International Council for the Exploration of the Sea

CM 1974/L:14
Plankton Committee

PRELIMINARY OBSERVATIONS ON THE FEEDING OF BOLINOPSIS INFUNDIBULUM

by

J C Gamble
Marine Laboratory, Aberdeen, Scotland

Summary

Laboratory experiments with the lobate ctenophore Bolinopsis infundibulum (O F Müller) showed it to feed very actively on 250 μ mesh retained inshore copepods. In 24 hour experiments where, depending on size, individual ctenophores were given between 50 and 200 copepods, an average of 78% of the copepods were ingested. Two individuals removed 94% and 95% of the prey respectively. A growth experiment lasting seven days was also conducted during which 200 fresh copepod prey were given daily. All undamaged ctenophores increased in size. Gross Growth Efficiency, by dry weight, ranged between 11.2% and 67.4% averaging 34%. The regression relationship Ln Dry Wt = (-2.494± 0.328) + (1.408± 0.104) in Oral-Aboral Length was calculated. The results suggest that B. infundibulum is an important predator in the inshore pelagic food chain.

Introduction

The extreme fragility of the lobate ctenophore Bolinopsis infundibulum (O F Müller) is undoubtedly a major reason for the dearth of information on its biology. Brief contributions by Nagabhushanam (1959), Kamshilov (1960) and Bishop (1969) all comment on the voracious nature of this predator while Kamshilou (1959) in particular emphasises the clear inverse relationship between the abundance of these ctenophores and their herbivore prey (see also Fraser, 1962).

A similar fall in copepod numbers concomittant with an increase in Bolinopsis was observed both in the natural situation and within experimental plastic enclosures at Loch Ewe, Wester Ross, Scotland. Consequently a preliminary study was started on the feeding behaviour of this ctenophore to investigate the voracity of the animal and its role in the observed decline of the herbivore population. Measurements were made of the intensive feeding over a short period of time and of the growth and gross feeding efficiency, by weight, during one week. Some observations were also made on the digestion rates and 'in situ' feeding state.

Methods

All animals used for feeding experiments were collected by diving using a 10 cm diameter, 20 cm long acrylic tube closed with sprung lids. The 10 or more Bolinopsis caught at a time were transferred to 20 l aquaria for holding until isolated for experimental purposes. All experiments were conducted at 10°C in constant dim light.

In the initial and the intensive feeding experiments the ctenophores were kept, according to size, in either 1 or 5 litre beakers together with a known number of 250 μ mesh retained prey. During the intensive feeding experiments each ctenophore was transferred, at known intervals, into fresh water containing the original concentration of prey. The remaining prey, usually copepods, were counted and the number removed by the ctenophores estimated.

As a prelude to the growth experiment a number of ctenophores were measured along their oral-aboral axis and then frozen for future dry weighing. Six animals within the size range measured were selected for the growth experiment and, after measurement, placed into 5 litre beakers containing 3 litres of 30 μ mesh filtered seawater. 200 copepods taken from the natural population, which were mostly Acartia but included Temora, Pseudocalanus and Centropages, were added to the water. The Bolinopsis were transferred daily into fresh water containing new batches of 200 copepods. Surviving copepods were filtered off and frozen for future counting and dry weighting. At the end of the experiment the Bolinopsis were re-measured and then frozen for eventual dry weighing.

Dry weights of ctenophores and uneaten copepods were measured following broadly the procedure outlined by Strickland and Parsons (1972) for particulate matter. 4.2 cm Glass Fibre (GF/F) filter paper, heated to 400°C and preweighed were used to separate and support the animal material for freeze drying overnight (15-18 hours). A Cahn Gram Electrobalance was used for weighing. Gross feeding efficiency for the entire week, was derived as follows:-

$$\frac{\text{Dry weight increase of Predator}}{\text{Dry weight of prey ingested}} \times 100$$

(Reeve, 1963, Conover, 1964).

Results

The initial feeding experiment, Table 1, showed Bolinopsis to be a very effective predator in the laboratory situation. The average of 78% removal of prey could be even higher if copepods alone were considered. Analysis of the uneaten prey in the series of 14.6.74 revealed that, in only one case (38% removal) were copepods remaining: all the other uncaptured prey were cladocerans of the genera Evadne and Podon. It is possible that the tendency of these cladocera to become stuck to the water surface was a factor in their immunity to predation but the relative numbers of those on the surface film to those free swimming suggests some predator selectivity could also have occurred.

The high percentage efficiency of two of these Bolinopsis (94% and 95% removal) implies that even at prey concentrations of less than 3 per litre feeding took place. However the results of the intensive feeding experiments, Table 2, with animals about 25 mm long, suggest that the animals do become satiated after a period of continual replenishment of prey, although it is possible that repeated handling of the animals at hourly intervals could interfere with their feeding activity.

Daily totals of copepods removed by the 6 ctenophora selected for the growth experiment are listed in Table 3; these can be converted to dry weight using the calculated average of 0.012$\pm$ 0.007 (S.D.) mg dry weight per copepod. Although the overall average of 59% removal is lower than that measured in the previous experiments it can be accounted for, in part at least, by the range of animal sizes and by the possibility of satiation. Figure 1, which shows the average weight of food consumed by each ctenophore, suggests that there might be a direct relationship between feeding rate and size of predator, although further information is required. It is also interesting to note the consistency of feeding of the ctenophores throughout the period: the greatest standard deviation was 35% of the mean while four S.D. values fell within 30 and 35%.

The oral-aboral length to dry weight relationship of Bolinopsis is illustrated in Figure 2. Using this data and the dry weight conversion of copepods it is possible to estimate the gross feeding efficiencies of the ctenophores during the period of the experiment. The steps and values obtained in this procedure are listed in Table 4. It should be noted that one of the ctenophores was damaged during transfer and could not be used in the final calculations. It is possible in Table 4 to derive two sets of values for both weight change and efficiency depending whether the final weight of the ctenophore is taken from the length:weight regression or by direct measurement. I have listed both values but consider that the growth and gross efficiency derived from the measured final weights as being the most reliable. The measurement of any ctenophore length parameter is extremely difficult because of the nature of the animal and furthermore it is possible that unseen damage to the animal caused by transference during the experiment could cause a regenerative reorganisation of the tissues (Coonfield, 1936) more noticeable in length than by weight measurement. All 5 apparently undamaged animals showed a weight increase based on direct measurement while only 4 did based on length measurement. Efficiencies ranged between 11.2% and 67.4% by weight and 4.5% and 38.0% by length.

Discussion

The feeding rate of Bolinopsis infundibulum measured here compares favourably with the data of other workers on the same genus (Nagabhushanam, 1959, Kamshilov, 1960 and Bishop, 1969), although the work of Bishop (1967) with Mnemiopsis leidyi suggests that the rate is related to both food concentration and predator size. Consequently it is difficult to extrapolate from laboratory experiments to the field in terms of predator effect since both the confining nature of the experiment and the unnaturally high prey concentration (2000 per litre in Bishop, 1967; 100-200 per litre in this work) must facilitate the task of the predator. Nevertheless it is interesting to speculate on the potential of Bolinopsis being a significant factor in the control of herbivore populations, particularly with the added observation of superfluous feeding in this present study and by Kamshilov (1960). Copepods were seen to be expelled through the stomodeum enveloped in mucus but undigested. In Loch Ewe when the Bolinopsis population averaged 10 per m^3 over a period of 5 weeks, at least 1 000 herbivores per m^3 could have been removed daily. This would very quickly diminish even the maximum springtime standing stock values of 10-20 000 copepods per m^3 (Nicol, pers. comm.). Such potential consumption rates alone explain the inverse correlation between numbers of ctenophores and their herbivore prey.

The highest week long growth rates measured of 30% and 50% increases in polar length compare well with the rates described by Greve (1970) for Bolinopsis infundibulum maintained for several weeks in his "double kuvette". Unfortunately Greve does not specify the food type nor the densities required for these rates. The shortage of data on feeding efficiency of pelagic organisms and of predators in particular has been emphasised by Reeve (1970). However the average 'measured' gross efficiency of B. infundibulum of 34.1% falls exactly within Reeve's list of values for other planktonic animals. In particular it is directly comparable with the values for the only other two planktonic predators measured: Euphausia pacifica by Lasker (1966) and Sagitta hispida by Reeve (1970). Such equivalence is encouraging considering the preliminary nature of this work and the intractability of Bolinopsis as experimental material. Clearly the voracity alone of B. infundibulum warrants detailed future study into its role as a predator and into its significance in the structure of the inshore, pelagic food chain.

Acknowledgements

I would like to thank D Johnston and A Murray for the important part they played in this study.

References

Bishop, J.W. 1967 Feeding rates of the ctenophore Mnemiopsis leidyi. Chesapeake Sci., 8, 259-264.

Bishop, J.W. 1969 A comparative study of feeding rates of tentaculate ctenophores. Ecology 49, 996-997.

Conover, R.J. 1964 Food relations and nutrition of zooplankton. Symp. exp. mar. Ecol. Occ. Publ. Narragansett mar. Lab. R.I. 2, 81-91.

Coonfield, B.R. 1936 Regeneration in Mnemiopsis leidyi, Agassiz. Biol. Bull. mar. biol. Lab. Woods Hole, 71, 421-428.

Fraser, J.H. 1962 The role of Ctenophores and Salps in zooplankton production and standing crop. Rapp. P.-v Réun. Cons. perm. int. Explor. Mer. 153, 121-123.

Greve, W. 1970 Cultivation experiments on North Sea ctenophores. Helgolander wiss. Meeresunters. 20, 304-317.

Kamshilov, M.M. 1959 Inter-relationships between organisms and the part they play in evolution. Zh. obshch. Biol. 20(5), 370-378 (In Russian)

Kamshilcv, M.M. 1960 Biology of Ctenophores of Murman. ICES CM 1960 Plankton Comm. Doc. No. 157 (mimeo).

Lasker, R. 1966 Feeding growth, respiration and carbon utilization of a Euphausiid Crustacean. J. Fish. Res. Bd Can. 23, 1291-1317.

Nagabhushanam, A.K. 1959 Feeding of a ctenophore Bolinopsis infundibulum O.F. Muller. Nature, Lond., 184, 829.

Reeve, M.R. 1963 Growth efficiency in Artemia under laboratory conditions. Biol. Bull. mar. biol. Lab. Woods Hole, 125, 133-145.

Reeve, M.R. 1970 The biology of Chaetognatha I. Quantatative aspects of growth and egg production in Sagitta hispida. In Marine Food Chains; edited by J.H. Steele, Edinburgh: Oliver and Boyd, 74-95.

Strickland, J.D.H. and Parsons, T.R. 1972 A practical handbook of seawater analysis. 2nd ed. Bull. Fish. Res. Bd Can., 167, 310.

Table 1 Bolinopsis infundibulum. Initial 24 hour Feeding Experiment

Date	Size*	Water Volume(l)	Initial Prey Number	Number Removed	% Removal	Number on Surface**
12.6.74	L	4.5	100	94	94	-
	L	4.5	100	87	87	-
	S	0.9	50	30	60	-
	S	0.9	50	42	84	-
	S	0.9	50	38	76	-
14.6.74	L	4.5	200	173	86.5	12
	L	4.5	200	190	95	10
	S	0.9	50	42	84	2
	S	0.9	50	35	70	6
	S	0.9	50	42	84	0
	S	0.9	50	19	38	3

*Animals not measured in this experiment: L > 30 mm, S < 30 mm oral-aboral length

**Estimated only on 14.6.74

Table 2 *Bolinopsis infundibulum*. Intensive Feeding Experiment

I. 28.6.74. 1 litre beaker. 100 prey per hour.

Hour	1	2	3	4	5
No. Prey Removed	57	53	45	0	8

Total 163

II. 12.7.74. 1 litre water. 100 per hour.

Hour		1	2	3	4	5	7	17
No. Prey Removed	(i)	12	0*	28	32	22	18	13
	(ii)	12	22*	10	26	4	51	50

Totals (i) 94 (5 hours) : 125 (17 hours)
(ii) 74 (5 hours) : 175 (17 hours)

* (ii) given 200 prey, (i) given 0; in error.

Table 3 *Bolinopsis infundibulum.*

Growth experiment: total number of copepods eaten per day.

Initial Animal length (mm)	31	23	18	34	26	12
7.7.74	103	133	130	141	121	65
8.7.74	112	127	106	137	100	53
9.7.74	167	108	138	165	128	60
10.7.74	153	139	134	125	128	104
11.7.74	163	149	149	181	179	66
12.7.74	131	68	108	128	77	68
13.7.74	128	107	104	125	57	64

Table 4 *Bolinopsis infundibulum*. Growth experiment: stages in calculation of gross feeding efficiency.

Initial length (mm)	Initial weight (mg) (estimated)	Final length	Final weight		Weight change		Weight change		Food consumed (mg)	Gross efficiency %	
			(measured)	(estimated)	(measured)	%	(estimated)	%		(measured)	(estimated)
31	10.49	34	11.72	11.83	1.23	11.7	1.34	12.8	11.01	11.2	12.2
23	6.82	24	8.32	7.25	2.84	41.1	0.43	6.3	9.56	29.7	4.5
18	4.83	24	11.56	7.25	6.73	139.3	2.42	50.1	9.99	67.4	24.2
34	11.83	34	17.44	11.83	5.61	47.4	0	0	11.52	47.4	0
26	9.11	22*	5.28	6.41	-	-	-	-	9.09	-	-
12	2.73	18	3.56	4.83	0.83	30.4	2.10	76.9	5.52	15.0	38.0

*Animal damaged on 12.7.74

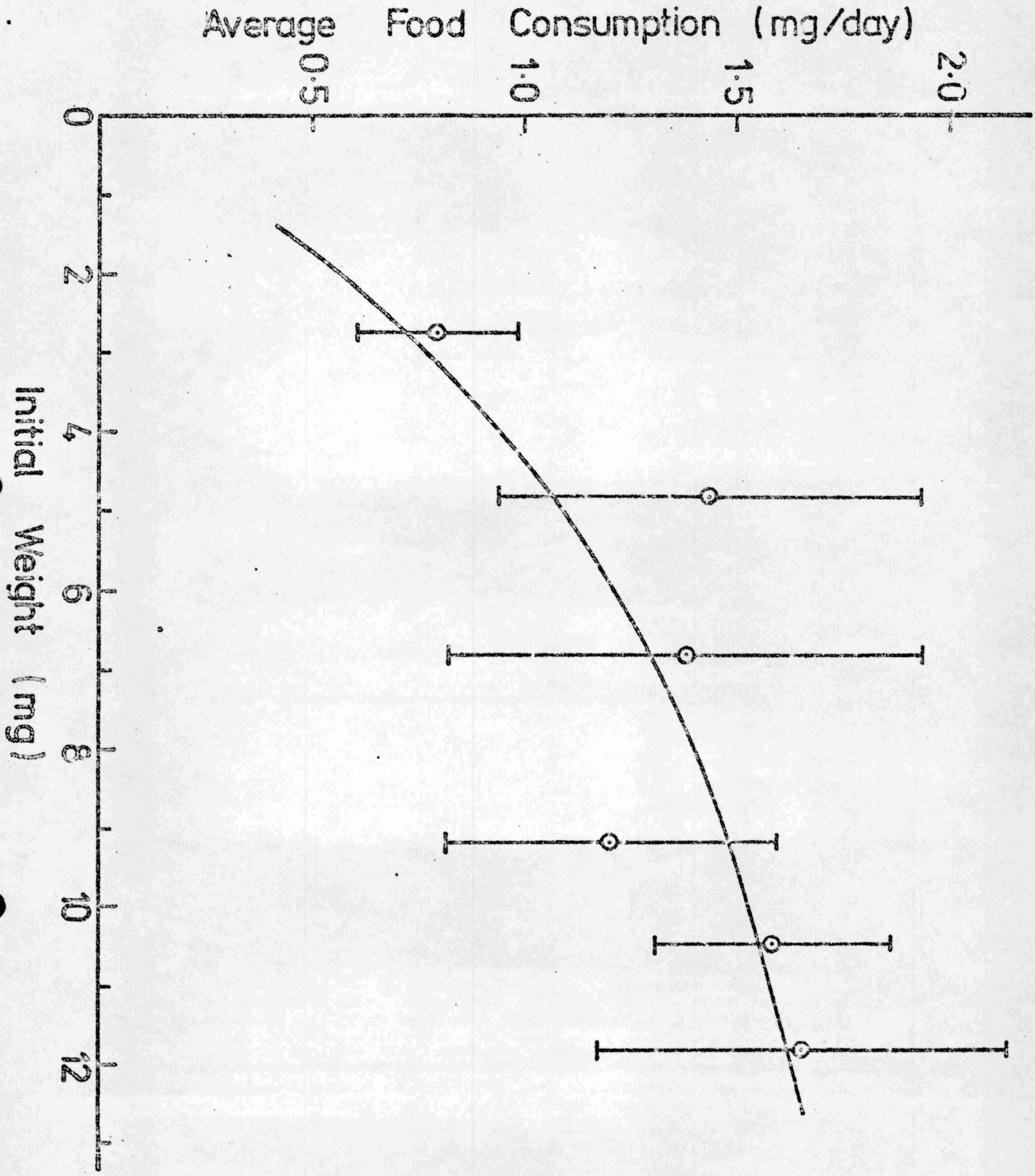

Figure 1 Average feeding rate of individual Bolinopsis infundibulum during 7 day growth experiment: mean and standard deviations shown.

Figure 2 Regression of Weight on Oral-Aboral length in *Bolinopsis infundibulum*. ln Wt = (-2.494±0.328) + (1.408±0.104) ln Length.