-1} hour^{-1}.

Observations of seasonal changes in oxygen consumption (Table 1) from direct experimental results showed that the oxygen consumption of animals investigated in the spring was similar at temperatures of 4°C and 9°C, amounting to 0.803 mm^3 O_2 per individual^{-1} hour^{-1} and 1.059 respectively. The level of metabolism in these shrimps was lower than in others. A considerable rise in the level of metabolism was observed in May (temp. 12°C) and June (temp. 15°C). During this period the oxygen consumption was three times higher than that of the preceding months at temperatures of 4° and 9°C.

Table 1. Wet weight, oxygen consumption and oxygen consumption rate of *Crangon crangon* females (F) and males (M) measured at different temperatures

Date	Temperature (°C)	Sex	Number of measurements	Weight (mg) Mean ± SD	Oxygen consumption (mm^3/individual/h) Mean ± SD	Mean and range of oxygen consumption rate (mm^3/mg/h)
4, 5, 6		F	14	108.1 ± 49.6	0.647 ± 0.157	0.006 (0.004 - 0.009)
April	4	M	19	143.3 ± 66.7	0.918 ± 0.227	0.007 (0.005 - 0.010)
1978		F + M	33	128.4 ± 61.7	0.803 ± 0.239	0.007 (0.004 - 0.010)
11, 12, 13		F	14	112.2 ± 48.2	1.129 ± 0.311	0.010 (0.007 - 0.014)
April	9	M	25	140.6 ± 58.8	1.020 ± 0.203	0.010 (0.005 - 0.010)
1978		F + M	39	130.4 ± 56.3	1.059 ± 0.254	0.008 (0.005 - 0.014)
27, 28, 29		F	15	218.9 ± 106.3	3.453 ± 1.038	0.017 (0.011 - 0.024)
May	12	M	11	221.2 ± 109.6	2.930 ± 1.008	0.014 (0.011 - 0.019)
1978		F + M	26	219.9 ± 105.5	3.232 ± 1.039	0.015 (0.011 - 0.024)
10, 11, 12		F	25	284.9 ± 168.3	4.086 ± 1.513	0.016 (0.010 - 0.026)
June	15	M	14	177.4 ± 103.1	2.491 ± 0.932	0.016 (0.010 - 0.024)
1978		F + M	39	246.3 ± 155.8	3.514 ± 1.531	0.016 (0.010 - 0.026)
3, 4, 5		F	12	177.2 ± 94.6	6.352 ± 2.484	0.038 (0.027 - 0.046)
August	18	M	10	188.8 ± 101.9	3.014 ± 1.112	0.017 (0.013 - 0.024)
1978		F + M	22	182.5 ± 95.8	4.834 ± 2.579	0.029 (0.013 - 0.046)
9, 10		F	14	297.0 ± 141.8	4.198 ± 1.367	0.016 (0.012 - 0.029)
September	10	M	10	220.6 ± 96.4	2.958 ± 0.864	0.014 (0.011 - 0.020)
1978		F + M	24	265.2 ± 128.4	3.682 ± 1.318	0.016 (0.011 - 0.029)
15, 16, 17 18		F	28	376.7 ± 121.6	3.290 ± 0.723	0.009 (0.006 - 0.015)
November	9	M	13	186.6 ± 64.3	2.083 ± 0.724	0.011 (0.006 - 0.016)
1978		F + M	41	315.4 ± 139.0	2.877 ± 0.902	0.009 (0.006 - 0.016)
12, 13, 14 15		F	23	407.1 ± 167.3	2.778 ± 0.724	0.007 (0.004 - 0.012)
December	4	M	18	238.8 ± 61.0	1.799 ± 0.634	0.008 (0.003 - 0.013)
1978		F + M	41	332.7 ± 155.7	2.348 ± 0.837	0.008 (0.003 - 0.013)

The highest oxygen consumption was observed in shrimps collected in the summer when the ambient temperature was 18°C. The rate of metabolism in these animals differed from other *C. crangon* investigated and the oxygen was 4.834 mm^3 O_2 per $individual^{-1}$ $hour^{-1}$ on average. The rate of metabolism slowed down 3.682 mm_3 per $individual^{-1}$ $hour^{-1}$ when the water temperature was 10°C.

A further drop in oxygen consumption took place in November and December, while the level of metabolism was twice as high as that of the shrimps investigated at the same temperature in spring. During spring the shrimps consumed smaller quantities of oxygen in similar temperature conditions than in autumn or at the beginning of winter. In general thought, the level of metabolism in the animals during the period from April to June and from September to November is similar. During these periods a plateau was observed in oxygen consumption (Fig. 1). This proves that temperature is not a factor which determines the rate of metabolism in shrimps. The mass and sex of *C. crangon* play an important part in the quantity of oxygen consumed. The influence of both these factors on the oxygen consumption of *C. crangon* acclimatized to different temperatures in the laboratory described Szaniawska (1980). While investigating the seasonal changes in the oxygen consumption by male and female of average wet mass each month (Fig. 2), it was observed that during the whole year and at different temperatures the females had a higher oxygen requirement than the males. The body mass of *C. crangon* is an important factor determining the quantity of oxygen consumed (Fig. 3). During the whole period of investigations it was observed that individuals with greater body mass consumed more oxygen. Thus, *e.g.* at temperature of 9°C (April) a female of 144 mg consumed 1.257 mm_3 O_2 per $individual^{-1}$ $hour^{-1}$ and one of 166 mg – 1 357 mm^3 O_2 per $individual^{-1}$ $hour^{-1}$.

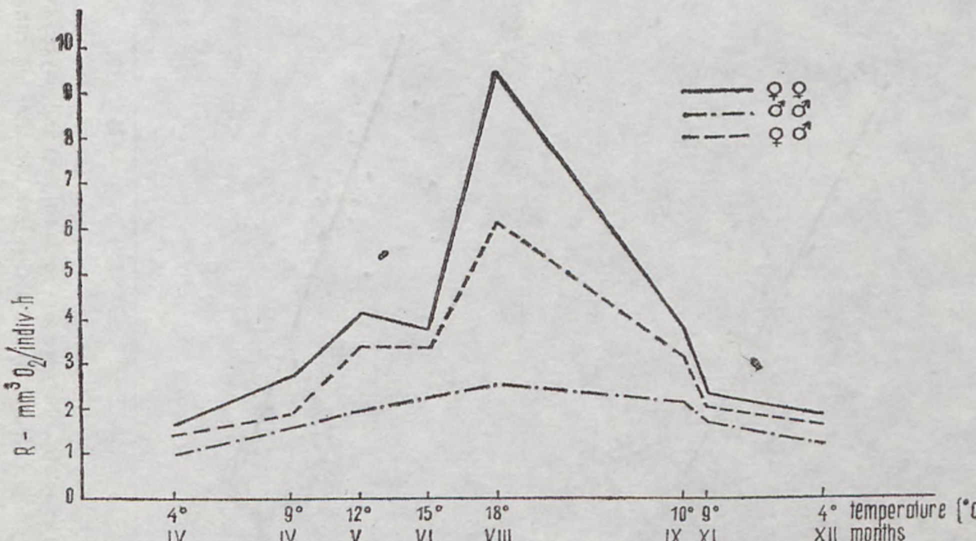

Fig. 2. Seasonal changes in the oxygen consumption by females, males and both sexes of the *C. crangon* together (the average wet mass of the animals was taken into account)

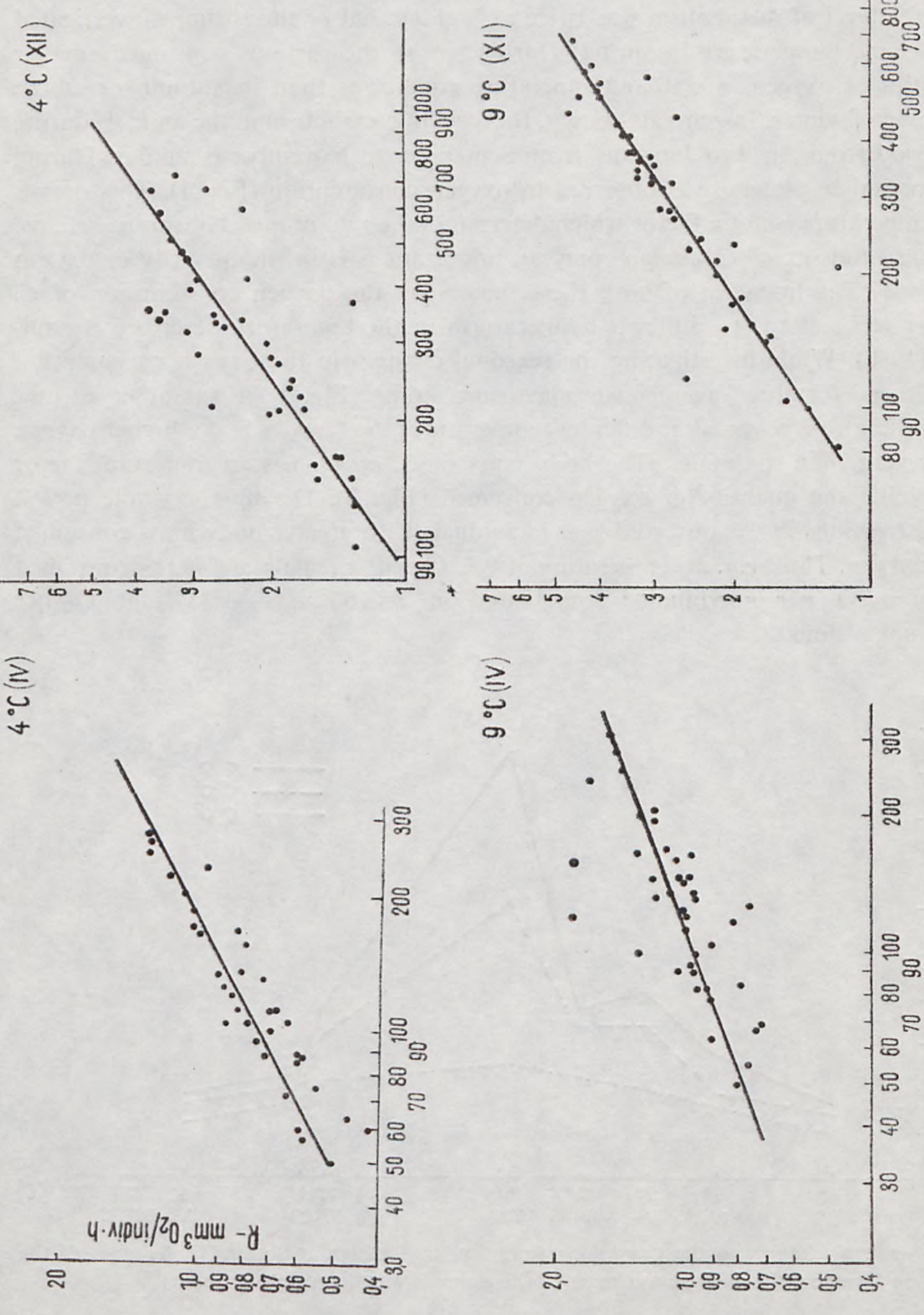

Fig. 3. The relation between wet mass (in mg) and oxygen consumption mm^3O_2 individual^{-1} hour^{-1} by the *C. crangon* at temperatures: 4°, 9°C (spring), and 9°C (autumn) and 4°C (winter) (double logarithmic scale)

4. Discussion

Temperature and salinity are considered the most important ecological factors influencing the quantity of oxygen consumed by marine animals. Water salinity in the Gulf of Gdańsk does not fluctuate considerably throughout the year (Communique of Institute of Meteorology and Water Management 1978), thus is not an important factor in metabolic processes. Hagerman (1970) found that *C. crangon* from the Danish inshore waters with salinity ranging from 10°/₀₀ to 33°/₀₀ reacts, by an increase in oxygen consumption, to both increasing and decreasing salinity. The rate of oxygen consumption by individuals with an average wet mass of ±400 mg from Danish waters ranged from 20–300 mm^3 O_2 g wet $mass^{-1}$ $hour^{-1}$, that of the *C. crangon* from the Gulf of Gdańsk over an annual cycle ranges from 0.007 mm^3 O_2 mg wet $mass^{-1}$ $hour^{-1}$ (at 18°C).

The average wet mass was 233 mg. This proves that the rate of metabolism of *C. crangon* from the Helsingør coastal waters is somewhat higher than that from Gdańsk Bay.

The temperature conditions of the southern Baltic influence to considerable extent, the rate of metabolism and the quantity of oxygen consumed by *C. crangon*. The highest experimental temperature was 18°C. In this temperature was observed the highest animals metabolism and it was six times higher than of the shrimp breathing at 4°C. Detailed data on the influence of temperature on oxygen consumption was obtained after experiments on acclimatized shrimps were carried out (Szaniawska 1980). The data concerning the effect of temperature on other species of shrimps are known. The rate of oxygen consumption by *Palaemon adspersus*, measured at 20°C was 0.094 mm^3 O_2 mg wet $mass^{-1}$ $hour^{-1}$ (Khmeleva 1973) while the average oxygen consumption by *C. crangon* at 18°C was 0.029 mm^2 O_2 mg wet $mass^{-1}$ $hour^{-1}$. This shows that the rate of oxygen consumption in *C. crangon* is lower than of the *Palaemon adspersus*. Temperature is not only factor affecting the respiration process; at temperatures ranging between 10° to 15°C a plateau in oxygen consumption was observed. Ranta and Hakala (1978) observed an inhibition in the oxygen consumption of *Mysis relicta* at optimal temperatures for this species 2°–7°C. In the experiments, temperature was only one of the most important indicators of the changing seasons. It was also observed that the oxygen requirements varied at the same temperatures, but in different seasons of the year. During the spring the oxygen consumption is low, this probably being due to the physiological adaptation of the shrimp to low winter temperature. The rate of metabolism is simultaneously lower. The rate of metabolism increases with higher water temperatures, which in turn, gives rise to a greater oxygen demand.

The highest oxygen consumption was observed in August at 18°C. The oxygen consumption by *C. crangon* of the same body mass and sex was higher in autumn than in spring at similar ambient temperatures. This is not probably due to certain physiological adaptations of the organism to the high summer temperatures. A further decrease in water temperature causes a drop in the rate of metabolism. As experiments were carried out throughout the year, the level of oxygen consumption was also

Table 2. The relationship between oxygen consumption R (mm³/individual) and wet weight (W, mg) of *C. crangon* females (F) and males (M). General form $R=aW^b$

Date	Temperature (°C)	Sex	Number of measurements	a	b	Correlation coefficient
4, 5, 6		F	14	0.0521	0.5425	0.90
April	4	M	19	0.0707	0.5213	0.97
1978		F+M	33	0.0461	0.5926	0.85
11, 12		F	14	0.0893	0.5396	0.72
April	9	M	25	0.0740	0.5345	0.96
1978		F+M	39	0.1101	0.4674	0.67
27, 28, 29		F	15	0.1291	0.6114	0.97
May	12	M	11	0.0826	0.6649	0.96
1978		F+M	26	0.1067	0.6359	0.89
10, 11, 12		F	25	0.1177	0.6336	0.98
June	15	M	14	0.1077	0.6130	0.97
1978		F+M	39	0.0831	0.6860	0.94
3, 4, 5		F	12	0.1307	0.7543	0.98
August	18	M	10	0.0909	0.6721	0.94
1978		F+M	22	0.1472	0.6608	0.87
9, 10		F	14	0.1425	0.5973	0.81
September	10	M	10	0.1047	0.6230	0.97
1978		F+M	24	0.0983	0.6522	0.85
15, 16, 17 18		F	28	0.1201	0.5590	0.79
November	9	M	13	0.0811	0.6179	0.49
1978		F+M	41	0.0832	0.6183	0.81
12, 13, 14 15		F	23	0.1336	0.5071	0.72
December	4	M	18	0.2106	0.3833	0.80
1978		F+M	41	0.0689	0.6065	0.52

determined according to the physiological state and condition of the animals. Body mass and sex of the animals have less influence on the oxygen consumption. When testing the oxygen consumption by animals at identical temperatures however, it was observed that females of the same body mass as males have greater oxygen requirements. A similar relation was noted in *C. crangon* while experimenting on the effect of temperature on acclimatized males and females (Szaniawska 1980).

When observing the relation between the body mass and oxygen consumption, it was observed that oxygen requirements increased with the higher body mass of individuals. A similar relation was observed in *Paramoera walkeri* (Amphipoda) (Klekowski *et al.* 1973) and the *Panaeus shmitti* shrimps (Shafer, Williams 1968). The relation between the body mass of *Idotea baltica* (Isopoda) and oxygen consumption is given by the equation: $R_{20°}=0.217W^{0.79}$ (Khmeleva 1973), while the equation for *C. crangon* is $R_{18°}=0.1472W^{0.6608}$ (Tab. 2).

For both crustaceans *Tecticeps japonicus* and *Diastylopsis dawsoni* the *b* – factor is 0.81 and 0.82 (Fuji and Nakao 1975) respectively, whereas the *b* – factor for the fresh water shrimp *Cardina fernandoi* is close to $b=1$.

b – values are similar for the species *Metapenaeus monoceros*. This proves that the oxygen consumption by these species is proportional to the body weight (Bertalanffy 1951), but in the *C. crangon* investigated, *b* was almost 0.66 which means that the metabolism in these animals depends upon the surface area of the individual.

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