The Biology of *Echinocardium cordatum*.

By

Hilary B. Moore, Ph.D.,

Marine Biological Laboratory, Plymouth.

With Plates I and II, and 5 Figures in the Text.

Contents.

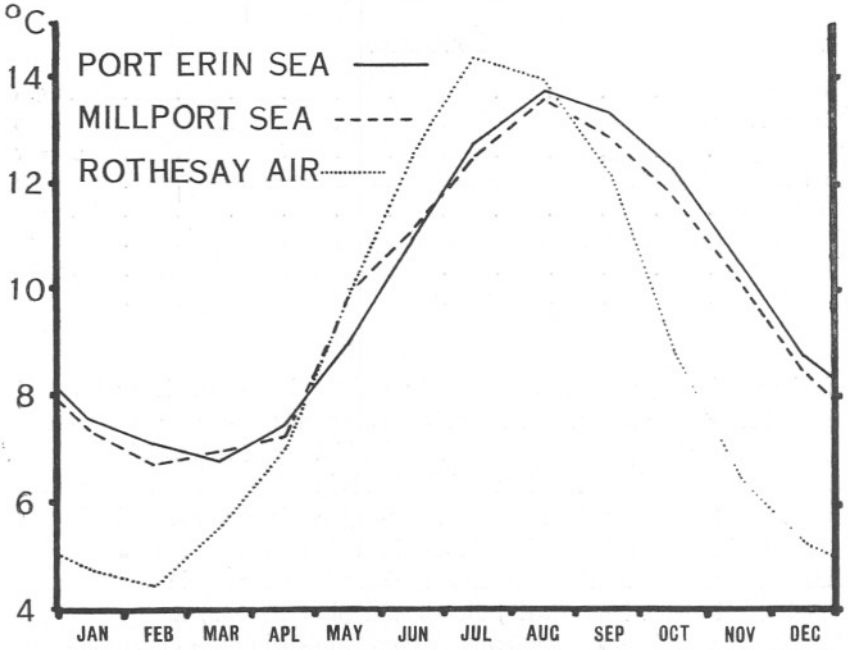
Introduction.

Echinocardium cordatum is essentially a littoral species, living in sand around low-water mark, and occurring more rarely in deeper water. The present paper comprises an account of the biology of this species at Port Erin, in the Isle of Man, and on Fairlie Sands in the Clyde. In both places it occurs abundantly from between low-water of neap and spring tides, downwards, and can be dredged in numbers close to the shore in depths of two to four metres. The general condition of the Port Erin sandy beach has been described by Pirrie, Bruce and Moore (1932) and by Moore (1933). Sea surface temperatures at Port Erin (being the mean monthly temperatures for the years 1903–1927) are shown in Text Fig. 1 and are taken from Bruce (1928). Sea temperatures taken at Keppel Pier, Millport, averaged over the period 1909–1921 (Elmhirst, 1923) are also given and can be taken as applicable to Fairlie Sands. Recent sea temperatures are not available for Millport, so air temperatures for Rothesay, as taken from the monthly weather reports of the Meteorological Office, are given.

Material and Methods.

From February to May, 1932, monthly samples of about twenty-five specimens were collected from the shore at low water at Port Erin, and their gonads examined. From February, 1933, to May, 1934, considerably larger samples were taken in order to improve the size distribution

analyses. The gonads also of a representative series of these were examined. At Fairlie Sands only a small number of scattered samples could be taken, but these proved most useful for confirming certain points, particularly with regard to the amount of growth in the first year. The length of the test of all urchins was measured from the anterior ambulacral groove to the posterior end of the test. Sliding calipers were used, reading to the nearest millimetre. As it is sometimes desirable to compare growths in terms of volume instead of length, a curve is given in Text Fig. 2 relating external volume to length of test. These volumes



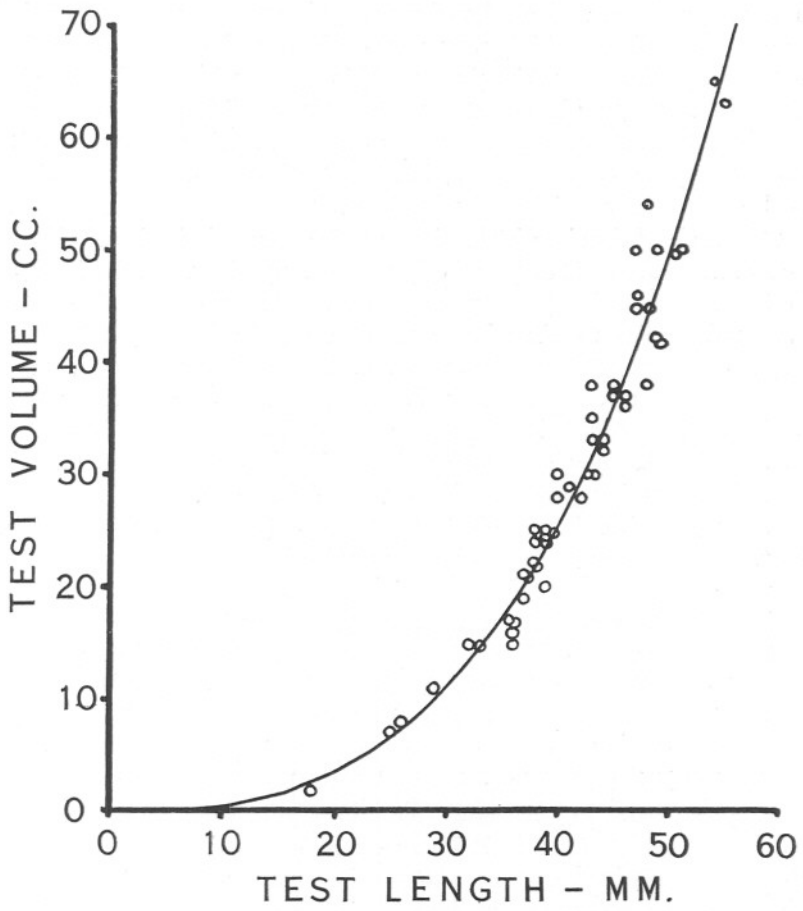
TEXT FIG. 1.—Mean monthly sea temperatures at Port Erin and Millport, and air temperatures at Rothesay.

were estimated by immersion of the urchin in a known volume of water in a measuring cylinder, and measuring the displacement. Gonad volumes were estimated in the same way, by removing the entire gonad from the test and dropping it into a known quantity of water in a measuring cylinder.

Gonad conditions are recorded from examination of a smear of the fresh gonad on a slide. Comparison of the degree of ripeness of males and females is always rather unsatisfactory. Females are not recorded as ripe unless more than 95% of the ova were mature. This gives a fairly representative picture of the condition in the gonad itself. But in the males, a smear swarming with active spermatozoa may be obtained

from an urchin still containing many developing stages, and thus far from fully mature.

Throughout the winter of 1933–34 a series of gonads were fixed and sectioned from animals of known year groups in order to verify the



TEXT FIG. 2.—Relation of test volume to length in fifty specimens of *E. cordatum* from Port Erin.

representativeness of the earlier examinations, most of which had been made on urchins of at least three years old.

GROWTH.

At Port Erin, at least three-year groups can be separated by the colour of the outside of the test, and, if confirmation is required, by the size and colour of the gonads. The first group consists of small urchins with a pale straw-coloured test and either small immature gonads or none at

all : when present these gonads are pale in colour. These urchins, as will be shown later by comparison with the Scottish material, are in their first year. The second group, comprising urchins in their second year, has darker coloured tests than the previous group, though not yet as dark as in adults, and has well-developed gonads, although these are still pale in colour. Sometimes a third group also stands apart from the older urchins, but usually all older urchins form one third group with a still darker test, and large, darkly pigmented gonads. These differences were quite clearly defined, and were of the greatest value in tracing the growth of the successive year groups as shown in Plate I. In the Scottish material no such marked colour difference was observable.

The whole of the size distribution data for Port Erin is given in Table I and in Plate I. In 1932 practically no small urchins were obtained, but in the two following years young urchins of four or five months old appeared in large numbers between tide marks in the spring, forming a large proportion of the whole population. The suddenness of their appearance in February, 1933, and in January, 1934, must not be taken as evidence of a sudden migration onto the shore, but rather as the result of a slow migration up the shore combined with the onset of better weather conditions allowing access to a lower zone of the shore.

In the case of *Echinus esculentus* at Port Erin (Moore, 1935) it was found that, except immediately after metamorphosis, the period during which growth of the test took place was limited to about three months in the spring, and that practically no shell growth took place for the whole of the rest of the year. In Echinocardium growth seems to continue throughout the year with the exception of a short cessation in February–March. This coincides with the time of minimum sea temperature at Port Erin (Fig. 1), and as soon as the temperature commences to rise, growth recommences.

The Port Erin material was incomplete in that the smallest stages were not represented. The material from the Clyde, comprising a series of scattered samples taken in 1933, 1934 and 1935, helped to fill this gap. Here the successive year groups cannot be so readily separated by colour differences as they can at Port Erin. In October, 1933, a number of very small Echinocardium about three mm. long were obtained, and were clearly ones which had metamorphosed that summer, probably about September (Text Fig. 3). They were dredged in a depth of two to four metres below low-water at Fairlie Sands, close inshore. Digging on the shore produced a single specimen only of that year group. Clearly these small urchins had not yet invaded the intertidal region. A sample dug

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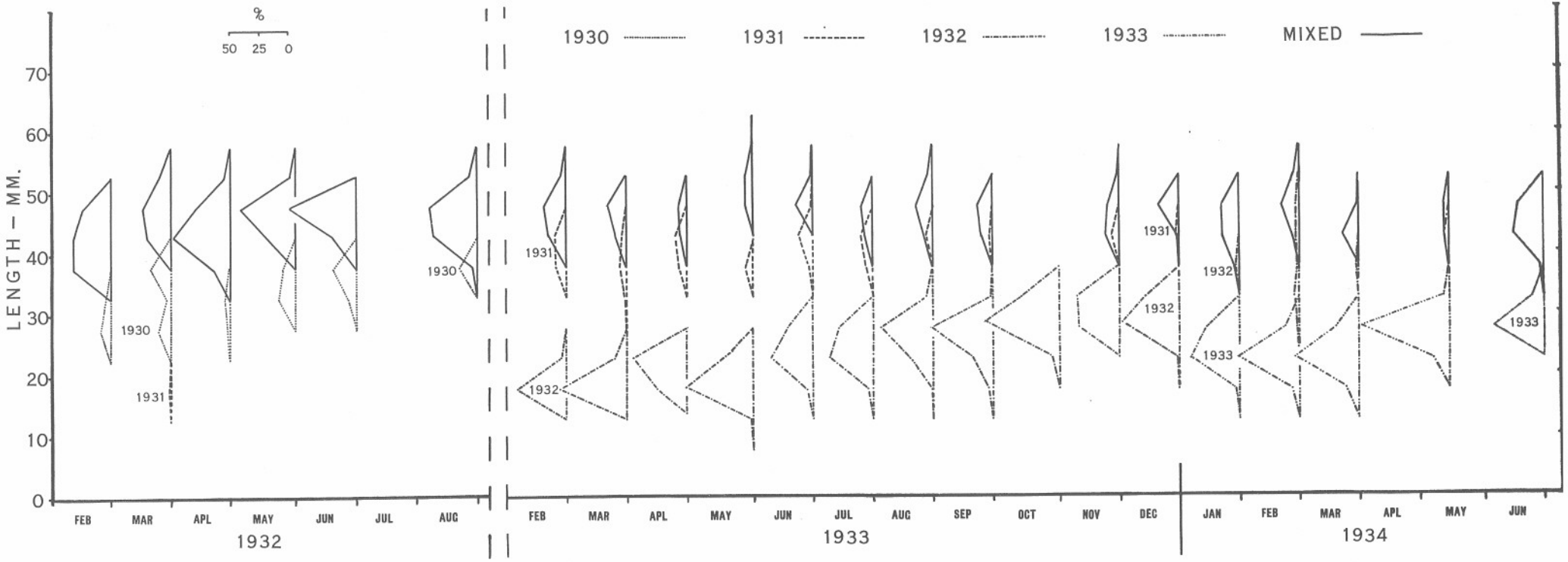
EXPLANATION OF PLATE I.

Percentage size distribution of *E. cordatum* at Port Erin. Those year groups which were separable by their colour are indicated.

PLATE I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LENGTH – MM.
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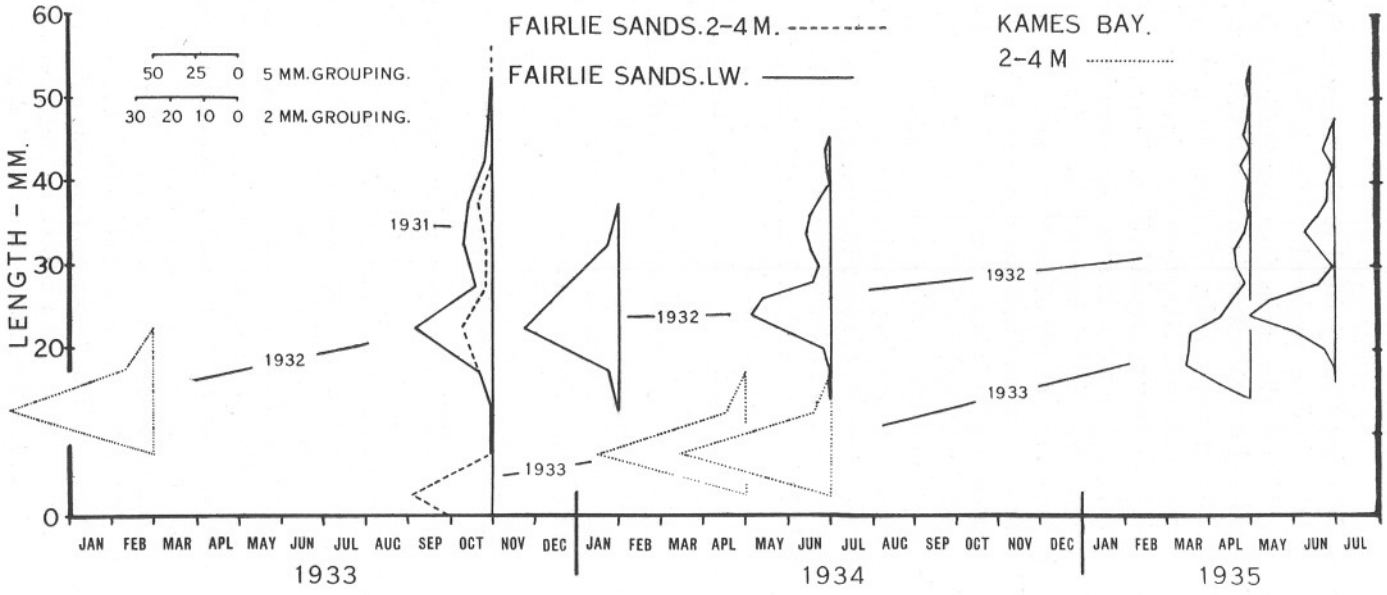
1932
1933
1934

at low water the following January failed to obtain any of these small urchins, and one taken in June produced only a single specimen, now 15 mm. in length. Two small samples from low water at Kames Bay (? dredged) in April and early June again obtained this 1933 brood at lengths of 11 and 13 mm. respectively. In April, 1935, when the 1933 brood was about twenty months old, they were taken in enormous numbers at low water at Fairlie, as they were again in June. They were now about 20 mm. in length. A sample taken in about 4 metres in Kames Bay, Millport in February, 1933, yielded large numbers of small urchins of about 12 mm. in length, and clearly of the 1932 brood, and these again were taken in very large numbers at low water at Fairlie Sands the following October at a length of about 22 mm. As both 1932 and 1933 produced quite unusually heavy broods of young Echinocardium, it was easy to follow the year groups on this ground despite the rather long intervals between successive samples ; and it seems clear that at Millport Echinocardium reaches a length of about 10 mm. in its first winter, and about twenty in its second. An attempt was made to find similar small stages at Port Erin in December, 1933, both by sieving sand from low water and by dredging samples of sand. The intertidal sand yielded none, and the dredged samples only a single specimen 9 mm. in length. However, there seems to be little doubt that the group which appeared in such large numbers at Port Erin in February, 1933, at a length of 18 mm. was the same brood as that which appeared at Kames Bay at the same time at a mean length of 14 mm. The Port Erin urchins therefore attain a length of 15 to 20 mm. in their first winter, and 30 to 35 in their second.

The Relation of Growth and Abundance to Temperature.

The growth rate at Port Erin, although varying somewhat from year to year, seems to be always greater than at Millport. Further, the maximum size attained is greater at Port Erin, and greater again at Salcombe, Devon. The difference in the sea temperatures at Port Erin and Millport seems too slight to account for this difference. There does, however, seem to be a marked correlation between temperature and both the abundance of settlement and the growth of the young urchins. At Port Erin, 1931 was a cold year, especially the summer, and the mean temperature for the year was 0·1° C. below the 25-years mean given by Bruce (1928). The year 1932 was warm, especially the summer, averaging 0·5° C. above the mean, while 1933 was very warm, averaging 0·9° C. above the mean. Similarly in the Clyde the air temperatures (sea temperatures were not available) were 0·4° C. below the mean in 1931, and 0·1°, 0·8° and 0·5° C. above the mean in 1932, 1933 and 1934 respectively (see Table III). At Port Erin we found in 1932 practically no representatives of the 1931



TEXT FIG. 3.—Percentage size distribution of *E. cordatum* in the Clyde—all localities combined. Note that some samples were limited to first-year urchins only. Also some samples were large enough to allow the use of two millimetre grouping and are therefore drawn to a different scale.

brood of Echinocardium, while the 1932 and 1933 broods were present in exceptionally large numbers in the years 1933 and 1934 respectively. At Fairlie Sands there are no data as to the abundance of the 1931 brood, but the 1932 and 1933 broods were present in exceptionally large numbers on the shore in 1934 and 1935. (Here the young urchins spend a longer period below low water, before appearing between tide marks, than they do at Port Erin.) Thus in both places the two warm years produced extra heavy settlement of young urchins, while the cold year, 1931, yielded very few young, at any rate, at Port Erin. This is closely comparable with the results observed in *Echinus esculentus* at Port Erin (Moore, 1935). For this species 1931 proved a very poor year so far as growth was concerned, while 1932 was a good year and 1933 an extra good one.

Migration.

E. cordatum is most abundant at Port Erin between low water of ordinary and extreme spring tides. It is fairly common throughout Port Erin Bay in depths of down to 10 metres, and occasionally specimens have been taken outside as deep as 34 metres. Both at Port Erin and at Millport very small urchins were taken by dredging in a depth of a few metres some time before the same year group was found between tide marks. It is, of course, to be expected that the small and very delicate newly metamorphosed urchins would require more shelter than they would get at low water. At Port Erin the first year urchins were first taken on the shore in February in 1933 and in January in 1934. In part their sudden appearance was no doubt due to improvement in weather and tide conditions rendering a lower zone accessible than it had been earlier in the winter; but that they do migrate is shown by examination of a sample taken near the extreme top of their distribution on the shore, where no first-year and few second-year urchins are to be found, and the population consists almost entirely of large urchins of three or more years of age. Further, in Port Erin Bay, no urchins more than 27 mm. long were ever dredged, suggesting that all the older urchins, i.e. those more than two years old, had migrated into the intertidal area.

At Port Erin this migration seems to commence at about four months after metamorphosis. At Fairlie Sands, on the other hand, although a similar migration clearly takes place, it seems to be delayed much longer. Of the large 1933 brood which was found below low water in October, 1933, none were found between tide marks in January, 1934, and only one specimen in June of that year. They were, however, very abundant between tide marks in April, 1935. Actually they had probably appeared on the shore soon after the June sample was taken, since large numbers of the 1932 brood were taken on the shore at Fairlie in October, 1933. At any rate, they do not seem to appear between tide marks at Millport

until about a year after metamorphosis, as compared with four months at Port Erin.

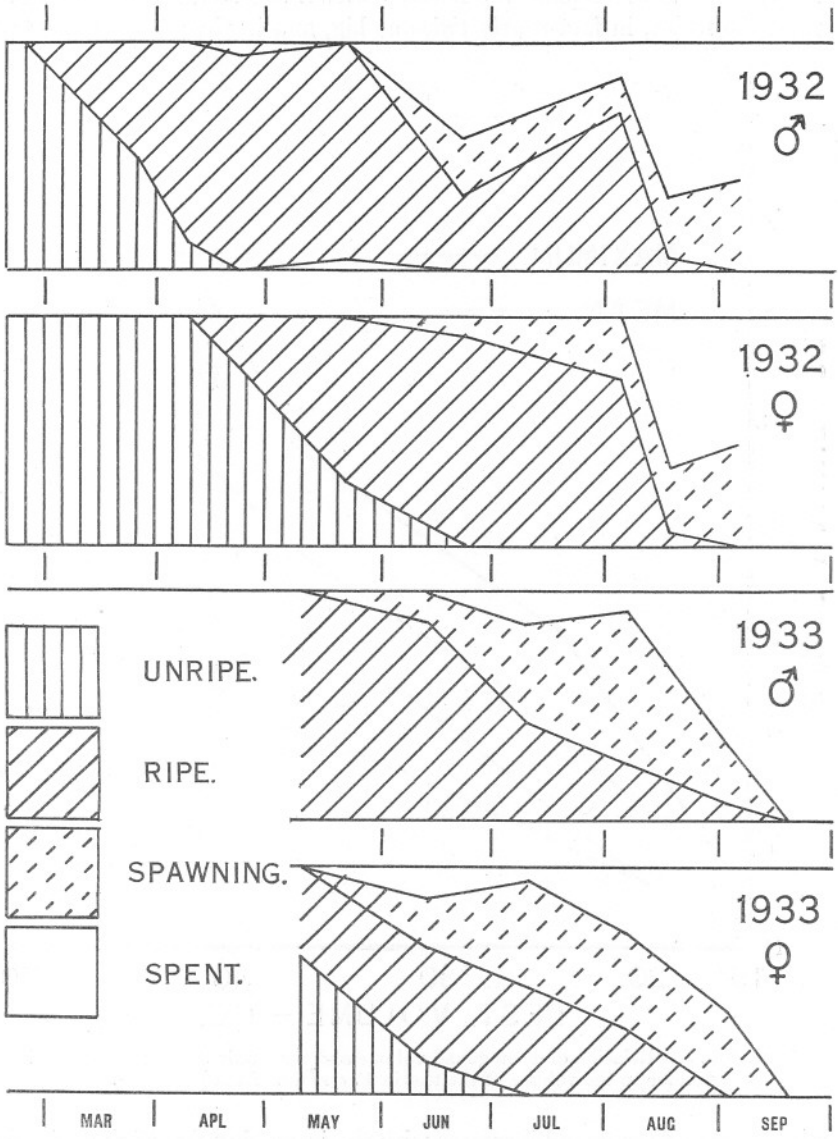
Maturation of the Gonads and Spawning.

The progress of maturation of the gonads was examined in sectioned material taken throughout the winter of 1933–34. In November, 1933, in the one-year-old urchins, the male gonads were very small, and their walls almost undifferentiated. The females contained plentiful oocyte about a quarter grown, but mostly still attached to the gonad wall. No nutritive bodies were present. Of two years old (1931 group), the males contained some quantity of relict sperm, and had not yet recommenced spermatogenesis. The females were all practically completely spent, and contained oocytes in a similar condition to those in the 1932 animals, but in this case plentiful nutritive bodies were present in the cavity of the gonad. Of the three-year-old (1930) and older urchins, the males were similar to those described above, as were the females, except for a number of relict and degenerating ova in the latter.

In samples taken in December and January, conditions were much the same except for an advance in the maturity of the oocytes, and for the appearance of early spermatogenesis stages in the males. The latter still contained a certain number of relict sperm from the previous summer. By February the female gonads were full of immature ova, while the male gonads were full of spermatogenesis stages with, in some cases, a few ripe sperm.

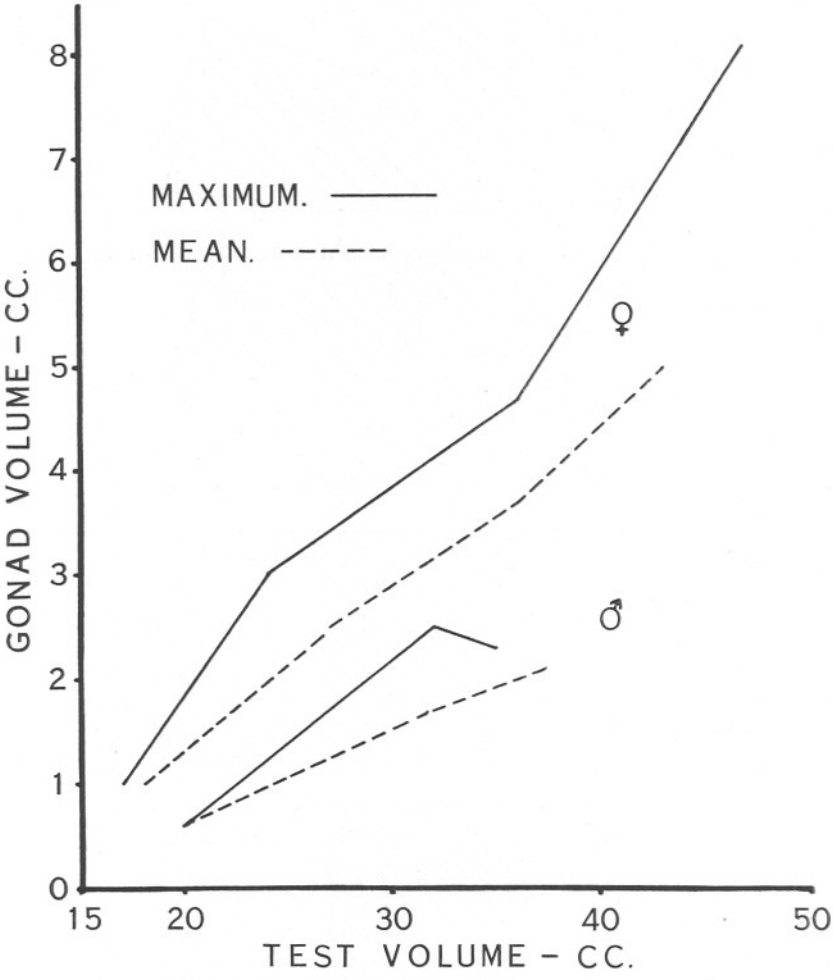
The process of spawning was recorded in detail in 1932 and 1933 (Text Fig. 4). The first sample taken in February, 1932, contained no fully ripe specimens of either sex, but by March about half the males, and by April practically all of them were ripe. In that year the females commenced to ripen in April, and were all fully ripe in June. Similar conditions obtained in 1933 : in the first sample taken in May all the males and about half the females were ripe. Spawning females were taken as early as April in 1933, but it was not until June of either year that any considerable numbers of either sex were found spawning.

In both years practically all individuals of both sexes were spent by the end of August, and in 1933, all were completely spent in mid-September. The same was probably the case in the previous year, but a sufficiently late sample was not taken to demonstrate it. Although a few spawning individuals may be found over a longer period, the main time of spawning may be taken as June–July–August. In the Plymouth Marine Fauna (1931) ripe specimens are recorded in April and June, and Elmhirst (1923) gives the spawning season in the Clyde as May to August. This is rather earlier than at Port Erin. The Port Erin results are summarised in Table V.



TEXT FIG. 4.—Seasonal changes in gonad condition at Port Erin.

In Text Fig. 5 and Table IV are given the size attained by full gonads of either sex (mean and maximum recorded size) in relation to the size of the animal. In the first place the females have a considerably larger gonad than the males, in fact nearly twice as big, and in the second place the



TEXT FIG. 5.—Relation of mean gonad volume and the maximum observed gonad volume to the volume of the test in *E. cordatum* from Port Erin.

relative size of the gonad increases with the increasing size of the animal. Thus a female with a test volume of 20 c.c. has a mean $\frac{\text{gonad volume}}{\text{test volume}}$ of 0·07, while in one of 40 c.c. the ratio is 0·11. It is probable that the accumulation of relict genital products, which in the female at least are

transformed into the nutritive bodies which serve to nourish the growing oocytes of the succeeding season, may contribute to this result.

The absence of these nutritive bodies in the gonads of the second-year females, which have not spawned before, and their presence at the same season in the ovaries of older urchins is of interest, especially as the oocytes of the former seem to be growing quite as fast in their absence, although in smaller numbers. Miller and Smith (1931) state that in *Echinometra lucunter* the nutritive bodies are formed from the cells of the gonad wall, which develop either into nutritive bodies or into oocytes. They were, however, working only on material which was nearly ripe, and an examination of less mature gonads might possibly have indicated an alternative source for them. At any rate, in the case of *Echinocardium* there is no doubt that they are absent in those individuals which have not spawned once, and present in all those which have already spawned ; and in the earlier part of the winter, the relict ova left in the gonads of the latter can be seen to be breaking down into bodies which appear to be identical with the nutritive bodies (Plate II). Finally, the nutritive bodies in Echinocardium are most numerous towards the centre of the follicle, as would be expected if they were formed from relict ova. Were they produced from the wall of the follicle it would be expected that they would be most numerous close to it. Such must therefore be taken to be the source of, at any rate, a large proportion of the nutritive bodies in this species. A series of photomicrographs illustrating the above statements is given in Plate II. It is interesting to note that the effect of the absence of nutritive bodies in those urchins which are spawning for the first time appears to be the smaller number of oocytes produced, and not any reduction in their size or rate of growth.

The young urchins seem definitely to be immature until towards the end of their first year, when gonads begin to develop, and they spawn for the first time when they are nearly two years old. There is evidence for this from both localities. At Port Erin the 1932 group contained undeveloped gonads throughout 1933, until the autumn of that year when they commenced to develop for the first time. Similarly, the 1933 group, when taken in the spring of 1934, contained no gonads. At Millport, the samples of the 1933 brood taken in Kames Bay in April and June, 1934, contained no gonads in even the largest individuals, while the 1932 group obtained at Fairlie the same June all had fair-sized mature gonads. Here also it is therefore clear that the urchin is immature for the first year, and commences to mature its gonads in its second year.

I wish to acknowledge my great indebtedness to Mr. R. Elmhirst for assistance in obtaining the Millport material, and also to the staff of the Biological Station at Port Erin.

SUMMARY.

1. Monthly samples of *Echinocardium cordatum* were taken at Port Erin in 1932, 1933 and 1934, and at intervals at Fairlie Sands in the Clyde.

2. Growth is continuous throughout the year with the exception of February–March. In their first winter the young urchins attain a length of about 10 mm. at Millport and 15–20 mm. at Port Erin. In their second winter they are about 20 mm. at Millport, and 30–35 mm. at Port Erin.

4. The year 1931 was cold and produced a very small brood of young urchins ; 1932 and 1933 were warm years and produced very large broods.

5. The young settle below low water and migrate into the intertidal zone after an interval of four to twelve months.

6. The gonads of the young urchins mature in their second year. Spawning takes place in June–July–August.

7. The nutritive bodies in the ovaries are shown to be derived from the disintegration of relict ova.

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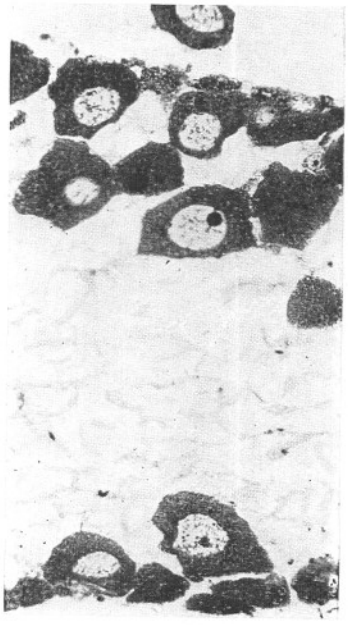
EXPLANATION OF PLATE II.

a. Transverse section of an ovary ripening for the first time, and showing oocytes, but no nutritive bodies. ×50.

b. Transverse section of a ripening ovary which has spawned at least once before, and contains numerous nutritive bodies, chiefly towards the centre of the follicle. ×50.

c.d. Transverse sections of relict ova in the ovary, showing stages in their break-down into nutritive bodies. ×370.

PLATE II.



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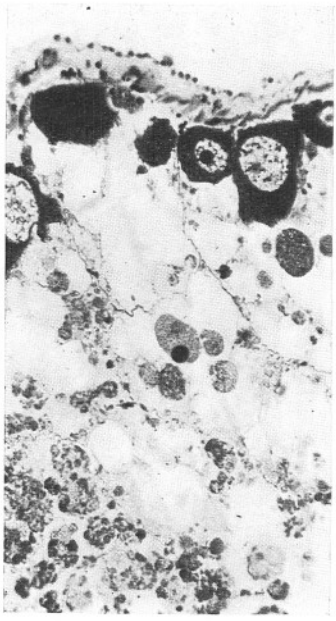

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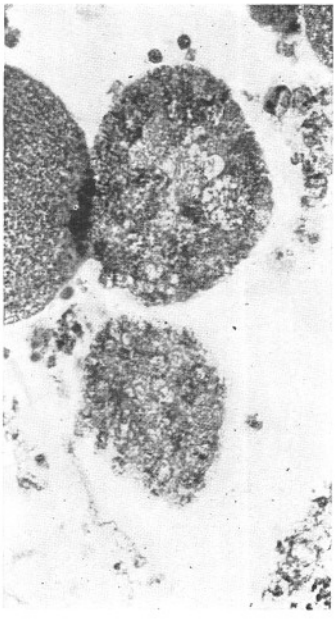

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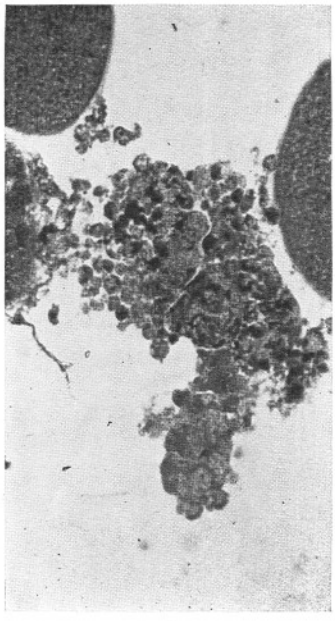

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TABLE I.

SIZE DISTRIBUTION AT PORT ERIN (PERCENTAGE), WITH THE DIFFERENT YEAR GROUPS DISTINGUISHED AS FAR AS POSSIBLE.

Lengths in mm.

Month.	Year Group.	Length of Test. 12·5	17·5	22·5	27·5	32·5	37·5	42·5	47·5	52·5	57·5	Number examined.
1932 Feb.	1930	–	–	–	8	4	–	–	–	–	–	25
	1929 or earlier	–	–	–	–	–	32	32	24	–	–	
March	1931	–	1	–	–	–	–	–	–	–	–	30
	1930	–	–	–	10	3	27	–	–	–	–	
	1929 or earlier	–	–	–	–	–	–	20	23	10	3	
April	1930	–	–	–	2	4	–	–	–	–	–	45
	1929 or earlier	–	–	–	–	–	13	47	29	4	–	
May	1930	–	–	–	–	13	11	–	–	–	–	47
	1929 or earlier	–	–	–	–	–	–	23	47	6	–	
June	1930	–	–	–	–	7	18	–	–	–	–	29
	1929 or earlier	–	–	–	–	–	–	18	54	4	–	
Aug.	1930	–	–	–	–	–	14	–	–	–	–	28
	1929 or earlier	–	–	–	–	–	4	36	39	7	–	
1933 Feb.	1932	–	42	4	–	–	–	–	–	–	–	53
	1931	–	–	–	–	–	8	8	–	–	–	
	1930 or earlier	–	–	–	–	–	–	15	19	4	2	
March	1932	–	55	10	–	–	–	–	–	–	–	58
	1931	–	–	–	–	2	5	3	–	–	–	
	1930 or earlier	–	–	–	–	–	–	9	16	–	–	
April	1932	–	25	45	–	–	–	–	–	–	–	55
	1931	–	–	–	–	–	7	9	–	–	–	
	1930 or earlier	–	–	–	–	–	–	5	7	–	–	
May	1932	1	56	25	–	–	–	–	–	–	–	72
	1931	–	–	–	–	–	6	–	–	–	–	
	1930 or earlier	–	–	–	–	–	–	–	6	6	1	
June	1932	–	5	40	21	–	–	–	–	–	–	168
	1931	–	–	–	–	–	3	12	1	–	–	
	1930 or earlier	–	–	–	–	–	–	2	14	1	–	

Month.	Year Group.	Length of Test. 12·5	17·5	22·5	27·5	32·5	37·5	42·5	47·5	52·5	57·5	Number examined.
July	1932	–	4	37	28	–	–	–	–	–	–	54
	1931	–	–	–	–	–	6	9	–	–	–	
	1930 or earlier	–	–	–	–	–	–	7	9	–	–	
Aug.	1932	–	1	18	49	5	–	–	–	–	–	88
	1931	–	–	–	–	–	–	5	–	–	–	
	1930 or earlier	–	–	–	–	–	–	6	14	3	–	
Sept.	1932	–	3	17	56	1	–	–	–	–	–	100
	1931	–	–	–	–	–	–	2	–	–	–	
	1930 or earlier	–	–	–	–	–	–	9	12	–	–	
Oct.	1932	–	–	7	62	31	–	–	–	–	–	29
	1931	–	–	–	–	–	–	–	–	–	–	
	1930 or earlier	–	–	–	–	–	–	–	–	–	–	
Nov.	1932	–	–	–	34	35	–	–	–	–	–	56
	1931	–	–	–	–	–	2	7	–	–	–	
	1930 or earlier	–	–	–	–	–	–	11	9	2	–	
Dec.	1932	–	–	2	49	28	–	–	–	–	–	53
	1931	–	–	–	–	–	–	2	–	–	–	
	1930 or earlier	–	–	–	–	–	–	2	17	–	–	
1934 Jan.	1933	–	3	40	27	–	–	–	–	–	–	112
	1932	–	–	–	–	–	3	–	–	–	–	
	1931 or earlier	–	–	–	–	–	1	13	13	–	–	
Feb.	1933	–	6	52	12	–	–	–	–	–	–	167
	1932	–	–	–	2	4	1	2	–	–	–	
	1931 or earlier	–	–	–	–	–	4	14	4	–	–	
March	1933	–	11	54	19	–	–	–	–	–	–	63
	1932	–	–	–	–	–	2	–	–	–	–	
	1931 or earlier	–	–	–	–	–	–	13	2	–	–	
April–May	1933	–	–	14	72	5	–	–	–	–	–	64
	1932	–	–	–	–	–	–	3	–	–	–	
	1931 or earlier	–	–	–	–	–	–	3	3	–	–	
June	1933	–	–	–	42	10	–	–	–	–	–	48
	1932 or earlier	–	–	–	–	–	2	25	21	–	–	
									Total			1444

TABLE II.

Size Distribution in the Clyde (Percentages).

Lengths in mm. L.W. = Low water.

Month.	Locality.	Depth.	Length of Test. 0·25	0·75	1·25	1·75	2·25	2·75	3·25	3·75	4·25	4·75	5·25	Number measured.
1933														
February	Kames Bay	4 m.	–	–	83	17	–	–	–	–	–	–	–	12
October	Fairlie Sands	L.W.	–	1	–	8	46	10	17	13	3	2	–	184
..	..	2–4 m.	47	–	–	8	17	4	4	8	–	4	8	24
1934														
January	..	L.W.	–	–	–	6	56	31	6	–	–	–	–	16
April	Kames Bay*	(4 m. ?)	–	88	12	–	–	–	–	–	–	–	–	7
June	.. *	(4 m. ?)	–	90	10	–	–	–	–	–	–	–	–	10
													Total	253

Month.	Locality.	Depth.	Length of Test. 16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	Number measured.
1934																						
June	Fairlie Sands	L.W.	0·7	–	3·5	14·7	26·6	22·4	4·9	3·5	5·6	7·0	6·3	2·8	–	0·7	1·4	–	–	–	–	143
1935																						
April	..	L.W.	10·0	18·0	17·0	16·0	9·0	6·0	2·0	4·0	5·0	2·0	1·0	2·0	1·0	3·0	–	2·0	1·0	–	1·0	100
June	..	L.W.	–	0·5	3·6	12·2	26·0	19·4	4·6	1·5	4·6	9·7	6·6	2·6	2·6	1·0	3·6	1·5	–	–	–	196
																				Total		439
																						+ 253
																						= 692

* indicates that only first year urchins are included in this count.

TABLE III.

Sea Temperatures at Port Erin and Millport.

Surface Sea Temperatures in Port Erin Bay (9 a.m.), being the monthly means for the years 1903–1927 (Bruce, 1928), and the percentage variations of the monthly means from these in the years 1930–1934.

Mean Monthly Sea Temperatures at Keppel Pier, Millport, for the period 1909–1920 (Elmhirst, 1923), and mean monthly air temperatures at Rothesay for the period 1926–1935 (Meteorological Reports).

All temperatures in °C.

	Port Erin Sea Temperatures. Departure (%) from mean.						Rothesay Air	Keppel Sea
Month.	Mean.	1930.	1931.	1932.	1933.	1934.	Mean.	Mean.
January	7·78	+0·8	+0·3	+1·4	+0·8	+1·0	4·76	7·36
February	7·08	0·0	0·0	+0·9	+0·2	+0·4	4·41	6·67
March	6·78	+0·1	−0·8	+0·7	+0·5	+0·2	5·53	6·95
April	7·43	0·0	−0·5	+0·6	+0·8		7·10	7·23
May	8·97	−0·1	−0·5	+0·1	+0·5		9·87	10·00
June	10·94	+0·5	−0·1	+0·3	+0·8		12·48	11·10
July	12·77	+0·3	−0·4	+0·5	+1·2		14·37	12·50
August	13·76	0·0	−0·3	+0·6	+1·1		13·96	13·60
September	13·32	+0·4	−0·1	+0·6	+1·4		12·17	12·82
October	12·29	+0·2	−0·9	−0·2	+1·1		8·80	11·80
November	10·44	+0·4	+1·1	+0·2	+1·0		6·50	10·13
December	8·74	+1·1	+1·4	+0·9	+0·8		5·33	8·47
Means	10·02	+0·3	−0·1	+0·5	+0·9		8·78	9·89

TABLE IV.

Relation Mean and Maximum Gonad Volumes to Test Volume (all in c.c.) in "Full" Urchins.

	Mean Test Volume.	Mean Gonad Volume.	No. of Specimens.	Test Volume.	Maximum Gonad Volume.
♂	20·0	0·6	1	20	0·6
	31·7	1·7	8	32	2·5
	37·4	2·1	5	35	2·3
♀	18·0	1·0	2	17	1·0
	24·3	2·4	3	24	3·0
	36·0	3·7	5	36	4·7
	43·4	5·0	7	47	8·1

TABLE V.

SEASONAL VARIATION IN THE CONDITION OF THE GONADS: EXPRESSED AS PERCENTAGES IN EACH SEX IN EACH SAMPLE.

Date.	MALES.				FEMALES.				Number examined.	
	Unripe.	Ripe.	Spawning.	Spent.	Unripe.	Ripe.	Spawning.	Spent.		
1932									♂♂	♀♀
Feb. 23	100	–	–	–	100	–	–	–	15	10
Mar. 26	50	50	–	–	100	–	–	–	18	12
Apr. 9	12	78	–	–	100	–	–	–	9	5
Apr. 23	–	94	6	–	77	23	–	–	18	13
May 22	5	95	–	–	27	73	–	–	21	26
Jun. 23	–	33	25	42	–	92	8	–	12	17
Aug. 5	–	69	15	15	–	73	27	–	13	15
Aug. 19	–	6	26	68	–	6	28	66	19	18
Sep. 1	–	–	40	60	–	–	44	56	15	16
1933										
May 10	–	100	–	–	60	40	–	–	7	5
Jun. 13	–	87	13	–	14	50	22	14	8	14
Jul. 11	–	43	43	14	–	47	47	6	14	15
Aug. 7	–	25	67	8	–	29	42	29	12	7
Sep. 4	–	8	25	67	–	–	36	64	12	11
Sep. 20*	–	–	–	100	–	–	–	100	?	?

* This sample was 100% spent, but only two specimens were of determinable sex—both females.