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To cite this article: Trevor G. Dix (1970) Biology of *Evechinus chloroticus* (echinoidea: Echinometridae) from different localities, New Zealand Journal of Marine and Freshwater Research, 4:4, 385-405, DOI: 10.1080/00288330.1970.9515355

To link to this article: http://dx.doi.org/10.1080/00288330.1970.9515355

Published online: 30 Mar 2010.
BIOLOGY OF *EVECHINUS CHLOROTICUS* (ECHINOIDEA: ECHINOMETRIDAE) FROM DIFFERENT LOCALITIES

3. REPRODUCTION

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*(Received for publication 28 October 1969)*

**SUMMARY**

Mean gonad indices of *Evechinus chloroticus* (Val.) at Kaikoura and Kaiteriteri, South Island, New Zealand, increased during the winter and spring to reach peak values during the summer and then decreased to minimum values in autumn. There was only one major summer peak at Kaikoura, but two at Kaiteriteri. The maximum mean gonad index of Kaiteriteri specimens was little higher than the minimum at Kaikoura. Absolute size of gonads and spawn production were also lower at Kaiteriteri, perhaps because of less food there.

At both localities gametogenic cycles were correlated with gonad index cycles, progressing from unripe to ripe from late autumn to spring, but Kaikoura urchins held ripe gametes over a longer period than Kaiteriteri urchins. The volume of spawn from females was greater than that from males but males had ripe gametes (and could be artificially induced to spawn) longer. At Kaikoura, some spawning probably occurred throughout summer with a major spawning in late summer or early autumn. Large urchins with small dark gonads were found throughout the year, particularly at Kaiteriteri; these were probably senile individuals.

Although at both localities *Evechinus* matured at 3-4 years, Kaikoura urchins were larger at maturity.

At Kaiteriteri sex ratios of mature *Evechinus* did not differ significantly from 1:1, but in some populations at Kaikoura males were significantly more prevalent than females.

**INTRODUCTION**

Boolootian (1966) reviewed the fairly extensive literature on reproductive biology of echinoids, but on the common New Zealand echinoid *Evechinus chloroticus* only McRae's (1959) structural observations and note that ripe gonads could be obtained throughout most of the year have been published.

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The aim of my study was to understand the general reproductive biology of *Evechinus* and to attempt to explain differences between populations at Kaikoura (42° 25' S, 173° 42' E) and Kaiteriteri (42° 02' S, 173° 01' E) (see Dix 1970 for locality maps). Aspects considered were:

- Seasonal variations in relative gonad sizes (gonad indices) and gametogenic stages;
- Annual volume of spawn production;
- Size and age at maturity, and
- Sex ratios.

**METHODS**

**REPRODUCTIVE CONDITION**

At both Kaikoura and Kaiteriteri monthly samples of 50 *Evechinus* were taken to determine the reproductive cycles. Kaikoura urchins (test diameter 9.5-15.0 cm) were collected at Seal Reef from May 1967-April 1968 and Kaiteriteri urchins (test diameter 4.5-8.1 cm) were collected from November 1967-November 1968. Other samples, mentioned below, provided additional information.

The gonad condition of mature urchins was judged from the appearance of intact and transversely cut gonads, from unstained fresh smears from the gonoducts, and from the relative gonad volume or gonad index as originally defined by Moore (1934):

\[
\frac{10 \times \text{Gonad volume (ml)}}{\text{Test volume (ml)}}
\]

Gonad volume was measured by displacement in a measuring cylinder and test volume (V) was calculated from regressions of V on test diameter squared (d²) × test height (h) (Table 1).

The gametogenic condition of gonads in mature *Evechinus* at Kaikoura were classified:

- **Unripe** ♀: gonads firm; subdivided into:
  (a) those with a few small ova all with visible nuclear membranes, and
  (b) those with more ova with visible nuclear membranes and few without.

- **Ripe** ♀: gonads pulpy, at least 90% of ova without visible nuclear membranes, ova readily extruded as a yellow granular stream on cutting the gonad and often from the genital pores on handling the urchins.

- **Spent** ♀: gonads very firm, thin, and with a brown fluid containing few ripe ova and much debris extruded from the gonad on cutting.

- **Unripe** ♂: gonads firm; subdivided into:
  (a) those with few or no active sperm and no milt (seminal fluid + sperm), and
  (b) those with many active sperm but only a small amount of milt.
TABLE 1—Least square regressions of test volume (V) on diameter squared times test height (d^2.h) for adult *Evechinus chloroticus* at Kaiteriteri and Kaikoura, 1967-68

<table>
<thead>
<tr>
<th>Locality</th>
<th>n</th>
<th>Regression Equation</th>
<th>t</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kaiteriteri</td>
<td>24</td>
<td>V = 0.67d^2.h + 8.63</td>
<td>35.58</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Kaikoura</td>
<td>75</td>
<td>V = 0.69d^2.h + 15.40</td>
<td>77.11</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

*Ripe* ♂: gonads pulpy, with large numbers of active sperm readily extruded as white milt on cutting the gonad and often from the genital pores when handling the urchins.

*Spent* ♂: gonads very firm, thin and yielding a brown fluid containing few sperm and sometimes a small amount of milt.

Although the gonads of mature *Evechinus* from Kaiteriteri were classed in the same way, these did not become as full, pulpy or extrude such copious amounts of milt or roe when ripe as did those of Kaikoura urchins.

The relationships between gonad index and test size were based on all monthly samples from Seal Reef, Kaikoura, and from Kaiteriteri. The effects of seasonal changes in gonad indices were eliminated by adding to or subtracting from individual gonad indices for each month the difference between the mean gonad index for that month and a constant (the overall mean gonad index for the year). This brought the adjusted mean for each monthly sample to a constant, the overall mean, as done by Moore *et al.* (1963a) for *Lytechinus variegatus*. Sexes were treated separately and the data were grouped into size classes based on test diameter.

**SPAWN VOLUME**

To estimate the annual volume of spawn (sexes combined), mean gonad volumes of ripe and spent urchins were compared and grouped into size classes based on test diameter (samples from Wakatu Point and Seal Reef, Kaikoura, and Kaiteriteri). Data were insufficient to compare sexes separately by size classes. Only one major spawning was evident at Kaikoura; ripe gonad volumes of January were compared with the volumes of spent gonads of April. At Kaiteriteri, however, 86% of the sample were ripe in December, 35% were spent in January, 86% were ripe in February and 60% spent in March. Accordingly, gonad volumes of ripe December specimens were compared with spent January specimens and ripe February specimens with spent in March. Because periods of gonad growth and spawning may occur between the times compared, estimates of spawn volume must be considered to be minima.
Maturity

The relationship of gonad development to test size and age was examined in samples from Wakatu Point, Kaikoura (July 1967) and Kaiteriteri (November 1967). As in McPherson's (1965) scheme for Tripneustes ventricosus, animals were divided into classes:

- Undeveloped, no or barely visible gonads, or gonads very small and transparent without recognisable sex cells;
- Immature, small pale gonads containing no mature gametes but with gametogenesis evident from gonad smears;
- Mature, developed gonads containing mature gametes.

The categories "undeveloped" and "immature" closely correspond with "neuter" and "developing virgin" defined by Fuji (1960a) for Strongylocentrotus intermedius and S. nudus.

Results and Discussion

Annual Reproductive Cycles

Seasonal variations in gonad index: Seasonal variations in the gonad indices of male and female Evechinus at Seal Reef and St Kilda Rocks, Kaikoura, and Kaiteriteri are shown in Figs 1, 2, and 3. The gonad indices of Seal Reef Evechinus tended to increase throughout the winter (June, July, August) and spring (September, October, November) and showed a sharp increase in late spring and early summer (November and December). A mid-summer maximum was maintained during January and February but this fell markedly in early autumn (March) (Fig. 1). An essentially similar pattern was observed at St Kilda Rocks, Kaikoura, in the following year (1968–69), although the sharp fall in gonad index was observed in late February (Fig. 2). At Kaiteriteri similar increases in gonad indices occurred during the winter and spring but there were two maxima during the summer. The second peak was followed in March by a decline which lead to minimum values in April. Higher gonad indices were recorded in November 1968 than in November 1967 (Fig. 3).

Seasonal variations in gonad indices (sexes combined) are compared in Fig. 4 for Seal Reef, Kaikoura, and Kaiteriteri. At Kaiteriteri the highest gonad index was just higher than the lowest at Kaikoura. The differences in gonad indices are also shown in Fig. 5 which also implies that the absolute size of Kaiteriteri gonads was much smaller. The absolute size of Kaiteriteri gonads ranged from 0.5–22.0 ml while that of Kaikoura gonads ranged from 20.0–257 ml over the size ranges indicated in Fig. 5.

Spawn production was also higher at Kaikoura. By combining sexes, estimates of spawn production related to test size at two Kaikoura localities (Fig. 6) ranged from 20.8–80.5 ml. These contrast markedly with the Kaiteriteri samples (Table 2).

Fig. 1—Seasonal variations in mean gonad indices and gametogenic stages of

GONAD STAGES

unripe (a)
ripe (q)
spent

unripe (e)
ripe (p)
spent

GONAD INDICES

Mean Gonad Indices

Gonad Index

5.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
-5.0

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Fig. 2—Seasonal variations in mean gonad indices (sexes combined) of mature *Evechinus chloroticus* at St Kilda Rocks, Kaikoura, July 1968-March 1969. Based on samples of 10 urchins per month.

Although too few urchins were examined at Kaiteriteri to show a clear trend in spawn production related to test size, mean production found by comparing spent January specimens with ripe December specimens was 4.6 ml and that based on spent March and ripe February specimens was 5.1 ml. Even if individuals spawned at both these times, lower production than at Kaikoura is indicated. Moore *et al.* (1963a) gave estimates of minimum annual spawn production of about 10-16 ml for *Lytechinus variegatus* of similar test size to *Evechinus* at Kaiteriteri.

Differences in the gonad indices, and presumably production, of urchin species living in different habitats also have been shown for *Echinus esculentus* (Moore 1934, 1937), *Echinometra lucunter* (McPherson 1969), *Strongylocentrotus purpuratus* (Lasker and Giese 1954; Boolootian 1960; Ebert 1968) and *S. intermedius* (Fuji 1960c; Kawamura 1964, 1965; Kawamura and Taki 1965). Usually low gonad indices were correlated with habitats having smaller amounts of food, although Boolootian (1960) suggested that temperature might be significant. Although temperatures were higher at Kaiteriteri than at Kaikoura (Dix 1970), *Evechinus* with larger gonads than those at Kaiteriteri were found further north in waters warmer than those at Kaiteriteri, which suggests that warmer temperatures do not restrict gonad size. Compared with Kaikoura, however, Kaiteriteri has a much less luxuriant algal flora (Dix 1970) and this may be a major factor influencing gonad size and production. Additional observations on *Evechinus* populations in neighbouring areas in the Marlborough Sounds, some with abundant algae and others without, showed that urchins in barren areas invariably had
Fig. 3—Seasonal variations in gonad indices, gametogenic stages, and proportions able to be sexed in mature *Evechinus chloroticus* at Kaiteriteri, November 1967–November 1968.
Fig. 4—Comparison of mean gonad indices (sexes combined) of mature *Evechinus chloroticus* at Seal Reef, Kaikoura, and Kaiteriteri, 1967-68.

Fig. 5—Gonad index related to test size of mature male and female *Evechinus chloroticus* at Seal Reef, Kaikoura, and Kaiteriteri.
TABLE 2—Estimates of minimum spawn production of male and female *Evechinus chloroticus* at Seal Reef, Kaikoura (February and March 1968) and Kaiteriteri (December 1967–March 1968)

<table>
<thead>
<tr>
<th>Locality</th>
<th>Sex</th>
<th>Numbers in sample</th>
<th>Mean gonad volume (ml)</th>
<th>Difference (ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Ripe</td>
<td>Spent</td>
<td>Ripe</td>
</tr>
<tr>
<td>Seal Reef (Feb-Mar 1968)</td>
<td>♀</td>
<td>23</td>
<td>26</td>
<td>142.9</td>
</tr>
<tr>
<td></td>
<td>♂</td>
<td>27</td>
<td>24</td>
<td>124.9</td>
</tr>
<tr>
<td>Kaiteriteri (Dec-Jan 1967-68)</td>
<td>♀</td>
<td>22</td>
<td>10</td>
<td>7.0</td>
</tr>
<tr>
<td></td>
<td>♂</td>
<td>18</td>
<td>6</td>
<td>7.7</td>
</tr>
<tr>
<td>Kaiteriteri (Feb-Mar 1968)</td>
<td>♀</td>
<td>22</td>
<td>14</td>
<td>9.14</td>
</tr>
<tr>
<td></td>
<td>♂</td>
<td>18</td>
<td>14</td>
<td>9.41</td>
</tr>
</tbody>
</table>

small gonads while those in nearby weed areas had large gonads. The effects of food supply on gonad growth were also studied in running sea-water aquaria at Kaikoura, by starving (except for detritus and microscopic growth) a sample of 20 Kaiteriteri *Evechinus* and feeding another 20 on a variety of macroscopic algae. After 6 months the gonads of all starved specimens were undeveloped, very thin threads with volumes (and thus gonad indices) approaching zero. Fed specimens showed greater gonad development with a mean gonad index of 0.39. Boolootian (1966) cites similar observations for other echinoderms.

Gonad indices of female *Evechinus* at Kaikoura generally were consistently lower than male indices during winter and spring and consistently higher during summer (Table 3; see Fig. 1). This indicates that the volume of gametes spawned by females was higher than that of males. Such a clear cut trend was not evident at Kaiteriteri (see Fig. 3). Estimates of minimum spawn outputs of male and female urchins at both Kaikoura and Kaiteriteri (see Table 2) show that females spawned larger volumes than males at both localities, but that this difference was greater at Kaikoura.

Larger spawn volumes in females than in males may be characteristic of urchins: Moore *et al.* (1963a) found that the spawn output of female *Lytechinus variegatus* was 36% greater than that of males; Fuji (1960a) found ratios of full to empty gonads were 4.4 : 1.0 in male and 5.0 : 1.0 in female *Strongylocentrotus intermedius*, and Moore and Lopez (1966) recorded that the mean gonad volume of the heart urchin *Moira atrops* was 15% higher in females.

GAMETOGENIC CYCLES: Proportions of different gametogenic stages at Kaikoura and Kaiteriteri for each month (Fig. 7, see Figs 1, 3) clearly show that gametogenic cycles are annual at both places. Development progresses from unripe (a) to unripe (b) in late autumn, winter, and spring, to ripe in late spring and early summer. Most animals were ripe throughout the summer and largest numbers of spent urchins were found in early autumn.
Fig. 6—Estimates of minimum spawn production of *Evechinus chloroticus* (sexes combined) for summer 1967–68 at Kaikoura.
TABLE 3—Gonad indices of *Evechinus chloroticus* at Wakatu Point, Kaikoura, 1967–68, based on samples of 25–75 urchins

<table>
<thead>
<tr>
<th>Month</th>
<th>$\varphi$</th>
<th>$\delta$</th>
</tr>
</thead>
<tbody>
<tr>
<td>July</td>
<td>1.30</td>
<td>1.46</td>
</tr>
<tr>
<td>October</td>
<td>1.82</td>
<td>1.90</td>
</tr>
<tr>
<td>January</td>
<td>1.99</td>
<td>1.81</td>
</tr>
<tr>
<td>April</td>
<td>0.91</td>
<td>0.98</td>
</tr>
</tbody>
</table>

There were, however, some differences between the gametogenic cycles at the two places. Firstly, in both males and females, the unripe (a) condition extended over a greater part of the year at Kaiteriteri than at Kaikoura. Secondly, males ripened before females at Kaikoura, but did not appear to do so at Kaiteriteri. Finally, there were more variations in gametogenic stages found during summer at Kaiteriteri.

In addition to showing the unripe (a) condition for a longer period at Kaiteriteri, a small percentage could not be sexed throughout the year (see Fig. 3). These animals generally had very thin, dark brown gonads contrasting with normal light brown, orange or yellow gonads. H. B. Moore (pers. comm.) also has encountered similar small gonads in his urchin samples. In contrast, at Kaikoura mature urchins could be sexed the year round and generally males had at least a small number of active sperm. Very large urchins, however, often had relatively small and dark gonads, although these generally contained apparently healthy gametes. As these urchins, and those with thin dark gonads at Kaiteriteri, were found at all times of the year, they were unlikely to be seasonally spent. Decreasing gonad index with increasing urchin size is evident at both places but plainer at Kaiteriteri (see Fig. 5). These observations suggest that *Evechinus* may become reproductively senile, and that this is more evident at Kaiteriteri than at Kaikoura. Swan (1966) cited possible reproductive senility in the seastar *Asterias rubens* and the heart urchin *Brissopsis lyrifera*.

As recorded at Kaikoura in 1967 and 1968 (see Figs 1 and 7), the ripening of males before females was found in *Echinus esculentus* (Moore 1934), *Strongylocentrotus purpuratus* and *S. franciscanus* (Bennett and Giese 1955), *S. intermedius* and *S. nudus* (Fuji 1960c), *Lytechinus variegatus* and *Mellita quinquiesperforata* (Brookbank 1968). In my study, gonad condition was examined during both 1967 and 1968, and induced spawning experiments were tried during 1968 using Tyler's (1949) method of injecting 0.5M KCl. These experiments, which were similar to those of Brookbank (1968), showed that males were capable of ejecting ripe gametes earlier in the year than females (see Fig. 7). At Kaiteriteri, males did not appear to ripen before females (see Fig. 3) but this may be more apparent than real: gametogenic classification “unripe
FIG. 7—Seasonal variations in gametogenic stages and proportions induced to spawn on injection of 0.5M KCl, for mature *Evechinus chloroticus* at St Kilda Rocks, Kaikoura, April 1968–March 1969. Based on monthly samples of 15–20 urchins.
specimens had a small amount of milt, but ripe males at Kaiteriteri always exuded less milt than Kaikoura males and thus some classed as "unripe (b)" could have been ripe.

**SPAWNING SEASON:** At Kaiteriteri, both spent and ripe urchins were found in January and March 1968, an indication of more than one major spawning. In contrast, at Kaikoura gonad indices and gametogenic cycles (see Figs 1, 2 and 7) showed only one major spawning each summer, although ripe gametes were present throughout late spring and early summer. Moore *et al.* (1963a), however, assumed that some spawning occurred in *Lytechinus variegatus* throughout the period when ripe gametes were present and Boolootian (1966) defined *breeding season* in echinoderms as "the time when mature, fertilisable gametes are present". Thus I decided to test the hypotheses:

(a) Does fractional spawning occur in *Evechinus* throughout the summer when ripe gametes are present; or

(b) Does only one major spawning occur?

To test fractional spawning and also to investigate environmental influences on breeding, between 30 December 1968 and 5 February 1969 samples of 35-40 urchins were taken at 3 day intervals from an aggregation occupying about 12 m$^2$ at Sharkstooth Point, Kaikoura. Sea conditions and temperature were noted at each collection. Within a few hours of collecting, each urchin was inverted over a beaker of sea water and injected with 5 ml of 0.5M KCl to see whether spawning could be induced; the amount of spawn produced was scored on a 0–4 scale. The urchins were sexed and gonad condition was assessed from gonad indices, gross appearance and sometimes gonad smears. Mean gonad indices, phases of the moon, percentages induced to spawn, mean scores of the amount of induced spawn, and sea condition and temperatures are shown in Fig. 8.

Although nearly all urchins were ripe over the sampling period, the gonad state changed. In gonad indices, a gradual decline followed by a fairly rapid rise separated peaks at 2 and 29 January 1969. Percentages induced to spawn were high (> 80%) over the sampling period but declined near the end of January. A similar decline occurred in the amount of induced spawn, and in both a brief peak occurred in early February.

Considered alone, the two peaks in gonad indices suggest that two spawnings occurred during the sampling period. But if the induced spawn amounts and percentages induced to spawn reflect the degree of gonad ripeness presumably these would increase as gonads reached peak ripeness, then decrease after spawning. However, little change occurred in these parameters after the first gonad index peak, although slight falls might indicate that a few animals spawned partially. Increases to peaks followed by decreases, which may indicate spawning, occurred in late January and early February and similar changes occurred in the number of urchins which spawned spontaneously when inverted over beakers of sea water (Table 4). Only a small drop in female gonad index occurred at the first peak, but greater falls in male and female gonad indices occurred at the second.
Fig. 8—Short-term variations in mean gonad indices, proportions induced to spawn and mean scores of the amount of induced spawn, and ambient sea temperatures for male and female *Evechinus chloroticus* at Sharkstooth Point, Kaikoura, December 1968–February 1969. Sea conditions and phases of the moon are shown in relation to mean gonad indices.
Table 4—Number of *Evechinus chloroticus* of both sexes spawning without injection. Observations were made for only part of the sampling period; all samples were different, and contained 33–35 urchins.

<table>
<thead>
<tr>
<th>Date</th>
<th>Number spawning</th>
<th>% spawning</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 January 1969</td>
<td>15</td>
<td>43</td>
</tr>
<tr>
<td>23 January 1969</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>26 January 1969</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>29 January 1969</td>
<td>16</td>
<td>46</td>
</tr>
<tr>
<td>1 February 1969</td>
<td>6</td>
<td>17</td>
</tr>
<tr>
<td>5 February 1969</td>
<td>8</td>
<td>23</td>
</tr>
</tbody>
</table>

Further, the gross appearance of gonads after the second peak suggested that many were partially spent, but their appearance after the first differed little, if at all, from fully ripe gonads.

The induced spawning evidence suggests two partial spawnings, the second more extensive than the first, and neither accompanied by large changes in gonad indices. That spawning can occur without a large change in gonad index was shown by a sample kept for 2 days in the laboratory at Kaikoura. Fifteen males, from a sample which was found to contain 29 males, were dissected on 16 January 1968. That night most (or all) of the remaining males spawned spontaneously in quantities which densely clouded the water of the 100-gallon running sea-water tank which they were in. These males were dissected the next morning. Only a small change in gonad index had occurred, from 1.86 to 1.76 (not statistically significant; \( t = 1.04 \) for 27 d.f. has \( P = 0.15 \)).

Fractional spawning, suggested from small changes in gonad state at Kaikoura is substantiated by:

(a) successful fertilisations performed throughout the late springs and summers of 1967–69;
(b) urchins which spawned spontaneously in running sea-water tanks at Kaikoura on 16 January (mid-summer) and 1 March (early autumn) 1968 did not become completely spent, and
(c) frequency distributions of egg diameters in gonad smears from four urchins examined in December 1968 and January 1969 were bimodal, with peaks at 60 \( \mu m \) (developing eggs) and 130 \( \mu m \) (fully ripe eggs). Possibly two generations of eggs were present, as Pearse and Phillips (1968) found for the continuously reproducing echinoid *Echinometra mathaei*.

The breeding season at Kaikoura may thus be regarded as extending over the three summer months (December, January, February), although major spawning occurred in late summer and early autumn, as indicated by the sharp fall in gonad indices and appearance of completely spent urchins at Seal Reef (see Fig. 1) and St Kilda Rocks (see Figs 2 and 7); at St Kilda Rocks in late February 1969, mean gonad indices fell from 1.85 to 1.00 in samples separated by only 13 days.
At Sharkstooth Point, Kaikoura, peaks in gonad indices just preceded full moon in both January and February (see Fig. 8). This might be considered evidence for lunar periodicity (Kobayashi 1967; Moore et al. 1963a) but apparently little if any spawning occurred at full moon in January and spawning appeared to occur nearly 2 weeks before full moon as well as at full moon in February, when, however, a marked rise in temperature may have stimulated spawning. During most of January seas were calm, little drift algae was present at the sampling site, and relatively large amounts of substrate (rock) with little macroscopic algae were found in the gut of urchins. I found that food quantity influences gonad size in urchins (p. 390) and possibly urchins were using food reserves stored in the gonad over the calm spell, thus reducing the gonad size. When seas became rough (22 January 1969), my field observations showed that urchins began feeding extensively on drift algae, and this may have resulted in the observed increase in gonad size. Kobayashi (1967) suggested that spawning of the urchin Mespilia globulus “... seemed to be hastened by rough water ...”. Interestingly, the suggested late January spawning of Evechinus coincided with the end of calm seas.

SIZE AND AGE AT MATURITY: At Kaikoura and Kaiteriteri, frequency distributions of undeveloped, immature and mature Evechinus in relation to test size and age were determined by growth ring analysis (technique to be described elsewhere). The distributions (Fig. 9) indicate that urchins at Kaiteriteri first mature at a smaller size (3.5–4.5 cm) than do those at Kaikoura (5.5–7.5 cm), although in both areas age at first maturity was 3 or 4 years. The Kaikoura sample was taken earlier in the year (July) than the Kaiteriteri sample (November), but this difference probably did not significantly affect the results. Some of the immature Kaikoura urchins would probably have matured between July and November but they would also have grown in this time; the size at maturity relationship would have been little altered.

Not much is known on the size and age at maturity in echinoids. McPherson (1965) gave data on size at maturity for Tripneustes ventricosus as did Fuji (1960b, 1967) and Kawamura (1964 and pers. comm.) for Strongylocentrotus intermedius. Kawamura found that urchins may mature in 1 year where food was very plentiful but that 1- and 2-year-old urchins could remain immature where food was limited; 3-year-old urchins were mature in all the localities he studied. Moore (1936) found that Echinocardium cordatum first spawned in its second year but Buchanan (1966) found that maturity may be deferred in some populations. Moore (1966) suggested that “where food is scarce, animals may go through their main growing phase before diverting energy to gonad production” (i.e., mature when older). Apparently food at Kaiteriteri is not sufficiently limited to suppress the formation and maturation of gonads but does restrict their size.
Fig. 9—Maturity of *Evechinus chloroticus* (sexes combined) with respect to test size and age at Wakatu Point, Kaikoura, and Kaiteriteri, 1967.

**SEX RATIO**

Sex ratios of mature *Evechinus* did not differ significantly from 1:1 at Kaiteriteri, Sharkstooth Point, Kaikoura, and in a series of samples from other Kaikoura localities (Table 5). But significantly more males than females were found at Seal Reef, Nine Pins, St Kilda Rocks and also for all Kaikoura samples combined. Sex ratios in urchins are generally at approximate parity (Harvey 1956; Fuji 1960b; Moore et al. 1963a), although McPherson (1965) found more females than males among larger *Tripneustes ventricosus*; in smaller specimens the sex ratio was about 1:1. McPherson suggested that differential growth, differential mortality, or hermaphroditism might be involved. Seasonal changes in sex ratios have been noted in some echinoderms (Reverberi 1940, 1947, and Neefs 1952, 1953; both authors cited by Delavault 1966).
### Table 5—Sex compositions in populations of mature *Evechinus chloroticus* from Kaikoura and Kaiteriteri

<table>
<thead>
<tr>
<th>Date</th>
<th>Locality</th>
<th>Sample details</th>
<th>n</th>
<th>(\varphi)</th>
<th>(\sigma)</th>
<th>(%\varphi)</th>
<th>(\chi^2)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>November 1967-1968</td>
<td>Kaiteriteri, Nelson</td>
<td>About 50 per month from many aggregations</td>
<td>550</td>
<td>270</td>
<td>280</td>
<td>49.1</td>
<td>0.18</td>
<td>0.75-0.50</td>
</tr>
<tr>
<td>January 1969</td>
<td>Sharkstooth Point, Kaikoura</td>
<td>Nearly all of one large aggregation</td>
<td>470</td>
<td>233</td>
<td>237</td>
<td>49.6</td>
<td>0.03</td>
<td>(\geq 0.90)</td>
</tr>
<tr>
<td>July 1967-November</td>
<td>Various localities, Kaikoura</td>
<td>Quadrat samples from different aggregations</td>
<td>284</td>
<td>137</td>
<td>147</td>
<td>48.2</td>
<td>0.35</td>
<td>0.75-0.50</td>
</tr>
<tr>
<td>1968</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>May 1967-April 1968</td>
<td>Seal Reef, Kaikoura</td>
<td>About 50 per month from several aggregations</td>
<td>596</td>
<td>273</td>
<td>323</td>
<td>45.8</td>
<td>4.19</td>
<td>0.05-0.025</td>
</tr>
<tr>
<td>November 1968</td>
<td>Nine Pins, Kaikoura</td>
<td>Most of two neighbouring aggregations</td>
<td>306</td>
<td>131</td>
<td>175</td>
<td>42.8</td>
<td>6.30</td>
<td>(&lt;0.005)</td>
</tr>
<tr>
<td>July 1968</td>
<td>St Kilda Rocks, Kaikoura</td>
<td>Quadrat samples from several aggregations</td>
<td>404</td>
<td>167</td>
<td>237</td>
<td>41.3</td>
<td>12.00</td>
<td>(&lt;0.005)</td>
</tr>
<tr>
<td>May 1967-January 1969</td>
<td>Combined samples, Kaikoura</td>
<td>All Kaikoura samples (above)</td>
<td>2060</td>
<td>941</td>
<td>1119</td>
<td>45.7</td>
<td>15.38</td>
<td>(&lt;0.005)</td>
</tr>
</tbody>
</table>
I cannot account for the different sex ratios of different *Evechinus* populations, particularly the preponderance of males in some of the Kaikoura samples. At least at Kaikoura, there is no reason to suspect sampling bias because samples were large and consisted of all or most individuals from clumps of urchins (in which the sexes are randomly distributed—Dix 1969) or from within quadrats.

Brookbank (1968) found more males in populations of the urchins *Lytechinus variegatus* and *Mellita quinquiesperforata* but based his result on the number of urchins of each sex which could be artificially induced to spawn. However, as found in the present study, males were capable of shedding gametes during a greater part of the year than females, and the results were thus biased towards males, except during the peak breeding season. In the present study all urchins were sexed by dissection.

In the population at Seal Reef, Kaikoura, there was no marked seasonal change in sex ratio (Table 6).

Most individuals in the samples were large (> 10.0 cm diameter at Kaikoura; > 5.0 cm diameter at Kaiteriteri) but although numbers were not large, evidently sex ratio did not change with size, at least in the St Kilda Rocks sample (Table 7).

To determine whether differential mortality gives rise to unequal sex ratio in *Evechinus* more intensive sampling (particularly of newly matured animals) and a consideration of factors involved in the survival of the sexes would be needed. Hermaphroditism is rare in echinoids (Moore *et al.* 1963a, 1963b) and no hermaphrodites were observed in my study.

### Table 6—Sex composition of mature *Evechinus chloroticus* from Seal Reef, Kaikoura, May 1967—April 1968

<table>
<thead>
<tr>
<th>Months</th>
<th>♀</th>
<th>♂</th>
<th>%♀</th>
</tr>
</thead>
<tbody>
<tr>
<td>May–June</td>
<td>45</td>
<td>53</td>
<td>46</td>
</tr>
<tr>
<td>July–August</td>
<td>42</td>
<td>56</td>
<td>43</td>
</tr>
<tr>
<td>September–October</td>
<td>48</td>
<td>52</td>
<td>48</td>
</tr>
<tr>
<td>November–December</td>
<td>43</td>
<td>57</td>
<td>43</td>
</tr>
<tr>
<td>January–February</td>
<td>49</td>
<td>51</td>
<td>49</td>
</tr>
<tr>
<td>March–April</td>
<td>46</td>
<td>54</td>
<td>46</td>
</tr>
</tbody>
</table>

### Table 7—Sex composition in relation to test size for *Evechinus chloroticus* at St Kilda Rocks, Kaikoura, July 1968

<table>
<thead>
<tr>
<th>Test diameter (cm)</th>
<th>♀</th>
<th>♂</th>
<th>%♀</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.0–8.9</td>
<td>10</td>
<td>15</td>
<td>40</td>
</tr>
<tr>
<td>9.0–10.9</td>
<td>38</td>
<td>64</td>
<td>37</td>
</tr>
<tr>
<td>11.0–12.9</td>
<td>44</td>
<td>69</td>
<td>39</td>
</tr>
</tbody>
</table>
CONCLUSIONS

Both Kaikoura and Kaiteriteri *Evechinus* populations show annual reproductive cycles and spawn in summer or early autumn but, as with their general biology (Dix 1970), differ in some aspects of gonad size, spawn output, and size at maturity; Kaikoura urchins mature at a larger size and when mature have much larger gonads (and higher gonad indices) and greater spawn output.

Similar differences in gonad size (and possibly spawn production) have been noted in other urchin species (Moore 1934, 1937; McPherson 1969; Ebert 1968; Fuji 1960c). The effects of genetic variation between populations are unknown but starvation experiments and circumstantial evidence suggest that, in *Evechinus* at least, gonad size may be governed environmentally by food availability. At Kaikoura, larger size at maturity may be related to faster growth, which will be dealt with in a later publication.

ACKNOWLEDGMENTS

The above work was supported by a New Zealand Post-graduate Scholarship. Professor G. A. Knox and Dr H. B. Wisely gave helpful criticism while Mr L. D. Bowring gave valuable field assistance.

REFERENCES


