Selective Feeding of the Sunflower Star, *Pycnopodia helianthoides*, in the Laboratory

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SELECTIVE FEEDING OF THE SUNFLOWER STAR, *Pycnopodia helianthoides*, IN THE LABORATORY

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ABSTRACT

Breen, Paul A. 1978. Selective feeding of the sunflower star, *Pycnopodia helianthoides*, in the laboratory. Fish. Mar. Serv. MS. Rep.1498: 10 p.

Six invertebrate prey were offered to the sunflower starfish, *Pycnopodia helianthoides*, in order to measure their selective feeding rate on green sea urchins (*Strongylocentrotus droebachiensis*). Highly selective feeding was observed, in this order from most to least selected: manila clams (*Venerupis japonica*), butter clams (*Saxidomus giganteus*), native littleneck clams (*Protothaca staminea*), green sea urchins, red sea urchins (*S. franciscanus*) and Pacific oysters (*Crassostrea gigas*).

These results do not support the idea that *Pycnopodia* are an important limiting predator on green sea urchins. They may limit the lower distribution of Manila clams in the intertidal zone. Feeding rates calculated from this study were estimated to be 28 kg wet wt/adult/year.

Key words: starfish, sea star, *Pycnopodia*, predation, clams, sea urchins, *Strongylocentrotus*.

RÉSUMÉ

Breen, Paul A. 1978. Selective feeding of the sunflower star, *Pycnopodia helianthoides*, in the laboratory. Fish. Mar. Serv. MS. Rep. 1498: 10 p.

L'étoile de mer *Pycnopodia helianthoides* s'est vue offrir six espèces d'invertébrés comme proies afin de déterminer dans quelle mesure elle préférait l'oursin commun (*Strongylocentrotus droebachiensis*). Ses préférances, très marquées, ont été, par ordre décroissant: l'assari (*Venerupis Japonica*), le clam jaune (*Saxidomus giganteus*), l'amande de mer indigène (*Protothaca staminea*), L'oursin commun, l'oursin rouge géant (*S. franciscanus*) et l'huître du Pacifique (*Crassostrea gigas*).

Les résultats infirment l'idée selon laquelle *Pycnopodia* serait un facteur limitant de l'oursin commun. Il se peut qu'elle réduise les classes d'âge inférieures de l'assari dans la zone intertidale. D'après cette étude, son alimentation a été estimée à 28 kg de poids frais par adulte et par année.

Mots clefs: Étoile de mer; *Pycnopodia*; prédation; clam; oursin; *Strongylocentrotus*.

INTRODUCTION

In many parts of the shallow subtidal zone of British Columbia, the sunflower starfish (*Pycnopodia helianthoides* Brandt) is the most numerous asteroid. Its density in suitable habitat often reaches $1/m^2$ and in aggregations may reach $20/m^2$ (E. B. Hartwick, Simon Fraser University, unpub. data).

Previous studies show this starfish to be a voracious predator, feeding on a wide range of foods (Fisher 1928; Greer 1961; Feder & Christensen 1966; Mauzey et al. 1968; Paine & Vadas 1969; Birkeland & Chia 1971; Low 1975; Paul & Feder 1975). Fisher (1928) reported that *Pycnopodia* "feeds greedily upon sea urchins, hermit crabs, or any other creature not too large and active to escape". Feder & Christensen (1966) list foods ranging from algae through sponges to molluscs, crustaceans and echinoderms. Greer (1961) fed a large selection of the Puget Sound fauna to captive *Pycnopodia*, and lists 37 taxa that were taken. His animals would not eat algae, and he concluded that *Pycnopodia* is carnivorous rather than omnivorous.

My interest in *Pycnopodia* arose from its potential as a controlling predator of green sea urchins (*Strongylocentrotus droebachiensis*). This echinoid is commonly found, but in low numbers, throughout Georgia Strait. Its normal density is frequently less than $1/m^2$. In 1975 I observed juveniles from the previous year's spawning at close to $10/m^2$ in Departure Bay, but these had nearly all disappeared by summer. This suggests that abundance is normally limited by predation. Local concentrations of *S. droebachiensis* may occur, in which extremely high densities completely cover the bottom and denude it of algae (Foreman 1977). A number of such localized population explosions developed in 1969, and Foreman suggests that this resulted from oceanographic conditions that were highly favourable to the planktonic larvae. This idea is not inconsistent with that of a controlling predator: the settling young may have been so numerous as a result of unusual physical conditions that they swamped the ability of the predator to reduce them to normal levels.

From published studies on other sea urchins, *Pycnopodia* seemed likely as an important predator on green sea urchins. Its effect on the intertidal pools of the exposed Washington USA) coast was described by Paine & Vadas (1969). When a tidepool is invaded by *Pycnopodia*, some purple sea urchins (*S. purpuratus*) are eaten and the rest flee. The release from sea urchin grazing pressure allows an algal succession to begin. Mauzey et al. (1968) found from examining stomach contents of living animals that *S. purpuratus* is the major item in the diet of *Pycnopodia* from the outer coast, but that butter clams (*Saxidomus giganteus*) are the predominant prey in the San Juan Islands, where *S. purpuratus* does not occur. Low (1975) found *Pycnopodia* to be one of the few predators of red sea urchins (*S. franciscanus*). Greer (1961) stated that *Pycnopodia* preferred green sea urchins to many molluscs in his laboratory, but does not give further details. Mauzey et al. (1968) found that butter clams were taken in preference to *S. purpuratus* and *S. droebachiensis*, and that these sea urchins were eaten at a higher rate than the clams *Protothaca* and *Mya*. In the inside waters of the San Juan archipelago and Georgia Strait, clams are normally much more abundant than green sea urchins, and they form the major part of the diet of the sunflower starfish. There are three possible explanations: 1) *Pycnopodia* are not selective; they eat prey according to their abundance, and something other than *Pycnopodia* predation controls green sea urchins; 2) *Pycnopodia* are selective; they prefer clams; and something other than their predation controls green sea urchins; 3) *Pycnopodia* prefer green sea urchins as Greer (1961) suggests; sea urchin abundance is low as a consequence and *Pycnopodia* are forced to eat clams as a lesser preferred but more available prey.

The purpose of this study was to test the third explanation, by measuring the prey selection of *Pycnopodia* in the laboratory.

METHODS

Four *Pycnopodia* were collected from Departure Bay in December 1974, from approximately 5 m below chart datum. When collected, all were feeding on mussels (*Mytilus edulis*) that had fallen from an experimental culture raft. The starfish ranged in diameter from 40-65 cm. They were placed in four round tanks, each 90 cm in diameter and 65 cm deep. Water temperature was held at summer levels ($15° C \pm 1° C$), and photoperiod was 12 hr. *Pycnopodia* were fed *Mytilus* until experiments began.

In feeding trials, six species of prey were offered. These were red sea urchins (*Strongylocentrotus franciscanus*), green sea urchins (*S. droebachiensis*), butter clams (*Saxidomus giganteus*), native littleneck clams (*Protothaca staminea*), Manila or Japanese littleneck clams (*Venerupis japonica*) and Pacific oysters (*Crassostrea gigas*). All 15 possible combinations of two prey species were offered once to each starfish. In order to avoid short-term learning effects, trials were arranged so that no prey species was offered in consecutive trials. Trials lasted 2 days, with no interval between. At the beginning of each trial, equal whole weights (2 kg) of the two prey species were placed on the bottom of each tank. (Because of the differences in size among the prey species, the number of individuals offered ranged from four[red sea urchins] to 40 [Manila clams]). At the end of each trial, all uneaten items and remains of eaten prey were removed. (*Pycnopodia* were not disturbed, so that if a clam was being eaten at the end of a trial, its shell was removed at the end of the next trial.)

Lengths of all prey were measured. The shell lengths or test diameters of eaten individuals were used to estimate the dry weight of tissue that had been consumed. This was done by using equations developed for this purpose by removing the soft tissues from a number of individuals, drying at 8° C to constant weight, then by regression obtaining the constants a and b in the power function:

$$W = aL^b$$

where W is dry tissue weight (g) and L is shell length or test diameter (mm).

RESULTS

Sea urchins behaved in a very different way from the bivalve prey, which remained on the floor of the tank. Both species of sea urchin climbed the walls of the tanks and clustered together at the water's edge. Green sea urchins showed a well developed running response and defensive behaviour, as described for S. purpuratus by Mauzey et al. (1968), and Greer (1961). When S. franciscanus were placed in a tank with Pycnopodia they immediately climbed to the top of the water and then ceased moving. Feeding encounters were not observed, except two that took place immediately after the animals were placed in the tank. The starfish simply moved over the sea urchin quickly and formed the humped position. This happened just after the sea urchin had been dropped into the tank thus results from feeding with red sea urchins may be unnaturally high.

The total number of individuals eaten from each prey species was determined (Table 1). This is not a good reflection of selectivity, because the prey species differed greatly in size, and were offered in equal abundance by whole weight. Thus many more small individuals, such as Venerupis, were offered. If the starfish attacked prey in proportion to their abundance, many more small items would be eaten than large. The proportion of individuals eaten was therefore calculated (Table 1). Starfish ate Venerupis in the highest proportion, followed in decreasing order by Saxidomus, Protothaca, S. droebachiensis, S. franciscanus and Crassostrea. The departure from random selection, in which prey would have been selected according to their abundance, was significant ($\chi^2 = 159.5$, d.f. = 5). Among the three species of clams alone, there was also significant non-random selection ($\chi^2 = 30.9$, d.f. = 2).

The dry weight of edible tissue consumed was calculated for each prey species. This measure of selection ignores differences in size and content among the prey species. The regression constants used to estimate dry weights are shown in Table 2 and estimates of dry weight are given in Table 3. The dry weight of S. franciscanus, only four of which were eaten, was estimated from relations given by Kramer and Nordin (1975). The order of selection was the same as seen in Table 1. The two clam species eaten most often comprised about 80% of total intake during the study.

The absolute numbers of prey eaten, the proportion of prey taken from the total number offered, and the dry weight of tissue eaten all measured selection in different ways, yet produced nearly the same qualitative result: starfish selected Venerupis at the highest rate, followed by Saxidomus, Protothaca, S. droebachiensis, S. franciscanus and Crassostrea. In each measure of selectivity, there were few differences between the order in which individual starfish selected items. In other words, all four individuals behaved in much the same way.

Feeding by size is shown in Table 4 for the three species of clams. The various sizes of Manila and butter clams were taken in proportion to the numbers available, but in littleneck clams there was significant selection of the larger sizes. Although only a few individuals of the other three species were eaten, they appeared to have been selected from throughout the range of sizes offered, except that the very largest sea urchins and oysters were not eaten.

DISCUSSION

In these trials, Pycnopodia demonstrated their ability to eat each of the prey species offered, but at the same time showed strongly selective feeding. Clams comprised about four-fifths of the total diet during the study, and green sea urchins most of the remainder. Selection patterns were the same among each of the four starfish used in the study, and they were the same no matter how selection was measured. These results indicate that, whatever factors cause selective feeding, they must be very strong.

Several points bear discussion before the results can be generalized. First, the laboratory situation differed from nature in two major ways: in the abundance of prey, and in its availability to the starfish. The absolute abundance of prey was within ranges that can be found in the field, but was higher than usual field values. Availability of prey to the starfish was higher than in nature: clams are normally buried in the substrate, and in addition are found only in the intertidal zone where feeding is regularly interrupted by the tides; and green sea urchins have a running response whose expression might have been limited by the laboratory set-up. The effect of increased abundance or availability is to increase the selectivity shown by the predator (Ivlev 1961). Second, the fact that sea urchins always climbed the walls of the tanks and so were spatially separated from the bivalve prey may have influenced the outcome. This situation is not different in quality from the natural one, where sea urchins are found on rocky shores and clams on soft substrate; and where Pycnopodia have to choose to feed in one habitat or the other. Third, the sizes of prey selected show that the size range of prey offered probably had little effect on the outcome. It might be argued, for instance, that green sea urchins were not eaten because the sizes offered were too large for the starfish to handle. The sizes that were eaten, however, were from all parts of the range offered, refuting the argument.

The results do not support the idea being tested: that preferential predation of green sea urchins by Pycnopodia might normally limit their population size. If predation is indeed important in regulation of green sea urchins, some other predator must be involved.

Among the clams, it is interesting that Venerupis were selected at a high rate while Protothaca were not. Venerupis is not usually found at tide levels low enough for it to be eaten by Pycnopodia, while Protothaca is found much lower (Quayle and Bourne 1972). Possibly Pycnopodia predation is important in determining the different lower limits of clam species in the intertidal zone.

Although this study was conducted at only one temperature, corresponding roughly to summer levels, and the availability of food was artificially high, it is possible to make a first estimate of annual feeding rate from the information obtained. If we assume that the feeding rate at 15° C in nature is only half these because of lower food abundance, and we further assume that Q_{10} for feeding rate is 2.0 (Hoar 1966), then using the 25-yr mean monthly surface temperatures for Departure Bay (Hollister 1967), we can estimate that each Pycnopodia consumes 28.8 kg wet weight of prey yearly. Although very rough, this estimate points to the importance of Pycnopodia as a major predator in the communities of which it is part.

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Table 1. The total number of individuals eaten by four *Pycnopodia*, the total number offered, and the proportion eaten (calculated as number eaten/number offered).

	Pycnopodia				
Prey species	1	2	3	4	Total
Venerupis	49/185 (0.26)	46/177 (0.26)	46/190 (0.24)	27/198 (0.14)	168/750 (0.25)
Saxidomus	26/88 (0.30)	15/84 (0.18)	13/81 (0.16)	7/80 (0.09)	61/333 (0.18)
Protothaca	12/137 (0.09)	13/132 (0.10)	22/138 (0.16)	3/127 (0.02)	50/534 (0.09)
S. droebachiensis	6/160 (0.04)	5/173 (0.03)	4/156 (0.03)	1/143 (0.01)	16/632 (0.03)
S. franciscanus	4/20 (0.20)	0/20 (0.00)	0/20 (0.00)	0/20 (0.00)	4/80 (0.05)
Crassostrea	0/78 (0.00)	2/72 (0.03)	0/86 (0.00)	1/82 (0.01)	3/238 (0.01)

Table 2. Constants used to estimate dry weight of edible tissue from length in five prey species. These constants, obtained by regression analysis, were used in the equation:

$$W = aL^b$$

where W is dry weight (g) and L is length (mm).

Species	a	b
Venerupis	4.61×10^{-6}	3.64
Saxidomus	8.54×10^{-5}	2.93
Protothaca	2.62×10^{-5}	3.17
S. droebachiensis	4.60×10^{-6}	3.40
Crassostrea	6.09×10^{-3}	1.46

Table 3. Estimated dry weights of tissue of each species consumed by *Pycnopodia* in the feeding study.

	Starfish				
Species	1	2	3	4	Total
Venerupis	206.5	251.3	241.3	162.5	861.6
Saxidomus	360.2	182.8	144.8	77.1	764.9
Protothaca	98.5	72.9	143.3	21.2	335.9
S. droebachiensis	10.8	8.0	8.2	1.9	28.9
S. franciscanus	32.6	0.0	0.0	0.0	32.6
Crassostrea	0.0	4.5	0.0	4.0	8.5
Total	708.6	519.5	537.6	266.7	2032.40

Table 4. Size selection of prey by *Pycnopodia*.

5 m size-class	*Venerupis*		*Saxidomus*		*Protothaca*	
	Offered	Eaten	Offered	Eaten	Offered	Eaten
20						
25						
30	16	6	2	2	29	1
35	115	22	14	2	114	5
40	200	36	9	3	114	8
45	196	49	26	5	89	7
50	171	40	54	14	89	17
55	43	13	76	11	65	8
60	0	0	46	12	22	3
65	9	0	39	4	12	1
70			36	7		
75			19	1		
80			2			
Total	750	166	333	61	534	50
χ^2	2.75 NS		7.51 NS		16.11 P = 0.01	