STUDIES ON THE ECOBIOLOGY AND FISHERY OF PAPHIA MALABARICA Chemnitz (VENERIDAE : BIVALVIA) FROM ASHTAMUDI ESTUARY, SOUTHWEST COAST OF INDIA

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Certified that this is the **bona fide** record of the work carried out by **Mr. K.K. Appukuttan**, a full-time Research Scholar, Department of Aquatic Biology and Fisheries, University of Kerala, Trivandrum under my guidance and supervision in partial fulfilment of the requirements for the Degree of Doctor of Philosophy in Aquatic Biology and Fisheries and no part thereof has been submitted for any other degree or diploma.

DEPARTMENT OF AQUATIC BIOLOGY & FISHERIES · TRIVANDRUM

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Supervising Teacher

DECLARATION

I do hereby declare that this is the authentic record of the work done by me under the supervision of Dr.C.M. Aravindan, Ph.D., Reader, Department of Aquatic Biology and Fisheries, University of Kerala in partial fulfilment of the requirements for the Degree of Doctor of Philosophy in Aquatic Biology and Fisheries.

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CHAPTER 1

GENERAL INTRODUCTION

India has potentially rich molluscan resources belonging to various taxonomic groups, distributed all along the extensive coastline in inshore waters, bays, backwaters and estuaries. Commercially important molluscs are mainly the mussels, clams, oysters, ark-shells, cockles, whelks, chank, cowries and a variety of edible and ornamental gastropods and bivalves, in addition to the much exploited cephalopods. However, till recently there was no organised exploitation of these molluscs, except for mussels and cephalopods, due to the priority often given to the exploitation of finfishes and crustaceans and also partly due to the lack of knowledge about the occurrence and abundance of molluscan resources in various parts of the country. Proper assesment of this resource from Indian coast, except cephalopods which often form by-catchtes in the commercial fishing, is lacking.

James Hornell, who could be considered the father of marine fisheries research in India, was the first to focus attention on the problems and prospects of molluscan resources in India (Hornell, 1916). Recently Mahadevan (1988) while reviewing the present status of molluscan fisheries in India indicated that there are 28 species of bivalves and 65 species of gastropods that are being commercially exploited. The molluscs contribute roughly 1% of the total Indian fish landing of 1.4 million tonnes. Cephalopods contribute much of this and except mussels, there are no precise landing data for gastropods and bivalves. Primary surveys conducted by Central Marine Fisheries Research Institute, from late eighties indicate excellent scope for better production of many species of molluscs from Indian waters. Recent obsrvations (CMFRI Annual Report, 1989) reveal that clam landings of the country vary from 35000 to 40000 t, annually. The average annual world production of molluscs for 1985-88 period was 64,09,688 t, with a maximum of 74,93,800 t in 1988 which was 7.65% of the total fish catch of the world (FAO, 1988). The detailed catch statistics of molluscs show that cephalopods contribute the maximum quantity, 29.8%, the clams, cockles and ark-shells ranking second, with 24.1% and edible bivalves, gastropods and freshwater molluscs contributing the rest. From the above details it is quite evident that India's contribution to the molluscan landings is comparatively low.

Molluscan research in India was initiated by Madras Fisheries Department and the earlier works were mostly confined to the reports on the occurrence of important resources along the coast (Hornell, 1922a, 1949a,b,c). From the late sixties the Central Marine Fisheries Research Institute began the biological studies on commercially important molluscs like edible oysters, clams, mussels, cepalopods and few gastropods. In early seventies experimental mussel culture was initiated by the Institute and susequently other National Research Institutes, University Research Departments and State Fisheries Departments of many maritime states have done several experiments to explore the possibilities of mussel culture in various parts of the country (Appukuttan, 1988). Farming experiments of the edible oysters, pearl oysters and a few other commercially important molluscs were also initiated in India during this period.

Of late there have been concerted attempts for increased production through greater fishing effort and also by adopting viable farming technology for certain commercially important species. Added to that the acceptability of molluscan meat as an item of food is getting positive response. Fishery experts opined that to achieve greater production of marine living resources, intensive fishing of the presently exploited species in the Exclusive Economic Zone (EEZ) alone will not be enough. The need is to exploit which are now neglected due to lack of information on the potentialities and availability in new areas. For increased production targets of molluscan resources, a basic understanding of the present status of distribution, abundance, population size, stock, recruitment to fisheries and basic biological features of the resource are essential. Development plans should thus take into consideration the present potential, the method of fishing, human resources available for exploitation/farming and exploitation rate and set targets which will not lead to exhaust the resource. The rise in world population, policies of the governments to produce more protein-rich food for local consumption as well as for export, employment opportunities through aquaculture and the need to compensate for well known fluctuations in the marine fish catches in many parts of the world are reasons that justify not mearly more intensive exploitation of conventional as well as new species, but also adoption of aquaculture techniques.

A perusal of literature on Indian molluscs shows that very little attention has been paid to the studies on molluscan resources during the last centuary and also in the early part of present centuary. since the middle of the present centuary attempts were made to understand molluscan resource characteristic, biology, biochemical composition, physiology and early development of commercially important bivalves and to develop hatchery and suitable farming techniques for oyster, pearl oysters, mussel and clams.

Early studies on the venerid clams from Indian waters include those on the revision of *Meretrix* (Hornell, 1917), the spawing activities of *M.casta* (Hornell, 1922a), distribution of commercially important molluscs (Hornell, 1922a). *M.casta* was studied for its spawning activities by Panikkar and Aiyar (1939). Venketaraman and Chari (1951) studied the biochemical composition of this species; Kasinathan (1963, 1964a, 1965) worked on the effect of insulin on carbohydrate metabolism, alloxin-induced 'diabetes', chemical constituents of crystalline style and the influence of neurosecretory cells on carbohydrate metabolism; Durve (1963, 1964b)on the filtration rate, seasonal gonadal changes and spawning; Durve and Dharmaraja (1965, 1970) on the dimensional variations and probable change of form in this clam during growth; Silas and Alagarswami (1967) on the pea-crab infestation and length-weight relationship, Seshappa (1967) studied the growth and spawning and Cheriyan (1973) on the habit and distribution of this species in Cochin harbour area.

Parulekar *et al* (1973, 1984) studied the biology and ecology, Durve and George (1973) on the condition index, Salih (1968, 1973, 1975, 1979) on the growth, biochemical composition, oxygen and temperature tolerence and fishery, Waffer (1974) on the biochemical composition, Harkantra (1975) on the biology and ecology, Vijayaraghavan et al (1975) on the Calorific value, Gopalakrishnan et al (1977) on the biochemical composition, Krishnakumari et al (1979) on the biology and biochemistry; Sreenivasan (1983a, 1983b) on the ecology, culture experiments and growth, Mohan et al (1984) on the allotmetric relationship, Parulekhar et al (1984) on the ecology and culture in simulated condition, Thangavelu and Sanjeevaraj (1985) on the fishery and biology, Balasubramanian and Natarajan (1988a, 1988b) on the age and growth, Rao (1988) on the biology from Mulki estuary, Joseph and Joseph (1988) on the biotic potential and environmental resistance and Modassir (1990) on the ecology and production of this species. Giant clam Meretrix meretrix from Indian waters were studied by Ranade (1964) on its fishery from Maharashtra and Ranade (1973) on the effects of salinity and temperature on oxygen consumption. The works of Alagarswami and Narasimham (1973) and Nayar and Mahadevan (1974) on fishery details, Nagabhushanam and Deshmukh (1976) on the body component indices and chemical composition, Rao and Rao (1983) on experimental transplantation of seed clams at Mulki and Nagabhushanam and Mane (1988) on the reproductive activities from Dakshina Karnataka and Ratnagiri are worth mentioning.

Katelysia opima was also studied in detail for its biology and fishery from Indian waters. Rao (1951) studied the biology of this species, Mane (1973, 1974a, 1974b, 1975a, 1975b) studied its adaptation to salinity fluctuation, growth and breeding habits, with special reference, to reproductive cycle. Ranade (1973) on the behaviour and adaptation to low salinity, Nagabhushanan and Mane (1973, 1975, 1988) on biochemical composition, reproductive cycle and neurosecretion, Fisher-Piette (1976) on the taxonomy, Kalyanasundaram and Kasinathan (1983) on the age and growth, Appukuttan *et al* (1985, 1988) on the fishery and biology and Mane and Nagabhushanan (1988) on the reproductive cycle. Joshi and Bal (1967) and Joshi (1967, 1969) studied the digestive diverticula, food and biochemical composition of *Katelysia marmorata*. *Paphia laterisulca* from Ratnagiri was studied for its neuro-endocrinology by Nagabhushanam and Mane (1988), and growth by Mane and Nagabhushanam (1979, 1988). Growth rate of *Paphia undulata* was studied by Winckworth (1931). *Paphia malabarica* was studied for its infestation of pea-crab and its effect on condition index by Krishnakumari and Rao (1974), calorific value by Vijayaraghavan *et al* (1975), ecology and culture under simulated condition by Parulekhar et al (1984) and a brief note on the biology from Mulky estuary by Rao (1988). Narasimhan (Per. com.) studied the early development and experimental transplantation of spat of this clam.

This review of literature would show that the available information even on basic biological characteristics of clams is not adequate to evolve proper fishery management policies and it is necessary to have deeper studied relating to resource characteristics and farming techniques.

Among the exploited molluscan resources of India, bivalves contribute the major portion and among the bivalves clams are the most important along both the east and west coasts. Venerid clams found in marine, estuarine and freshwater habitats form the major portion of clam catches in India. The family Veneridae is represented by several commercially important bivalves and *Paphia* which is found distributed, mostly in Indo-Pacific waters belongs to this family. Fifteen species of *Paphia* are recorded so far, of which 5 species are found distributed along the Indian coast. Of these *Paphia malabarica* is the most important species, on account of its wider distribution and continuous exploitation along the southwest coast for local consumption and also in recent years for clam meat export. *Paphia malabarica* is an important component of the fauna of many estuaries and coastal waters of India (Nayar and Mahadevan, 1974). Till recently its importance as a source of protein-rich food item was not understood. They were poorly exploited for their shells for making lime powder. However in recent years the awareness of the great demand for clam meat in the foreign market led to greater exploitation of this species from the southwest coast of India. Ashtamudi estury is second largest estury in Kerala and harbour a rich source for clams, particularly *P.malabarica*. The increased exploitation of this species from this estuary raised doubts regarding the possible decline of stocks, mainly because no aspects of its biology or fishery has been properly studied from this area or from elsewhere. It is in this context that the present study on the ecology, biology and fishery of this species gain added importance since the results obtained could be used for evolving suitable fishery management policies on current fishing activity in Ashtamudi estury as well as for initiating farming trials.

The results of the present study are given in the 6 chapters. Chapter 1. Introduction with a brief review of clam research in India, Chapter 2. On the present systematic position of *Paphia malabarica*, Chapter 3. on the detailed ecology of the study area, Chapter 4. on the biological aspects under four sections, Section I. reproduction, maturity, spawning and sex ratio, Section II. condition index, Section III. length- weight relationship and dimentional variations, Section IV. age and growth, Chapter 5. on the biochemical composition and chapter 6. on the fishery and stock assesment. A summary of the results and the references cited in the text are also given. In the appendix list of papers published and reprints of papers on clams of Ashtamudi estuary are given.

CHAPTER 2

SYSTEMATIC POSITION OF PAPHIA MALABARICA CHEMNITZ 1782

INTRODUCTION

Paphia malabarica Chemnitz comes under subfamily Tapetinae Adams and Adams of family Veneridae Refinesque and superfamily Veneracea Refinesque of Class Bivalvia in the Phylum Mollusca. In the present study the important taxonomic characters of super family Veneracea, family Veneridae and genus *Paphia* Roding with salient features of *Paphia malabarica* Chemnitz are given.

MATERIALS

P.malabarica specimens for the present study were collected from four centres along the west coast of Indian peninsula. 100 specimens from Dharmadam (Cannanore), 17 specimens from Mangalore, 16 specimens from Bombay and 150 specimens from Ashtamudi backwaters (Quilon) were examined.

Superfamily VENERACEA Rafinesque, 1815

Keen (1969) described the superfamily Veneracea Rafinesque 1815 in Treatise on Invertebrate Paleontology

(Ed. Raymond C. Moore) and she has included 12 subfamilies under this family. Vokes (1980) in Genera of Bivalvia-A systematic and Bibliographic Catalogue (Revised and updated) listed Paphia under superfamily Veneracea Rafinesque, 1815 of subfamily Tapetinae H & A Adams 1857. The unique characteristics of this superfamily are, shell ovate, ornamentation predominently concentric, but radial also seen in some with spine or lamellae over shell, mostly near posterior slope, beaks anterior, prosogyrate; cardinal hinge teeth generally three in either valve, ligament external, opisthodetic; pallial sinus usually present.

This superfamily has 5 families, Veneridae Rafinesque 1815; Petricolidae Deshayes, 1839; Cooperillidae Dall, 1900; Glauconomidae Gray, 1853 and Rzkakiidae Korobkov, 1954. Among these families, Veneridae is most important.

Family VENERIDAE Rafinesque, 1815

This family has 12 subfamilies (Keen, 1969, Vokes, 1980). The members of this family have shells ovate usually equivalve, thick, smooth or variously sculptured. Lunules more or less distinctly flattened or depressed and eschutcheon well developed. Three cardinal teeth in both the valves. The pallial sinus sinuate, varying in size and shape. There are two strong adductor impressions, slightly unequal in size. The subfamilies of this family are:

Venerinae Refinesque, 1815; Circinae Dall, 1896; Sunettinae Staliozka, 1870; Meretricinae Gray, 1847; Pitarinae Stewart, 1930; Samarangiinae Keen, 1969; Dosiniinae Deshayes, 1853; Cyclininae Frizzel, 1936; Gemminae Dall, 1902; Clementiinae Frizzell, 1936; Tapetinae Adams and Adams, 1857 and Chioninae Frizzell, 1936. Genera belonging to most of these subfamilies represent edible and commercially important species.

Subfamily TAPETINAE Adams and Adams

There are 19 genera under this subfamily. They are: Tapes Megerle von Muhlfeld, 1811; Cyclorisma Dall, 1902; Cyclorismina Marwick, 1927; Eumarcia Iredale, 1924; Eurhomalia Cossmann, 1920; Flaventia Jukes-Browne, 1908; Gomphina Morch, 1853; Irus Schmidt, 1818; Katelysia Romer, 1857; Legumen Conrad, 1858; Liocyma Dall, 1870; Marcia H. Adams and A.Adams, 1857; Paphia Röding, 1798; Paraesa Casey, 1952; Psephidia Dall, 1902; Sinonia Stephenson, 1953; Venerella Cossmann, 1886; Veneritapes Cossmann, 1886 and Venurupis Lamarck, 1818.

Fischer-Piette and Metivier (1971) while revising this subfamily have followed the classification by Myra Keen (1951). Among the 19 genera listed above, Paphia assumes greater importance since it contributes several commercially important species.

Genus Paphia Röding, 1798

Shell regular, not gaping, often well defined lunule, lunule (of both valves togather) much more than twice as long as broad. Hinge with three cardinal teeth, often with an additional tooth in front of the left valve and a depression in the right edge of the hollow being tooth-like process. Pallial sinus mostly with more or less defnite sinus. Shell usually much more elongate, hinge margin usually thin. Moderately thick and inflatted shell with weak concentric grooves, hind margin of shell narrow and rounded. The siphon is often long and seperate.

Fischer-Piette and Metivier (1971) while revising the subfamily Tapetinae listed 15 valid species of Paphia. They are as follows:

P.schellina Dunker, 1862; P.inflata Deshayes, 1852; P.cor Sowerby, 1853; P.malabarica Chemnitz 1782; P.crassisulca Lamarck, 1818; P.euglypta Philippi, 1847; P.lischkei Fischer-Piette and Metivier, 1971; P.amabilis

Paphia malabarica Chemnitz

A. Shell-external view

B. Shell-internal view

Philippi, 1847; P.lirata Philippi, 1848; P.exarata Philippi, 1847; P.vernicosa Gould, 1862; P.semirugata Philippi, 1847; P.papilionacea Lamarck, 1784; P.undulata Born, 1780 and P.textile Gmelin, 1784. Jukes - Browne (1914) has discussed the divisions and subdivisions of the genus Paphia and assigned the genotype as Paphia papilionacea Lamarck.

From Indian waters Melvill and Standen (1906), Prashad (1932), Crichton (1941), Gravely (1941), Ray (1949), Satyamurti (1956), Kundu (1965), and Fischer-Piette (1976) have recorded several species of Paphia, of which only 5 species are valid. They are, P.papilionacea Lamarck, P.malabarica Chemnitz, P.cor Sowerby, P.textile Gmelin and P.undulata Born. Among these, P.malabarica is most important since it has got a wider distribution and is being exploited commercially from Indian waters.

Paphia malabarica Chemnitz, 1782
[Plate I, Fig. A & B]

Venus malabarica Chemnitz 1782, Conch.Cab VI p.323, pl.31. Fig 324-325; Lamarck 1818, Anim.s.vert.V.p.604 (594); Wood 1828, Ind.Test, p.35, No.36, pl.7.Fig.36; Potiez and Michaud 1844, Galerie de Douai, 2, p.236, pl. 64 Fig.3,4; Chenu 1847, Illustr.Conchl.Tapes, pl.VI, Fig.4,4a,4b; Pfeiffer 1870, Conch.Cab, ed.2, p.175, pl.17, Fig.12.

Venus gallus Gmelin 1791, Syst.Nat.ed XIII, p.3277; 1792 Encyclopedia Methodique, I, pl.282, Fig.4.

Venus sinosus Lamarck 1818, Anim.s.vert. V,p.614 (604).

Venus rhombifera Hanley 1843, Cat.Rec.Biv.Sh, p.120, pl.13, Fig.45.

Tapes malabarica Sowerby 1852, Thes.conch.II.p.682, pl.145, Fig.6a,8; Reeve 1864, Conch.Icon, pl.VI, Fig.27; Romer 1870. Monogr. Venus II, p.34, pl.10, Fig.3 and pl.17 Fig.1; Smith 1884, Zool.Coll.H.M.S. "Alert" Molluscs. p.97; Melvill and Ambercrombie 1893, Mem and Proc.Manchester Liter.Philos.Soc, p.46; Melvill and Standen 1898, Jour.Conch, IX, p.83; Malvîll and Sykes, 1898, Proc.Malac.Soc.Lond, p.47; Melvill 1899, J.Linn.Soc.Zool; XXVII, p.196; Melvill and Standen 1906, Proc.Malac.Soc.Lond, p.382; Braga 1952, Anais Junt-Invest.Ultramar, VII, 3.p.54; Paes Da Franca 1960, Mem Junt-Ultramar 2(15) p.96; Barnard 1964, An.S.Afri.Mus, 47 (3) p.509.

Tapes sinosa Sowerby 1852, Thes.Conch, II,p.683 pl.145, Fig.10; Reeve 1864 Conch.Icon-pI.V, Fig.18; Romer 1870, Monogr.Venus II, p.35, pl.XI, Fig.1.

Tapes rhombifera Deshayes 1853, Cat.Biv.Sh.Brit.Mus, p.161.

Pullastra malabarica Chenu 1862, Man.Conchyl IIp.92, Fig.413; Frauenfeld, 1869, Verhandl.Zool.Bot.Ges.Wien 19, p.883.

Tapes malabaricus Von Martens, 1887, J.Linn.Soc.Lond., Zool, XXI, p.213; Crosse and Fischer, 1889, Journ. Conchyl., 37, p.293; Smith 1891, Proc.Zool.Soc.Lond., p.424; P.Fischer 1891, Bull.Soc.Hist.Nat.Autun,IV, p.150; Martnes and E.A.Smith 1895, Madras Government Museum Bull. no.3, p.129; Shopland 1896, J.Bombay Nat.Hist.Mus.,X, p.232; 1902; Proc.Malac.Soc.Lond., p.178; Hidalgo 1903, Mem.Real Ac.Cienc.Madrid, 21, p.250; Hidalgo 1905, Rev.Real Ac.Cienc.madrid. p.333; Lynge 1909, Mem.Acad.Roy.Danem, 7,V, p.141; Smith 1916, Proc.Zool.Soc.Lond, p.424; Serene 1937, Inst.Oceanogr.Indo-Chine, 30, p.62.

Tapes browniana Preston 1906, Ann.Soc.Roy.Zool et Malac. Belgique, XLI, p.73, Fig.6.

Tapes sinuosus Lynge 1909, Mem.Acad.Roy.Danem., 7.,V, p.238.

Paphia gallus Hedley 1918, Trans.Roy.Geogr.Soc.Austral. Sess. 1916-1917, p.6; Tomlin 1923, Proc.Malac.Soc. Lond., XV, p.313; Crichton 1941, J.Bombay Nat.Hist. Soc. 42p.338; Ray 1948, Rec.Ind.Mus., XLVI,p.119; Chuang 1961, On Malayan Shores p.168, pl.74, Fig.7.

Paphia malabarica Faustino 1928, Bureau of Science, Manila.Rep. 25,p.81; Melvill 1928, Proc.Malc.Soc. Lond., 18,p.93; Gravely 1941, Bull.Madras Govt.Mus. N.S.V (1), p.52 and 100, Fig.20; Satyamurti 1956, Bull.Madras Govt.Mus (Nat.Hist), I (2), pt.7, p.130, plXX, Fig.3a, 3b: Kundu 1965, J.Bombay Nat.Hist.Soc., 62 (2), p.211; Fischer-Piette 1968, Bull.Mus, 40 No.4, p. 793; Cheriyan 1968, Proc.Molluscan Symp., Mar.Biol.Asso.India., Pt.I, p.131; Fischer-Piette and Metivier 1971, N.S.Zool, LXXX, p.39, pIIX, fig.7; Fischer-Piette and Metivier 1971, Mem.Mus.Natl. Histoire Naturelle LXXXI, p.31-41, pl.9; Fischer-Piette 1974, Tethys 5(2-4), p.267-316; Fischer-Piette 1976, Rec.Zool.Surv.India, 70, p.235-257.

Tapes lentiginosus Lamy 1930, Bull.Mus., p.227.

Paphia sinuosa Prashad 1932, Lamellibr.Siboga, p.237; Altena 1945, Zool.Meded., XXV, p.151.

Acritopaphia transfusa Iredale 1936, Rec.Austral.Mus., 19, p.280, pl.20. Fig.12; Allan 1950, Australian Sh., p.334. col.pl.39, fig.4, pl.37, fig.18; Iredale and Mc Michael 1962, Ref.List Mar.Moll. N.S.W., Mem. Austr.Mus., XI, p.23.

Paratapes malabaricus Lamy and Fischer-Piette 1939, Bull. Mus., p.315.

Tapes semirugatus Allan 1950, Australian Sh., p.334, col.pl.39 fig.11.

Protapes gallus Rippingale and McMichael 1961, Queensland and Great Barrier Reef Shells, p.198, pl.28, fig.15.

Description

Shell thick, pale yellowish brown with distinct greyish brown bands and concentric sculpture over the shell in adults; in juveniles the colour is brighter with radiating bands, concentric striation feeble. The front and hind margins are narrowly rounded and the ventral margin almost straight, but slightly eduntated towards the hind end. The concentric striation over the shell is close set, slightly raised and rounded with interstitial grooves deeper, especially in adults. The striation is almost parellel to the ventral margin and corresponding eduntation is noted in the hind margin (Fig. A). Hinge bears three short, thick cardinal teeth, the tooth in front of the cardinal in the left valve and the depression in the right being rudimentary. Pallial sinus is 'U' shaped and deep. Inner surface of the shell smooth and the margin is not denticulated. Adductor impressions are deep, the posterior being larger (Fig. B). Lunule is shorter and broader. Long siphon with distal end seperated in to exhalent and inhalent siphons. Exhalent siphon has a siphonal membrane and radially arranged small tentacles in the rim of the aperature. In the inhalent siphon there are 24 longer tentacles, radially arranged in the rim of the siphon. The foot is large and wedge-shaped adapted for burrowing. Byssal gland is functional in juveniles. Posterior adductor muscle positioned ventral to the hinge margin, larger than the anterior adductor muscle.

Distribution

Durban, Mosambique, Aden, Muscat, Persian Gulf, Pakistan, India, Sri Lanka, Mergui Archipelago, Malayasia, Hong Kong, China, Thailand, Philippines, Java, Western Austrialia, Queensland and New South Wales.

From India this species is recorded from Gulf of Kutch, Bombay, Ratnagiri, Karwar, Ganguli, Mangalore, Cannanore, Cochin, Quilon along the west coast. Tuticorin, Mandapam, Karakal, Porto Novo, Madras along the east coast and also from Andaman Islands (Fig. 1).

DISCUSSION

Ansell (1961) while reviewing the functional morphology of British Veneracea stated that family Veneridae is probably polyphyletic in origin and include numerous bivalves living in a wide range of habitat in marine, esturine and freshwater condition. The shells also show wide variations within the species mostly according to the substratum where they live. Whereas veneridae could be considered as one of the successful group of bivalves without much anatomical variations among the species. P.malabarica seems to be one of the important species among family veneridae with a wide range of distribution from Durban to New South Wales. In India this species is recorded both from east and west coasts, with commercially exploitable beds in the west coast.

While discussing the status of *P.malabarica* Chemnitz, Fischer-Piette and Metivier (1971) observed that the figures of this species given by Reeve (1864) are different from that of Chemnitz and resembled that of *Paphia sulculosa*. They have also examined the type materials from the Museum of Copenhague and noted that some specimens resembled Chemnitz's figures and these specimens are reported as *malabarica* and others as *gallus*; the first name is preferred by many authors. They have also examined type materials of *lentiginosa* Reeve in British Museum and considered this as a synonym of *P.malabarica* as done by Tomlin (1923). They have also considered *Tapes turgidula* Reeve as a synonym of this species.

Out of the 15 species of *Paphia* so far recorded all over the world, 14 species are from Indo-Pacific area. From Indian coasts only 5 species are recorded till date. Fischer-Piette and Metivier (1971) indicated that the occurrence of *P.euglypta* from Indian waters is doubtful. Another spices of *Paphia* often referred in Indian literature is *P.laterisulca* (Mane and Nagabhushanam, 1979, 1988, Dhâmne and Mane, 1976). A close scrutiny of literature on taxonomy of genus *Paphia* reveal that this species does not come under genus *Paphia* and a detailed taxonomic study is required to fix the identify of this species.

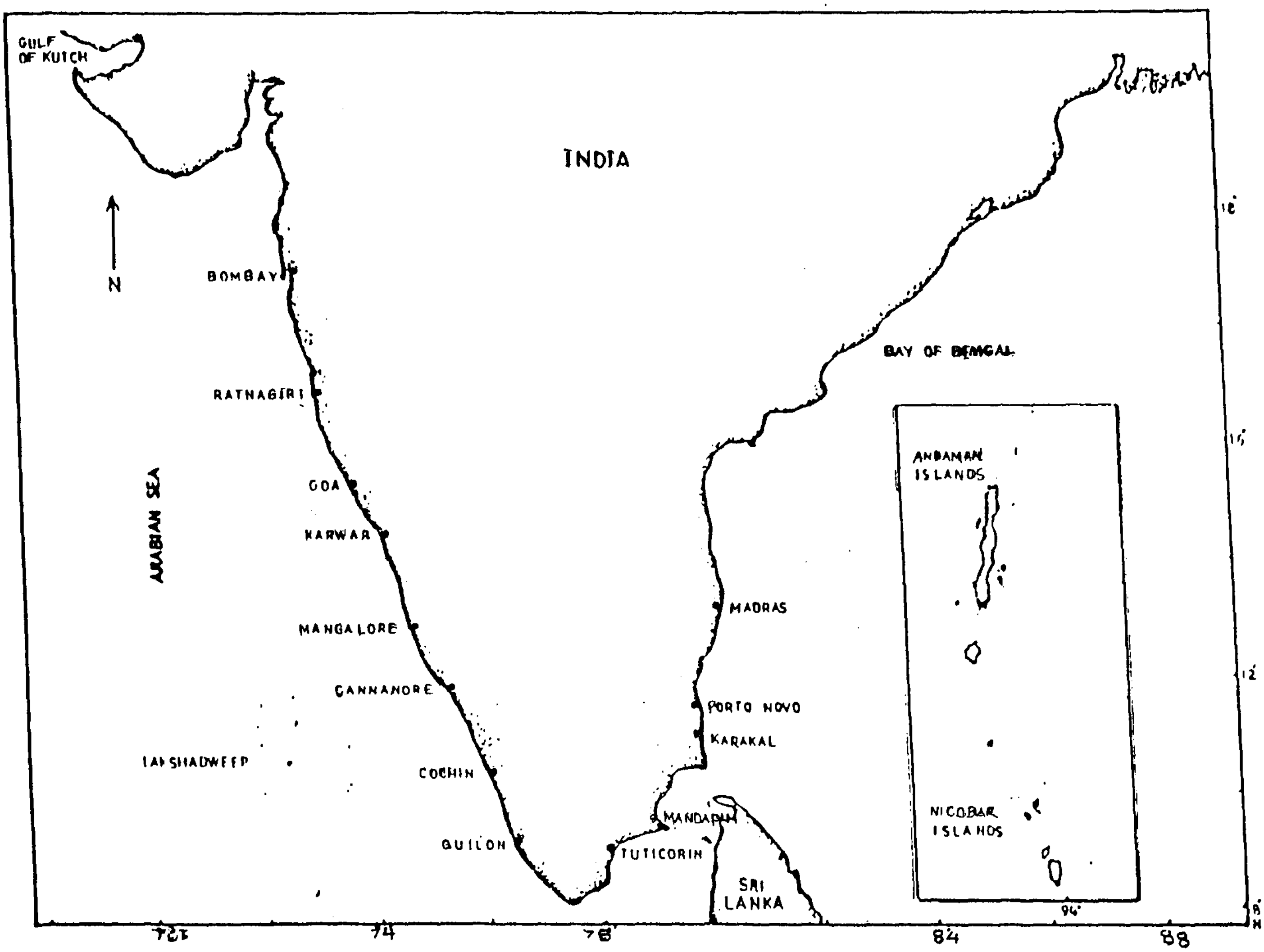


Fig. 1 Map of India showing places from where Paphia malabarica is recorded.

CHAPTER 3

ECOLOGY OF STUDY AREA

INTRODUCTION

A unique feature of the southwest coast of India is its extensive system of estuaries and backwaters lying parallel to the coastline. Estuaries and backwater bodies are locally known as 'Kayal' and exist in different shapes and size, having the bed levels about 1.5 to 1.8 m below mean sea level. The waters of 41 rivers in Kerala drain into the sea, through permanent or temporary (seasonal) openings.

Among all the estuaries of Kerala, Ashtamudi river system though second largest is little explored (Lat $8^{o}35'$ to $9^{o}02'$, N long. $76^{o}31'$ to $76^{o}41'$E) (Fig. 2). The entire river system is planimetric in shape with eight creeks radiating roughly from central portion having different names covering an area of 44.73km. Longitudinally the estuary lies perpendicular to the coast line. Kallada river with a river basin of 1554 sq.km. originates from the Western Ghat and a number of other streams enter the Ashtamudi estuary after traversing about 120 km and the river system carries an average annual run off of 75,000 million M^3 of freshwaters into the estuary (Nair and Azis, 1987a, 1987b).

On the northern side of the estuary there are extensive tracts of swampy regions interlying with aluvium and beach sand. There is volumnous fresh water flow into the estuary during monsoon months. From Kallada Irrigation Project a large quantity of water is being diverted to the interior areas for cultivation. Salt water incursion is experienced throughout the year into the river area.

For the greater part the estuary is a shallow water tract. The huge quantity of freshwater flow from Kallada river during the rainy season and the tidal cycle that floods the estuary daily are sources of sediment input and consequent siltation in the estuary. Nair and Azis (1987a) have given the depth profile of 8 zones of Ashtamudi during 1981 and found marine zone with a depth range of 1.29 to 3.6 m and fresh water zone (Ashtamudi) with a range of 1.83 to 3.14 m. The maximum depth was noticed in the confluent zone.

MATERIALS AND METHODS

Observations for the present study were made for a period of 12 months commencing from February, 1989 to January, 1990 from 3 stations in the Ashtamudi estuary, close to the marine zone, where Paphia malabarica beds are found (Fig. 3). Station I is close to the barmouth, Station II, two kilometre interior and Station III 2 km further upstream, where the marine zone bifurcates into northern part and southern part with central part of Ashtamudi area. The twelve months of observation are grouped broadly into three seasons viz., pre-monsoon (February-May), Monsoon (June - September) and post-monsoon (October- January). Fort-nightly samples were collected, during this period, of both surface and bottom water and also of the sediments, invariably in the fore-noon. Water samples were collected from the surface with a clean plastic bucket and from the bottom using casscella type sampling bottles. Light penetration was measured using a secchi disc, temperature was measured using an accurate mercury thermometer and pH using an Elico digital pH meter (Model-i-120), salinity was determined by Mohr's titration method. Dissolved oxygen was estimated by Winkler's method. Reactive phosphats, silicate, nitrite and nitrate were determined following Strickland and Parson (1965). Water samples for nutrient analysis were collected from the estuary from surface and bottom in polythene bottles of 150 ml. capacity. Samples were kept in deep freezer, since analysis was done only 24 hrs. after collection.

Samples of sediments from the clam beds were collected using a Peterson grab ($0.08m^2$). A portion of the fresh mud sample was transferred to a plastic bag and air-dried and stored for further granulometric and organic carbon content analysis. Sediment analysis was done by rapid particle analysis following Morgans (1956). Wentworth grade of classification was followed for grouping the grain size of sediment. The sand portion was grouped as coarse and medium sand as one group (above 250 μ), fine and very fine sand as one group (above 62 μ) and silt and clay as a third group (below 62 μ). Standard sieves were used for separating different groups of sediments.

The data on rainfall for the study period from Quilon was collected from the Meterological Department, Government of India, Trivandrum. Mean values of different environmental parameters in different seasons were computed and t-test was performed to compare the nature of variation between stations, seasons and between surface and bottom water. The r - value, correlation with biomass for different environmental factors, for Station I and II was also statistically tested to find out significant variations, if any. The water level of each station for all the months were taken using a nylon rope marked at equal intervals of 10 cm with a 5 kg weight at the bottom. Biomass estmation was done by taking randome sample of <u>Paphia malabarica</u> from 5 sub-stations, using transect method. A 25 x 25 cm metal square was used to collect sample from unit area in each sub-station. The mean number and weight of samples from each station were calculated and this was used in estimating the clam biomass of each station.

RESULTS

ENVIRONMENTAL DETAILS

Ashtamudi estuary receives the full benefit of southwest monsoon and a varying quantity of precipitation during northeastern monsoon. Salt water penetration is at its maximum during summer months, reaching far upstream through the bottom flow into the Kallada river and the fresh water influx from the river to the estuarine part is comparitively poor due to the diversion of fresh water in huge quantities for irrigation purpose. Pre-monsoon period is considered as the most stable one with hydrological conditions.

Water depths

The water depths at the sampling stations in different months are given in Table 1. In Station I depth ranged 240-380 cm with minimum in May and maximum in December. Post-monsoon months showed maximum depth in the station, possibly due to the heavy tidel incursion. In Station II the water level ranged from 200 cm to 350 cm with maximum during post-monsoon period. Water depth in the station was comparatively lower than the Ist Station in all the months, probably due to sedimentation caused by influx of freshwater and also by the tidal action from the seaward side. Station III has very low water level ranging from 75 cm 270 cm. The average for Ist Station was 350 cm and IInd Station 270 cm indicating clear variation in depth for both the stations. However, there was variations in the depth profile from season to season within each station.

Light Penetration

Transparency of water measured by secchi disc values varied from 45 to 190 cm in Station I with maximum light penetration in October and minimum in August. The high light penetration during post-monsoon period gradually decreased during pre-monsoon months. Light penetration was low when monsoon was at its peak during July to August, due to the influx of turbid river water to the estuary as well as the mixing up of sediments in the barmouth by heavy wave action. In Station II the secchi disc values ranged from 40 to 255 cm with minimum light penetration during July and maximum in October, this corresponds with the low values in monsoon and high values during post-monsoon months. The reason for low transparency during monsoon in Station II could be the same as for Station I, large influx of sediment-loaded river water and the mixing up of turbulent tidal flow. In Station III light penetration ranged from 35 to 100 cm with lowest values in July and highest in November corresponding to the monsoon and post-monsoon respectively. Among the three stations, maximum light penetration was observed in Station II whereas in Station I the mixing up of water due to tidal action and in Station III the inflow of dissolved organic matter and the effluents and sewages discharged into the river keep these areas with high sediment load. Mean values of light penetration in 3 stations in 3 seasons indicated maximum light penetration during post-monsoon and lowest during monsoon months. Statistically it was significant between stations and months (Table 2).

Water Temperature

Surface and bottom temperature of all the three stations were taken for 3 seasons, twice a month and the average value for each month is given in Fig. 4. Mean values indicate that temperature was high during pre-monsoon month in surface and bottom waters. In monsoon, lowest values were registered in all the stations followed by a gradual increase through post-monsoon months. The highest surface water temperature of 33.30^{o}C was observed in May and lowest, 25.8^{o} C in January; bottom water had 30.5^{o}C in May and 26.3^{o}C in May and 26.3^{o}C in August. Lowest water temperature in monsoon could be due to the continuous rainfall and the influx of river water to the estuarine system in these months. Annual average values showed higher temperature in the surface water. The variations between surface and bottom water in different stations were not significant, where as the temperature variation between seasons were significant in both surface and bottom waters (Table 2).

Salinity

Salinity fluctuations in 3 stations for 3 seasons indicate that the mean value was high during pre-monsoon followed by a sharp decline during monsoon and there was a recovering period in the post-monsoon months for both surface and bottom waters (Fig. 4). In Station I the mean value of surface water was 32.22% and for bottom 36.62% in pre-monsoon, it declined sharply to 8.15% and 9.32 respectively in monsoon and an increase in mean value with 31.29 and 32.75% was observed in post-monsoon. The annual mean value for the study area was 23.89% and 24.89%o for surface and bottom water respectively. In Station II also same trend was observed with an annual value of 22.3% and 24.94%o in surface and bottom water. In Station III monsoon period registered minimum salinity of 4.92% and 1.98%o in surface and bottom with annual value of 20.16 and 21.08%0 respectively. Between stations the maximum salinity was alwlays observed in Station I which is close to the barmouth and the minimum salinity in Station III in the upper reaches which is the confluent area of sea water and fresh water influx from rivers. Salinity thus showed a gradual decrease from Station I to Station III and there was significant variation in salinity during different seasons (Table 2).

Dissolved O_2

Dissolved oxygen values for 3 stations in 3 seasons have not shown any significant variations (Fig. 4). The annual average indicated that Station I and II had higher values in the surface water whereas in Station III bottom water had higher oxygen value. In general, monsoon period had more oxygen in both surface and bottom water in all the three stations. Between stations, IIIrd Station had maximum oxygen value (Table 2).

pH

pH values of surface and bottom water for 3 stations for 3 seasons are given in Fig. 4. The surface and bottom water remained alkaline throughout the year. Seasonal variation of pH in surface and bottom water was not significant. Due to the mixing up of sea water up to the upper reaches through the tidal action, the pH value remained almost uniform in all the stations. Comparativiely high values prevailed in the barmouth area and low value in the upper reaches (Station III).

Rainfall

Rainfall details from the study area for 1988 to 1990 are given in Fig. 5. The seasonal variation in rainfall indicate a peak period during monsoon which is followed by post-monsoon (October-January) and minimum rainfall in pre-monsoon months (February-May), Northeast monsoon causes heavy precipitation during post-monsoon months (October - November) and hence there is substantially good rainfall during this season also. River discharge to the estuary also had a corresponding maximum during monsoon, followed by post-monsoon months. In 1989, June-September (Monsoon) alone contributed 1321.7 mm out of the total rainfall of 2309.9 mm. (57.3%).

NUTRIENTS

Phosphate

Reactive phosphate values in different stations with their mean value for each season are given in Fig. 6. Bottom water in Station I and II had higher values with maximum during monsoon. In Station I minimum value was observed during pre-monsoon with the highest in the monsoon and gradual decline in post-monsoon months with an annual average of 0.67 µg-at/l and 1.27 µg-at/l) which gradually decreased in monsoon and post-monsoon month. The annual average values were 0.82 µg-at/l and 1.05 µg-at/l in the surface and bottom water respectively. In

Station III the phosphate values for surface water was high during monsoon and low during post-monsoon and bottom water had maximum during pre-monsoon and low during monsoon with an annual average of 0.85 µg-at/l and 0.80 µg-at/l in surface and bottom water. The results indicate that there is wide fluctuation in the phosphate content of the water in each station during different seasons. Maximum was observed in the IInd Station where good clam fishery exists. Somehow the variation from station to station and season to season in surface and bottom water was not statistically significiant (Table 2).

Silicate

Silicate values of all the 3 stations are given in Fig. 6. In station I the annual mean value was 14.61 µg at/l and 15.95 µg-at/l in the surface and bottom water respectively. In station II also same trend was observed with annual values as 14.50 µg at/l and 15.66 µg at/l in surface and bottom water respectively. In station III a reverse nature was observed with high value in the surface water in pre-monsoon period but in monsoon and post-monsoon showed higher values in bottom water. However the annual value was 15.96 µg at/l in bottom water 15.44 µg at/l in surface water (Table 2).

Nitrite

The mean value of nitrite (No_2) in 3 stations for 3 seasons were studies and showed wide fluctuation from station to station through seasons (Fig. 6). In Station I, high value was observed during monsoon period with low value during post-monsoon and the annual mean was 0.46 µg-at/l and 0.55 µg/at/l in surface and bottom water. In Station II high value was observed in pre-monsoon period with low nitrite in post-monsoon and the annual mean was 0.68 µg at/l and 0.76 µg-at/l in surface and bottom water. In Station III maximum value was recorded during monsoon in surface water and in post-monsoon period bottom water had maximum values. However surface water showed high annual average (0.44 µg-at/l) and minimum of 0.33 µg-at/l. The details are given in Table 2.

Nitrate

Nitrate (NO_3) values were comparitively poor and the details are given in Fig. 6. In Station I high values prevailed during pre-monsoon and low value in post-monsoon with annual means as 1.12 µg-at/l in surface water and 1.3 µg-at/l in bottom water. Same trend was noticed in Station II with an annual mean of 1 µg-at/l and 1.15 µg-at/l in surface and bottom water. In Station III during pre-monsoon, nitrate was not found in detectable level in both surface and bottom water, but in monsoon nitrate was available in surface and bottom water. During post-monsoon period there was gradual increase. The annual average was 0.69 μg-at/l and 0.46 μg-at/l in surface and bottom water respectively (Table 2).

SEDIMENT TEXTURE

Textural properties of sediments of clam beds at Ashtamudi are shown in Table 3. In Station I fine sand percentage was high ranging 46-86% with maximum in December and minimum in January showing wide fluctuation. The coarse sand percentage were 4.8 and 50% in January and December respectively. Silt and clay fraction ranged from 3.9% to 16%, the minimum in July and maximum in January. The sand fraction dominated in this station throughout the year and silt and clay fraction was found in high percentages during monsoon and post-monsoon. In Station II coarse sand dominated the sediment throughout with minimum value in November and maximum in February. The fine sand fraction ranged from 2.4 to 9.6% with minimum in January and maximum in August. Silt and clay fraction was comparitively high during monsoon and post-monsoon season in this station also. In Station III fine sand fraction dominated as noted in Station I, ranging from 76.6 to 90.4% with minimum in September and maximum in October. The coarse sand fraction varied from 1.6 to 10.4% only with minimum in June and maximum in September. Silt and clay fraction was high in this station compared with Station I & II indicating a range of 5.2 to 14.4% with minimum in October and maximum in August. In brief Station I had coarse sand as the dominant sediment fraction where as in Station I & III fine sand fraction dominated all through the seasons.

ORGANIC CARBON

Total carbon values present in the sediments of clam beds in 3 stations for 3 seasons of the year are given in Table 2. The values have not shown any significant variation among stations in different seasons. In Station I the mean value was high in post-monsoon and the annual mean was 1.0376 and in Station III the high value was observed in post-monsoon with annual mean of 1.2168. The total organic carbon content of sediment was high in Station II in pre-monsoon and monsoon period and in Station III it was highest in all the seasons.

BIOMASS OF CLAMS

In the study area, Paphia malabarica was found to occur in Station I and II throughout the year, where as in Station III spat settlement was noticed during post-spawning period but there was complete mortality of these spat in pre-monsoon months. Density of *Paphia malabarica* in Station I and II was estimated for 12 months by taking total number and weight of clams in unit area by random sampling. The density in the pre-monsoon, monsoon and post-monsoon was calculated and is presented in Table 4. In Station I the maximum number of clams was observed in pre-monsoon months, but majority of them were juveniles (10-20mm). The mean weight was comparatively low (162 g) but in monsoon months the weight increased to 217 g and number decreased from 152 to 98 (Table 4) with a size range of 25-45 mm. In post-monsoon period both numbers and weight decreased substantially. In Station II maximum weight was observed in monsoon with a mean value of 257 g, though the numbers were lesser than in pre-monsoon. Lowest number and weight were observed during post-monsoon. The size of the clam in this station was fairly large and the maximum exploitation was taking place in this station. A comparison of the densitiy of clams from both stations indicates that though dense juvenile settlement of clam was observed in Station I better growth was noticed in Station II as evidenced by higher mean weight as well as the presence of large-sized clams.

ASSOCIATED FAUNA

The important groups of animals that found associated with *Paphia* beds were polychaetes, bivalves, gastropods and crustaceans. Macro-algae such as Hypnea and Enteromorpha were also abundant in the bed. Tubiculous polychaete Diopatra neapolilina was the most abundant animal in thick carpet-like formation. Neries spp. were also recorded from all the three stations in good numbers. Among bivalves, Musculista arcuatula was the most common, found always attached over the tubiculous polychactes and together forming an excellent substatum for the settlement of clam spat. Other bivalves found were Modiolus plumicens, Perna viridis, Meretrix casta, Mercia recenes, Sanguinoloria sp, Arca sp, Gafrarium sp, Pholas sp Ensis sp Turetella sp., Cerithidia fluviatilis, Murex sp Dentalium sp, and Umbonium sp.

DISCUSSION

Results of the present study indicate that the ecological parameters show temporal and spatial variations in the collection sites. These variations are characterristic of other open estuaries of west coast of India like cochin backwaters (Qasim and Gopinath, 1959, Josanto 1971, Qasim, 1979), Korapuzha estuary (Rao and George, 1959, George and Kartha, 1963), Kali estuary (Harkantra, 1975, Bhat and Neelakantan, 1988) and Mandovi - Zuari estuary (Dehadrai and Bhargava, 1972, Parulekar et al, 1973, Qasim, 1979, Alagarswamy, 1991). Earlier studies on the ecology of Ashtamudi estuary

(Dharmaraj and Nair, 1979; Nair and Azis, 1987a, 1987b, Nair et al 1983, 1984a, 1984b, 1985) also confirm this observation. The major factors which govern the ecological condition of Ashtamudi estuary are undoubtedly the monsoons and the daily tidal rythm. The torrential monsoon rains bring huge quantities of freshwater to the estuarine part of the back water system through the Kallada river and its feeder tributaries. During monsoon months the influx of the tidal waters seems to be masked by the heavy inflow of the freshwater to the estuary. However during the post-monsoon and pre-monsoon seasons dense saline and cold sea water enters the estuary, moves upstream and may reach even the middle part of the river. This movement and the recent construction of Kallada Dam which prevents the inflow of freshwater from the river to the estuary throughout the year, Keeps the upper part of the estuary highly saline in most part of the year. However during monsoon the rainfall followed by the inflow of cold, nutrient rich, turbid flood water from the river flush the saline water from the estuary for a few months, diluting the water and bringing estuarine part to very low salinity. This flood water also brings a large quantity of silt, in addition to nutrients.

Comparison of environmental parameters between the stations during different seasons showed that light penetration was high in Station II. In Station I the constant tidal rythm and in Station III, the mixing up of freshwater from the river keeps the water turbid especially during monsoon month. Temperature did not show significant variations between stations, but it was low during monsoon in all the stations. Salinity was high during post-monsoon, low during monsoon and highest in Station I and low in Station III with medium salinity in Station II. Seasonal variations of dissolved O_2 and pH were not significant between stations. Nutrients do not show much variations between stations except for high values of silicate in Station III, which is close to confluent zone.

Organic carbon content was high towards the station nearer to river as was noticed by Damodaran and Sajan (1983) and Nair and Azis (1987a). Sediment analysis showed that Station I, which is nearer to barmouth, had fine sand fraction as major component followed by coarse sand and silt and clay. Station II where clam biomass was high, had coarse sand dominating throughout the year and Station III, where adult *P.malabarica* was not observed, had maximum silt and clay compared with other two stations. Studies by Nair *et al* (1984a) indicated that Neendakara zone of Ashtamudi backwater system had maximum productivity which they considered as the highest among all the estuaries of west coast. The present study showed that clam biomass was high on Station II, where medium salinity prevailed and coarse sand dominated the sediment. Higher percentage of silt and clay, organic carbon and low salinity are not suitable for survival and better yield of *P.malabarica*, as evidenced by the absence of this clam in Station III. Durve (1963) and Sreenivasan (1983a) observed that in *Meretrix casta* population density was high where salinity was medium and bottom was more sandy. In Ashtamudi initial spat settlement was observed in Station I and Station III where salinity was very high and low respectively, but higher adult biomass was observed in Station II with medium salinity. Effect of variations in the environmental characters on reproduction, condition index, meat weight percentage, biochemical composition and dimensional variations are disscussed in the corresponding chapters dealing with these aspects.

TABLE 1

Average water depth **in** Paphia malabarica **bed in Ashtamudi estuary from February 1989 to January 1990**

MONTHS	STATION I	STATION II
	Depth in cm.	Depth in cm.
FEBRUARY 1989	330	250
MARCH	250	201
APRIL	320	220
MAY	240	180
JUNE	290	320
JULY	260	260
AUGUST	320	250
SEPTEMBER	330	270
OCTOBER	370	340
NOVEMBER	360	350
DECEMBER	380	320
JANUARY 1990	360	320

TABLE 2

Environmental characteristics of Paphia malabarica beds in Ashtamudi estuary for 3 seasons from February 1989 to January 1990 at the 3 stations

SEASONS		STATION I		STATION II		STATION III	
		Mean	SE	Mean	SE	Mean	SE
TEMPERATURE (0°)							
PRE-MONSOON	SW	28.98	0.6489	30.4	0.8277	29.95	0.5188
	BW	29.22	0.6836	30.0	0.6770	30.25	0.1443
MONSOON	SW	28.1	1.500	28.07	0.3250	28.3	0.1472
	BW	27.58	0.4715	28.25	0.4592	28.12	0.1118
POST-MONSOON	SW	27.42	0.6258	28.12	0.4029	28.87	0.4308
	BW	27.62	0.3473	28.78	0.4148	28.87	0.4029
ANNUAL	SW	28.20	0.3372	28.86	0.4399	29.04	0.2929
	BW	28.14	0.3564	29.01	0.3539	28.08	0.2974
SALINITY (0/00)							
PRE-MONSOON	SW	32.22	0.3679	32.37	0.1469	32.37	0.1078
	BW	32.62	0.4699	32.68	6.4150	32.25	0.3845
MONSOON	SW	8.18	3.1589	4.79	1.7212	4.92	1.9810
	BW	9.32	4.3159	9.49	5.4115	5.36	2.2036
POST-MONSOON	SW	31.29	1.3646	29.74	2.4356	23.29	4.9829
	BW	32.75	0.6147	32.69	0.3875	25.62	4.0071
ANNUAL	SW	23.89	3.5118	22.30	3.8525	20.16	3.7756
	BW	24.89	3.5754	24.94	3.6786	21.08	3.7166
DISSOLVED O_2 (ml/1)							
PRE-MONSOON	SW	4.81	0.1131	4.88	0.1223	5.00	0.1004
	BW	4.71	0.1385	4.89	0.1327	4.99	0.0805
MONSOON	SW	4.91	0.0799	4.92	0.0400	4.88	0.0328
	BW	5.0	0.1348	5.01	0.0998	5.02	0.1294
POST-MONSOON	SW	4.85	0.0194	4.85	0.0331	5.00	0.4880
	BW	4.79	0.0451	4.82	0.0202	5.11	0.0765
ANNUAL	SW	4.86	0.4000	4.93	0.0427	4.96	0.0400
	BW	4.84	0.0706	4.91	0.0557	5.05	0.0525

SW - Surface water

BW - Bottom water.

Contd.....

pH

SEASONS		STATION I Mean	STATION I SE	STATION II Mean	STATION II SE	STATION III Mean	STATION III SE
PRE-MONSOON	SE	7.82	0.0578	7.5	0.0608	7.70	0.1010
	BW	7.70	0.0846	7.80	0.0527	7.75	0.0764
MONSOON	SW	7.61	0.0950	7.08	0.1105	7.06	0.0902
	BW	7.26	0.0651	7.12	0.1700	7.06	0.0962
POST-MONSOON	SW	7.66	0.1246	7.57	0.1584	7.60	0.2721
	BW	7.83	0.0303	7.76	0.0876	7.56	0.2908
ANNUAL	SW	7.69	0.0514	7.45	0.1107	7.45	0.1249
	BW	7.56	0.0914	7.56	0.1118	7.45	0.1437

LIGHT PENETRATION DEPTH (cm)

PRE-MONSOON	106	6.2500	123.33	12.5831	56.25	3.7500
MONSOON	100	20.6155	92.5	26.6536	56.25	10.8733
POST-MONSOON	170	8.4163	198.75	21.9256	75.75	6.2500
ANNUAL	125.41	11.8126	140.42	17.2596	62.75	5.2428

ORGANIC CARBON

PRE-MONSOON	1.131	0.0969	1.265	0.2267	1.1473	0.2913
MONSOON	0.879	0.2878	1.1382	0.1605	1.0956	0.1742
POST-MONSOON	1.1964	0.2878	1.0668	0.1292	1.3884	0.2050
ANNUAL	1.1811	0.1167	1.0376	0.0808	1.2168	0.1202

Contd.....

PHOSPHATE (ug-at/1)

SEASONS		STATION I		STATION II		STATION III	
		MEAN	SE	MEAN	SE	MEAN	SE
PRE-MONSOON	SW	0.26	0.2625	1.04	0.1635	0.80	0.4784
	BW	0.27	0.2700	1.27	0.1118	1.14	0.3843
MONSOON	SW	1.06	0.1119	0.79	0.2475	1.16	0.0895
	BW	1.16	0.1336	1.23	0.1300	0.61	0.3814
POST-MONSOON	SW	0.76	0.2566	0.62	0.2589	0.59	0.2246
	BW	0.76	0.7566	0.60	0.2825	0.48	0.2739
ANNUAL	SW	0.67	0.1504	0.82	0.1302	0.85	0.1763
	BW	0.73	0.1621	1.05	6.1298	0.80	0.1919

SILICATE (ug-at/1)

PRE-MONSOON	SW	14.43	1.1052	14.24	0.9040	16.76	1.4168
	BW	16.84	2.7631	16.75	2.1371	16.24	0.5406
MONSOON	SW	14.31	0.5044	14.30	0.2302	15.36	0.2735
	BW	15.19	0.3762	14.85	0.2211	15.83	0.3490
POST-MONSOON	SW	15.07	0.3971	15.39	0.2642	15.70	0.4450
	BW	15.82	0.5121	15.39	0.2642	16.16	0.4067
ANNUAL	SW	14.61	0.3982	14.50	0.4307	15.44	0.4222
	BW	15.95	0.8789	15.66	0.6959	15.96	0.2189

NITRITE (NO_2) (ug-at/1)

PRE-MONSOON	SW	0.41	0.2183	0.93	0.0714	0.19	0.1875
	BW	0.43	0.2255	1.11	0.0569	0.20	0.2025
MONSOON	SW	0.60	0.1592	0.76	0.0589	0.80	0.1145
	BW	0.77	0.0582	0.81	0.0441	0.38	0.2344
POST-MONSOON	SW	0.15	0.0596	0.36	0.0526	0.33	0.1486
	BW	0.30	0.1174	0.43	0.0512	0.43	0.0886
ANNUAL	SW	0.46	0.0994	0.68	0.0789	0.44	0.1117
	BW	0.55	0.0989	0.78	0.0886	0.33	0.1013

NITRATE (NO_3) (ug-at/1)

PRE-MONSOON	SW	1.61	0.1620	1.30	0.3566	0	0
	BW	2.06	0.4019	1.52	0.3143	0	0
MONSOON	SW	1.15	0.1178	1.14	0.1678	1.39	0.1928
	BW	1.26	0.1469	1.26	0.2300	0.71	0.4548
POST-MONSOON	SW	0.60	0.1877	0.58	0.0957	0.69	0.0901
	BW	0.61	0.1797	0.66	0.1159	0.69	0.1378
ANNUAL	SW	1.12	0.1487	1.00	0.1538	0.69	0.1820
	BW	1.31	0.2263	1.15	0.1635	0.47	0.1708

TABLE 3

Percentage of Coarse Sand, Fine Sand and Silt and Clay Fraction in the Sediments from Station I, II & III of Ashtamudi Estuary for the Period February 1989 to January 1990

SEASONS	MONTHS	COARSE SAND	FINE SAND	SILT & CLAY	COARSE SAND	FINE SAND	SILT & CLAY	COARSE SAND	FINE SAND	SILT & CLAY
PRE-MONSOON	February '89	36.4	58.0	5.6	62.4	33.2	4.4	4.8	81.6	13.6
	March	18.0	74.4	7.6	53.6	39.2	7.2	3.6	88.0	8.4
	April	28.0	65.2	6.8	40.0	52.4	7.6	7.2	81.6	11.2
	May	30.4	62.8	6.8	46.4	48.8	4.8	4.4	88.4	7.2
MONSOON	June	25.5	70.0	4.8	56.4	38.8	4.8	1.6	90.0	8.4
	July	34.0	50.0	16.0	31.6	63.2	5.2	3.6	86.8	9.6
	August	25.6	59.6	14.8	57.6	32.8	9.6	2.4	83.2	14.4
	September	28.0	60.0	12.0	51.6	42.7	5.7	10.4	77.2	12.2
POST-MONSOON	October	13.2	76.4	10.3	36.8	56.0	7.2	2.4	92.4	5.2
	November	11.2	77.6	11.2	29.6	64.0	6.32	2.0	90.0	8.0
	December	4.8	86.00	9.1	42.4	50.8	6.8	2.4	86.8	10.8
	January '90	50.0	46.0	3.9	42.8	54.8	2.4	--	--	--

TABLE 4

Details of Biomass of *Paphia malabarica* from Ashtamudi Estuary in two stations for February, 1989 to January, 1990

		STATION I				STATION II			
SEASONS	MONTHS	MEAN NOS for months	MEAN NOS for season	MEAN wt. for months	MEAN wt. for seasons	MEAN NOS for months	MEAN NOS for seasons	MEAN wt. for months	MEAN wt. for seasons
Pre-Monsoon	February '89	246		153		89		135	
	March	153		146		54		265	
	April	75		105		84		175	
	May	136	152.5	243	162.0	67	73.5	208	196.0
Monsoon	June	90		166		61		172	
	July	111		295		91		367	
	August	107		209		46		273	
	September	84	98.0	199	217.0	53	63.0	225	259.0
Post-Monsoon	October	42		82		32		176	
	November	15		70		43		217	
	December	37		125		36		60	
	January '90	21	29.0	70	112.0	23	33.5	137	147.0

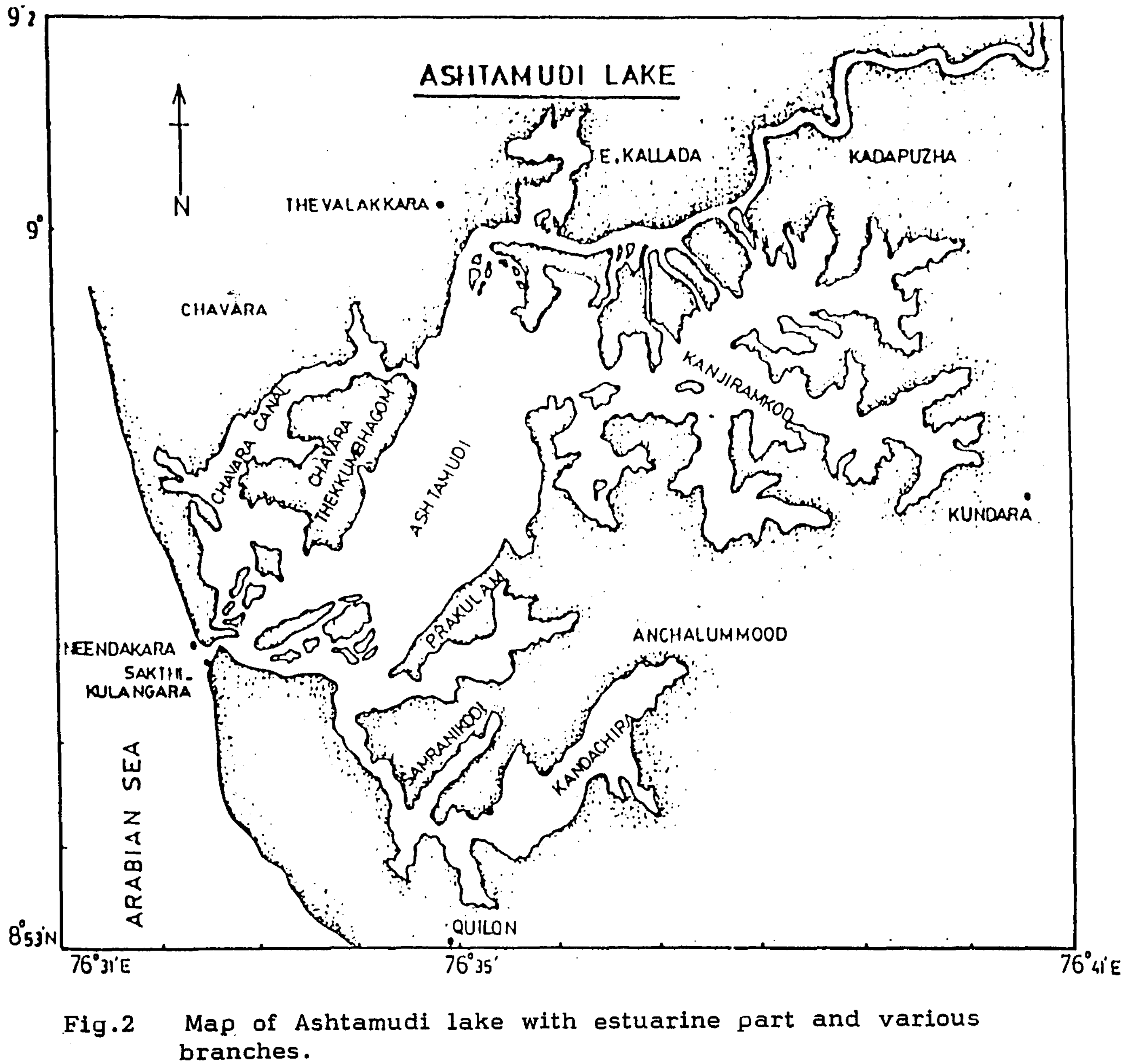


Fig.2 Map of Ashtamudi lake with estuarine part and various branches.

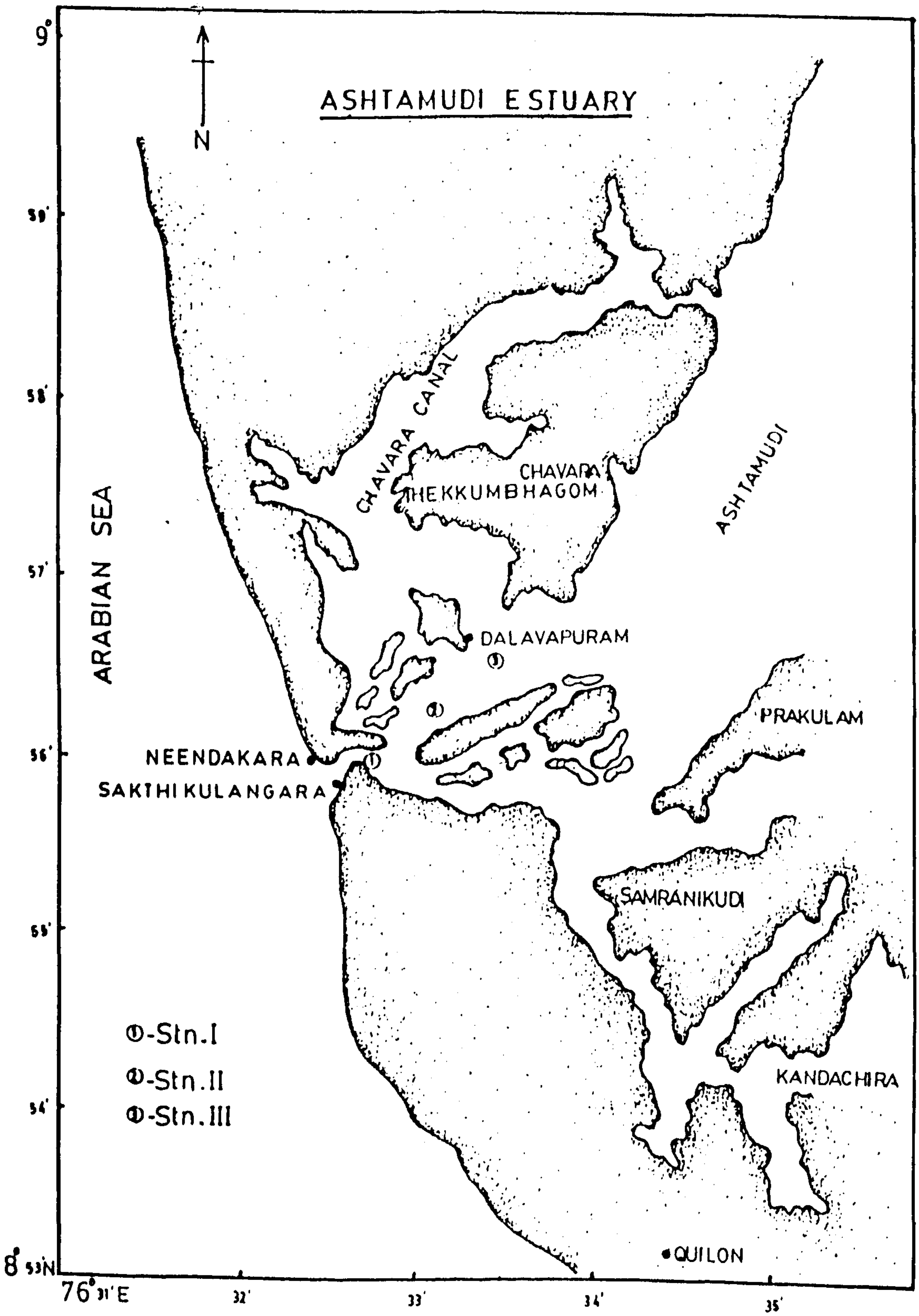


Fig.3 Map of Ashtamudi estuary showing clam bed area with 3 sampling stations

1. Station I - near the barmouth
2. Station II - 2km upstream
3. Station III- 4km upstream

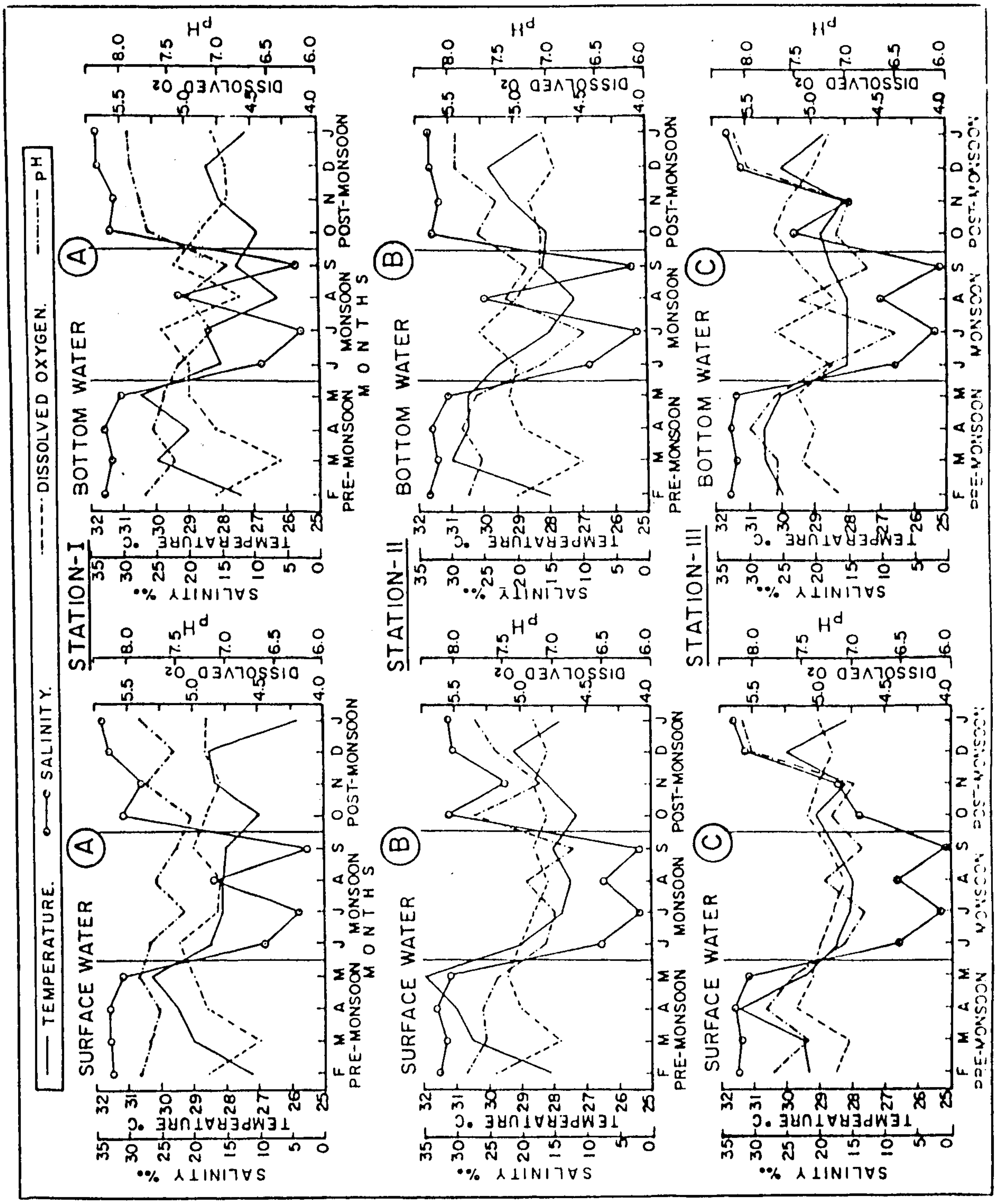


Fig. 4 Environmental details of Ashtamudi estuary from February 1989 to January 1990

A. Temperature, Salninity, dissolved O2 and pH in surface and bottom water of Station I

B. Temperature, salinity, dissolved O2 and pH in surface and bottom water of Station II

C. Temperature, salinity, dissolved O2 and pH in surface and bottom water of Station III.

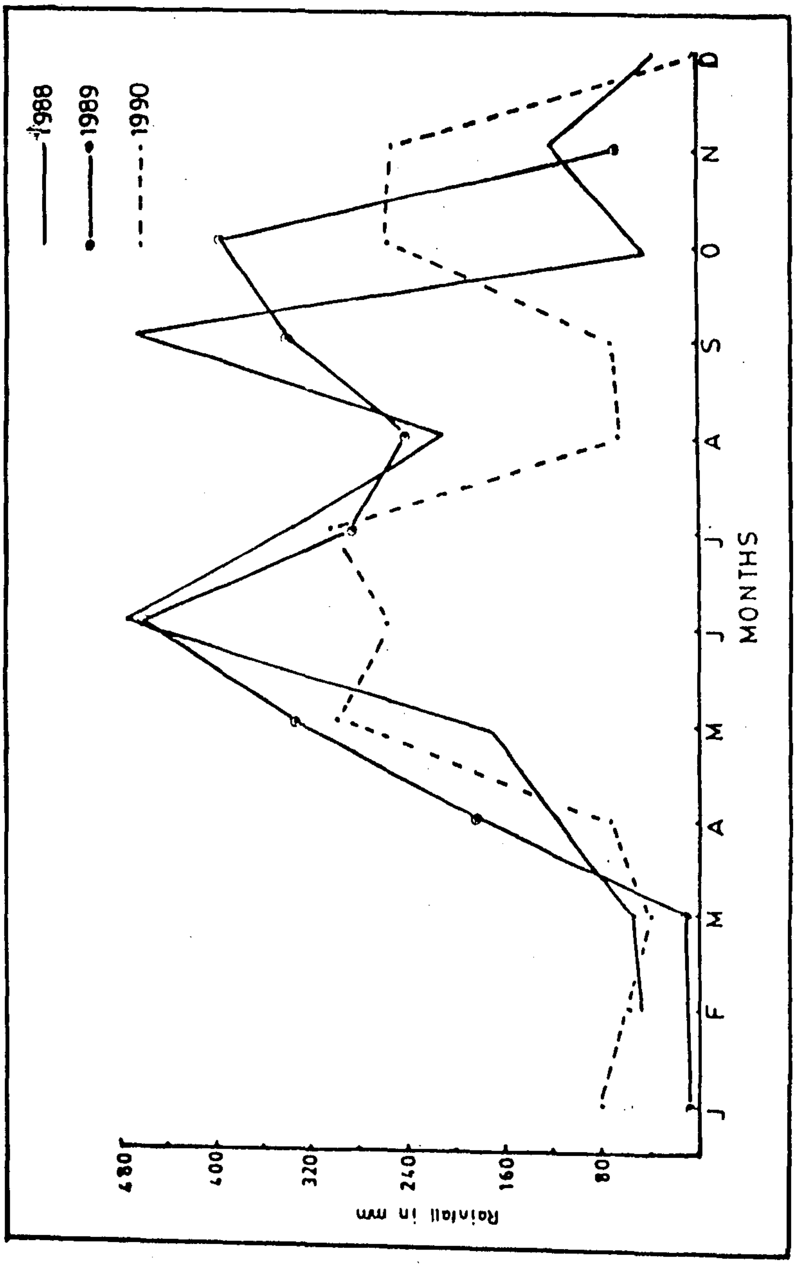


Fig. 5 Rainfall data of Quilon area for 1988, 1989 and 1990

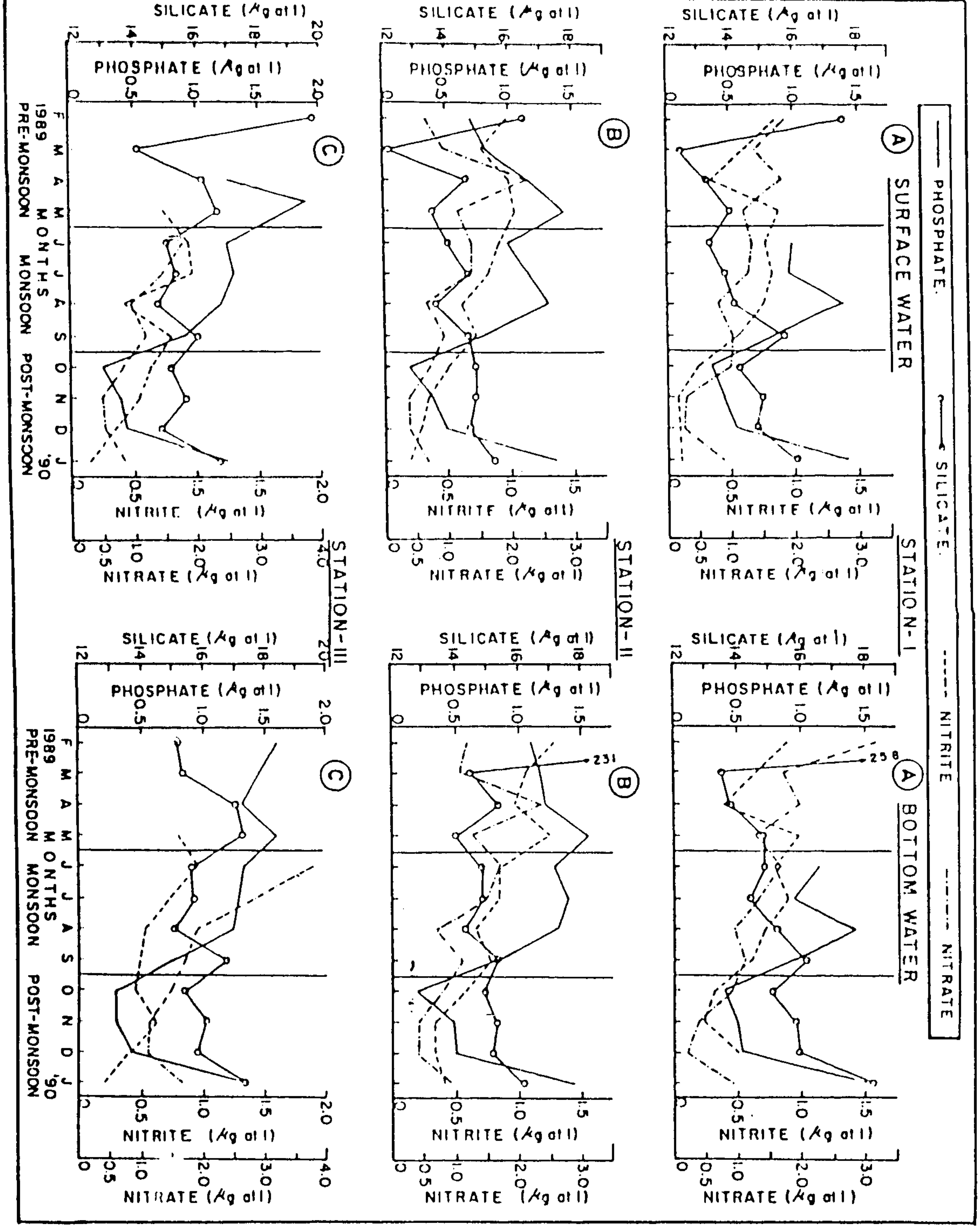


Fig. 6 Environmental details of Ashtamudi estuary from February 1989 to 1990.

A. Phosphate, silicate, nitrite and nitrate in surface and bottom water of Station I.

B. Phosphate, silicate, nitrite and nitrate in surface and bottom water of Station II.

C. Phospate, silicate, nitrite and nitrate in surface and bottom water of Station III.

CHAPTER 4

BIOLOGY OF *PAPHIA MALABARICA*

SECTION - I REPRODUCTION

MATURITY, SPAWNING AND SEX RATIO OF *PAPHIA MALABARICA* FROM ASHTAMUDI

INTRODUCTION

Reproductive activities of molluscs are mainly controlled by an interaction of exogenous and endogenous factors. Exogenous factors like temperature, salinity and food supply act as environmental indicators and synchronise the reproductive activities of the animals in the concerned environment. Endogenous control of reproduction, especially gametogenesis and spawning, is by the endocrine system and is more or less independent of the environmental changes (Giese and Pearse, 1974). Estuarine systems are subjected to highly dynamic changes and hence wider fluctuations in physical, chemical and biological factors. There are numerous works on the reproductive biology of bivalves and the effect of environmental changes on it. Most of them are from temperate waters. The cycle of gametogenesis and spawning has been extensively studied from temperate regions. Edible oyster *Crassostrea virginica* is the much studied species (Purchon, 1968), mainly because of its wider distribution. Important works on the reproductive biology of *Crassostrea virginica* are those of Coe (1938), Loosanoff (1942), Loosanoff and Davis (1950, 1952) Loosanoff and Nomejko (1951) Korringa (1952) and Galtsoff (1964); of mytilids are by Wilson (1886) Johnstone (1898) Williamson (1907) Field (1922) Battle (1932) Berner (1935) Coe and Fox (1942) Chipperfield (1953) Lubet (1957) Wilson and Hodgkin (1967) and Seed (1969); of hard clams *Venus mercenaria* are by Loosanoff (1936a, 1936b, 1937a, 1937b, 1937c), Coe and Turner (1938) Davis and Chanley (1956) and Ansell (1961), in Soft clam *Mya arenaria* are by Coe and Turner (1938) Rogers (1959) Pfitzenmeyer (1962) Shaw (1964, 1965) Ropes and stickney (1965) Porter (1974) and Brousseau (1978, 1987) and in bar clam *Spisula solidissima* are by Ropes (1968). Pathansali (1964) traced the spawning of the cockle *Anadara granosa* from Malayasian waters and Boydens (1971) made a comparitive study of reproductive cycle of the cockle *Cerastoderma edule* and *C. glaucum*.

From Indian waters biological studies of bivalves are very recent. The most important works on the reproductive cycle are in *Crassostrea madrasensis* (Preston) *Ostrea cucullata*, (Born), *Meretrix meretrix* (Linnaeus) *Meretrix casta* (Chemnitz), *Donax faba* (Gmelin) *Donax cuneatus* (Linnaeus), *Paphia laterisulca*, *Katelysia* opima (Gmelin), Perna viridis (Linnaeus), Perna indica Kuriakose and Nair, Anadara rhombea (Born), Anadara granosa (Linnaeus) Solen kempi Preston, Pinctada fucata (Gould) Villorita cyprinoides (Gray) and Placenta placenta (Linnaeus). Hornell (1910), Paul (1942), Rao (1951a, 1956, 1983), Rao and Nayar (1956), Durve (1964a, 1965), Rao (1974), Nayar and Mahadevan (1983), Purushan et al (1983), Joseph and Joseph (1983), Rajapandyan and Rajan (1983, 1987), Samuel (1983), Joseph and Madhyasta (1982, 1984) and Narasimham (1987) gave details on the spermatogenesis and spawning cycle of Crassostrea madrasensis. Nagabhushanam and Bidaker (1977) gave details of reproduction of Crassostrea cucullata and Durve (1965) and Mane and Nagabhusham (1976) on C.gryphoides. Abraham (1953), Durve (1963) and Rao (1988) on M.casta, Alagarswami (1966) on Donax faba, Nayar (1955), Rao (1967), Nagabhushanam and Talikhedkar (1977a) and Victor and Subramaniam (1988) on Donax cuneatus; Nagabhushanam and Mane (1988) on Paphia laterisulca, Rao (1988) on Paphia malabarica, Rao (1951b), Mane (1974a), Nagabhushanam and Mane (1975), Appukuttan et al (1985) and Joseph and Joseph (1987) on Katelysia opima. Mane and Nagabhushanam (1983, 1988) and Joseph and Joseph (1988) on Perna virids, Kuriakose (1973) and Joseph and Joseph (1987) on Perna indica; Narasimham (1985, 1988a) and Natarajan and John (1983) on the reproductive cycle of

Anadara granosa and *A. rhombea*. Information on the reproductive cycle of Indian pearl oysters was also provided by Herdman (1906) Hornell (1922b) Chacko (1970) and Chellam (1987). The details of reproductive cycle of back water clam *Villorita cyprinoides* was given by Joseph and Joseph (1988) and Achary (1988). Rao *et al* (1962) described the reproductive cycle of *Solen kempi* and Narasimham (1984) and Pota and Patel (1988) on *Placenta placenta* from Indian waters.

Studies on the reproductive cycle of bivalves from Indian waters are thus mostly on commercially important species. Studies on the reproductive cycle of *P.malalbarica* from Indian waters is confined to the work of Rao (1988) on the reproductive stages of this species in the commercial catches at Ratnagiri. Except for this report, no information exists regarding any aspects of its reproductive biology from India. In the ensuing chapter, the details of reproductive stages found during different seasons, breeding cycles, spawning activity and sex ratio of *P.malabarica* are reported for the first time from Ashtamudi estuary.

MATERIALS AND METHODS

Fortnightly samples of *P. malabarica* from Stations I and II in Ashtamudi were collected from February 1989 to

January 1990 using a hand dredge. The number of specimens examined in each sample ranged from 15 to 30 and the total number of specimens examined was 1082. For classification of the condition of gonad, fresh gonad smears were examined under microscope in 15 x 40 magnification. The microscopic appearence of individual gonad was recorded. Sex and stages of maturity were ascertained from fresh smears of gonad from individual clams. The shape of the eggs was also considered in fixing advanced female reproductive stages. External appearence of fresh gonad tissue after removing the shell was also noted for classifying the stages of maturity. The classification followed by Joseph and Madhystha (1982) and Appukuttan and Nair (1983) were adopted in fixing various gonads stages by microscopic appearence of gonad, as the objective of the present study was to observe the occurence of different reproductive stages in different seasons and also to determine the exact season of spawning. The details of the stages are given below:

Indeterminate

This stage is unique because of the presence of shrunken follicles, without any differentiation of cell in the tissue smear and demarkation of sex. Does not ooze when punctured. Site of gonad normally white.

Female

Stage I : Gonad size increases with the appearence of genital ductules over the tissue. Gonad somewhat flabby, but no oocytes present. Early developing stage.

Stage II : Gonad somewhat thick Pale yellowish with underlying genital ductules more prominent. Gonad smears show primary occytes with distinct nuclei.

Stage III : Gonad thick slightly yellowish in colour, with genital follicles enlarged, ramified and closely packed. Germ cells ooze out when gonad is punctured. Oocytes mostly ovoid or spindle shaped and partially yolked.

Stage IV : Gonad full, plumpy, creamy in colour and free oocytes emerge, when gonad is punctured. Perfectly spherical ova with round nuclei, fully yolked eggs, fully mature condition, ready for spawning.

Male

Stage I : Early developing stage. Gonad whitish, genital ductules start appearing, visible through body wall. Spermatocytes appear as spherical bodies.

Stage II : Tissue whitish in colour with thick gonad, the genital ductules more prominent. These follicles do not

RESULTS

Reproductive Cycle

The temporal distribution of maturity stages of *P.malabarica* in different months for 1989-90 period from Ashtamudi is given in Table 5. The gonadal stages of this clam is broadly classified into indeterminate stage, of smaller size groups without much demarkation of reproductive bodies, followed by stages of sexual maturity (from stage I to IV) and spent stage. The indeterminate and spent stages are sexually quiescent, whereas Stages I & II indicate renewal of gametogenetic activity and stages III and IV show the gamete production, gonad growth and commencement of spawning.

The progress of reproductive cycle of *Paphia malabarica* in different months could be traced as follows: The indeterminate dominated in February with 66% followed by stages I and II; and in March indeterminate was 31% and stage I 46%; the rest in stage II; in April there was 15% indeterminate with 63% stage I and 22% stage II; in May 14% indeterminate, 38% stage I and Stage II dominating by 48%. In June 12% indeterminate, 44% Stage I, 40% Stage II and 4% Stage III appeared in the sample; in July 22% indeterminate 22% Stage I, 36% Stage II and rest in Stage III; in August Stage I, 6.3%, Stage II, 46.3% and Stage III dominated by 48.4%; in September Stage I was only

1.4%, Stage II, 17.8% and the rest (80.8%) in Stage III; in October Stage III was 39.2 with the appearence of 60.8% of Stage IV; in November Stage III was 14.7% with rest of 85.7% in Stage IV and in December Stage IV was 23.5% and rest in spent Stage. In January 1990, Stage IV was only 6.5% and 93.5% in spent Stage (Table 5 and Fig. 7C). While examining the male and female clams separately it could be seen that (Table 5 and Fig. 7A,B) Stage I & II (maturing stages) dominate till June in both sexes, whereas active reproductive phases (Stage III & IV) of male appeared from June till November and female from July to November with spent stages dominating from December onwards (Fig. 7D). The reproductive cycle of clams thus shows that breeding season commences in October and lasts till January with peak spawning in October and November. Sexual activity commences in February and lasts till September. The peak somatic period could be as February-April when more numbers of indeterminate appear in the population.

Spawning

The peak spawning season for Paphia malabarica seems to be October-November when more than 60% of the population are with fully ripe gonad in spawning condition. This coincides with the post-monsoon period with recovered salinity and temperature after the low values that prevailed during the monsoon in the estuary. Spat fall in the natural bed was also noticed from December to February (Pers. observation).

Reproductive Cycle and Change in body weight

The meat weight increment in the clams in relation to the reproductive activity was also studied and the data showed that weight increased gradually from February and reached the peak during May-June period and then fell sharply in the month of October. This indicates that body weight was high during active maturing period and the weight declined during the spawing period (Table 9).

Size at first Maturity

In Table 6 the gonadic condition and size range of clams are given to denote the length at which reproductive activity commences in the population. In clams up to the size range 13-14 mm no reproductive body was discernible. In the size group 15-16 mm, ovary was found developed for the first time, whereas in 19-20 mm size alone testes was developed. Fully mature females and males appeared in 21-22 mm size group indicating active reproductive stages. Though ovary was differentiated in smaller animals, there was no distinct differences between size at first gametogenesis, maturity and spawning. Spawning size was 27-28 mm in female and 29-30 mm in male. Few individuals remained indeterminate even up to 29-30 mm size. Above 29-30 mm size group, there was no relationship between size and stage of maturity, but spent stages were invariably observed from 29-30 mm onwards.

Sex Ratio

The sex ratio of the population studied for one year is given in Table 7. Chi-square tests indicate that except for February and June, 1989 and January 1990, 1:1 ratio of male to female was observed. Test for homogenity showed heterogenous nature of the population. Indeterminates were present till July and from August to January.

DISCUSSION

Results of the present study indicated that by estimating the incidence of different maturity stages of the gonad, a reasonably correct assessment of the spawning season and spawning frequency could be arrived at in P.malabarica. This method of assessing spawning season and spawning frequency has been successfully employed in many other bivalves (Alagarswami, 1966; Victor and Subramanian, 1988). In addition to the follow up of maturity stages, condition index and meat weight increase have also been used to support and supplement the information regarding spawning season.

Results of the estimation and follow up of different maturity stages of gonad in *P.malabarica* indicated that the clam attains sexual maturity at the size of 15-20 mm in shell length. Fully mature specimens start appearing in the study area during the month of October and by November. The percentage of mature specimen reaches its maximum suggesting the presence of ripe ova in mature specimens during these months. The lowest occurence or even absence of fully mature gonads after the month of January is a clear indication of spawning taking place before that month.

Based on the information available from the literature and from their own investigations, Joseph and Madhystha (1982) have indicated that tropical and subtropical invertebrates in general have mostly semi-annual or annual breeding seasons. According to them continuous breeding season reported by several authors is not really continuous. Mane and Nagabhushanam (1988) while discussing the reproduction of edible bivalves from Ratanagiri coast, have reviewed the important works on reproductive biology of Indian bivalves, especially clams and oysters and suggested that many bivalves of tropical waters have continuous spawning and in few cases discontinuous. Important works on the spawning habits of clams from Indian waters and *Paphia* spp from European waters are summarised in Table 8. The literature cited in the table reveals that bivalves in general show three types of spawning periodicity *viz.* a) those which spawn only once in an year with a comparatively shorter duration b) those which spawn twice in an year and c) those which spawn for a prolonged period of time. Certain species sometimes show two types of spawning periodicities from two different localities. Hence these studies show that bivalves do not possess a defenite species specific spawning periodicity in Indian waters, but show variation according to climatic condition of the different localities which they inhabit. However in general the spawning season extends for a few months unlike in temperature waters, where it may be only for a shorter duration.

Joseph and Joseph (1987) studied the reproductive response of a few Indian bivalves from Mulky estuary taking into consideration the gametogenetic activity, gonadal growth and proliferation, initiation of spawning and gonadal activity or dormancy in relation to their environmental factors and indicated that the effect of salinity on reproduction of bivalves are not well understood but mostly Indian bivalves respond to salnity changes as far as their spawning habits are concerned (Hornell, 1910, Panikkar and Aiyar, 1939, Paul 1942:

Nagabhushanam and Mane, 1975, 1988, Joseph 1979: Joseph and Madhysta 1982, 1984).

In the present study the spawning period of Paphia malabarica was observed to be from October to January, with a single peak during November-December. P.malabarica from Ashtamudi estuary could thus be grouped under the category of clam with spawning once in an year with short spawning period. The maturation period could be distinctly correlated with the decline in salinity and temperature level caused by monsoon on the west coast (See Chapter 3). Sastry (1979) while reviewing the various exogenous and endogenous factors which influence the reproductive cycle in bivalves showed importance of temperature as well as salinity in initiating spawning in bivalves. The influx of freshwater during southwest monsoon and the consequent changes in the environment, particularly salinity, influence the reproductive cycle of the clam. The salinity variations from 4.92 to 32.75%, the lowest during monsoon and higher values during post-monsoon and pre-monsoon period and the occurence of ripe stages from June onwards and the fully mature clams from October to January (post-monsoon period), indicate that the clams spawn when salinity starts increasing after monsoon. Temperature variation was not significant but low temperature (27.58 to 28.12°C) prevailed during monsoon. Ansell et al (1972) and Joseph and Madhysta (1982) noted distinct correlation between meat weight increase and annual reproductive cycle in few species of Indian bivalves and indicated drastic decline in the meat wieght after spawning. The condition index also decrease during spawning period. P.malabarica from Ashtamudi also showed initial increase in body weight and subsequent sharp decline during spawning period. Condition index was high during monsoon period, when reproductive activities were initiated and low when spawning was at its peak. This also indicates that condition index and body weight of this clam are closely related with spawning activity.

According to Joseph and Joseph (1988) it is quite likely that in our search for a single factor hypothesis to explain reproductive synchronization with exogenous or endogenous factors, many aspects are overlooked, probably most marine bivalves respond to the net result of all exo and endogénous factors and synchronise their reproductive activities. Once the clam population reaches maturity, external factors may induce spawning. If the majority of the clams of the population react simeltaneously to the environmental change, gametes are released profusely for a short spell, giving a short period of spawning and hence the extent of spawning depends mainly on the synchrony of the correct stage of maturity and the factors that induce spawning. Though a number of factors seem to induce spawning, studies so far done in tropical waters and the present observations indicate that salinity rather than temperature plays the vital role. However, a total study of the processes would be necessary for a precise understanding of the prolonged or short nature of spawning noticed in tropical clams.

TABLE 5

Reproductive stages of *Paphia malabarica* from Ashtamudi estuary from February 1989 to January 1990 in percentage

MALE

MONTHS	ID	I	II	III	IV	V	Total Nos.
February 1989	-	80.0	20.0	-	-	-	20
March	-	61.5	38.5	-	-	-	26
April	-	71.4	28.6	-	-	-	28
May	-	28.0	72.0	-	-	-	50
June	-	35.7	51.1	7.2	-	-	56
July	-	12.5	50.00	37.5	-	-	32
August	-	-	41.9	58.1	-	-	62
September	-	-	15.2	84.8	-	-	66
October	-	-	-	20.7	79.3	-	58
November	-	-	-	21.1	78.9	-	38
December	-	-	-	-	21.4	78.6	28
January 1990	-	-	-	-	18.2	81.8	22

Contd.....

FEMALE

MONTH	ID	I	II	III	IV	V	Total Nos.
February 1989	-	-	100.0	-	-	-	4
March	-	72.7	27.3	-	-	-	22
April	-	75.0	25.0	-	-	-	40
May	-	66.7	33.3	-	-	-	36
June	-	75.0	25.0	-	-	-	32
July	-	39.1	43.5	17.4	-	-	46
August	-	12-1	48.5	39.4	-	-	66
September	-	2.5	20.0	77.5	-	-	80
October	-	-	-	63.6	36.4	-	44
November	-	-	-	6.7	93.3	-	30
December	-	-	-	-	33.3	66.7	30
January 1990	-	-	-	-	-	100.0	38

Contd.....

POOLED (MALE + FEMALE + ID)

MONTH	ID	I	II	III	IV	V	Total NOs.
February 1989	65.7	22.9	11.4	-	-	-	70
March	31.4	45.7	22.9	-	-	-	70
April	15.0	62.5	22.5	-	-	-	80
May	14.0	38.0	48.0	-	-	-	100
June	12.0	44.0	40.0	4.0	-	-	100
July	22.0	22.0	36.0	20.0	-	-	100
August	-	60.3	45.3	48.4	-	-	128
September	-	1.4	17.8	80.8	-	-	146
October	-	-	-	39.2	60.8	-	102
November	-	-	-	14.7	85.3	-	68
December	-	-	-	-	23.5	76.5	58
January 1990	-	-	-	-	6.7	93.4	60

TABLE 6

Percentage of Male and Female *Paphia malabarica* in different size groups with various gonadic stages in Ashtamudi estuary from February 1989 to January 1990, in percentage

SIZE GROUPS in mm	MALE STAGES ID	I	II	III	IV	V	FEMALE STAGES I	II	III	IV	V
9-10	1.6	-	-	-	-	-	-	-	-	-	-
11-12	-	-	-	-	-	-	-	-	-	-	-
13-14	3.1	-	-	-	-	-	-	-	-	-	-
15-16	6.2	-	-	-	-	-	1.6	-	-	-	-
17-18	20.3	-	-	-	-	-	-	-	-	-	-
19-20	15.6	2.2	-	-	-	-	-	-	-	-	-
21-22	6.2	2.2	-	1.6	-	-	1.6	-	1.6	-	-
23-24	12.5	6.7	1.4	1.6	-	-	4.9	1.9	4.8	-	-
25-26	12.5	15.5	2.8	-	-	-	11.5	-	3.2	-	-
27-28	12.5	8.9	2.8	3.1	-	5.0	8.2	3.7	3.2	11.1	-
29-30	9.4	20.0	9.9	7.8	4.7	15.0	13.1	9.3	6.4	7.4	10.3
31-32	-	8.9	11.3	14.0	11.6	10.0	3.3	7.4	9.5	14.9	31.0
33-34	-	17.8	9.9	4.6	18.3	35.0	8.2	12.9	9.5	14.9	27.6
35-36	-	8.9	11.3	18.8	20.9	20.0	14.8	14.8	9.5	24.2	20.7
37-38	-	8.9	18.3	14.0	16.3	-	14.8	22.2	20.6	7.4	10.3
39-40	-	-	8.5	12.5	9.3	15.0	8.2	12.9	7.9	3.7	-
41-42	-	-	7.0	1.6	11.6	-	1.6	3.7	7.9	3.7	-
43-44	-	-	7.0	6.3	4.7	-	6.6	3.7	9.5	7.4	-
45-46	-	-	7.0	9.3	-	-	-	3.7	3.2	-	-
47-48	-	-	2.8	1.6	4.7	-	1.6	1.9	1.6	3.7	-
49-50	-	-	-	1.6	-	-	-	1.9	-	3.7	-
51-52	-	-	-	1.6	-	-	-	-	1.6	-	-

ID - Indeterminate.

TABLE 7

Sex ratio of *Paphia malabarica* in the population from February 1989 to January 1990 with percentage of occurence of male and female in Ashtamudi estuary with the results of test of significance

MONTHS	MALE	FEMALE	INDERTERMINATE	SEX RATIO	SIGNIFICANCE
February 1989	28.57	5.71	55.71	1:0.2	10.66 *
March	37.14	31.43	31.43	1:0.9	0.333
April	35.00	50.00	15.00	1:1.4	2.1176
May	50.00	36.00	14.00	1:0.7	2.2790
June	50.00	32.00	12.00	1:0.6	6.5454 *
July	32.00	46.00	22.00	1:1.4	2.5128
August	48.44	51.56	-	1:1.1	0.1250
September	45.21	54.79	-	1:1.2	1.3424
October	56.86	43.14	-	1:0.8	1.9215
November	55.88	44.12	-	1:0.8	0.9411
December	48.28	51.72	-	1:1.1	0.0689
January 1990	36.67	63.33	-	1:1.7	4.2666 *

* Significant at 1% level.

TABLE 8

Spawning period and Spawning frequency of Commercially important Venerid clams from Indian Waters and 3 species of Paphia from temperate waters

SL.NO.	NAME OF SPECIES	SPAWNING SEASON	SPAWNING FREQUENCY	LOCALITY	AUTHOR'S	REMARKS
1.	Donax cuneatus	Jan. - April.	Once in an Year	Palk Bay	Nayar (1955)	
2.	Donax cuneatus	Jan. - April	Once in an Year	Mirya Bay	Thalikhedkar (1975)	
3.	Donax cuneatus	February - March	Once in an Year	Madras Coast	Victor and Subramanian (1988)	
4.	Katelysia opima	Dec. - Jan.	Once in an Year	Adayar Estuary Madras.	Rao (1951)	
5.	Anadara rhombea	Jan. - April	Once in an Year	Kakinada	Narasimham (1988)	
6.	Paphia malabarica	Oct. - Feb-	Once in an Year	Mulky estuary	Rao (1988)	
7.	P. rhombea	Oct. - Dec.	Once in an Year	Plymouth	Labour (1938)	Temperate waters.
8.	P. pullastra	Feb. - March	Once in an Year	Plymouth	Labour (1938)	
9.	P. decussata	Summer	Once in an Year	Plymouth	Labour (1938)	
10.	Meretrix casta	April to May & September	Twice in an Year	Madras	Hornell (1922)	
11.	Katelysia opima	Oct. - Nov. & March - April	Twice in an Year	Ratnagiri	Mane & Nagabhushanam (1988)	
12.	Donax cuneatus		Prolonged Spawning	Madras	Rao (1967)	
13.	D. cuneatus		Prolonged Spawning	West Coast	Nagabhushnam and Talikedkar.(1977)	
14.	Meretrix casta		Prolonged Spawning	Madapam Camp	Durve (1964)	
15.	Meretrix casta		Prolonged Spawning	Ratnagiri	Mane & Nagabhushanam. (1988)	
16.	Meretrix meretrix		Prolonged Spawning	Mandapam	Alagarswami (1966)	
17.	Donax faba		Prolonged Spawning	Porto Novo	Natarajan & John (1966)	
18.	Anadara rhombea		Prolonged Spawning	Porto Novo	Natarajan & John (1966)	
19.	Paphia laterisulca		Prolonged Spawning	Ratnagiri	Mane & Nagabhushanam (1988)	

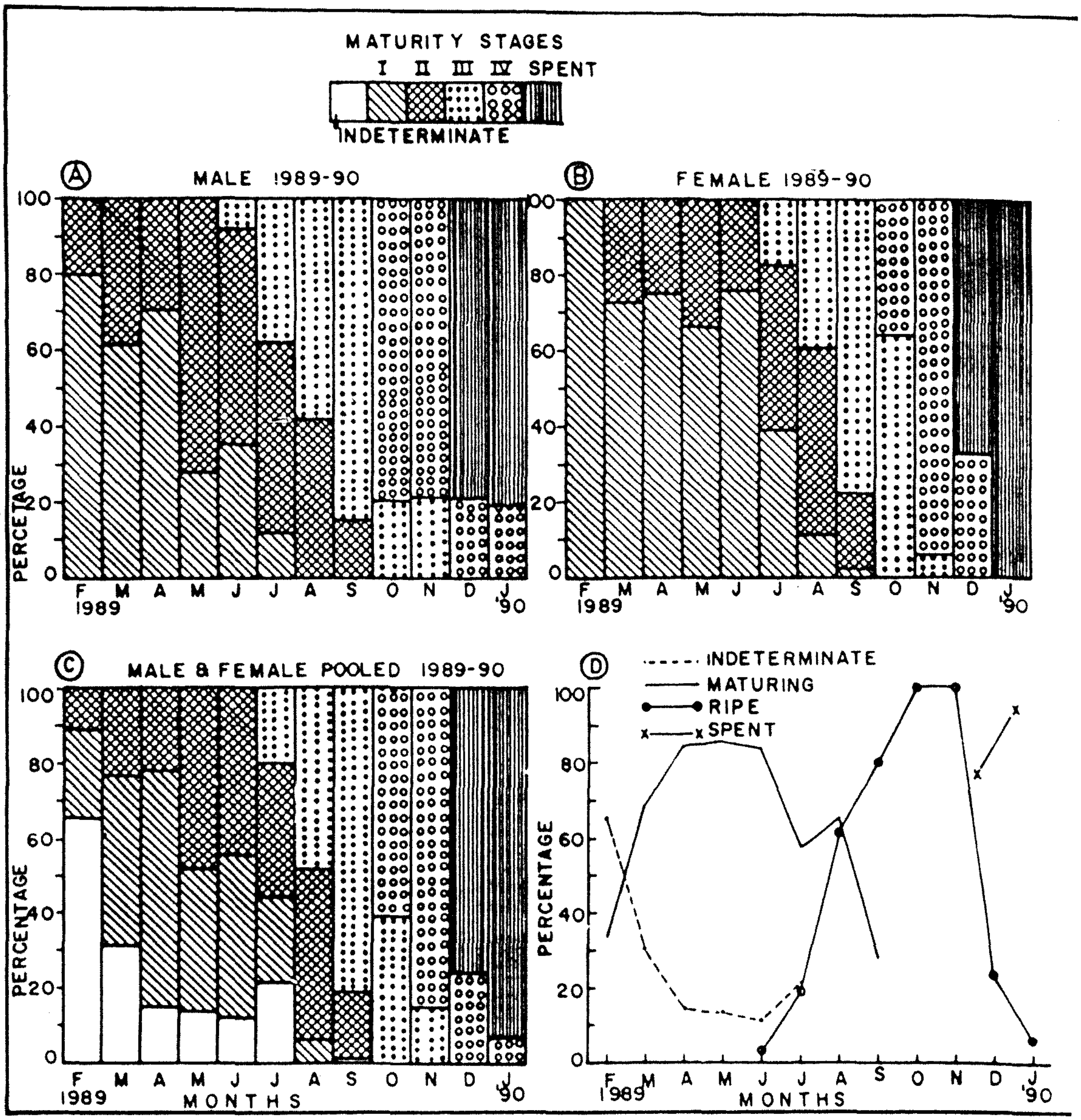


Fig. 7

A. Maturity stages in male <u>Paphia malabarica</u> in Ashtamudi estuary from February 1989 to January 1990.

B. Maturity stages in female <u>Paphia malabarica</u>

C. Pooled data on maturity stages of <u>Paphia malabarica</u>

D. Percentage of occurrence of indeterminate, maturing, ripe and spent stages of <u>Paphia malabarica</u> from February 1989 to January 1990.

SECTION II: CONDITION INDEX

INTRODUCTION

Variation in meat content is observed in most of the bivalve molluscs depending on their physiological condition and also changes in the environmental conditions. Generally the body growth prior to gonad development and spawning result in the increase in meat weight. The meat weight and the spawning activity of bivalves are two imoportant factors which should be taken into account in any judicious exploitation, especially to decide the time of harvest. A study of condition index of P.malabarica was taken up to observe the seasonal changes in condition index and to arrive at suitable harvest time of this clam with maximum meat yield.

From Indian waters, seasonal changes in condition index of bivalves were studied by Venketaraman and Chari (1951) Durve (1964a, 1970), Abraham (1953), Nayar (1955), Nagabhushanam and Dhamne (1957), Nagabhushanam and Talikhedkar (1977a, 1977b), Krishnakumari et al (1977) Mane and Nagabhushanam, (1979), Joseph (1979), Balasubramanian et al (1979), Ramamchandran (1980), Reddy (1980), Narasimham (1984, 1988a) Rajapandyan and Rajan (1987), Joseph and Madhystha (1987) Thippeswamy and Joseph

(1988) and Rao (1988). The important species that were studied include *Perna viridis* Linnaeus, *Villorita cyprinoides* (Gray) *Katelysia opima* (Gmelin) *Crassostrea madrasensis* (Preston) *Meretrix meretrix* (Linnaeus) *M.casta* Chemnitz, *Paphia malabarica* Chemnitz, *Donax faba* Gmelin, *D.incranatus* Gmelin, *D.cuneatus* Linnaeus *Placenta placenta* (Liinnaeus) and *Anadara rhombea* (Born). However, so far no studies on condition index of *P.malabarica* has been made from Indian waters.

MATERIALS AND METHODS

For objective assessment of condition of bivalves, the use of volumes of whole shellfish and meat had been found satisfactory. Many have used dry weight or glycogen content of meat as an index of condition, which is possibly more precise, but because of the time required for the preperation of the material, large samples cannot be used (Baird, 1958). The index of condition is assessed by measuring the volume of the shell cavity and the volume of meat contained therein while both are wet; dividing the meat volume by the shell cavity volume and multiplying by 100 (Baird, 1958). The index of condition is therefore the percentage of the shell cavity occupied by meat.

$$\left[\text{Index of condition} = \frac{\text{Meat volume}}{\text{Shell cavity volume}} \times 100\right]$$

By this method, the degree of fatness of meat is objectively measured, irrespective of shell thickness and to a certain extent the size of the clam, although a significant correlation often exists between length and condition in animals.

Twenty five specimens in each of two size groups, 22-30 mm and 30 mm and above in total length, which contributed to the commercial fishery were collected every month and the total volume and shell volume were measured by displacement method. Since the larger size groups had good demand for export and were exploited more, the two size groups were studied separately. Cavity volume was calculated by taking the difference between total volume and shell volume. Condition index for February 1989 to January 1990 for P.malabarica was calculated. A total of 600 specimens, ranging 22-45 mm, was used in the present study. For calculating the wet meat weight, clams of different sizes were opened and water drained out by keeping the meat on blotting paper. Specimens were then individually weighed. Meat weight percentage or percentage of edibility was calculated for samples by estimating the percentage of wet meat weight to the total weight of the sample and expressed as follows:

$$\frac{A - B}{A} \times 100$$

where A is the total weight of sample B whole weight of meat. By the same method dry meat weight percentage was also calculated. The wet meat was kept in a hot air over at 80^{o}C for 24 hours and then dry meat weight was taken. The percentage of wet and dry meat weight to the total weight was taken for the whole year and a regression fitted to test the significance.

RESULTS

The results of change in the condition index and percentage of meat weight during different months are given in Fig. 88. The condition index ranged from 32 to 58.25, the highest in January and lowest in February. From March, condition index showed gradual increase, reaching a maximum of 48 and 54 in July for smaller and large size groups respectively, although smaller size group showed a decline in May. A sudden decline in condition index was noticed in August in both the groups, but a subsequent increase to 51 to 52 was noticed in September. In November the index values declined to the lowest level of 34.6 and 36 in smaller and larger size groups respectively. The larger size group thus has higher condition index throughout the year except for a short fall in July and November.

Wet meat weight percentage was higher in smaller size group than in the larger. The percentage values varied from 18.6 to 24.8 in higher size group. The highest values were observed in June for both the size groups. In smaller size group another peak was observed in September and December, while in larger size group high values were noted again in August and November. Dry meat weight percentage varied from 2.9 to 4.5 in smaller size group with peaks during February, July, September and December whereas in larger size group the percentage varied from 3.2 to 4.5 with peaks in March, May, September and January. The details of condition index, wet meat weight percentage and dry meat weight percentage in two size groups for the entire period of observation is given in Table 9.

DISCUSSION

Condition index estimated for the two size groups of P.malabarica population from Ashtamudi estuari showed two peaks during June - September and January - May. The first peak coincided with high gonadal activity and intense gometogenesis. Following this peak, the lowest values obtained in November coincide with the intense spawning activity observed during this month. Highest percentage of spent gonads was found during December (Table 5). The subsequent peak June - September may represent the recovery phase of the gonads.

Variations in the condition index in shellfishes have been earlier attributed to the environmental factors and water quality of the habitat (Gallsoff et al 1947; Durve and George, 1973). Subsequent studies by Narasimham (1984), Joseph and Madhystha (1987), Thippeswamy and Joseph (1988), Narasimham (1988a) and Rao (1988) on various bivalves have attributed these variations in the condition factor to development of the gonads and its cyclical changes. These studies have indicated higher 'K' (condition index) values during peak gametogenesis and low values during/after spawning season. In P.malabarica Rao (1988) observed similar variations in condition factor in Mulky estuary which he attributed to the spawning cycle of this species. Results obtained in the present study also suggest a similar relation between condition index and spawning season and spawning periodicity of P.malabarica. Moreover the condition index and size of the clam also showed some relationship, as the larger size group always showed high index compared with the smaller size group, especially during pre-monsoon and post-monsoon periods. Condition index studies in relation to environmental conditions indicates that the index shows seasonal changes along with the changes in the salinity in smaller size groups which are inmature. During low salinity high condition index was observed for P.*malabarica* from Ashtamudi. During post-monsoon period when condition index is low, invariably low posphate, silicate and nitrate and nitrite were observed. From the above observation it is inferred that the condition index is high during pre-monsoon and monsoon period, when nutritive value, calorific value and percentage of edibility or meat weight is high and hence this is the ideal time for getting the maximum yield for P.*malabarica* from Ashtamudi.

TABLE 9

Condition index, wet meat weight and dry meat weight percentage in *Phaphia malabarica* for two size groups from Ashtamudi estuary during February 1989 to January 1990

Months	Condition Index		Wet meat weight %		Dry meat weight %	
	Smaller size	Larger size	Smaller size	Larger size	Smaller Size	Larger size
February 1989	33.3	31.8	25.8	18.8	4.5	4.2
March	40.0	48.0	23.8	22.1	3.5	4.5
April	40.0	47.4	25.3	20.5	4.3	3.5
May	33.3	46.7	23.9	22.0	3.8	4.0
June	45.0	48.0	29.2	24.0	3.0	3.2
July	48.0	54.1	25.2	21.5	4.5	3.7
August	44.2	47.5	24.2	22.8	3.8	3.7
September	56.7	52.2	25.5	22.4	4.5	3.8
October	38.5	44.6	18.5	18.6	3.8	3.7
November	37.0	33.3	21.5	23.9	2.9	3.8
December	47.9	44.8	28.4	22.6	4.1	3.7
1990 January	57.5	58.9	22.8	24.8	3.9	3.9

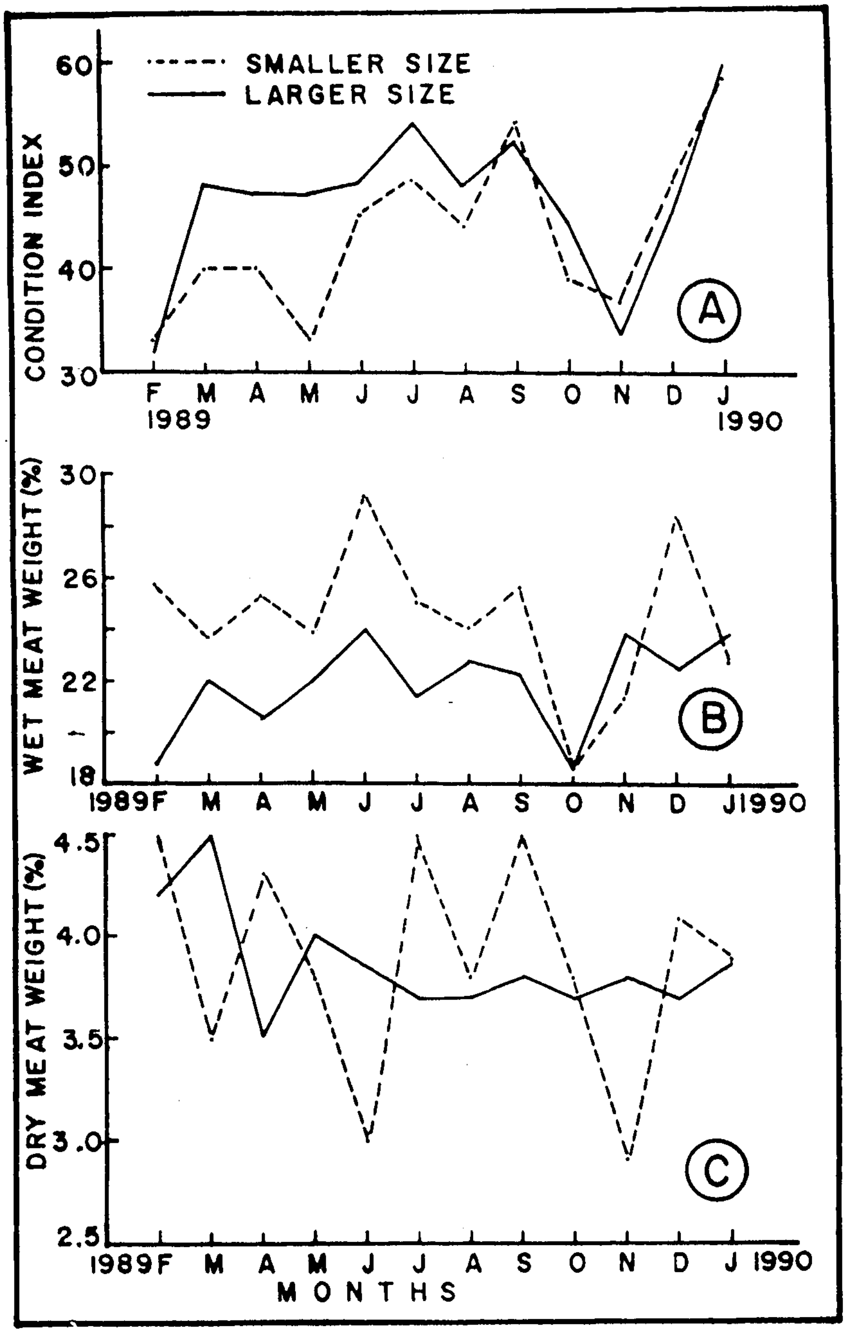


Fig.8

A. Condition index of smaller and larger size groups of Paphia malabarica in Ashtamudi estuary from February 1989 to January 1990

B. Wet meat weight percentage of Paphia malabarica in Ashtamudi estuary from February 1989 to January 1990

C. Dry meat weight percentage of Paphia malabarica in Ashtamudi estuary from February 1989 to January 1990.

SECTION III. LENGTH-WEIGHT RELATIONSHIP AND DIMENSIONAL VARIATIONS

INTRODUCTION

It is well known that the environmental factors, nature of the substratum and availability of food in the clam beds influence the dimensional relationship of clams (Durve and Dharmaraja, 1965, 1970). The length-weight relationship also sometimes varies on account of ecological conditions. The information on the allometry of clams will help to understand the ideal conditions under which they show proportionate growth and also to determine the size at which harvest can be intensified for obtaining maximum yield. Such studies also help in identifying beneficial areas for farming practices. The length-weight relationship is the most important, since it helps inter- conversion of variables. Thus in computation and analysis of catch statistics it aids to convert the sample weight to numbers in order to obtain the abundance of stock in space and time. Thus a knowledge of allometric relationship of commercially important bivalves is essential for successful exploitation of its fishery potential.

Newcomb (1950) studied the oysters of different origin and attributed dimentional variations mainly to the environmental changes in different habitats. Seed (1973) observed that shell morphology is influenced by growth rate and density and environmental conditions and suggested that shell morphology is phenotypic, older animals being more likely to exhibit a form which is characteristic of their particular habitat. Newell (1983) and Brousseau and Baglivo (1987) observed differences in growth allometry in *Mya arenaria* from different habitats.

In India, allometric relationship of several bivalves have been studied. The important works are those of Durve and Dharmaraj (1965, 1970), Nayar (1955), Alagarswami (1966), Parulekar *et al* (1973), Cherian and Cherian (1976), Mane and Nagabhushanam (1976) Thalikhedkar *et al* (1979), Alagarswami and Chellam (1977), Ansari *et al* (1978), Shafee (1978), Mohan (1980), Mohan and Damodaran (1981), Sreenivasan (1983), Mohan *et al* (1984) and Rao (1988). For *P.malabarica*, except for a study on length-weight relationship (Rao, 1988), there is no other work on the dimensional relationship of this species from Indian waters. In the present study the following relationships *viz*, length-weight, length-width, length-depth, total weight-shell weight, total weight-wet meat weight and total weight-dry meat weight were studied. All these relationships were statistically compared between stations, in order to find out both the ideal time of harvest of clam to obtain maximum meat yield and also to suggest suitable areas for farming where growth is proportionate.

MATERIALS AND METHODS

A total of 598 specimens of various lengths was studied for comparing body parameters from two stations, I and II. The clams were weighed in a chemical balance with a sensitivity of 0.1 g and length, width and depth were recorded using vernier calippers with 0.1mm accuracy. Maximum antero-dorsal length was taken as total length, maximum length in dorso-ventral axis from umbo as depth and maximum thickness of clam when both valves closed as width in the present study. Wet meat weight was taken by getting the meat removed, drained, blotted and weighed. Dry meat weight was taken after keeping the weighed wet meat in hot air over for 24 hours in $80^{o}c$ and then reweighing. Air dried shells were weighed to 0.1g accuracy. Samples from the two stations were analysed separately and values were obtained using standard statistical methods. The parabolic equation

$$W = AL^{B}$$

where W = the weight, L is the length and A and B constants was used in expressing the relationship between length and weight of clam. The above equation in logarithmic form was used for comparison between stations. Other allometric relationships between body parameters were expressed as Y = a + b x, where a and b are constant, Y is the body parameter and x length or weight. Test of significance by analysis of covarience (Snedecor and Cochran, 1967), of the two regression equations was applied for all parameters.

RESULTS

Results of analysis of covarience are shown in Table 10 and the mean values of dependent parameters and growth rates are given in Table 11. The graphical representation of all characters are given in Figs. 9, 10, 11 and 12. The results of all relationships are as follows:-

Length - weight relationship

Ist station $W = 0.1172\ L^{3.5176}$

IInd station $W = 0.1975\ L^{3.0682}$

Length - width relationship

$Y = 0.7588\ x - 0.1640$

Length - depth relationship

Ist station $Y = 0.6061\ x - 0.3983$

IInd station $Y = 0.5269\ x - 0.1702$

Total weight - shell weigh relationship

Ist station Y = 0.8203 x - 0.2230

IInd station Y = 0.7953 x - 0.1269

Total weight - wet meat weight relationship

Ist station Y = 0.1308 x + 0.2320

IInd station Y = 0.2031 x + 0.1336

Total weight - dry meat weight relationship

Ist station Y = 0.2780 x + 0.0428

IInd station Y = 0.0386 x - 0.0087

From the results of Table 10 and 11 it can be seen that the rate of growth in all relationship studied except length-width, showed significant difference ($P < .01$). The growth rate was better in Station I, except for rate of growth of wet meat weight, which was better in Station II. Though the mean values of dependent parameters did not show any significant differences between stations, except dry meat weight, with high average in Station I, where as all other parameters were always better in Station II in the present observation.

DISCUSSION

Durve and Dharmaraj (1965, 1970) studied dimensional variations in *Meretrix casta* from different localities and observed variations in the body proportions and attributed the reason for this to the environmental conditions and nature of substratum of two localities. Shafee (1978) noted that allometric relationship of mussel Perna viridis showed negative allometry for immature mussel and positive allometry for mature mussel. He indicated that allometric relationships involving weight and linear measurements of various parts of most molluses have a slope between 2.5 and 4.5. Alagarswami and Chellam (1977) noted dimensional variations in smaller and larger pearl oysters and did not attribute any definite reason for this. Ansari et al (1978) found dimensional variation in mussels from natural bed and cultured mussels, often the latter showing higher proportions. Mohan et al (1984) noted dimensional variations in Meretrix casta, where as there was no significant variations in allometric relationship in Donax incarnatus of all size groups (Mohan et al, 1986). Rao (1988) observed that length-weight relationship of P.malabarica from Mulky as $W = 0.000122443^{L3.2640}$.

In the present study, P.malabarica, from Ashtamudi showed variations ($P < .01$) in dimensional relationships except length - width and length-weight relationship for clams from two stations. In the Ist station growth in shell dimensions was better, whereas in Station II, though growth was low compared with Station I, the means of dependent parameters was higher and the net meat yield was better throughout the year. Thus the results of the present study indicate that dimensional relationship in P.malabarica show significant variations in Ashtamudi estury between stations. However better meat yield was noted in Station II as evidenced by better wet and dry meat proportions. The precise causes of heterogenity of shell characters and changes in the meat weight proportion from two stations are not clear. Severdrup et al (1942) indicated that in sea water the apparent solubility product of Ca CO_3 increases with chlorinity and decreases with temperature. It was also observed that lamelli- branches may remove calcium directly from sea water (Galtsoff, 1938). Hence the closeness of Station I to the barmouth could be one of the reasons for better shell growth indicating significant dimensional variations. In Station II, light penetration was high through out the year (See Table 2 and Chapter 3) giving opportunity for better primary production. Nair et al (1984a) showed better production in Neendakara zone which is close to the barmouth. The availability of more food for clam due to better productivity can be one of the reason for better meat yield in clams observed from this station where maximum fishing activity takes places throughout the year (Chapter 6).

Table 10

Comparing Differences among Adjusted means of *Paphia malabarica* from Ashtamudi Estuary between Station I and Station II

LENGTH-WEIGHT RELATIONSHIP

SOURCE	Df	MSS	F
Among slope	1	0.15113	
Among B	596	0.00959	15.760 (xx)
Among adjusted means	1	0.00001	0.001
Error	597	0.00983	

LENGTH-WIDTH RELATIONSHIP

SOURCE	Df	MSS	F
Among slope	1	0.00463	
Among B	596	0.01785	0.259
Among adjusted means	1	0.1383	
Error	597	0.01783	0.776

LENGTH-DEPTH RELATIONSHIP

SOURCE	Df	MSS	F
Among slope	1	0.2344	
Among B	596	0.02207	10.623 (xx)
Among adjusted means	1	0.05155	
Error	597	0.02242	2.999

TOTAL WEIGHT-SHELL WEIGHT RELATIONSHIP

SOURCE	Df	MSS	F
Among slope	1	1.35918	
Among B	596	0.14916	9.112 (xx)
Among adjusted means	1	0.55839	
Error	597	0.15119	3.693

TOTAL WEIGHT WET MEAT WEIGHT RELATIONSHIP

SOURCE	Df	MSS	F
Among slope	1	1.07473	
Among B	596	0.10535	10.202 (xx)
Among adjusted means	1	0.27967	
Error	597	0.10697	2.614

TOTAL WEIGHT DRY MEAT WEIGHT RELATIONSHIP

SOURCE	Df	MSS	F
Among slope	1	0.25000	
Among B	596	0.00404	61.846 (xx)
Among adjusted means	1	0.4473	
Error	597	0.00445	10.042 (xx)

(xx) Significant ($p < .01$)

TABLE 11

Means of the dependent parameter and growth rate in Dimentional variations of *Paphia malabarica* from Ashtamudi estuary

PARAMETERS	Y		B	
	Ist stn.	IInd stn.	Ist stn.	IInd stn.
LENGTH-WEIGHT	0.5894	0.5361	3.51755	3.06821
LENGTH-WIDTH	1.9277	2.4720	0.75811	0.74698
LENGTH-DEPTH	1.2757	1.6575	0.60612	0.52691
TOTAL WEIGHT-SHELL WEIGHT	3.8765	7.5548	0.82033	0.79529
TOTAL WEIGHT-WET MEAT WEIGHT	1.1355	2.0950	0.18079	0.20306
TOTAL WEIGHT-DRY MEAT WEIGHT	1.1818	0.3636	0.2781	0.03855

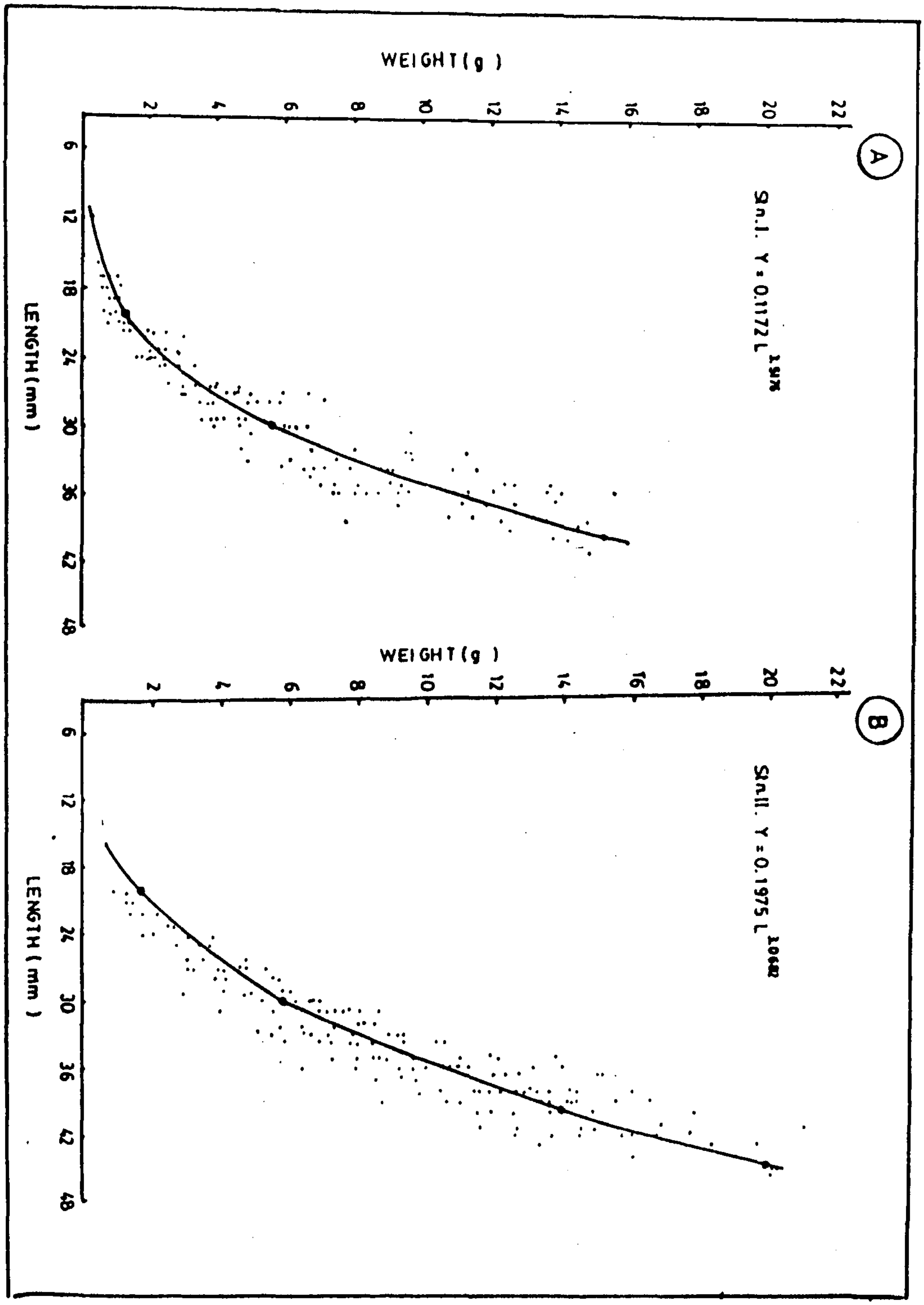


Fig. 9

A. Length-weight relationship of <u>Paphia malabarica</u> for Station I.

B. Length-weight relationship of <u>Paphia malabarica</u> for Station II.

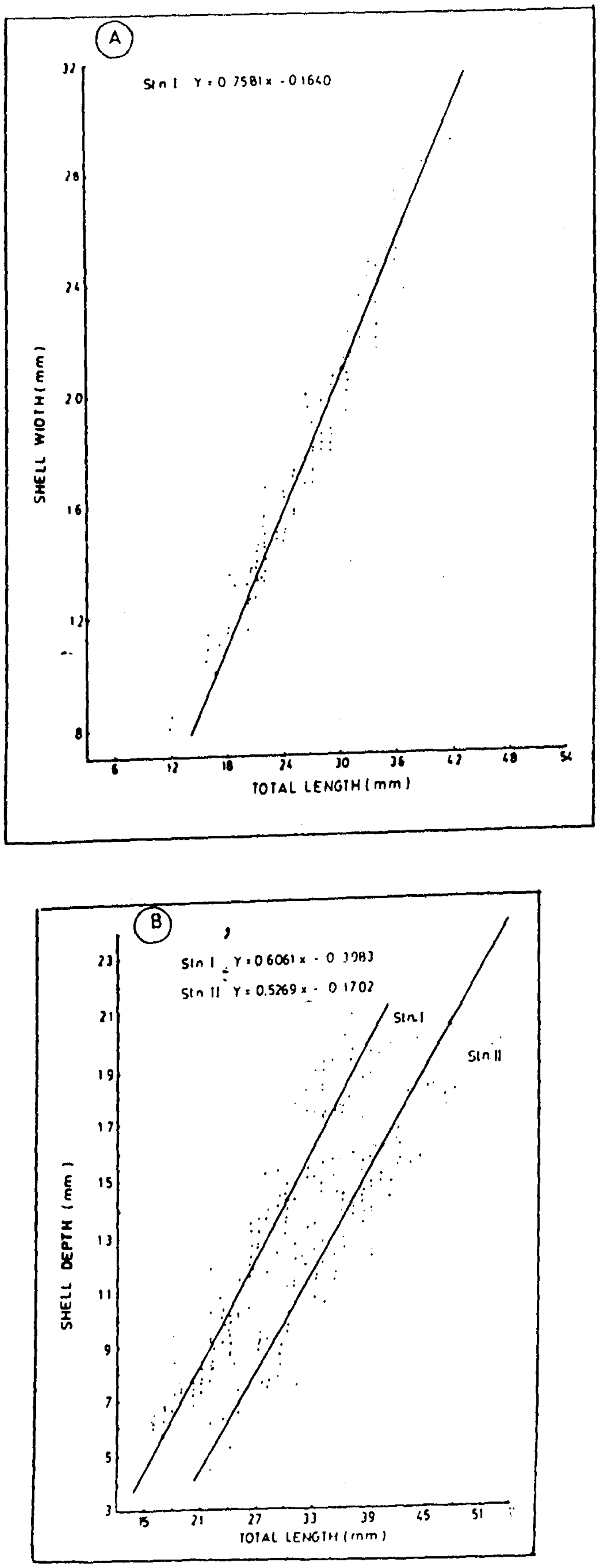


Fig. 10

A. Total length-shell width relationship in <u>Paphia malabarica</u>

B. Total length-shell depth relationship in <u>Paphia malabarica</u> for Station I and II.

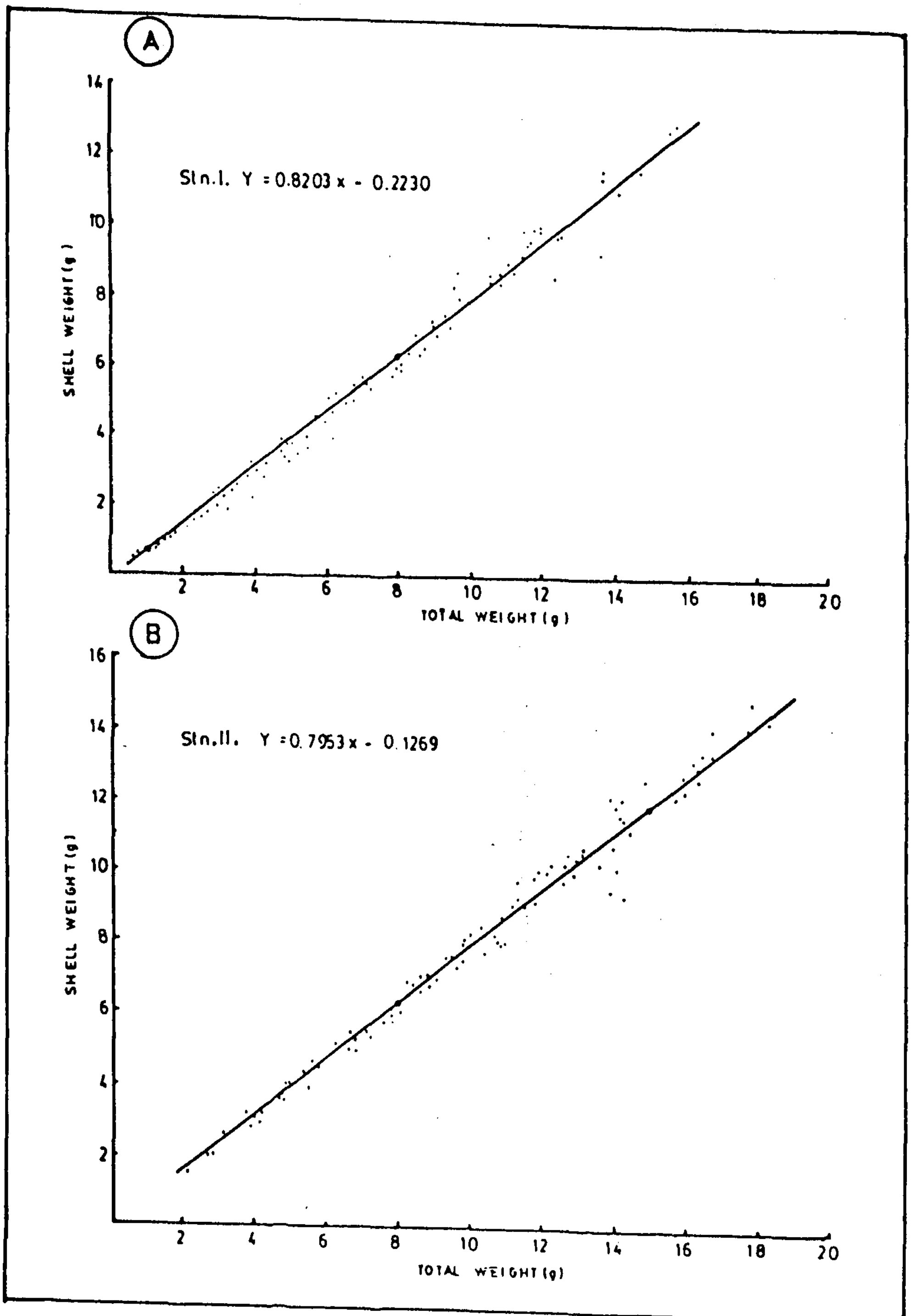


Fig.11

A. Total weight-shell weight relationship in <u>Paphia malabarica</u> for Station I.

B. Total weight-shell weight relationship in <u>Paphia malabarica</u> for Station II.

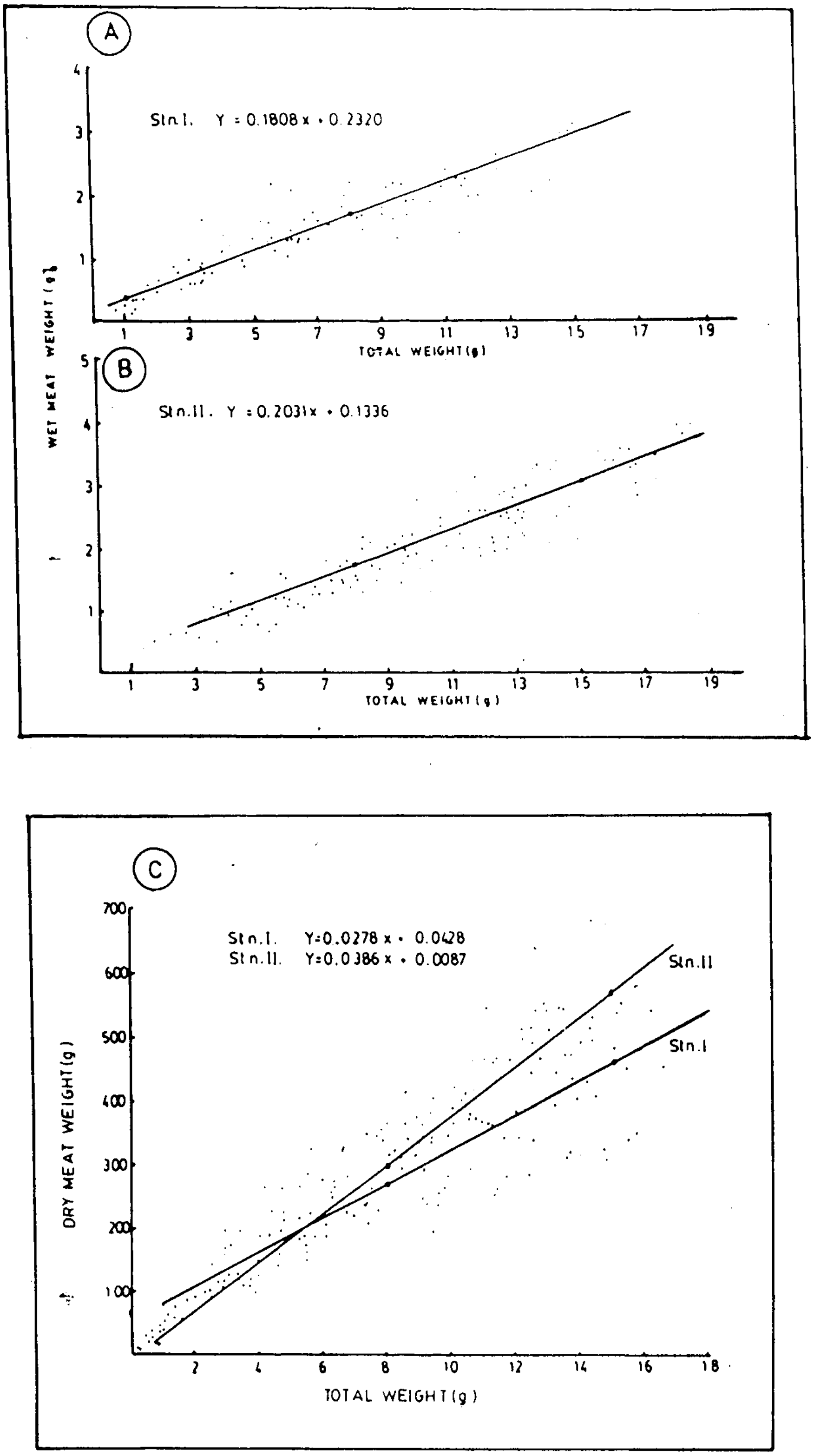


Fig.12

A. Total weight-wet meat weight relationship in <u>Paphia</u> <u>malabarica</u> for Station I in Ashtamudi estuary.

B. Total weight-wet meat dry weight relationship in <u>Paphia</u> <u>malabarica</u> for Station II in Ashtamudi estuary.

C. Total weight-dry meat weight relationship in <u>Paphia</u> <u>malabarica</u> for Station I and II in Ashtamudi estuary.

SECTION IV. AGE AND GROWTH

INTRODUCTION

The knowledge of age and growth of living resource is necessary for the study of their age at maturity, survival and mortality, longivity and maximum sustainable yield as well as for an assessment of their stock for the rational exploitation. Important studies on the age and growth of bivalves from Indian waters are on Paphia undulata (Winckworth, 1931): Mytilus viridis (Paul, 1942); Ostrea madrasensis (Paul, 1942; Katelysia opima (Rao, 1951, Mane, 1974a) Meretrix casta (Abraham, 1953; Durve, 1970; Salih 1973, Sreenivasan 1983b, Balasubramanian and Natarajan, 1988a; Rao 1988); Pinctada pinctada (Ghokhalae et al 1954); Donax cuneatus (Nayar, 1955, Talikhedkar et al 1976); D.faba (Alagarswami (1966); Perna indica (Kuriakose, 1973) Villorita cyprinoides (Harkantra, 1975, Nair 1975) Donax incarnatus (Nair, et al, 1978) Paphia laterisulca (Mane and Nagabhushanam 1979) Katelysia opima (Kalyanasundaram and Kasinathan 1983) Meretrix meretrix (Jayabalan and Kalyani, 1986) and Paphia malabarica (Rao 1988). However no information exists on stock of P.malabarica from Ashtamudi estuary where extensive exploitation is taking place in recent years. The present study was taken up with a view to filling this gap. The age and growth of Paphia malabarica was studied by continuous sampling of the population and analysing the changes in size frequency distribution. The growth pattern thus obtained was put in a mathematical form using the well known on von Bertalanffy's growth (VBG) equation (Bertalanffy, 1938).

MATERIALS AND METHODS

Samples for this study were collected from a unit area by transect method and from the pooled samples, sub-samples were used for estimation of growth. Fortnightly samples, from January to December 1989 were collected from the study area both from barmouth area and upper reaches, where active fishing is being done throughout the year. The total number of clams used for the present study was 3500. A vernier calipper with 0.01 mm accuracy was used for measuring the total length of the clam, which is the greatest dimension along the antero-posterior axis. The measurement was corrected to the nearest 0.1 mm and the specimens were grouped into 3 mm size group. Fortnightly samples were combined for each month and the percentage of different size groups for each month with peak and minor modes were estimated. A scatter diagram of range and modal values in the length frequency distribution during different months was drawn. From the shifting of modal values along the axis the growth of the individuals in the population was estimated. The modal values at the end of every third months were connected to get quarterly growth pattern. The grows parameters were estimated from this patters using von Bertalanffy growth (VBG) equation

$$Lt = L\infty \, [1 - e^{-k\,(t-t_0)}]$$

where:

Lt is the length at age t

$L\infty$ is the theoretical length the clam would reach if allowed to grow to a very old age (maximum or asymptotic length a clam can theoretically attain)

k is the growth coefficient

t is the age of clam and

t_0 is theoretical age the clam would have had at length zero if they had always grown according to the equation (t_0 generally has a negative value) (Pauly, 1983).

Estimation of parameters $L\infty$ and K was made by least square method. t_0 was estimated using Menzor and Taylor plot where:

$$-\text{Log } e \left[\frac{L\infty - Lt}{L\infty}\right]$$

was plotted. against the age in quarters and regression line fitted.

RESULTS

The study of monthly length frequency distribution of clam samples show that dominant modes are 10-12 mm in

January, 16-18 mm in February and March, 19-21 mm in April, 22-24 mm in May, 25-27 mm in August, September, 28-30 mm in June, July, October, November and December (Table 12 and Fig. 13). The initial recruitment to the population is in the size range of 4-6 mm which probably was the product of spawning in previous year in the months of November-December. Fig. 14A gives the length frequency distribution of Paphia malabarica during different months. Each line indicate the length range of the clams in the samples with closed circles indicating the dominant mode and open circle subsidiary modes. From maturity studies it was found that the peak period of spawning is in November and hence November was taken as the month of birth. The mode at 11 mm in January was taken as the size at second month which shifted to 17 mm in February, 23 mm in May, 26 mm in August, 29 mm in November, 32 mm in February and 35 mm in May. Beyond that prominant modes were not available for studying further growth. Hence the values of dominant modes observed in every quarter were used for estimating growth parameters as below:

Lt	Lt + 1
17	23
23	26
26	29
29	32
32	35

a = 8.4054
b = 0.8108
c = 0.986

From these values the growth parameters in VBG was estimated as follows:

$$L\infty = \frac{a}{1 - b} = \frac{8.4054}{1-0.8108} = 44.426$$

$$K = -\log b = -\log 0.8108 = 0.2027$$

for quarter which works out to 0.8389 on an annual basis.

Manzor and Taylor plot for estimation of t_0 is shown in Fig.14B, which gave a value of t_0 as -1.3808. This works out t_0 as -0.3452 in an annual basis. Thus the VBG equation for the species is as follows:

$$Lt = 44.426\ [1-e^{-0.8389\ (t\ +\ 0.3452)}]$$

Table 13 gives the observed and estimated length of P.malabarica in months for 1989 from Ashtamudi. These quarterly values do not show marked variations except in second quarter. Based on the VBG equation P.malabarica grow to 30.05 mm in 12 month. 38.21 mm in 24 months and 41.44 mm in 36 months and the longivity or probable span of life of P.malabarica at Ashtamudi is thus calculated as + 3 year. Very few specimens were collected beyond 41.44 mm, the maximum length observed was 52.3 mm in the commercial catch.

The relative growth of P.malabarica for different months was calculated and is given in Table13. The monthly growth rate and the length it attains in each month and both estimated and observed peak modes are given. In the first 6 months, clams show a growth increment of 9.15 mm with monthly average growth rate of 1.32 and in subsequent 6 months showed a growth increment of 7.49 mm with monthly average growth rate of 1.25 mm. In the next 6 months growth increment observed was 5.1 mm with 0.85 mm average monthly growth rate. By 24th month (2nd year), clams attained 38.21 mm with 2.6 mm growth increment for next 6 months and the average growth rate per month was 0.43 mm. In 3rd year growth increment was only 3.11 mm for 12 months with growth rate of 0.26 mm per month. This observation shows that in the first 6 months, stock of P.malabarica in Ashtamudi show faster growth followed by a low growth rate. The age group composition of commercial catches for 1988-89 is given in Table 14. The size at recruitment to commercial catches is 22 mm. A close scrutiny of the data on commercial catches reveal that one year-class ranked first with 1975 t (65.0%) followed by O-year class with 860 t (28.4%). Two-year class contributed 147 t (4.8%) and + 3 year classes together formed 54.3 t (1.8%). Month-wise analysis also indicated that in almost all the months one-year class dominated except in March when O-year class contributed 56.1%. The total estimated number of clam in O-year class was 88.3 million, one-year class 192.7

million, two year class 14.8 million and +3 year classes 5 million.

DISCUSSION

Winckworth (1931) while evaluating the growth rate of Paphia undulata from Indian waters indicated that this species lives less than two years, breeding during May-August and the young ones showing rapid growth. Rao (1957), while observing growth rate of Katelysia opima by length frequency studies fround 1st year class reaching 22.5 mm, where as in 2nd and 3rd year it grows to 31.5 and 40.5 mm respectively indicating faster growth rate in the 1st year. Abraham (1953) noted 15 mm growth in Meretrix casta within 2 months and 29.5 mm in 7 months, also showing rapid growth rate in the first two months. Nayar (1955) observed Donax cuneatus reaching 14 mm in 10 months 19 mm in 2 years and Alagarswami (1966) observed a growth of 19.5 mm in 1st year and 22.5 mm in second year in D.faba. Mane (1974), while studying the growth rate of Katelysia opima, noted the lengths attained by the clam in 1st, 2nd and 3rd years as 22 mm, 31 mm and 43 mm respectively. Mane and Nagabhushanam (1979) noted 23 mm, 38 mm and 47 mm as the growth of Paphia laterisulca for, 1st,2nd and 3rd year respectively in Kalbadevi estuary in the west coast of India. Parulekar (1984) while examining the growth and age of bivalves from temperate and tropical estuarine ecosystems, noted that annual growth rate in tropical species (Meretrix casta and P.malabarica) was 10-12 times more than in the temperate environment. No annual or seasonal growth rings were discernible in tropical bivalves. Rao (1988) followed Gulland and Holt (1969) method and growth rate derived at different mean lengths were plotted to fit a regression equation by the least square methods for P.malabarica from Mulky estuary. He estimated the growth rate as y = 0.2343, K = 0.0039/ day ie, 1.4253, $L\infty$ = 59 mm and t_0 62 days. The estimated length was 36.6 mm in 6 months, 43.1 mm in 9 months and 48.1 mm in one year, the largest specimen recorded was 51 mm. Hatchery studies on rearing of larva of P.malabarica showed that the spat reaches 555.6 μm and on 27th day the total length of spat is 1.05 mm (Narasimham, Personal Communication) However, observations of Rao (1988) on the growth of the same species indicate that growth rate is very high in Mulky estuary, attaining 48.1 mm in one year. In the present observation, P.malabarica at Ashtamudi reaches only 30.05 mm in one year. The reason for slow growth could only be attributed to the high population density, the nature of the substratum and the environmental conditions prevailing in this area. Rao et al (1989) observed that P.malabarica density in Mulky estuary was 10-85 per sq. mt, where as in Ashtamudi it ranged from 15-246. In the present study the samples collected were from an area of continuous commercial exploitation throughout the year and hence the availability of larger size groups was rare. Fig.16A shows the length frequency distribution of this species in commercial catches, which clearly indicates a bimodal distribution with dominant peak at 35 mm and a subsidiary peak at 29 mm. From the peak at 35 mm the frequency of numbers falls steeply showing that clams higher than 35mm size group are rare in the commercial catches. The larger size groups of clams alone are exploited continuously at Ashtamudi since smaller sizes are not used for export of frozen meat. Hence the larger size groups are heavly exploited during these years leaving very few clams to grow beyond 35 mm length. Growth rate of clams in the natural bed was also found slow after one year of growth. These factors might have resulted in obtaining an $L\infty$ value lower than the observed L max.

TABLE 17

Length frequency distribution of *Paphia malabarica* in numbers (Percentage in Paranthesis) for January 1989 to December 1989 at Ashtamudi estuary

Size group mm	January	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Total Nos.
4-6	1 (0.5)	1 (0.3)	-	-	-	-	-	-	-	-	-	-	2
7-9	22 (11.0)	15 (5.0)	4 (1.33)	5 (1.7)	-	-	-	-	-	-	-	-	46
10-12	38 (19.0)	24 (8.0)	11 (3.7)	13 (4.3)	1 (0.3)	3 (1.0)	-	-	1 (0.3)	-	1 (0.3)	1 (0.3)	93
13-15	18 (9)	29 (9.7)	33 (11.0)	28 (9.3)	5 (1.7)	14 (4.7)	5 (1.7)	-	5 (1.7)	4 (1.3)	2 (0.7)	4 (1.33)	147
16-18	2 (1)	48 (16.0)	43 (14.3)	40 (13.3)	12 (4.0)	16 (5.3)	10 (3.3)	17 (5.7)	2 (0.67)	3 (1.0)	4 (1.3)	3 (1.0)	200
19-21	14 (7)	40 (13.3)	33 (11.0)	50 (16.6)	37 (12.3)	23 (7.7)	22 (7.3)	34 (11.3)	24 (8.0)	17 (6.0)	8 (2.7)	11 (3.7)	313
22-24	6 (3)	14 (4.7)	39 (13.0)	42 (14.0)	73 (24.3)	43 (14.3)	37 (12.3)	46 (15.3)	59 (19.7)	59 (19.7)	19 (6.3)	33 (11.0)	470
25-27	3 (1.5)	7 (2.3)	24 (8.0)	38 (12.7)	49 (16.3)	51 (17.0)	70 (23.3)	63 (21.0)	84 (29.0)	56 (18.7)	66 (22.0)	72 (24.0)	583
28-30	16 (8)	22 (7.33)	39 (13.0)	23 (7.7)	31 (10.3)	70 (23.3)	74 (24.7)	49 (16.3)	37 (12.3)	74 (26.7)	74 (24.77)	83 (27.7)	592
31-33	20 (10)	39 (13.0)	21 (7.0)	23 (7.7)	26 (8.7)	36 (12.0)	33 (11)	38 (16.3)	22 (7.3)	34 (11.3)	60 (20.0)	50 (16.7)	402
34-36	31 (15.1)	31 (10.3)	20 (6.7)	24 (8.0)	33 (11.0)	24 (8.0)	21 (7.0)	30 (10)	32 (10.7)	28 (9.3)	49 (16.3)	19 (6.3)	342
37-39	19 (19.5)	24 (8.0)	20 (6.7)	10 (3.3)	26 (8.7)	17 (5.7)	19 (6.3)	17 (5.7)	31 (10.3)	16 (5.3)	13 (4.3)	9 (3.0)	221
40-42	9 (4.5)	4 (1.33)	12 (4.0)	2 (0.7)	3 (1.0)	3 (1.0)	7 (2.3)	5 (1.7)	2 (0.7)	8 (2.6)	4 (1.3)	11 (3.7)	70
43-45	1 (0.5)	2 (0.66)	1 (0.33)	2 (0.7)	1 (0.3)	-	-	1 (0.3)	1 (0.3)	1 (0.3)	-	1 (0.3)	11
46-48	-	-	-	-	2 (0.7)	-	2 (0.7)	-	-	-	-	1 (0.3)	5
49-51	-	-	-	-	-	-	-	-	-	-	-	2 (0.7)	2
52-54	-	-	-	-	1 (0.3)	-	-	-	-	-	-	-	1
Total Nos.	200	300	300	300	300	300	300	300	300	300	300	300	3500

TABLE 13

Observed and estimated length of *Paphia malabarica* in different months for 1989 from Ashtamudi estuary

Age in months	Estimated size in mm	Observed peak length. in mm
1	13.41	11.0 mm
2	15.51	17 mm
3	17.46	17 mm
4	19.28	20 mm
5	20.98	23 mm
6	22.56	26 mm
7	24.04	26 mm
8	25.42	26 mm
9	26.70	26
10	27.90	29
11	28.01	29
12	30.05	29
18	34.98	-
24	38.21	-
30	40.34	-
36	41.74	-

TABLE 14

Number, weight and percentage of year classes in the commercial catches of *Paphia malabarica* in Ashtamudi from February 1989 to January 1990

Months	0 - Year Class			Ist Year Class			2nd Year Class			+ 3 Year Class		
	Nos.	Wt (Kg.)	%	Nos.	Wt (Kg.)	%	Nos.	Wt (Kg)	%	Nos.	Wt (Kg)	%
February 1989	11565722	94801	34.6	20223596	166313	60.3	1093120	8960	3.27	544848	4384	1.6
March	26934814	260689	56.1	17213791	159387	34.3	4817854	44610	9.6	-	-	
April	2972960	34973	8.3	30588375	359846	85.4	1504415	17697	4.2	752165	8849	2.1
May	9787660	113810	26.3	24487726	284741	65.8	967586	11251	2.6	1972496	22935	5.3
June	5002510	52657	15.1	26436790	278283	79.8	1689575	17785	5.1	-	-	-
July	12544560	119471	44.5	14066900	133970	49.9	1043070	9935	3.7	535605	5101	1.9
August	6525232	56252	25.9	17157096	147907	68.1	1083324	9339	4.3	428272	3692	1.7
September	1742988	22346	10.1	14651676	187842	84.9	431418	5531	2.5	431418	5531	2.5
October	9879730	93205	45.3	11101062	104727	50.9	828708	7818	3.8	-	-	-
November	1249971	11261	9.0	12263946	110236	88.1	374958	3628	2.9	-	-	-
December	120540	1230	2.0	4490164	45818	74.5	1042720	10640	17.3	373576	3812	6.1
January 1990	-	-	-	-	-	-	-	-	-	-	-	-
Total	88326687	860695		192682000	1979070		14876748	147194		5028380	54304	

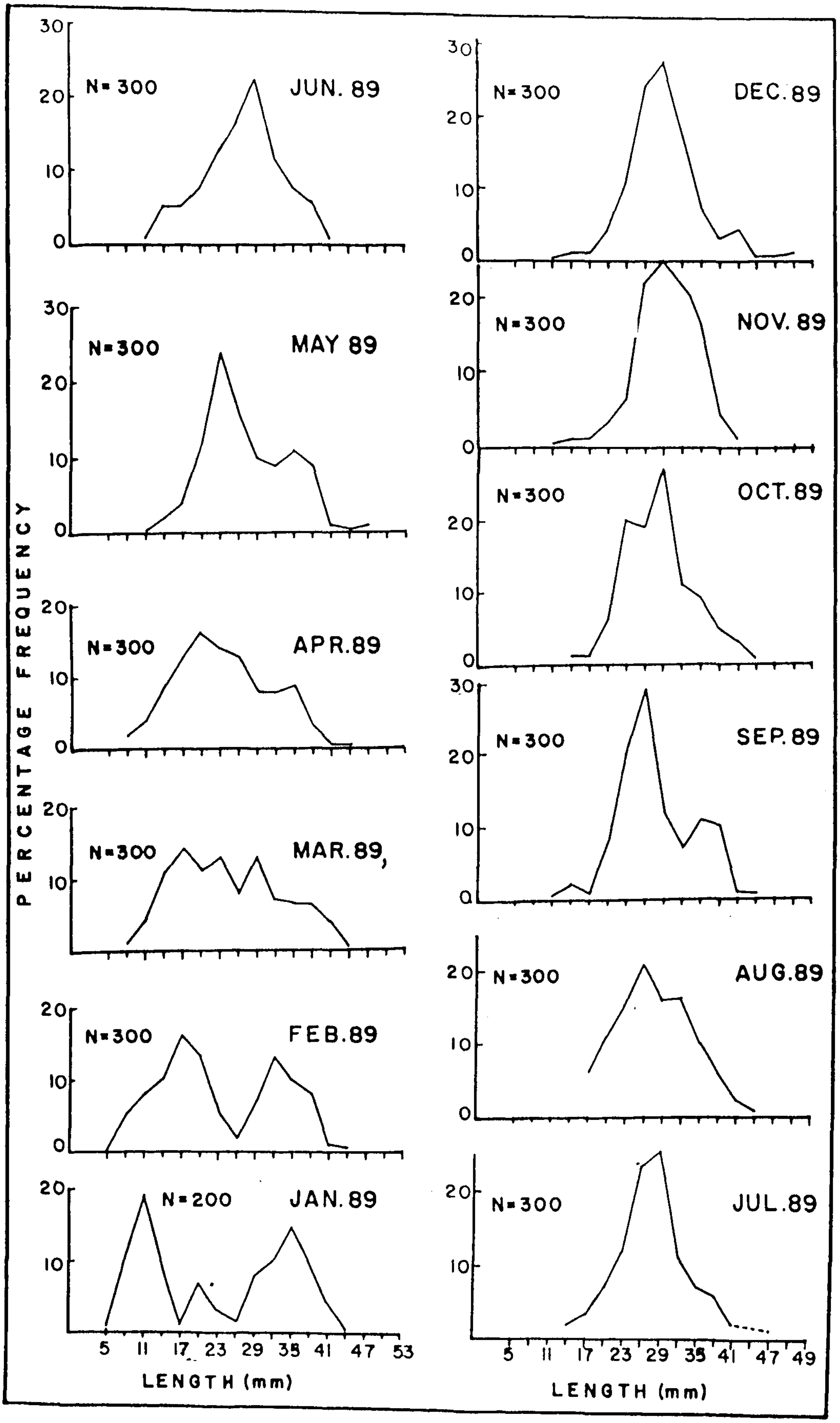


Fig. 13 Length frequency distribution of <u>Paphia malabarica</u> for one year from January 1989 to December 1989.

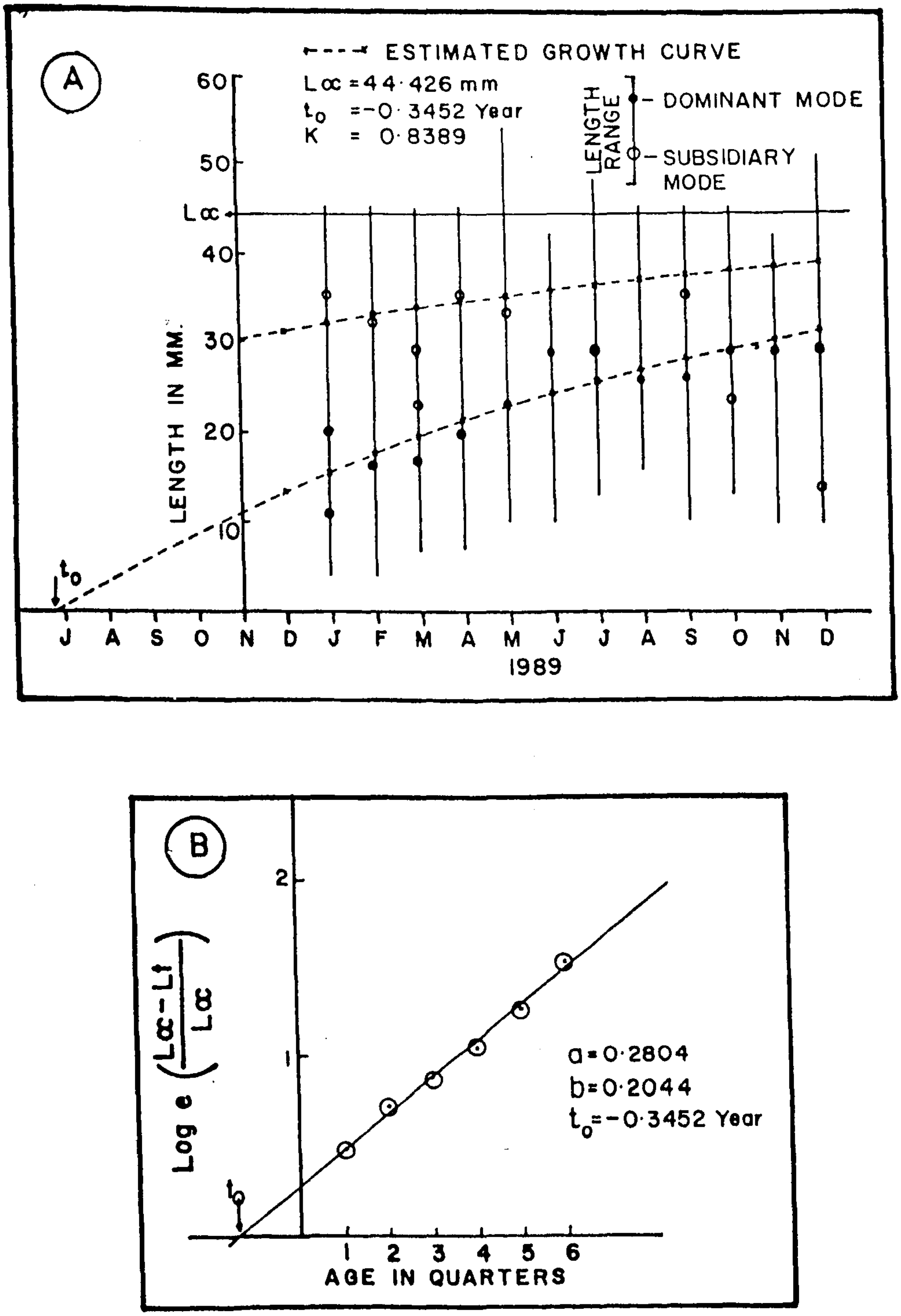


Fig. 14

A. Estimated growth curve of <u>Paphia malabarica</u> showing dominant and subsidiary modes in 1989 in Ashtamudi estuary

B. Manzor and Taylor plot for estimation of to in <u>Paphia malabarica</u>

CHAPTER 5

BIOCHEMICAL COMPOSITION OF *PAHIA MALABARICA*

INTRODUCTION

Studies on biochemical composition of animals are of considerable importance in understanding the physiological mechanism and the chemical constituents of its body. In view of the importance of molluscs as a source of protein rich food for man, there has been considerable work along this lines by many earlier workers on commercially important species of this phylum. Studies on the biochemical composition of the meat of many species have been done to understand the constituents of the body and its transformation within the body in different seasons in relation to biological activities (Ansell, 1972, Mc Lachlan and Lombard, 1980). In commercially important groups like Oysters, mussels, clams and cockles this study helps to evolve suitable management strategies for rational exploitation when the nutritive value is high. Observations on the seasonal variations in the biochemical composition in relation to the ecological condition in the environment in which bivalve live are also useful to develop profitable farming practices and also to conserve the resource without depletion.

Although the importance of studies on biochemical composition of bivalves was well understood from very early days, few such studies were done in the early part of the centuary. Compared with other groups of molluscs there is less literature on the bivalves and that too are mainly on edible oysters, mussels and clams from temperate waters. To mention some important works on bivalves, there are those of Chipperfield (1953), Galtsoff (1964) Ansell et al (1964), Ansell and Travellion (1967), Giese (1969), Ansell (1972, 1974a, 1974b, 1974c, 1974d), De Zwaan and Zandee (1972) Dare and Edwards (1975), Tayler and Venn (1979) Adachi (1979) Barber and Blake (1981).

Earlier studies in India were mainly concerned with the changes that occur in the composition and in calorific value through different seasons. Generally the whole body is subjected to analysis with no separate consideration on the component body parts or on correlation with the environmental parameters. A review of the literature reveals that important works from Indian region are those of Venkataraman and Chari (1957) on edible oysters, Durve and Bal (1965) on *Crassostrea gryphoides*, Salih (1975) on *Ostrea forskali*, Sarvaiya (1977) on *Crassostrea gryphoides* and *C. cucullata*, Easterson and Kandaswami (1988) on *Crassostrea madrasensis*. Desai *et al* (1979) and Dharmaraj *et al* (1987) studied the biochemical changes of Indian pearl oyster, *Pinctada fucata*. Studies on Indian mussels are those of Salih (1975) Mane and Nagabhushanam (1975) and Mohanan Kalyani (1989). Biochemical composition and their seasonal changes of wood boring bivalves from Indian waters were also studied in detail (Nagabhushanam, 1961; Sreenivasan, 1963; Sreenivasan and Krishnaswamy, 1964; and Saraswathy and Nair, 1969). Among clams, quite a number of works were done in recent years. Venketaraman and Chari (1951) studied the biochemical composition of *Meretrix casta*, Kasinathan (1964b) on the fat of marine bivalves, Joshi and Bal (1965) on *Katelysia marmorata*, Rahman (1966) on *Donax cuneatus* Krishnamurthy (1969) on various bivalve tissue, Suryanarayana and Alexander (1972) on nutritive value of few bivale clams, Ansell *et al* (1973) on *Donax incarnatus* and *D.spiculatum*, Nagabhushanam and Deshmukh (1974) on *Meretrix meretrix*, Salih (1975, 1979) on *Villorita cyprinoides*, *Meretrix meretrix*, *M. casta* and *Sunetta sp.*, Nagabhushanam and Dhamne (1977) on *Paphia laterisulca*, Sarvaiya (1977) on *Pitar erycina*, *Pinna vexillun*, *P. atropurpura*, *Solen truncatus* and *Placenta placenta*, Mane (1973) on *Katelysia opima*, Ansari *et al* (1981) on *Villorita cyprinoides* and Balasubramaniam and Natarajan (1988) on *Meretrix casta*.

So far no attempt has been made to study the nutritive value of *Paphia malabarica*, the meat of which is being exported for edible purpose from India in large quantities during recent years (per.obser). In the present study investigation on the biochemical composition of the whole body of two size groups of P. malabarica collected from Ashtamudi estuary was taken up to understand the nutritive value of the meat in different seasons. The molluscs do not possess localised nutrient storage depots, such as glycogen storing liver of the vertebrates or the subdermal and omental adepose tissues of mammals or fat bodies of lower invertebrates for storing fat; instead, nutrient storage appears dispersed over all the body compoenents (Giese, 1969). Giese (1969) while reviewing the methods available for biochemical studies of marine invertebrates pointed out that the size of the animal has some bearing on the various biochemical constituents. In the present study the percentage of dry meat weight is estimated to asses the variations in the percentage of edibility and the biochemical characteristics of the whole body, mainly the seasonal changes in the level of water content, protein, carbohydrate, lipid, ash and the calorific value in relation to the total dry weight of the body. The samples were classified into smaller and larger size group and no attempt was made to separate sex as this was difficult in the lower size groups and indeterminates after spent stage.

MATERIALS AND METHODS

Materials for the present study were collected during one year period from February, 1989 to January 1980, approximately at monthly intervals from Ashtamudi estuary. Using hand dredges, samples collected each month, were grouped into smaller size below 30 mm and larger size groups above 30 mm, the latter always forming the bulk of the commercial catch. From the smaller size group 25 numbers of clams and from the larger size group 15 numbers were taken for the observations. They were kept in filtered sea water for 24 hours for defeacation. The shells were then thoroughly cleaned of the encrusting animals. Total weight of all the clams together was taken first and then shells were opened, water allowed to drain and then weighed. After weighing, the meat was extracted from these groups separately. The meat was then homogenised and re-weighed and transferred to petridishes and dried in a hot air oven at 60°C for 24 hours and reweighed. The seasonal variations of protein, carbohydrate, lipid and ash in the entire body of the clam of two size groups were estimated using standard methods. The dried meat was minced and from this, weighed portions were taken for determination of biochemical constituents.

The biochemical compositions are given as percentage of dry weight.

Moisture content was determined by calculating the difference between the wet weight and dry-weight of meat samples and expressed as follows:

$$\frac{A - B}{A} \times 100$$

where A is the wet weight of the meat and B the dry weight. Protein content of the whole body was estimated by standard micro-kjeldahl procedure used to determine the total mitrogen in the clam homogenate, the percentage of protein in the dried clam meat was obtained by multiplication of conventional factor 6.25. Estimation of fat was done by adopting the soxhlet ether extraction method. This method consists of extracting the fat using the non-polar solvent, diethyl ether. A weighed amount of powdered dry meat was treated with diethyl ether in a soxhlet apparatus. Later ether was evaporated by warming under reduced pressure. The estimation was repeated two or more times to arrive at exact value.

The carbohydrate content was obtained by calculating the difference of the sum of protein, fat and ash fraction from 100%, value of glycogen which is the principal carbohydrate in lamellibranches and is in close agreement with the direct estimation of total carbohydrates (Dare and Edwards, 1975).

Ash content was determined by incinerating known weight of the dry powdered meat at temperature exceeding 500^{o}C. The ash was slightly yellowish. The ash content is the weight of the ash expressed as the percentage of the total dry weight of the sample. Calorific value was estimated for the entire animal in relation to different months. The method of estimation was by using calorific equivalent of protein (5.65 k cal/g), glycogen (4.2 K cal/g) and fat (9.45 K cal/g).

$$\text{Calorific value} = \frac{5.65\ p + 4.2\ c + 9.45\ f}{100}\ \text{K cal g}^{-1}$$

Where p.c and f represent the percentage content of protein, carbohydrate and fat respectively.

RESULTS

Results of the biochemical analysis of P.malabarica are presented graphically in Fig. 15. Summary of statistical analysis is shown in Table 14. Percentage of meat content of Paphia malabarica was high during monsoon in both size groups (Table 9). Values ranged from 22.2 to 29.2% in smaller size group and in larger size group it was between 21.5 and 24.0%. A decline in the meat weight was noticed during post-monsoon peirod when the percentage values ranged from 18.5 to 28.4% in smaller size group and 18.6 to 24.8%in larger size group. During pre-monsoon period, again there was a decline in the dry meat weight percentage showing a range of 2.9 to 4.5% in the lower size group and 3.2 to 4.5% in larger size group with the minimum observed in November and June respectively for smaller and large size groups.

Moisture content showed marked variation in the entire period of observation (Fig. 15). It was lowest in the smaller size group during November (79.4%) and February (19.46%) and it ranged from 79.4 to 86.83% for the entire period of observation. The highest percentage of moisture content in smaller size group was observed during monsoon period (82.27 to 86.83%) and minimum during July. In larger size group water content ranged from 70.14 to 85.64% with the lowest value in February and highest in September. In general water content showed gradual increase through the pre-monsoon period and the maximum was observed during monsoon period in both the size groups. After the monsoon there was a gradual decline.

Protein content of the meat of P.malabarica showed seasonal change in both the size groups. Protein value of smaller size group ranged from 40.75 to 66.35% with lowest value in November and highest in February. In larger size group protein values ranged from 42.62 to 71.94%, the lowest in January and highest in March. The protein value was thus highest in pre-monsoon period in both the size groups and low during monsoon and post-monsoon months.

Carbohydrate or glycogen content also showed seasonal variation in both the size groups. In smaller size groups high values of carbohydrate were observed during monsoon increasing from 33.55 to 39.55% with a maximum value in August. The values declined in November, but showed an increasing trend from May onwards. The low values during post-monsoon and pre-monsoon period ranged from 9.22 to 36.22% in the smaller size group with highest in October and lowest in March. In larger size groups the high carbohydrate values ranged from 20.08 to 43.06% with highest in August; while during post-monsoon and pre-monsoon period the value ranged from 5.04 to 33.88%, the highest in January and lowest in March.

In small size-group lipid values were high during pre-monsoon period, ranging from 6.09 to 9.97% with highest value in April. Fat content decreased during monsoon and was lowest ranging from 0.92 to 6.41% with the minimum in August. From October onwards the values increased and it ranged from 3.55 to 5.33%. In the larger size group also high lipid content was observed in pre-monsoon period ranging from 8.17 to 12.36% with maximum in the month of April. During monsoon there was decline in the value ranging from 6.42 to 9.35%. During Post-monsoon period the lipid content was low for larger size group ranging from 1.99 to 5.77% with minimum observed in November.

Ash content was generally higher in this species compared to other species studied. In the smaller size group ash content was high during post-monsoon period ranging from 10.18 to 20.55% with maximum in November. In pre-monsoon period the ash content gradually decreased and in monsoon lower level of ash content was observed. It ranged from 7.49 to 17.89% with minimum noted in July. For larger size group also ash content was high during post-monsoon period ranging from 13.47 to 19.45% with maximum in January. The values gradually decreased and the lowest values were observed in monsoon months. Values ranged from 7.79 to 12.93% with the minimum in September.

Calculated calorific values were high during pre-monsoon and post-monsoon period. In smaller size group the value ranged from 4.46 to 5.25 K cal/g with the maximum noticed in July, whereas in post-monsoon period it ranged from 4.17 to 4.52 with minimum in November. In the larger size- groups also high values prevailed in pre-monsoon and post-monsoon period ranging from 4.78 to 5.43 with the highest in March. During post-monsoon period the values ranged from 4.21 to 4.72 with lowest during October.

DISCUSSION

Results of the present study revealed that the differences in the percentage of meat content, moisture content and biochemical composition between the two size-groups studied were not significant. However seasonal variation in moisture content and biochemical composition existed. In temperate and boreal regions, the annual seasonal changes in the environmental parameters, mainly light, temperature and availability of food influence the biochemical composition of bivalves (Ansell and Travellion, 1967; Ansell, 1972).

While such variations in the availability of food rather than other factors are responsible for the seasonal changes of biochemical composition in temperate climate, bivalves living in tropical condition do not show any seasonal cyclical change in food storage and utilization (Giese, 1969; Ansell et al 1974a). In tropical bivalves the reproductive cycles are responsible for variations in biochemical changes (Giese and Pearse, 1974). In the present study also variations in the biochemical composition were more pronounced in the larger maturing size groups; the smaller size groups did not show any significant variations. This seems to support the view expressed by Giese and Pearse (1974).

In penisular India, the southwest and northeast monsoons play an important role in shaping the environmental conditions. Apart from this overall influence, specific food or environmental factors do not vary significantly in many of the estuaries. The monsoon influences the gonadal development and spawning in most of the invertebrates (Paul, 1942).

Values of biochemical constituents of P.malabarica were found to be higher in larger size-groups than in smaller in the present observation. A similar trend has been reported for the gastropod Turbo sarmaticus by Mc Lachlan and and Lombard (1980). This is attributed to the process of gonad development taking place in larger individuals. Conversion of food for gonad development is reported to be effected by molluces in two ways. According Giese (1969) the animal obsorbs food and directly transports the biochemical constituents to the gonad for oocyte development as in Strongylocentrotus. In other mollluces like Pisaster, the food may be stored in a particular part of the body and transported to the gonad only when necessary. In the present study no attempt was made to find out the existence of any such storage site, since the main intention was to estimate the overall biochemical content as a nutritional index in different seasons for two size groups.

Fluctuations in the different biochemical components in the two size groups studied showed monthly variations. A inverse relationship between carbohydrate and protein values was observed with decrease in protein during the monsoon months and an increase in carbohydrates. In large size group water content was minimum during February and March. But lipid and protein values were high during these months. Ansell (1972) and Mc Lachlan and Lombard (1980) found that lipid and protein reserves are used by molluscs during stress condition in winter. In the present study the effect of temperature was not found to be significant. Low salinity during monsoon may act as a stress and this may be the reason for the low value of protein and lipid during this season. Moreover water content of both groups was high during monsoon months due to the low salinity prevalent is the estuary. Hence the stress due to the influx of cold river water seems to be the main factor responsible for variations in the protein, lipids and water content of *P.malabarica* in the Ashtamudi estuary.

In the present study calorific value of the clam was high during pre-monsoon periods, gradually declining through monsoon and post-monsoon. The seasonal cycle of energy storage and utilization in marine bivalves is generally attributed to the reproductive cycle. (Giese, 1969, Sastry, 1979). In general, energy is stored prior to gameogenesis, when food is abundant, in the form of lipid, protein and glycogen substrates and utilized in the production of gametes, when metabolic demand is high.

TABLE 15

Comparing differences among biochemical composition of <u>Paphia malabarica</u> with mean and standard deviation between smaller size group and larger size group

MOISTURE

Source	DF	SS	MS	F
A	1	22.44	22.44	3.1340
B	2	114.99	57.50	8.0307 **
AB	2	26.36	13.18	1.84
Error	18	128.83	7.16	

PROTEIN

Source	DF	SS	MS	F
A	1	141.83	143.83	3.58
B	2	1123.88	70.92	1.79
AB	2	36.18	18.09	0.46
Error	18	713.71	39.65	

CARBOHYDRATE

Source	DF	SS	MS	F
A	1	71.173	71.173	2.037
B	2	2149.454	1074.727	30.7609 **
AB	2	17.987	8.9935	0.2574
Error	18	628.883	34.9379	

LIPID

Source	DF	SS	MS	F
A	1	20.332	20.332	2.9021
B	2	124.2826	62.1413	8.8697 **
AB	2	8.2871	4.14355	0.5914
Error	18	126.1095	7.006	

ASH

Source	DF	SS	MS	F
A	1	17.2041	17.2042	2.9503
B	2	234.7783	117.3892	20.1312 **
AB	2	83.2834	41.6417	7.1412
Error	18	104.9618	5.8312	

CALORIFIC VALUE

Source	DF	SS	MS	F
A	1	0.4428	0.4428	9.0806 **
B	2	1.8437	0.921875	18.91 **
AB	2	0.15625	0.078125	1.6032
Error	18	104.9618	5.8312	

** Significant.

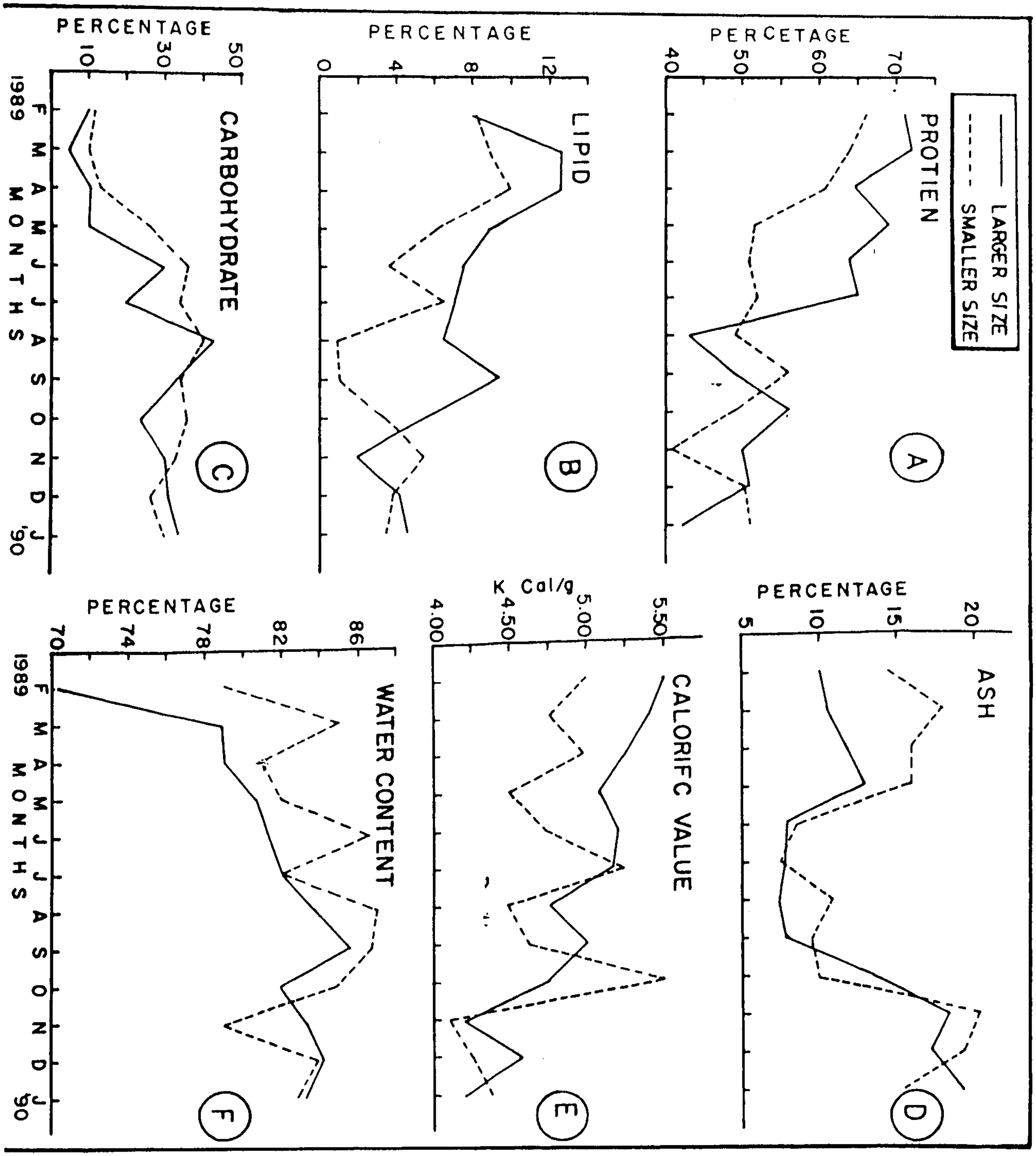


Fig. 15

Monthly variations in biochemical composition of Paphia malabarica from Ashtamudi estuary for smaller and larger size groups from February 1989 to 1990 January

A. Protein B. Lipid C. Carbohydrate
D. Ash E. Calorific value F. Water content

CHAPTER 6

FISHERY AND STOCK ASSESMENT OF *PAPHIA MALABARICA*

SECTION I. FISHERY

INTRODUCTION

Venerid clams are commercially exploited in most parts of the world and contribute the major share of clam landings in the world market. The world clam/cockle landings have been increasing steadily and the present total is 1.76 million tonnes (FAO, 1988). Currently the clam landing in major clam producing countries, *viz*, Japan, U.S.A and Europe, stand almost constant and thus it could be assumed that fishery from the natural bed alone cannot meet the increasing demand. It is suggested that suitiable farming practices are to be stimulated to augment production, mainly in South west Asian countries by Semi-culture like relaying method of clams and cockles. The international trade on clams has reached 300 million US dollar level in 1988, mainly countributed by catches from Europe and North America. In India venerid clams are being exploited from marine, estuarine and fresh water habitats from time immemorial. Of late there is organised attempt for an increased production through intensive fishing, fishing in new areas and also by adopting suitable farming techniques.

The important works on clam fishery of India are those of Alagarswami and Narasimham (1973), Rasalam and Sebastian (1976), Rao (1984), Rao and Rao (1983). Appukuttan _et al_ (1985, 1988), Joseph _et al_ (1987) and Rao _et al_ (1989). Appukuttan _et al_ (op. cit) have described the _Katelysia opima_ fishery and the clam fishery of Ashtamudi.

The clam fishery in India, especially along the west-coast, is age-old and considered as a source of protein-rich food for coastal population. Besides the shell formed raw material for lime production. The important species of clams that are being exploited from India on sustenance or higher levels are _Villorita cyprinoides_, _Meretrix meretrix_, _M.casta_, _Paphia malabarica_, _Katelysia opima_, _Donax cuneatus_, _Mesodesma_ sp, _Sunetta scripta_, and _Anadra granosa_. Among these _P.malabarica_ is exploited on commercial basis in recent years from Ashtamudi estuary, mainly for clam meat export. This clam alone contributes 80-90% of clam meat export from India for the last 10 years (1981-1990). The present study on the characteristics of fishery of _P.malabarica_ is thus essential for the judicious exploitation as well as for the conservation of this resource.

Ashtamudi estuary, boardered by Neendakara and Dalavapuram on the north, Sakthikulangara and adjoining islands in the south and South Chavara in the east has an area of 31 sq.km (Fig. 3), with 15.55 hectare Paphia bed extending from the barmouth upto 3-4 km upstream. The bed is exploited throughout the year with a break in monsoon months, when weather conditions are not favourable for fishing or when the demand for clam meat export decreases considerably.

MATERIALS AND METHODS

The data on the commercial landings of P.malabarica were collected from February 1989 to January, 1990 from landing centres around Ashtamudi estuary by regular weekly visits, in the fore noon when the fishing activity is at its peak. The total catch, number of units operated each day and number of fishermen engaged in each type of fishing were collected and the total catch and effort for each type of fishing unit computed for each month separately.

The duration of fishing activity was found to be uniform throughout the year for all the four units in operation ranging from 3 to 4 hours a day. Since hand dredge brought in high landings with minimum effort and since the maximum number of these units were in operation every day, this unit was considered as standard effort and efforts of other units were standardised accordingly and the total effort so derived was used to calculate the total landings for one year. Random samples of commercial catches taken fortnightly were used to observe length group composition, weight and number of clams in each size groups in the landings. From the estimated age, the age group composition of clams was calculated. The estimation of total stock of clams in the fishing area was arrived at by sampling five sub-station of two stations by random quadrate sampling method. Biomonthly samples were taken for the whole year. Station I near barmouth had an estimated total area of 50,500 sq.mt. and Station II, 105000 sq.m. Total average weight of clam in unit area in each sub-station were pooled together and average for whole area was taken in estimating the total stock.

RESULTS

FISHING METHODS

Four methods of clam collection prevail in Ashtamudi estuary. They are 1) Hand dredge operated from a dugout canoes 2) Two divers collecting from a canoe 3) Canoe with one diver and 4) Hand picking. First three methods of collections are done is deeper waters and the last method in shallow waters mainly by womenfolk and boys.

Clam Fishing

B.

Hand dredge operated from a canoe

A.

Hand dredge

Hand dredge operated from dugout canoes

This method of clam collection has been in practice in recent years, when the demand for P.malabarica increased and this method gave better yield. The hand dredge (Plate II, Fig. B) consists of a rectangular iron frame of 40-60 cm length and 25-30 cm width with number of iron spikes of 4-6 cm fixed along the base of the frame, pointed downwards or sharp metal plate in the base. In the upper middle part of the frame, an iron plate of 20 to 25 cm length and 3-4 cm width is revetted firmly to which long handles of 3 to 4 meter length is tied with nylon rope. Galvanised iron pipes, casuarina poles, teakwood poles and bamboo poles are often used as handles. A conical bag net of 20 to 25 mesh size with a length of 1 to 1.5 m and maximum width of 0.6 m, is tied to the iron frame for collecting dredged clams. Two thick nylon ropes are tied to the corners of the frame in the base portion and another long rope to the cod end of the bag net. Hand dredge is operated from the canoe (Plate II, Fig. A) with two persons in the canoe, one pushing the two handles and so keeping the dredge at the bottom, and the other person standing at the extreme end of the canoe, dragging the net using the foot ropes making the spiked dredge plouogh through the bottom. The bag is occasionally lifted to remove the mud and sand and also the smaller clams which can pass through the meshes. Once the bag is full with clams, it is lifted up washed thoroughly and unloaded to the canoe. This process is repeated several times for 3-4 hours a day and the average catch per day varies from 100 to 260 Kg. The number of units per day varied from 15 to 70.

Two divers collecting from a canoe

This method of collection was practiced in Ashtamudi from very early days, where two divers in turn dive and collect the clams from bottom by scooping the sediments using a sharp metal plate or with the help of his foot. The collected clams are stored in the net bag tied around their waists and once the divers reach the surface, they wash the contents of the bag to remove sediment and juvenile clams and empty the clam in to the canoe. The net bag used has 25 mm - mesh size so that most clams above 20-25 mm are retained in the bag. The operation lasts for 3-4 hours a day, when there is favourable tide.

Canoe with one diver

This method of clam picking was in practice from the very inception of Paphia fishery in Ashtamudi. After anchoring the canoe with nylon rope to an iron anchor or heavy granite blocks, the fisherman dive to the bottom and collect clams by scooping the sediment with the help of his foot or a sharp metal plate and deposit the clams in

Clam Fishing

A. Canoe with one diver

B. Hand picking

the net bag tied around his waist (Plate III, Fig. A). The operation lasts for 3 to 4 hours depending on the tide.

Hand Picking

Women folk and children collect clams from shallow waters by scooping the mud of the clam bed and picking out the clams and storing them in floating around aluminium vessels (Plate III, Fig. B). This method usually lasts for 3 to 4 hours depending on the underwater current.

Analysis of one year's catch data revealed that canoes with hand dredge contribute the maximum quantity of clams every month and the total for the year was 1475.8 t with maximum of 228.8 t in May and minimum of 23.8 t in December. Canoes with two divers ranked second contributing a total of 1078.6 t, canoes with one diver, 375.5 t and hand picking by individuals amounted to 110.8 t for the whole year (Table 16). After standardising the catches, taking canoe hand dredge as the standard unit, the annual exploited stock of P.malabarica was estimated as 3040.8 t. The total number of clams was estimated as 302.3 million in 22-51 mm size range. The catch data and estimated exploited stock show that maximum catch both in weight and numbers was in March, 465 t and 50.2 million respectively. Minimum catch was observed in December in all types of units, 61.5 t numbering 6 million clams (Fig. 16B). Maximum catch per effort was noticed in June and minimum in December (Table 17). Analysis of size group composition of clams in the commercial catches indicate that maximum number and weight are contributed by 34 to 36 mm size group, with 80.2 million and 820 tonnes respectively, followed by 28 to 30 mm size group. The minimum number and weight observed was in 49 to 51 mm group. In 34-36 mm size group maximum numbers of 13.4 million with 140.3 t landing was observed in April 1989 and minimum of 1.0 million with 85.7 t in February. The size of first entry of this clam in commercial catch was 22 mm and maximum size 51mm. (Table 18, Fig. 16A). The commerical catch was mainly composed of Ist year class and 0-year class followed by 2nd year class and +3 year class. Ist year class contributed 1979 t with 192.6 million clams, 0-year class 860.6 t and 88.3 million, 2nd year class 147.1 t and 14.8 million and +3 year class. 54.3 t and 5.0 million clams. The Ist year class landing was at its peak form April to June with maximum in April contributing 359.8 t. The lowest was recorded in December with 45.8 t. For 0-year class maximum landing was in March with 260.6 t and 2nd-year class gave maximum landing in June with 17.7 t and +3-year class contributed maximum landing in May with 22.9 t and 1.9 million numbers. The percentage composition of one-year class varied from 34.3 to 88.1% with maximum in November and minimum in March, 0-year class with 2 to 56.1, maximum in March and minimum in

December, two-year class ranged from 2.5 t 17.3%, minimum in September and maximum in December and +3 - year class having 1.6 to 6.1% with minimum in February and maximum in December (Table 14). The estimated total catch for the total area of 15.55 hectere was calculated as 11367.05 t for 1989-90 by taking the average production per sq.m. as 7.31 kg. The total average weight for the two stations for different months were taken for unit area by transect method and this indicates that in most of the months station II showed higher average weight ranging from 4.3 to 11.7 kg with minimum in August and maximum in March. Station I had a minimum of 3.1 kg in November and maximum of 10.79 kg in May. The pooled average ranged from 3.86 Kg to 10.01 with minimum in August and maximum in May. The pooled average for 12 months period was thus 7.1 kg/Sq.m (Table 19).

PROCESSING AND MARKETING

The day's catches are brought to the sheds adjoining the estuary by noon by the fishermen for purification and shucking. The clams after cleaning are kept in concrete purification tanks with clean well water or water drawn from the estuary for 10-16 hours, the water being changed once or twice. For easy shucking clams in batches are put in boiling fresh-water for 10-15 minutes and then stocked in baskets. The shucked meat is graded and washed in

Clam meat processing

A. Shucked meat of *Paphia malabarica*

B. Washing the meat in chilled water

Clam meat processing

A. Grading the meat

B. Packing 2.2 kg of meat each in polythene covers

<u>*Clam meat processing*</u>

A. Individual packets taken to freezer

B. Master carton with 20 packets of clams chlorinated water and kept in containers with ice blocks before transportation to freezing plants (Plate IV, Fig. A). As soon as the shucked meat reaches the processing plant, the meat is thoroughly washed in chilled water (Plate IV, Fig. B). Using an electric blower mud and sand particles adhering to the meat are removed. Meat is again washed in chilled water and taken to grading table (Plate V, Fig. A). The commercial grades of clams are U/300, 300/500, 500/700, 700/1000 and 1000/1500 per kg. The graded meat is packed in polythene covers, 2.2 kg per packet (Plate V, Fig. B). These packets are kept in trays for 3.4 hours at -20°C (Plate VI, Fig. A). The frozen clams are then packed in duplex cartons and 20 such slabs together form a master carton for export (Plate VI, Fig. B) Table 20 shows the monthly export figures of clam meat from India in 1988 and 1989. Though the value has increased slightly, there was a decline in the total meat export in 1989. Table 20 also gives the country-wise export and Japan is the main consumer of Indian clam meat. 80-90% of the clam meat exported from India is contributed by P.malabarica from Ashtamudi at present. The discarded shells of Paphia amounts to 2500 to 3000 t every year and this is often taken to Tamilnadu for use as raw material for carbide industry.

DISCUSSION

The details on *P.malabarica* fishery indicates that the hand-dredge operated from the canoe by two fishermen give maximum yield with less effort, since the diving by the fishermen to scoop the bottom is eliminated in this process. As the demands for clams increased, the local fishermen developed this easy method of clam collection and the mesh size of the bag of the dredge was always kept at 20-25 mm and hence the chance of exploitation of undersized clam was also eliminated. The three other methods involve comparatively more effort and lesser yield. Another advantage for the hand-dredge operation is that, it could be operated throughout the year, whereas diving and hands picking could be done only during post-monsoon and pre-monsoon months when water is clear and without strong under-water current. Considering all these aspects hand dredge unit was taken as standard gear in estimating the total exploited stock.

Large-scale exploitation of clams from Ashtamudi estuary was initiated in 1981 and in subsequent years the catches increased until 1988 the total meat export Figure of 311.1 t. In 1989 the quantity exported was 308.6 t showing a slight decline in the quantity. Though there is a self-imposed restriction on the collection of smaller clams from Ashtamudi, the increasing demand and intensive fishing can lead to over exploitation or indiscriminate fishing. At present there is no leasing system for clam beds in Ashtamudi. The chances of depletion of clam stock cannot be ruled out, unless conservation measures are taken up right from this stage.

The present world landing of *Paphia* spp is 98101 t (FAO, 1988), contributed mainly by Malaysia, Philippines and Thailand. India's contribution is insignificant, but it is felt that production can be increased by fishing in new areas and also by practicing relaying of seed clams to new suitable areas (*Semi- culture*). In Ashtamudi, a judicious exploitation coupled with *Semi-culture* practice can augment production in coming years. Ashtamudi estuary assumes greater importance in Indian clam export industry since *P.malabarica* exploited from this estuary alone contribute 80-90% of the present Indian clam export. It is also interesting to note that this 15.55 hectare area of clam bed has a production rate that could be compared with that under controlled farm conditions.

TABLE 16

Effort (Standard effort in paranthesis) and Catch per effort of <u>Paphia</u> <u>malabarica</u> in 4 types of fishing methods in Ashtamudi estuary

Months	CANOE WITH HAND DREDGE			CANOE WITH TWO DIVERS			CANOE WITH ONE DIVER			HAND PICKING		
	Catch-C in kg	Effort E	C/E	Catch-C in kg	Effort E	C/E	Catch-C in kg	Effort E	C/E	Catch-C in kg	Effort E	C/E
February 1989	86671	558	155.3	147264	981 (948)	150.1	37736	629 (243)	60.0	2301	77 (38)	29.9
March	188750	755	250	157000	785 (628)	200	96560	965 (483)	100	22375	360 (90)	62.2
April	141750	567	250	216300	1082 (864)	200	43365	620 (174)	70	19950	399 (80)	50
May	228800	962	238	127075	813 (533)	156	62888	719 (263)	87	13975	294 (62)	50
June	226850	858	264	89375	715 (339)	125	19500	260 (74)	75	13000	260 (49)	50
July	153065	908	169	102251	616 (605)	166	No catch	Nil	Nil	13161	225 (78)	58.5
August	84966	566	150	63308	633 (418)	100	53104	708 (354)	75	15872	258 (106)	61.5
September	115625	588	196.8	80000	800 (408)	100	21875	300 (111)	73	3750	75 (19)	50
October	121500	816	149.5	49375	400 (324)	121	32375	463 (217)	70	2500	50 (17)	50
November	104000	1040	100	21125	273 (210)	77	No catch	Nil	Nil	No catch	Nil	Nil
December	23875	135	176.9	25500	170 (144)	150	8125	105 (46)	77	400	80 (23)	50
January 1990	No catch	Nil	Nil	No catch	Nil	Nil	No catch	Nil	Nil	No catch	Nil	Nil
Annual	1475852	7721	2001.5	1078573	7268 (5421)	1545.1	375528	4769 (1965)	687	110884	2078 (562)	512.1
Monthly	134168	702	182	98052	661 (493)	140.5	41725	529 (218)	76	11088	208 (56)	51.2

TABLE 17

Total catch, effort, catch per effort and total number of *Paphia malabarica* in the commercial catches from February 1989 to January 1990

MONTHS	TOTAL CATCH In kg C	STANDARD EFFORT E	CATCH PER EFFORT-C/E	TOTAL NOS.
February 1989	273992	1787	153.3	33417264
March	464685	1956	237.6	50185980
April	421365	1682	250.5	35817895
May	432738	1820	237.8	37215468
June	348725	1320	264.0	33128875
July	268477	1591	169.0	25373885
August	217190	1444	150.4	28190634
September	221250	1123	197.9	17257500
October	205750	1374	150.0	21809560
November	125125	1250	100.0	13888875
December	61500	348	117.0	6027000
January '90	---	No Exploitation		--
Total	3040797	15695	2027.5	302.3 million
Average for the year	276436	1427	184.3	

TABLE 18

Number and weight of of clams in different size groups of *Paphia malabarica* in the Commercial Catches of Ashtamudi estuary From February 1989 to January 1990.

Size Groups	22-24 mm		25-27 mm		28-30 mm		31-33 mm		34-36 mm		37-39 mm		40-42 mm		43-45 mm		46-48 mm		49-51 mm	
Months	Nos.	Wt.	Nos.	Wt.	Nos.	Wt.	Nos.	Wt.	Nos.	Wt.	Nos.	Wt.	Nos.	Wt.	Nos.	Wt.	Nos.	Wt.	Nos.	Wt.
February '89	-	-	534848	4384	11030674	90417	4913916	40277	10395864	85769	4913794	40277	1093120	8960	534848	4384	-	-	-	-
March	1355021	12547	2760229	25558	24039085	222584	2760229	25558	5520458	51115	8933104	82714	4817854	44610	-	-	-	-	-	-
April	-	-	-	-	2972960	34973	11927795	140315	13430935	158012	5229925	61519	1504415	17697	752165	8849	-	-	-	-
May	-	-	3423532	39812	6363828	73996	4912406	57121	9787660	113810	9787660	113810	967586	11251	483836	5626	1488660	17309	-	-
June	-	-	1027045	10810	3975465	41847	12887130	135654	7288305	76720	6261355	65909	1689575	17785	-	-	-	-	-	-
July	535605	5101	2086035	19867	9922920	94503	3129105	29801	7808640	74368	3129155	29801	1043070	9935	535605	5101	-	-	-	-
August	-	-	1083324	9339	5441908	46913	5441908	46913	8238436	71022	3476752	29972	1083324	9339	428272	3692	-	-	-	-
September	-	-	1311572	16815	431418	5531	1760304	22568	6764940	86730	6126432	78544	431418	5531	431418	5531	-	-	-	-
October	-	-	-	-	9879730	93205	5757708	54318	3489520	32920	1853834	17489	828708	7818	-	-	-	-	-	-
November	-	-	-	-	1249971	11261	4249968	37538	6388938	57808	1625040	14890	374958	3628	-	-	-	-	-	-
December	-	-	-	-	120540	1230	2278206	23247	1169238	11931	1042720	10640	1042720	10640	-	-	186788	1906	186788	1906
January '90	No-catch																			
Total	1478337	17648	12226883	126585	75423697	716562	60018675	613310	80282934	820205	52379471	545565	14876748	147104	3168144	33181	1675448	19215	186785	1906

TABLE 19

Estimated total weight of Paphia malabarica per sq.m area in Kg by random sampling from February 1989 to January 1990 from Ashtamudi Estuary

Months	Ist Station	IInd Station	Average
February 1989	6.799	5.999	6.399
March	6.470	11.730	9.100
April	8.266	9.780	9.020
May	10.790	9.240	10.010
June	7.750	7.661	7.710
July	4.058	5.872	4.970
August	3.344	4.368	3.860
September	8.861	9.999	9.430
October	9.021	7.822	8.420
November	3.111	9.643	6.377
December	5.556	7.990	6.773
January 1990	5.330	6.088	5.709
Average Production per Sq.m.			7.31
Total clam bed area	50,500 sq.m.	10,5000 sq.m.	
Estimated total stock			1136.705t

TABLE 20

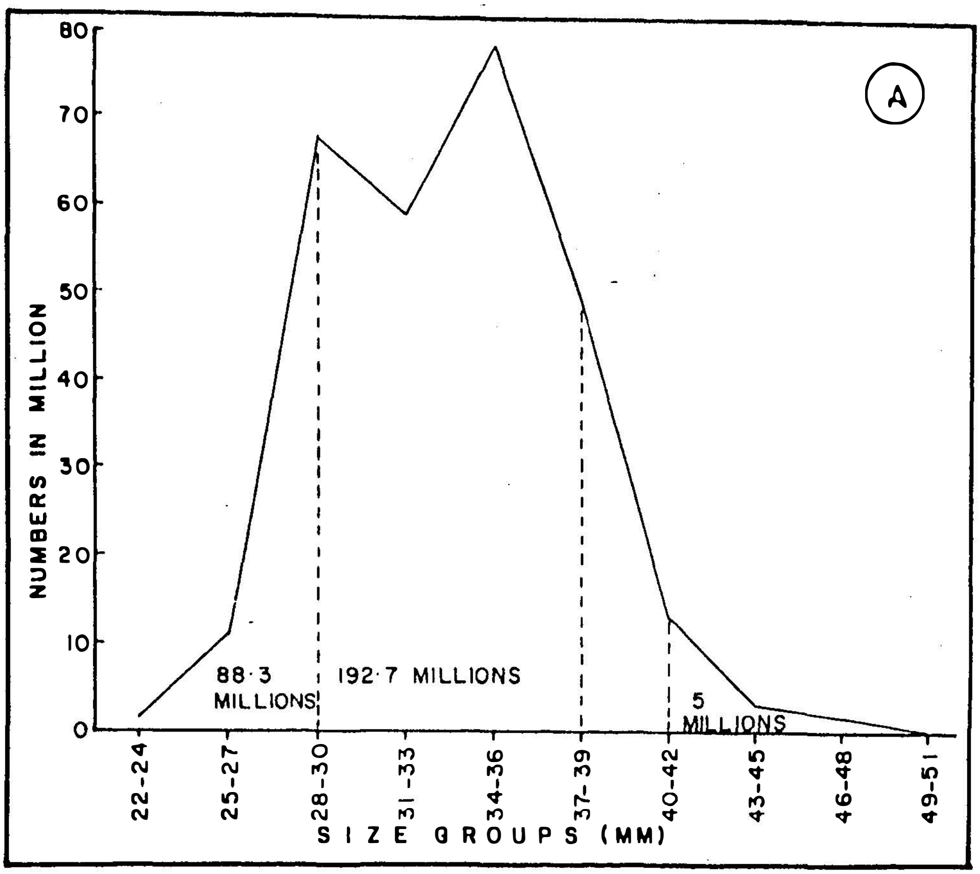
Month-wise Frozen clams export from India

Months	Year 1988 in kg	1989 in kg
January	7140	40000
February	----	23680
March	42620	47840
April	43980	43920
May	41740	48880
June	30168	18960
July	26260	44556
August	-----	14660
September	20000	19440
October	18920	3780
November	40260	2960
December	40380	-----
Total	311468	308676
Total value in Rs.	4386685/-	4903521/-

Country-wise Export of Frozen clam from India

Country	1988	1989
Singapore	19980	-
France	20220	53776
Fed.Rep. Germany	--	20000
Japan	142529	138840
USA	3000	
Belgium	125740	96060
Total	311468	308676

Source : Statistics of Marine Products Export. MPEDA.



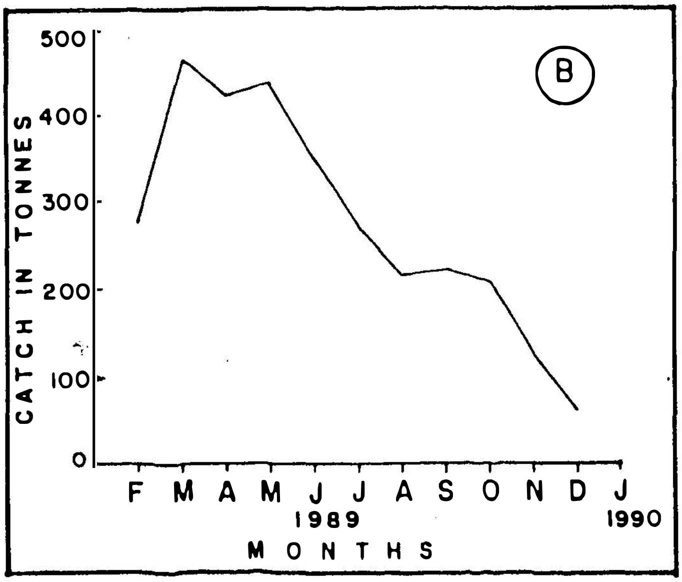


Fig. 16

A. Catch in numbers for different size groups of Paphia malabarica

B. Total catch of Paphia malabarica in different months.

SECTION II. STOCK ASSESSMENT

INTRODUCTION

The need to develop appropriate management strategies for exploitation of this species is felt necessary since this clam alone contribute to 80-90% of total clam meat export from India and is being exploited continuously from Ashtamudi estuary. Being a sedentary animal, clams are extremely vulnarable to over-exploitation. As the demand for clam meat for export is increasing day by day, the tendency for indiscriminate fishing is also a possibility which can ultimately lead to depletion of the clam population of this area. Hence it was felt that a study of the fishery and stock assesment of this species is necessary to suggest effective measures for maximum exploitation and also proper conservation of the resource. In the present study, stock assesment, mortality rates and maximum sustainable yield from the stock of P.malabarica from Ashtamudi estuary were estimated using standard statistical models. Except for the works of Narasimham (1988), on blood clam Anadara rhombea from Kakinada Bay, there is no other work on the population dynamics on Indian clams. Caddy (1989) while studying the population dynamics of scallop fishery, reviewed current developments and future possibilities of research on dynamics of molluscan population and suggested that the well known yield-per-recruit model of Beverton and Holt (1957) could be used in assessing the likely effect of different size limits and fishing intensities on fishery. It is assumed that a self replenishing population of clams have the advantage of free-swimming larval life of approximately one to two months, permitting a uniform dispersal and settlement in the fishing area. Considering these factors, in the present study, the stock assesment models used for population dynamics were applied in arriving at basic stock assesment parameters.

MATERIALS AND METHODS

$L\infty$, K and t_0 estimated in the Section IV on Age and Growth were used for the estimates of stock. $W\infty$ was estimated from the $L\infty$ value using the length-weight relationship.

$W = 0.1975\ L^{3.0682}$ was obtained in the Section III of chapter 5 on Length-weight relationship and Dimensional variations. The value of length-weight relationship of clams collected from Station II was taken for the present study since the maximum exploitation is being done from this station throughtout the year. Z was estimated by catch-curve method (Pauly, 1984) by sampling the multi-aged population of P.malabarica, then plotting the natural logarithm (log e) of the clam in each length group (N) against the respective age 't' or

$$\log e \quad N = a + bt$$

where the value of 'b' with sign changed provide the estimates of Z (Pauly, 1984). To avoid 'piling-up' effect of more age groups when converting length frequency samples to catch curve, the equation can be rewritten as:

$$\log e \ (N/\ t) = a + bt$$

where 't' is the time needed for growth from the lower (t_1) to the upper (t_2) limit of the given class, while t is the relative age corresponding to the mid-range of length class in question. The procedure to convert a length frequency to length structured catch curve is shown in Fig.17 and estimates of 'a' and 'b' are given in Table 21.

Lower size groups are not represented in the commercially exploited stock since smaller clams are not caught for export and hence Z was not calculated for smaller size group. The decending limb of the catch curve which represent the decrease in the population from the size of peak recruitment is used in estimating Z.

Usual method of estimation of natural mortality cannot be used in the present study because of limitation of data and hence the method followed by Gabral-Llana (1988) from Del Norte (1986) was used. According to them the M/K value for bivalve is 1.4 and hence in the present study M was estimated based on this assumption.

Yield-per-recruit studies were made using the formula of Beverten and Holt (1957) simplified by Ricker (1958) as used by Yohannan (1982) in population dynamics of Indian mackerel.

$$Yw/R = Fe^{-(M(tp' - tP))} W\infty \left[\frac{I}{F+M} - \frac{3e^{-K(t_{p'}-t_0)}}{F+M+K} + \frac{3e^{-2K(t_{p'}-t_0)}}{F+M+2K} - \frac{e^{-3K(t_{'p}-t_0)}}{F+M+3K} \right]$$

where Yw/R = yield per recruit, F and M the instantaneous rates of fishing and natural mortality, K, t_0 and W are the parameters in the von Bertalanffy growth equation. t_p or t_r = the age at recruitment and t_p' or t_c = age at first capture. Exploitation ratio E = F/Z and average standing stock is estimated by Y/F. The exploitation rate U is estimated using the formula:

$$U = \frac{F}{F+M} (1 - e^{-(F+M)}) \text{ (Ricker, 1958)}$$

where F is the fishing mortality and M natural mortality.

Total annual stock was estimated by the equation Y/U where Y is the annual yield.

Annual average standing stock was estimated by the formula Y/F. Maximum sustainable yield (MSY) from the stock was estimated by the equation:

$$MSY = R\,e \quad y/RF \;\; max$$

where Y/RF max is the yield per recruit at F max and Re is the recruit estimated by this equation.

$$\frac{Y}{y/\ R\ PF}$$

where y/ R PF is the yield per recruit at present F.

RESULTS AND DISCUSSION

Mortality

Total mortality Z was estimated separately for samples from commercial catches and transect samples. Both gave more or less identical results. Estimate from commercial catch was 2.26 and transect samples gave a value of 1.96 (Fig.17). Hence the average value of Z(2.11) was taken. M was estimated as 1.17 (1.4 x 0.8389). Substracting M vale from Z the value of F was 0.94.

Age at recruitment (t_r) and age at first capture (t_c)

The minimum size of P.malabarica in commercial catch was 22mm, the corresponding age was calculated as 0.5522, which was taken as t_r and the maximum numbers in the catch were of the size 29.5mm, the corresponding age being 0.955 which was taken as t_c.

Yield per recruit

Yield per recruit estimates were made using the following parameters:

$$W_\infty = 19.17$$
$$K = 0.8389$$
$$t_0 = -0.3452$$
$$t_c = 0.9550$$
$$t_r = 0.5522$$
$$M = 1.17$$

The estimates were made for different values of F for the present t_c value and t_c value of 1.2 and 1.6. The results are given in Fig.18. Under the present t_c the maximum yield is obtained at an F value of 2 which means, we have to double the present F to reach maximum sustainable yield (MSY).

Maximum sustainable yield (MSY)

MSY estimated at F max (2) from the present annual catch (Y) of 3040.8t at an F value of 0.94 is 3406.8t indicating an increase of 366.0 t (12%) of the present catch by doubling the present F. Hence, the gain will not be considerably high. To commensurate with the effort we put in, CPUE will decrease considerably. The present state of the fishery can be considered economically ideal.

For t_c value of 1.2 and 1.6 the F were beyond 5, Hence the increase in yield beyond an F value of 2 is negligible. If the age at first capture can be fixed before 2 years, the present fishing intensity can be increased without much reduction in catch per effort. At present the hand dredges for fishing of clams are so designed that the nets will retain only clams above 20-25mm length but if the mesh size is increased further, clams above 30mm (2-year class) can be collected in more numbers by increasing the fishing effort. It is important to note that for export of clam meat, the demand is always for higher size groups fetching better price and thus increase in the catches of higher size groups by mesh size regulation is advisable for P.malabarica fishery at Ashtamudi estuary at present. Another noteworthy observation is that the present fishing is not adversly affecting the stock and even doubling of the present fishing intensity will not cause over-exploitation.

Stock of P.malabarica

The stock estimated for P.malabarica in the present area of fishing are given below:

Exploitation rate	(U)	=	0.3915
Total annual catch	(y)	=	3040.80 t
Estimated total annual Catch	(y/U)	=	7767 t
Annual average standing stock	$\frac{(Y)}{F}$	=	3234.9 t
MSY		=	3406.8 t.

In the present study, one year data is used to estimate the basic characteristics of population dynamics of *P.malabarica* from Ashtamudi estuary. Continuous monitoring of the stock of the clam from estuaries are necessary for formulating effective fishery management policies for rational exploitation without depletion. However the results of the present study will be of immense help in initiating further research works on stock estimation of this commercially important species of bivalve from India.

TABLE 21

Data for the construction of catch curve in Fig.17 for *Paphia malabarica* from Ashtamudi estuary using samples from commercial catch

Class limits lower - upper	Mid Range	N	$t\frac{3/}{1}$	$t\frac{3/}{2}$	Δt	$\log_e \frac{N}{\Delta t}$	Mean relative age t3/	Mean relative age t3/-to
4.0 - 6.999	5.5	2	0.1124	0.2044	0.0914	3.0851	0.1575	-0.1877
7.0 - 9.999	8.5	46	0.2043	0.3039	0.0996	6.1352	0.2531	-0.0921
10.0 - 12.999	11.5	93	0.3039	0.4126	0.1087	6.7518	0.3570	0.0118
13.0 - 15.999	14.5	147	0.4126	0.5322	0.1196	7.1141	0.4709	0.1257
16.0 - 18.999	17.5	200	0.5322	0.6657	0.1329	7.3165	0.5968	0.2516
19.0 - 21.999	20.5	313	0.6652	0.8148	0.1496	7.6461	0.7377	0.3925
22.0 - 24.999	23.5	470	0.8148	0.9860	0.1712	7.9177	0.8974	0.5522
25.0 - 27.999	26.5	583	0.9860	1.1860	0.2000	7.9776	1.0818	0.7366
28.0 - 30.999	29.5	592	1.1860	1.4263	0.2403	7.8094	1.3002	0.9550
31.0 - 33.999	32.5	402	1.4264	1.7278	0.3014	7.1958	1.5671	1.2225
34.0 - 36.999	35.5	342	1.7279	2.1322	0.4043	6.7411	1.9130	1.5678
37.0 - 39.999	38.5	221	2.1324	2.7490	0.6166	5.8817	2.4013	2.0561
40.0 - 42.999	41.5	70	2.7492	4.0985	1.3493	3.9489	3.2426	2.8974
43.0 - 45.999	44.5	11	4.0985	-	-	-	-	-

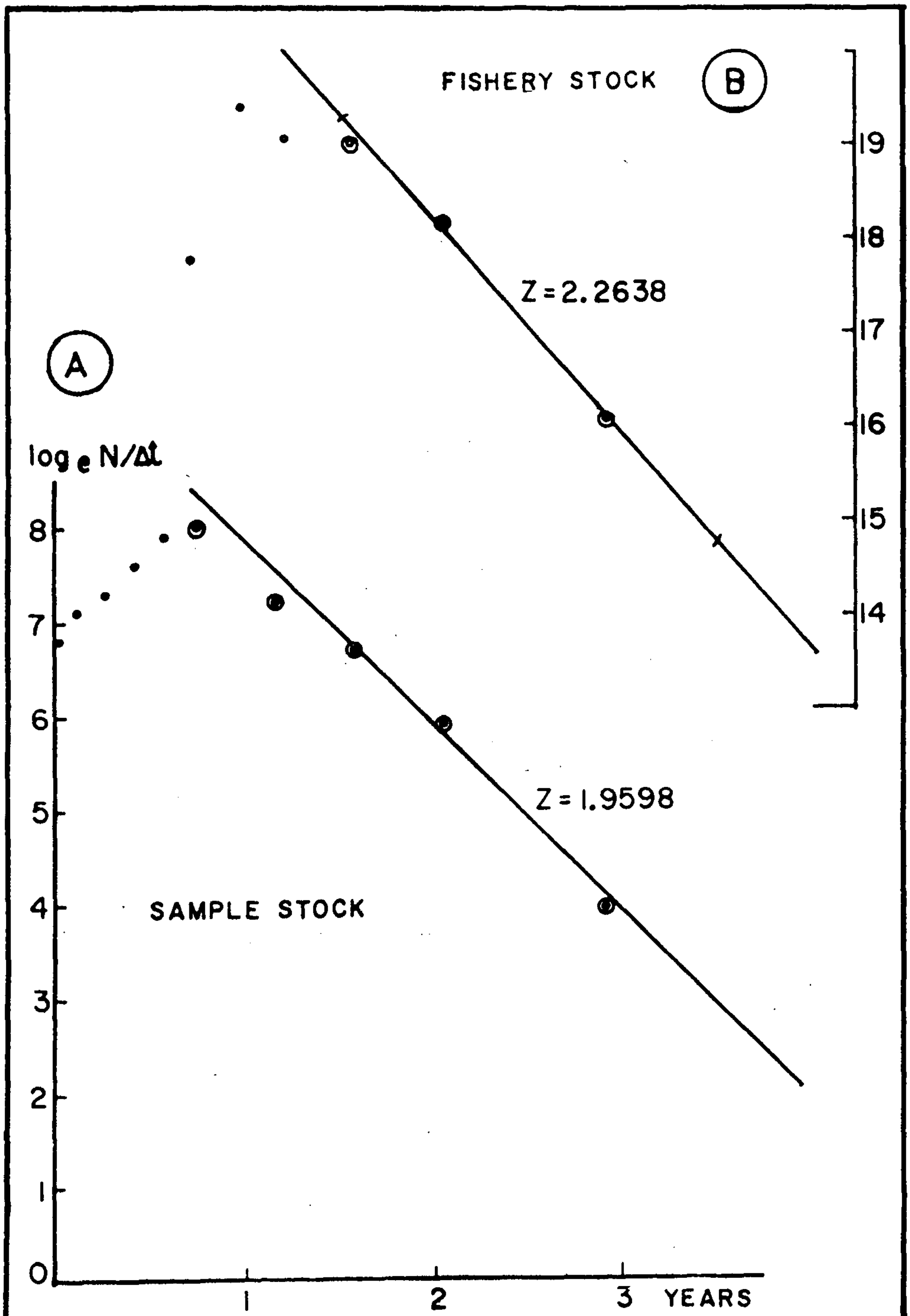


Fig. 17

A. Length structured catch curve of <u>Paphia</u> <u>malabarica</u> for sample stock

B. Length structured catch curve of <u>Paphia</u> <u>malabarica</u> for fishery stock.

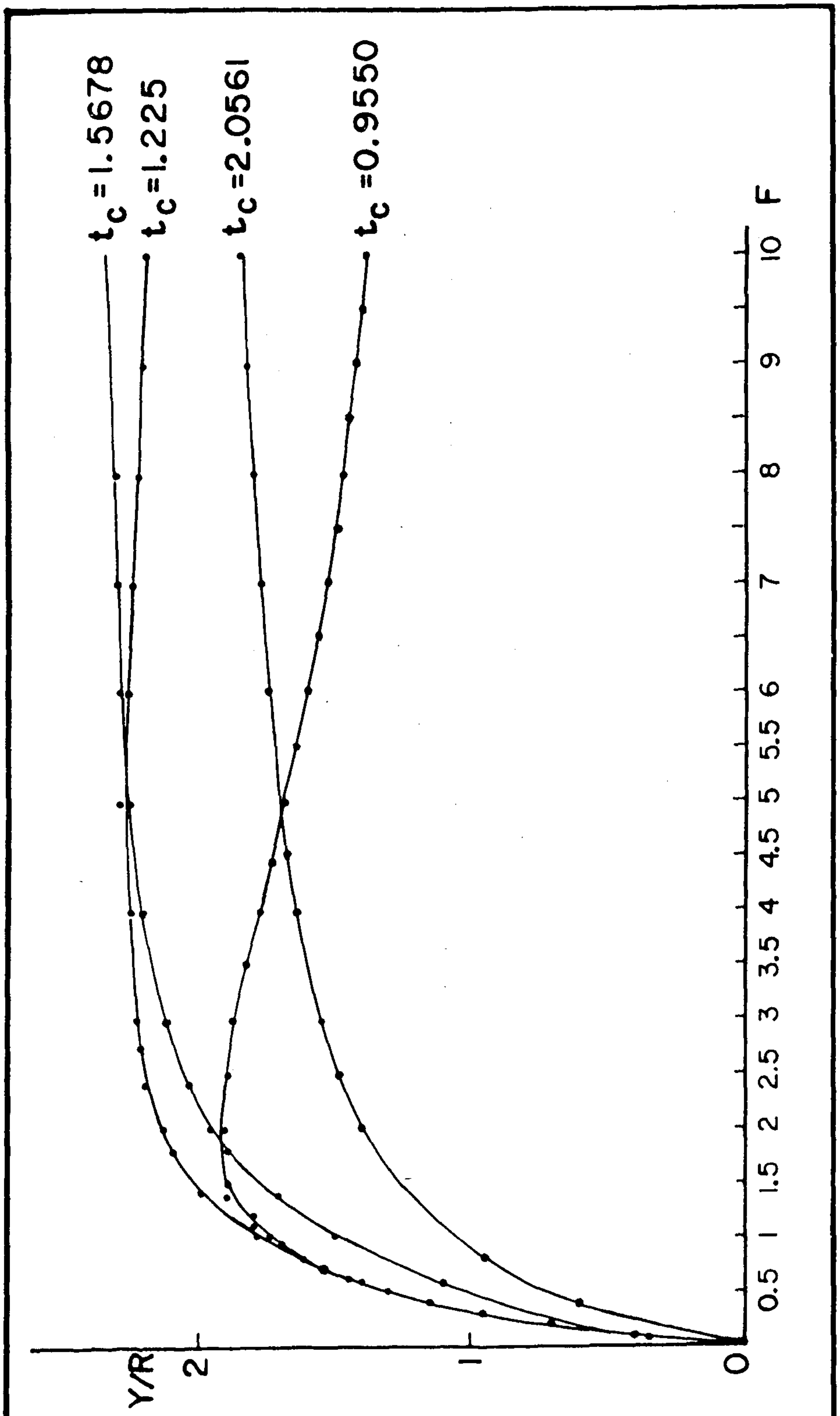


Fig. 18 Yield per recruit (Y/R) of <u>Paphia malabarica</u> from Astamudi estuary.

SUMMARY

The present study deals with systematic position, ecobiology, biochemical composition, fishery and stock assesment of Paphia malabarica, a commercially exploited bivalve belonging to family veneridae from Ashtamudi estuary, southwest coast of India. In recent years the demand for clam meat is increasing steadily both for internal consumption as well as for export. Though India's contribution towards world clam meat market is insignificant, it is quite interesting to note that 80-90% of the clam meat exported from India is collected from Ashtamudi estuary, wholly countributed by P.malabarica. There is no comprehensive information so far on the ecobiology, fishery and stock assesment of this species from Indian waters and the present study is the first detailed investigation on its biology and fishery. The results of the present study will help fishery biologists and management experts to evaluate and formulate future strategies for judicious exploitation of this clam and to impose conservation measures. The present investigations have been based on the regular samples collected from Ashtamudi estuary from January 1989 to January 1990 and also fishery data collected from landing centres in the Ashtamudi estuary.

A brief introduction with a review of literature on research works so far done on venerid clams from Indian waters is given and indicate that the available information even on basic biological characterstic of clam is not adequate to evolve proper fishery management policies.

The systematic position of P.malabarica has been reviewed and the important taxonomic features of superfamily Veneracea, family Veneridae and genus Paphia with special reference to and Paphia malabarica and its synonyms are given. Out of the 15 species of Paphia recorded, only 5 are reported so far from India. Pahia laterisulca, often referred in Indian literature does not come under genus Paphia. Distribution of P.malabarica along Indian coast in also given.

Ecological observations were made for a period of 12 months from 3 stations. Station I is close to barmouth, Station II 2km upstream and Station III 2km further upstream. Twelve months observations are grouped into pre-monsoon (February - May), monsoon (June - September) and post-monsoon (October - January). The ecological studies indicate that various ecological parameters of the clam bed show temporal and spatial variations. Environmental details such as water depth, light penetration, water temperature, salinity, dissolved O_2, pH and rainfall were collected. Nutrients viz., phosphate, silicate, nitrate and nitrite of these stations were also observed for the corresponding period for both surface and bottom water. Comparison of environmental features between stations have not shown marked variations, but variations between seasons was observed. Nutrients also do not show much variations except for high silicate value in Station II. Clam biomass was high in Station II, where medium salinity prevailed and coarse sand dominated the sediment. Organic carbon was high towards Station III, which is nearer to river zone, where maximum silt and clay was observed. Though spat fall of clams was found in this station, survival was negligible. By random sampling, density of clam in all the three stations was estimated for the study period. The present study reveal that dense juvenile settlement was observed in Station I, which is nearer to the barmouth, but better growth rate was observed in Station II. The important groups of animals associated with Paphia were polychaetes, bivalves, gastropods and crustaceans. Macro-alagae, Hypnea sp and Enteromorpha were also abundant is the clam bed.

Fortnightly samples of P. malabarica from Station I and Station II were collected for 1 year for studies on maturity, spawning and sex ratio. A totl of 1080 numbers of different sizes were examined to determine various development stages. The reproductive stages were broadly classified into indeterminate, sexually mature stages from I - IV and spent stage (Stage V). The reproductive cycle of P. malabarica showed that breeding season commence in October and lasts till January with peak spawning in October and November. The peak somatic period was February - April. In clams upto 13-14 mm no reproductive body was discernible, where as clam attain maturity at size from 15-20 mm. Sex ratio of samples indicated that 1:1 ratio of male to female was observed except in February and June 1989 and January 1990. Test of homogenity showed heterogenous nature of population. Important works on the spawning habits of clams of Indian waters were compared and three major types of spawning periodicity were identified. In P. malabarica spawning period was short with a single spawning in an year. The maturation period is correlated with the decline in salinity and temperature caused by monsoon. Present study shows that though number of factors induce spawning, salinity rather than temperature plays a vital role in reproductive activity.

Condition index of two size groups of P. malabarica for one year was studied. 600 clams of 22 - 45mm size were used for studies on condition index, wet meat weight and dry meat weight percentage. Condition index ranged from 32-58.25 with highest in January and lowest in February. Larger size group had higher condition index throughout the year. Wet meat weight percentage was higher in smaller size group. Peak condition index coincide with high gonadal activity and intense gametogenesis. The relation with condition index to salinity showed that the index changes along with the changes in salinity in smaller size group. During low salinity high condition index was observed. Condition index is high during pre-monsoon and monsoon period, when nutritive value, calorific value and percentage of edibility or meat weight percentage is high.

598 specimens of various lengths were examined for studies on length-weight relationship and dimentional variations of P.malabarica from Station I and II. Analysis of convarience and mean values of dependent parameters and growth rates were estimated. The length weight relationship of larger size group from Station II was $W = 0.1975\ L^{3.0682}$. Results of comparison of dimenstional variations showed that the rate of growth in all relationships, except length-width had significant differences. Growth rate was better in Station I except for wet meat weight, which was better in Station II. The precise causes of heterogenity of shell characters and

changes in the meat weight proportions from two stations are not clear. The closeness of station to the barmouth could be one of the reasons for better shell growth indicating significant dimensional variations.

Age and growth of P.malabarica was studied using samples collected from clam bed in the estuary from January to December, 1989. 3500 numbers of clams were used for age and growth studies by continuous sampling of population and analysing the size frequency distribution. The initial recruitment to the population is in the size range of 4-6 mm which was the product of earlier spawning. November was taken as the month of birth and the mode at 11 mm as the size at second month which shifted to 17 mm in February, 23 mm in May, 26 mm in August, 29 mm in November, 32mm in February and 35mm in next May. von Bertalanffy's growth equation of Lt= L $[1-e^{-k}(t-t_o)]$ was fitted to quarterly values of age-length data. $L\infty$ was estimated as 44.426. Menzor and Taylor plot for estimation of t_0 was used and t_0 was -1.3808. This work out to - 0.3452 on an annual basis. The estimated VBG equation for P.malabarica is as follows:

$$t = 44.426 \quad 1-e^{-0.8389\ (t\ -\ 0.3452)}$$

Based on this equation this species grows to 30.05 mm in 12 months, 38.21 mm in 24 months and 41.44mm in 36 months and the longivity or probable span of life at Ashtamudi is + 3 years. Growth rate for Ist six months was 1.32mm/month, next 6 months 1.25mm/month, next 6 months 0.85mm/month and in the subsequent 6 months 0.43mm/month. In the third year monthly growth rate was 0.26mm. One year class contributed the commercial landing followed by 0-year class, two year class and +3 year classes in the order of abundance.

Biochemical analysis of clams below 30mm and above 30mm were done separately and given as percentage of dry meat. Water content showed gradual increase through the pre-monsoon period with a maximum in monsoon. In post-monsoon there was a gradual decline. Protein value was high in pre-monsoon and low during monsoon and post-monsoon. Glycogen value also showed seasonal variation. Lipid showed peak values in pre-monsoon. Generally ash content was high for both the size groups in this species throughout the year compared with other bivalves. Calculated calorific value was high in pre-monsoon and post-monsoon periods. The values of moisture content, biochemical composition and calorific value between two size groups were not significant.

While observing the commercial catches of P.malabarica, details on total catch, number of units operated each day, number of fishermen engayed and total catch and effort for each unit, were computed for each month separately. Four methods of fishing for clam is in practice at Ashtamudi, of which hand dredge, operated from a dugout canoe, was taken as the standard gear, since this unit contribute maximum catch. The unit-wise landing, size group composition, year-class composition, number of clams in each size group contributing to fishery and catch per effort were calculated separately. The estimated total standing stock from 15.55 hectere clam bed was 11367.05t for 1989-90. The quantity of processed clam meat exported in 1989 was 308.6 t, mainly collected from Ashtamudi estuary, wholly contributed by P.malabarica.

For estimation of stock $L\infty$, K and t_0 derived from age and growth studies were used. $W\infty$ was estimated from $L\infty$ value using length-weight relationship. The method followed by Gabral-Llana (1988) from Del Norte (1986) was used in estimation of natural mortality. M/k value was taken as 1.4. Yield per recruit was estimated by using formula of Beverton and Holt (1957) simplified by Ricker (1958) as used by Yohannan (1982). The average value of total mortality Z was 2.11, M = 1.117, F = 0.94, W = 19.17, K = 0.8389, t_0 = -0.3452, t_c = 0.9550, t_r = 0.5522. Present study reveals that we have to double the present F to reach maximum sustainable yield (MSY). MSY estimated was

3404.8t indicating an increase of 366t (12%) of the present catch of 3040.80t by doubling the present F. Increase in yield beyond an F value of 2 is negligible. If the age at first capture can be fixed at 2 years, the present fishing intensity can be increased without much reduction in catch per effort. Present fishing is not adversely affecting the stock and even doubling of the present fishing intensity will not cause over-exploitation. Stock of P.malabarica was estimated as follows:

Exploitation rate (U)	=	0.3915
Total annual catch (Y)	=	3040.80t
Estimated total annual stock Y/U	=	7767t
Annual average standing stock $\frac{Y}{F}$	=	3234.9 t
MSY	=	3406.8t

Relevent tables, figures plates and references are also given in the text. An appendix with a list of publication and copies of two papers on studies on clam fishery of Ashtamudi estuary are also included.

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BABY CLAM (*KATELYSIA OPIMA*) FISHERY IN ASHTAMUDI BACKWATERS

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ABSTRACT

Katelysia opima known as baby clam is exploited from Ashtamudi Backwaters in large quantities. A study during 1982-83 showed that the annual landing is 5436.5 tonnes of this clam with a size range of 20-60 mm. 95% of the catch is utilized for export as frozen clam meat. A brief account on fishing method, fishery and utilization is given.

INTRODUCTION

SEVERAL species of clams found in the estuaries and backwaters of India contribute to sustenance fishery in the coastal areas. The baby clam *Katelysia opima* is third in abundance after Black clam *Villorita* spp. and Great clam *Meretrix* spp. It is known to occur in Kakinada Bay, Adayar Estuary, Vellar Estuary and Kundugal point in the east coast, Lalbadevi Creek in Ratnagiri and Tarkarli Creek near Malwan in Maharashtra in the west coast (Alagarswami and Narasimham, 1973). The fishery for this species in Ashtamudi Backwaters near Quilon in the southwest coast of India is reported here for the first time.

The authors are thankful to Dr. K. Alagarswami, Shri K. Nagappan Nair and Dr. P. N. Radhakrishnan Nair for critically going through the manuscript.

FISHING AREA

Ashtamudi is the second largest backwater system of Kerala, located between Lat. 8°45′-9°28′N and Long. 76°28′-77°17′E with a total extent of 32 sq. km area spread over Karunagappally and Quilon Taluks of Quilon District (Fig. 1). It remains connected with the Arabian Sea throughout the year. About fifteen hectares of area near the bar mouth surrounded by Neendakara and Dalavapuram villages in the north, Sakthikulangara village in the south, Chavara Thekkumbhagom in the east and Sakthikulangara Barmouth in the west (Fig. 1) is the clam fishing area. During March 1982 to February 1983 the salinity of the backwater in the clam bed varied from 10.8‰ to 33.88‰, temperature from 27°C to 35°C, dissolved oxygen from 3.2 ml/L to 5.06 ml/L and pH from 6.5 to 8.5. The depth of the fishing area ranges 1-3 m and the bottom was either muddy or a mixture of loose sand, gravel and broken shells.

FISHING METHODS

The clams (Pl. I A) are exploited either by the traditional method of hand-picking or by hand-operated dredges. Both men and women of the surrounding villages are engaged in hand-picking and fishing activity begins in the early morning, depending on the tide. From waist-deep water fishermen remove the sand either with their feet or by a metal piece, pick out the buried clams and collect them in net bags tied around their waist. A person collects approximately 40-50 kg of clams within 3 to 4 hours daily.

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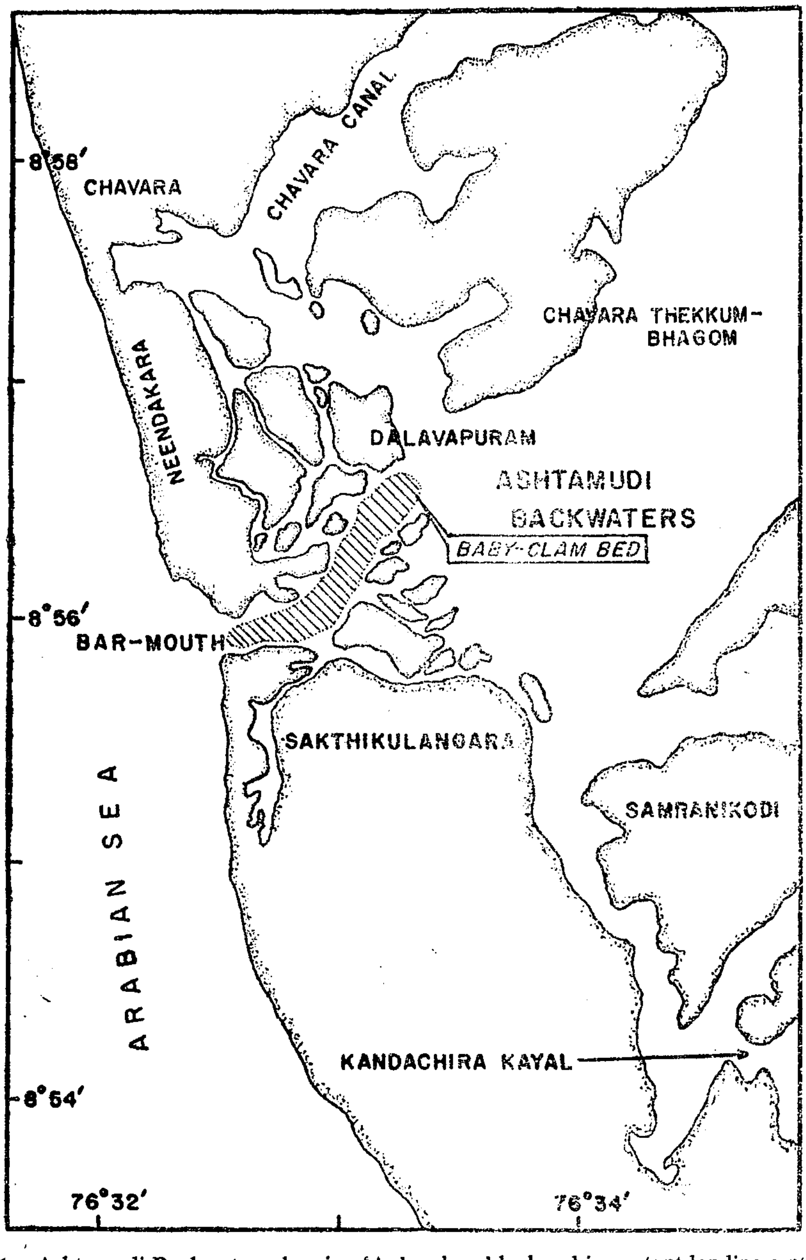

Fig. 1. Ashtamudi Backwaters showing ' baby clam ' bed and important landing centres.

In deeper areas two persons go in dugout canoes, dive in turn to depths ranging from 2 to 3 m and collect the clams. Few fishermen use scoop net made of semi-circular iron frame and a nylon net of 30 mm mesh size for collection. As the demand for clams increased the local fishermen started operating hand dredges, which has reduced much of the physical effort and also increased the catch substantially. The hand dredge consists of a rectangular iron frame with several iron spikes of 4-6 mm size on the base of the frame, pointed downwards. Bamboo, teakwood and casuarina poles or GI pipe of 4-5 m length are

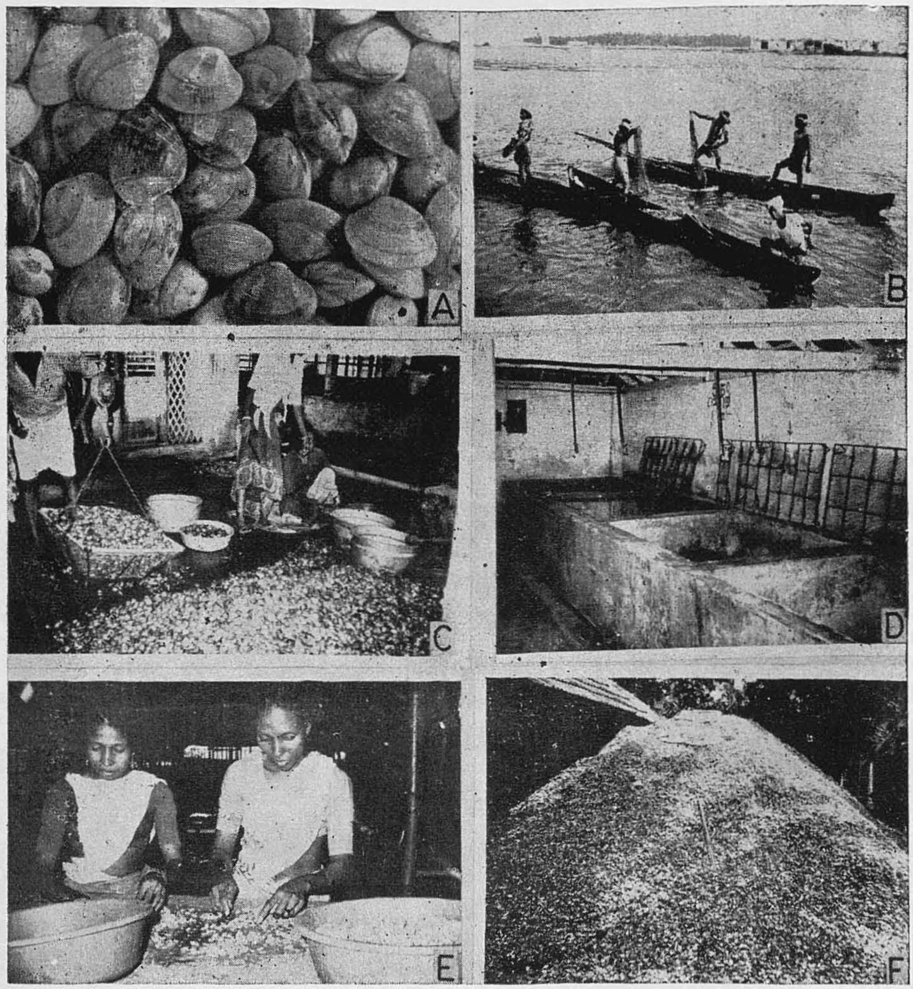

PLATE I. A. *Katelysia opima*, B. Clam pickers operating the hand dredge from dugout canoes, C. Clams brought to the processing sheds, D. Clam purification tanks with metal false bottom kept above, E. Grading of boiled clam meat and F. Heap of discarded clam shells.

used as the handle of the dredge. The handle is tied or riveted to the iron frame firmly and a conical bag net of 1 - 1.5 m length is attached to this to which the dredged clams are collected. The mesh size of the bag is 30 mm and hence only bigger sized clams are retained in it. Two long nylon ropes are tied to the corners of the free base of the iron frame and another long rope to the cod end of the bag net (Fig. 2). The dredge is operated in areas of 3-4 m depth ; first the dredge is driven to the bottom and the base of the dredge is pulled with the help of long ropes to a distance of 3-4 m. The spikes of the frame act as plough and clams are collected in the bag net. The bag net is slightly lifted occasionally to clear the mud and sand when the bag is fully loaded with clams, it is emptied into the canoe by lifting the dredge (Pl. I B). This process is repeated several times and a single unit usually collect 200-300 kg of clams within 2 to 3 hours every day.

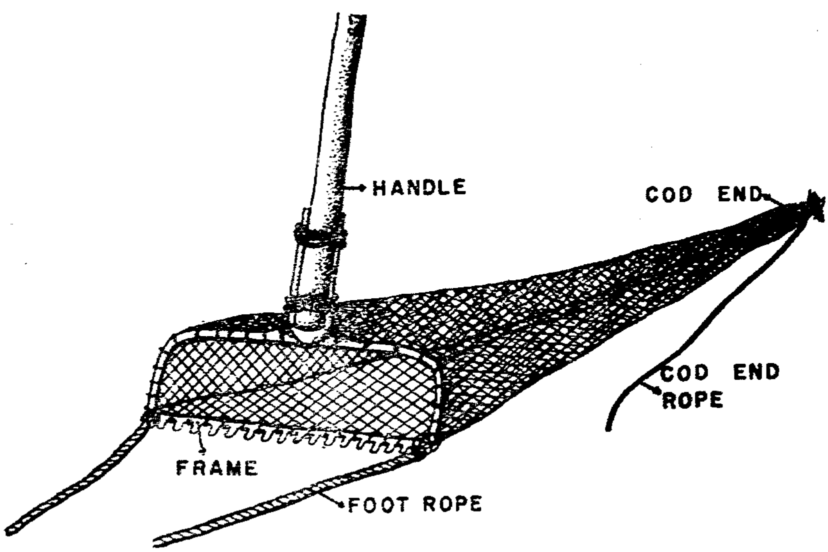

Fig. 2. Diagramatic sketch of hand dredge used for clam exploitation.

FISHERY

Details of ' baby clam ' fishery from March 1982 to February 1983 is presented in Table 1. Regular catch data was collected from landing centres by bimonthly observations on landings and by enquiry with the fishermen and agents who collect clam meat for export. The total clams exploited for the above period was estimated at 5436.5 t with a monthly average at 453.04 t. The maximum landing was observed in November, 1982 with 604.5 t and minimum in April 1982 with 258.75 t. A close examination of the data shows that from March to May 1982 the catch per month was only 285 t, much below the monthly average for the year. During this period only 20 independent clam pickers and an average 40 canoes were in operation per day for 25 fishing days per month. The catch per day for a diver was 50 kg and catch per canoe was 250 kg. As the export demand for meat increasd during the later period of observation as evidenced by the gradual increase in catch, there was increased effort for clam exploitation. From June 1982 onwards the average number of independent divers per day increased to 30 and the number of canoes operated to 70. This accounted for the increase in production all through these months. The total quantity

TABLE 1. *Size composition, average wet meat weight and monthly average catch of* Katelysia opima *from March, 1982 to February, 1983 from Ashatmudi Backwaters*

Months	Size composition								Meat wt. percentage	Monthly average catch in kg
	20-24 mm	25-29 mm	30-34 mm	35-39 mm	40-44 mm	45-49 mm	50-54 mm	55-59 mm		
March 1982 ..	—	—	2	32	65	1	—	—	17.40	303750
April ..	—	—	—	1	16	63	19	1	28.24	258750
May ..	—	—	13	1	23	48	15	—	17.80	292500
June ..	—	9.1	9.7	12.6	33.7	34.3	0.5	—	16.12	494000
July ..	—	1	14	9	14	51	11	—	13.27	494000
August ..	1.1	14.6	32.6	7.3	3.9	24.1	15.6	0.5	13.46	475000
September ..	—	—	24	27	18	29	2	—	15.82	361000
October ..	—	—	—	—	—	—	—	—	—	456000
November ..	2	11	19	48	20	—	—	—	15.29	604500
December ..	—	—	—	—	—	—	—	—	—	581150
January 1983 ..	1	—	20	30	39	10	—	—	23.62	581150
February ..	3	21	16	29	29	2	—	—	16.27	534750
Annual percentage	0.7	6.5	15.9	18.4	25.2	26.6	6.6	0.2		

of boiled clam meat collected for export during one year period was estimated at 543.6 t (10% of landed weight). The weight of shells would be around 3261.5 t.

The fishery is supported by clam of 20-60 mm length with the dominance of 30-49 mm group in all the months. The wet meat weight varied from 13.27% to 28.24% and the maximum was observed during April-May and December-January period. Spawning activity commences by December and lasts till February. Young ones were plenty in the clam beds from January to March.

The exporters collect the clam meat through local agents, who collect the live clams directly from the fishermen and do purification, boiling, meat extraction and grading. The cost of clams varies from Rs. 0.20-0.40 per kg and the meat price ranges from Rs. 3,50-7.00 per kg depending on the demand. The grades 300-500/kg and 500-700/kg always fetch the highest price. When there is good demand for meat, a clam picker could easily earn between Rs. 30-40 daily and two persons going in a canoe using and dredge earn around Rs. 90 a day. One tonne of shells fetch Rs. 150 and this is an additional income for the agents.

UTILIZATION

Till the middle of 1981, clams were collected from Ashtamudi Backwaters mainly for local consumption. The meat was marketed into nearby coastal villages around Quilon and the shells were used for preparing shell lime. By the end of 1981, export of clam meat commenced and the exploitation increased. The sucking of meat is done in 10-15 sheds located at Sakthikulangara, Dalavapuram and South hävara. The collected clams are brought to these sheds (Pl. I C), washed twice after sorting and are transferred to purification tanks. Cement tanks 1.5 × 1.5 × 1 m size with wire meshed false bottom are used as purification tanks (Pl. I D). Clams are kept in the tanks for 10-12 hours in well water and water is changed twice or thrice before they bulk of the meat is being sent to Japan. The details of export of frozen clam meat are given in Table 2. Out of the total catch only 5% of the live clam is utilized locally and the rest is exported. The clam shells (Pl. I F) are taken to Tamil Nadu in lorry loads for the calcium carbide industry and a small portion is utilized locally for lime production.

TABLE 2. *Export of frozen clam meat from India during* 1981-'83

Countries		1981	1982	1983	Total
Japan	Q ..	15,600	3,95,696	5,93,754	10,05,050
	V ..	1,11,340	84,42,325	73,60,026	1,59,13,691
U.A.E.	Q ..	—	1,643	—	1,643
	V ..	—	32,743	—	32,743
U.S.A.	Q ..	—	91	2,446	2,537
	V ..	—	3,500	1,17,517	1,21,017
Fed. Rep. of Germany	Q ..	—	—	12,422	12,422
	V ..	—	—	1,30,228	1,30,228
Total	Q ..	15,600	3,97,430	6,08,622	10,21,652
	V ..	1,11,340	84,78,568	76,07,771	1,61,97,679

Q — Quantity in kg. V — Value in rupees.

Source : Statistics of marine products exports 1983, MPEDA.

are taken out for shucking. Shucking of meat is made easy by keeping the clams in boiled water kept in metal bins of 50-75 litres capacity for 10-15 minutes. The shucked meat is graded according to the number of clams per kg weight (Pl. I E). The standard clam meat grades are 300-500, 500-700, 700-1000, 1000-1500 and 1500 and above. The graded meat is washed twice in chilled water, drained for 5 minutes, weighed in 2.2 kg, quick frozen for 3 hours and stored at - 20° C. On thawing the weight of the meat comes around 2.1 kg. Each frozen slab is packed in individual cartons for export. Three freezing plants in Sakthikulangara and two plants at Cochin were collecting the clam meat from Ashtamudi Backwaters for export. Frozen 'baby clams' from India are known as 'Asari' in Japan and

PRESENT STATUS AND PROSPECTS

Rasalam and Sebastian (1976) have given the details of lime shell fishery of Vembanad Lake and pointed out the prospects of shellfish industry in Kerala. The limeshell fishing rights and issue of licences are regulated by the State Department of Mining and Geology which administers the Kerala Minor Mineral Concession Rules 1967 and the rules made thereunder. Though there is a well established licensing system for the black clam *Villorita* spp. in the Vembanad Lake, the clam beds of Ashtamudi are not yet leased out for exploitation. At present the Department of Mining and Geology supervises and levies the sale of shells collected from this area. Though there is no indication of over exploitation of clams at present, the increase in demand may lead to depletion of clam resources. It is desirable to prohibit removal of juvenile clams and fishing during spawning period. This will give chances for replenishment of the stock. As the demand for meat is increasing day by day, regulations of fishing by licensing system is quite necessary and strict hygienic measures have to be taken to keep up the quality of meat exported. Like the case of shrimp, the clam meat export is increasing. Culture of this clam would offer the best scope for incresed production.

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(Indian Council of Agricultural Research)
P. B. No. 2704, E. R. G. Road, Cochin-682 031, India

4. CLAM RESOURCES OF THE ASHTAMUDI LAKE, WITH SPECIAL REFERENCE TO *KATELYSIA OPIMA* (GMELIN) FISHERY

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ABSTRACT

The clam fishery resources of the Ashtamudi lake are supported by several species belonging to *Villorita, Katelysia, Meretrix* and *Paphia*. However, *Villorita cyprinoides* and *Katelysia opima* contribute to the bulk of the resource. The extent of the major clam beds, the estimate of the present stock and the magnitude of the existing fishery suggest increased production. The exploitation and utilization of *Katelysia opima*, which has got great export potential, are dealt with in detail. Some steps for the judicious management of the clam resources are also suggested.

INTRODUCTION

Among bivalve molluscs, clams form an important resource as meat for human consumption and as lime-shell in cement and calcium carbide industries. Very little is known about the clam resource of the Ashtamudi lake situated on the southwest coast of India and second only to the Vembanad lake in Kerala in area and clam production. The only study is that made recently by Appukuttan et al (MS) on *Katelysia opima* (Gmelin). The present paper gives a baseline information on the status of the clam fishery with special reference to the fishery and utilization of 'baby clam', *Katelysia opima*.

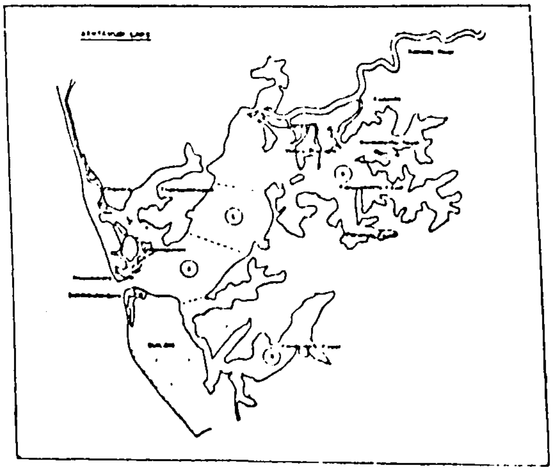

Fig 1. Map of Ashtamudi estuary. A. Dalavapuram B. Ashtamudi mud flat C. Kanachira Kayal D. Kanjirakottu Kayal.

AREA AND METHODS OF STUDY

The Ashtamudi lake is situated between lat. 8°45'-9°28' N and long. 76°28'-77°17'E. It has a waterspread of 32 km^2 and is connected to the Arabian Sea through a perennial opening, permitting an estuarine condition almost throughout the year. The Kallada river which joins at the northeastern part is the source of freshwater to the lake.

To assess the present status of the clam fishery and its prospects, survey of the Ashtamudi lake was undertaken in February 1984. For this the entire area was divided into 4 zones, viz. Dalavapuram, Ashtamudi mudflat (Neduvathu Thuruthu), Kandachira Kayal and Kanjirakottu Kayal (Fig. 1).

Areas of occurence of clams were first ascertained by enquiries with regular clam pickers and also by observing actual fishing. Stations were fixed at a minimum distance of 200 m from each other. Water samples were collected for temperature, salinity, dissolved oxygen, phosphate, nitrite, nitrate and pH analysis. Wherever the depth was more than 1 m, water samples from the bottom were collected with a Casella bottle for estimating these parameters. Sediments from very shallow areas were taken with hand, and when the depth was more the sediment that came along with the clams in the clam sampler was collected for determining the nature of the bottom. All the samples were analysed in the Mobile Laboratory.

A sampler designed by G. P. Kumaraswamy Achary was used for collecting samples of clams (Fig. 2, E). This is a hand-operated dredge having a rectangular iron frame 0.25 m long. There are small spikes on both the longer rims of the dredge. A 75-cm nylon netting of 10 mm mesh is tied to the frame. The codend of the net is open, which can be closed by tying a thread. A nylon rope is attached to the dredge for dragging it on the bottom. One haul with the dredge covering

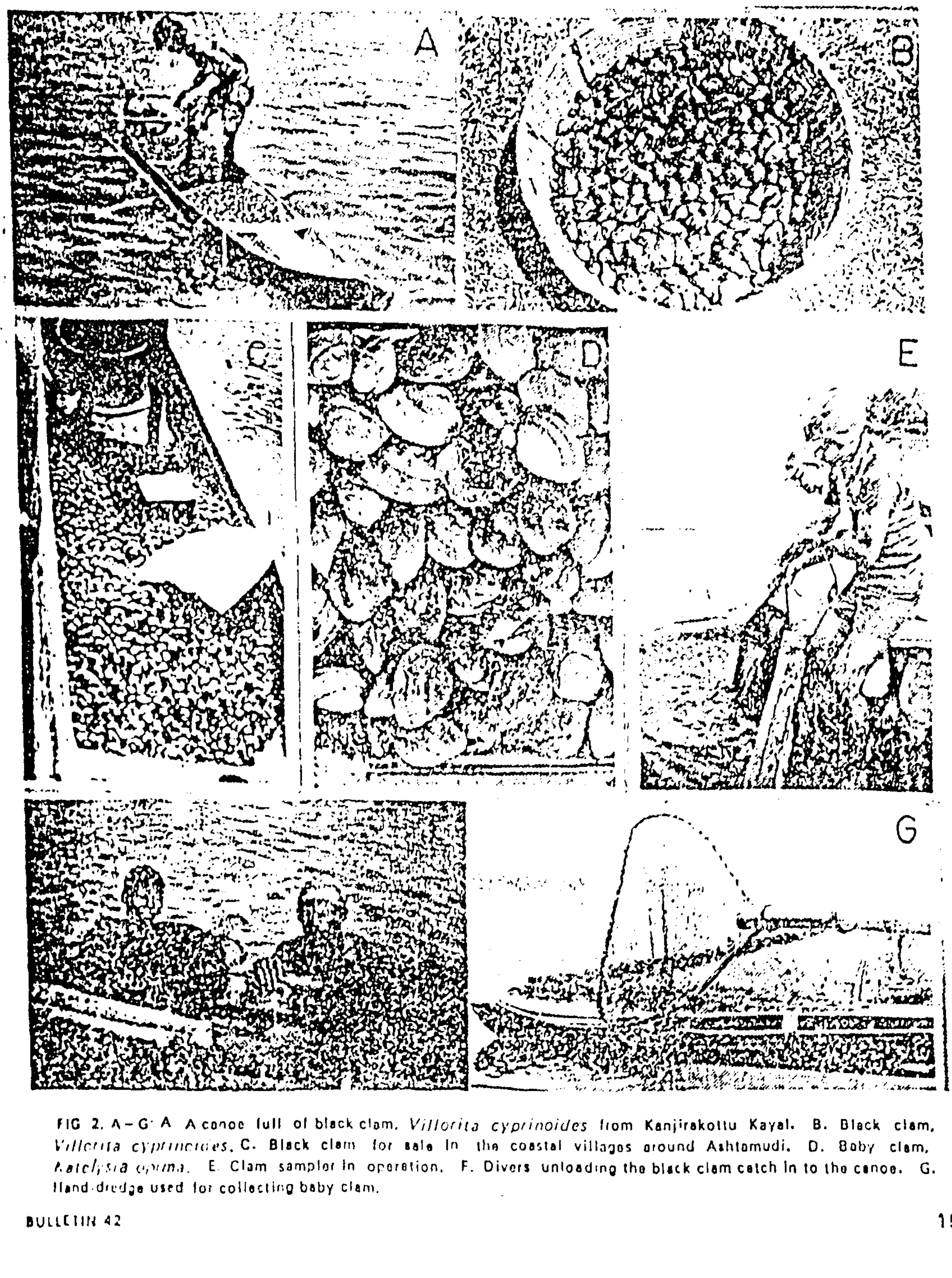

FIG 2. A – G· A A canoe full of black clam, *Villorita cyprinoides* from Kanjirakottu Kayal. B. Black clam, *Villorita cyprinoides*, C. Black clam for sale in the coastal villages around Ashtamudi. D. Baby clam, *Katelysia opima*. E. Clam sampler in operation. F. Divers unloading the black clam catch in to the canoe. G. Hand-dredge used for collecting baby clam.

Fig. 3. A.—H. A. Hand dredge is being operated from the canoe for baby clam collection at Dalavapuram B. Baby clam is being taken to the processing shed. C. Grading the clams before taking them to the purification tanks. D. Grading the boiled and shucked meat. E. 2-kg frozen slab of clam meat for export. F. Analysing clam samples inside the Mobile Laboratory during survey. G. Baby clam shells stocked for industrial use at Neendakara. H. Heaps of black clam shells at Munro Thuruthu.

one metre distance gives the clams available in 0.25 sq. m area.

Apart from collecting clams with the dredge, samples were taken from the regular fishery for qualitative studies and for comparing with the sampler collections.

OBSERVATIONS AND RESULTS

A. Dalavapuram: Dalavapuram area (Fig 1 A) harbours a rich clam bed of about 15 ha which sustains regular fishery. The species of clams is *Katelysia opima* (fig. 2, D); stray numbers of *Meretrix meretrix* and *Paphia* sp are also met with. Twelve stations were fixed in this area. The depth of these stations ranged from 0.5m to 3.5 m. The sediment was composed of coarse, medium and fine sand clay.

Water temperature varied from 29 C to 31.3°C at the surface and from 28.6°C to 31°C at the bottom. Surface salinity range was 23-28.3°/oo and the bottom salinity 22-28°/oo. Dissolved oxygen varied between 3.08 ml/l and 5.10 ml/l for surface waters and between 3.40 ml/l and 6.12 ml/l for bottom waters. The phosphate values were 1.23-2.31 µg/l for surface, 1.77-4.48 µg/l for bottom; nitrate: 23.65-30.65 µg/l and 23.65-35.32 µg/l; nitrite: 20.01-70 µg/l and 10-50.03 µg/l; pH: 7-8.5 for surface and 7.5-8.5 for bottom waters.

Fishing methods and fishery: Appukuttan et al (MS) have given the different methods employed in clam fishing which vary from the simple, traditional, hand-picking to scooping and dredging (fig. 2.) The fishing is generally done at low tides for 3-4 h and till the canoe is full with clams or the high tide begins. A canoe with 2 persons takes about 200-300 kg of clams per day. In the fishery for edible purpose, only the medium and large-sized clams are taken.

There is clam fishing throughout the year, with peak in February-March. During March-May 1982, there were 20 clam pickers and 40 canoes on an average per day. As the export demand for clam meat increased, the number of persons as well as canoes also increased, and on a single day in February 1984 there were 160 canoes with 271 persons fishing for clams.

Appukuttan et al (MS) gave the catch of *Katelysia opima* from Ashtamudi lake during March 1982 to February 1983 as 5,436.5 t. There has been good fishing in subsequent years and though the exact catch figures are not available, judging from the demand for clam meat in the export trade, the present level of production is estimated at 6,000 t to 6,500 t. Based on the present survey it is estimated that the existing stock of *Katelysia opima* in this area is around 10,000 t.

Size range: The size frequency of *Katelysia opima* collected with the sampler from Dalavapuram clam bed during February 1984 is given in Fig. 4A. The size ranged from 5 to 44 mm with a dominant mode at 17 mm; there were smaller modes at 26, 35 and 41 mm. Since spawning takes place during December-February (Appukuttan et al MS), there is a dominance of smaller size groups up to 20 mm. In the fishery the maximum exploited size is 30-40 mm.

Utilization: About 5% of the total clam production is consumed locally and the rest is being exported as frozen 'baby clam' Fig. 3 C, D, E). The export of clam meat which began in 1981 has reached 608.6 t. worth Rs. 7.6 million in 1983. The major buyer of Indian 'baby clam' is Japan; other importing countries are the U. A. E., U. S. A. and the Federal Republic of Germany.

During 1982-83 the price paid to the clam-picker varied from 20 to 40 paise per kg of whole clam, and Rs 3.50 to 7.00 for the meat; during the 1984 survey it was Rs. 1.25 and Rs. 7.50-12.00 respectively.

The bulk of the shells is taken to Tamil Nadu for the calcium carbide industry, and a small portion is used locally for producing lime (Fig 3, G).

Meretrix meretrix, locally called *'velle kakka'*, occurs in very small numbers along with *Katelysia opima*, especially in the upper reaches of this clam bed of Thekkumbhagom. The size range of the clam taken in the sampler in February 1984 was 10·51 mm (Fig. 4 B). The dominant mode was at 20 mm with two smaller modes at 29 and 44 mm. The entire catch is used for local consumption. It is gathered that there was illegal dredging of white clam shells till about 1982 in the northern part of the Ashtamudi at the entrance to Chavara canal.

B. Ashtamudi Mudflat: The Ashtamudi mudflat is on the eastern side of the Dalavapuram bed, about 10 km from the bar mouth (Fig 1B). It is a very shallow submerged mudflat, the maximum depth being about 1 m. The bottom sediment consists of coarse sand and mud. There was plenty of weeds on the bottom.

Only two stations were fixed in this zone, as there was no clam fishery. In both the stations the surface water temperature was 30°C, salinity 24-25‰ and dissolved oxygen 3.40-4.08 ml/1; phosphate gave a single value of 1.77 µg/1, and nitrite 30.65-32.99 µg/1. The pH of the water was 9.

The clam sampler was used at both the stations. There were a good number of *Modiolus* and dead shells of *Sanguinolaria*. A few seed clams *(Meretrix)* were hand-picked. However, adult clams were absent.

C. Kandachira Kayal: This zone is situated south of Dalavapuram zone,and consists of many narrow creaks and inlets. Six stations were fixed during the survey. The depth of these stations was 1 2m. The bottom sediments consisted of fine sand and mud. At some stations the sediments were black in colour, emitting strong smell of hydrogen sulphide because of extensive coconut rotting.

The surface temperature ranged between 30.5°C and 31.4°C, salinity 22-24‰ dissoloved oxygen 2.70-408ml/l, Phosphate was estimated at 2.31 µg/1, nitrite 28.32µg/l and pH 8.5-9.

In the clam sampler collection, no live clams were collected except for plenty of *Modiolus;* dead shells of *Villorita* and *Sanguinolaria* were hand-picked. It is learnt that previously there were live clams and small scale clam picking for domestic consumption.

Both white and black clams are brought in small canoes from Dalavapuram and Chavara areas and sold to coastal households. The price is about 25 paise for a measure by coconut shell which may contain 50-60 small and 20-25 large clams. Sometimes women bring fresh clam meat to the market and sell at the rate of 40-50 a rupee.

D Kanjirakottu Kayal: This is a very extensive area forming the eastern segment of the Ashtamudi lake which branches off into 3 arms, Kumbalathu Kayal, Kanjirakottu Kayal and Perumon Kayal with their many creeks (Fig. 1D). This is a very rich ground for the black clam *Villorita cyprinoides*, locally called *'Karimkakka'*.

Thirty-one stations were fixed in this zone and the depth of clam grounds was1-3.5 m. The nature of bottom varied greatly from gravel to clay but mostly it was muddy with fine sand and clay.

Temperature ranged between 30°C and 32.8°C for surface waters and between 30.2°C and 31.5°C for bottom waters. Saline conditions prevailed even at the uppermost reaches of the lake. Surface salinity range was 10.75-25‰ and for bottom salinity 21-26‰ Dissolved oxygen ranged between 2.72ml/l and 5.78ml/l for surface waters and between 0.34 ml/l and 6.12 ml/l for bottom waters. Other parameters estimated are: phosphate 0.69 2.85 µg·l for both surface and bottom; nitrite 30 65-32.99 µg/l for surface and 28.32µg/l for bottom; nitrite 20.01-30.02 µg/l for surface and 20.01-40 µg/l for bottom; pH 5-9 for surface and 5-9 for bottom.

In the Manakkadavu area there is good *Villorita* fishery. During February-April which is the peak season, about 150 people do clam fishing here, and the fishing may continue up to June. Clams are collected either by hand-picking or with a rectangular or semicircular metal frame attached with a net-bag. The frame is dragged on the bottom, pushing the clam into the net. The catch is emptied into canoes or submerged baskets. The meat is sold to coastal households and also in the markets at Kundara, Kallada and nearby places. Women do clam-picking in very shallow waters. Many women who work in the nearby cashew factories go for clam-picking when there is no work in the factory. There are about 100 such women who pick clams both for domestic consumption and for sale.

There is good demand for clam shell and 10 kg of shells fetch Rs. 1.25-1.50. Bigger canoes with 3-4 men are employed for collecting clams of all sizes. A heap of about 50 t of clam shells stocked for sale was observed in Munro Thuruthu (fig. 3 H)

The Kumbalathu Kayal of this zone is very rich in *Villorita* resource. Here also the peak fishing season is February-April, and from mid-June to October-November is the closed period. Over 150 people including 20-25 women go for clam fishing in good season. About 75-90 canoes are employed every day. Normally one person with a canoe takes about 100 kg of clams. People of all communities except Brahmins go for clam fishing and consume clam meat.

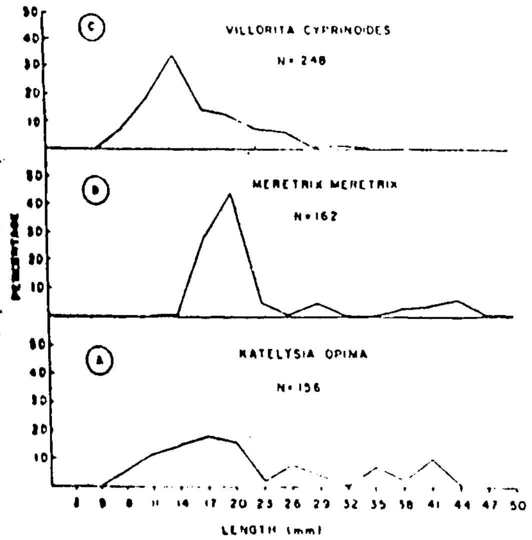

Fig 4. Length frequency distribution of clams. A. *Katelysia opima* B. *Meretrix meretrix* C. *Villorita cyprinoides*

Near Kumbalam on the southern bank of the Kumbalathu Kayal there is a lime kiln and a stocking place for shells. Recently collected clams are stocked under water in enclosures for completely decaying the meat. These are mostly very small clams collected for the shell. Fishermen collect the shells in canoes and sell to merchants at the rate of Rs. 1.50 per basket of about 20 kg.

Based on a few day's observation during the survey, the annual production is estimated at 5,000 to 6,000 t. The clam bed is spread in about 50 ha though it is patchy at many places with very stray occurrence of clams. The estimate of the present stock of *Villorita cyprinoides* is around 12,000 t.

In this bed the clams ranged in length from 4 to 33 mm with a mode at 14 mm (Fig 4 C).

REMARKS

Nair et al (1983) have studied in detail the physicochemical features of water and nutrients of sediment of this lake. According to them the heavy flow of fresh water from Kallada river into this lake minimises pollution by effluents from the Punalur Paper Mills.

With the beginning of export of clam meat in 1981 the production of *Katelysia opima* has increased but in 1984-85 there was a lull in export demand and with this an indiscriminate fishing for small clams started for the shell for industrial purposes. This created an alarming situation but the export was resumed and the fishermen concentrated on 30-49 mm size clams suitable for export. Though the fishermen claim that there is a self-imposed restriction that under-sized clams should not be collected, such restrictions are not often observed. During January-March period seed clams and youngones are plenty, and to prevent their exploitation fron Dalavapuram area regulation of the mesh size of the hand-dredge to 30 mm is recommended.

At present there is no licensing system for fishing in Ashtamudi lake. Such a system as followed in the Vembanad lake (Rasalam and Sebastian 1976) can be considered for adoption for this estuary also for preserving the valuable clam resources.

Though there is every possibility of increasing the production of black clam *Villorita cyprinoides* from the estimated 50-ha bed, indiscriminate fishing of smaller sizes (< 20 mm) was observed in certain areas. Such practice should be put to an end.

Vigorous quality control of the clam meat processed for export should be maintained. A consignment sent during September-October 1986 was rejected by Japan because of the presence of traces of kerosene.

To augment production, farming *Katelysia opima* by transplantation of seed clams to suitable areas in the estuary is suggested.

Another suggestion is that the meat of black clam can be canned or pickled, so that the consumer demand will increase.

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