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NOTE

Respiration rate and swimming speed of the necrophagous amphipod *Eurythenes gryllus* from Antarctic deep waters

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ABSTRACT: During the 35th JARE (Japanese Antarctic Research Expedition) Cruise, we collected large lysianassoid amphipods *Eurythenes gryllus* alive from 3186 m depth off Lützow-Holm Bay using a baited trap and measured the respiration rates and swimming speeds of amphipods on board (−0.5 to −1.0°C). The oxygen consumption rate (OC; μM ind.$^{-1}$ h^{-1}) was significantly correlated with the wet body weight (BW; g) for $\log_{10}$ transformed data; $\log OC = 0.190 + 0.647 \cdot \log BW$ ($p < 0.05$). The swimming speed (SS; cm s^{-1}), which was determined from video camera recordings made on amphipods placed in a plastic container, also showed a linear relationship with body weight for $\log_{10}$ transformed data; $\log SS = 0.412 + 0.515 \cdot \log BW$ ($p < 0.005$). Using the regression of the swimming speed, the population density of *E. gryllus* was estimated based on a modification of an existing model of the area where the amphipods were attracted to the bait.

KEY WORDS: Ammonia-N excretion rate · Antarctic deep waters · *Eurythenes gryllus* · Lysianassoid amphipods · Respiration rate · Swimming speed

Since Hessler et al. (1972) reported the attraction of a giant amphipod to bait on the deep-sea floor in the North Pacific Ocean, the use of baited traps in combination with acoustic releases and deep-sea camera systems has revealed the rapid aggregations of necrophagous crustaceans and fishes around prey items even on oligotrophic deep-sea floors (e.g. Gage & Tyler 1991). Of these animals, the lysianassoid amphipod *Eurythenes gryllus*, which is a cosmopolitan species widely recorded from the Pacific, Atlantic, Arctic and Antarctic (e.g. Barnard & Karaman 1991), has been the principal focus of ecological and physiological studies (e.g. Ingram & Hessler 1983, Christiansen et al. 1990, Thurston 1990). Most of these studies, however, have been performed on preserved specimens and/or observations *in situ* except for George (1979), although the recovery of living specimens has been reported in the several studies.

George (1979) collected *Eurythenes gryllus* from the central Arctic Basin at a depth of 1850 m and maintained them alive for more than 3 mo in an aquarium. He reported that respiration rates and the pleopod activity which reflects the degree of swimming activity in *E. gryllus* did not vary between 1 and 325 atm pressure. This allows an estimation of the *in situ* respiration rates and the activity of *E. gryllus* from experimental conditions under atmospheric pressure. Here, we report the results of on-board experiments on respiration rates and swimming speed of *E. gryllus* collected from the abyssal floor off Antarctica.

Materials and methods. On December 17, 1993, during the 35th JARE (Japanese Antarctic Research Expedition) Cruise, a baited trap modified from that used in the Hakuho-Maru KH-93-1 Cruise (Numachi 1994) was lowered from the icebreaker 'Shirase' to the sea floor, 3186 m deep off Lützow-Holm Bay (Fig. 1; 67° 43' S, 39° 10' to 39° 07' E). The ship was stopped in fast ice during the sampling period. The trap consisted of 4 chambers, each made of a PVC tube 100 cm long and 38 cm in diameter; the lower two were attached to the base of the frame, while the centers of the upper two were set 105 cm from the bottom. Inverted entrance cones, made of 1.0 mm mesh stainless steel and narrowing to an opening of 10 cm diameter, were set at both ends of the tubes. A mesh nylon bag which contained about 2 kg of coarsely chopped Pacific saury *Cololabis saira* (Brevoort) was set in each chamber. After keeping the trap for 6 h 20 min on the sea floor, we raised it at a speed of 0.5 to 1.2 m s^{-1}.

The ice conditions of Lützow-Holm Bay area during the 1993/94 austral summer was the worst during this

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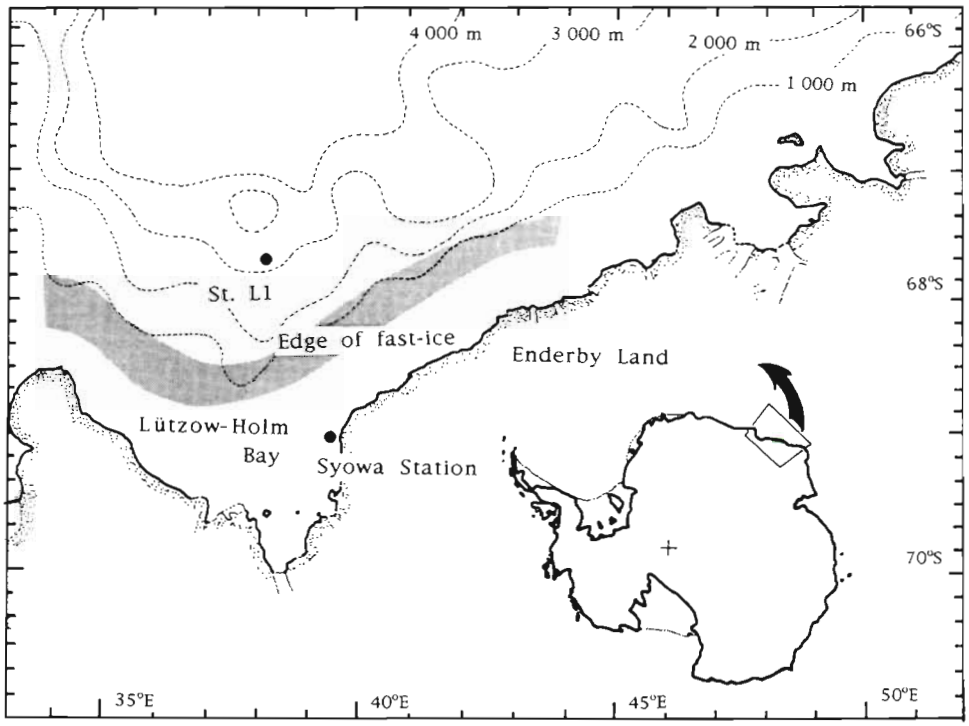

Fig. 1 Map indicating the sampling site off Lützow-Holm Bay, Indian Sector of Antarctica. Stn L1, the sampling site of the present study, is situated on the abyssal floor at 3186 m depth

decade, and hindered the 'Shirase' from approaching Syowa, the Japanese Antarctic Base (Watanabe 1994). This prevented us from conducting further baited trap collection from the abyssal sea floor off Antarctica.

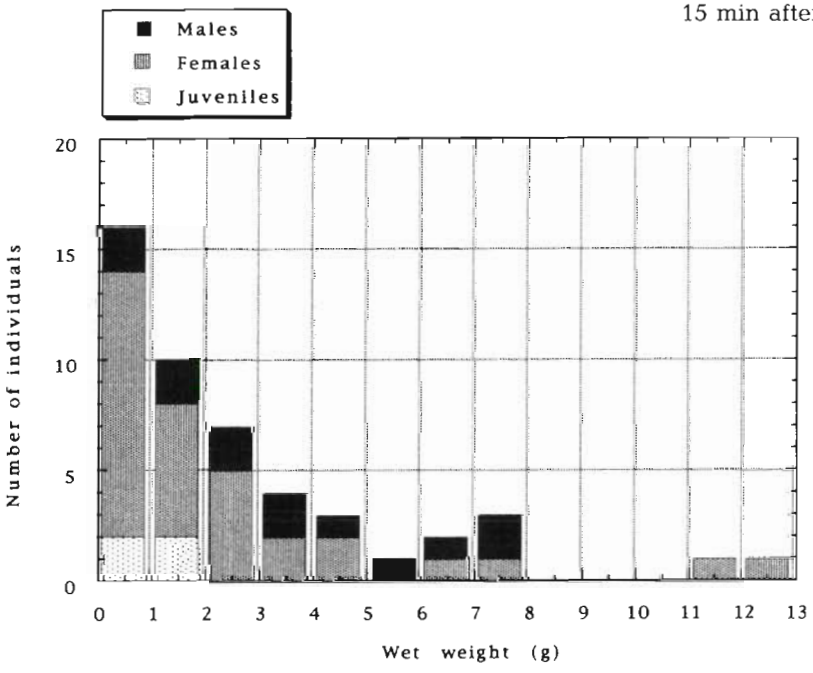

Fig. 2. *Eurythenes gryllus*. Size frequency distribution by wet weight of amphipods collected from 3186 m off Lützow-Holm Bay, Antarctica

Oxygen consumption was measured using a pulsed electronic dissolved oxygen meter (Endeco/YSI Type 1125). Amphipods were individually kept in 250 or 500 ml polycarbonate bottles; this prevented them from swimming freely. Recordings of the dissolved oxygen concentration at 5 min intervals were started 10 to 15 min after the amphipods were transferred into the bottles and the difference in the mean of the first 3 and the last 3 measurements was used to determine the oxygen consumption rate. Incubation time was 4 to 8 h depending on the size of the individual. The ammonia-N excretion rate was measured by the Indophenol blue method simultaneously with the measurement of oxygen consumption rate (The Oceanographic Society of Japan 1985). Swimming speed was determined from video camera (Sony Co. Ltd; Handy Cam CCD-TR3) recordings made of amphipods placed in a 26.6 cm diameter plastic container. Recordings were started 5 to 15 min after the amphipods were placed in the container. In the container the amphipod continuously swam along the inner wall. Swimming speed was estimated from the time required for amphipods swimming continuously to swim from 4 to 8 circuits around the

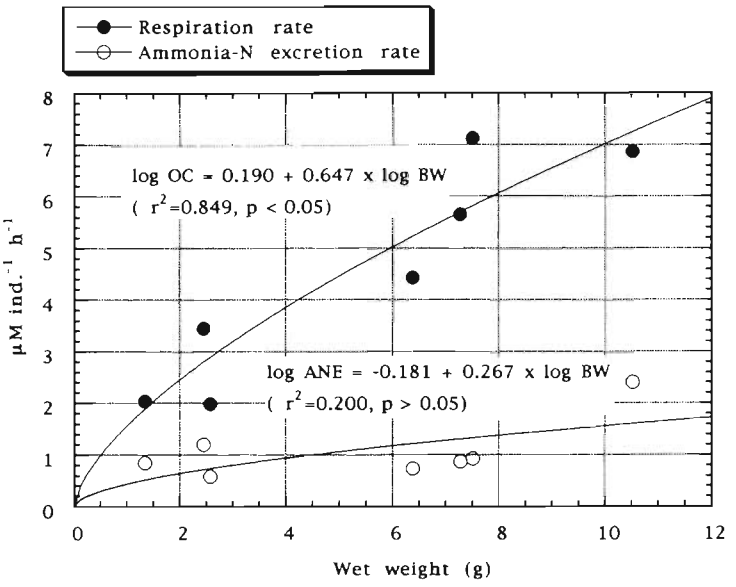

Fig. 3. *Eurythenes gryllus*. Oxygen consumption (OC) and ammonia-N excretion (ANE) rates at atmospheric pressure and −0.5 to −1.0°C. BW: body weight

container. The laboratory was maintained between −0.5 and −1.0°C with light from a 20 W incandescent lamp throughout the experiments.

After the experiments, the body length and fresh body weight of each amphipod, together with the other individuals which were not used in the experiments, were measured. Body length in the present study was measured from the anterior margin of the head to the basal part of the telson along the dorsal margin. Sex was determined by the presence or absence of the genital pipette.

Results. In total, 48 specimens of *Eurythenes gryllus* were collected, corresponding to 64.8% of the total number of necrophagous invertebrates retrieved (I. Takeuchi, A. Tanimura & K. Watanabe unpubl.).

The size frequency distribution by wet weight (g) of *Eurythenes gryllus* (wet weight ranged from 0.04 to 12.49 g) is shown in Fig. 2. Females outnumbered males with a sex ratio of 0.419 (males/females). The body length (BL; mm) correlated well with the body weight (BW; g) when $\log_{10}$ transformed ($p < 0.001$):

$$\log BW = -4.251 + 2.68 \cdot \log BL \quad (r^2 = 0.962) \quad (1)$$

The oxygen consumption (OC) rate increased from 1.99 to 7.13 µM ind.$^{-1}$ h^{-1}, and ammonia-N extraction (ANE) rate was 0.58 to 2.41 µM ind.$^{-1}$ h^{-1} (Fig. 3). Only respiration rate per individual was significantly correlated for $\log_{10}$ transformed data ($p < 0.05$).

$$\log OC = 0.190 + 0.647 \cdot \log BW \quad (r^2 = 0.849) \quad (2)$$

$$\log ANE = -0.181 + 0.267 \cdot \log BW \quad (r^2 = 0.200) \quad (3)$$

The mean atomic ratio of O/N of 9.07 ± 3.94 indicates that the amphipods' metabolism remained protein-dominated during the experiment.

The amphipods swam in a circular motion between 12 and 102 times during the observation periods. The swimming speed (SS) increased significantly from 2.736 ± 0.088 to 8.081 ± 0.798 cm s^{-1} with body weight ($p < 0.005$), as shown in Fig. 4.

$$\log SS = 0.412 + 0.515 \cdot \log BW \quad (r^2 = 0.959) \quad (4)$$

Discussion. Our knowledge on the behavioral and physiological aspects of *Eurythenes gryllus* has been accumulated mostly from *in situ* video camera and laboratory experiments on Ice Island in the Arctic. Laver et al. (1985), using a free-vehicle video camera at the abyssal floor of the North Pacific, reported on the *in situ* swimming speed of *E. gryllus*. They recorded speeds of 7.3 ± 3.7 cm s^{-1} with no significant correlation with body length ($p > 0.05$). The results of our swimming speed observations are contrary to theirs as we found a significant increase of speed with body length. The respiration rates of our study, 21.70 ± 7.35 ml g^{-1} at −0.5 to −1.0°C correspond to about one-third of the measurements by George (1979), which ranged between 60 and 64 ml g^{-1} at 2°C.

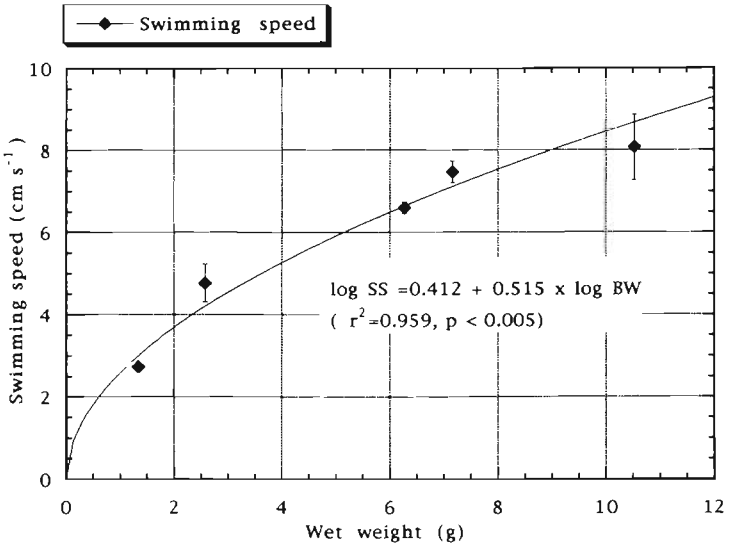

Fig. 4. *Eurythenes gryllus*. Swimming speed (SS) recorded at the atmospheric pressure and −0.5 to −1.0°C. BW: body weight

The lower respiration rates in the present study may have resulted from the difference of temperature between the 2 experiments.

The regression of swimming speed to body weight enables the model (Rowe et al. 1986) for estimating the area from which necrophagous animals are attracted to bait to be revised. The model is based on the horizontal mean current along the x-axis and on the physical dispersion on the y-axis of chemical stimuli from the bait. On the assumption that the amphipods start to swim to the bait after they detect any stimuli, the distance in both the x- and y-axes will depend on the swimming speed of the amphipods. As shown in Fig. 4, the speed is closely correlated with the body weight. Using this correlation, the formula in Rowe et al. (1986) can be modified as follows:

$X_i = ut_i = (m_i - u)(T - t_i)$ (u, current speed; t_i, the time at which amphipods start to swim after setting the trap; m, swimming speed; T, the bottom time of the trap) (5)

$Y_i = \sqrt{2K_{yi}T}$ (Ky_i, the diffusibility coefficient on the y-axis) (6)

$S_i = \frac{4}{3} \cdot X_i Y_i$ (S_i, estimated bottom area) (7)

$d_i = n_i/S_i$ (d_i, population density; n_i, number of individuals collected in the trap) (8)

Thus, the density (D) of *Eurythenes gryllus* at the collection site is estimated as:

$$D = \sum_i d_i \quad (9)$$

In the present study, the bottom time of the trap (T) was 6 h 20 min. Ishino (1989) showed that the current at depths greater than 1500 m along the 120° E meridian line near the Antarctic continent ranges from 0 to 2 cm s^{-1}. Assuming that a northerly current is restricted to the same range (0 to 2 cm s^{-1}), u in the collection site of this study is estimated to be 2.82 cm s^{-1} at its maximum. Using these assumptions, it is possible to conduct a preliminary estimation of *Eurythenes gryllus* at the collecting site. In the estimation, Ky_i ranged from 30.6 to 303.4 cm^2 s^{-1} based on the empirical relationship between the horizontal variance and diffusion time by Okubo (1971), and a density of 3.57×10^4 ind. km^{-2} with a biomass of 6.16×10^4 wet g km^{-2} was obtained.

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