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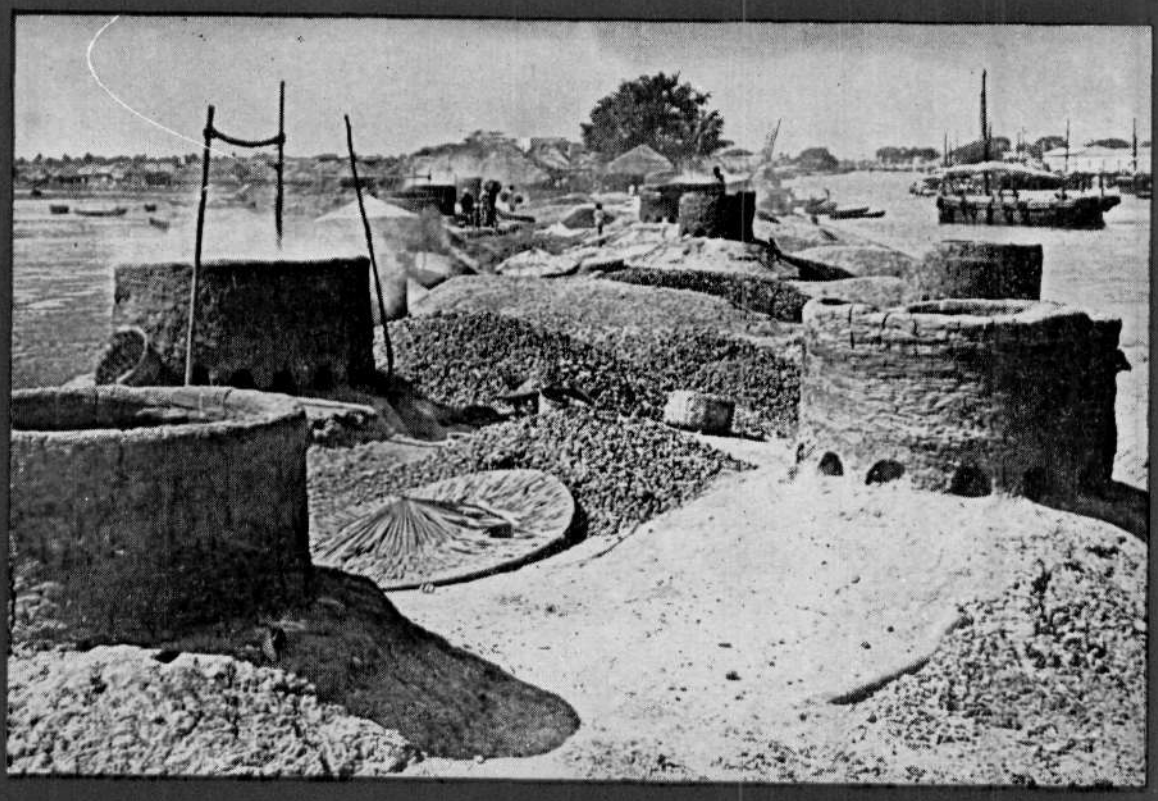

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THE MARINE FISHERIES INFORMATION SERVICE: Technical and Extension Series envisages the rapid dissemination of information on marine and brackish water fishery resources and allied data available with the National Marine Living Resources Data Centre (NMLRDC) and the Research Divisions of the Institute, results of proven researches for transfer of technology to the fish farmers and industry and of other relevant information needed for Research and Development efforts in the marine fisheries sector.

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THE MOLLUSCAN RESOURCES AND ECOLOGY OF KAKINADA BAY

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Introduction

In the Kakinada Bay several species of bivalves and gastropods are regularly fished and the annual production has been estimated to be about 6,000 t (Narasimham, 1973). Among them the windowpane oyster *Placenta placenta* (Linnaeus) and the blood-clam *Anadara granosa* (Linnaeus) are of particular interest. In India the latter forms a fishery only in Kakinada Bay while the former is fished also in Pindara Bay in the Gulf of Kutch and in Goa. The molluscs are mainly used as lime shell and the flesh is eaten locally to a limited extent. In general, the production during the last two decades has been static mainly due to low demand. However, in 1983 trial consignments of the frozen meat of the windowpane oyster and the blood-clam collected from the bay were exported to Japan by an entrepreneur and were received well. As the export market is being developed one would expect the picture to change rapidly. In the light of these developments it was felt that a quick survey of the bay to estimate the abundance of the constituent species would be useful to the industry. Further, such basic information is necessary to evolve, suitable managment policies. With these objectives a survey of the Kakinada Bay was conducted in March-April 1983. Also the results of a survey conducted in the last week of March 1979 of the Kakinada (Upputeru) canal have been incorporated in this report. Environmental data which may have bearing on the distribution and abundance of the molluscs were also collected.

Earlier works in the bay relevant to this study were mainly related to hydrography (Ramasarma and Ganapati, 1968), sediments and their organic carbon (Rao, 1967), bottom fauna (Radhakrishna and Ganapati, 1968) and molluscan resources (Narasimham, 1973 and Murthy *et al.*, 1979).

Physiography of the Bay

The bay lies between 16° 51′ N to 16° 59′ N and 82° 15′ E to 82° 22′ E and covers an area of 146 km². It opens into the Bay of Bengal in the north by a 5.6 km wide mouth, bordered on the west by mainland, on the south by extensive mangrove forests and on the east by a narrow sand bar called Hope Island (Fig. 1). It has a maximum length of 14.8 km and width of 13.0 km. The Kakinada (Upputeru) canal, Chollangi canal, Matlapalem canal, Coringa river, Gaderu river and Pillavarava creek, which

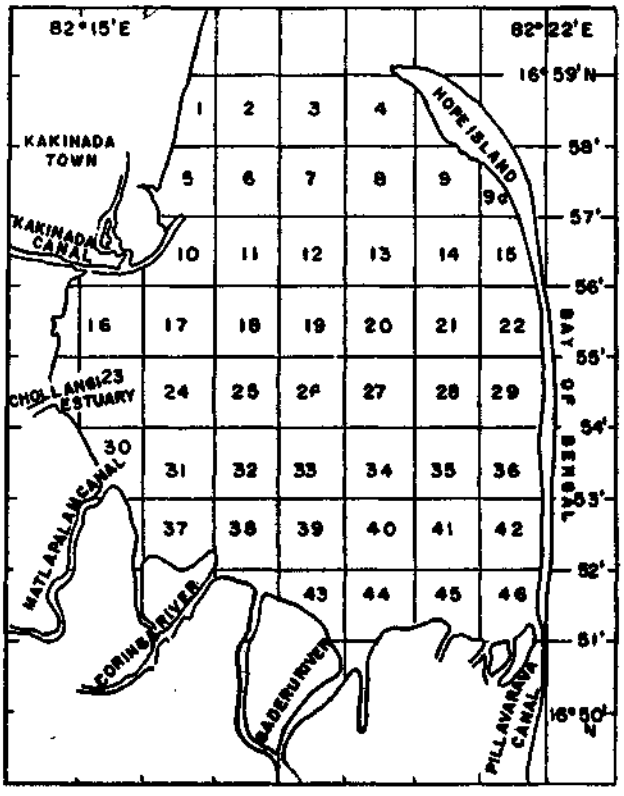


Fig. 1. Map of Kakinada Bay showing the squares.

are connected to the Gautami branch of the Godavari river, open into the Bay. It is shallow and large mud flats are exposed at low tide on the southern and western sides. The maximum depth is 6.8 m and only in the northern section, it is > 3 m. The tides are semi-diurnal and the maximum amplitude during spring tides is 1.8 m.

Survey methods

Following Murthy *et al.* (1979), the Bay was divided into 47 squares, each measuring 1 sq. nautical mile or 3.43 km² excepting those bordering the land which are smaller (Fig. 1 and Table 1). A 4 m fibreglass dinghy fitted with 7.5 h.p. outboard motor was used in the survey conducted from 22-3-1983 to 28-4-1983. In each square the following equipments were used/ samples collected manually.

Table 1. *Square-wise extent and depth (at low tide) of the Kakinada Bay and the dates of the survey*

Square No.	Area (m^2)	depth (m)	Date of survey
1.	15,94,950	0.8	7-4-83
2.	34,29,904	2.4	27-4-83
3.	34,29,904	5.2	27-4-83
4.	33,18,525	6.8	27-4-83
5.	25,38,200	1.0	5-4-83
6.	34,29,904	2.2	6-4-83
7.	34,29,904	3.1	27-4-83
8.	34,29,904	4.6	23-4-83
9.	27,44,000	3.0	23-4-83
9a.	8,23,200	2.0	22-4-83
10.	20,83,725	0.4	22-3-83
11.	34,29,904	2.4	2-4-83
12.	34,29,904	2.6	4-4-83
13.	34,29,904	2.8	22-4-83
14.	34,29,904	2.0	22-4-83
15.	21,43,750	1.8	23-4-83
16.	34,29,904	0.0	25-4-83
17.	34,29,904	1.2	25-4-83
18.	34,29,904	1.5	25-3-83
19.	34,29,904	1.8	13-4-83
20.	34,29,904	1.8	13-4-83
21.	34,29,904	0.9	21-4-83
22.	28,72,625	0.9	23-4-83
23.	34,29,904	0.0	26-4-83
24.	34,29,904	0.3	26-4-83
25.	34,29,904	0.9	26-4-83
26.	34,29,904	1.0	11-4-83
27.	34,29,904	1.5	11-4-83
28.	34,29,904	0.9	11-4-83
29.	28,89,775	0.3	10-4-83
30.	25,21,050	0.0	26-4-83
31.	34,29,904	0.6	28-4-83
32.	34,29,904	0.6	21-4-83
33.	34,29,904	0.3	21-4-83
34.	34,29,904	0.6	21-4-83
35.	34,29,904	0.3	21-4-83
36.	28,12,600	0.6	12-4-83
37.	28,89,775	0.0	28-4-83
38.	34,29,904	0.6	20-4-83
39.	34,29,904	0.0	20-4-83
40.	34,29,904	0.1	20-4-83
41.	34,29,904	0.3	20-4-83
42.	29,58,375	0.1	12-4-83
43.	21,86,625	0.6	19-4-83
44.	32,07,050	0.3	19-4-83
45.	29,24,075	0 0	19-4-83
46.	26,32,525	0.1	12-4-83
Total	14,60,37,945		

1. A dredge of 0.5 m opening and with 15 mm synthetic yarn mesh (Pl. 1) was hauled 4–6 times, each haul covering 5m² area.

2. A clam seed sampler of 0.5 m opening and with 4 mm synthetic yarn mesh (Pl. 2) was hauled twice, each haul covering 1m². The samples obtained by these gears were sieved through 1 mm mesh, species identified, counted, weighed and specimens in the subsample measured for length in the anteroposterior direction.

3. Van Veen grab covering 10 cm x 10 cm was operated once and the material was sieved through 0.5 mm mesh.

4. Sediment collected by the grab was analysed for particle size by using test sieves. Wentworth's grade scale (Welch, 1948) was followed.

5. Organic carbon of the sediment collected by the grab was analysed by the chromic acid titration method (F.A.O. 1975).

6. 10-minute plankton hauls with plankton net of 50 cm ring diameter and 0.3 mm mesh size were made. Subsamples were made using Folssom plankton splitter (Wickstead, 1976), and studied. The organisms were counted and estimates were made for whole sample.

7. Surface water samples were collected and analysed for temperature, salinity (Mohr's titration method), dissolved oxygen (Winkler's method), inorganic phosphate, silicate, nitrite and nitrate (Calorimetric method using spectrophotometer). Wherever desired transparency was studied. The samples were collected during 0600 to 1200 hrs. The Kakinada canal concrete embankments were surveyed by fixing stations 200 m apart and collecting samples from 1 m^2 area at each station.

Hydrography

Transparency: The water was highly turbid with secchi-disc reading not exceeding 50 cm except on the northeastern side where it was clear with secchi-disc values upto 150 cm.

Temperature: Water temperature varied from 25.6° to 32.5°C with maximum in square 22 and minimum in squares 20 and 21 (Fig. 2).

Salinity: Salinity values ranged from 28.9‰ to 35.0‰ (Fig. 3) with maximum in square 20 and minimum at Kakinada canal confluence (square 5) and Coringa confluence (square 38).

Dissolved oxygen: The range in the dissolved oxygen values observed was from 2.0 ml/l in squares 20 and 21 to 7.0 ml/l in squares 14, 23 and 41 (Fig. 4). The distribution of the low values of dissolved oxygen indicated the formation of an eye in the circulation pattern around squares 20 and 21 which is associated with low temperature and high salinity profile.

Inorganic phosphates: Phosphate values ranged between 1.00 and 3.00 μ g at/l (Fig. 5). The tidal flats on the western side had maximum phosphate content (2.7–3.0 μ g at/l) which may be due to land drain by the Kakinada, Chollangi and Matlapalem canals. Similarly the Pillavarava confluence on the southeastern side was relatively rich in phosphates (1.82–2.2 μ g at/l). While the Gaderu and the Coringa confluences had moderate phosphate content (1.2–1.85 μ g at/l) lowest values were obtained on the northeastern side of the bay in squares 8, 9 and 20.

Silicate: The values varied from 11.0 to 67.0 μ g at/l with maximum around Coringa confluence (squares 32 and 38) and minimum in square 8 (Fig. 6). The distribution showed low values (11–22 μ g at/l) on the northern side of the bay. However, a patch of high silicate values was recorded in squares 15 and 22, close to the bay opening into the sea.

Nitrite: The range in the nitrite values fluctuated between 0.36 and 1.45 μ g at/l with maximum in square 21 and minimum in square 8 (Fig. 7), where the silicate was also low. Similarly Coringa confluence had high nitrite content (1.21–1.33 μ g at/l) as is the case with silicate.

Nitrate: The values ranged from 1.1 to 4.0 μ g at/l with maxima in squares 1, 2, 4, 21, 22 and 23 (Fig. 8) and minimum at Pillavarava confluence. In general in the southern and western parts the nitrate was present in moderate concentrations.

Zooplankton: The foraminifera was represented by *Globigerina* sp. *Obilia* spp., *Liriope tetraphylla, Eutima mira, Aequorea* spp., *Aurelia* spp., *Bougainvillia* spp. and *Phialidium* spp. were the representative hydromedusae. On an average they formed 0.5% in zooplankton and were abundant in squares 41, 46 and 29. Siphonophores formed about 0.3% and were represented by *Lensia* spp., *Muggiaea* spp, *Dimophyes* spp. and *Eudoxides* spp. Ctenophores formed on an average 0.3% and were represented by *Beroe* spp. and *Pleurobrachia* spp. The chaetognaths contributed about 0.6% and the common species were *Sagitta inflata* and *S. robusta.* Cladocera and ostracoda accounted for 0.3% and were commonly represented by *Evadne* sp. and *Cypridina* spp.

At different stations the copepods contributed from 0.2 to 91.0% in total zooplankton (average 11.6%). Calanoid genera were common and were represented by *Calanus, Rhincalanus, Eucalanus, Calocalanus, Paracalanus, Pseudocalanus, Microcalanus Eucaheta, Temora, Centropages, Labidocera, Parapontella* and *Acartia.* Other genera in the samples were *Oithona, Corycaeus, Euterpina* and *Microstella.* Parasitic forms *Lernaea* spp. and *Caligus* spp. were encountered in squares 4, 10, 13, 19, 24–26, 32, 33, 43 and 44.

The amphipods formed less than 0.2%; *Hyperia* spp. and *Corphium* spp. being the common. The appendicularians constituted less than 0.2%. Adult decapods were represented by *Acetes indicus* and *Lucifer* spp. and they contributed from 0.02 to 84.4% in different squares with an average of 13.6%.

The decapod larvae contributed from 0.03 to 65.6% in different squares with an average of 10.5% of which the crab larvae belonging to Porcellanidae, Paguridae, Pinnotheridae, *Portunus* spp. and *Carcinus* spp. formed 9.4%. Others were phyllosoma larva, alima larva and various larval stages of penaeid prawns namely *Penaeus indicus, Metapenaeus brevicornis, M. affinis, M. dobsoni* and *M. monoceros.*

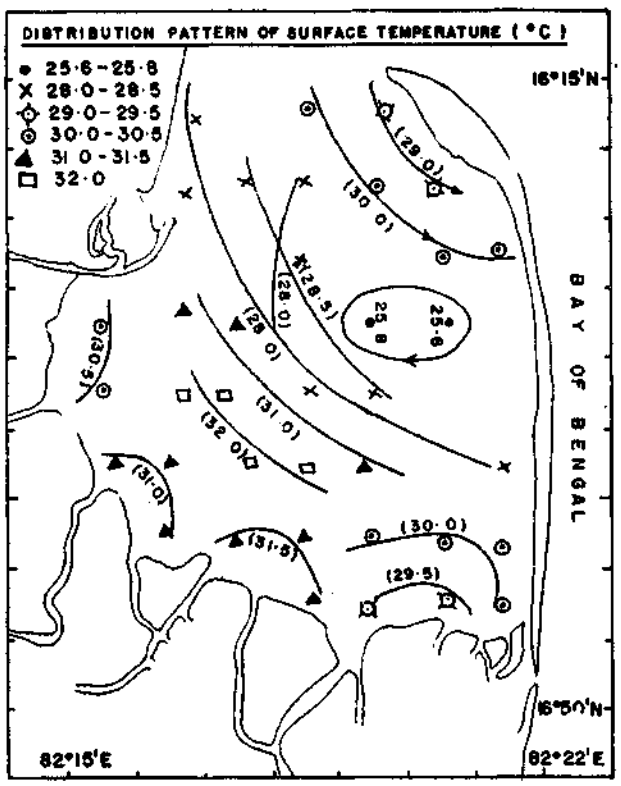


Fig. 2. Surface temperature (°C) of the water in the bay.

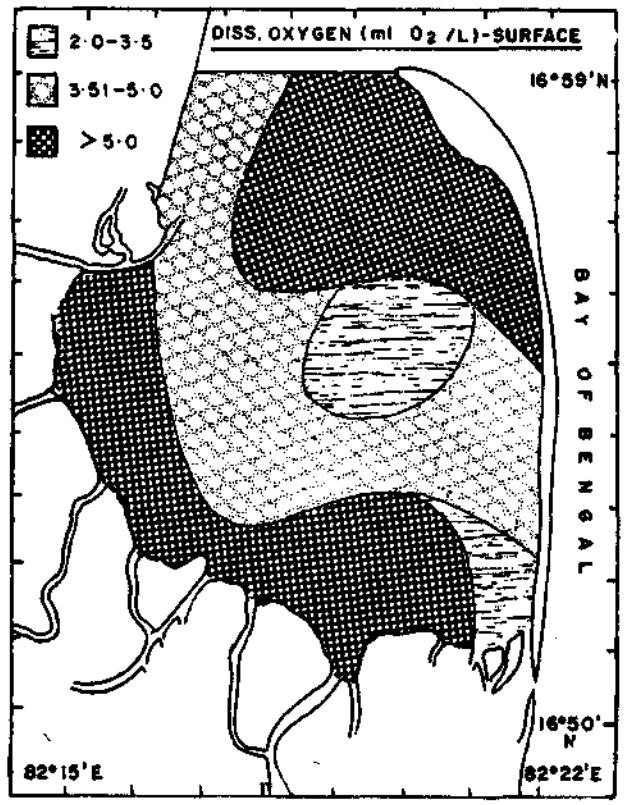


Fig. 4. Distribution pattern of dissolved oxygen (ml/l) in the bay.

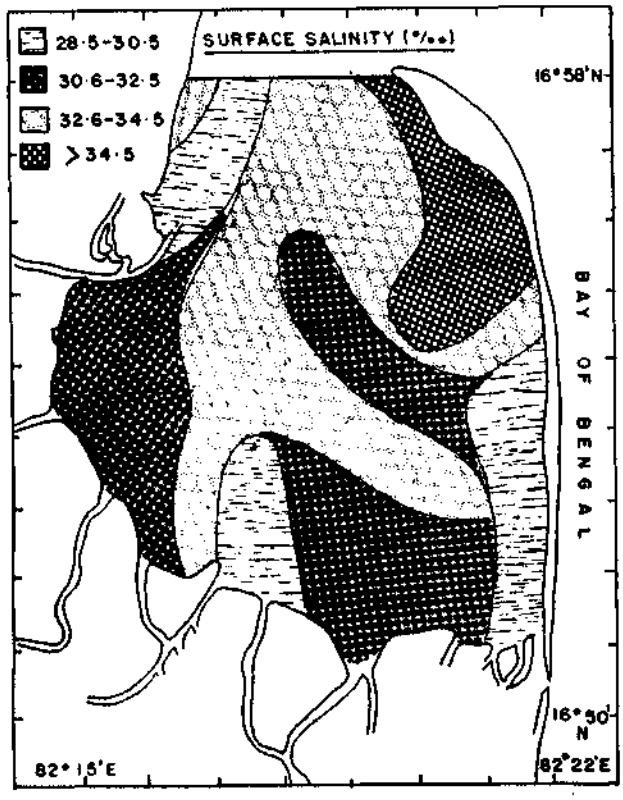


Fig. 3. Distribution pattern of salinity (‰) in the bay.

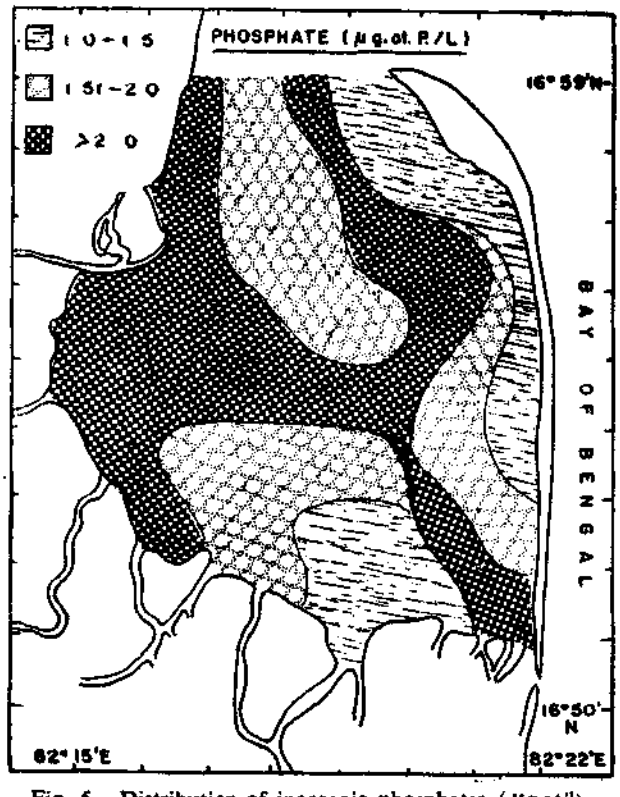


Fig. 5. Distribution of inorganic phosphates (µg at/l) in the bay.

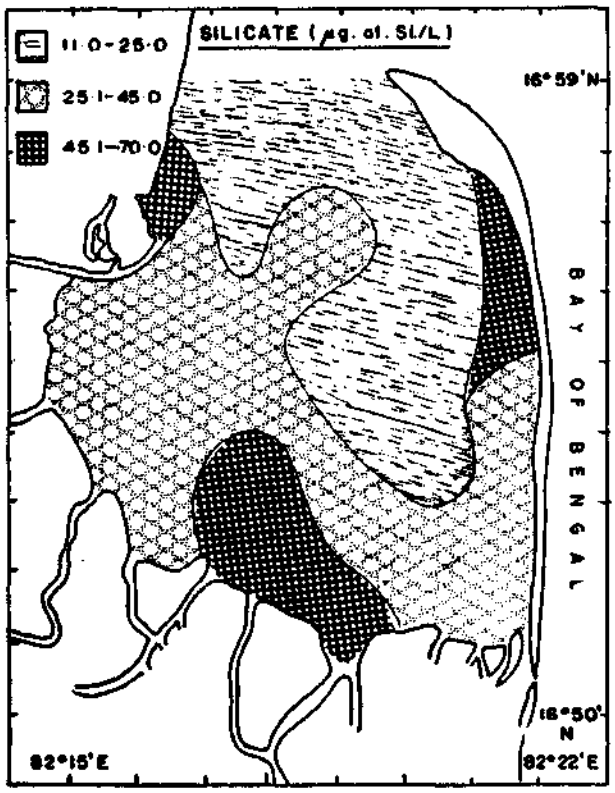


Fig. 6. Distribution of silicate (μg at/l) in the bay.

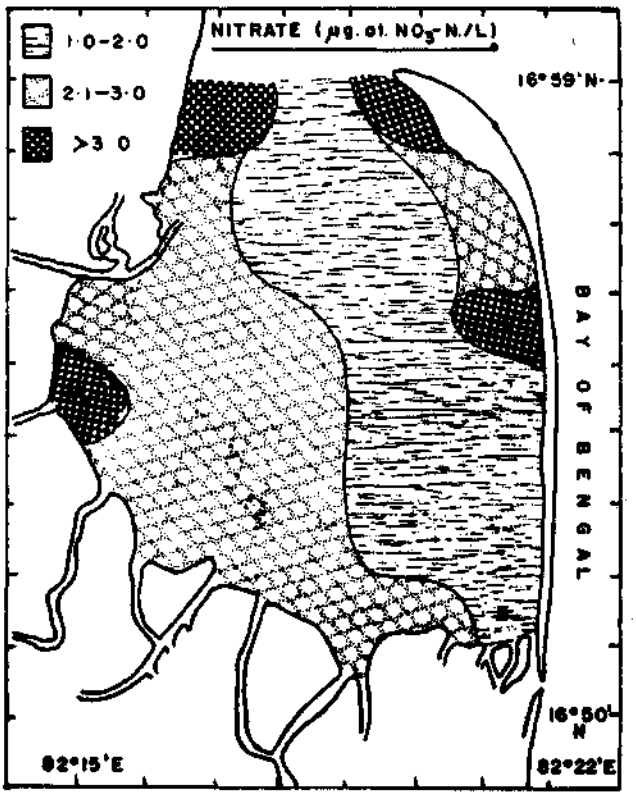


Fig. 8. Distribution of nitrate (μg at/l) in the bay.

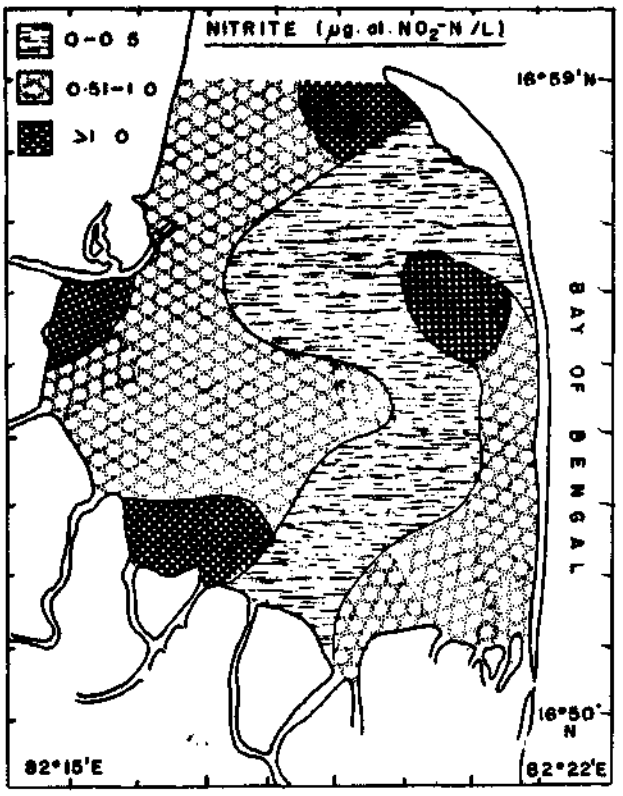


Fig. 7. Distribution of nitrite (μg at/l) in the bay.

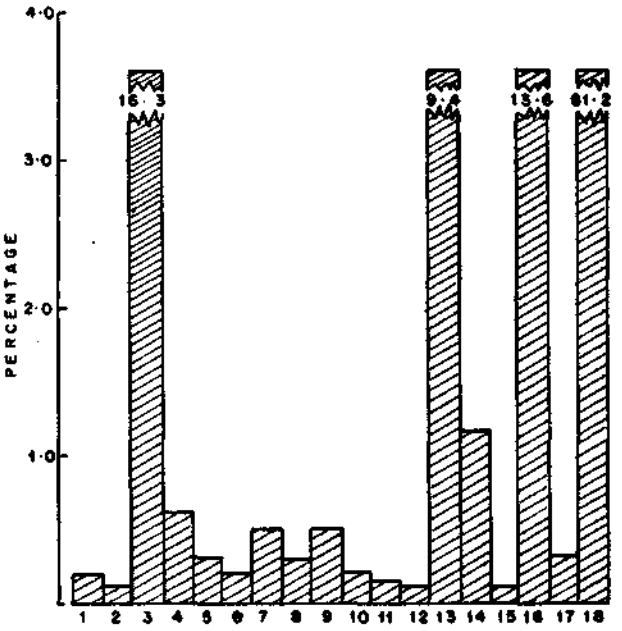


Fig. 9. Average zooplankton biomass in the bay. 1. Alima larvae 2. Amphipods 3. Copepods 4. Chaetognaths 5. Ctenophores 6. Cladocerans 7. Medusae 8. Mysids 9. Molluscan larvae 10. Oikopleura 11. Parasitic copepods and Isopods 12. Phyllosoma larvae 13. Crab larvae 14. Prawn larvae 15. Polychaete larvae 16. *Lucifer* 17. Siphonophores and 18. Fish eggs and larvae.

Polychaete larvae nepthyid and phyllodocid were encountered and the polychaete larvae contributed on an average of 0.03%. Bivalve veligers, young gastropods and pteropds formed about 0.6% in zooplankton. Bivalve larvae were common in squares 3–5, 7, 10, 13, 18–20 30, 33–36, 38, 40–44 and 46. The percentage composition of fish eggs and larvae varied from nil to 99.6 with an average of 61.2% in zooplankton (Fig. 9). The common forms were the eggs and larvae of clupeidae, Mullidae, Gobidae, Pleuronectidae and Belonidae.

As the survey was conducted in the summer months the hydrographical conditions as well as the composition of plankton in the bay were typically marine. Generally the plankton was rich in the variety of species. While the collections made between 6 and 8 hrs. were dominated by fish eggs and larvae, pelagic tunicates, crustacean larvae, *Lucifer* sp. and copepods, those made around noon comprised mostly of coelenterates and chaetognaths.

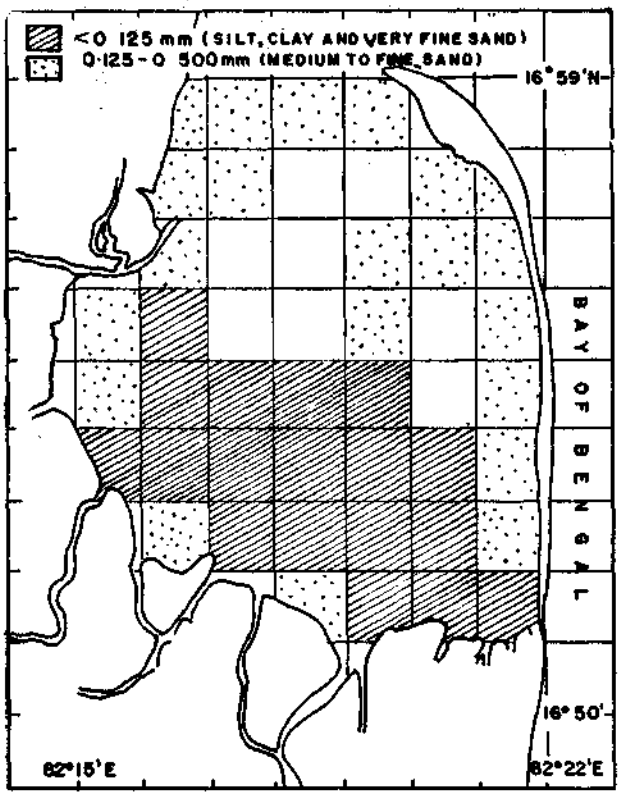


Fig. 10. Particle size of the sediments in the bay. Each category indicates the predominant type (over 50%)

Sediments

Particle size: The results of the particle size analysis by weight are shown in Table 2. In the southern and southwestern part of the bay the sediment is predominantly composed of clay, silt, and very fine sand (particle size < 0.125 mm) (Fig. 10). The rivers and irrigation canals bring in considerable quantities of these fine particles resulting in soft bottom in these areas. On the other hand, the sediments of the eastern and northern parts of the bay are predominantly made up by fine to medium sand (particle size between 0.125 to 0.500 mm) due to the influence of the strong tidal currents from the sea. The Hope island Itself is a sand bar.

Organic carbon: Organic carbon content in the sediments (Fig. 11) was highest along the southwestern tidal flats (0.9–11%) and lowest along the northeastern side close to the sand bar. Another diagonal belt of high values ranging from 0.87 to 1.02% was recorded in the central portion of the Bay in southeast to northwest direction. Coringa and Gaderu confluences had lower values (0.3–0.6%) while the northern side close to the mouth of the bay had median values (0.6 - 0.8%). The present study indicates that regions of fine sediments are generally rich in organic carbon.

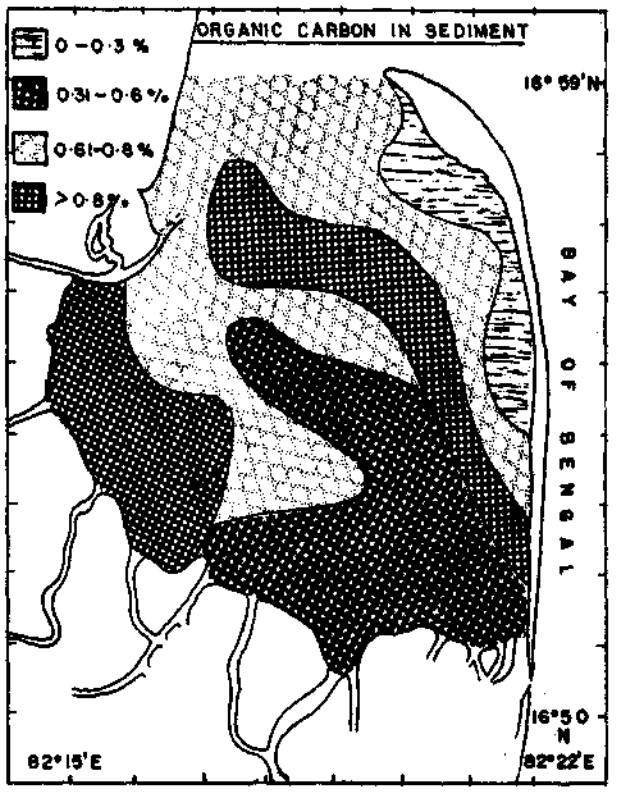


Fig. 11. Organic carbon (1%) in the sediments of the bay.

Molluscan resources

Based on the dredge collections the square-wise estimates of live molluscs and holothurians by weight and numbers are given in Table 3.

Table 2. *Particle size and organic carbon in the sediments*

Square No.	Particle size of sediments in % (by weight)							Organic carbon (%)
	>2000 Microns	1000–2000	500–1000	250–500	125–250	63–125	<63	
1.	—	—	13.7	22.8	28.0	34.8	0.7	0.74
2.	—	—	14.4	20.2	39.6	21.6	4.2	0.62
3.	—	—	10.3	9.2	48.7	28.3	3.5	0.60
4.	—	—	5.6	19.3	45.9	26.9	2.3	0.65
5.	—	—	—	47.2	49.3	3.1	0.4	0.71
6.	—	—	—	17.8	56.5	25.1	0.6	0.96
7.	3.0	—	13.8	19.1	22.2	40.7	1.2	0.77
8.	—	—	2.8	3.9	45.8	41.9	5.6	0.21
9.	0.2	—	1.8	3.2	50.4	42.8	1.6	0.21
9A	3.0	0.1	—	2.5	62.8	31.2	0.4	0.13
10.	0.6	—	—	11.5	41.4	43.7	2.8	0.71
11.	—	—	25.2	21.3	15.7	37.1	0.7	0.87
12.	8.5	—	30.1	20.1	21.8	9.9	9.6	0.97
13.	0.9	0.1	—	25.6	36.5	33.2	3.7	0.90
14.	1.0	—	—	18.2	44.8	34.2	1.8	0.66
15.	0.2	—	2.1	4.1	48.1	37.5	8.0	0.62
16.	0.2	—	7.7	12.7	52.9	23.7	2.8	0.99
17.	2.6	—	2.5	4.2	24.1	64.6	2.0	0.65
18.	0.5	—	18.6	17.6	20.0	23.4	19.9	0.50
19.	—	—	17.8	23.6	22.6	24.2	11.8	0.74
20.	0.5	0.1	—	—	57.3	40.6	1.5	0.71
21.	0.8	—	22.4	19.9	24.1	22.7	10.1	1.02
22.	—	—	—	7.3	80.0	12.7	—	0.06
23.	1.1	—	—	37.1	27.3	21.8	12.7	1.10
24.	—	—	—	10.5	28.5	59.4	1.6	0.71
25.	—	—	—	16.8	25.5	51.8	5.9	0.91
26.	0.8	—	2.5	5.0	33.0	56.2	2.5	0.40
27.	1.0	—	4.0	5.5	32.9	46.9	9.7	0.37
28.	—	—	9.0	10.9	35.9	42.4	1.8	0.87
29.	0.9	—	16.7	21.0	31.7	28.5	1.2	0.13
30.	—	—	4.4	0.6	7.0	69.4	18.6	0.87
31.	0.2	—	7.2	7.2	17.5	53.3	14.6	0.87
32.	0.8	—	—	32.4	12.6	47.5	6.7	0.71
33.	0.7	—	13.2	15.4	20.2	48.1	2.4	0.77
34.	—	—	4.6	7.6	21.1	63.7	3.0	0.71
35.	1.2	—	3.9	7.6	34.0	49.5	3.8	0.59
36.	—	—	—	18.8	35.8	40.3	5.1	0.75
37.	—	—	—	18.7	42.8	38.1	0.4	0.99
38.	—	—	—	9.9	30.9	57.2	2.0	0.59
39.	—	—	10.0	9.8	27.7	48.1	4.4	0.59
40.	—	—	—	7.2	22.8	57.8	12.2	0.47
41.	—	—	2.9	6.9	28.8	56.0	5.4	0.44
42.	1.4	—	—	25.9	29.9	41.8	1.0	0.90
43.	0.4	—	—	8.8	44.9	44.3	1.6	0.34
44.	—	—	3.5	5.2	8.7	75.8	6.8	0.31
45.	—	—	—	12.1	24.6	54.6	8.7	0.56
46.	1.6	—	6.4	3.7	20.9	51.8	15.6	0.50

Table 3. *Molluscan and holothurian resources of the Kakinada Bay* (t: *in tonnes* & Nos. : *in lakhs)*

Square No.	*Placenta placenta*		*Anadara granosa*		*Paphia textille*		*Tellina* sp		*Pinctada chemnitzi*		*Meretrix meretrix*		*Hemifusus pugilinus*		*Cerithidea fluviatilis*		*Acaudina molpadioides*	Others
	t	Nos.	t	Nos.	t	Nos.	t	Nos.	t	Nos.	t	Nos.	t	Nos.	t	Nos.	Nos.	t
1.	—	—	22.3	7.97	2.6	10.10	—	—	—	—	—	—	—	—	—	—	—	—
2.	21.2	8.00	35.7	20.6	18.4	21.72	3.0	16.07	—	—	—	—	—	—	5.9	4.6	4.57	2.1
3.			—	—	20.6	80.95	4.4	19.21	—	—	—	—	—	—	—	362.2	160.52	15.0
4.	—	—	—	—	—	—	—	—	—	—	—	—	56.4	8.29	—	—	—	—
5.	—	—	129.5	47.38	12.4	42.30	—	—	—	—	—	—	14.3	5.92	—	—	—	11.3
6.	—	—	—	—	23.0	117.76	—	—	—	—	—	—	—	—	—	—	—	4.0
7.	—	—	137.5	53.51	17.8	89.18	2.7	24.70	—	—	—	—	20.6	2.74	—	42.5	39.79	—
8.	—	—	—	—	—	—	3.8	44.59	—	—	—	—	8.6	1.71	—	25.7	10.30	—
9.	—	—	—	—	—	—	—	—	105.4	27.44	—	—	5.5	2.20	—	—	—	—
9a.	—	—	—	—	5.1	19.76	—	—	—	—	—	—	—	—	—	—	—	—
10.	300.1	83.35	118.4	42.51	—	—	—	—	—	—	—	—	4.2	1.67	—	—	—	1.7
11.	452.9	139.94	186.6	82.32	1.4	9.60	—	—	—	—	—	—	6.9	2.74	—	—	—	5.5
12.	111.7	28.58	20.0	10.29	144.7	176.07	—	—	—	—	—	—	22.0	2.29	—	—	—	5.8
13.	—	—	—	—	49.7	178.35	—	—	—	—	—	—	17.2	3.43	—	—	—	—
14.	—	—	—	—	25.0	13.2	—	—	—	—	—	—	22.6	3.43	—	—	—	—
15.	—	—	7.1	2.86	4.7	18.58	1.1	22.87	—	—	—	—	—	—	—	2.9	2.86	—
16.	347.1	85.06	137.2	150.92	1.4	10.98	—	—	—	—	—	—	—	—	—	308.7	31.55	—
17.	381.4	94.66	561.8	271.65	20.9	174.24	—	—	—	—	—	—	13.7	4.12	—	238.7	15.09	—
18.	835.8	217.23	296.3	107.47	—	—	—	—	—	—	—	—	6.9	1.14	21.7	24.1	20.58	11.7
19.	—	—	402.0	145.43	27.6	97.41	—	—	—	—	—	—	—	—	—	—	—	—
20.	—	—	—	—	21.3	83.69	1.5	6.86	—	—	—	—	—	—	—	4.8	4.12	3.3
21.	—	—	7.2	5.14	64.3	260.67	—	—	—	—	—	—	—	—	—	—	—	14.1
22.	—	—	—	—	—	—	—	—	196.2	32.83	124.8	52.53	1.3	1.64	—	—	—	—
23.	115.9	38.41	381.4	163.26	—	—	2.1	12.35	—	—	—	—	—	—	46.0	—	—	2.1
24.	219.3	48.02	772.4	305.95	2.1	5.49	14.5	185.21	—	—	—	—	14.4	2.74	54.9	105.6	10.98	—
25.	236.0	48.02	541.9	262.04	2.7	5.49	23.3	96.03	—	—	—	—	—	—	—	82.3	8.23	—
26.	702.4	193.45	164.6	57.62	7.4	38.41	—	—	—	—	—	—	12.3	1.37	—	24.7	15.09	—
27.	1,483.4	349.80	—·	—	18.0	65.16	—	—	—	—	—	—	17.2	3.43	—	1.7	1.71	—
28.	94.3	29.15	50.4	30.87	39.3	133.37	6.0	44.59	—	—	—	—	—	—	—	—	—	1.7
29.	—	—	26.0	8.67	11.1	57.80	—	—	5.8	1.44	281.8	59.24	7.5	2.89	—	—	—	—
30.	12.6	4.03	373.1	186.56	—	—	5.0	61.51	—	—	—	—	—	—	83.7	—	—	5.0
31.	531.6	158.92	716.8	302.97	26.6	42.30	13.6	75.46	—	—	—	—	—	—	8.0	2.3	2.29	2.1
32.	1,004.3	197.56	496.0	235.98	—	—	—	—	—	—	—	—	—	—	—	119.4	13.72	2.9
33.	2,503.8	515.86	75.5	45.27	3.7	13.72	—	—	—	—	—	—	—	—	—	233.2	28.81	9.6
34.	1,443.3	318.29	41.0	19.21	—	—	—	—	6.9	1.37	—	—	11.0	2.74	—	8.2	5.49	—
35.	71.3	20.60	13.0	13.72	63.78	71.34	—	—	—	—	—	—	4.1	1.37	—	30.9	8.23	5.5
36.	168.8	24.75	14.1	12.38	8.7	52.88	—	—	—	—	355.5	69.75	6.8	2.25	—	38.3	48.37	12.7
37.	143.2	29.58	538.4	150.29	—	—	3.2	14.20	—	—	—	—	—	—	13.0	—	—	3.6
38.	192.8	86.43	278.5	113.87	—	—	—	—	—	—	—	—	—	—	42.5	—	—	7.5
39.	212.7	61.74	163.9	107.01	—	—	0.3	4.12	—	—	—	—	—	—	—	43.2	15.09	2.3
40.	305.3	85.06	31.0	12.35	5.4	15.09	14.0	135.82	—	—	—	—	—	—	—	315.6	12.35	9.5
41.	78.9	9.60	6.9	5.49	2.1	38.41	6.7	71.3	—	—	—	—	—	—	—	157.8	32.93	71.6
42.	1.2	17.75	1.8	1.18	3.9	13.02	4.6	40.23	—	—	319.5	66.27	2.4	1.18	—	16.6	44.97	14.2
43.	105.8	14.87	15.2	7.87	1.0	3.50	2.1	26.24	—	—	—	—	—	—	11.4	—	—	24.8
44.	112.2	25.66	39.3	16.04	—	—	—	—	—	—	—	—	1.6	1.60	—	—	—	26.5
45.	54.6	7.80	23.2	17.54	4.1	19.50	2.0	40.22	—	—	—	—	2.9	0.97	1.7	21.4	3.90	10.9
46.	174.8	49.49	69.3	44.23	3.9	24.22	1.3	16.85	—	—	—	—	—	—	—	51.6	31.59	2.1
Total	12,418.7	2991.66	6895.3	3,068.4	664.7	2,004.66	115.2	948.43	314.3	63.08	1081.6	247.79	280.4	61.86	288.8	2,270.0	573.13	289.1

Placenta placenta (Linnaeus): This species (Pl. 3) ranked first with an estimated 12,420 t (approximately 300 million). Good beds of the windowpane oyster were observed in squares 33, 27, 34, 32, 18, and 26 in their order of abundance (Fig. 12). The highest density of 15.04/m² or 730g/m² was obtained in square 33 while at square 26 the density was 5.64/m² or 206 g/m². These 5 squares covering an area of about 17.1 km² sustained a population of 7,973 t or 64.2% of the total. In squares 31, 11, 17, 16, 40, 10 and 38 the oysters were less abundent; the density varied from 4.60/m² (155/gm²) to 2.48/m² (56 g/m²). These squares comprise an area of 22.7 km² and account for 2,511.2 t or 20.2% of the population. In other areas the windowpane oyster was either absent or it occurred in small numbers (< 2/m²). The spat was scarce. Young oysters measuring 17–42 mm were collected in squares 8, 16, 24 and 30. The overall length frequency (Fig. 13a) showed that the oyster measured 17 to 151 mm with dominant length groups in the range 87 to 118 mm.

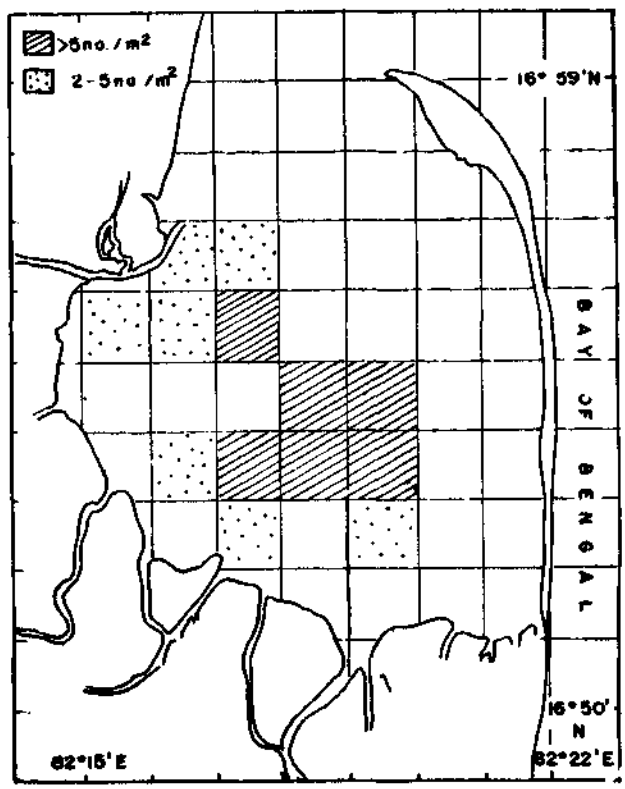


Fig. 12. *P. placenta* distribution in the bay.

Anadara granosa (Linnaeus): This species ranked second with 6,895 t and in numbers 307 million (Pl. 4). It was abundant along the western side of the bay (Fig. 14) in squares 24, 31, 17, 25, 37, 32 and 30 in their order of abundance. These 7 squares covering 22.6 km2 area accounted for 4,000 t or 58.0% of the blood-clam population. Their density varied from 9/m² (225 g/m²) in squares 24 to 5/m² (186 g/m2) in square 37. Considerable quantities of the clam were available in squares 19, 23, 18, 38, 11, 39 and 16 which covered an area of 24.0 km². These squares supported a population of 1,846 t which formed 26.8% of the total clam population. The density in these squares varied from 4.76/m² (111 g/m²) in square 23 to 2.40 /m² (54 g/m²) in square 11. In other squares either there were no clams or their population was below 2/m². Their length varied from 15 mm to 63 mm (Fig. 13d) with dominant size groups at 25–45 mm.

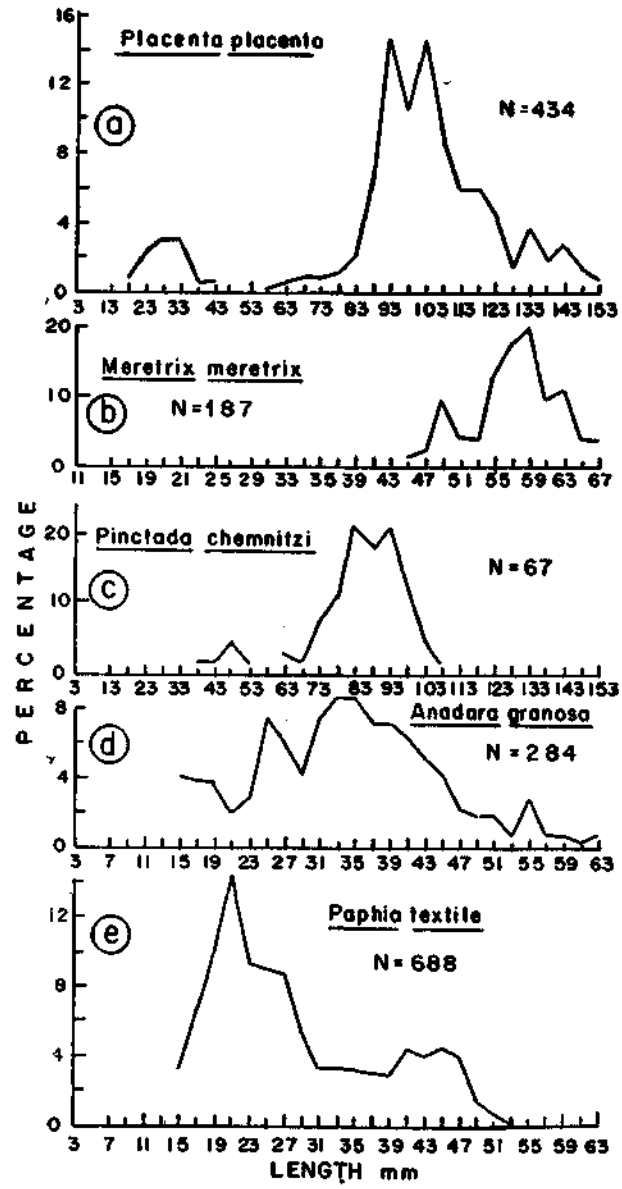


Fig. 13. Length frequency distribution of some bivalves collected by the dredge in the bay.

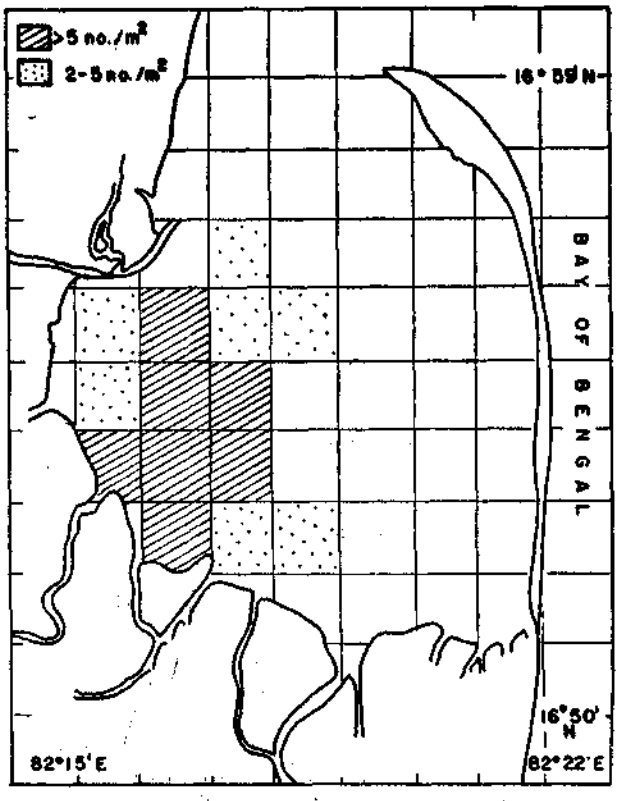


Fig. 14. A. *granosa* distribution in the bay.

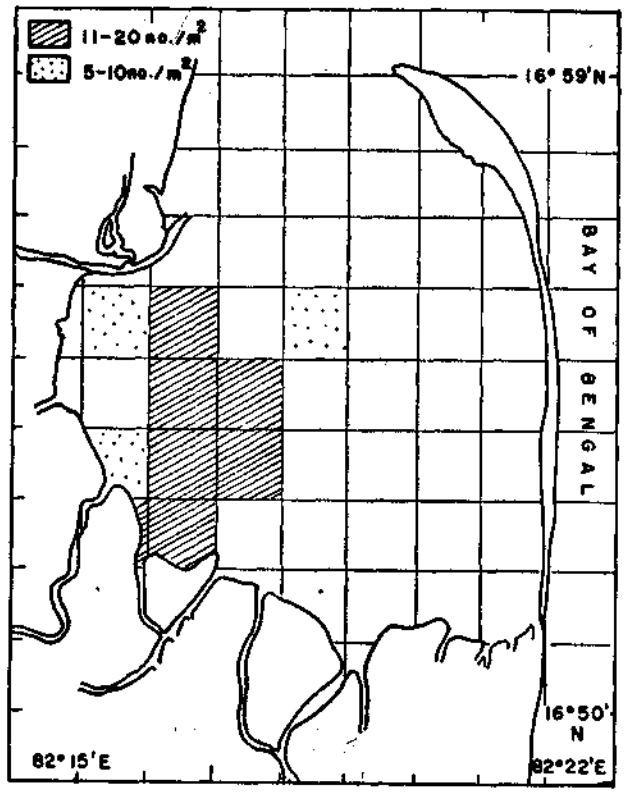


Fig. 15. A. *granosa* seed availability in the bay.

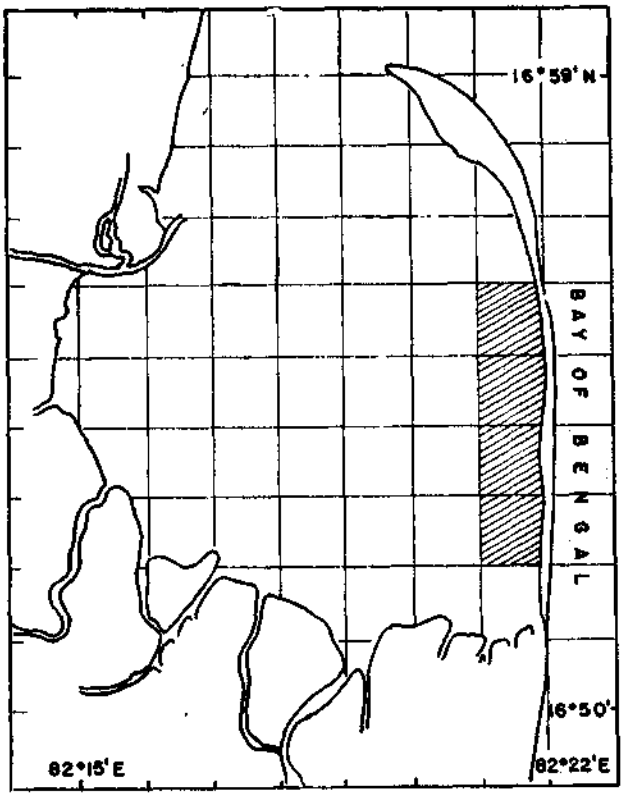


Fig.. 16. *M. meretrix* distribution in the bay Stripes indicate the squares where this species is available.

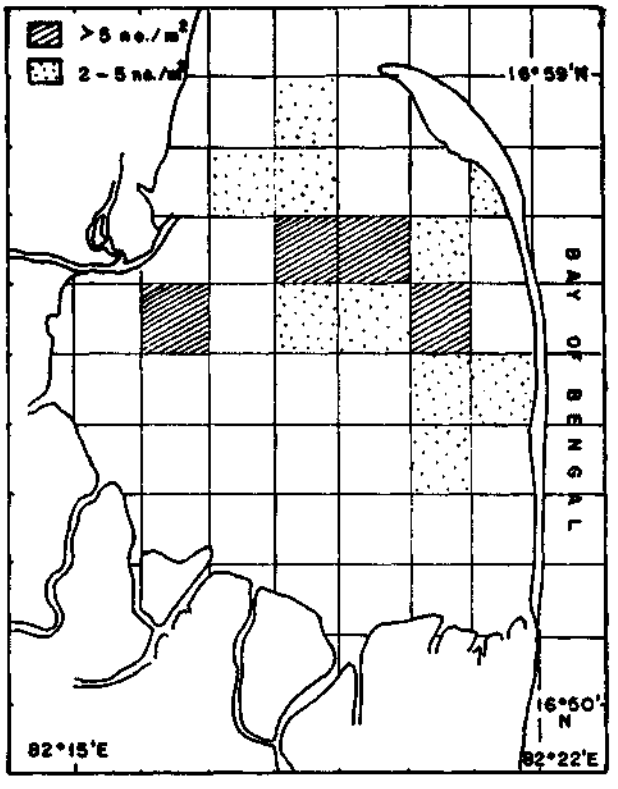


Fig. 17. *P. textile* distribution in the bay.

Seed resources of A. *granosa*: All the clams collected by the clam seed sampler were included here. Their length varied from 4 to 59 mm. However, vast majority of them (71%) were < 25 mm which is the size used in experimental culture (Narasimham, 1980). The distribution of the seed is limited to the western side of the Bay (Fig. 15) and is within the area where the adult population occurs. The density was high in squares 31, 24, 17, 37, 253 2and 16. It varied from 19/m² in square 31 to 11/m² in square 16. The Van Veen grab genrally gave a lower density of the blood-clams and this is probably due to the fact that very small area was sampled by the grab.

Meretrix meretrix (Linnaeus): This species (Pl. 5) ranked third among the molluscs and occurred at 4 squares *viz.* 36, 42, 29 and 22 along the eastern side of the bay (Fig. 16). The population was estimated at 1,082 t. The density was low and varied from 3/m² (126 g/m²) in square 36 to 2 /m² (43 g/m²) in square 22. The size ranged from 45 to 67 mm with 55–63 mm group dominating (Fig. 13b).

Paphia textile (Gmelin): This species (Pl. 6) was distributed in major part of the northern section of the Bay. The population was estimated at 665 t (200 million) and it was abundant in squares 21, 13, 12 and 17 (Fig. 17). These squares covered an area of 13.7 km² and accounted for 42.0% of the population. Their density varied from 8 /m² in squares 21 to 5/m² in square 17. In squares 28, 14, 6, 19, 7, 20, 9a, 3, 35 and 29 the density was low and varied from 2/m² (in square 29) to 4/m² (in square 28). These 10 squares covered an area of 31.2 km² and accounted for 38.3% of the population. Their length varied from 14 to 52 mm and 17–29 mm clams were dominant (Fig. 13e).

Seed resources of P. textile: The clams collected by the seed sampler varied in length from 3 to 48 mm and majority of them (66.2%) were < 20 mm in length. The seed occurred in the northern and eastern parts of the bay. Very high densities of 80/m² in square 12, 39/m² in square 35 and 31/m² in square 42 were obtained (Fig. 18). In squares 3, 11, 8, 1, 36 and 28 moderate densities which varied from 16/m² (square 3) to 11/m² (square 28) were recorded. Seed occurrence was low in squares 21, 17, 34, 33, 2, 6, 5, 13, 26, 27, 9, 41,14, 15 and 22 which varied from 10/m² (square 21) to 5/m² (square 22). Generally seed was available in much larger area when compared to the distribution of adult population.

Pinctada chemnitzii (Philippi): The population was estimated at 314 t (6.3 million) and was limited in distribution to squares 22, 9, 34 and 29. They were found attached among them and to dead windowpane oyster shells (Pl. 7), in groups of 3 to 16 forming a lump. Within the square their distribution was patchy. They measured 37 to 106 mm (antero-posterior axis) and 73–98 mm oysters were dominant (Fig. 13 c).

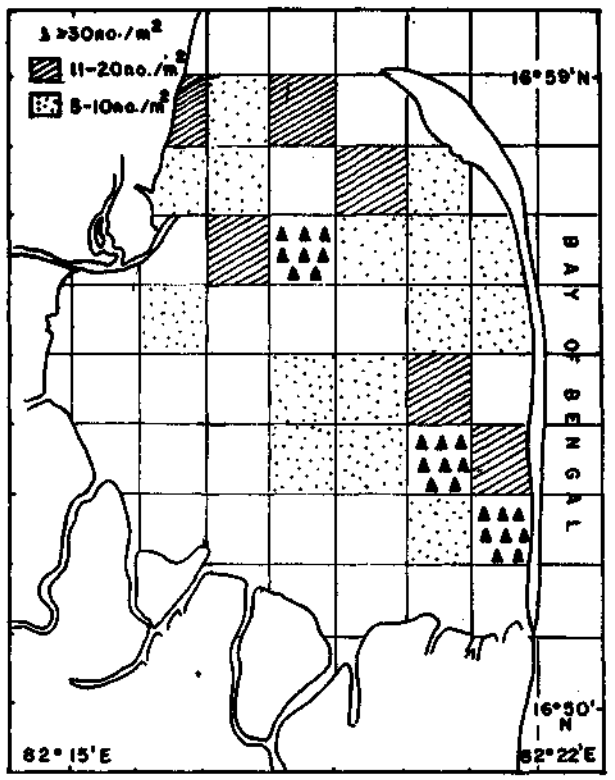
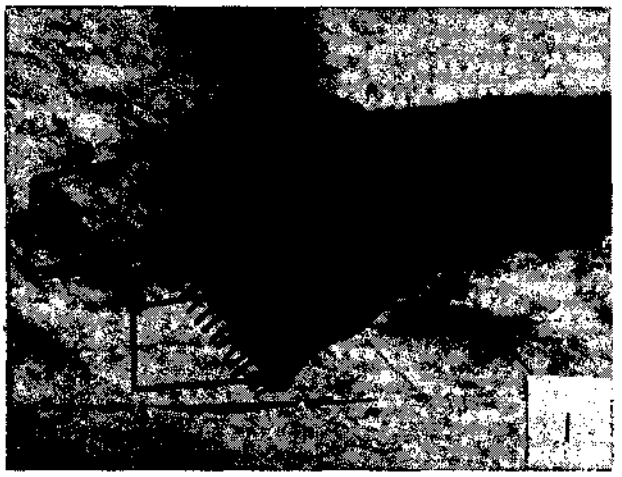


Fig. 18. *P. textile* seed availability in the bay.

Tellina spp: The resource was meagre at 115 t and was available in squares 25, 24 and 31. The size varied from 14 to 28 mm and because of the brittle shell and small size, the species does not have a fishery potential.

Hemifusus pugilinus (Born): This gastropod resource was small at 280 t and was mainly encountered in squares 4, 14, 13 and 7. It measured (apex to lower opercle edge) 28 to 98 mm in length. The opercle of this species finds use in the Unani system of medicine and is priced at 30 paise a piece locally while the shell is used in lime preparation.

Crithidea fluviatilis (Potiez and Michaud): An estimated 289 t was available in the bay. Their distribution was mainly confined to squares 30, 24, 23 and 18. This species measured (apex to lower opercle edge) 17 to 24 mm in length.



Pl. 1. The 0.5 m dredge

Other species: Fairly rich beds of *Modiolus* sp. were present in squares 10, 23, 38, 41 and 44. Polychaetes were abundant in squares 13, 14, 21, 25 and 32 and they often clogged the dredge. Large concentration of *Umbonium gestiarium* (Linnaeus) was encountered is square 9a. Mostly they passed through the dredge (Length 4–12 mm) but were collected by the seed sampler. Other species caught in stray numbers were *Katelysia opima* (Gmelin), *Donax* spp, *Telescopium* (Linnaeus) and *Paphia malabarica* (Chemnitz).

Pl. 2. The 0.5 m clam seed sampler

Holothurian resources

Acaudina molpadioides (Semper): The resource was estimated at 2,270 t and was abundant in squares 3, 40, 16, 17 and 33. It measured 20-160 mm.

Shell resources

The shells of molluscs remaining on the bed or superficially covered (upto 10 cm depth) by the sediment after death are dealt here under shell resources as distinct from subfossil shell deposits which may extend upto a few meters depth. The total shell resources were estimated at 21,097 t (Table 4).

Placenta placenta: The shells of this oyster were estimated at 8,200 t and they occurred in all the squares except 3, 4, 13 and 15. The shell was available in considerable quantities in squares 27, 31, 29, 16, 36, 18 and 34. The distribution is similar to the live population except for its presence in squares 29 and 36.

Anadara granosa: An estimated 1,817 t of shell was present. Major areas of abundance were squares 16, 24, 18, 32 and 25 which agrees with the distribution of live clams.

Other shells: Excepting the shells of the window-pane oyster and the blood-clam, the shells of other species dealt under the live resources were estimated at 1,1062 t. They were abundant in squares 4, 6, 13, 35, 12, 18, 11, 7, and 5. Their concentration in the northern section of the bay, which is generally poor in live populations, except for *P. textile,* suggests that the shells are probably carried by the currents.

Molluscan resources of the Kakinada canal

This irrigation cum navigation canal, originating from the Godavari river, opens into the bay at Kakinada. The banks are made by concrete structures and estuarine conditions prevails upstream upto 5 km length of the canal from the mouth. The concrete banks extend into the bay and harbour rocky fauna both on the inner canal side and outer bay side. The extent of its concrete banks and the estimated oyster population are given in Table 5.

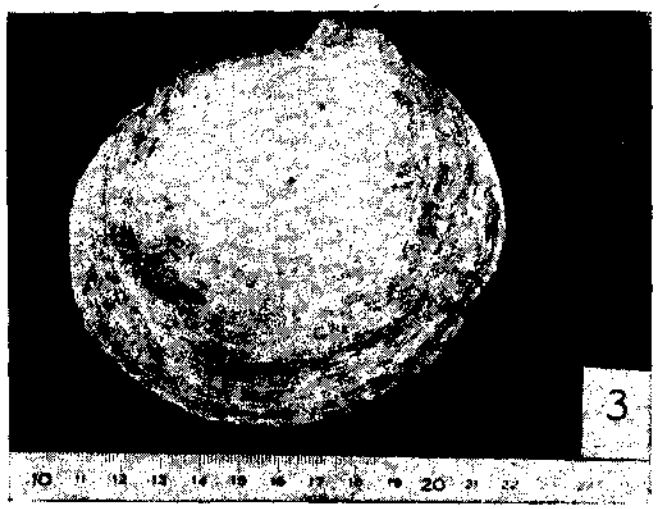
Oyster resources: The average width of the banks inhabited by the oysters is 3 m and except the bay side of the left bank the oyster bed extended upto a distance of 2.3 km upstream. However, the density of the oysters was high close to the mouth of the canal. The total spread of the oyster bed is 2.25 ha and the estimated weight of the population is 90 t (11.7 million) which gave a density of about 40 t/ha. At many sampling stations there was a thick mat of oysters and a maximum of 1,882/m^2 were counted. The rock oyster *Saccostrea cucullata* (Born) formed a negligible proportion (nil to 5.5%) while *Crassostrea madrasensis*

Table 4. *Abundance of shells in the Kakinada Bay (in tonnes)*

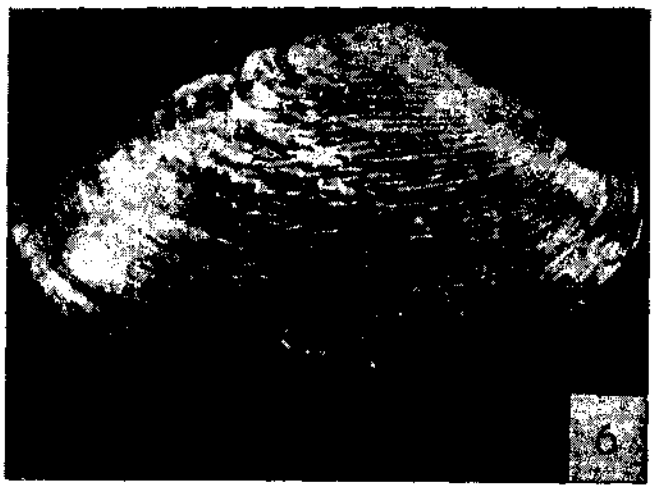
Square No	*Placenta placenta*	*Anadara granosa*	Others	Square No.	*Placenta placenta*	*Anadara granosa*	Others
1.	12.2	18.6	156.4	24	178.4	356.7	157.8
2.	20.0	11.4	24.0	25	205.8	117.3	260.7
3.	—	—	10.3	26	196.5	17.2	94.7
4.	—	—	1,431.9	27	737.4	8.5	47.2
5.	30.5	34.7	405.3	28	214.4	11.1	61.2
6.	15.4	15.4	903.2	29	578.0	3.6	218.6
7.	102.9	—	419.1	30	26.5	14.1	222.9
8.	20.6	—	119.2	31	679.1	33.2	14.9
9.	286.5	—	107.6	32	149.5	134.3	159.8
9a.	26.3	—	16.1	33	133.1	12.5	144.1
10.	205.0	38.8	231.3	34	347.8	—	331.3
11.	219.5	27.4	592.0	35	46.6	—	702.4
12.	354.4	8.0	662.7	36	436.5	6.0	186.2
13.	—	—	788.9	37	26.0	—	156.2
14.	21.4	—	320.7	38	98.9	19.3	34.3
15.	—	—	13.0	39	105.0	37.0	71.3
16.	493.9	473.3	75.5	40	226.4	3.8	51.8
17.	37.0	34.3	150.9	41	188.1	35.0	128.6
18.	380.7	174.9	646.5	42	75.7	35.5	127.8
19.	225.3	38.4	119.1	43	95.1	3.0	6.0
20.	221.6	1.4	35.7	44	166.8	20.8	77.0
21.	169.8	6.3	262.4	45	21.2	8.1	11.7
22.	262.6	—	26.4	46	121.7	5.8	34.7
23.	57.6	51.4	242.8				
Total:					8,217.7	18,17.1	1,10,62.2

Table 5. *Edible oyster resources of the Kakinada canal*

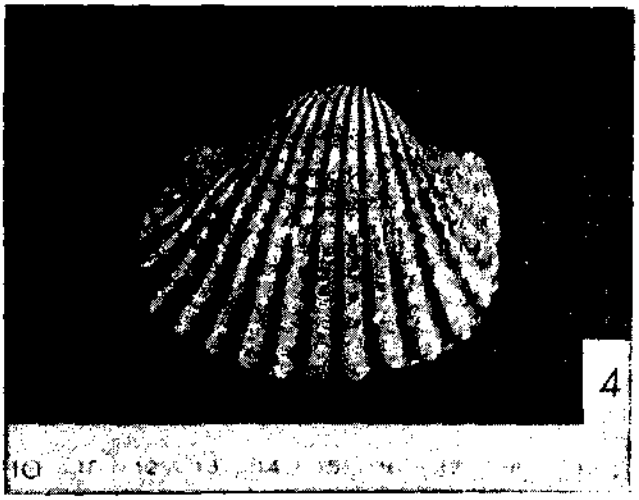
Sl. No.	Extent of bed	Range in nos/m² (Average)	Range in weight kg/m² (Average)	Estimated number for the bed	Estimated wt. kg for the bed	Species composition by numbers
1.	Left bank, bay side 1,800 m²	818–1,860 (1,510)	2.90–7.40 (5.82)	27,18,000	10,476	*S. cucullata* 3.9% *C. madrasensis* 96.1%
2.	Left Bank, canal side 6,900 m²	100–1882 (858)	1.20–7.50 (3.63)	59,20,200	25,047	*S. cucullata* 5.5% *C. madrasensis* 94.5%
3.	Right bank, canal side 6,900 m²	154–228 (200)	3.14–4.80 (4.18)	13,80,000	28,842	*S. cucullata* 0.8% *C. madrasensis* 99.2%
4.	Right bank, bay side 6,900 m²	112–384	2.6–4.4	16,56,000	25,530	*C. madrasensis* 100%
Total:	2.25 ha	—	—	1,16,74,200	89,895	



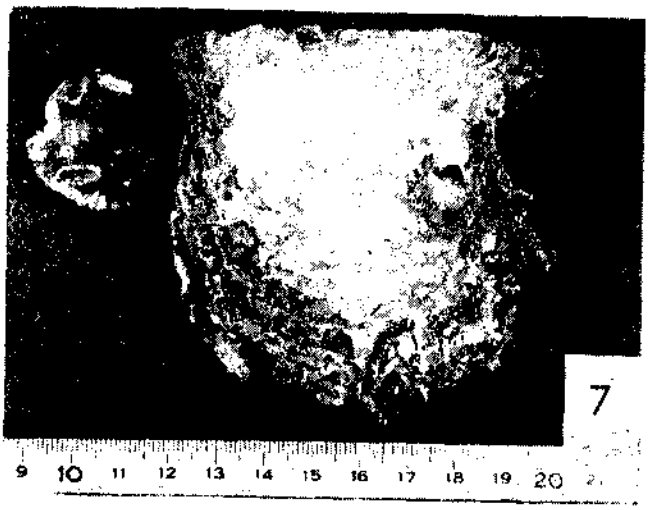
Pl. 3. *Placenta placenta*



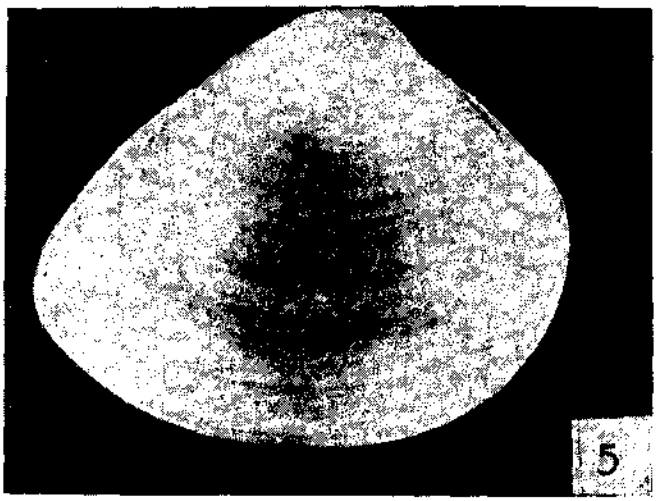
Pl. 6. *Paphia textile* (48 mm)



Pl. 4. *Anadara granosa*



Pl. 7. *Pinctada chemnitzi*



Pl. 5. *Meritrix meretrix* (66 mm)

Pl. 8. Oysters in the market.

(Preston) was dominant (94.5 to 100%). It varied in length (dorso-ventral axis) from 7 mm to 142 mm and majority measured below 30 mm in length.

Perna viridis (Linnaeus): This species occurred in patches along with the oysters closer to the low water mark. The total area inhabited by the mussel is 0.75 ha. Density varied from nil to 12/m2 with an average of 1/m². A total of 586 kg of mussles (7,650) were estimated to be present. They varied in length from 68 to 137 mm.

Discussion

The studies by Rao (1967) indicate that more than 60% sand occurs opposite the Gaderu confluence, a small patch south of the Kakinada canal and along the western side of Hope Island. The present observations agree with the above but show that the northern section of the bay is also predominantly sandy. Sediment analysis of the natural beds of *A. granosa* in Malaysia (Pathansali, 1964) showed, barring one exception, that more than 95% of the particles were less than 0.124 mm; particles < 0.031 mm constituted 63 to 87%. The results obtained by him on culture beds were comparable to the natural beds but the particles < 0.031 mm were generally much less (25–79%). In the present study *A. granosa* and *P. placenta* were generally abundant in areas where more than 50% of the sediment particles were < 0.125 mm. It is well known that the pediveliger larvae of bivalves delay metamorphosis until the conditions are suitable for settlement (Wilson, 1958). The availability of substratum with finer particles which is rich in organic carbon seems to be an important factor limiting the distribution of these two species. On the other hand *P. textile* and *M. meretrix* occurred in considerable numbers in areas where the particle size of the sediment was coarse (>0.125 mm).

Rao (1967) observed that the organic carbon in the sediments was the highest (> 1%) in the tidal flats along the western side of the bay and lowest (< 0.4%) in the sands of the Gaderu confluence. He noted that the organic carbon was high in sediments of finer particle size than in coarser sediments. The results obtained in the present study are generally in agreement with the observations of Rao (1967).

Radhakrishna and Ganapati (1967) observed that *A. granosa* and *P. placenta* were restricted in distribution along the western and southern side of the Bay. The present study indicates considerably wider area and also overlapping in the distribution of these two species than what their figure 2 indicated.

Narasimham (1973) estimated the annual landings of *A. granosa* at 1,000 t and *P. placenta* at 4,000 t out of a total catch of 6,000 t of molluscs from the Bay. Recently Silas *et al.* (1982) gave the annual production of *A. granosa* in the bay as 2000 t. The present estimate of 6900 t of blood-clam in the Bay suggests that the resource is extremely limited. Since the blood-clam is a sedentary organism it becomes easily vulunerable to over fishing when the demand for its meat increases due to an export potential. Further its distribution is limited to shallower region, not exceeding 2.2 m depth. Techniques for the culture of *A. granosa* in the Bay were developed (Narasimham, 1980) which gave very encouraging results with regard to growth, survival and production. However, the seed resources in the Bay are not abundant (density below 20/m²) and cannot be depended upon for large scale clam culture. The only alternative is to go in for hatchery production of seed. Realising this the Central Marine Fisheries Research Institute is working on a project at Kakinada for the controlled production of the seed of *A. granosa.*

Murthy *et al.* (1979) estimated the live population of *P. placenta* in the Bay at about 9,000 t and dead oyster shell at about 43,000t. The present study indicated the live windowpane oyster resource at about 12,500 t and the gap between the present catch and the potential is narrow.

In the case of *M. meretrix* also the gap between the present catch of 400 t and the estimated resource at 1,080 t is narrow. *P. textile* is not exploited at present as it is distributed in the northern section of the Bay, in slightly deeper waters and is beyond the reach of the fishermen who collect the molluscs in the Bay at low tides by hand picking without any diving aids. It needs to be investigated whether the holothurian *A. molpadioides* has any economic importance.

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