LIST OF PUBLICATIONS


Regeneration of the proboscis of cymatiid *Cymatium pileare* (Gastropoda: Prosobranchia)

P Muthiah & K Sampath
Department of Zoology, V O Chidambaran College, Tuticorin-628 008, Tamil Nadu, India
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Cymatiids cause considerable damage to bivalve stock in molluscan culture. Bivalves are preyed upon by cymatiids with insertion of proboscis and interaction of radula and jaws. Rate of regeneration of proboscis in cymatiid was faster than predatory thasiid and muricid gastropods.

Prosobranchs of muricids, cymatiids and buccinids are reported for their predation on oysters\(^1\). Cymatiids caused 13% mortality of farm oysters\(^2\). Muthiah *et al.*\(^3\) reported that cymatiids feed on oysters with radular mechanism by inserting their proboscis in between the two valves of oyster. The regenerative ability of proboscis tip of muricid gastropod *Urosalpinx cinerea* is on record\(^4\). Experimental amputation studies on *Thais haemastoma* and in *U. cinerea* have been reported\(^5-6\).

The present study was conducted to determine the rate of proboscis regeneration occurrence in *C. pileare* after experimental proboscisectomy in the laboratory.

Twenty specimens of *C. pileare* collected from pearl oyster farm at Tuticorin (lat.8° 48’ N, long. 78° 11’E) were maintained in a FRP tank of size 75 × 50 cm. During May-June 1993, 12 snails of size ranging from 45-72 mm were separately employed for this study and provided with oysters for feeding. Proboscisectomy was done when the gastropods were actively feeding on oysters at dusk. Snail as well as oyster which was preyed upon were removed from the tank. The valves of oysters were pressed tightly so as to avoid withdrawal of proboscis by the snail and the proboscis was cut quickly. The amputed portion of proboscis having complex buccal mass that remained inside the oyster was taken and measured. The length ranged from 7-11 mm and width 3-5 mm. For recuperation, proboscisectomized snails were kept individually in a numbered perforated plastic basket of 15 cm diameter having a lid. Five oysters of length 25-57 mm were always maintained in each basket and 6 such baskets were kept in a FRP tank (75 × 50 cm) having filtered seawater. Daily, while changing the seawater, observations were made for the oysters preyed upon by snails, and if any, replaced from 26°-29°C and the salinity varied from 35.5-36 × 10\(^3\) and pH value averaged to 8.18.

One snail out of 12, laid egg case 14 days after proboscisectomy and incubated it; it was not taken into account. Other snails resumed feeding on oysters indicating the proboscis with its associated structures being regenerated and functional. The rate of regeneration of proboscis and resumption of feeding ranged from 15-25 days. The rate of regeneration of proboscis of cymatiids was faster than other group of molluscs; *Thais haemastoma*\(^5\) took 3 weeks for regeneration of distal proboscis portion and that of *U. cinerea* and *Eupleura caudata* regenera\(^6\) in 11 to 34 days.

The larger snails in 60-70 mm length group resumed feeding on 20-21 days after amputation whereas 50-60 mm size gastropods took 15-20 days. Some in the length group of 45-50 mm started feeding 23-25 days after amputation. Snails in 30-45 mm size group resumed feeding 25-30 days after amputation. These smaller snails were of 45-50 mm size, and the amputation was done to determine the rate of regeneration in this size group. The larger snails in 60-70 mm length group resumed feeding on 20-21 days after amputation whereas 50-60 mm size gastropods took 15-20 days. Some in the length group of 45-50 mm started feeding 23-25 days after amputation.

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![Fig. 1—Feeding resumption after proboscisectomy to shell length of *C. pileare*](image-url)

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days after proboscisectomy. The relationship between the length of proboscisectomized snails to the number of days for their feeding resumption was not significant (Fig. 1). Similar observation was made in *E. caudata* to the days of feeding after excision of accessory boring organ.

The present study is the first to report on the regeneration of proboscis in cymatiids, though it has been reported in the thiasids and muricids. The rapid regeneration of feeding organ ensures their better survival and best adaptiveness for the predatory behaviour. These observations on cartilage regeneration in invertebrates will be useful in the study on cartilage and skeletal regeneration.

**References**

Introduction

Large quantities of the edible oyster, *Crassostrea madrasensis* (Fig. 1) growing wildly in most of the tidal creeks and estuarine regions along the east coast of India are allowed to perish unexploited. The shell lime industry, however, quarry agglutinated dead shells from rugged beds and those found as subfossil deposits in river beds. Realising the edibility of the oyster meat, Hornell initiated oyster culture experiments as early as in 1910 at Pulicat lake. For some unaccountable reasons this was not followed up by later workers.

As a part of global strategy for developing oyster farming following the great strides made in this venture by developed nations, the Central Marine Fisheries Research Institute focussed its attention in developing systems for the culture of edible bivalves, identifying edible oyster farming and mussel farming as priority areas for Research and Development. Evaluation of the resources potential, identification of suitable water spread and areas for culture, evolving proper techniques to collect required seed for farming, introducing an appropriate method of farming and establishing a model farm formed the broad objectives of the project initiated in 1975 on edible oyster culture.

The existence of considerable expanse of natural beds in several of the tidal inlets (Fig. 2) and the presence of shallow bay area in the vicinity of Tuticorin facilitated oyster farming experiments to be started at Tuticorin. Regular sampling of the oysters in the bed showed a biannual spawning habit with a peak spawning period in April-May and the water quality in the area exhibited favourable factors for healthy oyster growth. By employing suitable method for spat collection and providing better growing conditions for the seed so collected it appeared distinctly possible to raise large number of oysters achieving faster growth rate and better meat yield. Weighing the pros and cons of the different systems of oyster culture followed in other countries and bearing in mind the local conditions, it was decided to experiment with the 'rack' system of culture. By this system oysters kept on a wooden platform above the bottom but below the water surface will receive maximum quantity of water filtration and feeding promoting physiological efficiency towards fast growth and flesh weight increment.

Spat collection

Of the several types of spat collectors like bamboo reapers, concrete blocks, nylon meshed net pieces, bamboo

*Prepared by S. Mahadevan, K. Nagappan Nayar and P. Muthiah, Tuticorin Research Centre of CMFRI.*
Table 1: Details of spat collection in 1978 and 1979.

<table>
<thead>
<tr>
<th></th>
<th>No. of tiles</th>
<th>Minimum No. of Spat/tile</th>
<th>Maximum No. of Spat/tile</th>
<th>Average/ tile</th>
<th>Area of collection</th>
</tr>
</thead>
<tbody>
<tr>
<td>April–May 1978</td>
<td>27,000</td>
<td>5</td>
<td>64</td>
<td>24</td>
<td>Karapad creek beds</td>
</tr>
<tr>
<td>September–October 1978</td>
<td>30,000</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>April–May 1979</td>
<td>18,000</td>
<td>11</td>
<td>97</td>
<td>33.5</td>
<td>Tuticorin bay near creek</td>
</tr>
<tr>
<td>10,000</td>
<td>1</td>
<td>21</td>
<td>10.8</td>
<td>Creek proper</td>
<td></td>
</tr>
<tr>
<td>20,000</td>
<td>1</td>
<td>16</td>
<td>8.7</td>
<td>Near natural beds</td>
<td></td>
</tr>
<tr>
<td>September–October 1979</td>
<td>20,000</td>
<td>—</td>
<td>5</td>
<td>5.0</td>
<td>Tuticorin Bay</td>
</tr>
</tbody>
</table>

mats, strings of coconut shells, rens of green mussel and oyster shell valves, country tiles (with and without lime coating) tried in different locations around the bed, the most satisfactory results were obtained from twice lime-coated semicylindrical country tiles (Fig. 3) laid completely submerged on wooden platforms. Determining accurately the spawning period of oysters and laying tiles just at the right time of release of oyster spawn increases the percentage of success. April–May spawning period proved to be the ideal time for large scale collection work. September–October period was not so effective. The results of spat thus collected are shown in Table 1.

Post spat collection period

a) Spat removal: Spat settled on collectors (Fig. 4) were allowed to grow on them up to a size of 30 mm–35 mm after which removal of individual spat is easily done without injuring the fleshy interior. Pressure slightly exerted dislodges the spat without damage. After the removal of spat the tiles can be stored and recycled for use in the next season. Depending on handling they are good for at least four seasons.

b) Initial transplantation: Initially the scraped oysterlings are put in nylon meshed (12 mm mesh size) cages of 6 mm iron rod frame for a period of two months (Fig. 5). Each cage (measuring 40 x 40 x 10 cm) can easily hold 200 oysterlings. Later they can be transferred to large rectangular cages of 22 mm meshed nylon netting (size 90 x 60 x 15 cm).

Fig. 4 Oyster spat settled on tiles

Fig. 5 Just transplanted oyster spat grown in box type cages

Erecting racks for growing oysters

Each rack is so constructed as to occupy an area of 26.5 sq.m. with a length of 13.2 m and breadth of 2 m. A midwater wooden platform of interconnected teakwood stubs of 2 m length is put up supported by two parallel rows of 6 teakwood poles each planted vertically down at a distance of 2 m, pole to pole. All wooden materials are treated with tar prior to being used in the rack erection. The platform in each rack can carry a total of 20 rectangular cages of 150–200 oysters each and is
so positioned that only during the lowest low tide periods the cages get partially exposed (cover photo).

During initial stages of experiments 30 such racks were set up side by side in Karapad creek. Siltation in the farm area and erosion of creek bunds posed problems. Notwithstanding these, growth of oysters was fast and harvestable size of 90 mm length was attained in 12 months. The various processes involved from spat collection to oyster growing were streamlined by the experience during this experimental period. In 1978 the oyster farm was shifted to the nearby open sea coast and as many as 90 racks were erected. Spat collected in 1979 spawning season were transferred to racks, each rack carrying 3,000 oysters in 20 cages. During the early stages of growing in farm, unexpected predation of oysters of size 35-45 mm was noticed by a gastropod, Cymatium cingulatum which caused a mortality of 15% of the stock. This problem was tackled by removing the predators by hand-picking. No other disease problem was encountered. Oysters reached 85-90 mm size in 12 months time with a meat weight of 8-10%, each oyster weighing 120 g (shell on) with a meat weight of 10 g. A total of 2,00,000 oysters attained harvestable size.

**Prospects**

The oyster culture experiments successfully carried out at Tuticorin marks only the first stage in ushering in an era of oyster industry in India. Based on the experiences during the course of these experiments several areas of research and development efforts appear to be warranted on priority basis before total success can be achieved.

Spat collection is one aspect where the present experiments have indicated the enormous potentiality of the coastal regions which can be usefully tapped to get adequate seed supply from natural sources. Although only a few lakhs of spat were collected for the experiments at Tuticorin, it appears distinctly possible to collect several millions by employing large number of spat collectors using the lime coated tile technique. The rack culture system yielded fruitful results in harvestable oysters being made available within a short span of 12 months unlike in other countries where growing period is protracted. Production of an average of 0.48 tonnes of oysters from a single rack has been demonstrated at Tuticorin. In one hectare it is possible to put up at least 280 racks and stock nearly one million oysters resulting in an yield of a minimum of 135 t. oysters (with shell) with a total meat yield of 13.5 t. Experiments are in progress to evolve modifications towards bringing down the capital investment on materials. Future research in this direction would aim at employing less costly materials for rack erection as well as for the trays used for growing oysters.

Marketing oysters is one area that warrants our immediate attention in as much as there is very little market either locally or in the interior places for the oyster meat. Extension work like market development, marketing the products at competitively low rates, ascertaining the consumer preferences of the quality of the flesh before marketing are all areas which will have to be taken up for intense developmental study during the course of next few years. Proper technology of oyster meat preservation to satisfy consumer taste and foreign market is another aspect needing immediate attention. In the extensive culture of oyster in the coastal areas, care has to be shown to avoid locating farm sites in places which are likely to interfere with the use of such water areas by the local fishermen for traditional fishing. Concerted efforts to tackle the above problems will hasten the establishment of a new production oriented seafood industry in India.
INTRODUCTION

In all aquaculture practices the detrimental effects of cohabiting organisms are either by predation, competition, disease or parasitism. Hanson (1974) stated that limited predation can serve to weed out some diseased members of a crop and also help in controlling epizootic infections. But large-scale mortalities result in economic loss by reduction in the tended stock. Control of predation also means additional expense on the production cost (Mackenzie, 1970a). While evolving culture methods for fish or shellfish, identifying and proper use of methods to prevent and control numerous predators of cultivable organisms is absolutely essential to maximise production. In spite of having evolved control measures in oyster culture, developed countries like N. America, Britain and France still face periodical predator problems of serious threat to the stock under culture. In India, while conducting a series of experiments in the culture of oysters by rack and tray method at Tuticorin during 1977—1984 we have come across some problems of predation and competition in the oyster farm. Very often several transplanted oysters of size ranging from 25-85 mm were found dead in the growing trays in which were found large numbers of live gastropods (PI. I a) later identified as Cymatium cingu-latum (Lamarck). This led us to suspect the possibility that these might have been responsible for mortalities of oysters. Subsequent observations confirmed this.

This chapter chiefly describes the predatory role played by Cymatium and the extent of damage done to the tended stock.

BRIEF REVIEW OF COMMON PESTS AND PREDATORS

Among algae, Gracilaria sp. grows densely on the oyster cages kept in the farm which indirectly affects the regular water flow inside the cages. Boring sponges and clams are very rare and mortality of oysters due to these are not seen at Tuticorin. Occurrence of polyclad turbellarians on the spat settled on culches and inside dead oyster spat are also noticed in the farm. But the intensity of its predation in Tuticorin Bay is negligible. Lunz (1947) found that oysters heavily infested with Polydora sp. were often poor in quality. Medcof (1946) confirmed that such infection does not noticeably decrease the condition of oyster but affects the market value in half-shell trade because of mud-blisters giving disagreeable appearance. Polydora ciliata and P. armata have been noticed in Athankarai estuary. Such a possibility at Tuticorin was effectively overcome by resorting to off-bottom culture and also periodical cleaning of oyster shell surface. Since it was feared that Balanus spp. settled on oysters and teak poles of the racks would compete with oysters for food and space, periodical cleaning helped to minimise the settlement. Slipper-shell Crepidula fornicata, notorious for causing mortality among young oysters, was totally absent in the farm area.

Lunz (1947) identified crabs as one of the most probable serious predators of oysters in 5 to 30 mm size. In the oyster farm at Tuticorin though some of the spat settled on tiles and rens were destroyed by crabs Scylla serrata and Pagurus sp. the loss due to this was negligible. The presence of commensal crabs among the oysters grown at Tuticorin was negligible.

Predation by starfish also was not noticed at Tuticorin Bay, apparently there is no population of sea stars in the surroundings. Mackenzie (1970 b) stated that if starfishes are present more than 1/m² the oyster stock would be reduced to non-commercial level. Predation by fishes and birds did not arise in the bay area perhaps due to the non-occurrence of these predators in considerable numbers in the bay.

Predatory gastropods known as oyster drills are considered as the deadliest among the enemies of oysters. In this country Thais radolphii has been
noticed to bore young oysters at Athankarai estuarine region (CMFRI, 1974). In the oyster farm at Tuticorin, *Cymatium cingulatum* caused 13% of mortality of farm oysters (Thangavelu and Muthiah, 1983). Therefore pointed attention was paid to tackle this problem.

**MODE OF ATTACK**

The gastropod gains entry into the trays and by remaining near the oysters or sometimes on the oyster shell, it introduces the proboscis when the valves are slightly open. The pleurembolic proboscis, having permanent sheath, functions due to muscles of the wall best suited to feeding on material not immediately accessible. The jaws consist of two thin chitinous subtriangular plates (Pl. I b) having numerous longitudinal rows of scales. The jaws are lateral and appear to aid in opening the proboscis during feeding. An anaesthetizing fluid is injected on to the tissues of the unwary prey. Houbrick and Fretter (1969) found that the fluid which is exuded from the mouth of *C. nicobaricum* is acidic (pH 2.0). Day (1969) reported that the pH of pure secretion from proboscis gland of *Cymatium* *argobuccinum* *argus* is 1.1. The acidic secretions poured into the oyster may create optimal conditions for certain enzymatic activities. In this case also a toxin similar to neurotoxin tetramine found in cymatid *Fusitriton* (Russell, 1965) might have been employed by *C. cingulatum* in narcotising the oysters. Later the flesh is torn due to action of radula. Day (1969) pointed out that presence of calcium carbonate dissolving mechanism in cymatids indicated that they are also able to drill the shell for feeding on bivalves.

**RELATION BETWEEN SIZE OF CYMATIUM AND THE RADULA**

The radula is of taenioglossan type (Pl. I c). In *C. cingulatum* of size ranging from 21 mm to 72.5 mm in shell length, the radula varies from 2.07 to 5.33 mm in length and 247 μ to 600 μ in width. The study disclosed that within the size range of 21 to 73 mm increase in shell length was accompanied by a proportionate increase in radular dimensions. There is a close correlation between the length of radula and the shell length (r=1) eventhough radular dimensions vary sometimes among the individuals of the same shell length.

**SIZE RELATIONSHIP BETWEEN CYMATIUM AND OYSTERS PREYED**

*Cymatium cingulatum* attacked oysters of size 25 to 85 mm and the modal size of oysters killed was 53.3 mm (Thangavelu and Muthiah, 1983). Nearly 75% of mortality occurred in the size group of 40-65 mm.

In order to find out the relationship between size of oysters preyed and size of *Cymatium*, 100 oysters size 35 to 88 mm with *C. cingulatum* of known were put in 12 box-type cages. Each cage wasobserved at fifteen days interval. From Table 1, it could be seen that 45 mm *C. cingulatum* preyed upon oysters of size 39 to 64 mm with a mean size of 49.7 mm. The size of oyster increased to 68.5 mm for the *Cymatium* of 74 mm in shell length. The correlation coeff (r=0.5) shows fair degree of relationship between size of gastropod and the size of oysters preyed.

**RELATION BETWEEN OYSTER STOCK AND PREDATOR POPULATION**

During 1978, totally 320 *C. cingulatum* were reared in the of this predatory triton in the farm swelled to 4,500 (Table 2). As Hanson (1974) pointed out the predators are appearing to be increasely attracted with the prey abundance, thus aggravating the problem of predation.

**Table 1. Relationship of size of *Cymatium* and mean size of oysters preyed**

<table>
<thead>
<tr>
<th>Size of <em>Cymatium</em> (mm)</th>
<th>Range of oysters Preyed (mm)</th>
<th>Mean size oysters (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>45.0</td>
<td>39.0-64.0</td>
<td>49.7</td>
</tr>
<tr>
<td>52.0</td>
<td>34.0-64.0</td>
<td>48.6</td>
</tr>
<tr>
<td>52.0</td>
<td>39.0-65.0</td>
<td>50.2</td>
</tr>
<tr>
<td>52.5</td>
<td>49.0-84.0</td>
<td>59.4</td>
</tr>
<tr>
<td>58.3</td>
<td>53.0-86.0</td>
<td>68.0</td>
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<td>49.0-84.0</td>
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<tr>
<td>63.2</td>
<td>41.0-84.0</td>
<td>54.4</td>
</tr>
<tr>
<td>64.0</td>
<td>39.0-70.0</td>
<td>55.0</td>
</tr>
<tr>
<td>65.0</td>
<td>42.0-83.0</td>
<td>63.8</td>
</tr>
<tr>
<td>69.0</td>
<td>37.0-68.0</td>
<td>54.0</td>
</tr>
<tr>
<td>72.5</td>
<td>35.0-80.0</td>
<td>64.7</td>
</tr>
<tr>
<td>74.0</td>
<td>47.0-88.0</td>
<td>68.5</td>
</tr>
</tbody>
</table>

**Table 2. Number and Size of *C. cingulatum* collected in Oyster farm in 1980**

<table>
<thead>
<tr>
<th>Month</th>
<th>Number</th>
<th>Size (mm)</th>
<th>Mean (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Min.</td>
<td>Max.</td>
</tr>
<tr>
<td>July</td>
<td>20</td>
<td>9.0</td>
<td>39.6</td>
</tr>
<tr>
<td>August</td>
<td>1497</td>
<td>7.5</td>
<td>71.2</td>
</tr>
<tr>
<td>September</td>
<td>2315</td>
<td>6.5</td>
<td>80.5</td>
</tr>
<tr>
<td>October</td>
<td>238</td>
<td>19.5</td>
<td>65.5</td>
</tr>
<tr>
<td>November</td>
<td>146</td>
<td>16.4</td>
<td>68.0</td>
</tr>
<tr>
<td>December</td>
<td>29</td>
<td>18.2</td>
<td>65.0</td>
</tr>
</tbody>
</table>

OYSTER CULTURE
PLATE I.  a Cymatium cingulatum inside oyster rearing cage;  b Jaw plate;  c Radula with portion enlarged;  
d Different sizes of C. cingulatum.
GROWTH RATE

The period of occurrence starts from late July to the end of December. The number increased from 20 in July, 1980 to 2,315 in September and decreased to 29 in December, 1980. Size ranges, mean and mode for C. cingulatum collected from the oyster cages during the months of July to December, 1980 are presented in Table 2. From this, it may be observed that the mode for July, 1980 was 21.6 mm which increased to 38.45 mm in August. In September it decreased to 27 mm and in the subsequent month it reached 45 mm. The size distribution curve (Fig. 1) was drawn from the measurements taken on the individuals occurring at the same site. The irregular progression of mode indicates that at most more than one year group is present. Because of their cannibalistic behaviour, the individual growth rate is difficult to follow. The wide range of size (Pl. I d) possibly suggests an extended breeding season as Thomson (1973) noticed in Morula marginalba. The maximum size of C. cingulatum collected from the farm was 80.5 mm, higher than C. nicobaricum (7.6 cm) recorded by Howbrick and Fretter (1969). The growth of C. cingulatum seems to be more rapid than Urosalpinx cinerea observed by Cole (1942) and growth of M. marginalba reported by Thomson (1973).

GENERAL REMARKS

Drills can be controlled by treatment with chlorinated benzenes which are toxic to drills (Loosanoff et al., 1960 a, b). Mackenzie (1970 a) standardized the polystream (a mixture of polychlorinated benzenes) treatment at the rate of 9.5 kl/ha. Since the chemical treatment does not appear practical in the farm, elimination by handpicking was resorted to. During the season of its occurrence, all cages were constantly examined by employment of labour task force and the predators were removed. While future research should develop methods for economical and non-labour intensive treatment emphasis should also be paid on ways to prevent predation.

An important factor in the spread of diseases and predators in cultured shellfish population is through transfer of seed stock to growing areas. Japanese oyster drills Ocenebra japonica and carnivorous flat worms were imported to United States (Galtsoff 1964, Hanson 1974). Korringa (1942) described how Crepidula sp. was brought to Europe. Werner (1948), Chapman and Banner (1949) described the introduction of Crepidula sp. along with import and relaying of oysters in Germany and America respectively. These studies point out that very often spread of predators is unwarily done due to import of seed stock from one geographic area to another.
Controlling of predators means additional cost in the production of oysters. MacKenzie (1970a) gave that average cost of treating one acre of bottom with polystream for eradication of predatory gastropods was about $40 a year. In culture operations which involves crowding the animals, density problems of this nature are bound to arise and it becomes unavoidable to earmark a portion of the capital investment in extensive culture systems to achieve maximum production.

REFERENCES


LARVAL REARING, SPAT PRODUCTION AND JUVENILE GROWTH OF THE BLOOD CLAM ANADARA GRANOSA

P. MUTHIAH *, K. A. NARASIMHAM, C. P. GOPINATHAN AND D. SUNDARARAJAN

Central Marine Fisheries Research Institute, Cochin-682 031

ABSTRACT

The blood clam Anadara granosa spawned in the Shellfish Hatchery Laboratory, Tuticorin on two occasions. The fertilised eggs measured 50-60μ in diameter, morula larvae developed in 3-4 hrs and the trochophore stage was reached in 5 hrs. The straight hinge stage was attained in 20-26 hrs after fertilization and these larvae measured 83μ length and 65.5μ height. Advanced umbo stage was reached on day 12 (size 155.3 x 140.5μ) and on day 16, majority of the larvae were in pediveliger stage with an average size of 182.7 x 162.9μ. Settlement began on day 16 and majority of the larvae were set on day 18. The growth of the spat in the hatchery is described by the exponential equation \( L = 0.0002739 D^{2.2613} \) where \( L \) is length in mm and \( D \), days. On day 59, the spat attained an average size of 2.42 x 1.70 mm. A total of 8090 spat were produced. During the nursery rearing in the field, the seed clam attained 20 mm average length in the following 5 months. In India, A. granosa seed were produced for the first time. The significance of this study for the mass production of the blood clam seed in the hatchery and its relevance to undertake blood clam culture are highlighted.

INTRODUCTION

Among the clams belonging to the family Arcidae, the blood clam Anadara granosa (Linnaeus) is widely distributed and is cultured for its food value in China, Japan, Malaysia, Taiwan and Thailand (Broom, 1985; Chen, 1976; Nie, 1982). In India, it forms a fishery of considerable magnitude only in the Kakinada Bay (Narasiinham et al., 1984). The results given in this paper form a part of the programme undertaken to develop appropriate technology for the hatchery production of the seed of commercially important Indian clams. From India, the present study is the first to report upon the production of the seed of A. granosa in a hatchery.

From Malaysia, Wong et al. (1986) gave an account on induced spawning, larval development and juvenile growth of this species.

The authors are thankful to Dr. P. S. B. R. James, Director for encouragement. They place on record sincere thanks to Shri S. Mahadevan, Tuticorin Research Centre of CMFRI for the facilities, encouragement and valuable suggestions for improvement of the manuscript.

MATERIAL AND METHODS

The work was carried out at the Shellfish Hatchery Laboratory of the Tuticorin Research
Centre. Twenty-five specimens of *A. granzosa* (Pl. I A), ranging in length from 39 to 74 mm, were collected from the Tuticorin Bay and transferred to 100 l FRP tank containing seawater. The clams were kept in the conditioning room (water temperature 24-26°C) and fed intensively with the Haptophycean flagellate *Isochrysis galbana*, cultured in the laboratory as outlined by Nayar et al. (1984). After 15 days, they were transferred to 100 l perspex tank and the water temperature was raised to 32°C by thermostat controlled heating element. Whenever there was no spawning the clams were transferred back to the conditioning room and the experiment repeated after 10-15 days. Two spawnsings occurred, one on 4-2-1988 and the other on 26-2-1988 and both were in the conditioning room. The fertilized eggs were washed in 40μ and 100μ sieves to remove excess sperms, debris, etc. and released in 1 tonne FRP rearing tank. Sand filtered sea-water was supplied to the rearing tank through a hose, the delivery end of which was plugged with surgical cotton. The water was changed completely on alternate days and half the volume of water replaced on the days preceding complete water change. Gentle aeration was provided in the rearing tank. Periodically 20 larvae/spat were measured for length in antero-posterior axis and for height in dorso-ventral axis. The average of these measurements were given for different growth stages. *Isochrysis galbana* was given as food once a day after determining the cell concentration with haemocytometer.

The hatchery produced seed were reared in the Tuticorin Bay from day 60 onwards in 40×40×10 cm cages made of 6 mm iron rod and covered with an inner 0.6 mm and outer 20 mm mesh synthetic webbing. These cages were hung from a rack in 1 m depth. Each cage contained 100 clam seed.

Although both the seed clams and adults of *A. granzosa* are known to thrive well in soft sediment, comprising particles predominantly of <125μ size (Narasimham et al., 1984) in the present study, no sediment was provided in the rearing experiments either in the hatchery or in the field.

During the two larval/spat rearing experiments, the water temperature in the hatchery ranged from 27° to 32°C and salinity from 31.8% to 33.6%. In the Tuticorin Bay, where the juveniles were reared in cages, the water temperature ranged from 24.5 to 29.2°C and salinity from 33.6 to 35.5%.

The results obtained in the two rearing experiments are comparable and those of the first experiment are described. Though spawning was profuse in the second experiment, due to space constraint in the laboratory, 6000 larvae alone were used in rearing and the rest of the larvae were released in the Tuticorin Bay.

**RESULTS**

**Early development and larval rearing**

The eggs were spherical, light pink red in colour and measured 50-60.7μ with an average of 51.9μ. Fertilization occurred within minutes and soon after the eggs became opaque (Pl. I B). Cell division (Pl. I C, D) was observed within 10 minutes. After passing through the blastula and gastrula stages, the morula larvae (Pl. I E) developed in 3-4 hrs, trophophore stage (Pl. I F) in 5 hrs and the D-shaped larvae (Pl. II A) in 20-26 hrs after fertilization. On day 1, the minimum size of the straight hinge larvae was 80μ in length × 65μ in height, maximum size 90 × 70μ with an average of 83 × 65.5 μ. Beginning on day 1, *I. galbana* was given as food at 5,000 cells/larva/day. On day 5, the straight hinge larvae attained an average size of 111.2 × 98.8 μ. Early umbo stage was observed on day 7 and the larvae measured 131.6 × 106.3 μ. At this stage, the feed was increased to 7,000 cells/larva/day. Advanced umbo stage was reached...
on day 12 when the larvae measured 155.3×
140.5 μ (Pl. II B). On day 14, some of the
larvae developed foot and on day 16, majority
developed foot, marking the advent of pedi-
veliger stage (Pl. II C); at this stage the average
size of the larvae was 182.7×162.9 μ with
a minimum size 169.5×156.9 μ and maximum
of 207.5×172 μ. The hinge of 12-16 days
old larvae showed 14-16 teeth, arranged in a
linear series, leaving a gap in the middle.
Also the prodissoconch of these larvae showed
8 - 10, more or less evenly spaced concentric
growth lines. The rate of feed was increased
to 10,000 cells/larva/day from day 14. Settle-
ment of the larvae was first observed on day
16 and majority were set on day 18. The
relationship between the length and height
of the larvae is described by the equation:
\[ H = -8.9333 + 0.9351L \]
Where \( H \) and \( L \) represent height and length
in μ respectively (Fig. 1). The coefficient
of correlation between the parameters studied
is 0.9901.

**Spat rearing**

On day 20, the post set clam measured
259.1×232.8 μ and the algal cell ration was
increased to 12,000 cells/larva/day. On day
22, the shell of the spat measuring 283 μ in
length showed 18 ribs, a characteristic feature
of adult \( A. \) granosa (Pl. II D). On day 25,
the average size was 350.1×316.6 μ and
on day 31, it was 653.7×524 μ; at this stage
spiny periostracum was observed on the shell
of the spat (Pl. II E). The food was increased
to 15,000 cells/spat/day on day 25 and it was
further increased to 20,000 cells/spat/day on
day 40. The spat attained an average size of
1.114×0.953 mm on day 40; 1.87×1.48
mm on day 48 and on day 54, wide disparity
in the growth of the spat was observed (Fig. 2).
The minimum size of spat was 1.127×0.966
mm, maximum size 4.508×2.672 mm with
an average of 2.35×1.67 mm. Food was
increased to 25,000 cells/spat/day on day
48 to day 59. On this day, the spat attained
an average size of 2.42×1.70 mm. In the
hatchery, the growth of the post set clams
was curvilinear and the following exponential
equation describes their growth:
\[ L = 0.0002739D^{2.2123} \]
Where \( L \) is length in mm and \( D \) is the number
of days after spawring (Fig. 2). The \( r \) value
obtained is 0.9944 which indicates high degree
of correlation.
PLATE I. Adult clams and early developmental stages of *A. granosa*: A. Adult specimens, B. Fertilized egg (60μ), C, D. Cleavage stages, E. Morula stage and F. Trochophore larvae.
I. MONTHS

1. Growth of the juveniles of *A. granosa* in the Tuicorin Bay. Vertical line represents the length range and the monthly mean lengths are connected by a curve drawn by eye.

DEVELOPMENT OF BLOOD CLAM

In view of their importance in aquaculture, several species of blood clams were studied for induced spawning and larval development; in some cases spat production was achieved (Broom, 1985). Induced spawning in bivalves by thermal stimulation is well established. By this method, spawning was induced and in some instances, larval development studied in *Anadara broughtonii* (Kanno and Kikuchi, 1962; Kanno, 1963; Imai and Nishikawa, 1969; Yoo, 1969; Kim and Koo, 1973) in *A. subcrenata* (Ting et al., 1972) and in *A. transversa* (Loosanoff and Davis, 1963). From Malaysia, Wong et al. (1986) observed that *A. granosa* spawned on several occasions when exposed for the second time from 17±1°C to 34±1°C. However, in the present study, on both the occasions, spawning occurred in ripe *A. granosa* when the temperature was brought down from 32°C to 24°C.

Wong et al. (1986) conducted the rearing experiments of *A. granosa* at a temperature of 26-30°C and salinity of 32%. Their study showed that the fertilized eggs of *A. granosa* measure 50-60μ, trochophore larvae 55-65μ and the straight hinge larvae which developed in 20-24 hrs. measure 7090μ in length. The umbo stage was developed on day 12 and there was settlement between 21 to 23 days after fertilization. These results are comparable to those obtained in the present study except that the larval development was faster in this study. The most distinctive character in the larve of *Anadara* spp. is the presence of a series of hinge teeth. While Wong et al. (1986) made no mention, Pathansali (1963) described the presence of 16 comb like teeth on the larval hinge of *A. granosa*, collected from plankton. In the present study also 14-16 teeth were observed in 12 and 16 day old larvae. In *A. broughtonii*, Tanaka (1971) found 3-7 teeth. Pathansali (1963) also reported on the presence of 10 concentric
PLATE II. Larval stages and seeds of *A. granosa*: A. Straight hinge stage — Length 90 μ x height 7 B. Umbo stage — 155.3 x 140.5 μ, C. Pediveliger stage — 182.7 x 162.9 μ, D. Post set cl measuring 350 μ in length showing ribs, E. Spat measuring 660 μ showing spiny periostrac, and F. Clam seed measuring 1.8 to 3.5 mm.
lines on the larval shell of *A. granosa*. In this study also 8-10 concentric growth lines were observed on the shell of 12 and 16 days old larvae. In the prodissoconch of *A. broughtonii* and *A. subcrenata* also concentric growth lines were present (Tanaka, 1971). Similar growth lines were observed by the authors in two species of venerid clams reared recently and this character does not appear to have any diagnostic value.

According to Wong *et al.* (1986), in Malaysia, the spat of *A. granosa* attained 1.1 to 1.2 mm length in 2 months from spawning under laboratory conditions and in an upwelling system maintained in the laboratory, these spat attained average shell length of 18 and 19.7 mm after another 7½ months rearing. Thus from spawning, the clam seed attained <20 mm length in 9½ months. In the present study, the growth of *A. granosa* was faster, both in the hatchery and in the field since the spat reached 2.42 mm average length in the hatchery in 2 months from spawning and in the field they attained 20 mm average length in the following 5 months. Thus the overall growth in 7 months from spawning was 20 mm. The faster growth in this study may be due to favourable experimental/field conditions under which *A. granosa* was reared or it may be a genetic character of the population occurring in the Tuticorin Bay or both. It is of interest to note that *A. granosa* also grew faster under field culture in India (Narasimham, 1985) when compared to its growth in the culture fields in Malaysia (Broom, 1985).

Simple techniques for the culture of the blood clam were developed by Narasimham (1980) and a production of shell on weight of about 40 t/ha/5-7 months were obtained under field conditions in the Kakinada Bay (Silas *et al.*, 1982). For the transfer of clam culture technology to the farmers, the seed availability in nature proved to be a major constraint. In this context, the present study is significant as it developed the basic technology required for the hatchery production of the seed of *A. granosa*. Some of the techniques followed here, no doubt, need improvements so as to optimise the seed production both in terms of survival and growth. Towards this end further work is in progress.

**References**


DEVELOPMENT OF BLOOD CLAM


Not referred to original.