Feeding, defaecation and absorption efficiency in the sea-urchin, *Parechinus angulosus* Leske

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Feeding, defaecation and absorption rates were estimated for a controlled laboratory population of *Parechinus angulosus*. Both feeding and defaecation were power functions of mass. Expressed for an animal of standard size, annual population consumption was estimated as 14% of the annual kelp production at Oudekraal, Cape Peninsula. Absorption efficiency did not vary with size of animal and was shown to be considerably higher than the predicted value of Ricklefs (1973).

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Die tempo's waarteen voeding, misuitskeiding en assimilasie plaasvind is in 'n gekontroleerde laboratoriumbevolking van *Parechinus angulosus* bepaal. Voeding en misuitskeiding was ablei magfunksies van massa. Dit word bereken dat die jaarlikse inname van seebamboes deur *P. angulosus* by Oudekraal, Kaapse Skiereiland, uitgedruk in terme van 'n standaardgrootte dier, 14% is van die jaarlikse seebamboesproduksie van die gebied. Die assimilasie-doeltreffendheid is nie beïnvloed deur die grootte van die dier nie en was aansienlik hoër as die verwagte waardes volgens Ricklefs (1973).

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Sea urchins are the dominant herbivores in many kelp-bed communities (Miller & Mann 1973), although the actual percentage of kelp biomass consumed may be low. Their importance in governing community structure may arise from their ability to check kelp population growth by chewing through the kelp stipes or by grazing sporelings (Ogden, Brown & Salesky 1973; Fricke 1979). Greenwood (1980) studied population dynamics and energetics of the South African sea urchin *Parechinus angulosus* (Leske), while Stuart & Field (1980) dealt with respiration. Feeding rates, however, have been neglected except for preliminary experiments conducted by Greenwood (1974). In this study the feeding, faecal production and absorption of kelp by *P. angulosus* were measured.

Materials and Methods

Experimental animals were collected at Oudekraal on the west coast of the Cape Peninsula (33°58'S, 18°20'E) from a depth of 15 m. They were placed in circulating sea water aquaria and allowed to acclimatize for 4 days at 13°C under natural light conditions in the laboratory. During this period they were fed an excess of the kelp *Ecklonia maxima*.

At the start of each experiment animals were separated into groups of similar test diameter and each group placed in separate aquaria under the physical conditions described above. The minimum number of animals required in each experimental tank depended upon their size. This avoided overcrowding and hence possible competition for food. Experiments were initiated by adding a known wet mass of *Ecklonia* frond to each tank. The urchins were then left to feed undisturbed except that faeces were siphoned off every 12 h. Faeces were filtered onto pre-weighed Whatman's No. 1 filters and dried to constant mass at 60°C for 48 h. A control tank without urchins was monitored to detect any possible change in kelp mass due to leaching.

After 72 h the remaining kelp was removed, weighed and replaced with fresh kelp. The experiment was then repeated for a further 72 h. Wet mass of kelp was converted to dry mass using the equation:

$$DM(g) = -0,11 + 0,15 \times WM(g) \quad (r = 0,84; \; n = 20),$$

determined using the kelp obtained from the control aquarium. At the end of each experiment the urchins were

removed and placed on tissue paper for 60 s to drain off excess water. They were then weighed and finally returned to the holding aquarium. The wet mass of urchins was converted to dry mass using the equation:

$$DM(g) = 0,26 + 0,26 \times WM(g) \ (r = 0,99; \ n = 10),$$

obtained by drying animals to constant mass at 60°C.

Results

The daily rate of feeding, defined as the amount of food ingested per day as a function of the total mass of the urchin (Fuji 1967), and daily faecal production, similarly defined, are summarized in Table 1. The mean of two rates within each experiment are plotted against the mean mass of the animals in that experiment. Plotted against dry mass of urchin (Figure 1) both daily rate of feeding and daily faecal production are power functions of mass and show an increase in rate with a corresponding increase in animal size.

Dividing the mean urchin mass into the daily rate of feeding for each experiment, the mass specific rate of feeding or consumption rate may be calculated. This is summarized in Table 1 and presented graphically in Figure 2. The results show considerable variability amongst small animals, but a clear reduction in the mass specific rate with increasing size is apparent.

Table 1 Summary of feeding experiments, showing daily rate of feeding, defaecation, consumption and absorption efficiency. (Each set of figures represents a different experiment)

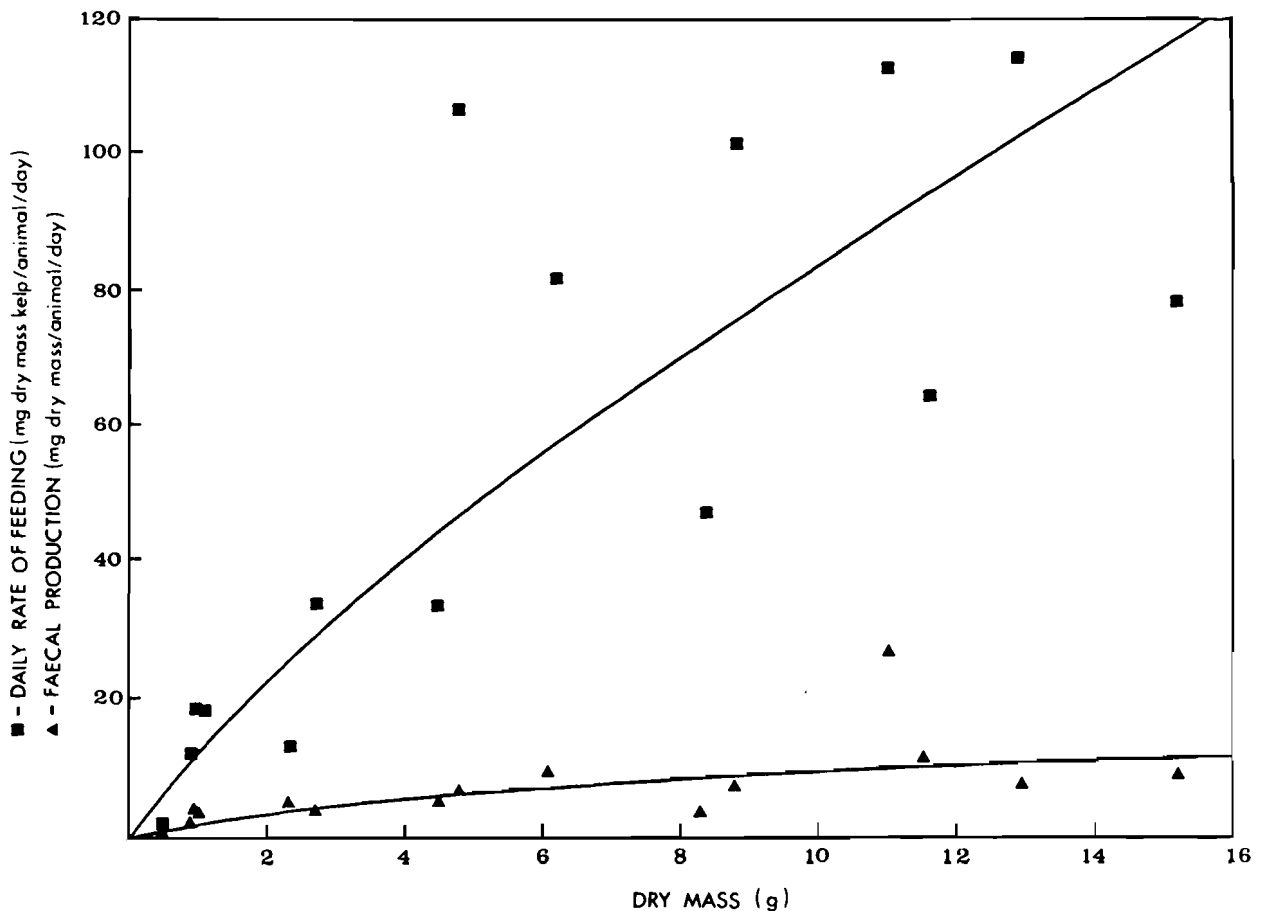| No. of urchins	Mean dry mass (g)	Daily rate of feeding (mg animal^{-1} day^{-1})	Consumption (mg g animal^{-1} day^{-1})	Faecal Production (mg animal^{-1} day^{-1})	Absorption efficiency %
18	0,58	4,70	8,10	0,68	85,5
6	2,34	13,80	5,90	5,00	63,8
3	11,10	112,70	10,15	27,60	75,5
5	4,89	105,10	21,49	6,80	93,5
7	2,71	33,60	12,39	3,90	88,4
3	15,23	78,10	5,13	9,10	88,3
6	4,52	33,80	7,48	5,40	84,0
15	0,90	12,00	13,33	2,40	80,0
10	0,95	18,90	19,89	4,10	78,3
10	1,10	18,50	16,82	3,00	83,8
3	8,46	47,20	5,58	3,80	91,9
3	6,17	82,60	13,38	9,50	88,5
4	8,83	102,30	11,58	7,20	92,9
3	11,61	64,40	5,55	11,80	81,7
3	12,99	114,90	8,85	7,80	93,2

Figure 1 Daily rate of feeding (DRF) and faecal production (FP) of *P. angulosus* plotted against dry mass of urchin.
DRF = 12,82 × DM^{0,81} (r = 0,91) n = 15
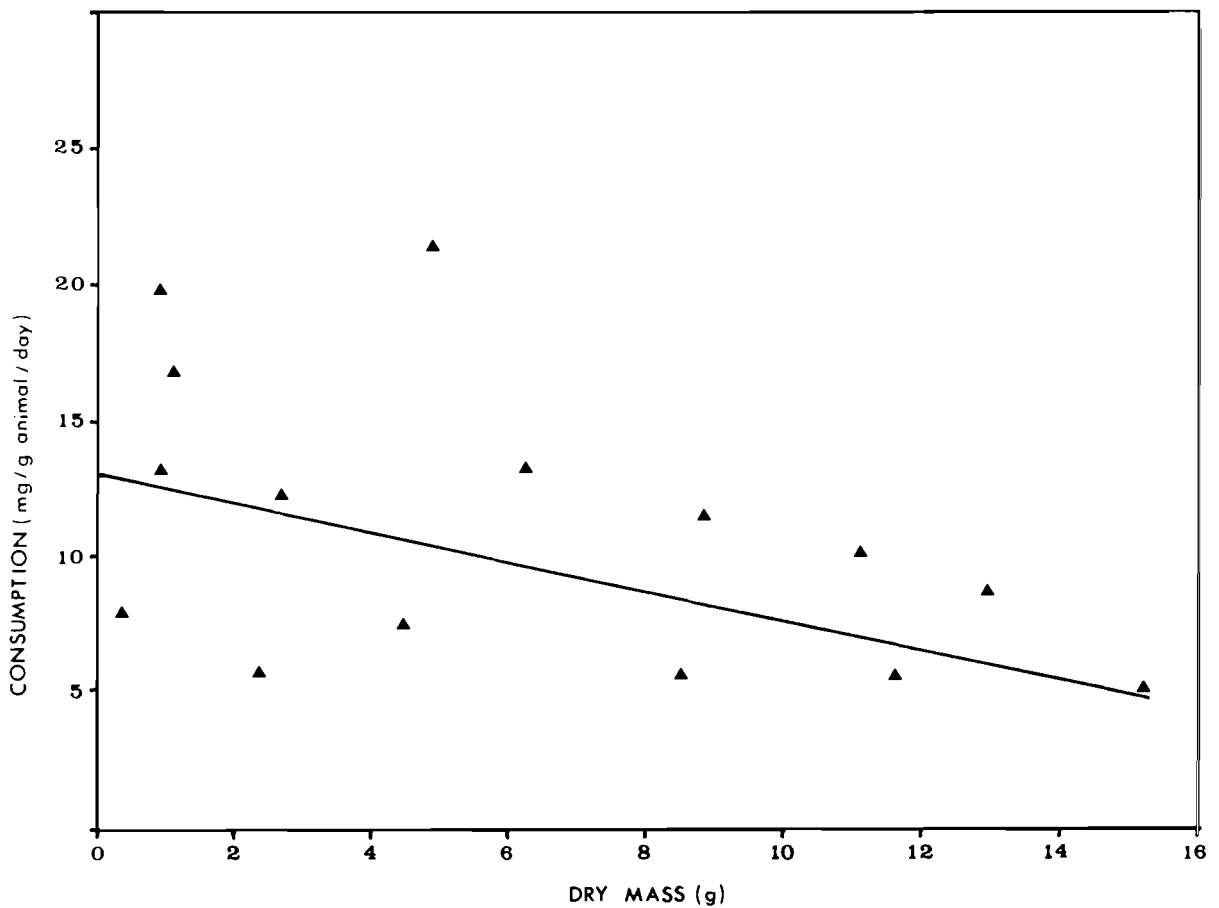FP = 2,23 × DM^{0,59} (r = 0,81) n = 15

Figure 2 Consumption (mass specific feeding rate) of *P. angulosus* plotted against dry mass of urchin.
C = 14,83 × DM − 0,61 (*r* = 0,01) *n* = 15

Absorption efficiency was calculated gravimetrically using the method described by Fuji (1962);

$$\text{Absorption efficiency} = \frac{\text{Dry mass of food absorbed}}{\text{Dry mass of food eaten}} \times 100$$

where dry mass of food absorbed = daily rate of feeding − faecal production. The results are summarized in Table 1.

Discussion

Greenwood (1974) found that urchins below 10 mm in test diameter exhibited a slower growth rate than their larger counterparts. A similar situation exists for the Pacific urchin *Strongylocentrotus intermedius,* which Fuji (1967) showed was a result of a change in diet. Small urchins fed predominantly on organic detritus obtained on the ocean floor, while larger urchins consumed whole kelp, obtained from both living plants and floating kelp debris. In preliminary experiments designed to test the preference of different sized *P. angulosus* for either debris or detritus, Buxton (1977) showed that small urchins preferred detritus although results were difficult to quantify.

Excluding urchins below 10 mm in diameter, Greenwood (1974) found that the mean size of the *P. angulosus* population at Robben Island, 20 km north of Oudekraal, was 19 mm in diameter. This represents an animal of 3,2 g. Using this as an indication of west-coast urchin populations in general, this study shows that the daily rates of feeding and faecal production of a mean sized animal would be 35,5 mg day^{-1} and 5,0 mg day^{-1} respectively (Figure 1). The daily rate of feeding is significantly lower (Mann-Whitney *U* test, *U* = 89, *p* < 0,05 for 16,6 d.f.) than that calculated for the Robben Island population of 50,0 mg day^{-1} (Greenwood 1974). Considerable variation in the amount of food ingested by urchins has been shown and may be affected by temperature, season, animal size and the physiological state of the animal (Lawrence 1975).

Considering the urchin population at Oudekraal of 173 g m^{-2} (Field, Jarman, Dieckmann, Griffiths, Velimirov & Zoutendyk 1977), equivalent to 54,06 mean sized animals per square metre, daily rates of feeding and faecal production amount to 1919,2 and 270,3 mg m^{-2} day^{-1} repectively. Using the calorific equivalent for *Ecklonia maxima* of 11,4 J mg^{-1}, annual population ingestion is calculated as 7985,8 kJ m^{-2} yr^{-1}. This is 14% of the estimated annual production of kelp at Oudekraal of 53 950 kJ m^{-2} y^{-1} (Field *et. al.* 1977), which compares with the findings of Fricke (1979) who estimated that urchins consume 20% of the kelp production in False Bay per year.

There was very little variation in the calculated absorption efficiency between small and large urchins (Table 1), which agrees with work by Fuji (1962, 1967) on *Strongylocentrotus intermedius.* Combining the data a mean of 83,61 ± 8,46% was obtained. This is considerably higher than the figure given by Ricklefs (1973) of 30 − 40% for

browsers and grazers, but falls within the range of values determined for a wide range of urchin species (Lawrence 1975). Optimal feeding conditions during the experiments allowed the animals to achieve a fullness equilibrium (Miller & Mann 1973) during which feeding and defaecation were continuous. Bacterial enrichment (Lasker & Boolootain 1960) under these conditions appears to be minimal as faeces are formed as compacted pellets of recognizable origin. In contrast, when food becomes limiting, ingested material is held for longer periods in the gut. Farmanfarmaian & Phillips (1962) have shown that bacterial action in the gut, under these conditions, may result in more complete breakdown of the algae and the resultant faeces are amorphous. The calculated absorption efficiency in this study may therefore be an underestimate of the value attained under natural conditions if food was limited.

Acknowledgements

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