NOTE ON SELECTIVE FEEDING BY *CALANUS*

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The rates at which *Calanus finmarchicus* eat both carmine particles and the diatom *Nitzschia closterium* have been investigated by Fuller & Clarke (1936) and Fuller (1937). They found that the number of *Nitzschia* or of carmine particles, eaten by a *Calanus* in unit time, was proportional to the concentration of *Nitzschia* or of particles in the water. Lucas (1936) also found that *Neomysis* and *Eurytemora* ate *Nitzschia* at rates which were roughly proportional to the concentration of diatoms in the water over fairly wide limits.

During 1935 I had made, as part of another investigation, three experiments on the rate at which *Calanus* eat diatoms of larger size. This happened much more rapidly than Fuller found to be the case with suspensions of *Nitzschia*. Meanwhile Lowndes (1935) had concluded, from direct observations, from the anatomy of their mouth-parts and from observations by Lebour and Marshall, that *Calanus* should be able to catch and select food. He concluded that *Calanus* does not depend entirely upon its (automatic) filtering mechanism for all the food it obtained.

The quantitative data which I had collected in these three experiments, in conjunction with those published by Fuller & Clarke (1936, 1937), were suitable for examining this contention. They suggested that the animal when fed with diatoms of moderate size selected by catching the species it preferred, while it automatically filtered the minute *Nitzschia*. With these possibilities in view, experiment N 90 was made in order to link up the three experiments with the numerous experiments made by Fuller (1937).

Experimental

Stages V and VI of *Calanus finmarchicus* were recognized by their larger size, transferred from a tow-net catch into filtered sea water, to which some particular species of diatom was added as food, and were kept for some days. At the start of the experiment the required number were transferred to a litre beaker half-filled with sea water to which diatoms had been added from a culture. These diatom suspensions were made the previous day and kept overnight in the dark, in order that the number of diatoms increasing by division during the course of the experiment should be reduced to a minimum.

After adding the *Calanus* the water in the beaker was kept stirred by means of an oscillating glass plate. This proved an efficient method of stopping any

diatom or animal settling on the bottom. It has since been used for rearing hydroids, and details of the apparatus are shown by Rees & Russell (1937).

During the experiment the beakers were kept in the dark in order that the diatoms should not divide.

Samples of the water in the beakers were taken for counting the diatoms, which was done by the sedimentation method using an inverted microscope.

EXPERIMENT A. *Calanus* were transferred from a tow-net catch on April 17 to filtered sea water to which *Ditylium brightwellii* was added daily. After 8 days seven *Calanus* were transferred to a beaker containing 425 c.c. of a mixture of *Lauderia borealis* and *Ditylium*, in 5·9 c.c. of which 464 *Ditylium* and 1290 *Lauderia* were counted. After 7 hr. in the dark a sample was withdrawn and 8·2 c.c. found to contain 191 *Ditylium* and 1386 *Lauderia*.

EXPERIMENT B, carried out at the same time as A, differed in that the *Calanus* were fed on *Lauderia* for the 8 days previous to being transferred to 355 c.c. of the mixed culture. A sample of this was withdrawn after 7 hr. and 313 *Ditylium* and 1500 *Lauderia* were counted in 11·0 c.c.

EXPERIMENT C. *Calanus* caught on March 7 were fed on *Lauderia* for a week and then transferred to a mixture of *Lauderia* and *Chaetoceros* sp., containing sixteen *Lauderia* per c.c. After 48 hr. in the dark the population of *Lauderia* was reduced to 1·9 per c.c., and after 3 days to 0·37 per c.c. without any considerable reduction in the *Chaetoceros* population.

EXPERIMENT N 90. *Calanus*, stages V and VI, were transferred from a tow-net catch into filtered sea water and kept for 3 days. On June 6 they were again transferred and a small amount of both *Lauderia borealis* and *Nitzschia closterium* forma *minutissima* was added as food. On June 7 twenty-five individuals were transferred to a beaker containing 500 c.c. of a culture of *Lauderia* and *Nitzschia*. A second beaker was also half-filled with the culture, and both were kept in the dark with moving plates to keep them stirred. Samples of the water were taken out after 4, 10¼ and 24 hr., and the cells in measured volumes counted.

At start of experiment:	353 *Lauderia* were counted in 2 c.c. 158 *Nitzschia* were counted in 1 mm.^{3}
After 4 hr. in beaker with *Calanus*:	290 *Lauderia* were counted in 3 c.c. 157 *Nitzschia* were counted in 1 mm.^{3}
After 8¼ hr. in beaker with *Calanus*:	94 *Lauderia* in 3 c.c.
After 24 hr. in beaker with *Calanus*:	5 *Lauderia* in 3 c.c. 123 *Nitzschia* in 1 mm.^{3}
After 24 hr. in beaker without *Calanus*:	151 *Nitzschia* in 1 mm.^{3}

If the number of diatoms caught and eaten by a *Calanus* is directly proportional to the population density or concentration of the diatoms, then

$$P_2 = P_1 e^{-kt},$$

where P_1 is the initial concentration of diatoms, P_2 the concentration after time t, and k is a constant. Further, if v is the volume of water per *Calanus*,

then *vk* is the volume of water "swept free" from diatoms by one *Calanus* in unit time.

Collecting the data for the rate at which *Calanus* eat the various species we obtain the following values for *vk*:

	P_1 Initial concentration diatoms per c.c.	P_2 Concentration after t hr. diatoms per c.c.	t hr.	v Vol. per *Calanus* c.c.	*vk* Volume "swept free" by one *Calanus* in 1 hr. c.c.
		Lauderia borealis			
Experiment A	220 ± 6	168·5 ± 4·5	7	61	**2·2**
Experiment B	220 ± 6	136 ± 3·4	7	51	**3·3**
Experiment C:					
First 48 hr.	13	1·9	48	50	**2·0**
Subsequent 24 hr.	1·9	0·37	24	50	**3·1**
Experiment N 90:					
First 4 hr.	176·5 ± 9·4	97 ± 8·5	4	20	**2·9**
Subsequent $6\frac{1}{4}$ hr.	97 ± 8·5	31 ± 3	6·25	20	**3·6**
Subsequent $13\frac{3}{4}$ hr.	31 ± 3	1·6 ± 1·2	13·75	20	**4·0**
		Ditylium brightwellii			
Experiment A	79 ± 3·5	23·3 ± 2·5	7	61	**10·0**
Experiment B	79 ± 3·5	28·4 ± 1·7	7	51	**7·0**
		Nitzschia closterium forma *minutissima*			
Experiment N 90	154,500 ± 8,800	123,000 ± 11,000	24	20	**0·19** (0·31–0·05)
Fuller (1937, p. 234)			Mean value		**0·045**
		Carmine particles			
Fuller & Clarke (1936, p. 318)			Mean value		**0·23**

The experimental error in counting the diatoms amounts to the square root of the total number counted. This was calculated and reduced to terms of diatoms per c.c. as shown in the table.

A reasonable agreement is even shown between the values obtained for *Nitzschia* by Fuller and in Experiment N 90, in which the experimental error was necessarily large. The range of values of *vk* (0·31–0·05) calculated from P_1 and P_2 after applying the experimental errors, and of those obtained by Fuller (0·07–0·025) overlap.

I am indebted to Mr G. M. Spooner for a statistical examination of some of the data. This showed that the difference between Experiments A and B is just significant. They can be stated more clearly in the following form:

EXPERIMENT A. *Ditylium*-fed *Calanus* ate in 7 hr.

23·4 ± 3·5 % of the *Lauderia*
70·5 ± 6·3 % of the *Ditylium*
in the mixed culture.

EXPERIMENT B. *Lauderia*-fed *Calanus* ate in 7 hr.

38·4 ± 3·4 % of the *Lauderia*
64 ± 5·9 % of the *Ditylium*
in the mixed culture.

It is not suggested that this pair of experiments, standing alone, shows that the species eaten previous to the experiment had affected the animals' preference when presented with a mixture.

It is, however, clear that a very significant difference existed between the rate at which the three diatoms were "eaten".

Since the feeding rate of *Calanus* is now being investigated elsewhere, no further experiments were made.

Fuller (1937) suggests that the *Calanus* are probably able to capture large objects more readily than small ones. It is noteworthy that the *Ditylium*, which were most readily captured, were twice or three times the size of the *Lauderia*, while *Nitzschia* is extremely small compared with either.

I have pleasure in acknowledging not only help from Mr Spooner in treating these data, but gifts of diatom cultures from Dr H. C. Gilson and Dr Fabius Gross, and help by Dr M. V. Lebour in separating the stages of *Calanus*.

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