CMFRI
bulletin 29

SEPTEMBER 1980

COASTAL AQUACULTURE :

# MUSSEL FARMING

## PROGRESS AND PROSPECTS

**CENTRAL MARINE FISHERIES RESEARCH INSTITUTE**
**(Indian Council of Agricultural Research)**
**P.B. No. 1912, Cochin 682 018, India**

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Bulletins are issued periodically by Central Marine Fisheries Research Institute to interpret current knowledge in the various fields of research on marine fisheries and allied subjects in India.



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# PREFACE

During the seventies, the Central Marine Fisheries Research Institute gave a lead in researches on mariculture and has carved for itself a pioneering role in the R & D programmes of mariculture in the country which has been well recognised. Impressed by the outstanding contributions made during the decade, the infrastructure facilities built up and, above all, the scientific and technical competence it has acquired, an UNDP/ICAR Centre of Advanced Studies in Mariculture has been instituted at the Central Marine Fisheries Research Institute since June 1979. The Centre aims at providing postgraduate education in the new discipline of Mariculture and improving the quality of research through doctoral and post-doctoral research programmes in identified areas.

One of the priority areas of mariculture in India is mussel culture. Although considered a poor relation of the oyster in Europe, mussel has one of the highest potentials in India for increasing production of protein-rich sea food. Mussel gives the highest conversion of primary producers (phytoplankton) to human food and culture production in column waters enhances the yield several fold. India has a traditional sustenance fishery for the mussels at a few centres but the scope for increasing natural production from the existing beds is rather limited.

At the Central Marine Fisheries Research Institute, attention has been paid towards the development of technique of mussel culture since 1971 with the establishment of a research project at Vizhinjam on the brown mussel *Perna indica*. Subsequently a project was started in Calicut in 1976 for the green mussel *Perna viridis*. The programme was extended to the east coast at Madras the same year. Some experimental work has also been carried out at Tuticorin and Waltair on transplantation of green mussel. The Vizhinjam programme aimed at developing suitable techniques for mussel culture in the bay, whereas at Calicut and Madras the efforts were towards open-sea mussel farming. Raft culture has been adopted as a rule and an experiment on pole culture of mussels at Madras proved a failure on account of the strong currents of the coastal waters.

Besides the CMFRI, other organisations such as the National Institute of Oceanography at Panaji, Goa and the Marine Biological Research Station of the Konkan Krishi Vidyapeeth at Ratnagiri, Maharashtra have also conducted certain researches on mussel culture. With initial technical support from the CMFRI, the Department of Fisheries, Government of Kerala has taken up a pilot project on mussel culture at Vizhinjam.

All these programmes have shown the technical feasibility of mussel production employing raft culture techniques. It has also been possible to give some economic projections in certain cases. The CMFRI has, as a part of extension programme, taken up an Operational Research Project at Kovalam, near Madras, on the integration of mussel culture with the capture fisheries with the involvement of the fishermen community. Another programme of extension is the Lab-to-Land Experimental Transfer of Technology taken up at Calicut.

Thus, over the last few years, an infrastructure for the R & D programmes on mussel culture has been built up and also the foundation for development through extension has been laid. However, this reflects only the availability of a gross technology for mussel culture which is sound to the extent of demonstrating the high production potential by adopting certain basic techniques. Many problems intrinsic to biology, physiology, ecology and system of mussel farming remain to be tackled.

The present publication intended as a compendium of the state of art of mussel culture, while dealing mainly with the different aspects of mussel culture based on the results of the work at the CMFRI, also touches upon the developments in other mussel farming countries. Timing this issue with the Workshop of Mussel Farming to be held under the auspices of the Centre of Advanced Studies in Mariculture at Madras during

25-27 September, 1980 is to facilitate use of the publication as a background material and a source of reference by the participants at the Workshop.

Several scientists of the Molluscan Fisheries Division of the Institute have made contributions to the development of the techniques of mussel culture. Shri G. P. Kumaraswamy Achari initiated the project on brown mussel culture at Vizhinjam which has subsequently been taken up by Shri K. K. Appukuttan. Dr. P. S. Kuriakose has been working on the green mussel culture at Calicut. Shri K. Rangarajan and Shri S. J. Rajan have been working on mussel culture at Kovalam. As the project leader, Shri S. Mahadevan has contributed to the growth of the project. Shri K. Nagappan Nayar, Head of the Molluscan Fisheries Division, has given necessary guidance and coordination. Along with him, Shri S. Mahadevan and Dr. K. Alagarswami edited the papers and Shri P. T. Meenakshisundaram gave assistance in the printing of the publication. I wish to record my appreciation to all the above scientists and the technical staff of the project for the valuable contributions they have made.

E. G. SILAS
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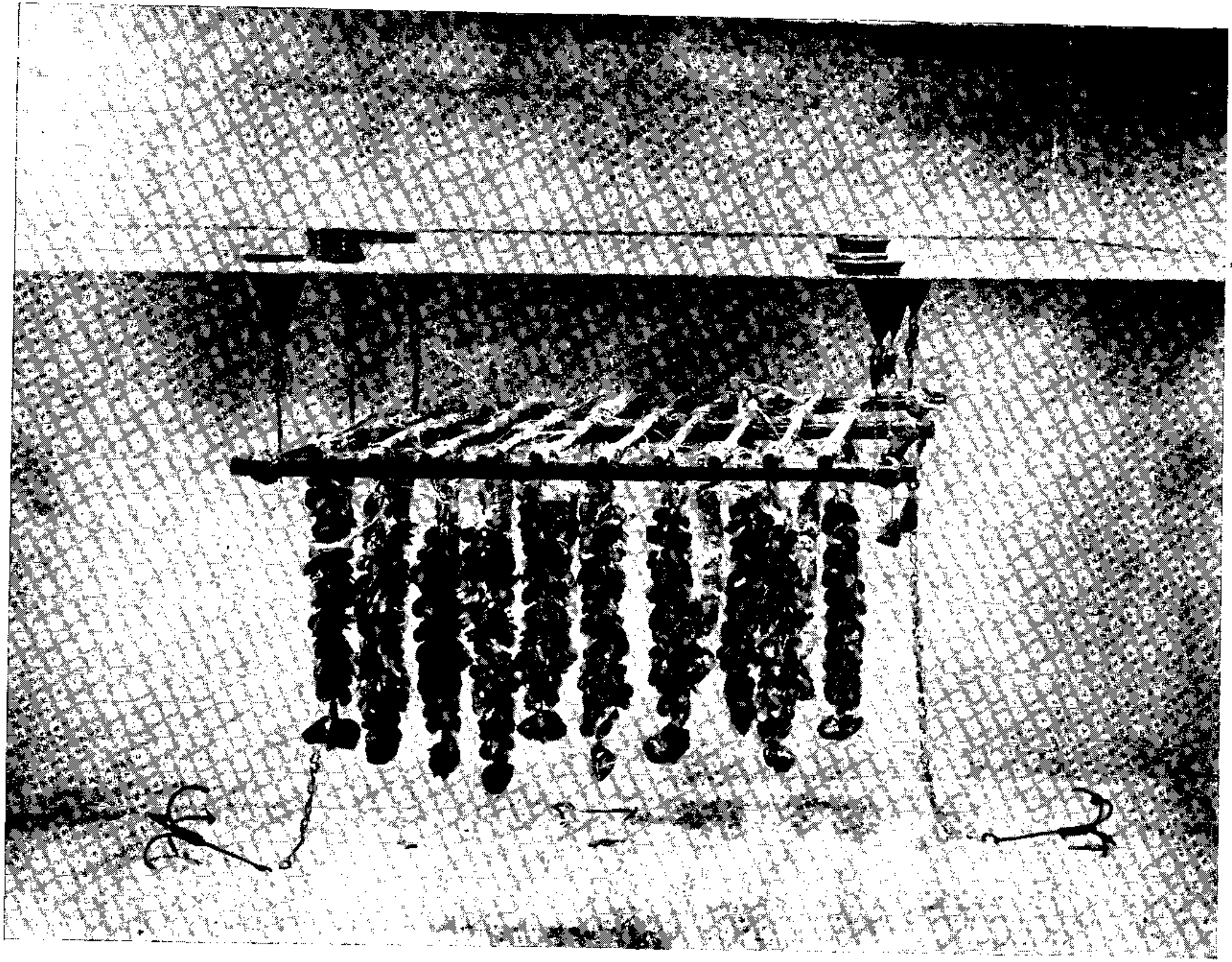

Model of Submerged Mussel Raft in Work (p. 46)

# I

# MUSSELS (MYTILIDAE: GENUS *PERNA*) OF THE INDIAN COAST

P. S. KURIAKOSE

The redesignation of the Indian species of mussels to the genus *Perna* instead of *Mytilus* has been done. Description of two species of *Perna* viz *P. viridis* and *P. indica* found along Indian coast is given, together with diagnostic features distinguishing both species.

## INTRODUCTION

Working on the systematic position of the mussel species in India, Kuriakose and Nair (1976, *Aqua. Biol.*, **1** : 25-36) concluded that the genus *Mytilus* does not occur in India and that the species *Mytilus viridis* (green mussel) should be redesignated as *Perna viridis* following their findings that the genus occurring in India is referable to *Perna*. The brown mussel was identified as a new species, *Perna indica* by them. Along the Indian Coast only these two species have been so far recorded. The present paper gives the details of taxonomy of the Indian species showing the distinguishing features of both.

Mussels belonging to the family 'Mytilidae' are easily recognised from other bivalve molluscs by the following characters :—

Shell equivalve, very inequilateral with prosogyre umbones near the anterior end ; ligament elongate, deep seated generally on nymphae, the inner resilial part typically connected with the nymphae by a calcareous white ridge, mantle lobes united below the anal siphonal opening, branchial opening confluent with the pedal opening ; posterior part of the mantle edges pigmented and furnished with papillae ; anterior adductor muscle absent and posterior adductor very prominent ; anterior byssal retractors small, fastened behind umbones ; posterior retractor generally confluent with the posterior adductor ; foot finger-shaped with a posterior furrow ; byssal gland behind the foot and highly functional ; gills filibranch and ventricle embracing the rectum. (Soot-Ryen, 1955, *Allan Hancock Foundn. Pac. Expdns.* **20** : 1-154).

## TAXONOMY

| | |
|---|---|
| Phylum | Mollusca |
| Class | Pelecypoda |
| Order | Filibranchia |
| Sub-Order | Mytilacea |
| Family | Mytilidae |
| Genus | Perna |

## GENUS *Perna*

*Perna* is characterised by the presence of only one or two well developed hinge teeth ; the absence of anterior adductor muscle, the wide separation of the two posterior byssal retractors, the recurrent loop of the mid-gut lying at the left lateral side of the stomach and in the separation of the crystalline style-sac from the mid-gut. But in the case of *Mytilus* the hinge area consists of 3 to 5 teeth, anterior adductor muscle well developed, posterior byssal retractors of 5 to 7 muscle bundles which are closely arranged along the dorsal shell margin in front of the posterior adductor, the recurrent loop of the straight intestine lies at the ventral side of the stomach making a dorsal loop at the region of the oesophagus and the crystalline style-sac and the mid-gut conjointed (Table 1). *Perna* is more restricted in distribution than *Mytilus* which has a circumglobal distribution.

TABLE 1. *Diagnostic Characters separating Genus* Perna *from Genus* Mytilus

| Diagnostic characters | *Perna* | *Mytilus* |
|---|---|---|
| External colour | Green or brown | Green, blue or bluish-green |
| Shape of the anterior end | Pointed, straight or little down turned | Pointed, more down turned |
| Hinge teeth | One or two | Three to five |
| Resilial ridge | Pitted | Compact |
| Anterior adductor muscle | Absent | Present |
| Posterior byssal retractors | Thick, split into two main bundles, widely separated | Thin, six to eight form a single bundle |
| Course of the pedal retractor before insertion to the shell | Through the anteriomedial aspects of posterior retractor | Through antero-lateral aspects of posterior retractor |
| Crystalline style-sac and mid-gut | Widely separated | Both conjoint |

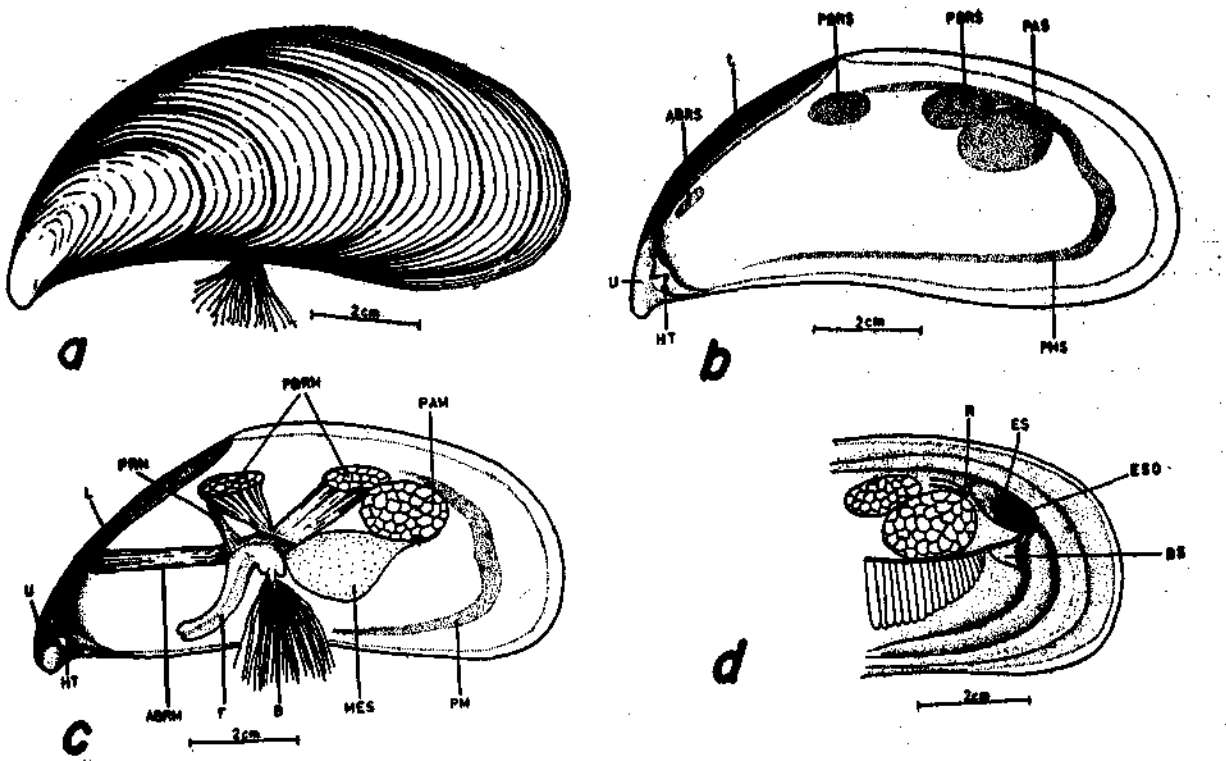


Fig. 1. *Perna viridis* (Linnaeus): a. Lateral view of the animal; b. Internal view of right valve showing muscle impressions, ligament and hinge teeth; c. Internal view showing the arrangement of muscles, foot and byssus apparatus; and d. Internal view of the posterior part showing the mantle margin and opening of the excurrent aperture into the mantle cavity. (Abbreviations used: ABRM—Anterior byssal retractor muscle, ABRS—Anterior byssal retractor muscle scar, AU—Auricle, B—Byssus, BS—Branchial septum, ES—Excurrent siphon, ESO—Excurrent siphonal opening, F—Foot, HT—Hinge teeth, L—Ligament, MES—Mesosoma, MG—Midgut, OES—Oesophagus, PAM—Posterior adductor muscle, PAS—Posterior adductor muscle scar, PBRM—Posterior byssal retractor muscle scar, PBRS—Posterior byssal retractor muscle scar, PM—Pallial muscle, PMS—Pallial muscle scar, PRM—Pedal retractor muscle, R—Rectum, RI—Recurrent intestine, SS—Style-sac, ST—Stomach, T—Tentacle, U—Umbo, and V—Ventricle).

**Perna viridis (Linnaeus) 1758**

(Fig. 1 ; a-d)

*Myaperna* Linnaeus, (1758, *Systema Naturae* ed. **10** : 671).

*Mytilus* (*Chloromya*) *viridis* Lynge, (1909, *Mem. Acad. R. Sci. Lett.* Denmark : **5** : 23) ; Lamy (1937, *Journ. de. Conchol*, **80** : 5-71 ; 99-132 ; 169-197).

*Mytilus smaragdinus* Annandale, (1916, *Mem. Ind. Mus.* **5** : 350-360), Hornell (1917, *Madras Fish Bull.* **11** : 1-51) ; Rao (1941, *Sci. Cult.* **7** : 69-78).

*Mytilus viridis* Hornell, 1921, p. 156 ; Gravely (1941, *Bull. Madras Govt. Mus.* **5** : 35-37 ; Paul (1942, *Proc. Ind. Acad. Sci.* **15** ; 1-10) ; Jones (1951, *J. Bombay Nat. Hist. Soc.* **49** : 519-528) ; Satyamurti (1956, *Bull. Madras Govt. Mus. New Ser.* **1** : 1-202) ; Kundu (1956, *J. Bombay Nat. Hist. Soc.* **62** : 84-103) ; Menon et al. (1966, *Research Bull.* (N.S.) *Punjab Univ.* **18** : 317) ; Rao (1974, *CMFRI Bull. No.* **25** : 5-12).

*Perna viridis* Kuriakose & Nair (1976, *Aqua. Biol.* **1** : 25-36).

### *Description :*

Shell thick, equivalve, inequilateral, elongate, triangularly ovate in outline reaching upto 230 mm in length and 72 mm in height. Umbo terminal, hinge plate well developed extending slightly ventrally, provided with two small teeth on the left valve and one large on the right valve. Dorsal ligamental margin curved, mid-dorsal margin arcuate ; posterior margin rounded and ventral margin highly concave. Periostracum thick, smooth and shining. Sculpture consisting of irregularly spaced concentric ridges and growth lines. Ligament very thick, internal, extending from the umbo to one third of the dorsal shell margin, resilial ridge thick, white and pitted. External colour beautiful green, but in older specimens bluish-green at the anterior half. Interior of the shell margaritaceous and shining ; muscle scar deeply impressed.

Anterior adductor muscle absent. Posterior adductor large, cylindrical, surface slightly elongate and located in the posterior half of the shell a little above the antero-posterior axis of the body. Anterior byssal retractors cylindrical, thin, elongate, and join the shell a little behind the umbonal cavity ; posterior byssal retractor arise as a common bundle from the base of the byssus apparatus which splits into two short, thick bundles and diverge in the form of a 'V', the anterior bundle inserting the shell below the posterior termination of the ligament and the posterior bundle joining the shell along with the posterior adductor bundle at its antero-dorsal side. Pedal retractor muscle thin, elongate, arises from the base of the foot and inserts the dorsal shell margin after crossing through the antero-mesial aspect of the anterior bundle of the posterior retractor. Mid-gut or straight intestine lies at the left lateral side of the stomach. Crystalline style-sac and mid-gut widely separated, the former lying at the left ventral side of the latter. Mantle margin smooth, thin, slightly extensible and tentacles or papillae absent. The mouth of the excurrent aperture oval, wide and the passage into the mantle cavity very small being restricted by a septum ; rectum and posterior adductor not visible through the opening. Foot finger-shaped, thick and extensible. Byssus apparatus large situated at the posterior base of the foot ; byssus threads emanate from the byssus stem. The threads are long, thick, strong with a well developed attachment disc at their distal ends.

### *Distribution :*

Northern Indian ocean and around the mainland coast of South-East Asia, the Philippines, South Africa and New Zealand (Barry Wilson, personal communication) China and Siam (Lamy, 1937). This species occurs all along the east and west coast of India. On the east coast it occurs as small beds along Chilka Lake, Visakhapatnam, Kakinada, Madras, Pondicherry, Cuddalore, Porto Novo and Port Blair. On the west coast extensive beds occur along Quilon, Alleppey, Cochin, Calicut to Kasargode, Mangalore, Karwar, Goa, Bhatia Creek, Malvan, Ratnagiri and Gulf of Kutch.

### *Habitat :*

In addition to the rocky open coasts and harbours, these are found in the mouths of estuaries and rivers where the salinity is almost equal to the sea water. They occur from intertidal zone to a depth of 15 metres attached to rocks, pilings and other hard objects.

**Perna indica** Kuriakose and Nair, 1976.
(Fig. 2 ; a-f).

### *Description :*

Shell thick, equivalve, inequilateral, elongate, triangularly ovate in outline reaching upto 121 mm in length and 48 mm in height. Umbos terminal, umbonal beaks poorly developed, terminal or slightly downturned in adults ; hinge plate narrow and thin with a well developed tooth on the left valve fitting into a corresponding depression on the right valve. Dorsal ligamental margin straight ; mid-dorsal margin highly angular with a well developed hump where the shell measures the maximum height ; posterior margin rounded and the ventral margin straight. Ligament long, thick and internal ; resilial ridge white and highly pitted. External colour dark brown and the interior highly margaritaceous and shining. Muscle scars deeply impressed.

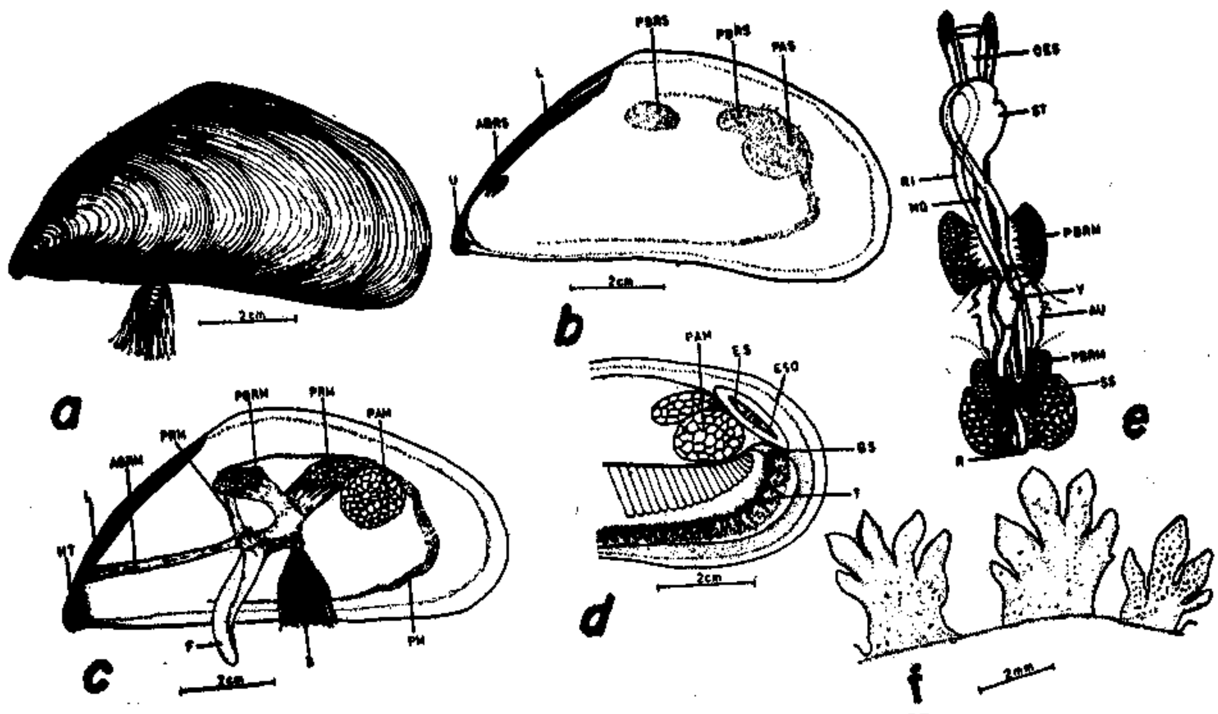


Fig. 2. *Perna indica* Kuriakose and Nair: a. Lateral view of the animal; b. Internal view of right valve showing the muscle impressions, hinge tooth and ligament; c. Internal view showing the arrangement of muscles, foot and byssus apparatus; d. Internal view of the posterior part showing the branched tentacles on the ventral mantle margin and the opening of the excurrent aperture into the mantle cavity; e. Dissection showing the disposition (dorsal view) of musculature, pericardium, alimentary tract and crystalline style-sac, and f. Enlarged view of the tentacles of the ventral mantle margin (Abbreviations as in Fig. 1).

Anterior adductor muscle absent. Posterior adductor muscle rounded, located towards dorsal shell margin at about mid-way between the posterior termination of the ligament and posterior shell margin. Anterior byssal retractors elongate, thin and insert at a little behind the umbonal cavity; posterior retractors arising as a single bundle from the base of the byssus apparatus and split into two thick short bundles which diverge in the form of a 'V'. The anterior bundle inserts the dorsal shell margin below the posterior termination of the ligament and the posterior bundle inserts the shell together with the posterior adductor at its antero-dorsal side. Mid-gut or straight intestine reaches posteriorly over the posterior adductor and recurrent loop of straight intestine lies at left lateral side of the stomach. Crystalline style sac and mid-gut widely separated. Mantle margins bordering incurrent aperture very thick, non extensible; inner fold of the mantle margins with 18-22 long, stout and brown branching tentacles. Excurrent aperture oval and wide; its mouth and passage into the mantle cavity of uniform width; rectum and posterior adductor muscle prominently seen through the aperture. Foot finger-shaped, byssus apparatus large, located close to the base of foot. Byssus threads emanating from the byssus stem, are elongated and strong, with attachment discs at their distal ends. Distinguishing characters of *P. viridis* and *P. indica* are given in Table 2.

*Distribution :*

*P. indica* has a very restricted distribution occurring along the south west coast of India from Varkalai near Quilon to Cape Comorin and south east coast from Cape Comorin to Tiruchendur. Important Centres are Cape Comorin, Colachal, Muttom, Poovar, Vizhinjam, Kovalam, Varkalai and Quilon.

*Habitat :*

This species forms dense population along the rocky coasts from the intertidal region to a depth of 10 metres. Large sized mussels are found in 0.5 to 2 metre depth.

TABLE 2. *Diagnostic Characters separating the Species of* Perna

| Diagnostic characters | *Perna viridis* | *Perna indica* |
|---|---|---|
| Shape of anterior end | Pointed, beak-like, downturned | Pointed and straight |
| Size of hinge plate | Thick, broad, extends slightly to the ventral border | Thick, narrow, terminal |
| Number and size of hinge teeth | Two small on the left valve and one on the right valve | One large on the left valve and a corresponding depression on the right valve |
| Dorsal ligamental margin | Curved | Straight |
| Mid-dorsal shell margin | Arcuate | A distinct dorsal angle or hump present |
| Ventral shell margin | Highly concave | Almost straight |
| External colour | Green | Dark brown |
| Maximum size (recorded length) | 230 mm | 121 mm |
| Mantle margin colour | Yellowish-green | Brown |
| Excurrent aperture opening | Mouth oval and wide; passage into the mantle cavity small; restricted by reptum and rectum and posterior adductor not visible through the opening | Mouth and passage into the mantle cavity are of same width; rectum and posterior adductor prominently visible through the opening |
| Ventral mantle margin | Inner fold of the posterior ventral mantle margin thin, extensible, smooth, tentacles or papillae absent | Inner fold of the posterior mantle margin very thick not extensible; provided with 18-22 thick branching tentacles |
| Posterior byssal retractors | Two, short, thick bundles; anterior bundle arises from the posterior and diverges in the form of a 'V' | Two, short, thick bundles; anterior bundle arises from the posterior and diverges in the form of a 'V' |

# II

# FISHERY AND BIOLOGY OF THE BROWN MUSSEL, *PERNA INDICA* KURIAKOSE & NAIR

K. K. APPUKUTTAN,
T. PRABHAKARAN NAIR

On the culture ropes in the Vizhinjam bay brown mussel show an average growth rate of 35 mm per year. In the open sea, mussels on ropes grow to 25 mm in 5 months. The weight increase is 9.29 g/annum in the bay and 9.72 g for 5 months in open sea. The condition index is maximum in August (i.e. before spawning). The spawning lasts from May to September, with a peak in August.

## INTRODUCTION

In Europe, mussels have been traditionally gathered from natural beds and cultured extensively in Spain, France and the Netherlands to meet market demands. The popularity of the brown mussels along the south-west coast of India led Jones (1950, *J. Bombay Nat. Hist. Soc.* 49: 519-528[1]; 1968, *Sea-food Exporter*, 3 : 21-28[2]) and Jones and Algarswami (1973, *Proc. Symp. Living Resources of the Seas around India*: 641-647[3]), to investigate the distribution and fishery. Kuriakose (1973, Ph.D. thesis, Univ. of Kerala, 347 pp.[4]) has studied the growth rate, breeding habits and early development of this mussel. Additional details on the biology and fishery of the brown mussel in the Vizhinjam area are presented here to increase our understanding of the subject.

## Fishery

From September to April regular exploitation of brown mussel commences every year from Cape Comorin to Vizhinjam. The details of commercial landings of mussels at Vizhinjam from 1976 to 1979 are given in Fig. 1. Fishing methods are comparatively simple. Jones (1950') has described in detail the fishing method of brown mussel from this area. The mussel fishing is done as an off time occupation by the fishermen, but during peak season most of them are engaged full-time in mussel fishing. The fishing is done mainly during 9 a.m. to 4 p.m. Lowtide, clean water and clear sunny days are good for fishing. They collect mussels from intertidal rocks (Plate I, a) using iron implements like chisels with or without wooden handle or a knife, during lowtide. Mussels thus collected are kept in coir or nylon bags tied around their waist. After fishing, they swim back and reach the shore and empty the catch. The mussels are cleaned to remove fouling organisms, (Plate I, b) graded according to size and then disposed off to consumers and merchants in fresh condition. Cycle loads of mussels are taken to interior markets around Trivandrum city during peak fishing season (Plate I, c). In 1976-77, the fishery lasted till March with peak landings in October-December period. In 1977-78 fishery started by September and lasted till January. In 1978, fishery commenced by October and lasted till January 1979. During 1977, 1978 and 1979 the mussel fishery at Vizhinjam was poor, since the settlement of mussels around Vizhinjam and nearby places was a failure compared to previous years. In recent years the fishermen exploit mussels from the natural bed even before the mussels reach the harvestable size.

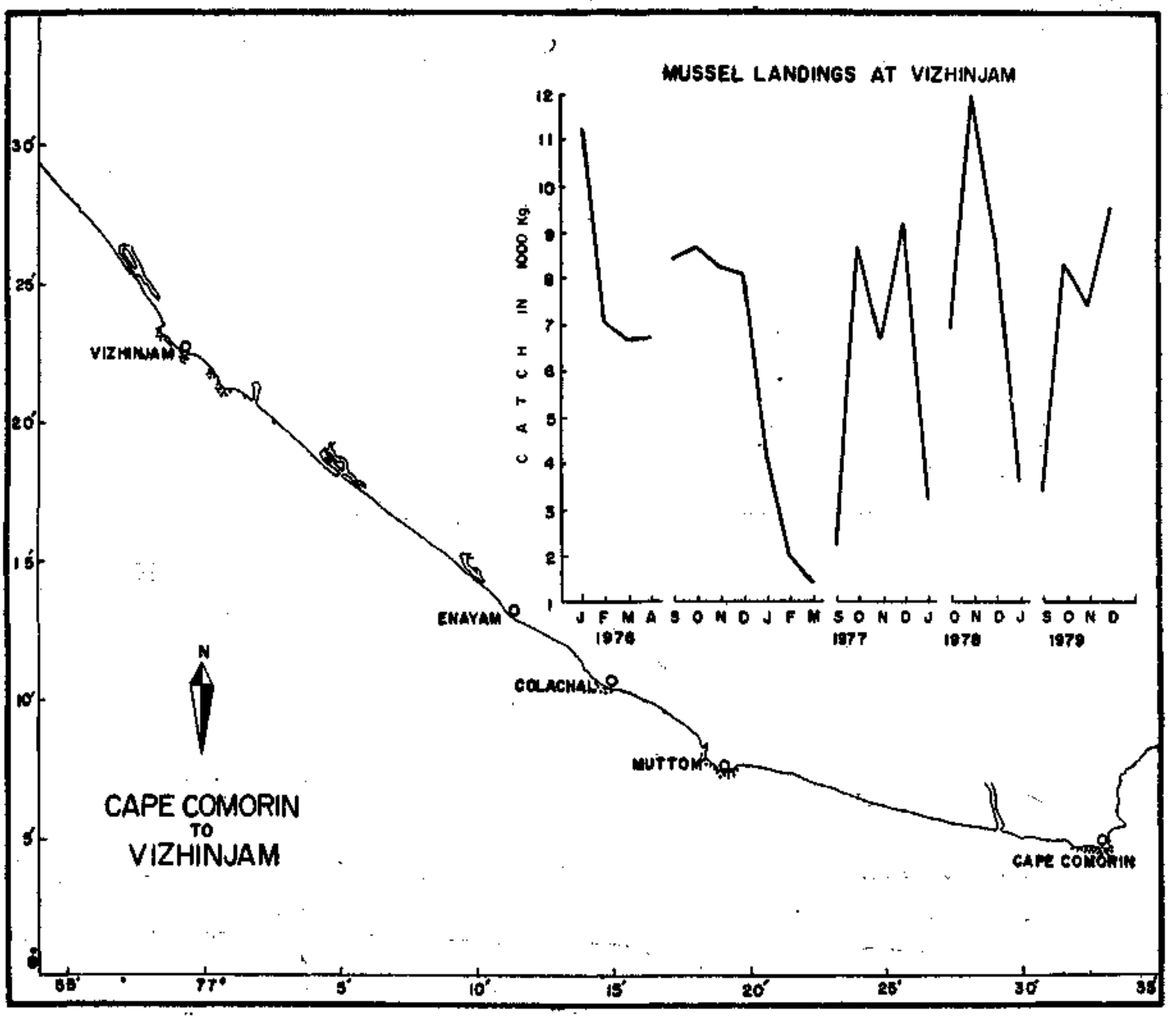


Fig. 1. Cape Comorin to Vizhinjam showing important mussel fishery centres and mussel landings at Vizhinjam from 1976-79.

PLATE I. a. Exploitation of mussel from natural bed around Vizhinjam.
b. Cleaning and grading of mussels collected from natural bed.
c. Disposal of mussels to interior markets.

## Biology

The data presented here were obtained from the cultured mussels in the farm at Vizhinjam bay and open sea during 1976-79 and 1978-79 respectively.

*Growth rate :*

The growth rate inside the bay from 1976 to 1979 is given in Fig. 2. Analysis of data collected for each year has shown that the growth rate in all the three years follows an identical pattern. In 1976-77 the growth

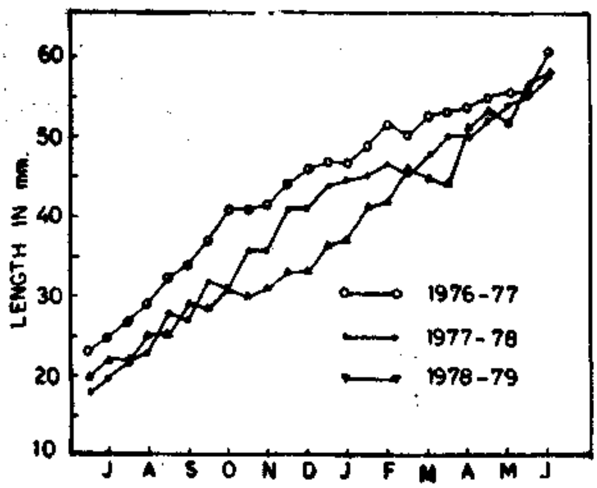


Fig. 2. Growth rate of cultured mussel in the bay for 1976-77, 1977-78 and 1978-79.

increment per year was 35 mm and in 1977-78, 35.6 mm and in 1978-79, 36.3 mm. Thus the average annual growth rate calculated was 35.33 mm. Open sea mussels on ropes showed a growth rate of 25 mm in five month period (Fig. 3). The growth rate per month

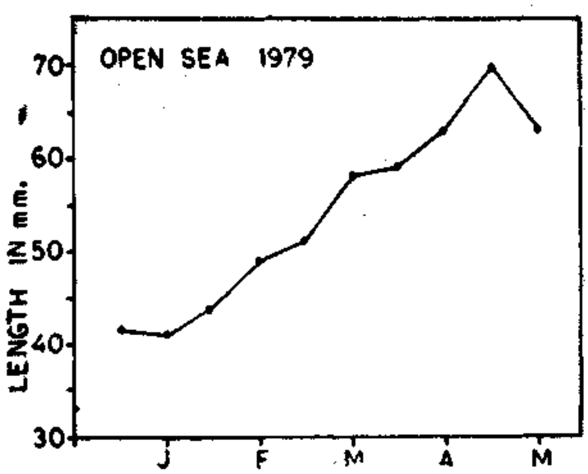


Fig. 3. Growth rate of cultured mussel in the open sea for 1979.

was calculated as 5 mm. It is quite evident that in open sea conditions mussels grow faster.

*Increase in total weight and flesh weight :*

In 1976-77 the increase in total weight was 10.75 g for 12 months, in 1977-78, 9.24 g and in 1978-79, 8.9 g thus showing an average increase in weight of 9.29 g per year inside the bay. The average total weight increase calculated was 0.77 g/month. The increase in flesh weight for 1976-77 was 4.9 g, in 1977-78, 3.49 g and in 1978-79, 3.52 g with an average increase in flesh weight of 3.77 g/year inside the bay. The calculated flesh weight increase per month was 0.32 g. The details of increment in total weight and flesh weight are given in Figs. 4 and 5 respectively. An uniform pattern of increase in various months was observed in all the three seasons inside the bay.

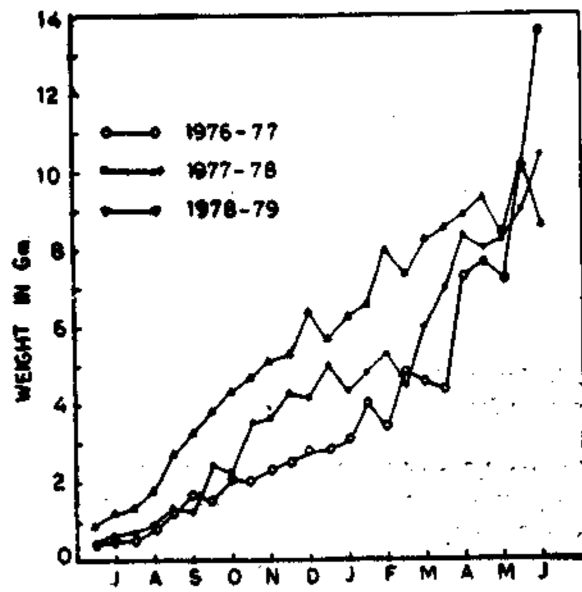


Fig. 4. The total weight increment of mussel inside the bay for 1976-77, 1977-78 and 1978-79.

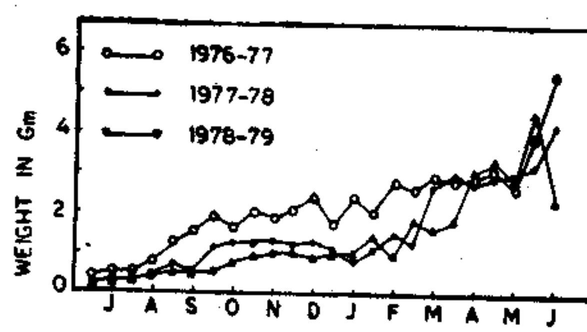


Fig. 5. The meat weight increment of mussels inside the bay for 1976-77, 1977-78 and 1978-79.

In the open sea samples the increment in total weight and flesh weight was greater than that observed in bay (Fig. 6). The increase in total weight for 5 months was 9.72 g with 1.94 g/month of flesh weight increment for the same period. In natural bed increase in total

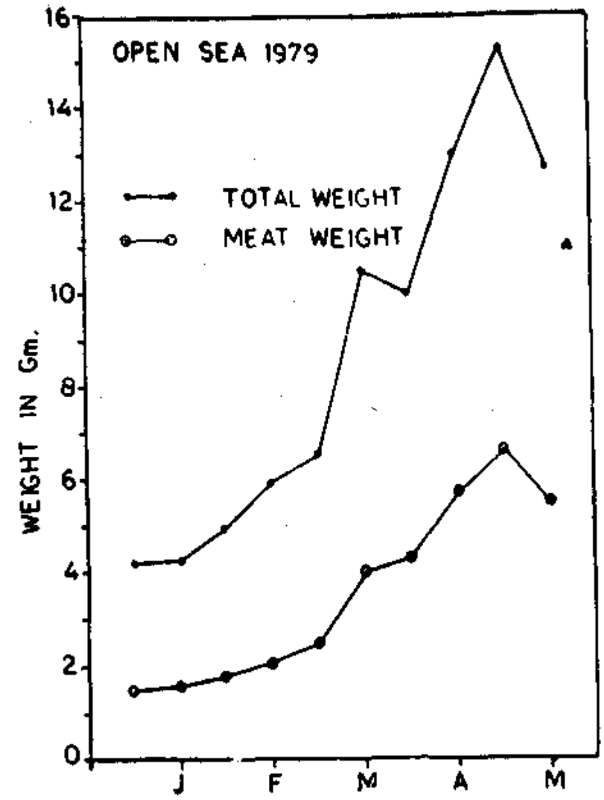


Fig. 6. Increase in total weight and meat weight of mussels in the open sea for 1979.

weight was 4.5 g with 0.9 g per month of flesh weight increase. The total weight-flesh weight-relationship is given in Table 1.

TABLE 1

The total weight-meat weight relationship for bay mussel for 1976-77, 1977-78 and 1978-79 and open sea mussel for 1978 and 1979.

| Months | | Bay 1976-'77 | Bay 1977-'78 | Bay 1978-'79 | Open sea 1978 | Open sea 1979 |
|---|---|---|---|---|---|---|
| July | .. | 38.20 | 47.58 | 38.24 | .. | .. |
| August | .. | 38.40 | 31.45 | 37.04 | .. | .. |
| September | .. | 38.30 | 37.90 | 37.85 | .. | .. |
| October | .. | 37.95 | 38.78 | 41.73 | .. | .. |
| November | .. | 39.60 | 35.92 | 40.97 | .. | .. |
| December | .. | 37.95 | 36.72 | 42.26 | .. | .. |
| January | .. | 34.80 | 21.31 | 35.38 | 27.31 | 36.37 |
| February | .. | 33.58 | 26.17 | 35.29 | 28.18 | 36.31 |
| March | .. | 34.94 | 26.24 | 32.88 | 30.98 | 38.41 |
| April | .. | 33.15 | 37.44 | 40.69 | .. | 43.58 |
| May | .. | 32.62 | 37.28 | 41.31 | .. | 43.33 |
| June | .. | 40.53 | 33.78 | 39.19 | .. | .. |

*Condition index :*

The condition index for each month was calculated after Baird (1966, *Fishery Invest* London, Ser. 2, **25** (2): 33 pp.[5]). The details of variations in the condition index is given in Fig. 7. The analysis shows that in 1976-77 from July to December the condition index showed increase, whereas in January and February it was decreasing. Again in March and June there was another increase. In 1977-78 the maximum condition index noticed was in June 1978. In 1978-79 period the maximum condition index was noticed in September. The minimum condition index was generally observed mainly during January to May. In all three years highest percentage was usually observed before the spawning. The changes in the decline of condition index appears to vary according to the time of the onset of monsoon during each year.

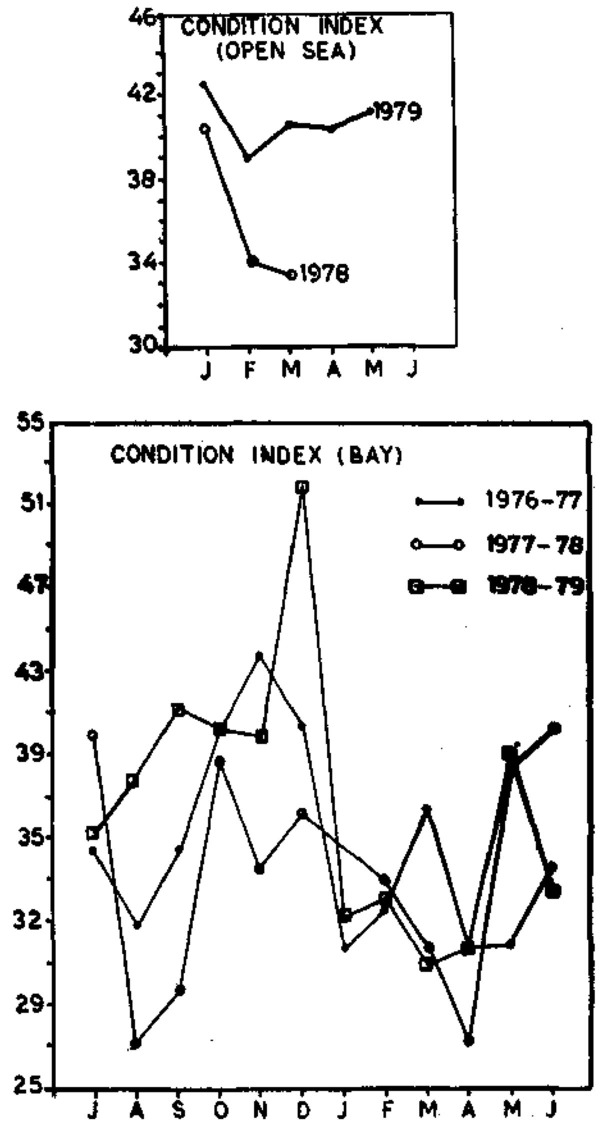


Fig. 7. Variation in condition index in open sea and bay.

*Spawning :*

The stages of gonad were classified as follows :—

Stage—I : Ova have not attained regular shape ; sperm non-motile.

Stage—II : Granulation in the ovary observed ; ovary without regular shape ; sperm non-motile.

Stage—III : Spherical ova ; ovary in brick-red colour, sperm motile.

Stage—IV : Spent.

For determining the stages of maturity in each month 50-300 numbers of specimens of size above 15 mm only were examined. In 1976-77, stage-I was observed from July to March, stage-II from December to April and stage-III in July and from April to June and stage-IV in July and August. In 1977-78 stage-I was observed from September to March, stage-II from November to March and stage-III in July, November, December and from March to June, stage-IV from August to November. In 1978-79 stage-I was present from October to March, Stage-II from November to December and in March, stage-III in July/August and April to May period, stage-IV in September and June. In the open sea samples observed in 1979, stage-I was dominant from January to March and from April to May stage-III alone was found in the sample. By examining the gonadic stages it could be seen that from April onwards farm-grown mussels reach sexual maturity and spawning commences by the end of May lasting till September with peak during July to August. Spent stages could be observed from June. Natural settlement of spat in mussel beds was noticed from July and peak period of settlement in good concentration was found from September till November.

*Fouling community of the farm area :*

In the suspended mussel ropes various fouling organisms were encountered. Among them, *Balanus amphitrite* was the most important and next was *Crassostrea cucullata*. An interesting observation during 1977 in the farm area was the unusual heavy fouling by *Modiolus* sp. The settlement of this bivalve starts by May, which almost coincides with the settlement of brown mussel in this area. One of the reasons for poor settlement of *P. indica* in the natural bed around Vizhinjam during 1977-79 period could be attributed to the heavy spat-fall of *Modiolus* sp., before the mussel spat settlement. It was also observed that during March-April *Avicula vexillum*, was found settling on mussel ropes and also in spat settlers in large quantities. *Aloides sulculosa*, a bivalve and simple ascidians of *Ascidia* spp. were also commonly found on the mussel ropes throughout the year.

Several genera of crabs, *Thalamita* sp., and *Procellana* sp. were found on the ropes. *Pinnotheras* sp. was found inside the mussels as a commensal. Encrusting tubiculous polychaeta, nematodes, crinoids, flatworms and algae were also found over the cultured mussel ropes. *Haliclilona tenuiramosa, Callyspongia diffusa, C. fibrosa* and *Mycale mytilorum* were seen encrusting on the mussel shells. None of them pose serious problems for mussel farming. *Modiolus* spat settlement alone seems to compete for space.

## REMARKS

There is a decline in mussel landing during the last three years. The probable reason for the decline in mussel catch is mainly due to the indiscriminate fishing by the local fishermen during this period and also due to the poor settlement of mussels in the natural bed. Local fishermen usually start exploiting the mussel stock when mussels are in young stage.

Growth rate in the open sea condition appears to be faster when compared to the growth rate in natural bed. Compared with the growth rate of green mussel cultured at Calicut (discussed elsewhere) and also at Goa, the growth of brown mussel is not fast. The total weight increment shows variation in open sea and bay condition. Weight increment is greater in the open sea. The total weight-flesh weight relationship showed an increment from May to December which is the ideal season for harvest. Spawning of *Perna indica* commences by May and lasts till September with peak period during July to August.

# III

# FISHERY AND BIOLOGY OF THE GREEN MUSSEL, *PERNA VIRIDIS* (LINNAEUS)

K. A. NARASIMHAM

The green mussel in the natural beds at Kakinada Bay attains an average length of 63 mm in 6 months, 92.2 mm in 1 year and 129 mm in 3 years. The mussel stock show a considerable variation from year to year, in spawning activity although it extends from December to July with peak activity in January to May. At Kakinada there appears to be no appreciable difference in the biological cycle of the farm grown mussels and those in natural beds.

## INTRODUCTION

Most of the available literature (Ranade *et al.*, 1973, *Curr. Sci.* **42** (16) 584[1], Nagabhushanam and Mane, 1975, *Bull. Dept. Mar. Sci. University of Cochin*, (2)377-387[2], Rao *et al.*, 1975, *Indian J. Mar. Sci.* **4** : 189-197[3], Rao *et al.*, 1976, *Indian J. Mar. Sci.* **5** (1) 113-116[4], Wafer *et al.*, 1976, *Indian J. Mar. Sci.* **2** : 252[5], Qasim *et al.*, 1977, *Indian J. Mar. Sci.*, **6** : 15-25[6]) concerning the rate of growth, reproduction and spawning behaviour of the green mussel of India relate to the population existing along the west coast. Precise knowledge of the biology of *Perna viridis* found in the east coast was considered essential to get an overall idea. The scientific information presented here is based on the results of investigations carried out at Kakinada.

## MUSSEL BED AT KAKINADA

In the Kakinada area, at the mouth of the Upputeru canal which opens into the Kakinada Bay, there is a limited green mussel bed spread on granite stone embankments of the canal. Mussels are removed from this bed, mainly for local consumption as food and the annual production is estimated at 7 tonnes (Jones and Alagarswami, 1973, *Proc. Symp. Living Resources of Seas around India, C.M.F.R.I.*, 641-647[7]). The bed is a narrow one, with an average width of 3 m, spread on either side of the banks of the Upputeru canal. Mussels occur on the left bank upto 600 m stretch while on the right bank they are distributed upto a distance of 2.3 km, upstream from the canal mouth. Their distribution is patchy ; they occur from intertidal to subtidal region, upto 3 m depth.

The mussel bed was surveyed in 1974 and an estimated 1,27,200 mussels weighing 11 tonnes were found in the 1.47 ha bed. The density varied from 0 to 20 mussels/m$^2$. The size range of the mussels varied from 27-160 mm.

### *Fishery*

Fifteen fishermen, all belonging to Yetimoga fishing village (3 km from the mussel bed) are engaged seasonally during March-May in fishing the mussels from the Upputeru canal. Two or three of them set out in a plank built boat and pick the mussels by hand at low tide. A crowbar may be used to lift larger stones for collecting the mussels underneath. Diving also is resorted to often. Annually 5 tonnes are fished. The size range of the mussels collected varies from 60-160 mm and they are sold at Rs. 10 to 20 per 100 numbers, depending on the size. Compared to the magnitude of green mussel fishery at Calicut (Malabar Coast) the fishery at Kakinada is insignificant. Kuriakose (Personal communication Table 1) estimates an annual landing of 900 tonnes at Calicut.

The Upputeru canal, being navigation channel is regularly dredged and the dredged earth is dumped on the mussel bed. It is possible that this practice is denuding the bed of mussel population in recent years.

### *Environmental conditions*

Surface temperature in the bay varies from 26°C in December to 33.5°C in April/May, then decreases

TABLE 1. *Total mussel landings from Calicut to Mahe area during different months (in tonnes)* (Kuriakose, Personal Communication)

| Months | | 1975 | 1976 | 1977 | 1978 | 1979 | Average catch in tonnes |
|---|---|---|---|---|---|---|---|
| January | .. | 74.40 | 161.00 | 97.84 | 37.95 | 112.80 | 96.79 |
| February | .. | 53.88 | 178.08 | 142.50 | 32.00 | 147.40 | 110.77 |
| March | .. | 75.60 | 191.32 | 93.15 | 34.40 | 131.20 | 105.13 |
| April | .. | 81.82 | 175.03 | 48.60 | 31.00 | 119.00 | 91.09 |
| May | .. | 63.64 | 145.75 | .. | 10.20 | 93.00 | 62.52 |
| June | .. | .. | .. | .. | .. | .. | .. |
| July | .. | .. | .. | .. | .. | .. | .. |
| August | .. | .. | .. | .. | .. | .. | .. |
| September | .. | 70.65 | 109.80 | 30.97 | .. | .. | 42.28 |
| October | .. | 94.83 | 174.00 | 46.97 | 106.00 | 108.62 | 106.08 |
| November | .. | 174.73 | 210.00 | 30.91 | 255.00 | 104.48 | 155.03 |
| December | .. | 167.81 | 244.00 | 49.60 | 153.00 | 82.65 | 139.41 |
| Total | .. | 857.35 | 1,588.98 | 540.54 | 659.55 | 899.15 | 910.72 |

until September after which there is a rapid fall through December. The salinity ranges from 1.45‰ in October to 31.5‰ in May. It is moderate to high from January to August and low during the rest of the year. The dissolved oxygen in 1974 varied from 3.44 to 7.84 ml/l. In 1975 it ranged from 4.20 to 6.48 ml/l. The pH varies from 7.0 to 7.8 in 1974 (7.0 to 8.2 in 1975) and the water is slightly alkaline (Fig. 1).

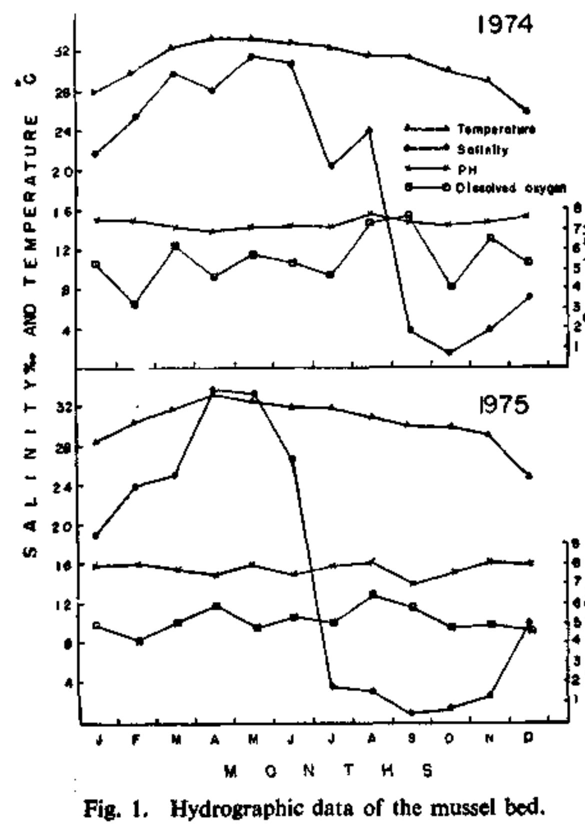


Fig. 1. Hydrographic data of the mussel bed.

## AGE AND GROWTH

*Natural bed : Length—frequency analysis*

In this study only those modes which could be traced for an year or more were considered. The smallest mode 'E' measured 27 mm in February 1976 (Fig. 3). Rao *et al.*, (1975[3]) observed that in the laboratory the time required from fertilisation to spat settlement is under 3 weeks in *Mytilus viridis* (= *P. viridis*) and commented that it may be still less in nature. 10 mm spat of *P. viridis* reared in a cage at Kakinada grew to 26 mm in one month. Maturity studies indicated that 32% of the mussels from the natural bed were in spawning condition in December 1975. Based on these considerations it is reasonable to assume that the mode at 27 mm in February 1976 was the result of spawning in December 1975 and hence 2 months old. In June 1976 when 6 months old, it reached a length of 63 mm and could be traced to 87 mm by December 1976 when one year old. In September 1975 mode 'D' was present at 57 mm (Fig. 2) and it was allotted 5 months age since mode 'E' attained 63 mm in 6 months. Mode 'D' shifted to 69 mm by November 1975 when 7 months old, 93 mm by April 1976 when 12 months old and it could be traced to 111 mm by December 1976 when 20 months old. Mode 'C' appeared at 63 mm in August 1974 and was considered as 6 months old. It was traced to a length of 93 mm by February 1975 when 12 months old and 105 mm by August 1975 when 18 months old. Mode 'B' measured 93 mm in January 1974. It was considered as one year old based on the modal progression of 'C', 'D' and 'E'. It shifted to 105 mm in July 1974 when 18 months old, 117 mm in January 1975 when 2 years old and 129 mm

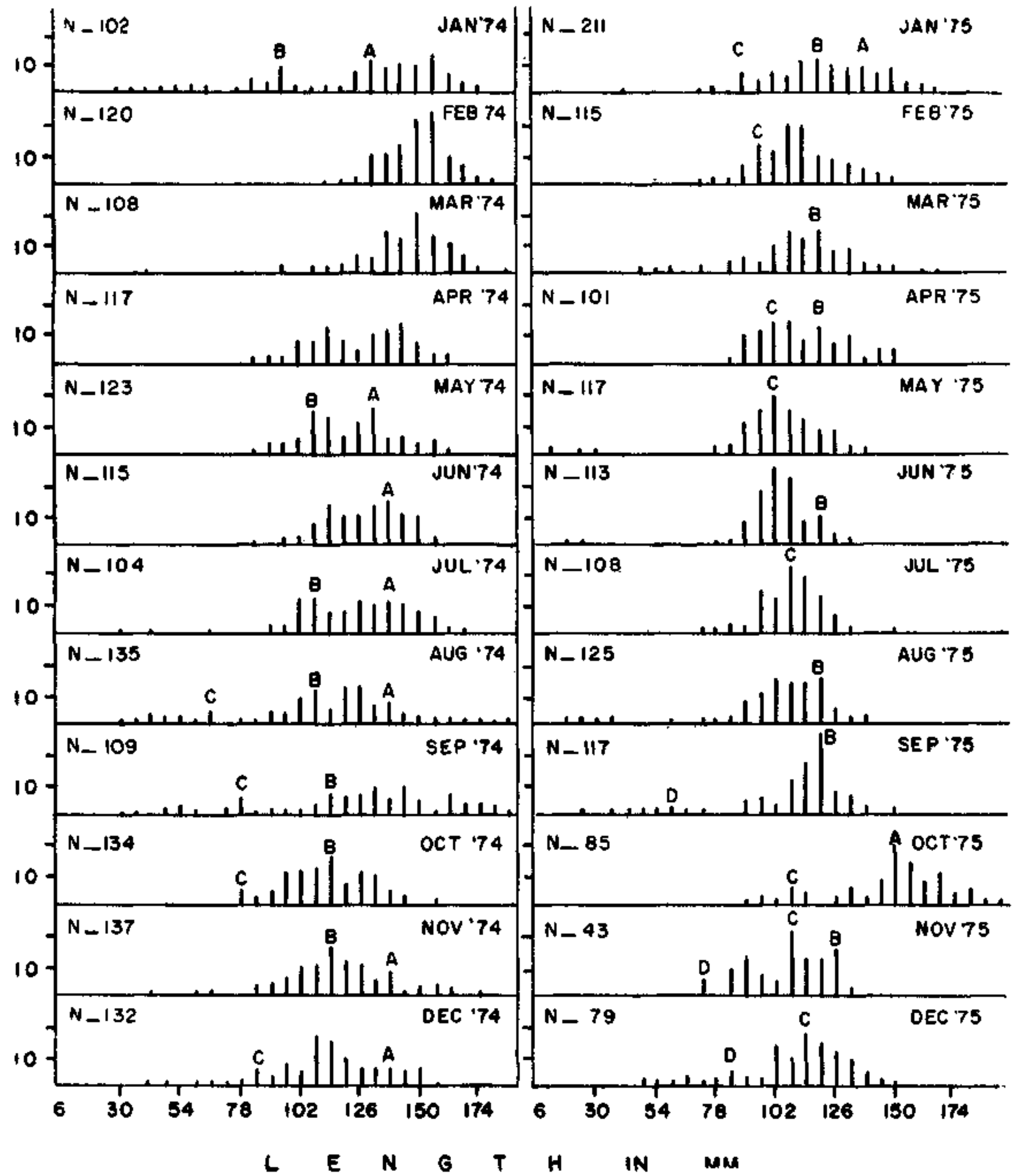

Fig. 2. Length-frequency distribution of *P. viridis* in 1974 and 1975. N indicates the number of mussels. Length group 0-6 mm indicated by 6 mm.

in January 1976 when 3 years old. Mode 'A' was present at 129 mm in January 1974 and it was considered as 3 years old since 'B' attained that modal length in 3 years. This mode progressed to 135 mm by January 1975 when 4 years old.

Based on the above observations in the natural bed the calculated average length at age are given in Table 2. It may be seen from the table that *P. viridis* attains an average length of 63 mm in 6 months, 91.5 mm in one year, 107 mm in 1.5 years, 117 mm in 2 years, 129 mm in 3 years and 135 mm in 4 years.

*Farm*

In raft grown mussels, spat of 21.7 mm mean length noticed in collectors in May grew in 4 months time to 58.6 mm and in 5 months to 66.6 mm mean size giving an average rate of growth 9 mm per month. Since the size of the 21.7 mm mussels is about 2 mm—,

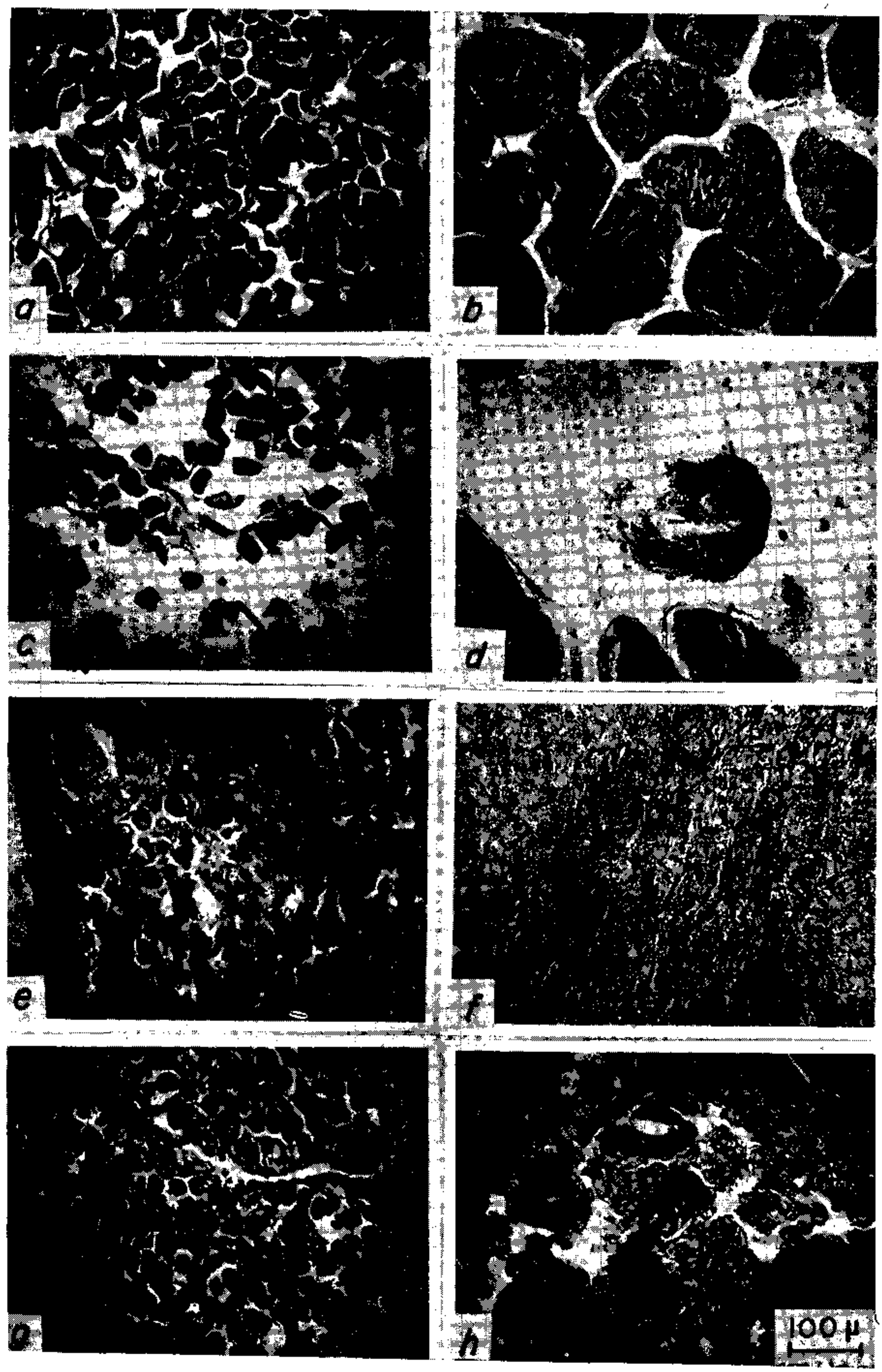


PLATE I. a and b. Fully ripe female and male gonads. c and d. Partially spawned female and male gonads. e. Spent female with few residual ova. f. Indeterminate gonad with interfollicular tissue. g and h. Developing female and male gonads.

the mussels attained a mean length of 58.4 mm in about 6 months. This growth is close to 63 mm in 6 months from natural beds.

TABLE 2. *Modal lengths in mm in* P. viridis

| Modes | 0.5 | 1.0 | 1.5 | 2 | 3 | 4 | Remarks |
|---|---|---|---|---|---|---|---|
| | | | | Years | | | |
| A | — | — | — | — | 129 | 135 | *Indicates the calculated length based on the position of the preceeding/succeeding modal length. |
| B | — | 93 | 105 | 117 | 129 | — | |
| C | 63 | 93* | 105 | — | — | — | |
| D | 63* | 93 | 111 | — | — | — | |
| E | 63 | 87 | — | — | — | — | |
| Average length | 63 | 91.5 | 107 | 117 | 129 | 135 | |

## REPRODUCTION AND MATURITY STAGES

Although mussels are known to be unisexual 0.8% were observed to be hermophrodites. The mature female can easily be distinguished by its bright orange red colour from that of the male which is cream yellow. Four main stages in the reproductive cycle are recognised *viz.* spent/resting, developing, ripe and spawning. In the spent/resting stage the sex may be distinguishable or indeterminate. In the recently spent mussels the gonad is shrunken, majority of the follicles are empty and few residual gametes may be present (Plate 1, e). In the indeterminates the gonad may be moderately developed with enormous development of the connective tissue (Plate 1, f). In the developing stage there is an increase in the gonad size and it is half the final size. Gametogenesis begins and the follicles contain developing gametes (Plate I, g & h). In the late developing condition the gonad is two-thirds its final size and the follicles contain both developing and ripe gametes. In the ripe stage the gonad is fully distended. In females the ova are ripe with narrow stalk and fill practically all the intervesicular space (Plate I, a). In males the follicles are full with ripe sperms (Plate I, b). In the spawning stage, with the emission of gametes the gonad becomes flabby and a reduction in the density of ripe gametes is evident (Plate I, c & d). In the mostly spawned condition the gonad is shrunken and the follicles contain few ripe gametes.

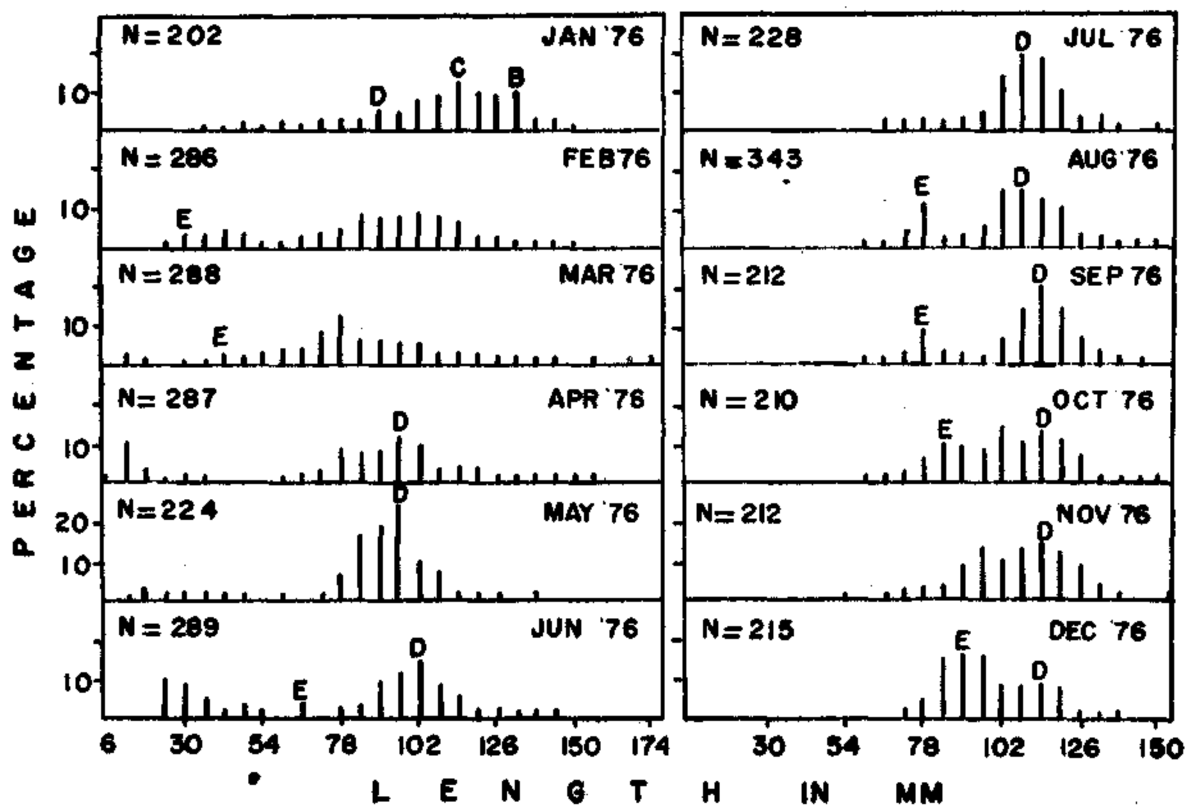


Fig. 3. Length-frequency distribution of *P. viridis* in 1976. N indicates the number of mussel. Length group 0-6 mm indicated by 6 mm.

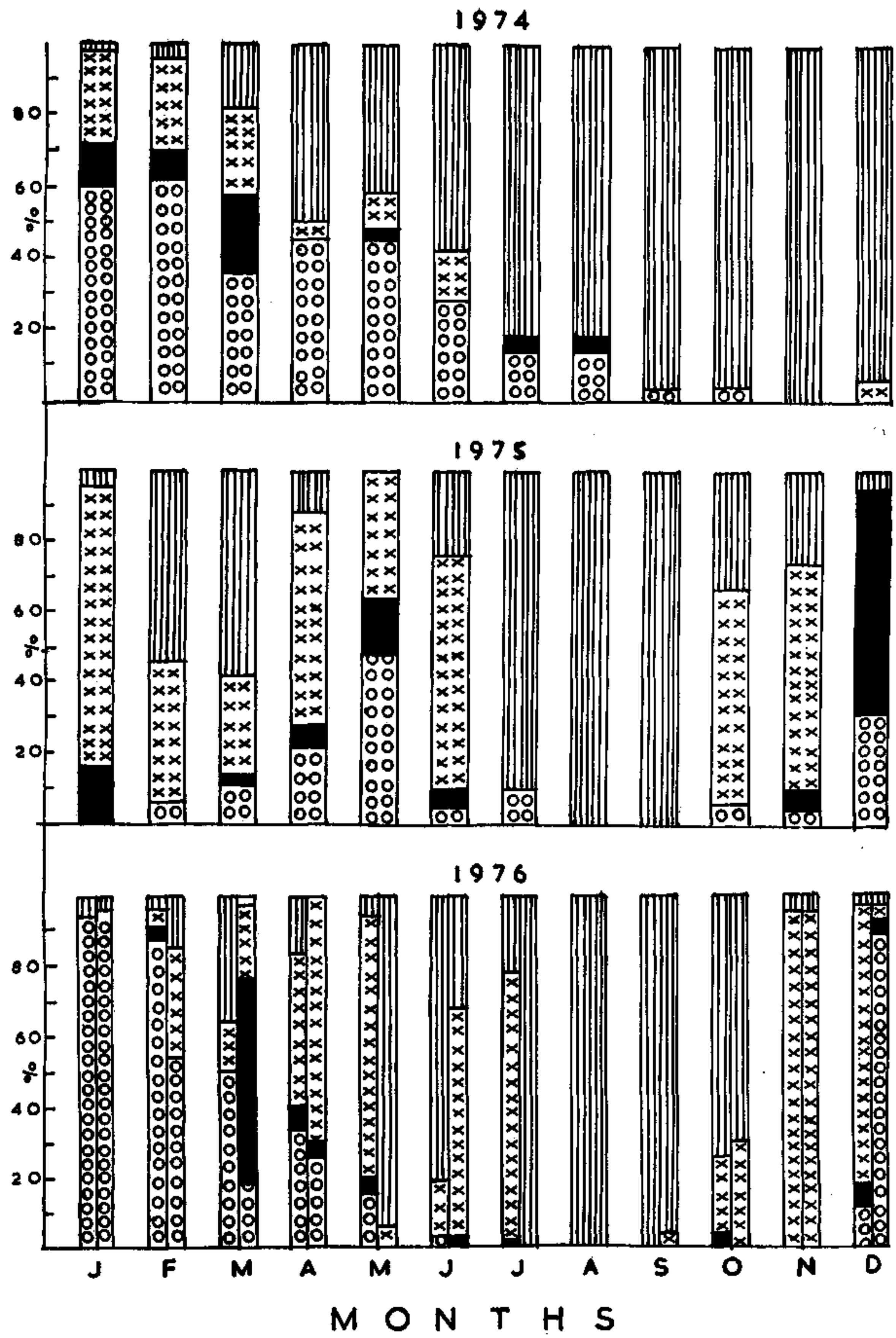


Fig. 4. Percentage occurrence of different maturity stages in *P. viridis* (Vertical stripes-spent/resting, crosses-developing, shaderipe and circles-spawning). During 1976 the maturity stages for the 2 fortnights of a month are shown separately.

*Spawning*

The percentage occurrence of different maturity stages are given in figure 4. In 1974 about 60% of the mussels were in spawning condition in January and February. During the March-June period the percentage of spawning mussels varied from 28 to 46 and this was further reduced to 14 in July and August. During the remaining four months there was no spawning except for isolated cases. Thus the spawning period is prolonged extending from January to August with peak spawning activity at the beginning of the season. Concurrent with the reduction in the number of spawners there was an increase in the number of spent/resting mussels from June onwards until November when all the mussels were in the resting stage. In December, gametogenesis was in progress in 6% of the mussels while the remaining were resting.

In 1975, spawning commenced in February when 6% of the mussels were in this condition. The number of spawning mussels increased to 12% by March, 22% by April and peak spawning activity was noticed in May when 48% of the mussels were in spawning stage. In June and July the number of spawners was reduced to 4 and 8% respectively. In August and September all the mussels were in spent/resting condition. Again there was minor spawning activity in October-November and by December while 64% of the mussels were ripe, spawning was in progress in 32%. The spawning period in 1975 differs from the preceeding year in that the spawning commenced late ; the peak activity was attained late. There was spawning in December and above all the intensity of spawning was low as revealed by the low percentage occurrence of spawning mussels.

During 1976, peak spawning activity was attained in January and February when 98 and 54% of the mussels respectively were spawning. In the following three months there was a rapid reduction in the number of spawners and by June only 4% of the mussels were in spawning stage. In the June-October period spent/resting mussels predominated while in November vast majority (96%) were in developing stage. Spawning commenced in the first quarter of December and by the month end 93% of the mussels were in spawning stage. The spawning in 1976 has much similarity with the events in 1974 except that during June-August there was no spawning in 1976. Both in 1975 and 1976 there was spawning in December. Thus the spawning period in the mussels at Kakinada is prolonged, usually extending from December to July with peak activity in January-May.

Ripe gonads were found in mussels measuring 22 mm onwards and most of the mussels attained sexual maturity at 28 mm length when they are about 2 months old.

## Index of Condition

The trend in the values of the index of condition (termed IC) studied by the four methods (indicated in Fig. 5) is essentially the same except for a few anomalies observed in some of the values, particularly in the IC based on the meat weight—total weight ratio. This may be due to the varying quantities of water retained in the mantle cavity of the mussel which would affect the total weight. The IC of the mussels can be studied by adopting any one of the other three methods, provided uniform procedures were followed. However, the study of the IC based on the dry meat weight—wet meat weight ratio is time consuming.

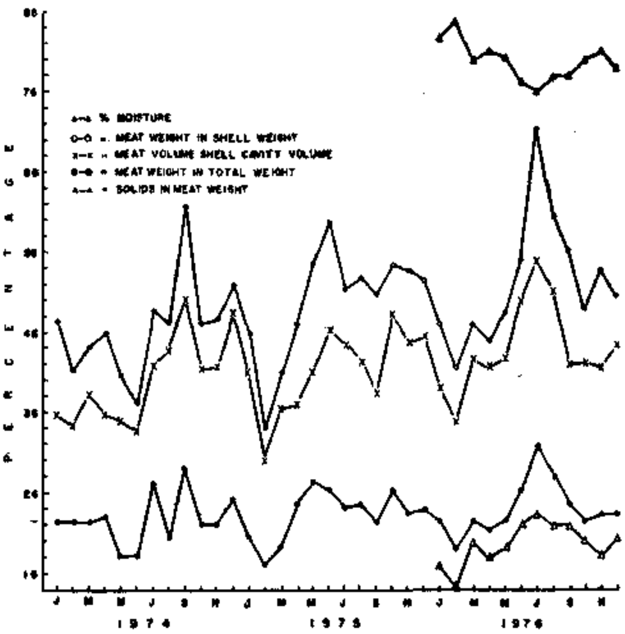


Fig. 5. Percentage moisture and index of condition in *P. viridis*.

In 1974 the IC fluctuated during January-April, dropped low in June and showed high values during July-December. There was a major peak in September and a minor one in December. In 1975 the IC was very low in February and generally high in May-December. A major peak was obtained in June, followed by a minor one in October. In 1976 also very low IC was recorded in February. This was followed by a minor peak in March. The IC values were high during May-September with a prominent peak in July.

The data suggest that, in general, the condition index was low in February and high during the second half of the year.

The percentage of moisture varied from 76 to 84.2 and showed an inverse relationship with the condition index (Fig. 5).

## Discussion

Paul (1942, *Proc. Indian Acad. Sci.*, **15B** : 1-42[6]) observed that *M. viridis* (= *P. viridis*) grows to 14.5, 34.5, 52, 77.5 and 103 mm in 30, 84, 164, 241 and 445 days respectively in the Madras harbour. Ranade *et al.*, (1973[1]) stated that in Ratnagiri waters the green mussel spat which measured 8 mm in October 1972 had grown to 61 mm in May 1973 giving an average growth rate of 7.55 mm/month. These data compare favourably with the results obtained at Kakinada. Rao *et al.*, (1975[3]) found that the green mussels reach 60 mm length in about 6 months on floating buoys. They further observed that on the natural bed the mussels reach 96, 132 and 156 mm in 1, 2 and 3 years respectively. Kuriakose (Personal Communication) reports that the growth at Calicut in the first year reaches 72 mm, in the second year it progresses by 38 mm and the third year increment is 10 mm. Qasim *et al.*, (1977[6]) noted that the mussels grow at about 8 mm/month on ropes. These observations are generally in agreement with the growth of the green mussel at Kakinada except that the length-at-age arrived at by Rao *et al.*, (op. cit[3]) for the 2nd and 3rd year mussels were on the higher side.

In the present study it was observed that growth in the mussels was fast in the first 6 months and slow in the second half of the year. While the range in the temperature variation was only 8.5°C the salinity showed much pronounced variations. Fast growth was recorded during the period when the salinity was high and the temperature showed a rising trend touching peak in April-May. Poor growth was noticed when the salinity was low and the temperature showed a rising trend touching the lowest in December. Various factors like temperature, salinity, light, food supply etc., were known to affect the growth of mussels (Seed, 1976, *Camb. Univ. Press publn.* (Ed.) *B. L. Bayne* : pp. 13-60[9]). In temperate countries growth is rapid in spring and summer and slow or absent in the cold winter months and this seasonal pattern in growth is generally attributed to temperature. The temperature requirements for optimum growth are known to vary and higher temperatures beyond the optimum have resulted in slow growth (Coe, 1945, *Jour. Exptl. Zool.* **99** : 1-14[10]). Also temperature alone could not be isolated as a controlling factor for the growth of mussels (Seed, 1976[9]). Among the various factors, high salinity and raising temperature seem to accelerate the growth of the green mussel at Kakinada.

Rao *et al.* (1975[3]) stated that the green mussel breed throughout the year along the Goa coast. Paul (1942[8]) arrived at similar conclusion regarding the spawning period of the same species in the Madras harbour. Nagabhushanam and Mane (1975[3]) have recorded two spawning periods at Ratnagiri ; one from June to early September and the other a minor one in February-March. Kuriakose has stated that spawning in natural beds at Calicut starts in July and extends to November, with a peak in August to October (Personal Communication). At Kakinada the spawning season in the green mussel was observed to be prolonged from December to July with considerable differences between the years. Various stimuli which can be grouped as exogenous and endogenous have been suggested as important in controlling the reproductive cycles of marine lamellibranchs (Seed, 1976[9]). Among them temperature has received the maximum attention. Increase or decrease in temperature are reported to induce spawning. Salinity changes are listed as equally important in estuaries and tropical waters. At Kakinada, peak spawning period (January-May) coincided with rising water temperatures and high salinities and the mussels were mostly in resting condition during the period when the temperature showed a decreasing trend and the salinity was low.

Paul (1942[8]) observed that a 15.5 mm green mussel contained ripe ova. Rao *et al.*, (1975[3]) stated that some mussels measuring 15.5 mm had ripe gonads and spawned in the laboratory. They further stated that ripe gonads were found in almost all the mussels at 25 mm length. In the present study the mussels seem to reach sexual maturity at a higher size (28 mm).

The index of condition is generally related to the reproductive cycle. The low value of IC in June 1974 may be due to completion of spawning in majority of the mussels. After the spawning the mussels recover to normalcy and enter the resting stage to become 'fatty' which accounts for the high IC in July-December. In February 1975 the IC was low for which the reasons are not clear. The high IC values in June-November 1975 could partly be related to the resting condition of the gonad after spawning. The low IC in February 1976 may be attributed to the progress of spawning. Again the high IC values in May-September may be due to the resting conditions of the mussels. Thus during the non-spawning period the index of condition was high. In the absence of knowledge about the biochemical changes associated with the condition it is difficult to interpret the fluctuations in the index of condition.

It may be mentioned that the very low salinities observed in October 1974 and September-October 1975 may not be typical for the months since the data were collected only once in a month. It is well known that in estuaries salinity variation is related to tidal cycle and freshwater drain. Since no mass mortality of the mussels was observed, it is presumed that these low salinities prevailed for a very short duration so as not to adversely affect the mussels.

The best period for farming at Kakinada would be to seed the ropes hung from the raft during February-April and to harvest by September before the commencement of North-East monsoon.

# IV

# REVIEW OF OPEN SEA ENVIRONMENTAL CONDITIONS ALONG INDIAN COAST

D. C. V. EASTERSON
S. MAHADEVAN

The open sea environment in the east and west coasts of India plays a key role in deciding the future of mussel culture along Indian Coast. A review and analysis of the effects of various factors like wind, wave action, currents, tides, hydrology, upwelling and phytoplankton production are given.

## INTRODUCTION

The mussels are gregarious sessile bivalved molluscs with a wide range of distribution occurring in tropical, temperate and boral coasts. They favour damp ledges and platforms rather than verticals. There is a marked increase in number and size toward the submerged lower levels and grow on rocks, shingle and mud flats of mid littoral. Soot-Ryen (1955, *Allan Hancock Pacific Expeditions* **20** : 1-174[1]) considers that there are only three or four valid species of mussels with clear cut characters. All other species according to him are mainly geographical and ecological derivatives. Although one species of mussel may be cosmopolitan in distribution living in wider regimen of salinity and temperature, reproductive behaviour, metamorphosis and survival of larvae and adults of a population living in a particular geographical region are limited within a specific limits. Here too spawning is possible within a still narrower temperature and salinity conditions. Therefore the ecophysiological parameters between ecological races of mussels cannot be considered the same as a general rule. In this context the ecophysiological parameters of each ecological race of mussels are to be studied.

The total absence of mussel population in the south-east coast and the restricted distribution of the brown mussel to the extreme south-west coast cannot be explained easily to causes other than the absence of a combination of environmental parameters in the areas of absence. The presence or absence of a suitable hard substratum alone for the attachment of mussels does not seem to be the only criterion for mussel population thriving in the area. Further, variations in population density between apparently similar sites suggest physical factors alone are not the sole influence. Therefore, an appraisal of other environmental parameters appear to be necessary to understand their full impetus on mussel.

## PHYSIOGRAPHY OF INDIAN COAST

The shoreline from Bombay upto Karwar and that of Andaman and Nicobar Islands is irregular and crenulate. The deltaic and estuarine regions are marshy and protuberant and the rest is wavy and at times geometrically straight. In between Karwar and Janjira the coast is indented and rocky with moderate to high cliffs, notches, stacks, promontories, sea coves and embayments with offshore rocky projections. Similar evidences of submergence are also discernable in Andaman and

Nicobar Islands. South of Chilka lake, the regions of Vishakapatnam, Mahabalipuram, south of Tiruchendur, between Cape Comorin and Colachel and upto Quilon are rocky and often with cliffs.

### Shelf

In the shallow coastal and shelf waters the amount of organic matter reaching the bottom and thus available to attached forms like mussels is high for three reasons, namely phytoplankton production is higher than the further offshore areas, the distance through which material has to sink and hence the opportunity for it to be consumed in the water column is less and there is lateral transport from the areas of intensely high primary productivity in seaweed beds, coastal marshes and estuaries. The continental shelf is widest in the Gulf of Cambay being more than 400 km and narrowest off the delta of Krishna and Sunderbans, wherein it is less than 30-35 km. The eastern shelf is nearly one third of the width of the west. On the east coast, slope of the shelf is usually 21′ and in the west it ranges from 10′ near Cape Comorin to 1′ in Gulf of Cambay (Ahmed, 1972 *Coastal Geomorphology of India*, Orient Longmans Publish, 222 pp.[2]). The 10 fathom line is usually parallel to the coast while 5 fathom line which is of considerable importance for mariculture show considerable variation. The 5 fathom line generally lies very close to the shore in areas of high cliffs, near promontories and canyons. The Rann of Kutch is a dry swamp for most part of the year. The Gulf of Kutch and Palk Strait are shallow. The shelf is narrow and steeper in the south west coast from Cape Comorin to Trivandrum, wherein it is occasionally less than 30 metres. In east coast the 5 fathom shelf extends for 200 m to 23 km from Hooghly to Mahanadi and further south it is 200 to 1200 metres.

### Wind

The four seasons are : 1. Winter—from December to February, 2. Summer or premonsoon—from March to May, 3. South-West Monsoon—from June to September and 4. Postmonsoon in October and November. The bulk of rain is due to the South-West Monsoon which first establishes in the south-west coast of Kerala and progresses northwards upto Bombay and thereafter progresses towards Assam in land. The fifty yearly mean for establishment is May 29 while the earliest and latest dates are May 7 and June 10 (Ramdas, 1974, '*In-Ecology and Biogeography*' *in India* : 99-134, Dr. W. Junk, b.v. publishers, The Hague[3]). The coasts of Kerala, Konkan and Maharashtra which are important as mussel growing areas receive more than 250 cm of rain. The east coast, except the southern most sector also receives considerable rain ranging from 75 to over 125 cm during South West Monsoon. The South-West Monsoon starts retreating by the beginning of September and on further retreat transforms itself into North-East Monsoon during November and December. The rainfall during the North-East Monsoon in the months of September to November is not heavy compared with South-West Monsoon. During this time with the onset of winter, local heat and moisture give rise to tropical cyclones, most of which originate near Andaman Islands and move in westerly, north-westerly direction towards the east coast. The rains lash along with wind the Circar and Coromandal Coasts and the southern districts during October to December. Severe cyclonic storms originating in Arabian Sea and Bay of Bengal in combination with heavy rains occur on an average one or two during the transitional period of April-June and two or three in the postmonsoonal period. Tidal waves may also lash the coastal regions especially on the east coast during this period. (Ramdas, 1974[3]), Mani, (1974, In—'*Ecology and Biogeography in India*' : 135-158., W. Junk b. v. publn. The Hague[4]). Rao and Mahadevan (1958, *Andhra Univ. Mem. Oceanogr.* **2** : 33-47[5]) give a chronological table of storms in east coast during 1937 to 1954.

### Wave

In the west coast the most important wave generating winds are the South-West Monsoon and in the east coast it is the North-East Monsoon. The South-West Monsoon strikes the west coast orthogonally and on the Orissa Coast it is roughly parallel or slightly oblique and causes local littoral current. The North-East Monsoon is powerful on the coast south of Krishna delta during mid September to mid April and is mostly transverse to the shore, which stirs up bottom sediments and the water becomes turbid. The size of the wave is due to the velocity and the distance travelled (fetch) by the wave generating wind. Theoretically for a fetch of 5 to 500 km the height of the wave ranges from 0.9 to 6.2 m. Further for a wind of 5 to 20 metre per second the height of the wave could be 1 to 10 m. In India the monsoonal winds blow continuously for a reasonably long duration. Further the South-West Monsoon originates about the north of equator and travels a distance of about 3000 km and the North-East Monsoon about 1500 km before reaching the Indian Coast whereby facilitating a longer fetch (Ahmed, 1972[2]).

### Surface Currents

In Indian Ocean the current system is peculiar in the respect that the surface circulation in the North Indian Ocean is subject to alternating monsoons. Herein the system is comparable to that of the Pacific and Atlantic during the North-East Monsoon (November-March/April). Generally the currents go round Ceylon and so they do not affect drastically the Palk Strait and the Gulf of Mannar and do not enter Gulf of Cambay. The year round general pattern for Bay of Bengal has been worked out in detail (Ganapati and Sarma, 1958, *Andhra Univ. Mem. Oceanogr.* 1 : 168-192[6]). During November-April strong surface current enters into the Bay of Bengal through the Strait of Malaca and forms an anti-clockwise gyral restricted to south-west region, to which water from the equatorial region of the Indian Ocean is also drawn. In December the counter clockwise circulation slowly disappears with the establishment of Westerly Drift. In January in the head of the Bay a clockwise current appears having its southern limit north of 15°N, which spreads later towards south and gets established covering the Bay and remains so until April. For a short duration a counter-clockwise circulation is observable at the head during April which soon fades away. In May with the changing wind pattern deflection of water from the east coast of India south of 15°N in the north-easterly direction results. This East Drift continues upto June and July. Currents along the coast which is of our concern pertaining to the spread of larvae is north to south and turbid during November, December and on the opposite *i.e.* south to north and more transparent during February to May. In January it is transitory. In July/August a counter clock current originates at the head of the Bay having its centre around 'swatch of no ground' and spreads the entire Bay. In the same period off Madras and in the south-west of the Bay clockwise circulation is observable. In September the clockwise circulation off Madras fades off, the anticlockwise gyre still centered near the head is fully established and an anticlockwise circulation in the Gulf of Martaban is formed for a short duration. In addition, a clockwise circulation east of Nicobar group of islands is also present. During October, while the gyre of Gulf of Martaban disappears a counter clockwise circulation appears centered off Madras. Thus there are two anticlockwise and one clockwise currents present in October. In November, clockwise gyre positioned east of Nicobar and the anticlockwise current centered off Waltair which have by now become weakened fade away, thus resulting in one anticlockwise circulation within the whole of Bay having its centre about 10°N and 85°E.

In the Arabian Sea the circulation is clockwise with a strong southward drift along the west coast of India especially between Calicut and Karwar during South-West Monsoon. With the weakening of South-West Monsoon the current too becomes weak and the northward coastal current associated with sinking occurs along the west coast by December.

*Tides*

The tides are generally semidiurnal in east coast mixed with preponderance of semidiurnal in the west coast. As usual the range between the high and low tides is larger at Spring, *i.e.* close to full and new moon and narrower at neap *i.e.* at first and the third quarter. It is usually maximum at solstices and the diurnal inequality, namely the differences in height of successive highs is generally maximum about the solstices (June and December). The tidal range is near the annual average about equinoxes (March and September), when the diurnal inequality is the minimum. The tidal amplitude is low near the Cape Comorin and it increases with latitude. The amplitude in metres during the spring and neap is as follows : Daman 4.72, 2.16 ; Bombay 3.66 and 1.44 ; Ratnagiri 1.74 and 0.94 ; Vengurla 1.44 and 0.78 ; Karwar 1.44 and 0.67 ; Calicut 0.80 and 0.33 ; Cochin 0.63 and 0.23 ; Quilon 0.61 and 0.24 ; Tuticorin 0.70 and 0.16 ; Madras 1.01 and 0.41 ; Kakinada 1.34 and 0.53 ; Vishakapatnam 1.43 and 0.54 ; and Diamond Harbour (Calcutta) 5.00 and 2.28. In nature, though the zonation of the mussel varies, to a certain extent generalisation resulting in so called 'Mytilus line' is possible. The upper limit of the 'Mytilus line' varies in position and form in the beginning of settlement and with growth becomes sharp. In slopy damp surface it is in line with mean high water neap and in vertical wave beaten facets may lie above extreme high water spring. Where such a line exists the main bernacle population is restricted to the upper part of eulittoral zone (Lewis, 1964, *Ecology of rocky shores, Hodder & Stoughton, London* : 323 pp[7]). Immediately below the line the mussel population is dense enough to exclude all barnacles and limpets. A characteristic feature is the tendency of the adult mussels to form discrete, irregularly shaped patches. The general location of the mussels is the eulittoral zone which is below extreme high spring and above extreme low spring. In heavily predated and fished areas presence of mussel beds a few metres below the tide mark is not uncommon. Rao *et. al* (1975, *Indian J. Mar. Sci.*, 4 : 189-197[8]) have recorded *P. viridis* in Dona Paula, Goa 8 m below the level of low water spring.

*Hydrology*

The Bay of Bengal is surrounded on all the three sides by land and nine major rivers totally empty about

1300 million acre feet of freshwater per year into it along with huge quantity of silt. Therefore salinity at surface and in the coastal regions is brought low. The salinity in the head of the bay varies from 17-24‰ and at times during monsoon it may go still low. The yearly average salinity is 30-33‰ (Pannikar and Jayaraman, 1966, *Proc. Indian Acad. Sci.*, **64** (5): 231-240[9]). In the coastal waters off Waltair it is maximum—34.7‰ during March to May and minimum during October, November, 24.4‰. (Ganapati and Rao, 1959, *J. mar. biol. Ass. India*, **1** (2): 224-227[10]). At times it may go as low as 21.81‰ during December (Mojumdar 1967, *J. mar. Biol. Ass. India*, **9**(1): 164-172[11]), depending on the intensity of North-East Monsoon. In the north at Saugor the salinity is high during March to June and lowest (17.47‰) in October. In Madras, surface salinity ranges between 19.25‰ in November to 28.13‰ in June while at 8 fathoms 34.63‰ in March and 26.24‰ in November. Mandapam area receives little rain during South-West Monsoon and further the influence of drainage from the north is also minimum. Therefore the salinity is high during August, September 36.02-36.47‰ and minimum during December, January, 27.47‰-29.50‰. The salinity minimum is ascribable to the only rainy season which is during the middle of October to November and the influx of low saline water from the north due to the change in current system with the onset of North-East Monsoon. (La Fond, 1958, *Andhra Univ. Mem. Oceanogr.*, **2**: 12-21[12]). Further during South-West Monsoon high saline water enters from south due to currents which contributes to rise in salinity (Jayaraman, 1954, *Indian J. Fish.*, **1**: 345-364[13]).

In Saugor Island the waters are warmest during August to October averaging about 29.0°C and coolest during January to March (23.2°C). In Waltair sea, surface is warmer during June to September (29.5°C) and cool in January, February (24.92°C). The temperature in the coastal water of Madras ranges from 26.2-29.4°C. It is usually high during April-June and again during September-October (29.2-29.4°C) and cooler during December. Since temperature plays a vital role in the reproduction of molluscs, the short period within which mercury drops is noteworthy. In the far south at Mandapam the surface water is warmest during April, May (29.0-29.7°C) falls by one or two degree in the following months and again it is elevated during August to October (28.1°C). January is the coolest (25.2°C) (La Fond, 1958[12]).

The dissolved oxygen in the surface water of Madras ranges between 2.5-5.0 ml/l, while at Waltair and Mandapam 2.96 to 5.59 ml/l and 3.5 to 4.6 ml/l respectively. In Bay of Bengal silicates are usually high while inorganic phosphate is low. Andaman Sea water is reported to be rich in phosphate, probably due to volcanic activity. In Waltair, inorganic phosphate is higher during December, January (1.66 μg-at P/l) and low in March, April (0.27 μg-at P/l). The average maximum for silicate in Waltair is 29.91 μg-at Si/l during September, October and minimum, 7.0 μg-at Si/l during January, March, (Ganapati and Rao, 1959[10]).

Though hydrology of Arabian Sea has been studied in detail the main emphasis had been on vertical profile. Since mariculture of the molluscs is done very close to the shore information about the chemistry and temperature of the coastal waters is needed most. The near shore waters are influenced by the monsoonal drainage and currents. In the west coast upwelling is very close to the shore and oceanic conditions have been observed to be prevalent close to the shore.

The surface temperature shows a bimodal fluctuation and the sea is generally warmer in the south. The maxima and minima vary for different years. Five yearly average for Karwar region show that the yearly temperature range is 24.0 to 32.6°C, with maximum in April/May and minimum in August/September. Primary and secondary peaks generally occur in May and November respectively while in August and January primary and secondary low occur (Noble, 1968, *J. mar. biol. Ass. India*, **10** (2): 197-223[14]). The physiology of maturity and spawning in molluscs are influenced by spurt in fall and rise of temperature. The difference between the mean monthly temperatures for the following months are above one degree; February-March + 1.15°C; March-April + 1.35°C; May-June − 1.81°C; and July-August − 1.39°C. (Calculated from Noble, 1968[14]).

Salinity is unimodal, high during summer (April-May) and low during the South-West Monsoon. In certain years during December-January a slight fall has been observed particularly south of Calicut. Since North-East Monsoon is little felt here this low has been attributed to north-west coastal current which brings in low saline water from the south-east coast of India, Subramanyan, (1959, *Proc. Indian Acad. Sci.* **50** B(4): 189-252[15]). The near maximum salinity along west coast is 38.4‰ in May and at times salinity values as high as 40.8‰ also been recorded off Bombay. Further there is a tendency for salinity values to increase towards north, which may be due to the high saline Red Sea water entering and the low precipitation level in the bordering, north-west, north and north-east arid regions. Further due to the coastal currents during the South-West Monsoon the drainage from the rivers are usually pushed south along the coast, while to the northern coast currents bring high saline waters.

Dissolved oxygen is usually 3.45 to 5.13 ml/l along the west coast. It is usually high during rainy season and very low while upwelled waters move towards the coast. The inorganic phosphate along the coastal waters along the west coast is bimodal. The values are high during February-April and June-October. In waters off Bombay average value is 0.21-0.35 $\mu$g-at P/l while values around 1.15 $\mu$g-at P/l also been recorded. In Calicut it may go as high as 1.92 $\mu$g-at P/l and usually ranges 0.13 to 1.68 $\mu$g-at P/l. At Karwar it varies between 0.12-2.42 $\mu$g-at P/l and at times 4.17 $\mu$g-at P/l also has been observed. Unlike phosphate, silicates show a unimodal seasonal fluctuation. In Bombay, silicates are usually high during January-March, in Karwar July-August and at Calicut July-September. Silicates are usually very high near river months—260.0 $\mu$g-at Si/l near Korapuza river mouth (Rao and George, 1959, *J. mar. biol. Ass. India,* 1(2) : 212-223[16]) and near Kali river it is 149.25 $\mu$g-at Si/l, Noble, (1968).[18] Generally silicates are above 5.0 $\mu$g-at Si/l at Calicut and over 1.2 $\mu$g-at-Si/l in Karwar Coast.

*Upwelling and production of phytoplankton*

Upwelling is a phenomenon in which deeper oxygen deficient, colder, and nutrient rich water comes up. This is a very important factor ecologically not only because it enriches the euphotic zone, whereby production is geared up along the marine trophic levels, but also the cold water has greater dissolving power of carbonate sediments, whereby upwelling introduces an abnormal rise in calcium carbonate compensation depth. This is a factor of importance for shell bearing organisms like mussels wherein calcium carbonate is a major component.

Outside the limits of the Indian Coastal waters upwelling has been reported during the North-East Monsoon between 50°E and 110°E around mean latitude of 7°S and further north of equator upwelling zones are scattered and are at 5°N to 6°N around 58°E to 70°E. During South-West Monsoon along the Somali Coast of Africa, at about 9°N, strong upwelling occurs wherein, like the Peruvian upwelling, surface temperature drops as low as 13-14°C.

During pre-and early South-West Monsoon season upwelling occurs extensively along the west coast of India, with the maximum intensity in Calicut-Karwar regions. La Fond is of the view that off Godavari delta in the Andhra Coast around March-May upwelling occurs while sinking of the surface water happens during September-November period (La Fond, 1954, *Andhra Univ. Mem. Oceanogr.*, **1** : 94-101 and 117-121[17]). Further there are evidences to show upwelling East of Andaman group of islands.

Primary production along the west coast of India is high and is comparable with any other high productive area, while that of the east coast is not so. Average production in the west coast within 50 m depth is estimated to be 1.19 gC/m$^2$/day. Off Alleppey, during the postmonsoon period, production ranges from 0.38-1.11 gC/m$^2$/day. In the wadge Bank the highest value recorded for the Indian coastal region is 4.55 gC/m$^2$/day while at a station 38 m deep it was 2.09 gC/m$^2$/day. In Gulf of Mannar and Palk Bay there are two peaks of production, one in April-May and another in October. On an average the estimated production is 3.0gC/m$^2$/day. The annual production works out to about 230gC/m$^2$/year for eastern shelf while that of the west coast within 50 m depth it is 434 gC/m$^2$/year. An extensive treatment of production levels has been given by Nair (1970, *Bull. cent. mar. Fish. Res. Inst.*, **22** : 1-56[18]).

Phytoplankton biomoss show, on the south-east coast, peaks in March, May and October or February, August and November depending on the setting and the intensity of the monsoons. At Madras there are two distinct peaks one in April-June and a minor one in November-December, while in Waltair phytoplankton blooms once in April-May and in the west coast during June-August period. According to Subramanyam and Sarma (1960, *Indian J. Fish.*, **7** : 307-336[19]), 37 phytoplankters, of which 1 blue green alga, 7 dinoflagellates and the rest diatoms, are known as mass forms, which contribute 70-80% of the total biological process in west coast. Standing crop of phytoplankton of east coast is said to be not even 1/4 of the west coast (Jones and Banerji, 1979, In . *Proc. Symp. Living Resources of the Seas around India,*'*CMFRI*: 1-17[20]). In the inshore waters of west coast during South-West Monsoon phytoplankton standing crop average for a period of five years for net hauls in terms of number has been estimated to be 29 $\times$ 10$^6$ cells/l. Minimum is to be found during November when it is about 2$\times$10$^5$ cells/l. The nanoplankton which are 2.20 $\mu$ in size vital for mussels as larval feed and so also for the adults have been estimated to range from 30-85% while at times may even be of the order of 96%. In terms of pigment units 248000 Harvey Units/m$^3$ has been recorded during South-West Monsoon.

# V

# REVIEW ON PRODUCTION OF MUSSEL SEED

K. ALAGARSWAMI

Production of mussel seed requires priority attention for the expansion of mussel culture as an industry in India. Procurement of adequate seed from the wild beds even for the current experimental programmes is faced with problems. Two lines of approach have been suggested for enhancing seed production.

The first approach is to harness the production of seed in nature through three ways, namely exploitation of the mussel seed settling on the stone embankments and groynes laid as an anti-sea erosion measure, enhancement of spat fall on artificially laid collectors in the farms; and selecting areas where the current system and other environmental factors are conducive for larval transport and settlement of the pediveliger stage in the sites where breeding reserves of adult mussel are provided.

The second approach is through hatchery system. Although mussel hatcheries do not exist in Europe where world mussel production is concentrated in view of plentiful supply of natural seed, it is imperative for India to develop the hatchery technology as the natural seed availability is severely limited.

While discussing the above aspects of seed production, the paper reviews the larval history of mussel and the technologies available for induced spawning and larval rearing, with particular reference to larval food and diseases.

## Introduction

Production of seed or young ones is one of the vital aspects of any farming activity either on land or in water. The ontogeny of marine organisms is such that the environment, which is dynamic and ever changing, plays the key role in the dispersal of the population and the success or failure of a brood in reaching its appropriate destination. This explains the uncertainty of availability of young ones for any mariculture operation and the need for human effort to ensure seed production through culture.

During the last few years technologies of mariculture have been developed in India for several economically important organisms but commercial culture can become truly successful only upon the availability of viable technologies for the production of seed. Culture of the green mussel *Perna viridis* and the brown mussel *P. indica* is one of the areas where considerable advances have been made on the techniques of farming but the basic seed material has always been obtained from the wild. Removal of seed mussel from the beds for farming comes in conflict with the interests of the natural fishery. The mussel beds in Europe—in Spain, the Netherlands, France and Italy—are extensive and spatfall has always been abundant. This is one of the reasons for the absence of mussel hatcheries in these countries. On the other hand, the mussel beds on the Indian coast are limited and scattered, and rocky surface area for spatfall is also restricted. The natural seed resource on the beds cannot support mussel culture industry of some magnitude. These factors make it imperative to develop techniques for seed production.

## Larval History of Mussels

The reproductive 'strategy' of mussels is one of high fecundity, small eggs, external fertilisation and a pelagic larva that feeds on the phytoplankton (Bayne, 1976 *Marine mussels: their ecology and physiology* Camb. Univ. Press, 506, pp.[1]). The fecundity of the Indian species of mussels has not been worked out. However, some estimates are available for the European mussel *Mytilus edulis* which, though not accurate, may give an indication of the order of fecundity. Bayne (1975, in *physiological ecology of estuarine organisms* (Ed. Vernberg, Univ. Calif. press, 259-277[2]) estimated half a million eggs per female of 4-5 cm in shell length. At the other extreme, Fretter and Graham (1964, *Reproduction in physiology of Mollusca*, Ed K. M. Wilbur and C. M. Yonge, Acad. press, N.Y., 127-164[3]), quoting Pelseneer gave an estimate of 10 million eggs.

The larval development of *Perna viridis* has been described by Rao *et al.* (1976, *Indian J. mar. Sci*,, **5** : 113-116[4]) and that of *P. indica* by Kuriakose (1980, Abs. 169, *Symp. Coastal Aquaculture*, Mar. Biol. Ass. India[5]). As reviewed by Bayne (1976[1]), development of mussels of other geographical regions has been studied in detail by several workers and the larva of *M. edulis* is one of the most frequently described of all lamellibranch larvae. In general, subsequent to external fertilisation, the embryo, through a process of cleavage and gastrulation, develops into the first stage of larva called trochopore, thence to a veliger. On the secretion of the larval shell, prodissoconch I, by the shell-gland of the veliger, the larva attains the straight-hinge or D-shaped stage. The mantle of the veliger then secretes the second larval shell, prodissoconch II, and the larva is called a veliconcha. As the larva approaches metamorphosis, a pedal organ develops and the larva with its functional foot is called the pediveliger. It is at this stage that the larva descends down from the plankton to sea bottom. Through a pattern of swimming and crawling behaviour it selects the substratum and attaches itself by the secretion of byssus threads after which metamorphoses, when a series of changes takes place in the organ systems towards adult organisation becomes possible. After metamorphosis, the adult shell dissoconch is secreted. The young post-larva with adult shell characteristics is described as a plantigrade (Bayne, 1976[1]). It derives the name spat and the process of settlement of a brood of spat is called spatfall.

The spawned egg of *M. edulis* is 68-70 μm in diameter and during the veliconcha stage there is considerable growth in size (from 110-250 μm in shell length); at 220-260 μm the larva acquires a pair of pigmented spots and subsequently, with the development of a foot, becomes a pediveliger (Bayne, 1976[1]).

Kuriakose (1980[5]) has observed that the ripe ovum of the brown mussel *Perna indica* measures 55 μm and at the early pediveliger stage the larva is 300 × 260 μm. When the larva is about 10-12 days after fertilisation, the pediveliger (325 × 265 μm) settles down on a substrate. The spawned eggs of the green mussel *P. viridis*, as observed by Rao *et al.* (1976[4]), measures 45-50 μm in diameter and the pediveliger is about 300 μm in shell length, the stage being reached after the 16th day from fertilisation.

The time required for development to various stages depends on the species and the environmental factors, of which temperature is the most significant. The mussel larvae (in temperate waters) require between 15 and 35 days to grow from fertilisation to the pediveliger stage when settlement and metamorphosis become possible, and a larval period of 3 weeks is a reasonable approximation (Bayne, 1976[1]).

Considering the fecundity estimates available for mussels, the survival rate from egg to adult stage is very low. In the case of marine bottom invertebrates, Thorson (1946, 1950) and Mileikovsky (1971), as cited by Bayne (1976[1]), have estimated that mortality during the free-swimming larval period is considerable, possibly approaching 99%. The main mortality factors have been identified as predation, excessive dispersal to areas where suitable sites for post-larval survival do not exist and death due to extreme physical factors. Excessive larval dispersal may cause the fluctuations and uncertainties of spatfall in the natural beds.

## Utilisation of Wild Seed in Mussel Culture

Given the reproductive strategy of mussel, as indicated earlier, the pelagic larvae in different stages of development can be expected to be present in abundance in the coastal waters during the spawning season. Since the natural mussel beds are restricted to a few rocky patches it can be presumed that only a fraction of the larval population gets a chance to settle on these beds and the rest suffers mortality due to various reasons. Spatfall on the beds is more or less abundant and Jones (1950, *J, Bombay nat. Hist. Soc.*, **49** (3) : 519-528[6]) observed that 'there is absolutely no dearth for mussel spat'. Appukuttan (pers. comm.) has estimated a density of 10-15 kg of mussel seed (shell length 20-35 mm) per square metre of rocky surface in good collection grounds near Vizhinjam. The current experimental and demonstration mussel farms in India largely use the seed collected from the natural grounds (Calicut-Tellicherry, Vizhinjam-Neendakara ; Ennore-Cuddalore). However, seed supply from these grounds cannot meet requirements for expansion of mussel culture as an industry. The experimental programme on the east coast near Madras already faces the problem of seed inadequacy. It has also been stated earlier that collection of seed from the exploited natural beds comes in conflict with the interests of the existing sustenance fishery. Therefore it is necessary to organise a system of seed production for commercial use.

Based on current knowledge on natural seed production, three approaches seem possible. The first one is the profuse spatfall that takes place on granite embankments and groynes laid along the coast of central Kerala for prevention of sea erosion. Jones and Alagarswami (1973, *Proc. Symp. Liv. Res. Seas around India*, 641-647[7]) have drawn attention to the remarkable feature of carpet-like settlement of young mussels of *P. viridis* on these rocks. Later, Nair *et al.* (1975, *Indian J. Fish.*, **22** (182): 236-242[8]) surveyed the area between Shertalai and Cochin and found the density of spat to be 220-248 per 100 cm² on the rocks submerged most of the time and 112-170 spat per 100 cm² in less favourable, surroundings. Natural beds of mussel in this region are not known and the settlement must be from the pelagic phase larvae dispersed in the coastal waters. Since the peak mussel spawning along Kerala coast is during the south-west monsoon (July-August) it is not easy to collect the spat by other means such as laying spat collectors. The stone embankments can form one source of supply of seed for mussel culture.

Secondly, spatfall occurs in the mussel culture farm itself at Vizhinjam and Calicut and it is collected on the frills of split nylon ropes and other cultch materials (Appukuttan, 1980, *Mar. fish. Infor. Serv. T & E. Ser.*, **16** : 13-16[9]). At Vizhinjam the spat collected in the farm is also used for culture but the quantity is inadequate to meet the seed requirements of the farm. There is need for improvement of the techniques of spat collection towards increasing seed production by this method.

The third possibility is production of seed in the farm by keeping a breeding stock of mussels as has been demonstrated in the farm near Madras (Rangarajan, 1980, Abst. 164, *Symp. Coastal Aquaculture.*, Mar. Biol. Ass. India[10]). Dense spatfall on tiles has been obtained by this method. It is probable that the coastal current system at the site of farm (Kovalam) is favourable so that the pediveliger larvae in the pelagic phase reach the farm area for settlement. It is also worthwhile examining the principle of artificial biocoenosis by the application of which animals with gregarious habits can be concentrated (Achari, 1980, Abst. 29, *Symp. Coastal Aquaculture.*, Mar. Biol. Ass. India.[11]).

These three possibilities need further consideration and intensive experimental work with a view to establishing mussel seed farms, even if seasonal, for supply of seed to culture farms. Economic considerations will weigh upon such attempts, although technical feasibility may be established.

### Artificial Production of Seed

Artificial seed production has the advantage of assured seed supply and stock improvement through genetic manipulation. During the last three decades there has been a growing interest in the world for the production of seed of cultivable molluscs through hatchery system. Loosanoff and Davis (1963, *Adv. mar. biol.*, **1** : 136[12]) and Imai (1977, *Aquaculture in shallow Seas* ; Oxford & IBH Publishing House, New Delhi, 615 pp[13]) have produced comprehensive treatises on the subject. Although techniques have been developed for several species, commercial hatcheries exist only for a selected few species such as the edible oysters, clams and abalones (Davis, 1969, *Trans. American Fish. Soc.*, **98** (4): 743-750[14]). Ukeles (1975, *Proc. First Internat. Conf. Aquacult. Nutrition*, 127-162[15]) mentions that there are about 35 pilot plants and commercial shellfish hatcheries in the United States and a considerable number abroad. Mason (1976, *Marine mussels : their ecology and Physiology* (Ed. B. L. Bayne), Camb. Univ. Press ; 385-410[16]) considers that the cost of rearing mussel larvae could not be supported owing to the lower price fetched by mussels than oysters and that for this reason mussel cultivation is based on the collection and raising of naturally settled spat. Seed availability had not been a restrictive factor for mussel culture in Europe. According to Korringa (1976, '*Farming of marine organisms low in the food chain* ; Elsevier Sci' Publ. Amsterdam, 264 pp.[17]) 60 to 70% of the seed used for mussel farming in Galicia, Spain, comes from the settlement of young mussels on the rocks in the intertidal zone and the rest from spat collection with the aid of ropes hung from the floating parks. But inadequacy of natural seed is a constraint in India in view of the nature of distribution of the mussel beds. It would, therefore, be necessary to develop capability for hatchery production of seed. Korringa (1976)[17] states that though it is still uncertain whether hatcheries will ever play an important role in providing shellfish farms with the seed stock they need on a truly commercial scale, it should be realised that the development of these techniques may prove to be of the greatest importance for the future of these industries. The process of artificial production of seed is generally common for many species of bivalves as is seen from the fact that, in U.S.A., an oyster hatchery switches over to clam seed production easily. The techniques of seed production of mussels and constraints thereof are briefly outlined below.

*(a) Induced spawning*

Field (1922, *Bull. Bur. Fish. Wash*, **38** : 127-260[35]) who is one of the earliest workers on the biology of mussel, found that rough handling of *M. edulis*, such as shaking them in a dish of sea water, would induce spawning. Iwata (1949, *Bull. Jap. Soc. sci. Fish.*, **15** : 439-442[18], **15** : 443-446[19]), (1951 **17** (1) : 15-18[20]), (**17** (3) : 91-93[21]), (**17** (3) : 94-95[22])' (67 : 96-97[23]), (1952 **17** (6) : 157-160[23]) *b Biol. J. Okayama Univ.*,) **1**(1-2) : 1-11[23]) has done considerable work on the spawning of *Mytilus edulis*. He (1949 [19]) reported that spawning could be induced by stimulation. A stimulation by 20 volts of 5 seconds duration was sufficient to induce the discharge of gametes from every ripe mussel.

Iwata (1951[22], 1952[23]) conducted experiments on chemical stimulation of spawning by dipping the mantle piece of *M. edulis* for 10 minutes in M/2 aqueous solution of $NH_4Cl$ and M/3 solution of $BaCl_2$ and found them effective. Morse *et al.* (1978, *Proc. World. Maricult. Soc.*, **9** : 543-547[24]) used hydrogen peroxide in an alkaline medium to induce spawning in *M. edulis* and *M. californianus*.

Thermal stimulation has also been employed by some workers on mussels. Iwata (1951[23]) found that spawning could be induced in *M. edulis* by a sudden rise of temperature from 7° to 15°C. Rao *et al.* (1976[4]) obtained spawning in *Perna viridis* by raising the temperature from 26.5°-28.0°C to 32°-35°C. Bayne (1965 *Ophelia*, **2**: 1-47[25]) observed adult *M. edulis* in a condition responsive to spawning by raising the temperature from 7° to 13°C over 25-30 days. Hrs-Brenko (1973, *Aquaculture* **2**: 173-178[26]) was successful in conditioning mussel for spawning by raising the temperature from 1° to 18°C within 13 days.

Loosanoff and Davis (1963[12]) failed with the usual methods of spawning induction on *M. edulis*. They found that a simple method of gently touching the adductor muscle several times with the point of a needle or inserting a small wooden wedge between the shells to stretch the adductor was very effective to induce spawning in the species.

*(b) Rearing of Larvae*

Compared to the work on the culture of larvae of oysters and clams, rearing of mussel larvae has received very little attention. Loosanoff and Davis (1963[12]) have spawned *M. edulis* in the laboratory and reared the larvae to metamorphosis and settling. They fed the larvae with an algal mixture consisting chiefly of *Chlorella* and other green forms and the larvae grew remarkably well. They found that there were large variations in size even among larvae that originated from the same parents and that the size at which the larvae metamorphosed varied almost by 90 μm. Hirano and Oshima (1962), as cited by Imai (1977[13]), used *Chlamydomonas* sp. as food for *M. edulis* larvae. Rao *et al.* (1976[4]) reared the larvae of *Perna viridis* with cultures of *Chlorella, Tetraselmis gracilis, T. chui* and *Synechocystis* sp. and found that growth was good when the larvae were fed on a mixture of *T. gracilis* and *Synechocystis*. The larval rearing was carried out in finger bowls and no larval settlement had occurred although the larvae were reared up to 56 days (Rao *et al.*, 1976[4]). Kuriakose (1980[5]) succeeded in getting the larvae of *Perna indica* metamorphose and settle on ground glass and fragments of filamentous algae without artificial feeding. The work so far carried out at CMFRI (1978 *Anuual Report*, 78., CMFRI., 115 pp.[27]) on the rearing of larvae of *P. indica* at Vizhinjam and *P. viridis* at Madras have given only partial success up to the straight-hinge veliger stage.

The experiment of AQUACOP (1980 Abstr. 95, *Symp. Coastal Aquaculture*, Mar. Biol. Ass. India[28]) on mass production of green mussel *Perna viridis* in Tahiti (French Polynesia) is of great interest for tropical mussel culture, particularly to India where the same species is of considerable importance. Feeding the mussel larvae with *Chaetoceros gracilis* and *Isochrysis* sp. AQUACOP (1980[28]) had achieved from 30 to 60% spat settlement on nylon meshes between the 15th and 20th day. This is one of the very few works on hatchery development for seed production of molluscs in the tropical waters.

*(c) Problems of hatchery production*

The major technical components of any shellfish hatchery programme include spawning of adults and handling the young up to a stage when they can be transplanted to the natural beds or culture farms. Several methods for inducing the mussel to spawn are available as mentioned earlier and a concerted effort on use of these techniques on the Indian species can quickly determine an effective and cheap method. It is in the second area of handling the larvae through development to settlement that success would depend on several factors. These are water quality, larval food and disease control. These problems have been reviewed in detail by several workers (Loosanoff and Davis, 1963[12] ; Davis, 1969[14] ; Loosanoff, 1971 *Proc. Conf. Artificial Propagation of Commercially valuable shelfish-oysters*, College of Marine Studies Univ. Delaware ;[29] Ukeles 1971, 1975 *Proc. Conf. artificial propagation of Commercially valuable shelfish oysters ;* College of Marine. Studies, Univ. of Delaware[30]). The sea water used for larval rearing has to be assessed for its freedom from suspended matter and pollutants, temperature, salinity and pH range and nutritional value as each of these factors may play a critical role. Ukeles (1975[15]) states that observations in laboratories, pilot plants and commercial hatcheries emphasize the importance of sea water quality to the successful culture of bivalves.

Feeding the bivalve larvae is a major constraint in the hatcheries. On top of the list of problems in the bivalve larval rearing laboratories and commercial aquaculture plants is the one of providing an optimal nutritional support that is efficient and economical for culturing animals under controlled conditions (Ukeles, 1975[15]). The naked flagellates *Isochrysis galbana* and *Monochrysis lutheri* have almost become the universal food for the early larval stages of most of the bivalves in rearing. Bayne (1965[25]) reared *M. edulis* larvae on the diet of *I. galbana*. Mussel larvae have also been successfully reared using *Chlorella* (Loosanoff and Davis, 1963) or *Chaetoceros* (AQUACOP, 1980[28]). In the field of larval nutrition considerable effort is required in India to identify suitable food organisms for the different stages of larva and culture them on a mass scale.

Disease of larvae, although little understood, can cause heavy mortalities. Davis *et al.* (1954, *Science*, **120:** 36-38[31]) have described how a fungus can occasionally acquire epidemic proportions in some larval cultures, killing most of the larvae in 2-4 days. Vishniac (1955, *Mycologia*, **47:** 633-645[32]) found that the fungus *Sirolpidium zoophthorum* was responsible for the above mortality among clam larvae. Guillard (1959, *Biol. Bull.*, **117:** 258-266[33]) isolated two virulent bacterial clones, one of which appeared to be a species of *Vibrio* and the other of *Pseudomonas*. Tubiash *et al.* (1965 *J. Bacteriol*, **90:** 1036-1044[34]) found bacillary necrosis among larval and juvenile molluscs. Ciliates are commonly found among dead and moribund larvae of bivalves in the culture vessels.

Loosanoff and Davis (1963[12]) found that precautionary measures consisting of cleanliness of the rearing tanks and ultraviolet treatment of the seawater can to a large extent control fungus infections. They observed that antibiotics at low concentrations such as streptomycin, aureomycin, Combistrep (a mixture of dihydrostreptomycin and streptomycin sulphate) and Sulment (sulphamerazine) increased the rate of growth of clam larvae. Loosanoff and Davis (1963[12]) have also suggested control measures against fouling and competing organisms. The above problems are common to larval rearing of any bivalve and, with regard to mussel, detailed work will become necessary as progress is made in larval culture technology.

# VI

## TECHNOLOGY OF MUSSEL FARMING

K. NAGAPPAN NAYAR
S. MAHADEVAN

A review of the mussel seed collection in the various countries of the world shows that the dependence is on natural seed stock. The rope culture technique for farming mussels appears to be universal although in countries like France and Philippines other systems are followed to grow mussels in the tidal flats. Progress of ' rope culture ' technique adopted in India is given.

### Introduction

The major mussel producing countries are Spain, the Netherlands, France and Italy each with its own system of culture contributing 93% of the total 328,500 tonnes produced throughout the world by farming. (Pillay, 1978 in *Advances in Aquaculture* : 1-10. Fishing News Book Ltd., England,[1] Yugoslavia, Chile, Philippines, Federal Republic of Germany, Korea, New Zealand and Tunisia contribute the rest. There are other countries like Russia, U.S.A., U.K. (Scotland and Ireland) Venezula, Australia and India where culture practices have begun yielding fruitful results. At this stage it would be of interest to know the methods followed in many of these places for the collection of seeds and culture. It may be stated that in mussel culture, as in oysters, wild source supply is being depended upon by culturist forcing them to operate in close proximity to established, reliable high productivity spawning and settling grounds where young ones may be recruited from natural stocks. An account of the seed collection methods and system designs developed by each country fitting with the environmental conditions is given to understand the present status.

### Spain

During the breeding season, April-September, seed collectors such as loosely woven and heavily tarred ropes, 12-15 cm diameter made of spart grass or nylon are lowered from the rafts used for growing mussels. 12 mm wooden spacers are used to avoid slipping down of mussels. The ropes are 10 m long and well above the bottom. In the event of failure of spat settlement seed collection from natural beds from rocky shores is resorted to.

Seed mussels thus collected are tied round ropes in clumps using a fine, large-meshed rayon netting which disintegrates in a few days time leaving the mussel seed firmly attached to ropes. These ropes are then suspended from rafts floated over ' Rias ' (sunken river beds). The growth here is fast. When the ropes become heavy, exceeding a certain limit, the mussels are thinned out and distributed over greater length of rope. The harvested mussels are sold to canneries or placed in purification tanks before export.

### The Netherlands

Government allows farmers to collect mussel seed from public seed beds during certain limited periods. The natural seed that settle at the bottom of the shallow sea-bed are gathered by special mechanical mussel boats with dredging arrangements. One dredge load will bring about 500 kg of mussels. At times 15,000 kg of mussel seed are landed per day. A mussel boat can hold up to 50,000 kg of seed mussels. Mussels collected thus are transferred to private plots leased out to individuals and allowed to grow at the bottom. The half-grown mussels are later transplanted to plots for further growth and fattening. Thus the system is a semi-culture.

## France

Initially, rows of poles called 'Bouchots', interwoven with branch-wood are placed in the intertidal zone to allow mussel seed to settle during breeding season. When the seed grow slightly bigger they are transferred to 'bouchots' placed at somewhat higher in the same zone. Nowadays 'bouchots' are obsolete and forbidden since they cause silting. At present seed collection is carried on by supporting loosely woven cocoa fibre ropes, 13 mm diameter and 3 m long in the intertidal area near natural beds during May-July. Seed settlement takes place in 2 weeks time, between the rope strands. These ropes are removed and wrapped round Oak poles, 15-20 cm thick, 4 m long and driven 2 m into the ground. The mussels attain marketable size on the poles.

## Italy

Mussel seed is collected from natural beds as well as by employing spat collectors. Seed collection from beds is done by scraping with the aid of 'raschiette' (sharp blade). The season of collection is from April-May and about 100-1000 kg are collected per day per boat of two persons. Special spat collector ropes 'filimbindo' of 25 mm diameter are also used. This consists of 3 intertwined strings of polythene hung horizontally in parks called 'Vivai', with the help of thin ropes. For a park of 40×25 m, 135 m long rope is used. Seeds which settle in January are removed by April-May and restrung in ropes to be hung in the park for further growth. Formerly ropes of sparto grass were used for twisting round clustered mussels. Now 'Netlon' netting is used. The net is closed with synthetic strings and hung from a horizontal rope in the park. These are called 'Pergolari'. A park of 1000 $m^2$ carries 715 pergolari. These are periodically inspected and if found heavier the nets are cut into small sections of 1 m length and mussels transferred to thick gauze nets for further growth to marketable size. Periodically the mussels are exposed for 2 hr to kill larval fouling community settling on shells.

## Philippines

To collect mussel seed, extensive bamboo structures are erected in places with muddy bottom. Spat collection and growing are combined since no transplantation is done once spat settle down. The mussels grow to marketable size in 6 months time. Divers pull out the planted poles, strip them clean of grown mussels on board a boat. Well graded and cleaned, the stock is transported rapidly to market. Formerly 'wigwam' method using 8 long bamboo poles in a circle of 4 m dia. around a central pole and nailed together with short horizontal bamboo braces just above low water mark was followed using central pole as pivot. Slender bamboo poles were thus kept inside the frame. This was found unsuitable resulting in overcrowding of mussel and poor growth. This has been replaced now by 'stage' system of rectangular bamboo structures. Culture is done subtidally in sheltered sites.

Bardach *et al.*, (1972, *Aquaculture:* 868 pp. Wiley-Inter-science[2]) report that mussel seed already settled are removed from their natural substrates and reattached for culture. Reattaching is accomplished by placing the seed in a 2 m × 1 m tray with a quantity of cultch of oyster shells or bamboo stakes. The tray is suspended on poles, submerged in water.

Oyster shells with attached mussels are strung in groups of five on No. 10 wires. Strings of shells are above 1 m long provided with loops and spacers and are suspended from bamboo platforms. About 1000 strings can be suspended from a platform of 1 m × 10 m. Bamboo stakes used as cultch consists of the whole tip of spiny bamboo, five cm in diameter at base and 2 m long, but are placed in the tray so that only the upper half is exposed to the mussels. After attachment the bare half of the stakes is driven into the bay floor for growth.

## Russia

Rich mussel beds exist in the northern and western sections of BlackSea over muddy bottom even to a depth of 65 m. Mussel parks set up at 5-6 m depth consist of 2 rows of 6 pine poles, each pole 10 m apart with a space of 10 m between 2 rows. The total area covered is 500 $m^2$. Each pole is 15 cm thick and of a height to achieve 2 m projection above water surface. They are held in place by employing 6 mm steel wires and 16 anchors. Once the park is in position 10-12 mm kapron chords are stretched from pole to pole and from row to row just above water level. Plates of 8 × 3 cm diameter are inserted 8 cm apart in kapron chords and these are hung as collectors from mussel parks.

There are several other countries where mussel resources are available which are experimenting with culture and spat collection following one or the other of the above methods with local modifications. For instance in Venezula bamboo poles are used as spat collectors and rafts of 7×7 m made of bamboo poles and styrofoam floats are used. Due to vulnerability of the bamboo poles to marine borers attack, this system is now being changed. In the west coast lochs of Scotland (Sound of Jura) coir rope is used for spat collection and buoyed frames support the ropes used in culturing the mussel. In the inlets of western Ireland coast rafts of timber using expanded poly-styrene as floats are used for rope culture. In the Baltic Sea area of Germany narrow rafts made of 25 cm diameter polythene pipe are used for suspending ropes of different materials. Long net bags of polyethylene (2.5 cm long × 20 cm dia, with 1 to 2 cm mesh) are filled with mussel seed and suspended from the rafts for growing the mussel. In Australia rafts made of timber supported by 200 litre drums to achieve floating are used for suspending ropes of coir and polypropylene blend on which the mussel seed had settled down earlier. In New Zealand concrete rafts are employed for suspending seeded sisal rope for spat settlement and growth.

Experiments in India adopting rope culture of the green mussel and the brown mussel have succeeded in producing harvestable stock in a period of 5 months and 8 months respectively. Seed collection is done from inter-tidal rocky beds during spat settling season. Spat collectors like frilled nylon ropes and roof tiles are also employed. Seeding is done on coir or nylon ropes of chosen lengths depending on the water depth of the culture site. Mosquito netting or bandage cloth is employed to bring about attachment of seed to the ropes as done in other countries.

Floating rafts of 6 × 6 m or 8 × 8 m fabricated out of teak wood poles and bamboo poles duly buoyed and anchored firmly are used for suspending culture ropes in the coastal sea areas at depths ranging from 5-15 m. Marketable size is reached in 5 months in green mussel and in 8 months in brown mussel. In order to withstand the severity during monsoon periods experiments are being conducted with rafts kept positioned below sea surface wherefrom ropes are suspended.

## Remarks

From the foregoing account it is clear that mussel farming throughout the world, including the leading country Spain, depends entirely on nature for the procurement of seed. This is done either by scraping the seed from the natural bed or by employing suitable spat collectors. So far hatchery production of seed has not become necessary to meet the requirements of the culturists. Another point that emerges is that in most of the countries the culture work goes on in sheltered and protected areas. The Spanish style of raft-rope system of mussel culture suitably modified seems to be universal.

An organism cannot be deemed to be a serious contender for large-scale culture until its seed or juveniles are economically made avilable in sufficient numbers. This implies control over the seed production system. Although natural seed availablity in most of the major mussel producing countries does sustain the current culture operations, the magnitude of future expansion depends on the technology of quality seed production and supply. Development thus becomes an inter-play between objectives, resources and measures. Assured seed supply should be accomplished through operation of a managed breeding programme controlling the gametogenesis of the animal. This has not been done for all the species because of lack of knowledge of a cluster of enigmatic variables which influence the inter action of many biological and reproductive physiological aspects of marine animals. These may differ from one eco-system to the other and is therefore a priority area for research and development in the future proposed system of open sea mariculture.

# VII

## CULTURE OF BROWN MUSSEL AT VIZHINJAM

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Results of experiments on the culture of brown mussel in the Vizhinjam Bay and in the open sea are given. 25-29 mm spat collected during October and November from natural beds and grown on coir ropes suspended from 5 × 4 m rafts grow to 66 mm size in a period of 8 months, giving an average growth of 3.5 mm/month. In the open sea rafts the growth is still faster reaching 66 mm in 5 months at the rate of 5 mm growth per month. The possibility of a production of 150 tonnes of mussels/ha in the bay has been indicated.

### INTRODUCTION

Jones (1968, *Seafood Exporters*, 3:21-28[1]) and Davies (1970 *Proc. symp. Mollusca* 3 : 873-884[2]) have indicated the scope of mussel culture in India and in 1971, initial experiments on mussel culture work were taken up at Vizhinjam (Achari, 1975, *Indian Farming* **25** (6) : 36-37[3]). Various experiments conducted at Vizhinjam bay from 1971 have shown that floating raft culture is ideal along Indian coast owing to the enhanced growth rate and simple culture technique. If favourable conditions exist, raft culture or suspended culture of mussels is the most efficient method. This method avoids most serious problem of mussel culture, the predation of young mussels by starfishes and crabs. In the present account the results of experiments conducted on brown mussel culture at Vizhinjam inside the bay and in open sea from 1976 to 1979 are given.

### DESCRIPTION OF FARM AREA AND ENVIRONMENTAL FEATURES

Vizhinjam is situated in the Neyyattinkara Taluk, in the Trivandrum District, south-west coast of India about 16 km south of Trivandrum city (Long. 76°59′E –" Lat. 8°22′ 30"N). The beach is a narrow one and the bay area is enclosed by the breakwater construction of the Harbour jutting into the sea on the western side and Kottappuram on the eastern side (Fig. 1). This bay is a protected area, ideally suited for culture work. The depth of the bay varies from 10 to 15 m and the area opposite to the breakwater in the open sea is 15 to 25 m deep. Natural settlement of mussel seed is abundant along the intertidal rocky area around Vizhinjam.

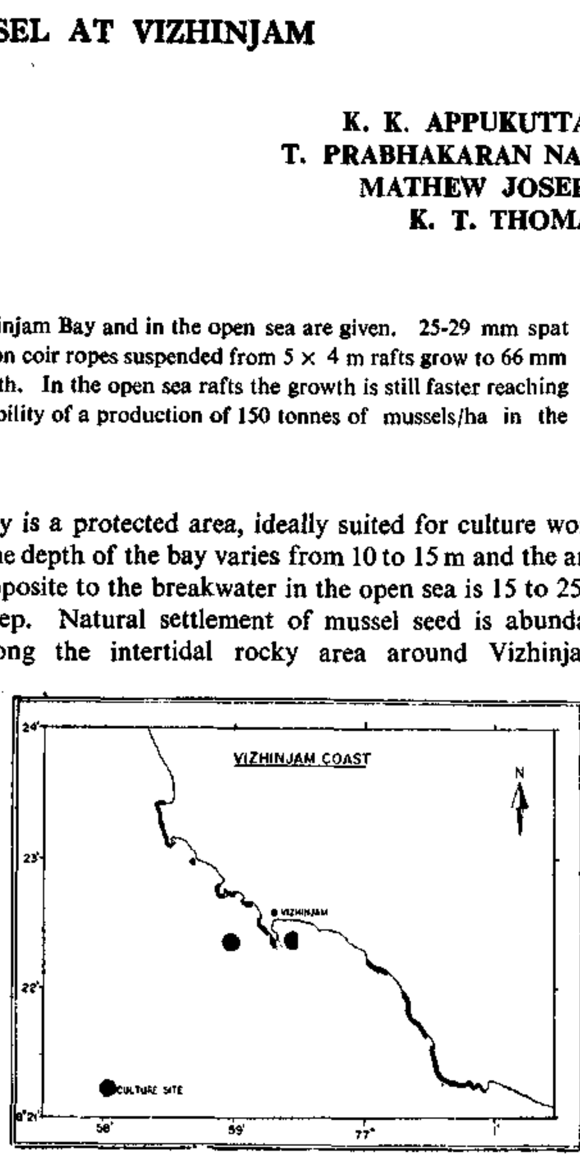


Fig. 1. Vizhinjam coast showing the culture sites

The seed mussel required for the experiments was collected easily from this area. The bay is protected from heavy wave action during monsoon and hence experiments could be continued round the year without disturbance. But the heavy surf action and drift restricted open sea mussel culture from December to


PLATE I. a. Floating rafts inside Vizhinjam bay.
b. Collection of mussel seed from natural beds.
c. Cleaning of mussel spat settlement.
d. Seeding of mussel ropes.
e. Spat settlers viz. roof tile, split nylon rope with young mussel attached to it.
f. Iron hapa with mussel spat settlement.

May in 1978 and 1979. The bottom of the farm site is muddy mixed with loose sand. Water is clear upto 2 m depth.

The variation in salinity and temperature studied did not show marked changes in bay and open sea during this period. Water temperature ranged from 20.75° to 30.05°C, the lowest recorded in July 1978 and the highest in January-February period in 1977. In general, from May to October there was decline in the water temperature due to the onset of monsoon. The salinity ranged from 31.5 to 36.31‰. The minimum salinity observed was during monsoon (May-July) and maximum in the month of March and October. Similarly during monsoon period the silting percentage showed an increase and water is very turbid from May to October.

## Rope Culture Method

*Description of rafts, floats, anchors, ropes and seeding technique :*

Small rafts were used for all experiments at Vizhinjam. Square or rectangular rafts of 6 × 6 m or 5 × 4 m were launched in the bay and open sea (Plate I, a). The rafts were fabricated with teak wood and bamboo pole lashed by coir or nylon rope of 5 to 7 mm thickness. Metal drums of 200 litre capacity treated with anticorossive paints were used as floats to give buoyancy for the rafts. Number of floats used for a single raft depended on the size of the raft. The rafts were moored by anchors with required length of anchor chain. For mussel seeding coir rope and nylon ropes with 12 to 14 mm thickness were used. Nylon rope was found more durable for seeding.

Brown mussel starts spawning in May which lasts till September and settlement of young mussels starts even from June. But the period of peak spawning is July to August and maximum settlement occurs from September to October. Seed in the size range of 25 to 29 mm is considered ideal for seeding. As the monsoon is active till early September, seed collection can be done for farming from October to December. Mussel seed is also available from nearby centres such as Avaduthura, Mulloor and places like Enayam, Colachal, Muttom and Neendakara.

Mussel seeds were collected from the natural bed using iron chisel along the Vizhinjam and adjacent area (Plate I, b). Estimated quantity of mussel seed available per sq. m area in and around Vizhinjam varies from 10 to 15 kg. Split nylon ropes, roof tiles, string of coconut shells, iron hapas covered with nylon screen, split old bamboo poles were also used in the farm site to collect young mussels for seeding. Split nylon ropes, roof tiles and iron hapas showed good settlement of mussel spat during spawning period (Plate I, e & f). The seed mussel collected by divers from natural bed were cleaned to eliminate all fouling organisms (Plate I, c). These were spread over old cotton fishing net or cheap bandage cloth or mosquito netting of 25 mm width and the rope was kept over the netting. To avoid slipping of mussels in the initial stage of growth wooden pegs were inserted in the ropes at fixed intervals. The net was wrapped over the rope securing the mussel seeds and both the edges of netting were stitched using cotton twine (Plate I, d). After seeding the full length of the rope, the rope was suspended from the raft. The net disintegrated within a week. By this time the mussels got attached to the rope. Periodical cleaning and thinning of rope had to be done to eliminate fouling organisms and overcrowding of mussels.

In 1976, four rafts with 13 seeded coir ropes and 110 nylon ropes of average 6 m length each were suspended from the rafts. In 1977 two new rafts were launched in the open sea side with 36 ropes of 10 m length and kept there for 3 months from January to March. In 1978 to 1979 period 3 rafts with 114 ropes of 5.5 m average seeded length were kept in the open sea and 144 ropes were suspended in 6 rafts kept in the bay. The ropes kept in rafts were examined regularly for fouling organisms and other animals causing destruction to mussels. Due to heavy monsoon wave action, 2 rafts out of the 3 kept in open sea were completely damaged during June. The experiments showed that the mussel reaches the harvestable size of 50-55 mm inside the bay and 65-70 mm in the open sea farm by May.

## Results

In the Vizhinjam bay, the brown mussel reached the modal size of 55 to 66 mm, in 8 months, giving an average growth of 2.94 mm per month. In the 1979 experiments the growth rate observed was 3.54 mm. The ratio of flesh weight to shell weight was 41.31:58.69 in May. After June due to influx of freshwater there was a tendency for farm grown mussels to fall out. In the open sea relatively faster growth rate was observed. A modal size of 60-65 mm was attained within 5 months recording 5 mm growth per month. The flesh weight constituted 43.33% of the total weight of mussel in May. The average weight of mussel seed per meter length of rope (seeded portion) ranged from 1.4 to 2 kg and it attains 10 to 15 kg in 7 months in bay and 15 kg in the open sea in 5 months.

An estimated yield of 150 tonnes from one hectare area inside the bay appears possible. The cost of raft of 6 × 6 meter size with all material required, including seeding, is Rs. 2500 to 3000. The price of mussel per tonne is estimated between Rs. 1,600 to 2,000 and from a single raft 3 tonnes of mussels could be harvested thus giving a total yield of Rs. 4,800 to 6,000. This estimate is based on the production rate inside the bay. In the open sea the production and cost have not been worked out.

## Discussion

Brown mussel culture as has been experimented upon at Vizhinjam is a semi-culture and needs only marginal attention in farm maintenance, thus making it easy for bringing it within the scope of small-scale and traditional fishermen to be enagaged profitably utilizing their leisure hours. The expenses on the capital input and maintenance are also not prohibitive. The entire process of culture points to a production possibility of 150 tonnes of mussels per hectare in an environment like the bays. When compared with the low output from the natural bed, this yield can be considered as very profitable and dependable. Properly maintained, the rafts and the ropes employed for the culture can be recycled into use for atleast a peroid of 3 to 4 years. In the open sea conditions off Vizhinjam several difficulties had been encountered of which, the most important is the instability of the raft during monsoon period. Methods to overcome by developing a suitable technique are being tried out. But even as at present it is possible to obtain a minimum of a single harvest during a year taking advantage of the following factors :—

(1) Seed availability in size ranging from 20-25 mm from natural grounds during October-November.

(2) Post monsoon lull extending from November to June.

(3) Ability of the brown mussel to reach the harvestable size of 60-65 mm within this period.

(4) Absence of noticeable disease problem amongst the stock under farming conditions.

Although predation is not a serious problem, it has been seen that due to some man-made disturbances in the surrounding ecoystem sporadic cases of invasion by predators like *Rhabdosargus* takes place, but this problem has to be studied in full depth before concluding whether it is a constant threat or only a passing phase. Tackling other bottom dwelling predators is an efficiency inherent in the rope culture itself, wherein the ropes are suspended well above the bottom. But attacks like those from lobsters as noticed in this area do require careful planning to device methods like trapping them in this area.

Open sea mussel culture off Vizhinjam is beset with a few problems of social nature as well. The objection raised by the local fishing community that the rafts positioned in the near shore waters interfere with their gill netting and boat seining activity is a problem which has to be solved. Very often their action has resulted in our withdrawing the rafts to safer areas. It would be necessary therefore to evolve a mutually acceptable approach while trying to establish open sea mussel culture off the coastal areas of Vizhinjam. The profitability of mussel culture and the lucrative price that may be offered for the produce are two factors which would influence the future of open sea mussel culture.

# VIII

# OPEN SEA RAFT CULTURE OF GREEN MUSSEL AT CALICUT

P. S. KURIAKOSE

Employing coir ropes of 5-8 m length, suspended from 6 × 5 m and 8 × 8 m teak wood rafts anchord in the open sea off Calicut at depths 8-10 m, transplanted green mussel seed (20-30 mm size) show a fast growth ranging from 10.6 mm to 13.5 mm per month reaching harvestable size of 80 mm in 5 months. A production range of 4.4 kg to 12.3 kg per metre length of rope has been achieved. Meat content ranges from 34.82-40.5 %.

## Introduction

India has a vast resource of green mussel along the coastal areas, but this resource still remains underutilised. Brown mussel fishery along the Trivandrum coast and fishery for green mussel in the Malabar coast had been going on for several years past. In 1973 CMFRI initiated expermental culture of brown mussels at Vizhinjam. Later, culture of green mussel on suspended substrata in the open sea was started in 1975 at Calicut. This programme carried out at Calicut during 1975-1980 demonstrated that mussels can be grown to marketable size in a short period of 5 months by adopting rope culture technique.

## Environmental conditions in the mussel Farm

The selected mussel farm area in the open sea at Calicut was an active fishing zone and free from industrial pollution and fresh-water influx from rivers. The bottom was muddy at the farm site. During the experimental period October 1975-April 1976 the surface salinity of the area varied from 32.44 to 33.68 ‰ while it was 31.99 to 33.45 ‰ over the bottom (Fig. 1). The water temperature for the same period varied from 27.44°C to 30.66°C at the surface and from 26.70°C to 30.26°C at the bottom (Fig. 2). The dissolved oxygen content of the surface water was almost uniform and the values were between 4.43 ml/l and 4.62ml/l. Slightly lower values from 3.79 ml/l were recorded at the bottom (Fig. 3). The sediment load of the surface water was negligible, while higher values were noticed at the bottom (Fig. 4). In December, the sediment load reached a peak of 4.79 ml/l when the clarity of the sea water was the lowest. Hydrographical features of the natural mussel bed at Elathur about 10 km north of

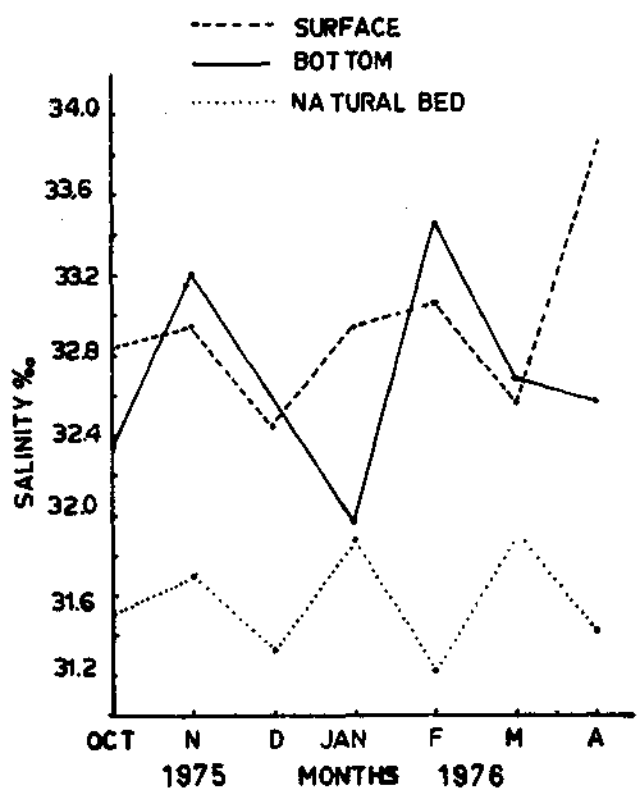


Fig. 1. Monthly average salinity at the farm site and natural bed.

farm area during this period are also presented in Figs. 1-4.

## Method of Culture

*Raft construction :*

Rafts were fabricated using teak wood and bamboo poles lashed together with coir and nylon ropes (Plate I, Fig. A). The poles were treated with coal-tar. Each

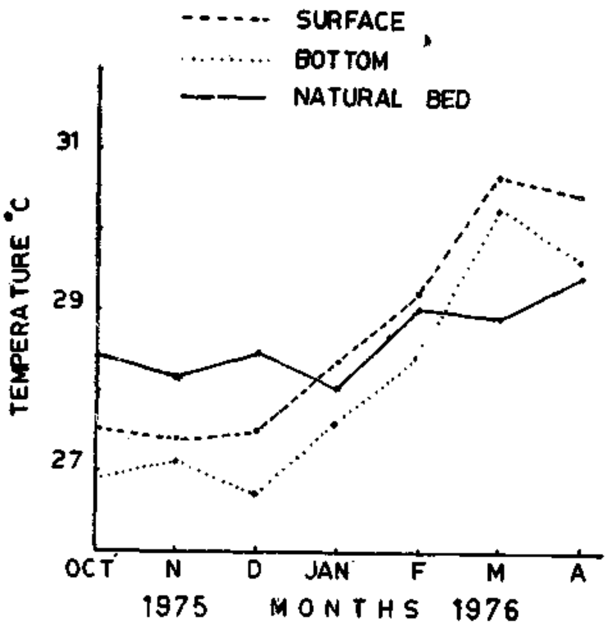


Fig. 2. Monthly average temperature at farm site and natural bed.

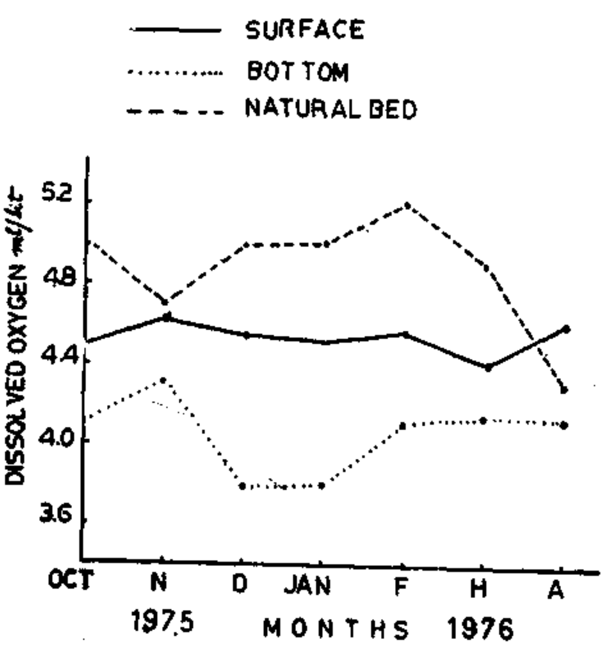


Fig. 3. Monthly average dissolved oxygen at the farm site and natural bed.

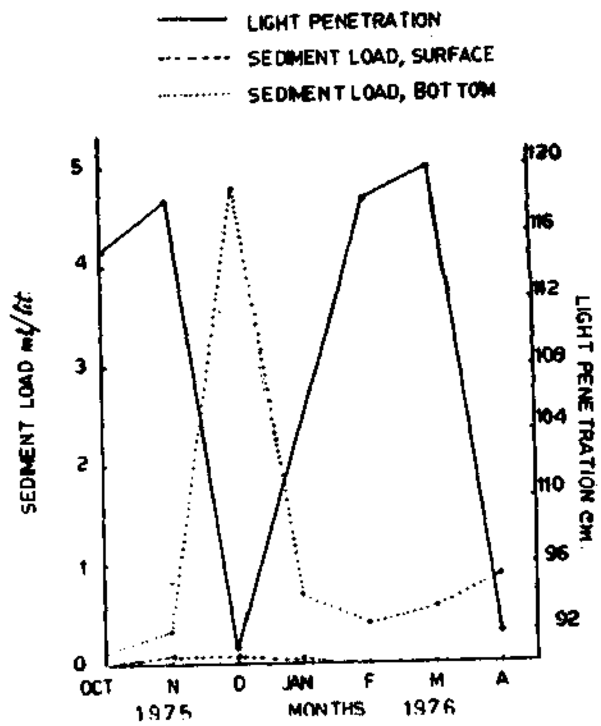


Fig. 4. Monthly average sediment load and clarity of the sea water at the farm site.

raft was mounted over five sealed empty metal drums of 200 l capacity, painted with anticorrosive paint. A few rafts were floated using high density plastic drums of 200 l capacity coated with antifouling paints. Four of these drums were fixed at the four corners and one at the centre fastened with iron bands. A few wooden planks were fixed on the raft to provide working space. Rafts of the size 6 × 5 m to 8 × 8 m were fabricated and used for the experiments. Each raft was anchored using 3 irons anchors weighing 100 kg each with iron chain links of 13 mm diameter. The rafts were abchored at depth ranging from 8 to 10 m in the open sea about 1-1.5 km away from the shore.

*Seed collection and transplantation :*

The collection of seed for the culture experiments was made from a marked area of the natural bed at Elatur and Thikkodi so that periodic observations could be made on the rate of growth of mussels in that area (Plate I, Fig. B). Before transplantation, the seed were cleaned in sea water to remove the adhering mud and epifauna. The size of the mussel seed at transplantation, ranged from 20 to 30 mm. Usually 500 to 700 g of juvenile mussels were seeded in one metre length of rope. The seeds were kept around the rope and securely attached by enclosing and stitching in knitted cotton cloth of 25 cm width (Plate I, Fig. C). Coir ropes ranging from 20-25 mm diameter and nylon rope of 14 mm diameter were used for growing mussels from the rafts. The seeded portion of the rope varied from 5-8 m and ropes were suspended from the rafts 0.5 to 1 m apart with the lower free end about 2 m above the bottom. The seeded mussels get attached over the ropes within two to three days and the cloth cover disintegrates in sea water in about 10 days.

*Growth*

During 1975-76 seed mussels with an average length of 26.7 mm weighing 1.9 g transplanted in October grew to a size of 80 mm weighing 37.3 g within a period of five months, registering an average monthly growth rate of 10.6 mm and 5.9 g in weight (Table 1 and Figs. 5 & 6). During 1977-78, the average monthly growth rate observed in the culture farm was 11.3 mm in length and

TABLE 1. *Showing the growth rate of the farm mussels* (Perna viridis)
(*The figures of length and weight are averages of* 100 *to* 200 *specimens*)

| Months | | Length mm | Total weight (g) | Shell weight (g) | Meat weight (g) | Mantle water weight (g) | Percentage of shell weight | Percentage of meat weight | Percentage of mantle water weight |
|---|---|---|---|---|---|---|---|---|---|
| **1975-1976** | | | | | | | | | |
| November (seed) | 1975 | 26.7 | 1.92 | 0.84 | 0.64 | 0.44 | 43.7 | 33.3 | 23.0 |
| December | 1975 | 40.6 | 6.60 | 2.55 | 2.53 | 1.52 | 38.6 | 38.3 | 23.1 |
| January | 1976 | 53.1 | 11.86 | 4.76 | 4.36 | 2.74 | 40.1 | 36.8 | 23.1 |
| February | 1976 | 62.8 | 18.10 | 6.96 | 6.96 | 4.18 | 38.5 | 38.5 | 23.0 |
| March | 1976 | 76.5 | 29.73 | 11.68 | 11.19 | 6.86 | 39.3 | 37.6 | 23.1 |
| April | 1976 | 80.0 | 37.30 | 13.75 | 14.95 | 8.60 | 36.9 | 40.1 | 23.0 |
| **1976-1977** | | | | | | | | | |
| November (seed) | 1976 | 21.7 | 0.80 | 0.37 | 0.24 | 0.19 | 46.0 | 30.1 | 23.9 |
| December | 1976 | 28.8 | 2.00 | 0.77 | 0.77 | 0.46 | 38.5 | 38.5 | 23.0 |
| January | 1977 | 40.9 | 9.80 | 3.28 | 3.52 | 3.00 | 33.5 | 35.8 | 30.7 |
| February | 1977 | 52.2 | 11.40 | 4.09 | 4.42 | 2.89 | 35.9 | 38.7 | 25.4 |
| March | 1977 | 67.1 | 21.60 | 7.90 | 8.70 | 4.99 | 36.6 | 40.3 | 23.1 |
| April | 1977 | 77.0 | 30.20 | 11.20 | 12.11 | 6.89 | 37.1 | 40.1 | 22.8 |
| May | 1977 | 89.5 | 41.00 | 15.09 | 16.48 | 9.43 | 36.8 | 40.2 | 23.0 |
| **1978-1979** | | | | | | | | | |
| November (seed) | 1978 | 23.6 | 1.10 | 0.50 | 0.40 | 0.20 | 46.0 | 38.0 | 16.0 |
| December | 1978 | 36.0 | 4.50 | 1.72 | 1.74 | 1.20 | 38.3 | 38.6 | 23.1 |
| January | 1979 | 50.6 | 9.60 | 3.58 | 3.81 | 2.21 | 37.3 | 39.7 | 23.0 |
| February | 1979 | 63.7 | 12.60 | 5.00 | 5.59 | 2.00 | 39.7 | 44.4 | 15.9 |
| March | 1979 | 74.9 | 28.60 | 10.67 | 11.40 | 6.49 | 37.4 | 39.9 | 22.7 |
| April | 1979 | 88.2 | 37.50 | 14.32 | 15.18 | 7.98 | 38.2 | 40.5 | 21.3 |
| **1979-1980** | | | | | | | | | |
| November (seed) | 1979 | 20.4 | 0.90 | 0.37 | 0.33 | 0.24 | 40.6 | 36.3 | 23.1 |
| December | 1979 | 35.9 | 3.70 | 1.43 | 1.45 | 0.82 | 38.8 | 39.1 | 22.1 |
| January | 1980 | 50.0 | 9.10 | 3.31 | 3.68 | 2.10 | 36.4 | 40.5 | 23.1 |
| February | 1980 | 59.9 | 13.50 | 5.33 | 5.21 | 2.95 | 39.5 | 38.6 | 21.9 |
| March | 1980 | 73.6 | 24.10 | 7.49 | 9.01 | 5.59 | 39.4 | 37.4 | 23.2 |
| April | 1980 | 85.0 | 36.40 | 12.88 | 13.21 | 10.30 | 35.4 | 36.3 | 28.3 |

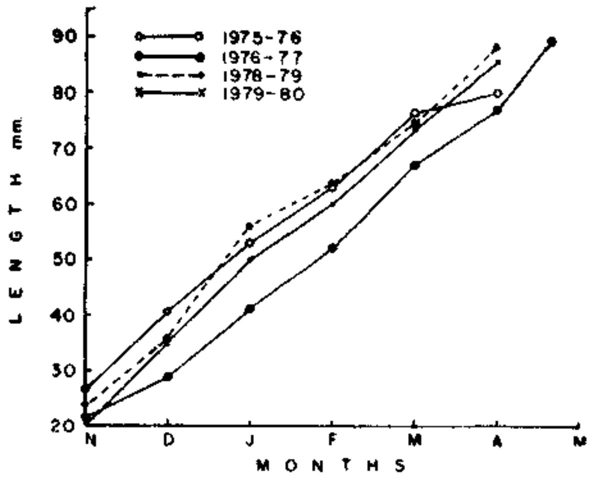


Fig. 5. Growth rate of mussels in the farm.

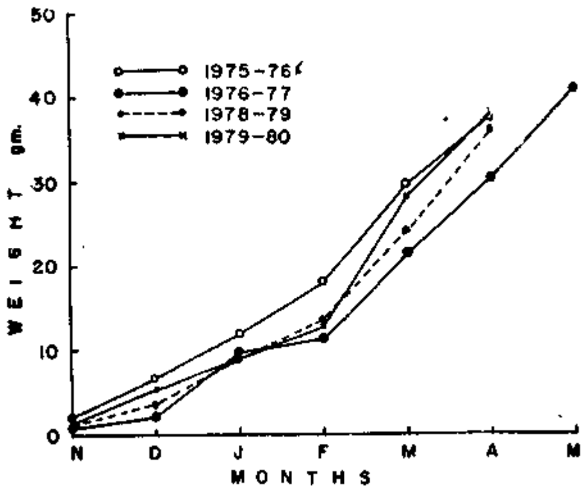


Fig. 6. Monthly average weight of cultured mussels.

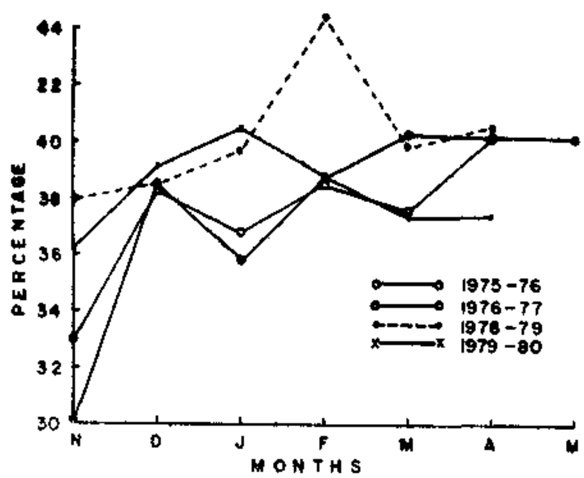


Fig. 7. Monthly average meat yield of cultured mussels.

6.7 g in weight. However, in 1978-79 the monthly growth rate observed was very high, being 13.5 mm in length and 7.3 g in weight. In 1979-80 the monthly growth rate was only 12.9 mm in length and a monthly increment 7.1 g in weight. Compared with this the average monthly growth rate of the mussels in natural bed was only 6.9 mm in length and 3.6 g in weight and 8.6 mm in length and 3.8 g in weight in 1975-76 and 78-79 respectively (Table 2 ; Figs. 8 & 9).

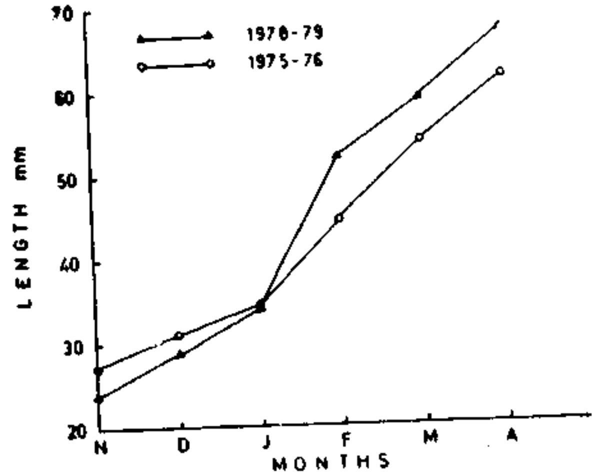


Fig. 8. Growth rate of the mussels in the natural bed.

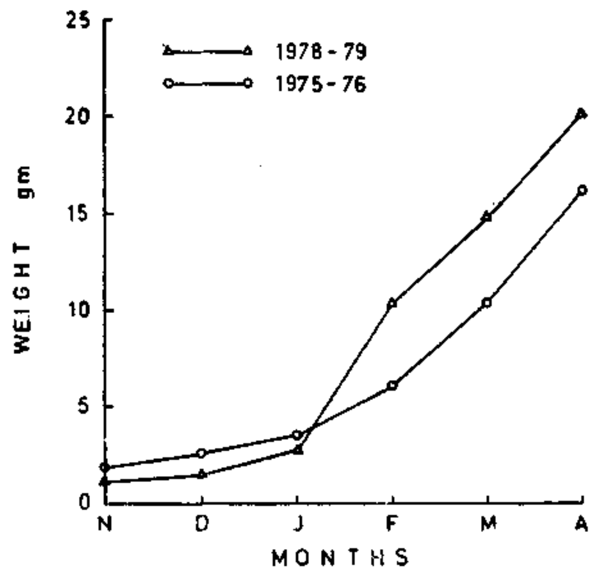


Fig. 9. Monthly average weight of mussels in the natural bed.

*Fouling organism*

Fouling of mussels and raft materials in the farm was a serious problem. Accumulation of silt and growth of plants over the mussels was negligible. Very often, heavy settlements of the barnacle, *Balanus amphitrite,* was observed within a period of 30 days after transplantation, the settlement being intense at the upper 2 m length of the suspended ropes. The growth of the barnacles over the shell valves was very rapid. In 1976-77, in a particular instance after 60 days, nearly

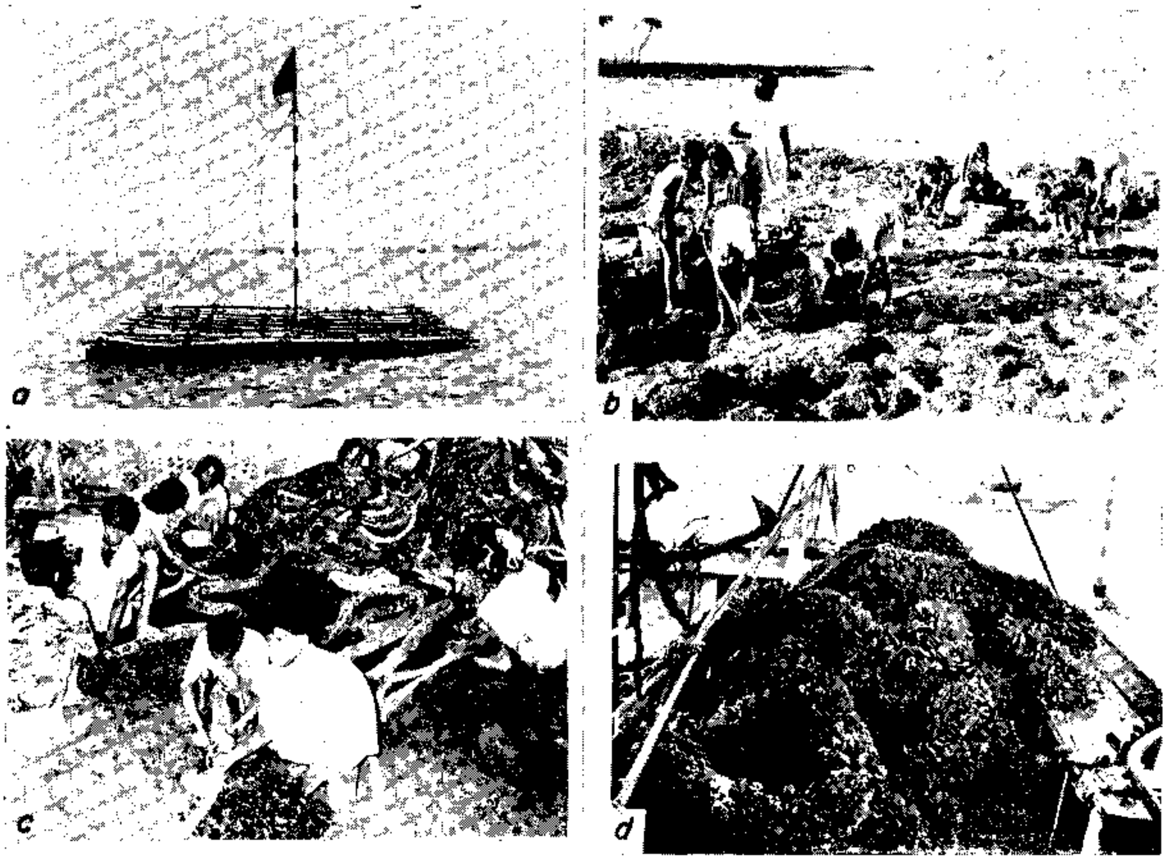

PLATE I. a. Raft used for mussel culture. b. Collection of seeds from the natural beds. c. Seeding of ropes. d. Harvested mussels.

TABLE 2. *Showing the growth rate of mussels* Perna viridis *in the natural bed* 1975-76
(*The figures of length and weight are averages of* 100 *specimens*)

| Months | | | Length mm | Total weight (g) | Shell weight (g) | Meat weight (g) | Mantle water weight (g) | Percentage of shell weight | Percentage of meat weight | Percentage of mantle water |
|---|---|---|---|---|---|---|---|---|---|---|
| November | 1975 | .. | 26.7 | 1.92 | 0.84 | 0.64 | 0.44 | 43.8 | 33.2 | 23.0 |
| December | 1975 | .. | 31.2 | 2.49 | 1.10 | 0.82 | 0.47 | 44.2 | 32.9 | 22.9 |
| January | 1976 | .. | 34.5 | 3.12 | 1.41 | 1.00 | 1.72 | 44.9 | 32.1 | 23.0 |
| February | 1976 | .. | 44.2 | 6.01 | 2.74 | 1.88 | 1.48 | 45.6 | 31.3 | 23.1 |
| March | 1976 | .. | 52.9 | 10.35 | 4.62 | 3.22 | 2.51 | 44.6 | 31.2 | 24.2 |
| April | 1976 | .. | 61.7 | 16.16 | 7.23 | 5.01 | 3.92 | 44.7 | 31.0 | 24.3 |
| | | | | 1978-1979 | | | | | | |
| November | 1976 | .. | 23.6 | 1.1 | 0.49 | 0.30 | 0.21 | 45.5 | 27.2 | 27.3 |
| December | 1976 | .. | 28.9 | 1.4 | 0.83 | 0.42 | 0.15 | 58.9 | 29.8 | 11.3 |
| January | 1977 | .. | 34.3 | 2.7 | 1.36 | 0.80 | 0.54 | 49.6 | 29.2 | 21.2 |
| February | 1977 | .. | 52.0 | 10.3 | 5.1 | 2.80 | 2.40 | 49.2 | 29.4 | 21.4 |
| March | 1977 | .. | 59.0 | 14.8 | 7.3 | 4.10 | 3.40 | 49.2 | 27.6 | 23.2 |
| April | 1977 | .. | 66.9 | 20.1 | 9.8 | 5.90 | 4.40 | 49.2 | 29.4 | 21.4 |

202 barnacles measuring 1-9 mm, in diameter at their base (weighing 23.3 g) were found to have settled over the shell valves of a single mussel. The settlement of barnacles appeared to have adverse effect on the fast growing shell margins of the mussels. The settlement of the barnacles larvae was observed to continue during the entire period of 5 months from November to March. During November and December heavy settlement of larvae of bivalve *Mytilaster arculatula* (the marine mat forming mytilid) was noticed all over the submerged part of the raft materials and on the submerged ropes. Tubiculous polychaetes, ascidians, coelentrates and bryozoans were also common on the mussels and suspended ropes.

*Production :*

In table 3, the details of production from mussel culture during different seasons are given. In 1975-76, 35 ropes of 4 m length were seeded and suspended from a raft 6 × 5 m. During 1976-77, 533 ropes were suspended from 10 rafts each having 7 × 6.5 m. The seeded length of the rope was 8. In 1978-79, 2400 ropes (of 7 metres seeded length) were used for culture from rafts covering a surface area of 1650 sq. m. During 1979-80, 1000 (ropes of seeded length 6 m) were suspended from 10 rafts each of size 8 × 8 m. The production per metre length of rope in 1975-76 was 5. 1 kg using 0.7 kg of seeds. In 1976-77, from a seed weight of 0.5 kg the yield per metre length of ropes was 4.4 kg showing an increase of 9 times over the seed weight. The production was highest in 1978-79, the yield from a seed weight of 0.57 kg being 12.3 kg/m which is 21 times the initial weight of the seed used for culture (Plate I, Fig. D). The average production per metre length of rope in 1979-80 declined to 5.8 kg/m of rope, the yield being only 7.8 times of the seed weight.

TABLE 3. *Showing estimated production rate of mussels by rope culture in the open sea at Calicut*

| Particulars | | 1975-76 | 1976-77 | 1978-79 | 1979-80 |
|---|---|---|---|---|---|
| Total area of the rafts in the sea | .. | 35 sq. m | 450 sq. m | 1650 sq. m | 640 sq. m |
| Total number of ropes suspended | .. | 35 | 533 | 2400 | 1000 |
| Length of the rope seeded and suspended | .. | 4 m | 8 m | 7 m | 6 m |
| Weight of seed used for one rope | .. | 2.9 kg | 4 kg | 4 kg | 4.5 kg |
| Average production from one rope | .. | 20.25 kg | 34.1 kg | 86.2 kg | 34.1 kg |
| Production per metre length of rope | .. | 5.1 kg | 4.4 kg | 12.3 kg | 5.8 kg |

The results indicated that ideal depth for mussel culture in Calicut region is from 8-10 m with a seeded rope of 6-7 m.

The farm mussels gave a better meat yield than the mussels from the natural bed (Fig. 7). The average edible portion of the meat in cultured mussels ranged from 34.82-40.5% whereas in the natural bed the meat yield was only 27.2 to 33.2% of the total weight (Fig. 10).

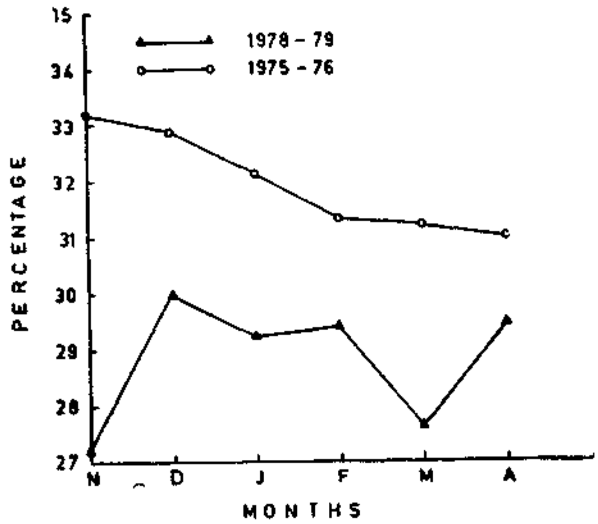


Fig. 10. Monthly average meat yield of natural mussels.

## Farm Management

The collected seed can be kept alive in moist condition only upto 24 hrs. Therefore seeding has to be completed within this time. Knitted cotton cloth having a mesh size of 5 mm appears to be ideal for seeding as the above material gradually disintegrates while the mussels start growing. Periodical inspection of the farm is very important. There are possibilities of holes developing in the drums used as floats. These should be replaced immediately. The farm area should be demarcated with suitable light fitting and flags in order to avoid damage to the rafts by fishing boats operating in the vicinity, especially during night. Periodical thinning of the ropes is necessary so as to increase the growth rate of the mussels. The growth and condition of the mussels has to be observed periodically in order to take the harvest when the mussels are in the prime condition.

## Remarks

The success of the mussel-farming along the south-west coast of India depends to a great extent on the type of rafts and floats and the changing weather conditions. The sea becomes rough towards the end of April and some of the rafts and harvestable mussels were destroyed in the rough weather. The metallic oil drums used for floating the rafts could withstand for only about 4 months getting corroded and developing holes, thereby causing the rafts to sink. The barrels sometimes collapse with the increase in weight of the fast growing mussels. However, it was found that high density plastic floats used during 1979-80 withstood the rough seas even after suspending 100 ropes from rafts of 8 $\times$ 8 m size. To avoid loss of cultured mussels it is only appropriate that the crop is harvested in April before the sea becomes rough, by which time the mussels reach the marketable size of 80 mm. The production per metre length of rope varied from 4.4 to 12.3 kg. The above results were obtained using rafts of different sizes. It was found that average production of 12.3 kg/m of rope can be achieved by adopting proper culture methods.

# IX

# MUSSEL FARMING ON THE EAST COAST OF INDIA

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At Kovalam bay (Madras) rafts made of casuarina poles have been used to suspend mussel seed transplanted ropes for culture. An average growth of mussel at the rate of 12.8 mm per month is reported. Harvestable size of 75 mm is reported to have been reached in 3½ months time. However similar experiments done at Kakinada (Andhra Coast) and Ennore (north of Madras) did not yield conclusive results.

## INTRODUCTION

Although green mussel population is restricted along the east coast of our country the very fact that the mussels here grow to large size in the natural beds indicates that the ecological characteristics of the water mass over the natural beds favour settlement and growth as in the case of west-coat. The absence of adequate settling and growing grounds appears to be one of the handicaps for the patchy occurrence of mussel beds. Even the existing natural grounds in many areas face the serious problem of siltation due to developmental activities in the estuarine regions as is happening in the case of Courtalayar Estuary at Ennore and Uppateru canal mouth joining the Kakinada Bay. Mussel culture practice is one sure method of overcoming some of these problems whereby dense stock of mussel seed can be kept in suitable substrates and grown. Another objective in taking up mussel culture in the east-coast was to try and evolve an appropriate technique of growing mussels to suit local environmental conditions. There is a distinct difference in the pattern of monsoon system in the east-coast when compared with the west coast. The intense season of choppy sea and floods in the rivers happens to be between October to December in the East Coast. It is not uncommon also to come across cyclonic storms during this season. Occasionally summer cyclonic storms are also witnessed during May-June affecting the area between Pondicherry to Masulipatnam. The mussel spat settling season in the east-coast also shows a marked variation from that of the west-coast. Therefore the success in mussel farming depends on how best the seed availability and favourable weather conditions are exploited. One encouraging factor in hoping to achieve the above goal is the ability of the green mussels of our waters to grow to marketable size in a short period of less than 150 days as has been shown by the experiments at Calicut.

The above considerations formed the basis of the experiments in mussel culture conducted at Kovalam (near Madras), Ennore back-water and at Vekalapudi near Kakinada. Rope culture using rafts was tried at Kovalam in the open sea. At Kakinada, nylon-mesh cages were hung from rafts in which mussels were kept and grown in the open sea. Because of the shallowness of the Ennore Estuary, casuarina pole frames were erected over the bottom and ropes were suspended in the shallow water.

## CONDITIONS IN THE FARM AREA

### *Kovalam Bay*

The annual rainfall varies from 150-180 cm, the maximum precipitation occurs during October-November. The tidal range in the Kovalam Bay (Madras) is about a metre. During rough weather, waves ranging in height from 2-4 m are seen in the Bay. The salinity fluctuates between 20.14 to 34.55‰. After January the salinity values go up showing high values from March to September with little fluctuations. During the North-East Monsoon, the surface salinity becomes low.

The oxygen values in the Bay varies from 3.80 to 5.25 ml/l. During summer months there is very little fluctuation. The plankton in the bay is rich. Blooms of phytoplankton consisting of *Chaetoceros*, *Thallasiothrix*, *Skeletonema*, *Coscinodiscus*, *etc.*, occur during March-May.

During May, strong surface winds blow from land to sea carrying lot of sand particles making the water quite turbid. During September-October before the onset of the North-East Monsoon, the water in the Bay is quite clear.

*Kakinada :*

The temperature of the sea water off Vakalapudi near Kakinada varies from 26.0 to 30.5°C and the salinity from 23.2 to 34.88‰.

## Seeding Technique

In Madras, mussel seed of size range 10-20 mm were collected at Ennore from concrete piles and large iron buoys used by Madras Electricity Supply and transported to Kovalam. The seed were removed with a sharp knife, cleaned of the ,fouling organisms and seeded to coir ropes with the help of a strip of knitted cotton cloth about 6 m long and 20 cm wide. The cleaned seed were uniformly spread at the rate of 0.5 kg/m along the rope which was placed over the cloth, the edges of the cloth tightly rolled and stitched all along the rope. The two ends of the cloth were firmly tied to the rope and a granite stone of about 2 kg was tied to the rope so that they could be vertically hung from the raft. Both coir ropes and nylon ropes were used for seeding the mussel at Ennore and Kovalam. Seeding of the ropes was generally carried out early in the morning or in the night to avoid seed mortality. At Kakinada, mussel seeds were kept in nylon cages.

## Raft

The rafts used at Kovalam were fabricated out of casuarina poles covering an area of 25 sq. m. Each raft was buoyed up with the help of sufficient number of diesel oil drums and anchored by 25 m long tested anchor chain using stalkless anchors weighing 60 kg each. The rafts were floated at depths ranging from 8 to 10 m. At Kakinada, rafts were anchored in identical fashion at slightly shallower water in the open sea (5 m depth).

## Growth

From the experiments at Ennore it was noticed that the mussels grow to 64 mm in 8 months showing a growth rate of about 8 mm per month. The growth of mussels in the open sea (Kovalam) was found to be much faster. During a period of 3 months in 1978 the cultured mussels grew from an average length of 13.63 mm to 52.0 mm showing an average growth rate of about 12.8 mm per month. The weight during the same period increased from 0.30 to 12.3g. During the 1979 season the mussels grew from a seeding size of 25-30 mm to the harvesting size of 70-75 mm in 3½ months showing a growth rate of 13 mm per month. The average weight attained by the mussels was 17.5 g. 4.5 kg of seed used on a rope attained a weight of 39 kg during 3½ months showing a nine-fold increase in weight.

Off Vakalapudi, near Kakinada, during a period of 5 months the mussels grew from 13-25 mm (mean 21.7 mm) to 53-70 mm (mean 66.6 mm). The increase in mean size was 44.9 mm giving an average growth of 9 mm per month. In the natural bed at Kakinada, the mussels were known to attain an average length of 63 mm in 6 months, 92.2 mm in 1 year, 117 mm in 2 years, 129 mm in 3 years and 135 mm in 4 years. In natural bed, growth was fast in the I and II quarters accounting for 68.6% of the annual increase in length.

A differential growth rate was observed on the culture rope, the mussels at the upper layers showing a slightly higher average length than those at the bottom level. The slightly higher growth rate at the surface might be due to the availability of more food at the surface. As the mussels grew in length the percentage of flesh weight decreased. The percentage of shell weight and flesh weight was more or less equal in mussels of average length of about 55 mm. In older mussels the shell weight often accounted for two-third of the total weight of the mussel.

## Production

Based on the percentage edibility values, mussels of size range 75 mm to 80 mm are harvestable. In the case of Kovalam each raft accommodating 50 ropes of 6 meter length produced about 2 tonnes of mussels in a period of 4 months (*i.e.* when the mussel reaches 75 to 80 mm). Although experiments are yet to be conducted by floating rafts over vast stretches to calculate the actual yields per hectare the values obtained from the experiments conducted now are encouraging.

Comparable production figures in respect of Ennore estuarine conditions and in the Kakinada Bay could not be given due to farm management difficulties encountered during the period of culture.

## Remarks

Open-sea mussel culture in the east-coast is beset with many problems that need attention before large-scale attempts are made.

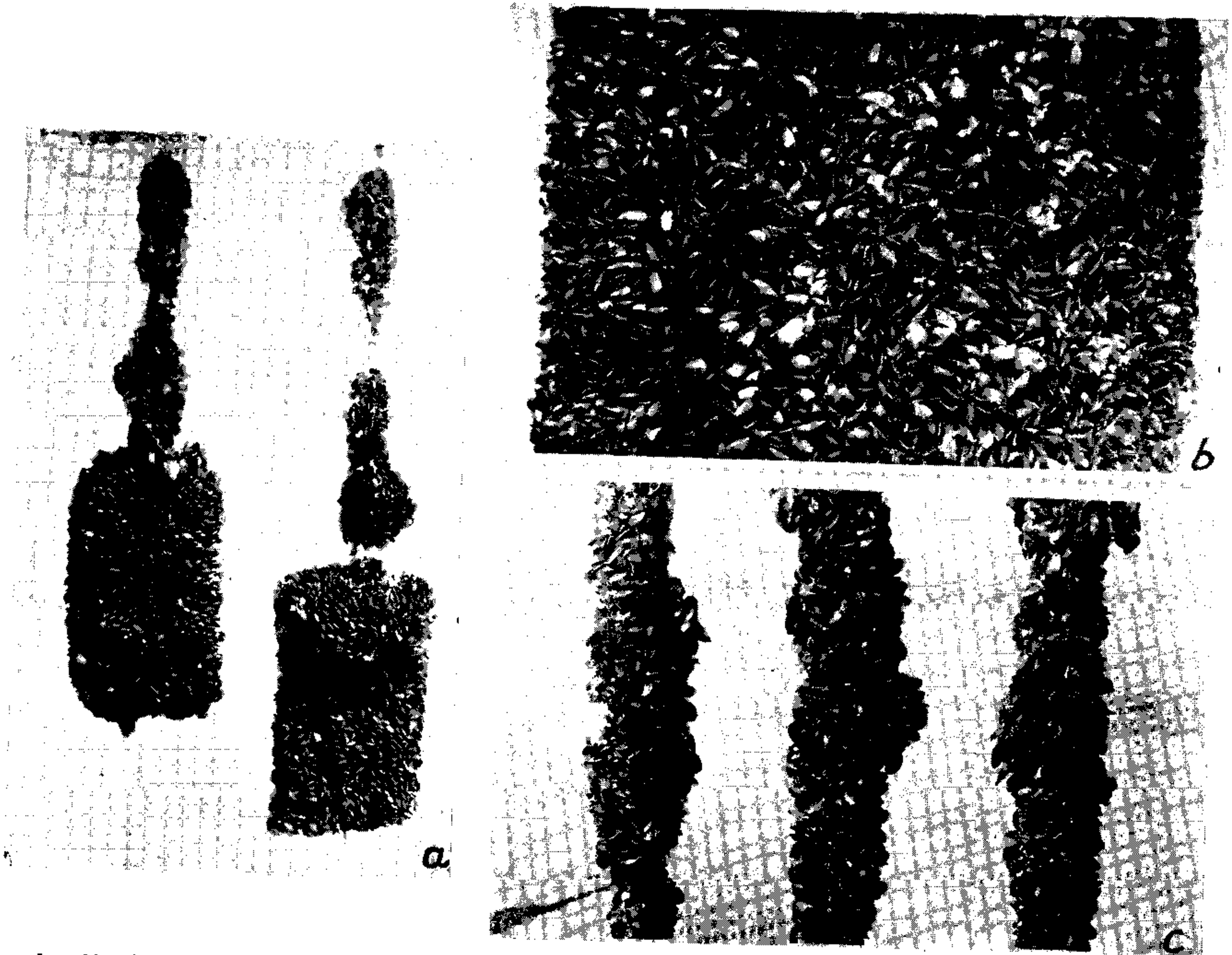


PLATE I. a. Mangalore tiles showing intense mussel spat fall. b. A close up view of a tile showing mussel seeds. c. A close up view showing the mussels growing on ropes.

(*a*) Interference to normal fishing activities in the coastal area due to the anchoring of large-sized rafts in a series, over expansive stretches. The present mood of the fishermen is against this effort since they report that their operation of boat-seines and drift-nets are drastically obstructed to.

(*b*) East coast is a cyclone prone area, the severity of which is felt almost every year during May-June and October-December period. Therefore any attempt in open-sea mussel culture all the year round needs stabilisation of appropriate technique to keep the seeded ropes and the stock thereon from large-scale destruction, causing economic loss to the culturist. This calls for developing all-weather proof raft structures at low cost or change in the technique of culture. Fending of the wave action by encircling the raft floated areas by laying automobile tyres may help to prolong the life of the raft tiding over difficult choppy seas. This method is being tested for its efficiency. Experiments using submerged raft are also in progress here to withstand rough sea conditions.

(*c*) The third problem, is making available large quantity of mussel seed that may be needed for commercial-scale farming. Collection of seed by suspending Mangalore tiles from the rafts had succeeded to a limited extent at Kovalam enabling collection of seed of 15-20 mm size upto 10 kg/tile (Plate 1. a & b). Intensifying these efforts in the area may help to a very great extent to procure large quantities of spat not only from this area but also in the adjacent mussel populated coastal strips. Alternate method of hatchery production of mussel seed is being developed to meet large-scale demands.

(*d*) At present, predators, parasites, diseases and pollution problem have not cropped up in the culture experiments. But these are some of the potential dangers to be tackled and research efforts in this direction have been initiated.

(*e*) Regarding the market for the mussels in the east coast, there is at present very little demand. Even the people living along the coastal areas including the fishermen very rarely use the mussels in their diet. They are occasionally sold in the Madras City market at the rate of 15 per rupee. There is an urgent need to popularise the use of mussels as food among the coastal people. A post-harvest technology should be developed for the utilization of the mussels.

# X

# MICROBIAL FLORA OF MUSSELS IN THE NATURAL BEDS AND FARMS

C. THANKAPPAN PILLAI

Quantitative estimation of the bacterial load of the brown mussels cultured at Vizhinjam has been shown as $10^6$. The occurrence of Coliforms, *Escherichia coli*, faecal streptococci and coagulate positive staphylococci is reported. *Pseudomonas*, *Vibrio* and *Micrococcus* are seen as normal flora.

## INTRODUCTION

In India quite encouraging results have been achieved, in culture of the economically important species of brown mussel (*Perna indica*) and green mussel (*P. viridis*). However, adequate care has to be taken against diseases, that can occur to these animals, as they can deplete the stock as a result of mass mortality. Moreover, infestation can result in poor growth, thin meat, change of normal colour and failure of byssal development (Sindermann, 1970 in *Principle diseases of Marine Fish. and Shell-fish*, Acad., Press, 369 pp[1].). Paralytic shelfish poisoning is another problem (Mason, 1971, *Underwater Journal*, 3 : 52-59[2]). Hence, studies on the life history of the aetiological agents of various diseases, treatment of diseases and necessary prophylactic measures against diseases are significant areas for investigations for the success and development of mussel culture.

## Material and Methods

In view of the above, a preliminary study of microbial flora of suspended cultured mussels (*P. indica*) in Vizhinjam, Trivandrum and surface sea water in that environment was made. Similar investigations were carried out in the mussels of the natural beds also at Kovalam, Trivandrum for comparison.

The mussels were aseptically collected in sterile containers. Surface sea water samples were collected aseptically in sterile glass bottles both from the culture site and from the environment of the natural mussel beds. The collected samples were immediately transported to the laboratory for further investigation. In the laboratory, the mussels were aseptically opened and the mussel meat along with fluid was separated and suitably diluted in sterile sea water. Similarly, water samples were also diluted. The diluted samples were inoculated into sea water agar. The samples were further plated in selective media for coliforms, *Escherichia coli*, faecal streptococci and coagulase positive staphylococci. The inoculated petri dishes were incubated at room temperature for 2-3 days and readings taken. The selected colonies, from the sea water agar, were transferred into see water agar slants for further observation.

The isolates, were tested for their purity, and identified using the system of classification of Buchanan and Gibbons (1974, *Bergey's Mannual of Determinate Bacteriology*, 8th ed. Williams & Wilkins Co., Baltimore ; 1246 pp[8].)

## Results

The results of the quantitative and qualitative studies are presented in Table 1 and 2 respectively.

Table 1. *Quantitative Aspects of the Bacterial Flora in Mussels and in Sea-water*

| Organisms | | | Meat emulsion of the cultivated mussels | Meat emulsion of the mussels from the natural bed | Sea water from the culture site | Sea water from the natural mussel bed area |
|---|---|---|---|---|---|---|
| | | | Average counts per millilitre | | | |
| Total bacterial counts : | Oct. 1977 | .. | $2.5 \times 10^{6}$ | $2.2 \times 10^{5}$ | $1.7 \times 10^{6}$ | $2.0 \times 10^{5}$ |
| | May 1979 | .. | $3.4 \times 10^{6}$ | TNC | $1.2 \times 10^{6}$ | TNC |
| Coliforms : | Oct. 1977 | .. | $1.0 \times 10^{4}$ | $1.6 \times 10^{3}$ | $3.5 \times 10^{4}$ | $2.8 \times 10^{4}$ |
| | May 1979 | .. | $2.2 \times 10^{4}$ | TNC | $6.3 \times 10^{4}$ | TNC |
| *Escherichia coli* : | Oct. 1977 | .. | $3.0 \times 10^{3}$ | $1.0 \times 10^{3}$ | $1.4 \times 10^{3}$ | $7.0 \times 10^{3}$ |
| | May 1979 | .. | $7.0 \times 10^{3}$ | TNC | $1.9 \times 10^{3}$ | TNC |
| Faecal streptococci : | Oct. 1977 | .. | Nil | Nil | Nil | Nil |
| | May 1979 | .. | $1.0 \times 10^{3}$ | TNC | $2.7 \times 10^{3}$ | TNC |
| Coagulase positive staphylococci : | Oct. 1977 | .. | $6.1 \times 10^{3}$ | $1.5 \times 10^{3}$ | $2.8 \times 10^{3}$ | $1.2 \times 10^{3}$ |
| | May 1979 | .. | Nil | TNC | Nil | TNC |

Nil — No growth. TNC — Test not made

Table 2. *Qualitative Aspects of the Bacterial Flora in Mussels and in Sea water*
(In percentage)

| Material | | | *Pseudomonas* Spp. | *Vibrio* Spp. | *Micrococcus* Spp. |
|---|---|---|---|---|---|
| Meat emulsion of the cultivated mussels : | Oct. 1977 | .. | 50 | 34 | 16 |
| | May 1979 | .. | 60 | 40 | — |
| Meat emulsion of the mussels from the natural bed : | Oct. 1977 | .. | 50 | 25 | 25 |
| Sea water from the culture site : | Oct. 1977 | .. | 50 | 25 | 25 |
| | May 1979 | .. | 50 | 33 | 17 |
| Sea water from the natural bed : | Oct. 1977 | .. | 37.5 | 37.5 | 25 |

Quantitatively, the bacterial load of the suspended culture of mussels was relatively higher than that of the mussels in the natural bed. It was $10^6$ and $10^5$ respectively. Similar situation was also noticed in the case of sea water. The occurrence of coliforms, *Escherichia coli*, faecal streptococci and coagulase positive staphylococci were almost steady both in mussels and sea water. Faecal streptococci was not noticed in October 1977 but noted in May 1979. Coagulase positive staphylococci which was present in October 1977 was absent in May 1979.

As the normal flora in mussels and in sea water, species of *Pseudomonas*, *Vibrio* and *Micrococcus* were present. Species of *Pseudomonas* predominated both in the mussel and sea water. All the isolates of *Vibrio* were luminescent. The results of this investigation are almost in agreement with those of Colwell and Liston (1962, *J. Insect. Pathol.*, **4**: 23-33[4]) and Karthiayani and Iyer (1975, *J. mar. biol. Ass. India*, **17**(1) : 96-100[5]).

## Discussion

In the present investigation, species of *Pseudomonas*, *Vibrio* and *Micrococcus* are found as the normal flora of the mussels. Aquatic bacteria such as *Pseudomonas*, *Aeromonas* and *Vibrio* are potential pathogens and can cause diseases to the aquatic animals especially when the animals are under stress (Bullock, 1964, *Dev. Indust. Microbiol.*, **5** : 101-108[6]).

In the present study, *Escherichia coli*, an indicator organism of faecal pollution, was present in the mussels and sea water both at Kovalam and Vizhinjam. This reveals the possibilities of outbreaks of epidemics like gastro-enteritis if the polluted mussels are consumed without proper washing and cooking. If these mussels are to be marketed alive, they may first be depurated as discussed by Wood (1969, *Lab. leaflet*, **20** (N.S.), Lowestaft Fisheries Lab., 15 pp[7].) and Mason (1971 and 1976, in *Marine mussels : their ecology and physiology*, Camb. Univ. Press : 585-410[8]) by storing the mussels in sterile sea water for 2 days. The depurated mussels should be well washed and cooked for human consumption.

Disease causing bacteria, fungi, viruses, protistans and other parasites have been better studied in the case of oysters and clams than in mussels. Apart from the large-scale mortality of mussels caused by the parasitic attack of *Mytilicola intestinalis* in American and European waters, pathogens like *Labyrinthomyxa marina*, *Monilia* sp., *Ostracobiabe implexa* and *Sirolpidium zoophthorum* are known to cause mortality among shellfishes. It is quite possible that under certain conditions mussels in the farm might also be affected by the above organisms. A haplosporidian, *Chytridiopsis mytilorum* is known to destroy mussel eggs in North Atlantic waters. Similarly *Haplosporidium tumefacientis* invades the digestive glands of mussels causing mild mortality. The gregarine *Nematopsis schneideri* causes mortality of mussels destroying the gill region. In Baltic waters, *Hypocomides mytili* and *Kidderia mytili* have been identified to cause mortality of mussels. *Ancistrocoma pelseneeri*, a ciliate, also causes considerable damage to the digestive system of mussels resulting in mortality. Species of *Aeromonas* and *Vibrio* are particularly dangerous to the hatchery produced molluscan larvae.

The above instances only go to show the potential dangers to be foreseen from different sources. Fortunately cases of diseases and mortality among mussels in India have not been so far reported. It is possible that this is not because of the absence of the diseases but due to inadequacy of attention to this aspect. Future investigations might throw light on this aspect.

Taking steps to prevent the outbreak of diseases is very important. In this context, the following points appear to warrant our attention.

(1) Selection of farm site free of biological and chemical contamination after studying the extent of contamination.

(2) Selection of disease resistant seed for culture.

(3) Avoiding overcrowded stocking in order to minimise the ill effects of epizootics.

(4) Care in handling the cultured stock to avoid contamination.

(5) Periodical investigation of the level of pathogenic organisms in the culture system to assess the status of the stock population.

(6) Eliminating other source of disease transmission by selective removal of reservoir host of pathogens.

(7) Routine disinfection of materials used in culture (materials like buckets, rope etc.) and

(8) Timely harvesting of stock reducing the vulnerability of older stock to diseases.

# XI

## PREDATION ON MUSSELS IN CULTURE BY SILVER BREAM, *RHABDOSARGUS SARBA*

K. K. APPUKUTTAN

*Rhabdosargus sarba* shoals, as observed in Vizhinjam area during 1979, play havoc to the cultured mussels. 250 ropes containing good quantity of harvestable mussels are reported to have been completely destroyed by predation by this fish. Attempts to control predation did not yield results. In addition to lobster predation noticed commonly in the area, *Rhabdosargus sarba* has added a new dimension to the problem.

### INTRODUCTION

Davies (1970, *Proc. Symp. on Mollosca*, 3 : 873-884, M.B.A. India[1]), while dealing with mussel as world food resource has discussed various problems in culture and attached great significance to the predation caused by animals in the farm. Important among them are crabs, fish, and also flat-fishes from European waters. He has also mentioned about damages caused by diving ducks and oyster catchers preying on intertidal mussels and pointed out that in the development of mussel culture in new areas, completely different predation problems may arise, for example midwater predation, and concludes that raft culture is not a sure remedy for predation.

### OBSERVATIONS

Experiments on floating raft culture at Vizhinjam Bay from 1976 showed that predation by fishes was not a serious problem till 1979. While examining the seeded ropes in 1976 browsing of mussels by fishes was noticed. Fish traps were kept in the rafts to collect these fishes in the vicinity of the raft area. *Diodon hystrix*, *Arius* sp., *Arothron nigropunctatus*, *Ostracion* spp., *Chaetodon* spp., and *Acanthurus* sp., were collected and the stomach contents of these fishes were examined. It was found that the first three species of fishes feed on young mussels of 20 to 30 mm size. Out of 16 numbers of *Diodon hystrix* collected during October (ranging from 175-295 mm in total length) 8 specimens had mussels in their stomach. All the three specimens of *Arius* sp. had stomach full of mussels and out of 5 specimens of *Arothron nigropunctata*, two had mussels. However, samples of fishes collected in subsequent months failed to reveal mussels in the stomach contents. The damage caused to the seed on the ropes was observed to be very negilible. In 1977 and 1978 also only the three species mentioned above caused minor damage to the seed.

During January 1979, 250 seeded ropes released in the floating rafts inside the bay, were attacked by a shaol of silver bream, *Rhabdosargus sarba*. Efforts to catch the fishes by hook and line did not succeed. However fish traps kept in the bay enabled collection of fishes ranging from 360 to 470 mm in total length during the first week of February. Examination of the stomach contents revealed stomach full of crushed mussels, clearly indicating that these fishes were heavily feeding on mussels on the rope. By the end of February, the entire stock of seeded mussels was eaten up by the shoals of fish (Plate I, a). Control of predation by gill netting was tried but it was not effective. It was also understood that 1500 seeded ropes kept in the floating rafts of the Pilot Project on mussel culture of Kerala State Fisheries Department were also reported to have been completely destroyed by the shoals of the same species, *Rhadosargus sarba* by the end of April.

Full grown mussels on ropes kept suspended from rafts in the Bay were also not spared from predation. The fishes crushed the shells and fed upon the flesh

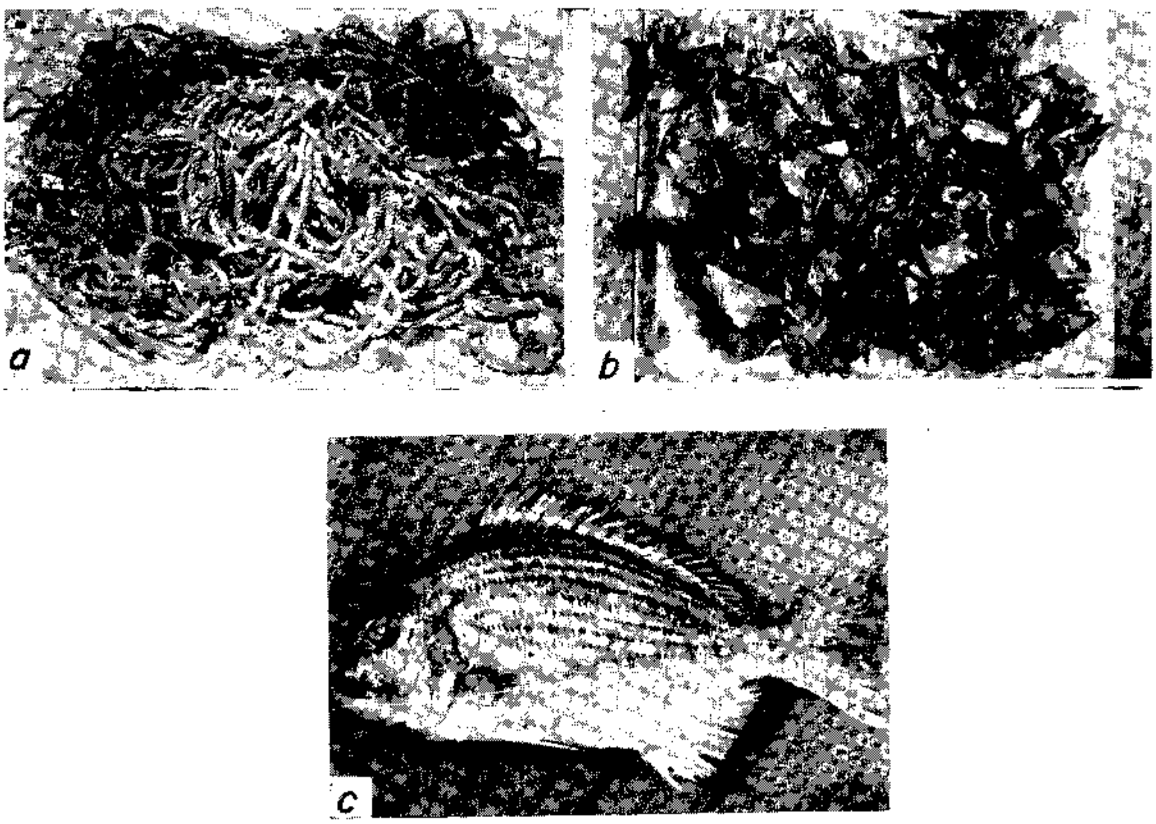


PLATE I. a. Damaged mussel ropes. b. Crushed shells of full grown mussels. c. *Rhabdosargus sarba.*

leaving remnants of empty shell still attached to ropes (Plate I, b).

This Silver bream, locally called 'Thavanupara' (family : Sparidae) are carnivorous, inhabiting shallow waters. The body is silvery with golden longitudinal lines along scale rows. A yellow streak across belly is present. (Plate I, c). In the upper and lower jaw, rows of compressed incissors and rounded molars are present. Posterior molar in each jaw greatly enlarged. The teeth structure is well adapted for crunching hard objects.

## REMARKS

It may be of interest to mention here that this fish does not form significant fishery in this area. The only fish so far been reported as causing damage to mussel in natural bed is flat fishes (Davies, 1970[1]) in European waters. The present report shows that silver bream may pose serious problems for mussel culture at Vizhinjam area. It may not be out of place to mention that during experiments on mussel culture inside the bay it was observed that lobsters also cause damage to cultured mussels on a minor scale. Lobster cages were kept in the farm and found that during November to January period number of lobsters could be collected from the farm area. In the natural bed around Vizhinjam also mussel predation by lobsters was observed. They cut the live shells and eat away the flesh leaving the broken shells attached to substratum. It may be of interest to note that the lobster fishermen keep mussels collected from the natural bed inside the cages as bait, for luring lobsters into the trap. It is understood from fishermen that mussels are considered as the best bait for lobster fishing.

Mahadevan (Personal communication) has stated that unusually large shoals of *Drepane punctata* appear in the pearl banks during pearl fishery times attracted by the rotting flesh of the pearl oysters at the bottom, discarded earlier by fisher-folk cutting open oysters while the fishing is in progress. Similarly the probable reason for the entry of shoals of silver bream in the area can be attributed to the dynamiting for fishing in this area. During January and February the local fishermen were dynamiting around the breakwater area for mackerel and caranx shoal. There is every possibility of the silver bream shoal being disturbed from the natural habitat and accidentally entering the mussel culture area. As the fishermen could collect only a fraction of the fishes by dynamiting, the rest get battered attracting pugnacious feeding by the silver bream.

Several methods have been developed in foreign countries to solve the problem of large scale predatory attacks. Hanson (1974, *Open Sea Mariculture*, Dowden, Hutchinson & Ross. Inc. 410 pp.[2]) lists, air barriers, electrical barriers, acoustical barriers, chemical controls and animal barriers amongst them. It has to be seen whether the present instance of predation by *Rhabdosargus* is an isolated event or is a perennial nuisance in the area before we can think of suggesting measures, within the frame-work of practicability to overcome the attacks.

# XII

## EXPERIMENTS ON SUBMERGED RAFT FOR OPEN SEA MUSSEL CULTURE

S. J. RAJAN

Submerged raft made of 10 bamboo poles fixed on a teak wood frame from which 150 ropes can be suspended in the open sea, has been found to withstand rough sea conditions. The rafts are buoyed by conical floats of oil drums. Success of this experiment will enable open sea mussel culture all the year round.

### INTRODUCTION

In India mussel culture is of very recent origin. In European countries where mussel culture was started about a century ago and in Philippines where it was started more recently, Mussel farms are located in protected waters like bays and fjords. In Europe such sheltered areas are already fully utilised. Davies (1970, *Proc. of Symp. on Mollusca*, 3 : 873-884 ; M.B.A. India[1]), opined that the possibility of expanded market demand for mussel would perhaps be limited by this 'shelter' factor. He further suggested that large areas of inshore waters can grow good quantity of mussels, and if it was found that good mussels could be grown at depths below the storm water zone of the open sea it could represent a major break-through to sea farming on a vast new scale. Practical and scientific investigations on feasibility of inexpensive, indigenous infrastructure supported mussel culture in the open sea for adoption on an extensive scale by fisherfolk of coastal villages of India are engaging our attention today since enough information is available on sophisticated methods adopted by developed countries.

Experiments on open sea mussel culture by the floating raft method conducted at Kovalam, 40 km south of Madras from 1976 onwards revealed the possibility of reaping a harvest by suitably adopting the time of seeding during June, avoiding the high velocity winds of South West Monsoon and harvesting the stock during October before the commencement of North East Monsoon which often develops into severe cyclonic storms. For a successful farming operation of this kind, the rafts are to be positioned at sea throughout the year, which may result in two or three harvests, simultaneously providing natural seed from the farm area. From our experience with the surf beaten nature of this coast, exposed to variable winds and severe cyclonic storms, necessity arose to develop a very strong submersible raft with suitable buoys. Having difficulties in using conventional floating rafts with cylindrical buoys, at the suggestion of Dr. E. G. Silas, an alternate method of keeping the raft submerged with inverted conical buoys made of oil drums has been tried.

### DESCRIPTION OF SUBMERSIBLE RAFT

The submersible raft consists of a nine metre square frame made of 50 to 60 cm thick teak-wood poles suitably joined at the ends by a cross halving joint with iron bolts and nylon cord lashing. (Plate I, a). Another pole at the middle of the frame acts as a rib (Plate I, b) providing the required strength. Ten bamboo poles of nine metre length are lashed to the frame with nylon cord at intervals of 0.75 m (Plate I, c). At the rate of 15 ropes of 4 metre length per bamboo pole, 150 ropes can be tied in addition to the 50 ropes which can be tied to the five teak wood poles of the frame.

The inverted conical floats are made out of 200 litre oil barrel drums, cut and reshaped into a cone (Plate I, d). The significance of this float over the conventional cylindrical buoys which exert great resistance to waves and currents is its least resistance. The apex of the cone is slightly weighted on the inner side to which an iron ring is firmly welded. This inverted conical

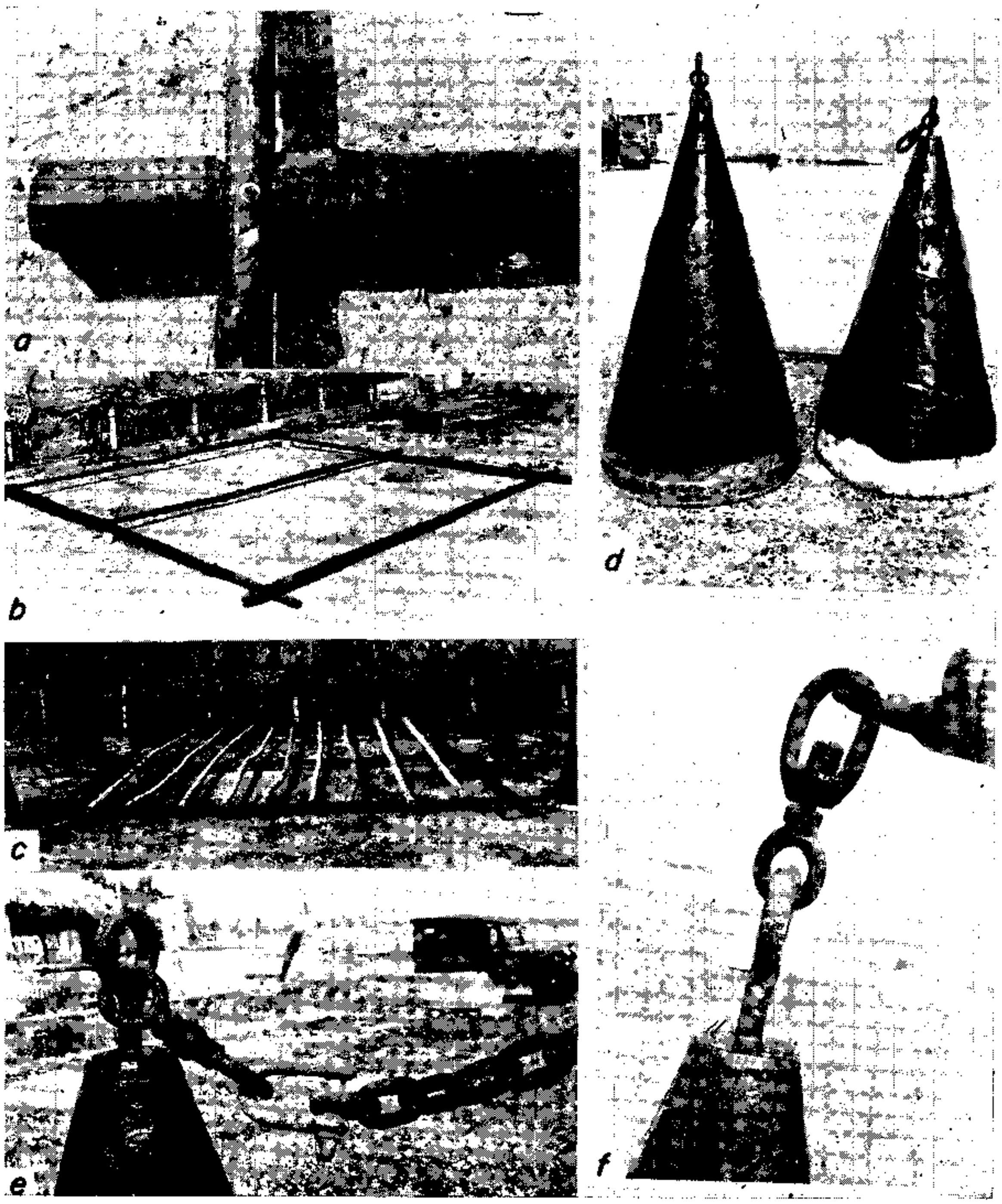


PLATE I. a. Cross halving joint with bolt used in the frame work of the raft. b. The frame. c. General view of raft showing the position of conical floats and anchors. d. Conical float. e. Swivel fixed to the conical float. f. Fixing of float chain with shackle.

buoy when put in water floats half submerged exposing the broad side above water level. To the ring in the apex, a swivel is fixed (Plate I, e) to take in the twist on the chain caused by the currents and waves. One end of the two metre long 3/8" chain is fixed to the swivel with a 'U' shackle (Plate I, f). The floats are given a basal anticorrosive coating of red oxide followed by an over coat of lacoloid black paint. Anchors of different types and weights can be fixed. It is found that the grapnel type anchor weighing 80 kg is ideally suited for a sandy bottom. The type of anchor and weight will depend largely on the size of the raft, the nature of the sea bottom and the strength of the current obtainable in the operational zone. Welded anchor chains of 3/8" and 1/2" thickness were tried which under very rough weather snapped off at the point of welding of the links. Therefore forged chains without joints appear to be ideally suited. Two such anchors at opposite ends for each raft are used to keep the raft in position. The length of the chain should be 4 to 6 times the depth in which the raft is to be fixed to allow for possible drift at the time of strong currents and high waves.

The raft without buoys is towed to the farm area and anchored. The raft has to be kept on the surface of the sea till seeding work is completed, for which four cylindrical 200 litre drums are lashed closely to the upper four corners of the raft. After, all the seeded ropes are in position, the cylindrical drums are replaced by the conical floats, by shackling the free end of the 2 m chain of the float to the raft. Now the raft will get submerged and only the top half of the floats will be visible above water. As the mussel grows bigger and heavier more floats are added to keep the raft at the desired depth. Normally half the conical drum should be visible above the water surface. The depth at which the raft is to be submerged is controlled by suitably varying the length of the float chain. At the time of harvesting the whole raft has to be brought up by hauling in the float chains one by one and lashing the buoys closely to the raft. Once the raft is on the water surface, a person can walk on it and remove the ropes.

With the growing awareness of large scale mussel culture and dearth of sheltered areas suitable for mussel culture, open sea mussel culture appears to be a distinct possibility in the near future. Various types of culture practices are followed the world over and the appropriate type of culture depending on peculiarities of environment has to be evolved. The submerged raft tried at Kovalam (Madras) for open sea mussel culture is only a first step in this direction, which can be further modified and perfected to suit various sea conditions obtainable in different areas.

# XIII

## WORK DETAILS FOR ROPE CULTURE OF MUSSELS

P. S. KURIAKOSE
K. K. APPUKUTTAN

**Work details showing the salient features of various aspects of materials needed and methods followed in mussel culture are detailed in this paper.**

### General

Species of mussels that are culturable are *Perna viridis* (green mussel) and *P. indica* (brown mussel) (Fig. 1 & 2). The former is known to grow upto a size of 230 mm and the latter to a size of 125 mm. But the size commonly observed in the natural beds is 180 mm in the case of green mussel and 80 mm in brown mussel.

*Distribution :*

Green mussel is found in the rocky areas of the coasts of Orissa, Andhra, North Tamil Nadu (Pondicherry to Pulicat), Kerala and Maharashtra. Brown mussel is characteristic of the rocky areas of extreme south-west and south-east coast of India.

*Local Names :*

Green mussel is known as 'Kakkai', 'Vakunda' or 'Shintale' (Goa-Jaithpur area), 'Kulachi' (Malwan area), 'Neelkallu' (North and South Kanara), 'Kallumeikai', 'Kadukka' (Kerala) and 'Alichippalu' (Andhra). Brown mussel is called 'Chippi', 'Muthuva', 'Muthuvachippi' (Kerala), 'Kallikai', 'Chippi', 'Kalluthodu' (Tamil Nadu).

*Season of Fishery :*

A. Green mussel :

| | | |
|---|---|---|
| Ratnagiri region | : | November to April |
| Malwan region | : | September to May |
| Karwar region | : | December to May |
| Cannanore—Calicut region | : | November to May |
| Cochin region | : | December to May |
| Madras region | : | January to September |
| Kakinada region | : | May |

B. Brown mussel :

| | | |
|---|---|---|
| Vizhinjam area | : | October to May |
| Colachal—Muttom area | : | November to April |
| Cape Comorin area | : | November to April |

*Price in the market :*

A. Green mussel : per 100 numbers :

| | | |
|---|---|---|
| at landing centre | .. | Rs. 2-3 |
| at the market | .. | Rs. 3-5 |
| meat alone packed in polythene bags | .. | Re. 5-6 (per kg) |

B. Brown mussel : per 100 numbers :

| | | |
|---|---|---|
| (80-110 mm) | .. | Rs. 7-10 |
| (55-80 mm) | .. | Rs. 3-5 |

## Biochemical Composition of Meat

The Indian mussels are said to contain 8-10% protein, 1-3% fat and 3-5% glycogen. In addition to this calcium, phosphorous, manganese, iodine and iron are also present. This compares favourably with blue mussels of Europe, where the protein value is said to go upto 14%. The calorific value has been worked out for green mussel meat as 6.28 Cal/gm (dry weight). The percentage of meat weight (edible portion) to the total weight ranges from 40 to 50 for green mussel and 35 to 45 for brown mussel in the marketable size.

## Collection of Seed and Seeding

(i) *Seed availability :*

Green mussel seed can be obtained during September to December all along the west coast, in areas where rocky substrata exist. The potential of seed availability has not been thoroughly worked out, but several lakhs of seed which may otherwise perish because of exposure can be profitably utilised. Coasts of Kasargode, Cannanore, Tellicherry, Mahe, Thikkodi, Elatur and Calicut are the potential areas of green mussel seed. The size of the seed available during the season is between 15-25 mm.

In the east coast Cuddalore—Pondicherry region, Madras—Ennore region, Kakinada Bay area and the estuarine regions of Orissa can meet the requirement of seed for mussel culture. May to July appears to be ideal season for seed collection in the east coast.

Brown mussel seed occur along the submerged and partially exposed intertidal rocky areas from Vizhinjam to Cape Comorin from July to November, with a peak season in September. Several lakhs of seed ranging from 25-30 mm can be collected during this period.

(ii) *Methods employed for seed collection :*

(*a*) From natural bed :

(1) Hand picking from the intertidal area just below the low tide level. The seed is scraped with a sharp instrument so that the byssal threads are not completely destroyed; in otherwords, plucking should be avoided as far as possible.

(2) From deeper areas, similar removal by diving operation.

(*b*) Spat collection :

Mussel spat can be collected from natural bed and farm area during spawning season by employing several methods like suspending coir and nylon ropes over the mussel bed or by suspending spat settlers like frilled polyester ropes or iron hapas covered with nylon netting.

(iii) *Method of transport :*

Mussel being sturdy can stand transportation without much mortality upto a maximum of 24 hr provided one of the following conditions are given :

(a) Seeed are kept in containers with sea water being periodically changed to avoid rise in temperature.

(b) The mussel seed are always kept wet with sea water either by water drip or placing them under soaked wood shavings, gunny bags or seaweeds.

(iv) *Seeding technique :*

Nylon rope, polypropylene rope (12 mm thick) or coir rope (14 & 20 mm) can be used for seeding. Coir rope will last only for one season whereas synthetic ropes can be used for atleast 4 seasons. Though the initial investment is more, synthetic ropes are more durable and can hold the complete weight of full grown mussels.

Since the idea of collection of seed is to transplant them on to a substratum to which they can attach themselves it is necessary that the seed are kept very close to that object for sufficient duration (ranging from 3 to 4 days). During this period byssal attachment takes place enabling the mussel to hold on to the rope fast. This principle is made use of in the rope culture by the following technique described below :—

The cleaned mussels kept in sea water are spread uniformly over mosquito netting of 25 cm width. The seed is securely wrapped around the coir or nylon ropes. The edge of both end of nettings is stitched using cotton thread. The seeded ropes are once again wound with thin plain coir rope at an interval of ½ metre to avoid slipping of mussels when the netting gets disintegrated within 2 to 4 days. Single rope of 6 m length can be seeded within 20 minutes and two persons can normally seed 30 to 35 ropes a day. Seeding can be done on lengthy tables or on cemented floor near the farm area.

(v) *Points to be observed while seeding :*

(1) Seeding is to be done during the cool hours of the day under shade.

(2) Overcrowding of seed is to be avoided by distributing the seed uniformly to cover the required length of rope. Wooden spacers or pegs can be used to promote firm grip for the mussel on the ropes. From experience, the following quantity of seed appears to be reasonable limit for seeding a given length of rope.

| | |
|---|---|
| brown mussel | .. 1.5 kg/metre |
| green mussel | .. 500-700 g/metre |

Care should be taken to avoid seeding the entire length of ropes giving sufficient free space to remain free above water level depending on the tidal amplitude. While suspending the ropes in rafts, the seeded ropes should not touch the bottom of the sea. It is ideal to give clearance of atleast 2 to 3 m from the bottom. Ropes can be suspended 50 to 70 cm apart in the raft. The bottom end of the rope is weighted in the initial stages by using sinker stones so as to keep it vertical. This should ensure utilizing maximum advantage by entire column of water in the area.

## Raft Construction

The standard sizes of rafts used are 6 × 6 m and 8 × 8 m dimension. The materials required are given below :

| *Materials for raft :* | 6 × 6 m raft | 8 × 8 m raft |
|---|---|---|
| 1. Teak wood pole for outer frame work 7.5 cm diameter | 8 nos (6 m long) | 10 nos (8 m long) |
| 2. Bamboo poles (Kallan) for trellis work | 12 nos. | 12 nos |
| 3. Country wood (¼ × 3 m) planks for providing space for on-raft work. | 2 nos | 2 nos |
| 4. Coir or nylon rope to lash the poles together (3-4 mm thick) .. | 5 kg | 6-7 kg |
| 5. Floats—oil barrels 200 litre capacity, leak proof, thickly coated with anticorrosive paint or high density plastic barrels with antifouling paint. | 4 nos | 5 nos. |

(Diagramatic sketch of raft with culture ropes is given in Fig. 1)

*Materials for mooring the raft :*

(1) Anchor—Grapnel or admiralty type of iron anchors. 50-100 kg—3 to 4 nos. depending on the place of mooring and size of rafts.

(2) Anchor chain—Tested forged link chains coated with anti-corrosive paint ; at the rate of 5 lengths for every metre of water depth—12 or 9 mm diameter chains can be used.

*Precautions :*

Normally the rafts are moored at a depth ranging from 10-15 m. It would be useful to mark the position of the raft by installing winking lights or providing self-ignition lamps for the night and a flag with white and red colour to show the position during day time. Number of ropes to be suspended may vary from 50-100 depending on the size of the raft and the total weight of the harvest expected from each raft. The length of seeded portion of rope should be so adjusted as to avoid entangling amongst the ropes due to wind and current.

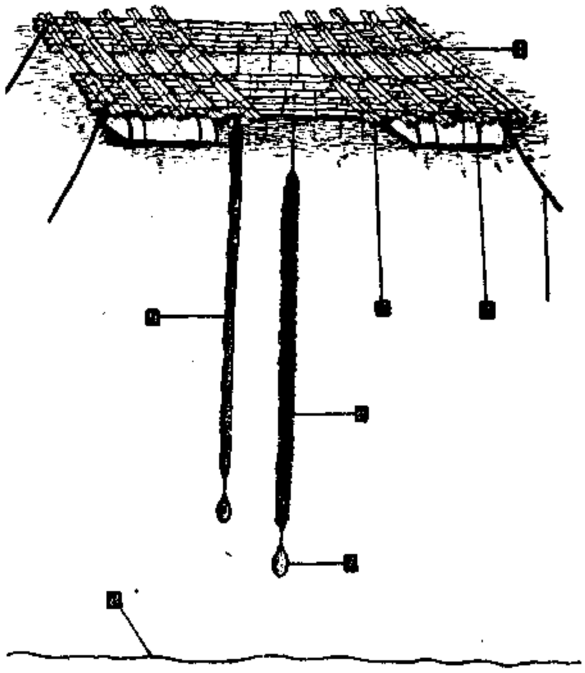

Fig. 1. *Diagram of a typical mussel raft*

1. Frame work of raft.
2. Bamboo pole.
3. Metal float.
4. Anchor rope.
5. One seeded rope.
6. Seeded mussel rope after a week.
7. Sinker.
8. Sea bottom.

## FARM MAINTENANCE

After launching the rafts in the farm area with seeded mussels a close watch over the rafts is necessary. Periodical visit to the farm by atleast two persons to observe the following are necessary:-

1. Thinning of ropes with crowded seed settlement to avoid slipping and also to transplant the seed to fresh ropes.
2. Examination of ropes for fouling organisms, cleaning operations and elimination of predators.
3. Periodical mending of raft structure wherever necessary.
4. Supervising the raft once in a week to check the position of the raft and the condition of seeded ropes.
5. A close vigilance over the farm site will avoid poaching and pilferage of raft materials and farm grown mussels.

It is necessary to have a canoe to reach the farm site and a good diver can help checking the position of the anchors.

## PROGRESSION OF GROWTH OF MUSSELS IN THE FARM

(i) *Green mussel :*

Growth in the Farm :

| Month | | Total Length (in mm) | Total wt. (in grams) | Meat wt. (in grams) |
|---|---|---|---|---|
| Nov. | .. | 20.6 | 1.1 | 0.40 |
| Dec. | .. | 36.0 | 4.5 | 1.74 |
| Jan. | .. | 50.6 | 9.60 | 3.81 |
| Feb. | .. | 63.7 | 12.60 | 5.59 |
| Mar. | .. | 74.9 | 28.60 | 11.40 |
| Apr. | .. | 88.2 | 37.50 | 15.18 |

*Average growth rate :*

| | | |
|---|---|---|
| First month | .. | 15.4 mm |
| Second month | .. | 13.6 mm |
| Third month | .. | 13.1 mm |
| Fourth month | .. | 11.2 mm |
| Fifth month | .. | 13.3 mm |

| | | |
|---|---|---|
| Total growth in a period of five months | .. | 67.6 mm |
| Total weight increase in five months | .. | 36.4 g |
| Total meat increase in five months | .. | 14.7 g |

(ii) *Brown mussel :*

| Month | Bay Total length (in mm) | Bay Total wt. (in gm) | Bay Meat wt. (in gm) | Open Sea Total length (in mm) | Open Sea Total wt. (in gm) | Open Sea Meat wt. (in gm) |
|---|---|---|---|---|---|---|
| October | 28 | 1.5 | 0.5 | .. | .. | .. |
| November | 30 | 2.0 | 0.9 | .. | .. | .. |
| December | 33 | 2.5 | 1.0 | .. | .. | .. |
| January | 37 | 2.8 | 1.0 | 41.3 | 4.3 | 1.5 |
| February | 41 | 4.0 | 1.4 | 44.2 | 5.0 | 1.5 |
| March | 46 | 4.7 | 1.8 | 51.0 | 6.5 | 2.5 |
| April | 54 | 4.8 | 1.8 | 58.8 | 10.0 | 4.3 |
| May | 55 | 7.6 | 3.3 | 69.3 | 15.3 | 6.6 |
| June | 57 | 10.2 | 4.5 | .. | .. | .. |

Growth rate in the open sea brown mussel is faster and the meat weight percentage is also higher than those in the bay. The ideal period for suspending the ropes for culturing the brown mussel along Vizhinjam—Cape Comorin zone is September-November period. Similarly for green mussels in the west coast November-December is ideal period. In the east coast June-July appears to be ideal for releasing seeded ropes.

### Production Expected by Culturing

(i) *Green mussel :*

Seed weight used for a metre length of rope 500-700 g

Full grown mussels (per metre length) after 5 months .. 6.9 kg

The total production for a single rope of 6 metre length (6 m × 6.9 kg) .. 41.4 kg

Maximum number of ropes of 6 metre length in one raft .. 100

Production that can be anticipated from each raft (100 × 41.4) .. 4,140 kg

(ii) *Brown mussel :*

Seed weight used for a metre length of rope is 1.5 kg and they grow to 10 kg within 8 months (giving allowance for accidental slipping during growth and 5% mortality in the initial stages).

Total production for a single rope .. 6 m × 10 kg = 60 kg

Approximate production for a raft ..50 × 60 kg = 3000 kg

# XIV

## MUSSEL CULTURE IN INDIA—CONSTRAINTS AND PROSPECTS

E. G. SILAS

Europe has been the centre of commercial mussel farming in the world and production has been nearly stagnating over the past decade in the major mussel producing countries—Spain, the Netherlands, France and Italy, due to common problems of high cost of production through advanced technologies, limitations of growing grounds and the price structure not being commensurate with cost of production. It is believed that any substantial increase in world production of mussels can come about only through expansion of mussel culture programmes in the developing countries, including India.

Due to several limitations, natural production of mussels in India cannot be increased more than 2-3 times the present sustenance level. The technology of mussel culture which has been developed at the Central Marine Fisheries Research Institute has shown the high production potential and field extension programmes have already been taken up. In the paper, the constraints for expansion of mussel culture into the level of a small industry have been identified.

The need for research thrusts for improving the technology and increasing production rate has been highlighted. Areas which need such efforts are seed production, transplantation of mussels, studies on ecology and physiology of mussels, experiments on mixed farming, improvements in the culture system specific to our coastal conditions, pollution and disease problems and post-harvest technology. Legal aspects relating to lease of water areas and navigational problems have been touched upon.

The immediate need is for a perspective planning for the development of mussel culture as an industry with the full realisation of its potential. Governmental support and assistance from public financing institutions with an element of risk coverage in the initial stages would help the establishment and growth of the industry.

### Introduction

The world mussel production has been stagnant around 400,000 tonnes over the last decade despite the realisation that mussel culture has the highest potential for production as compared to the culture of any other organisms—fin-fishes, crustaceans or other molluscs. This has been mainly due to the fact that mussel farming as a business has concentrated only in Europe, particularly in four countries—Spain, the Netherlands, Italy and France, and developments elsewhere have not been significant to any degree as to contribute perceptibly to the world production. Certain common factors have affected the growth of mussel culture in Europe. They are limitations of growing grounds, increasing labour costs and farming risks, pollution problems and prices not being commensurate with increasing production costs as a result of introduction of mechanisation, technological innovations and material sophistication. This situation is likely to continue until there is a price tilt in favour of cultured mussel.

While there is a long history of exploitation and farming of mussels in Europe, recognition of its importance has been slow to develop elsewhere in the world. In the Far East, where mussel had been considered a pest, there has been an awakening and the Philippines, Thailand and more recently, Singapore have taken up small ventures of mussel culture. New Zealand, Australia, South Africa and South America are some of the other regions where experimental work as well as production-oriented programmes have been initiated in the recent years. The two major aquaculture countries—Japan and U.S.A.—do not show any interest in mussel culture due largely to consumers' non-favour.

It would therefore appear that any substantial increase in world production of mussels can come about only through expansion of the current development programmes in the non-traditional regions such as the South, South East and Far East Asia, South America, South Africa, Australia and New Zealand. The commonest advantages of Asian mussel culture would be its tropical waters where the mussel attains harvestable size within 5-6 months as against 2-2½ years in some parts of Europe and the cheap labour. The problems likewise common, would be making mussel acceptable as food for the large population and holding the price structure remunerative to the mussel farmer and within the reach of the poor who are in need of protein food most for improving nutritional standards.

Davies (1970, *Proc. Symp. Mollusca,* **3** : 873-884[1]), based on map reading, estimated a million and a quarter acres of creeks and gulfs between Karachi, Ceylon and the Ganges and projected that, at a yield of a ton per acre, this area, if cultivable, would produce a million and a quarter tonnes of mussels, enough to give 20 million people day's protein ration once a week throughout the year. This projection for India, although might appear speculative, is indicative of the scale of probable production if an all-out effort were to be made to realise this potential.

In India we have built up the primary infrastructure, that is the technology of mussel culture, which has been good enough to attract some governmental investment and interest of fishermen. Extention and expansion would depend on fixing developmental priorities and aiding the process carefully through integrated measures of production and marketing.

## Natural Production of Mussels

Jones and Alagarswami (1973, *Proc. Symp. liv. Res. Seas India,* 641-647, Spl. Publ. CMFRI[2]) made a preliminary estimate of the natural production of mussels (exploited) at 823.4 tonnes and also believed that an estimate of 1000 tonnes as the total marine mussel landings of India will not be wide of the actual figures. Since the above estimate was made there has been some increase in the landings, particularly in the mussel zones of Calicut-Tellicherry and Vizhinjam-Colachal-Muttom.

The natural distribution of mussels along the Indian coast is patchy. While dense settlement of the green mussel *Perna viridis* is seen along the Malabar Coast (Cannanore-Calicut), it is scattered/scanty in other areas including the Andaman Islands. New settlements of green mussel on the submerged parts of sea wall and groynes between Quilon and Narakkal along the Kerala coast have been seen in recent years, but the resource is very limited. The brown mussel *Perna indica* is restricted to the south-west coast (Quilon-Cape Comorin) and is not reported from elsewhere. Thus the mussel beds are very much restricted and there does not appear to be much scope for increasing production from these areas by the traditional fishing methods beyond 2 or 3 times the present level even if the effort were to be increased. The only alternative for stepping up production is through adopting culture techniques.

## Status of Mussel Culture in India

The Central Marine Fisheries Research Institute has carried out pioneering researches on mussel culture in India. Starting its work at Vizhinjam on the brown mussel *Perna indica* in the early seventies, the Institute has developed the techniques of floating raft culture in the Vizhinjam Bay (*CMFRI Spl. Publn.* 2, 1978[3]). Since 1978 experiments on open-sea mussel culture have been conducted outside the bay (*Mar. Fish. Infor. Serv. T & E Ser.*, No. 16, 1980, CMFRI[4]). The relative merits of mussel farming in the bay and open-sea have been identified. While growth of mussel is faster in the open sea, maintenance of rafts during the south-west monsoon has been found to be a major problem in taking advantage of this factor.

Experiments on the culture of the green mussel *P. viridis* were initiated at Calicut in 1975 and have provided valuable data and an insight into the problems of open-sea culture. The production has been high in suspended culture and indications are that it could be as high as in the Galician Bays of Spain, the leading mussel culture centre of the world, if farm management could be improved upon. The south-west monsoon forces the harvest to be taken in April/May, the seeding being done in November/December, and the mussel attains marketable size within these five months.

At Kovalam near Madras, culture of green mussel in floating rafts faces the problem of rough sea conditions including periodic cyclones. An experiment on the French-style pole culture has proved a failure as the poles could not withstand the strong currents and cyclone. Submerged raft culture has been tried with partial success in 1979 and the system is under improvement. Along this coast also *P. viridis* attains marketable size within 5-6 months.

The production rate in suspended rope culture of mussels has been 10-15 kg per metre length of rope in 5 to 6 months and length of individual ropes has ranged from 5-7 m according to the depth of the experimental farm. This compares very favourably with about 25 kg (½ cwt) of mussel yield in a 10 ft. long rope within 16 to 18 months of settlement in a Scottish loach (Mason, 1969, *World Fishing*, 18(4) 22-24[5]).

In the open-sea culture the distance of the mussel farm has been 0.5-1.0 km off Kovalam and about 3 km off Calicut.

The seed grounds for collection of seed for the experimental farms have been identified and transportation methods have been evolved. So far wild stocks of seed have largely been used in farming and seed obtained on untwisted nylon ropes in the farm itself has also been used to a limited extent at Vizhinjam. Spat settlement and commencement of culture operations in the farm do not coincide both at Calicut (south-west coast) and Kovalam (Madras coast). At the latter centre, where green mussel was transplanted, suspension of a breeding stock from the raft results in good spatfall on the 'Mangalore type' baked tile cultch. Apparently the circulation pattern in the inshore waters off Kovalam appears conducive to the growth of the larvae and settlement of spat in the same area without drifting away from the area of spawning.

Based on the results obtained over the years, extension programmes on mussel culture have been initiated with the involvement of the scientists in the work. An Operational Research Project for the blending of culture of mussels with the traditional capture fisheries of the fishermen has been taken up at Kovalam.

The Lab-to-Land programme on mussel culture, where the technology is transferred to fishermen, functions at Calicut (S.W. coast) and Karikattukuppam, a fishing village adjacent to Kovalam (Madras coast). A pilot project on brown mussel culture is in operation at Vizhinjam by the Department of Fisheries of Government of Kerala.

Some work has been done on development of mussel products acceptable to consumer's at the Central Institute of Fisheries Technology, Cochin, under an Inter-Institutional Project with the Central Marine Fisheries Research Institute. The former (CIFT) has also carried out extension programmes on mussel products.

## Development Constraints in Mussel Culture

Despite the fact, that the technology of mussel culture has been developed and some demonstrations have been conducted through extension programmes, there has been no large-scale adoption of the technology so far for increasing production. The constraints faced in developing mussel farming as an industry can be summed up as follows :

(*a*) Mariculture as a whole is a new venture for the country and therefore there is some hesitation on investments for any work in the sea.

(*b*) Acceptance of mussel as food is very low and is restricted to a few pockets in the coastal areas. The present wild production more or less meets the demands of this limited consumer sector. There is an urgent need for enlarging acceptability through a well-organised nutrition programme.

(*c*) The seafood processing industry has not taken any serious note of the export potential and efforts have so far been lacking for exploring export markets for the Indian mussel.

(*d*) The present selling price of wild mussels is related only to the labour costs as no capital investments, barring that on the canoe, are involved. Mussel farming, by the raft method, involves some capital expenditure and maintenance costs and, therefore, any venture would presuppose realisation of higher prices for cultured mussels than for the wild. Unless demand increases considerably either for internal consumption or for exports it would be difficult to get a favourable price structure for cultured mussels.

The above constraints are the foremost stalling the development of a mussel culture industry in the country and these are areas for governmental consideration for taking appropriate measures. There are good reasons for providing this support as mussel culture would increase production of animal protein to meet the needs of the fast growing population, create employment opportunities and earn foreign exchange through production of high priced commodities. This would also lead more meaningfully towards diversification in our fisheries and socio-economic improvements in the small-scale fisheries sector.

## RESEARCH THRUSTS

Although the basic technology for mussel culture has been developed, there are several aspects which need research efforts for improving the technology and increasing production.

*(a) Seed production*

One of the major constraints a mussel culture industry would face is the shortage of seed supply for the farms. Availability of mussel seed in the wild is severely restricted to a few rocky patches and this cannot meet the demands. It would be necessary to identify strategic sites for collection of mussel seed through suspension of spat collectors which could act as the seed farms. The groynes laid along some parts of the Kerala coast as an anti-erosion measure have proved to be good collectors of the plantigrades of green mussel (Nair *et al.*, 1975, *Indian J. Fish.*, **22** : 236-242[6]). As mentioned earlier, suspension of breeding stock from the raft at Kovalam has resulted in good spatfall on several occasions. These are indicative of the types of experimental work needed to be carried out for locating sites for seed farms and developing appropriate methods for attracting the spat to settle. The Forest Research Institute at Dehra Dun has, over the years, carried out extensive work on marine fouling organisms by laying panels at different centres and at different depths and it would be worthwhile sifting the records for data on mussel ' fouling ' to get an indication of the areas where further intensive efforts could be spent.

Another aspect of seed production is the development of hatcheries. There has been very little attention in the world for developing hatcheries for mussels although oyster, calm and abalone hatcheries have been developed on a commercial scale. The mussel industry of Europe has not faced any crisis of seed shortage due to abundant natural supply. Unless low-cost natural seed farms could be developed as envisaged, it would be imperative to go in for hatchery technology for production of mussel seed.

*(b) Transplantation*

Strategies for transplantation of spat or seed mussel to areas of poor spatfall but high phytoplankton productivity and thus conducive for culture will have to be developed for large-scale development programmes in mussel culture.

*(c) Ecology and physiology of mussels*

Information on the biology of the green and brown mussels is scanty and is limited to growth studies and spawning periodicity. Some work has been done on larval development. There is need for intensive researches on reproductive biology, larval history, spatfall, larval and adult nutrition, diseases and parasites and mortality, physiological studies on biochemical composition, metabolsim, osmotic adaptations, neurosecretory control of reproduction, tolerance limits to salinity and temperature changes, suspended materials and feeding efficiency, reactions to photic changes and other stimuli, byssus secretion and locomotory capability of mussel from spat onwards. Knowledge on these aspects can be utilised in improving various aspects of mussel culture.

*(d) Mixed farming*

It has been suggested that multispecies aquaculture systems would be more efficient and productive than single species systems for oysters, clams and mussels (Tenore, K.R., J. C. Goldman and J. P. Clarner, 1973. *J. exp. mar. Biol. Ecol.* **12** : 157-165[7]). In this context, the food chain dynamics, especially ecological efficiency of mussels, need detailed studies. The utilization of the same mussel rafts simultaneously for cage culture of fin-fish and lobsters should be considered. Part of the mussels collected in the process of thinning the ropes could also be used as feed for these organisms.

*(e) Culture ecosystem*

Another important aspect for research is the mussel culture environment. There is need for a survey of the coastal areas and identification of suitable sites for mussel culture with reference to coastal configuration, sea and wind conditions, land drainage, physico-chemical factors and pollution susceptibility. The productivity of the sites should be studied in greater detail to understand the potential of biomass production.

Silting would be a major problem in large-scale mussel culture as the entire water column is used for production. Besides accumulation of suspended matter, the faecal discharge of the massive population in the farm will in itself amount to a considerable suspension load and might act as a source of pollution.

These factors would bring about a change in the ecosystem itself and their effect on the efficiency of filtration of mussel which is also the mechanism of its feeding should be understood. These studies would help in determining the carrying capacity of a given water body, including the number of rafts to be used in a given area.

The growth potential of mussel in different ecosystems—estuaries, bays and open sea—needs investigation. Biofouling and boring are two major aspects affecting the production of a farm ; the former is a serious problem in post-harvest treatment. Economical and effective control measures should be developed. Predation by fish and lobsters has already been observed in the mussel farm and this could be a major factor affecting production.

*(f) Pollution and disease problems*

Molluscs are well known for their uptake and retention of pollutants. They are also usually a source of bacterial and virus diseases. Faecal pollution is known to affect mussels, both in the farm as well as in natural beds.

Could the green or brown mussel be used as an indicator of pollution, particularly the accumulation of toxic heavy metals from the sea water ? Little is known about the accrual of cadmium, zinc, copper, mercury and other heavy metals in the tissues of mussels, their storage and excretion. The kinetics of this need study to understand better the mechanisms of immobilisation and detoxication of metals, if any, in mussels. Tolerance levels should be fixed and regulations formulated and enforced, and depuration techniques adopted so that only clean mussel meat is passed on to the consumers.

Paralytic shell-fish poison in mussel flesh has been reported in Britain and some other countries due to outbursts of certain species of dinoflagellates which are taken by the mussels. Continuous monitoring of mussel farms will be necessary to prevent such outbreaks. In our waters, the effects of noxious blooms of dinoflagellates such as *Hornellia marina* and other organisms need special study, as destructive blooms occur along the south-west coast periodically. Sale of mussels during such periods may have to be stopped.

*(g) Genetics*

In mussel culture, genetics may play an important role though not in the immediate future. This may be in developing viable strains with desirable meat quality or delayed maturation so that better growth conversion is obtained or in producing strains resistant to diseases.

*(h) Post-harvest technology*

Post-harvest technology has an important role in developing products both for the export market and for internal consumption. The first task would be to develop suitable low-cost process for depuration. Processes such as chlorination, ozonation or ultraviolet light treatment are used for purification of oysters in other countries. The one which would be within the reach of a common mussel farmer and effective at the same time should be developed.

The technology of suspended culture is basically dependent on the byssal attachment of mussels to the ropes and shells. In this process the mussels develop a strong byssus the removal of which is a laborious task after harvest. Suitable technique should be developed for simple mechanical removal of byssus without injuring the body tissue.

It has been found that the mussels in the farm exhibit a pronounced reproductive phase within the five-month period of culture and the gonads acquire a strong brick-red colour. Consumer acceptance may be affected by the colour of the gonad. The culture technology as well as post-harvest technology should devote attention to this aspect.

Some work has been done on processing and product development of mussels. An intensified effort is necessary in this direction taking into account market demands, acceptability and purchasing power of the consumers. Elsewhere Mussel Protein Concentrates has been developed for the European consumers.

*(i) Farming technology*

The farming technology itself needs innovations. Raft culture as practised today has severe limitations for our open-sea conditions. Buoyancy, stability and mooring of rafts are the three aspects which need improvement with regard to durability and in terms of reduction of costs. The entire system of raft culture should be improved to suit the open coastal conditions and to withstand the monsoon so that year-round culture with two harvests becomes possible. At present farming is done only half the year and the rafts are beached in the unfavourable season. Submerged rafts are under trial and, if successful, would form a solution. Buffering the wave action with automobile tyres, flexible rafts, and long-line culture are some of the aspects for experimentation. The system of farming must be made less tiresome for the people who work on it. Thus there has to be a detailed reconsideration of all aspects of the farming system for evolving a suitable technology for open-sea mussel culture. Marine farm engineering has to come into play in this development.

### Legal Aspects

For farming of any organism either on land or in water, ownership or lease right with protection against encroachment is a pre-requisite. In all the countries where mariculture is in vogue, there is a system of leasing of public water areas to individuals or groups so that the farming activities are carried out without interference. India is just entering into mariculture and it is time that aspects of leasing of water areas are considered in detail and regulations formulated.

Development of mariculture in the coastal areas might often come in conflict with the traditional coastal fisheries in regard to areas of operation, right of navigational passage, possible change in resource structure and damage to fishing or culture equipment. In anticipation of such problems, suitable measures should be worked out for a healthy growth of both the capture and culture fisheries sectors.

Ship navigation is another important aspect and mariculture activities should not infringe on navigational requirements.

### Prospects of Mussel Culture

It has been well recognised that the marine living resources should be increasingly exploited to meet the protein requirements of the people. In terms of production potential, mussel is one of the best resources of the sea and quantitatively it surpasses the production rates of any currently cultivated animal on land or in the sea. To this must be added the fast growth rate of mussels in our waters. It is therefore only judicious that this advantage is converted into practical application. The present annual marine fish production of India is around 1.4 million tonnes. This could be substantially augmented if mussel culture is taken up on a large scale. Besides meeting part of protein requirements of the people of the country, it offers scope for foreign exchange earnings, employment potential in the coastal areas and in putting the presently under-utilised areas into better production. There is also scope for blending of mussel farming with the traditional vocation of the marine fishermen community for providing an additional occupation with income potential.

The immediate need is for a perspective planning for the development of mussel culture as an industry with the full realisation of its potential. The constraints—technological, developmental and extension needs—have been indicated earlier in the paper. These aspects should form a part of the integrated approach. Governmental support and assistance from public financing institutions with an element of risk coverage in the initial stages would help the establishment and growth of the industry. Mussel culture should, at least to begin with, be viewed as a social necessity with a bias on nutritional improvement of the people. Later the industry would be governed by the usual norms of demand and supply.