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Ecological and Physiological Studies of the Antarctic Limpet *Nacella concinna* in King George Island

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Abstract: The shell length & weight relationship, size frequency, density & biomass, oxygen consumption, ammonia excretion and faecal egestion of the Antarctic limpet *Nacella concinna* have been investigated in King George Island during the austral summer of 1992-1993. The limpets were mainly sampled from a tide pool and an exposed boulder on intertidal zone. For the materials sampled on Feb. 6 in the tide pool, the limpet density was 326.3 ind. m^{-2} and biomass was 76.57 g dry weight m^{-2}. A 250 mg limpet with the length of 24.1 mm consumed 35.71 $\mu g\ O_2\ h^{-1}$, and produced 2.29 $\mu g\ N\ h^{-1}$ and 591.32 μg faeces h^{-1}. The O/N ratios were between 8.9-18.3 which indicated that protein was the main metabolic substrate being used by *N. concinna*. With the increasing body weight, the metabolic rate per individual increased, but the rate per unit weight decreased.

Key words: Antarctica, *Nacella concinna*, King George Island, limpet ecology, limpet physiology.

INTRODUCTION

The Antarctic limpet *Nacella concinna* is the most dominant species in the intertidal and subintertidal areas of the west Antarctica (Ralph and Maxwell, 1977). It was formerly named *Patella polaris* (Hombron and Jaquinot, 1841) and *Patinigera polaris* (Powell, 1973). The limpets graze on diatoms, algae and detritus (Shabica, 1971, 1976). On the other hand, it is consumed by sea bird, fish and other carnivorous invertebrates (Shabica, 1971), thereby playing an important role in marine food chain in the coast area. In the last two decades, many studies have been done on growth, longevity, respiration, faecal production and ammonia excretion at Anvers, South Georgia and South Orkney Islands (Shabica, 1971; Ralph and Maxwell, 1979; Clarke, 1990). Walker (1972) suggested that there were two populations for *Nacella concinna*: one was the intertidal and shallow subintertidal population, and the other was the deep subintertidal population. Most of the previous studies dealt with the second population.

Since the establishment of a Chinese Antarctic base, the Great Wall Station, in Fildes Peninsula on King George Island, some studies have been made on the limpet. Yang *et al.* (1992a,b) also pointed out that *N. concinna* was the most abundant and important herbivorous animal along the rocky shore of Fildes Peninsula. Therefore, to get a better understanding on the intertidal ecosystem in Fildes Peninsula, it's necessary to study the ecology and physiology of *N. concinna*. In this paper, oxygen consumption, ammonia excretion and faecal egestion were measured in the intertidal zone of this area.

MATERIALS AND METHODS

The limpets were sampled from three sites during the austral summer of 1992-1993 (Fig. 1). Site 1 was a shallow tide pool in the north of Adelie Island. It was in the low intertidal zone, covered with macro algae *Iridaea obovata* and *Adenocystis utricularis*, the mean water depth was about 30cm at the lowest ebb tide, and the substrate consisted mainly of small gravel. Site 2 near the Great Wall

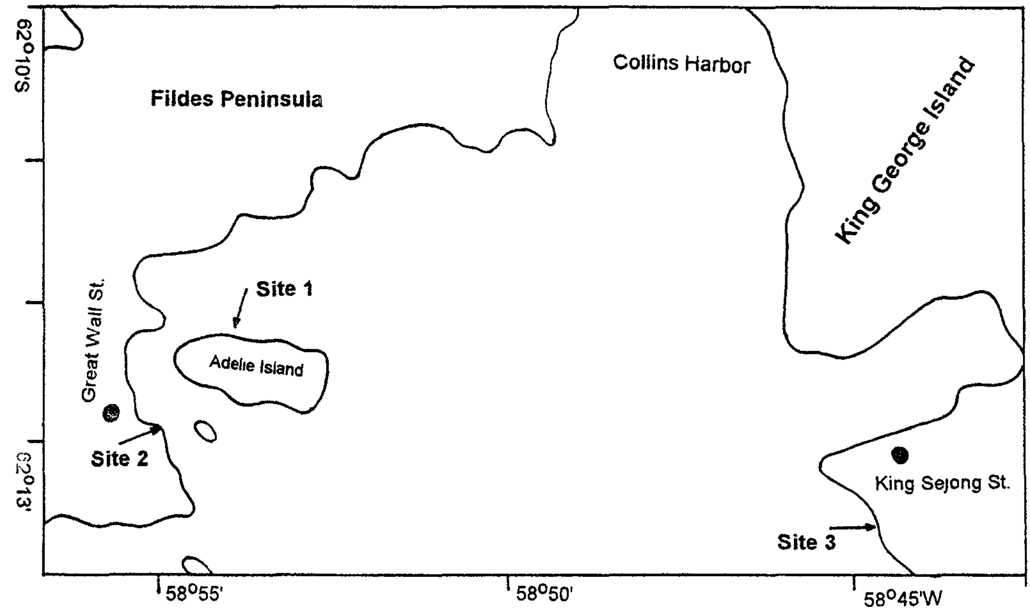

Fig. 1. Geographic location of the sampling sites in King George Island.

Station, was an exposed boulder area from mid to low intertidal zone. Site 3 was a broad beach 500 m south of King Sejong Station, the Korean base.

The animals were collected at random between 0900-1200. The shell length, sometimes the shell width of each limpet was measured using a venier caliper to the nearest of 0.2 mm, sorted into groups with length span of 2.0 mm. After measuring, limpets were immediatly placed into labled glass vessel (41) filled with aerated sea water and provided with algae as a food source.

All the sea water used in the experiments was prefiltered with glass fibre filter and aerated prior to use in experiments.

Faecal egestion measurement was initiated between 1500-1600 at the day of sampling. Each of the groups of limpets was transfered into a new glass vessel filled with prefiltered sea water. Seawater in each vessel was aerated gently during the experiment. The number of limpets in each group varied from 5 to 15 depended on the size. Twenty four hours later, the faecal pellets were collected with a pipette and washed with distilled water gently. The waste materials were picked out. Finally, the faeces were dried at 65°C for 48 hours.

For oxygen consumption and ammonia excretion experiments, 4 groups of healthy limpets acclimated for one day were taken out from the vessel next morning at 9:00, put into 1L glass bottles and reincubated with food for 4h to allow for recovery from the effects of manipulation. At 13:00 the water was decanted out and the bottles with limpet were washed with filtered sea water carefully. New filtered sea water was added and the bottles were covered tightly. In every experiment, each group of limpets had 8 subgroups of samples, 4 for oxygen test, 4 for ammonia test, and the time series of oxygen and ammonia measurements were conducted every 1 hr for 4 consecutive hours. Each subgroup contained 3-5 limpets depended on the size. Meanwhile, 8 bottles of sea water with no animal were used as controls. Oxygen and ammonia concentrations were determined in duplicate by Winkle Technique and Oxidation Method.

The experiments were carried out at 3.6 to 5°C with a maximum variation of 0.2°C within one experiment. After the experiment finished, the tissue part of each limpet was removed from the shell, dried at 65°C for 48 hours, and weighed to the nearest of 0.1 mg.

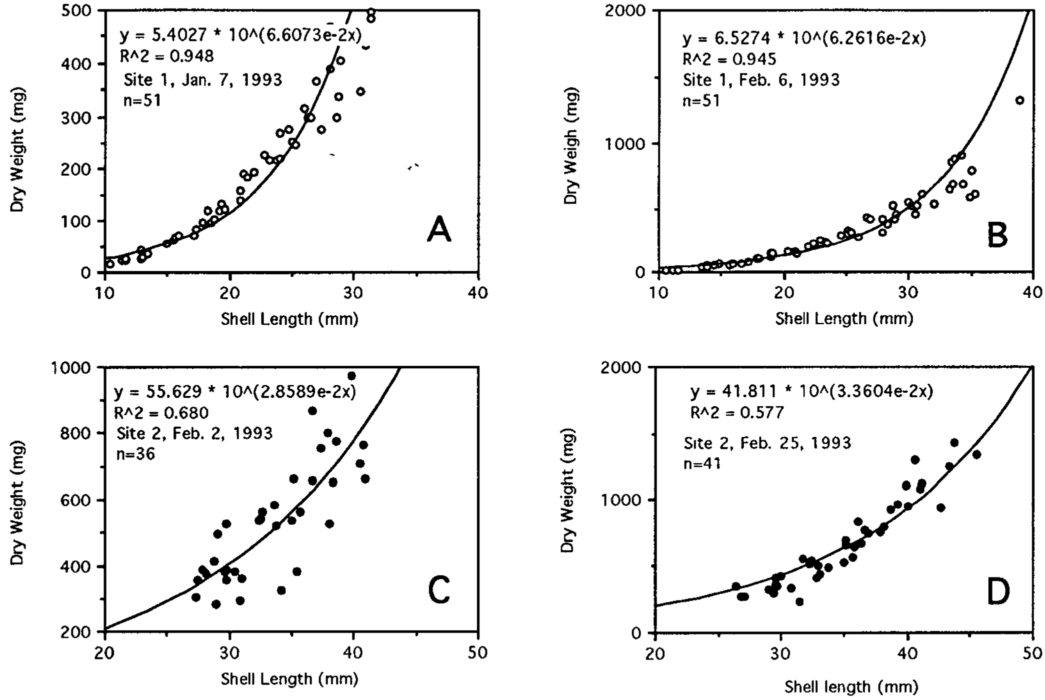

Fig. 2. Relationships between shell length and dry weight of *Nacella concinna* from different sampling sites and times, A-D.

RESULTS

1. Shell Length and Weight

The correlation between the shell length and tissue dry weight were shown in Fig. 2(A-D). For the same length, the weight of limpet from Site 1 is heavier than that from Site 2.

2. Size Frequency

Fig. 3 showed the summarized size frequency distribution in 7 different sampling times at Sites 1 and 2. The size frequency curve of limpet from the tide pool of Site 1 showed size range of 9-39 mm in shell length with an obvious depression at 21-27 mm; The shell length of the limpets sampled from the mid intertidal zone above the tide pool of Site 1 ranged from 23 to 39 mm, and the largest limpet was nearly the same size as that from the tide pool. The curve of Site 2 had the similar feature to that from the mid intertidal zone, but the size ranged from 27 to 45 mm.

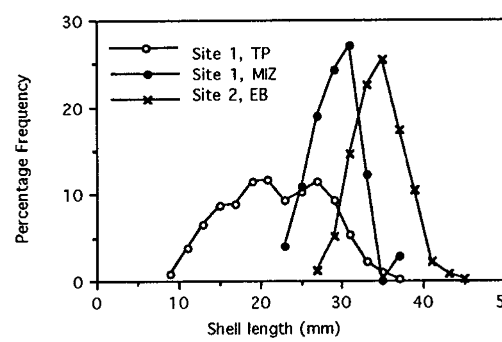

Fig. 3. Size frequency distribution of *Nacella concinna* in Site 1 and Site 2. TP = Tide Pool, n = 165 (Dec. 25) + 614 (Jan. 7) + 520 (Jan. 24) + 629 (Feb. 6) = 1928; MIZ = Mid Intertidal Zone, n = 74; EB = Exposed Boulder, n = 273 (Feb. 2) + 297 (Feb. 25) = 570.

Fig. 4. showed us at Site 3 near the Korean Station, the limpet was small (16-25 mm) in the intertidal zone. In the mid intertidal zone, the limpet was larger (19-31 mm). Empty shells of the

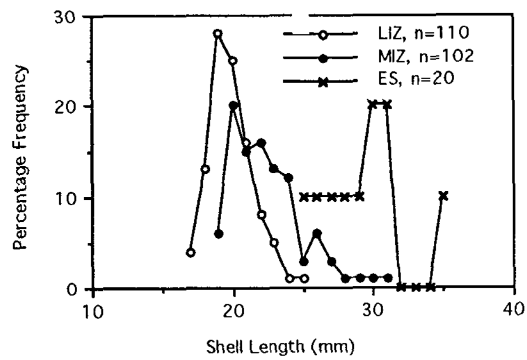

Fig. 4. Size frequence distribution of *Nacella concinna* at Site 3. LIZ = Low Intertidal Zone, MIZ = Mid Intertidal Zone, ES = Empty Shell.

limpets were collected several meters away from the bank, and the size ranged from 25 to 35 mm.

3. Density and Biomass

On Feb. 6, 1993, 40 samples were collected from each sampling area of 20 × 20 cm^2 in the tide pool of Site 1. A total of 522 limpets were collected and the density was 326.3 ind. m^{-2}. Biomass was estimated as 76.57 g dry tissue wt. m^{-2} based on the length and weight relationship in Fig. 2B and size frequency relationship in Fig. 3.

4. Feacal Production

Four experiments of faecal production of limpet from Site 1 and Site 2 were conducted. Figure 5 (A-D) indicated that the larger a limpet was, the more faecal pellets were produced, but the faecal products produced per tissue dry weight decreased. The faecal egestion rate of the limpet from the tide pool (Site 1) was much higher than that from the intertidal zone of Site 2. For example, a 400 mg limpet from the tide pool (6 Feb.) produced 854.1 μg faeces per hr., but the same-sized limpets from Site 2 produced only 1886.6u μh^{-1} on Feb. 2 and 341.8 $\mu g\ h^{-1}$ on Feb. 25.

5. Oxygen Consumption and Ammonia Excretion

Figure 6 (A-D) showed the relationship between oxygen consumption (Y) and tissue dry wt (X) at

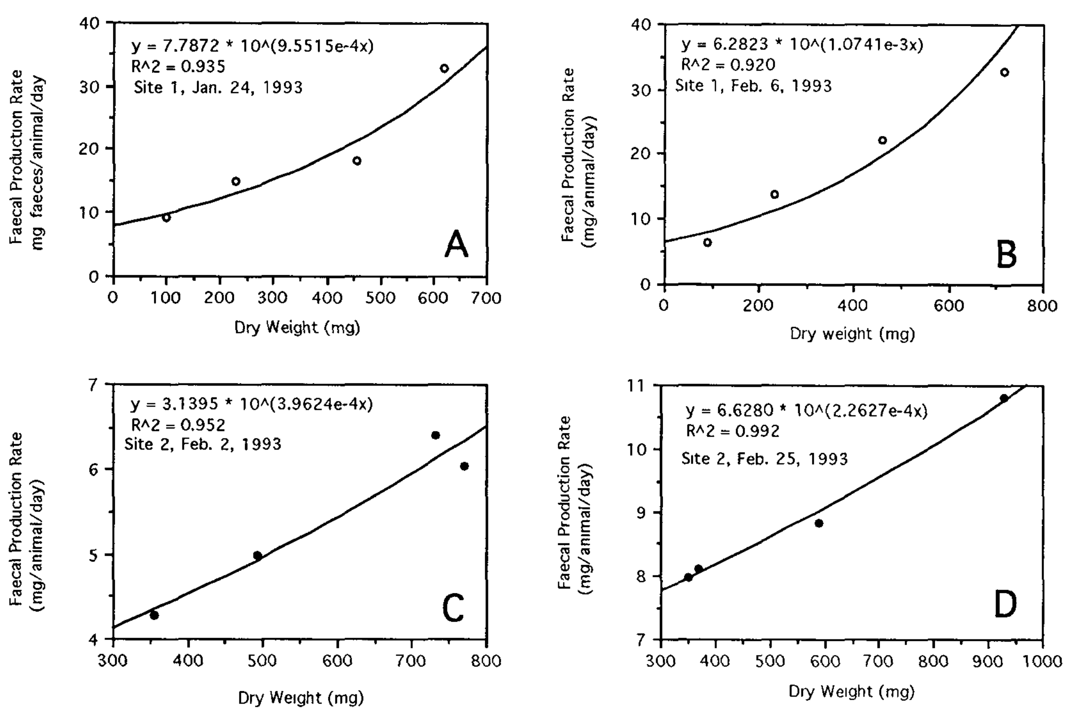

Fig. 5. Relationships between dry tissue weight and faecal production rate of *Nacella concinna* from different sampling sites and times, A-D.

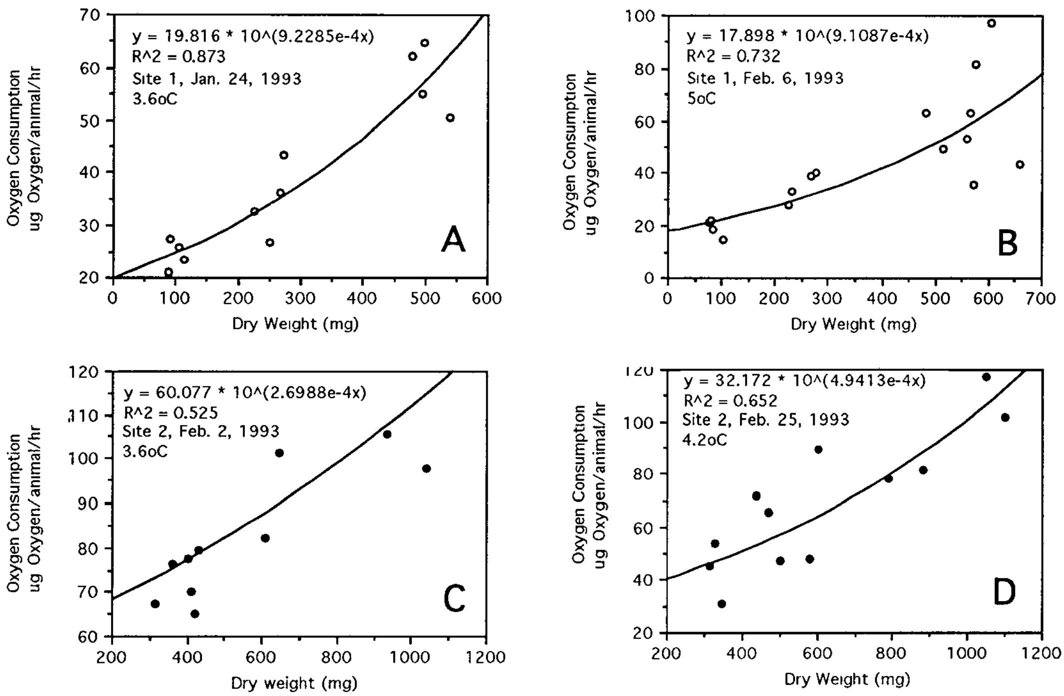

Fig. 6. Oxygen consumption of *Nacella concinna* from different sampling sites and times in relationship to tissue dry weight, A-D.

the four different experiments. It revealed that as the weight increased, the oxygen consumption per individul also increased, but the rate per unit weight decreased.

The regression analysis showed that the variation in dry tissue weight of limpets can account for the variation in ammonia excretion (Fig. 7A-D). The ammonia excretion rate per individual increased with the increasing body weight, but the ammonia excretion rate per unit weight were in the opposite trend.

DISCUSSION

Shell Length and Weight:

The relationships between tissue dry weight and shell length of *N. concinna* have already been studied in South Georgia (Ralph and Maxwell, 1977), in South Orkney (Picken, 1980). For a 26 mm length limpet, the dry weight from Ralph and Maxwell was 262.8 mg; from Picken was 196.3 mg; our data of Site 1 was 305.4-323.8 mg and Site 22 227.6-293.2 mg. It's obvious that for the same length of animal (>20 mm), the limpets weight from Signy Island (Picken, 1980) were much smaller than those from South Georgia and Fildes Peninsula. The difference may be attributed to that Picken's result was based on a year round observation, which included a long period of food absence, but the other two results were based on the data obtained in austral summer (January and Feburary), during which the limpet can get sufficient food to gain weight.

Size Frequency

Studies on size and frequency relationship of *N. concinna* have been made by Shabica (1971) at Palmer Station and Picken (1980) at South Orkney Island. Walker (1972) indicated that in Sign Island two limpet population existed: one was the littoral and shallow sublittoral population (<4 m), the other was the deep sublittoral population (>4 m). If this is the same case in Fildes Peninsula, in our experiments, limpets should be included into the littoral

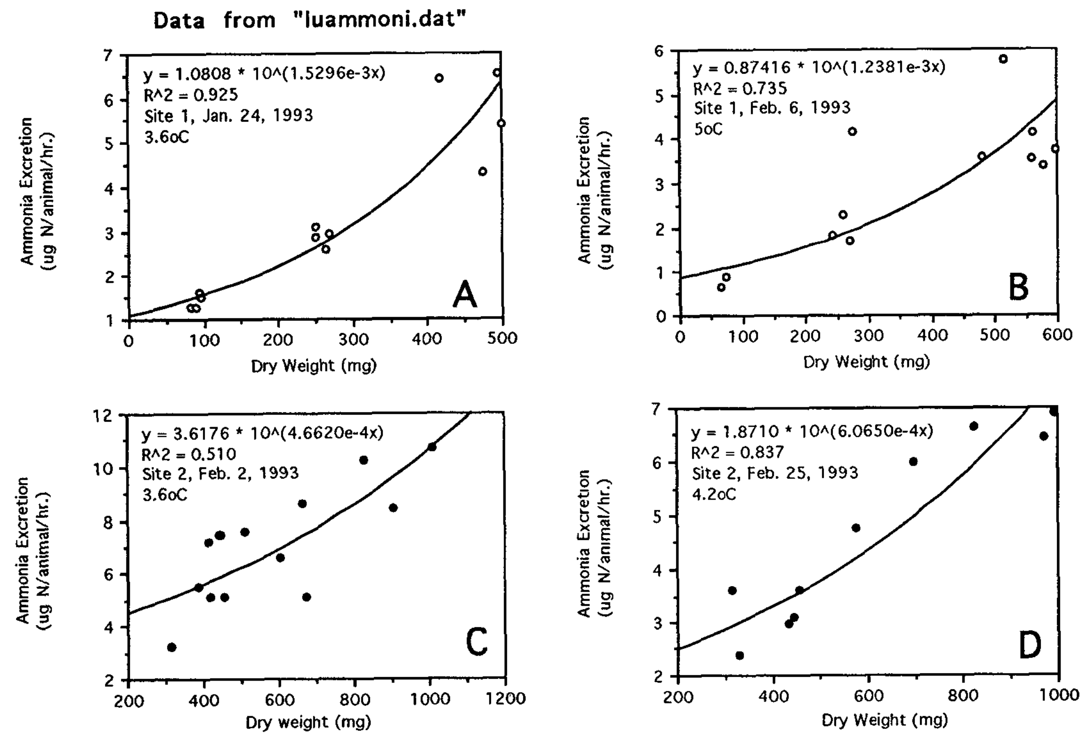

Fig. 7. Ammonia excretion of *Nacella concinna* from different sampling sites and times in relationship to tissue dry weight, A-D.

and shallow sublittoral population.

From Fig. 3 we found the combined curve of the tide pool depressed markedly at size 23-27 mm, and in the mid intertidal zone above the tide pool, the smallest limpet was 23 mm. In Fig. 4, the curve of mid intertidal zone depressed sharply at 24-25 mm length, and the smallest shell empty length occured at 25 mm. The above phenomena suggested that the sharp change in the size frequency relationship may be due to the animal loss, either by animal climbing out of the area, or by predation.

The limpets sampled from the intertidal zone of Site 2 reached to the shell length of 45 mm, much larger than that from Site 1 (39 mm). If the two groups of animals were originated from the same population, the difference may be due to environment conditions. In Site 1, the wind was mild and the temperature was warmer; the substratum consisted maily of small gravels and the coast slope was gentle. But in site 2, the above factors were totally different. Therefore in Site 2 much bigger limpets settled there, for they were more tolerant to the harsh environment condition.

Density and Biomass

Hedgpeth (1969) found the limpet density at Palmer Station was 200 m^{-2} at 2-3 m water depth, Walker (1972) reported the density of 320 m^{-2} at 1m below mean tide level at Signy Island, and Picken (1980) reported the mean monthly density was 123.1 from the sublittoral area in South Orkney Island. Our result of 326 m^{-2} from the tide pool is comparable with Walker's maximum density of 320 m^{-2}.

Picken (1980) also reported the mean biomass of *N. concinna* at Billie Rocks as 13.7 gm^{-2}. Compared with his result, the biomass of 76.57 gm^{-2} in the tide pool of Adelie Island in Feburary was much higher, nearly five-fold difference. This may be due to the high density of limpet and the warmer sampling season in the Adelie Island which provided the animals with the most favorable conditions

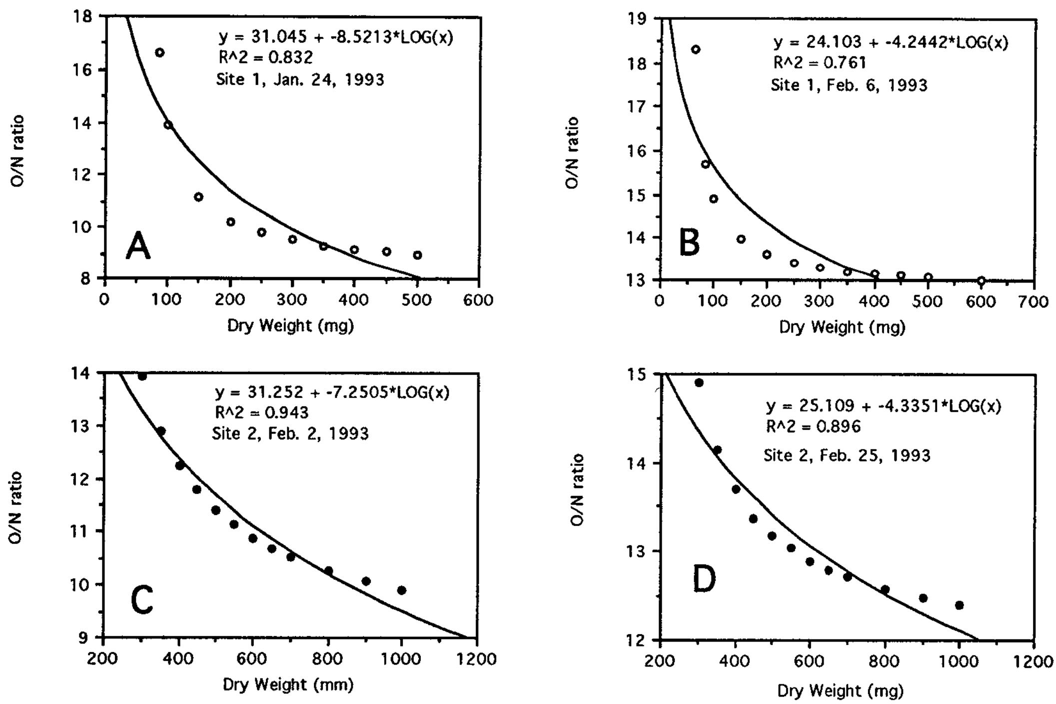

Fig. 8. O/N ratio of *Nacella concinna* from different sampling sites and times in relationship to tissue dry weight, A-D.

such as sufficient food.

Faecal Production

In this experiment, the faecal egestion rate of limpets from the tide pool is 2-4 times higher than the values of the limpets from the intertidal zone of Great Wall Cove. The difference may be related to food availability and food items. The limpet seemed to get more food in the tide pool which covered with macro algae such as *Iridaea obovata*.

In Clarke (1990), the amount of faeces egested by a 250 mg *N. concinna* at Signy Island for 24 hours was 8.7% of its body dry weight. In the present study, the same weight limpet produced faeces about 6% (Site 1) and 2-3% (Site 2) of the body dry tissue weight.

Oxygen Consumption

Ralph and Maxwell (1977) showed that a 250 mg *Nacella concinna* consumed 52.08 $\mu g\ O_2\ h^{-1}$ at 5°C, while the same weight limpet from Site 1 consumed 37.76 (at 3.7°C) and 33.82 $\mu g\ O_2\ h^{-1}$ at 5°C, respectively. The difference may be ascribed to different population and different experiment condition.

The respiration rate of *N. concinna* per unit body weight decreased with the incresing body size, implying that the younger animals have higher metabolic rate.

Ammonia Excretion

Nitrogen excretion of *Nacella concinna* from deep water (>4 m) has been studied by Clarke (1990) at Signy Island. Compared with his results (i.e., the mean ammonia excretion rate of 2.27 $\mu g\ Nh^{-1}$ for a 250 mg *N.concinna*), slightly higher rates have been observed in this study from the tide pool impets: a 250 mg limpet excreted 3.12 μg N per hour in the January expriment and 2.29 μg N per hour in the Feburary experiment. The excretion rates for the site 2 limpets are even more high.

From size frequency, density, biomass and ammonia excretion rate in the Feburary experiment in tide pool of Site 1, the population ammonia production was calacualated, and the value of 16132 $\mu g\ N\ m^{-2}\ day^{-1}$ was obtained, which was five times higher than 210 μ mol day^{-1} (about 2940 $\mu g\ N\ m^{-2}\ day^{-1}$) at Signy Island (Clarke, 1990).

According to Clarke (1990), *N. concinna* excreted not only ammonia, but also a small amount of urea. If this is also true in the present study, the measurement of only ammonia may underestimate the total amount of nitrogen excreted.

O/N Atomic Ratio

Oxygen to Nitrogen atomic ratio has been widely used to estimate the fraction of metabolic energy substrate provided by protein. The lower the value is, the greater the proportion of protein is utilized (Peck *et al.*, 1986). If protein is the only substrate used, the O/N ratio is about 7 (Clarke, 1990).

Combined with his own ammonia data with others' oxygen data (Ralph and Maxwell, 1977; Houlihan and Allan, 1982), Clarke (1990).suggested the O/N ratios of 30-50 for *N. concinna* from the deeper water population.

In our oxygen consumption and ammonia excretion experiments, not only the animals were sampled from the same population, but also the tests were carried out simultaneously under the same condition. In the present study, the ratios in the four experiments were between 8.9-18.3 (Fig. 8 A-D), indicating that protein was the main substrate being metabolized. Similar value of 8.1 has also been observed in the Antarctic brachipod *Liothyrella uva* (Peck *et al.*, 1986).

Fig. 8 clearly illustrates that, the O:N ratio of *N. concinna* from the intertidal population was decreased with the increment of dry weight, indicating more fraction of protein was used.

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