PRELIMINARY OBSERVATION ON THE MATURATION OF THE BURROWING SEA URCHIN, *ECHINOSTREPHUS ACICULATUS* (A. AGASSIZ), IN THE VICINITY OF SETO[1]

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A vast rocky shore of sand stone, sloping down rather gently and forming some flats on it, stretches at several sites in the vicinity of the Seto Marine Biological Laboratory. And, from around the low water mark down to several meters deep on the exposed side of these rocky substrata, there are found a number of remarkable colonies of sea urchins, that are generally consisting of three species, *Anthocidaris crassispina* (A. Agassiz), *Echinometra mathaei* (Blainville) and *Echinostrephus aciculatus* (A. Agassiz). The first two are distributed more generally, under or between the stones or in crevices, than the last that is limited at least around the low water mark to the more or less protected areas on the exposed side, furnished with a number of pits on the surface, in which respective urchins are fitting.

E. aciculatus widely found in the Indo-Pacific, inclusive of the Hawaiian, Gilbert, Society Islands and Lord Howe Island and the waters extending from the Sulu Islands to Japan and from the low water mark to 50 m deep (Mortensen, 1943), is distributed in Japan up to Tateyama near the mouth of Tokyo Bay (Shigei, 1973). Especially in the vicinity of Seto, it is one of the commonest sea urchins in the area, occupying more than half of the population at many of the sea urchin colonies mentioned previously.

Although the clinging power of *E. aciculatus* is much less than that of *A. crassispina* or *Echinometra mathaei* of the same body size, it is quite safe on rather exposed shore for its burrowing habit in the rocky pit (Yamanishi and Tanaka, 1971). Thus, this sea urchin seemingly seldom changes its nest pit (Yamanishi and Tanaka, 1971) and therefore its population is very stable even in the habitats around the low water mark, that are exposed to the most effective wave action, unless the habitats are exposed to the unusual cold at the lowest-water in winter. However, to maintain its stable population steadily for long time as observed on the western reef of Hatake-

1) Contributions from the Seto Marine Biological Laboratory, No. 612.

Publ. Seto Mar. Biol. Lab., XXIII (1/2), 57–62, 1976. (Article 4)

zima Island for 13 years (Biological data 1 in Publ. Seto Mar. Biol. Lab.), it is indispensable that this sea urchin can obtain enough food by some method other than grazing. Gathering floating algal pieces as food by using spines has been confirmed on this sea urchin (Yamanishi and Tanaka, 1971), too, as it is described in detail in its relative *E. molaris* (Blainville) (Campbell et al., 1973). Although gathering algal pieces by tube-feet is seen generally in so-called heaping sea urchins and collected pieces may be supplementarily served as food in some urchin (Yanagisawa, 1972), these are the only food for *E. molaris* and *E. aciculatus* living around the low water mark. It is wondered if the supply of floating algal pieces is enough to bring *E. aciculatus,* significantly larger than *E. molaris,* to maturity, but it is doubtless that this sea urchin attains the maturity in the habitat around the low water mark, as Onoda (1936) made an observation on the early developmental stages to the young pluteus of this sea urchin collected from around the low water mark in the vicinity in the summer season (under the name of *E. molaris*).

On the other hand, a number of *E. aciculatus* may be caught entangled with the gill-nets for spiny lobster fishery set a few to several fathoms deep in the vicinity from October to April. As the nets are set in the evening and raised next morning, this shows that *E. aciculatus* moves around at night on the rocky floor at some depths and then it can graze freely. The amount of food grazed on the sea bottom might be larger than that obtained by grasping floating algal pieces by spines on the rocky shore. If so, in *E. aciculatus,* the individuals living on the rocky bottom and grazing freely will mature better than those living on shore and collecting floating debris, and then the main reproductive population will be the deeper assemblages rather than the shallow colonies. The following observations were made in order to learn whether or not this is the fact.

Material and Method

The GT ratio, namely the ratio of the gonad weight to the test weight was calculated to indicate the maturation grade, and this ratio was compared between the individuals of *E. aciculatus* collected respectively from the colony found around the low water mark and from the rocky floor, 2 to 3 m deep. The urchins from the former habitat may be signed hereafter as shallow-urchins, while those from the latter habitat as deep-urchins. The breeding season of *E. aciculatus* seems to extend from June to August in the vicinity of Seto (Kobayashi, 1969) and the collection of materials was made three times at fixed sites, on May 22, July 24 and September 6, 1975, respectively shortly before the lowest water of May 25 (full moon), July 23 (full moon), and September 6 (new moon). This is because many sea urchins are known to spawn around the spring tide (Kobayashi, 1969) and therefore the largest weight of gonads may be seen in those days. In mature urchins observed the test weight ranged from 13.4 g to 39 g or slightly over through both sexes. Together with the measurement of the test and gonads, fresh smear preparations of squashed gonad were examined under microscope.

Table 1. Maturation grades.

Grade of ripening	GT ratio	Gamete in smear	State of gonad
I	< 3%	empty	wholly spent
II	3– 5.9%	almost empty	spent
III	6– 8.9%	germ cells in various stages of ripening	ripening
IV	9–11.9%	germ cells mostly ripen	mature
V	12< %	full of ripe germ cells	fully mature

$$\text{GT ratio: } \frac{\text{Gonad weight}}{\text{Test weight}} \times 100$$

The maturation grade of gonads was divided arbitrarily into 5 classes according to the GT ratio in both sexes as seen in Table 1. The gonadal contents in respective maturation grades in *E. aciculatus* were quite similar to those in *Mespilia* (Kobayashi, 1967), *Diadema* (Kobayashi and Nakamura, 1967), and *Tripneustes, Echinometra* and *Anthocidaris* (Kobayashi, 1969).

Results (Table 2)

I. Observation on May 22: Four female shallow-urchins were all advanced over the maturation grade III, 2 being mature and fully mature respectively, while 2 female deep-urchins were still in the state of wholly spent and spent respectively. Five of 6 male shallow-urchins were over the grade III and 3 were mature, while 3 of 4 male deep-urchins were spent or wholly spent and only a single male was ripening. Evidently shallow-urchins had entered the breeding season already in the end of May, but deep-urchins were remaining still in spent to ripening states. In the shallow water, the female seemed more advanced than the male.

II. Observation on July 24: Six female shallow-urchins were all mature or fully mature, while 3 female deep-urchins were all spent or wholly spent. Of 5 male shallow-urchins, 3 were spent but a single was mature, while 5 male deep-urchins were all spent or wholly spent. Shallow-urchins were clearly in more advanced maturation grades than deep-urchins. Evidently sea urchins were at the peak of the breeding season when observed. In the shallow water, the female was in more advanced maturation grade than the male. However, it is difficult to judge whether this shows the protogynous maturation of this sea urchin or indicates that male urchins examined had discharged already when collected.

III. Observation on September 6: Five female shallow-urchins were all below the ripening state, 3 being spent, and 5 female deep-urchins were all spent or wholly spent. Five male shallow-urchins were also below the ripening state, 3 being spent, and 4 male deep-urchins were all wholly spent or spent. Both the shallow- and

Table 2. Maturation grade in examined sea urchins.

Date	Sex	Shallow-urchins Test weight (g)	Shallow-urchins GT ratio	Shallow-urchins Maturation grade	Deep-urchins Test weight (g)	Deep-urchins GT ratio	Deep-urchins Maturation grade
22/V	♀	25.71	7.82	III	19.92	5.52	II
		23.60	14.19	V	14.36	2.16	I
		22.70	9.91	IV			
		20.11	8.55	III			
	♂	19.22	6.66	III	19.36	3.72	II
		23.48	6.94	III	18.11	7.18	III
		25.40	11.42	IV	17.35	1.27	I
		22.15	9.26	IV	15.85	5.36	II
		17.56	5.13	II			
		15.52	11.66	IV			
24/VII	♀	39.12	21.01	V	25.93	1.44	I
		34.72	10.75	IV	26.32	1.72	I
		20.46	10.82	IV	21.48	4.15	II
		19.05	12.19	V			
		17.92	14.54	V			
		19.17	8.98	IV			
	♂	36.14	5.82	II	19.71	2.31	I
		22.28	4.17	II	19.55	1.57	I
		20.91	9.62	IV	19.47	3.92	II
		13.53	6.73	III	22.41	2.27	I
		16.83	5.42	II	18.93	5.86	II
6/IX	♀	18.23	8.12	III	22.78	3.07	II
		14.31	3.63	II	21.38	3.51	II
		13.36	3.75	II	16.90	2.96	I
		13.73	5.54	II	15.71	1.08	I
		15.71	7.96	III	13.64	1.32	I
	♂	25.19	4.80	II	20.01	2.90	I
		19.74	6.69	III	15.50	2.06	I
		20.13	7.20	III	13.42	3.73	II
		15.07	5.64	II	13.41	1.49	I
		14.15	4.59	II			

deep-urchins were evidently in the end of the breeding season in both sexes, though a small part of shallow-urchins remained still in the ripening state.

Conclusion

Although the number of sea urchins examined was not great enough, it was shown clearly, through the three preliminary observations, that the individuals from the shore around the low water mark were in more matured states than those from the sea bottom, 2 to 3 m below the low water mark, at least in the breeding season.

On the other hand, it is reported that in both sexes of *E. aciculatus* the germ cells attain the maximum one to three days before the full or new moon in the breeding season (Kobayashi, 1969). However, it is still unknown whether this occurs quite similarly in deep-urchins as well as in shallow-urchins. Differences in the maturation grades between shallow- and deep-urchins might be related to this point.

Rough comparison of the stomach contents between shallow- and deep-urchins examined revealed that the quantity of ingested algal foods was larger in shallow-urchins than in deep-urchins. In spite of their possible grazing at night of deep-urchins, they seem unable to maintain sufficient food supply. Less matured state of deep-urchins may probably reflect the lower level of nutrition, though partly lower water temperature during the breeding season. All these seem to demonstrate the great significance of the supply of floating debris by wave action to *E. aciculatus* and suggest that the colonies found on the exposed shore around the low water mark constitute the principal reproductive population of this sea urchin. And this might explain the rich sessile fauna on the moderately exposed shore, too. There are left, however, the following two points to be confirmed: (1) if the deep-urchins can never attain the maturity, and (2) if the most part of nutrient necessary for maturation has been stored since probably the spring season when the supply of floating algal pieces may be greatest.

The authors wish to express their hearty thanks to the staff of the Seto Marine Biological Laboratory for a fund and the facilities given to the first author in carrying out the researches at the laboratory, particularly to Dr. M. Imafuku for his help in collecting urchins.

REFERENCES

Campbell, A. C., J. K. G. Dart, S. M. Head and R. F. G. Ormond 1973. The feeding activity of *Echinostrephus molaris* (de Blainville) in the Central Red Sea. Mar. Behav. Physiol., Vol. 2, pp. 155–169.

Kobayashi, N. 1967. Spawning periodicity of sea urchins at Seto. I. *Mespilia globulus*. Publ. Seto Mar. Biol. Lab., Vol. 14, pp. 403–414.

Kobayashi, N. and K. Nakamura 1967. Spawning periodicity of sea urchins at Seto. II. *Diadema setosum*. Publ. Seto Mar. Biol. Lab., Vol. 15, pp. 173–184.

Kobayashi, N. 1969. Spawning periodicity of sea urchins at Seto. III. *Tripneustes gratilla, Echinometra mathaei, Anthocidaris crassispina* and *Echinostrephus aciculatus*. Sci. Eng. Rev. Doshisha Univ., Vol. 9, pp. 254–269.

Mortensen, Th. 1943. A monograph of the Echinoidea, III–3, Fam. Echinoidae. Copenhagen.

Onoda, K. 1936. Notes on the development of some Japanese echinids with special reference to the structure of the larval body. Japanese Jour. Zool., Vol. 6, No. 4, pp. 637–654, pls. 10–14.

Shigei, M. 1973. A check list of echinoids found in Sagami Bay with brief notes on each species. J. Fac. Sci., Univ. Tokyo, Sec. IV, Vol. 13, pp. 1–33.

Yamanishi, R. and A. Tanaka 1971. Contributions to the biology of littoral sea urchins I. Measurements of clinging power and observations on stability of sea urchin colonies. Publ. Seto Mar. Biol. Lab., Vol. 19, pp. 2–15.

Yanagisawa, Y. 1972. Preliminary observations on the so-called heaping behaviour in a sea urchin, *Hemicentrotus pulcherrimus* (A. Agassiz). Publ. Seto Mar. Biol. Lab., Vol. 19, No. 6, pp. 431–435.