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ORIGINAL PAPER

Effect of temperature on the respiration of an Antarctic freshwater anostracan, *Branchinecta gaini* Daday 1910, in field experiments

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Abstract The Antarctic crustacean *Branchinecta gaini* (Branchiopoda, Anostraca) occurs in nine fresh water lakes near the Polish H. Arctowski Station. In one of the largest, Lake Wujka (Lake Uncle in English), we determined how temperatures affect its respiration and whether this is sex dependent. Experiments were carried out on males and females bearing eggs over a range of temperatures from 0.5 to 10°C. An ANOVA showed that while the amount of oxygen consumed increased with temperature ($P < 0.001$) males consumed more oxygen than similarly-sized females bearing eggs ($P < 0.001$).

Keywords Respiration · *Branchinecta gaini* · Antarctic lake · Temperature

Introduction

In recent years, much interest has been given to questions concerning the factors that limit an organism's distribution (Peck 2004). In extreme environments, physical factors become dominant in delimiting a species' distribution, so polar faunas are more at risk than those from lower latitudes (Peck 2002a, b).

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One of the most important factors for water animals is temperature. In global environmental change the water temperature average warming of 2°C in the oceans and around 4°C on land is predicted (Murphy and Mitchell 1995). It is connected with air temperature in the Maritime Antarctic, which is increasing at a rate that is amongst the fastest on earth. Water temperature in lakes and pools in this region is rising even faster than air temperature, because of the amplification effect, caused by decreasing ice cover (King 1994; King and Harangozo 1998; Quayale et al. 2002, 2003).

The anostracan fairy shrimp *Branchinecta gaini* (Branchiopoda, Anostraca) inhabits freshwater lakes and pools in Antarctica—one of the most hostile environments on earth where it is the largest freshwater invertebrate (mean length of males: 19.6–22 mm, females: 19.2–20 mm) (Jurasz et al. 1983; Pociecha unpublished data). *B. gaini* is herbivorous, and filter-feeds on organic particles and bottom detritus (Paggi 1996). It is found from South Patagonia to the Antarctic Peninsula (Paggi 1996) where it survives temperatures up to 25°C in summer and passes the winter as cysts when the temperatures fall to –25°C. It exhibits great physiological flexibility, including temperature fluctuations (Peck 2004, 2005). This physiological flexibility allows *B. gaini* to exploit its extreme environment.

The aim of our study was to determine how ambient temperatures affect the respiration of *B. gaini* and whether this effect is sex dependent.

Study area

Lake Wujka (62°09′28.3″, 58°27′56.3″) is situated near the Polish H. Arctowski Station on King George Island, the largest of the South Shetland Archipelago

(total area 1,312 km^2). The island is comprised of volcanic rock with 90% of its surface covered with ice (Rakusa-Suszczewski 1992). Lake Wujka has a maximum depth of 138 cm and is situated on a marine beach behind a storm ridge and regularly receives wind-blown sea-spray. Ice-free for 7 months of the year the lake freezes solid in winter. The lake bottom is composed of muddy sediments (20–40 cm thick), 5–20% of which is covered with filamentous green algae (Janiec 1993; Pociecha unpublished data) (Fig. 1). The lake receives water from a nearby Ecology Glacier and Moss Creek (Polish, Potok Mchowy). During violent storms, sea water breaches the lake, and temporarily rendering it saline. The lake flushes to the sea during spring and fall, as well as sometimes in winter.

Materials and methods

Experiments were carried out during the austral summer 2004. Water sampling was followed by laboratory measurements of oxygen—using an OXI-197 oxygen electrode from WTW, Wilheim, Germany; conductivity—using an LF-197 conductometer from WTW, Wilheim, Germany and pH—using an HI 9025 pH-meter by Hanna Instruments. Water temperature was measured in situ with a mercury thermometer.

Branchinecta gaini (males and females bearing eggs) were collected by netting from the shallow part of the lake just before the experiments began. Individuals were placed in closed experimental vessels (volume 69 ml) containing lake water that had been filtered through a 10 μm mesh. The experimental vessels were exposed at 20 cm depth in lake water and incubated in situ for 2 h. The oxygen levels were measured at the beginning and end of the experiment (by an oxygen electrode OXI-197, WTW, Germany) for 20 animals plus two empty controls for each of five temperatures (0.5, 3.5, 7.2, 8.5 and 10.0°C).

The respiration rate is expressed as:

$$R = \frac{V \times O_2 \times 1.429}{T},$$

where:

R oxygen consumption (μlO_2/ind/h)
V volume of vessels (ml)
O_2 oxygen consumed (mg/l)
T time in hours

ANOVA (two ways) was used to test differences between the temperature and oxygen consumption by males and females. Statistical calculations were carried out using the program SPSS for Windows Version 11.5.0.

Results

Apart from the fifth experiment, when an inflow of seawater caused a slight increase in the conductivity, the physical–chemical parameters of Lake Wujka were fundamentally similar (Table 1).

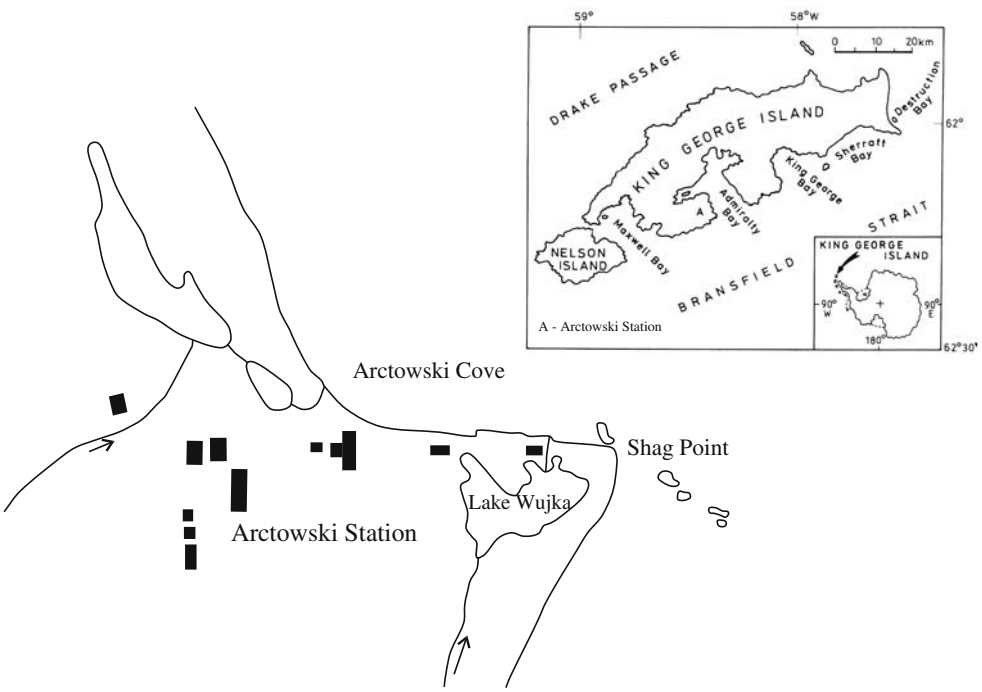

Fig. 1 Location of Lake Wujka

Table 1 Physico-chemical variables of the lake water and *Branchinecta gaini* body length and oxygen consumption

Data	Physico-chemical parameters				*B. gaini*						
	T (°C)	O_2 (mg/l)	pH	Conductivity (μS/cm)	Density (N)		Length (cm)		*R* [μlO_2/ind/h]		
					Female	Male	Female mean ± SD	Male mean ± SD	Both sexes mean ± SD	Female mean ± SD	Male mean ± SD
1 27.01	10.0	11.53	8.50	170.2	4	16	1.93 ± 0.10	2.18 ± 0.22	45.72 ± 11.94	30.66 ± 10.72	49.49 ± 9.04
2 31.01	8.5	11.98	8.47	175.4	7	13	2.03 ± 0.13	2.18 ± 0.10	33.75 ± 6.72	29.66 ± 4.18	35.95 ± 6.91
3 04.02	7.2	12.13	7.68	146.2	6	14	2.13 ± 0.19	2.18 ± 0.15	34.95 ± 6.87	32.63 ± 4.72	35.95 ± 7.54
4 16.02	3.5	12.79	7.78	181.0	7	13	2.10 ± 0.06	2.31 ± 0.23	24.04 ± 7.50	18.21 ± 5.84	27.18 ± 6.44
5 18.03	0.5	11.89	7.35	899.0	7	13	2.13 ± 0.24	2.15 ± 0.18	17.52 ± 5.35	15.77 ± 4.47	18.47 ± 5.70

Also similar sized animals were chosen for each of the five experimental temperatures. *B. gaini* consumed more oxygen at higher temperatures than at lower ones. We found differences in oxygen consumption between males and females. Females consumed less oxygen than males and the consumption of both varied with temperature. At 0.5°C the oxygen consumption of both males and female bearing eggs was very similar, but at 10°C the consumption was higher in males (Table 1).

The increase in oxygen consumption between 1 and 10°C was equated to a Q_{10} of 2.74. A two-way ANOVA showed that temperature influenced respiration significantly ($P < 0.001$) and respiration was significantly different in both sexes ($P < 0.001$). Thus, respiration changed significantly with temperature and respiration in males was significantly faster than in females bearing eggs.

Discussion

Anostraca are well known survivors in extreme environments (especially in hot, cold or saline lakes, even in desert habitats), which they survive by encysting thereby tolerating extremes of temperature and desiccation. This makes them very successful in ephemeral pools around the world (Brendonck 1996; Hamer and Brendonck 1997; Brendonck and Riddoch 2000; Graham 2002; Ripley et al. 2004; Peck 2004). *B. gaini* is a large anostracan with an univoltine life cycle (Peck 2004), whose adults can survive relatively high summer temperatures, but encyst in the winter when the lake is frozen solid. For ectotherms the relationship between minimum resting metabolism at low temperature and maximum oxygen consumption following an incremental temperature rise is a measure of physiological scope, or the capacity that an organism has to do work (Peck 1998).

The mean oxygen consumption of *B. gaini* (for both sexes) in Lake Wujka at 0.5°C was 17.52 μlO_2/ind/h (=0.782 μmolO_2/ind/h) whereas at 10°C it was 45.73 μlO_2/ind/h (=2.041 μmolO_2/ind/h). Peck's (2004) laboratory studies showed that the mean oxygen consumption at 1°C was 0.093 μmolO_2/ind/h whereas at 20°C it was 0.366 μmolO_2/ind/h. Above 15°C there was a marked increase in variability of oxygen consumption in *B. gaini* possibly indicating this is the upper physiological temperature limit for this species (Peck 2004).

Whereas the females *B. gaini* in our study had a lower oxygen consumption than males. Peck (2004) found that the male of *B. gaini* had an 18% lower rate of oxygen consumption than females, and explained this result as females having a greater ability to raise oxygen consumption in relation to temperature than males. Our males from Lake Wujka were far more active both in the lake and experimental vessels which undoubtedly explains why they consumed more oxygen than the ovigerous females which were observed to swim more slowly and economically.

ANOVA showed that temperature influenced oxygen consumption significantly and that respiration was significantly different in both sexes, yet it is interesting that in our field experiments males consumed more oxygen than ovigerous females.

Different results in both studies could be caused by differences in methodology, e.g, laboratory experiment—filed study, handling stress in our studies.

In Peck's (2004) and our study over the range 1–10°C oxygen consumption in *B. gaini* rose with temperature and were equated to a Q_{10} of 2.03 and Q_{10} of 2.74, respectively. A Q_{10} of both studies indicates a doubling of oxygen consumption rate for a 10°C rise in temperature, which is within the normal range of 2–4 for biological systems (Peck and Conway 2000).

Knight et al. (1975) investigated the oxygen consumption (in a temporary pond in southern Michigan) of two species of fairy shrimp—the euryhaline species

Chirocephalopsis bundyi (Forbes) and *Eubranchipus vernalis* (Verrill), a stenothermal species—over a range of temperatures from 5 to 20°C. The oxygen consumption of male C. *bundyi* increased between 5 and 15°C and decreased thereafter while after an initial increase the female rate remained unchanged between 10 and 20°C. The males consumed more oxygen than the females from 5 to 15°C. The results for *E. vernalis* showed a similar pattern though this time males consumed less oxygen than the females between 10 and 15°C. Knight et al. (1975) considered that the oxygen consumption of *C. bundyi* was dependent on temperature, shrimp weight and collection site, while that for *E. vernalis* was dependent only on shrimp weight and temperature. (The authors did not specify if the females were bearing carried eggs). *B. gaini* from Lake Wujka behaved like the euryhaline *C. bundyi*. If the oxygen consumption in *B. gaini* depends on the characteristics of the collection site then the fact that Peck (2004) specimens were collected from ponds from Anchorage Island (there are no inhabitants and the island remains uncultivated) near the Antarctic Peninsula some 120 km south of King George Island may well be an important contributory factor.

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References

Brendonck L (1996) Diapause, quiescence, hatching requirements: what we can learn from large freshwater branchiopods (Crustacea: Branchiopoda: Anostraca, Notostraca, Conchostraca). Hydrobiologia 320:85–97

Brendonck L, Riddoch BJ (2000) Egg bank dynamics in anostracan desert rock pool populations (Crustacea: Branchiopoda). Arch Hydrobiol 148:71–84

Graham TB (2002) Survey of aquatic macroinvertebrates and amphibians at Wupatki National Monument, Arizona, USA: an evaluation of selected factors affecting species richness in ephemeral pools. Hydrobiologia 486:215–224

Hamer ML, Brendonck L (1997) Distribution, diversity and conservation of anostraca (Crustacea: Branchiopoda) in Southern Africa. Hydrobiologia 359:1–12

Janiec K (1993) The freshwater micro- and meiofauna of Admiralty Bay, King George Island, South Shetland Islands. Proc NIPR Symp Polar Biol 6:133–138

Jurasz W, Kittel W, Presler P (1983) Life cycle of *Branchinecta gaini* Daday, 1910, (Branchiopoda, Anostraca) from King George Island, South Shetland Islands. Polish Polar Res 4:143–154

King JC (1994) Recent climate variability in the vicinity of the Antarctic Peninsula. Int J Climatol 14:357–369

King JC, Harangozo SA (1998) Climate change in the western Antarctic Peninsula since 1945: observations and possible causes. Ann Glaciol 27:571–575

Knight AW, Lippson RL, Simmons MA (1975) The effect of temperature on the oxygen consumption of two species of fairy shrimp. Am Midl Nat 94:236–240

Murphy JM, Mitchell JFB (1995) Transient response of the Hadley Centre coupled ocean-atmosphere model to increasing carbon dioxide. Part II: spatial and temporal structure of response. J Climatol 8:496–514

Paggi JC (1996) Feeding ecology of *Branchinecta gaini* (Crustacea: Anostraca) in ponds of South Islands, Antarctica. Polar Biol 16:13–18

Peck LS (1998) Feeding, metabolism and metabolic scope in Antarctic marine ecotherms. In: Pörtner HO, Playle RC (eds) Cold ocean physiology. Society for Experimental Biology Seminar Series no 66. Cambridge University Press, Cambridge, pp 365–390

Peck L (2002a) Ecophysiology of Antarctic marine ectotherms: limits to life. Keynote contribution, Antarctic Treaty Organisation Scientific Committee on Antarctic Research, Ecology of the Antarctic Sea Ice Zone, Bremerhaven, June 1999. Polar Biol 25:31–40

Peck L (2002b) Coping with change: stenothermy, physiological flexibility and environmental change in Antarctic seas. In: Proceedings of the 14th international congress on comparative physiology. La Troina, Sicily. http://www.liv.ac.uk/ciliate/climate/peck.html

Peck L (2004) Physiological flexibility: the key to success and survival for Antarctic fairy shrimps in highly fluctuating extreme environments. Freshw Biol 49:1195–1205

Peck L (2005) Prospects for surviving climate change in Antarctic aquatic species. Front Zool 2:9. http://www.frontiersinzoology.com/content/2/1/9

Peck L, Conway LZ (2000) The myth of metabolic cold adaptation: oxygen consumption in stenothermal Antarctic bivalves. In: Harper EM, Taylor JD, Crame JA (eds) The evolutionary biology of the Bivalvia. Geological Society (Special Publications, 177), London, pp 441–445

Quayale WC, Peck LS, Ellis-Evans CJ, Peat HJ, Harrigan PR (2002) Extreme responses to climate change in Antarctic lakes. Science 295:645

Quayale WC, Convey P, Peck LS, Ellis-Evans CJ, Butler HG, Peat HG (2003) Ecological responses of maritime Antarctic lakes to regional climate change. Antarct Res Ser 76:335–347

Rakusa-Suszczewski S (1992) Zatoka Admiralicji. Antarktyka, Oficyna Wydawnicza, Instytut Ekologii PAN, Dziekanów Leśny

Ripley BJ, Holtz J, Simovich MA (2004) Cyst bank life-history model for a fairy shrimp from ephemeral ponds. Freshw Biol 49:221–231