

SEASONAL REPRODUCTIVE CYCLE IN THE MUSSEL, *LAMELLIDENS CORRIANUS*

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Abstract

Seasonal reproductive cycle of the freshwater mussel, *Lamellidens corrianus* has been studied. These mussels are functional or simultaneous hermaphrodites. The spawning was at its peak during the months of September to December. The gonads were in growing stages with reduced gonadal activity during January to April, whereas the maturation of gonads was found to be intense during May to August.

Introduction

The breeding habits and the reproductive cycles of a number of bivalves have been studied. Most of the work was done on oysters (Amemiya, 1929; Coe, 1932; Galtstoff, 1938; Loosanoff, 1942, 1962; Tranter, 1958a, b), on *Teredo* (Coe, 1936), on *Cyprina* (Loosanoff, 1953), on *Venus* (Loosanoff, 1937a, b; Loosanoff & Davis, 1950) and on *Mya* (Coe & Turner, 1938; Shaw, 1964, 1965; Ropes & Stickney, 1965). However, only a few studies have been made on freshwater bivalves: *Anodonta* (Bloomer, 1934, 1935), *Corbicula* (Fuji, 1957), *Pisidium* (Heard, 1965) and *Parreysia* (Lomte & Nagabhushanam, 1969).

The freshwater mussel, *Lamellidens corrianus*, is most common in ponds and large bodies of perennial waters in the Indian subcontinent. The present study was undertaken to elucidate the seasonal changes in the gonads.

Material and methods

The freshwater mussels, *L. corrianus*, were collected from the river Godaviri between the 10th to 15th of every month from March 1972 to February 1973, cleaned and kept in a large aquarium for one day. Healthy adult mussels ranging from 55-60 mm. in length were selected for observations. The gonads of 27-37 specimens were fixed in Bouin's fluid for detailed monthly histological studies by the smear method, dehydrated in alcohol, cleared in xylene and embedded in paraffin wax and sectioned at 6 to 8 μ . The sections were stained with Delafield's haematoxylin and counterstained with eosin. 4-6 sections passing through different regions of the gonads were observed under the microscope to ascertain the stages.

Observations

Lamellidens corrianus has quite large gonads, constituting a major part of the visceral mass. The gonads are initially paired, and separated by the intestine. In adults the gonads are massive and are embedded in the intestinal coils lying on the dorsal side of the foot and posteroventral to the digestive gland. In young mussels, the gonads are white in colour, in mature adults they are yellowish.

Nature of gonads

The gonads of almost all the adult mussels showed both ovarian and testicular follicles in some stage of the reproductive cycle. Hence the mussels are hermaphrodites. The testicular follicles were generally found to lie on the outer sides of the ovarian follicles mostly occupying the interior of the gonad. However, gonads with mixed follicles were also observed.

The testicular follicles are mostly oval or elongated, whereas the ovarian follicles show great diversity in shape and size. Both follicles are externally lined with a thin layer of connective tissue and internally lined with a single layer of germinal epithelium and held together with connective tissue. The testicular follicles showed all stages of spermatogenesis at the same time throughout the year and contained, in most cases, groups of rounded cells of varying size. The mature follicles showed the presence of spermatozoa with somewhat rounded head and a long tail. The ovarian follicles showed different stages depending on the gonadal activity. Each follicle contained a few oögonia and numerous nurse cells. During the active phase, the ovarian follicles contained 2-4 ripe ova with a complete depletion of nurse cells. A ripe ovum is a large, spherical or round body with a large nucleus.

Seasonal gonadal changes

The annual reproductive cycle of *L. corrianus* has been studied monthwise and identified into different stages as described in Table I. These stages are:

- A : Growing
- B₁ : Maturing
- B₂ : Mature
- C₁ : Partially spawned
- C₂ : Spent
- D : Recovery

The monthwise analysis of the gonadal activity is given in Table II. Percentages have been calculated and presented in Table III. From these tables it is evident that the gonad is active throughout the year, the activity increasing considerably during the breeding season.

As stated previously *L. corrianus*, is a hermaphrodite. Hence, each gonad contained testicular as well as ovarian follicles. However, for the sake of convenience the two cycles are described separately.

Male cycle

The activity of the testicular part of the gonad, as measured by the presence of fully developed spermatozoa, continued for all the twelve months. However, this activity increased from May onwards and is more intense in the months of June, July and August, i.e., in the pre-spawning period (Table III). Whereas, with the peak spawning period starting from September and continued till December, the activity decreased. The lowest number of gonads with mature follicles was found in January. From February till May, the activity was found to be intermediate.

Table I. Histological details of gonad stages in *Lamellidens corrianus*.

| Stage | Description |
|---|--|
| A. <i>Growing</i> | This stage follows the post-spawning period with short recovery. The gonads increase in size overlapping the intestinal coils. As such they are not externally visible. Germ cells give rise to gonia with clear cytoplasm. <i>Male</i> : Early gametogenesis takes place producing spermatogonia and spermatocytes, that lie within the follicles. <i>Female</i> : Oogonia and oocytes are produced that lie attached to the wall of follicles. |
| B ₁ . <i>Maturing</i> | After the gonads are fully developed, the follicles are compactly arranged with slight interfollicular connective tissue. <i>Male</i> : Narrow centripetal bands of spermatogonia, spermatocytes and spermatids with free spermatozoa in the lumen of the follicles. <i>Female</i> : Follicles contain young oocytes, some of them attached to the wall of follicles and other free in the lumen. |
| B ₂ . <i>Mature</i> | Gonad follicles attain maximum size and are packed with fully ripe gametes; if pierced gametes come out. <i>Male</i> : Lumen of follicles full of spermatozoa, at many places 'plugs' occur. <i>Female</i> : Female follicles packed with fully grown oocytes. Ripe eggs loose contact with follicular wall and lie free in the lumen. Each egg is oval or round in shape and contains a large nucleus. |
| C ₁ . <i>Partially spawned</i> | Gonad size is reduced. Few gametes come out, if pierced. <i>Male</i> : Majority of the follicles are empty with residual spermatozoa and spermatids. <i>Female</i> : Most of the follicles collapsed in size. |
| C ₂ . <i>Spent</i> | Gonads considerably reduced in size, follicular wall shrunken. Intestinal coils usually visible. <i>Male</i> : Follicular empty with residual sperms and spermatids. Spermatocytes are rare. <i>Female</i> : Follicles empty with occasional oocytes. |
| D. <i>Recovery</i> | This stage follows the spawning one and is very sharp. The shrunken gonads of the spent stages grow. Newly formed cells appear. Intestinal loops are occasionally visible. Gonads increase in size, if pierced free water oozes out. <i>Male</i> : Follicles with few spermatogonia. Much of connective tissue between the follicles. <i>Female</i> : Spent follicles recover by producing new young oogonia. Follicles slightly grow in size. Unspawned eggs undergo autolysis. |

Table II. Numerical data of the monthwise stages of the gonads of *Lamellidens corrianus* (Figures in the table indicate the number of mussels identified for the particular stage).

| Year and Month | Testicular part | | | | | | Ovarian part | | | | | | Total in sample |
|----------------|-----------------|----------------|----------------|----------------|----------------|----|--------------|----------------|----------------|----------------|----------------|---|-----------------|
| | A | B ₁ | B ₂ | C ₁ | C ₂ | D | A | B ₁ | B ₂ | C ₁ | C ₂ | D | |
| <i>1972</i> | | | | | | | | | | | | | |
| March | 14 | 8 | 4 | 2 | 2 | — | 22 | 3 | 3 | — | — | 2 | 30 |
| April | 12 | 2 | 3 | 8 | 2 | — | 17 | 2 | 4 | 2 | 2 | — | 27 |
| May | 11 | 6 | 3 | 7 | 3 | 1 | 13 | 14 | 2 | 1 | — | 1 | 31 |
| June | 6 | 10 | 2 | 4 | 6 | 2 | 9 | 13 | 3 | 2 | 2 | 1 | 30 |
| July | 2 | 15 | 2 | 3 | 5 | 2 | 7 | 12 | 3 | 3 | 2 | 2 | 29 |
| August | 6 | 8 | 12 | 1 | 3 | 2 | 4 | 8 | 16 | 3 | 1 | — | 32 |
| September | 2 | 3 | 8 | 8 | 5 | 3 | — | 2 | 17 | 8 | 2 | — | 29 |
| October | — | — | 5 | 4 | 23 | 4 | — | — | 14 | 15 | 4 | 3 | 36 |
| November | 3 | 2 | 4 | 4 | 15 | 8 | 1 | 1 | 7 | 17 | 9 | 1 | 36 |
| December | 3 | — | 5 | 10 | 7 | 12 | 3 | — | — | 9 | 17 | 8 | 37 |
| <i>1973</i> | | | | | | | | | | | | | |
| January | 13 | — | 2 | 2 | 6 | 10 | 22 | 3 | 2 | — | 3 | 3 | 33 |
| February | 10 | 5 | 5 | 2 | 5 | 5 | 23 | 4 | 2 | 2 | 1 | — | 32 |

With the decline in activity in September, the testicular follicles were found to be partially or completely empty because of the discharge of spermatozoa. Thus spawning, although it is continuous throughout the year, was found to be more intense from September till December. The peak of spawning was in October and November. The percentage of the recovery stage increased in the months of November, December and January. With the increased percentage of the recovery stage in January, the percentage of the growing stage was found to be increased. This increase continued in the months of February, March, April and May. Thus from January to May the majority of the gonads were in the growing stage.

Although the percentage of the recovery stage increased in the months of November, December and January, the increase was not proportionate as expected from the percentage of spawning in the previous months. This indicates that the recovery is rather sharp. This contention is strengthened by the fact that along with the increased percentage of the recovery stage, the percentage of growing stage also increased in January.

In brief it may be stated that the testicular part is active more or less throughout the year. However, the peak of maturity was during June to September, spawning started in September and was extended upto December. The peak of the growing period was from January to May.

Table III. Monthly percentages of *Lamellidens corrianus* for the different stages of gonads.

| Year and month | Testicular part | | | | Ovarian part | | | |
|----------------|-----------------|-------------------|---------------------------|----------|--------------|-------------------|---------------------------|----------|
| | Growing | Maturing + Mature | Partially spawned + spent | Recovery | Growing | Maturing + Mature | Partially spawned + spent | Recovery |
| <i>1972</i> | | | | | | | | |
| March | 46.67 | 40.00 | 13.33 | — | 73.33 | 20.00 | — | 6.67 |
| April | 44.44 | 18.51 | 37.05 | — | 62.97 | 22.22 | 14.81 | — |
| May | 35.48 | 29.03 | 32.26 | 3.23 | 41.94 | 51.60 | 3.23 | 3.23 |
| June | 20.00 | 40.00 | 33.33 | 6.67 | 30.00 | 53.33 | 13.33 | 3.34 |
| July | 6.90 | 58.62 | 27.58 | 6.90 | 24.14 | 51.72 | 17.24 | 6.90 |
| August | 18.75 | 62.50 | 12.50 | 6.25 | 12.50 | 75.00 | 12.50 | — |
| September | 6.90 | 37.93 | 44.82 | 10.35 | — | 65.52 | 34.48 | — |
| October | — | 13.89 | 75.01 | 11.10 | — | 38.89 | 52.78 | 8.33 |
| November | 8.33 | 16.67 | 52.78 | 22.22 | 2.78 | 22.22 | 72.23 | 2.77 |
| December | 8.11 | 13.52 | 45.94 | 32.43 | 8.11 | — | 70.28 | 21.61 |
| <i>1973</i> | | | | | | | | |
| January | 39.40 | 6.06 | 24.24 | 30.30 | 66.66 | 15.16 | 9.09 | 9.09 |
| February | 31.25 | 31.25 | 21.88 | 15.62 | 71.88 | 18.75 | 9.37 | — |

Female cycle

The ovarian part of the gonad, like the testicular part, showed activity throughout the year (Tables II & III). The ripe ova were found in the gonads in all the months except in December. The maximum number with ripe ova were found in the months of August, September and October (Table II). In the previous months of May to July, the majority of the specimens showed gonads in the maturing stage. The maximum activity in terms of maturing was found from May to September (Table III). Spawning, either partial or complete occurred in all the months except March. However, the spawning was found to be increased in September and continued in the following months of October, November and December.

The percentage of recovery was maximum in December. However, the recovery stage was considerably less, as was the case with the male cycle, than what would be expected. This was probably because of a very sharp recovery and rapid growing stage that followed the recovery stage. In the postspawning period from January to April, the percentage of the growing stage increased considerably. From May onwards, the ovarian follicles entered in the active stage of maturation.

In brief, the female cycle showed a peak of maturing from May to September, spawning from October to December and growing from January to April (Table III).

In view of the hermaphrodite nature of the mussels, two different cycles, male and female, do not exist. It is therefore essential to combine these two cycles.

Both the testicular and ovarian part of gonads showed that the peak of growing period was from January to April and was also continued in May. Early maturation of gonads started in May and continued upto August (Table II). Fully matured gonads with ripe ova and spermatozoa increased in number from August to October. In September the spawning started and continued upto December. In both, the recovery stage was sharp and was observed in a comparatively smaller number.

From Table II it is evident that the gonads were active throughout the year although at different tempi. This was particularly true for the testicular part as this showed some maturation process in all the twelve months. Similarly, spawning was also seen in the gonads in all the months, except in March, when there were no specimens showing spawning in females.

Although the mussels are hermaphrodite and the maturation and spawning period of both the male and female parts is the same, male and female sections of a

particular gonad did not mature or spawn simultaneously. Hence the testicular and ovarian parts of a gonad were found to be in two different stages. However in a few cases both parts were found to be in the same stage, either mature or spawned. Thus in most cases, there were no chances of self-fertilization.

The average monthwise temperature of the habitat water (Table IV) showed that it started increasing from January onwards with the highest temperature of 32.5°C in May. From June the temperature gradually decreased upto September and suddenly from October to December with the lowest temperature of 20°C in December.

Discussion

The sex in Lamellibranchia is a matter of great interest. Although the majority of the bivalves have separate sexes, a considerable number of cases is known that produce gametes of both types, either at the same time or at different times (Fretter & Graham, 1964). Those that produce both types of gametes at the same time are true hermaphrodites while others, producing first male and then female gametes at different times, are protandrous. Protandry was reported in *Ostrea virginica* (Coe, 1938), in *Teredo navalis* (Coe, 1941), in *Martesia striata* (Ganapati & Nagabhusanam, 1953) and in *Pinctada albina* (Tranter, 1958a). Coe (1943) recognised four categories of hermaphrodites, namely functional or simultaneous, consecutive, rhythmical consecutive and alterna-

Table IV. Average monthwise temperature of the water of river Godavari

| Year and month | Temperature °C ± S.D. |
|----------------|--------------------------|
| 1972 | |
| March | 27.0 ± 0.5 |
| April | 30.0 ± 1.0 |
| May | 32.5 ± 0.5 |
| June | 29.5 ± 0.5 |
| July | 28.0 ± 0.5 |
| August | 27.5 ± 0.5 |
| September | 26.0 ± 0.3 |
| October | 24.0 ± 0.5 |
| November | 22.0 ± 0.4 |
| December | 20.0 ± 0.5 |
| 1973 | |
| January | 22.5 ± 1.0 |
| February | 24.0 ± 1.0 |

or spawn simultaneously in parts of a gonad were. However in a few cases the same stage, either in most cases, there were no temperature of the habitat started increasing from a temperature of 32.5°C and gradually decrease from October to December, 20°C in December.

Matter of great interest in bivalves have separate cases is known that either at the same time (Graham, 1964). Those cases at the same time are producing first male and female at different times, are protandrous. *Ostrea virginica* (Coe, 1932), in *Martesia striata* (Coe, 1933) and in *Pinctada alabamica* (Coe, 1933) are recognised four categories: simultaneous or simultaneous and alternating.

Temperature of the water of

Temperature °C
S.D.

30.0 ± 0.5
30.0 ± 1.0
30.5 ± 0.5
30.5 ± 0.5
30.0 ± 0.5
30.5 ± 0.5
30.0 ± 0.3
30.0 ± 0.5
30.0 ± 0.4
30.0 ± 0.5

30.5 ± 1.0
30.0 ± 1.0

ive. The majority of the hermaphroditic bivalves fall into Coe's category of simultaneous or functional hermaphrodites (Fretter & Graham, 1964). Oldfield (1961) reported that *Lasaea rubra* and *Montacuta substriata* are simultaneous hermaphrodites whilst *Kellia suborbicularis* and *Montacuta ferruginosa* are protogynous consecutive hermaphrodites. *Mysella cuneata* (Gage, 1968a), *Montacuta elevata* (Gage, 1968b) and *Pseudopythina subsinuata* (Morton, 1972) were reported as protandrous consecutive hermaphrodites.

The freshwater mussels under the present study fall under Coe's category of functional or simultaneous hermaphrodites since they produce gametes of both types at the same time. Another species of the same genus, *L. thwaitisii* was reported as hermaphrodite by Bloomer (1931). However, Ghosh & Ghose (1972) reported that *L. marginalis*, another Indian freshwater mussel, shows separate sexes. Thus, different species belonging to the same genus exhibit differences so far as the sex is concerned.

The gonads of the bivalves may be active throughout the year or the activity may be restricted to a certain period. Thus in *Pinctada albina* (Tranter, 1958b) and in *Sphaerium simile* (Zumoff, 1973), it was observed that the bivalves breed throughout the year with definite variations in different reproductive activities at different times. In other bivalves, such as *Donax cuneatus* (Rao, 1967), *Parreysia corrugata* (Lomte & Nagabhushanam, 1969), *Placopecten magellanicus* (Naidu, 1970) and in many others, the activity is restricted to a certain period of the annual cycle. In the present study, it was found that *L. corrianus*, breeds throughout the year but with definite peaks, as is also true for *L. marginalis* (Ghosh & Ghose, 1972).

There may be one or two cycles of the reproductive activities. In *Mya arenaria* (Shaw, 1964, 1965), *Mytilus edulis planulatus* and *Xenostrobus pulex* (Wilson & Hodgkin, 1967) and *Katelaysia opima* (Mane, 1973), there are two reproductive cycles with two peaks of spawning. Whereas in *Mya arenaria* from North Cape Cod. (Ropes & Stickney, 1965), *Donax cuneatus* (Rao, 1967), *Parreysia corrugata* (Lomte & Nagabhushanam, 1969), *Placopecten magellanicus*, (Naidu, 1970) and in *Sphaerium simile* (Zumoff, 1973), there is a single reproductive cycle. In *Lamellidens corrianus*, intense spawning was observed from September to December. However, spawning occurred at a reduced pace in other months as well.

It is still a matter of controversy whether or not spawning is accelerated by some factor of the environ-

ment. Temperature as an important factor for spawning was first reported by Orton (1920). However, Loosanoff & Engle (1942), Stauber (1947, 1950) and Korringa (1957) showed that the breeding in *Ostrea edulis* and *Crassostrea virginica* is not dependent upon temperature but in these cases physiological races are involved.

In the present study, it was found that the peak of spawning (September to December) coincided with decreasing temperature and the growing stage with increasing temperature from January to May. The peak of maturation period (June to August-September) was found to be under intermediate temperature. However, the role of temperature in the reproductive cycle is not clear.

Summary

1. Seasonal gonadal changes have been studied in the freshwater mussel, *L. corrianus*, for a period of one year.
2. The mussels are functional or simultaneous hermaphrodites, producing gametes of both types at the same time.
3. The peak of spawning was observed from September to December.
4. The gonads during January to April were in the predevelopment or growing stage with reduced gonadal activity.
5. The maturation of gonads was found to be intense during May to August, when mature gametes were present in large number.
6. Since the gonadal activity was throughout the year, the recovery stage was sharp.

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