

THE BIOLOGY OF *ASTERIAS RUBENS* L. IV. VARIATION IN THE SEX RATIO

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(Text-fig. 1)

There are few records in the literature of the relative proportions of the sexes in natural populations of echinoderms, and the samples studied have mostly been small. Selenka (1867) has stated that in Holothurians in general males are rarer than females, and Becher (1907) found that males were very rare in *Rhabdomolgus ruber*. Koehler (1907) noted that in the ophiuroid *Ophiacantha vivipara* there were more females than males.

Among the echinoids records of sex ratios are more numerous, but the samples used were mostly taken over a short period of the year. In a group of *Centechinus setosus* from Suez there were 400 males and 370 females, and in two samples of *Strongylocentrotus lividus* from Alexandria there were 291 males : 259 females and 238 males : 266 females (Fox, 1924). In a sample of 358 *Echinocardium cordatum* from Port Erin, Moore (1935) found 181 males : 177 females. Ikeda (1931) has recorded a sex ratio approaching equality (100 : 101.8) in the Japanese echinoid *Temnopleurus toreumaticus*. The most valuable contribution to these records is the work of Neefs (1938) on *Strongylocentrotus lividus* from Roscoff. She found that the sex ratio in this species varied from month to month. The percentages of females in her monthly samples, taken over more than one year, were: January, 26.5 and 1; February, 44; March, 45.5; April, 47 and 57; May, 40 and 50; June, 41 and 53; July, 46; August, 46 and 51; September, 62 and 56; October, 62; November, 53, 50.5 and 51; December, 41 and 45. These figures show clearly a preponderance of females in September, October and November. The reason for these fluctuations is not clear although it is possible that they may be connected with the hermaphroditism found in this species (Neefs, 1937).

Pelseneer (1926, p. 157) found that in a sample of 400 *Asterias rubens* taken at Wimereux in summer 1924 there were 184 males and 216 females.

SEX RATIOS IN MEDIUM AND LARGE STARFISHES

In a recent study of large numbers of *Asterias rubens* from four populations in the Plymouth area samples taken throughout the year have yielded further data on the sex ratio in this species. An account of the growth, reproduction and situation of these populations has already been given (Vevers, 1949), and additional material has been collected since then.

The percentage of females in each population, as given in Table I, has been calculated from the total number of medium and large starfishes of each sex caught by otter trawl on the grounds at all times of the year, during the period 1947-50.

It has already been shown that the mean body size of *A. rubens* caught by the otter trawl is larger at E I and in the Outer Grounds than it is in the Rame-Eddystone Grounds and Plymouth Sound (Vevers, 1949). It will be seen from Table I that populations with larger starfishes have an excess of females over males (Outer Grounds and E I area). In populations with medium-sized starfishes, as in Plymouth Sound and the Rame-Eddystone Grounds, the sexes are almost equal in number with a slight preponderance of females.

TABLE I

	Mean radius (cm.)	Percentage of females in population	No. of samples	Total in all samples
Rame mud (Agassiz trawl)	3.11	45.6	2	187
Plymouth Sound	9.40	53.6	5	266
Rame-Eddystone Grounds	10.48	51.3	23	1066
Outer Grounds	15.47	55.1	32	2337
E I area	19.61	70.3	6	336

TABLE II. ANALYSIS OF HAULS OF *ASTERIAS RUBENS* ON RAME MUD IN 1949

(Measurements in centimetres.)

Date	Total in catch	Males			Females			Percentage of females in sample
		No.	Range	Mean	No.	Range	Mean	
12. v. 49	103	57	1-5.5	3.15	46	1-6.0	3.20	44.7
1. vi. 49	84	45	2-6.0	3.09	39	1-6.0	3.01	46.4

SEX RATIO IN SMALL-SIZED STARFISHES

It is not possible to obtain representative samples of small-sized starfishes (radius less than 6 cm.) with the otter trawl, but on three occasions they have been caught in sufficiently large numbers by Agassiz trawl. All these catches were taken on or near the Rame mud area, south-west of Plymouth Sound. The first catch of ninety-five starfishes taken in April 1948 was not sexed, but the other two catches have been satisfactorily sexed and their radius lengths recorded (Table II).

These analyses show that in this population of small starfishes the males tend to be more numerous than the females.

SEASONAL VARIATIONS IN THE SEX RATIO

As the number of samples is relatively large the percentage of females in each catch from the Outer Grounds and Rame-Eddystone populations can be separated, according to season of capture, into six equal (two-monthly)

periods covering the year (Table III and Fig. 1). It is then found that in these large and medium-sized starfishes the proportion of females is below 50% during the winter months (November–February), but rises to 55% and even more during the spring and summer.

TABLE III. PERCENTAGE OF FEMALES IN THE OUTER GROUNDS AND RAME-EDDYSTONE GROUNDS POPULATIONS AT DIFFERENT TIMES OF THE YEAR

	Outer Grounds	Rame-Eddystone Grounds
January–February	48.3	46.6
March–April	57.1	54.6
May–June	57.1	54.9
July–August	53.9	54.8
September–October	51.9	52.5
November–December	49.4	47.6

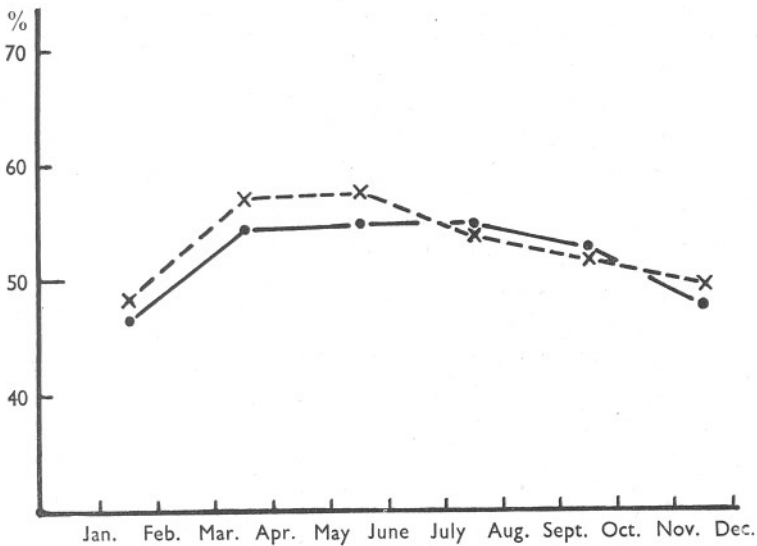


Fig. 1. Percentage of females in two populations at different times of year.
● Rame-Eddystone Grounds; × Outer Grounds.

There are insufficient data for this analysis to be carried out on the samples from the E1 area, Plymouth Sound and Rame Mud populations.

The curves in Fig. 1 are similar, with that for the Outer Grounds showing a higher percentage of females, at any rate during the spring and early summer.

DISCUSSION

Pelseneer (1926) has shown that in animals in general the males are more numerous at birth or metamorphosis while females are more numerous among the adults of a species. He considered that males were probably a little weaker in constitution and died earlier in life than females. He gave examples

which showed that, in some molluscs, insects, fishes, birds and mammals the male is more liable to parasitization than the female.

From the present data on *Asterias rubens* it is apparent that in starfishes over about 6 cm. radius the population samples tend to have relatively more females as the mean body size of the individuals increases.

Seasonal variation in the sex ratio of a population of animals may be associated with selective swarming of one sex, with protandrous hermaphroditism of the type found in *Asterina gibbosa*, with parthenogenesis as in aphids, or with a greater mortality rate in one sex. In *Asterias rubens* there is no evidence of hermaphroditism as a generally occurring phenomenon. Over 4000 specimens of this species have been examined to determine body size and the state of gonad development, and there has been no instance of a gonad showing traces of a change in the nature of its sexual elements.

Kirk (1912) has described a sample of thirty specimens of the crinoid *Actinometra japonica* from one locality in which there were no males, and the females all contained nearly ripe eggs. He considered that this was a case of swarming due to sexual activity, and that it might account for the large isolated masses of the fossil *Uintacrinus* which are often found, pointing out that such a large crinoid with an elaborate system of plankton-gathering arms could not normally live and feed in such dense masses.

At first sight the seasonal change in sex ratio in *Asterias rubens* might appear to be due to a selective swarming of females on the breeding grounds. However, if this happened, and the lacking males still survived, it is difficult to account for their absence from trawl hauls taken over such large uniform areas. It is scarcely possible that large and medium-sized males could hide on an even, flat sandy bottom of the type found on the Outer Grounds, the source of all the larger catches. Nor is there any evidence for long distance movements of starfishes.

There is, however, a possibility of a differential mortality, due to an inherent weakness in the male or to infection by parasites. Although there is no direct evidence of a difference in viability of adult males and females, it has been observed that when a large catch of *A. rubens* (taken by otter trawl) is brought into the laboratory the mortality during the first 2 days of captivity is invariably higher in the males than in the females. This suggests that the males may be more susceptible to the bruising of the ciliated epithelium and other organs which is inevitably suffered in the cod end of the otter trawl.

It is also possible that a differential rate of mortality between the sexes is related to the occurrence in the testes only of infestations of the ciliate parasite *Orchitophrya stellarum* (Vevers, 1951). Not only does this parasite cause complete atrophy of the testes, but it has also been observed that many infected males show very weak carotenoid pigmentation of the aboral integument and a general flabbiness of the body which lacks the fresh turgid appearance of a healthy specimen. It is considered that these infestations may

materially affect the mortality rate of the males. It is noteworthy that in the Outer Grounds the larger percentage of females in the population is accompanied by a very heavy parasitic infection of the males in that area. In the Rame-Eddystone Grounds, on the other hand, where the sex ratio is nearer equality, the gonad parasite has not been recorded. In the Plymouth Sound population the percentage of females was slightly higher than in the Rame-Eddystone Grounds, and this may similarly be associated with the presence of the parasite in the former population, causing greater mortality of males, thus giving an increase in the percentage of females. The parasite has not been recorded in the E1 area, but the few samples from that locality were all taken too late in the season for the presence of the parasite to be expected. Nor has the parasite been recorded in the Rame Mud population of small starfishes.

The parasite only occurs in the testes during January–April with an occasional occurrence in May. It is reasonable to suppose that, if the parasite *Orchitophrya* has an adverse effect on the mortality rate of the male starfishes, the losses due to it should occur around that time, i.e. spring and early summer. It is, in fact, considered that the rise in the percentage of females which occurs at that time is due to a differential mortality caused partly by the weakening effects of the parasite *Orchitophrya* which only attacks medium- and large starfishes with well developed gonads, and partly by a general weaker constitution and shorter life span of the males. These factors would tend to reduce the percentage of males in a population of large and medium sized starfishes. This decline in the numbers of males in a population would be cumulative if it were not made good by the growth of smaller males, which reach a size large enough to be taken by the trawl and are thus included in the population samples, or by the gradual immigration from poorly fed populations of small starfishes such as that on the Rame Mud which have an excess of males.

SUMMARY

The sex ratio of *Asterias rubens* in five populations near Plymouth has been obtained from observations on over 4000 specimens. The overall percentage of females in samples of large and medium-sized starfishes was 51·3 in the Rame-Eddystone Grounds, 55·1 in the Outer Grounds and 70·3 in the E1 area; in the isolated Plymouth Sound population the percentage was 53·6. In the Rame Mud population of small starfishes (taken only by Agassiz trawl) the percentage of females was 45·6.

On the Outer Grounds and Rame-Eddystone Grounds the percentage of females was found to vary according to the time of year, being highest in March–June and lowest in January–February.

In a general discussion of these results it is considered that they are probably not related to any change of sex in the individuals, as no trace of hermaphroditism has been found in many thousands of gonads examined. It is also

unlikely that there is any degree of differential sexual swarming. It is, however, considered possible that the rise in the percentage of females is due to a greater mortality rate in the males. There is indirect evidence that males are in general less resistant to injury than females, and it is known that they are liable to gonad parasitization by *Orchitophrya*. It is suggested that a greater male mortality rate among medium and large starfishes may be due to both these factors, and that the resulting deficiency in males is made good by recruitment of small starfishes among which males preponderate, either from the same grounds or from neighbouring grounds.

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