SOUTH ASIA CO-OPERATIVE ENVIRONMENT PROGRAMME

Strengthening the Capacity of Regional Centres of Excellence in the Management of the Coastal and Marine Environment

A Proposal

Submitted to

The Director General
South Asia Co-operative Environment Programme
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Sri Lanka

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19 September 2001

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CERTIFICATE

This is to certify that this Institution is fit to receive grants under South Asia Co-operative Environment Programme and that all necessary facilities will be provided to the Proponent to organise the Regional Centre in the Management of the Coastal and Marine Environment.

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THE GENESIS

There has been growing concern about the impact of the ongoing new industrial 'revolution' on the marine environment, industrial structure and societal systems, especially of the developing countries. This resulted in the adoption of the UN Convention on the Law of the Sea in 1982, the setting up of the World Commission on Environment and Development in 1985, and the Regional Seas Program, operational from 1974 onwards, of UNEP. The result of various studies, reports etc. has been an emerging consensus: on the need for restructuring institutions (global, regional and national) if the challenges arising out of the new industrial revolution are to be met; for reducing the technological 'gap' between the industrialized and industrializing nations; and for having technological trajectories which are both socially and environmentally harmonious. On the basis of these considerations, the UN Convention on the Law of the Sea has mandated the establishment of regional centers in marine science and technology in a fairly detailed manner.

Drawing upon these ideas, the ICCOPS (International Center for Coastal and Ocean Policy Studies), Geneva held in May 1998 a Conference on 'Education and Training in Integrated Coastal Area Management'. One of the expected results and outcome has been the establishment of a Regional Center (RC) for Mediterranean region to network information and materials concerning the sustainable development of ocean provinces in that locality.

In the context of Human Resource Development through the Strengthening of Regional Centers of Excellence, under the South Asia Cooperative Environment Program for the Indian sub-continent, a number of roles, in an interfacing module organized concept, could be visualized for the proposed RC at this place. Some of them could include:

- Collect and disseminate information relating to marine scientific research in chosen areas of specialization
- Provide consultancy and advisory service
- Further development in the identified areas of environmental measures
  - acting as a catalyst
  - networking different research institutes
  - acting as a coordinator and synthesizer
- Promote development of scientific and technological skills through training programs, seminars and symposia
- Promote establishment of efficient, innovative and effective management systems in the field of research and development, environmental control and marine resource exploitation.

1. THE ORGANIZATION :

Department of Zoology - A Profile

The Department of Zoology, one of few professional post-graduate schools in natural sciences in the University is endowed with an educational program that provides a fertile and stimulating environment for students preparing for careers in marine biology, parasitology, animal physiology and fishery science. Chartered in 1946, the Department had a tripartite mission of education, research and advisory service that resulted in the establishment of an institution prepared to impart knowledge to qualified researchers, resource managers and educators needed for the future of the country.

Under the stewardship of Dr. Eugene C. LaFond, a Fullbright visiting Professor from US in 1952 and, late Professor P.N. Ganapati, Head of the Department at that time, a number of scientific investigations were carried out on nearshore hydrography, plankton, primary productivity and intertidal ecology. Results of these studies were published as Andhra University Memoirs in Oceanography, Series 1 & 2 during the years 1954 and 1958. In the year 1959, the Indian Council of Agricultural Research, New Delhi funded a research project on "Hydrobiological and faunistic survey of Godavari estuary" which study had yielded invaluable data considered among scientific circles as a unique piece of work even now. The early 60s also witnessed yet another significant development in the Department's efforts to promote marine research through its active participation in an International endeavor in the Indian Ocean Expedition jointly organized by over 25 countries at that time.

Taking cognizance of the overall development, the University Grants Commission, New Delhi had during the 2nd and 3rd Plan periods come forward to assist the Department in its activities in Marine Biology by providing a substantial grant of over Rs. 5 Lakhs. The Department by then had a number of trained faculty to conduct specialized teaching and research in Marine Biology as a result of which a full-fledged course in Marine Biology was introduced at the M.Sc. level. Between 1970-'73, the Indian National Science Academy granted a major research project to Professor Ganapati to conduct an investigation on pollution effects on marine life in the harbour and coastal waters thereby recognizing the importance of growing industrialization and urbanization of Visakhapatnam City. The late 70s and early 1980 witnessed further development through the University Grants Commission's funding through Special Assistance Program, Phases I (1985-'90), II (1992-'97), III (1998-2003), and the COSIST program for the years 1998-2003. So far, over 20 major Research projects were undertaken in marine biology in the Department funded by various national and International agencies such as ICAR, DOD, DST, MoEF, CSIR, UGC, DAE etc. Perhaps an important contribution made in recent years relates to work carried out in the Indo-Belgium International collaborative

research project funded by the European Commission, Brussels on the "Assessment of the Ecological Importance of Mangroves of Kakinada Area, Andhra Pradesh". During this investigation, carried out for a period of three years (1994-'97), in-depth studies on the hydrographic conditions, phyto and zooplankton distribution, benthos and mangrove ecodynamics were made and a database created. It is noteworthy that three candidates have obtained their Ph.D. degree for work carried out by them in the project and a few more are waiting. Based on the progress made, the European Commission offered funding for a second term for further work in this area. At present, Phase II (1998-2001) of the project is in operation with the participation of additional member countries (Netherlands, Sweden, Belgium, Kenya and Sri Lanka) and the French Institute at Pondicherry. An important outcome of the project would be to estimating mangrove resilience to human impacts documenting the socio-economic role of mangroves regarding forestry and fisheries resources in that area. Other important ongoing projects held by the Marine Biology Division are: 1."Geographic information system based study for Coringa Mangroves" 2. "Predictive models for the fisheries of north coastal Andhra Pradesh: An ecosystem approach" 3. "Benthic productivity for the EEZ of India" 4. "Determination of No-Impact Zone for Coringa", and 5. "Mangrove ecodynamics and applications through remote sensing - A case study for Coringa", to name a few. These projects are multidisciplinary in nature and more than a few University Departments and national Institutes are involved and they are all funded by the Department of Ocean Development, New Delhi. As a spin off, a separate Marine Biological Laboratory with adequate facilities for field sampling and data analysis was set up in June 1995 and it is very satisfying that six Ph.D. theses have come out of this Laboratory since then. More importantly, the IAPSO (International Association for the Physical Sciences of the Oceans) and the Andhra University jointly published Andhra University Memoirs in Oceanography - Series 3 released in August 1997. In recent years, as a part of the University's efforts for Resource Mobilization, the Department is undertaking consultant service in Environmental Impact Assessment for various organizations within the State and outside Andhra Pradesh.

2. SPECIALIZATION AND EXISTING RESEARCH :

CONTEMPORARY STUDIES IN MARINE BIOLOGY OFF NORTH ANDHRA COAST: CONTRIBUTIONS FROM ZOOLOGY DEPARTMENT- AN OVERVIEW

The Andhra University being one of the maritime Universities in India there has been special emphasis on the development of marine biological teaching and research. In this context, the Department of Zoology had during the last five decades carried out some pioneering investigations on the taxonomy and ecology of marine organisms inhabiting the coastal waters in this area. Over the years, the investigations have revealed presence of rich and varied life on this coast that supported a variety of marine organisms. During the course of these studies, species

new to science have been discovered and their biology and ecology studied adequately. Perhaps, the most significant contribution made in this direction by researchers in the Department relates to the extensive work carried out on the "Hydrobiological and faunistic survey of the Godavari estuarine systems", a project funded by the Indian Council of Agricultural Research (ICAR), New Delhi (ICAR Report, 1964) This unique piece of work is comparable next only to the monumental contributions made by Professor J.H. Day (1981) on estuaries in South Africa (c.f. Estuarine Ecology with particular reference to South Africa, 1981, A.A. Balkema/Rotterdam Publication) on account of its content, originality and depth of investigation. Other important works carried out in the Department of Zoology relate to nearshore hydrography, plankton, benthos, intertidal ecology, estuarine biology, marine biodeterioration, pollution ecology and fisheries. Fig. 1 shows marine scientific research evolution at the Department of Zoology during the last 50 years. The following is a brief account of some of these investigations.

Nearshore Hydrography :

As a basic part of the marine biological investigations, systematic analyses of sea water from the nearshore areas have been made to find out the distribution of salinity, temperature, nutrients and dissolved gases (Ganapati and Murty, 1954, 1955; Ganapati et al. 1956; Bhavanarayana and LaFond, 1957; LaFond and Bhavanarayana 1957; Satyanarayana Rao, 1957, Ganapati and Rama Sarma, 1958; Ganapati and Satyanarayana Rao, 1959, 1962; Satyanarayana Rao and Chalapati Rao, 1962; Chalapati Rao, 1965; Ganapati, 1973a, 1973b). These studies have revealed that the hydrographic conditions of the nearshore waters off Waltair are to a large extent influenced by the prevailing monsoons and currents and also by the enormous influx of freshwater into the Bay of Bengal from the large river systems on the East Coast of India. Simultaneous investigations by other Departments in the University consisted of studies on surface circulation, temperature/salinity seasonal cycles and vertical variations, coastal currents, upwelling and sinking, coastal geomorphology and sea floor sediments (Memoirs in Oceanography , 1954, 1958, Andhra University, Series Nos.49 and 62) (Figs. 2-5).

Plankton :

Studies on the distribution of plankton in space and time in relation to the prevailing hydrographic conditions in the north-west Bay of Bengal also formed an important aspect of the investigations. Taxonomic studies of some groups of planktonic organisms have resulted in the record of several new forms, which have not been previously known. The studies dealt with chaetognaths (Ganapati and Satyanarayana Rao, 1954; Satyanarayana Rao, 1956, 1958a, 1958b; Satyanarayana Rao and Ganapati, 1958), copepods (Ganapati and Rama Mohana Rao, 1954; Ganapati and Shanta Kumari, 1961), pelagic tunicates (Bhavanarayana, 1970) and

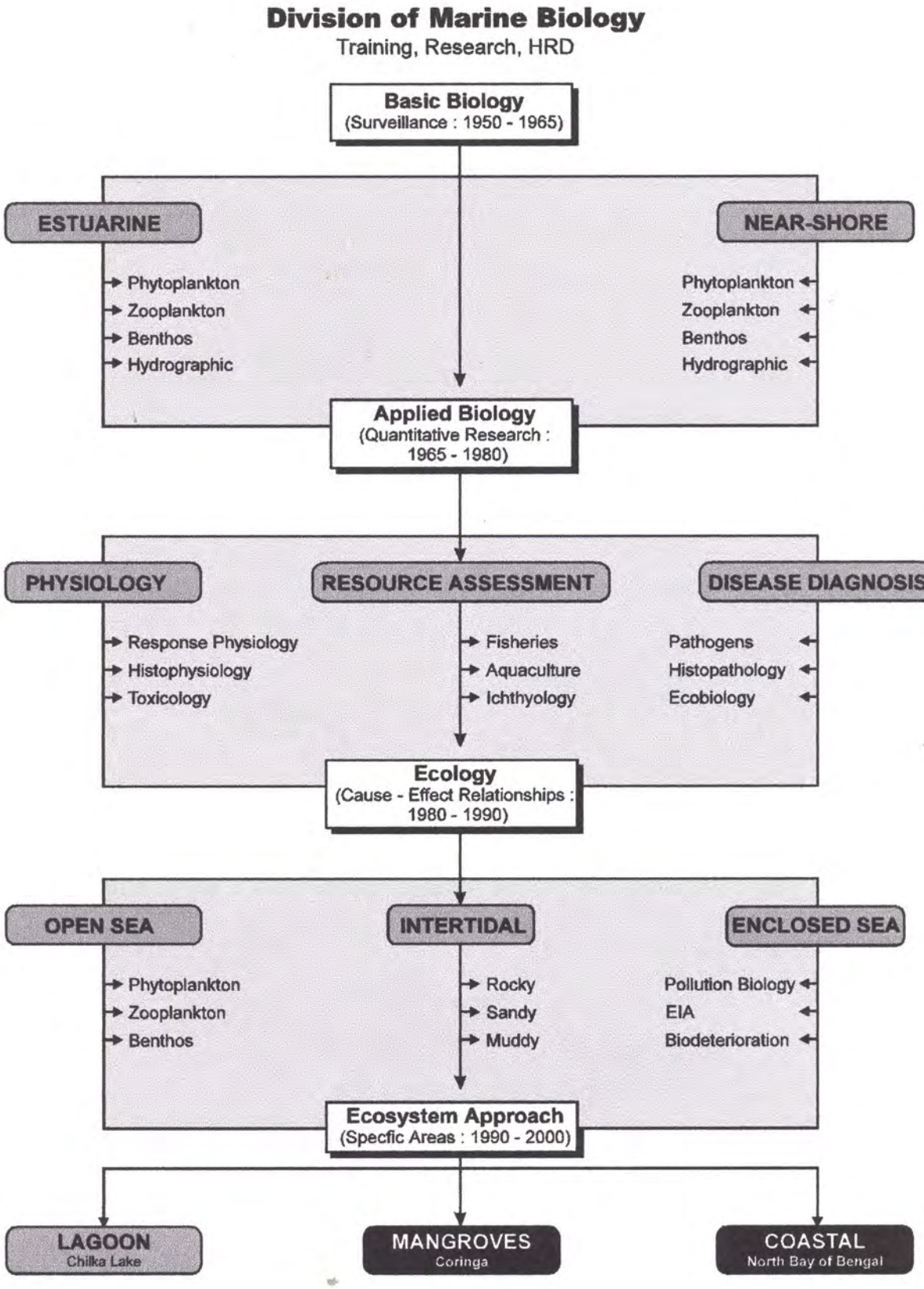


Fig. 1 : Marine Scientific Reseach at the Department of Zoology, Andhra University : Evolution over the years (1950 - 2000)

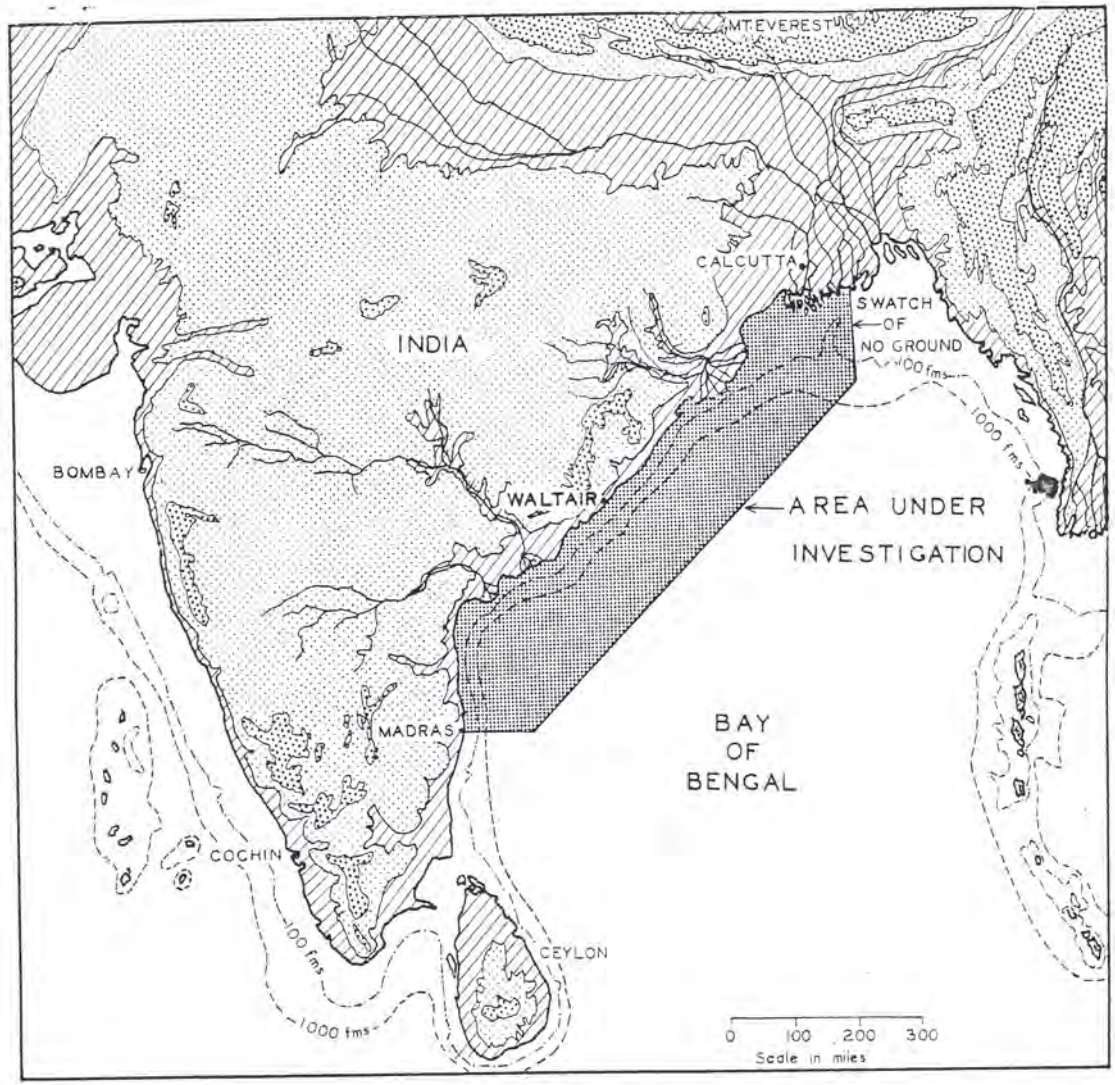


Fig. 2 showing study area for the Oceanographic cruises by Andhra University, 1952 - 54

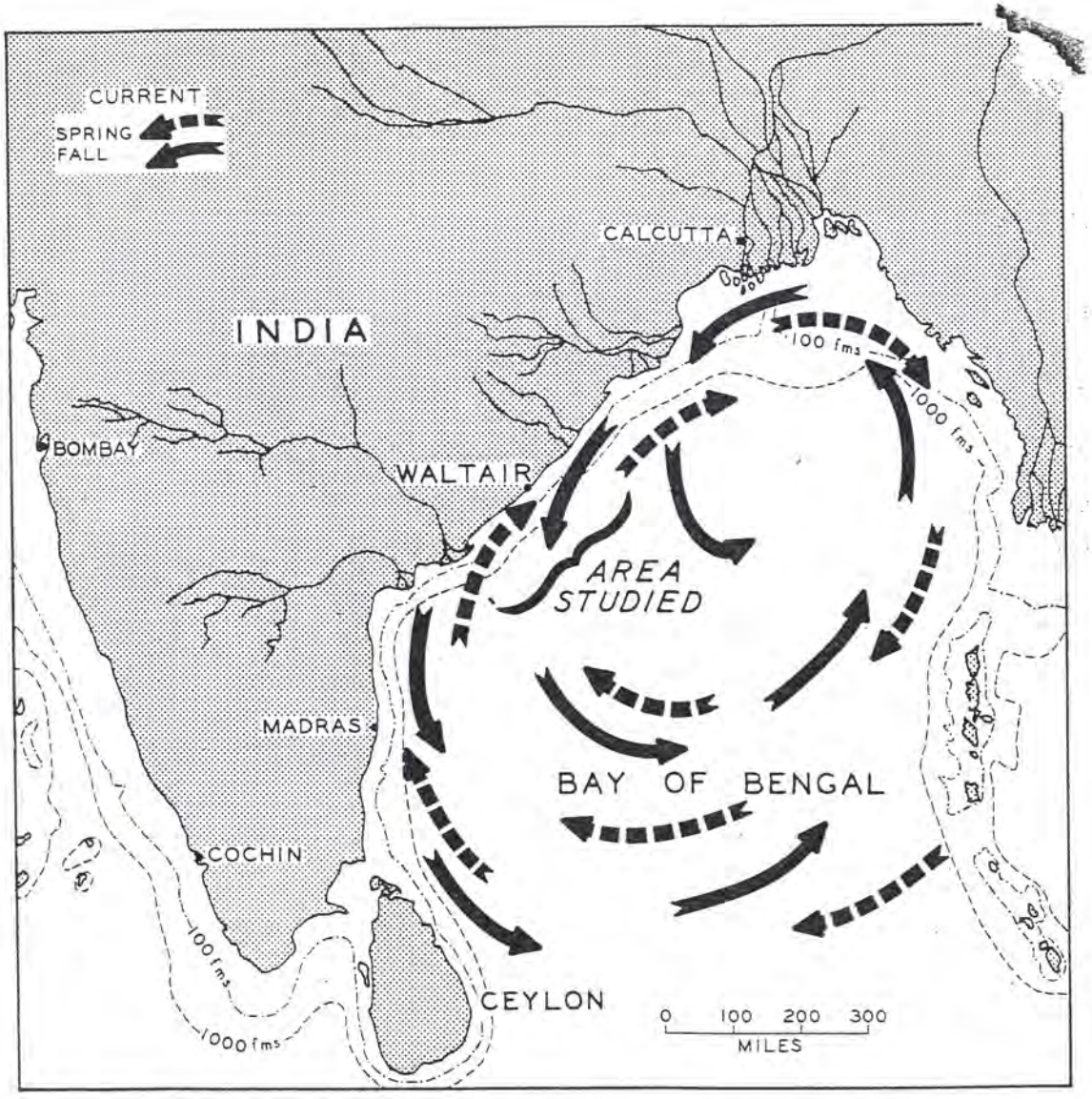


Fig. 3 : Surface circulation in Bay of Bengal, A.U. Memoirs in Oceanography, Series 49 & 52

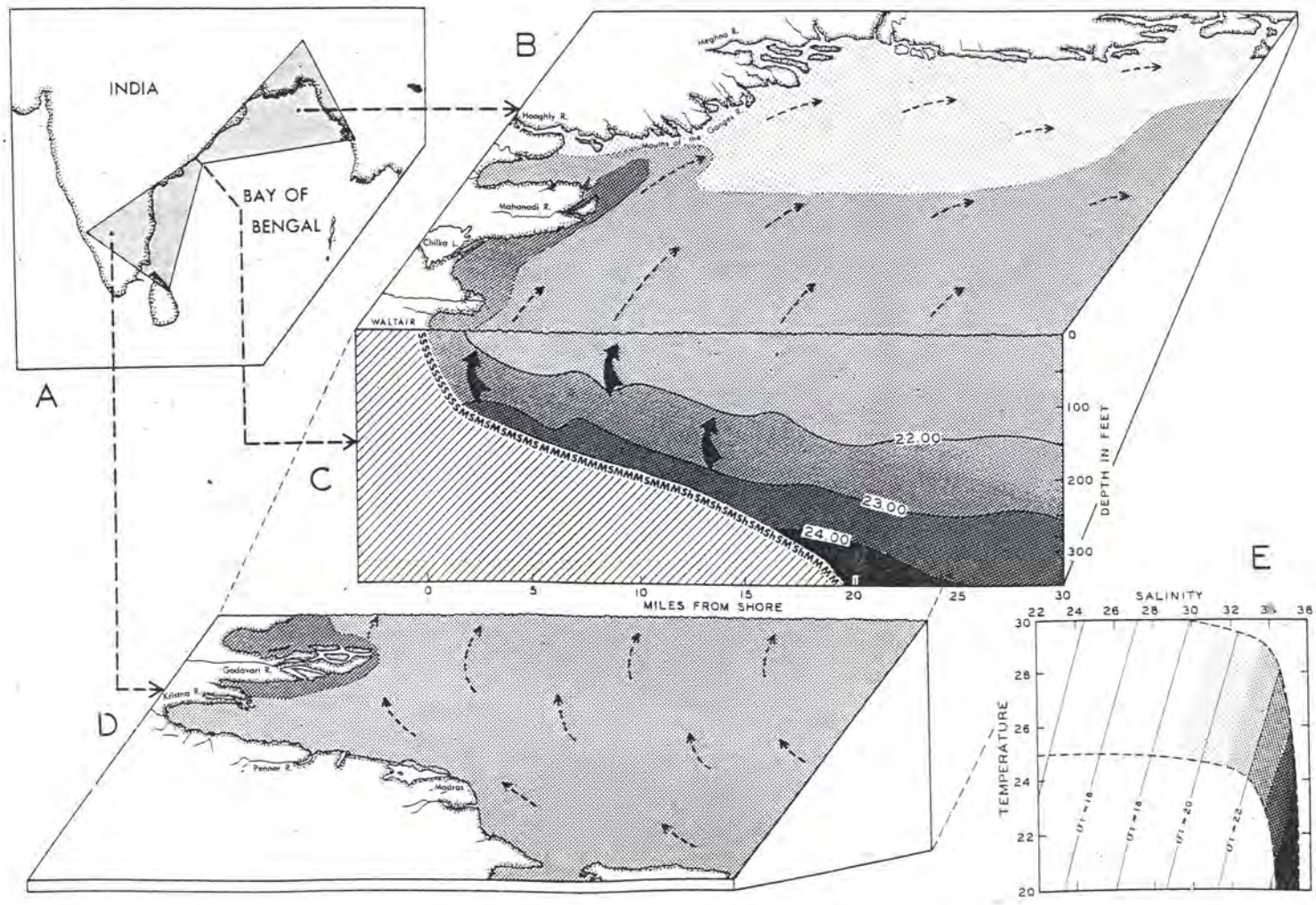


Fig. 4 : Water masses and Salinity distribution (upwelling, March) in Bay of Bengal off Visakhapatnam, A.U. Memoirs in Oceanography, Series 49 & 52

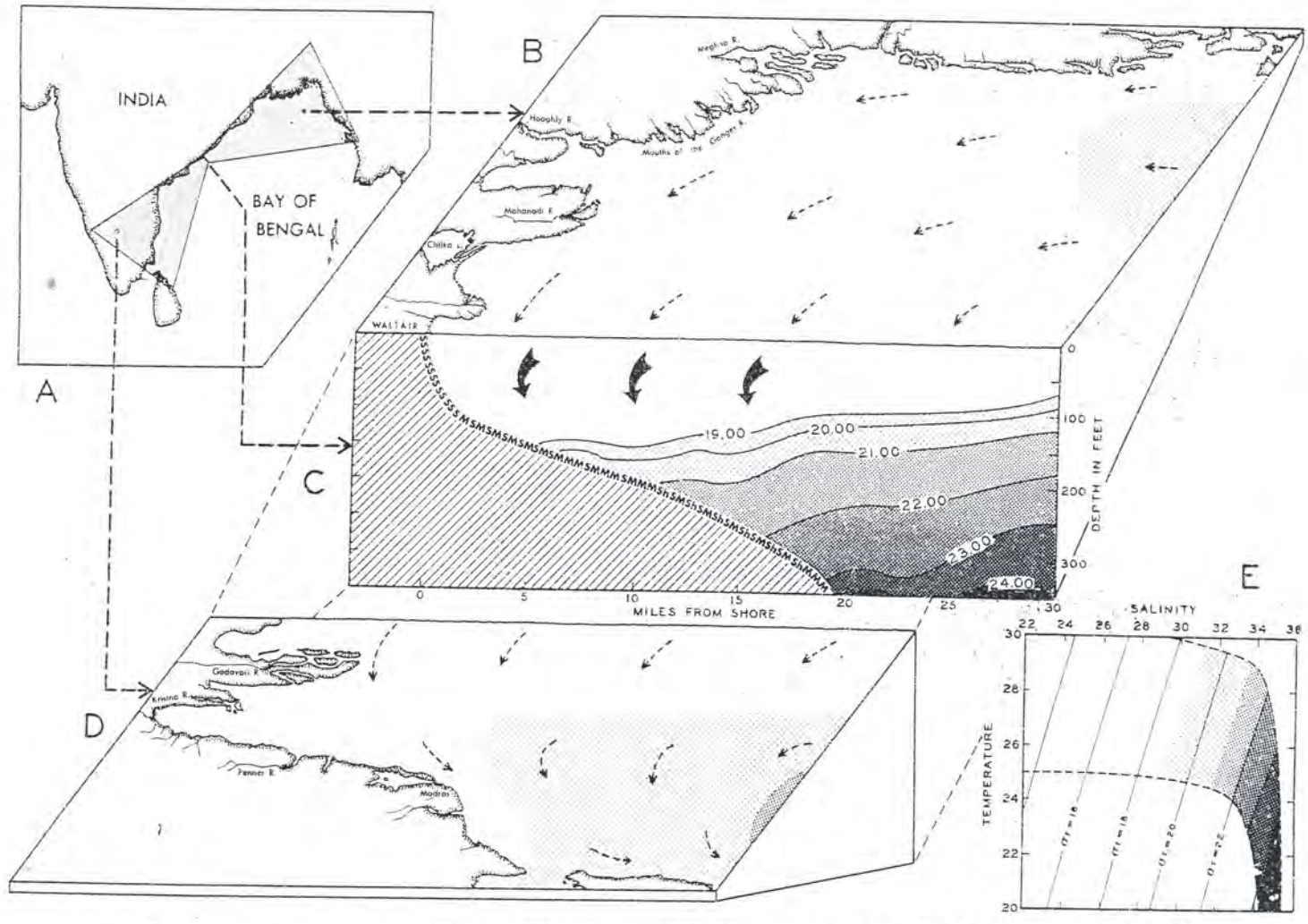


Fig. 5 : Water masses and Salinity distribution (sinking, October) in Bay of Bengal off Visakhapatnam, A.U. Memoirs in Oceanography, Series 49 & 52

hydromedusae, polychaete larvae, amphipods, mysids and fish eggs and larvae (Ganapati and Radha Krishna, 1958; Ganapati and Nagabhushanam, 1958; Ganapati and Shyama Sundari, 1962; Solman Raju, 1966; Ramana Murthy, 1972; Ramana Murthy and Ganapati, 1975). More recently, Somasekhar (1991) carried out a detailed investigation on the zooplankton of Lawson's Bay.

Investigations on phytoplankton consisted of quantitative distribution in relation to space and time and the prevailing hydrographic conditions. As many as 200 taxa were described which included a great variety of organisms belonging to Bacillariophyceae, Dinophyceae and Euglenophyceae that exhibited characteristic response patterns in relation to water quality and associated ocean phenomena. Primary productivity was measured for the first time employing labeled carbon and the data successfully used to estimate biological productivity (Ganapati and Subba Rao, 1957, 1958; Subba Rao, 1967, 1969).

Discoloration of coastal waters following *Noctiluca scintillans* swarm was observed during April, 1988 off Visakhapatnam. High velocity winds accompanied by intense upwelling and north ward flow were considered as probable reasons for convergence nearshore and aggregation of *Noctiluca* (Raman et al., unpublished). Primary productivity, photosynthetic efficiency, chlorophyll a and phaeopigments were investigated at 28 stations in the south-west Bay of Bengal during December 1986. It was found that surface productivity and chlorophyll values were relatively high in shelf waters than at other regions (Phani Prakash and Raman, 1990). Similarly, investigations on qualitative and quantitative composition of phytoplankton in surface waters at 57 stations in the north-west Bay of Bengal during March-April 1987, revealed altogether 109 species represented by blue-green algae, diatoms, and dinoflagellates. Among them, *Trichodesmium thiebautii*, *T. erythraeum*, *Nitzschia seriata*, *Rhizosolenia cylindrus*, *Thalassiothrix longissima*, *Dinophysis* sp., *Noctiluca scintillans* and *Ceratium* sp. constituted the most important species (> 76%). Based on Principal Component Analysis, it was possible to identify 5 assemblages in the study area each of that exhibited characteristic species of phytoplankton as determined by the prevailing hydrographic conditions (Phani Prakash and Raman, 1991).

Benthos :

These included a representative collection of littoral benthos from the continental shelf area along the East Coast of India during the 56 oceanographic cruises conducted onboard the Indian Navy mine-sweepers during the years 1952-'56. These investigations revealed existence of rich and varied life on the sea bottom in this region. Several new species were discovered among foraminiferans, polychaetes, crustaceans, molluscs and echinoderms (Ganapati and Satyavati, 1958; Ganapati and Sarojini, 1962; Ganapati and Lakshmana Rao, 1962; Radha Krishna, 1964; Radha Krishna and Ganapati, 1969).

In recent years (1986-88), a comprehensive investigation on macrobenthos from the littoral areas off Visakhapatnam (Department of Environment Report, 1989) was undertaken (Raman and Adiseshasai, 1989 and Adiseshasai, 1992) (Fig.6). The study carried out for a period of 2 years, showed altogether 201 species of benthic organisms belonging to 19 groups namely, Anthozoa, Polychaeta, Stomatopoda, Decapoda, Ostracoda, Cumacea, Isopoda, Amphipoda, Gastropoda, Bivalvia, Scaphopoda, Asteroidea, Ophiuroidea, Echinoidea, Holothuroidea, Sipunculida, Echiura, Brachiopoda and Cephalochordata (Plates 1-8). Polychaetes followed by bivalves, gastropods and echinoids were numerically the most dominant. Based on faunal distribution and abundance data, distinct species grouping namely, *Clypeaster-Nassarius-Charybdis-Oliva* community characterizing silty sediments; *Mactra-Macoma* community, the sandy areas and *Mactra-Charybdis* community in the transitional region were distinguished. The fauna exhibited characteristic response gradients in relation to sediment texture and distribution. At present, these studies are continued under Marine Living Resources related research for the EEZ of India.

Intertidal Ecology :

Pioneering work on the taxonomy and ecology of intertidal organisms of Waltair coast has been carried out for several years. These investigations which covered different facets of intertidal ecosystems dealt in great detail with population parameters such as faunal composition, abundance and species diversity. In addition, studies were also made on the biology and ecology of select species of organisms inhabiting the coast. The most comprehensive study made in this direction relates to the work on the interstitial fauna of the sandy beaches of Waltair coast . This study carried out for over 15 years revealed presence of myriad of species some of which unknown to science, belonging to Protozoa, Turbellaria, Gastrotricha, Kinorhyncha, Archiannelida, Ostracoda, Tardigrada, Mollusca, Echinodermata and many other groups (Ganapati and Chandrasekhara Rao, 1962; Chandrasekhara Rao, 1965; Chandrasekhara Rao and Ganapati, 1967a, 1967b, 1968a, 1968b). More recent studies on the interstitial fauna of sandy beaches at five selected locations along Visakhapatnam coast showed many more organisms. Turbellarians dominated the fauna followed by copepods (Sivaramasarma, 1988).

In early 70s, an important study was carried out on the phytal fauna of Visakhapatnam coast. Altogether 13 species seaweeds were examined. A total of 235 species of animals belonging to 19 taxonomic groups were identified. These faunules were described in terms of their composition, distribution and abundance as influenced by environmental factors namely, tidal level, morphology of the alga, sediment accumulation, surf action and such other physico-chemical variables (Sarma, 1972; Sarma and Ganapati, 1972). The highly interesting bivalved gastropod - a taxonomic link between Gastropoda and Bivalvia - unknown to Indian coasts

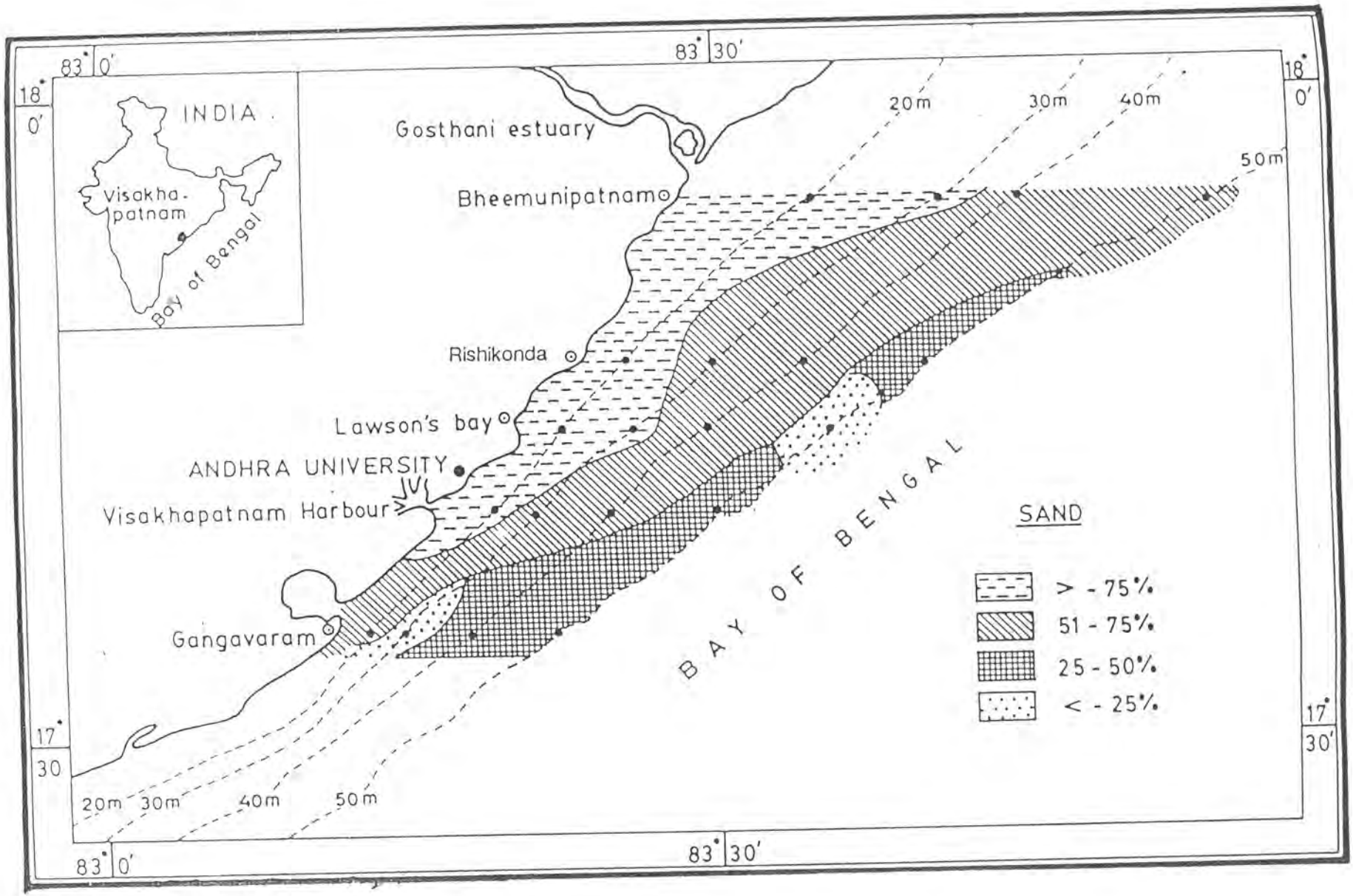
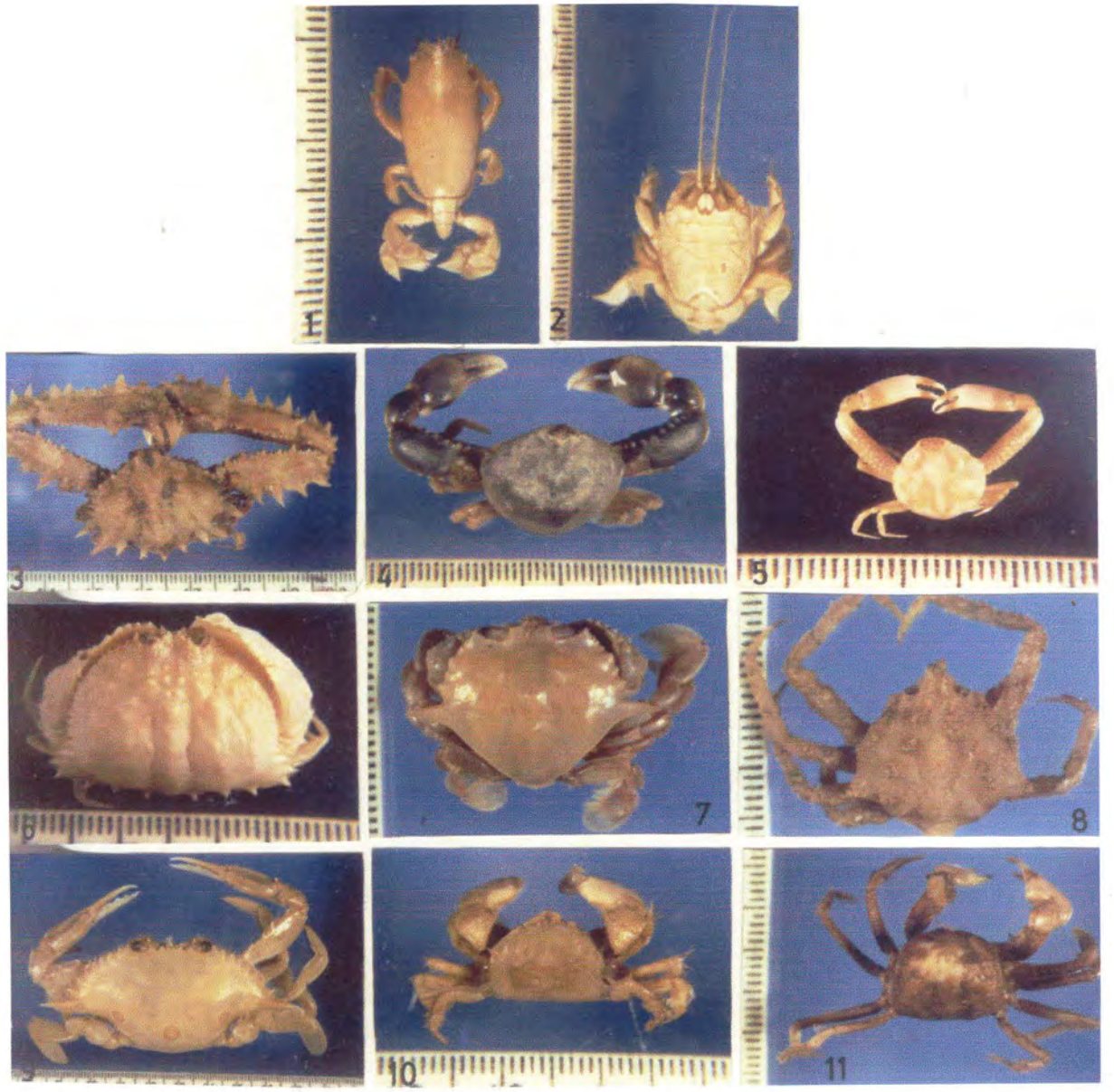


Fig.6 : Spatial distribution of sand (%) in the littoral sediments off Visakhapatnam.

Plate : 1

1. *Sphenopus arenacus* 2. *Heterocyathus aequicostatus* (Anthozoa); 3. *Aphroditid* 4. *Diopatra* sp. 5. *Lumbrineris* sp. (Polychaeta); 6. *Oratosquilla perpensa* 7. *Harpiosquilla annandalei* (Stomatopoda); 8. *Diogenes custos* 9. *Dardanus hessii* (Decapoda).

Plate : 2



1. *Raninoides serratifrons* 2. *Albunea symnista* 3. *Nursia* sp. 4. *Leucosia longiforns* 5. *L. haematostica* 6. *Calappa lophos* 7. *Matuta miersi* 8. *Lambrus prensor* 9. *Charybdis bimaculata* 10. *Heteropilumnus* 11. *Chasmocarcinops gelasimoides* (Decapoda)

Plate : 3

1. *Callistoma tranquebarica* 2. *Minola caste* 3. *Polinices melanostomus* 4. *P. tumidus* 5. *Sinum delesserti* 6. *Natica lineata* 7. *N. vitellus* 8. *Turritella columnaris* 9. *Strombus labiosus* (Gastropoda).

Plate : 4

1. *Distorsio reticulata* 2. *Bursa crumena* 3. *Nassaria nivea* 4. *N. variegatus* 5. *Ficus variegata* 6. *Murex tribulus* 7. *Babylonia spirata* 8. *Bullia traquebarica* 9. *Amalda ampla* 10. *Oliva vidua* (Gastropoda).

Plate : 5

1. *Oliva mutellina* 2. *Agaronia nubulosa* 3. *Marginella angustata* 4. *M. ventricosa*
5. *Scalptia scalariformis* 6. *Turricula tornata tornata* 7. *Lophiotoma indica*
8. *Gemmula speciosa* (Gastropoda).

Plate VI

1. *Brachytoma crenularis* 2. *Conus eburneus* 3. *C. aculeiformis* 4. *C. acutangelus* 5. *C. inscriptus* 6. *Conus* sp. 7. *Hastula strigilata* 8. *Terebra nebulosa* 9. *T. pretiosa* 9. *Architectonica perdix* (Gastropoda).

Plate : 7

1. *Scapharca pipula* 2. *Trachycardium asiaticum* 3. *Mactra mera* 4. *Tellina iridiscens* 5. *Macoma bruguieri* 6. *Mytilopsis sallei* 7. *Sunetta effosa* 8. *Bassina calophylla* 9. *Paphia undulata* 10. *Timoclea arakuna* (Bivalvia).

Plate : 8

1. *Astropecten velitaris* (Asteroidea); 2. *Amphioplus depressus* (Ophiuroidea); 3. *Clypeaster rarispinus*
4. *Echinodiscus auritus* 5. *Salmaciella dussumieri* (Echinoidea); 6. *Pseudocnus echinatus*
7. *Leptopentacta javanicus* 8. *Stolous baccalis* 9. *Cucumaria* sp.
10. *Actinocumis typicus* (Holothuroidea) 11. *Lingula* sp. (Brachiopoda)

was discovered (Ganapati and Sarma, 1972). Later, Radha Krishna (1985) made a detailed study on the phytal ciliates at select locations along Waltair coast and some 68 species were described.

There is a rich and varied bryozoan fauna at several foreshore localities along the northeast coast of India. At Visakhapatnam, abundant growth of bryozoa are seen in dense bands, measuring as much as 80 cm in width on the under and vertical surface of rocks. Detailed investigations were conducted on the quantitative aspects of bryozoan distribution and zone patterns in intertidal regions at selected stations at Visakhapatnam (Satyanarayana Rao, 1976; Satyanarayana Rao and Ganapati , 1986). The study revealed that Bryozoa are conspicuous faunules in lower midlittoral to infralittoral zones occupying considerable areas of protected and semi-protected rock surfaces. A luxuriant and distinctive "bryozoan band", consisting primarily of *Thalamoporella gothica var. indica, Hippopetraliella magna* and *Steganoporella buskii* was discovered and incorporated into a tripartite zone pattern (Fig. 7). The study, the first of its kind from tropical shores, clearly indicated the quantitative significance of this important but hitherto little investigated group. Other significant work on bryozoa was conducted recently by Viswanadham (1988) . The ancestrular characters and early astogony of six species of melacostegan Bryozoa (Ectoprocta) occurring along Visakhapatnam coast were studied (Satyanarayana Rao and Viswanadham, 1987).

Sunitha Rao and Rama Sarma (1988) carried out studies on the physico-chemical properties of water collected from the intertidal region at three places in Visakhapatnam. The findings showed that the region near coastal battery was more polluted relative to Palm Beach on account of discharge of wastewater from the harbour. Crevice inhabiting animals of the shingle beds at Palm Beach (Sunitha Rao, 1989) formed a brief investigation of their taxonomy .

Studies on marine benthic Ostracoda from selected marginal marine environments along the north Andhra coast are being continued (Annapurna, 1979). Several new species have been added and their ecology adequately described (Annapurna and Rama Sarma, 1985, 1986a, 1986b, 1986c, 1987a, 1987b, 1988a, 1988b) (Plates 9-10).

Among investigations on autecology, mention should be made of works on the limpet, *Cellana radiata* (Balaparameswara Rao, 1970); *Turbo intercoastalis* (Rama Sastry, 1971); sea urchin, *Stomopneustes variolaris* (Sastry, 1979); snails, *Clypeomorus* sp. (Manmadha Rao 1978); *Euchelus asper* (Kamala, 1984); *Morula granulata* (Uma Devi, 1984); *Thais* (Rajyalakshmi Bhanu, 1980), *Bullia vittata* (Azgar Ali, 1984); physiology of the barnacle *Balanus* (Prasada Rao, 1966) oligochaetes *Pontodrilus bermudensis* (Subba Rao, 1975) and cerithids in general (Prabhakara Rao, 1981). Balasri (1998) carried out a study on the sandy shore fauna of this coast (Fig. 8)

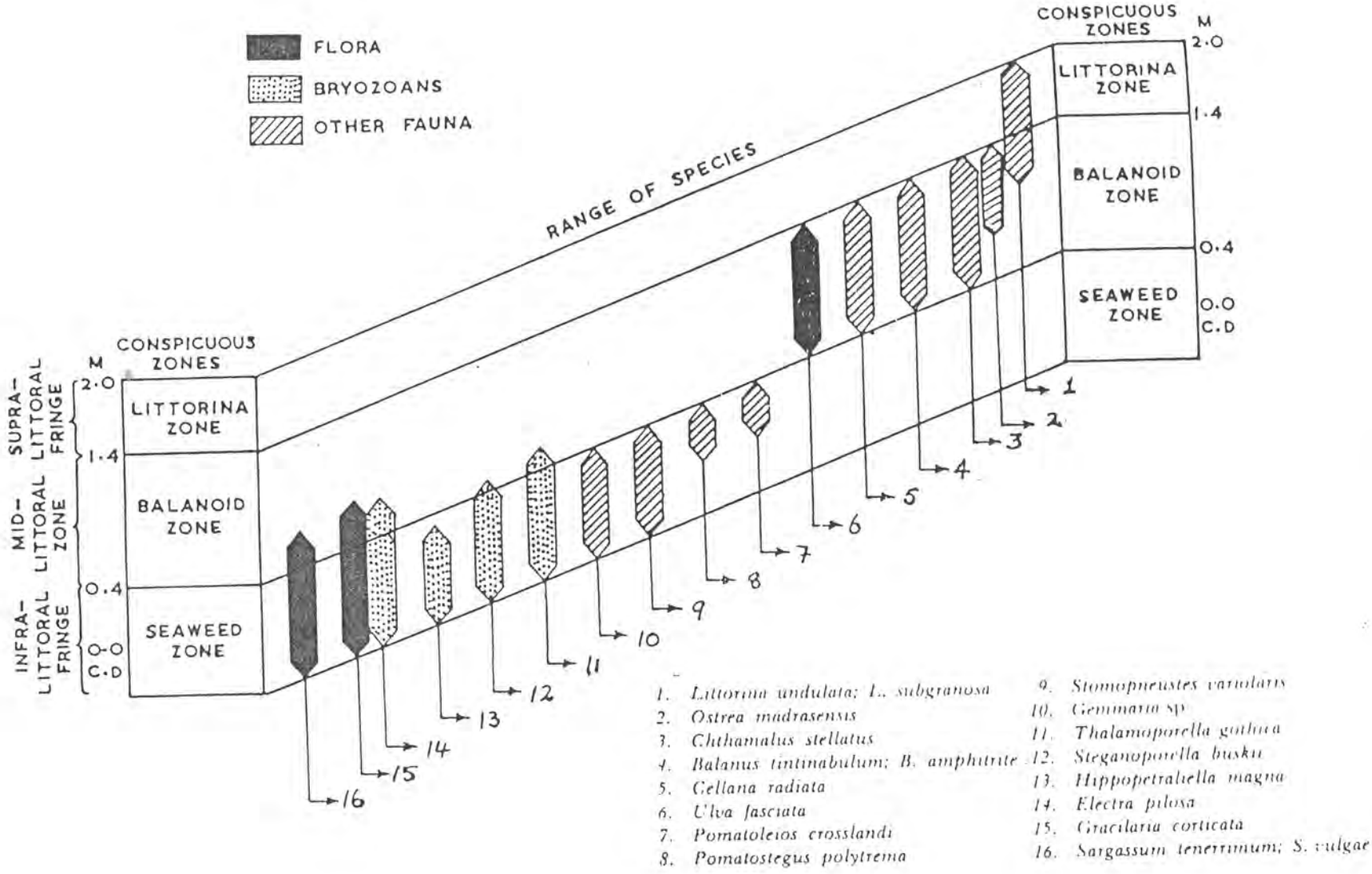
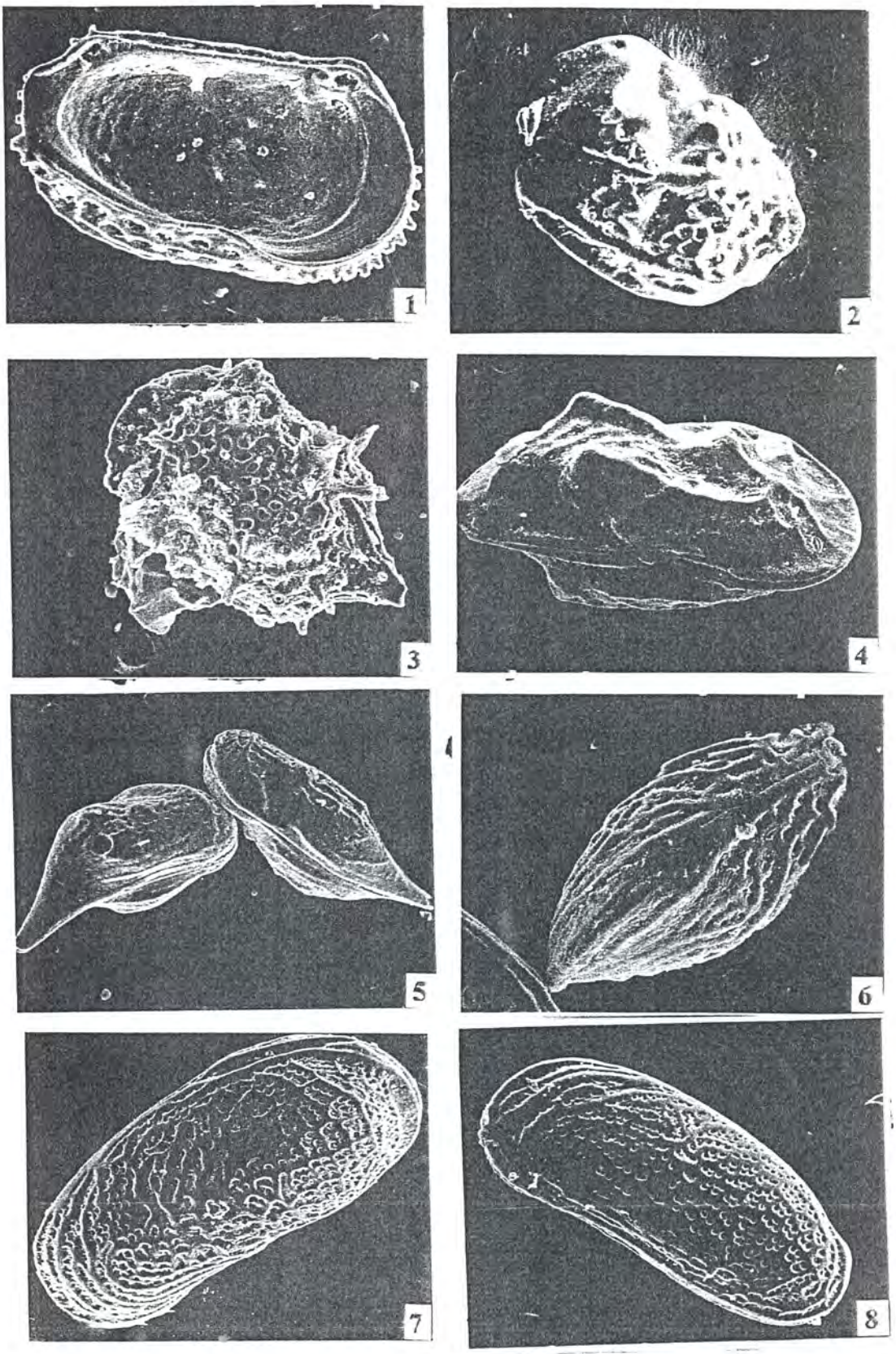
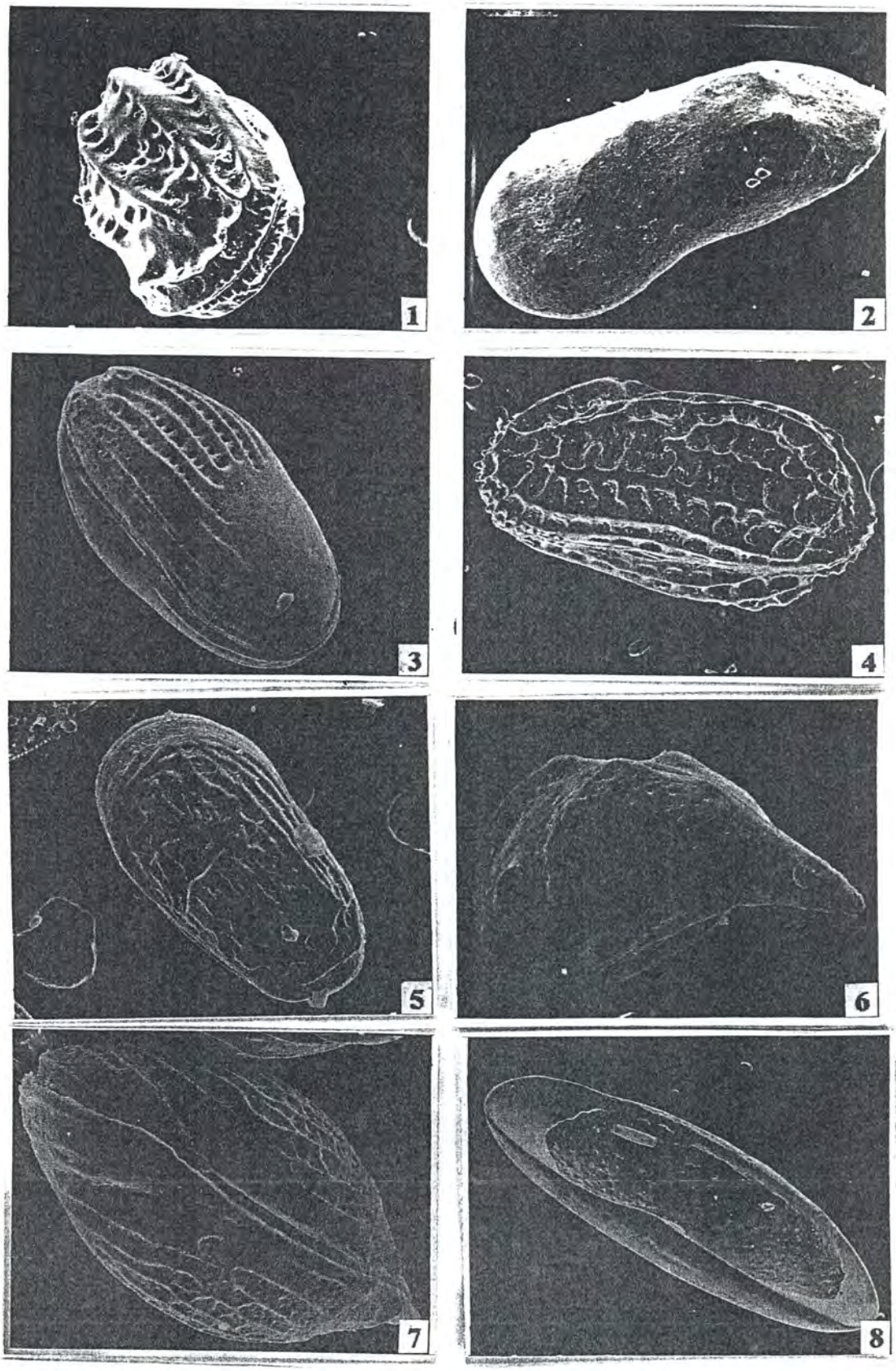


Fig. 7 Bryozoan zones at Visakhapatnam



New species of benthic ostracoda: 1. *Cythere dentaculatum*: 2. *Neomonoceratina indica*: 3. *N.spinosa*: 4. *Palmenella mckenzii*: 5. *Eopaijenborchella subcaudatum*: 6.*Tanella estuarii*: 7. *T.indica*: 8. *T.kingmaii*.

Plate 10



New species of benthic ostracoda: 1. *Costa quadricostatum*; 2. *Puriana krishnai*; 3. *Campylocythere gopalai*; 4. *Bradleya ganapatii*; 5. *Atjehella multicostatum*; 6. *Paijenborchellina caudatum*; 7. *P.reticulatum*; 8. *Phlyctenophora indica*;

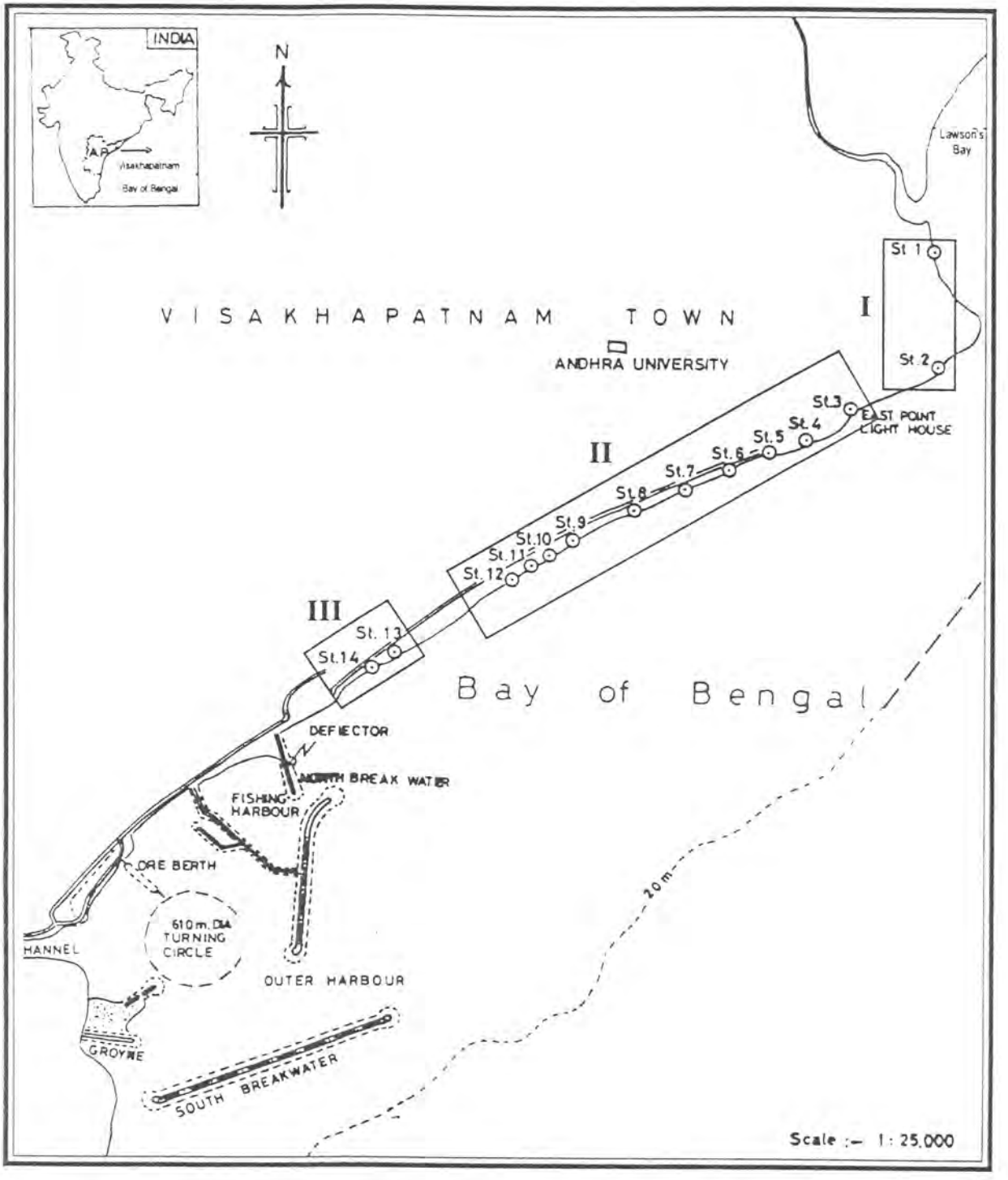


Fig. 3 Visakhapatnam Coast showing station locations

Marine Biodeterioration :

Work on marine biodeterioration as a result of fouling and boring organisms in Visakhapatnam harbour has been in progress for over thirty years now. Over one hundred species of marine fouling organisms and 22 species of woodborers (teredinids, pholadids and crustaceans) were recorded from Visakhapatnam harbour and its vicinity. The anatomy, general biology and physiology of the wood borer, *Martesia striata*, were studied in great detail as also some aspects of ecology of other shipworms, *Teredo* and *Bankia* (Ganapati and Nagabhushnam, 1955a, 1955b; Nagabhushnam, 1956, 1958). Settlement of biofouling organisms in relation to colour, texture, angle of immersion and current were investigated and their seasonal abundance recorded (Ganapati et. al., 1957, 1958; Ganapati et al 1971; Satyanarayana Rao and Ganapati, 1978; Balaji, 1990; Raju et al., 1988). Natural durability of several species of Indian timber and their endurance after preservative treatment also constituted an important part of the investigation (Satyanarayana Rao, 1986). These investigations were carried out in collaboration with the Wood Preservation Center (Marine) of the Institute of Wood Science and Technology located in the Zoology Department till recently.

Perhaps the outstanding contribution made in this direction relates to work on the success and spread of the exotic fouling bivalve, *Mytilopsis sallei* (Recluz), in Indian waters (Ganapati and Satyanarayana Rao, 1968; Satyanarayana Rao et al., 1989). *M. sallei* was introduced to Indian seas in late 1960's presumably through shipfouling. Since then, the species had met with an astounding success, gaining almost monospecific dominance in fouling communities in certain localities in Visakhapatnam harbour. The environmental conditions in the harbour appeared very favourable to the species where it could grow enormously even up to 100 kg/m2/year. The species has since become a serious pest to underwater structures in the harbour.

A study on the accumulation of copper by *Mytilopsis* (Satyanarayana Rao and Balaji, 1990) at concentrations ranging from 120- 1080 mg/l at different time intervals, 24, 48, 72 and 96 hrs. indicated that the bivalve is capable of accumulating high concentrations of copper ranging from 50-72 mg/g; 69-105 mg/g and 77-113 mg/g at the above periods of exposure respectively. Since *M. sallei* is a fouling species, the nature of copper accumulation in the animal could prove useful for formulating antifouling measures as copper is extensively used in antifouling paints. Investigations on the recruitment of *M. sallei* on metallic/non-metallic surfaces in Visakhapatnam harbour (Raju et al., 1988) showed that it was heaviest on asbestos followed by timber and very light on copper and brass. Balaji (1990) carried out a detailed investigation on biofouling at two ports in Andhra Pradesh. The areas selected included Visakhapatnam Harbour, a major port gaining increasing importance which had witnessed considerable hydrological changes in the recent past. The other region

was Godavari estuary near Kakinada 220 km south of Visakhapatnam. Satyanarayana Rao and Balaji (1988) presented a comparison with other Indian ports.

Observations on sublittoral fauna inhabiting the piers at three selected stations in Visakhapatnam harbour, subjected to pollution, revealed presence of a large number of small sized individuals mainly nauplii, polychaete larvae, nematodes, and copepods. Overall, *Polydora ciliata, Capitella capitata* (Polychaeta), *Mytilopsis sallei* (Bivalvia) *Sphaeroma terebrans, Balanus amphitrite* (Crustacea) were the dominant organisms. There was considerable heterogeneity spatially in the composition of species inhabiting these structures attributable to ambient water quality. Near sewage source where the environmental conditions were relatively unstable (Salinity 14.7-34.7 ppt; dissolved oxygen 0-13 mg/l), there was a preponderance of nematodes (76%). On the basis of copepods: nematode ratio (1:60 to 1:2), it was possible to distinguish the effects of pollution on these organisms (Jayaprada, 1991).

Fishery Biology :

Research in Ichthyology and fishery science began in 1954. Since then, a number of studies were carried out on fish taxonomy, biology of commercially important fishes, osteology and phylogeny, haematology, histology and histochemistry, pollution effects on fish populations, catfish fishery, aquaculture and trawl fisheries (Ganapati and Srinivasa Rao, 1957, 1959, 1962; Srinivasa Rao and Ganapati, 1977; Srinivasa Rao, 1975, 1985, 1987; Srinivasa Rao & Janardhana Rao, 1979; Janardhana Rao, 1981; Manikyala Rao, 1981; Manikyala Rao & Srinivasa Rao, 1981, 1983, 1986; Murthy, 1982; Usha Rani, 1981, Rambhaskar, 1985; Lakshmi, 1986; Lakshmi and Srinivasa Rao, 1989; Rambhaskar and Srinivasa Rao, 1985, 1987, 1989; Rama Murthy, 1989; Durga Prasad, et al. 1989; Durga Prasad, 1990; Panduranga Rao, 1990; Sivani, 1994; Srinivasa Rao and Lakshmi, 1984, 1986, 1988, 1989, 1999; Padmaja, 1998; Paul Pandian, 1999). Sudarsan (1983) made a detailed investigation on the demersal fishery of Visakhapatnam coast in relation to a number of abiotic and biotic factors. The study that is based on many years of data took into account possible future variations in the fishery along this area.

In 1998, the Department of Ocean Development, New Delhi funded an important project on A New Line of Research - *Development of Predictive Models for Marine Fisheries for north coastal Andhra Pradesh.* A predictive ecosystem research made a pluralistic approach. Retrospective studies reveal the initial cause of ongoing ecological change. Expected environmental changes often have to predict ecological events.

A shift of emphasis from retrospective studies to predictive/ forecasting models is not only a natural sequels but also a designed and pelagic fisheries of the North

Andhra Coast are being subjected to intensive analysis using the latest methodologies such as Artificial Neural Nets (ANN) using back propagation, *Marquardt* and BFGS algorithms.

The inputs for modeling being developed at the Marine Biological Laboratory, Department of Zoology, Andhra University are the data on catch and effort in different seasons and months on demersal and pelagic fisheries in general and specific fisheries such as shell fish, mackerel, sardine, ribbon fish etc. and other net and oceanographic parameters such as winds, currents, salinity and temperature as well as biological aspects such as length, frequency, growth, maturation and spawning, recruitment, natural and fishing, mortality etc. Therefore, a new line of multidisciplinary research with projected outputs which have more or less immediate application in the filed has been initiated. This pertains to the development of fishery forecast capabilities by adapting an ecosystem approach.

In the Indian context, barring a few tentative efforts at prediction such as abundant and migration of prawns and lobsters there have been practically no exercise in this region. The method involves two approaches:

a. Classical approach of analysis of historical data to establish co-relations and empirical relationships, which would be, made use of for forecasting purposes.
b. Collection of simultaneous field data on parameters of crucial relevance to recruitment, growth, mortality etc., of fish and shell fish.

These approaches are first being adopted in respect of demersal fisheries in general and the most important pelagic fisheries namely the Indian mackerel *Rastrelliger kanagurta* and the oil sardine *Sardinella logiceps*. Interim results of analysis are indicating some exiting possibilities of reliable modals for prediction. However, further validation is essential before any catagoric statements could be made.

Estuarine Studies :

Professor Ganapati's work on the hydrobiological and faunistic survey of the Godavari estuarine system (Fig. 9) remains one of the most comprehensive works carried out so far on the Indian estuaries (ICAR Report, 1964). During this investigation, detailed studies on the hydrographical conditions of the estuary and the nearby Kakinada Bay have been made in relation to diverse environmental variables, particularly freshwater inflow. Hydrographical studies indicated unique circulation patterns and changes in the physico-chemical parameters as determined by Annual River flow and tides (Ganapati and Ramasarma, 1965; Ramasarma, 1966,1975; Rama Sarma and Ganapati, 1968,1971, 1972).

Zooplankton investigations in the estuary consisted of qualitative and quantitative enumeration of organisms in relation to the prevailing hydrographical

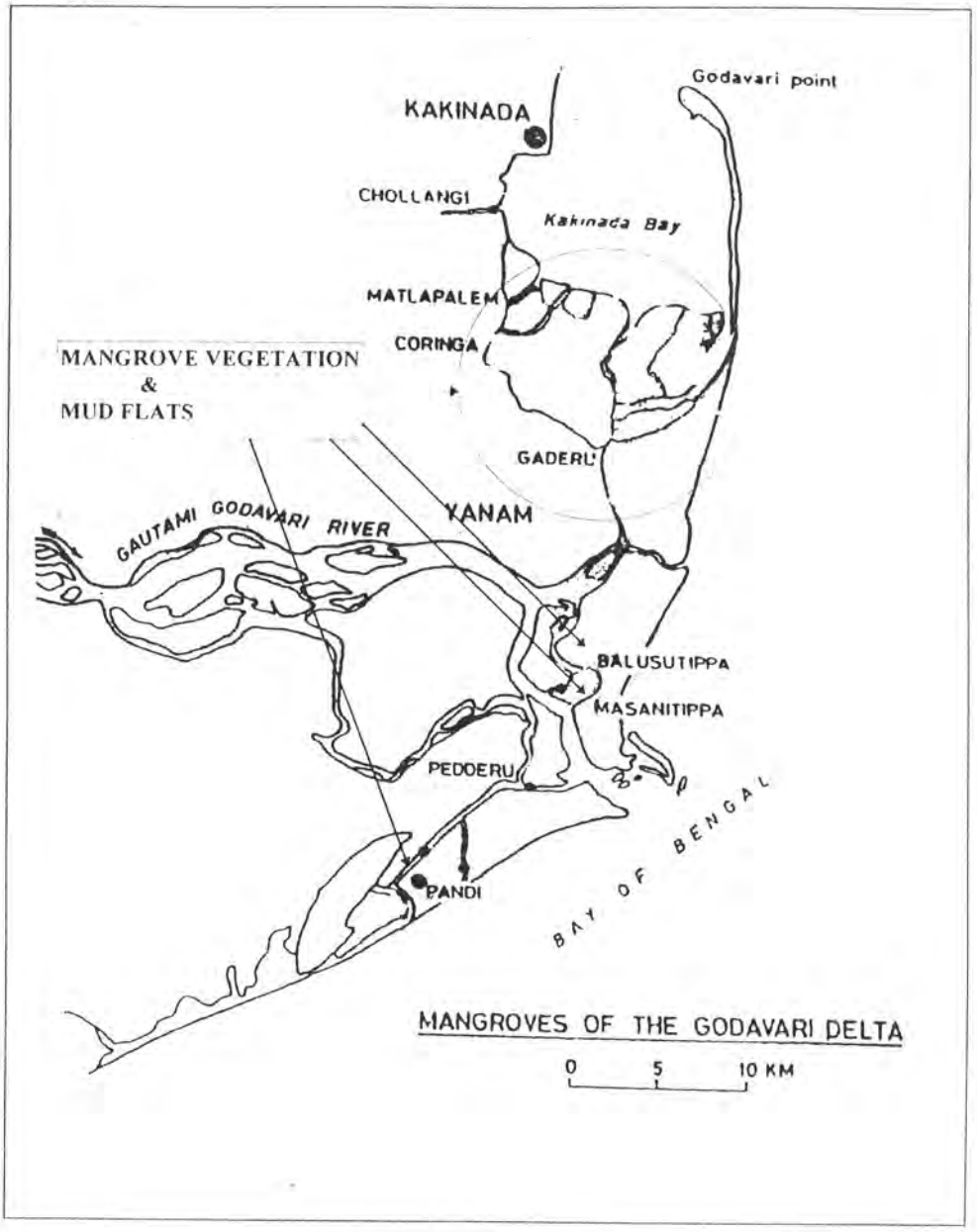


Fig. 9. Map of Gautami-Godavari Delta with Gautami-Godavari river and it's branches, south of Kakinada town in the state of Andhra Pradesh. Gaderu, Coringa canals together with Matlapalem, Chollangi creeks are shown. Mangrove vegetation and mudflats occurrence in the area is approximately indicated by a circle and lines with arrow marks. Mangroves occur far south up to Pandi.

conditions and changes on account of seasonal inflows. Essentially, two important components were noticed among the fauna namely, typically estuarine forms and emigrants from the sea (Chandra Mohan, 1964).

A systematic study of the bottom fauna with special reference to polychaetes, molluscs and echinoderms in the lower reaches in Godavari estuary and Kakinada Bay was made. Overall, the fauna consisted of many diverse species of organisms that could be divided into those inhabiting the tidal mud flats, fauna of the mangroves and the estuary proper. In Kakinada Bay, altogether three distinct benthic zones could be distinguished namely, rocky, sandy and muddy zones. It was noticed that the organisms exhibited characteristic responses as determined by sediment texture, organic matter, ambient salinity and currents. The study also brought to light presence of characteristic assemblages of fauna in the estuary and Kakinada Bay (Radha Krishna, 1964; Radha Krishna and Ganapati, 1969).

Other important investigations carried out simultaneously related to the fishery of the estuary. The prawn fauna of Godavari estuary has been found to be extremely rich with over 25 species of Palaemonids and Penaeids. During the investigation, detailed studies were made on the life histories, ecology and biology of these species in relation to the changing hydrographical conditions in the estuary (Ganapati and Subrahmanyam, 1964; Subrahmanyam, 1966; Subrahmanyam and Ganapati, 1971). Studies were also conducted on the fin-fishery in the estuary (Visweswara Rao, 1968) and the clupeoids in particular (Babu Rao, 1967). Perhaps, an important study after the ICAR Project on Godavari estuary relates to the work carried out by (Srinivasa Rao 1979, Srinivasa Rao and Ramasarma, 1980, 1981a, 1981b; Ramasarma and Srinivas Rao, 1981) on benthic polychaetes. The study conducted for a period of two years yielded invaluable information on the polychaete assemblage patterns in the estuary.

A comprehensive survey on pre-pollution status of Vashista Godavari estuary was undertaken in order to assess the possible impact of pollution following exploration of oil in its basin (Sai Sastry, 1987; Sai Sastry and Chandra Mohan, 1990). Baseline data for various physico-chemical parameters were obtained. The investigations showed that the influence of seawater in the estuary could be felt up to a distance of 40 km from the confluence towards the upper reaches. In the estuary, the lower reaches were more turbid than the middle and upper regions. Often there was supersaturating oxygen. Inorganic phosphate was comparatively low than nitrite. There was sufficient silicate even during non-flood period. Information on the zooplankton of the estuary revealed altogether 19 species of hydromedusae, 3 species each of scyphomedusae, siphonophores and ctenophores mostly in the lower and middle reaches in the estuary. 23 of the 28 species recorded were euryhaline marine forms and 15 were first reports from this area. Coelenterate

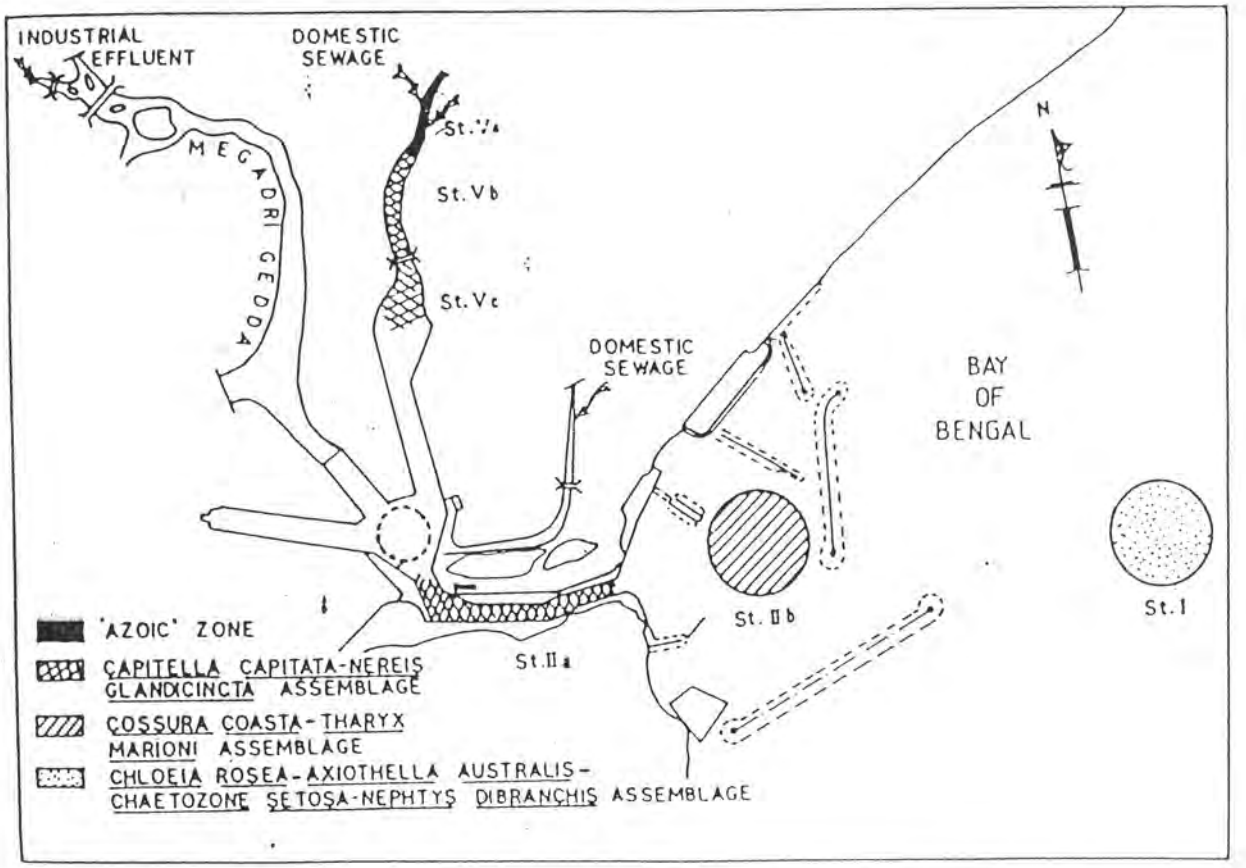


Fig. 10 : Benthic polychaete assemblages in Visakhapatnam harbour

diversity in general increased with increasing salinity (Sai Sastry and Chandra Mohan, 1989) .

Kameswara Rao (1990) carried out studies on some aspects of water quality and taxonomy of Foraminifera in the backwater regions of Machilipatnam. During the study, attempts were made to delineate temporal changes in the abundance of Foraminifer population and relate them to sediment factors such as organic matter.

Nearer Visakhapatnam, Vishnuswarup (1987) made a brief survey on the hydrography and zooplankton of Gosthani estuary. Other contemporary works include those of Syada Rao (1981) on Polychaetes and Sriramamurthy (1983) on benthos of Champavathi backwaters.

Probably the most significant investigation on Gosthani estuary carried out during recent times consisted of a detailed study on the hydrography and meiobenthos of that area (Sunitha Rao, 1990). During the study (1986-'88), water samples were collected from four selected locations in the estuary for temperature, salinity, dissolved oxygen, nitrite, nitrate and silicate. There were pronounced gradients in salinity the overall range being between 0.2 to 39.12‰ The sediments were predominantly sandy and supported rich populations of nematodes, harpacticoids, foraminiferans, ostracods and molluscs in the order of their abundance (Sunitha Rao and Ramasarma, 1990).

Pollution Ecology :

Visakhapatnam harbour, a semi enclosed water body on the east coast of India (Fig. 10), underwent massive changes following effects due to recent industrialization and urbanization. Studies carried out during the last 25 years in the harbour showed marked changes in the physico-chemical and biological characteristics attributable to pollution load and stagnation of waters. Over the years, the harbour has become highly eutrophic on account of an abnormal increase in the concentrations of inorganic nitrogen and phosphorus caused by the discharge of city sewage and fertilizer factory effluents. Frequent outbursts of phytoplankton, dominated by a few species characterized the harbour waters. In the interior channels, mass fish kills have become commoner following depletion of dissolved oxygen which brought in its wake other attendant evils (Ganapati and Raman, 1973; 1976a, 1976b; 1979; Raman, 1980; Raman and Ganapati, 1983, 1986a, 1986b; Raman, 1995).

Benthic polychaete association patterns in the harbour closely corresponded to gradients in water quality. Four ecological zones could be distinguished. At the sewage outfall, where the environmental conditions were most severe, the bottom was devoid of any macroscopic life (dead zone). At the adjacent locality with less severe pollution (polluted zone), only pollution tolerant worms (*Capitella - Nereis assemblage*) dominated. In the outer harbour area (marginal zone) characterized by

improved water quality, *Cossura coasta* and *Tharyx marioni* occurred in large numbers. In the unaffected open sea location, the conventional marine macrofauna prevailed (Raman and Ganapati, 1986a).

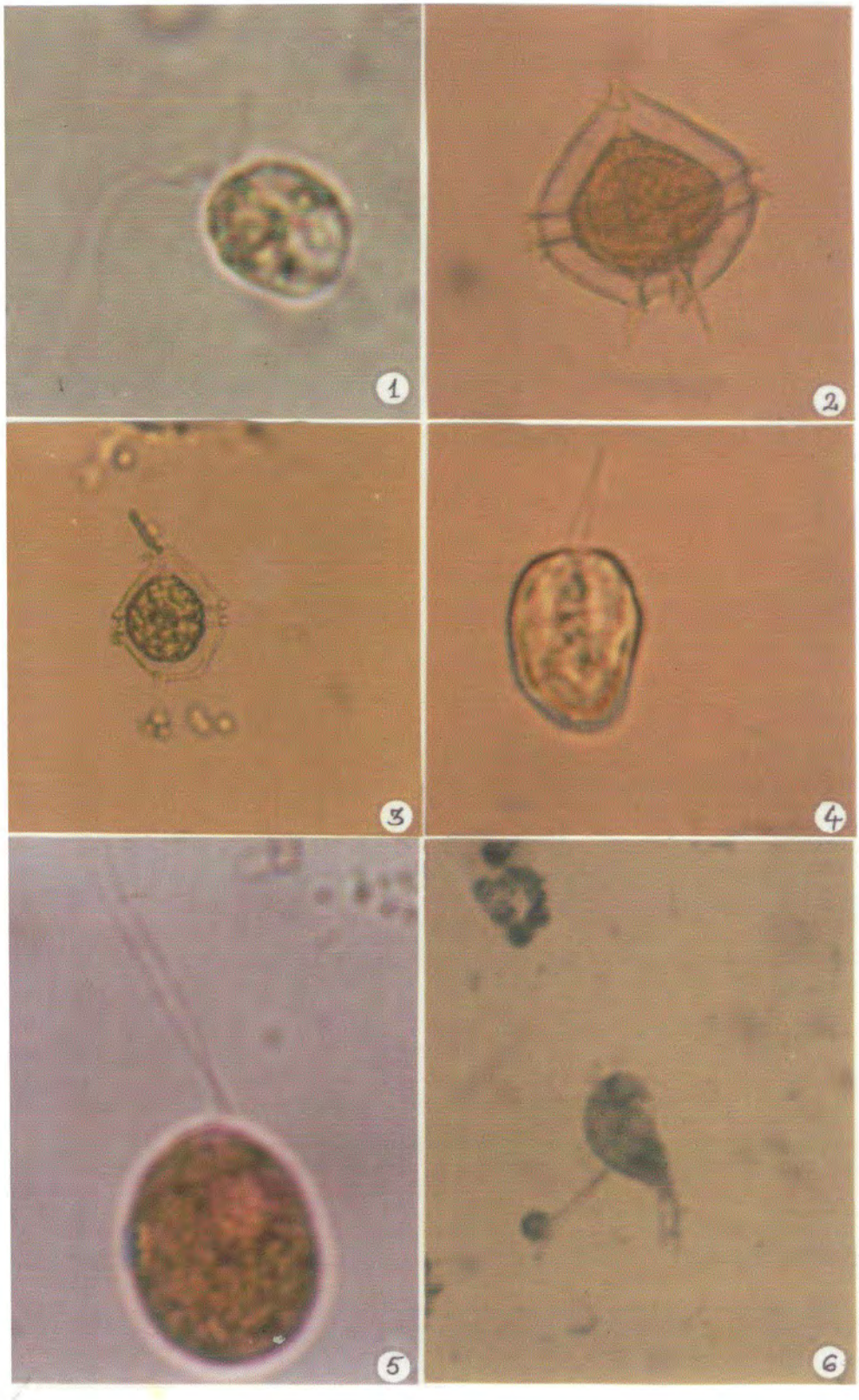
The harbour are characterised by abnormally high concentrations of nutrients, poor transparency, fluctuating salinity, high B.O.D. and highly varying dissolved oxygen in contrast to near normality at the open sea station. High inputs of industrial and domestic wastes containing phosphorus and nitrogen coupled with sluggish circulation caused eutrophication of waters in the harbour (Raman and Ganapati, 1986b) .

A one-year study (April, 1985 - March, 1986) on water quality and macrobenthic organisms at two stations (Vb and Vc) in the North Channel in the harbour revealed appreciable changes since 1976 survey. For instance, ambient salinity decreased to nearly 3-4‰ indicating greater dilution through sewage inputs and dissolved oxygen from 6.3 to 4.4 mg/l. At st. Vc data on inorganic nutrients showed that reducing conditions prevailed attributable to pollution increase. Sediment organic carbon registered a marked raise over earlier times. Faunistically, certain species of worms namely, *Capitella capitata* and *Nereis glandicincta*, which once occurred in large numbers had almost disappeared now. At present, these are replaced by a tubificid worm, *Monopylephorus* sp., known for its tolerance to extreme environmental conditions (Bismillah, 1986).

Studies on phytoplankton in the harbour (Phani Prakash, 1989) revealed a total of 115 species of phytoplankton belonging to 52 genera and 23 families. There were diatoms, dinoflagellates, phytoflagellates, euglenoids and blue-green algae. In general, phytoplankton abundance was markedly high in the harbour subject to pollution, than unaffected open sea location, the relative proportion of which decreased in the direction of the sea as water quality improved . While phytoplankton density decreased along the gradation of pollution, species diversity increased. The findings revealed a close approximation between water quality and phytoplankton composition and abundance . For instance at st. Vc, close to the outfall, the nannoflagellates, *Tetraselmis* sp. and *Dicrateria* sp. were the characteristic forms. At the downstream location (St. IIa), the diatom, *Skeletonema costatum* and the flagellate, *Cryptomonas* sp., were important. Further down (St. IIb) the principal components were *Thalassiosira pseudonana* and *Chaetoceros diversus*. At the unaffected open sea condition (St. I), marine forms such as *T. subtilis, C. socialis* and *Asterionella japonica* existed (Raman and Phani Prakash, 1989a, 1989b).

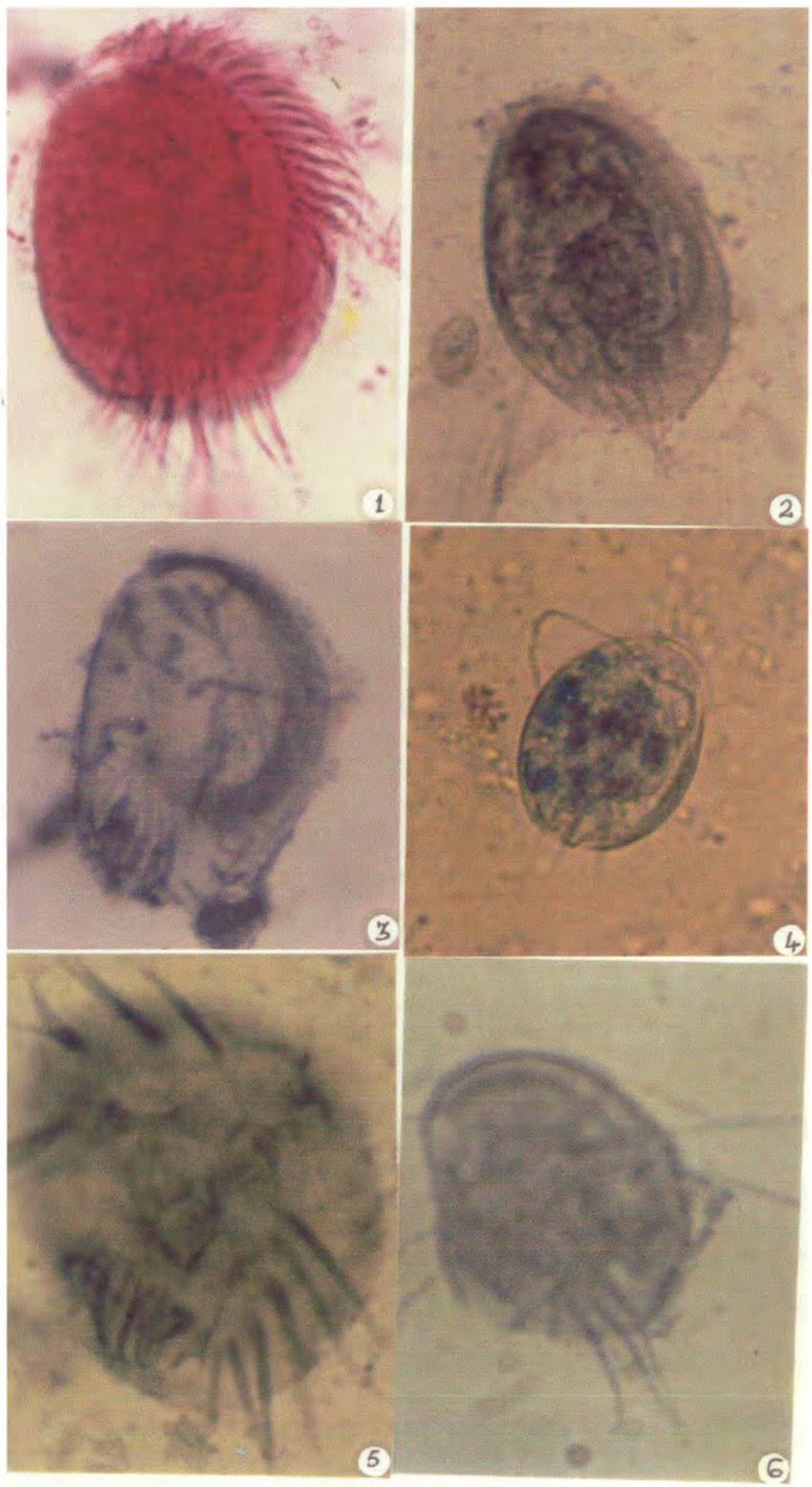
More recently (1993-'96), these investigations were also extended to the planktonic protozoa (Plates 11-12) in relation to pollution in that area. Altogether 18 species of flagellates and 59 species of ciliates were identified that showed distinct spatial and temporal variations in their distribution. Characteristic assemblages of polysaprobic species, represented by *Dunaliella* sp., *Monas* sp. and *Tetrahymena*

Plate : 11



Biologically Important Species (BIS) of flagellates encountered during the study
1. *Spumella* sp. 2 & 3. *Peridinium granii* 4. *Chromulina* sp.
5. *Dunaliella* sp. 6. *Dinematomonas littorale*

Plate : 12



(BIS), Ciliates, Group III 'Transient species' :
1 - 3. *Euplotes charon* (Stained with Eosin, Ehrlich's haematoxylin, Nigrosin)
4 & 5. *Aspidisca costata* (stained with Crystal violet, Nigrosin)
6. *A. lynceus* (stained with Nigrosin)

pyriformis, known for their tolerance to pollution were identified in the north arm in Visakhapatnam harbour subject to a high degree of organic sewage. Downstream, in the entrance channel, the assemblage consisted of pollution sensitive species such as *Lagynophrya* sp. and *Heliophrya* sp. (Oligosaprobic in nature). During the study, it was found that the protozoans exhibited two types of succession one initiated by bacterial bloom and the other by autotrophs. It was noticed that a bacterial bloom was usually followed by mixotrophs (*Chlorogonium* sp., 3120 cells/ml) and carnivores (*Prorodon* sp., 900 cells/ml; *Euplotes* sp., 200 cells/ml) while autotrophs were succeeded by grazers (*Strobilidium* conicum, 2187 cells/ml) and carnivores (*Prorodon* sp., 1200 cells/ml; *Euplotes* sp., 1058 cells/ml). Overall, the ambient water quality in that area was found to be responsible for the observed findings (Kalavati et al., 1996; Ratna Bharati, 1992, 1997; Ratna Bharati et al., 1999a, 1999b).

Another important study conducted during this period (1993-'96) is an investigation on the benthic microalgae in relation to pollution in the harbour area. As many as 90 species belonging to 53 genera were identified . The studies have revealed a preponderance of Cyanophyceans at st. VIa located near the southern lighter channel and st. Vc in the north arm, where the incidence of pollution is relatively high (Jayaprada, 1997).

Chilka Lagoon - A case study (1987-'97) :

Studies on the hydrography and phytoplankton (Satyanarayana, 1988; Raman et al., 1990) of Chilka Lake, a brackishwater lagoon on the east coast of India included investigations on water quality and qualitative and quantitative distribution of phytoplankton at 100 predetermined locations (Fig.11) in relation to diverse environmental conditions. Based on the salinity and phytoplankton distribution, the lagoon could be divided into five zones namely, Zone I a- mesohaline (15.1 - 10.9‰); Zone II and Zone V b-mesohaline (10.0-0.55‰) Zone III a - oligohaline (5.0 - 3.0‰) and Zone IV b-oligohaline (3.00 - 0.55‰). Appreciable differences existed in the nature of conditions at these zones. For instance, there was a steady decrease in the overall depth from 1.9 m in Zone I to 0.9 in Zone IV in the north evidently due to heavy siltation caused by river inflow in that region. Similarly, salinity varied from (average) 13.14‰ in Zone I to 1.31‰ in Zone IV; dissolved oxygen from 5.3 to 16.9 mg/l in Zone I; 2.0-8.3 in Zone II, 6.0-8.2 in Zone III, 6.3-12.6 in Zone IV to 5.2-7.0 mg/l in Zone V. During the study, mean nutrient levels (nitrogen, phosphorus, and silicon) increased in the direction of Zone V (Raman et. al., 1990). Altogether, 97 species of phytoplankton belonging to 5 families and 51 genera were encountered in the lagoon. The organisms consisted of chiefly members of families Cyanophyceae, Euglenophyceae, Dinophyceae, Bacillariophyceae and Chlorophycea. In Zone I, where the salinity was high, the dominant forms were dinoflagellates. In the intermediate area (Zone II, III), the Cyanophyceae were more

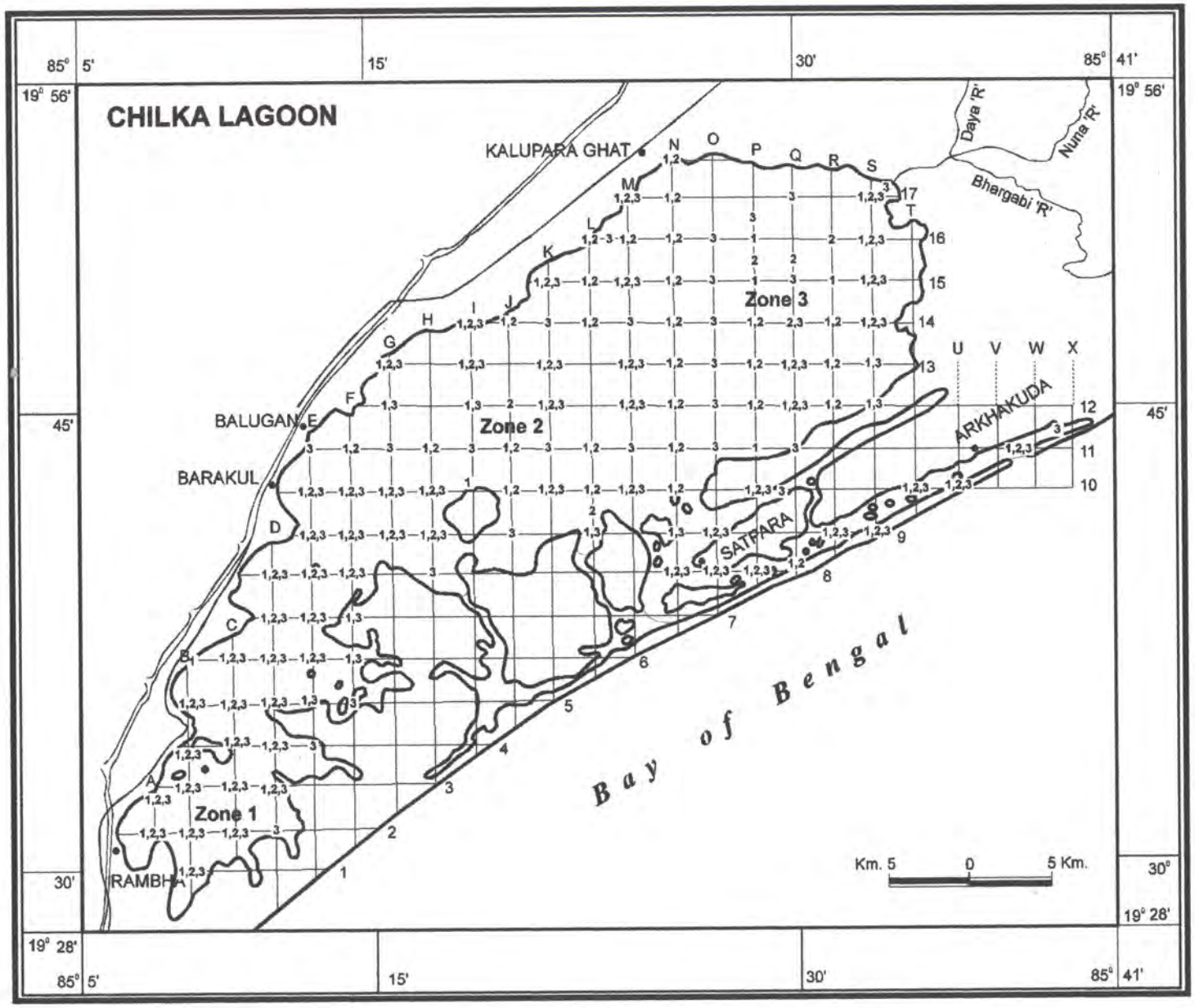


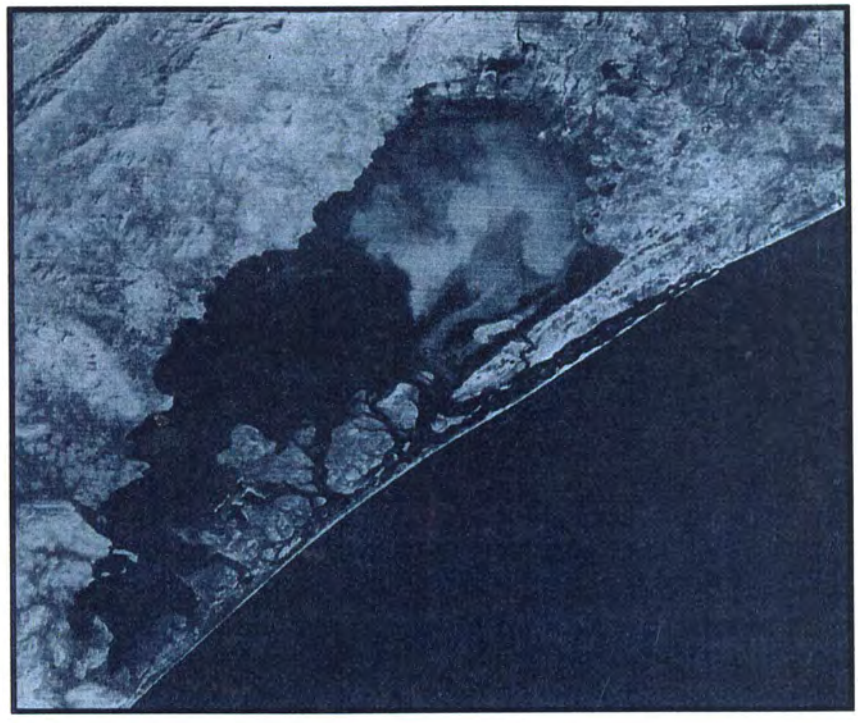
Fig. 11 : Hydrographic and Phytoplankton charecteristics : Sampling locations and schedule
(1 - September, 1987; 2 - April, May, 1996; 3 - October, 1997)

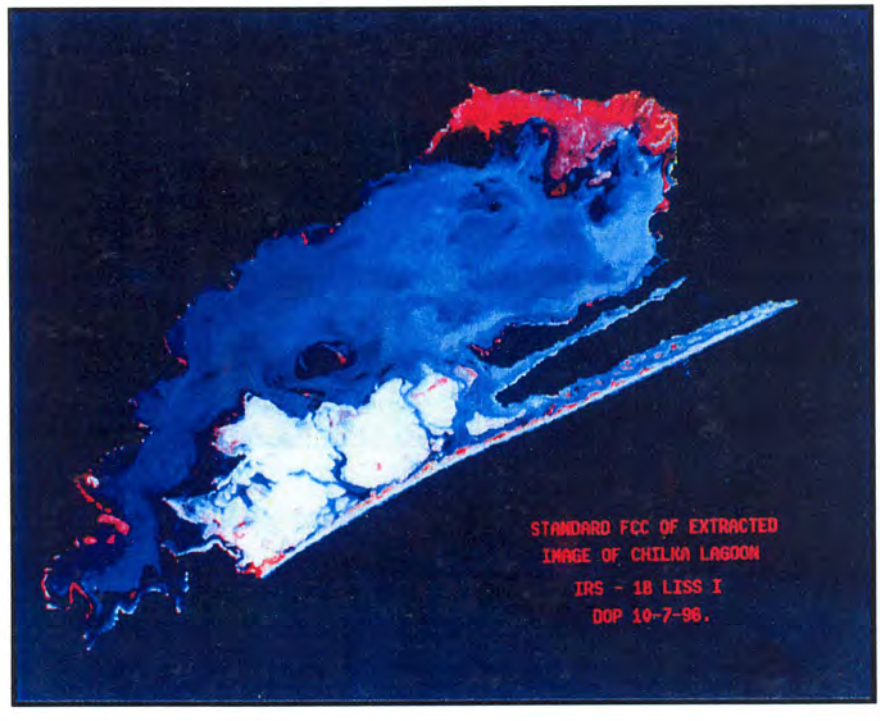
conspicuous . In the region of maximum dilution (Zone IV), the population was dominated by diatoms and chlorophyceans. In the outer channel (Zone V) influenced by sea, the inhabitants were mostly of marine origin. The study also consisted of a detailed investigation on the distribution of chlorophyll a, b and c in relation to other physico-chemical and biological factors (Satyanarayana, 1988).

The past few decades have witnessed the near toll of the Chilka Lake following mainly unrelenting economic exploitation and attendant anthropocentric activities. About 60,000 fishermen from around 122 villages in its vicinity earn their livelihood. This has led to concomitant mushrooming of brackish water fish farms, fish landing and processing centres, all obviously at a heavy price. Conditions in the Lake worsened owing to encroachment of thousands of acres of water area through creation of 'gheries' (patches enclosed with bamboo and nets) by commercial entrepreneurs belonging to non-fishermen communities allegedly with the patronage of local administration and influential politicians. Fishermen are prevented from fishing and also rowing their boats inside the Lake freely because of the gheries. Further to it, there has been considerable reduction in the free flow of water particularly in the outer channel area that is already heavily silted (Plate 13a). Over the years, the fish and crab yields from the Lake have consistently dropped from 8,872 tonnes in 1986-'87 to a mere 780 tonnes in 1996-'97. The idyllic beauty, scenic landscapes of islands and hills and, the breathtaking range of resident and migratory birds offer irresistible fare to the increasing number of tourists to Chilka Lake every year and consequent environmental issue in this area. In mid 80s, the Indian Navy had setup a training establishment (INS Chilka) on its West Bank with a sprawling accommodation of more than a few hundred acres. Understandably, there is growing need now to save Chilka Lake from the perilous situation, the major areas of concern being its protection from silting, weed growth, pollution, unsound practices of shrimp culture and increasing fishing pressure.

During 1995-'98, the University Grants Commission (UGC), New Delhi took cognizance of the issue and funded the Marine Biology Division at Andhra University through a research project for further studies on Chilka. Following this, two major investigations were carried out in April-May 1996 and October 1997, representing the pre- and post-monsoon conditions respectively. The main objective of this study was to find out decadal changes, if any, in the hydrographic conditions and phytoplankton distribution as a result of changes in the environmental conditions particularly salinity and inorganic nutrients in the lagoon since the 1987 expedition. A Ph.D. thesis (Satyanarayana, 1999) was submitted on this subject that contains an account of the findings made during the above two seasons and comparisons with data collected in September 1987. As many as 91-94 GPS fixed locations were covered according to a pre-determined grid and methodologies employed earlier. Plates 13-15 show results on salinity distribution, chlorophyll and phytoplankton content over the years.

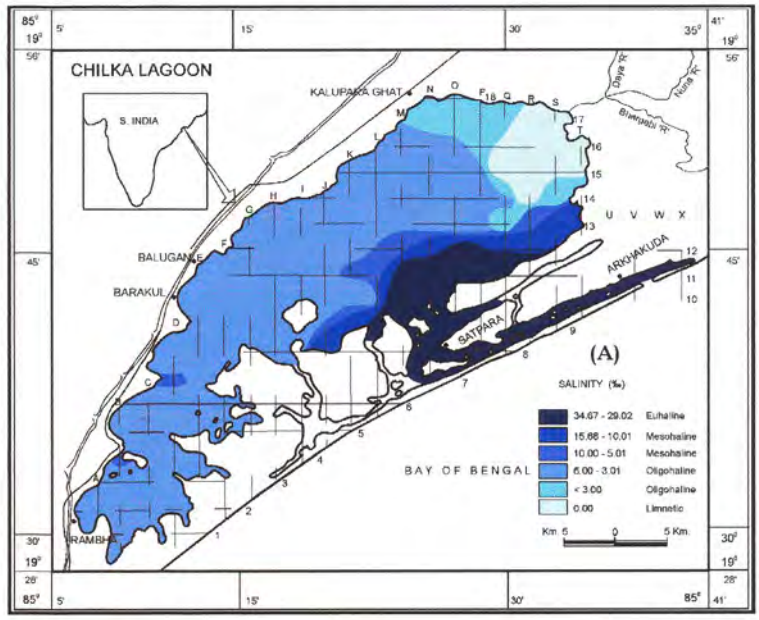
Plate 13a

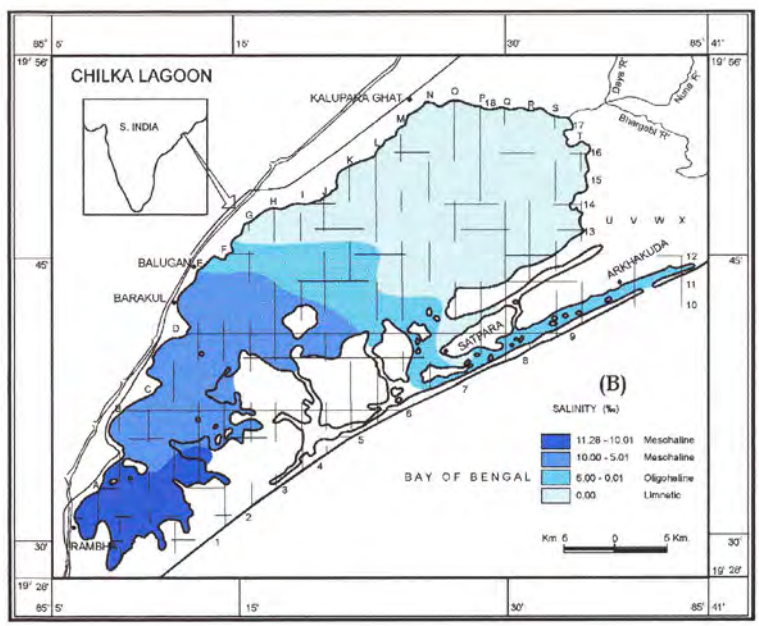


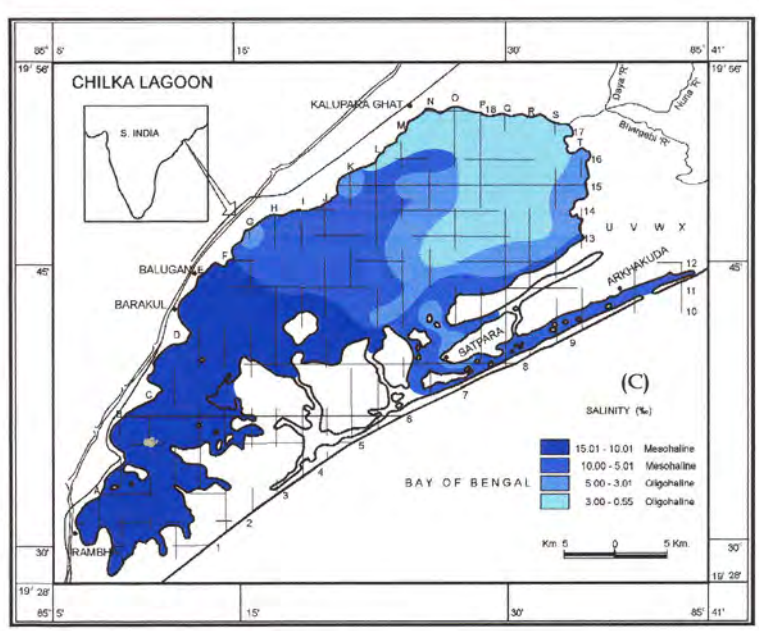


Chilka lagoon : (A) Landsat (band 6) of 7-11-1972 showing high suspended sediments and weeds,(B) IRS 1B LISS I of 10-07-1996. Also, note topographical changes (courtesy: Dr. A.S. Rajawat, Space Application Centre, Ahmedabad & Dr. P.K. Mohanty, Department of Marine Sciences, Berhampur University).

Plate : 13

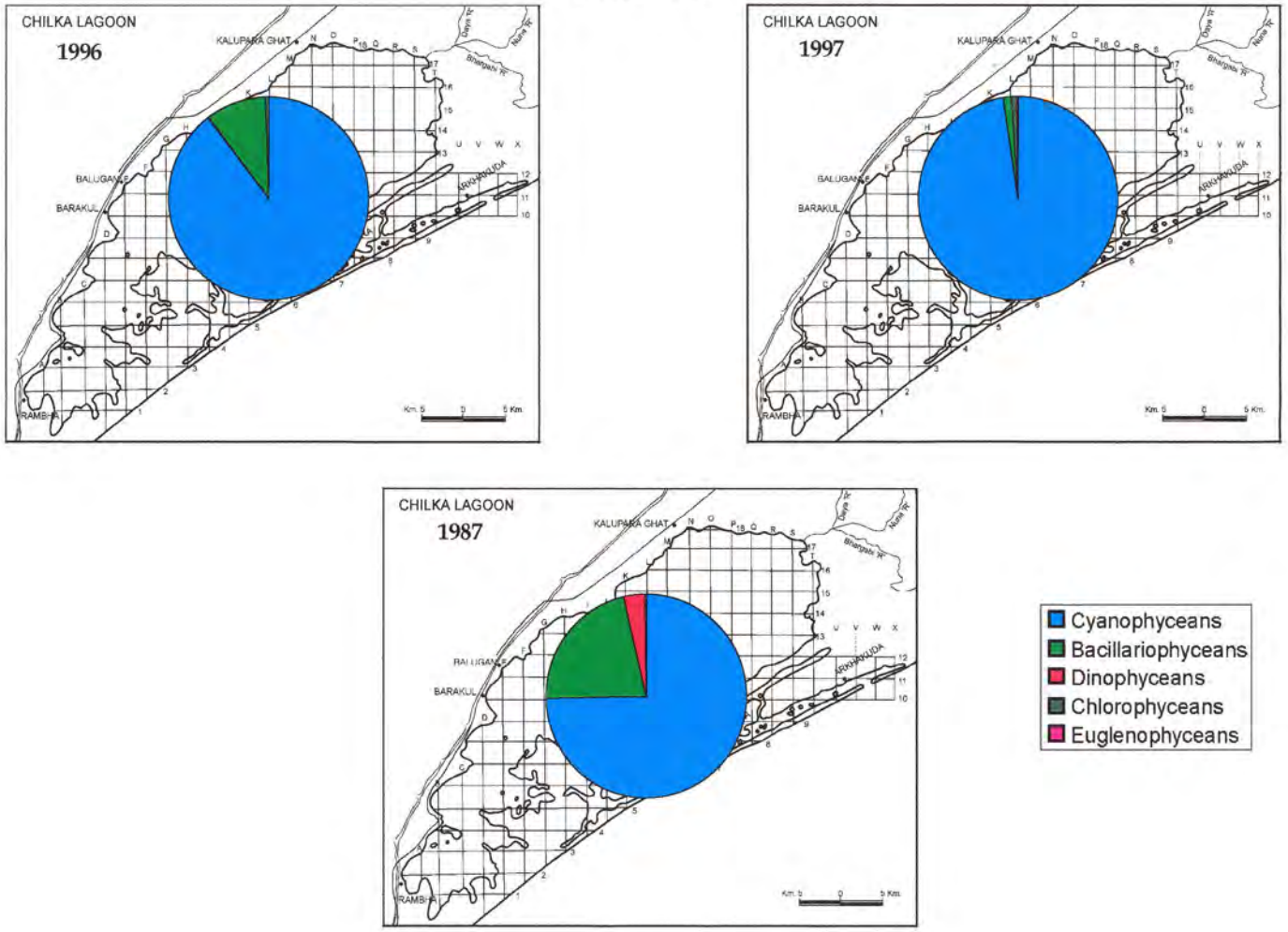






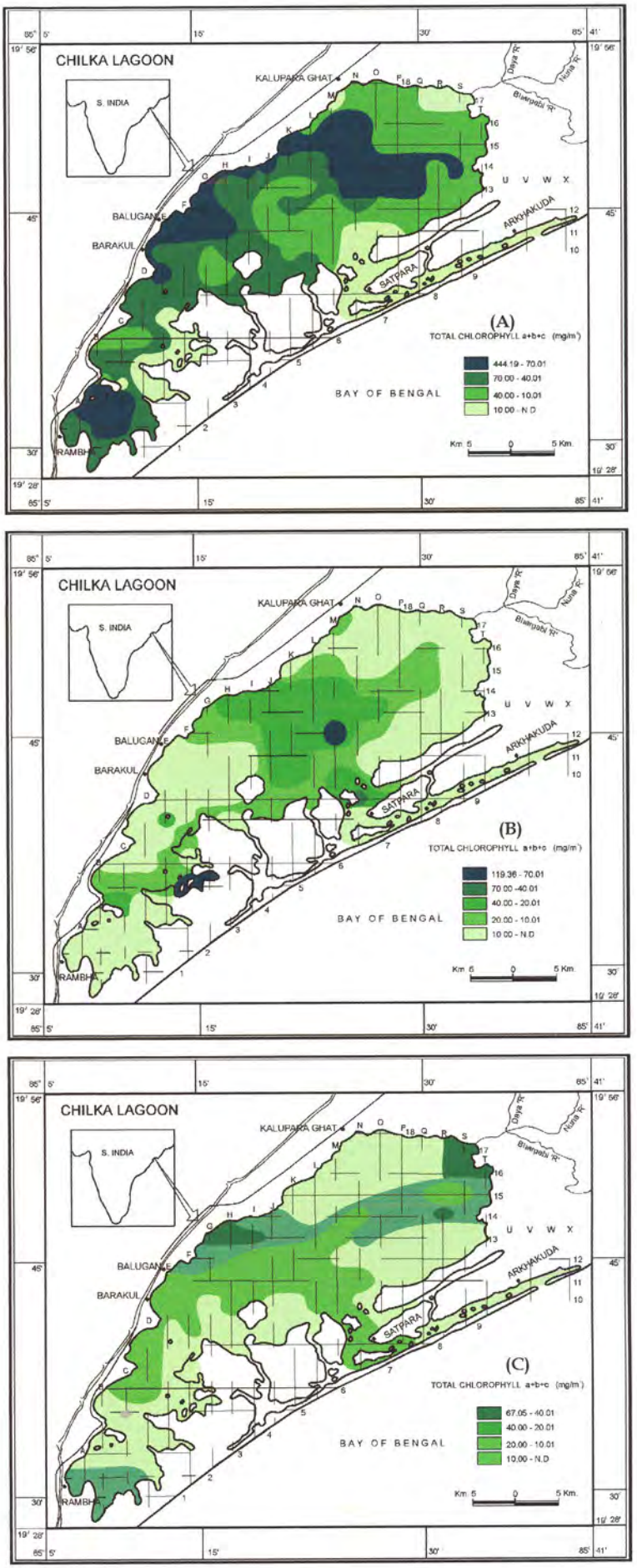
Salinity (A) April - May 1996, (B) October 1997, (C) September 1987

Plate : 14



Phytoplankton composition in Chilka lagoon

Plate : 15



Total Chlorophyll (A) April - May 1996, (B) October 1997, (C) September 1987

Mangrove Ecology :

Under the aegis of EC International Scientific co-operation, a collaborative Research Project between Vrije University of Brussels and Andhra University on the Mangroves of Godavri Estuary in Kakinada Area, Andhra Pradesh was organized. During the study (Phase I) carried out for a period 3 years (1994-'97), several aspects including hydrography, phytoplankton, zooplankton, benthos, floristics, C/N ratio etc. (C.E.C. Final Report, 1997) were covered. At present Phase II is in operation. These are discussed later in the Proposal (vide Page 18).

Aquaculture :

Keeping in view the upcoming industry, research in brackishwater aquaculture began in this Department in early 90s. As a prelude to these efforts a number of studies on the brachyuran, *Menippe rumphii*, (Babu, 1978); the mud crabs, *Scylla serrata* and *S. oceanica* (Manjulatha, 1992); tiger prawn, *Penaeus monodon* (Rama Rao 1996, Janakiram,1999); embryonic development of *Xantho bidentatus* (Babu, 1987) and structure and modification of integument and tissues and feeding biology of the hermit crab, *Clibanarius logitarsus* (Babu and Anger, 1987; Babu, 1988; Manjulatha and Babu, 1991) were carried out. The more pertinent accounts relate to the mud crab *Scylla serrata* and its usefulness as a 'candidate species' for aquaculture, pond design and maintenance, physiology, seed procurement and the importance of the species for export (Babu and Manjulatha, 1991; Manjulatha and Babu, 1994; Udayabhanu and Babu, 1994; Babu and Manjulatha, 1995a, b, c). Simultaneously, work on the microbial, protozoan and helminth diseases of select cultivable species of finfish and shrimps is also being envisaged (ICAR Project on Disease Implications in Brackishwater Aquaculture, 1996-'99; Aravindan, 1999).

Ecotoxicology :

Ecotoxicology is one of the important emerging areas of science concerning with the safety and environmental monitoring of organisms. Research in this area has been initiated in the Department of Zoology in 1985 and some significant studies were conducted since then. The rationale has become obvious in view of the recent industrialization and urbanization of the Visakhapatnam City and the dumping of large quantities of domestic and industrial wastes into the harbour which eventually contaminate the coastal waters. Work on ecotoxicology in the Department has been carried out on many marine and estuarine organisms with particular emphasis on heavy metal toxicity. The earliest report on this subject relates to copper accumulation in two fouling organisms, *Balanus amphitrite* and *B. tintinnabulum*, found locally (Prabhakara Rao et. al., 1986). Copper, cadmium zinc and mercury effects on the estuarine fiddler crab, *Uca*, were investigated in great detail (Uma Devi and Prabhakara Rao, 1989). Two intertidal gastropods, *Nerita albicilla* and *N. chemaeleon*, were exposed to different heavy metals and their

tolerance, metabolism and accumulation patterns were also studied (Praveen Kumar, 1990). A similar investigation on cadmium toxicity was carried out on the top-shell *Turbo intercostalis* (Srilakshmi, 1992) and penaeid post-larvae (Satyavati, 1999)

Parasites of Marine Organisms :

Parasitological investigations on marine organisms consisted of essentially two aspects namely, Protozoa and Metazoa. Among Protozoans, the most significant findings relate to Microsporean parasites of fishes of Bay of Bengal (Sandeep, 1982); Myxosporean parasites of mullets, *Mugil cephaalus* (Anuradha, 1991), *Liza macrolepis* (Padma Dorothy, 1991); fishes of Chilka lagoon (Vaidehi, 1992); Trypanosomes of certain fishes (Department of Environment Report, 1990; U.G.C. S.A.P Report, 1991) and gregarine parasites of a variety of marine organisms collected in the nearshore regions, backwater areas and the harbour. Observations made on board *FORV Sagara Sampada* in Bay of Bengal during 1989 showed 12 species of Protozoan parasites from deep-water fishes (Narasimhamurti et. al., 1989).

The helminth investigations dealt mainly with faunistic accounts of Monogenea (Vijaya Raju, 1976), Digenea (Madhavi, 1968), Cestodes (Venu Rao, 1972), Copepods (Uma Devi, 1976) and Acanthocephalans. More recently, a comprehensive study on the Didymozoid parasites of the highly migratory species such as Tunas of Bay of Bengal was undertaken (Meenakshi, 1992).

To sum up, Andhra University and the Department of Zoology in particular, had during the last four decades made some significant contributions to our knowledge concerning the ecology and biology of marine and estuarine organisms inhabiting the coastal and nearshore waters in this area. The University Grants Commission, New Delhi, now supports the Department with Special Assistance for teaching and research in Marine Biology. During this attempt to present a review of the work done based on 90 Doctoral Theses, 31 M.Phil. Dissertations and 153 published papers, while all care was taken to include as many references as possible, some works might have been missed. However, the account is complete with respect to all major research conducted by the Department in Marine Biology so far.

3. Capacities and Infrastructure :

Over the years, the Division of Marine Biology acquired considerable expertise in diverse areas of research. Two major themes of work could be identified. These are: (i) Mangorve Ecosystems and (ii) Coastal and Marine Biodiversity.

Within the frame work of INCO-DC (International Cooperartion with Developing Countries) a detailed investigation on the hydrobiological and faunistic aspects of the Kakinanda Bay - Gautami Godavari esturine complex, one of the India's largest mangrove ecosystems, was undertaken for a period of three years from July, 1994 to June 1997. The project which was funded by European Commission (EC fixed

contribution contract noC11*-CT93-0320) was mailny intended to provide the state-of-the-art information on the mangrove ecodynamics, water quality and the fauna with the sole objective of assessing the changes in the ecosystem as a result of severe human interventions through industrial and urban development in that area.

After the successful completion of Phase I, the EC granted a second term (1998-2001) to the project with the participation of more member countries from the Netherlands and Sweden, and Sri Lanka as an additional DC partner. These details are given below. Work on coastal and marine biodiversity began nearly 15 years ago. The primary objective was to study seabed (Benthic) organisms (Adiseshasai, 1992; Page 5 in this Report). This work is now extended to other regions along the east coast of India, under Marine Living Resources related research onboard FORV Sagar Sampada, one of India's premier research vessels. Several one-day cruises are also conducted and, a strong database exists now on this subject. The following is an account of these two major researches held at present.

AN ASSESSMENT OF THE ECOLOGICAL IMPORTANCE OF MANGROVES IN THE KAKINADA AREA, ANDHRA PRADESH, INDIA

E.C. International Scientific Cooperation Project
Contract No CII*-CT 93-0320
(1994-'97)

Introduction :

Kakinada Bay, a shallow bar-built water body on the east coast of India within the State of Andhra Pradesh (82°14' and 82°22' E longitude; 16°51' and 17° N latitude), is bound by dense mangrove vegetation and extensive mud flats interspersed by estuarine gullies and streams emanating from one of India's largest river systems namely, the Godavari (Plate 16). In the lower reaches, river Godavari branches into two as Vashista Godavari and Gautami Godavari before joining the sea, the Bay of Bengal, near a place called Bhairavapalem. The extensive estuarine areas north of Gautami Godavari open into Kakinada Bay via branches namely, Gaderu and Coringa and multiple and other channels and creeks. The area between Gautami Godavari and the Kakinada Bay has dense mangrove vegetation and constitutes the Coringa Wildlife Sanctuary covering an area of approximately 100 km2. In recent years, large scale conversion and reclamation activities for shrimp farming in this area have led to much denudation of mangrove vegetation with severe impingement in some localities. During the last eight years or so, some 25 km2 mangrove area has been lost on account of this reason and this illegal practice is still continuing and unauthorized occupations increasing every year. Observations have shown that much of the mangrove waterways are adversely affected by outwelled water from the shrimp farms raising water quality concerns. Industrialization and urban effects of Kakinada township have similarly brought in their wake further changes. The Kakinada canal is largely responsible for the deteriorating water quality in the Bay bringing into fore several ecological considerations.

Plate 16

Satellite picture showing mangrove waterways and the Bay environment of Kakinada

Local Scenario :

Kakinada Bay, and the nearby waterways especially Gaderu, Matlapalem and Coringa support a variety of fin and shell-fish resources as evidenced by intensive fishing practiced by villagers in these areas. Beginning each south-west monsoon, a full scale of operation of collection of prawn seed (mostly *Penaeus mondon* and *P. indicus*) commences involving almost every household among the fishermen communities. Agents fetch the freshly caught prawn seed from the local fishermen and sell to prospective buyers. The seed is even transported to the neighbouring states of Orissa and Tamil Nadu. This wholesome activity constitutes a major and often only source of income for many people who make a living on this. Another important activity relates to harvesting shell-fish for lime production. Several hundred tones of bivalve (*Anadara, Cardium, Meretrix*) and gastropod shells (*Telescopium, Cerithedia*) are removed (mostly through hand-picking during low tide) from the swamps on the west side of the Bay and intertidal areas facing the mangroves (Plates 17-18). It is difficult to imagine for how long the existing fisheries resources can sustain the demands of evergrowing population of this area. The co-existence of mangrove forests along the Gautami Godavari delta area and the productive fisheries and prawn nurseries suggest that the former sustains an energy flux to the adjoining waters. However, the increasing pressure on the mangrove forests with intensive prawn culture installed at the expense of the mangrove forests highlights the threat to this ecosystem. Mangrove deforestation and landscape destruction is spreading towards Kakinada Bay with the ongoing construction of tanks and bunds for aquaculture.

Aims and Objectives :

The study spread over a period of three years (1994-'97) was aimed at understanding the role of the environment, positioned at the land-sea boundary, in the material exchange process between these two areas and the significance of mangroves as nutrient source to higher trophic level in the Estuary-Bay-Sea complex. The objectives of the investigation were:

1. General ecological study of the area in terms of physico-chemical gradients in the aquatic environment and of mangrove, plankton and benthos biodiversity

2. Determination of relative importance of main primary producers (mangroves, phytoplankton) as sources of organic carbon to the coastal and bay ecosystems and the specific role of mangrove litter and,

3. Determination of carbon and nitrogen flow patterns in the trophic food chain of the mangrove ecosystem.

Plate : 17

Overexploited molluscs
a. ***Cerithidea cingulata*** **b.** ***Telescopium*** **sp.**

Plate : 18

c. *Meretrix* sp. b. *Anadara granosa*

Field Description and Research Methods :

A total of seventeen stations were fixed for sampling in Gaderu, Coringa and Kakinada Bay (Fig.12). Furthermore, two field plots one with *Avicennia officinalis* (canopy, 80%; mean ht. 5 m) and the other with *Excoecaria agallocha* (canopy 90%; mean ht. 2 m) were chosen to carry out litterfall and leaf decay experiments. A total of 75 GPS fixed locations were selected to determine species composition, structure and diversity of mangroves within Coringa Wildlife Sanctuary (Fig.13). Sample collection techniques and analysis, layout and design of experiments were all based on standard protocols.

Results and Discussion :

Mangrove vegetation :

The vegetation in the mangrove swamp of Coringa consisted of a total of 36 species of plants of which 19 species represented by 11 families and 14 genera were mangroves. There were 8 associate plants represented by 5 families and 6 genera and 9 halophytes belonging to 5 families and 8 genera (Plates 21). Among the mangroves, *Avicennia marina, A. officinalis, A. alba, Acanthus ilicifolius, Aegiceras corniculatum, Bruguiera gymnorrhiza, B. cyliundrica, Ceriops decandra, Excoecaria agallocha, Rhizophora apiculata, R. mucronata, Sonneratia apetala* and *Xylocarpus granatum* were important. *Clerodendrum inerme, Ipomoea tuba, Hibiscus tiliaceous, Thespesia populnea* and *Cesalpinea crista* represented the associates. The halophytes consisted of *Suaeda maritima, S. monoica, Salicornia brachiata, Paspalum distichum, Tamarix* sp. and *Aeluropus lagopoides* (Satyanarayana et al., 2000). Fig.14 shows relative distribution of the mangroves at individual sites. *A.marina* was found to be the dominant species among others. *A. officinalis* was characterstic at land ward locations. *E. agallocha* was next in order and distributed rather widly along the entire stretch from the coast to inland areas along with *A. marina. R. apiculata* and *R. mucronata* were noticed at seaward locations. *S. apetala* is seen extensively where Coringa joins Kakinada Bay (st. Q25). This is probably the most important pioneer along this coast. *S. caseolaris* on the other hand remaind sparsely distributed being found at a single location (st. U27). The spiny *Ac. Ilicifolius* and *Myriostachya wightiana* along with *Clerodendrum inerme* forms dence fence on the banks of creeks and canals.

Overall tree density varied from 47 stems/0.1 ha (st. O23) to 1,731 stems/0.1 ha (st. M23). Basal area ranged between 2m2/0.01 ha (st. S39) and 380m2/0.01 ha (st. O31). Species-wise, *A. marina* met with maximum tree density (1,731 stems/0.1 ha, st. M23). This is followed by *E. agallocha* (1,412 stems/0.1 ha, st. O29), *Ae. Corniculatrum* (202 stems/0.1 ha, st. X39) and *A. officinalis* (118 stems/0.1 ha, st. O29). As regards basal area, *A. officianalis* occupied the first position 379m2/0.01 ha (st. O31) followed by *A. marina* 146m2/0.01 ha (st. Y33) and

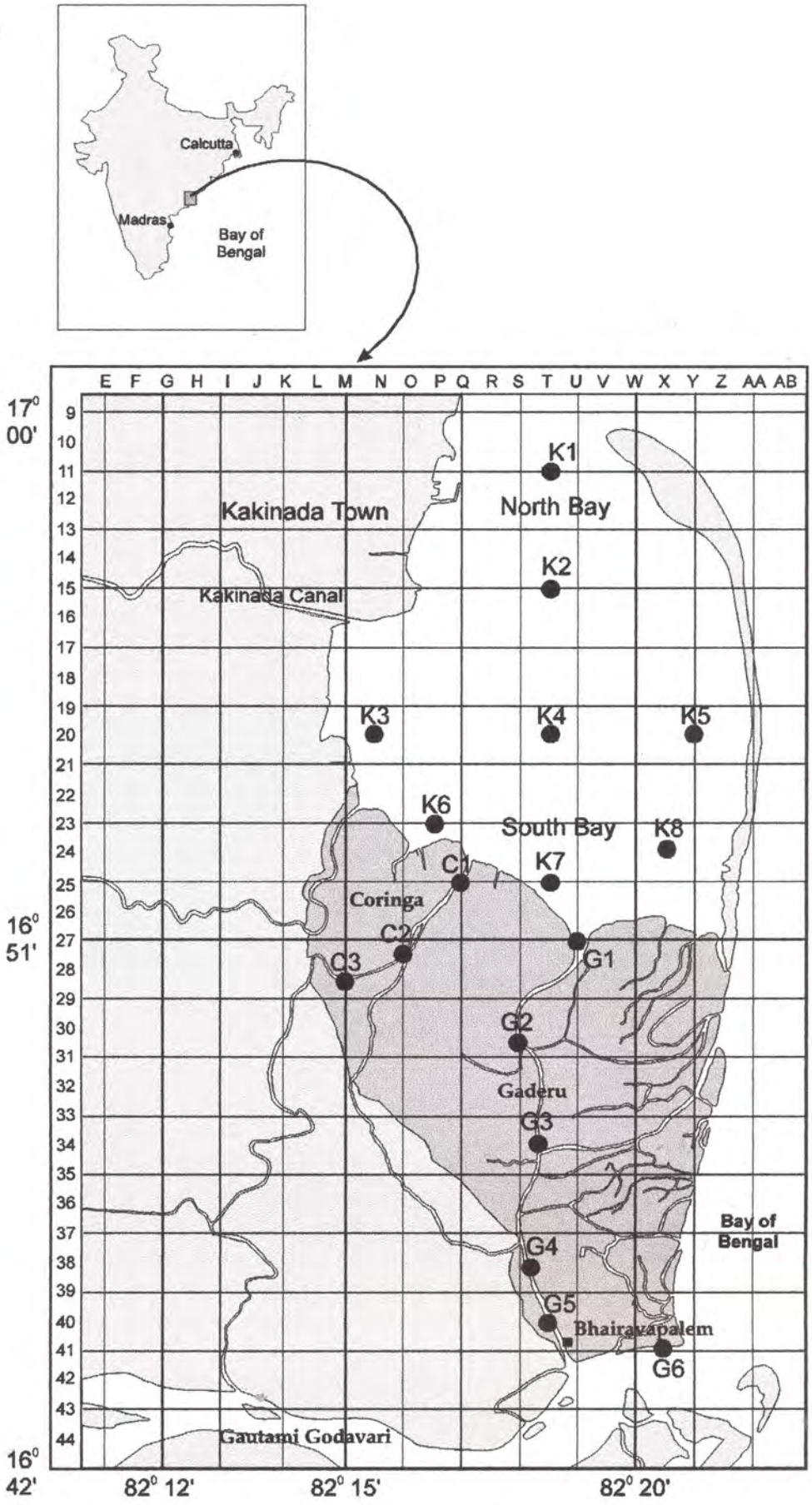


Fig. 12 : Study area showing samping locations
(Dark shaded area refers to Mangroves)

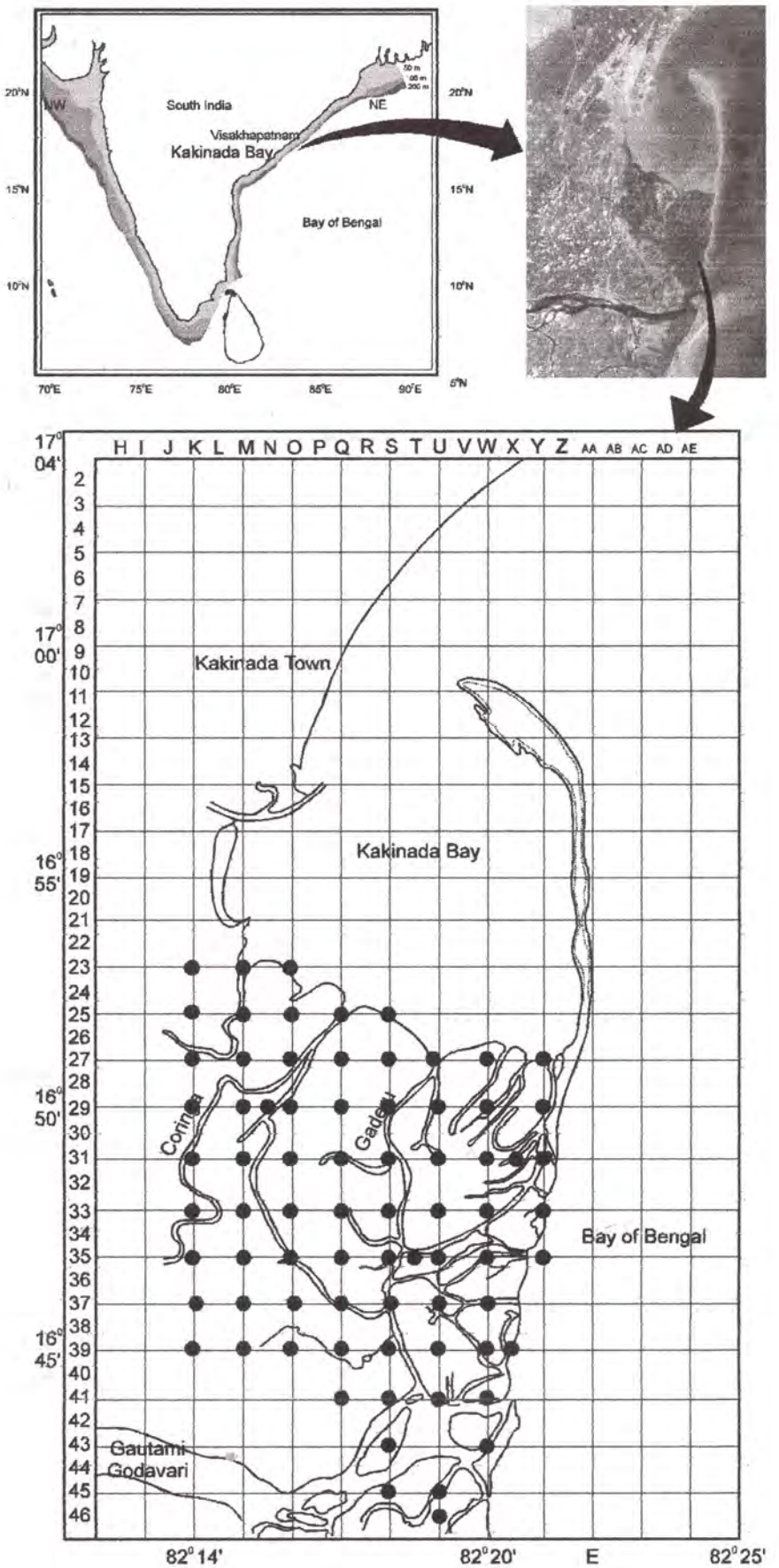


Fig. 13 : Study area showing sampling locations

Plate : 19

Avicennia marina

Avicennia officinalis

Plate : 20

Excoecaria agallocha

Bruguiera gymnorrhiza

Plate : 21

Rhizophora mucronata

Xylocarpus mekongensis

Rhizophora apiculata

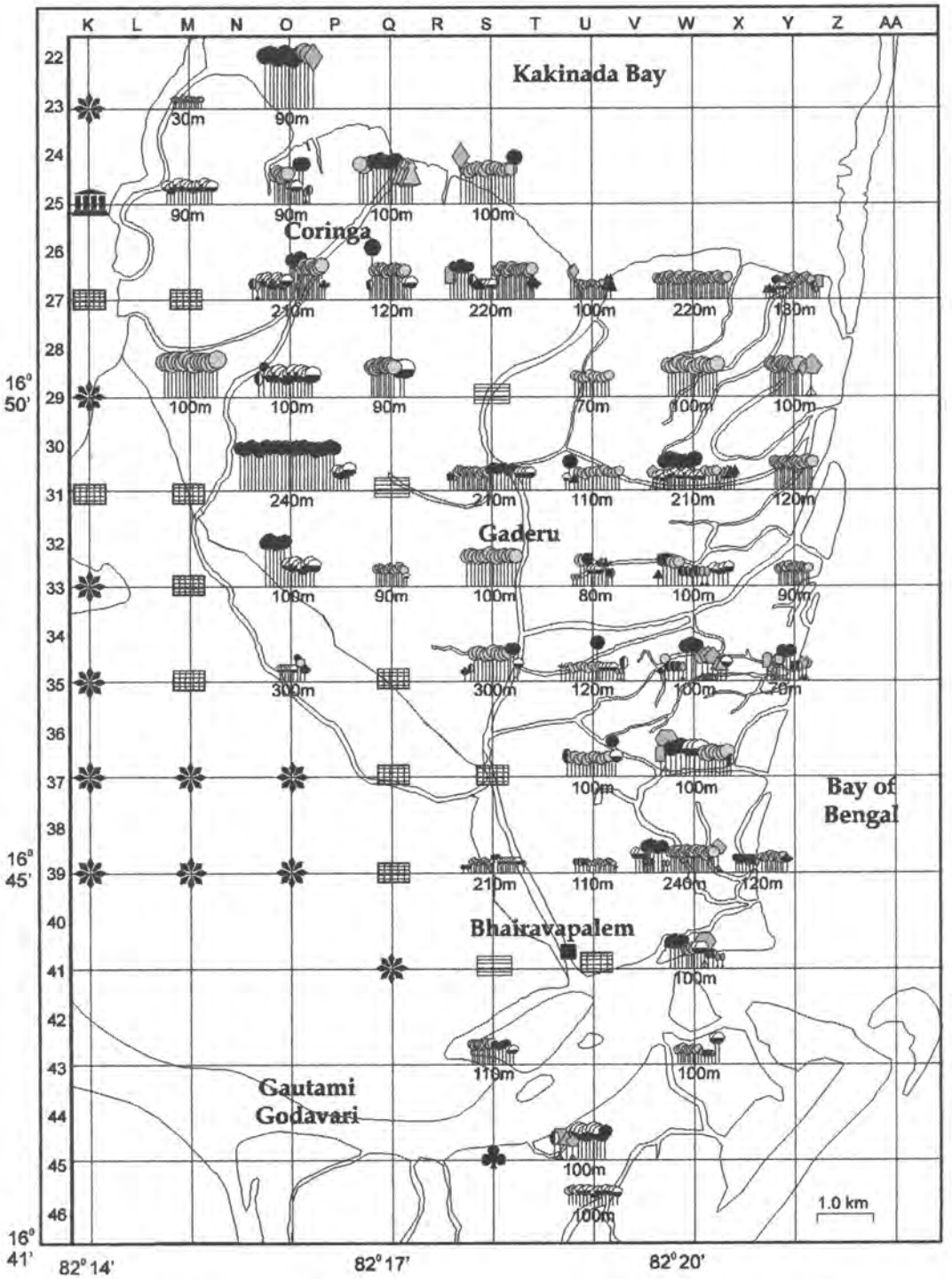


Fig. 14 : Species composition and relative distribution of Coringa Mangroves

Avicennia marina *A. officinalis* *A. alba* *Aegiceras corniculatum*
Bruguiera gymnorrhiza *B. cylindrica* *Ceriops decandra* *Excoecaria agallocha*
Lumnitzera racemosa *Rhizophora apiculata* *R. mucronata* *Sonneratia apetala*
S. caseolaris *Xylocarpus mekongensis* Terrestrial vegetation Shrimp ponds
Paddy Fields Unvegetated area Rural settlement

Scale : Number of trees, each line represents 1-3; height = 5 meters
Figures below each site indicate distance travelled
Note : Sites N29, T35 & X31 are not represented

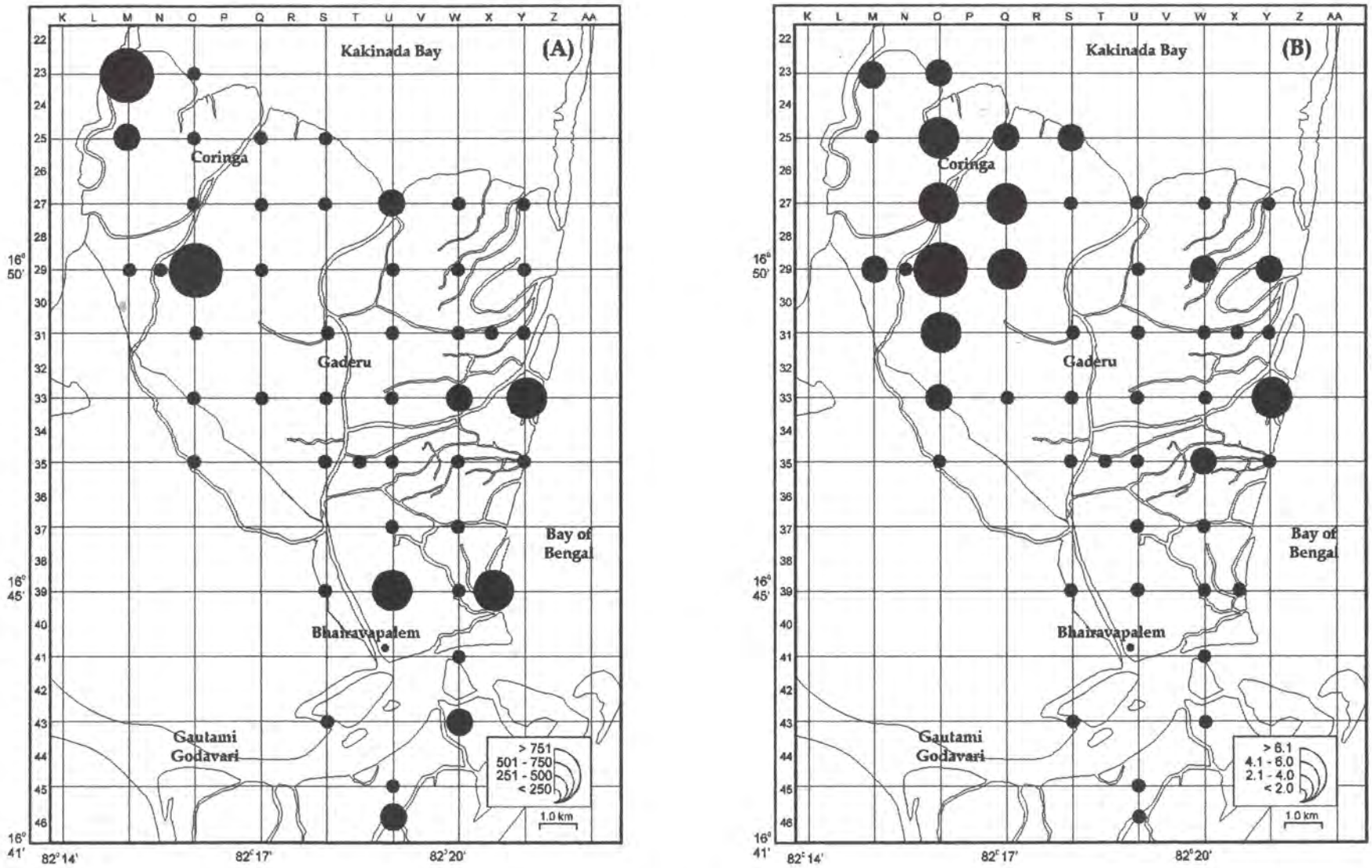


Fig. 15 : (A) Total density (stems/0.1 ha) and (B) Basal area (m^2/0.01 ha) of Coringa mangroves

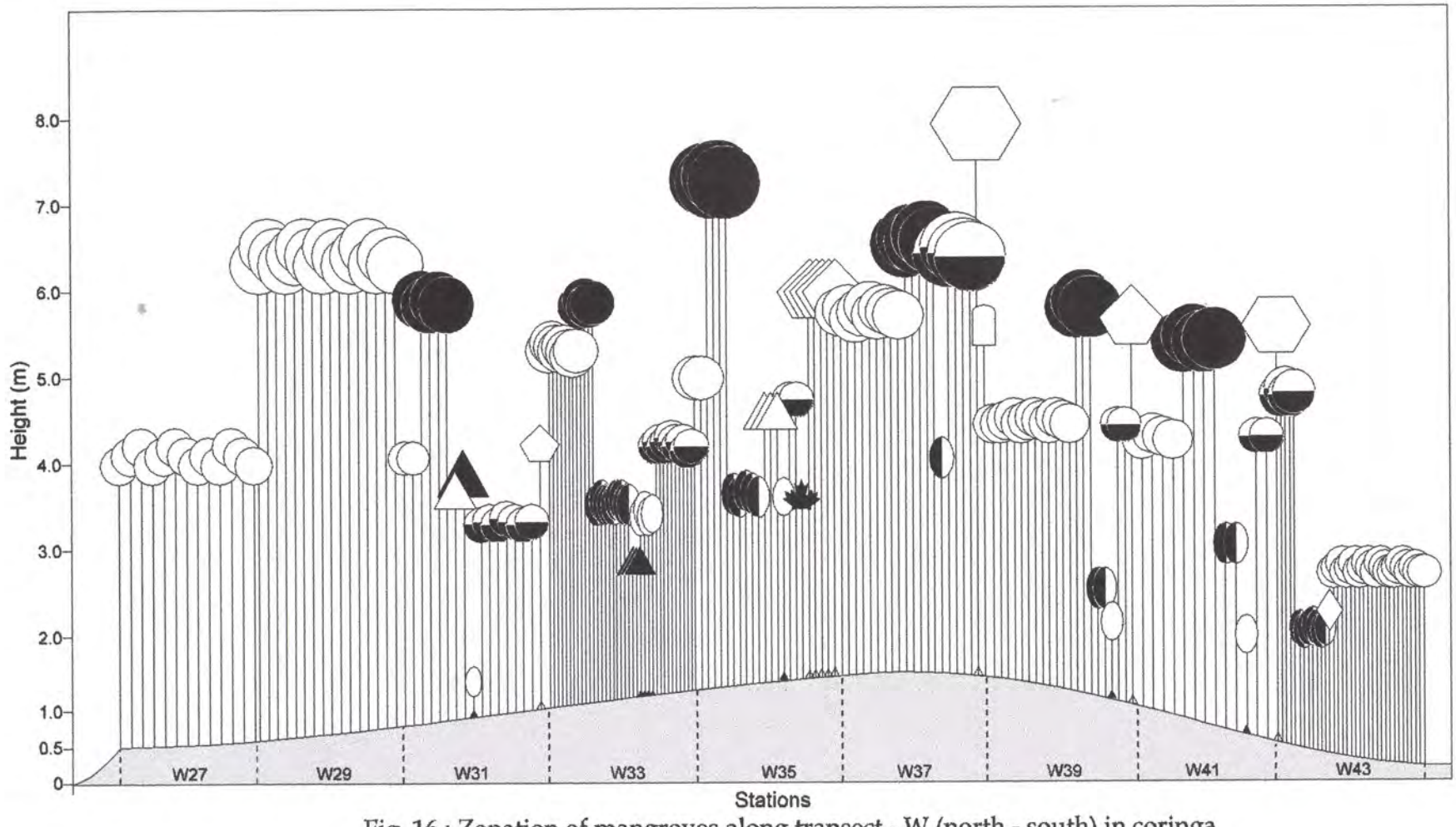


Fig. 16 : Zonation of mangroves along transect - W (north - south) in coringa

Avicennia marina *A. officinalis* *A. alba* *Aegiceras corniculatum* *Bruguiera gymnorrhiza* *B. cylindrica* *Ceriops decandra*

Excoecaria agallocha *Lumnitzera racemosa* *Rhizophora apiculata* *R. mucronata* *Xylocarpus granatum*

E. agallocha 287m2/0.01 ha (st. O29) (Fig.15).

Fig.16 shows zonation of mangroves along stansect - 'W' in Coringa. Nine sites (W27, W29, W31, W33, W35, W37, W39, W41 and W43) located along a 16 km. gradient (north - south) between the Bay and estuary were exmained in relation to tidal height and extent of inundation. The overall pattern from the Bay side towards interior areas and upto estuary was *Avicennia* in the lower intertidal region (sts. W27 and W29), *Bruguiera, Rhizophora, Ceriops, Aegiceras* and *Lumnitzera* in the middle region (sts. W31, W33, W35) and *Xylocarpus* at elevated ground (st. W37). Sites W39 and W41 towards estuary were characterised by the presence of *Rhizopora* and *Bruguiera* species. The double distribution of *Avicennia* at st. W43 closest to estuary was evident.

Litterfall and Decay :

Litterfall in the *Avicennia* and *Excoecaria* field plots was recorded from April 1995 till June 1996 (Rao, 1997). Litterfall in *Avicennia* field plots does not seem to follow a clear seasonal pattern, the values ranging between 1.08 (November-December, 1995) and 6.97 g m-2 d-1. In the case of *Excoecaria* plot, litter fall is relatively high (upto 9 g m-2 d-1) during April-May, 1995 but reduced to a mere zero from June, 1995 to March, 1996 (Fig.17). Overall, mangrove litter input to the Bay-Estuary system was about twice as large for *Avicennia officinalis* as for *Excoecaria agallocha*. It was also noticed that despite smaller geographical coverage (40%) and smaller litter fall, there is evidence that imprint on the composition of suspended organic matter in the mangrove creeks and in Kakinada Bay is mainly by *Excoecaria*. Experiments on leaf decay have shown that in the case of *Avicennia*, the C/N (atomic) ratio changed from an initial 78 (senescent leaf) to 51 in 45 days of decay during summer and from 78 to 29 in 52 days during rainy season. In *Excoecaria*, C/N ratios changed from 71 to 24 in 45 days during summer and from 76 to 28 in 33 days during rainy season. These experiments revealed that since relative carbon content of the litter was not changing over time, the decrease in C/N ratio should indicate nitrogen enrichment in leaves during decomposition. The main reason for the relative enrichment of leaf litter with nitrogen probably resides in the fact that leaf litter becomes colonized by bacteria, bacterivorous protozoa and fungi immobolising nitrogen from the aquatic system on the decaying leaves. Observations have shown that in both seasons the decay rate of *Excoecaria* was faster than that of *Avicennia*.

A rich population of heterogeneous microorganisms (40 species) represented by bacteria, fungi, flagellates and ciliates was encountered during leaf litter decomposition experiments (Plate 22). In general, bacteria outnumbered all others constituting 80-90% of the population. Among protozoans, flagellates (8.6x103 ml-1), microciliates (4.3x103 ml-1), sessile ciliates and suctorids were found in

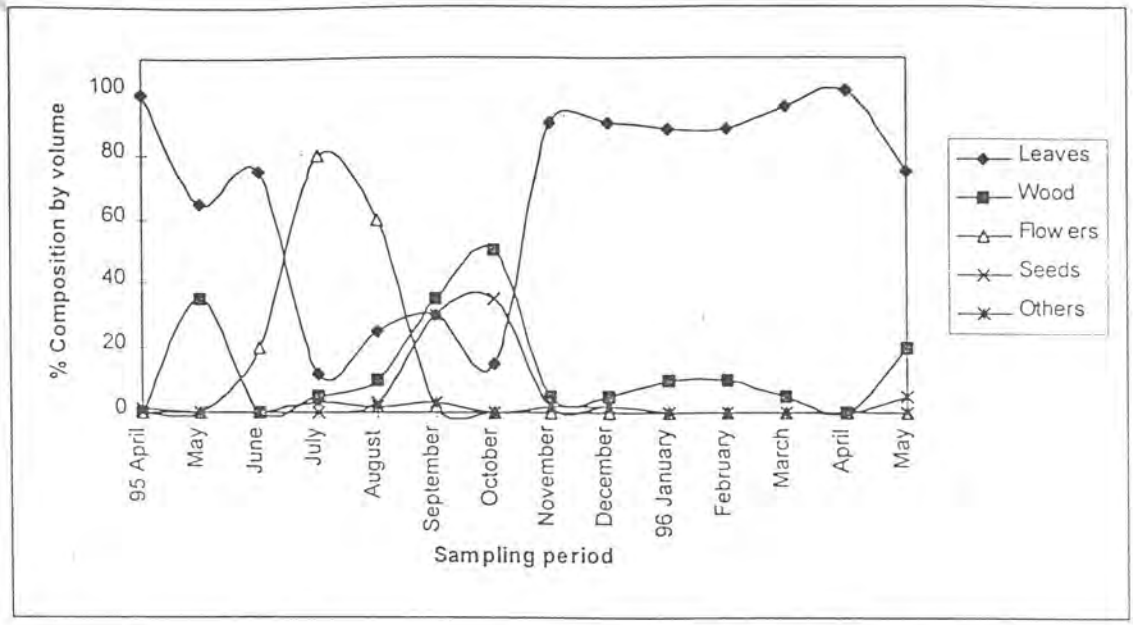


Fig. 17 A Litterfall components in *Avicennia officinalis* during the sampling period.

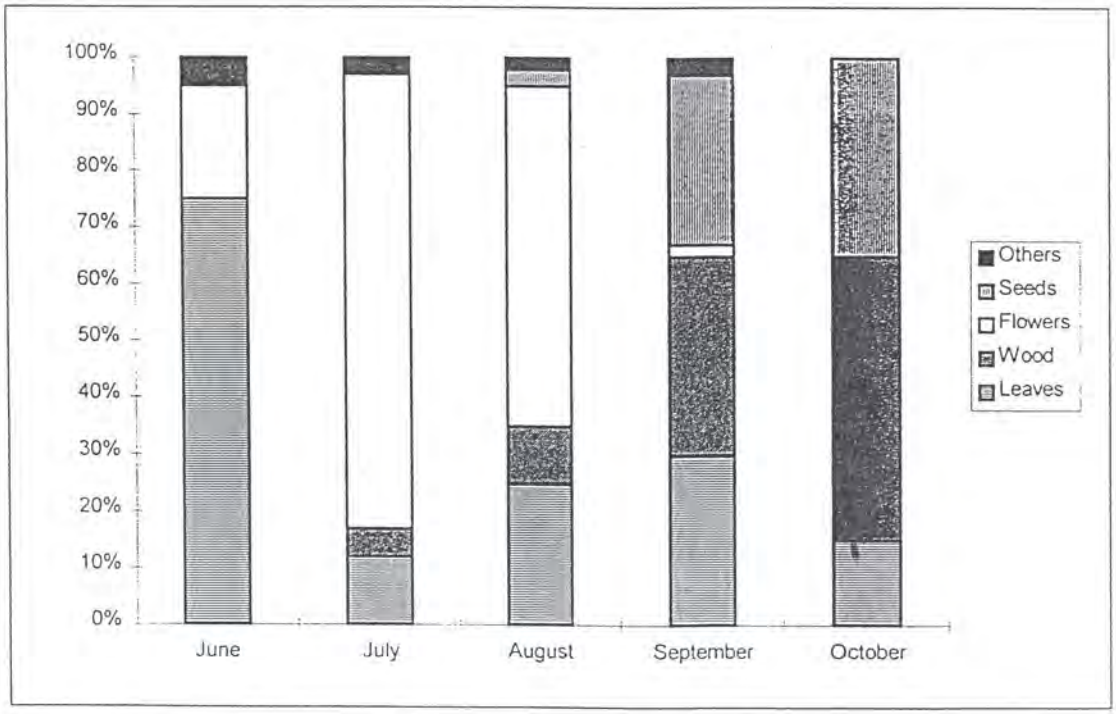
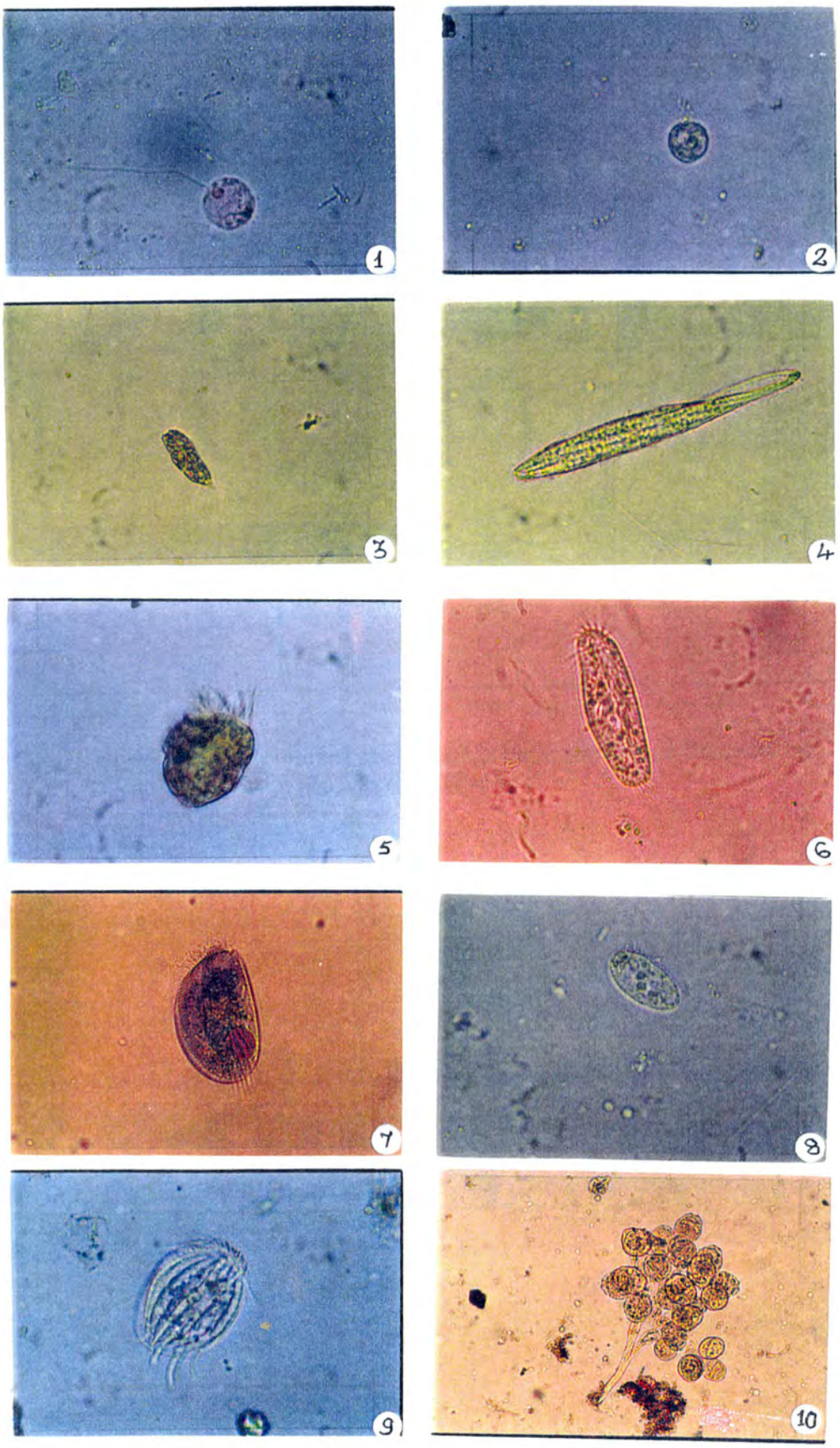


Fig. 17 B. Percentage composition of litter in Avicennia during June to October 1995. Since June, July and August is the flowering season, the litter consists of flowers and from September onwards, seeds and seedlings started to show up. During October the percentage of wood was higher which, evidently, was caused by falling of twigs due to a cyclonic storm. From October onwards till May, leaves are the major components of litter as shown in Figure 4.1A.

Plate 22



Dominant protozoa: 1. *Chromulina* sp., 2. *S.socialis*.sp., 3. *E.acus*., 4. *Litonotus* sp., 5. *Halteria* sp., 6. *Holosticha* sp., 7. *Stylonychia* sp., 8. *Prorodon* sp., 9. *E.aediculatus*., 10. *Zoothamnium* sp.,

order of their abundance. The predominant genera were the cytolytic bacteria, *Micrococcus* sp., the flagellates, *Chromulina* sp., *Spumella socialis, Astasia* sp. and *Heteronema* sp. and the ciliates, *Stylonychia pustulata, Prorodon* sp and *Euplotes aediculatus.* Colonisation began with bacteria and fungi followed by grazing protozoans represented by heterotrophic nannoflagellates (*Astasia* sp., *Heteronema* sp. and *Chromulina* sp.), bacterivorous microciliates (*Prorodon* sp., *Cyclidium* sp. and *Nassula* sp.), carnivorous ciliates (*Stylonychia pustulata* and *Euplotes aediculatum*) and sarcodines (*Acanthoamoeba* sp.) and then, by sessile ciliates (*Vorticella* sp.) and suctorids. Appearance of nematodes was the culmination. It was noticed that the rate of colonisation and species composition varied with the nature and chemical composition of the leaf. Colonisation was relatively slow in Avicennia officinalis (8 days) than *Excoecaria agallocha* (5 days) evidently due to the early leaching of free fatty acids and soluble carbohydrates in *E. agallocha.* It is noteworthy that in *A. officinalis* the free fatty acids remained at low levels even after 24 days. Futhermore, it was noticed that protozoan grazing was slow in *Avicennia* than *Excoecaria* which should in part explain the differences observed. Seasonally, microbial settlement and succession of organisms was faster (14-16 days) during summer months than during monsoon period (24-32 days) (Kalavati et al., 1997).

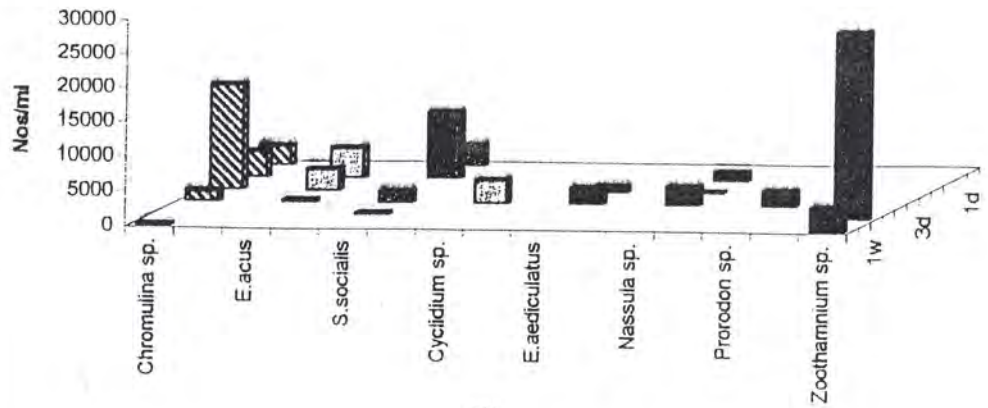
During the study, tracing carbon flow using natural isotopes was carried out for the bay, estuary and mangrove environments (Fig. 19). It was noticed that under all circumstances suspended organic matter is controlled to a significant extent by mangrove litter input, as indicated by stable carbon isotopic composition. However, there was a clear gradient of increasing importance of the mangrove carbon from the open Kakinada bay to the mangrove creeks, where mangrove detritus represents the major carbon source. The findings have revealed that a carbon and therefore an energy flow from the mangroves sustain organisms from different trophic levels thriving in the mangrove channels and creeks as well as in the southern part of Kakinada Bay. There seems to be a clear impact of mangrove outwelling but it is spatially restricted.

Hydrographical Conditions :

Water quality variables during this study included secchi-disc transparency, turbidity and suspended matter, sea temperature, salinity, pH, dissolved oxygen and inorganic nutrients (nitrite, nitrate, phosphate, silicate). The observations have revealed that the Bay-Estuary environment is characterized by unique hydrographical conditions, the variability of most of parameters investigated being determined to a great extent by the relative seasonal change in monsoon regime and associated rainfall which is likely a major control process in this area. Rainfall pattern recorded over the length of the present investigation, shows high values for November, 1994; the period from May to October, 1995 and for June 1996. In general, the waters are highly turbid (mean 22-134 NTU) (mean secchi-disc, < 0.3 m) evidently due to heavy inflows from land during rainy season and suspended sediments caused by

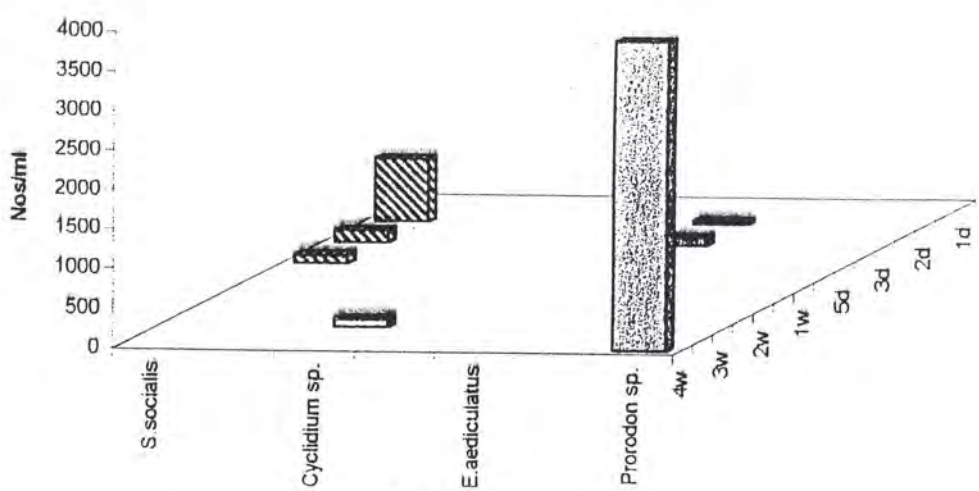
Fig. 18a

Succesion of dominant species of protozoans in *A.officinalis* during summer



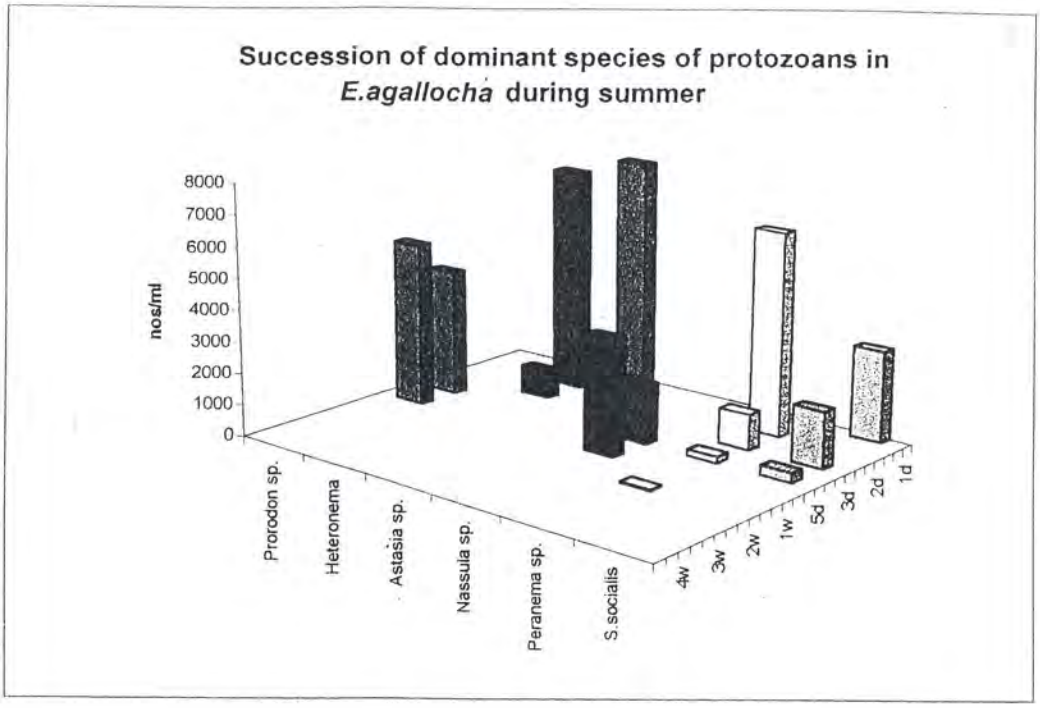
(A)

Succesion of dominant species of protozoans in *A. officinalis* during monsoon



(B)

Fig. 18b


Succession of dominant species of protozoans in
E.agallocha during summer
nos/ml
8000
7000
6000
5000
4000
3000
2000
1000
0
Prorodon sp.
Heteronema
Astasia sp.
Nassula sp.
Peranema sp.
S.socialis
4w
3w
2w
1w
5d
3d
2d
1d

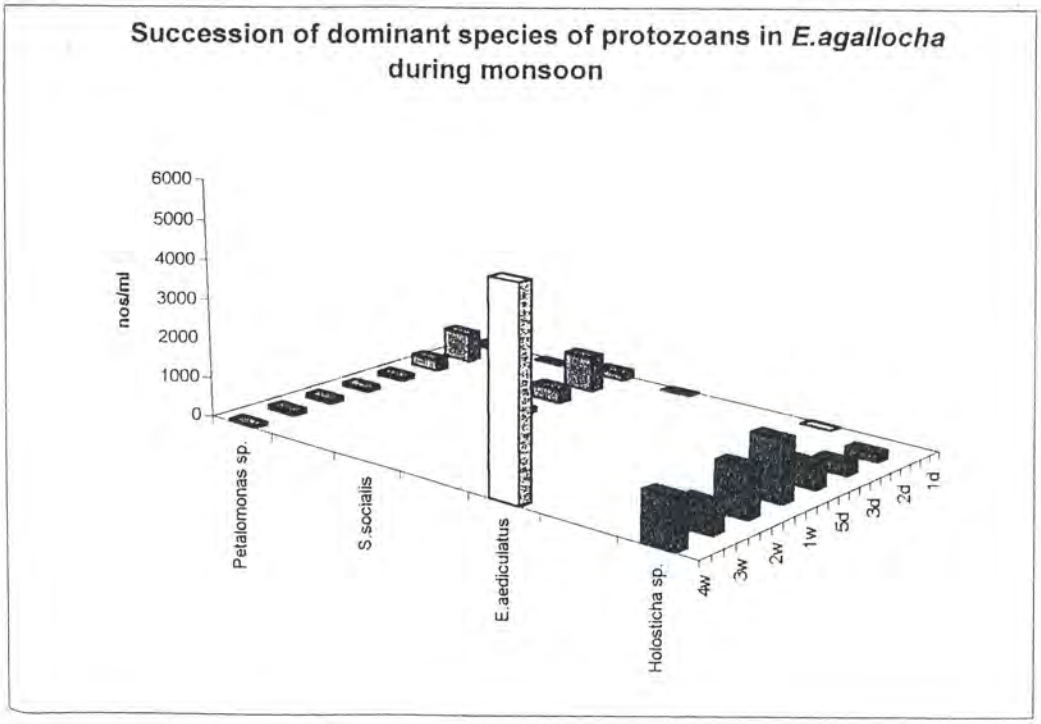
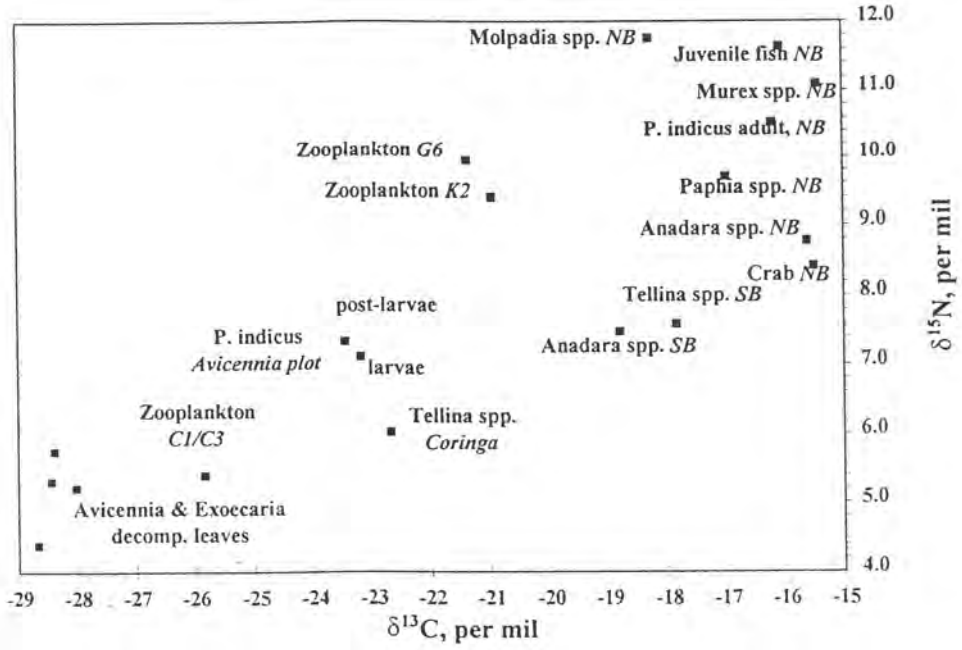
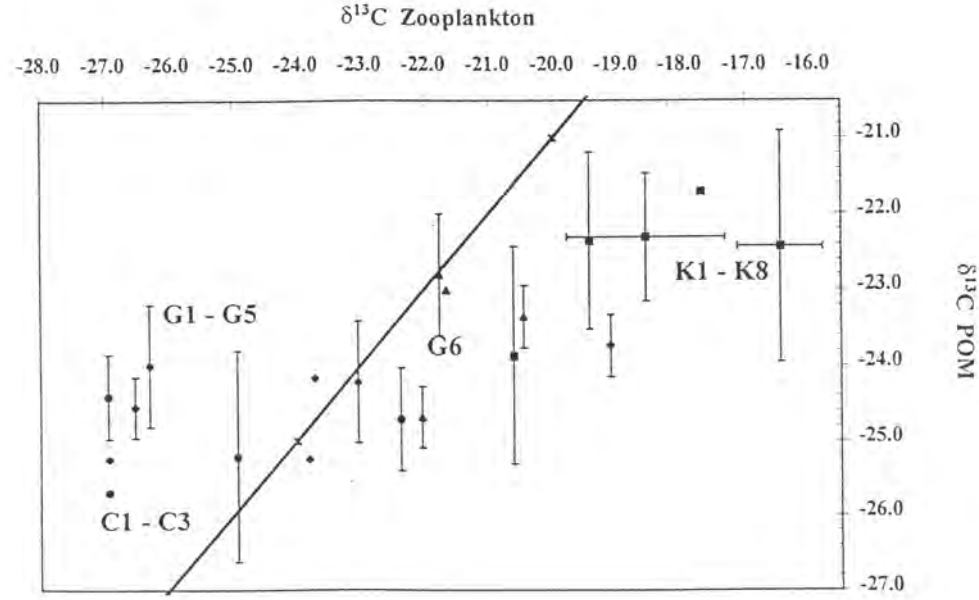

Succession of dominant species of protozoans in E.agallocha
during monsoon
nos/ml
6000
5000
4000
3000
2000
1000
0
Petalomonas sp.
S.socialis
E.aediculatus
Holosticha sp.
4w
3w
2w
1w
5d
3d
2d
1d

Fig. 19


Molpadia spp. NB
Juvenile fish NB
Murex spp. NB
P. indicus adult, NB
Zooplankton G6
Zooplankton K2
Papnia spp. NB
Anadara spp. NB
Crab NB
Tellina spp. SB
post-larvae
P. indicus
Avicennia plot
larvae
Anadara spp. SB
Zooplankton
C1/C3
Tellina spp.
Coringa
Avicennia & Exoecaria
decomp. leaves
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
δ15N, per mil
-29 -28 -27 -26 -25 -24 -23 -22 -21 -20 -19 -18 -17 -16 -15
δ13C, per mil


δ13C Zooplankton
-28.0 -27.0 -26.0 -25.0 -24.0 -23.0 -22.0 -21.0 -20.0 -19.0 -18.0 -17.0 -16.0
G1 - G5
G6
K1 - K8
C1 - C3
-21.0
-22.0
-23.0
-24.0
-25.0
-26.0
-27.0
δ13C POM

tidal action. The predominant factor has been salinity (Fig.20). In Kakinada Bay, while salinity is relatively high (mean 25.18‰), in the mangrove channels it varied from total freshwater conditions to a maximum of 33.24‰ (mean 17.37‰). Based on (median) salinity distribution, it was possible to distinguish the Bay-Estuary environment into 3 regions namely, polyhaline zone (salinity 27.19‰), mesohaline zone (19.54 ‰) and oligohaline zone (1.4 ‰). Dissolved oxygen fluctuated from a minimum of 2.15 mg.l-1 to a maximum of 12.01 mg.l-1. Photosynthetic oxygenation was the main source. It is noteworthy that dissolved oxygen mostly remained at saturation levels and never reached critical (reducing) concentrations. Inorganic nutrients registered high values and exhibited appreciable variations on a spatio-temporal scale. The maximum values (ug.at.l-1) were: nitrite, 10.76; nitrate, 83.52; phosphate, 52.0 and, silicate 1000. These high values are suggestive of the possible effects of anthropogenic additions (fertiliser factory, shrimp farms and municipal sewage) into these waters and the ongoing eutrophication.

Phytoplankton :

During the study, altogether 106 species of phytoplankton represented by bacillariophyceans, dinophyceans, cyanophyceans, and, eugelenophyceans were encountered (Rohini, 1997). *Skeletonema costatum* (17.3%), *Navicula salinarum* (12.37%), *Pleurosigma angulatum* (10.5%), *Nitzschia closterium* (6.51%), *Thallassionema nitzschiodes* (5.61%), *Nit. delicatissima* (4.43%) and *Nit. seriata* (3.79%) together accounted for over 60% of the total phytoplankton population numerically. Spatially, differences in species composition and abundance patterns were discernible. In the Bay environment, there were 87 species. Mean numerical abundance varied between 1,460 nos/ml (st. K8) and 2,917 nos/ml (st. K3). At stations K1, K2, K4 and K5 nearer the marine end (mean salinity 27.1 ‰), *S. costatum* (29.76%), *Nit. seriata* (8.37%), *P. angulatum* (6.58%), *T. nitzschiodes* (5.61%), *Nit. closterium* (4.34%), *Nit. delicatissima* (3.9%), *Ditylum sol* (3.72%) and *Thallassiothrix frauenfeldii* (3.15%) were characteristic and constituted 65.43% of the total phytoplankton by numbers. In the south Bay (sts. K3, K6, K7, K8), influenced by river flow and and mangrove outwelling (mean salinity 21.74‰), the predominant species were *S. costatum* (27.53%), *P. angulatum* (16.42%), *T. nitzschiodes* (6.6%), *Nit. closterium* (5%), *Nit. delicatissima* (4.96%), *P. aestuarii* (3.5%) and *Nit. seriata* (3.37%) which together formed 67.38% of the total population numerically. In Gaderu (sts. G1-G6) marked by a relative decrease in salinity (mean 16.68‰), the important species in the order of their abundance were *P. angulatum* (14.31%), *Nit. closterium* (9.91%), *Nit. delicatissima* (8.12%), *T. nitzschiodes* (7.37%), *S. costatum* (6.76%), *Oscillatoria latevirens* (4.01%), *O. limosa* (3.9%), *Thallassiosira subtilis* (3.69%), *O. agardhii* (3.1%), *Nit. seriata* (2.9%) and *P. aestuarii* (2.8%) forming 66.87% of total numbers at these locations. In Coringa (st.s C1-C3) (mean salinity 6.93‰), *Navicula salinarum* alone constituted the bulk (55.14%) of the population.

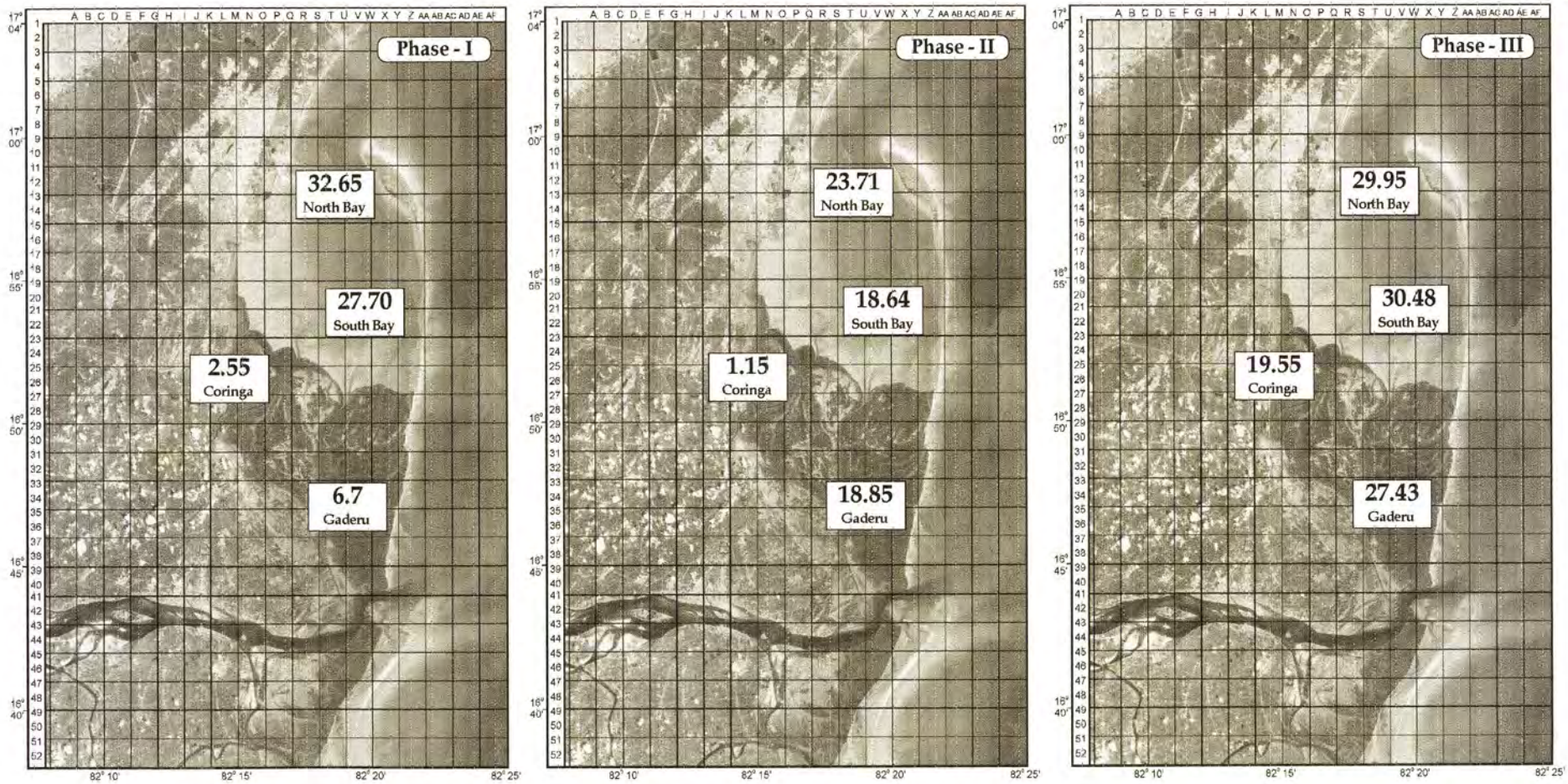
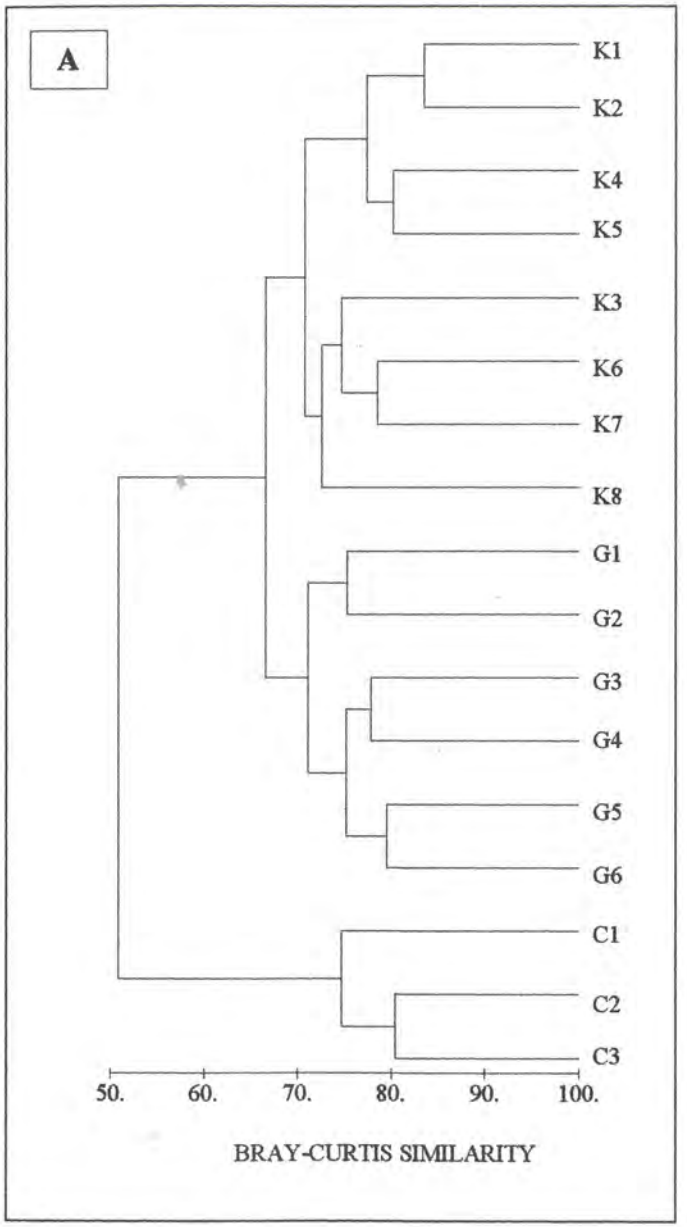


Fig. 20 : Mean surface-bottom salinity (‰) in the north & south Bay and Coringa-Gaderu mangrove locations

Other species included *Nit. closterium* (6.76%), *O. agardhii* (6.07%), *S. costatum* (3.72%), *P. angulatum* (3.6%), *Nodularia* sp. (3.07%) and, *Spirulina laxa* (2.58%) that together formed 80.94% of the population numerically. Mean total chlorophyll levels in the north Bay were significantly lower (19.71 ug/l) relative to south Bay, Gaderu or Coringa. Indices related to species diversity (d, H', J') were calculated by using the entire set of species in each location. The ranges of these indices as well as those parameters related to abundance revealed appreciable differences in community structure among samples. Fig. displays results of hierarchical clustering using group average linking on the phytoplankton species abundance data for the 17 sites in the Bay-Mangrove waterways. Bray-Curtis similarities (through PRIMER) were calculated on the 4th root transformed data and, from the resulting dendrogram (Fig.21a), it was possible to define the locations into three groups determined at 70% similarity. These consisted of (Group-A) stations K1-K8 (upper dendrogram) representing the Bay environment; Group-B stations, G1-G6 (middle dendrogram) Gaderu and, Group-C stations, C1-C3 (lower dendrogram) corresponding to Coringa. The dendrogram provided a sequence of fairly convincing groups of stations confirmed by MDS plot (Fig.21b) for the same locations. Fig.22 shows MDS plots superimposed with environmental data. Abnormally high levels of nitrogen and phosphate presumably derived from fertiliser factory wastes, town's sewage, drainage from farm lands and, shrimp culture ponds led to conditions that caused periodic outbursts of phytoplankton. Total chlorophyll values varied from undetectable levels to a maximum of 182.72 mg.m^{3}. Primary productivity (14C) was measured on 5 occasions and it was noticed that the net production was highest (536.2 mgC m^{2} day^{-1}) in Kakinada Bay where comparatively stable conditions prevailed.

Zooplankton :

Altogether 80 species represented by seven taxonomic groups namely, coelenterates, cladocerans, copepods, mysids, polychaetes, tunicates and chaetognaths were encountered during the study. In addition, a variety of decapod larvae and molluscan veligers constituted the bulk of meroplanktonic population. In the mangrove channels (st. G3), copepods were numerically the most dominant group (74.23%) followed by molluscan (16.87%) and decapod larvae (3.86%). Mean population abundance was 60,098 nos. m^{-3} and biomass (wet wt.), 0.99 ml.m^{3}. Secondary productivity (mg. dry wt. m^{-3} day^{-1}) ranged between values 5.92 and 75.46, the mean value being 33.1. Based on the species composition and their relative distribution and abundance, it was possible to categorise the zooplankton populations as those inhabiting predominantly the mangrove channels; the shallow areas of south Bay of relatively brackish conditions and north Bay characterised by the proximity of the open sea (Chandramohan et al., 1999; Srinivas, 1999).



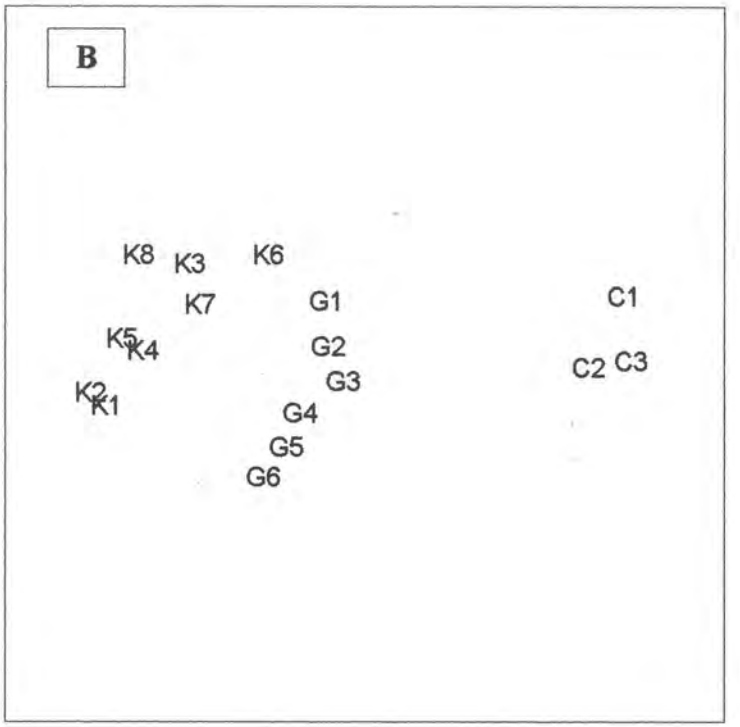


Fig. 21: Phytoplankton of Bay-Mangrove waterways. (A) Dendrogram of 17 stations using 4^{th} root transformation of phytoplankton abundance data and (B) MDS configuration for the same locations (stress 0.07)

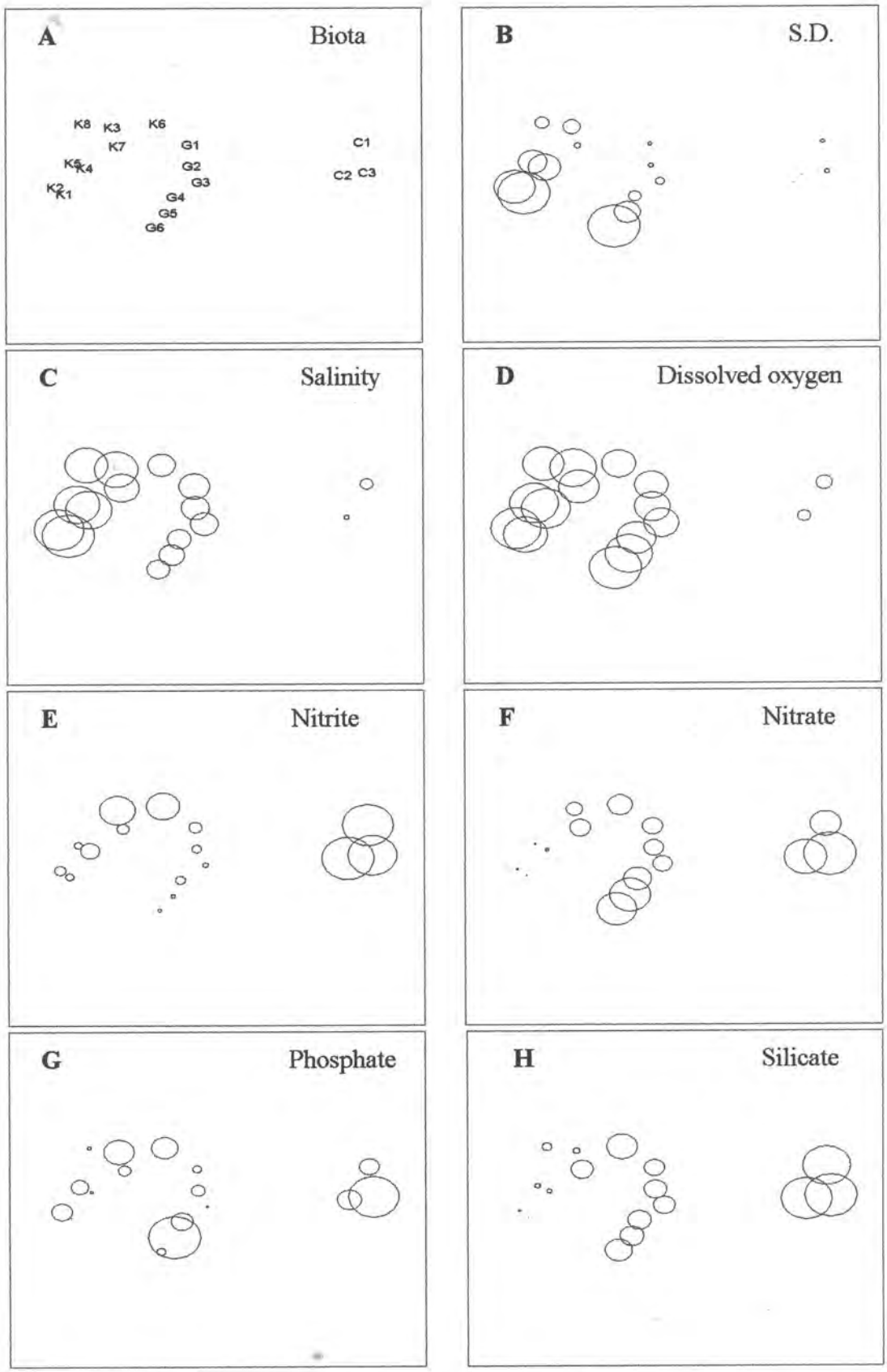


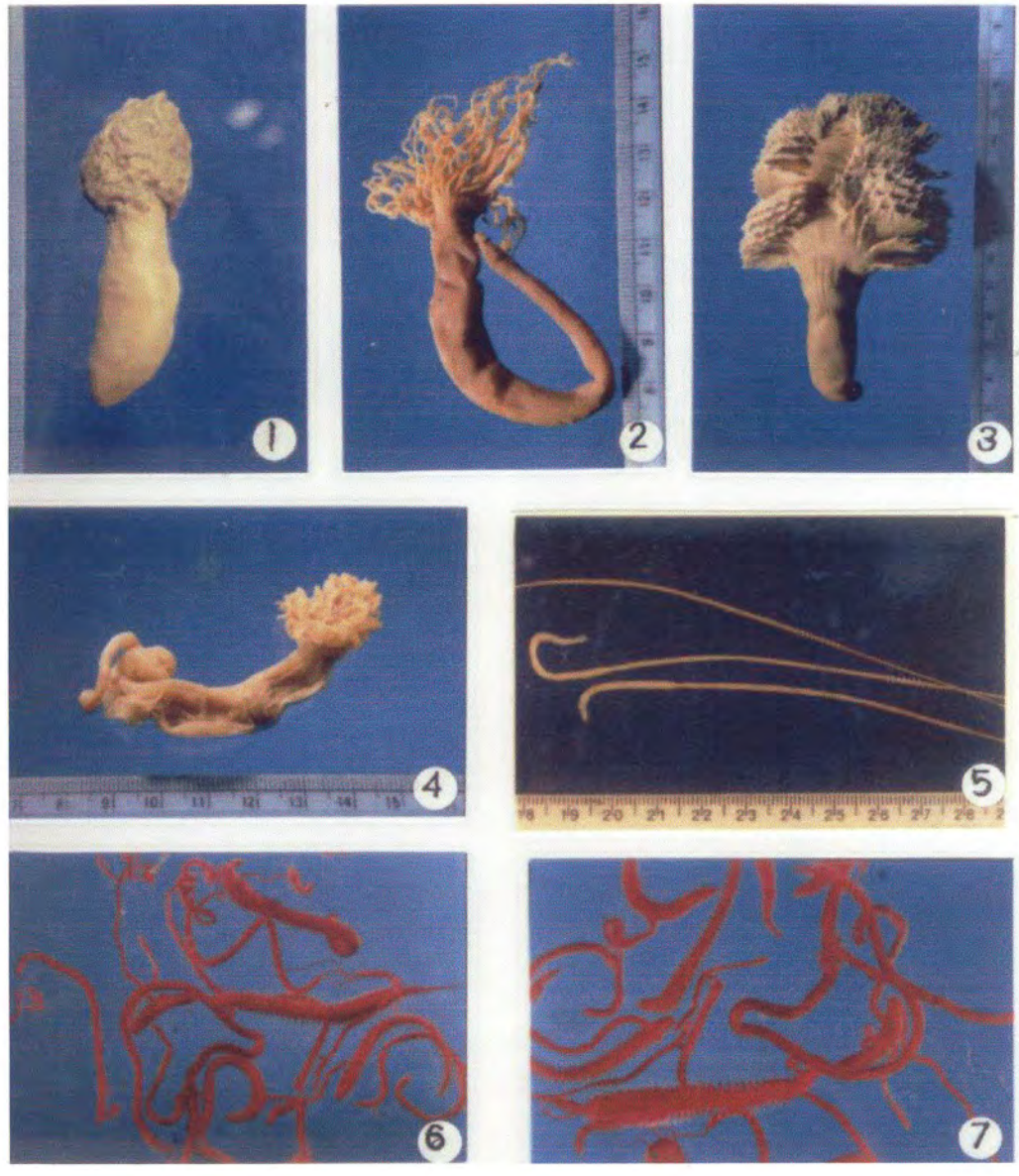
Fig. 22: Phytoplankton of Bay, Mangrove waterways: (A) MDS plots (Biota) of 17 sampling sites, superimposed with (B) S.D.; (C) Salinity; (D) D.O.; (E) Nitrite; (F) Nitrate; (G) Phosphate and, (H) Silicate (stress 0.07)

Benthic Macrofauna :

Altogether 114 species of macrobenthic organisms (dredge and grab hauls) represented by as many as 8 major taxa namely, porifera, cnidaria, annelida, arthropoda, mollusca, echniodermata, echiura, and chordata were encountered during the study (Dipti Raut, 1997) (Plates 23-28). Overall, polychaetes formed by far the most dominant group (65.98%) followed by crustaceans (25.53%), bivalves (6.55%), anthozoans (1.19%), ophiuroids (0.18) and other groups. Of these, Prionospio cirrifera (Polychaeta) outnumbered (32.74%) numerically all other species in the collections while *Cirithedia cingulata* (Gastropoda) constituted the bulk (31.78%) of the population in the dredge hauls. Data on sediment characteristics (texture and organic carbon) revealed a close approximation of cause-effect relationships with benthic diversity and abundance (Figs. 23 & 24). Sediments close to mangroves supported a rich biomass (Fig. 25). There ware as many as 52 Biologically Important Species in the study area, which could be categorised into specific faunal assemblages through Principal Component Analysis (PCA) (Figs. 26 & 27). A notable feature of this study is that the one time dominants namely, *Tonna dolium* and *Turritella acutangula* (Gastropoda) found in large numbers in a study carried out in this area in 1958, have dwindled now. Similarly, there has been a substantial reduction in the numbers of echinoderm populations in the Bay. Over the years, species diversity (d) decreased from 0.83-2.83 noticed earlier (1958) to 0.74-1.4 in the present study. Sanders' rarefaction analysis indicated similar changes in the overall community structure (Fig. 28). The investigations have also revealed that some of the earlier assemblages (*Placuna placenta, Anadara granosa*) have either faded out totally or modified spatially attributable to changes in sediment nature (texture, organic content) and other physico-chemical factors during the intervening years.

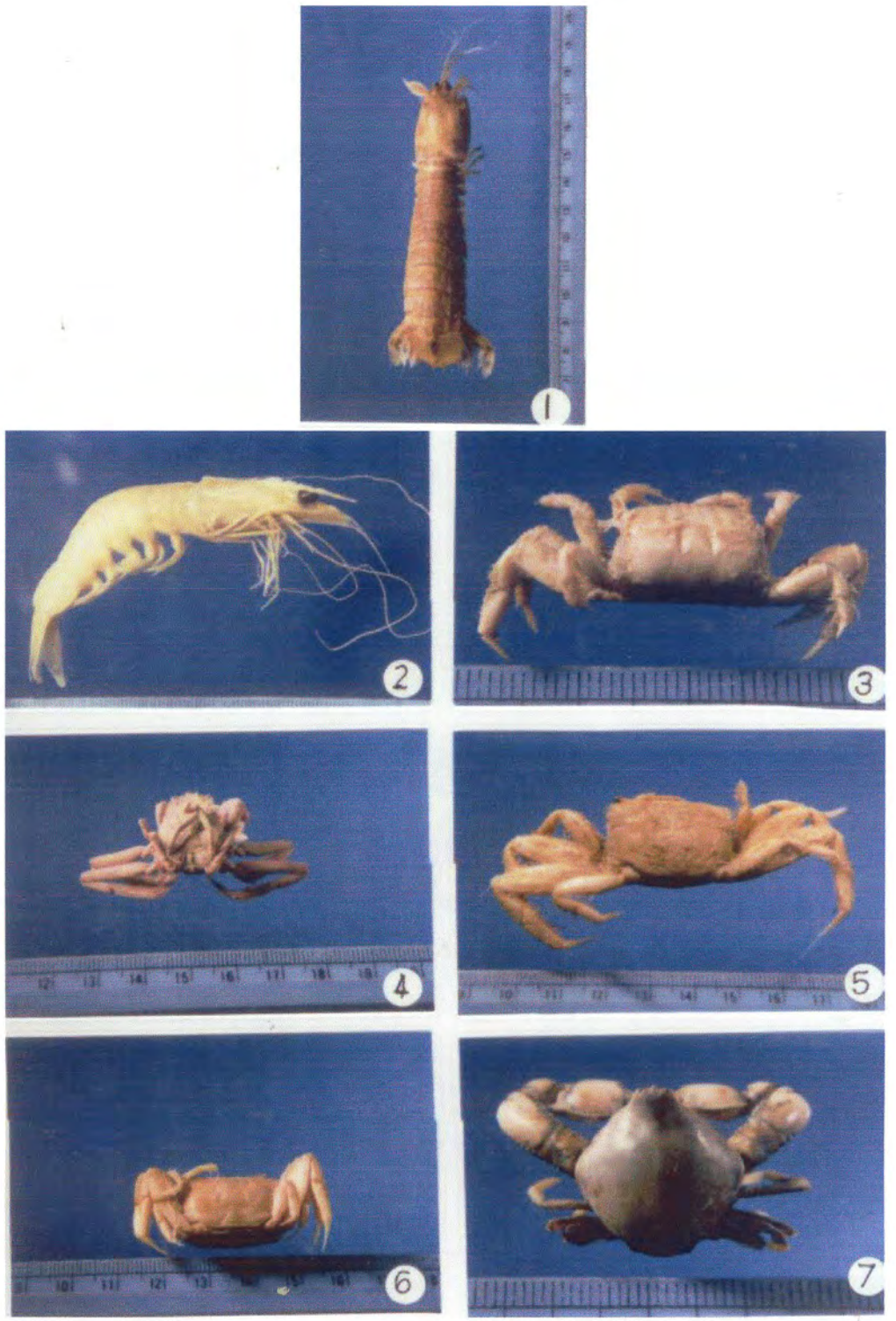
To sum up, the present study has revealed that the Bay-Estuary environment close to the mangroves of Kakinada underwent considerable physiographic and other changes since earlier times attributable to severe human interventions through mangrove destruction, location of new industrial undertakings and intense aquaculture practices. While much of the mangrove areas are already in a state of serious threat through unauthorised reclamation by locals, the regions within Coringa Wildlife Sanctuary may even now be considered species-rich and structurally diverse. Different climate regimes as well as topographical and hydrodynamic factors are thought to be at the basis of various mangrove types (C.E.C. Report, 1997). While it is obvious that many human activities such as fisheries, wood extraction, aquaculture relay on the presence of mangrove forests, the intrinsic interrelationship between natural occurrence and productivity of specific crustancean, shellfish and fin-fish communities on the one hand and mangroves on the other is but poorly known. This is a paradox, since deleterious effects of human activities on the normal functioning of a mangrove ecosystem on which they are apparently dependent compromises sustainability. A will to protect and manage the mangrove forest can

Plate : 23



1. *Tetilla dactyloidea* 2. *Cerianthus* sp. 3. *Pteroides* sp. 4. *Phytocoetopsis ramunii*
5. *Virgularia* sp. 6 & 7. Polychaetes

Plate : 24

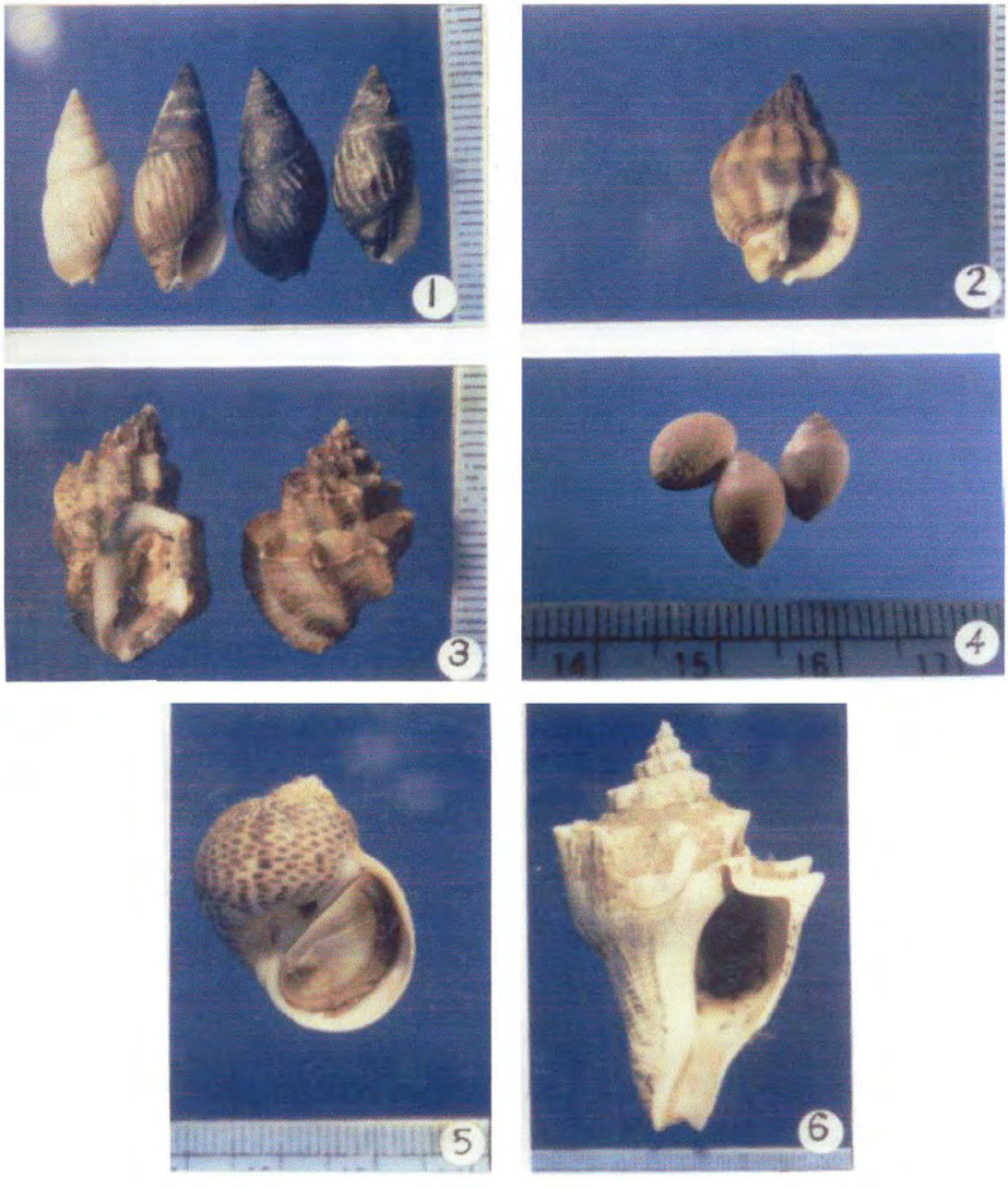


1. *Harpiosquilla* sp. 2. *Penaeid* sp. 3. *Typhlocarcinus* sp. 4. *Dorippe* sp.
5. *Metaplax dentipes* 6. *Macrophthalmus* sp. 7. *Leucosia* sp.

Plate : 25

1. *Umbonium vestiarum* 2. *Sinum haliotoideum* 3. *Turricula javana* 4. *Tonna dolium*
5. *Cerithidea cingulata* 6. *Murex tribulus* 7. *Thais lacera* 8. *Babylonia spirata*

Plate : 26



1. *Nassarius foveolatus* 2. *N. stolatus* 3. *Scalptia scalariformis* 4. *Melampus ceylanicus* 5. *Natica tigrina* 6. *Pugilina* sp.

Plate : 27

1. *Nucula convexa* 2. *Anadara rhombea* 3. *A. granosa* 4. *Striarca lactea*
5. *Modiolus undulatus* 6. *Placuna placenta* 7. *Diplodonta* sp. 8. *Neosolen aquaedulcioris*

Plate : 28

1. *Siliqua albida* 2. *Tellina iridescens* 3. *Macoma gubernaculum* 4. *Gari maculosa*
5. *Abra maxima* 6. *Paphia textrix* 7. *P. malabarica* 8. *Marcia penguis*

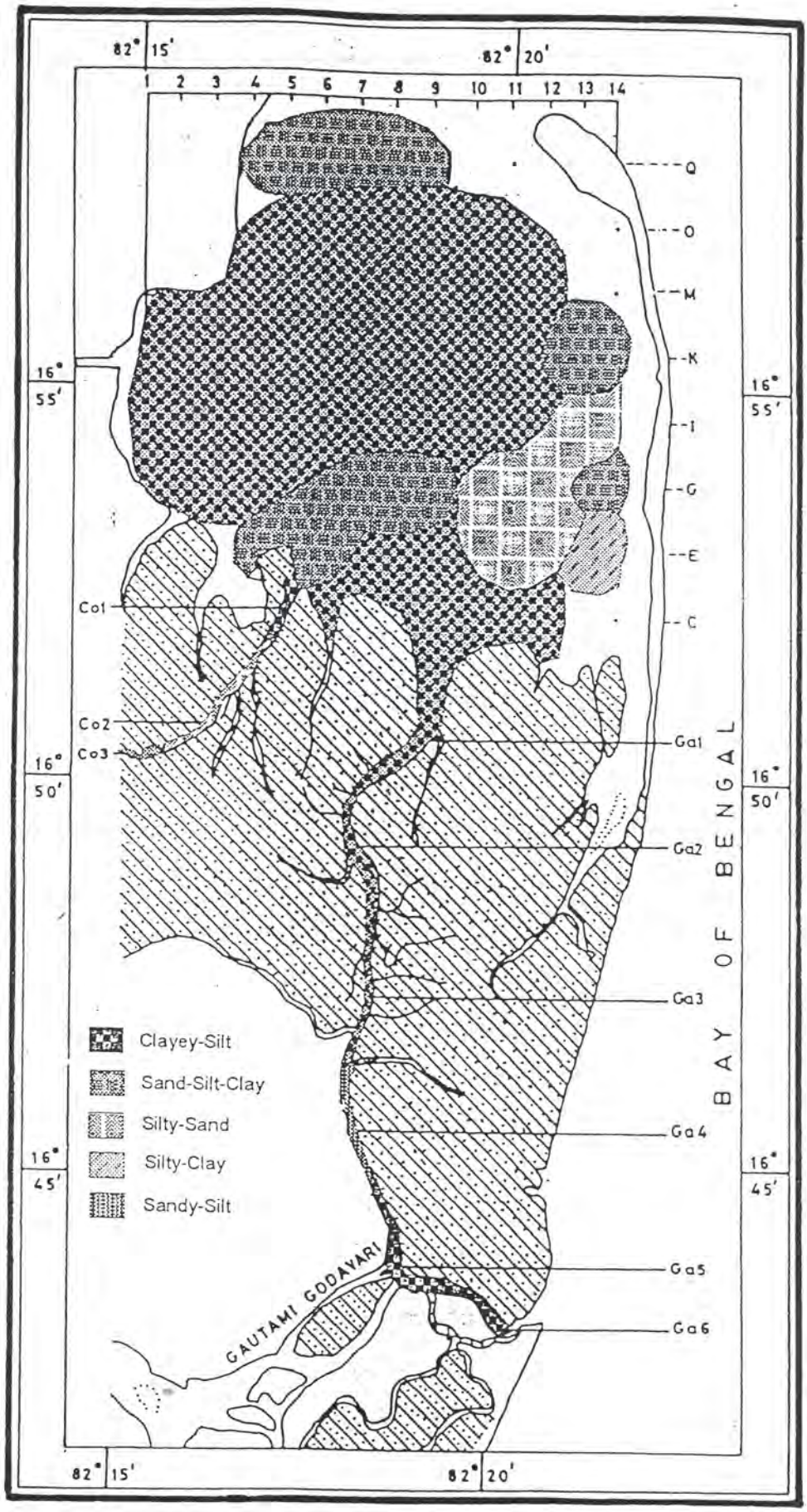


Fig. 23 Distribution of sediment textural classes in the study area (1995-'96)

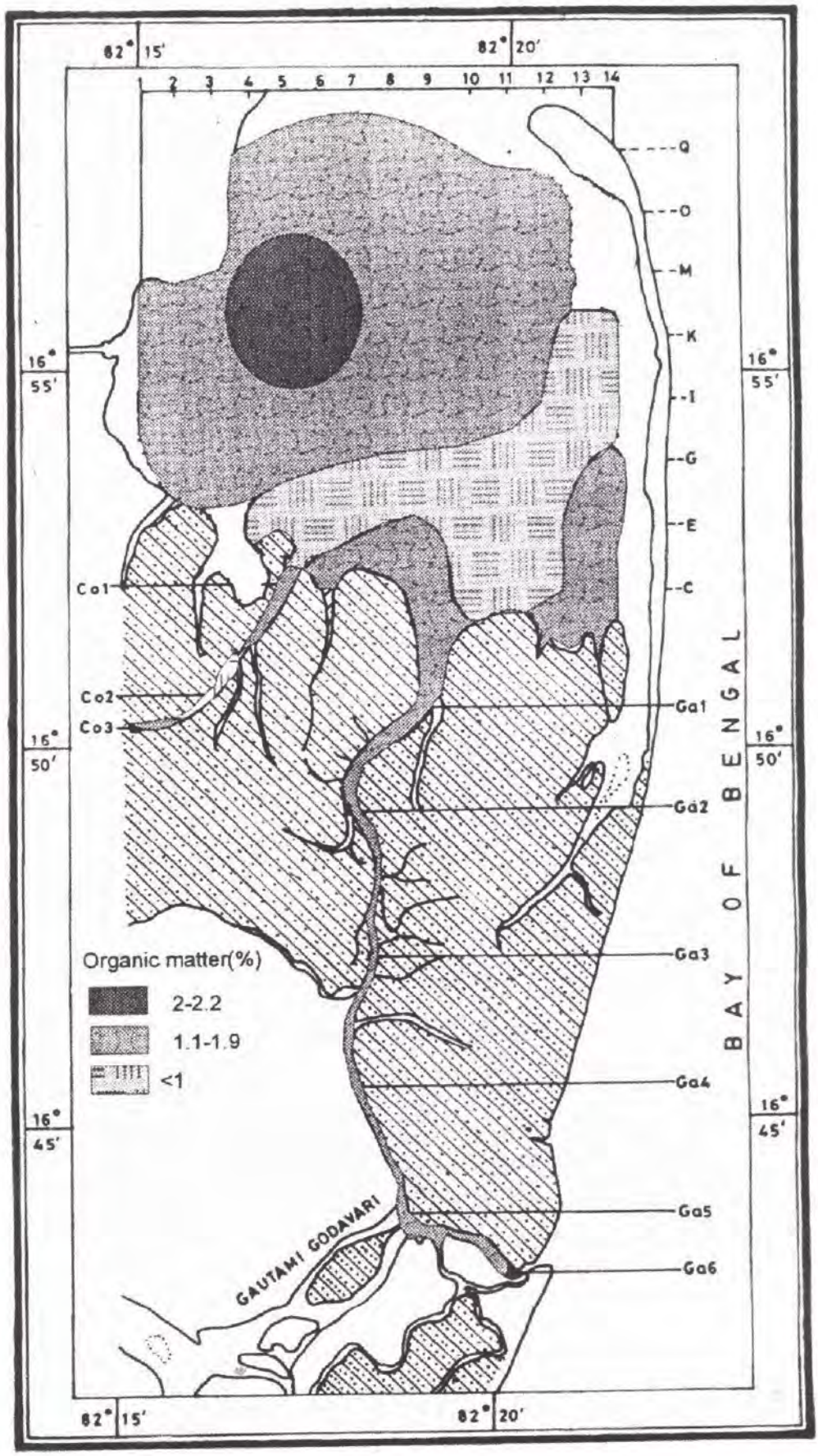


Fig. 24 : Sediment Organic matter in the study are (1995-'96)

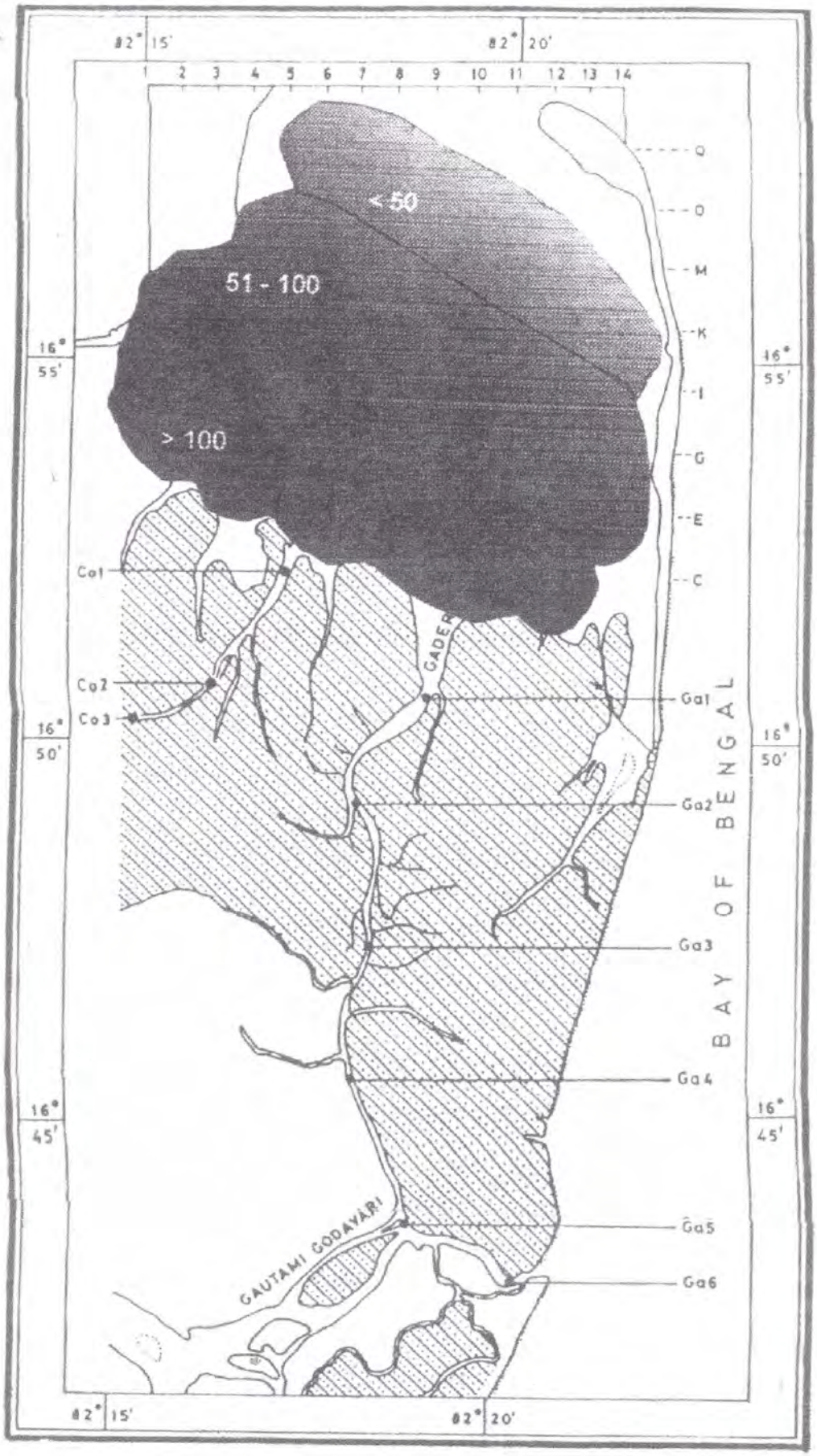


Fig. 25 : Faunal density (based on pooled mean) of epifauna (n°/haul) in Kakinada Bay

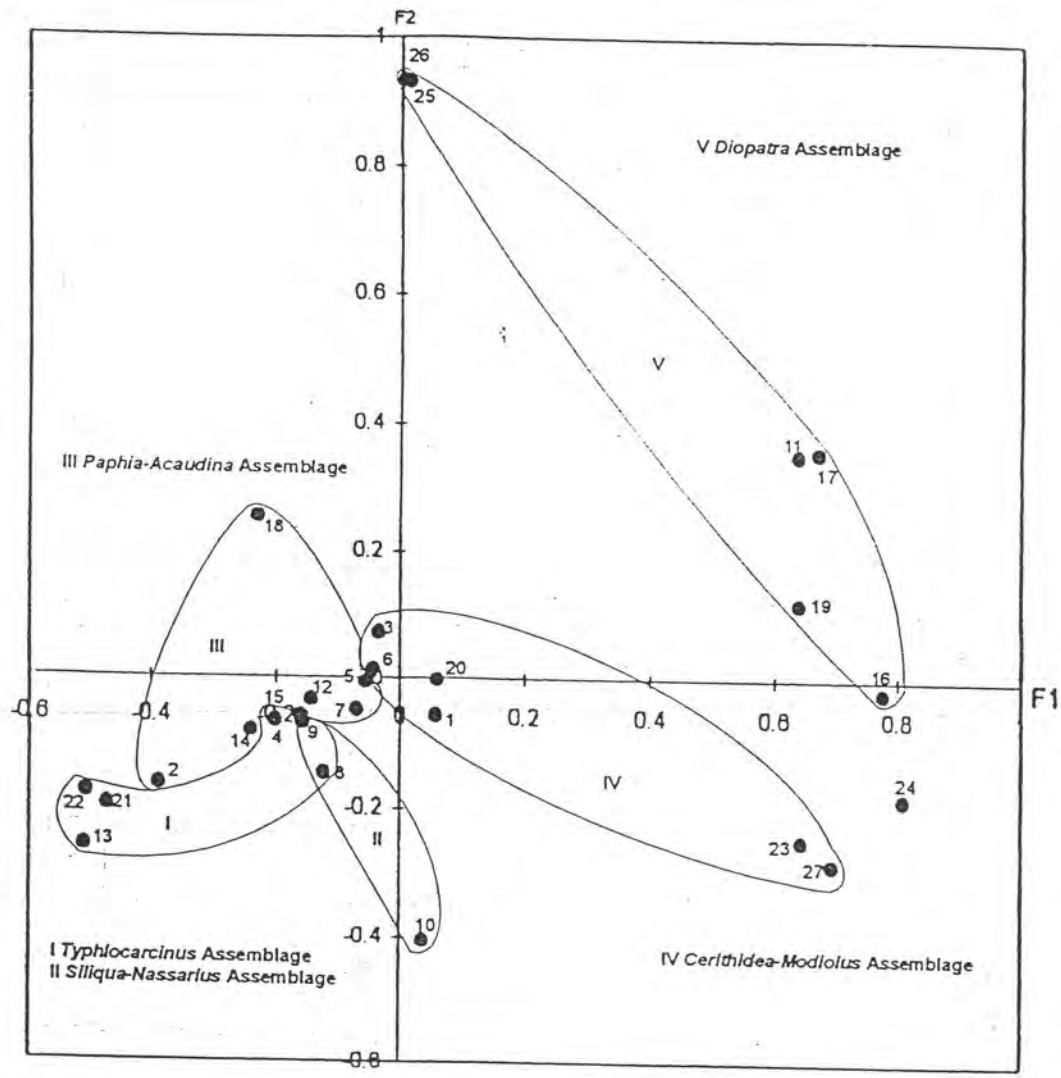


Fig. 26 Position of species (dredge hauls) on factors 1 and 2 in the Q-mode of factor analysis
(Nos. indicate BIS rank)

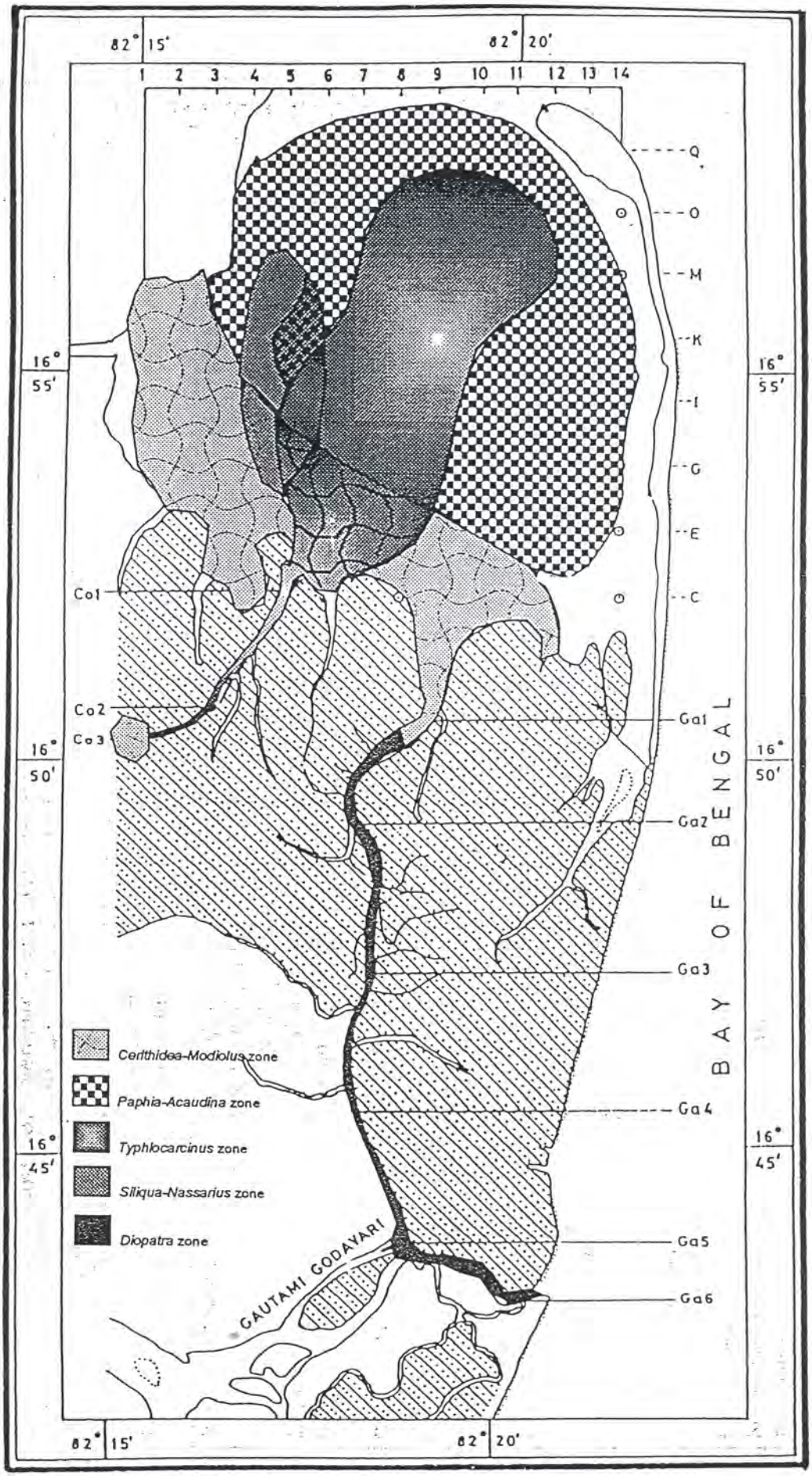


Fig. 27 Benthic macrofaunal Assemblages (dredge fauna) in the study area (Apr '95-Feb'96)

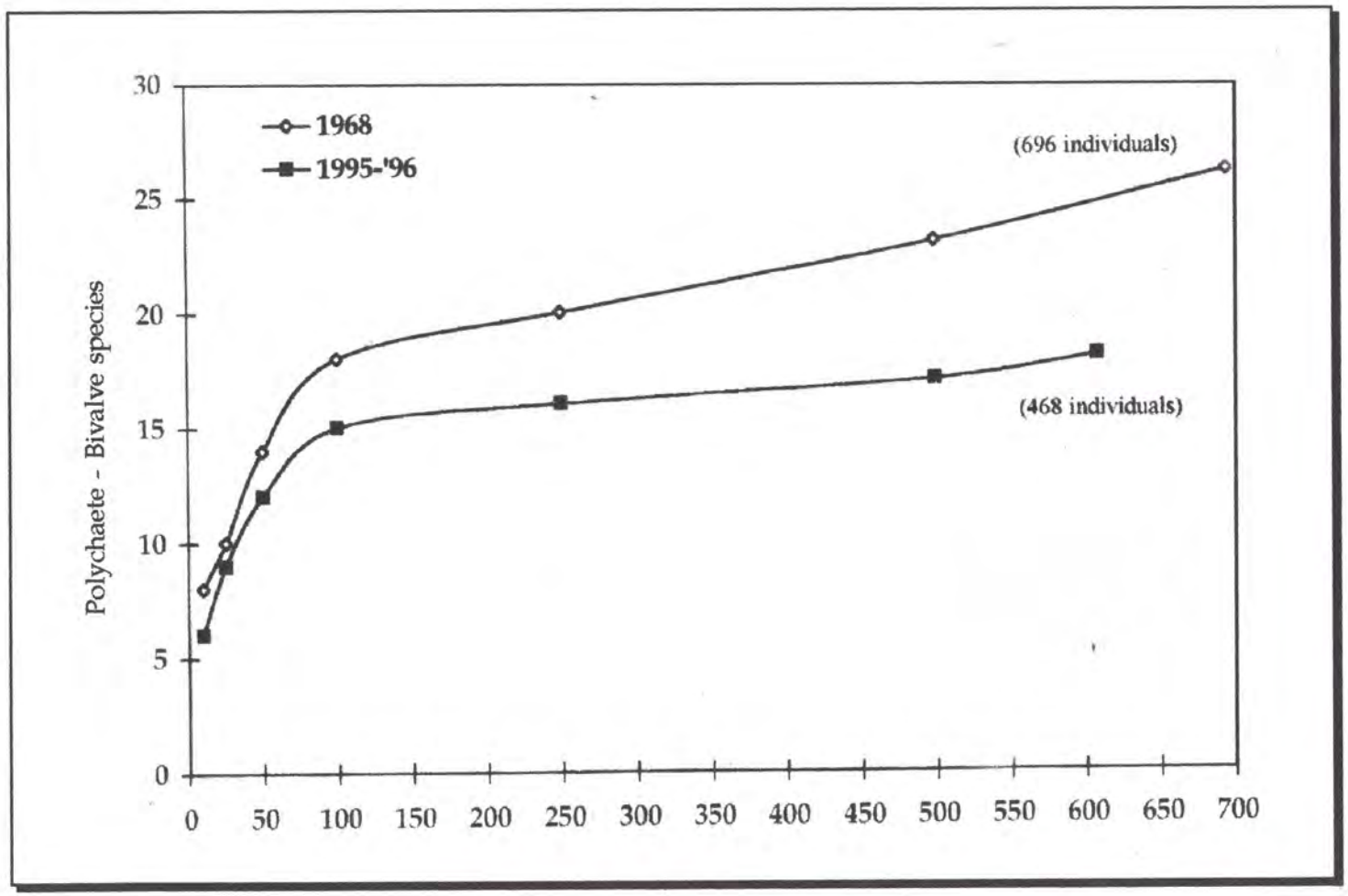


Fig. 28 : Sanders rarefraction curves, 1968 and 1995-96. Polychaeta-Bivalve component, Kakinada Bay (<2.5)

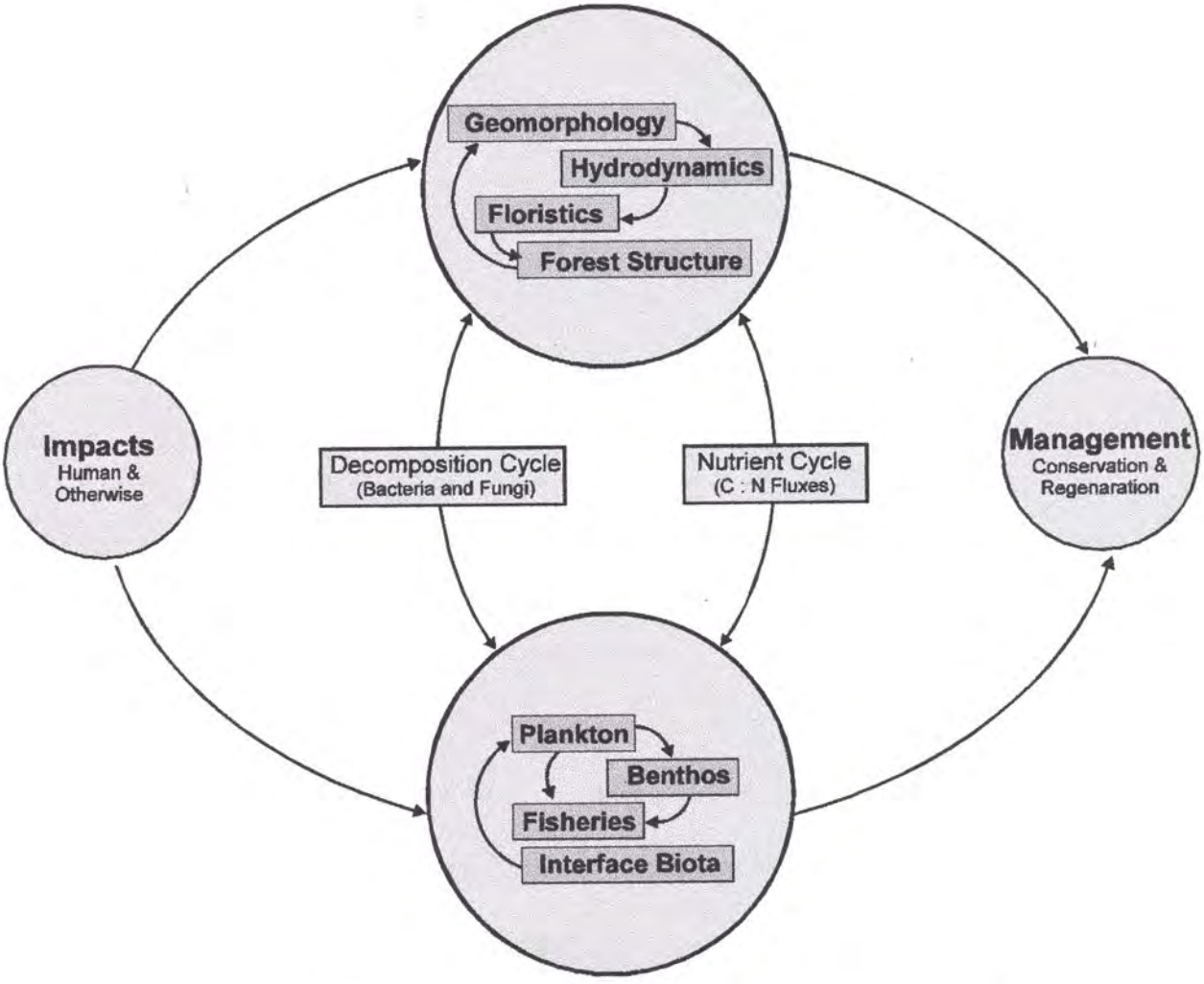


Fig. 29 : Coringa Mangroves : An Ecosystem Approach for Sustainable Development

clearly be discerned. At present, this is however not matched by our understanding of factors governing their establishment, dynamics and regeneration, which impedes rational management plants.

Fig. 29 shows the information flow for future work mangroves. The emphasis would be on food chains within mangrove habitat and the resources of energy and carbon. Aspects such as direct grazing on mangrove tissue, turn over of mangrove litter, decomposition processes, role of bacteria, higher consumers, export from mangrove habitats particulate carbon, DOC, influence of mangrove carbon on adjacent systems and below ground processes, not studied earlier, form the core programme of future work.

MARINE LIVING RESOURCES (MLR) RELATED RESEARCH
For the EEZ along Indian Sea coast
(DOD/10/MLR/10/97/OD-II)
1998-2003

As a part of DOD's efforts towards MLR Related Research for the EEZ along Indian Sea coast, Cruise171 of FORV Sagar Sampada was organised in Bay of Bengal on 6-24 January 1999. The primary objective of the study was to collect information on the Benthic productivity in the EEZ of India on the East Coast.

Altogether, 44 stations were covered between 11 o N and 20 o N beginning at Karaikal in the south and up to Paradeep in the north (Fig.30). At each transect (limited to the shelf area), samples were collected at 30, 50, 100, 150 and 200 m depth sites depending on the width (narrowness) of the shelf. Details of station locations, depth where samples collected, date-wise schedules are given in Table 1. Since the overall emphasis was clearly the benthic productivity, adequate attention was paid to this aspect and samples collected accordingly (Cruise Report, 1999).

BENTHIC PRODUCTIVITY

Meiobenthos

Methodology :

At each station, a Smith-McIntyre grab was operated. With the help of a glass corer (2.5 cm diameter), replicate sediment samples of 10 cm long cores were drawn and each core was divided into two equal halves of upper five and lower 5 cm. The samples were in toto transferred to polythene containers, labeled and the material preserved in 70% alcohol for further examination. Samples for textural properties were same as macrobenthos. On arrival at the Marine Biological Laboratory, Andhra University, the sediment samples were washed with distilled water and then treated with 4% neutral formalin and Rose Bengal for biological (group-wise) sorting and meiofaunal enumeration. The fauna, which passed through 5 mm sieve (while sieving), but retained on 62mm sieve were considered as meiofauna.

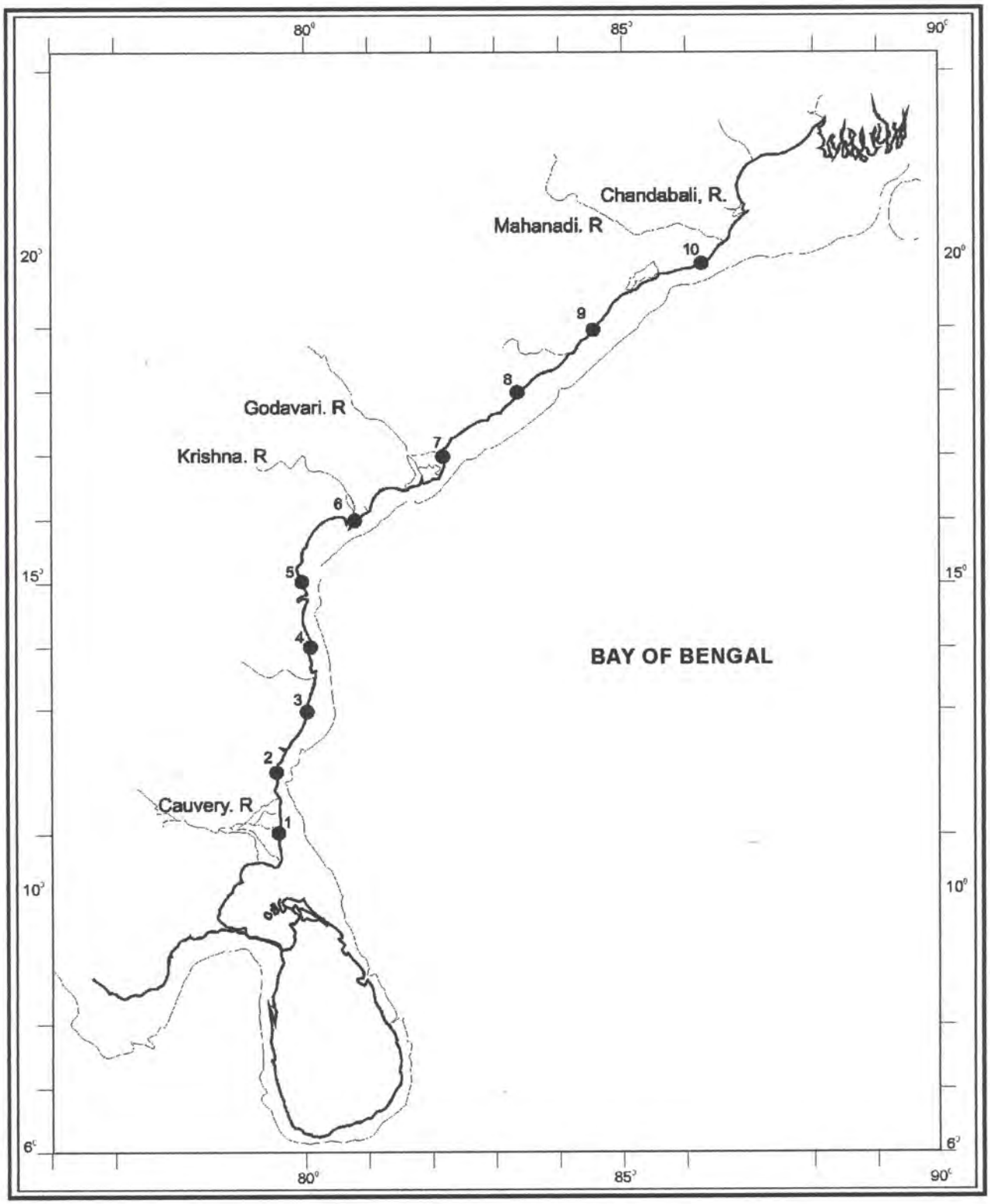


Fig. 30 : Sampling locations, FORV Sagar Sampada Cruise 171:
1. Karaikal, 2. Cuddalore, 3. Chennai, 4. Krishnapatnam, 5. Kavali, 6. Divi Point, 7. Kakinada, 8. Visakhapatnam, 9. Barua, 10. Pradeep

So far, 24 samples each of the 24 stations sampled were examined. Altogether eight groups namely, Foraminifera, Turbellaria, Nematoda, Polychaeta, Archianneldida, Ostracoda, Copepoda and Acari were encountered (Sheeja, 1999). Numerically, 4,344 individuals of meiobenthic forms from both upper (0-5 cm) and lower half (5-10 cm) of the cores were enumerated. Overall, nematodes constituted the bulk (39.34%) of the population followed by foraminiferans (27.12%), copepods (9.25%) and polychaetes (7.11%) (Fig.31). The investigations have also revealed considerable spatial differences. For example, transect 9 (off Barua, stations 203-206) accounted for 29.03% of the total meiobenthic population followed by transects 6 and 7 (off Divi point and Kakinada respectively) represented by stations 190-199 of population size 23.05-23.94% (Fig.32). Samples-wise, faunal numbers varied from values as low as 20/10 cm2 (st.205) to a maximum of 497/10 cm2 (st.204A1) depending on the location, depth and nature of the sediment. As regards depth, samples collected at 30 m accounted for over 44% of the fauna collected numerically (Fig.33). Abundance decreased proportionately with depth being 19.68%, 15.88% and 4.08% at 50, 100 and 150 m respectively. It is, however, noteworthy that at 200 m (sts. 190 & 199) where the sediments are very clayey, there has been a four-fold increase in the numerical abundance of fauna (15.68%) largely attributable to nematodes that constituted over 50% of the total numbers collected at this depth (Fig.34). During the study, it was also noticed that while the upper half of the core (0-5 cm) supported a much greater wealth of life numerically (mean 150/10 cm2), the lower half (5-10 cm) exhibited a general paucity (mean 34 nos./ 10 cm2) of fauna.

MACROBENTHOS

Methodology :

A Smith-McIntyre grab (0.10m^2) was used for unit sampling. Immediately after collection, the sediment samples were washed through 1 mm or 0.5mm sieves depending on their texture. For coarse sediments, 1mm sieve was used prior to a 0.5mm sieve. Sieving was carried out on a (wooden) platform meant for the purpose. Samples for meiobenthos and sediment nature were collected separately, the latter for textural characteristics (sand, silt, clay and % organic content). Textural samples were oven dried onboard (600) and stored in polythene bags for later analysis. In the case of biological samples, the faunules were carefully separated after sieving and together with residual sediment, if any, they were fixed in 7% (buffered) formalin, labeled and stored for further examination.

During the study, a naturalist's dredge was used to collect the epifauna. The dredge made of metal frame (40x40 cm), fitted with a nylon mesh (1 cm2) and, appropriately weighted, proved very useful and worked quite satisfactorily up to 150m depth. At each location, the dredge was hauled for varying times (10 to 42 minutes) depending on the location (depth), nature of bottom etc. In areas where

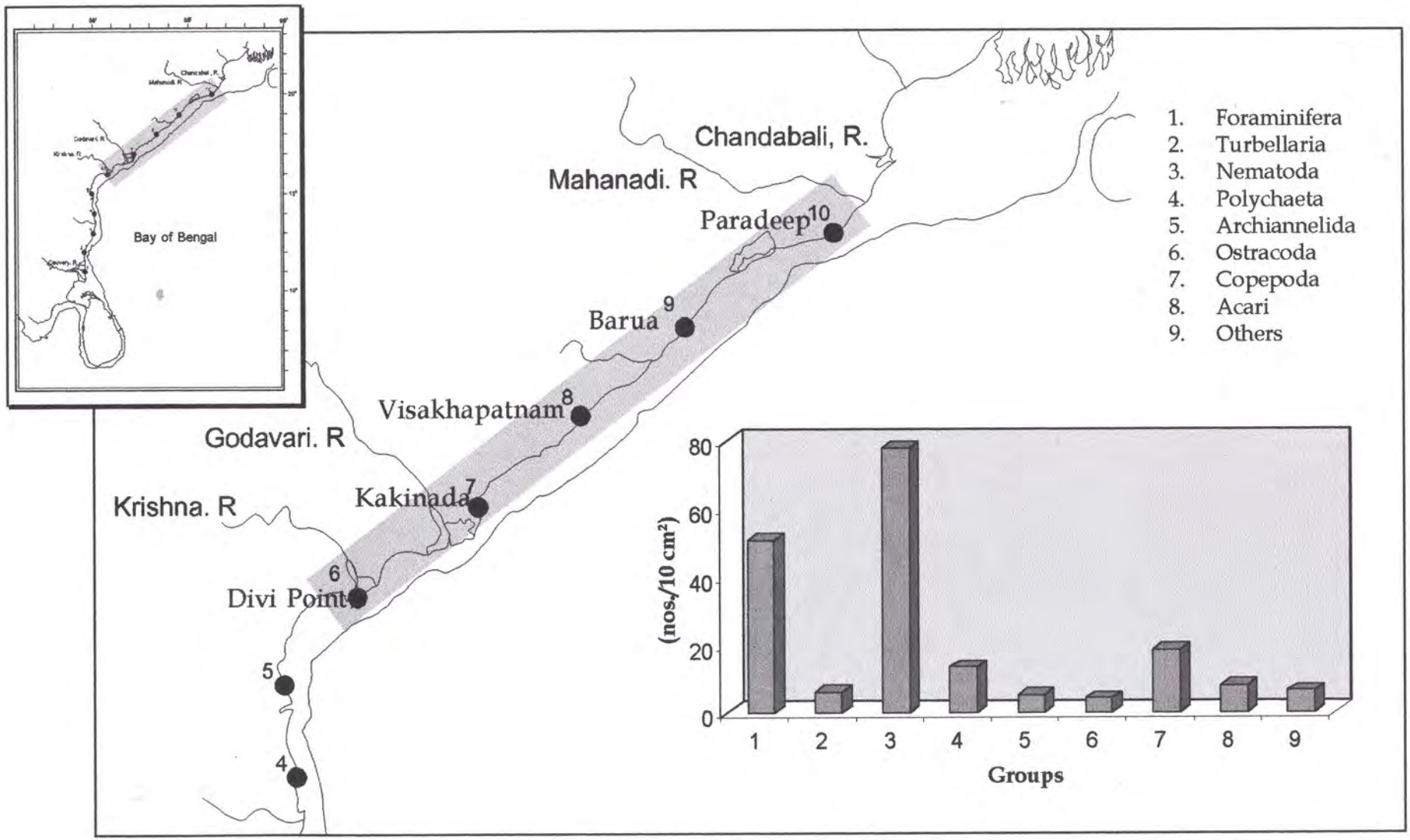


Fig. 31 : Meiobenthos of the north east coast of India: Overall numerical abundance (mean nos./10 cm²), Cruise 171

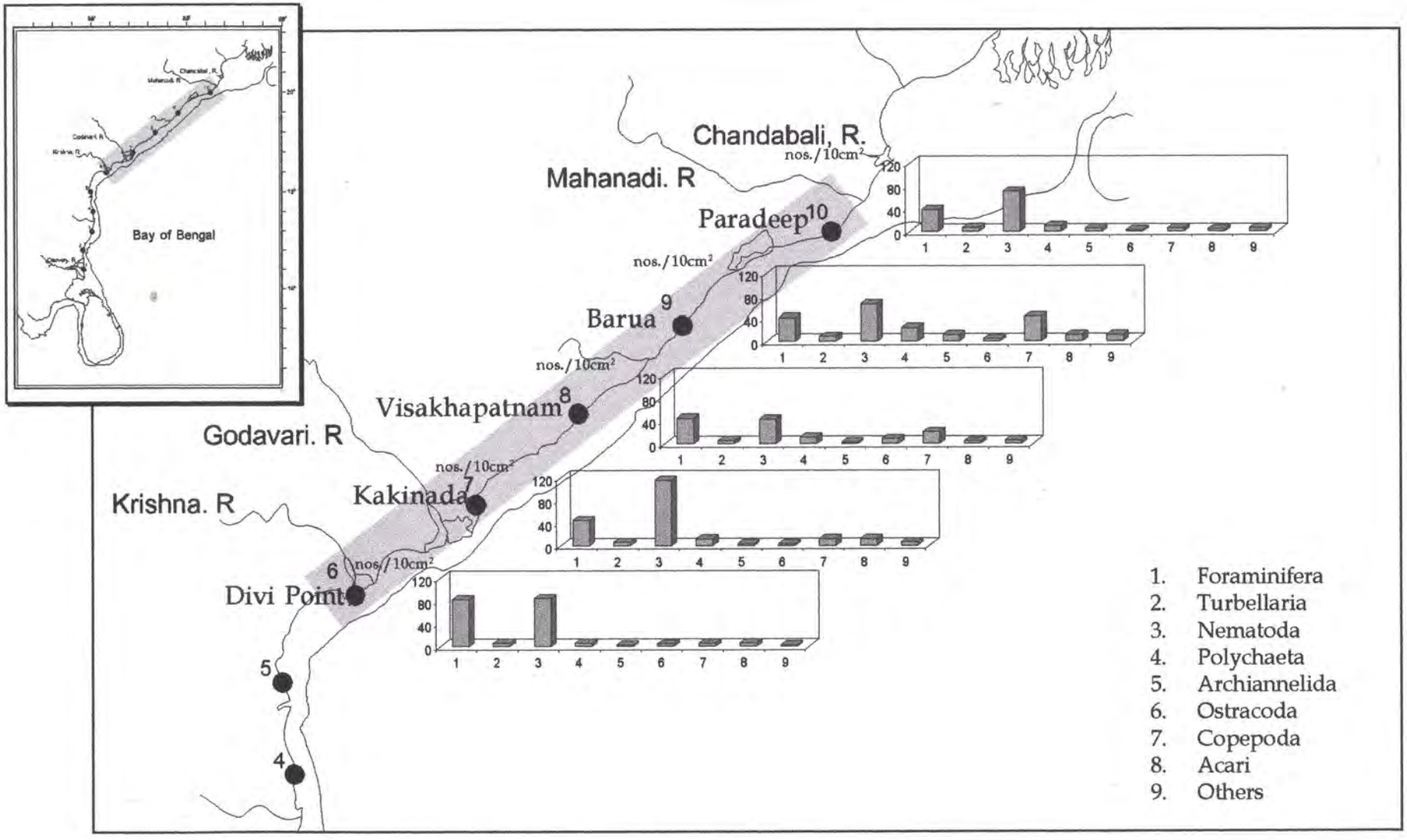


Fig. 32 : Meiobenthos of the north east coast of India: Numerical abundance (mean nos./10 cm²) at each transect, Cruise 171

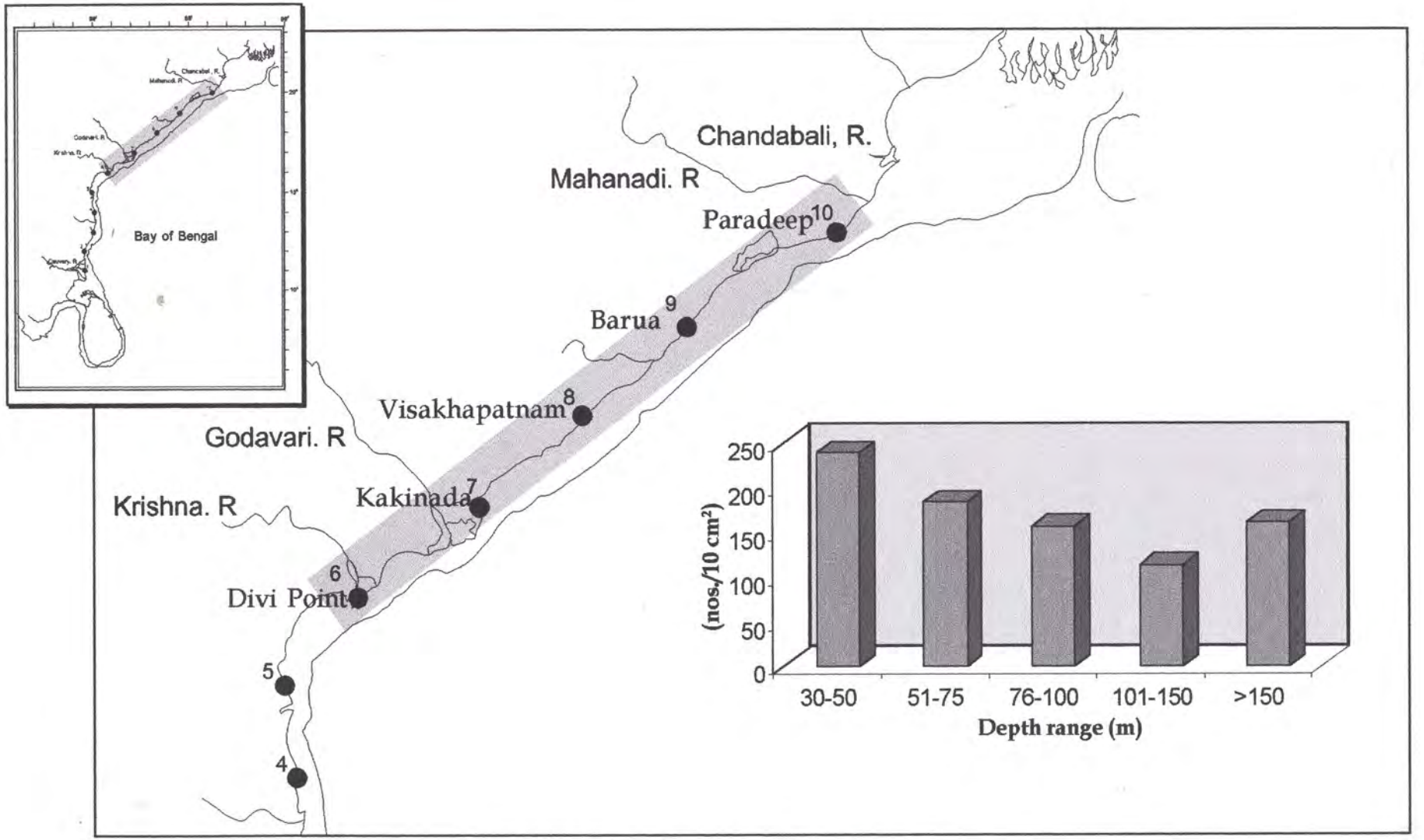


Fig. 33 : Meiobenthos of the north east coast of India:
Numerical abundance (mean nos./10 cm²) at varying depth ranges, Cruise 171

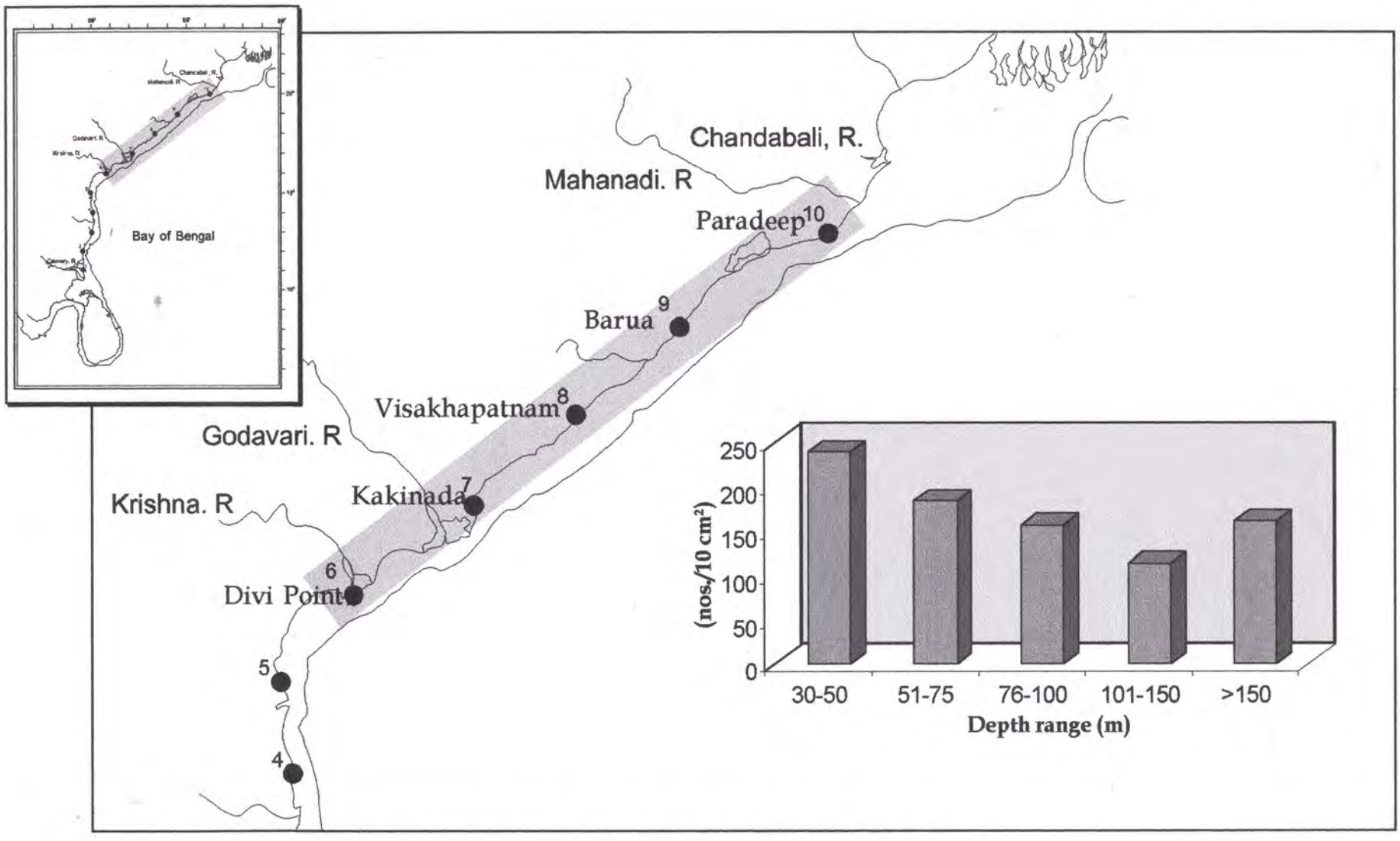


Fig. 33 : Meiobenthos of the north east coast of India: Numerical abundance (mean nos./10 cm²) at varying depth ranges, Cruise 171

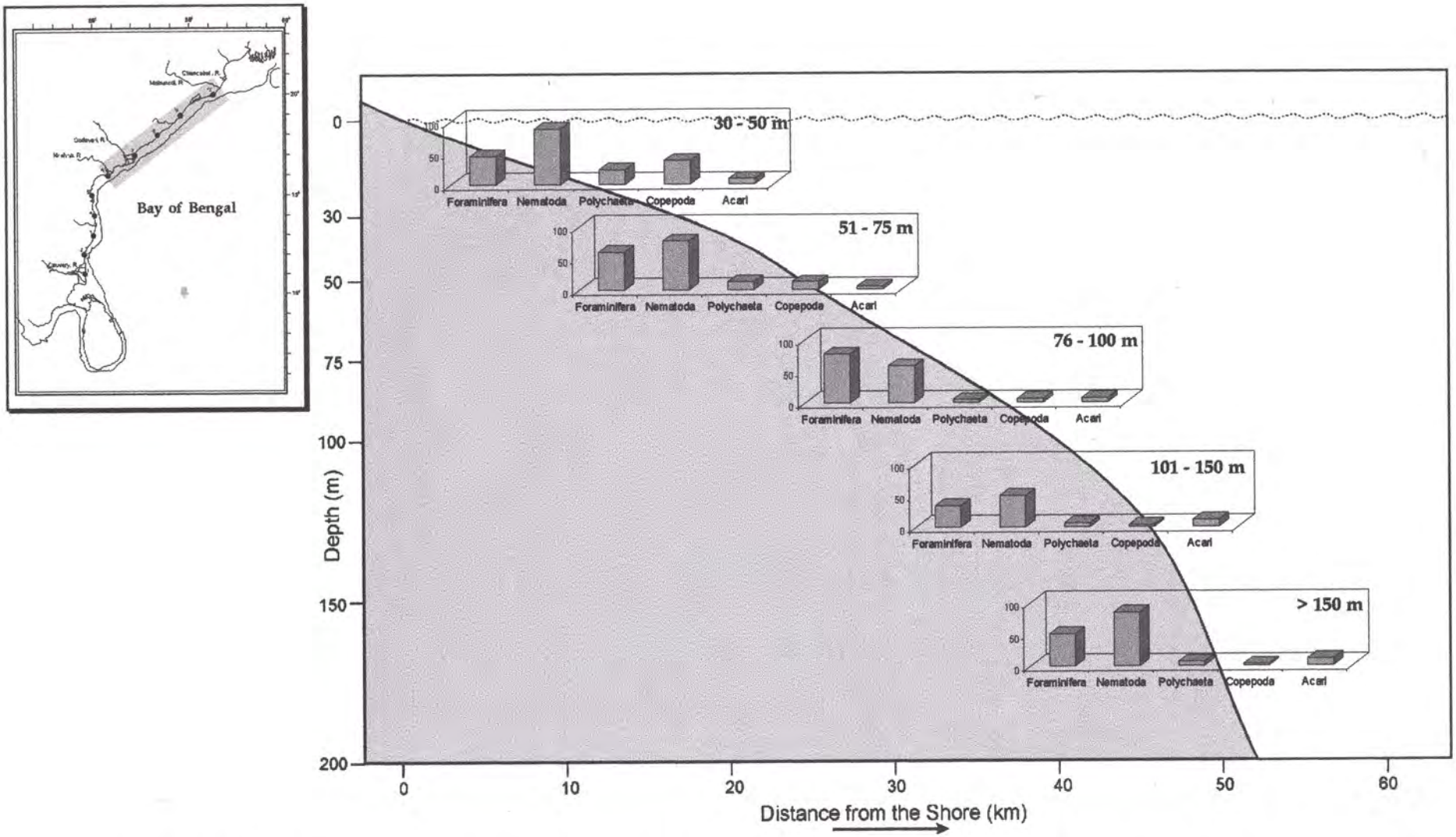


Fig. 34 : Meiobenthos of the north east coast of India: Numerical abundance of dominant groups (mean nos./10 cm^2) in relation to depth, Cruise 171

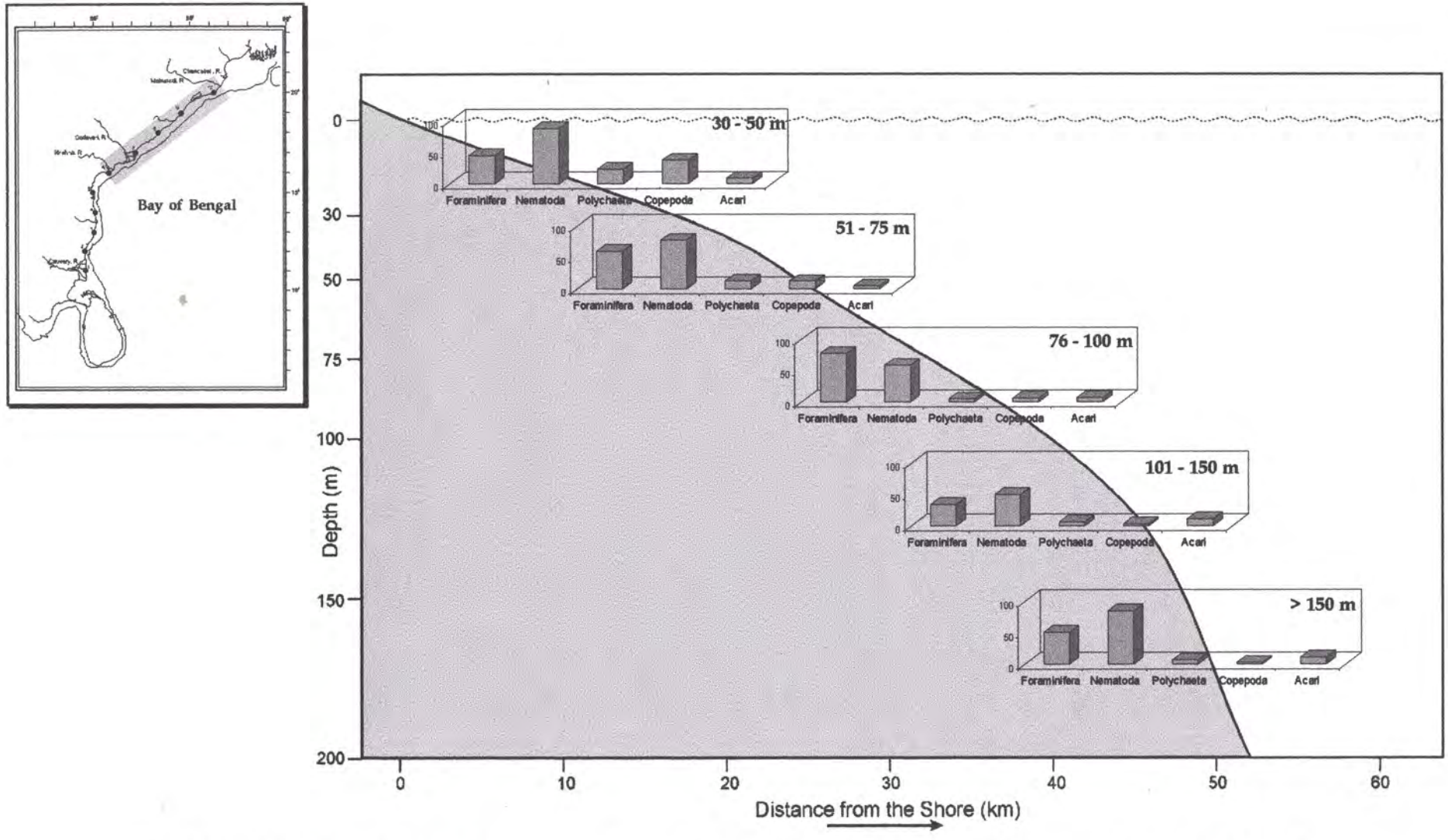


Fig. 34 : Meiobenthos of the north east coast of India: Numerical abundance of dominant groups (mean nos./10 cm^2) in relation to depth, Cruise 171

the depth was more (>50 m), it was operated for a longer duration acquiring a better coverage.

In the dredge hauls, there were altogether 12 diverse groups of organisms represented by Anthozoa, Polychaeta, Stomatopoda, Decapoda, Gastropoda, Scaphopoda, Bivalvia, Ophiuroidea, Echinoidea, Holothuroidea, Sipuncula and Pisces (Ganesh, 1999). Of these, gastropods and bivalves were by far the most diverse and represented by as many as 51 species (eg. Plates 29-34). The common species of gastropods included *Conus* sp., *Terebra* sp., *Natica gaulteriana* and *Nassaria coramendalica*. Among bivalves *Mactra mera* and *Macoma* sp., were important. Next in importance were polychaetes and decapods (identification in progress). Numerically, there were altogether 705 individuals (excluding 18 numbers of sediment burrowing eels, Anguiliformidae) from 12 stations. Table 6 contains group-wise abundance at different locations (depths). It may be seen that st.207 (30 m) off Paradeep accounted for 32.1% (or 226 numbers/haul) of the total individuals collected during the study followed by stations 195 (30 m) and 201 (50 m) consisting of 12.91% (91 nos./haul). Numerically, polychaetes (38.87%) followed by decapods (28.79%) outnumbered all other groups (Fig. 34). Fauanl density decreased appreciably with depth being 62.4%, 27.5% and 10.1% at 30, 50 and 100 m respectively (Fig. 35). The grab samples are being analysed for the moment and our findings have revealed a preponderance of polychaetes (aphroditidae, eunicidae, nephtyidae, glyceridae, spionidae, maldanidae, cossuridae, capitellidae, terebellidae, sabellidae etc) and amphipods (*Gammaridae* and *Ampliscidae*).

SECONDARY PRODUCTIVITY

(Zooplankton)

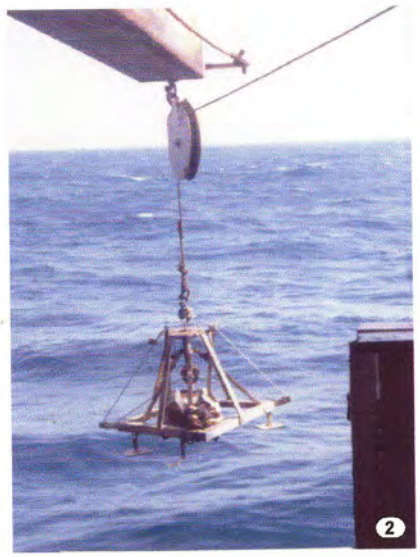
This work was carried out as a part of the environmental studies and estimating secondary productivity for the east-coast coast. Altogether 38 stations (nos.169-210) beginning at Karaikal (N11°; E 79°58'00") and up to Paradeep (N20° 86°46'18"E) were covered. Overall 57 samples were collected for species composition, distribution, and 48 for biomass (secondary productivity) estimation.

Methodology :

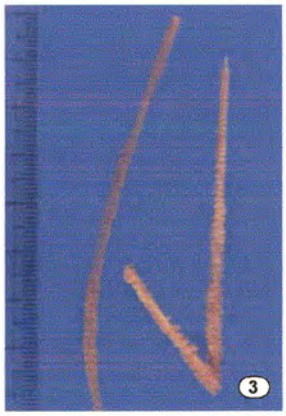
Surface (2-3 m depth) zooplankton samples were obtained with the help of a Bongo net. The net together with the flow meter (Hydrobios) was lowered alongside ship and operated for about 5-7 minutes. A Multiple Plankton Sampling System (MPSS) was put to use at every 200m depth for purposes of determining vertical heterogeneity, if any. Two sub-samples (200 to 50 m and 50 m to surface) were obtained.

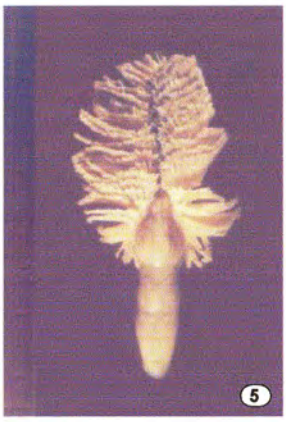
The investigations have revealed presence of as many as 29 groups of Zooplankton including copepods, ostracods, cladocerans, amphiopods, pteropods,

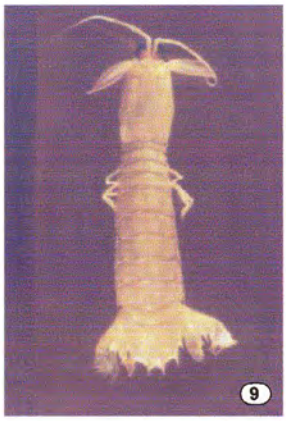
Plate : 29

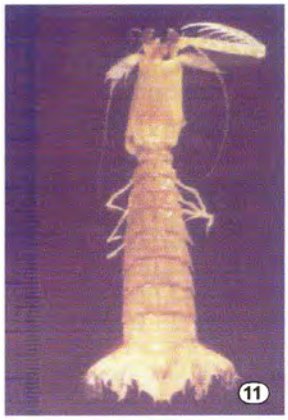


1. CTD in operation; 2. Smith McIntyre Grab lowered; 3. Grab hauled;
4. Over the sieving platform; 5 & 6. Sieving in progress; 7, 8 & 9. Naturalist's Dredge









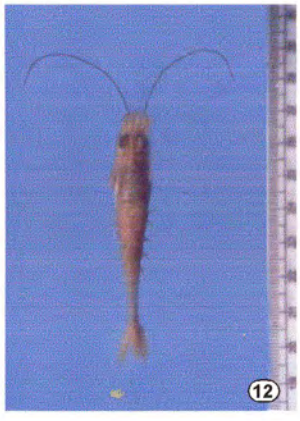


Plate - 30

1. Sphenopus arenaceus; 2. Heterocyathus aquicostatus; 3.*Virgularia* sp. 4. *Pteroides* sp. 1
5. *Pteroides* sp. 2; 6. Aphroditid (UI); 7. *Sternaspis scutata;* 8. *Lenisquilla* sp.;
9. *Oratosquilla* sp.; 10. *Harpiosquilla raphidea*;* 11. *H. annandalei;*
12. *Trachypenaeus* sp.; 13. Sicyonid prawn (UI)

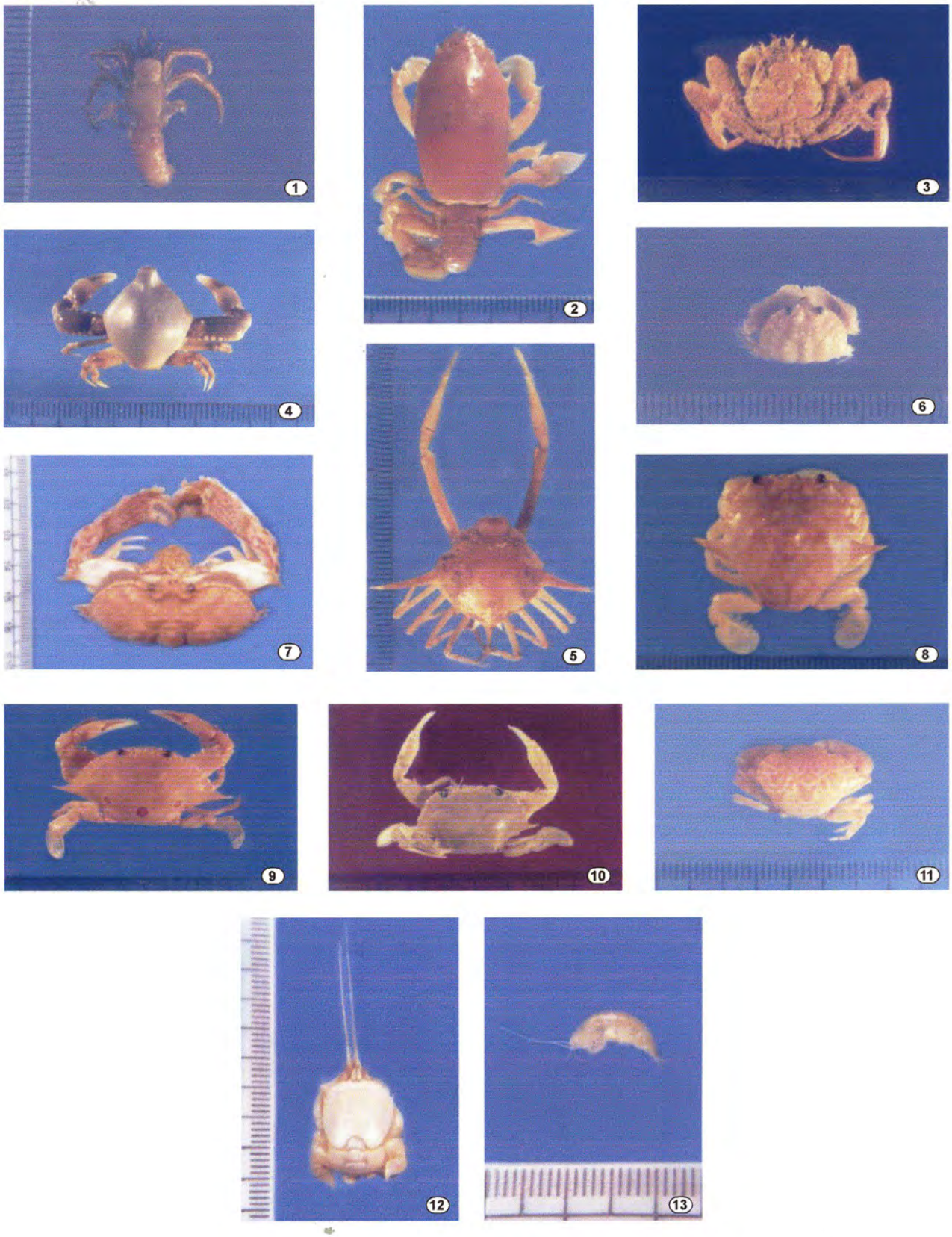


Plate - 31

1. Dardanus sp; *2. Raninoides* sp.; *3. Dorippe* sp.; *4. Leucosia* sp.; *5. Arcania* sp.; *6. Calappa* sp.1; *7. Calappa* sp.2; *8. Matuta* sp.*; *9. Portunus sanguinolentus**; *10. Charybdis* sp.; *11. Liagore* sp.; *12. Albunea* sp.; *13.* Amphipod (UI)

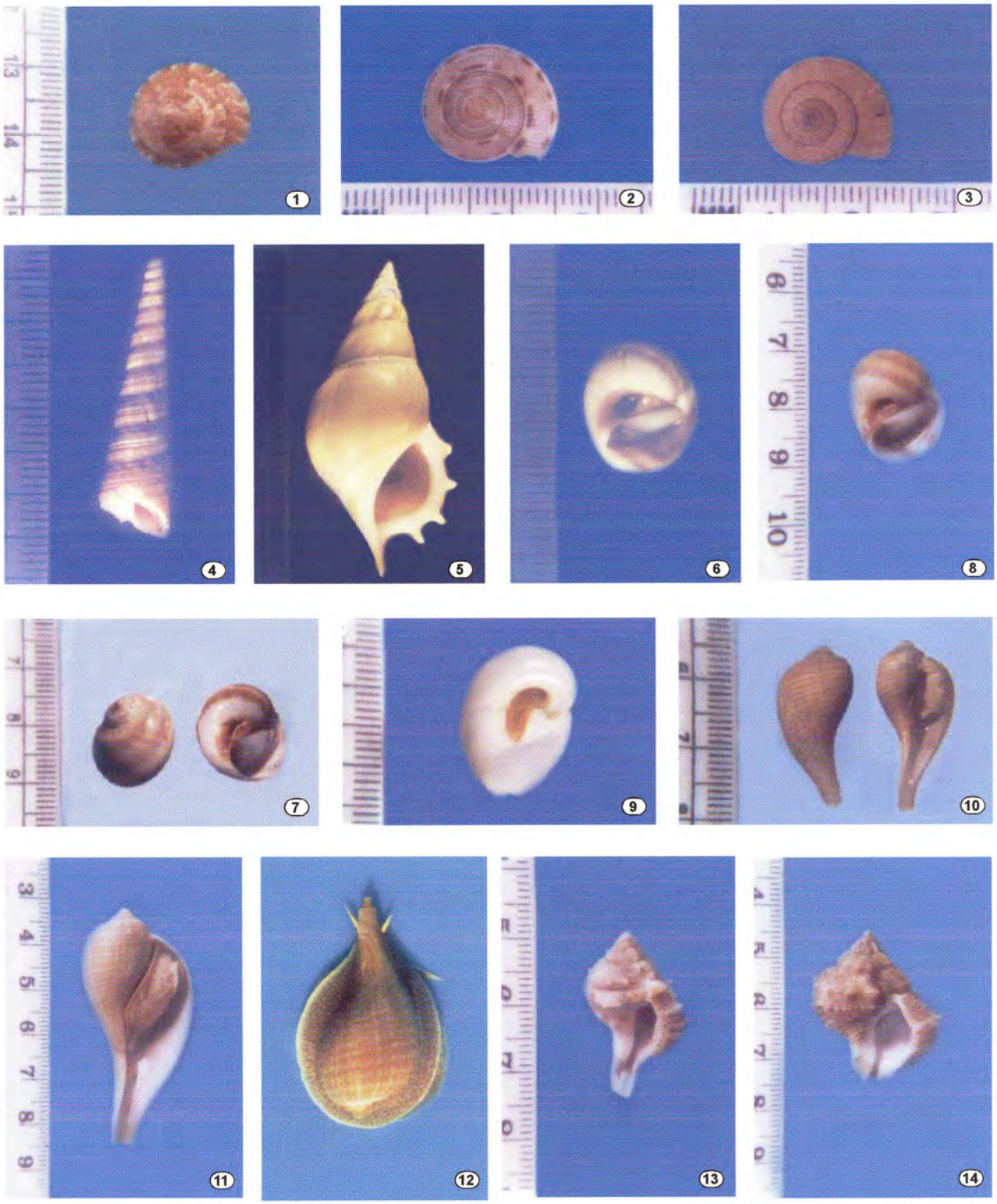


Plate - 32

1. *Calliostoma tranquibarica;* 2. *Architectonica laevigata;* 3. *Heliacus stramineus;* 4. *Turritella* sp.; 5. *Tibia delicatula;* 6. *Natica* sp.; 7. *N. vitellus;* 8. *N. gaulteriana;* 9. *Polynices* sp*; 10. *Ficus gracilus;* 11. & 12. *F. variegata* (12. onboard Sagar Sampada) 13. *Bursa* sp.; 14. *B. rana*

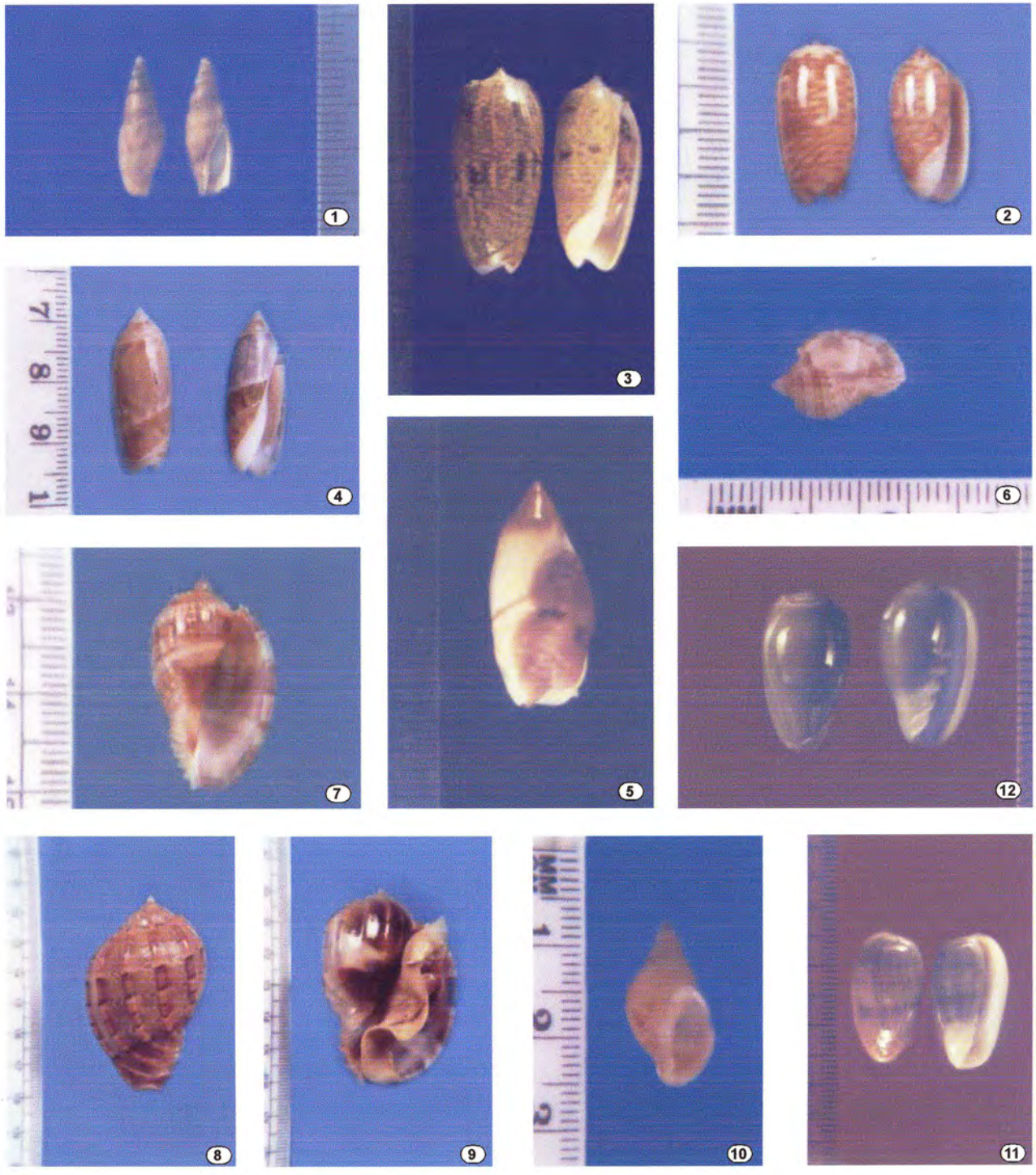


Plate - 33

1. Bullia sp.; *2. Oliva mustellina; 3. O.vidua; 4. Agaronia nebulosa; 5. Amalda ampla*; 6. Harpa sp.*1; *7. Harpa sp.*2; *8. H. ?canoidalis; 9. H. ?canoidalis* (opercular view); *10. Cancellaria oblonga; 11. Marginella angustata; 12. Persicola ventricosa*

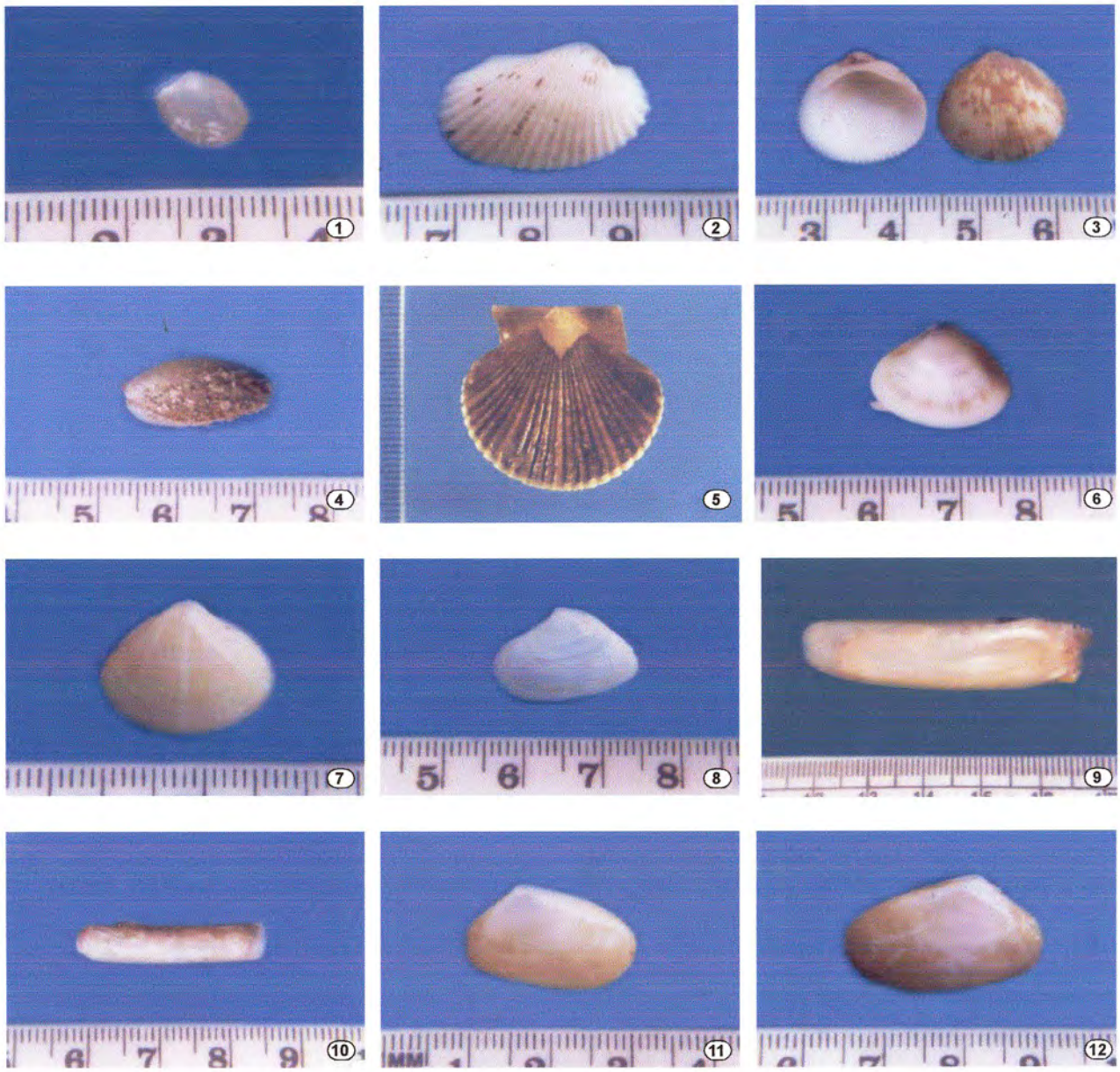


Plate - 34a

1. *Nucula convexa;* 2. *Scapharca clathrata;* 3. *Glycymeris tenuicostatus;* 4. *Modiolus* sp.; 5. *Pecten sp.;* 6. *Mactra mera;* 7. *M.grandis;* 8. *M. revesi;* 9. Cultellid bivalve (UI); 10. *Neosolen* sp.; 11. *Tellina* sp. 12. *T. lanceolata*

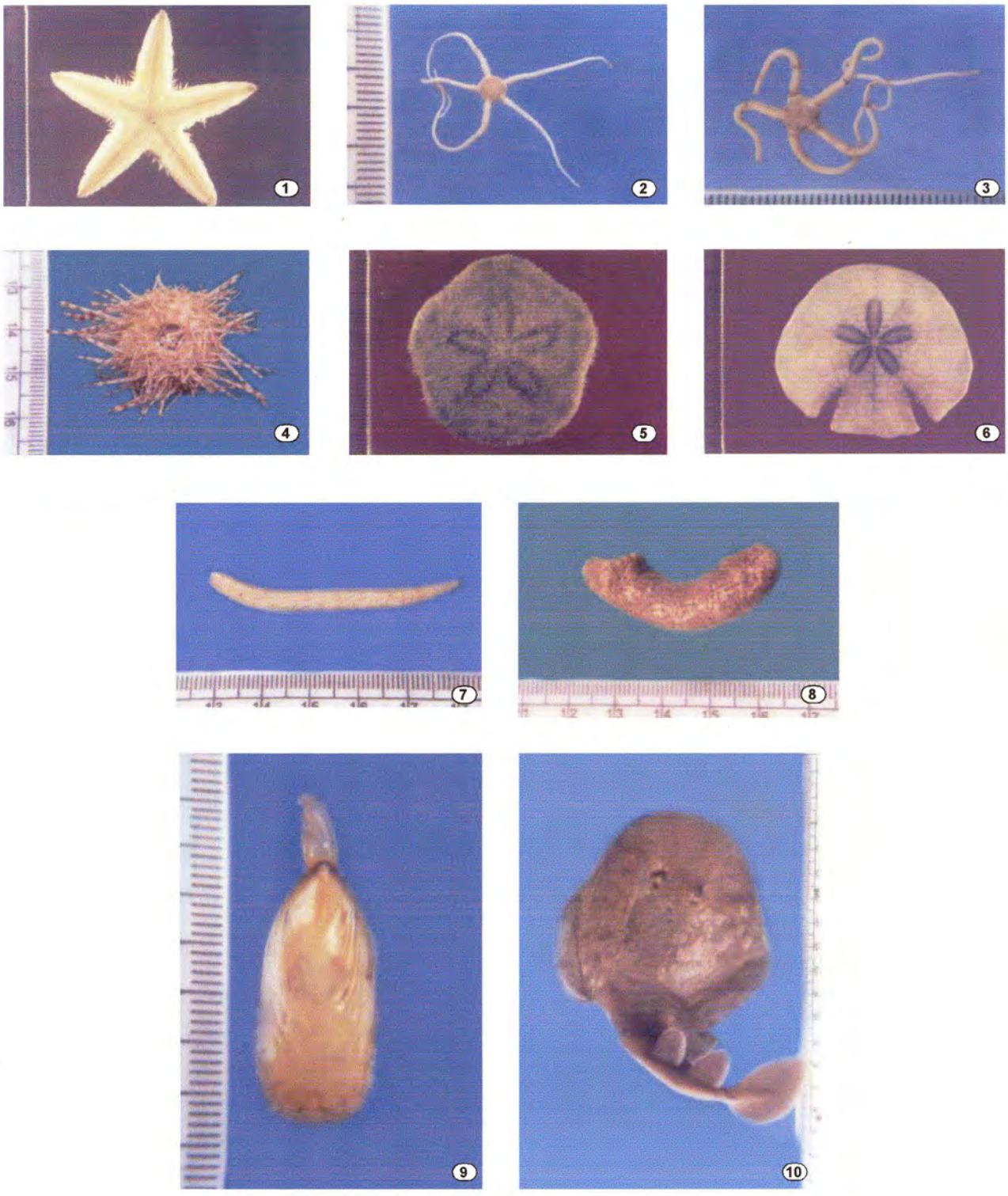


Plate - 34

1. Astropecten sp.; 2. Amphiurid sp.1; 3. Amphiurid sp.2;
4. Temnopleurus toreumaticus; 5. Clypeaster rarispimus; 6. Echinoxdiscus auritus;*
7. Leptopentaca sp.; *8. ?Stolus buccalis; 9. Lingula sp.* 10. Ray fish (UI)

* Collected during separate cruises

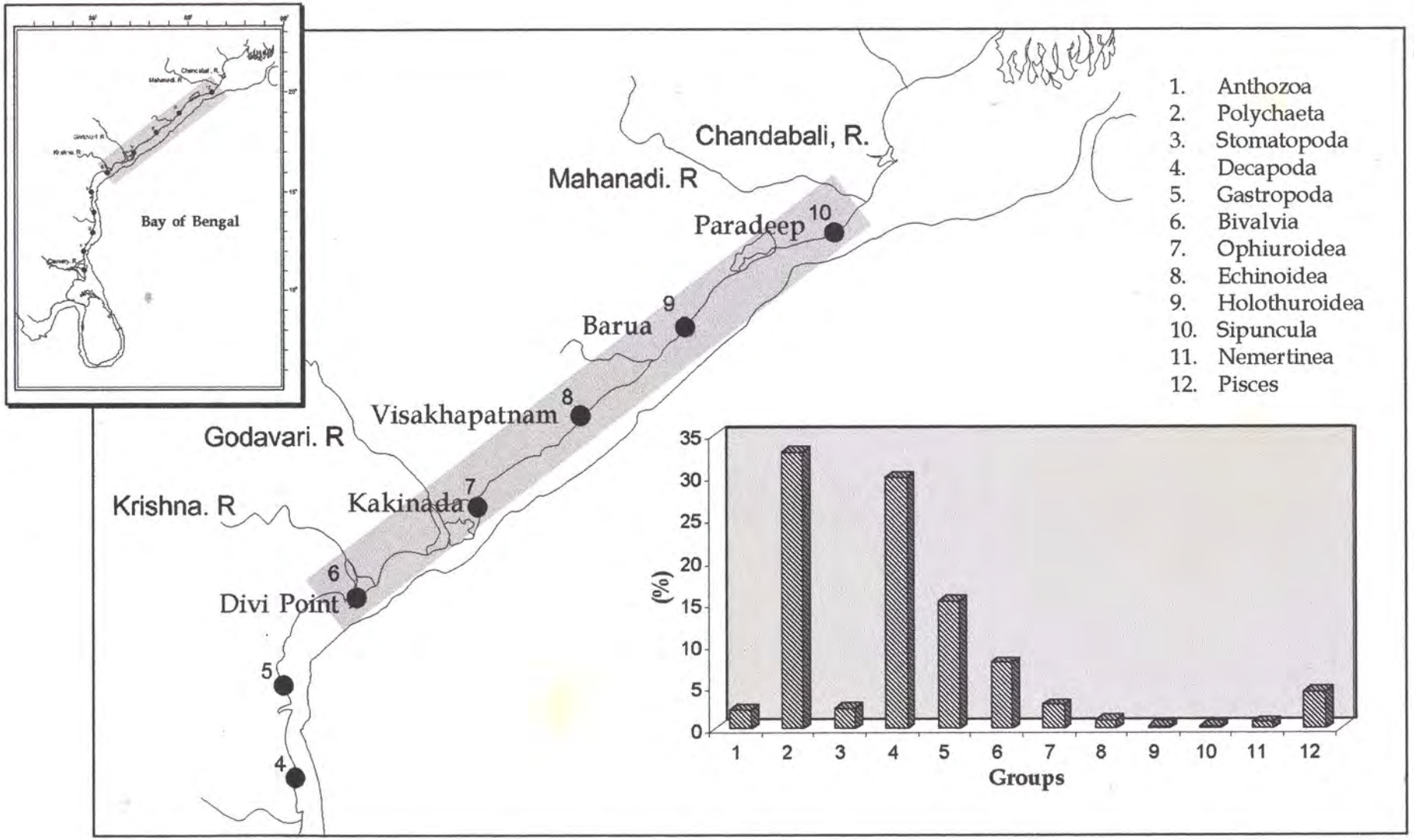


Fig. 35 : Macrobenthos of the north east coast of India: Overall faunal composition (%) in the dredge hauls (Cruise 171)

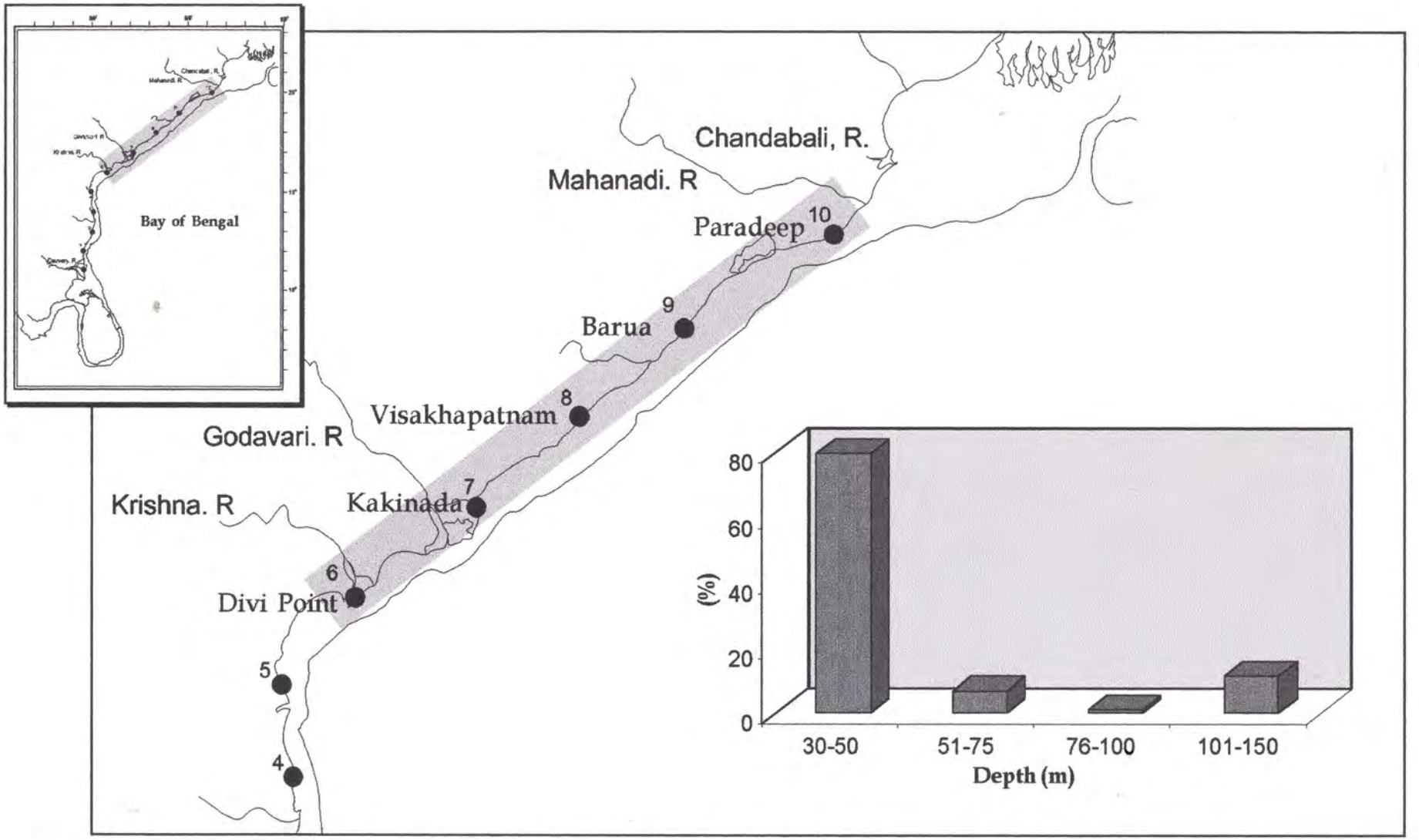


Fig. 36 : Macrobenthos of the north east coast of India: Faunal composition (%) in the dredge hauls at varying depths (Cruise 171)

siphonophores chaetognaths, appendicularians, doliolids, Salpa, juvenile Amphioxus, foraminiferans, radialarians, Globigerina, hydrozoans, scyphozoans, tentaculates, euphausiids, mysids, larval forms of stomatopods, decapods, polychaetes, gastropods, bivalves, echinoderms, fish eggs and larvae, ephyra, young cephhalopods and brachiopod larvae in that order of abundance (Rakhesh, 1999). There were appreciable differences in the overall composition and abundance of zooplankton between the selected locations. Overall the population consisted of mostly holoplankton (91.23%) and very few larval forms (8.77%) (Fig.37). For example, copepods were by far the most dominant group and accounted for as much as 51.01% of the total zooplankton volume. Chatognaths, 11.72%, ostracods 10.61%, cladocerans 4.36% and appendicularians 4.09% together with copepods formed over 81% of the total zooplankton numbers (Fig.38). Spatially, the south Bay of Bengal (transects 1-3) appeared relatively rich since it consisted of 38.04% of the total Zooplankton density. In the central Bay (transects 4-7), the abundance was 31.64% while it was 30.31% in the north Bay of Bengal (transects 8-10) (Fig.39). This could be due to the prevailing hydrographical conditions (eg. upwelling) in the south Bay of Bengal during theis part of the year. The observations have also revealed much heterogeneity between different depths. For example, samples collected at 100 m were comparatively rich (28.63%) relative to 30 m (26.89%), 50 m (25.36%) or 200 m (19.12%) (Fig.40). The high zooplankton density at 100 m could be due to the presence of large numbers of copepods (45.81%), ostracods (14.69%), chaetognaths (11.79%), cladocerans (4.49%), siphonophores (4.51%) and innumerable decapod larvae (4.07%) as against the diminished population size of certain of these groups at shallower areas. At 200 m, there appears to a general paucity of Zooplankton except that ostracods and cladocerans have registered a marginal increase as also young cephalopods in appreciable numbers.

Overall, zooplankton volume (data need calibration with a flow meter) varied from a minimum of 2ml per haul (st.173) to a maximum of 56 ml (st.171). Dry-weight values on the other hand ranged between 10 mg/haul (st.173) to a maximum of 645 mg (st.171). The following conclusion could be drawn:

- Studies revealed a diversity marine benthic life in the shelf sediments along the north East Coast of India. This was evident from over 50 species of gastropods and bivalves found so far. Similarly, we expect a similar diversity in the case of other groups particularly polychaetes and decapods which constituted over 38% and 28% of the total benthic biomass respectively.
- The meiobenthos have exhibited similar richness. Altogether some 12 groups were recognised. Though the taxa are yet to be finalised, it is contended that biologically the diversity of copepods and nematodes, the two most abundant groups, could be equally high.

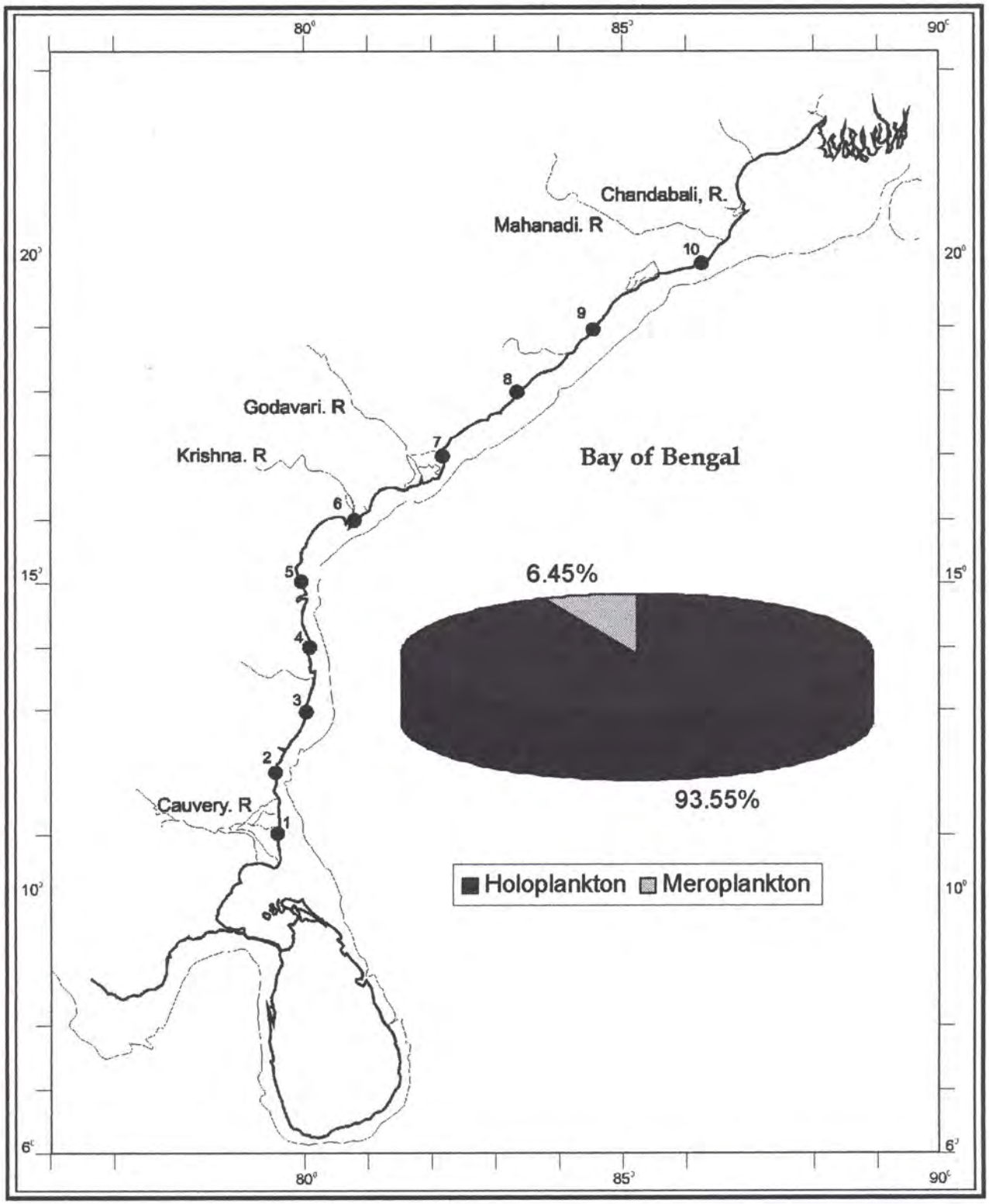


Fig. 37: Holo- and meroplankton composition (%) at selected locations during Cruise 171 (January 1999)

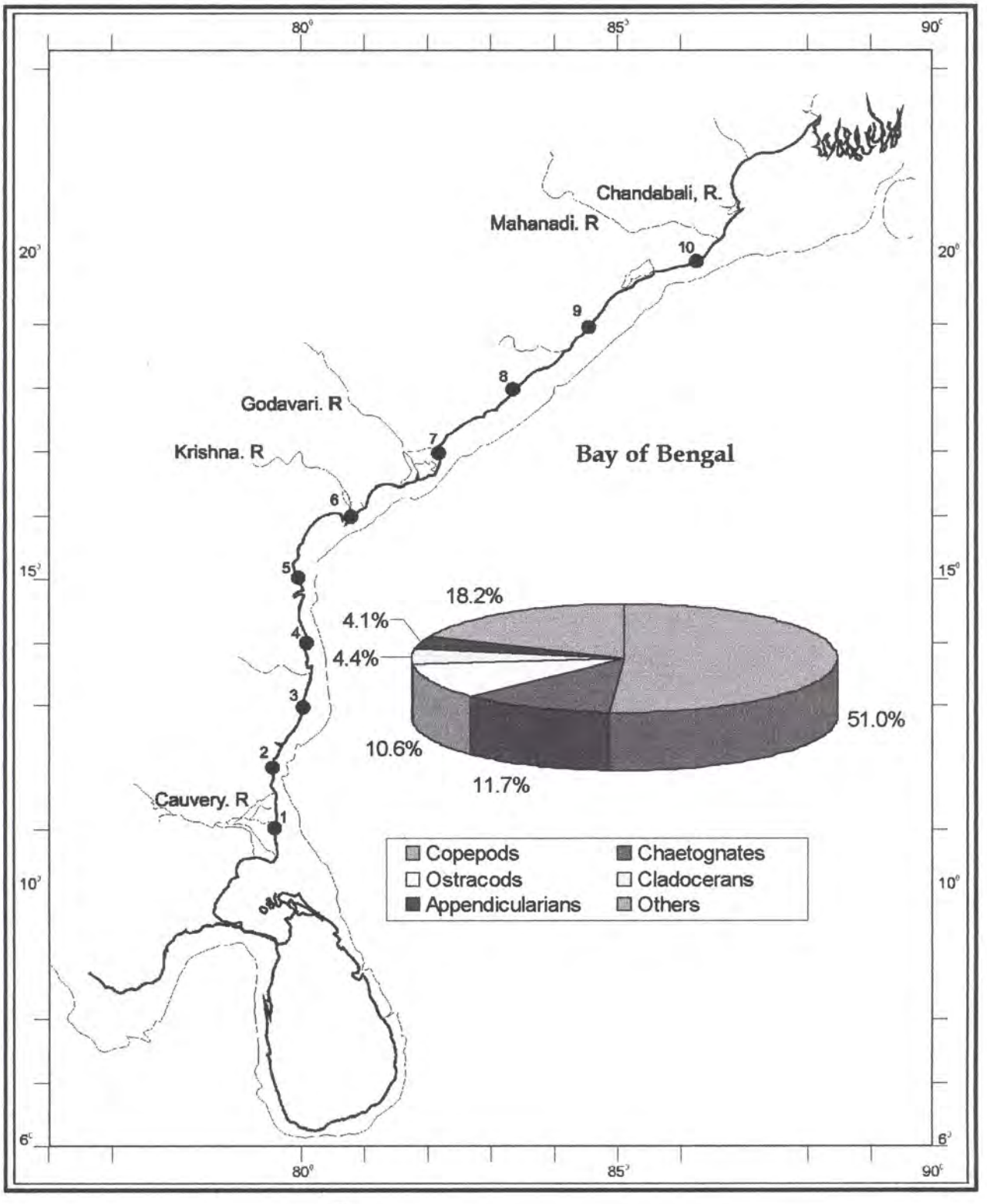


Fig. 38 : Dominant zooplankton taxa (%)
(January 1999, Cruise 171)

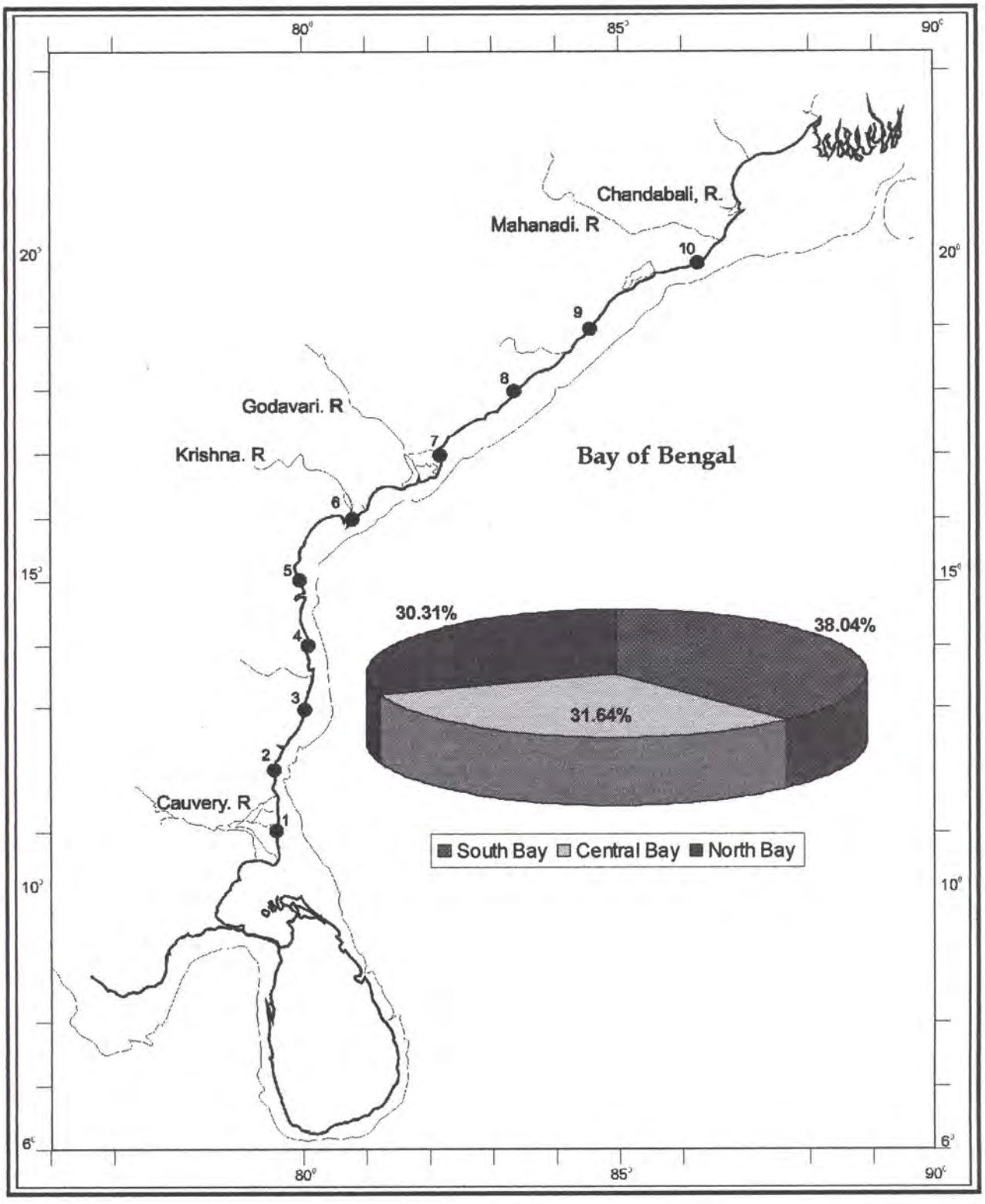


Fig. 39 : Region-wise abundance of zooplankton (%)
(Cruise 171, January 1999)

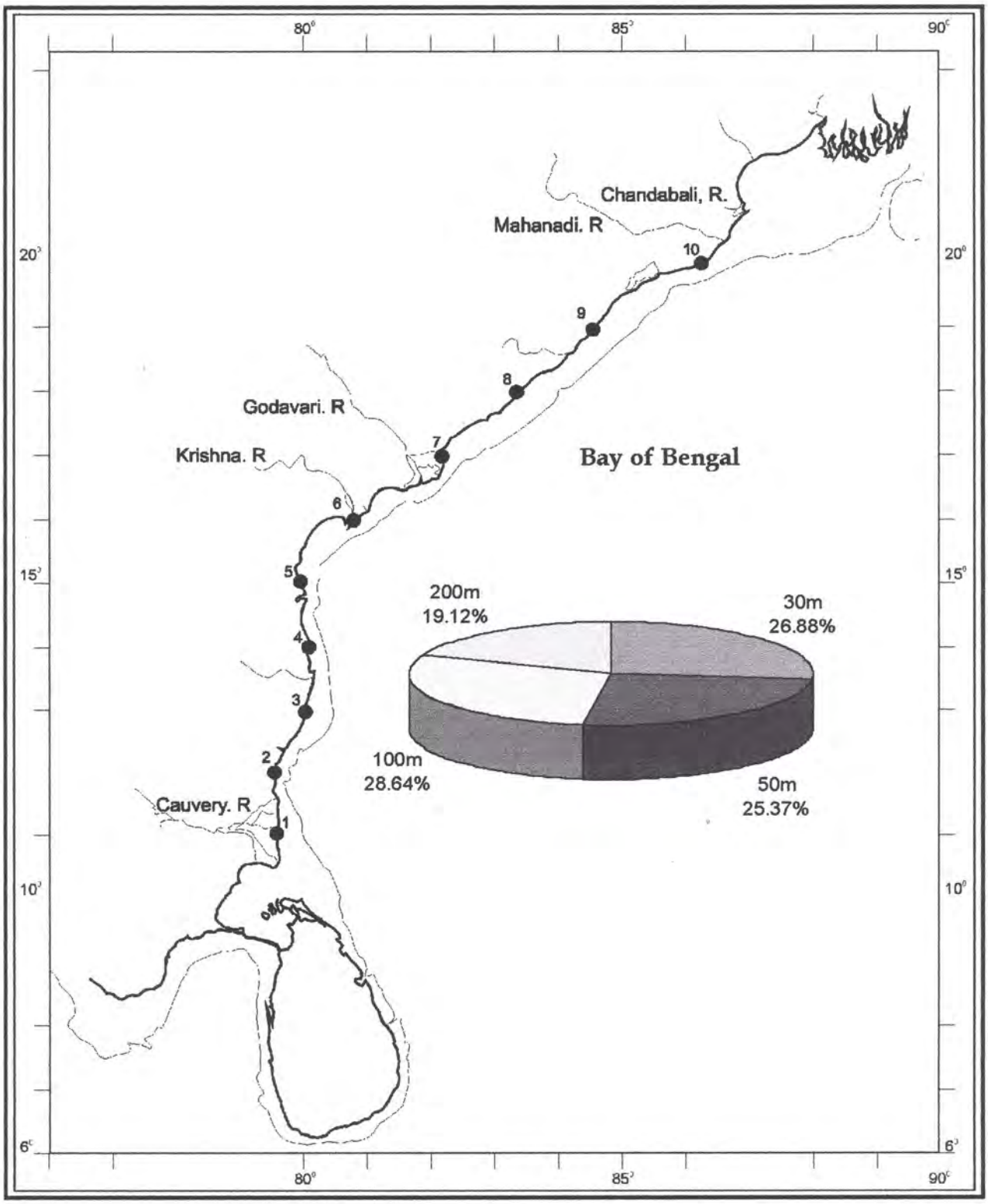


Fig. 40 : Depth-wise abundance of zooplankton (%)
(Cruise 171, January 1999)

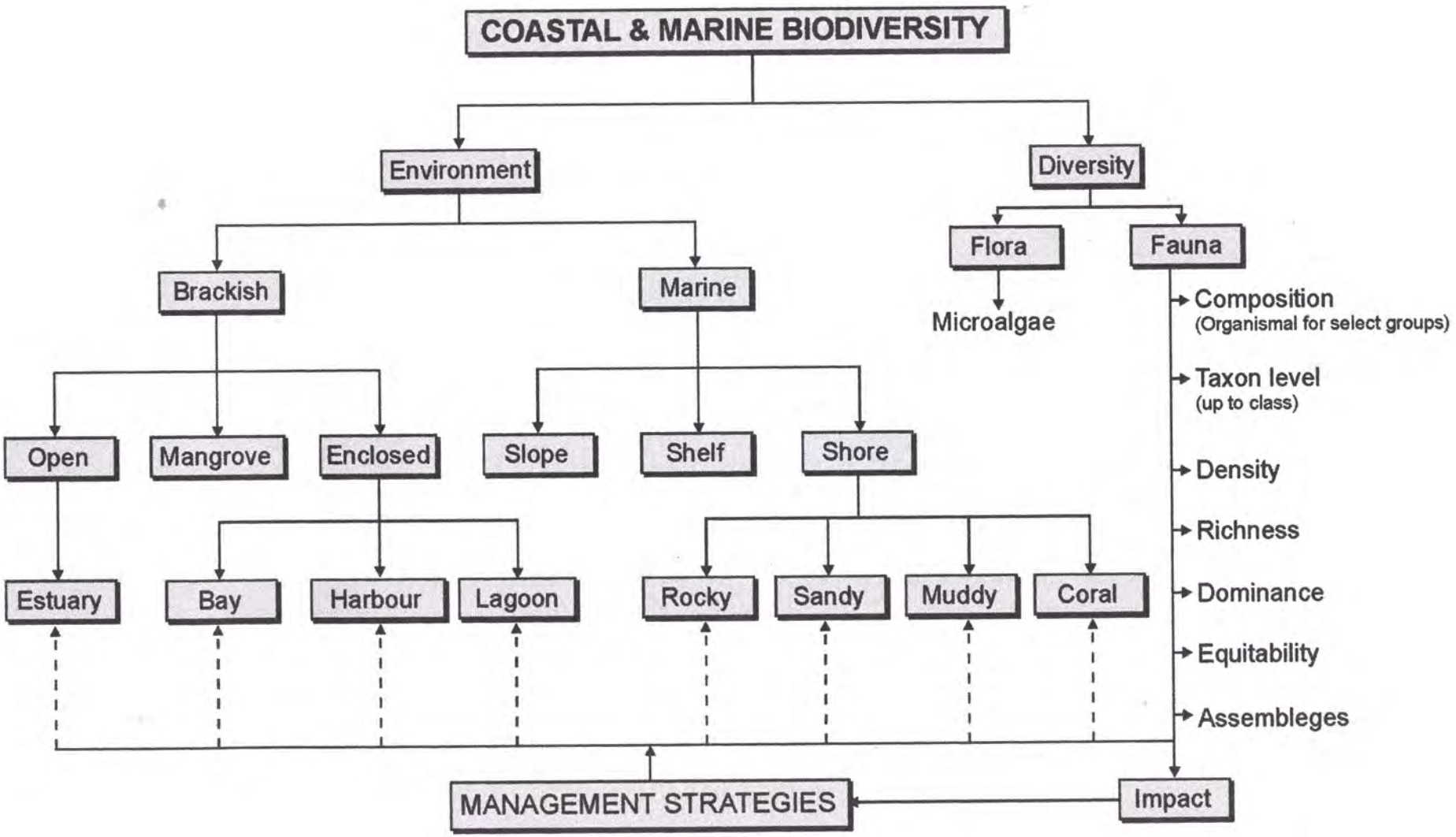
- Pronounced spatial and taxonomic gradients were evident. It is felt that environmental variables such as depth, sediment nature (texture and organic content) could be the determining factors.
- Observations on secondary productivity revealed a south-north gradient in the taxa and numerical abundance of constituent groups. The holoplankton accounted for over 90% of the zooplankton biomass. Nearer shore (30 m), there is evidence to suggest that larval plankton was proportionately rich.

At present this work is extended to coastal waters off Visakhapatnam, where enormous scope exists for studying the biodiversity. The topic of biodiversity has recently become one of intense discussion amongst the scientific, decision-making and other communities particularly as a consequence of deliberations made in important international fora. During the first session of the conference of the parties to the Convention on Biological Diversity (Nassau, Bahamas, 28 November - 9 December, 1994), a distinct consensus stressed the importance of coastal and marine biodiversity. Atleast 43 of the more than 70 phyla of all life forms are known to occur in the oceans, while only 28 are found on land (Lasserre, P. In: IMS News Letter 75/76:526, 1995). Some recent findings have shown that marine biodiversity is probably as great as or even greater than, that found on land. In recent times, new forms of life have been described from estuarine to coral reefs and the deep sea. In addition, the magnitude of diversity of hard bottoms and soft sediments has emerged as a key area in our understanding of the functioning of marine ecosystems (eg. intertidal rocky shores; mangroves and wetlands, estuaries, lagoons, deep sea). The general objective of the present proposal is to contribute to our understanding of the rich marine life found along Andhra region and to assess how man's activities are altering these. The proposal is submitted in three parts of which Part-A deals with assessing sea shore and subtidal life; Part-B, protistan taxonomy and ecology and, Part-C, the parasitic diversity of marine fish. The following specific tasks shall be addressed.

- Carry out faunal surveillance studies for assessing coastal and marine biodiversity.
- Study littoral (~ 50 m) life with emphasis on Species-Abundance-Biomass patterns in relation to spatial and temporal gradients.
- Study taxonomy and ecology of marine protistans.
- Estimate parasite diversity among fish helminths off Coromandal coast.

Fig.41 shows the approaches for future work. It is proposed to take up surveillance studies in estuaries, bays and lagoons along coastal Andhra pradesh and Orissa states for faunal investigations. Samples will also be collected from shelf sediments for distinguishing communities based on sophisticated computer programs (eg. PRIMER) of the kind employed at Plymouth Marine Laboratory, UK.

Fig. 41


COASTAL & MARINE BIODIVERSITY
Environment
Diversity
Brackish
Marine
Flora
Fauna
Microalgae
Composition
(Organismal for select groups)
Taxon level
(up to class)
Density
Richness
Dominance
Equitability
Assembleges
Open
Mangrove
Enclosed
Slope
Shelf
Shore
Estuary
Bay
Harbour
Lagoon
Rocky
Sandy
Muddy
Coral
MANAGEMENT STRATEGIES
Impact

Expertise :

In the recently conducted study (198-'99) on the "GIS Based study of Coringa mangroves" (Fig.42), a multidisciplinary research project funded by the Department of Ocean Development, New Delhi, five University Departments took part. Table 2 contains details of personnel deployed and the expertise (GIS Reports, 1998, 1999). Furthermore, the Depertment of Zoology has 23 faculty members of whom five have had their basic training in Marine Biology. Besides, services of Dr. D. Sudarsan, formerly Director General, Fishery Survey of India, Government of India and, Dr. Durvasula V. Subba Rao, Adjunct Professor, Dalhousie University, Scientist, Bedford Institute of Oceanography and Senior Scientific Advisor on Marine Affairs to the Republic of Kuwait, and Honorary Professors in the Department could be utilized.

Infrastructure :

The Department of Zoology, Andhra University, which will act as nodal agency for the propsoed R.C. is one of the few oldest Departments in the University which took up marine scientific research as early as 1952-'54. Over the years, a number of scientific investigations were carried out by the Department on diverse aspects of oceanography published as Andhra University Memoirs in Oceanography (Series 1, 2 & 3) during the years 1954, 1958 & 1997 respectively. The Faculty members engaged in various Research Projects funded by the DOD and other national and international agencies have specialised in Marine Biology and allied subjects. Currently the proponent (AVR) is associated with a major research project on the mangroves of Kakinada Bay funded by the European Commission under International colloborative research between the Governments of India and the EC member nations (Belgium, the Netherlands and Sweden). Regarding the facilities, the Department has full-fledged Marine Biological Laboratory with excellent equipment to collect seawater samples and marine organisms. The logistic support includes facilities for road transport, movement in shallow water and an out station laboratory at the Post-Graduate Centre, Kakinada. The Marine Biological Laoratory is adequately eqipped with analytical equiment and for biological examination, including sophisticated microscopes. In the main Department, there is a central instrumentation facility with AAS, HPLC, Liquid Scintillation System etc. Other allied Departments in the University namely, Marine Geology, Marine Chemistry, Environmental Sciences and Meteorology and Oceanography are also well established. In the Department of Geology, the major facility includes a Sedigraph 5001 (particle size analyser) and Scanning Electron Microscopes (SEM, Jeol). In the Chemical Oceanography Department, the important analytical equipments are a UV-visible Spectrometer, Anode Stripping Voltameter, Multichannel Analyser with appropriate detectors; Mercury Analyser, Ultra Filtration equipment etc. The Department of Meteorology and Oceanography is similarly well equipped with in situ T.S.meters, current meters and graduated wave staffs etc.

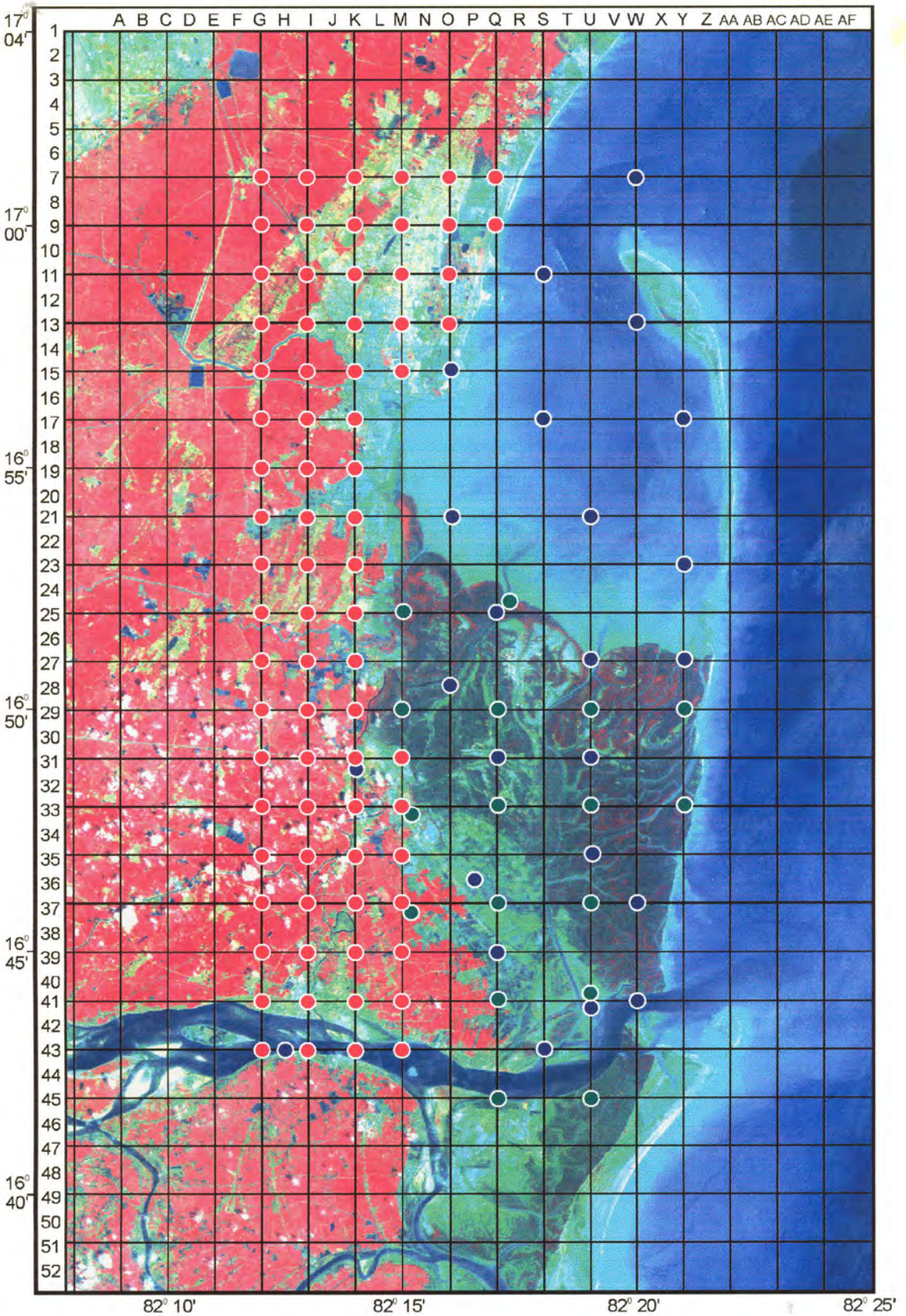


Fig. 42 : GIS Study on Coringa mangroves - Station locations

● Terrestial (Buffer) ● Mangroves ● Aquatic

Table - 2

GIS Based Study for Corniga Mangroves
(1998 - 1999)

PARTICIPATING MEMBERS

Dr. A.V. Raman, Professor Division of Marine Biology, Department of Zoology.	:	Coordinator & Principal Investigator

Investigators

Dr. C. Kalavati, Professor, Department of Zoology	:	Microbiology & Microbenthos
Dr. B.S.R. Reddy, Professor Meteorology & Oceanography	:	Physical Oceanography
Dr. Y. Prabhakara Rao Associate Professor, Zoology Department	:	Environmental Data
Dr. I.M. Rao, Associate Professor Chemical Oceanography	:	Water Quality
Dr. E.U.B. Reddy, Associate Professor Environmental Sciences	:	Terrestrial Environment (Buffer zone)
Dr. P. Bhanumurthy, Assistant Professor Geology Department	:	Marine Geology
Dr. C. Annapurna, Assistant Professor Department of Zoology	:	Meiobenthos (Bay, Estuary)

Supporting Staff

Dr. K. Padma Dorothy, Res. Associate	:	Pathogenic microorganisms
Dr. V. Ranga Rao, Project Associate	:	Physical Oceanography
Mr. N.V. Prasad, Sr. Res. Fellow	:	Zooplankton and Sec. Productivity
Mr. B. Satyanarayana, Sr. Res. Fellow	:	Mangroves
Ms. M. Padma, Jr. Res. Fellow	:	Microbenthos
Mr. T. Vijay Kumar, Jr. Res. Fellow	:	Marine Geology

Scientist Associates

Prof. P. Chandramohan (Retd.) &	:	Zooplankton
Prof. D.V. Ramasarma (Retd.) Department of Zoology	:	Meiobenthos

Collaborators

Dr. K.V.S. Janardhana Rao, Reader Government Degree College, Rajahmundry	:	Tertiary Productivity
Dr. G. Sunitha Rao, Pool Officer, CSIR	:	Meiobenthos (Mangrove sediments)
Mrs. T. Rohini, Sr. Res. Fellow, CSIR	:	Phytoplankton
Mrs. C. Sheeja, Jr. Res. Fellow, DOD	:	Meiobenthos
Mr. T. Ganesh, Jr. Res. Fellow, DOD	:	Macrobenthos
Mr. N. Aravindan, Sr. Res. Fellow, ICAR	:	Word Processing

Colloborative Programmes :

Over the years, the Department has several colloborative research projects with Zoological Survey of India, Calcutta; Central Marine Fisheries Research Institute, Waltair Centre; Fishery Survey of India, Visakhapatnam Zonal Office; National Institute of Oceanography, Waltair Regional Centre. More recently, work schedules are also arranged colloboratively with Space Application Centre, Ahmedabad; Cochin Unversity Department of Marine Sciences, Cochin; CAS in Marine Biology, Annamalai University; Centre for Ocean Development, Anna University, Chennai etc.

4. National Policies, Commitments and Perspectives :

In recognition of the felt need for environmental protection, including the marine ecosystems, the Government of India over the past 20 years or so have taken various regulatory and promotional measures. These include the following:

- Wildlife (Protection) Act, 1972, amended in 1983, 1986 and 1991
- The Water (Prevention and Control of Pollution) Act, 1974, amended in 1988
- The Water (Prevention and Control of Pollution) Cess Act, 1977, amended in 1991
- The Forest (Conservation) Act, 1980, amended in 1988
- The Ocean Policy Statement (OPS) of 1982 of the Department of Ocean Development (DOD), Government of India, was by far the most pertinent that envisages suitable exploitation of living and non-living resources of EEZ. The DOD oversees and coordinates ocean-related matters. The strength of India's policy is that it is open and simple.
- Another important policy of the Government of India to conserve and protect the marine environment and organisms relates to the Environment (Protection) Act (EPA) 1986 of the Ministry of Environment and Forests (MoEF).
- Coastal Regulation Zone (CRZ) Notification of MoEF of 1991
- National Environment Tribunal Bill, 1992
- UN Convention on the Law of the Sea, ratification in November 1997
- Constitution of National Coastal Zone Management Authority (NCZMA) in 1998
- Introduction of Biodiversity Bill on 4.2.2000

A number of Government agencies namely the Department of Environment in 1980 and the integrated Ministry of Environment & Forests in 1985, Department of Science and Technology, Department of Biotechnology, Department of Ocean Development, Department of Space, Department of Non-Conventional Energy Sources, Energy Management Centre, Council of Scientific and Industrial Research etc. at the Centre, Departments of Environment at the State and Union Territory level are involved.

5. Capacity Building and Infrastructure - Requirements :

The proposed RC could take up activities relating to (1) Information collection, collation and dissemination (2) Provision of advisory and consultancy services (3) pursuing R&D besides bay as a catalyst through networking, coordination etc and (4) promotion and development of scientific and technological skills and the establishment of appropriate management systems. Successful R&D is very much dependent on a select and skilled labor force capable of generating new ideas and methods of being proven by analysis and testing besides having the skills necessary to integrate large systems. This would mean that the RC would have to deploy adequate manpower of diverse skills and should be able to contain for a period of five years atleast. In the following tabulation these requirements are presented. Total costs (vid Financial Form, Table 3) for a 5-year period would workout to Rs. 175 lakhs or US $ 397,727.00.

According to a survey conducted by the IOI, Chennai (Voice for the Oceans, Report to the Independent World Commission, IIT, 1996), population pressure, impact of ports, solid waste disposal, wastewater disposal, impacts of aquaculture, thermal dischars of power plants, coastal erosion, coral reef destruction and of mangroves threaten the proper management and sustainable development of coastal zone in India. Poverty, educational backwardness, unemployment during monsoon are the major problems faced by coastal communities in India. In the same context, the IOI also noted CZM and protection of mangroves should be the two priority areas in which there appears to be a need for human capacity building. At the proposed RC, besides conventional R&D, the following programmes could therefore be taken up:

- Training and Capacity Builiding.
- Participation of Coastal Communities.
- Participation of NGO
- Alternatives for coastal settlements for fuel and fodder
- Village development activites near crtical habitats
- Role of women coastal resources
- Train local panchayats/Village heads
- School teachers
- Forest guards and other officials
- Corporators
- Special orientation for MLA's and MP's

The EUREKA / EUROMAR systems could be fitted into the above working regime of the proposed R.C. Its development from the nucleus would be dependent on its performance and the speed with which it builds up confidence in the local government of the country concerned and and its ability to deliver the goods, performance, thus would get established as an important parameter in its

Table 3 : Financial Statement

	Requirements	No. of Persons	Years					Total
			1st	2nd	3rd	4th	5th	Rs. in Lakhs
A	RECURRING							
1	Man Power							
	Scientist @ Rs. 12,000/- PM consolidated	1	1.44	1.44	1.44	1.44	1.44	7.20
	Sr. Research Fellows @ Rs. 6,000 - 6,400 + HRA PM	2	1.68	1.68	1.78	1.78	1.78	8.70
	Jr. Research Fellows @ Rs. 5,000 - 5,400 + HRA PM	2	1.44	1.44	1.58	1.58	1.58	7.62
	Graphics Designer @ 5,000/- PM	1	0.60	0.60	0.60	0.60	0.60	3.00
	Tech. Assistant @ Rs. 4,000/- PM	1	0.48	0.48	0.48	0.48	0.48	2.40
	Admin. Assistant @ Rs. 3,500/- PM	1	0.42	0.42	0.42	0.42	0.42	2.10
	Field Assistant @ Rs. 3,500/- PM	1	0.42	0.42	0.42	0.42	0.42	2.10
	Driver @ Rs. 3,500/- PM	1	0.42	0.42	0.42	0.42	0.42	2.10
	Messenger @ Rs. 2,000/- PM	1	0.24	0.24	0.24	0.24	0.24	1.20
	Sub-Total		**7.14**	**7.14**	**7.38**	**7.38**	**7.38**	**36.42**
2	Contengencies		0.50	0.50	0.50	0.50	0.50	2.50
	Travel TA/DA		1.20	1.20	1.20	1.20	1.20	6.00
	Library		0.50	0.50	0.50	0.50	0.50	2.50
	Boat Hire		3.00	3.00	3.00	3.00	3.00	15.00
	Consumables		1.20	1.20	1.20	1.20	1.20	6.00
	Maintenance		0.10	0.10	0.10	0.10	0.10	0.50
	Lab Work Tables		2.00	0.15	0.15	0.10	0.10	2.50
	Sub-Total		**8.50**	**6.65**	**6.65**	**6.60**	**6.60**	**35.00**
B	NON-RECURRING							
1	Equipment		30.00	-	-	-	-	30.00
	Vehicle		5.00	-	-	-	-	5.00
	Sub-Total		**35.00**	**-**	**-**	**-**	**-**	**35.00**
2	Infrastructure Development (Laboratory Plan Enclosed)		25.00	-	-	-	-	25.00
	Sub-Total		**25.00**	**-**	**-**	**-**	**-**	**25.00**
	Total		75.64	13.79	14.03	13.98	13.98	**131.42**
	Add esclation 2 - 3 %							3.58
	Grand Total							**135.00**

organisational growth trajectory. The permanent staff could be 1 scientist supported by appropriate administrative and technical personnel such as Graphics designer (1), laboratory maintenance (1), administrative assitance (1), fieldman (1), Vehicle driver (1) and Messenger (1). On a contractual basis, Research fellows (Post-Doctoral/ Senior/Ph.D, 4) could be recruited as per Government norms. Annual expenditure (towards R&D) would workout to Rs. ~ 7.0 Lakhs. Initially, a substantial grant of Rs. 60.0 Lakhs is needed to build / strengthen the infrastructure. The overall costs for a 5-year period are as follows:

Manpower	Rs.	36.42 Lakhs
R & D	Rs.	70.00 Lakhs
Infrastructure	Rs.	25.00 Lakhs
Total	Rs.	131.42 Lakhs
+ Escalation @ 2 - 3%	Rs.	3.58 Lakhs
Gross Total	**Rs.**	**135.00 Lakhs**

Note : Citations in text available in Annexures I - IV.

Annexure - I

RESEARCH PROJECTS SANCTIONED TO THE DEPARTMENT IN MARINE BIOLOGY (1994-2000)

University Grants Commission, New Delhi:

1. Phytoplankton and epiphytic ciliates in relation to water quality in Chilka Lake, a brackish water lagoon, on the east coast of India." (1995-'99)
   Principal Investigator: Prof. A. V. Raman
   Co-Investigator: Prof. C. Kalavati
   Total Outlay: 3.2 lakhs
2. Studies on the reproductive and larval behaviour of mud crabs, Scylla serrata and S. oceanica," (1995-'98)
   Principal Investigator: Dr. D. E. Babu
   Total outlay: 3.2 lakhs
3. Metallothioneins and their role in cultivable species of crustaceans: A multifunctional approach" (1999-2002)
   Principal Investigator: Dr. Y. Prabhakara Rao
   Total outlay: Rs. 4.9 lakhs

European Commission, Brussels :

4. Assessment of ecological importance of mangroves of Kakinada area, Andhra Pradesh (1994-1997)
   Contractors: Prof. A. V. Raman & Prof. P. Chandra Mohan
   Total outlay: Rs. 35 lakhs
5. Assessment of mangrove degradation and resilience in Indian subcontinent: The cases of Godavari estuary and southwest Srilanka" (1998-2001)
   Contractors: Prof. A. V. Raman Prof. P. Chandra Mohan & Prof. C. Kalavati
   Total outlay: Rs. 45 lakhs,

Indian Council of Agricultural Research, New Delhi :

6. Implications of diseases in aquaculture with special reference to Andhra Padesh (1996 1999)
   Principal Investigator: Prof. R. Madhavi
   Co-PI: Prof. C. Kalavati
   Total out lay: 10.8 lakhs.

Department of Ocean Development, New Delhi:

7. Predictive models for Marine Fisheries off North Andhra Coast. An ecosystem approach." (1998-2001)
   Principal Investigator: Dr. D. Sudarsan, Honorary Professor
   Total outlay: 40 lakhs.

8. Geographical information system based study for Coringa mangroves, Kakinada Bay." (1998-1999)
   Principal Investigator: Dr. A. V. Raman
   Total out lay: 18.00 Lakhs

9. Benthic productivity in the EEZ off north East Coast of India (1998-2003)
   Principal Investigator: Dr. A. V. Raman
   Total out lay: 6.4 lakhs.

10. Secondary productivity and fish stock assessment studies in the EEZ, MLR Related research. 1998-2003
    Principal Investigator: Dr. D. Sudarsan, Honorary Professor
    Co-P.I: Dr. A.V. Raman.
    Total outlay: 4.1 lakhs.

11. Determination of No- impact zone for Coringa" (1999-2002)
    Principal Investigator: Dr. A. V. Raman
    Total outlay: 30 lakhs.

12. Application of Remote Sensing to Coastal Habitat Studies (In collaboration with Space Application Centre, Ahmedabad, 1999-2003)
    Principal Investigator: Dr. A. V. Raman
    Total outlay: 6.6 lakhs.

Department of Environment and Forestrs, New Delhi :

13. Capacity building in Taxonomy with particular reference to Mollusca" (2000-2001)
    Principal Investigator: Dr. A. V. Raman
    Total out lay: Rs. 4.06 lakhs.

Industry/Organisation sponsored projects :

14. Oil and natural gas corporation - Environmental studies around Pasaralpudi Blow-out well" (Interdisciplinary project), 1992. Total out lay: Rs. 2.0 lakhs (A.V. Raman).

15. Marine biological investigations prior to laying a submarine pipeline in Kakinada, 1995. Total out lay: Rs. 30,000 (A.V. Raman).

16. Mecon India Ltd., Ranchi, Impact of shipbreaking on oil marine life at Alang, Gujarat, 1996. Total outlay: Rs. 2.6 lakhs (A.V. Raman)

17. Hindustan Petroleum corporation Ltd. Studies on biofouling to cooling water systems of oil refinery of Hindustan Petroleum Ltd., Visakhapatnam, 1995-'98. Total outlay: 8.0 lakhs (P. Chandra Mohan)

Annexure II

TITLES OF Ph.D. THESES IN MARINE BIOLOGY (1955-2000)

MARINE ECOLOGY

1. Satyanarayana Rao, T.S. 1956. Studies on the Chaetognatha in relation to hydrography of the Indian coast.
2. Chandrasekhara Rao, G. 1965. Studies on marine interstitial fauna inhabiting the sandy beaches of Waltair coast.
3. Solman Raju, N. 1966. Studies on eggs, larvae and juveniles of marine fishes off Waltair coast.
4. Subba Rao. D.V. 1967. Studies on hydrography, phytoplankton and primary production off Waltair coast, Bay of Bengal.
5. Balaparameswara Rao, M. 1970. Studies on some aspects of the biology of limpet Cellana radiata (Born) (Gastropoda, Prosobranchiata) of the Waltair coast.
6. Bhavanarayana, P.V. 1970. Studies on hydrography and distribution of pelagic tunicates in the western part of Bay of Bengal.
7. Rama Sastry, R.V. 1971. Studies on the biology of a littoral snail. Turbo intercoastalis (Menke) (Gastropoda, Turbinidae) of the Waltair coast.
8. Sarma, A.L.N. 1972. The phytal fauna of littoral algae of Visakhapatnam coast, Bay of Bengal .
9. Ramana Murthy, K.V. 1972. Quantitative and qualitative survey of nearshore zooplankton off Visakhapatnam. (Bay of Bengal).
10. Subba Rao, B.V.S.S.R. 1975. Ecology of littoral oligochaete, Pontodrilus bermudensis Beddard.
11. Satyanarayana Rao, K. 1976. Studies on the systematics and some aspects of ecology of the littoral bryozoa on the north east coast of India .
12. Babu, D.E. 1978 Studies on Menippe rumphii (Fabricius) (Crustacea:Brachyura) from Waltair coast.
13. Manmadha Rao, L 1978. Studies on some aspects on the biology of a littoral snail, Clypeomorus sp. (Gastropoda : Cerethidae)
14. Annapurna, C. 1979. Systematics and ecology of benthic ostracoda from selected marginal environments, east coast of India.
15. Sastri. D.R.K.1979. Ecobiological studies of a littoral echinoid, Stomopneustes variolaris (Lamarck) together with the taxonomy of some Indian Echinoidea (Echinodermata).
16. Rajyalakshmi Bhanu, R.C. 1980. Studies on gastropod Genus Thais Roding with special reference to Thais bufo Lamarck.

17. Rayudu G.V. Studies on cephalopods of Visakhapatnam with special reference to Sepia aculaeata.
18. Venkata Reddy. P.V. 1983 Studies on Zooplankton of waltair coast with special reference to polychaete larvae.
19. Azgar Ali, S. 1984. Studies on ecobiology of a marine sandy shore whelk Bullia vittata on the east coast of India .
20. Kamala, B. 1984. Studies on the ecobiology of a marine intertidal gastropod, Euchelus asper inhabiting the palm beach shingles of Visakhapatnam coast.
21. Joseph, A. 1987. Indigenous techniques for studying meiobenthos with special reference to the ecobiology of an oligochaete Aelosoma hemprichi EHR in backwaters of Visakhapatnam
22. Gayatri Rao. 1987. Some aspects of stomatopod crustaceans of Visakahapatnam coast.
23. Viswanadham, B. 1988. Studies on littoral Bryozoa (Ectoprocta) at Visakhapatnam, Bay of Bengal, India.
24. Chetty, P.M. 1988 Systematics and some aspects of ecology of polychaetes around Visakhspatnam and Kakinada.
25. Balaji, M. 1990. Investigations on biofouling at two ports in Andhra Pradesh, India: Some aspects of toxicity of copper to the fouling bivalve Mytilopsis sallei.
26. Devika,N. 1990 Stomatopod crustaceans of Visakhapatnam coast with special reference to biology of Harpiosquilla harpex
27. Kameswara Rao, P.S. 1990. Studies on some aspects of water quality and systematics of foraminifera of Machilipatnam harbour channel.
28. Adisesha Sai, K. 1992. Littoral macrobenthos off Visakhapatnam, India.
29. Rajeswararao.N. 1993. Studies on pelcypoda of Visakhapatnam Coast with special reference to wedge calm, Donax cuneatus Linnaeus.
30. Satyanarayana Ch, 1999, On the Hydrography and phytoplankton characteristics of Chilka Lake, a brackish water lagoon, East Coast of India.

POLLUTION BIOLOGY

31. Raman, A.V. 1980. Ecobiology of pollution in Visakhapatnam Harbour, Bay of Bengal
32. Radhakrishna, G. 1985. Ciliates associated with algae of Waltair coast.
33. Vishnu Swarup, B. 1987, Studies on some aspects of Hydrography and Zooplankton of the Gostani Estuary, Bheemunipatnam.
34. Phani Prakash, K. 1989. Phytoplankton ecology in relation to pollution in Visakhapatnam harbour, Bay of Bengal.

35. Durgaprasad, Y.V.K. 1990. Pollution studies on haematology and bioaccumulation in relation to heavy metals in Liza macrolepis (Smith) and Liza parsia (Hamilton and Bucchanan) from Visakhapatnam harbour
36. Balaji. M. 1990. Investigations on biofouling at two ports in Andhra Pradesh and some toxicity of copper to the fouling bivalve, Mytilopsis sallei
37. Raghu Prakash, R. 1996. Studies on tolerence of the bivalve Mytilopsis sallei in relation to pollution in the harbour waters of Visakhapatnam.
38. Varaha Prabhakar, Ch. 1997. Studies on marine biofouling with reference to Mytilopsis sallei (Recluz) occuring in sea water intake systems of an oil rrefinery.
39. Jayaprada, C. 1998 Ecology of benthic microalgae in relation to pollution in Visakhapatnam harbour
40. Ratnabharati, V. 1998. Protozooplnkton in relation to pollution in Visakhapatnam harbour.

BIOLOGICAL OCEANOGRAPHY

41. Chalapati Rao, V. 1965. Chemical Oceanographic studies in Bay of Bengal
42. Rama Sarma, D.V. 1966. Hydrography of the Godavari estuary
43. Somasekhar, K. 1991. Studies on some aspects of hydrography and zooplankton off Visakhapatnam coast, Bay of Bengal.

ESTUARINE & MANGROVE BIOLOGY

44. Chandra Mohan, P. 1964. Studies on zooplankton of Godavari estuary.
45. Radha Krishna, Y. 1964. The systematics and ecology of bottom fauna Of Godavari estuary
46. Subrahmanyam, M. 1966. Prawn fishery in Godavari estuarine systems.
47. Babu Rao, M. 1967. Studies on Clupeoid fishes of Godavari estuary.
48. Visweswara Rao, V. 1968. Studies on fisheries of Godavari estuary.
49. Srinivasa Rao, D. 1979. Systematics and ecology of intertidal annelidan polychaetes in Vasista Godavari estuary.
50. Syada Rao, G. 1981. Studies on systematics and ecology of polychaete fauna of Gosthani estuary.
51. Sriramamurty, R. 1983. Hydrography and benthic macrofauna of Gosthani and Champavati estuaries.
52. A.G.R.Saisastry. 1987 Studies on the hydrography and plankton of a tropical tidal estuary (The Vasishta Godavari) on the East Coast of India.
53. Sunitha Rao, G. 1990. Studies on hydrography and meiobenthos of the Gosthani estuary.
54. Uma Rani A, 1996 The fishes of mangroves of Andhra Pradesh with special reference to some aspects of histology, histrochemisty, parasitology and pathology of Lates calcarfer (Bloch).

55. Dipti Raut, 1997. Macrobenthic fauna of mangrove waterways and the bay environment of Kakinada

56. Raghavendra, G. Rao. 1998. Tracing carbon flow in the Mangrove ecosystem of Godavari Delta, India.

57. Srinivas N, 1999. Zooplankton production and distribution in mangrove habitat of Godavari estuary, Kakinada.

FISHERY BIOLOGY AND AQUACULTURE

58. Srinivasa Rao, K. 1973. The fishery and biology of seer fish from Indian waters.

59. Janardhana Rao, K.V.S. 1981. Studies on biology and biochemistry of a sciaenid fish, Pennahia macropthalmus Bleker with observations on the sciaenid fishery off Visakhapatnam.

60. Manikyala Rao, D. 1981. Studies on biology and biochemistry of threadfin beam, Nemipterus japonicus (bloch) with observations on nemipterid fishery off Visakhapatnam

61. Usha Rani, K. 1981. Haematology of Mugil cephalus, Linnaeus, Liza macrolepis (Smith), Valamugil cunnesius (Valenciennes) and Nematolosa nausus (Bloch) from Visakhapatnam harbour.

62. Murthy, D.S. 1982. Studies on maximising production of major carp seed in commercial fish farming in Andhra Pradesh, India.

63. Sudarsan, D. 1983. Studies on demersal and trawl fisheries off Visakhapatnam.

64. Rambhaskar, B. 1985. Haematology of Chanos chanos (Forskal) from brackishwater fish farms of Kakinada.

65. Lakshmi, K. 1986. Osteology and interspecific hybridisation and fishery of some Indian Ariid catfishes with observations of phylogeny of Siluroids.

66. Ramamurti, M. 1989. Studies on the flat fishes (Osteichthyes: Pleuronectiformis) from east coast of India: Taxonomy, comparative osteology and phylogeny.

67. Manjulatha, C. 1992 Studies on moulting, growth, autotomy and regenration in the estuarine mud crabs Scylla serrata and S. oceanica.

68. Sivani, G. 1994. Studies on the biology and fishery of some commercially important fishes of Gosthani estuary near Visakhapatnam.

69. Padmaja G. 1998 Studies on ecobiology of Megalops cyprinoides in relation to industrial pollution in Visakhapatnam.

70. Rama Rao, K. 1996. Studies on the feeding behaviour, oxygen requirements and growth of larval and adult of Penaeus monodon (Fabricius 1798; Crustacea: Decapoda).

71. Paul Pandian, 1999. Fishery biology, stock assessment and utilization of Indian drift fish, Ariomna indica (Day, 1870) from the upper East coast of India.

72. Janakiram, P. 1999. Farming of Penaeus monodon in barckish water ponds of Andhra Pradesh: An analysis of water and soil quality and production.

73. Aravindan, N, 1999. Microbial Infections among Penaeid post-larvae of North Coastal Andhra Pradesh, India.

PHYSIOLOGY OF MARINE ORGANISMS & ECOTOXICOLOGY

74. Nagabhushanam, R. 1958. Studies on Marine Wood - Boring Mollusca off Visakhapatnam Harbour.

75. Prasada Rao, D.G.V. 1966. Studies on respiration in Barnacles

76. Prabhakara Rao, Y. 1981. Studies on respiration of Cerithids

77. Uma Devi, V. 1984. Studies on intertidal gastropod Morula granulata (Duclos) with special reference to respiration, starvation and seasonal changes in some biochemical constituents.

78. Paduranga Rao, D. 1990. Studies on bioaccumulation of Heavy metals and haematology in Mugil cephalus (L.) and Mystus gulio (Ham.) in the polluted waters of Visakhapatnam harbour.

79. Praveen Kumar, K. 1990. Studies on some aspects of heavy metal toxicity and respiration on two tropical intertidal gastropods, Nerita chamaeleon and Nerita albicilla

80. Patnaik, R.M.S. 1995. Studies on the influence of industrial heavy metal pollution on Mystus vittatus.

81. Sreelakshmi, P. 1997. Ecotoxicology of intertidal gastropod Turbo intercostalis exposed to cadmium

82. Satyavathi Chinni 2000, Studies on the toxicity of lead in postlarvae of Penaeus indicus

MARINE PARASITOLOGY

83. Madhavi, R. 1968. Study on female reproductive systems with special reference to egg formation in some digenetic trematodes.

84. Vijaya Raju, V. 1976. Monogenetic trematodes of marine fishes of Andhra coast

85. Venu Rao, 1977. Studies on tetraphyllid, trypanorhynchid and proteocephalid cestodes of Andhra coast fishes.

86. Sandeep, B.V. 1985. Microsporidian parasites of Marine fishes of Visakhapatnam.

87. Padma Dorothy, K. 1990. Studies on Myxosporidian parasites of Liza macrolepis (Smith) (Mugilidae).

88. Anuradha, I. 1991. Myxosporidians of the common stripped mullet, Mugil cephalus Linn. of Visakhapatnam coast.

89. Meenakshi Murugesh 1992. Studies on the helminth parasites of Scombroid fishes of Visakhapatnam coast, Bay of Bengal.

90. Vaidehi, J. 1992. Myxosporean parasites of fishes of Chilka Lake, India.

TITLES OF M. PHIL. DISSERTATIONS

MARINE ECOLOGY

1. Nagapadmaja, A. 1981. Studies on some ecobiological aspects of intertidal rockpools of the Visakhapatnam coast.
2. Suresh Babu, V. 1981. A systematic report on the marine intertidal molluscs of Visakhapatnam coast.
3. Subba Rao, K.V. 1982. Studies on some aspects of marine intertidal sand dwelling molluscs of Visakhapatnam.
4. Rajya Lakshmi, M. 1986. Studies on Zoolopankton in the Lawson's Bay, Waltair.
5. Janaki Rama Rao, V. 1987. Further studies on hydrography and phytoplankton off Waltair coast.
6. Sivarama Sarma. N. 1988. Interstitial fauna of Sandy beaches of Visakhapatnam.
7. Satyanarayana, Ch. 1988. Chilka lagoon expedition, September 1987. Studies on hydrography and phytoplankton.
8. Sivarama Sarma, N. 1988. Interstital fauna of sandy beaches of Visakhapatnam
9. Prabhudas, P. 1990. Planktonic larvae of Bay of Bengal, Cruise No.10, R.V. Gaveshani.
10. Sri Krishna Pradsad, P. 1990. Systematics and seasonal distribution of Visakhapatnam, Bay of Bengal.
11. Someswari Devi, C. 1991. Chaetognatha of Bay of Bengal, Cruise No.201, R.V. Gaveshani.
12. Durga Rani, G. 1991. Studies on zooplankton of Bay of Bengal, Cruise No.200, R.V. Gaveshani.
13. C. Srikanth.1991. Fauna associated with algae in the littorl zone of Visakhapatnam.
14. M. Ramesh Kumar 1991 Observations on the plankton of the surf zone in the near shore waters of Visakhapatnam.
15. Jayasri Madan raj, 1995. Planktonic chaetognaths of Kakinada bay.
16. Anuradha, U. 1997. Observations on rock-pools of Visakhapatnam coast.
17. Balasri. M. 1998. Studies on the sandy shore fauna of Visakhapatnam coast.

POLLUTION BIOLOGY

18. Bismillah Shaik. 1986. Ecology of macrobenthos in relation to pollution in the north arm of Visakhapatnam harbour.

19. Jayaprada, C. 1991. Epigrowth fauna in relation to pollution in Visakhapatnam harbour.
20. Ratna Bharati, V. 1992. Planktonic protozoa in polluted North Channel in Visakhapatnam harbour.
21. Dipti Raut.1994. Hydrographic and benthic faunal changes in a newly built boat harbour in Visakhapatnam.

MANGROVES AND ESTUARINE BIOLOGY

22. V.Ramesh.1985. Studies on seasonal distribution of polychaete larvae at Antervedi (Vasishta Godavari estuary).
23. Suhasini.T.D.1986. Studies on the planktonic copepods of Vasishta Godavari estuary.
24. Chetty, P. M. 1986. Polychaete larvae of Vasista Godavari estuary.
25. Devika, N. 1987. Larval of ecology of some decapods from Godavari estuary (Vasista Godavari).
26. Narasimham, P.V. 1987. Hydromedusae of Vasista Godavari estuary.
27. Kiranmayi, D. 1988. Systematics and seasonal distribution of copoepoda of Godavari estuary.

BIOLOGICAL OCEANOGRAPHY

28. Joga Rao, G.R. 1989. Studies on physico-chemical conditions of the Vasishta Godavari estuary off Narspur, East Coast of India.

FISHERIES AND AQUACULTURE

29. Narasimha Rao, B. 1986. Seasonal distribution of sardines in relation to food and feeding habits at Visakhapatnam.
30. Suresh, P. 1994. The Lutjanid fishes of Visakhapatnam.

PHYSIOLOGY OF MARINE ORGANISMS AND TOXICOLOGY

31. Srilakshmi, P. 1992. Studies on cadmium induced toxicity in an intertidal gastropod Turbo intercoastalis.

Annexure III

SIGNIFICANT RESEARCH PUBLICATIONS IN MARINE BIOLOGY

(1955-2000)

1. Annapurna, C. and Rama Sarma, D.V. 1985. Occurrence of podocopan ostracod Palmenella mckenzii sp. nov. in the marginal water bodies, east coast of India. J.Geol. Soc.India. 26: 141-144.
2. Annapurna, C. and Rama Sarma, D.V. 1986a. Taxonomic studies on the marine ostracod from India, Family: Leptocytheridae Haneri, 1957. J. Bombay Nat. Hist. Soc. 83: 642 - 645.
3. Annapurna, C. and Rama Sarma, D.V. 1986b. A new species of podocopan ostracod, from the East Coast of India (Aljehella multicostatum). J.Bombay Nat. Hist. Soc. 84: 628 - 631.
4. Annapurna, C. and Rama Sarma, D.V. 1986c. Distribution of living benthic ostracods in the Bhimili backwaters (Gosthani estuary), east coast of India. Ind. J. Mar. Sci. 15: 174 - 176.
5. Annapurna, C. and Rama Sarma, D.V. 1987a. Taxonomic studies on the marine ostracods from the East Coast of India. J. Bombay Nat. Hist. Soc., 84:628-631.
6. Annapurna, C. and Rama Sarma, D.V. 1987b. Taxonomic studies on the marine ostracods from the East Coast of India. Family: Cytherruridae, Muller, 1894. J. Bombay Nat. Hist. Soc., 84:628-631.
7. Annapurna, C. and Rama Sarma, D.V.1988a. Taxonomic studies on the marine ostracods from the East Coast of India. Geobios New reports. 7: 24 - 27.
8. Annapurna, C. and Rama Sarma, D.V.1988b.Studies on the marine ostracods from the East Coast of India. Family: Cypridídae, Martin, 1940. J.Bombay Nat. Hist. Soc. 85: 364 -365.
9. Babu, D.E. 1988. Glandular pockets of the intugument and feeding mechanism in Pagurus bernhardus (L.) (Crustacea: Anomura). Mar. Biol. 99:315-323.
10. Babu, D.E. 1987. Observations on the embryonic development and energy source in the crab Xantho bidentatus. Mar. Biol. 95:123-127.
11. Babu, D.E. 1995a Candidate species for aquaculture other than shrimp Proc. INDAQUA '95 MPEDA 1-8.
12. Babu, D.E. 1995b. Importance of crab farming in Indian brackish water aquaculture-marketing based technology. Export Inspection XII (2) 17-19.
13. Babu, D.E. and Anger, K. 1987. The structure and modification of intugumental tissues in Pagurus bernhardus (L.) (Crustacea: Anomura). J. Exp. Mar. Biol. Ecol. 112:267-281.

14. Babu, D.E. and C. Manjulatha 1995a. Technology in crab culture. Fishing Chimes 15:41-43.

15. Babu, D.E. and C. Manjulatha 1995b. Zymogen secreting cells in the haepatopancreatic duct of Pagurus bernhardus and Clibanarius longitarsus Crustaceana 68: 616 -628.

16. Babu, D.E. and C. Manjulatha. 1995c. Methods in crab culture-A need in Indian coastal aquaculture. Fishing Chimes 15:41-43.

17. Bhavanarayana, P.V. and La Fond, E.C. 1957 On the replenishment of some plant nutrients during the upwelling period on the east coast off India. Ind. J. Fish vol. 4 : 75 - 79.

18. Chandramohan P 1986. Estuaries as trasitional zones with reference to plankton in the near shore waters UNESCO, Tech. Mar. Sci.

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3. UGC - SAP Report. 1991. Ecology, pathobiology and physiology of Aquatic organisms of Coramandel region. (Compiled by A.V. Raman) Submitted by

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4. C.E.C. Final Report 1997. An assesment of the ecological importance of mangroves in the Kakinada Area, Andhra Pradesh, India (submited by A.V. Raman, Marine Biological Laboratory, Department of Zoology, Andhra University, Waltair- 530003 (EC Fixed contribution contract No. CH*-CT93-0320, unpublished), pp. 64, Tables 1-26, Fig. 1-69, Plates 1-10.
5. Abstracts on: An international seminar on mangroves jointly organised by Vrije University, Brussels, Belgium and Department of Zoology, Andhra University, sponsored by European Commission, 25th - 27th March 1997, pp. 71.
6. Impact of shipbreaking on marine life at Alang, Gujarat, 1996. (Submitted by Dr. A.V. Raman) Mecon India Ltd., Ranchi, 1997, pp. 35, Tables 1-22, Figs. 1-2, Plates 1-18.
7. GIS Based study on Coringa Mangroves, Phase I - June-July 1998 (submitted by Dr. A.V. Raman), ICMAM Directorate, Department of Ocean Development, Chennai-25, pp. 57, Tables 1-61, Figs. 1-33, Plates 1-21.
8. GIS Based study on Coringa Mangroves, Phase II December 1998-January 1999 (submitted by Dr. A.V. Raman), ICMAM Directorate, Department of Ocean Development, Chennai-25, pp. 39, Tables 1-53, Figs. 1-30.
9. DOD Report, 1999. Marine Manpower Development Programme - MLR Related Research Onboard FORV Sagar Sampada. Cruise No. 171, pp. 22, Tables 1-7, Figs. 1-11, Plates 1-6.
10. GIS Based study on Coringa Mangroves, Draft Final Report October, 1999 (submitted by Dr. A.V. Raman), ICMAM Directorate, Department of Ocean Development, Chennai-25, pp. 58, Tables 1-43, Figs. 1-69.

SOUTH ASIA CO-OPERATIVE ENVIRONMENT PROGRAMME

Strengthening the Capacity of Regional Centres of Excellence in the Management of the Coastal and Marine Environment

Marine Biological Laboratory,
Department of Zoology, Andhra University,
Waltair - 530003

EQUIPMENT AND OTHER INFRASTRUCTURE NEEDS

Requirements under the Head Equipment could include Sampling devices (plankton, benthos, water), laboratory needs (Scanning Electron Microscope, Research Microscopes, filtration units, counting chambers, deep freezers, refrigerators, high speed centrifuges, A/c rooms), analytical instruments (U.V. visible Spectrophotometer, accessories to Gas Chromatography, AAS and Liquid Scintillation counter), computation facilities (Servers, printers, PCs), communication needs (Fax, Telephone, E.Mail), audio-visual aids (slide and overhead projectors, digital systems) and the like. M/s Federal Instruments, 101 Gillnagar, III Street, Madras - 600094 representing KC Denmark; M/s Central Kagaku Co. Ltd., Tokyo Centra PO Box 1618 Tokyo 03 (3670 8211; M/s KLB Instruments, 1E/ 17 Jhandewalan Extn. PO Box 5726 New Delhi - 110055 representing Hydrobios, Germany; M/s ELICO Ltd., 209 Model House, 6-3-456/A/1 Punjagutta, Hyderabad - 500082; M/s Millipore (India) Ltd., 50A2nd Phase, Ring Road, Peenya, Bangalore - 560058 representing Millipore Intertech, US; M/s Towa Optics, A-1 1st Floor Gajel Apartments, 152 Greams Road, Chennai - 600006 representing NIKON, Japan; M/s Afcloset Balances, 5-10-188/1 Hill Fort Road, Hyderabad - 500004 representing A&D Company, Japan; M/s SICO, Scientific Instrument Company Ltd., Khivraj Complex, 480/3 Mount Road, Nandanam Chennai - 600035 and M/s Chemito India Ltd., Hyderabad are some of the concerns who could be approached for the above needs. It is also proposed to procure a four wheeler (Jeep) for road transportation. A sum of Rs. 50.00 Lakhs is requested for this purpose (vide Table 3, Financial Statement).

MALMAA ARCHITECTS
A.U. Plot No. 2, Sector 11,
M V P Colony, Visakhapatnam - 530 017.
Phone : 532116, Email : malmaa@vsnl.com

Date : 17-01-2000

To
The Coordinator,
Department of SAP, Zoology,
Andhra University,
Visakhapatnam.

Sir,

Sub : Fees towards Architectural Services - Dept. of Marine Biological Laboratory, Department of Zoology – Reg.

Appropos our conversation dated 12-01-2000, please find enclosed the presentation drawings and estimates of the proposed Marine Biological Laboratory, Department of Zoology, Andhra University, Visakhapatnam.

At this juncture we would like to quote the fess towards Architectural Services rendered by our firm, put at 4.0% of the total cost of construction of the structure.

This fees is inclusive of a limited number of site visits at various pre-determined intervals. If needed we would also arrange for a contractor who would carry out the construction.

The fees mentioned above has been fixed considering the nature of project being an enductional one, which would otherwise be higher. The amount of fees will be fixed once the detailed estimates have been prepared and submitted.

We assure you the best of our services and we keenly look forward to an early progress in the project.

Thanking you,

Yours sincerely,

(P.V.P. RAJU)
Authorised Signatory

MALMAA ARCHITECTS
A.U. Plot No. 2, Sector 11,
M V P Colony, Visakhapatnam - 530 017.
Phone : 532116, Email : malmaa@vsnl.com

Estimate for the proposed Department of Marine Biological Laboratory, Department of Zoology, Andhra University, Visakhapatnam

Ground Floor :	a)	Total Plinth Area - 2300 Sft. @ 330/-	= 7,59,000-00
	b)	Total Service area i.e. Corridors & Stair Case – 750 Sft. @ 190/-	= 1,42,500-00
	c)	Electification and plumbing @ 7%	= 63,105-00
		Total	= **9,64,605-00**
First Floor :	a)	Total Plinth Area - 2300 Sft. @ 360/-	= 8,28,000-00
	d)	Total Service area i.e. Corridors & Stair Case – 750 Sft. @ 205/-	= 1,53,750-00
	e)	Electification and plumbing @ 7%	= 68,722-50
		Total	= **10,50,472-50**
Total construction including Ground Floor and First Floor			= **20,15,077-50**

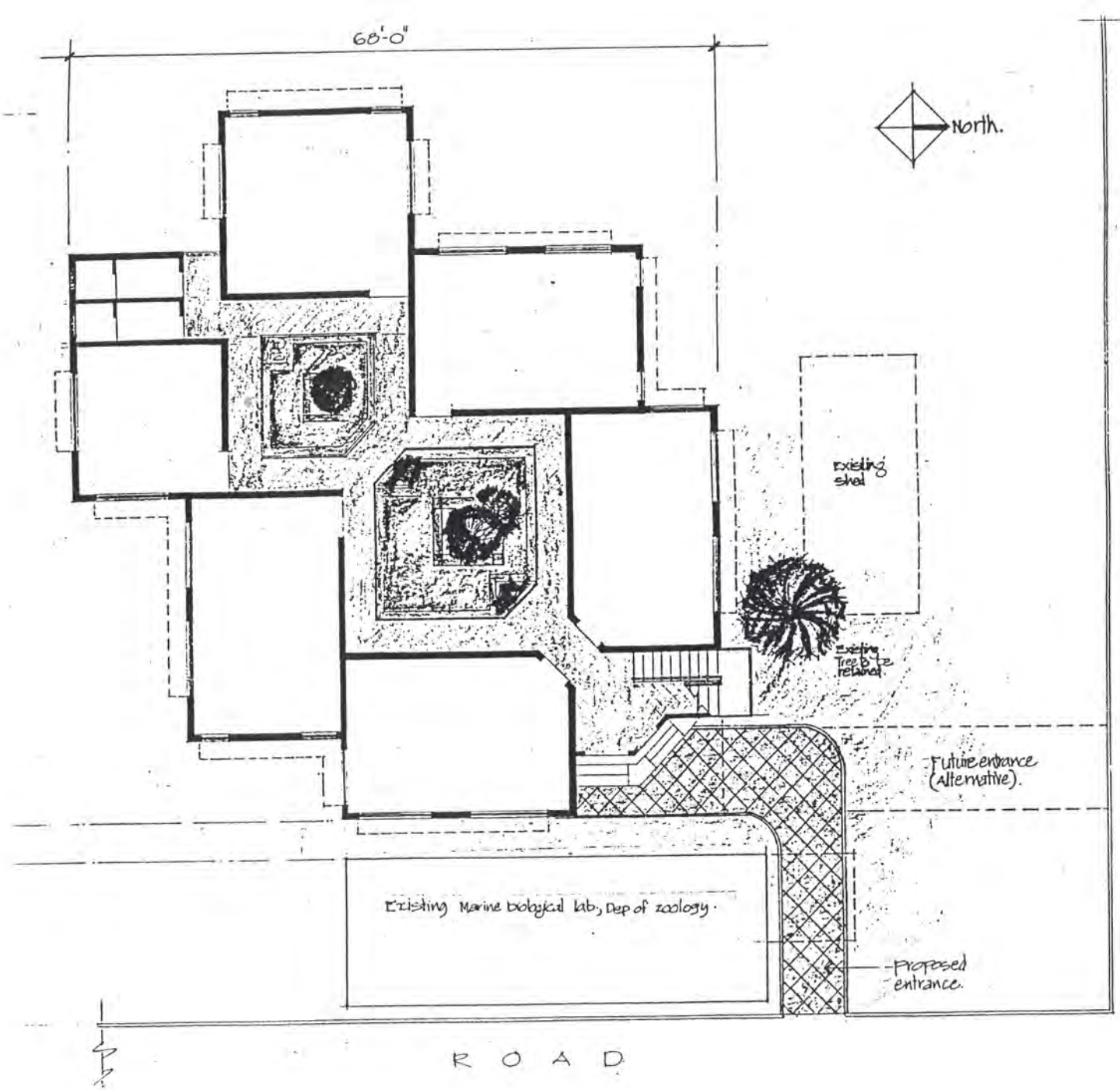
(P.V.P. RAJU)
Authorised Signatory

MALMAA ARCHITECTS
A.U. Plot No. 2, Sector 11,
M V P Colony, Visakhapatnam - 530 017.
Phone : 532116, Email : malmaa@vsnl.com

Estimate for the two labs of Marine Biology Laboratory, Department of Zoology, Andhra University, Visakhapatnam, to be constructed in First Phase

Total Plinth Area	768 Sft. @ Rs. 330/-	=	Rs. 2,53,440-00
Add for Electrification @ 2%		=	Rs. 5,068-00
Total		=	**Rs. 2,58,508-00**

(P.V.P. RAJU)
Authorised Signatory



BIOLOGICAL LABORATO

DEPARTMENT OF ZOOLO

ANDHRA UNIVERSITY.

VISAKHAPATNAM

SITE PLAN

MALMAA ARCHITE
A.U. Plot No. 2, Sector 11,

PROPOSED MARINE

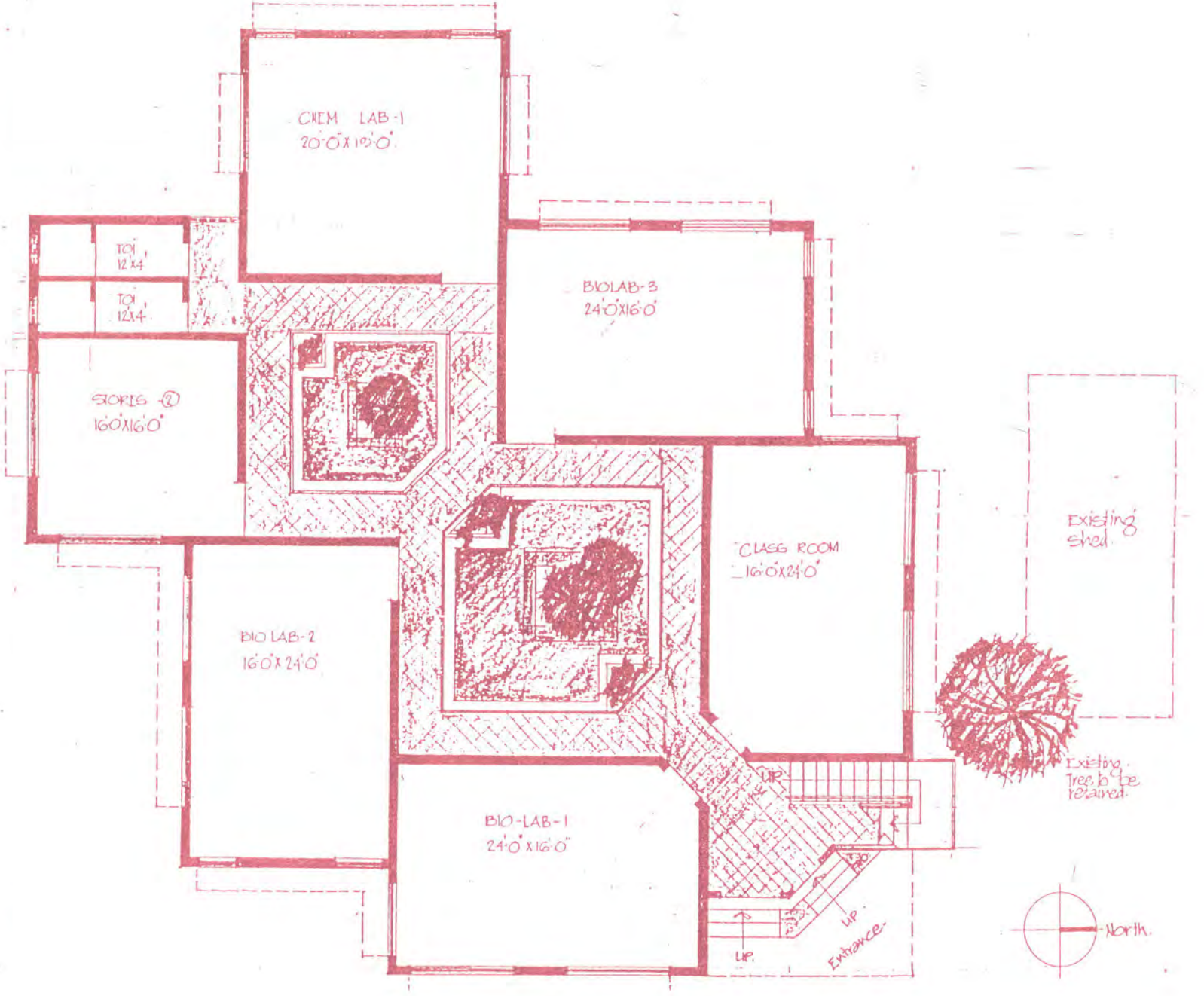
BIOLOGICAL LABORATORY,

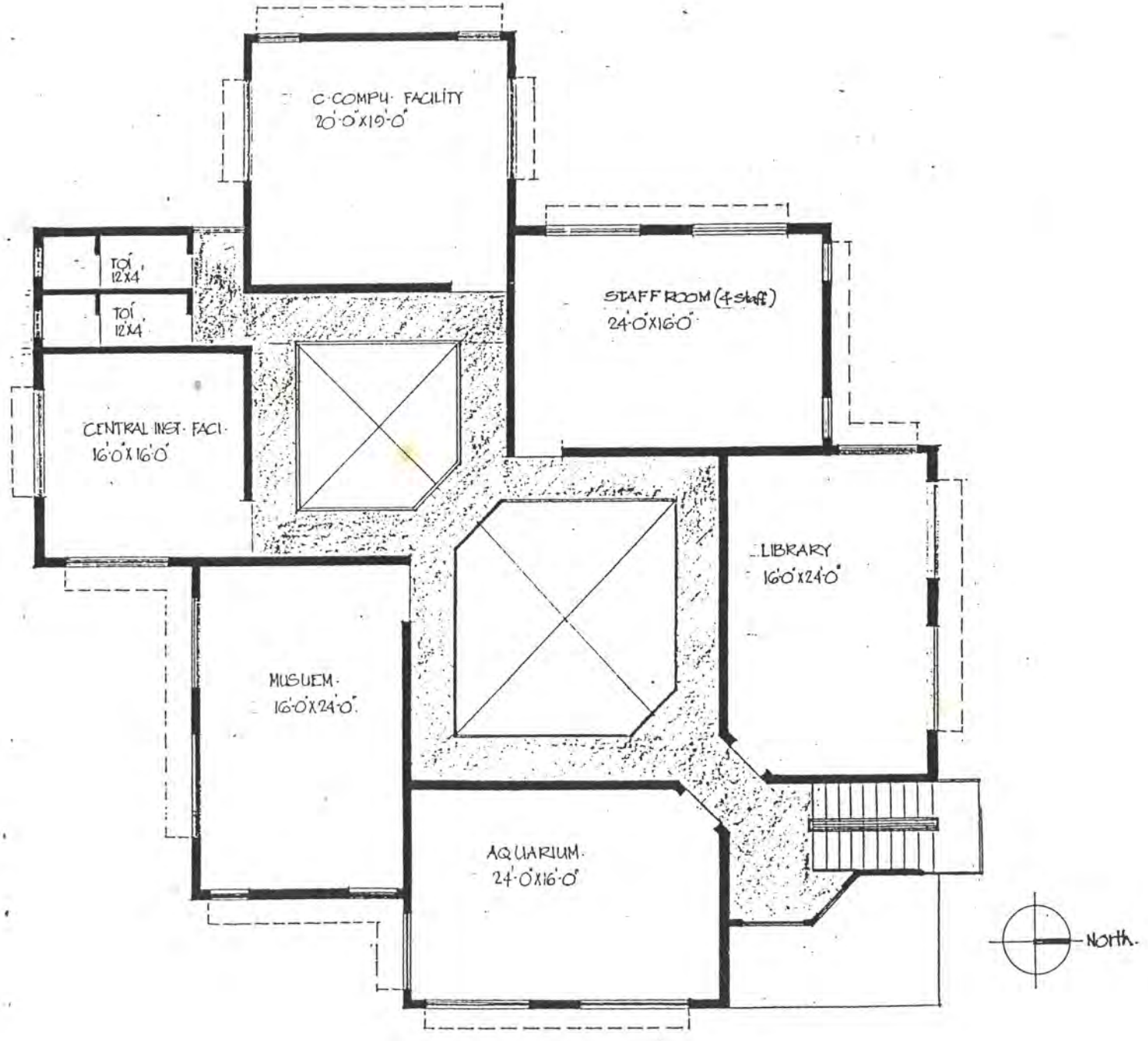
DEPARTMENT OF ZOOLOGY,

ANDHRA UNIVERSITY,

VISAKHAPATNAM

GROUND FLOOR PLAN





PROPOSED MARINI

BIOLOGICAL LABORAT

DEPARTMENT OF ZOOL

ANDHRA UNIVERSIT

VISAKHAPATNAM

FIRST FLOOR PL.

MALMAA ARCHITE