

## Life cycle of *Boeckella poppei* Mrazek and *Branchinecta gaini* Daday (King George Island, South Shetlands)

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**Abstract** In Lake Wujka, a shallow, polymictic Antarctic lake situated at 15 m from the seashore, several yearly cohorts occur of the copepod *Boeckella poppei* and one of the fairy shrimp *Branchinecta gaini*. There is circumstantial evidence that the two species compete for food, and perhaps adult fairy shrimp feed on the nauplii of the copepod. Both species are positively influenced by a measure of salinity. However, when autumn storms massively sweep seawater into the lake, all fairy shrimp are wiped out; no hatching occurs until next spring. In *B. poppei*, some nauplii and copepodites survive or hatch after the salt flows out of the lake. This is an advantage to the copepod that may balance its coexistence with the shrimp. Its cycle is, however, aborted by the freezing of the lake. In contrast to many other Antarctic lakes, the life cycle of the crustaceans is therefore controlled by salinity rather than freezing.

**Keywords** *Boeckella poppei* · *Branchinecta gaini* · Environmental factors · Freshwater lake · Antarctica · Life cycles

### Introduction

The life cycles of fairy shrimp and copepods living in temporary waters are controlled by an alternation of phases of inundation and drying. In Antarctica, in contrast, life cycles are controlled by phases of liquid water and ice.

The freshwater Antarctic crustacean fauna is impoverished. Only few species adapt to the long period of freezing (Jurasz et al. 1983). During the “liquid phase”, their life history is influenced by the abiotic environment and by other biota present. Elucidating the controls of the life history of such crustaceans aids in understanding their distribution and perhaps predicts how they might be affected by environmental change (Swadling et al. 2004).

Here, we describe the life cycles of *Branchinecta gaini* and *Boeckella poppei* living in Lake Wujka, a freshwater lake close to the Henryk Arctowski station of the Polish Academy of Sciences, across a study period of 1 year and attempt to determine which variables affect the dynamics of *B. poppei* most.

### Study area

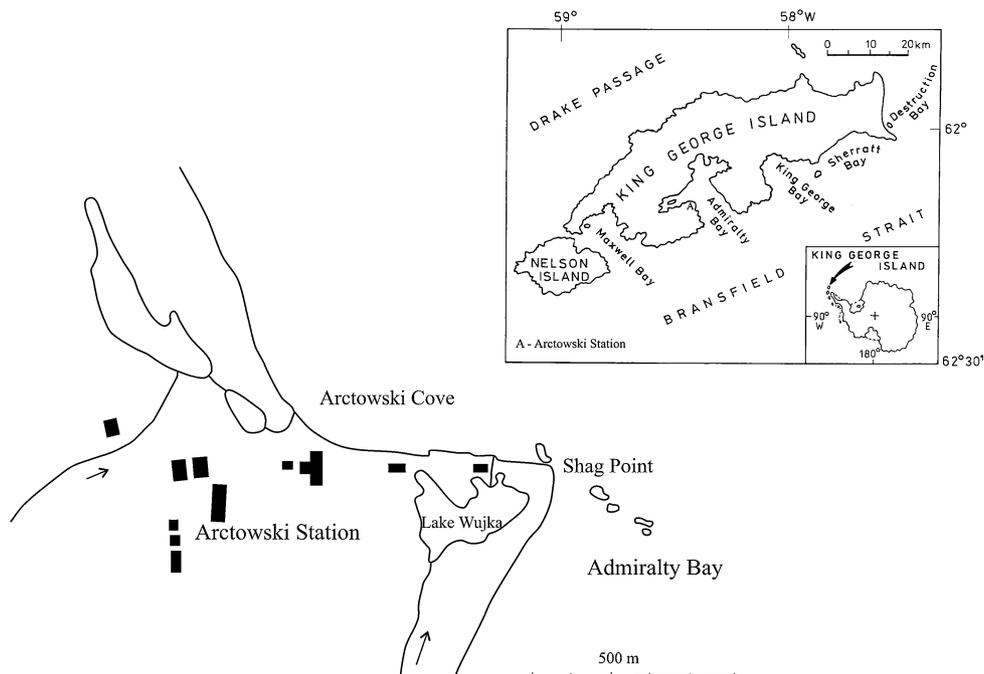
King George is the largest island of the South Shetland archipelago (area 1,312 km<sup>2</sup>). It is composed of volcanic rock and is 90% ice-covered (Rakusa-Suszczewski 1992). Our study was carried out in Lake Wujka (62°09'28.3'', 58°27'56.3'', surface area 800 m<sup>2</sup>), located near the Henryk Arctowski Polish Antarctic Station (Fig. 1). This freshwater lake (maximum depth 1.38 m) is situated on a marine beach behind a storm ridge. Its surface is ice-covered in April–May and from October to December, and it freezes to the bottom from June till September. Its water is supplied by a nearby glacier via a creek. Being situated only 15 m from the high water mark, the lake receives wind-blown spray

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**Fig. 1** Location of Lake Wujka

and is breached by violent storms. One massive breach occurred in May 2004, temporarily rendering the lake saline (up to 24.3 psu). It flushes back to the sea during spring and fall, as well as sometimes in winter.

Phytoplankton is represented by 14 diatom genera. The most abundant are *Achnanthes* and *Pinnularia* (Ochwanowski and Pocięcha 2005). Five species of monogonont rotifers are on record, plus an unidentified bdelloid (Janiec 1996; Pocięcha 2007).

## Materials and methods

Crustaceans were sampled at 3-day intervals between 24 November 2003–27 May 2004 and from 7 October to 8 November 2004. Samples were collected in duplicate using a 3 l sampler, and provide a quantitative estimate for copepods but probably not for fairy shrimp, which are notoriously patchy. However, for a presence/absence study, and for identifying the number of generations per annum, the method is adequate. Samples were filtered through a plankton net (mesh size 35  $\mu\text{m}$ ), fixed in 4% formalin, identified, and counted under a microscope at 10–20 $\times$  magnification.

Five developmental stages were considered: nauplii, metanauplii, adult females, females with egg-sacs, and adult males in *B. gaini* and nauplii, copepodites, adult females, females with egg-sacs and adult males in *B. poppei*.

We also routinely recorded salinity (LF-197 conductometer from WTW, Wilhelm, Germany), oxygen (oxygen electrode OXI-197, WTW, Germany), pH (HI 9025 pH-meter, Hanna Instruments) and water temperature (mercury thermometer).

Spearman's non-parametric correlation coefficient was computed (using SPSS for Windows Version 11.5.0.), in order to identify possible influences of salinity.

## Results

Dissolved oxygen was always near saturation; pH was circum-neutral, while water temperatures rose to about 9°C (Table 1). Saline incursions occurred at intervals. An especially massive one occurred in May 2004 with salinity jumping over 20 psu and temperature down to  $-0.5^\circ\text{C}$ .

In early October, when the ice thawed, *B. gaini* nauplii first appeared (40 individuals  $\text{l}^{-1}$ ), and lasted until Decem-

**Table 1** Means values for physico-chemical factors of Lake Wujka

	November	December	January	February	March	April	May	October	November
Temperature ( $^\circ\text{C}$ )	0.25	0.65	5.00	4.77	2.42	0.98	-0.45	0.50	0.64
Salinity (psu)	0	0.05	0	0	0.16	0.01	11.5	0.57	2.95
pH	6.91	7.30	7.39	7.85	7.71	8.00	7.28	6.71	7.14
$\text{O}_2$ ( $\text{mg l}^{-1}$ )	11.84	9.83	10.69	11.26	11.12	11.50	10.62	10.82	9.15

ber. From November to January we found metanauplii. Both stages were not observed afterwards (Fig. 2). Adults were seen from January to early May. Their maximum density was: females: 1 ind l<sup>-1</sup>; females with eggs: 5 ind l<sup>-1</sup>; males: 9 ind l<sup>-1</sup> (Fig. 2).

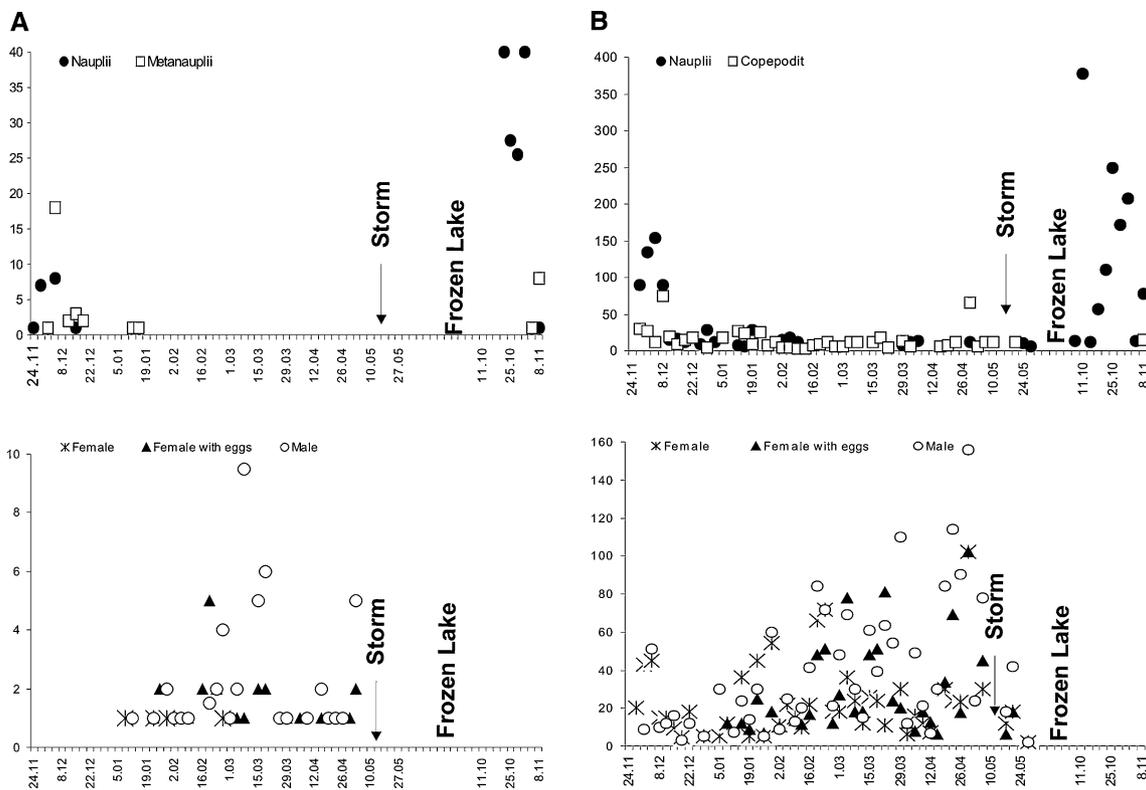
In October, nauplii of *B. poppei* appeared in high numbers (378 ind l<sup>-1</sup>). Copepodites appeared one month later in November. Their maximum densities were: 75 ind l<sup>-1</sup> in December, 27 ind l<sup>-1</sup> in January and 66 ind l<sup>-1</sup> in April. We observed at least three cohorts of nauplii and copepodites. No nauplii were observed from February to late March (Fig. 2). Females and males first appeared at the end of November and December; the first females with eggs were noted in January, again in several cohorts. The highest density was noted for adult stages in April (females: 102 ind l<sup>-1</sup>, females with eggs: 102 ind l<sup>-1</sup>, males: 156 ind l<sup>-1</sup>) (Fig. 2). Spearman’s non-parametric correlation coefficient showed that salinity positively correlated with *B. poppei* immature stages (nauplii:  $r_s = 0.471$ ,  $P = 0.027$ ) and females with eggs ( $r_s = 0.421$ ,  $P = 0.036$ ).

**Discussion**

One aspect of the ecology of lakes from the Antarctic that may determine their biota is food. Food could certainly

influence the life cycle of *B. gaini*. This shrimp is an aselective filter-feeder. Like many others, its diet is determined by the food sizes it can handle; it collects benthic Cyanobacteria and diatoms, protozoa, rotifers, as well as fragments of appendages of *B. poppei* and of *B. gaini* itself (Paggi 1996; Björck et al. 1996). Whether these fragments are from live or from dead specimens are currently uncertain, yet, adults of similar-sized species elsewhere have been found to feed on their own nauplii and on those of copepods (Dumont and Ali 2004). On the other hand, diatom density ranged from 66,000 cells l<sup>-1</sup> in December to 18,702,000 cells l<sup>-1</sup> in March (Ochwanowski and Pocięcha 2005). Also, rotifers reached high densities (up to 150 ind l<sup>-1</sup>) (Pocięcha 2007), and are probably part of the diet. We conclude that Lake Wujka offers rather abundant food to fairy shrimp.

The life cycle of *Branchinecta* is also controlled by the properties of the environment. Adaptations to local conditions consist of adjusting the duration of development, and production of resting eggs (Jurasz et al. 1983; Peck et al. 2006). The resting phase of the life cycle of *B. gaini* is in winter (June–September), when the lake freezes. Nauplii hatch in October when ice cover is still extant but thin. Their active life lasts for over 6 months (late October–early May). One generation of *B. gaini* occurs in a year. Jurasz et al. (1983) concluded that freezing of the eggs



**Fig. 2** Density (ind l<sup>-1</sup>) dynamics of immature and adults stages of *Branchinecta gaini* (a) and *Boeckella poppei* (b) in Lake Wujka

during winter might be necessary for development. This, however, remains to be demonstrated for several reasons. First, it is uncertain that the eggs lying in the sediment really freeze. It has been shown that in Antarctic lakes, by salt extrusion from the water above, a thin bottom layer rarely, if ever, freezes (Toro et al. 2007). Second, in fairy shrimp living in waters where drought and wet phases alternate, it was long believed that no eggs hatch until subjected to a dry period. This, however, has recently been questioned, since Dumont and Ali (2004) discovered that adults often cannibalize their own young, and late hatchers are eaten by older sibs. Whether this also applies to *B. gaini* remains to be studied in the laboratory, but its diet at least suggests such a possibility (see further). Successfully hatched animals reach sexual maturity after about one month; we found the first adults in early January and females with full egg-sacs in late January. Jurasz et al. (1983) found that females with eggs increase from January to March and decrease again from March to May with a peak in early March.

Salinity stimulated immature and mature fairy shrimp, but within limits. Thus, the violent storms of May 2004 swept enough seawater into the lake to kill off the entire active population. Because of the density increase that is involved in this salinity upsurge, dead, heavily pigmented animals became trapped at the water surface, and were washed ashore, forming a red line along the lake edge.

*B. gaini* co-exists with *B. poppei* but the copepod is rare inside patches of *Branchinecta* (personal observation; Bertilsson et al. 2003), suggesting a conflict. Copepods and *Branchinecta* may compete for larger (*Fragilaria*) and smaller (bacteria) food particles. Heywood (1970) provided evidence that *B. gaini* negatively affects copepods in a maritime Antarctic lake (Heywood 1970; Bertilsson et al. 2003). Perhaps the fairy shrimp not only competes for food with the copepod, but also preys on its nauplii.

The salinity crisis of May 2004 afflicted a great mortality to the copepod population, but did not wipe it out. Thus, while *B. gaini* is the superior feeder, it is more sensitive to external conditions. The success of *B. poppei* in Antarctica is therefore likely a consequence of its capability to live under rapidly fluctuating temperatures, salinities and oxygen levels (Heywood 1970; Weller 1977; Izaguirre et al. 2003; Peck et al. 2006). In lakes located on Byers Peninsula, Livingston Island, *B. poppei* and *B. gaini* co-occur in relatively high numbers in temperature, oxygen and pH conditions similar to those of Lake Wujka (Toro et al. 2007). Phytoplankton too is dominated by the same genera of pennate diatoms as in Lake Wujka (Ochwanowski and Pocięcha 2005). Our conclusion for Lake Wujka might thus apply to most Antarctic coastal lakes.

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