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OYSTER CULTURE—STATUS AND PROSPECTS

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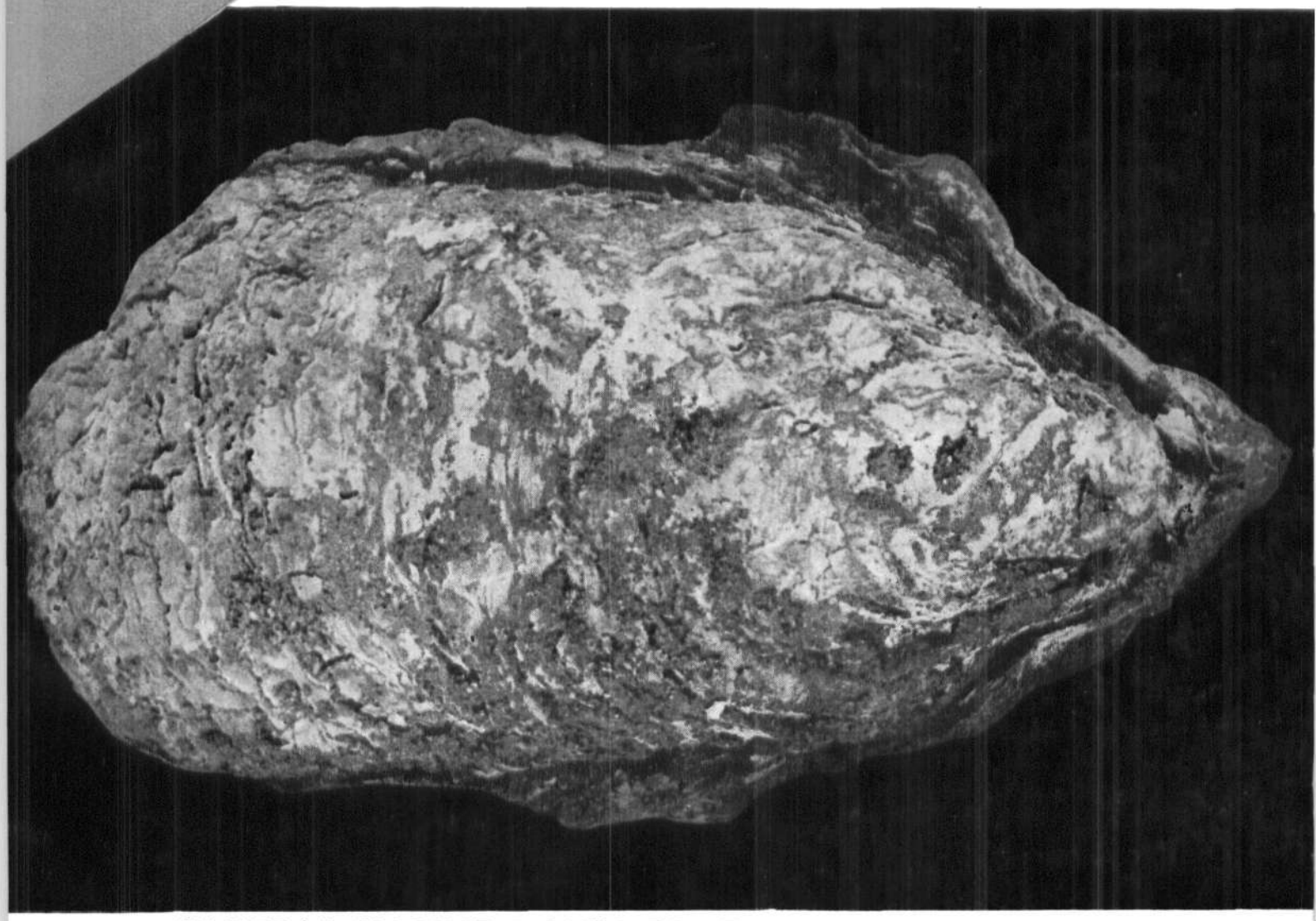

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OYSTER RESOURCES OF ATHANKARAI ESTUARY, SOUTHEAST COAST OF INDIA

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INTRODUCTION

The oyster *Crassostrea madrasensis* is distributed at several places along the east and southwest coasts of India (Rao 1969, Alagarswami and Narasimham 1973) and has good economic potential but so far resources survey of the shellfish populations has not been carried out in any area. Estimates of the standing stocks are essential for planning exploitation of the oyster resources. A precise knowledge of the natural stocks and the ecological conditions in which they abound is especially necessary to plan and conduct oyster culture which is essential for large scale exploitation. Beds of oysters belonging to the species *Crassostrea madrasensis* are present in Athankarai Estuary at Athankarai near Mandapam Camp on the southeast coast of India. The highly nutritious shellfish resources are not exploited by people of the area for food. Only occasionally oyster shells are collected and burnt in small kilns and converted into lime. The oyster resources of the estuary have been surveyed. The general features of the Athankarai estuary, hydrological conditions, ecologically associated fauna and flora, distribution and magnitude of standing stocks of oysters, and seasonal changes in meat of oysters have been studied and the results are presented here.

MATERIAL AND METHODS

The occurrence of oyster beds in the estuary was throughly searched by preliminary inspection and diving in the estuary. The oysters occur in patches or larger-sized formations. The shape of each patch was determined by noting its length and breadth at intervals of 1 metre (Pl. I A-C), plotting the measurements on a graph sheet and the shape and area were found out. For determining the density of oysters, all the oysters present throughout the height of the patch in $\frac{1}{4}$ metre square area were counted and the number of oysters per sq. m. was taken as the density of the oysters. Counts of oysters were made in two to four $\frac{1}{4}$ metre square quadrats and the averages of the same were taken as the density in the patch or formation. From the density, the total number of oysters present in each patch or formation was calculated. The total weight of oysters (shell on) present in $\frac{1}{4}$ metre square area was determined and from the average weight of oysters in 2 to 4 half metre square quadrats in each patch, the oyster biomass in the total area of each patch was calculated. The total meat weight of oysters in the various patches was also similarly estimated. Data on the size, weight, meat weight and stages of maturity of oysters as also epiflora and epifauna were recorded. Oyster shell and concrete piece spat collectors were kept suspended from horizontal bamboo poles supported on casurina poles in the different parts of the estuary viz., near the mouth, middle and upper portions of the estuary to determine the intensity of spatfall. Data were also collected on the temperature, salinity and dissolved oxygen content of water over oyster beds in the estuary. The resources survey was conducted between July and September, 1975.

A random sample of ten oysters of *Crassostrea madrasensis* was collected every month from Athankarai Estuary from August to July, cleaned and weighed. The oysters were shucked with a chisel and weight of meat of the oysters determined. The weight of meat of an oyster expressed as a percentage of total weight of the oyster is the percentage edibility. Then the stage of maturity of the oysters was determined by microscopic examination of the gonads. Oysters in various stages of maturity viz., immature, maturing, mature, partly spawned, spent, hermaphrodite, indeterminate and recovering were recorded in all the periods of the year. The entire soft parts of each oyster were uniformly pressed between two pieces of Whatman No. 42 filter paper and adhering mantle fluid removed. The meat of the oysters was weighed to constant weight in a hot air oven at 100°C. Oven drying method was adopted instead of drying over sulphuric acid using suction pump as the material retained some moisture even after prolonged drying in the latter method. The total solids content was determined calculating

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the dry weight of meat of each oyster as percentage of the wet weight of the oyster. The water content was similarly calculated from the difference between the wet and dry weights of meat of each oyster. The dried oyster meats were homogenized and the lipid content was estimated by extracting 100 mg of homogenized meat in a soxhlet apparatus with ethyl either and drying the ether extract.

from Mandapam Camp. The Athankarai Estuary meanders into this region from west running parallel and close to the National Highway 49 and curves to a northern course when about 1.82 km from the imbochure (Fig. 1). The width of the estuarine system ranges from 130 m (upper reaches) to 356 m very near to the estuary mouth. The estuary gets cut off from the sea in the period from April to June due to the forma-

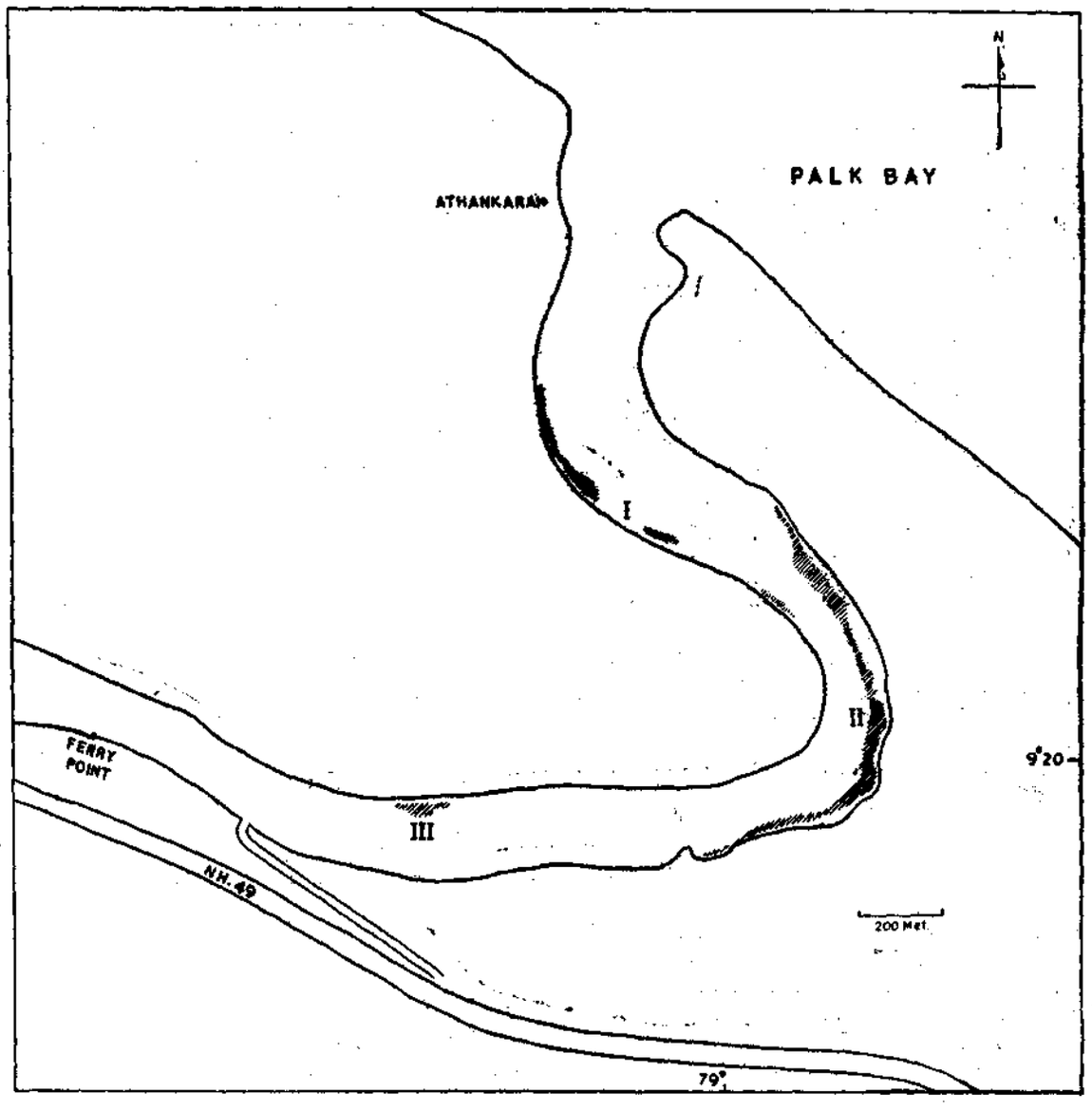

Fig. 1. Map showing location of the I, II and III oyster beds in Athankarai Estuary.

General Features of Athankarai Estuary

River Vaigai confluences with the sea on the Palk Bay side (Durve and Alagarswami, 1964) on the eastern side of Athankarai village which is situated at Lat. 9°.20′ N and Long. 79° E and is at a distance of 25 km

tion of sand bar which opens when the river receives freshets on account of southwest monsoon rains. In some years the sand bar is formed early in January itself. The estuary is shallow with a maximum depth of 3 m in the middle while near the banks it varies from 1 to 2 m. Due to the estuary becoming inundated

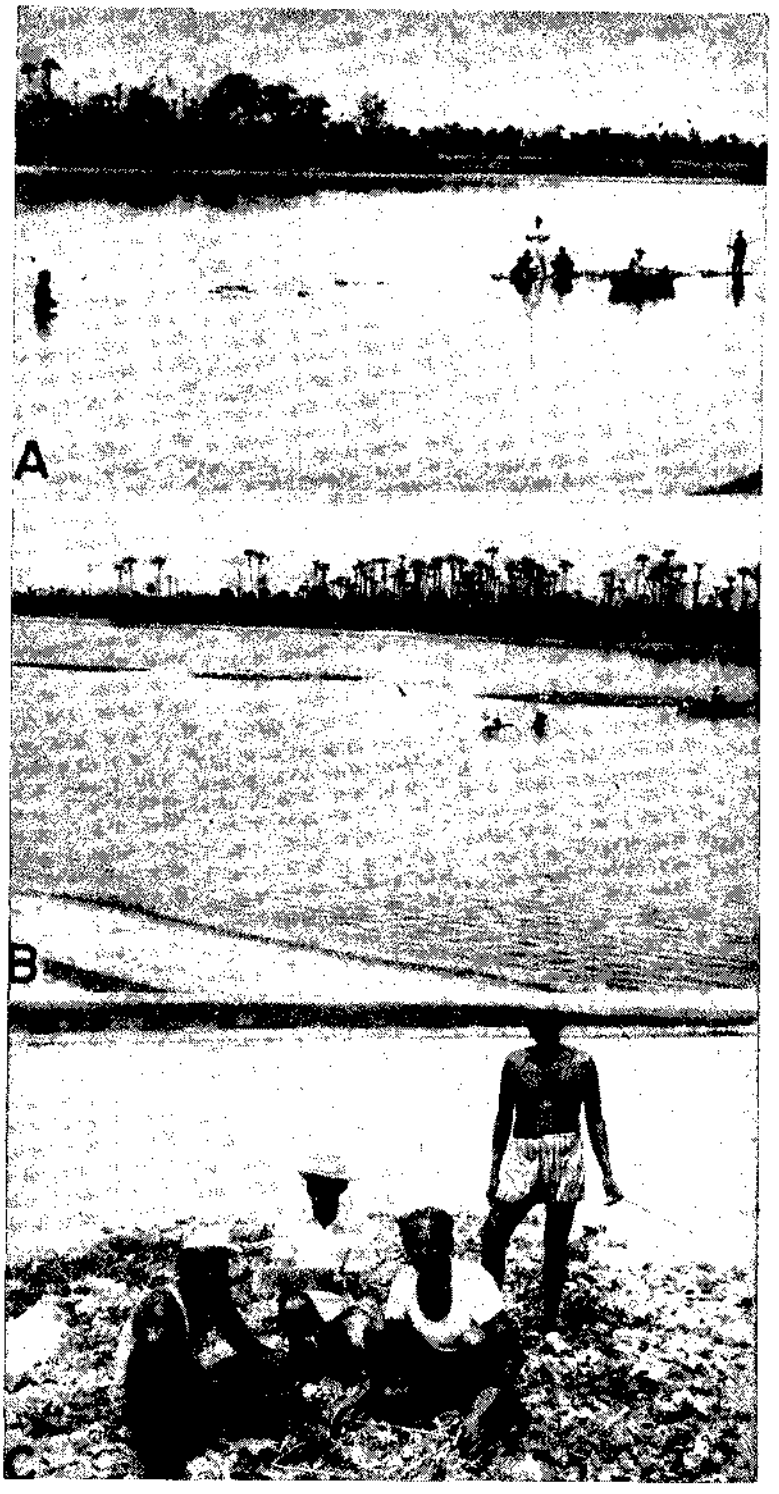

PLATE I. A and B. Recording of measurements of oysters beds in Athankarai estuary. C. Counting of oysters from an oyster patch exposed at low tide, in a $\frac{1}{4}$ metre square quadrat.

during the northeast monsoon period October-December, the depth near the banks increases to 3 m and that at the middle to 4 m.

The bottom of the estuary is throughout muddy with an admixture of sand and a large amount of organic detritus. The mud is grey in colour. The seagrasses *Cymodocea serrulata, C. isoetifolia* and *Halophila ovalis* are found growing in the estuary especially near the banks. A variety of fishes such as *Himantura alcockii, Amphotistius imbricatus, Thrissocles mystax, Tachysurus thalassinus, T. caelatus, Mugil cephalus, M. parsia, Apogon aureus, Therapon spp., Leiognathus jonesi, Gerres filamentosus, Scatophagus argus* and *Tripterygion fasciatum* and three prawns *Penaeus indicus, Penaeus semisulcatus* and *Metapenaeus burkenroadi* are found in the estuary. The clam *Meretrix casta* and the prosobranch gastropod *Cerithidea fluviatilis* also occur, the former forming beds in the middle and upper parts of the estuary. The salinity of the estuary shows a steep fall to 17.83‰ in some months but *Crassostrea madrasensis* which thrives well in brackish waters survives in the low salinity conditions.

Hydrology of the Estuary

Recorded data on the temperature, salinity and dissolved oxygen content of Athankarai estuarine water over the three oyster beds in the period July, 1975 to September, 1976 are given in Table 1. It may be seen from the Table that water temperature of the estuary varied from a minimum of 27.5°C recorded in December, 1975 to a maximum of 34.5°C observed in August, 1975. In the period December, 1975 to February, 1976 coinciding with the monsoon and winter periods the temperatures were low, being 27.5°C to 29.2°C and in the other months the temperature was higher. The water temperature at stations I and II did not show distinct difference but those at Station III were slightly lower than at station I except in September, October and December, 1975 and January, February, August and September, 1976. Salinity varied from 17.83‰ (April, 1976) to 71.21‰ (September, 1976). Except in July, 1975 and January, February, July and August 1976, in all other months the salinity values were slightly higher at Station III than at Station I. The salinity values at Station II were same or slightly different from those at Station I. The estuary was not connected with the sea from the last week of January, 1976. The highest salinities 48.43—53.12‰ recorded in August, 1976 and 62.43—71.21‰ in September, 1976 were due to excessive evaporation of estuary water. The dissolved oxygen concentration showed a range of 0.86 ml/l in July, 1976 to 8.74 ml/l in March, 1976. High content of dissolved oxygen 4.89—8.74 ml/l was noted in all the three stations in February—March 1976. Clearly marked differences in the dissolved oxygen concentrations between the three stations of the estuary were, however, not discernible.

Table 1. *Water temperature, salinity and dissolved oxygen in the period July, 1975 to September, 1976 at three stations where the three oyster beds are situated in Athankarai Estuary.*

	Temperature° C Stations			Salinity (‰) Stations			Dissolved oxygen (ml/l) Stations		
	I	II	III	I	II	III	I	II	III
July, 1975	32.5	31.0	30.0	21.35	20.10	19.36	4.74	4.35	4.06
August	34.5	34.5	34.2	33.23	33.00	32.52	3.77	4.34	6.47
September	33.0	33.2	33.2	34.26	35.10	36.24	3.46	4.06	5.32
October	30.7	31.0	30.7	32.40	33.45	33.58	5.16	5.18	5.36
November	30.0	29.7	29.5	30.88	31.17	31.11	2.27	3.76	4.12
December	27.5	27.7	27.7	25.95	24.74	25.25	4.60	4.18	4.77
January, 1976	28.5	28.5	28.7	23.43	22.28	23.27	4.52	4.55	4.79
February	29.2	29.2	29.2	24.38	23.56	24.01	5.94	4.89	7.09
March	31.5	31.0	31.0	27.81	27.81	29.80	8.74	8.58	6.72
April	31.5	31.0	31.0	17.83	17.96	18.30	4.86	5.42	6.02
May	32.7	30.4	30.7	24.29	24.28	25.98	4.54	4.49	3.87
June	32.9	32.0	32.0	30.29	30.29	35.84	3.71	4.31	3.33
July	28.9	28.7	26.5	37.18	37.18	34.20	4.04	4.67	0.86
August	28.7	29.5	29.7	62.99	62.43	71.21	2.44	2.44	2.68
September	27.8	28.2	28.5	62.99	62.43	71.21	2.44	2.44	2.54

Distribution of Oyster Beds in the Estuary

The survey revealed that oysters belonging to a single species, *Crassostrea madrasensis* (Preston) along with stray individuals of *Saccostrea cucullata* occur in the estuary. There are three oysters beds in the estuary, each bed consisting of a number of patches and larger formations with clusters of oysters forming large irregular structures (Fig. 1). The first oyster bed is found along the western bank of the estuary commencing at a distance of 0.72 km from the mouth of the estuary and extending for a distance of 0.93 km. The second oyster bed is present along the eastern bank in the upper portion of the estuary. The first formation of this bed is located 1.03 km from the mouth of estuary and the bed extends over a distance of 1.28 km. The third bed is present still further up in the upper portionof the estuary near the northern bank 2.94 km from the mouth of the estuary and it extends over a limited distance of 120 m. There are no oyster beds near or west of the Ferry Point which is 3.75 km. from the mouth of the estuary.

A. I Oyster Bed

The oyster bed consists of 41 patches and formations which are close to the western bank of the estuary at a distance of 1.5 m to 3 m from it (Fig. 1). The patches and formations are in a row, one behind the other, most of them at intervals of less than a metre or 1 to 37 metres from one another. Patch 29 and formation 34 are 134 m and 124 m respectively from the previous patches. They are low in the case of beds 1 and 2 and others are raised to a height of 0.2 m to 1.4 m from the bottom of the estuary. Most of the oyster patches of this bed are small sized with an area of 0.25 sq. m. Formations 5, 6, 30, 31 and 34 are larger, their area varying between 117 sq. m. and 176.5 sq. m. The estimated total area of all the 41 patches and formations of the bed is 1,366.84 sq.m (Table 2). The shape of patches 1 to 4, 16, 22, 32, 35, 37, 39 and 41 is approximately round or cordate while others are irregular. In this bed the density of oysters varied in different patches. In patches 1 to 4, 8, 12, 14, 27 and 28, the density of oysters is only 56 to 96 per sq. m. High density of 300-520 oysters per sq.m. was observed in patches 19, 29, 32 and 35 and formations 30, 31, and 34. In the other twenty four patches the oyster densities ranged from 105 to 288 per sq.m. The number of oysters per patch varied from 14 in patch 1 to 62, 930 in formation 31. The estimated total number of oysters present in the bed is 3, 44, 116. The estimated total or absolute biomass of oysters per patch ranged from 2.09 kg in patch 1 to 9, 691.22 kg. in formation 31 with an average of 1,183.09 per patch and the estimated over all total biomass of oysters in the bed was 48,506.89 kg. (Table 2). The estimated total meat weight of oyster per patch in the bed varied from 0.13 kg. in patch 1 to 358.70 kg in formation 31 with an average of 48.43 kg. for the patch and the estimated total meat weight of oysters in the bed was 1,985.79 kg.

Biological aspects of oysters

In this bed the oysters ranged from 31 mm in size with average size of 100 mm (for 629 oysters). 83% of the oysters were in the size range 61-140 mm (Fig. 2)

Table 2. *The estimated area of the three oyster beds in Athankarai Estuary and the estimated number of oysters, biomass of oysters and meat weight of oysters in the three beds*

Serial number of oyster beds	Estimated area of the oyster beds (sq. m)	Estimated number of oysters in the beds	Estimted biomass of oysters in the beds (kg)	Estimated meat weight of oysters in the beds (kg)
I Bed	1,366.84	3,44,166	48,506.89	1,985.79
II Bed	13,692.85	30,50,533	3,25,164.92	11,111.72
III Bed	562.22	77,923	15,249.48	576.59

Oysters below 50 mm in size formed only 3.7%. The weight of the oysters ranged from 29 gm to 232 gm with an average of 112.6 gm and meat weight from 1 gm to 15.6 gm with an average value of 4.7 m. Oysters setting on oyster shell cultch and 8-24 on concrete piece cultch in the period October to March. On the other hand only stray spat set on cultch kept suspended near the mouth of the estuary.

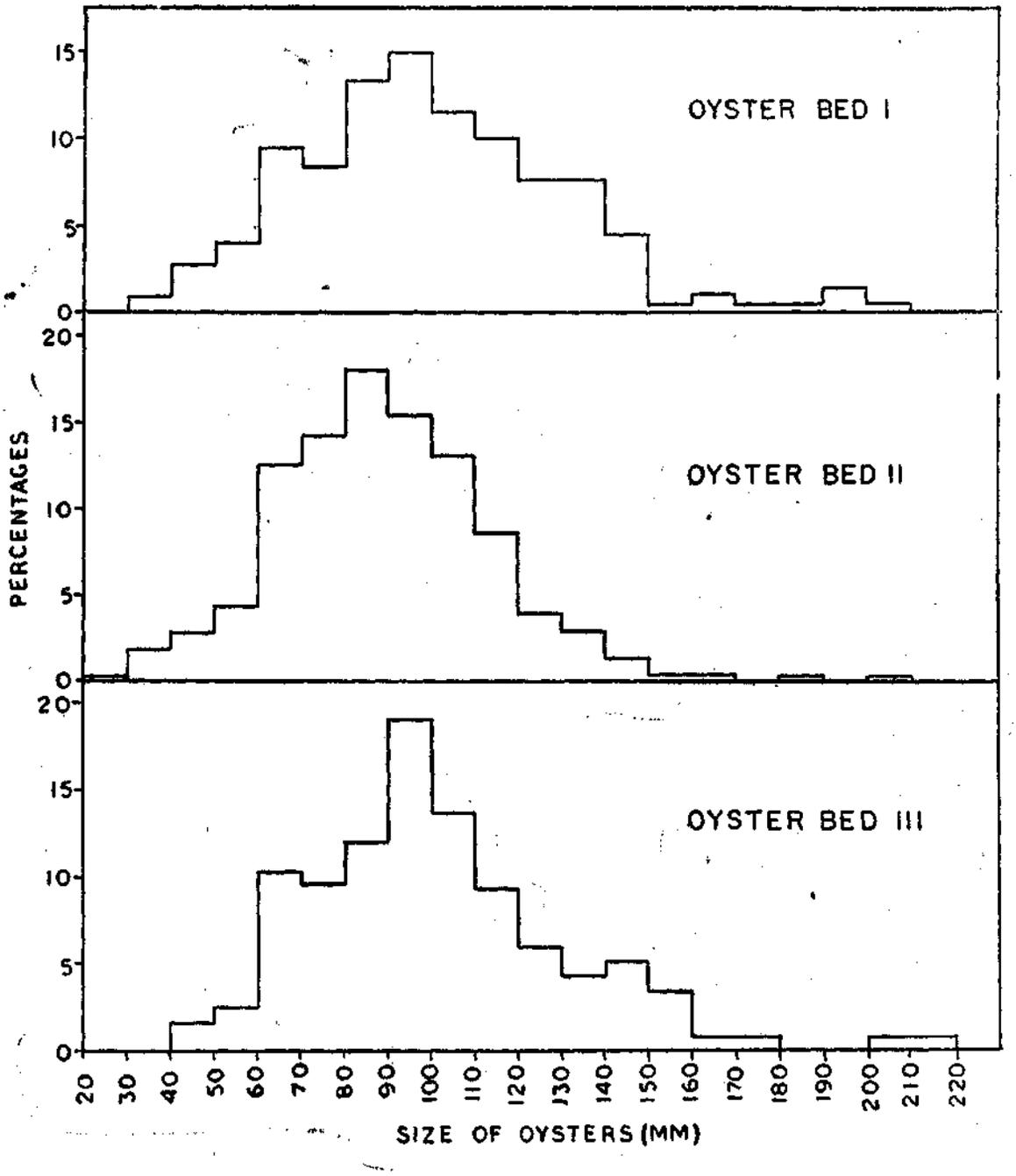

Fig. 2. Percentage frequency of oysters in I, II and III oyster beds in Athankarai Estuary.

of both sexes were in immature, maturing or sexually ripe stage. The meat of the ripe oysters was thicker than that of immature and maturing ones. There was good spatfall in this area with about 6 to 12 oyster spat

Ecological Conditions

The algae *Enteromorpha* sp. and *Polysiphonia* sp. were common and formed a felt-like covering on the outer surface of valves of oysters but they did not cause any

significant damage to the oyster valves as they were strong and unaffected. Blue-green algae also occured on the valves of oysters in density. The weaving mussel *Modiolus undulata* and the barnacle *Balanus amphitrite communis* were present in small numbers as epifauna. The boring polychaete *Polydora ciliata* was noticed in some oysters. Only a few individuals of the oyster drill (*Thais rudolphi*) were recorded on the oyster bed. Hermit crabs (*Pagurus* sp.) were recorded in small numbers and these were predators of oyster spat and oysterlings. Stray individuals of the crabs *Carpilodes margaritatus*, *Xanthe* (*Leptodius*) *euglyptus* and *Scylla serrata* were seen on the oyster bed. There was heavy settlement of barnacles on the poles and cultch used for studying spatfall.

B. II Oyster Bed

51 oyster patches and formations constitute this bed. These are located 4-11 m from eastern bank as in the case of formations 1, 3, 15, 22, 35 to 37, 45 and 48 and patches 2, 38, 39 to 44, 46 and 47 are 20-45 m from the eastern bank as in the case of formations like 6, 12, 20, 21, 23, 31, 32 and 35. The oyster patches of this bed had a height of 0.2 m to 1.75 m from the bottom, the patches farthest away from the bank having a height of 1 to 1.75 m from the bottom. In this bed thirty patches *viz.*, 2, 9, 10, 13, 14, 16 to 19, 21, 24, 26 to 29, 31, 33, 34, 38 to 44, 46, 47 and 49 to 51 were small, measuring 3.25 sq. m. to 85.37 sq. m. in area. Eighteen formations 1, 3, 4, 5, 7, 11, 12, 15, 20, 22, 25, 30, 32, 35 to 37, 45 and 48 were larger with an area ranging from 113.12 sq. m. to 621.62 sq. m. Oyster formations 6, 8 and 23 were very extensive with areas of 2,207.37 sq. m. 2,705.62 sq. m and 2,208.37 sq. m. respectively. The estimated total area of the bed is 13,692.85 sq. m. (Table 1). The smallest patches were round, oval or cordate while medium size ones were mostly irregular. Formations 6, 8 and 23 were very long and broad with length ranging between 188.5 m 231.5 m and width ranging between 24 m and 29.5 m.

In this bed the density of oysters varied from 124 to 608 per sq. m. In some areas 1 to 5, oysters in high densities of 340 to 480 per sq. m. were recorded. In the remaining localities, the density of oysters ranged from 108 to 272 per sq. m. The estimated total number of oysters present per formation in the bed varied from 598 in patch 44 to 5,43,829 in formation 8 which is also the largest formation in the estuary. The estimated total number of oysters present in this bed is 30,50,533. The estimated total biomass of oysters per formation in this bed ranged from 78.45 kg in patch 44 to 58,026 kg in formation 8 with an average of 6,375.78 kg for a formation and the estimated over all total biomass of oysters in this bed was 3,25,164.92 kg. (Table 2). The estimated total meat weight of oysters varied from 3.22 kg to 1,731.13 kg with an average meat weight of 217.87 kg and the estimated overall meat weight of oysters in the bed was 11,111.72 kg.

Biological aspects of oysters

The oysters in this bed showed a size range of 24 mm to 206 mm with an average of 99 mm for 835 oysters. 88.3% of oysters were in the size range of 61-140 mm. Oysters below 50 mm in size formed 4.9% which is higher, compared to that in the previous bed. The weight of oysters varied from 22 gm to 320 gm with an average weight of 106.5 gm and the meat weight of oysters from 1 gm to 8 gm with an average of 4.1 gm. In addition to male and female oysters, hermaphrodite oysters showing sex reversal were observed. Immature, maturing, ripe, partly spawned and spent stages were recorded. The meat of the maturing oysters was moderately thick, that of ripe ones was thick and cream coloured and that of partially spawned and spent ones thin and watery. Good oyster spatfall was observed with 3 to 4 spat setting on oyster shell cultch and 16 to 21 spat on concrete cultch.

Ecological Conditions

Enteromorpha sp., *Polysiphonia* sp. and Myxophyceae were found as epifauna of oysters. In addition *Padina* sp. was also found in some places. Barnacles (*B. a. communis*) occurred in small numbers. *Modiolus undulata* were very common on the oysters. Only a few oyster drills *Thais rudolphi* were found on the oyster beds. The polychaetes *Marphysa gravelyi*, *Eunice* sp. and *Polynoe* sp. were found in the crevices between oysters. The boring polychaete *Polydora ciliata* was seen in some cases causing damage to valves of oysters. Sponges (*Hyatella cribriformis*), amphipods and alpheids were common as epifauna. *Modiolus undulata* and barnacles settled in large numbers on cultch and poles employed in collecting oyster spat in the neighbourhood of this bed also.

C. III Oyster Bed

This is a small bed with a limited number of eleven patches and formations located further up in the estuary along its northern bank 2.94 km from the mouth of estuary, at a distance of 19 m to 36 m from the bank Patches 1 to 9 of this bed were at a distance of 19 m from the left bank while formations reached a height of 0.4 m to 0.6 m. The area of the oyster formations varied from 6.25 sq. m. (patch 8) to 201 sq. m. (formation 10). The estimated total area of the bed was 562.22 sq. m (Table 2).

The density of oysters varied from 96 per sq. m. in formation 10 to 238 per sq. m. in patch 1. The average density of oysters and standard deviations of the same in the three beds in the estuary were found to be 198±113 in bed I, 215±90 in bed II and 158±35 in bed III. These figures indicate that there are no well defined differences in the average density of oysters in the three beds. The number of oysters per patch varied from 775 in patch 8 to 19,296 in formation 10 with an average of 7,083 oysters. It has been estimated that a total of 77,923 oysters were present in this bed (Table 1). The estimated total biomass of oysters ranged from 151.66 kg in patch 8 to 3,775.22 kg in formation 10 with an average of 1,386.31 kg for formation and the estimated total biomass of oysters in the entire bed was 15,249.48 kg. The total meat weight of oysters per patch varied from 5.73 kg in patch 8 to 142.79 kg in formation 10 with an average of 52.41 kg and the estimated total meat weight of oysters in the bed was 576.59 kg.

Biological aspects

Oysters were of the size range from 49 mm to 212 mm with an average of 103 mm for 294 oysters. 84.1% of the oysters were in the size range of 61-140 mm. Oysters below 50 mm formed only 1.7%. The weight of oysters varied between 22.5 gm and 501.5 gm. The shells of most of the oysters in these beds were massive and hence the increased weight of the oysters. The averge weight of the oysters was found to be 195.7 gm. The meat of the oysters showed a range of 2.0 gm to 12.3 gm with an average value of 7.3 gm. Males and females as well as hermaphrodite oysters were recorded. All maturity stages *viz.*, immature, maturing, ripe, partially spawned and spent ones in indeterminate phase were recorded. As in the earlier two beds, the meat of ripe oysters was cream coloured and thick and those of partially spawned and spent ones thin and watery. There was setting of only stray numbers of spat on cultch kept near this oyster bed.

Ecological conditions

There was not much difference in the epifauna and epiflora communities from those of beds I and II except that *Modiolus undulata* were found were found in comparatively smaller numbers in bed III.

Seasonal Variations in Meat of Oysters

Meat Weight

The meat weight of male oysters varied from 4.5862 gm to 17.7010 gm and that of female oysters from 5.9536 gm to 19.2248 gm (Table 3). The meat weight of oysters exhibited fluctuations in the different months (Table 4). Well-defined differences in the meat weight were not seen in relation to sex and stages of maturity. The average meat weight showed a slight decrease from 9.1469 gm in August to 8.1961 gm in September, and an increase to 11.3333 gm in November, after which it fell again. The average meat weight increased later in May to 13.3434 gm. The minimum meat weight and maximum meat weight were observed in October and November, 1975, respectively.

Percentage edibility

Like meat weight the percentage edibility also exhibited large fluctuations in all months of the year. It varied from 2.07 to 6.16 in males and from 2.10 to 7.04 in females. The percentages edibility of male and female oysters in different maturity stages showed similar ranges. The average percentage edibility increased from 3.23 in August to 4.66 in November, and decreased to 3.50 in December. After a four months period of more or less same values, it rose gradually during March-April. The average percentage edibility was 4.63 in May and decreased to 4.39 and 4.16 in May and June. The lowest value of 0.85 was seen in August and the highest of 7.04 in November.

Water

Water is the major constituent of oyster meat forming 66.48% to 89.64% wet wt. In males the content ranged from 67.59% to 89.15% wet weight and in females from 67.5% wet wt to 89.64 % wet wt. In hermaphrodite oysters it varied from 75.22% to 88.22% wet wt. The mean values of water content of oysters of the two sexes in various maturity stages did not show significant differences. The average water content decreased from 79.17% in August to 77.59% in October, increased to 83.26% in November and showed a gradual fall in succeeding months attaining 69.96% in July.

Total solids

The total solids content ranged from a minimum of 10.36% to 33.52% wet wt. Males showed variation from 10.85% to 33.52% wet wt. and females showed a similar range of 10.36% to 32.46% wet wt. In hermaphrodite oysters total solids also did not show significant difference in relation to sex and stages of maturity. The average total solids content showed an inverse relation to water content (Fig. 3). It increased from 20.83% wet wt in August to 22.43% wet wt. in September, declined to 16.73% in November and thereafter it slowly increased in succeeding months with values of 19.81% wet wt. in January, 22.65% in March and 30.03% in July.

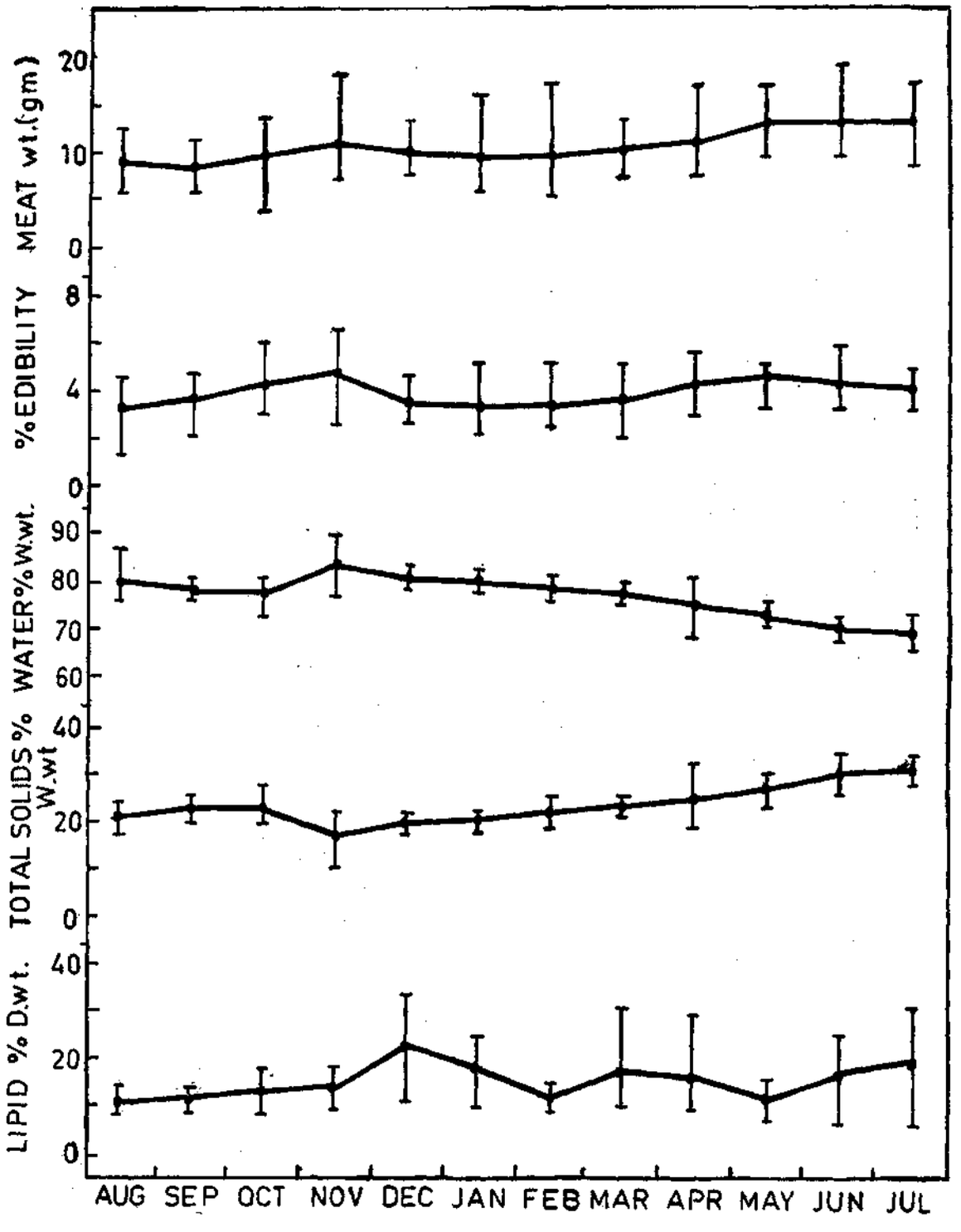

Fig. 3. Seasonal variations in meat weight, percentage edibility and water, total solids and lipid contents of *Crassostrea madrasensis* of Athankarai Estuary.

TABLE 3. *Meat weight, percentage edibility, total solids and lipid content of* Crassostrea madrasensis *of Athankarai Estuary in different maturity stages (Mean values with S.D. and ranges)*

	Meat weight (gm)	Percentage edibility	Water (% wet weight)	Totalfisolids (% wet weight)	Lipid (% dry weight)
1. Immature males ..	13.7920 ± 4.7297 (7.1370 — 17.7010)	40.40 ± 1.24 (2.65 — 5.33)	74.41 ± 3.89 (69.02 — 78.07)	25.58 ± 3.89 (21.93 — 30.98)	12.6 ± 2.7 (9.6 — 16.2)
2. Maturing males ..	12.2217 ± 2.8611 (6.8073 — 16.6650)	4.25 ± 0.72 (3.17 — 5.19)	75.67 ± 2.86 (79.25 — 78.85)	24.32 ± 2.86 (21.15 — 29.75)	13.1 ± 3.4 (9.0 — 19. 4)
3. Mature males ..	9.5747 ± 2.9836 (4.5862 — 17.3812)	3.84 ± 0.97 (2.07 — 6.09)	77.58 ± 2.37 (72.57 — 82.01)	22.41 ± 2.37 (17.99 — 27.43)	13.84 ± 6.18 (8.0 — 32.2)
4. Partly spawned males	9.0164 ± 3.1543 (6.5280 — 15.1434)	3.69 ± 1.29 (2.35 — 6.16)	80.88 ± 4.22 (77.86 — 89.15)	19.11 ± 4.22 (10.85 — 22.14)	11.4 ± 1.2 (11.0 — 13.4)
5. Spent males ..	12.0856 ± 2.2894 (9.6930 — 15.0728)	4.79 ± 1.03 (3.53 — 6.06)	75.97 ± 5.78 (67.59 — 82.13)	24.03 ± 5.78 (17.87 — 32.41)	20.6 ± 5.9 (10.4 — 28.8)
6. Recovering males ..	14.2317 ± 3.7955 (12.1834 — 16.9396)	4.83 ± 0.86 (3.49 — 5.69)	72.06 ± 3.19 (66.48 — 76.99)	27.93 ± 3.19 (23.01 — 33.52)	14.1 ± 3.4 (10.2 — 20.0)
7. Immature females ..	8.3675 ± 1.2849 (6.6042 — 10.1624)	3.06 ± 0.38 (2.44 — 3.52)	78.10 ± 0.28 (77.62 — 78.38)	21.89 ± 0.28 (21.62 — 22.38)	11.1 ± 1.4 (9.2 — 13.0)
8. Maturing females ..	8.8468 ± 1.7277 (7.0780 — 11.6386)	3.30 ± 0.74 (2.10 — 4.61)	75.95 ± 2.41 (71.73 — 78.72)	24.04 ± 2.41 (21.28 — 28.27)	14.1 ± 7.0 10.0 — 26.2)
9. Mature females ..	9.6268 ± 2.6208 (5.9536 — 14.1332)	3.68 ± 0.59 (2.30 — 4.63)	77.12 ± 2.51 (71.77 — 80.46)	22.87 ± 2.51 (19.54 — 28.23)	13.2 ± 6.3 (5.6 — 33.0)
10. Partly spawned females ..	12.9772 ± 3.7699 (7.2136 — 19.2248)	4.51 ± 1.34 (3.09 — 7.04)	79.94 ± 7.28 (67.54 — 89.64)	20.06 ± 7.28 (10.36 — 32.46)	18.0 ± 4.5 (9.4 — 32.0)
11. Spent females ..	8.2478 ± 1.8441 (6.1784 — 10.9808)	3.05 ± 0.51 (2.47 — 3.78)	77.27 ± 3.96 (71.12 — 81.45)	22.72 ± 3.96 (18.55 — 28.88)	12.3 ± 3.5 (6.2 — 23.6)
12. Recovering females ..	11.5214 ± 2.4306 (8.4414 — 15.3546)	4.03 ± 0.63 (3.28 — 4.76)	74.68 ± 3.15 (70.40 — 79.69)	25.32 ± 3.15 (20.31 — 29.60)	15.4 ± 8.1 (8.2 — 31.0)
13. Indeterminate oysters ..	11.2975 ± 3.0252 (5.8376 — 19.7056)(	3.79 ± 0.95 0.85 — 5.32)	76.46 ± 5.14 (68.62 — 86.24)	23.53 ± 5.14 (13.76 — 31.38)	15.1 ± 7.0 (6.4 — 30.8)
14. Hermaphrodite oysters (male to female sex) ..	4.0152	5.67	77.85	22.15	13.0
15. Hermaphrodite oysters (female to male sex) ..	9.0652 ± 2.6814 (5.9288 — 14.5380)	3.59 ± 1.33 (2.29 — 6.11)	82.03 ± 4.71 (75.22 — 88.22)	17.96 ± 4.71 (11.78 — 24.78)	12.6 ± 2.8 (10.0 — 18.6)

TABLE 4. *Seasonal changes in meat weight, percentage edibility, water, total solids and lipid content of* Crassostrea madrasensis of *Athankarai Estuary*
(Mean values with S. D. and ranges)

	Meat weight (gm)	Percentage edibility	Water (% wet weight)	Total solids (% wet weight)	Lipid (% dry weight)
August ..	9.1469 ± 1.9797 (5.8376 — 12.5326)	3.23 ± 1.02 (0.85 — 4.42)	79.17 ± 3.50 (76.60 — 86.24)	20.83 ± 3.50 (13.76 — 23.40)	10.2 ± 0.3 (8.0 — 12.4)
September ..	8.1961 ± 1.7936 (4.5862 — 11.3006)	3.61 ± 0.71 (2.07 — 4.73)	77.56 ± 1.50 (74.94 — 80.86)	22.43 ± 1.50 (19.14 — 25.06)	10.2 ± 0.4 (8.6 — 13.4)
October ..	9.4139 ± 2.7027 (4.0152 — 13.8000)	4.27 ± 0.90 (3.10 — 6.09)	77.59 ± 2.14 (72.57 — 80.46)	22.41 ± 2.14 (19.54 — 27.43)	12.3 ± 2.6 (8.0 — 17.4)
November ..	11.3333 ± 3.8803 (7.4966 — 19.2248)	4.66 ± 1.07 (2.70 ± 7.04)	83.26 ± 5.26 (76.74 — 89.64)	16.73 ± 5.26 (10.36 — 23.26)	13.0 ± 2.4 (10.0 ± 18.6)
December ..	9.8915 ± 2.4864 (7.2136 — 13.4362)	3.50 ± 0.51 (2.72 — 4.62)	80.17 ± 0.99 (78.99 — 82.01)	19.81 ± 0.98 (17.99 — 21.01)	22.1 ± 7.1 (11.0 — 33.0)
January ..	9.2399 ± 3.2755 (5.9536 — 15.7284)	3.32 ± 0.98 (2.18 — 5.36)	80.18 ± 1.40 (77.86 — 82.13)	19.81 ± 1.40 (17.87 — 22.14)	17.2 ± 5.9 (10.0 — 25.0)
February ..	9.2008 ± 3.1111 (5.9288 — 16.5382)	3.31 ± 0.83 (2.29 — 5.24)	78.23 ± 1.27 (76.15 — 80.41)	21.76 ± 1.27 (19.59 — 23.85)	10.9 ± 0.4 (9.2 — 13.0)
March ..	10.3985 ± 2.1350 (7.0780 — 13.4714)	3.72 ± 0.86 (2.10 — 5.19)	77.34 ± 1.20 (75.22 — 78.85)	22.65 ± 1.20 (21.15 — 24.78)	16.3 ± 7.1 (9.6 — 30.8)
April ..	10.8696 ± 3.1607 (7.7270 — 16.9396)	4.32 ± 0.86 (3.27 — 5.69)	75.64 ± 4.38 (67.59 — 81.38)	24.35 ± 4.38 (18.62 — 32.41)	15.1 ± 5.8 (9.4 — 28.8)
May ..	13.3434 ± 2.2751 (9.6182 — 17.3812)	4.63 ± 0.70 (2.93 — 5.54)	73.32 ± 1.38 (73.91 — 76.48)	26.67 ± 1.38 (23.52 — 28.09)	10.9 ± 2.7 (6.4 — 16.0)
June ..	13.6450 ± 2.9631 (10.5742 — 19.7056)	4.39 ± 0.91 (3.28 — 6.06)	70.27 ± 1.53 (68.62 — 73.63)	29.72 ± 1.53 (26.37 — 31.38)	16.2 ± 5.8 (6.2 — 26.2)
July ..	13.2118 ± 2.6235 (8.4414 — 17.7010)	4.16 ± 0.66 (3.28 — 5.33)	69.96 ± 1.74 (66.48 — 71.89)	30.06 ± 1.74 (28.11 — 33.52)	19.0 ± 7.7 (5.6 — 32.0)

Lipid

The lipid content showed a range of 5.6% to 33.6% dry weight. In males the lipid content varied from 8% to 32.2% and in female oysters from 5.6% to 33% dry wt (Table 3). The content of hermaphrodite oysters showed a lower range of 10% to 18.6% dry wt. As in the case of water and total solids, the lipid content of male and female oysters too did not show significant difference correlated with maturity stages and there is overlapping of the lipid content of oysters in different stages of maturity. While the lipid content of individual oysters showed wide fluctuations in various months (Fig. 4) the average lipid content increased from 10.2% in August to 13.0% in November and 22.1% in December. Thereafter, it decreased to 17.2% in January and 10.9% in February. It increased again to 16.3% in March, decreased to 10.9% in May and rose to 16.2% in June and 19.0% in July. Thus average lipid content showed a rise thrice in an annual period in December, March and June-July.

Discussion

The total area of the three oyster beds in the estuary is 15,621.91 sq. m or 1.56 hectares. Of this, the bed II alone has 13,692.85 sq. m. an area constituting 87.6% of the total oyster bed area. The area of the bed I is only 1366.84 sq. m. which is 8.7% of the total area while the III bed has an extent of 562.22 sq. m forming 3.7% in the total area. In the I bed the area of a single oyster patch ranges from a very small size of 0.25 sq. m. to 176.5 sq. m. The oyster patches and formations in III bed are slightly bigger with a range of 6.25 sq. m. to 201 sq. m. In the II bed thirty patches are 3.25 sq. m. to 85.37 sq. m. in area while eighteen formations 1, 3, 4, 5, 7, 11, 12, 15, 20, 22, 25, 30, 32, 35 to 37, 45 and 48 are larger with an area of 113.12 to 621.62 sq. m. Oyster formations 6, 8 and 23 are the largest beds in the estuary with areas ranging from 2,207.37 sq. m. to 2,705.62 sq. m.

The density of oysters in the three beds is highly variable with a range of 43 to 520 oysters per sq. m. The highest densities of 300 to 480 or 520 per sq. m. have been recorded in patches 19, 29 to 32 and 35 in I bed and in formations 1 to 5 in II bed.

There are a total of 34,72,572 oysters in Vaigai estuary at Athankarai including 3,44,116 oysters in I bed, 30,50,533 in II bed and 77,923 in III bed. The largest number of oysters are present in the II bed which also has the most extensive area of oyster beds. The richness of the density and abundance of oysters in the II bed is ascribed to the constant mixing when the estuary is connected with Palk Bay of fresh water coming from the upper portion of the estuary and sea water from seaward side during the course of tidal oscillations every day. The constant mixing of fresh and sea water appears to be very favourable for the growth and increase in population of *Crassostrea madrasensis* in the estuary. Rao and Nayar (1956) have pointed out that growth of *C. madrasensis* was better in Adyar estuary than in marine environment of Madras Harbour.

The estimated total biomass of oysters in Vaigai estuary is 3,88,921.29 kg and the estimated total meat weight of the oysters 13,674.10 kg. The estimated total biomass of oysters in bed II is largest being 3, 25, 164.92 kg and the total meat weight of oysters in the bed is 11,111.72 kg. In bed I the the estimated total oyster biomass is smaller, 48. 506. 89 kg and the total meat weight is 1,985.79 kg corresponding to the much smaller total area of bed. In bed III where the total area is only 562.22 sq. m. the total oyster biommass is 15,249.48 kg and the total meat weight 576.59 kg.

The size, total weight and meat weight of oysters in the I and II beds do not show marked differences. The total weight and meat weight of oysters in bed III are higher than in the other two. The average total weight and meat weight of oysters in bed III are 195.7 gm and 7.3 gm respectively compared to 112.6 gm and 4.7 gm in bed I and 106.5 gm and 4.1 gm in bed II.

Although seaweeds and epifauna and pests belonging to different groups such as sponges, whelks, weaving mussels, polychaetes, amphipods and barnacles are present on oysters, only *Modiolus undulata* and barnacles seem to be serious pests. *Modiolus undulata* are competitors for space as they settle in large numbers on the surface of live oysters and over empty oyster shells where oyster spat could set and grow as was noticed in bed II. The barnacle *Balanus amphitrite communis* also settles in large numbers on cultch in the lower and middle portions of the estuary. The danger posed by the boring polychaetes of *Polydora* sp. does not appear to be much as they are not common in the area.

The pea crab *Pinnotheres* sp. has been reported in *Ostrea* (=*Saccostrea*) *cucullata* by Awati and Rai (1931) and in *C. gryphoides* by Durve (1964) along Bombay coast but pea crabs have not been recorded in *C. madrasensis* in Athankarai estuary. Algae, sponges, hydroids, polychaetes and barnacles have also been recorded on the surface of valves of *C. cucullata* in marine environment by Awati and Rai (1931). Preda-

tory whelks and hermit crabs are not common in Athankarai estuary. In U.S.A. the oyster whelks *Urosalpinx cinerea, Eupleura caudata* and *Thais* spp. are destructive to the American oyster *Crassostrea virginica* (Galtsoff, 1964).

The investigation has brought to light considerable population of *Crassostrea madrasensis* in Athankarai estuary. Until now the valuable oyster resources are not being utilized properly by the people of the area. The oysters of the estuary are nutritious and as they occur in very large quantities in beds, the natural stocks should be exploited for consumption at least to some extent. Oyster shells could be burnt and converted into lime. The need for utilization of natural stocks is all the more great as otherwise there is heavy mortality of oysters in certain years due to steep increase in salinity following evaporation of water or prolonged flooding of estuary with freshwater due to heavy rains.

The existence of the large population including spawners and good spatfall which takes place in the estuary are favourable for culturing *C. madrasensis* in the estuary. The estuary is connected with the sea for a greater part of the year and phytoplankton is available for oyster larvae, spat and adults. Oyster spat could be collected in large numbers using oyster shell, concrete piece and tile cultch and growing oysters could be reared to marketable size in trays kept on racks. (Rao 1976, Rao, Sivalingam and Unnithan, 1983). Spatfall took place from January to April in Athankarai estuary and generally only small numbers of spat were seen to set on cultch in the other periods of the year. Studies on the growth of spat and oysterlings indicate that growth of oysters is rapid in the estuary and an average size of 87 mm. and maximum size of 110 mm are attained at the end of one year. Average and maximum sizes of 90 mm and 130 mm are attained at the end of 14 months and thereafter, there is retardation of growth. The fast rate of growth will be very advantageous for conducting oyster culture successfully in the estuary.

In some years there is large increase in salinity in the premonsoon months and in certain other years there is prolonged flooding of the estuary with freshwater in the north-east monsoon season causing large mortality of oysters. In October, 1977 following very heavy monsoon rains, the Vaigai Estuary at Athankarai was in spate and as a consequence of continuous flow of freshwater there was a large scale mortality of oysters in the natural beds in the estuary. However, there was re-colonization of oysters and revival of oyster beds in 1979. Large-scale mortality of oysters due to environmental factors has been mentioned by Yonge (1960) and Galtsoff (1964) in *Ostrea edulis* and *Crassostrea virginica* in which freezing temperatures in winter, shooting up of temperature in summer or flooding of estuaries lead to extensive mortality of oyster beds. During such times cultured oysters have to be transferred to racks installed in nearby coastal waters. Extremes of salinities are prevalent only in some years in Athankarai estuary and is not a regular feature. Commercial exploitation of oysters from natural beds will lead to depletion of resources. Therefore, when a beginning is made in the utilization of resources, it is very desirable that culture practices are adopted.

The average meat weight of *Crassostrea madrasensis* shows a slight increase in November followed by a fall and rise in April-July period. The average percentage edibility which is an index of the condition of meat shows a similar trend and is higher twice in the annual period in November and again in April-July. In *Crassostrea madrasensis* of Ennore backwaters Venkataraman and Chari (1951) found the percentage edibility to be low in July and fairly high in October and Rao (1956) observed three peaks in meat weight and percentage of meat weight in whole weight of oysters in February, July-August and November.

The maximum water content of *C. madrasensis* of Athankarai area 89.64% wet wt. is higher than 85.04% wet wt. recorded in the same species of Ennore backwaters by Venkataraman and Chari (1951) and much higher than 74.5% wet wt. recorded by Giese (1969) in the mussel *Mytilus edulis*. Total solids constituted on an average 16.73% to 22.65% wet wt. in the period August to March in *C. madrasensis* of Athankarai Estuary but steadily increased to 24.35% wet wt. in April and as much 30.03% wet wt. in July.

Venkataraman and Chari (1951) found that the maximum lipid content of *C. madrasensis* occurring in Ennore backwaters was 14.8% of dry wt. The maximum lipid content in the present studies has been observed to be more than double that value, being 33% dry wt. The Athankarai oysters are much richer in lipid than Ennore oysters. Compared with the lipid values given by Galtsoff (1964) for the American oyster *Crassostrea virginica* (12.8% of dry wt.) and the European oyster *Ostrea edulis* (13.2%) recorded by Gaarder and Alsaker (1941) the lipid content of oysters recorded in this work (33% dry wt.) is much higher. The present studies indicate inverse relationship between water and lipid contents of oysters in the estuary. In this context, it may be mentioned here that similar findings have been made by Masumoto, Masumoto and Hibino in

Ostrea (=*Crassostrea*) *gigas* and by Durve and Bal (1961) in *Crassostrea gryphoides*.

Absence of well-defined quantitative changes in meat weight and chemical constituents in *C. madrasensis* of Athankarai Estuary in relation to reproductive stages is attributed to the absence of periodicity in breeding of the species in the Athankarai estuary resulting in constant acumulation of organic constituents in the body of oysters for maturation of goands and energy requirements of the body.

One interesting finding of the present work is that the levels of water, total solids and lipid of meat of male and female oysters of Athankarai estuary are more or less same and there are no distinct differences in relation to sex of the oysters. However, the lipid content of hermaphrodite oysters changing from male to female phase, is lesser than that of males or females. This could be ascribed to breakdown of lipids during the course of disintegration of gonads of one sex for the formation of reproductive follicles of the other sex.

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