THE OXYGEN CONSUMPTION OF THE ANTARCTIC LIMPET
Nacella (Patinigera) concinna

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Abstract. The oxygen consumption of the patellid limpet *Nacella (Patinigera) concinna* has been measured at 5° C. The mean animal tissue dry weight was 384 mg. and the oxygen consumption of a *N. concinna* of this size was 56·6 µg. O_2/hr. When compared with the temperate limpet *Patella vulgata*, *N. concinna* does not show any cold adaptation of its oxygen consumption.

The only Antarctic representative of the widespread limpet family, Patellidae, has had a varied taxonomic history. First described as *Patella polaris* by Hombron and Jaquinot (1841), it was placed in a new genus as *Patinigera polaris* by Powell (1951), with a subspecies *P. p. concinna* occurring in deeper water at South Georgia. In a recent review of the patellid limpets of the world, Powell (1973) relegated *Patinigera* to a subgenus of the genus *Nacella;* he also queried the validity of the subspecies *concinna* and described the single Antarctic patellid as *Nacella concinna* (Strebel, 1908). Powell's terminology has been adopted in this paper.

Nacella concinna is a dominant member of the littoral and sub-littoral fauna of the west Antarctic. Its type locality is South Georgia but it is also found at the South Orkney and South Shetland Islands, on the Antarctic Peninsula, at Bouvetøya and at other small Antarctic and sub-Antarctic islands (Powell, 1960). The littoral zone in the Antarctic is influenced by seasonal ice formation and has an impoverished fauna when compared with lower latitudes. *N. concinna* occupies a similar ecological niche to the European limpet *Patella vulgata;* some aspects of its ecology have been investigated by Walker (1972), while Berry and Rudge (1973) have looked at variations in *N. concinna* from different areas.

N. concinna is commonly predated by the Dominican gull, *Larus dominicanus*, and the sheathbill, *Chionis alba*. The brown skua, *Catharacta skua lönnbergi*, will also take them but it is the gull that is the most important terrestrial predator. Gulls eat the limpets whole and the shells are regurgitated later, often unbroken. This habit means that some estimate could be made of the predation rate and the energy flow from the littoral to the terrestrial system. Examination of fish stomach contents at Signy Island (Richardson, 1975) showed that *N. concinna* constituted 35 per cent of the molluscs taken in the diet of the fish *Notothenia neglecta*. At King Edward Cove, South Georgia, *N. neglecta* is less commonly found though stomach contents from this species examined there were also found to contain shells of the semi-digested limpets *N. concinna* (paper in preparation by J. G. H. Maxwell). This paper presents data on the oxygen consumption of *N. concinna* in relation to body weight and shell length.

MATERIAL AND METHODS

The animals were collected from rocks and boulders along the shoreline of the inner part of King Edward Cove, South Georgia, in January and February (mid-summer) 1974. The water temperature in this area at this time was around 5° C, fluctuating by a degree or two depending upon the state of the tide and the time of day. In the laboratory, the animals were kept at 5° C and all experiments were carried out at this temperature.

Oxygen consumption rates were measured by a closed bottle Winkler technique, the Winkler determinations being carried out by the macro-method described by Barnes (1959) using the modified titration flasks of Strickland and Parsons (1968). The respiration bottles were screw-capped with a volume of approximately 135 ml. and the experiments usually lasted for 1 hr. but were longer for the smallest animals. A correction was applied for the volume occupied by the animals themselves and a bottle with no animal was used as a control in each set of measurements. The oxygen concentration in the bottles at the end of an experiment was never less than 75 per cent of the initial concentration. At the end of an experiment the shell lengths of the animals were measured, the soft parts dissected away from the shell, wet weighed, dried at 60° C and re-weighed. Oxygen consumption was calculated as µg. O_2/animal/hr.

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RESULTS

The relationship between tissue dry weight and shell length is shown in Fig. 1 plotted on logarithmic scales. The linear regression equation for the data is

$$\log Y = 2 \cdot 851 \log X - 1 \cdot 614,$$

where Y is the tissue dry weight in mg. and X is the shell length in mm.

The relationship between tissue dry weight and wet weight is of less value because of the inherent inaccuracy involved in weighing wet tissue. However, measurements were made on 17 individuals and tissue dry weight was $19 \cdot 5$ per cent of the wet weight with a standard deviation of $1 \cdot 6$ per cent.

The results of the oxygen consumption measurements are shown in Fig. 2 plotted against dry weight, again on logarithmic scales. The regression equation is

$$\log Y = 0 \cdot 7485 \log X - 0 \cdot 1803,$$

where Y is the oxygen consumption in µg. O_2/animal/hr. and X is the dry tissue weight in mg.

The mean weight of the animals used was 384 mg. and an individual of this weight has a calculated oxygen consumption of $56 \cdot 6$ µg. O_2/hr.

DISCUSSION

There is a well-established relationship between oxygen consumption (Y) and body weight (X), taking the form $Y = aX^b$ (Zeuthen, 1947; Prosser and Brown, 1961). This is more conveniently expressed logarithmically as

$$\log Y = \log a + b \log X.$$

The value of the regression coefficient b has received much attention and Hemmingsen (1960) suggested that a value of $0 \cdot 75$ may be general for poikilotherms. The value of $0 \cdot 749$ for *N. concinna* is in good agreement with this.
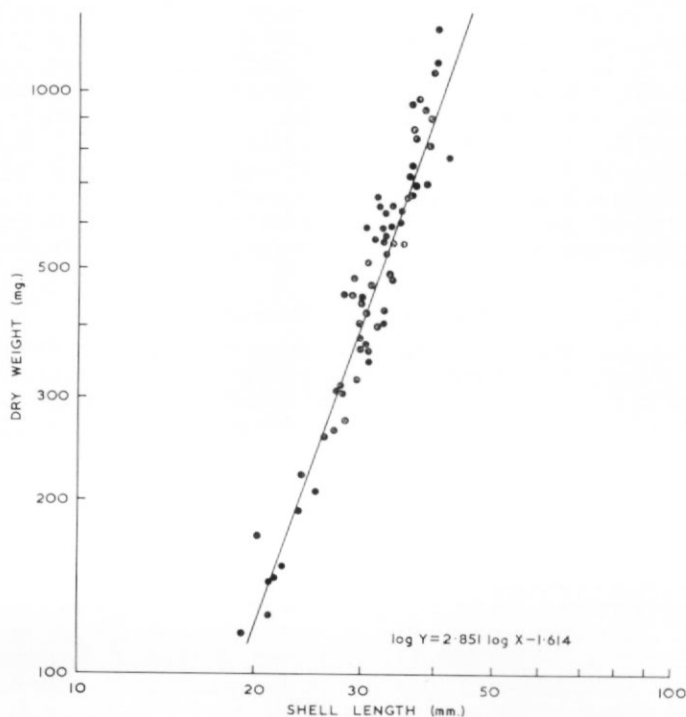

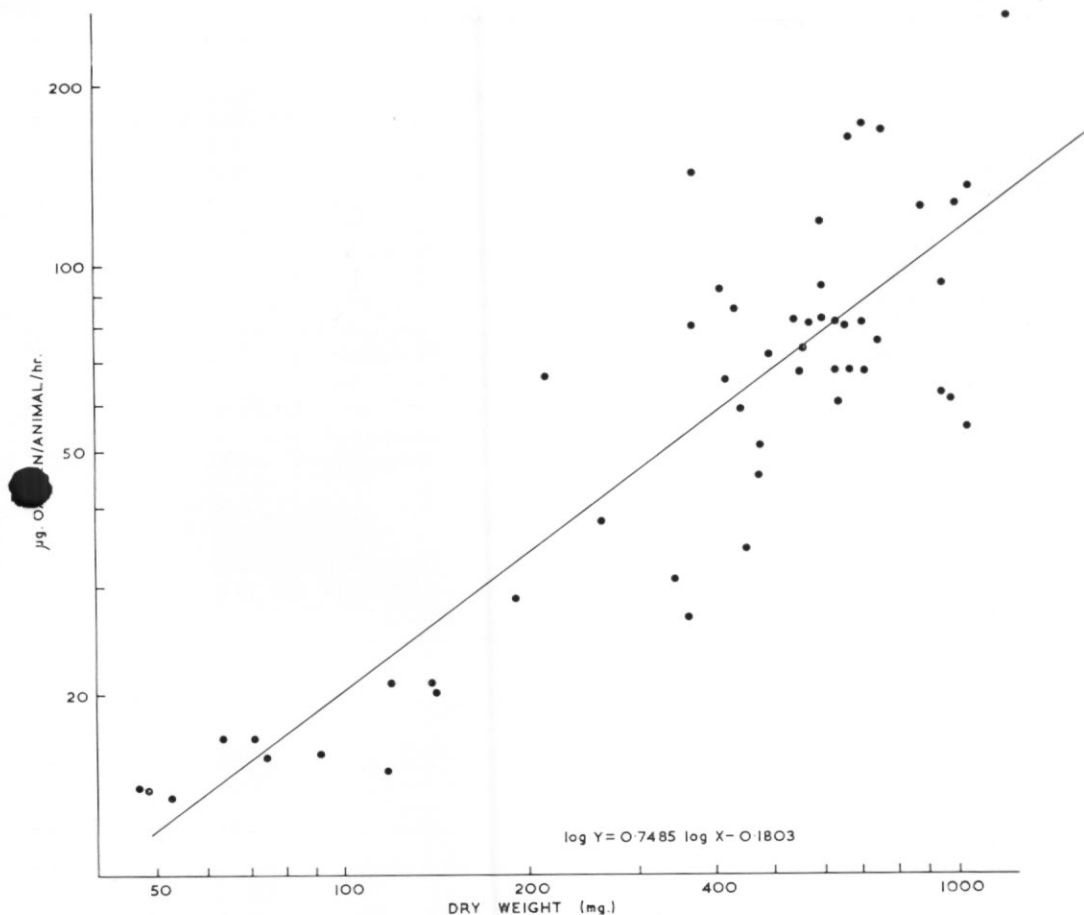Fig. 1. The relationship of dry weight to shell length for *Nacella concinna*.

Fig. 2. The oxygen consumption of *Nacella concinna* at 5° C plotted against dry weight.

There appears to be no information on the oxygen consumption of other Antarctic molluscs with which the results for *N. concinna* can be compared. However, Davies (1966) has investigated the effect of body size and temperature on the metabolic rate of the temperate limpet, *Patella vulgata*. He expressed his results as oxygen consumption per unit wet weight of tissue, but, using the value for *N. concinna* of 19·5 per cent for dry to wet tissue weight, a direct comparison can be made.

The oxygen consumption of a 1 g. dry weight *N. concinna* at 5° C is 115 μg. O_2/hr. Davies (1966) found that there were differences in the respiratory rate of *P. vulgata* depending upon the season of the year and whether individuals came from high or low levels on the beach; however, a mean figure for comparison here can be taken as 145 μg. O_2/hr. for a 5 g. wet weight animal at 5° C. The respiration rates of the two species are broadly similar at this temperature but it must be borne in mind that 5° C is probably close to a summer maximum temperature for *N. concinna* and to winter minimum for *P. vulgata*. The latter species can increase its rate of oxygen consumption to 340 μg. O_2/hr. at 15° C and to 518 μg. O_2/hr. at 25° C, both values calculated for a 5 g. wet weight animal. In most parts of its range *N. concinna* will rarely experience temperatures higher than 2° C.

The subject of cold adaptation in arctic and northern temperate poikilotherms has been extensively reviewed by Scholander and others (1953), Bullock (1955), and Prosser and Brown

(1961). It has also been described in several species of Antarctic fish by Wohlschlag (1964). However, Holeton (1974) has questioned the experimental work on which the whole concept of cold adaptation in Arctic fish is based and suggested that the phenomenon may be an experimental artifact. Studies on the Antarctic isopod *Glyptonotus antarcticus* (White, 1975) and on the bivalve *Gaimardia trapesina trapesina* (Ralph and Maxwell, 1977) showed that neither species exhibited cold adaptation which supports the view that this feature of respiratory metabolism is not a prerequisite for marine invertebrates living at polar latitudes. In addition, Holeton (1974) pointed out that much of the concept depends upon the use of Krogh's (1916) standard metabolism curve to extrapolate data over a wide temperature range. The low-temperature end of this curve is based on very little experimental work and Holeton (1974) suggested that in view of more recent data it is no longer reasonable to use Krogh's (1916) curve for extrapolation of data from temperate and tropical animals to polar temperatures.

It is not clear how much a consideration of individual experimental techniques will influence the concept of cold adaptation in invertebrates but certainly the criticism of the use of Krogh's (1916) standard curve will apply to invertebrates as much as to fish.

In comparison with *P. vulgata*, *N. concinna* seems to show no cold adaptation of its metabolic rate, although more work needs to be done on its oxygen consumption at other temperatures and on other parameters such as heart rate, growth rate, longevity and so on.

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