SELECTIVE FEEDING ON THE SEVERAL BIVALVE MOLLUSCS BY STARFISH, *ASTERIAS AMURENSIS* LÜKEN

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It is generally known that useful bivalve molluscs are inflicted damage by starfish in shellfish culture beds. After a study by Romans (1883), a number of papers were published on the ecological observation with regard to the feeding habit of the starfish. Of these, the names of the following authors should be mentioned: Milligan (1915), Galtsoff & Loosanoff (1939), Shoji (1939), Smith (1940), Loosanoff (1944), Hancock (1955), Tamura (1956), Vevers (1956), Christensen (1957) Hatanaka & Kosaka (1958), Burnnett (1955; 1960) and Thomas (1960).

Most of them put the stress on the quantitative studies of food, feeding behaviour, and the mechanism of shell opening by starfish. However, the selective feeding of the starfish has been left untouched. Among the problems of feeding on animals, one of the important facts is that predators take only some parts or a limited kind of various foods which are found in the surroundings. Needless to say, all animals more or less possess selectivity for food. The study on the selective feeding of the starfish may be significant in order to get further knowledge of its feeding habit, and to have a wide scope on the damage done to useful shellfish.

For the purpose of clarifying selective feeding on some useful bivalve molluscs by the starfish, some observations have been carried out on the behaviour of the starfish reared under divergent conditions.

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Materials and Method

From September 1967 to July 1968, the present study had been carried out in the sea water circulation tank equipped in the Faculty of Fisheries, Hokkaido University, using living *Mytilus edulis*, *Scapharca broughtoni*, *Patinopecten yessoensis*, *Tapes japonica* and *Crassostrea gigas* as prey to the starfish *Asterias amurensis*.

To know the relation between prey size and selective feeding of the starfish,

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three groups of starfish different in size were used as predators, each group consisting of five individuals of starfish (L-group, 121 mm in mean arm length, M-group, mean arm length 83 mm, and S-group, mean arm length 53 mm). On the other hand, three individuals of bivalve molluscs showing 10 mm in every size interval were used as prey. The size of the preys ranged from 20 mm in shell length in *Tapes japonica* and *Scapharca broughtoni*, or from 20 mm in shell height in *Mytilus edulis*, *Patinopecten yessoensis*, and *Crassostrea gigas* to 1.5 times as long as the arm length of the starfish, and the number of individuals of shellfish was examined after every 24 hours. The prey to the starfish was replenished every 24 hours for succeeding observations. The prey was released evenly, and the opportunities of predation by the starfish were tried to be equal. In the experiment of selective feeding on different kinds of prey by the starfish, the one having the highest value in electivity index was chosen, and that observation was conducted for the following two examinations. In one of them the prey was distributed evenly in the rearing tank having no shelter at the bottom, and the prey could be easily taken by the starfish. In the other, 10 cm thick of sand and mud were both placed at the bottom of the tank so as to make it possible for *Tapes japonica* and *Scapharca broughtoni* to enter and live in it like under natural circumstances.

The results of the observations under each condition were indicated by electivity index (E), preference (Ep) and accessibility (A), and the calculation was obtained from Ivlev's formula as shown below.

$$E = Ep + A$$
$$E = (ri - pi)/(ri + pi)$$
$$Ep = (pri - pi)/(pri + pi)$$
$$A = (ri - pi)/(ri + pi) - (pri - pi)/(pri + pi)$$

Consequently, *ri* is a relative content of any ingredient in the ration as percentage of the whole, *pri* a relative content of the same ingredient in the ration as percentage of the whole, when accessibility is maximum, and *pi* a relative value of the same ingredient in food complex of the environment.

All the observations were repeated from six to fourteen times, and the values obtained were averaged, e.q., in case where each value was approximate, the numbers were reduced, but when the values showed divergence, the experiments were repeated again and again, thus the number of experiments was increased. Among the prey, *Tapes japonica* being small size in nature, was observed regarding S-group only, and *Mytilus edulis* M-group and S-group. *Scapharca broughtoni* more than 100 mm in shell length was not available for the present experiment.

Results and Consideration

Selective feeding by starfish on different sized prey: The result of the observation is presented in Fig. 1(A-E). The distribution curve of electivity index shows very characteristically, according to the kinds of prey. It is understood that the relation between selective feeding by starfish and the different sizes of prey has a close correlation. Fig. 1-A shows the electivity index of each starfish group when *Patinopecten yessoensis* is provided as prey, and the modes of the electivity index of M-group and L-group indicate an asymmetrical curve both moving from the median to the smaller in the size of prey. The individuals belonging to L-group, 40–50 mm in size, those belonging to M-group 20–40 mm in size, and S-group, 20–30 mm in size are mostly selected, and the damage of young shellfish was generally perceived. The mode of electivity index, which shifted to the young shellfish, excluding every S-group, can also be seen in *Mytilus edulis* as well as in

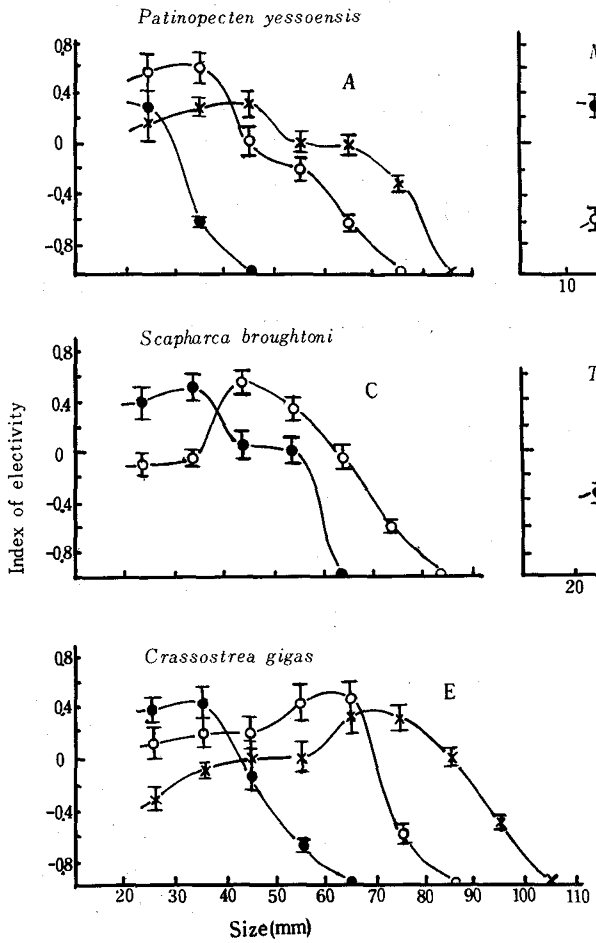

Fig. 1. Showing the distribution curve of electivity index on different sized living prey of respective species of *Patinopecten yessoensis*, *Mytilus edulis*, *Scapharca broughtoni*, *Tapes japonica* and *Crassostrea gigas*

Patinopecten yessoensis. The fact may be due to the physiological and morphological characters of the prey, and its self-defensive nature against enemies.

The size limit of *Patinopecten yessoensis* to be eaten by the starfish is 80 mm in shell height in L-group, 70 mm in M-group, and 30 mm in S-group. These values are considered to be 0.7, 0.8 and 0.6 times the arm length of the starfish in each group respectively, and the average value is estimated to be 0.7. In *Tapes japonica* and *Crassostrea gigas*, the modes of electivity index shift to the larger portion from the median in the size of prey being eaten, showing a clear contrast to *Patinopecten yessoensis*. In *Tapes japonica*, individuals, 40–45 mm in shell length indicate the highest value in the electivity index. The size of prey fed to starfish belonging to S-group seems to have the limit at 50 mm in shell length, and this size equals to 0.9 time the arm length of the starfish.

From the fact mentioned above, it is presumed that the maximum shell length of *Tapes japonica* eaten by the starfish is nearly similar in size to the arm length of the predator.

It is known that *Crassostrea gigas* is suitable as a prey in size of 60–80 mm in L-group, 50–70 mm in M-group, and 30–40 mm in S-group. The ratio of the maximum shell height of damaged *Crassostrea gigas* to the arm length of the starfish showed 0.8, 0.9, and 1.3 in L-, M-, and S-group respectively. Although there seems to be a tendency that the maximum shell height of damaged *Crassostrea gigas* becomes small with the increase of the arm length of the starfish, the average value showed 1.03 which is nearly equal to that of the arm length of the starfish.

The fact that electivity index shifts to the larger direction as seen in the cases of *Tapes japonica* and *Crassostrea gigas* is explained by Ivlev (1955) that the predator tries to take large-sized prey. In *Patinopecten yessoensis* and *Mytilus edulis*, however, the modes of electivity index by the starfish shift from the median of the size to the smaller direction. This may be due to the physiological character of the prey. The maximum value of electivity index in *Scapharca broughtoni* lies at the size of 40–50 mm in shell length in M-group, and at 30–40 mm in S-group. The maximum size in shell length eaten by the starfish is 80 mm in the M-group and 60 mm in the S-group. In *Mytilus edulis* the highest value of electivity index lies at the size of 30–40 mm in M-group, and 10–20 mm in S-group. The largest size of *Mytilus edulis* fed to starfish is approximately similar in each group to the arm length of the predator; it is the same with *Tapes japonica, Crassostrea gigas,* and *Scapharca broughtoni*.

Needler (unpub. Ms.) reported that the oyster can be eaten by the starfish till the shell height attains 1.5 times the arm length of the starfish (cf. Smith, 1940). Tamura *et al.* (1956) stated on the basis of rearing experiment of the starfish that the number of shellfish eaten by this animal is divergent according to the stomach content of the predator. In short, the maximum size in shell length eaten by the

the starfish differs a little according to the condition of the stomach content of the predator and to the quantity of suitably sized food found in the environment. The results of this experiment are all derived from the data observed when the starfish is in gluttonical situation.

Relationship between the varieties of prey and the selective feeding of the starfish: In Table 1 are given electivity, preference and accessibility obtained by Ivlev's formula showing the relative values between various prey. Of the five species of shellfish used for the experiment, the highest value of preference by the starfish was observed to be first *Tapes japonica*, second *Scapharca broughtoni*, and third *Crassostrea gigas*. Yet no sign of preference was observed at all in *Patinopecten yessoensis*, and only a slight preference in *Mytilus edulis*. As already mentioned, the fact that the mode of electivity index on different sized prey in *Patinopecten yessoensis* and *Mytilus edulis* shifts to the left may reasonably be interpreted to have some relationship with the behaviour of starfish avoiding these two species of shellfish. On the other hand, the electivity was observed under artificial conditions similar to any ordinary natural environment, that is, sand and mud on the tank bottom 10 cm thick so as to let *Tapes japonica* and *Scapharca broughtoni* live in.

Table 1. Relationship between the varieties of prey and the selective feeding of the starfish

Species of prey	E	Ep	A
Patinopecten yessoensis	-0.33 ± 0.01	-1.00 ± 0	0.66 ± 0.01
Mytilus edulius	-0.14 ± 0.07	-0.27 ± 0.06	0.13 ± 0.08
Scapharca broughtoni	0.32 ± 0.07	0.25 ± 0.02	0.07 ± 0.09
Tapes japonica	-0.17 ± 0.06	0.32 ± 0.02	-0.50 ± 0.04
Crassostrea gigas	-0.02 ± 0.01	-0.19 ± 0.08	0.16 ± 0.07

E; electivity index, Ep; preference index, A; accessibility index

In *Tapes japonica* electivity index dropped down because of the markedly decrease of accessibility, whereas the predator showed the highest preference in a previous experiment when the tank had no sand or mud bed, and *Scapharca broughtoni* showed predominance in electivity index. The highest value in electivity index observed in *Scapharca broughtoni* in spite of its burrowing behaviour is due to the ecological factor of this shellfish. In other words, *Scapharca broughtoni* is apt to be discovered rather easily by the enemy, for this shellfish is used to protrude a part of ventral margin over the mud surface while breathing and feeding, unlike *Tapes japonica* which has a siphon for the same purpose. *Patinopecten yessoensis* showed a slight electivity owing to the decrease of accessibility of *Tapes japonica*. When released in the tank equipped with sand or mud, the electivity index of

Crassostrea gigas showed the low value. Hancock (1955) reported in his paper, "The feeding behaviour of the starfish on Essex Oyster Beds", that *Asterias* is not such a serious enemy of the oyster as was previously supposed, and that under certain conditions, its presence may be beneficial to oyster culture.

From the result of the present study, it seems that the starfish is not a positive enemy of *Patinopecten yessoensis* in the presence of the bivalve molluscs.

Summary

1. For the purpose of clarifying selective feeding on some usful bivalve molluscs by the starfish, observations have been carried out on the behaviour of the starfish under divergent conditions reared in the circulating sea-water tank.

2. The highest value of electivity index of same-sized prey differs according to their species. No definite correlationship was found between the size of prey of the same species and the electivity index as to their size variation.

3. The maximum size of such prey taken by the starfish is nearly similar in size to the arm length of the predator in regard to *Tapes japonica, Crassostrea gigas, Scapharca broughtoni* and *Mytilus edulis* with the exception of *Patinopecten yessoensis* which shows 0.7 times to the arm length of the starfish.

4. In electivity index on the varieties of the prey by the starfish, *Scapharca broughtoni* showed the highest value, and *Patinopecten yessoensis* the lowest.

5. The highest value in preference by the predator was seen in *Tapes japonica* but no preference in *Patinopecten yessoensis* at all.

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