BREEDING BIOLOGY OF *VILLORITA CYPRINOIDES* (GRAY) IN RELATION TO SALINITY GRADIENTS

By
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THESIS

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DEDICATED

TO

MY PARENTS

DECLARATION

I hereby declare that this thesis entitled BREEDING BIOLOGY OF VILLORITA CYPRINOIDES (GRAY) IN RELATION TO SALINITY GRADIENTS is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree diploma associateship fellowship or other similar title of any other University or Society

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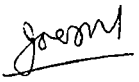
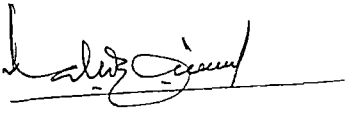
1	Dr T M Jose Major Adviser Assistant Professor Department of Fishery Biology College of Fisheries Panangad	
2	Dr P Rabindranath, Member Professor & Head Department of Fishery Biology College of Fisheries Panangad	
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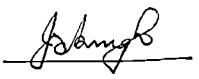
4	Dr I S Bright Singh Member Lecturer School of Environmental Studies Cochin University of Science & Technology	

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INTRODUCTION

I. INTRODUCTION

Clams are the chief molluscan resource of the estuaries and backwaters of our country Compared to other bivalves clams are regularly fished and utilized because of the relatively simple method of collections employed viz by hand picking or by scoop nets using small canoes They form a cheap source of protein-rich food for the fishermen and the lower middle class people They also form a major source of calcium carbonate Many states in India which do not have natural lime stone deposits depend on clam shells as raw material for industries like cement calcium carbide textile paper etc Although there exists a good seasonal fishery for many clam species in the backwaters and estuaries of our country there has been no systematic effort so far to study their resource potential or to exploit them in a rational manner

Of the estimated 53 000 tons of clam production of India Kerala ranks first contributing to more than 60% of the total production (32 340 tons C M F R I 1986) The black clam Villorita cyprinoides (Gray) forms the most abundant bivalve resource of our country

Vembanad Lake with its 200 Sq km of water spread is the major source of clam production in Kerala (21 900 tons C M F R I 1986) According to Jurup et al (1989) the exploited quantity of black clam from the lake during July 1988 to June 1989 was 7025 06 tons Earlier reports by Hornell (1921) show the presence of the backwater clam Meretrix spp in considerable quantities in the lake But recently

Kurup et al (1989) reported that the clam fishery of the lake is at present almost exclusively contributed by the black clam Villorita cyprinoides and that the distribution of Meretrix spp is confined to only a narrow region along the high saline barmouth area

Hornell (1921) reported that Villorita cyprinoides (Gray) is originally a freshwater species which later reacquired the tolerance for salinity conditions in the brackishwater area According to Prashad (1921) this species occur in brackishwater areas and sometime seen in freshwater also In addition he also reported two varieties viz V cyprinoides var cochinensis (Hanley) and V cyprinoides var delicatula (Preston) Cheriyan (1968) reported that V cyprinoides var cochinensis is capable of tolerating wide range of salinity upto a maximum of 34‰ and is found near the barmouth Nair & Shynamma (1975 a 1975 b) studied the salinity tolerance rate of growth and reproductive biology of V cyprinoides var cochinensis inhabiting the Cochin backwaters

In recent years several man-made changes have occurred in the Vembanad Lake A salt water barrier the Thanneermukkam barrier was commissioned in 1976 inorder to protect the Kuttanad area from the influx of saline water during the dry season This has resulted in the separation of the lake into two entirely different ecosystems the northern sector (Cochin to Thanneermukkam region) retaining the estuarine conditions and the southern sector (Thanneermukkam to Alleppey) being transformed into a freshwater lake (Kurup et al 1989) Commissioning of the Idukki hydro power project provided a perennial flow of

freshwater in the Muvattupuzha river which discharges into Chempu - Poochackal area of the lake It is quite possible that these drastic changes in the environment have affected the biology of the various animal populations inhabiting these two regions

In this respect it is worthwhile to mention that no detailed study has so far been undertaken to elucidate the effect of the above said hydrographic changes in the Vembanad lake in relation to the bionomics of Villorita cyprinoides (Gray) Hence the present study is undertaken with a view to bring out differences existing in the breeding biology of V cyprinoides inhabiting the northern and southern sectors of the lake in relation to the salinity gradients These studies will be useful in elucidating the impact of the Thanneermukkam barrage on the black clam resources of the lake and also help in formulating necessary conservation measures An attempt is also made to understand whether there is any significant difference in the size group composition of the landings from the two regions

REVIEW OF LITERATURE

II REVIEW OF LITERATURE

2 1 Environmental Parameters

For many years the hydrography of the Cochin backwaters has been a subject of intensive study The information available includes the seasonal distribution of temperature salinity dissolved oxygen pH alkalinity and nutrients George (1958) analysed the environmental parameters of the Cochin backwaters for understanding their influence on zooplankton distribution George & Kartha (1963) have studied the surface salinity of the backwater in the Ernakulam channel for 5 years and found that tidal influence on the salinity of the channel surface is practically nil Ramamritham & Jayaram (1963) analysed the hydrographical condition of the backwaters around Willington Island Josanto (1971) conducted a study on the bottom salinity characteristics and the factors that influence the salt water penetration into the Vembanad Lake from Cochin towards Alleppey and found that the pattern of salinity distribution at the bottom is closely associated with the freshwater inflow and its variation from season to season Haridas et al (1973) conducted a study on the salinity temperature dissolved oxygen and zooplankton biomass of the backwaters from Cochin to Alleppey Pillai et al (1975) studied the hydrography primary and secondary production of the lake and the influence of environmental factors on the plankton production Silas et al (1975) conducted a similar study while assessing the seasonal fluctuation in zooplankton abundance in relation to environmental factors Lakshmanan et al (1982)

studied the seasonal variation of temperature and salinity in the Cochin backwaters from Cochin barmouth upto Thanneermukkam region Antony & Kuttyamma (1983) analysed the salinity in the Vembanad Lake from Cochin barmouth to Alleppey while studying the distribution and abundance of polychaetes in relation to salinity Anirudhan et al (1987) studied the distribution pattern of salinity and silicon and their interrelationships in Cochin backwaters from barmouth to Alleppey About twenty physical and chemical parameters were analysed taking monthly samples from the Vemabanad Lake during 87 89 period by the Indo-Dutch Study Team (Kuttanad water balance study Project Final Report 1989)

2 2 Reproductive Biology

Considerable diversity exists in the patterns of reproductive cycles of marine and estuarine invertebrates These patterns have been generally associated with the environmental conditions to which the populations are exposed The reproductive cycle is a genetically controlled response to the environment (Sastry 1979) Temperature salinity day length and food abundance influence the reproductive cycle (Giese 1959) In marine molluscs inhabiting temperate waters many workers have shown a close relationship between the ambient temperature fluctuations and gonadal conditions (Loosanoff & Nomej Ko 1951 Loosanoff & Davis , 1952) salinity may affect reproduction decisively in areas where it undergoes pronounced changes like in the estuaries (Kinne 1971)

Several workers reviewed reproduction in clams and oysters and also the effect of environmental parameters like temperature and salinity on their reproduction Among these those of Loosanoff (1937) on Venus mercenaria Butler (1949) on Ostrea virginica Loosanoff and Davis (1952) on Crassostrea virginica Ansell (1961) on Venus stratula Sastry (1966) on Aequipecten irradians and Bayne (1975) on Mytilus edulis are noteworthy In India studies by Abraham (1953) on Meretrix casta Nayar (1955) Rao (1967) Nagabhushanam & Talikhedkar (1977) on Donax cuneatus Nagabhushanam & Mane (1975 a) on Mytilus viridis Nagabhushanam & Dhamne (1977) on Paphia laterisulcata Natarajan & John (1983) Narasimham (1988) on Anadara rhombea Rao (1951a), Nagabhushanam & Mane (1975 b) and Jayabal & Kalyani (1986) on Katelysia opima are worthy of mention

Loosanoff (1937) reported that in Venus mercenaria the most active period of gametogenesis and the production of the years crop of sex cells occur in the autumn and early winter when there was a decrease in water temperature Butler (1949) found that in Ostrea virginica exposed to freshwater for prolonged periods gametogenesis was inhibited until the salinity rose above 6‰ Following the salinity increase the oysters rapidly improved their gonadal condition but required 3 to 4 months to attain the same final level of gonad activity as the unaffected group According to Loosanoff & Davis (1952) the rate of progress of gametogenic activity and the beginning of spawning in Crassostrea virginica in Atlantic coast were to a large extent influenced by the temperature of the sorrounding water Chipperfield (1953) observed rapid spawning of the mussel Mytilus edulis from British

coast as a result of the sudden rise in temperature According to Loosanoff (1953) gametogenesis in Cyprina islandica occurs in late fall and early winter and spawning begins near the end of June or early July when the water temperature is approximately 13 5°C Tranter (1958) reported that the Australian pearl oyster Pinctada albina although breeding continuously throughout the year the most active season was during April and May when the sea temperature begins to fall He also pointed out that the species eventhough resembling the majority of tropical marine invertebrates in having a continuous year round breeding activity differs from them in having the most active breeding during a period when the water temperature begins to fall According to Ansell (1961) in Venus stratula in Kames Bay Mill Port the spawning takes place at intervals throughout the year He also reported that spawning in this species can be induced by rise of temperature or stimulation by sexual products Loosanoff (1962) found that in the European Oyster Ostrea edulis of Maine spawning begins approximately during the second or third week of July and continues until about the end of August Stickney (1963) described the reproductive system of the soft shell clam Mya arenaria Sastry (1966) indicated that in Bay Scallop Aequipecten irradians gametogenesis can be initiated in the resting stage by an increase in temperature Allen (1969) found that in Zirphaea crispata along the Northumberland coast breeding occurs from March to October with two main peaks one from March to May and the other from August to October Moore & Reish (1969) reported that in Mytilus edulis in the Alamitos Bay California mature sperms were found to be present throughout the year but mature ova were noticed only from November

through May They also reported that the number of indeterminate individuals varied directly with water temperature

Boyden (1971) while making a comparative study of the reproductive cycles of the cockles Cerastoderma edule and C glaucum found that gametogenesis occur in both the species during spring C edule spawned in May whereas C glaucum did not spawn until July Orertzen (1972) reported that the Baltic sea bivalves Cardium lamarchi Cyprina islandica Macoma baltica and Macoma calcarea spawn over a relatively short period in the spring and summer but Astarte elliptica and Astarte borealis retain mature gonads for over long periods and begin to spawn apparently only in winter or early spring According to Bayne (1975) in Mytilus edulis gametogenesis occurs from October to May followed by spawning in summer and a period of quiescence from August through September In the autumn and winter increased temperature in the laboratory induced more rapid development of gametes than in the field Sastry (1975) described the interrelation between the exogenous factors mainly temperature and food and endogenous factors mainly neurosecretory cycle age and metabolism and their effect on the reproductive cycles of Aequipecten irradians

Information regarding the reproductive biology of clams from Indian waters is plenty Hornell (1921) observed two spawning periods in Meretrix casta from the east coast one during April to May and another during September Rai (1932) reported that in Meretrix meretrix along the Bombay coast the principal breeding season lasts from March to June and they breed all the year round except during the monsoon

season Rao (1951a) found that in the estuarine clam Katelysia opima of the Adayar estuary gametogenesis takes place between April and August and the spawning which commences in December gets completed in January According to Abraham (1953) Meretrix casta in Adayar estuary spawns several times a year with two peaks one in March to May and another in October to November He also reported that the period of active spawning shows slight variation from year to year in the same environment due to the inconsistency in the onset and duration of monsoon which determines the salinity Nayar (1955) reported that in the wedge clam Donax cuneatus in Palk Bay spawning commences in January and lasts till about April According to Durve (1964) Meretrix casta in Mandapam fish farm have a prolonged breeding period with slight peaks during certain months In Crassostrea gryphoides in the Kelva waters Durve (1965) found that spawning takes place during July to September and the main spawning stimulus appears to be the sudden lowering of salinity due to monsoon Alagarswami (1966) reported that Donax faba from Mandapam coast has a prolonged breeding period with two peaks one in November to December and the other in May to June Lowering of temperature and salinity due to the north east monsoon in November acts as a stumulant for the spawning activity Based on the trends of occurrence of the juvenile clams in Beypore and Korupuzha estuary Seshappa (1967) suggested two spawning peaks for Meretrix casta during the year According to Rao (1967) in Donax cuneatus of Madras coast spawning takes place during December to January when water temperature and salinity are high Salih (1973) reported two spawning seasons for Meretrix casta inhabiting the Cochin barmouth one in June and the other in October

According to Nagabhushanam and Mane (1975 a) Mytilus viridis at Ratnagiri spawned twice a year one during July to August when there was a sudden decrease in salinity due to the south west monsoon and the other during February to March when the salinity was high Katelysia opima in the Kalbadevi estuary of Ratnagiri coast has two spawning periods a major one occurring in October to November and a minor one in March to April (Nagabhushanam and Mane 1975 b) They also found that the major spawning coincided with an increase in salinity after the monsoon season According to Nair & Shynamma (1975 b) Villorita cyprinoides var cochinensis in the Cochin backwaters has two peaks of breeding activity one from late May to August and the other from January to late March Rasalam and Sebastian (1976) reported that Villorita cyprinoides var cochinensis in the Vembanad Lake breeds from January to July when the salinity is higher in the lake Veliger larvae were recorded only from January to July and the gonad during this period was found to have sperm in the males and fully ripe ova in females Nagabhushanam & Dhamne (1977) found that Paphia laterisulcata has a prolonged spawning period extending from mid September to the end of March with two peaks the first in October to November and the second in February to March The spawning stimulus in this species appeared to be the sudden increase in salinity in September at the end of monsoon In the wedge clam Donax cuneatus from Ratnagiri Nagabhushanam & Talikhedkar (1977) observed that the spawning period extended from October to January with peak spawning during November to December It is also reported that the increase in salinity and temperature soon after monsoon appeared to promote gametogenesis and initiate spawning Stephen (1980) reported that Crassostrea madrasensis

in the Mulki estuary in south west coast of India have two restricted spawning periods a major one from mid April to June and a minor one during late October to November period He also found that the major spawning activity is associated with decreasing salinity (mid April to June) a gametogenically inactive phase occurring during the low salinity periods (June to September) and a minor spawning occurs during the rising salinity periods Joseph & Madhyastha (1982) while studying the gametogenesis of Crassostrea madrasensis inhabiting Mulki estuary noticed that gametogenesis in this species commences during late September or early October correlated with the increase in salinity Mane & Nagabhushanam (1983) observed that the green mussel Perna viridis spawns in Bhatia creek at Ratnagiri from July end to early September and again in February to March According to Reddy (1983) in Villorita cyprinoides inhabiting the Nethravathi stretch of Nethravathi - Gurupur estuary gametogenesis commenced during October to November with an extended breeding period from December to early April and peak spawning during February to March He also reported that increase in salinity and temperature soon after monsoon appeared to promote gametogenesis and initiate spawning in this species Natarajan & John (1983) reported that Anadara rhombea from the backwaters of Porto Novo has an extended spawning period from February/March to September Maximum spawning in this species was recorded during high salinity periods Rajapandian & Rajan (1983) conducted a study on the maturity stages and spawning periodicity of Crassostrea madrasensis at Tuticorin Bay and found that this species has a biannual spawning periodicity peak period of spawning activity being March to April and August to September They also found a broad correlation between diurnal

temperature difference and spawning of Crassostrea madrasensis Apparao et al (1984) found that the spawning period of Meretrix casta in the Bheemunipatanam backwaters was between April and May According to Thippeswamy (1985) the wedge clam Donax incarnatus inhabiting the Perambur beach near Mangalore has an extended breeding season from November to May According to Jayabal and Kalyani (1986) Meretrix meretrix Meretrix casta and Katelysia opima in Vellar estuary have an extended breeding period from February to September They also found that these bivalves prefer moderate salinity (23 to 29‰) for spawning Victor and Subramoniam (1988) reported that in Donax cuneatus of Madras coast spawning commenced in February and extended upto July They also found that temperature and salinity influenced the breeding of the clams In the edible ribbed clam Anadara rhombea from Kakinada Bay Narasimham (1988) found that spawning takes place during December to April months with peak spawning in January to March Increase in the ambient water temperature and salinity seem to induce spawning Rao (1988) observed that the major spawning season of Meretrix casta and Paphia malabarica in the Mulki estuary are September to March and October to February respectively According to Sukumar and Joseph (1988) in Saccostrea cucullata inhabiting Someshwar coast near Mangalore reproductive cycle commences with gametogenic activity during January and spawning extends from June to December with two peaks one from late June to early September and the other one from November to December

Spawning coincided with a dip in the salinity values of the coastal waters According to Kattıcaran (1988) gonad development in Sunetta scripta appeared to be correlated to ambient salinity fluctuations with a recovery and slow gametogenic phase occurring during the low salinity period a gametogenically active phase associated with the period of rising salinity and spawning activity associated with high and relatively stable salinity Appukuttan et al (1989) found that the brown mussel Perna indica in the south west coast of India spawns from June to August

2 3 Size Frequency studies

Size-frequency studies have been undertaken for many species of clams with a view to study the growth and to understand size groups constituting fishery Important works from abroad include those of Hamai (1935) on Meretrix meretrix Coe (1947) on Tivela stultorum Allen (1969) on Zirphaea crispata Anderson (1972) on Panopejenerosa Greene (1979) on Mercenaria mercenaria William (1979) on Tapes japonica and Richardson et al (1980) on Cerastroderma edule

From Indian waters a good deal of data is available on the size frequency studies of clams which were mainly attempted with a view to understand the growth pattern Important works are those by Rao (1951a) Mane (1974) Kalyanasundaram & Kasinathan (1983) on Katelysia opima Abraham (1953) Durve (1970) Salih (1973) Apparao et al (1984) on Meretrix casta Nayar (1955) Talikhedkar & Mane (1976) on

Donax cuneatus Alagarswami (1966) on Donax faba Narasimham (1968) on Anadara granosa Nair & Shynamma (1975 b) on Villorita cyprinoides var cochinensis Mane & Nagabhushanam (1979) on Paphia laterisulcata and Kurup et al (1989) on Villorita cyprinoides

MATERIALS AND METHODS

III. MATERIALS AND METHODS

3 1 The Environment

The Vembanad Lake is the largest brackishwater body on the west coast of India It has a length of about 90 km between Alleppey in the south and Azhikode in the north (Kurian et al 1975) From the Cochin barmouth in the north to Alleppey in the south the lake has a length of about 60 km situated between latitudes 9° 30 N and 9° 58 N and longitudes 76° 15 E and 76° 25 E (Haridas et al 1973) The depth of the lake varies from 10-12 m around Cochin Harbour channel to 1 m at Alleppey (Haridas et al 1973)

Hydrological conditions of Cochin backwaters are greatly influenced by seawater intrusions and riverwater influx Five rivers open into the lake viz Pamba Muvattupuzha Meenachil Achenkovil and Manimala In addition as already mentioned in the introduction the Thanneermukkam barrier also exerts a significant influence on the hydrological conditions of the lake

The Vembanad Lake is subjected to great seasonal variations in salinity (Josanto 1971) Extensive and dense beds of black clam Villorita cyprinoides occur at various places in the Vembanad Lake throughout the year For the present study two stations with perennial beds of V cyprinoides which differ greatly in salinity conditions were selected for monthly sampling Station I located near the Perumbalam

Island on the northern sector (north of Thanneermukkam barrier) is having a high influx of salinewater while Station II located near South Aryad - Punnamada region on the southern sector is having a low influx of salinewater (Fig 1)

The monthly sampling programme was carried out from May 1989 to June 1990 during the last week of every month

3 2 Environmental Parameters

Surface and bottom water samples were taken from the two selected stations for estimating the environmental parameters viz salinity temperaature dissolved oxygen and pH Surface samples were collected using a clean plastic bucket and bottom samples using a bottom water sampler Temperatures of both surface and bottom samples were recorded at the time of collection itself using a mercury bulb thermometer with an accuracy of 0 1°C For oxygen estimation water samples were fixed in B O D bottles using Winkler A and Winkler B reagents at the collection spot itself and kept for further analysis using standard Winkler s method (Strickland and Parsons 1972) pH of the water samples were estimated by Electrometric method using ELICO digital pH meter Salinity of the samples were determined by Mohr-Knudson titrimetric method given by Strickland and Parsons (1972)

3 3 Reproductive Biology

Monthly random samples of black clams covering almost all size

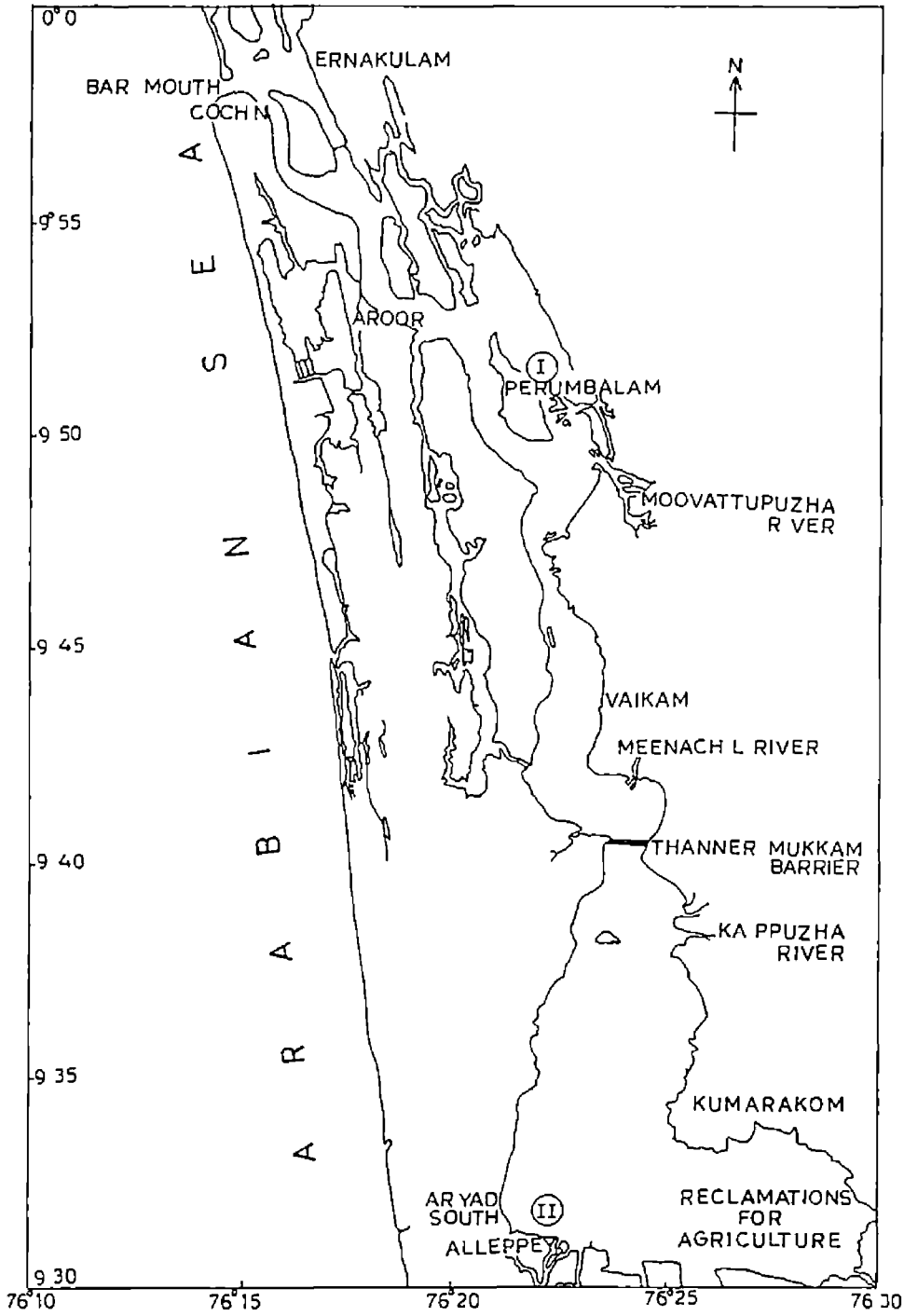


Fig 1 Map of the Vembanad Lake showing the two selected stations Station I & Station II

groups were collected from the fishermen from the two selected stations They were then preserved in 4% formalin and brought to the laboratory

The external appearance of the gonad and microscopic examination of fresh gonad smears were not very helpful in the present study in understanding the gametogenic activity Hence histological preparations were used to ascertain the actual stage of maturity and other aspects of gametogenesis A random subsample of 15 clams per month from each station was used for the purpose Entire body of each clam was fixed in Buoin s solution Middle part of the body containing gonadal tissue was further processed (paraffin embedding method) and sectioned at 6 μ m thickness and counterstained with eosin A total of about 430 clams were used for this study

The scheme of classification of maturity stages followedwas adapted from Joseph & Madhyastha (1982) The developing gonad is categorised into three developing stages in males (MD_1 MD_2 & MD_3) and four developing stages in females (FD_1 FD_2 FD_3 & FD_4) MD_3 & FD_4 stages are the ripe gonad conditions for the male and female respectively The spawning condition is divided into two stages for both sexes MR_1 & MR_2 in males and FR_1 & FR_2 in females R_1 (MR_1 & FR_1) indicates partially spawned condition and R_2 (MR_2 and FR_2) indicates spent and resorbing gonad condition

3 4 Size-Frequency studies

Shell lengths of individual clams were measured to the nearest 0 1 mm using a vernier calipers The greatest antero posterior measurement was taken as length The data were arranged in size groups of 2 mm interval As the number of total observations varied from month to month length frequencies were converted into percentages

Percentage frequencies for various size groups for different months were pooled for the entire study period inorder to get an idea on the size group which constitute the clam fishery of the two selected stations

RESULTS

IV RESULTS

4 1 Environmental Parameters

The data on salinity temperature dissolved oxygen and pH of the bottom and surface water samples of Station I and Station II during the period (May 1989 to June 1990) are presented in Tables 1 & 2 respectively

4 1 1 Station I

Distributions of salinity temperature dissolved oxygen and pH of bottom and surface water samples are represented graphically in Figs 2 & 3 respectively

4 1 1 1 Salinity

Salinity at this station showed pronounced seasonal variation Bottom salinity values during the study period ranged from 0 0 to 18 12‰ whereas the surface salinity ranged from 0 0 to 17 0‰ During may 1989 when the investigation commenced the bottom salinity was 17 84‰ With the onset of south west monsoon during June the level came down to 0 88‰ During July August and September months freshwater conditions prevailed in bottom and surface layers From October onwards the salinity showed gradual increase and reached the peak levels of 18 12‰ for the bottom and 17 0‰ for the surface waters during April 1990 During May 1990 salinity showed a steep decline

Table 1 Distribution of environmental parameters - Station I

Months	Salinity (‰)		Temperature (°C)		Dissolved Oxygen (ml/l)		pH	
	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface
May 1989	17 84	14 65	32 5	33 0	3 6	3 8	7 50	7 0
June	0 88	0 86	29 0	29 5	4 0	4 0	6 45	6 80
July	0	0	27 5	28 0	5 0	5 4	6 00	6 02
August	0	0	27 5	28 0	5 0	5 2	6 10	6 40
September	0	0	28 2	28 5	2 0	2 1	7 02	6 92
October	3 10	2 84	28 5	29 2	2 8	3 0	7 00	7 00
November	6 10	5 82	28 8	29 4	3 1	3 4	7 00	6 95
December	9 24	8 76	30 0	30 2	3 2	3 5	6 85	7 00
January 1990	11 20	10 00	30 2	30 8	2 8	2 8	6 80	6 45
February	16 00	14 93	30 5	31 0	2 4	2 6	7 26	6 88
March	16 85	15 98	32 1	32 5	3 0	3 0	6 90	7 00
April	18 12	17 00	32 4	33 0	3 1	3 2	7 00	7 05
May	4 82	3 0	31 2	31 8	4 6	4 8	6 98	6 95
June	0	0	30 0	30 4	4 8	5 0	7 00	7 18

Table 2 Distribution of environmental parameters Station II

Months	Salinity (%)		Temperature (°C)		Dissolved oxygen (ml/l)		pH	
	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface
May 1989	2 12	1 86	30 0	30 5	4 2	4 4	6 42	6 82
June	0	0	28 2	28 8	4 8	5 0	6 80	7 00
July	0	0	27 5	28 0	6 2	6 8	6 30	6 24
August	0	0	28 0	28 4	6 0	6 2	7 02	7 12
September	0	0	28 1	28 3	2 8	3 1	7 38	7 50
October	0	0	28 8	29 0	3 2	3 4	7 20	7 46
November	0	0	28 5	29 0	4 0	4 2	6 75	6 98
December	1 00	0 82	29 2	29 8	3 4	3 4	6 00	6 12
January 1990	1 21	1 00	29 4	30 0	2 8	3 0	6 74	6 78
February	1 80	1 54	30 0	30 8	2 3	2 4	6 80	6 88
March	1 90	1 70	31 8	32 4	3 8	4 0	7 00	7 10
April	2 00	1 80	32 0	32 8	3 1	3 2	6 98	6 90
May	0	0	30 0	30 2	4 7	4 8	6 8	7 00
June	0	0	29 8	30 0	5 2	5 5	6 95	6 90

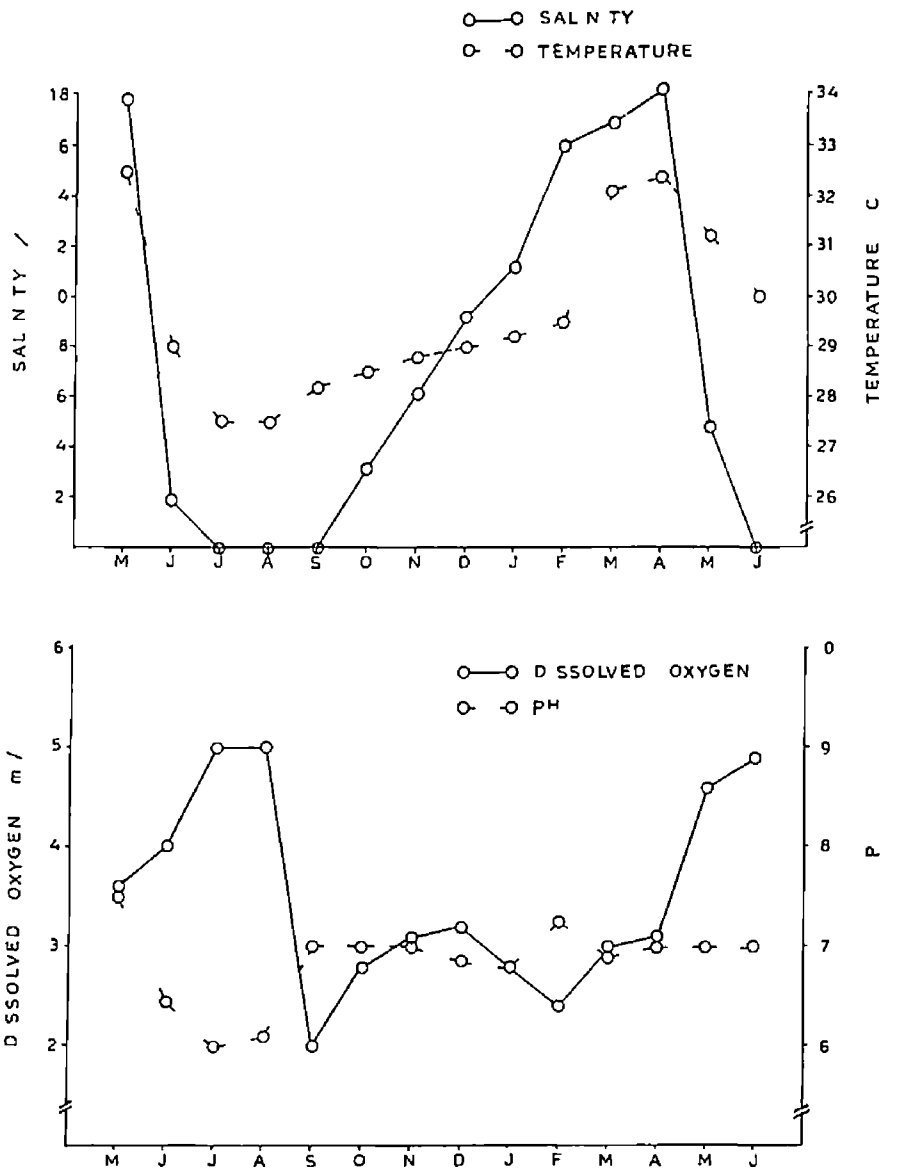


Fig 2 Distribution of salinity temperature dissolved oxygen and pH of the bottom water samples - Station I

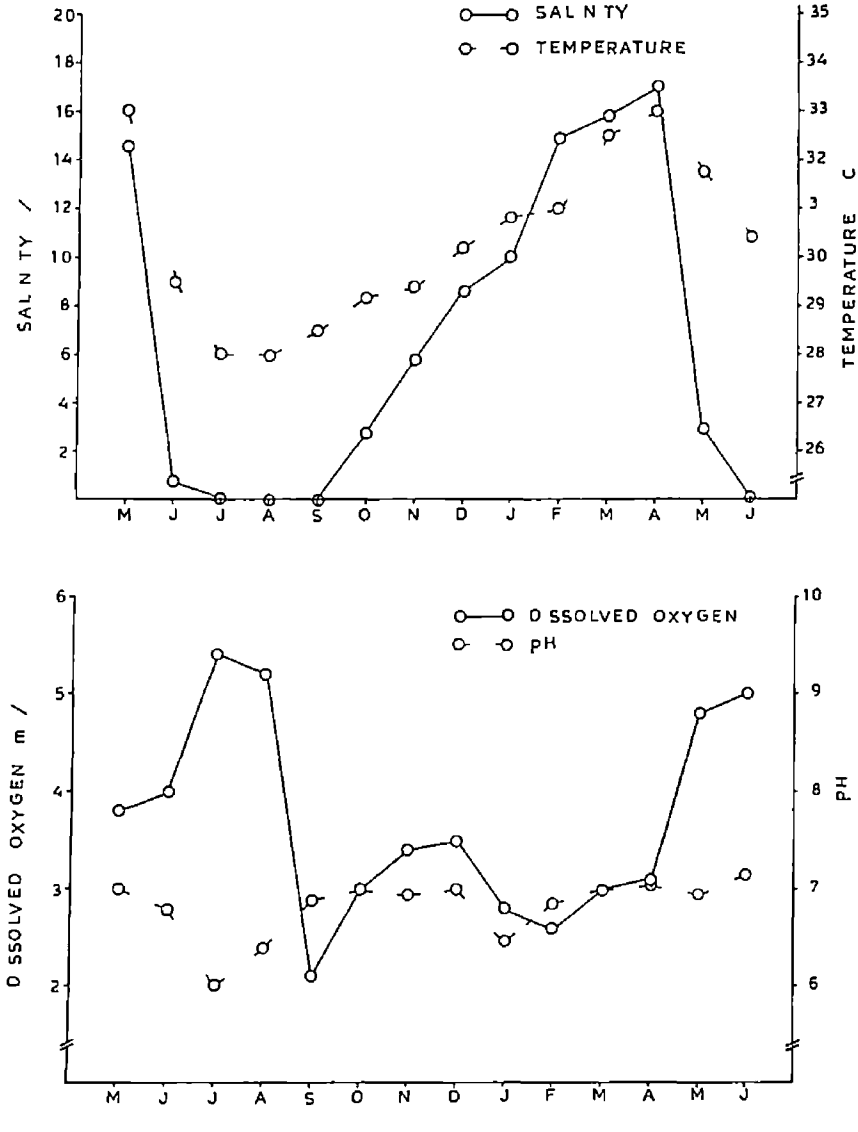


Fig 3 Distribution of salinity temperature dissolved oxygen and pH of the surface water samples - Station I

to 4 82‰ for the bottom and 3 0‰ for the surface waters coinciding with the early monsoon showers and during June the area attained freshwater conditions

4 1 1 2 Temperature

Bottom temperature fluctuated between 27 5°C and 32 5°C and the surface temperature between 28 0°C and 33 0°C during the study period Highest value recorded for bottom water temperature was during May 1989 (32 5°C) similarly the lowest value was recorded during July and August 1989 (27 5°C) For surface water also the highest value was recorded during May 1989 and April 1990 (33 0°C) and the lowest value during July and August 1989 (28 0°C)

4 1 1 3 Dissovled Oxygen

Dissolved oxygen values ranged from 2 0 to 5 0 ml/l for the bottom and 2 1 to 5 4 ml/l for the surface waters For both the bottom and surface water samples the maximum and minimum dissolved oxygen values were recorded during July and August 1989 and September 1989 respectively From Septemeber 1989 to April 1990 the dissolved oxygen values fluctuated within a narrow range ie between 2 0 ml/l and 3 2 ml/l for bottom and 2 1 ml/l and 3 5 ml/l for surface waters Again during May and June comparatively higher values are recorded coinciding with the early monsoon

4 1 1 4 pH

pH values fluctuated within a narrow range between 6 0 and 7 5 for bottom and 6 02 and 7 18 for surface waters The highest pH values for bottom waters were during May 1989 (7 5) and February 1990 (7 26) The lowest values were during July 1989 (6 0) and August 1989 (6 10) For surface waters the highest values were during June 1990 (7 18) and April 1990 (7 05) The lowest values were reported during July 1989 (6 02) and August 1989 (6 40)

4 1 2 Station II

Distributions of salinity temperature dissolved oxygen and pH of bottom and surface water samples are represented graphically in Figs 4 & 5 respectively

4 1 2 1 Salinity

At this station freshwater and low saline conditions were maintained throughout the year with the values fluctuating between 0 0 to 2 12‰ for bottom and 0 0 to 1 86‰ for surface waters The maximum values for salinity during the study period were recorded during May 1989 viz 2 12‰ for bottom and 1 86‰ for surface waters From June to November the station showed freshwater condition After that salinity gradually increased upto April 1990 (2 0‰ for bottom and

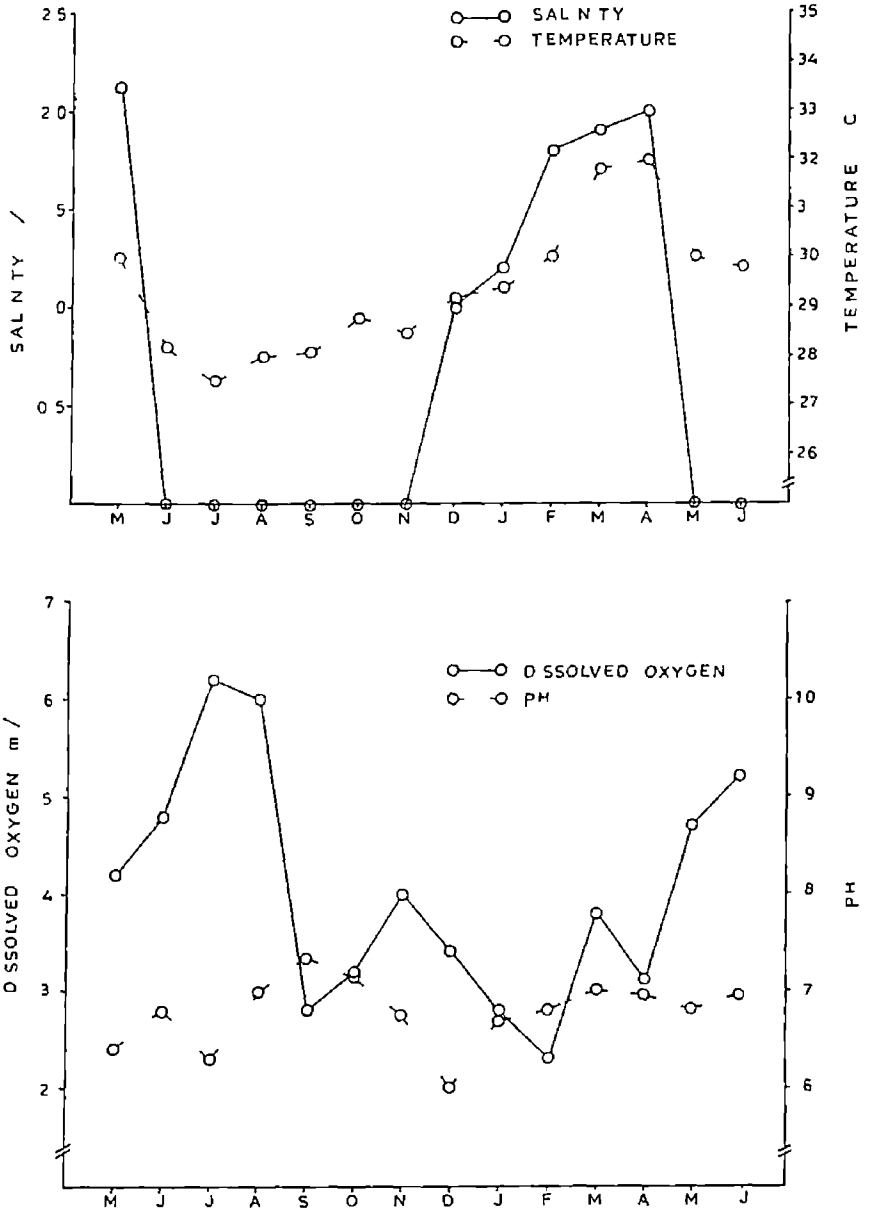


Fig 4 Distribution of salinity temperature dissolved oxygen and pH of the bottom water samples - StationII

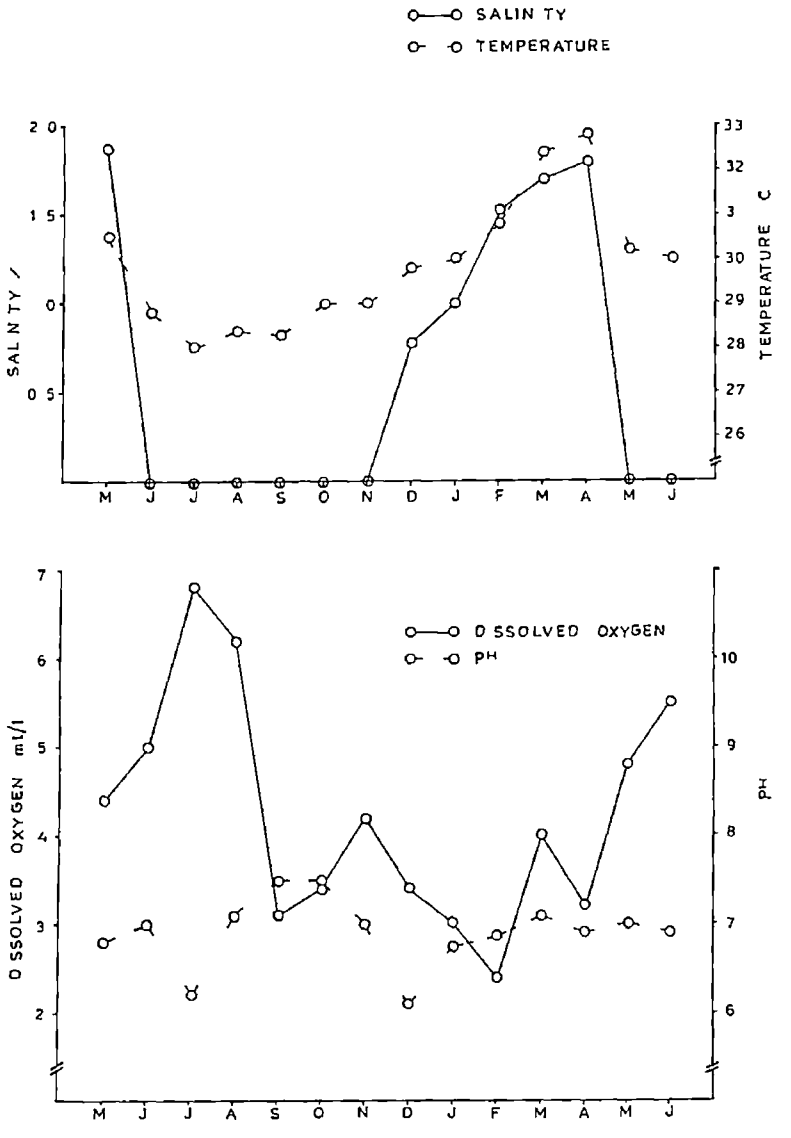


Fig 5 Distribution of salinity temperature dissolved oxygen and pH of the surface water samples - Station II

1 8‰ for surface waters) During May and June 1990 the station again attained freshwater condition

4 1 2 2 Temperature

Temperature values fluctuated between 27 5°C and 32 0°C for bottom and 28 0°C and 32 8°C for surface waters during the study period Highest temperature values for bottom and surface waters were during April 1990 (32 5°C and 33 0°C respectively) Similarly minimum values were recorded during July 1989 (27 5°C for bottom and 28 0°C for surface waters)

4 1 2 3 Dissolved Oxygen

Dissolved oxygen values ranged from 2 3 to 6 2 ml/l for bottom and 2 4 to 6 8 ml/l for surface waters The maximum values for bottom and surface waters were recorded during July 1989 and the minimum values during February 1990 From September 1989 to April 1990 the values fluctuated between 2 3 ml/l and 4 0 ml/l for the bottom and 2 4 ml/l and 4 2 ml/l for the surface waters Comparatively higher values are recorded during monsoon months

4 1 2 4 pH

The pH values fluctuated within a narrow range between 6 00 and 7 38 for bottom and 6 12 and 7 50 for surface waters The lowest pH values for bottom waters were during December 1989 (6 00) and July

1989 (6 30) Highest values wer during September 1989 (7 38) and October 1989 (7 20) For surface waters the lowest values were obtained during December 1989 (6 12) and July 1989 (6 24) and highest values during September 1989 (7 50) and October 1989 (7 46)

4 2 Reproductive Biology

4 2 1 Classification of Maturity Stages

Classification of maturity stages was adapted from the scheme of classification given by Joseph & Madhyastha (1982) Histological studies showed that in Villorita cyprinoides follicles in different stages of maturity could be observed in the same gonad itself So a gonad was categorised into a particular maturity stage on the basis of the condition of majority of the follicles

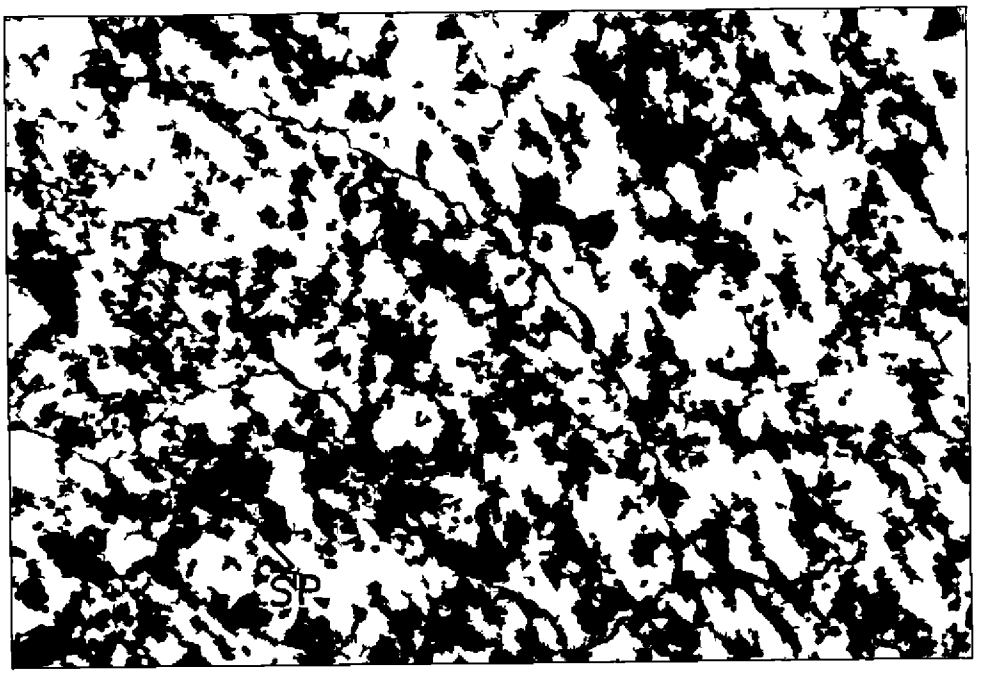
4 2 1 1 Maturity Stages of Male

Stage MD_1

Follicles appear as small round or oval patches Spermatogonial cells found to lie scattered in the follicles A few spermatids are also visible as dark patches (Figs 6 & 7)

Stage MD_2

Spermatocytes and spermatids form wide centripetal bands along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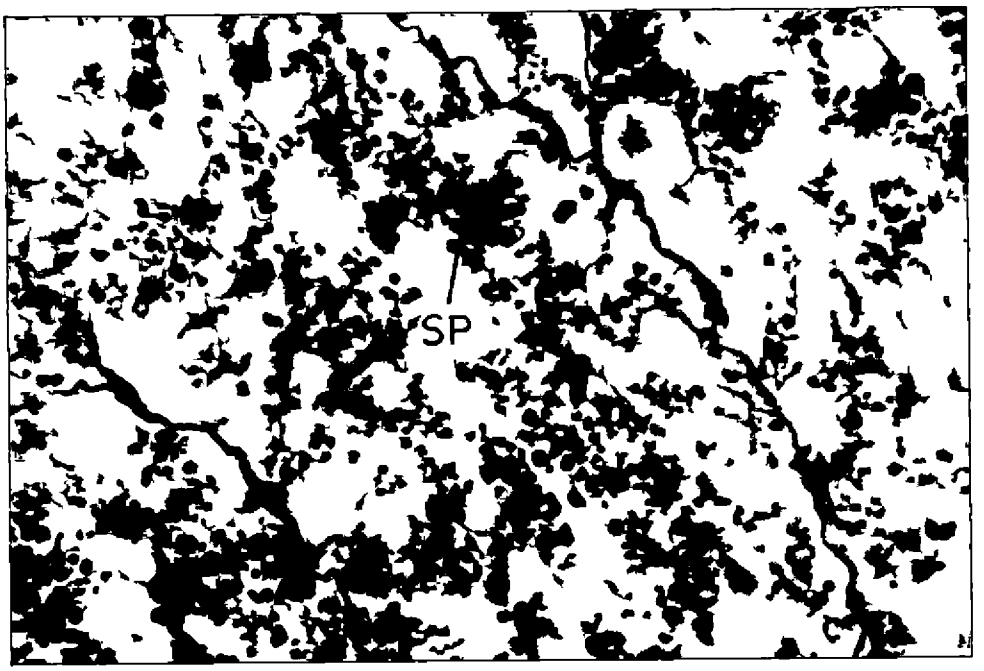
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the follicular wall A few spermatocytes appear in the follicular lumen (Fig 8)

Stage MD_3

Follicles fill up the entire area of the gonad Large number of free spermatozoa occupy the entire lumen of the follicles while a few spermatids trail between the centre and follicular wall Bands of spermatocytes along follicular wall are narrow (Figs 9 & 10)

Stage MR_1

Follicles appear partly empty with the central portion devoid of spermatozoa (Fig 11)

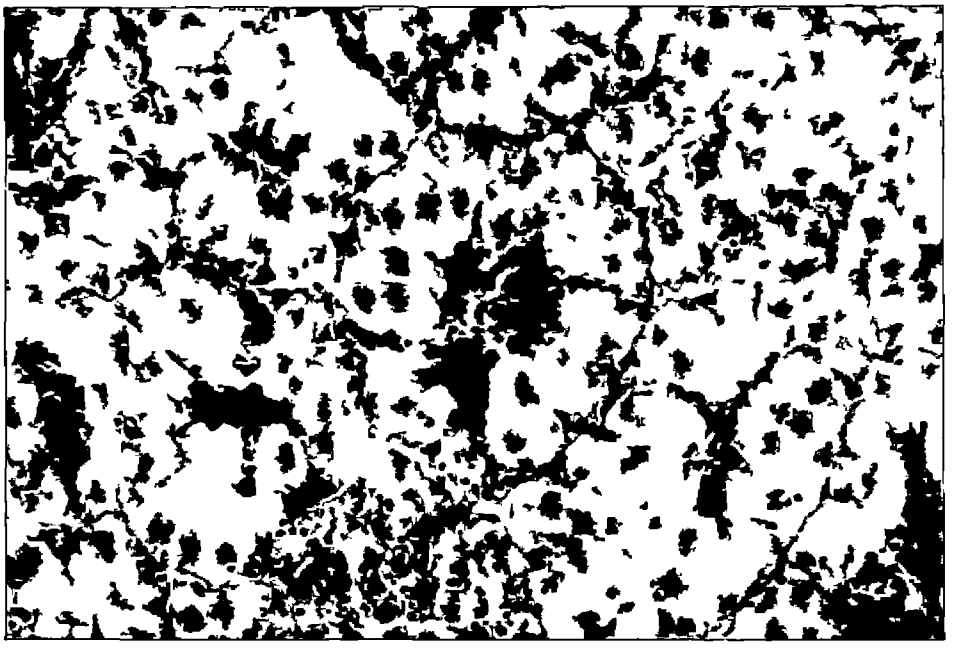
Stage MR_2

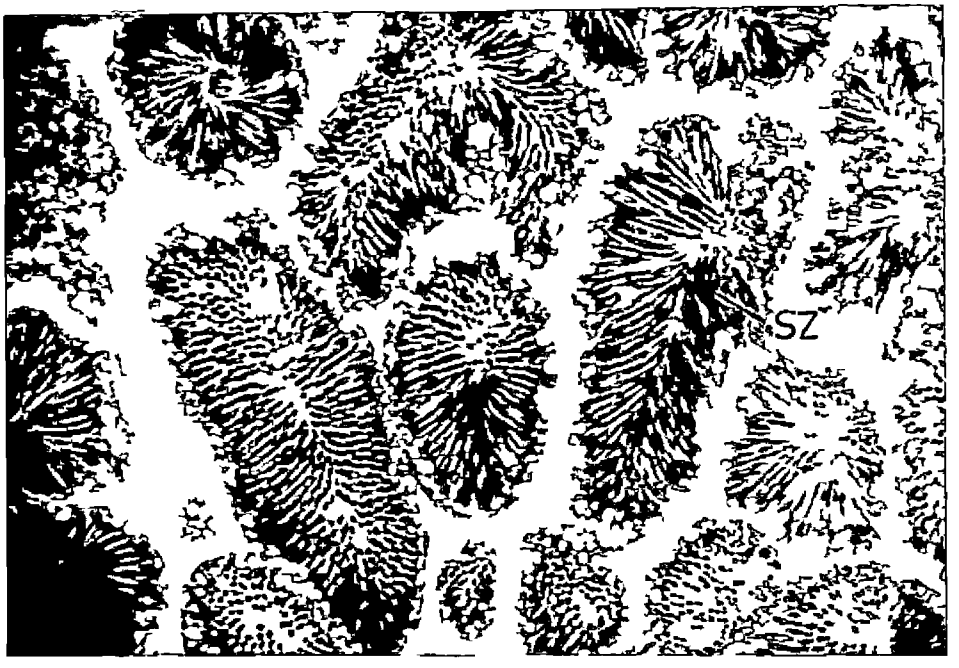
Follicles appear empty except for patches of unspent spermatozoa (Fig 12)

4 2 1 2 Maturity Stages of Female

Stage FD_1

Follicles small in size Follicular wall lined with oogonia and oocytes (Figs 13 & 14)

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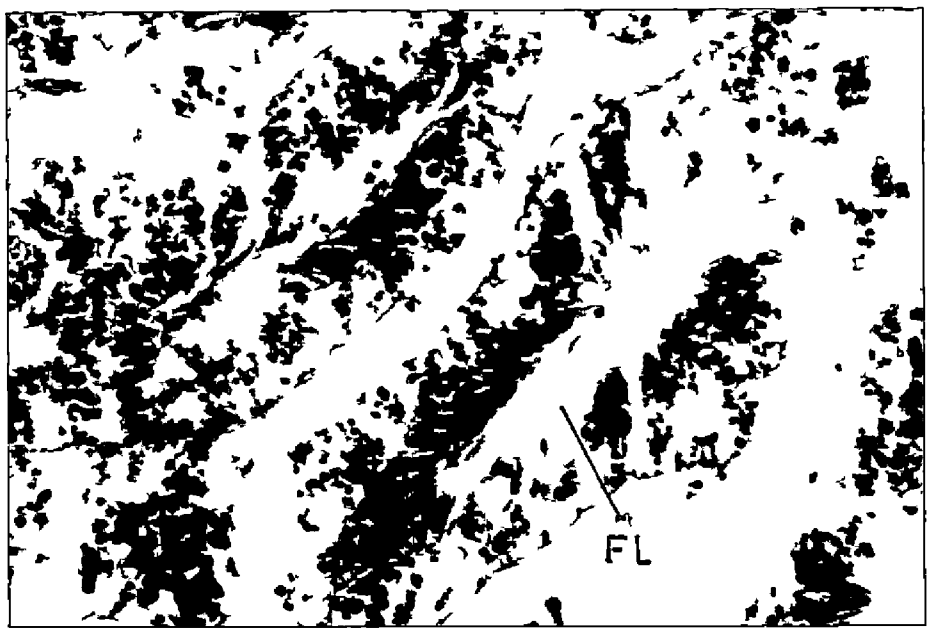
SZ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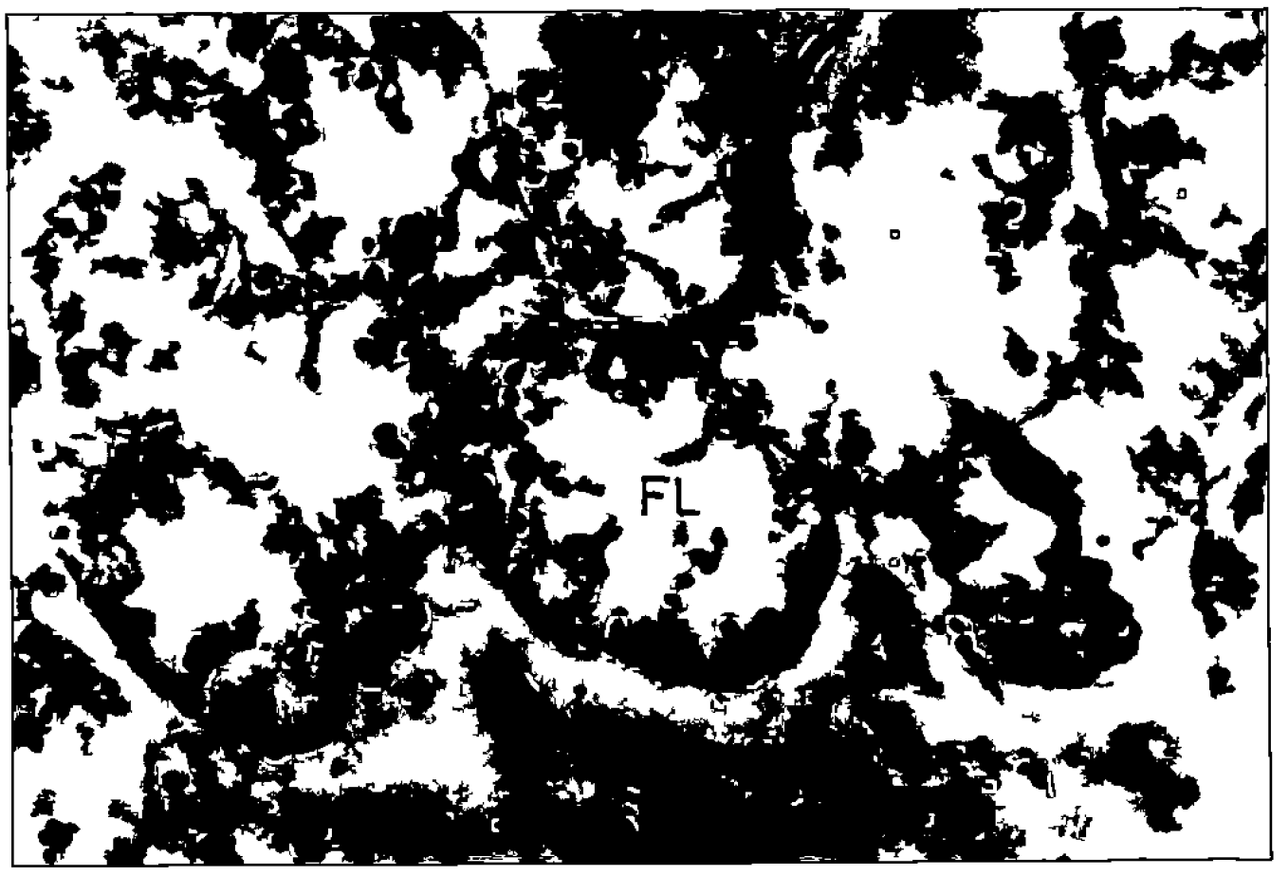
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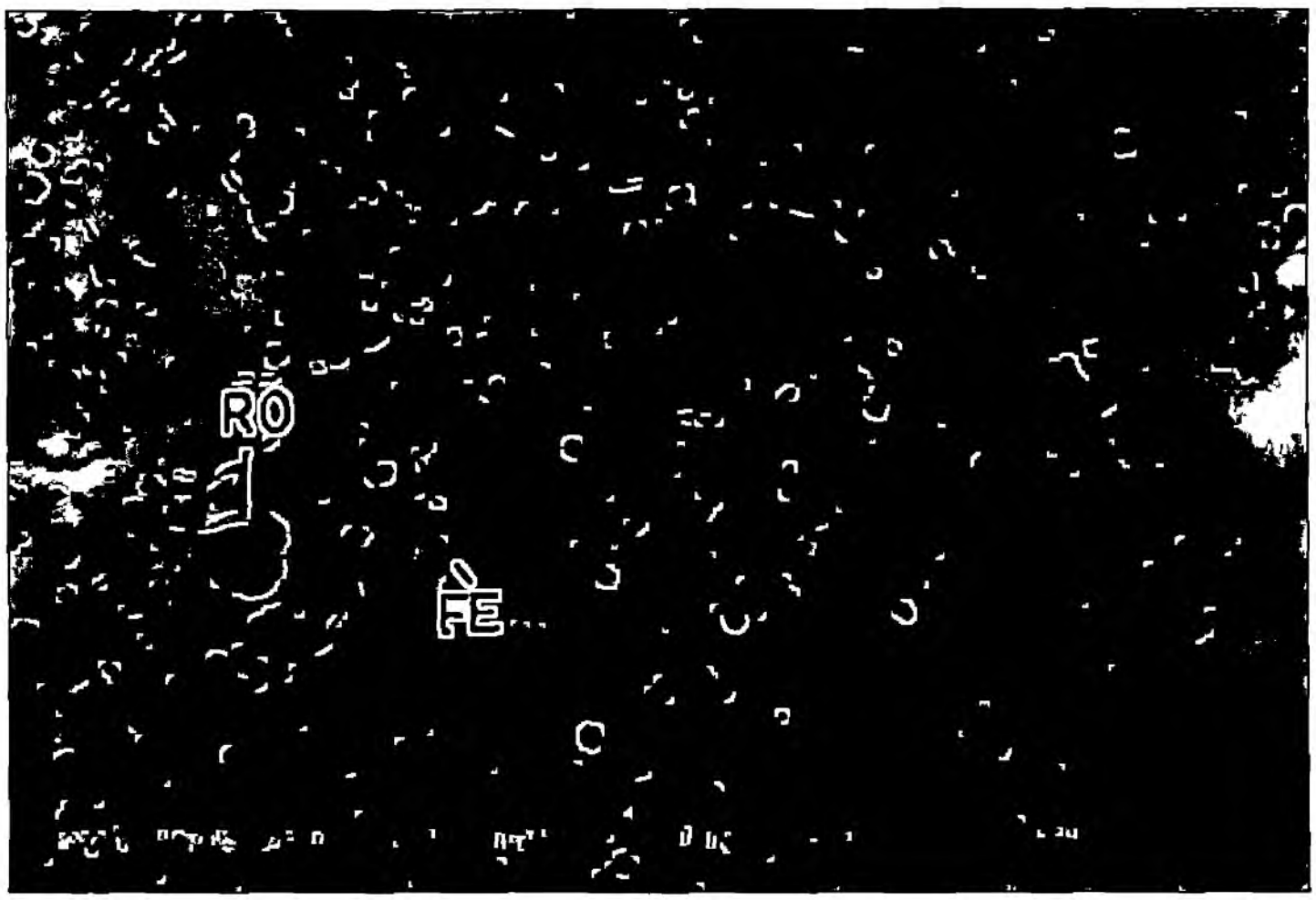
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Stage FD_2

Follicles appear larger in size Follicular wall lined with a few pedunculate secondary oocytes (Fig 15)

Stage FD_3

Follicles enlarged in size and extent lumen filled with secondary oocytes shape pedunculate or sub oval Primary oocytes and free oocytes few Secondary and free oocytes with nucleoli (Fig 16)

Stage FD_4

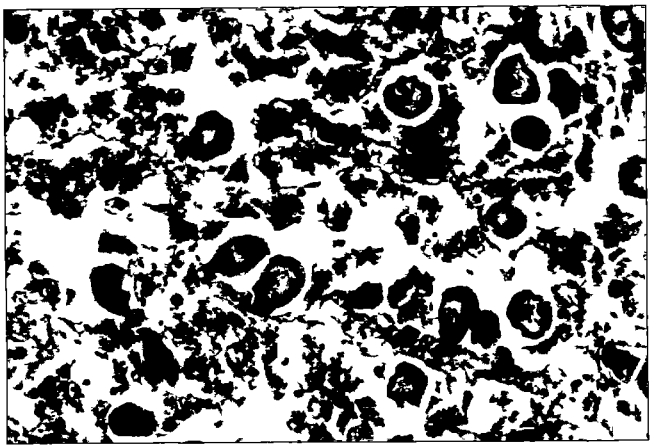
Follicles appear thickly packed in the gonad Free oocytes of size 27 to 39 μ m fill up the lumen of the follicles Pedunculate secondary oocytes few (Fig 17)

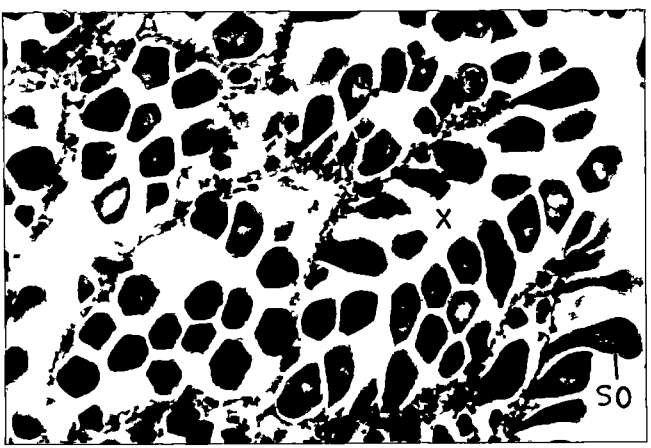
Stage FR_1

Follicles appear partly shrunken Follicular lumen empty except for a few large unspent residual ova Sometimes second series of secondary oocytes seen on the follicular wall (Figs 18 & 19)

Stage FR_2

Follicles appear shrunken and follicular lumen empty A few

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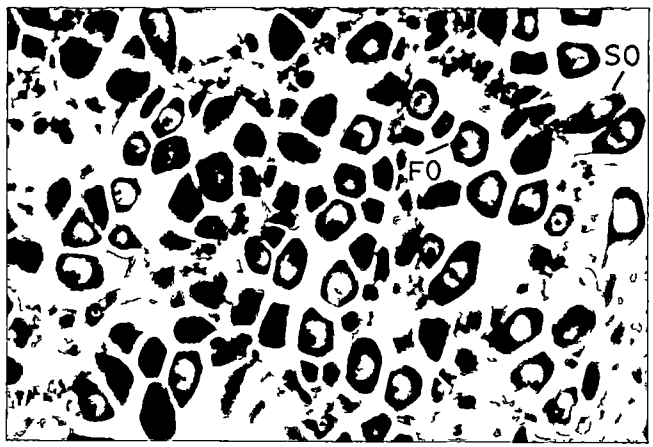
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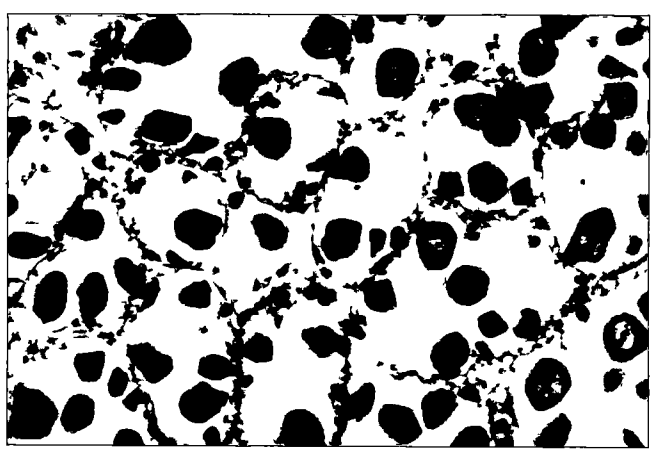

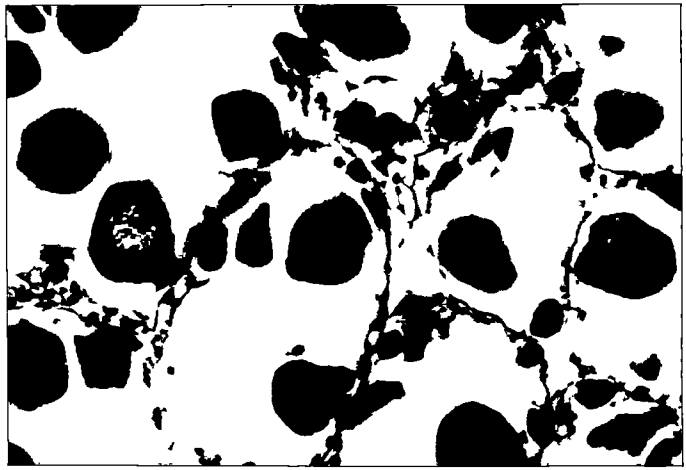

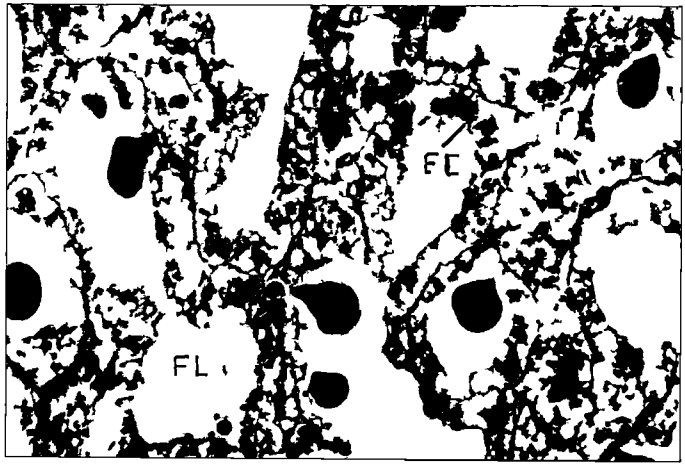
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relict ova which are large sized appear in the lumen of the follicles Phagocytes seen in large numbers Follicular wall thickened A few follicles showing initiation of oogenesis (Fig 20)

4 2 2 Annual Reproductive Cycle

Percentage occurrence of clams in different stages of maturity was calculated out of the total number of animals examined irrespective of sex

4 2 2 1 Station I

Table 3 gives the percentage occurrence of different maturity stages In May 1989 when the observation commenced the gonads of all the clams were either in partially spawned condition or in advanced stage of spawning (R_1 27% R_2 - 63%) By the month of June about 93% of the individuals were in the spawning stages while 7% were in early developing stage (FD_1) During the months of July and August all the animals observed were in the early developing stages (FD_1 MD_1 and MD_2) No mature individuals could be observed during these months Histological studies showed that in the males gametogenesis commenced little earlier than the females From September onwards fully mature individuals started to appear in the collections (MD_3 25% FD_4 - 15%) Spawning was also found to have started from September onwards (MR_1 5% FR_1 - 15% during September) Spawning was found to be well synchronized in both the sexes

Table 3 Percentage occurrence of maturity stages of V cyprinoides at Station I

Gonadal stages	1989								1990					
	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
FD_1	0	7	47	50	5	19	0	0	0	0	0	0	0	5
FD_2	0	0	0	0	10	0	0	0	0	0	0	0	0	0
FD_3	0	0	0	0	0	0	11	0	13	0	0	0	0	0
FD_4	0	0	0	0	15	13	39	33	13	7	5	0	0	0
FR_1	0	7	0	0	15	6	0	20	27	13	21	6	7	0
FR_2	60	60	0	0	0	6	0	7	7	0	37	50	73	32
MD_1	0	0	47	19	5	0	0	0	0	0	0	0	0	0
MD_2	0	0	6	31	20	6	0	0	0	0	0	0	0	0
MD_3	0	0	0	0	25	31	50	20	20	53	5	6	0	0
MR_1	27	20	0	0	5	13	0	20	20	27	32	38	20	21
MR_2	13	6	0	0	0	6	0	0	0	0	0	0	0	42

Maturity stages of males and females are classified into 3 main stages viz developing mature and spawning and their percentage frequencies are given in Table 4 The frequency polygon of 3 main stages are given in Figure 21 As per the table and figure the percentage frequency of spawning individuals (FR_1 FR_2 MR_1 & MR_2 stages) showed a gradual increase from September 1989 onwards with an interruption in November and reached peaks in March April May and June months with 89% 94% 100% and 95% respectively Eventhough in November there were no gonads in the R_1 and R_2 stages 89% of the individuals were in the mature stage (FD_4 39% and MD_3 50%) each gonad has a number of follicles in R_1 and R_2 stages indicating that spawning activity persisted in November also Thus clams inhabiting station I show a protracted spawning season extending from September to June with peak spawning activity during March to June

Bottom salinity profile and percentage frequency of mature and spawning individuals (pooled data) are plotted in Fig 22 inorder to bring out the relationship between salinity and gonadal maturation and spawning

4 2 2 2 Station II

Percentage occurrence of the different stages of maturity are given in Table 5

When the investigation commenced during May 1989 80% of the individuals were in spawning stage (R_1 & R_2) About 20% of the

Table 4 Percentage occurrence of developing mature and spawning stages of V cyprinoides at Sation I

Gonadal stages	1989								1990					
	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
Developing (FD_1+FD_2+FD_3 +MD_1+MD_2)	0	7	100	100	40	25	11	0	13	0	0	0	0	5
Mature (FD_4+ MD_3)	0	0	0	0	40	44	89	53	33	60	11	6	0	0
Spawning (FR_1+FR_2+ MR_1+MR_2)	100	93	0	0	20	31	0	47	54	40	89	94	100	95

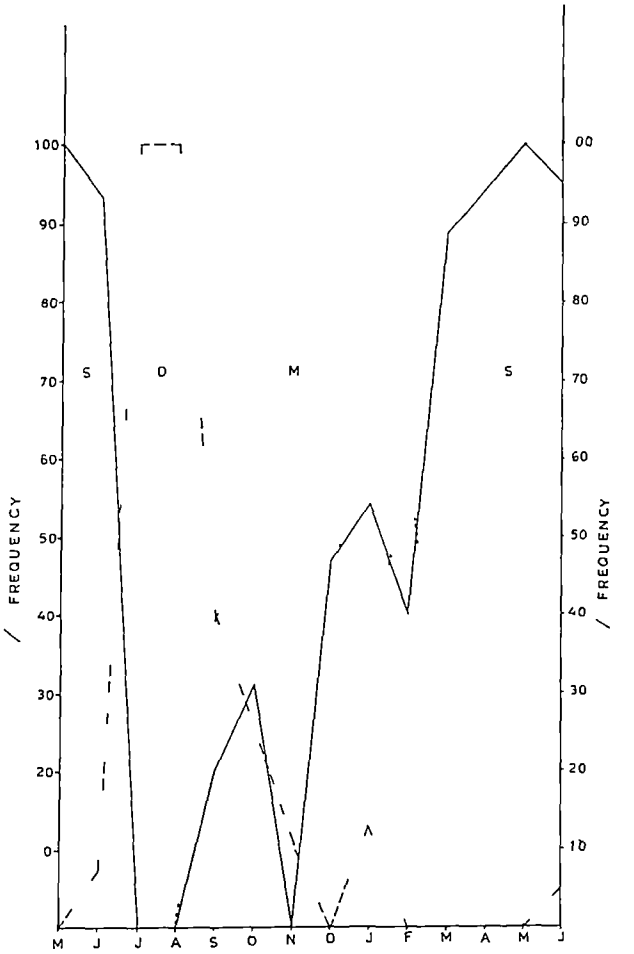

Fig 21 Frequency polygon of developing mature and spawning stages of V cyprinoides at Station I
D - developing stage M mature stage
S - spawning stage

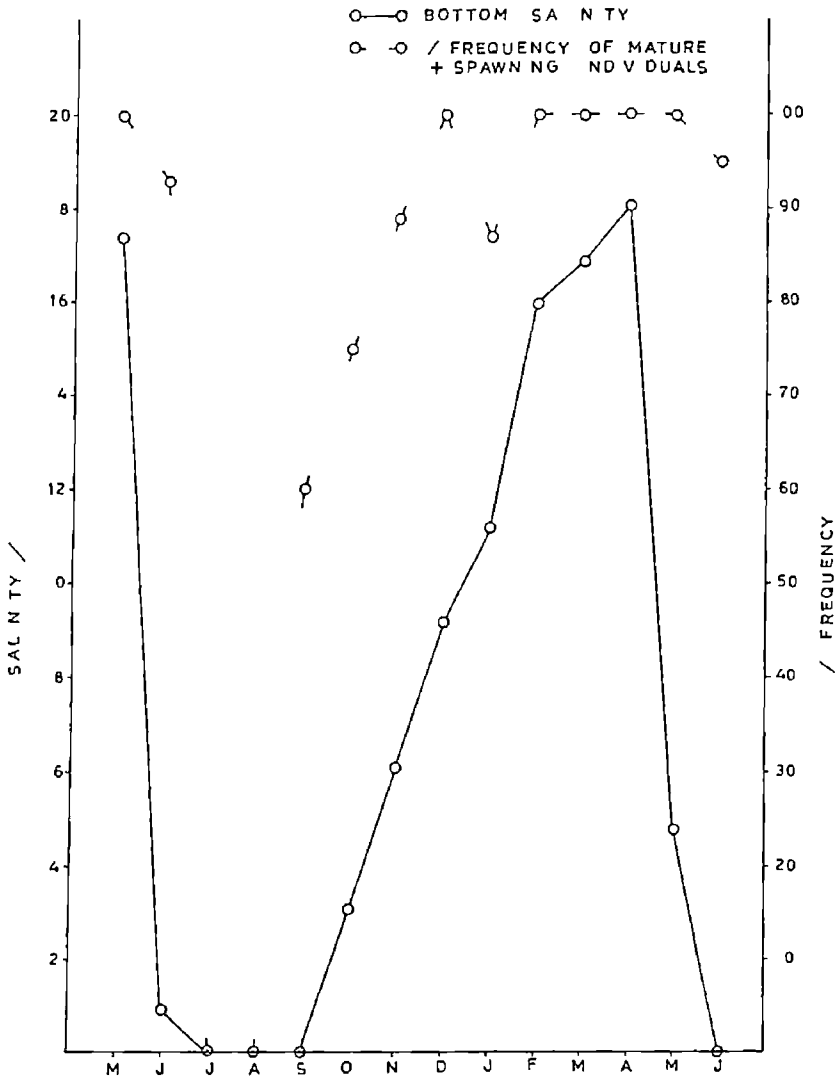

Fig 22 Bottom salinity profile and percentage frequency of mature + spawning individuals Station I

Table 5 Percentage occurrence of maturity stages of V cyprinoides at Sation II

Gonadal stages	1989								1990					
	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
FD_1	20	33	67	19	67	40	53	28	13	7	13	0	0	47
FD_2	0	0	0	0	0	13	13	28	33	20	27	0	0	0
FD_3	0	0	0	0	0	0	0	0	0	20	7	19	0	0
FD_4	0	0	0	0	0	0	0	0	0	13	7	12	0	0
FR_1	7	0	0	0	0	0	0	0	0	0	0	6	7	0
FR_2	27	0	0	0	0	0	0	0	0	0	7	13	20	20
MD_1	0	53	20	81	13	20	14	11	0	0	0	0	0	20
MD_2	0	0	13	0	20	27	20	22	40	7	6	0	0	0
MD_3	0	0	0	0	0	0	0	11	14	33	33	6	40	0
MR_1	20	14	0	0	0	0	0	0	0	0	0	38	33	0
MR_2	26	0	0	0	0	0	0	0	0	0	0	6	0	13

individuals were in early stages of development (FD_1) By the month of June there was an increase in the percentage of developing individuals About 86% of the individuals were in early stages of development (FD_1 & MD_1) From July onwards only developing individuals could be observed upto November Gonadal development was found to be in a quiescent stage during those months No mature individuals could be observed during that period Here also gonadal development commenced little earlier in the males than the females By December 11% of individuals were found to be in mature condition (MD_3 11%) From then onwards the percentage of fully mature individuals (FD_4 & MD_3) increased upto May 1990 Only from March onwards spawning individuals could be noticed The data show that spawning commenced by March and continued upto June 1990 Spawning was found to be well synchronized in both the sexes

The percentage frequencies of the three main stages viz developing mature and spawning are given in Table 6 and represented in a frequency polygon in Figure 23 The table and figure show that the percentage of spawning individuals showed an increase from March onwards and reached the peak values ie 62% and 60% during April and May months respectively and after that the percentage came down to 33% during June 1990 indicating a more or less restricted spawning period from March to June with peak spawning during April and May months

Bottom salinity profile and percentage frequency of mature and spawning individuals (pooled data) are plotted in Fig 24

Table 6 Percentage occurrence of developing mature and spawning stages of *V. cyprinoides* at Station II

Gonadal stages	1989								1990					
	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
Developing ($FD_1+FD_2+FD_3+MD_1+MD_2$)	20	87	100	100	100	100	100	89	87	53	53	19	0	67
Mature (FD_4+MD_3)	0	0	0	0	0	0	0	11	13	47	40	19	40	0
Spawning ($FR_1+FR_2+MR_1+MR_2$)	80	13	0	0	0	0	0	0	0	0	7	62	60	33

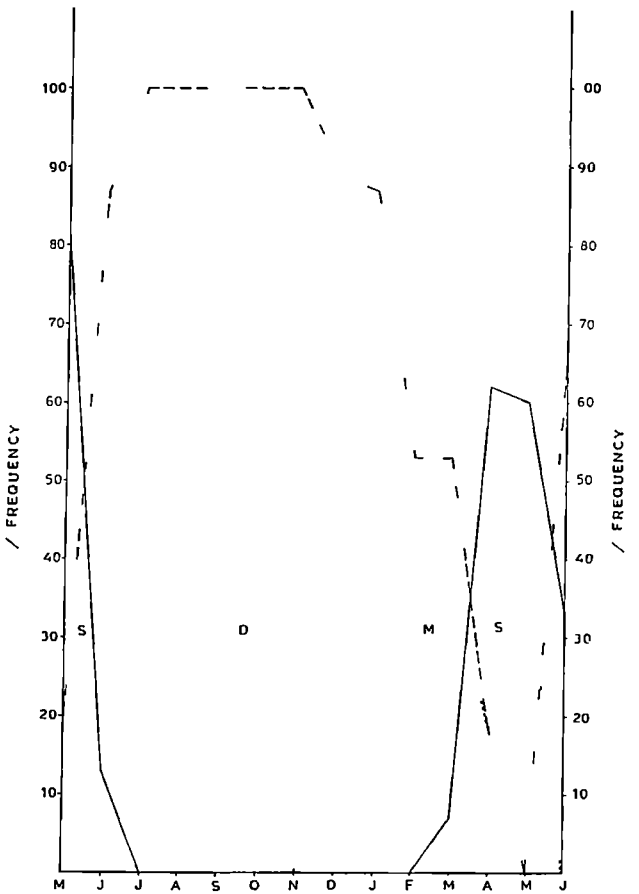

Fig 23 Frequency polygon of developing mature and spawning stages of V cyprinoides at Station II
D developing stage M mature stage
S spawning stage

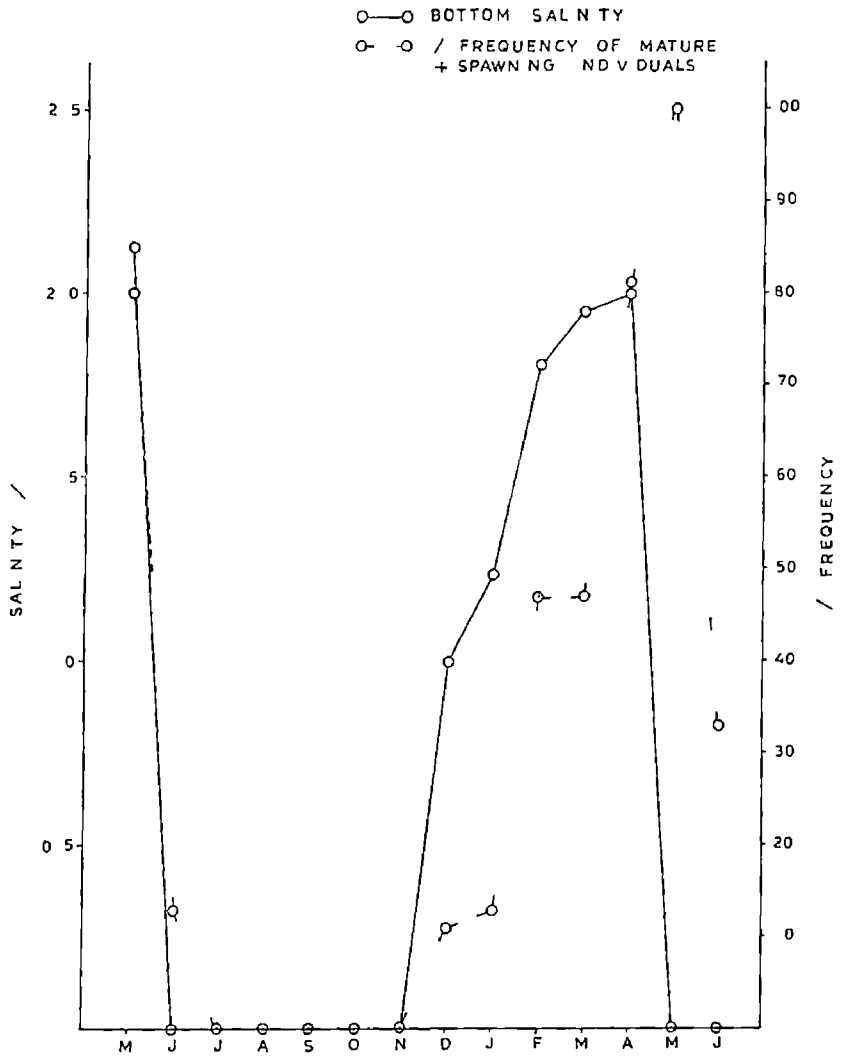

Fig 24 Bottom salinity profile and percentage frequency of mature + spawning individuals - Station II

4 3 Size-Frequency Studies

4 3 1 Station I

Monthly percentage frequency of different size groups are given in Table 7 The clams collected from this station ranged in size from 11 1 mm to 37 2 mm

Table 8 & Figure 25 represent the percentage frequencies of different size groups pooled together stationwise for the entire study period Bulk of the clams (78 47%) collected from station I were in the size range of 14 1 to 24 0 mm The size groups dominating the fishery of this station are 16 1 - 18 0 mm (22 10%) followed by 18 1 - 20 0 mm (21 42%) and 14 1 - 16 0 mm (13 07%) It is clear from the data that clams of size above 30 0 mm are very rare in the collection (1 85%) Another important feature is that 63 4% of the clams collected from this station were below 20 0 mm size

4 3 2 Station II

Table 9 gives the monthly percentage frequencies of different size groups The size of the clams collected from station II ranged from 13 9 mm to 41 2 mm

Bulk of the clams (73 0%) collected from this station were in the size range of 20 1 to 30 0 mm (Table 8 & Figure 25) The dominant size groups constituting fishery of this station is found to be

Table 7 Percentage frequency distribution of different size groups of V cyprinoides at Station I

Size class	1989								1990					
	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
10 1 12 0	0	0	0	)	0	10 71	21 24	3 95	0	0	0	0	0	0
12 1 14 0	0	3 33	8 92	1 27	4 85	12 50	7 08	22 37	0	0	0	0	0	0
14 1 16 0	17 32	31 67	49 68	27 22	9 71	5 36	0 88	14 47	2 56	14 04	0	11 63	0	0
16 1 18 0	33 86	33 33	32 48	46 84	30 10	40 18	7 08	25 66	32 05	14 91	7 84	6 40	1 38	0
18 1 20 0	34 65	25 83	5 10	17 09	44 66	24 32	18 58	17 11	44 87	27 19	15 69	17 44	7 59	2 40
20 1 22 0	10 24	5 83	0 64	1 90	2 91	3 57	0 88	5 92	17 95	18 42	28 43	34 88	34 48	8 80
22 1 24 0	3 94	0	0	0	2 91	0	0 88	1 32	1 28	13 16	10 78	32 56	38 62	28 80
24 1 26 0	0	0	0	0	0 97	0 89	0 88	0	1 28	10 53	12 74	6 98	17 24	30 40
26 1 28 0	0	0	1 91	0 00	2 91	0	31 86	1 32	0	1 75	9 80	0	0 69	24 00
28 1 30 0	0	0	0 64	1 27	0 97	1 79	3 54	1 32	0	0	9 80	0 58	0	5 60
30 1 32 0	0	0	0 64	0 63	0	1 79	3 54	3 9ɔ	0	0	4 90	0	0	0
32 1 34 0	0	0	0	1 90	0	0 89	3 54	1 32	0	0	0	0	0	0
34 1 36 0	0	0	0	0	0	0	0	1 32	0	0	0	0	0	0
36 1 38 0	0	0	1 90	0	0	0	0	0	0	0	0	0	0	0

Table 8 Percentage size-frequency distribution of V cyprinoides at Station I & Station II (May 1989 to June 1990)

Size Class (mm)	Station I	Station II
10 1 - 12 0	2 54	0 00
12 1 - 14 0	4 27	0 06
14 1 - 16 0	13 07	0 75
16 1 - 18 0	22 10	2 23
18 1 - 20 0	21 42	6 57
20 1 - 22 0	12 38	11 19
22 1 - 24 0	9 50	15 25
24 1 - 26 0	5 80	19 55
26 1 - 28 0	5 26	12 80
28 1 - 30 0	1 81	14 21
30 1 - 32 0	1 09	7 01
32 1 - 34 0	0 54	4 73
34 1 - 36 0	0 09	3 75
36 1 - 38 0	0 13	0 94
38 1 - 40 0	0 00	0 59
40 1 - 42 0	0 00	0 38

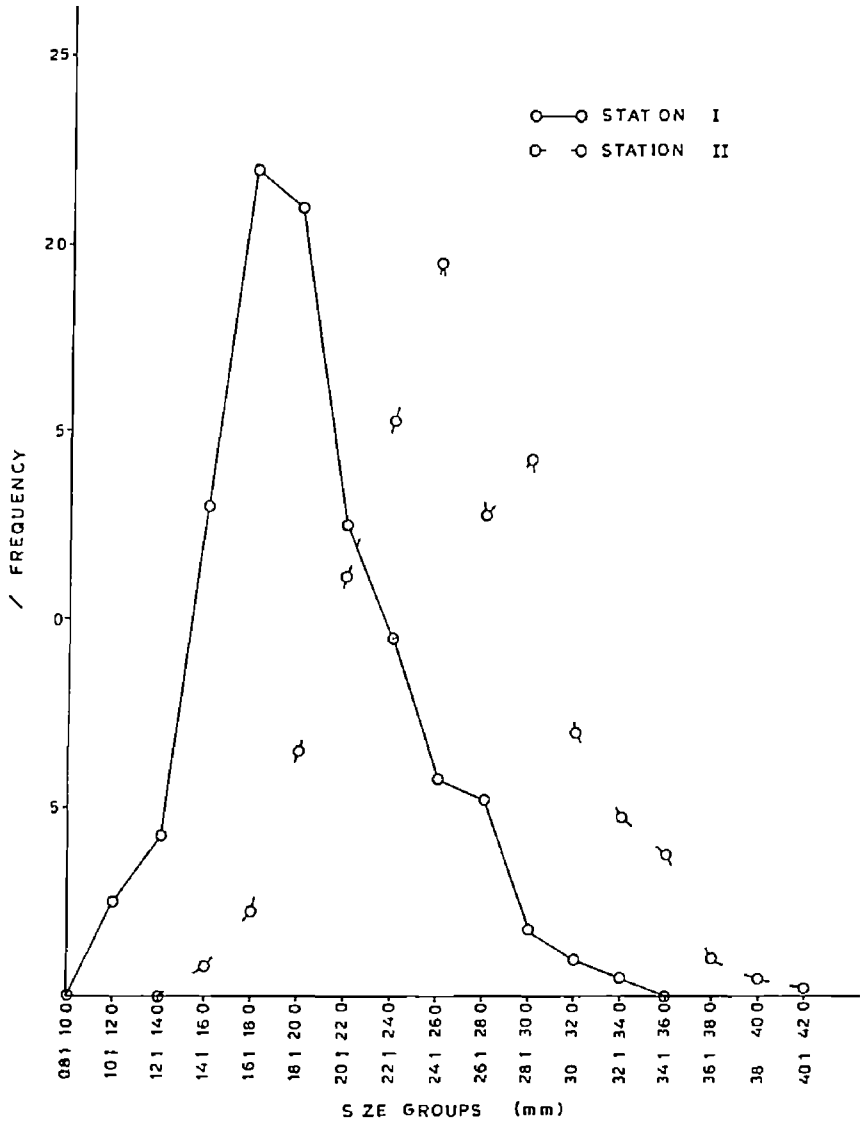

Fig 25 Percentage size-frequency distribution of V cyprinoides at Station I and Station II (May 1989 to June 1990)

Table 9 Percen age frequency dis ribution of different size groups of V cyprinoides at Station II

Size class	1989								1990					
	May	June	July	Aug	Sept	Oc	Nov	Dec	Jan	Feb	Mar	Apr	May	June
10 1 12 0	0	0	0	0	0	0	0	0	0	0		0	0	0
12 1 14 0	0	0	0	0	0	0	0	0	0 84	0	0	0	0	0
14 1 16 0	0	0	6 84	0 79	0	0	0	0	0 84	0	0	1 98	0	0
16 1 18 0	0	0	22 22	0 79	1 80	0	0	0	3 36	0	0	97	0	0
18 1 20 0	0	2 00	31 62	6 35	29 73	0	0	0	10 08	0	0	6 93	1 28	4 00
20 1 22 0	4 00	0	20 51	11 11	42 34	0	0	2 04	25 21	0	0	29 70	7 69	14 00
22 1 24 0	15 33	12 00	15 38	14 29	20 72	14 00	14 71	4 08	21 85	0	6 25	30 69	23 08	31 00
24 1 26 0	36 00	31 00	3 42	18 25	1 50	7 00	26 47	12 24	21 85	? 36	18 75	19 80	35 90	36 00
26 1 28 0	20 00	20 00	0	16 67	0 90	10 00	17 65	28 57	11 76	7 09	12 50	5 94	23 08	5 00
28 1 30 0	19 33	22 00	0	11 90	0	10 00	35 29	36 73	2 52	11 81	31 25	0 99	8 97	8 00
30 1 32 0	4 67	9 00	0	11 90	0	18 00	2 94	14 29	0 84	18 90	15 63	0 99	0	1 00
32 1 34 0	0 67	4 00	0	7 14	0	18 00	0	2 04	0 84	26 77	6 25	0	0	1 00
34 1 36 0	0	0	0	0 79	0	21 00	0	0	0	21 26	9 38	0	0	0
36 1 38 0	0	0	0	0	0	6 00	0	0	0	7 09	0	0	0	0
38 1 40 0	0	0	0	0	0	3 00	2 94	0	0	2 36	0	0	0	0
40 1 42 0	0	0	0	0	0	3 00	0	0	0	2 36	0	0	0	0

24 1 - 26 0 mm (19 55%) followed by 22 1 - 24 0 mm (15 25%) and 28 1 - 30 0 mm (14 21%) Clams above 30 0 mm size are more at this station (17 40%) compared to Station I (1 85%) But clams of size below 20 0 mm were very less at this station (9 61%) compared to Station I (63 40°)

DISCUSSION

V. DISCUSSION

5 1 Environmental Parameters

5 1 1 Salinity

The pattern of salinity distribution of the lake is closely associated with the freshwater inflow and the tidal influx (Josanto 1971)

Station I is having pronounced seasonal changes in salinity The effect of monsoon can be easily seen from the decreased salinity gradient during June to September During this period the influence of sea water is negligible and the station shows freshwater condition It may be mentioned here that during late September though salinity showed nil value dissolved oxygen pH and temperature showed changes commensurate with postmonsoon condition showing a discrepancy in the correlation between these factors This points towards the need for more frequent sampling for hydrographical parameters during periods of rapid fluxes like the beginning and end of monsoons During the postmonsoon period (October to January) salinity values show an upward trend During the premonsoon months (February to May) maximum influx of sea water into the backwater takes place and the station shows high salinity values (> 16 0‰ during May 1989 and February to April 1990)

Since Station II is on the southernmost part of the Vembanad Lake the tidal influx is very low Owing to the closure of the shutters

of the Thanneermul kam barrier the sea water influx is checked during the major part of the year The station showed freshwater condition during June to November From December onwards there was a slight increase in salinity and the maximum values were recorded during the premonsoon period (2 12‰ in May 1989 2 0‰ in April 1990)

The effect of monsoon and seawater influx of the salinity distribution of the lake was well demonstrated in the reports of Josanto (1971) Haridas et al (1973) Pillai et al (1975) Silas & Pillai (1975) and Antony & Kuttyamma (1983)

Prior to commissioning of the Thanneermukkam barrier a study conducted by Josanto (1971) reported bottom salinity values of 10 84‰ during the dry season (March 1970) and less than 0 16‰ during the freshwater season (October 1970) from Punnamada region (Alleppey) Haridas et al (1973) found that during the premonsoon months (January to April) the surface salinity varied between 2 5 and 13 0‰ with a mean value of 8 0‰ and the bottom salinity ranged between 3 9 and 13 0‰ with a mean of 8 5‰ in this area

The present study shows that at Station II during the premonsoon season the salinity values reach only upto 2 12‰ for the bottom and 1 86‰ for the surface waters indicating the influence of the Thanneermukkam barrier on the salinity condition of the southern sector of the lake

5 1 2 Temperature

The temperature values for the entire period of observation from both the stations reflect to a certain extent the climatic conditions During the monsoon period comparatively lower values are recorded for both bottom and surface waters after which the values gradually increase during the postmonsoon season and reach maximum values during the premonsoon period Similar observations were made by Haridas et al 1973 Pillai et al 1975 Silas & Pillai 1975 and the CWBSP 1989

5 1 3 Dissolved Oxygen

Dissolved oxygen values show a seasonal pattern of variation in the two stations Highest values are recorded during the monsoon months June to August Haridas et al (1973) also made a similar observation Subsequently there is a sudden fall in dissolved oxygen values in both stations during September At Station I this is followed by an increase in dissolved oxygen and the levels show low magnitude fluctuations thereafter (between 2 4 ml/l and 3 2 ml/l in bottom waters and 2 6 ml/l and 3 5 ml/l in surface waters) At Station II dissolved oxygen levels show more fluctuations during the postmonsoon period from October to April reaching high levels during November March and May intermittent with low levels

5 1 4 pH

The extent of fluctuations in pH values is small (6 0 to 7 5) in both the stations This is comparable to the observations made by Silas & Pillai (1975) and the K W B S P (1989) At Station I the lowest values are recorded during monsoon From September to May the values show minimum fluctuations around 7 excepting a small peak in February for the bottom waters and a dip in January for the surface waters At Station II apart from monsoon months low pH values are also recorded during December Peak values are obtained during September From January to May the pH show minimum fluctuation around 7

Among the four environmental parameters studied salinity and temperature showed a regular annual cycle in both the stations whereas dissolved oxygen and pH showed irregular fluctuations And also the levels of temperature dissolved oxygen and pH showed a comparable pattern of variation in Station I and Station II But the pattern of salinity variations showed great difference between the two stations So it may be reasonably concluded that among the four different environmental parameters considered in the present study variation in salinity might have influenced the difference in the gonadal maturation and spawning

5 2 Reproductive Biology

The present study reveals that at Station I (northern sector) Villorita cyprinoides has a protracted breeding season from September to June with peak spawning during March to June At Station II (southern sector) the species has a short duration spawning season from March to June with peak spawning activity during April and May

A detailed observation on the gametogenic activity of Villorita cyprinoides from the two selected stations reveals that the gonadal recrudescent activity in both the population commenced by June and July at a slow rate Histological studies show that in this species gametogenesis commence little earlier in males than the females A similar condition is also reported in Crassostrea madrasensis (Stephen 1980) and Mytilus viridis (Nagabhushanam & Mane 1975 a) But in C madrasensis Stephen (1980) found that spawning commenced earlier in the males and concluded later than the females In the present study it is found that spawning is well synchronized in both the sexes as observed by Nagabhushanam & Mane (1975 a) in Mytilus viridis At Station I the data show that in late September there is an immediate advancement of gametogenic activity resulting in the initiation of spawning Increased spawning activity is noticed during the succeeding months correlating with increase in salinity which extended upto June with peak spawning during March to June (Fig 22) The break in spawning activity coincides with the freshwater phase (July and August)

At Station II the data show that gametogenesis is at the initial stage during late June From June to November the gonads remain quiescent in the developing stages (Table 6 & Figure 23) This period correlates with the freshwater phase (0 0‰ salinity) During December as the salinity shows a slight increase from 0 0 to 1 0‰ a few of the individuals show further development with 11% reaching gonadal maturity From then onwards the percentage of mature individuals show a gradual increase correlating well with the increase in salinity Spawning is observed to commence by late March with the bottom salinity at 1 9‰ and is extended upto June with peak activity during April and May (Fig 24)

These findings are in contrast with the findings of Nair & Shynamma (1975 b) According to them the clam Villorita cyprinoides var cochinensis inhabiting Cochin backwaters spawns twice a year The primary spawning occurs during the monsoon period from late May to August/September and the secondary spawning takes place from January to late March Primary spawning occurs when the salinity and temperature are reduced considerably But Rasalam and Sebastian (1976) reported that V cyprinoides var cochinensis breeds in the Vembanad Lake from January to July when the salinity is higher in the lake Reddy (1983) reported that in Villorita cyprinoides inhabiting Nethravathi estuary (where the salinity ranged from 0 0 to 13 25‰ during the study period) spawning commenced during January and extended to early April Increase in salinity and temperature soon after the monsoon season appeared to promote gametogenesis and initiate spawning He also found that gametogenesis progressed in Villorita cyprinoides

along with increasing salinity and spawning started subsequently The present study is thus in broad agreement with Reddy (1983) on the role of salinity on gonad development and spa ning Regarding the role of temperature the present study shows that temperature alone is not having a primary influence on gametogenesis since at Station II increase in temperature after the monsoon did not produce any change in the gonadal condition Thus salinity appears to be the primary environmental factor which influences gametogenesis and spawning in Villorita cyprinoides However in both the stations the period of peak spa ning activity was during the pre-monsoon period coinciding with high values in temperature (> 30 0°C) also

Environmental parameters especially salinity and temperature have a regulatory role in the reproduction of bivalves of shallow marine areas and estuaries (see below) Under temperate conditions variations in temperature have been recognised as the main stimulus for maturation and spawning (Loosanoff 1937 Lossanoff & Davis 1952) Chipperfield (1953) observed that in Mytilus edulis from British coast rapid spawning was due to rapid rise in temperature Tranter (1958) reported that in Pinctada albina most active breeding occurs alongwith fall in sea temperature Ansell (1961) observed that spawning in Venus stratula could be induced by rise of temperature or stimulation by sexual products In Aequipecten irradians Sastry (1966) observed that gametogenesis could be initiated by an increasing temperature Bayne (1975) found that in Mytilus edulis also increased temperature induced spawning Butler (1949) observed inhibition of gametogenesis in Ostrea virginica inhabiting low salinity area

Under tropical conditions of Indian coasts water temperature does not fall below the optimum requirement of many molluscs and is relatively stable (Durve 1964) Taking into consideration this fact he suggested that temperature may not influence the spawning of marine and estuarine bivalves of Indian waters He found salinity to be the most important factor influencing the breeding cycles of tropical marine and estuarine bivalves

Abraham (1953) found that low salinity induced spawning in Meretrix casta in Adayar estuary He also reported that the period of active spawning varies slightly from year to year in the same environment due to the inconsistency in the onset and duration of rainy season which controls the salinity Durve (1965) reported that in Crassostrea gryphoides lowering of salinity due to monsoon acts as the main stimulus for spawning A similar observation was also made by Alagarswami (1966) on Donax faba from Mandapam coast In Crassostrea madrasensis inhabiting Mulki estuary Stephen (1980) found the major spawning activity to be associated with sudden decrease in salinity He also reported a gametogenically inactive phase occurring during the low saline period and a minor spawning during rising salinity period Lowering of salinity inducing spawning was also observed in Mytilus viridis by Nagabhushanam & Mane (1975 a)

Increased salinity is found to induce spawning in many bivalves as in the case of Donax cuneatus (Rao 1957) Katelysia opima (Nagabhushanam & Mane 1975 b) Paphia laterisulcata (Nagabhushanam & Dhamne 1977) Donax cuneatus (Nagabhushanam & Talikhedkar 1977)

and Anadara rhombea (Narasimham 1988) According to Joseph and Madhyastha (1982) gametogenesis in Crassostrea madrasensis commenced with increase in salinity In Villorita cyprinoides (Reddy 1983) and Anadara rhombea (Natarajan & John 1983) increased salinity induced spawning Jayabal & Kalyani (1986) reported that Meretrix meretrix Meretrix casta & Katelysia opima in the Vellar estuary preferred moderate salinity 23-29 ‰ for spawning According to Kattıcaran (1988) the spawning in Sunetta scripta was associated with high and relatively stable salinity

The spawning periodicity of bivalves inhabiting temperature and tropical waters has been extensively studied Some of these studies have shown that bivalves of the temperate waters such as Venus mercenaria (Loosanoff 1937) Ostrea virginica (Butler 1949) Crassostrea virginica (Loosanoff & Davis 1952) Mytilus edulis (Chipperfield 1953) Cyprina islandica (Loosanoff 1962) Aequipecten irradians (Sastry 1966) and Mytilus edulis (Bayne 1975) have more or less well defined short duration spawning periods

From Indian waters works on estuarine and marine bivalves have shown that the various species fall into different categories ranging from the ones having a restricted spawning season to those breeding more or less continuously throughout the year

Rao (1951 a) reported a single but restricted spawning season for Katelysia opima According to Nayar (1955) Rao (1967) and

Nagabhushanam & Talil hedkar (1977) Donax cuneatus also has a restricted spawning season A similar observation was also made for Crassostrea gryphoides by Durve (1965)

For Meretrix casta Hornell (1921) reported two spawning periods one during April to May and the other during September Salih (1973) also found two spawning periods for the same species inhabiting the Cochin barmouth Katelysia opima (Nagabhushanam & Mane 1975 b) Mytilus viridis (Nagabhushanam & Mane 1975 a) Villorita cyprinoides var cochinensis (Nair & Synamma 1975 b) and Crassostrea madrasensis (Stephen 1980 Rajapandian & Rajan 1983) also breed twice during the year

Some other bivalves exhibited a protracted breeding season Meretrix meretrix breeds all round the year except during monsoon (Rai 1932) A protracted breeding season is also reported for Meretrix casta (Durve 1964) Donax faba (Alagarswami 1966) Paphia laterisulcata (Nagabhushanam & Dhamne 1977) Villorita cyprinoides (Reddy 1983) Anadara rhombea (Natarajan & John 1983) and Donax incarnatus (Thippeswamy 1985)

Regionwise intraspecific variations in the annual reproductive cycles have been reported for clams (Nagabhushanam & Mane 1975 b) Meretrix casta of the Madras coast and Cochin barmouth spawn twice in an year (Hornell 1921 and Salih 1973) whereas Meretrix casta of Adayar estuary and Mandapam has a protracted spawning season

(Abraham 1953 Durve 1964) Rao (1951 b) in Ostrea madrasensis observed continuous breeding under marine environment and discontinuous breeding under estuarine environment showing the effect of salinity on the breeding activity of oysters Donax cuneatus from Madras coast and Palk Bay has only one reproductive cycle although in the former locality breeding is relatively much longer (Nayar 1955) Hatelysia opima breeds only once in Adayar estuary (Rao 1951 a) whereas on the west coast they spawn twice in a year (Nagabhushanam & Mane 1975 b) In the present study Villorita cyprinoides populations inhabiting the two diverse salinity zones in the Vembanad Lake show differences in their reproductive cycles exhibiting regionwise intraspecific variations In the northern sector retaining the estuarine conditions the clam has a protracted almost year round spawning season (September to June) while in the southern sector a predominantly freshwater zone the clam has a short duration spawning season (March to June) Probably its ability to colonize high saline areas is significantly related to reproductive adaptation in the form of protracted spawning in addition to physiological salinity tolerance

5 3 Size Frequency Studies

On observing the size-frequency distribution it is clear that Station II is dominated by larger size groups compared to Station I At Station II bulk of the clams (73 0%) collected were in the size range of 20 1 to 30 0 mm (dominant size class 24 1 to 26 0 mm) At Station I bulk of the clams (78 47%) collected were in the size

range of 14 1 to 24 0 mm (dominant size class - 16 1 to 18 0 mm)

Since Station II having freshwater condition during greater part of the year is dominated by larger size groups it may be inferred that a low saline condition is favourable for better growth of the species These findings support the observations of Hornell (1921) in that Villorita cyprinoides is a purely freshwater species and that its presence in brackishwater conditions indicate a marked change in its habitat and a re-acquired tolerance for salinity conditions Kurup et al (1989) also found that larger size groups flourished in the low saline areas of the lake He reported that the modal size group constituting fishery of the southern sector (Thanneermukkam to Alleppey) was 20-24 mm in contrast to 15-19 mm in the northern sector (Cochin to Thanneermul kam) of the lake

Observation on the reproductive biology of the species from the two selected stations also corroborate the above observations Since at Station I the species is having a protracted spawning season (September to June) more energy may be diverted for the reproductive purpose So only less energy is available for somatic growth (Adiyodi & Subramoniam 1983) and this may be the reason for the dominance of smaller sized clams in this station But at Station II the species is having a restricted breeding season (March to June) with a prolonged quiescent period in gonadal development (July to November) During this period the energy expenditure for reproductive purpose is minimum So more energy is available for somatic growth and this may be the reason for the dominance of larger sized clams in the station

Rasalam & Sebastian (1976) mentioned the problem of overfishing and exploitation of undersized clams existing in the Vembanad Lake They also suggested that a strict enforcement of Kerala lime shells (Control) Act was essential for prohibiting the exploitation of clams below 19 mm size Kurup et al (1989) found that the overall decline in the clam production of Vembanad Lake was due to the decline in the landings of the northern sector and that the commissioning of the Thanneermukkam barrier has brought about no marked adverse effect on the black clam resources in the southern sector of the lake They also found that the increased fishing pressure and the exploitation of undersized clams might have contributed to the declining trend in the northern sector The present study also support the finding that exploitation of undersized clams is very high in the northern sector 63 4% of the clams collected from Station I (northern sector) were below 20 0 mm size whereas only 9 61% of the clams collected from Station II (southern sector) were below 20 0 mm size Thus apart from increased fishing pressure and indiscriminate exploitation (Kurup et al 1989) in the light of the reproductive biological data obtained from the present study it appears that the protracted spawning and resultant diversion of energy away from somatic growth might have resulted in the dominance of smaller sized clams in the northern sector Growth studies are necessary for further confirmation

In conclusion it may be noted that Station II in the southern sector has provided ecological condition similar to the homeground of the species The annual reproductive cylce appears to be perfectly

tuned to the slow increase in salinity and later also temperature culminating in a short term spawning period (March to June) There apppears to be a well balanced sharings of energy for reproduction and growth resulting in dominance of large sized clams at Station II compared to that at Station I

At Station I the clams acquire maturity and spawning during September and the spawning activity is extended throughout the post monsoon period attaining peak spawning during pre monsoon period This is correlated with increase in salinity and temperature Hence this population appears to be diverting a larger portion of energy for reproduction which may be the reason for dominance of small sized clams in the population in comparison to that at Station II It may be concluded that the population expansion into the saline zone of the lake is achieved through enhanced reproductive activity and the survival of those young ones which have more resistance to salinity

SUMMARY

VI. SUMMARY

1 The objectives of the study were to understand the process of gametogenesis and spawning in Villorita cyprinoides (Gray) inhabiting two different ecological zones of the Vembanad Lake with reference to salinity fluctuations and also to understand differences in the size groups constituting the fishery

2 Two stations one on either side of the Thanneermukkam barrier with perennial clam beds were selected for sampling Station I located in the northern sector region between Cochin and Thanneermukkam and Station II located in the southern sector between Thanneermukkam and Alleppey

3 Environmental parameters such as salinity temperature dissolved oxygen and pH of the bottom and surface waters of the two selected stations were analysed between May 1989 and June 1990 on a monthly basis

4 The simultaneous assessment of these environmental parameters helped in making a comparison of the two stations

5 At Station I the salinity values ranged between 0 0 and 18 12‰ for the bottom waters and 0 0 and 17 0‰ for the surface waters Temperature values fluctuated between 27 5°C and 32 5°C for the bottom and 28 0°C and 33 0°C for the surface waters It was also

observed that dissolved oxygen values ranged between 2 0 ml/l and 5 0 ml/l for the bottom and 2 1 ml/l and 5 4 ml/l for the surface waters pH values fluctuated within 6 0 and 7 5 for the bottom and 6 02 and 7 18 for the surface waters

6 At Station II the salinity values fluctuated between 0 0 and 2 12‰ for the bottom and 0 0 and 1 86‰ for the surface waters Temperature values ranged between 27 5°C and 32 5°C for the bottom and 28 0°C and 32 8°C for the surface waters Dissolved oxygen values fluctuated between 2 3 ml/l and 6 2 ml/l for the bottom and 2 4 ml/l and 6 8 ml/l for the surface waters pH values ranged between 6 00 and 7 38 for the bottom and 6 12 and 7 50 for the surface waters

7 The present study also showed that the onset of monsoon is accompanied by a sudden decrease in salinity pH and temperature and an increase in dissolved oxygen While the temperature and salinity showed steady increase during the post monsoon and premonsoon seasons dissolved oxygen and pH showed further fluctuations during these periods

8 Among the four environmental parameters observed maximum seasonal fluctuations were noticed in the case of salinity It also showed variations between the two stations Further the duration of the freshwater phase showed variation in the two stations at Station I it extended from June to September and at Station II from June to November

9 Gonadal tissue from 15 clams each selected at random from each station on a monthly basis were processed using standard histological techniques in the study of reproductive biology during the period May 1989 to June 1990

10 The scheme of classification given by Joseph & Madhyastha (1982) was adapted for the classification of the maturity stages In males five maturiy stages and in females six maturity stages were identified

11 In both the stations gonadal recrudescence was observed by late June At Station I by September the gonads attained maturity followed by spawning in September But at Station II the gonadal development was quiescent for about five months At both the stations it was found that in the males gondal development commenced slightly earlier than in females although spawning in both sexes was well syncronized

12 At Station I the species was found to have a protracted spawning season from September to June with peak activity during March to June But at Station II the species showed a short duration spawning season from March to June with peak spawning during April and May

13 While there existed a positive correlation between the bottom salinity values and the gonadal maturation and spawning temperature appeared to have only a minor role as a spawning cue

14 For size-frequency studies the largest antero posterior measurement was taken as length and the data were arranged in size

groups of 2 mm interval Percentage frequencies for the various size groups for the different months were pooled for the entire study period inorder to get an idea on the size group dominating the fishery

15 At Station I smaller sized clams dominated the collection compared to Station II The size group dominating the fishery of Station I was 16 1 - 18 0 mm whereas that of Station II was 24 1 - 26 0 mm About 63 4% of the clams collected from Station I were below 20 0 mm size as against 9 61% at Station II Also clams above 30 0 mm size were very rare representing only 1 85% of the collections at Station I but at Station II 17 4% of the collections were above 30 0 mm size

16 The above mentioned data is suggestive of a correlation between a predominantly brackishwater condition with moderate salinity and a protracted period of spawning in the species Villorita cyprinoides at Station I Diversion of energy resources to reproduction has probably unfavourably affected somatic growth resulting in abundance of smaller sized animals at this station In contrast at Station II there seems to exist a correlation between a predominantly freshwater condition with low salinity and restricted spawning season This is conducive to increased growth resulting in dominance of large sized clams at Station II Thus the Thanneermukkam barrier has provided an experimental condition in the lake to understand the relationship between salinity variations breeding biology and growth in Villorita cyprinoides

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BREEDING BIOLOGY OF *VILLORITA CYPRINOIDES* (GRAY) IN RELATION TO SALINITY GRADIENTS

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VIII. ABSTRACT

The present study was undertaken to investigate the influence of salinity variations on the breeding biology of populations of black clam Villorita cyprinoides (Gray) inhabiting two different ecological zones of the Vembanad Lake Two stations with perennial clam beds but differing greatly in salinity conditions were selected for the study Station I in the northern side of Thanneermukkam barrier has more influx of sea water and Station II in the southern side has low saline influx Monthly collections of black clams and bottom and surface waters were made from May 1989 to June 1990 Major environmental parameters such as salinity temperature dissolved oxygen and pH of bottom and surface waters were estimated with a view to understand the circannual variations within and between the stations Among these salinity was found to be the most important parameter showing prominant variations At Station I the bottom salinity values ranged from 0 0 to 18 12‰ and in Station II from 0 0 to 2 12‰

Histological studies of the clams collected from the two stations revealed that animals inhabiting Station I a predominantly brackishwater zone have a protracted almost year round breeding season extending from September to June with peak spawning during March to June and coinciding with the peak salinity levels and temperature At Station II a predominantly freshwater zone the clams have a short duration spawning season extending from March to June with peak spawning during April and May again coinciding with the

peak salinity levels and temperature It is also observed that there exists a positive correlation between the bottom salinity and gondal maturation and spawning

Size-frequency studies of the clams collected from the two stations revealed that at Station I the clam fishery was dominated by small sized animals when compared to Station II This may be related to the differences observed in the extend of spa ning activity between the population of the two stations resulting in the divergent apportio ment of energy resource for somatic growth versus reproduction