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OXYGEN CONSUMPTION OF THE DEEP-SEA CRABS *CHACEON FENNERI* AND *C. QUINQUEDENS* (BRACHYURA: GERYONIDAE)

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Abstract—1. Oxygen consumption rates (VO_2) were determined for the deep-sea crabs *Chaceon fenneri* and *C. quinquedens*, two important members of the continental slope megafauna in the eastern Gulf of Mexico.

2. The VO_2 of *C. fenneri* declined from 0.014 ml O_2/g/hr at 12°C to 0.010 ml O_2/g/hr at 6°C; VO_2 of *C. quinquedens* showed a decline from 0.012 ml O_2/g/hr to 0.008 ml O_2/g/hr over the same temperature range.

3. The VO_2 of *C. fenneri* and *C. quinquedens* are comparable to those of similar size shallow water decapod crustaceans that inhabit equivalent temperatures.

4. The oxygen consumption rates of *C. fenneri* and *C. quinquedens* decline with increasing depth of occurrence purely as a function of temperature.

INTRODUCTION

It is well documented that the physiological rates of pelagic fishes and crustaceans show a decline with increasing depth of occurrence that greatly exceeds the effects of the concomitant decline in temperature (Childress, 1975; Torres *et al.*, 1979; Childress *et al.*, 1980; Torres and Somero, 1988). The decline in metabolism in deeper living species has been attributed to the reduced musculature and locomotory abilities that are selected for by reduced locomotory demands (Childress *et al.*, 1990). A lower incidence of visual predation in the dimly lit midwater allows deep-living pelagic species the luxury of a less robust chemical composition and lower energy utilization in an environment characterized by reduced food levels (Childress and Nygaard, 1973). Their lower metabolic rates are reflected in a similarly low activity of intermediary metabolic enzymes (Childress and Somero, 1979).

Only recently has attention focused on the metabolic rates of deep-sea benthic invertebrates. In contrast with the pelagic species, the available literature suggests that regardless of depth of occurrence, oxygen consumption rates of deep-sea benthic organisms are dependent solely on temperature, and are often comparable to rates of shallow-water counterparts found at similar temperatures (Mickel and Childress, 1982; Smith, 1983; Childress and Mickel, 1985; Childress *et al.*, 1990).

We report on the oxygen consumption rates of two species of deep-sea crabs; the golden crab *Chaceon* (*Geryon*) *fenneri* and the red crab *C. quinquedens*. These large brachyurans are major components of the continental slope megafauna and often rank among the top ten species in both numerical abundance and biomass (Haedrich *et al.*, 1975; 1980). Thus, they are important members of continental slope benthic assemblages.

Geryonid crabs typically exhibit large size (Manning and Holthuis, 1984, 1989), slow growth (Melville-Smith, 1989), late maturity, delayed and iteroparous reproduction, and low fecundity (Erdman and Blake, 1988; Hines, 1988; Erdman *et al.*, in press).

Two species are present in the eastern Gulf of Mexico: the golden crab *Chaceon fenneri*, and the red crab *C. quinquedens*. Each species is segregated by depth with little overlap in bathymetric distribution; *C. fenneri* is found between depths of 311 to 770 m, while *C. quinquedens* shows a minimum depth of occurrence greater than 670 m (Lockhart, 1988; Lockhart *et al.*, 1990).

MATERIALS AND METHODS

Specimens of *C. fenneri* and *C. quinquedens* were collected quarterly during 1987 and 1988 from depths of 311 to 677 m in the eastern Gulf of Mexico (for sampling methods see Lockhart *et al.*, 1990). Bottom water temperatures were recorded at each sample depth using reversing thermometers and XBTs. Mean bottom temperatures throughout the quarterly sampling period ranged from 11.6°C at 311 m to 7°C at 677 m. All animals were held aboard ship in a refrigerated recirculating seawater system ($T = 9$°C) for transport purposes.

In the laboratory, crabs were held at ambient pressure in two refrigerated aquarium systems maintained at 9°C (±0.5°C) and 35.0 ppt; lighting was reduced to near darkness. All crabs were fed scallop meats, shrimp, and squid. Mortality of captive animals was less than 5%.

Temperatures were raised or lowered to experimental temperatures of 6 and 12°C over periods of 12–14 days. Once experimental temperatures were reached, crabs were acclimated for 14 days prior to measurement of respiration rates (VO_2). Experimental animals were not fed during the acclimation period.

Oxygen consumption rates were determined by allowing individual crabs to deplete the oxygen in a sealed, seawater filled 22.0 l Plexiglass chamber. Experimental temperatures of 6 and 12°C (±0.2°C) were maintained in the chamber by circulation of refrigerated water through a surrounding water jacket. The entire chamber was insulated to prevent temperature fluctuations and covered with black plastic to

reduce light to minimum levels. Three crabs of each species were tested at each experimental temperature. All experimental animals were of equivalent size and weight to preclude size-related variations in oxygen consumption rates.

Seawater used in each experiment was vacuum filtered through a 0.47 μm glass fiber filter. Streptomycin and Neomycin (25 mg/l each) were added to minimize microbial activity. To control for potential microbial oxygen consumption, the experimental animal was removed after selected runs, its volume replaced by fresh seawater, and the oxygen consumption measured for an additional 4–6 hr. Microbial respiration was negligible in all cases.

Partial pressure of oxygen was continuously measured with a Clark-type O_2 electrode. To insure adequate circulation, a stirring bar was placed in a 7.5 cm diameter perforated plexiglass cylinder attached upright to the bottom of the chamber. The cylinder partially enclosed the O_2 electrode and protected it from contact by experimental animals. The stirring bar was run at minimum speed to prevent excessive turbulence within the chamber. Electrodes were calibrated for each experiment using air and nitrogen saturated seawater. As the same animals were utilized at each experimental temperature, experiments were terminated when oxygen partial pressures approached 25 mm Hg. Experimental run times ranged from 16–20 hr at 12°C, and 24–29 hr at 6°C. At the end of each experiment, the crab was blotted dry, the wet weight recorded to the nearest 0.1 g, and the animal returned to the holding system.

Data were recorded on a potentiometric strip chart recorder. Each chart was then scaled for total run time and total oxygen concentration (ml O_2/l). The change in oxygen concentration over time was then measured directly from the scaled strip chart using a Houston Instruments Complot large format digitizing table and recorded on a microcomputer. To eliminate elevated rates due to handling during the initiation of each experimental run, data from the first 3–4 hr were not used in rate calculations. Respiration rates were measured between pO_2s of 110 and 30 mg Hg. Weight specific VO_2s were calculated in ml O_2/g wet wt/hr. Activity levels of each animal were observed every 2 hr during each experiment.

RESULTS

At each experimental temperature, the oxygen consumption rates of individual animals of each species remained fairly constant over the pO_2 range of 110–30 mm Hg. Mean respiration rates of *C. fenneri* and *C. quinquedens* as a function of temperature are shown in Table 1. VO_2s of each species were approximately equal at each experimental temperature. Q_{10}s for each species are also shown in Table 1; these values were also equivalent for each species over the 6°C range of experimental temperatures.

Table 1. Routine respiration rates (VO_2) and Q_{10}S of *Chaceon fenneri* and *C. quinquedens* acclimated and measured at 6 and 12°C

Species	T °C	*N*	VO_2 (range)	Weight (range)	Q_{10}
C. fenneri	6	3	0.010 (0.009–0.012)	484 (454–512)	1.82
	12	3	0.014 (0.012–0.017)	488 (450–507)	
C. quinquedens	6	3	0.008 (0.008–0.010)	411 (375–440)	1.78
	12	3	0.012 (0.012–0.013)	400 (362–438)	

N represents the number of individuals tested at each temperature. VO_2 is expressed as ml O_2/g/hr and weight is expressed in grams.

Although not quantified, *C. fenneri* showed greater activity than *C. quinquedens* during experiments at 12°C. *Chaceon fenneri* moved about the chamber and often hung on the perforated column used to protect the oxygen electrode. *Chaceon quinquedens* usually remained quiescent on the bottom of the chamber at 12°C. Both species showed greater activity levels at 6°C and were often observed hanging on the perforated column surrounding the oxygen electrode.

Observations of activity levels were also made on each species while in the refrigerated holding system. At 12°C, *C. fenneri* was quite active and was often observed to climb on the artificial habitat present in the holding system. Conversely, *C. quinquedens* was usually quiescent and only became active in the presence of food. Both species were quite active at 6°C regardless of the presence of food.

DISCUSSION

At each experimental temperature, the rate of oxygen consumption of individual *C. fenneri* and *C. quinquedens* remained nearly constant over the pO_2 range of 110–30 mm Hg. In crustaceans, this is usually achieved by increased ventilation volume and per cent oxygen utilization (Wolvekamp and Waterman, 1960). These observations suggest that *C. fenneri* and *C. quinquedens* are efficient oxy-regulators and would be able to tolerate any reduced oxygen concentrations encountered on the continental slope.

The Q_{10} values obtained for each species show that temperature is a major factor affecting the respiration rates of *C. fenneri* and *C. quinquedens*. The increase in rates over the 6°C experimental temperature range approximate a Q_{10} of 2.0 which indicates no temperature compensation in the oxygen consumption rates of these species.

The routine respiration rates reported here differ from those reported for *C. fenneri* and *C. quinquedens* by Henry *et al.* (1990). Although they report a comparable rate for *C. quinquedens* at 5°C (0.007 ml O_2/g/hr), the rate reported for *C. fenneri* (0.003 ml O_2/g/hr) is approximately one third of the rate reported here. Major differences in experimental methodology may be responsible for the dissimilarities noted between each study.

Although metabolic data on deep-sea benthic crustaceans are scarce, the present data may be compared to rates of shallow water counterparts that inhabit similar temperatures. Using an assumed Q_{10} of 2.0, the adjusted VO_2s of five species of shallow water decapods that inhabit cold temperatures are shown in Table 2. The species considered (*Cancer pagurus*, *C. magister*, *Maia squinado*, *Chionocetes bairdi*, and *Homarus americanus*) are all of equivalent size to our study animals. In all cases, the VO_2s of *C. fenneri* and *C. quinquedens* are comparable to those of shallow water cold temperature counterparts.

The data presented here agree with those of Childress *et al.* (1990) who suggest that metabolic rates of deep-sea benthic decapod crustaceans decline with increasing depth of occurrence purely as a function of temperature. We also conclude that the visual interaction and food limitation hypotheses (see Childress *et al.*, 1990 for review) that are proposed to explain the observed relations among depth,

Table 2. Comparative routine respiration rates for large cold temperature shallow water crustaceans. VO_2 is expressed as ml O_2/g/hr and weight in grams. Values in column 3 represent the oxygen consumption rate and experimental temperature as reported in source literature

Species	Source	Weight range	VO_2 T °C	VO_2* 6°C	VO_2* 12°C
Cancer pagurus	A	363–753	0.010 (10)	0.008	0.011
Cancer magister	B	343–1073	0.013 (7.5)	0.012	0.018
Maia squinado	A	510–679	0.010 (10)	0.008	0.011
Homarus americanus	C	380–520	0.021 (12)	0.014	0.021
Chionocetes bairdi	D	340–350	0.014 (7)	0.013	0.020

*Rate shown derived from cited sources using a Q_{10} of 2.0.
A: Aldrich, 1975a, 1975b.
B: Prentice and Schneider, 1979.
C: McLeese, 1964.
D: Paul and Fuji, 1989.

temperature and metabolic rates in the pelagial, do not apply in the benthos.

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