STUDIES ON THE INTERSTITIAL SALINITY AND RELATED ENVIRONMENTAL PARAMETERS OF CERTAIN SELECTED BRACKISH WATER PRAWN CULTURE ECOSYSTEMS

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CERTIFICATE

This is to certify that this dissertation is a bonafide record of work carried out by Shri D. Sathyajith under my supervision and that no part thereof has been presented before for any other degree.

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PREFACE

There has been an increasing demand for Indian shrimps in the domestic as well as foreign markets as a supplementary source of protein and as a favoured food item. But this demand is not fully met by the produce from the presently exploited regions of the sea around India, which of late shows a stagnation in production levels. This is a result of increased exploitation without judicial management. Hence the present trend is to develop aquaculture as a means of augmenting the shrimp production to meet the demand.

The necessity to culture shrimps to meet the demand in domestic and foreign markets requires a thorough knowledge of their biology and ecological preferences to make farming more efficient.

The soil substratum plays an important role in prawn culture systems particularly in its productivity as a major source for nutrients and acts as the immediate surrounding environment for the burrowing prawns. The interstitial water found in the spaces between the soil particles is an integral part of this substratum and plays a vital role in culture systems.

As elsewhere along the Kerala coast also, juvenile penaeid prawns are found to inhabit low saline water bodies and are cultured mainly in ponds, coconut groves and mangrove areas. During the south-west monsoon the salinity of the column water in these systems decreases to almost freshwater ranges, and prawns are found to survive even in these unfavourable low saline conditions. This could be due to the comparatively higher range of salinity and a desired level of nutrients of the interstitial waters.

Though a lot of studies have been carried out on the sediments of culture system, very little work has been done to study the chemical nature of the interstitial water of culture systems. The present study aims at analysing the salinity and related environmental and chemical parameters of certain prawn culture systems. The inappropriateness of the various samplers used in earlier studies on interstitial water of other systems necessitated the fabrication of a distinctly different indigenous sampler for the sampling of interstitial water for the present work. An attempt has also been made to study the growth of the penaeid prawn P. indicus in relation to the varying salinity in the column water and upper layer of the interstitial water.

I express my gratitude to my research supervisor Shri.P.E.Sampson Manickam, Senior Scientist, Central Marine Fisheries Research Institute for his valuable guidance and support throughout my study. I express my sincere thanks to Dr. P.S.B.R.James, Director CMFRI for his keen interest and encouragement in my study. I am extremely grateful to Dr. V. Kunjukrishna Pillai and Dr. Vedavyasa Rao, Senior Scientists for their valuable suggestions. My thanks are due to Dr. Manpal Kaur, Sanhotra, Dr. K.J. Mathew, Dr. K.R.Manmathan Nair and Dr.V.Girija Vallabhan for their timely help during my dissertation. I am grateful to Shri.T.V.Sathianandan for helping me to statistically analyse my data. Dr. M.M. Thomas

OIC, Krishi Vigyan Kendra, Narakkal) was very helpful in setting up my experiment in the culture pond at KVK. I also thank Dr. Lakshmi Narayan (OIC, CIBA), who allowed me to use the equipment at CIBA, Narakkal for the scientific analysis of my samples. The timely assistance of Shri. Nandakumar and Shri. Aboobaker, Technical Assistants, helped me in my sample analysis. My sincere thanks to my friends Imelda Joseph, Jaideep Kumar, Rathnakala, Shanth Begum, Shoba Viswanathan and each of my classmates for their help and companionship throughout the period of study. I am also thankful to ICAR, for offering me the Junior Research Fellowship.

INTRODUCTION

Prawns play a dominant role in India's seafood export trade. In 89-90 it constituted 52% by volume and 72% by value (Ganapathy, 1991). Although there is an increasing demand for this product in the international market such as Japan, USA, Europe etc. we are unable to increase our shrimp export due to stagnation in our shrimp production from the wild. This and the sudden spurt in shrimp production through farming from a few tropical countries in Asia and Latin America, has resulted in our position among shrimp producing and exporting countries, being pushed down from the first to the third and fourth places in major markets (Ganapathy, 1991). The importance of prawn in earning valuable foreign exchange has necessitated the development of prawn farming practices to augment the produce from the sea.

To make the prawn culture practices more successful and flawless a thorough knowledge about the biology and ecological preferences of the cultured organism is essential. In India currently, the two species of penaeid prawns which are preferred widely for culture are *Penaeus monodon* and *P. indicus*. Of these *P. indicus* is distributed abundantly along the east and west coast of India (Kurian & Sebastian, 1976). In Kerala, which accounted for 36% of Indian Prawn production 1966-70) and 6% of world (1966-70) (of which *P. indicus* formed sizeable portion) (Kurian & Sebastian, 1976), the juvenile prawns are found inhabiting mainly the back waters which are the nursery grounds of these species and are cultured in mangroves, coconut groves and culture ponds. It is seen that the prawns survive and grow well in these ecosystems even during the south-west monsoon when the column water salinity drops very low (0.5 ppt). According to Hindley (1975) most penaeids are nocturnal and they burrow or remain inactive during the day. Hence it could be the burrowing substratum that affords these prawns a comparatively better range of environmental parameters particularly salinity that helps them to survive and grow. The interstititial fluids form a significant component of sediments - upto 90% (w/w) (Malcolm and Stanley, 1982). It is under these contexts that the present work was undertaken to study the interstitial salinity and related parameters, comparing them with the same parameters of the column water.

"Interstitial" is defined in the dictionary as that occurring in the small spaces between closely set substances. In the present context 'Interstitial Water' refers to that water found in the interstices of the soil. This water though in direct contact with the overlying column water in culture systems is by itself a distinct entity with a different chemical composition.

Though the interstitial water has been worked on by many researchers there has been very little work towards understanding the nature and characteristics of interstitial water in culture systems. The sampling procedure adopted by the earlier workers in interstitial water studies have varied widely depending on their varying objectives.

Peenak (1940) deviced one of the earliest devices to collect water samples from 4 cm depth from sandy beaches. It consisted of a volumetric pipette with a coarse bolting silk fastened to one end to prevent the entry of sand and debris. A suction force exerted at the other end helped to collect water in the device.

Ganapathy and Rao (1962) used the same apparatus in their study on the ecology of the interstitial fauna of sandy beaches for sampling interstitial water upto a depth of 15 cm. They studied the variation of salinity, temperature and pH in comparison with the overlying water.

Weiler (1973) used a gravity corer (Benthos model 2170) to obtain sediment samples from which the interstitial water was squeezed out at room temperature with Helium or Nitrogen as the pressurizing gas. This was done during his study on the interstitial water composition of sediments of lakes. He sampled the water upto a depth of 40 cm.

Hesslein (1976) and Mayer (1976) were among the first to introduce 'in situ' sampling of interstitial water by dialysis. This method was analysed and improvised by , . Carignan (1984) mentioning the advantages and disadvantages of the use of various membrane types like cellulose based membranes and poly-carbonate.

Squeezing out the interstitial fluids with stainless steel squeezers is the popular method of its extraction in deep sea drilling projects according to Gieskes (1983).

Collection of interstitial water using a "pneumopress" by wringing of oceanic sediments was done by Kosov (1983).

Centrifugation was used as a method of extraction of interstitial water from coarse, sandy sediments of porosity (upto 31%) using polyethylene centrifuge tubes by Saager et al. (1990).

The nitrate profiles in interstitial waters were studied by Bender et al (1977). Nitrate in interstitial waters were also studied by Malcolm and Stanley (1982). They described the interstitial waters as a relatively enriched medium into which most of the chemically labile and biologically important compounds and elements are mobilized during diagenesis and it exerts an important control on the dominant bacterial activities present in sediments.

pH, nitrites and nitrates of the interstitial environment of bivalve habitats in several Northern German low lands were studied by Buddensiek et al. (1990).

The present investigation comprises a study and comparison of the salinity, temperature, pH nitrate and nitrite in the interstitial water and the overlying column waters. The interstitial water was sampled from 5 different depths (i) 0-5 cm (ii) 5-10 cm (iii) 10-15 cm (iv) 15-20 cm (v) 20-25 cm using a specially designed interstitial water sampler. The samples were collected in a 60 day period over the months of August and September 1992, at 5 day intervals from 3 ecosystems - a mangrove site in Puduvyppu, a coconut grove in Narakkal and a culture pond at Krishi vigyan kendra, Narakkal. All the above collection sites are situated on Vypeen island, near Cochin. At the culture pond alone simultaneously, growth studies were conducted on Penaeus indicus by growing the juveniles in one square metre pens errected at 4 corner stations in which they were grown for a 60 day period with an objective to study the effect of the various hydrologial parameters of the column water and interstitial water on its growth.

MATERIALS AND METHODS

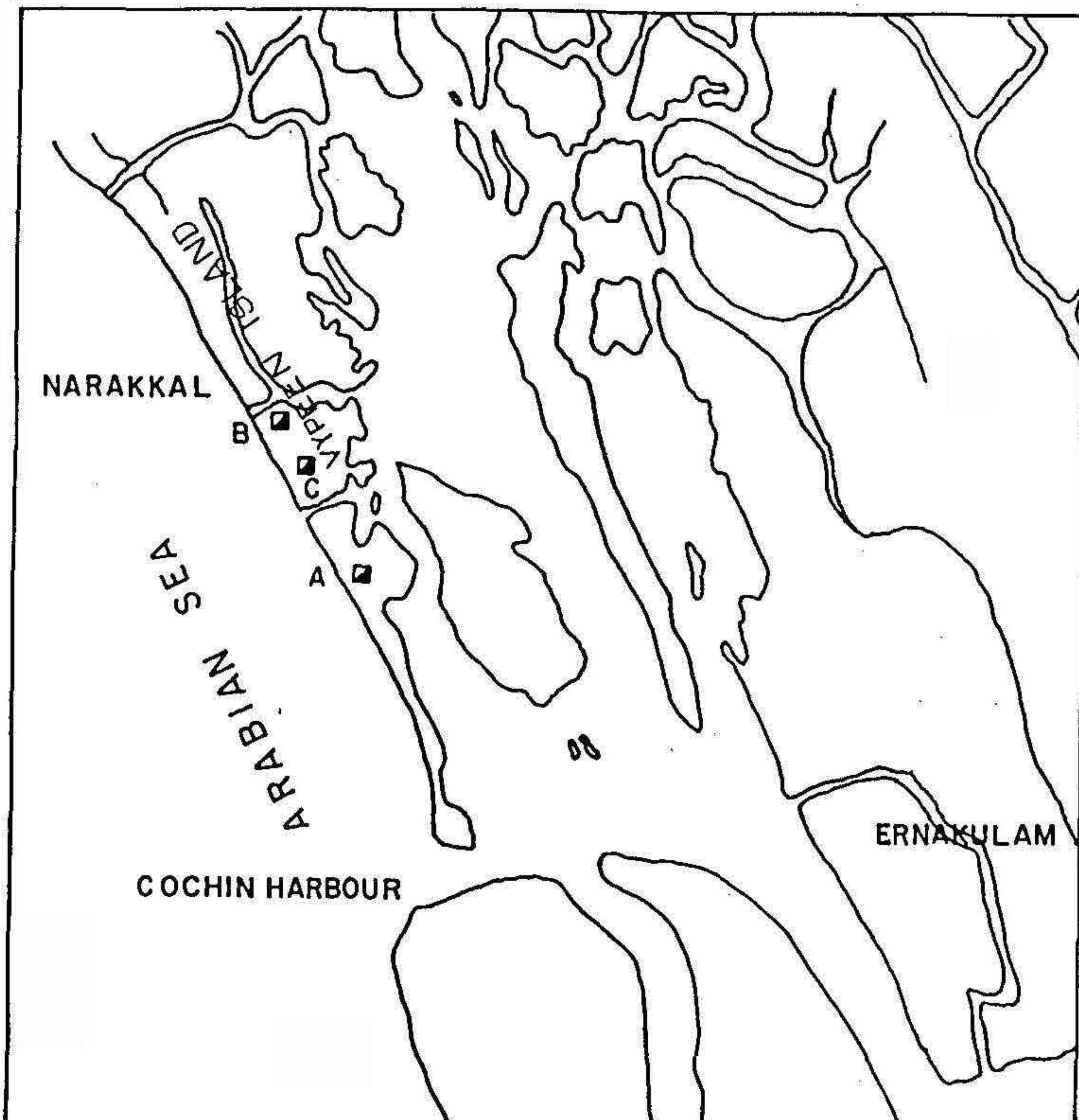
Site Description

The study is based on the scientific data collected from 3 tide influenced ecosystems viz. a mangrove site, a coconut grove and a prawn culture pond - all of which are situated on Vypeen Island, Kochi at about 2-3 km distance from each other. (Page No. 7).

The mangrove station is a tidal canal bordered by mangrove vegetation. The flora at the mangrove station is dominated by Acanthophora spp. The canal is about 3-5 m wide, and it has a direct perenial connection with the sea (Plate No.1).

The coconut grove situated at Narakkal has 5 m wide perennial water canals running between parallel rows of coconut trees. The water entering the canals is controlled by a sluice gate. The station is a central canal with rows of coconut trees and canals on either side. The water source is from a system of backwater canals which also have freshwater inflows and open out into the sea (Plate No.2).

The prawn culture pond has a water area of 422 m^2 with a depth range of 0.2 to 1 m. It is one of the 4 experimental ponds at Krishi Vigyan Kendra, Narakkal and is enclosed on 2 sides by culture ponds and backwater canals on the other 2 sides. 4 sampling stations were marked



STUDY AREA

Collection centres
A Mangrove site
B Culture pond
C Coconut grove

PLATE NO.I The Mangrove site

PLATE NO.II The Coconut grove

PLATE NO.III The Culture pond (Control pen)

PLATE NO.IV The Culture pond showing the control pen (right) and Experimental pen I (left)

PLATE NO.V The Culture pond showing the Experimental Pen II (left) and Experimental pen III (right) with the sluice gate in the centre.

by 1 square metre pens errected on the centre of each side with about 1.5 m distance between the pen wall and the bund on that side (Plate Nos. 3, 4 & 5). The net material used in the construction of the pens had a mesh size of 5 mm and was made of nylon fibres. Around this an outer net with 2 cm mesh was fixed, away from the inner net and its lower portion is burried deep in the soil to prevent the entry of predators. Though 4 pens were used for the growth studies, data for ecological parameters from one pen alone (used as the control in the growth studies) was used to compare with the data obtained from the other two ecosystems. (Fig. B(ii), Plate VIII)

The study period was of continuous 60 day duration and extended over the months of August and September 1992. In these 2 months column water and interstitial water were sampled regularly at an interval of 5 days in the prenoon hours between 8 hrs and 12 hrs.

The column water was sampled both from the surface and the bottom in 50 ml plastic bottles. For the surface samples the opened bottles were dipped, filled and taken out. For the bottom samples the bottles were sent stoppered to the bottom and opened just above the soil surface. When the bottles were filled they were closed at the bottom itself and then brought to the surface.

The interstitial water was sampled using a specially designed interstitial water sampler designed and fabricated for the purpose. The samples were collected from 5 different depths from the soil surface viz. (i) 0-5 cm (ii) 5-10 cm (iii) 10-15 cm (iv) 15-20 cm and (v) 20-25 cm in all the stations. A schematic diagram of the sampler is given in page 10.

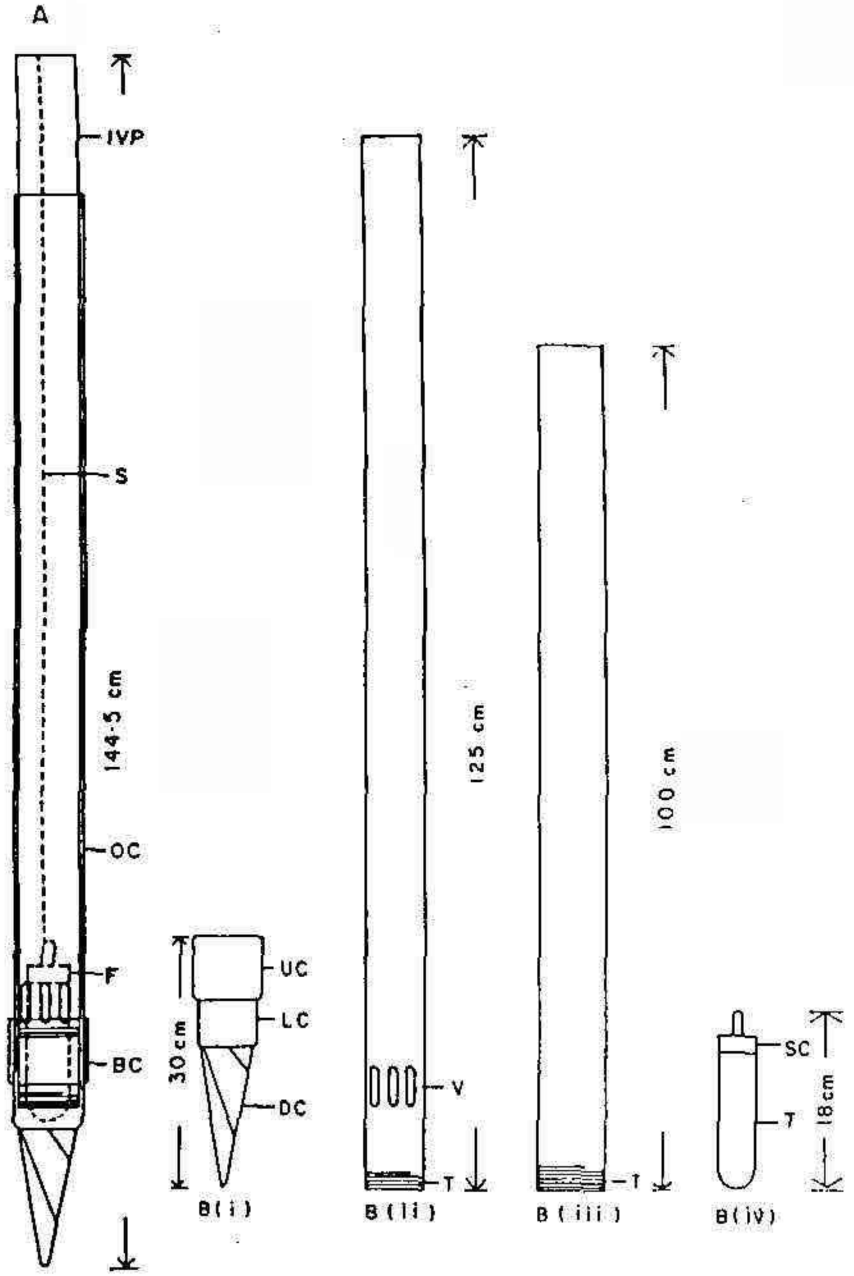
The interstitial water sampler:

The interstitial water sampler is a water tight, leak-proof instrument having a total length of 144.5 cms and consists of 4 detachable parts: (i) the basal cone (ii) the inner ventilated PVC Pipe (iii) the outer GI Pipe casing and (iv) the filter-candle with string. (Fig. 4, Plate VI).

(i) Basal Cone *(with two threaded adapters)*

The driving cone was made out of a Galvanised Iron (GI) pipe of 2 inches diameter which was cut, twisted and welded to form a pointed leak proof hollow cone which enables the easy penetration of the instrument to the required depth. It has a length of 18 cms. To the upper end is welded a GI coupling of 2 inches diameter and 5½ cm length with close threading in the interior. It is into the upper end of this threading that the ventilated PVC pipe threads in. Another GI coupling of 2½ inches diameter and 7½ cm length is welded into the lower coupling slightly encasing it. The GI pipe that forms the outer casing threads into this coupling. The whole of the basal cone with threaded adaptors measures 30 cm in length. (Fig. B(i), Plate VII).

(ii) The high density Poly-Vinyl Chloride (PVC) pipe has an inner diameter of 2 inches and a length of 1.25 m. It is threaded on the outside at one end and at a distance of 10 cm from this end ventilations are made in the form of 6 longitudinal slits of 5 cm length and 1 cm width which are equidistantly placed along the circumference. These ventilations allow the inner filter to come in contact with the outer soil when the instrument is being operated. The outer threading as mentioned earlier



SCHEMATIC DIAGRAM OF THE INTERSTITIAL WATER SAMPLER

BC - Basal Cone, DC - Driving Cone, F - Filter

NP - Inner ventilated pipe, LC - Lower Coupling, OC - Outer casing

S - String, SC - Steel Cap, T - Threaing, UC - Upper Coupling
V - Ventilation.

PLATE NO.VI The interstitial water sampler

PLATE NO.VII The basal cone with threaded adaptors

PLATE NO.VIII The PVC pipe with ventilations

PLATE NO.IX The encasing GI pipe

PLATE NO.X The 'filter candle'

fits into the thread of the lower coupling of the basal cone.

(iii) The GI Pipe has a length of 1 m and an inner diameter of 2½ inches. It is threaded on the outside at one end which helps to fasten it to the thread on the upper coupling of the cone. This part of the instrument helps to keep it sturdy and also covers the windows of the PVC pipe thus preventing the filter from contact with soil layers and column water while the instrument is penetrating the soil to the desired depth. *(Fig. B(iii), Plate IX).*

(iv) The 'filter' is the actual water filtering and collecting unit. It is a 'candle' used in commercial domestic water filters made of ultra high porosity ceramic material. It is 18 cm long and cylindrical with 4 ½ cm diameter, open at one end and closed and rounded at the other with an inner cavity of 2½ cm diameter. The open end is covered by a steel coated plastic cap with a tubular outlet to facilitate the removal of the water collected inside by tilting or by suction. A copper wire fastened to the cap helps in lifting and lowering the filter candle for sampling, without lifting out the instrument itself which was driven in with considerable effort. (Fig. B(iv), Plate X).

The filter was tested in the lab and its efficiency and time taken for filtering was calculated in different clay samples before it was used in the field.

Operation

The GI pipe casing was at first fixed to the cone by threading it into the upper coupling. Then the water depth was measured and the same was marked on the outside of the GI pipe casing measuring from the tip of the cone. From this point 5 markings were made upward at 5 cm intervals to mark the different depths sampled viz. (i) 0-5 cm (ii) 5-10 cm (iii) 10-15 cm (iv) 15-20 cm and (v) 20-25 cm from the soil surface downwards.

The cone together with GI pipe casing was driven into the soil either by pushing it in with the hand when the substrate was clayey or by driving it in with a hammer when the substrate was hard. At the desired depth (known from the external markings) the PVC tube was lowered into the GI and threaded tightly into the lower coupling of the cone. The filter was then lowered until its upper end coincided with the upper end of the windows of the PVC pipe and it was held in position by fastening the copper wire to the upper end of the PVC pipe. Now the GI pipe was slowly threaded out and lifted off thus exposing the soil layers of the desired depth to the filter candle through the windows. The instrument position was left undisturbed for 10 minutes after which the filter was lifted out by the string and the water collected poured out into labelled 50 ml plastic bottles.

The column water and interstitial water samples were analysed to find their salinity, temperature, pH, nitrate and nitrite contents.

The salinity was estimated by titrating against silver nitrate using potassium chromate as indicator (Strickland & Parsons, 1968).

The temperature of the different depths was measured using a mercury thermometer calibrated from 0 to 50°C. The temperature of the surface and bottom water samples were measured by directly immersing the thermometer into the water sample immediately on collection. The temperature of the different soil layers were taken using the PVC tube of the interstitial water sampler as a core. The unthreaded end was used to core out soil upto a depth of 25 cms and this soil mass was pushed to the ventilations at the other end using a piston. The temperature was recorded for each of the consecutive 5 cm layers of soil as they were exposed through the windows at the other end of the PVC pipe.

The pH of the water samples were measured using Elico pH meter model LI-10T.

Nitrate was estimated by the method given by Strickland and Parsons (1968) and Nitrite estimation was done using the spectrophotometric method (Mullin and Riley 1955).

For the growth studies conducted in the 4 pens erected at the prawn culture pond in KVK, Narakkal Penaeus indicus of the size range of 4 to 7 cm were stocked at the intensive rate of 25 animals/m^2. They were grown in the same 60 day period during which the water samples were collected and 5 specimens from each pen were sampled at 5 day intervals to record the length and weight data. The prawns in station I were kept as control with no supplementary feed provided while those in station II, III and IV were fed with a diet of 36 % protein at the rate of 12% body weight per day and were fed once daily in the evening hours. Supplementary feed was given only one week after stocking.

The relation between the different parameters were statistically analysed using two-way ANOVA and correlation matrix as explained by Snedecor and Cochran (1967).

RESULTS

Environmental parameters

The environmental parameters viz - Salinity, temperature, pH, nitrate and nitrite were studied in the column water and interstitial water from three ecosystems - a mangrove area, a coconut grove and a culture pond. The column water was sampled from the surface and bottom and the interstitial water was sampled from five depths from the soil surface viz (i) 0-5 cm (ii) 5-10 cm (iii) 10-15 cm (iv) 15-20 cm (v) 20-25 cm. The interstitial water was sampled using a specially designed interstitial water sampler designed and fabricated as described in the chapter on materials and methods. The following is the presentation of the data of the environmental parameters collected meticulously at five day intervals during the full months of, August and September, 1992. (Appendix I)

Salinity

In the mangrove station during the study period of sixty days the salinity values from the different depths; column as well as subsoil, showed a minimum in the first week of August and a maximum in the third week of September. The surface salinity varied from the lowest value of 2.25ppt to the highest value of 11.16ppt. The bottom salinity of coloumn water varied from 2.59ppt to 11.47ppt. In the interstitial water from the 0-5cm depth the minimum salinity recorded was 3.68ppt and the maximum was 12.50ppt. In the 5-10cm depth the least value was slightly lower than the 0-5cm depth at 2.86ppt and the highest at 11.99ppt. The 10-15cm depth showed an increase with the minimum value at 3.75ppt and maximum at 13.92ppt. 4.36ppt was the least value from the 15-20cm depth and the highest was 14.76ppt. The 20-25cm recorded the highest salinity values with the minimum being 4.43ppt and maximum 16.42ppt. (Table 1, Fig 1)

In the culture pond station mostly the minimum values of salinity from the column as well as the interstitial water samples were found in the first week of August while the maximum values were found in the third week of September. In the coconut grove station the surface salinity had the least value of 0.75ppt and the highest value of 10.56ppt. In the bottom water this increased slightly with the least value being 1.29ppt and the highest 10.87ppt. 0.54ppt, which was the least salinity recorded from the coconut grove, was from the 0-5cm depth sample and the highest salinity from the same depth was 11.68ppt. The lowest salinity period from the 5-10cm depth deviated a little from the other depths and was recorded in the second week of August but the highest value of 11.03ppt was again recorded in the third week of September. 10.63ppt was the minimum value in the 10-15cm depth and 12.59ppt was the maximum value. The 15-20cm depth showed the minimum salinity at 4.31ppt and the maximum was 13.62ppt. The 20-25cm depth showed the lowest salinity value as 5.19ppt and 14.34ppt as the highest salinity

TABLE NO. 1. <u>SALINITY</u> (ppt) (MANGROVE)

	1	2	3	4	5	6	7	8	9	10	11	12
Surface	2.25	3.70	3.94	7.36	6.62	5.91	10.21	6.32	9.78	11.16	6.42	5.18
Bottom	2.59	3.98	4.57	7.59	6.96	5.87	10.41	6.94	10.27	11.47	6.86	5.48
0 - 5 cm	3.68	4.63	5.02	8.72	7.83	5.62	10.93	7.52	11.82	12.50	7.44	6.03
5 - 10 cm	2.86	4.27	4.85	8.33	7.41	5.73	11.06	8.31	11.52	11.99	6.81	5.81
10 - 15 cm	3.75	4.50	5.76	8.98	8.54	6.34	11.43	9.11	12.96	13.92	8.00	7.26
15 - 20	4.36	4.78	6.50	10.0	8.88	6.78	12.63	9.70	14.06	14.76	8.72	8.39
20 - 25	4.43	5.22	8.12	10.56	9.60	8.51	13.11	10.05	15.78	16.42	9.96	8.70

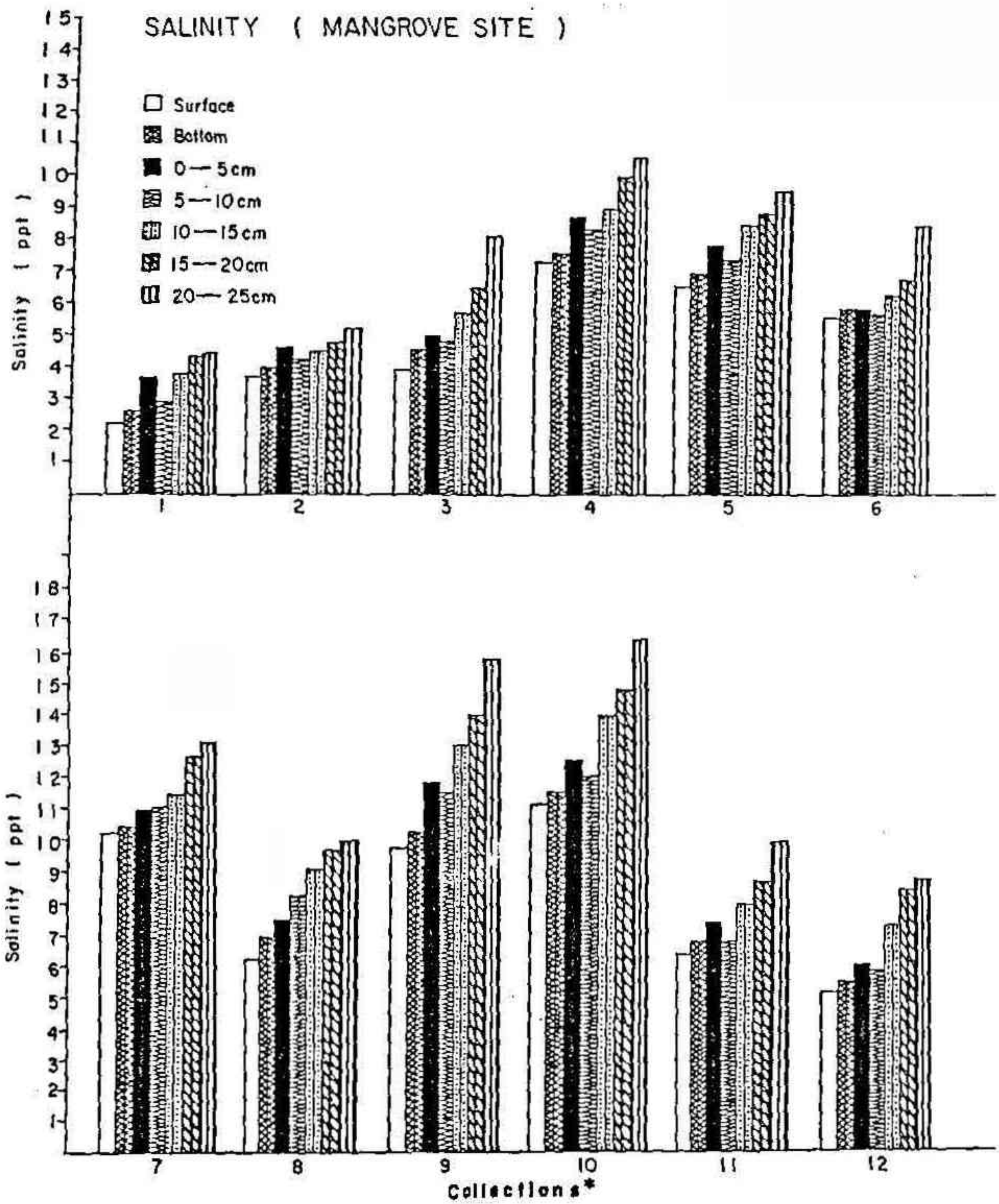


Fig. 1

(*Refer Appendix 1)

TABLE NO. 2. <u>SALINITY</u> (ppt) (COCONUT GROVE)

	1	2	3	4	5	6	7	8	9	10	11	12
Surface	0.75	2.04	1.50	4.62	5.53	4.87	8.62	4.67	7.89	10.56	5.67	4.20
Bottom	1.29	2.45	1.70	4.85	5.89	4.98	8.98	4.97	8.21	10.87	5.89	4.29
0 - 5 cm	0.54	3.17	2.63	5.92	6.41	5.79	9.76	5.77	8.87	11.68	6.18	5.68
5 - 10 cm	3.54	2.90	2.18	5.23	6.00	5.32	9.78	5.06	8.16	11.03	6.06	5.18
10 - 15 cm	1.63	3.98	3.82	6.84	7.27	6.67	10.52	6.42	9.72	12.59	7.80	6.87
15 - 20 cm	4.31	4.54	4.54	7.74	7.82	7.86	11.80	7.16	10.11	13.62	8.19	7.89
20 - 25 cm	5.19	5.35	5.55	8.36	8.86	9.07	12.36	7.84	10.98	14.34	8.86	8.34

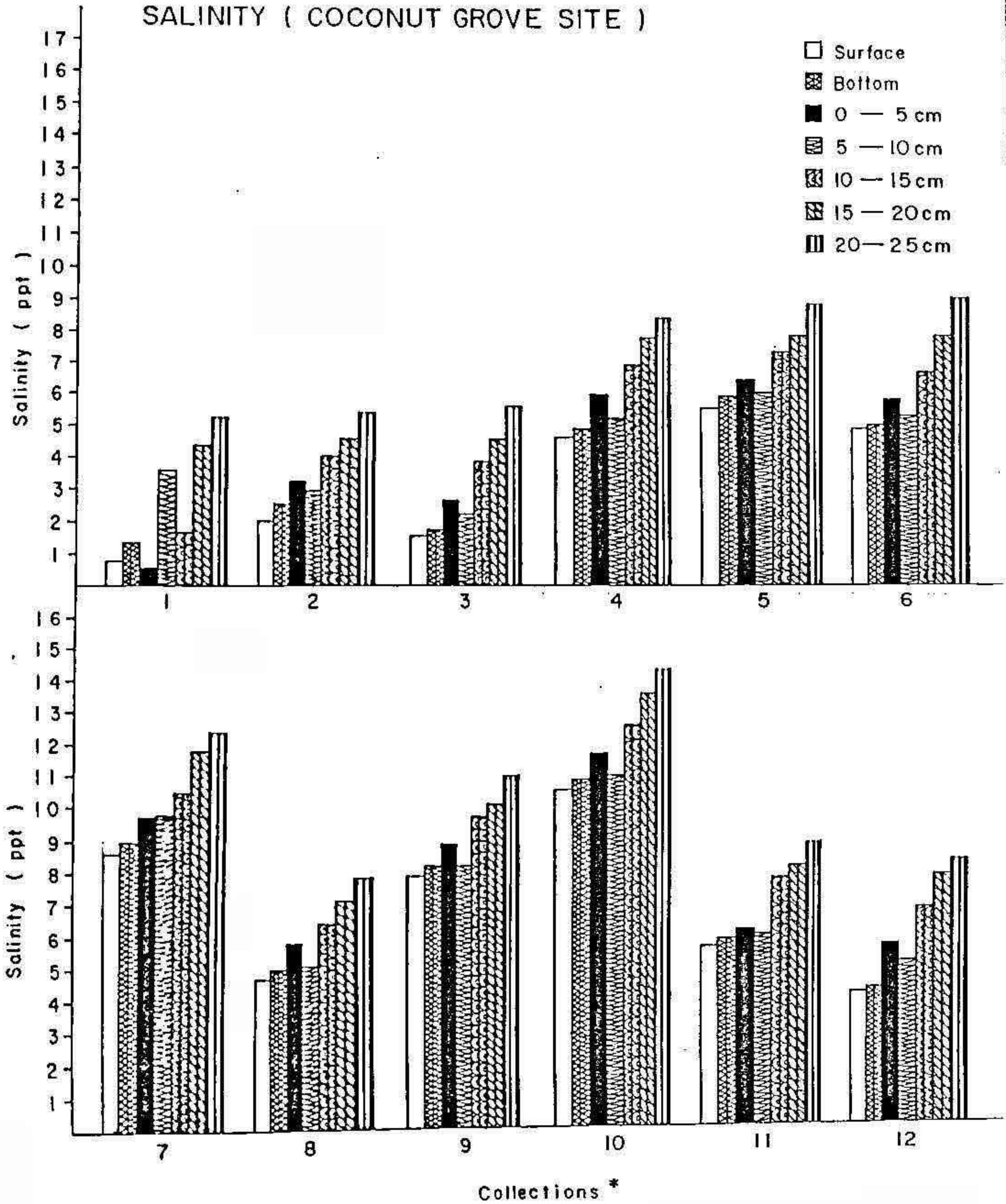


Fig. 2.

(*Refer appendix 1)

TABLE NO. 3. SALINITY (ppt) (CULTURE POND)

	1	2	3	4	5	6	7	8	9	10	11	12
Surface	1.16	2.86	1.75	4.89	5.62	4.96	8.98	4.90	8.23	11.27	6.23	5.06
Bottom	1.29	2.97	1.92	5.04	5.78	5.11	9.27	4.99	8.42	11.68	6.74	5.66
0 - 5 cm	0.68	3.68	2.87	5.76	6.88	6.27	10.63	6.23	9.67	12.96	7.89	6.78
5 - 10 cm	2.18	3.07	2.32	4.98	6.04	6.00	10.18	5.76	9.32	12.40	7.33	6.09
10 - 15 cm	4.62	4.89	3.41	6.66	7.36	6.77	11.54	6.89	10.65	13.79	8.97	7.48
15 - 20 cm	5.87	6.11	4.27	7.81	8.54	7.81	12.79	7.49	11.79	15.37	10.16	8.62
20 - 25 cm	7.33	7.26	5.62	8.42	9.22	8.50	13.50	8.66	12.97	16.29	11.27	9.31

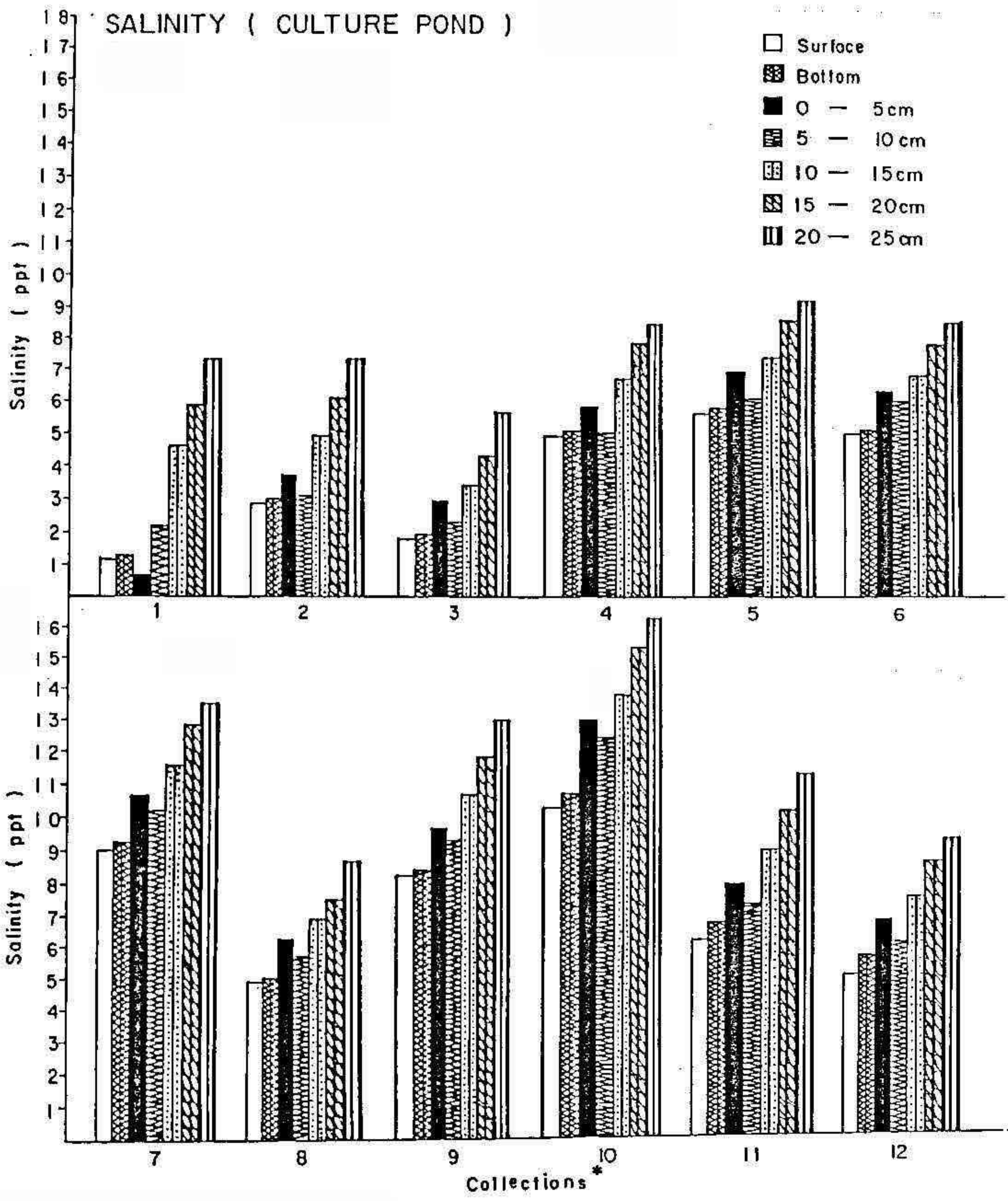


Fig. 3.

(*Refer appendix 1)

which was the highest salinity from the coconut grove. (Table 2, Fig2)

The culture pond station had the minimum salinity values from all the sampling points in the vertical depth transect recorded in the first week of August while all the maximum salinity values coincided with the third week of September. In the surface water, salinity ranged from 1.16ppt, to 11.27ppt while in the bottom water the range was from 1.29ppt to 11.68ppt. The lowest salinity from the interstitial water of the 0-5cm depth which was 0.68ppt was the least recorded from the culture pond while the highest in the same depth was 12.96ppt. In the 5-10cm depth the least salinity was 2.18ppt and the highest had fallen compared to the 0-5cm depth to 12.40ppt. The 10-15cm depth showed 4.62ppt as the minimum value while 13.79ppt was the maximum value. 5.87ppt was the lowest salinity recorded from the 15-20cm depth while 15.37ppt was the highest. In the 20-25cm depth the lowest value was recorded as 7.26ppt and the highest value was 16.29ppt which was the highest salinity value recorded from the culture pond. (Table 3, Fig 3)

Generally it was found in all the three environments that the salinity of the bottom water was higher than the surface though the difference was not very marked. The interstitial water was found to be more saline than the column water with the salinity of the 5-10cm depth samples lower than the 0-5cm depth. Below the 5-10cm depth sample the salinity mostly increased by about

1ppt per 5cm depth reaching a maximum in the 20-25cm depth. The mangrove station showed higher salinities than the other two ecosystems with the coconut grove showing the lower values.

In the two way ANOVA analysing the salinity values from the different depths and those from the different ecosystems the significance was found to be at 1% level.

Temperature

In the mangrove station the lowest atmospheric temperature recorded was 25°C in the second week of August while the highest was 32°C in the first and last weeks of August. The surface water temperature had the least value of 26°C in the second week of August. In the bottom water where comparitively lower temperature were recorded the minimum was 25.5°C in the second week of August and the maximum was 31.5°C in the first week of August. The 0-5cm depth of soil had the lowest temperature of 25.5°C in the second week of August while the highest temperature was 31.5°C recorded from the first week of August and the last week of September. The lowest temperature recorded from the mangrove station was 25°C from the 5-10cm depth and the highest from the same depth was 32.5°C. The lowest temperature from the 10-15cm depth was 15.5°C in the second week of August and the maximum was 34°C in the last week of September. In the 15-20cm depth the lowest value was 27°C in the second week of August and the highest was 34.5°C in the last week of September. In the lowest depth sampled viz-20-25cm the least temperature recorded was 28°C in the second and third weeks of August while the highest temperature remained at 34.5°C as in the 15-20cm depth in the last week of September and this was the maximum temperature recorded from the mangrove station. (Table 4, Fig 4)

In the coconut grove the atmospheric temperature had a minimum of 25.5°C in the third week of August and 30°C in the fourth week of August. In the surface water 27°C was the lowest temperature recorded in the second and third weeks of August and 30.5°C was the highest recorded in the first and last weeks of August. In the bottom the lowest was at 26°C in the third week of August and the highest was 30°C from the last weeks of August and September. In the soil 26.5°C was the minimum temperature recorded in the third week of August and the maximum temperature of 31°C was recorded in the first and last weeks of August and the last week of September in the 0-5cm depth. In the 5-10cm depth the minimum was higher up at 26.5°C in the second and third weeks of August and the maximum had reached 31°C in the last week of August. The minimum temperature of 27°C in the 10-15cm depth was recorded in the second and third weeks of August while the maximum had become 31.5°C in the first and last weeks of August. 27.5°C was the lowest temperature recorded in the 15-20cm depth in the second and third weeks of August and the highest temperature was recorded in the last week of September viz 32.5°C. In the 20-25cm depth the soil temperature ranged from 28°C in the third

TABLE NO. 4. TEMPERATURE (°C) (MANGROVE)

	1	2	3	4	5	6	7	8	9	10	11	12
Atm. Temperature	25.5	32	25	27	26.5	32	27.5	30	29	28.5	27	30.5
Surface	28.0	32.0	26.0	28.0	27.0	32.5	28.0	31.0	30.0	29.0	27.5	31.0
Bottom	27.5	31.5	25.5	27.0	26.5	31.0	27.5	30.0	28.5	28.0	26.0	30.0
0 - 5 cm	27.5	31.5	25.5	27.5	27.5	31.0	28.0	30.5	29.0	28.5	27.0	31.5
5 - 10 cm	25.5	30.5	25.0	26.5	26.5	30.0	27.5	30.0	29.0	27.5	26.5	32.5
10 - 15 cm	28.0	32.0	25.5	27.0	27.5	31.5	28.0	31.0	29.5	28.0	28.0	34.0
15 - 20 cm	28.5	32.0	27.0	28.0	28.0	32.5	28.5	31.5	30.5	29.0	28.5	34.5
20 - 25 cm	29.0	33.0	28.0	28.0	29.0	33.0	29.0	32.5	31.5	30.5	29.0	34.5

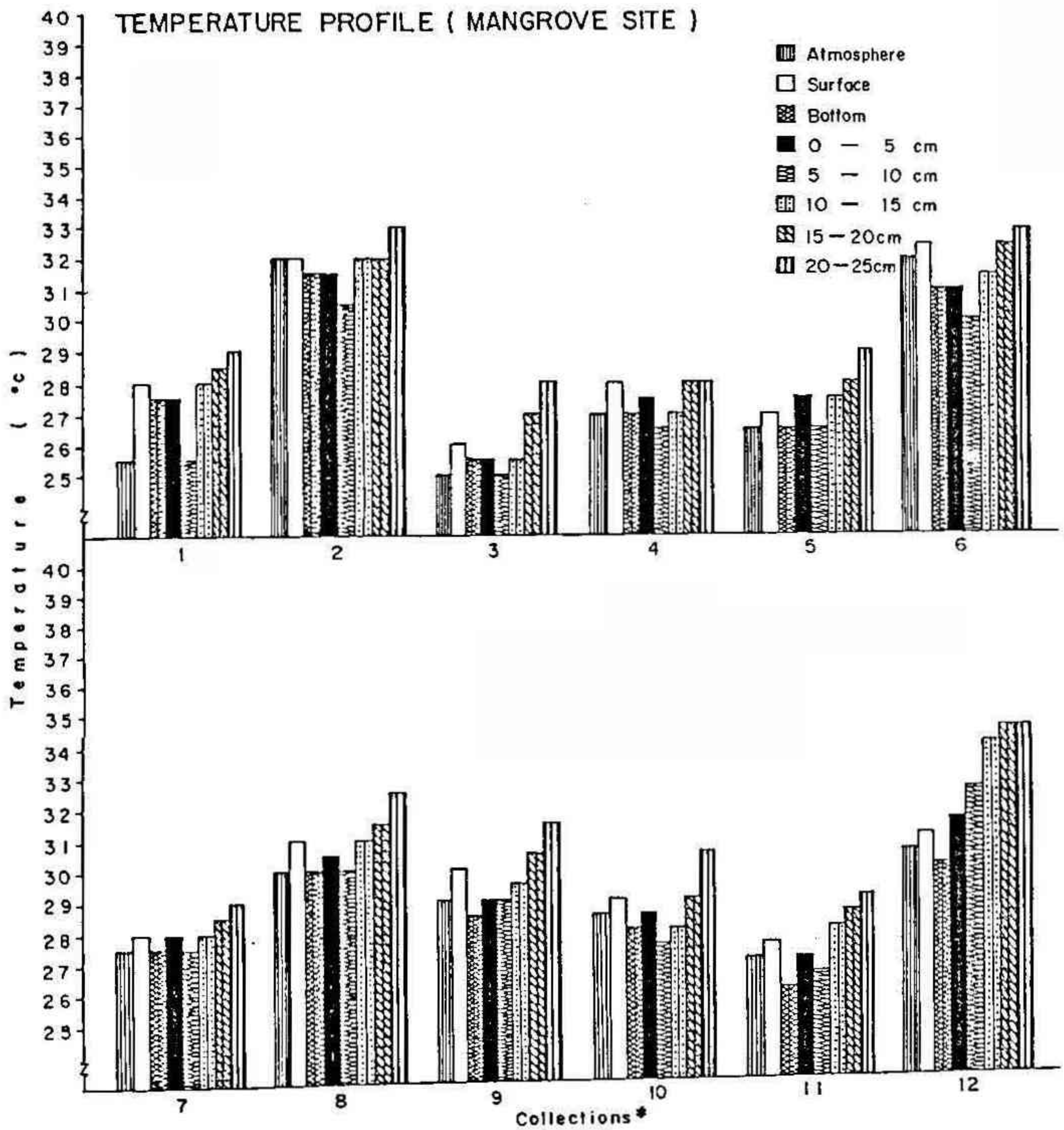


Fig. 4.

(*Refer appendix 1)

TABLE NO. 5. TEMPERATURE (°C) (COCONUT GROVE)

	1	2	3	4	5	6	7	8	9	10	11	12
Atm. Temp.	28.0	29.0	26.0	26.5	25.5	30.0	27.0	29.0	28.0	27.0	26.5	29.0
Surface	28.5	30.5	27.0	27.0	27.0	30.5	27.5	29.5	28.5	28.5	27.5	30.0
Bottom	27.5	29.5	26.5	26.5	26.0	30.0	27.0	29.0	27.5	28.0	27.0	30.0
0 - 5 cm	28.0	31.0	27.0	27.5	26.5	31.0	28.0	29.5	28.0	29.0	28.0	31.0
5 - 10 cm	28.5	30.5	26.5	26.5	27.0	31.0	27.0	30.0	27.0	28.5	27.5	30.5
10 - 15 cm	29.0	31.5	27.0	27.0	28.0	31.5	28.0	30.0	28.5	29.0	28.5	31.5
15 - 20 cm	30.0	32.0	27.5	27.5	28.5	32.0	28.5	31.0	29.5	29.5	29.0	32.5
20 - 25 cm	30.0	33.0	28.5	28.0	29.0	32.5	29.0	32.0	30.0	29.5	29.5	33.5

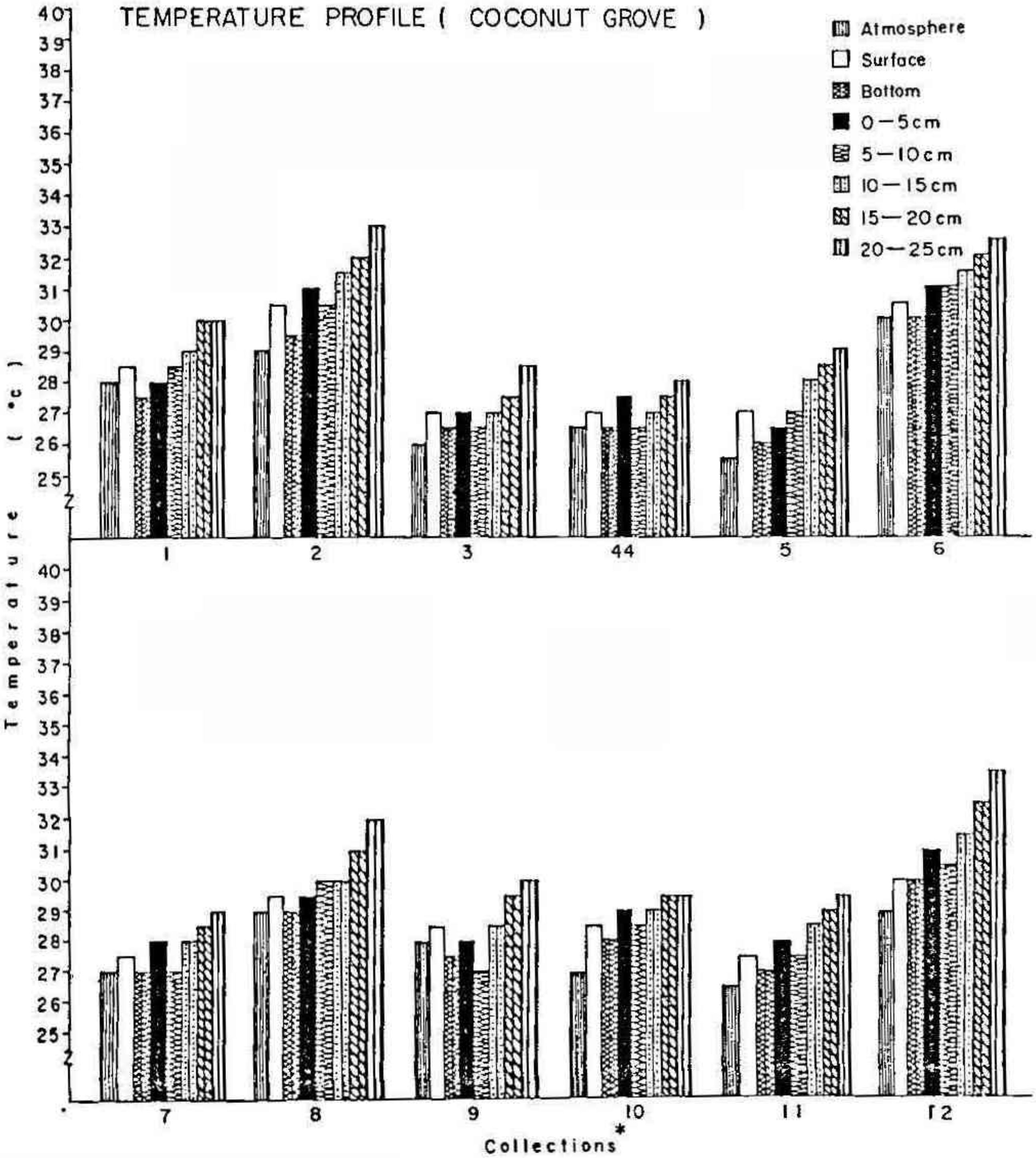
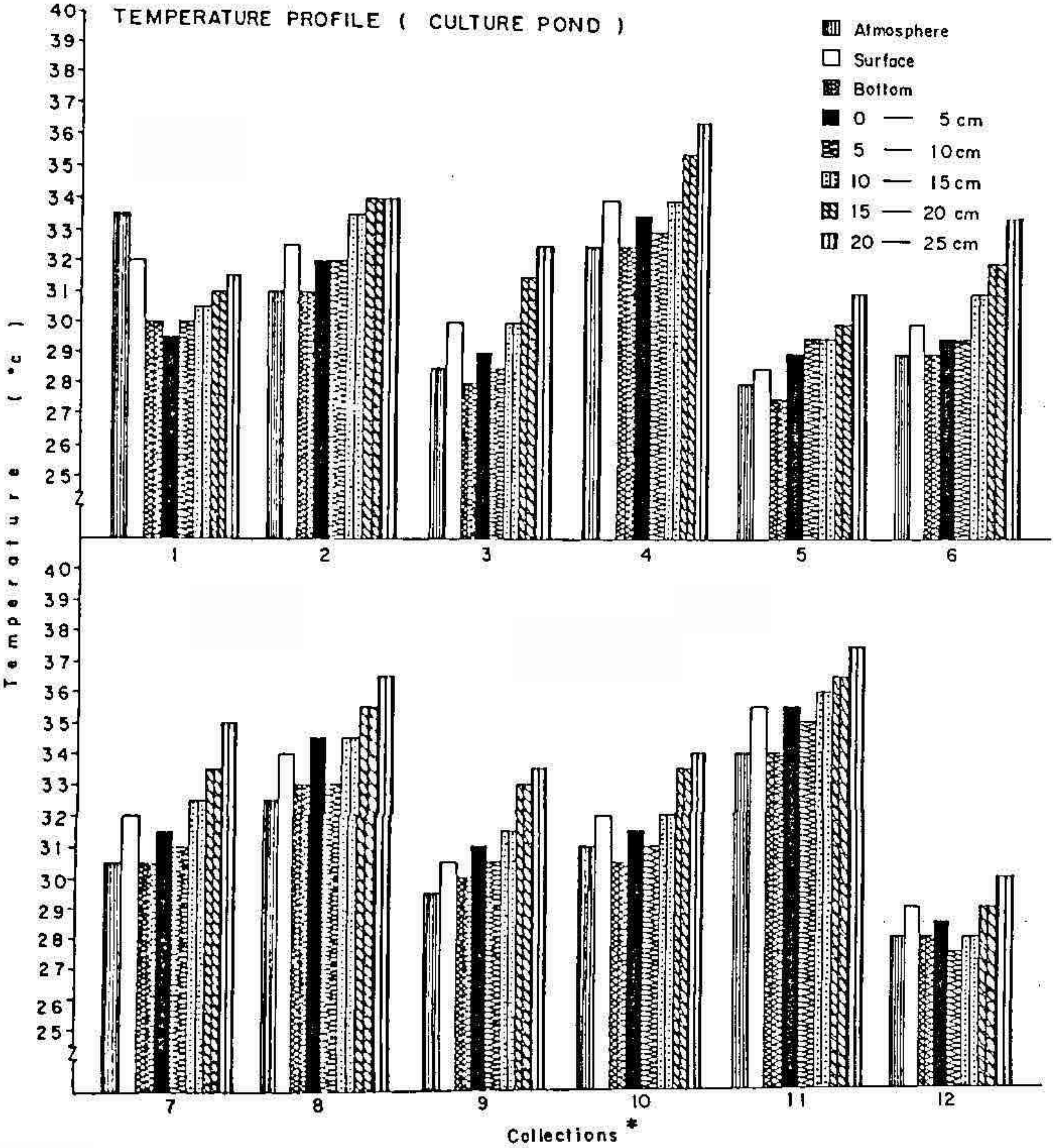


Fig. 5

(*Refer appendix 1)

TABLE NO. 6. TEMPERATURE (°C) (CULTURE POND)

	1	2	3	4	5	6	7	8	9	10	11	12
Atm. Temp	33.5	31.0	28.5	32.5	28.0	29.0	30.5	32.5	29.5	31.0	34.0	28.0
Surface	32.0	32.5	30.0	34.0	28.5	30.0	32.0	34.0	30.5	32.0	35.5	29.0
Bottom	30.0	31.0	28.0	32.5	27.5	29.0	30.5	33.0	30.0	30.5	34.0	28.0
0 - 5 cm	29.5	32.0	29.0	33.5	29.0	29.5	31.5	34.5	31.0	31.5	35.5	28.5
5 - 10 cm	30.0	32.0	28.5	33.0	29.5	29.5	31.0	33.0	30.5	31.0	35.0	28.5
10 - 15 cm	30.5	33.5	30.0	34.0	29.5	31.0	32.5	34.6	31.6	32.0	36.0	28.0
15 - 20 cm	31.0	34.0	31.5	35.5	30.0	32.0	33.5	35.5	33.0	33.5	36.5	29.0
20 - 25 cm	31.5	34.0	32.5	36.5	31.0	33.5	35.0	36.5	33.5	34.0	37.5	30.0



(Fig. 6

(*Refer appendix 1)

week of August to the overall maximum of 33.5°C in the last week of September. (Table 5, Fig 5)

In the culture pond the atmospheric temperature ranged from a minimum of 28°C in the third week of August and the last week of September to a maximum of 34°C in the third week of September. 28.5°C was the lowest recorded temperature from the surface water in the third week of August and 35.5°C was the highest in the third week of September. In the bottom the range was between 27.5°C in the third week of August to 34°C in the last week of September. Throughout the soil depths the lowest temperature was recorded in the last week of September and the highest in the third week of the same month. In the 0-5cm depth the range was from 28.5°C to 35.5°C. The 5-10cm depth showed the minimum at 27.5°C and the maximum at 35°C. 28°C was the lowest temperature recorded from the 10-15 cm depth while the highest was 36°C. In the 15-20 cm depth the minimum was 29°C and the maximun 26.5°C. The 20-25cm depth had the lowest and highest temperature readings at 30°C and 37.5°C respectively. (Table 6, Fig 6)

Generally the bottom water samples had a lower temperature than the surface. There was an increasing trend of temperature from the soil surface downwards with the 20-25cm depth having the highest temperature. But with a significant exception the temperature in the 5-10cm depth layer had lower values than the zones above and below it.

Among the three ecosystems the coconut grove had the least temperature values and the culture pond had the highest in general in the depth transect.

The two way ANOVA of the temperature data from the different depths including the atmospheric temperature and those from the different ecosystems showed that they were significant at 1% level.

pH

In the mangrove station the highest values of pH were recorded from all the depths in the third week of September. In the surface the least pH of 7.7 was recorded in the last week of August while the highest was 9.0. In the bottom the least pH was further below at 6.0 in the first week of August while the highest was at 8.8. The interstitial water from the 0-5 cm depth had the minimum value again in the first week of August at 6.1 while the highest remained at 8.8. In the 5-10 cm depth the minimum was more or less the same at 6.2 in the first week of August while the maximum was 9.0. 8.0 was the least pH recorded from the 10-15 cm depth in the last week of August while 9.5 was the highest. The least pH remained at 8.0 in the 15-20 cm depth in the first week of August while the highest pH became 9.6. The lowest pH dropped to 6.5 in the 20-25 cm while the highest rose to 9.7 (Table 7, Fig. 7).

In the coconut grove the least pH value from all the depths sampled coincided with the first week of August while the highest values were from the third week of August. In the surface water the range was

TABLE NO. 7. pH (MANGROVE)

	1	2	3	4	5	6	7	8	9	10	11	12
Surface	7.9	7.9	8.1	8.4	7.8	7.7	8.1	8.4	8.4	8.0	9.0	8.0
Bottom	6.0	7.0	8.0	8.4	7.8	7.8	8.2	8.4	8.3	8.0	8.8	8.1
0 – 5 cm	6.1	7.8	8.0	8.3	7.6	7.9	8.2	8.5	8.4	8.2	8.8	8.1
5 – 10 cm	6.2	7.8	7.9	8.3	7.7	7.8	8.3	8.3	8.5	8.1	9.0	8.2
10 – 15 cm	8.2	8.1	8.2	9.0	8.3	8.0	8.8	8.7	8.6	8.6	9.5	8.6
15 – 20 cm	8.2	8.0	8.3	8.8	8.2	8.2	9.0	8.8	8.6	8.5	9.6	8.6
20 – 25 cm	6.5	7.9	8.1	9.1	8.2	8.1	9.0	8.6	8.8	8.6	9.7	8.5

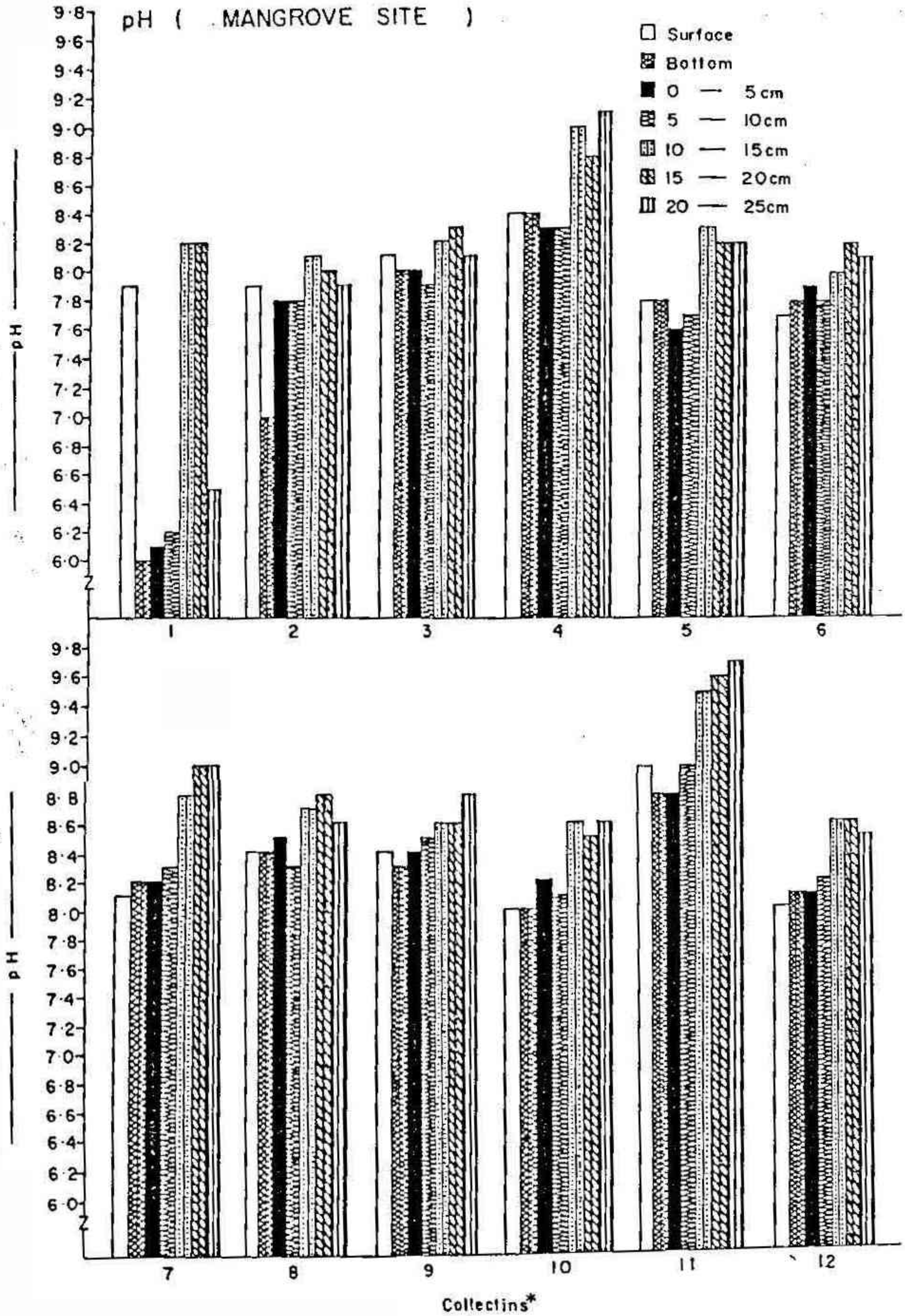


Fig. 7
(*Refer appendix 1)

TABLE NO. 8. <u>pH</u> (COCONUT GROVE)

	1	2	3	4	5	6	7	8	9	10	11	12
Surface	7.0	7.9	7.7	9.0	8.9	8.7	8.4	8.5	8.4	8.2	8.1	7.9
Bottom	7.0	8.1	7.8	8.9	8.9	8.7	8.3	8.4	8.4	8.1	8.0	7.8
0 - 5 cm	6.5	8.0	7.8	8.9	9.0	8.75	8.4	8.4	8.3	8.1	8.1	7.9
5 - 10 cm	6.1	8.0	7.7	9.0	9.0	8.7	8.4	8.3	8.4	8.1	8.0	8.1
10 - 15 cm	6.5	8.1	7.9	9.4	9.2	8.9	8.6	8.5	8.6	8.2	8.2	8.3
15 - 20 cm	7.5	8.3	8.2	9.4	9.2	9.0	8.6	8.5	8.6	8.3	8.2	8.4
20 - 25 cm	7.5	8.4	8.0	9.3	9.2	8.9	8.5	8.6	8.7	8.5	8.4	8.45

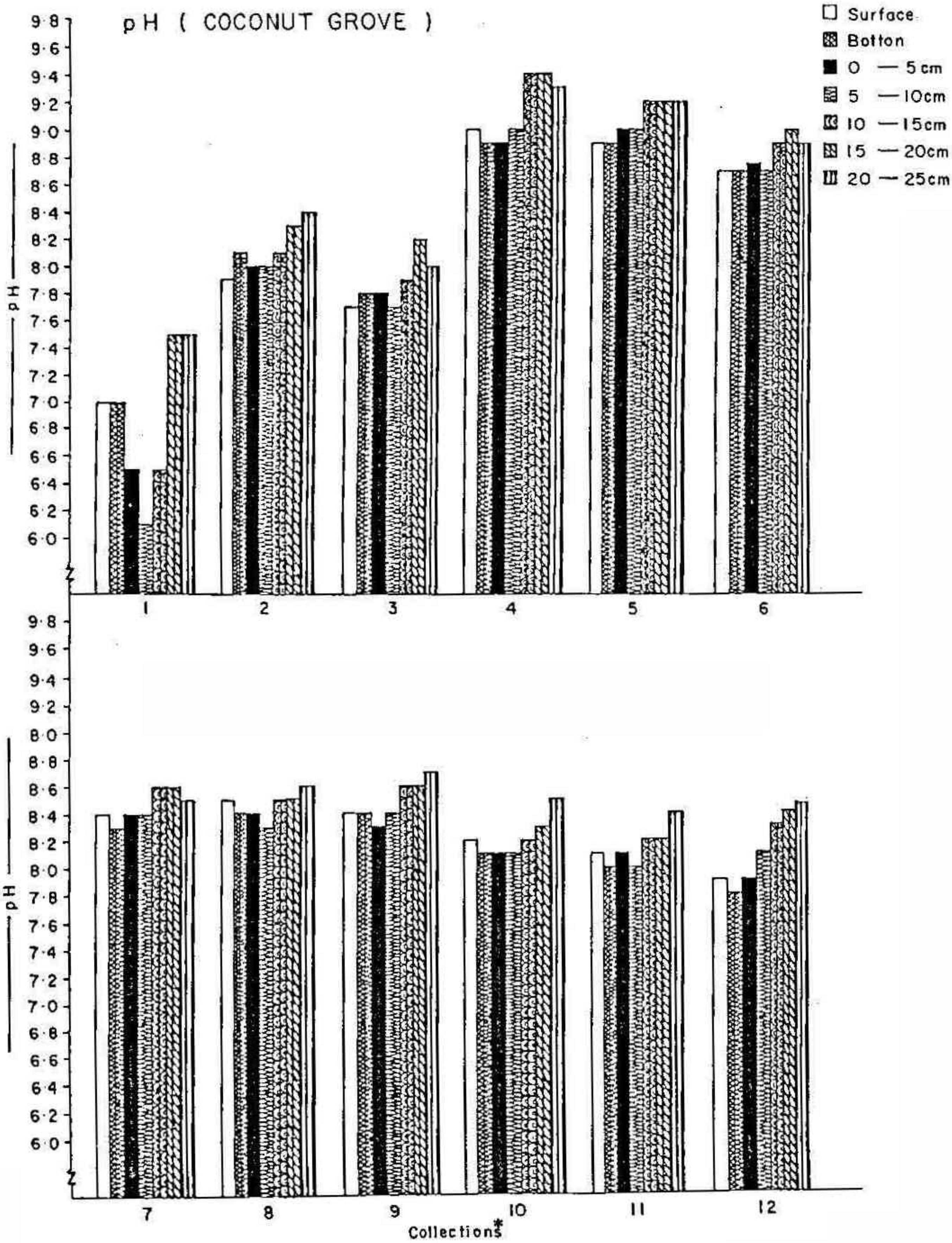


Fig. 8
(*Refer appendix 1)

TABLE NO. 9. pH (CULTURE POND)

	1	2	3	4	5	6	7	8	9	10	11	12
Surface	6.8	7.6	9.0	8.85	9.1	9.3	9.5	9.1	9.2	9.1	9.2	9.5
Bottom	6.9	7.8	9.0	8.7	9.2	9.3	9.4	9.2	9.1	9.0	9.0	9.4
0 - 5 cm	6.7	7.7	8.9	8.8	9.2	9.4	9.5	8.9	9.1	8.9	9.1	8.9
5 - 10 cm	6.8	7.8	8.8	8.9	9.0	9.0	9.0	8.9	9.2	9.0	8.9	8.9
10 - 15 cm	7.0	7.9	9.0	9.1	9.3	8.9	8.9	8.8	9.0	8.5	8.6	8.5
15 - 20 cm	6.9	7.9	9.1	9.1	9.4	8.8	8.9	8.9	8.9	8.4	8.6	8.6
20 - 25 cm	7.1	7.9	9.2	9.2	9.4	8.8	9.0	8.7	8.9	8.4	8.7	8.6

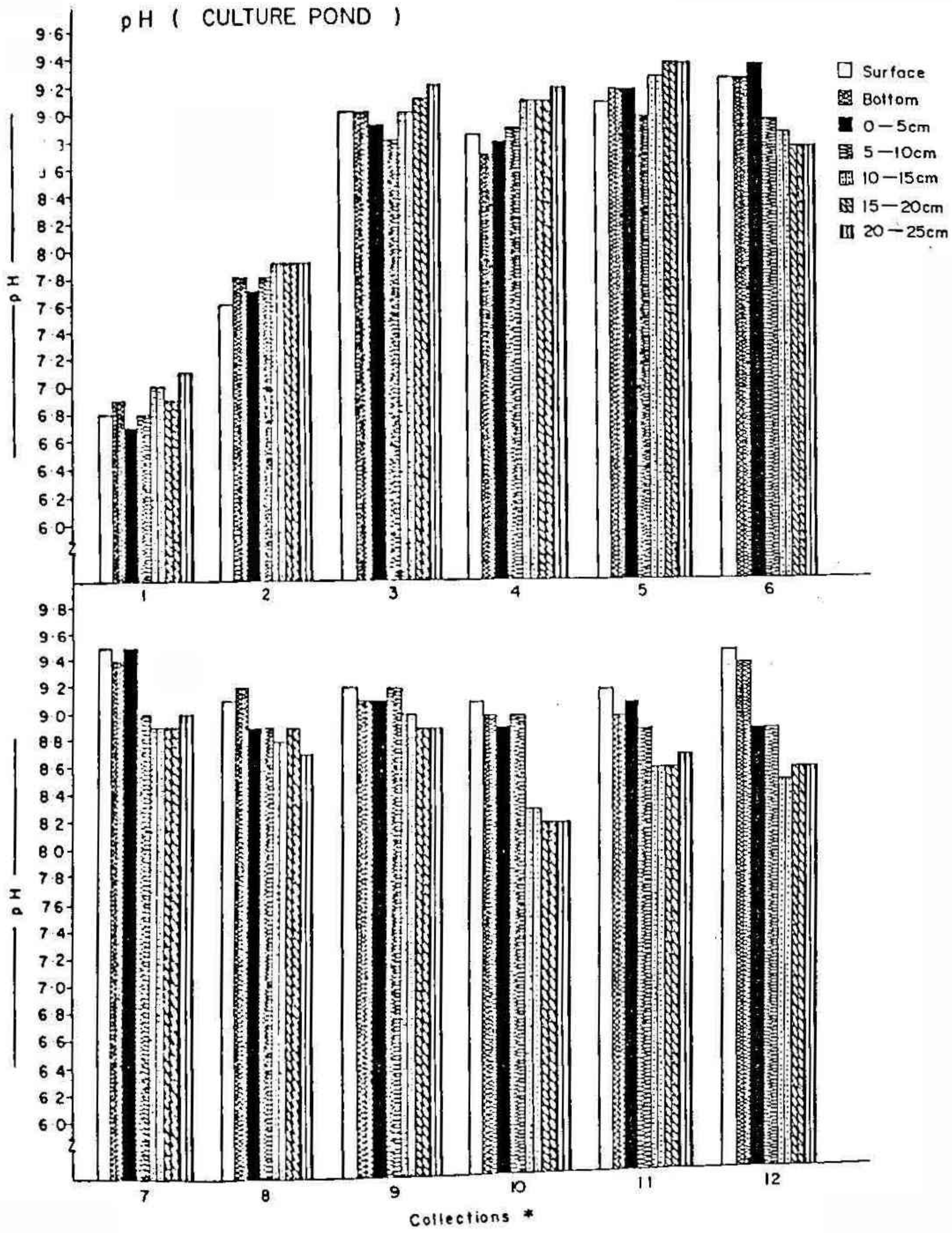


Fig. 9
(*Refer appendix 1)

from 7.0 to 9.0 while in the bottom water it was from 7.0 to 8.9. In the interstitial water from the 0 -5 cm depth this range became 6.5 to 9.0. In the 5-10 cm depth the minimum pH was 6.1 and the maximum 9.0. In the 10-15 cm depth the pH range shifted from a minimum of 6.5 to a maximum of 9.4. The minimum pH increased to 7.5 in the 15-20 cm depth while the maximum remained at 9.4. In the lowest sampled depth the minimum remained at 7.5 but the maximum pH changed slightly to 9.3. (Table 8, Fig. 8).

The culture pond had a surface water pH range from 6.8 in the first week of August to 9.5 in the first and last weeks of September. In the bottom water the least pH was 6.9 in the first week of August and 9.4 in the first and last weeks of September. In the pH of the interstitial water the 0-5 cm depth had a minimum of 6.7 in the first week of August to 9.5 in the first week of September. The range in the 5-10 cm depth was 6.8 in the first week of August to 9.2 in the second week of September. The least pH in the 10-15 cm depth was 7.0 in the first week of August and the maximum was 9.3 in the third week of the same month. In the 15-20 cm depth the least pH was 6.9 in the first week of August and the highest was 9.4 in the third week of August. The lowest pH of the 20-25 cm became 7.1 in the first week of August while, the highest remained at 9.4 in the third week of the same month (Table 9, Fig. 9).

In the three ecosystems it was noticed that pH in the 0-5 cm depth was more or less the same as that in the column water, but below this layer generally an increase in pH was noticed.

While comparing the different ecosystems the culture pond had comparatively higher values of pH than the mangrove and coconut grove stations.

The two way ANOVA of the pH values from the different depths were found to be insignificant even at 5% level while those from the different ecosystems were found to be significant at 1% level (Appendix IV).

Nitrate:

The maximum values of nitrate in the mangrove station in all the depths were observed in the third week of September. In the surface water the values ranged from 0.098 μg at/l in the first week of August to 1.578 μg at/l. In the bottom water the minimum value was 0.076 μg at/l in the first week of September to 1.492 μg at/l. In the interstitial water higher values were recorded with 0-5 cm depth having minimum of 0.166 μg at/l in the last week of August to a maximum of 2.243 μg at/l The 5-10 cm depth sample had a minimum value of 0.491 μg at/l in the last week of August and a maximum of 3.678 μg at/l. In the 10-15 cm depth the least value of nitrate recorded was 0.436 μg at/l in the first week of September and the highest was 2.163 μg at/l. 0.236 μg at/l was the least value of nitrate in the 15-20 cm depth sample in the first week of August while the highest was 2.340 μg at/l. In the lowest sampled depth of 20-25 cm 0.067 μg at/l was the least value of nitrate and 1.926 μg at/l was the highest (Table 10, Fig.10).

In the coconut grove the minimum value of nitrate in the surface water was recorded in the third week of August which was 0.033 μg at/l while the maximum value for the same was 0.306 μg at/l in the third week of September. In the bottom water the minimum was 0.052 μg at/l in the third week of August and the maximum was 0.327 μg at/l in the third week of September. In the interstitial water in the 0-5 cm depth the minimum recorded value of nitrate was 0.083 μg at/l in the third week of August and the maximum recorded value was 0.448 μg at/l in the third week of September. In the 5-10 cm depth the minimum value increased to 0.122 μg at/l while the maximum became 1.877 μg at/l 0.017 μg at/l was the least recorded value of nitrate from the 10-15 cm depth in the third week of August while 0.92 μg at/l was the highest in the second week of August. The least value of the 15-20 cm depth was 0.028 μg at/l in the third week of August and the highest was 0.760 μg at/l in the second week of August. In the 20-25 cm depth the nitrate value ranged from a minimum of 0.024 μg at/l in the third week of August to 0.620 μg at/l in the first week of August (Table 11, Fig. 11).

The culture pond had nitrate values in the surface water ranging from 0.002 μg at/l in the beginning of the first week of August to 0.374 μg at/l at the end of the first week of August. In the bottom water the values ranged from 0.036 μg at/l in the third week of August to 0.485 μg at/l in the first week of the same month. In the interstitial water sampled from 0-5 cm depth the minimum nitrate value recorded

TABLE NO. 10. NITRATE (μg at/L) (MANGROVE)

	1	2	3	4	5	6	7	8	9	10	11	12
Surface	0.124	0.098	0.237	0.412	0.455	0.142	0.186	0.108	0.496	0.411	1.578	0.116
Bottom	0.304	0.288	0.397	0.563	0.670	0.089	0.092	0.076	0.410	0.436	1.492	0.126
0 - 5 cm	0.359	0.356	0.424	0.702	0.693	0.166	0.264	0.265	0.578	0.827	2.243	0.500
5 - 10 cm	1.008	1.007	1.417	2.841	3.113	0.491	0.627	0.723	1.806	1.926	3.678	1.877
10 - 15 cm	0.796	0.757	0.991	1.839	1.775	0.600	0.436	0.458	1.001	0.724	2.163	0.708
15 - 20 cm	0.236	0.396	0.798	0.978	0.946	0.679	0.510	0.526	0.642	0.636	2.340	0.511
20 - 25 cm	0.094	0.067	0.426	0.622	0.799	0.812	0.628	0.599	0.836	0.321	1.926	0.511

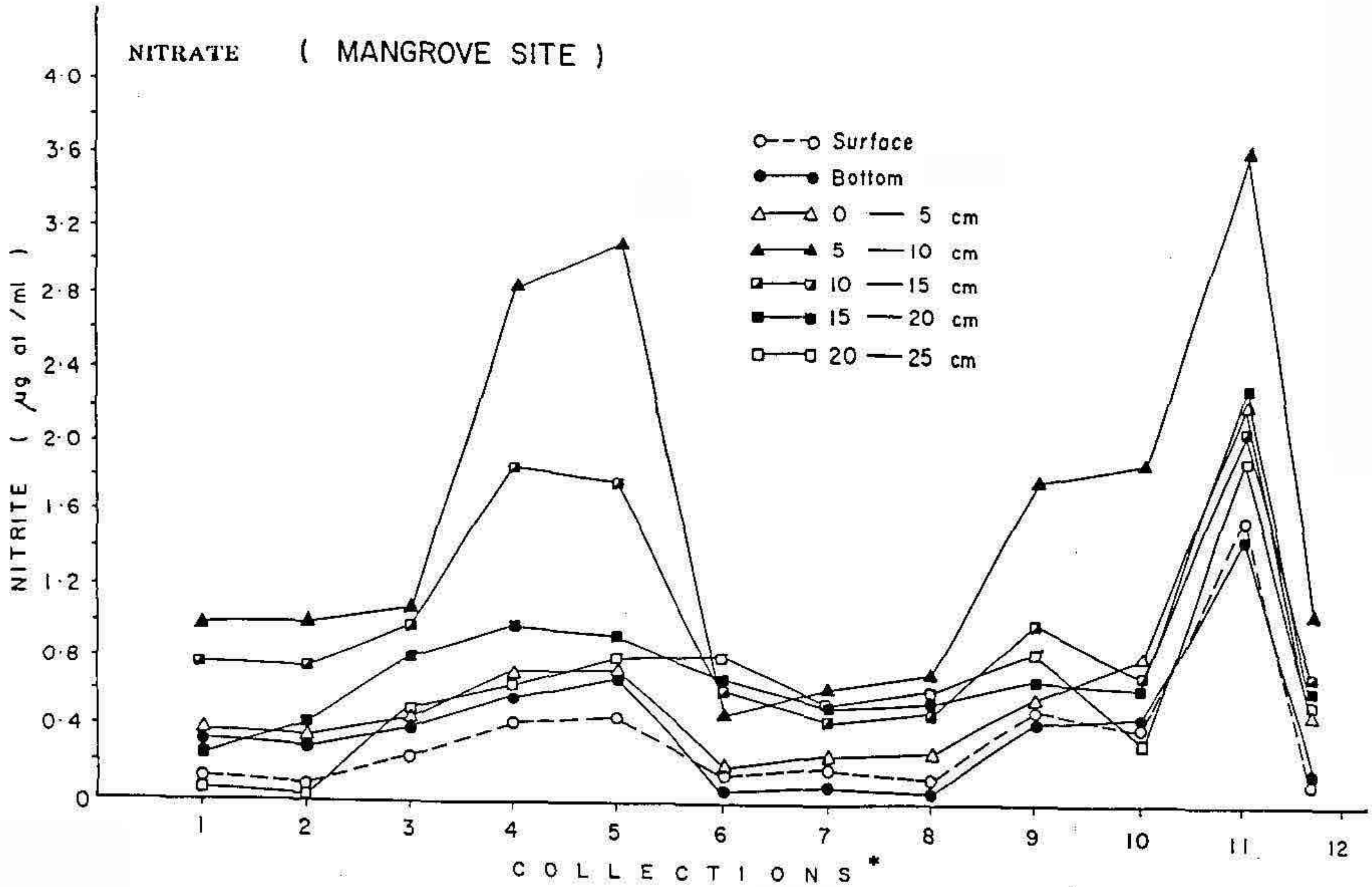


Fig. 10

(*Refer appendix 1)

TABLE NO. 11. NITRATE (μg at/L) (COCONUT GROVE)

	1	2	3	4	5	6	7	8	9	10	11	12
Surface	0.121	0.084	0.098	0.033	0.052	0.081	0.097	0.113	0.281	0.306	0.139	0.157
Bottom	0.149	0.132	0.118	0.052	0.062	0.087	0.126	0.120	0.299	0.327	0.157	0.189
0 - 5 cm	0.172	0.193	0.426	0.083	0.093	0.099	0.264	0.278	0.417	0.448	0.188	0.276
5 - 10 cm	1.765	1.666	1.877	0.122	0.131	0.141	0.373	0.416	0.526	0.555	0.374	0.484
10 - 15 cm	0.254	0.843	0.921	0.031	0.017	0.062	0.117	0.182	0.278	0.376	0.142	0.198
15 - 20 cm	0.231	0.727	0.760	0.028	0.048	0.069	0.138	0.197	0.282	0.398	0.150	0.209
20 - 25 cm	0.166	0.620	0.531	0.024	0.051	0.071	0.150	0.242	0.289	0.420	0.157	0.230

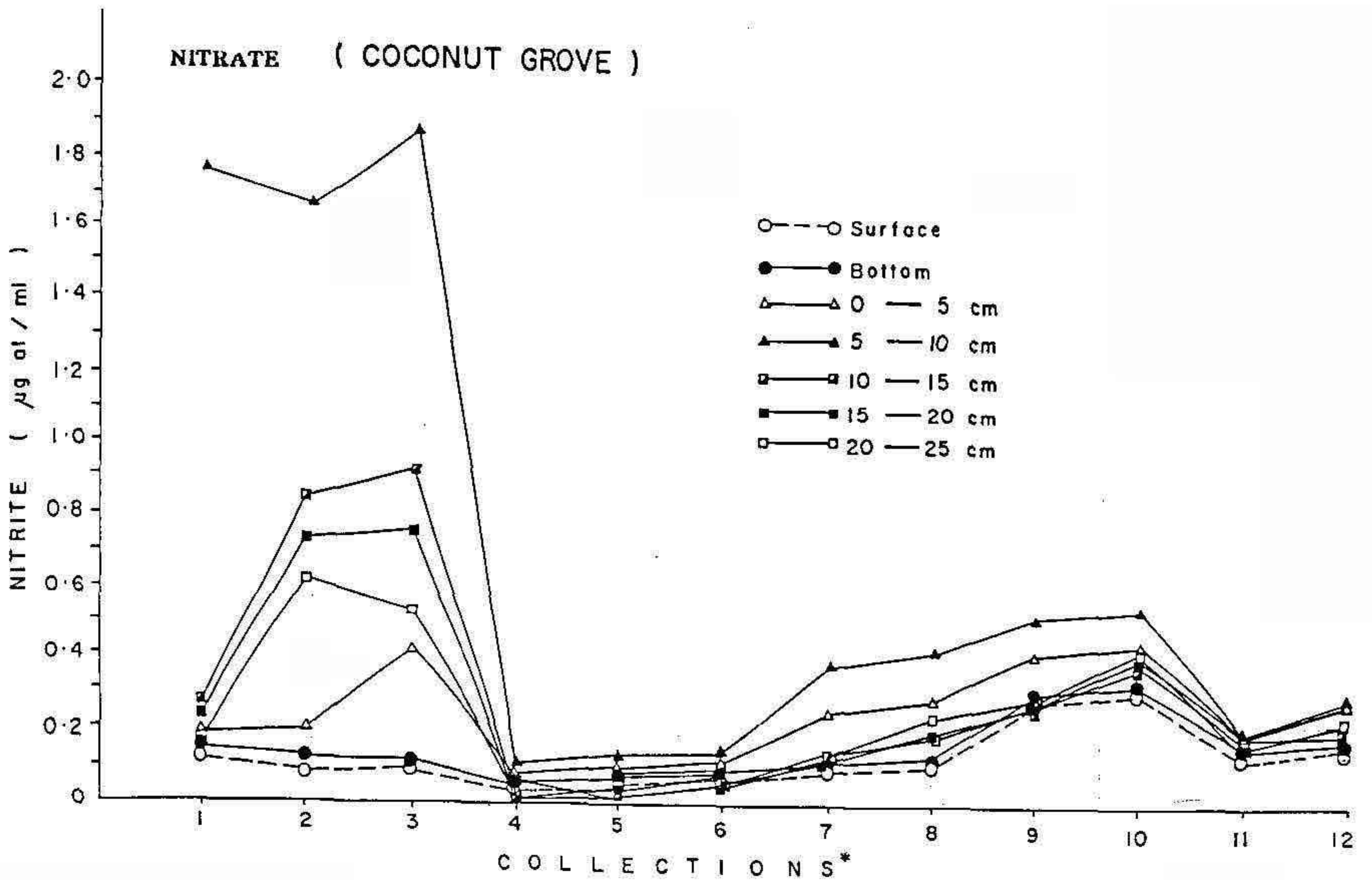


Fig. 11

(*Refer appendix 1)

Table no. 12. NITRATE (μg at/L) (CULTURE POND)

	1	2	3	4	5	6	7	8	9	10	11	12
Surface	0.002	0.374	0.263	0.206	0.018	0.071	0.074	0.020	0.074	0.052	0.081	0.126
Bottom	0.050	0.485	0.298	0.287	0.036	0.106	0.139	0.047	0.186	0.079	0.117	0.174
0 - 5 cm	0.805	1.236	0.679	0.497	0.110	0.286	0.412	0.164	0.222	0.156	0.359	0.589
5 - 10 cm	0.857	1.897	0.911	0.856	0.236	0.414	0.987	0.363	0.526	0.333	0.964	2.624
10 - 15 cm	0.623	0.827	0.301	0.212	0.057	0.111	0.326	0.118	0.102	0.026	0.008	0.642
15 - 20 cm	0.667	0.896	0.327	0.256	0.060	0.174	0.264	0.127	0.128	0.087	0.026	0.686
20 - 25 cm	0.686	0.932	0.358	0.289	0.086	0.212	0.400	0.180	0.156	0.092	0.074	0.714

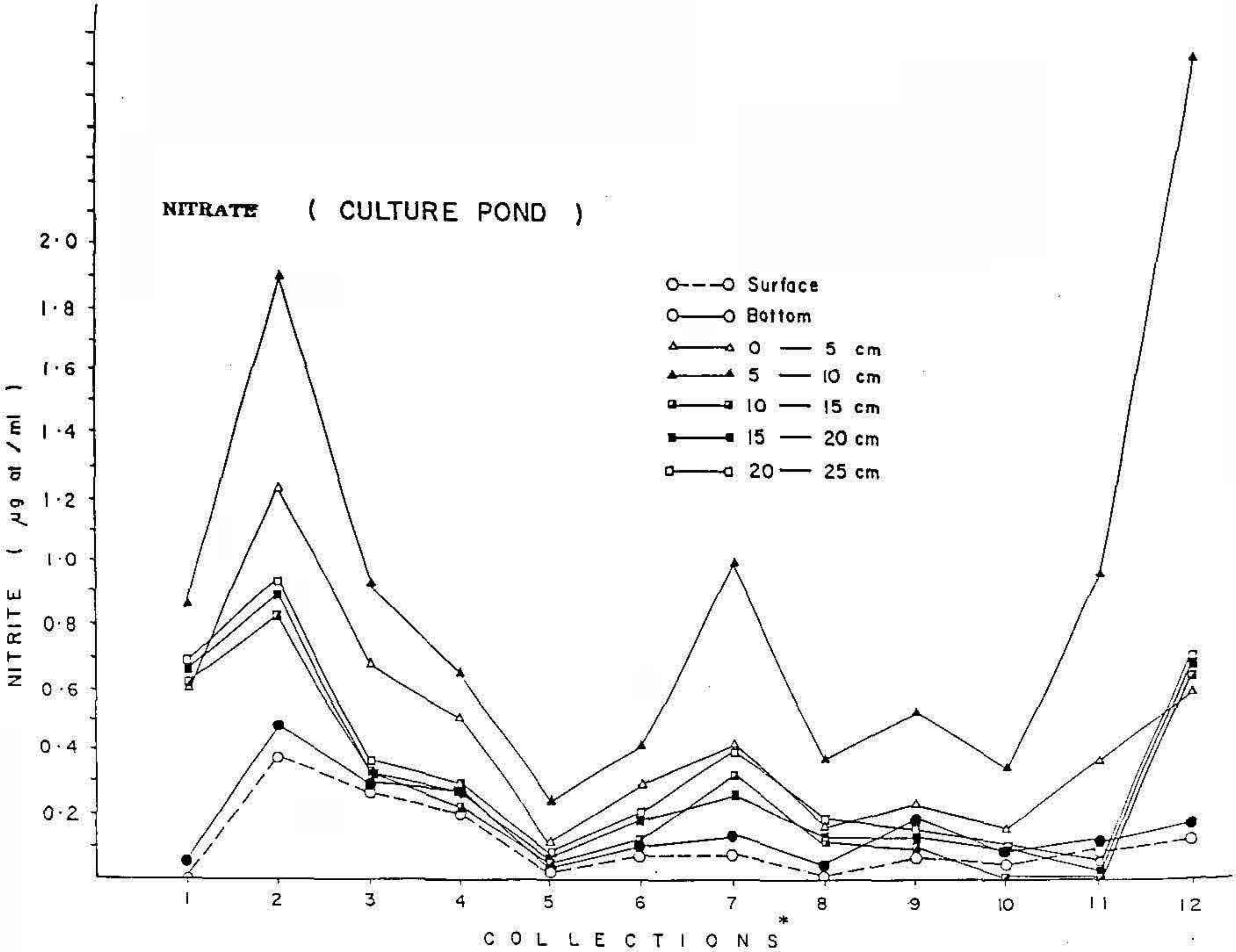


Fig. 12
(*Refer appendix 1)

was 0.110 μg at/l in the third week of August and the maximum was 1.236 μg at/l in the first week of that month. The minimum value of nitrate in the 5-10 cm depth increased to 0.236 μg at/l in the third week of August to 2.624 μg at/l in the last week of September. In the 10-15 cm depth the least value of nitrate sank to 0.008 μg at/l in the third week of September to 0.827 μg at/l in the first week of August. In the next sampled depth viz. 15-20 cm the minimum value was 0.060 μg at/l in the third week of August while the maximum value was 0.896 μg at/l in the first week of the same month. In the 20-25 cm depth the minimum nitrate value was recorded in the third week of September viz. 0.074 μg at/l and the maximum was 0.932 μg at/l in the first week of August (Table 12, Fig. 12).

The nitrate values increased from the surface to the bottom in the column water. The interstitial water samples also showed an increase in the first two layers (0-5 cm and 5-10 cm) after which a progressive decrease was noticed.

Among the ecosystems covered the higher values were noticed in the mangrove site while the coconut grove showed the least values.

The two-way ANOVA of the nitrate values from the different depths and those from the different ecosystems were found to be significant at 1% level (Appendix V).

Nitrite

The surface water of the mangrove station had nitrite values ranging from the least value of 0.028 μg at/l in the first week of August to 0.071 μg at/l in the third week of September. In the bottom the range was between 0.026 μg at/l in the first week of August to 0.082 μg at/l in the first week of September. The interstitial water from the 0-5 cm depth showed a range in nitrite values from 0.043 μg at/l in the last week of August to 0.092 μg at/l in the third week of September. The 5-10 cm depth had 0.042 μg at/l as the least value of nitrite recorded in the first week of September with the highest value of nitrite recorded in the third week of September viz. 0.099 μg at/l. In the 10-15 cm depth 0.027 μg at/l, the least nitrite value was recorded in the first week of August and 0.071 μg at/l the highest nitrite value, was recorded in the first week of September. The least value of nitrite in the 15-20 cm depth was also recorded in the first week of August which was 0.029 μg at/l and the highest value of 0.079 μg at/l was recorded in the first week of September. In the 20-25 cm depth the least nitrite values recorded were 0.031 μg at/l in the third and last week of September and 0.090 μg at/l was the highest value recorded in the first week of September (Table 13, Fig. 13).

In the coconut grove the least nitrite values were recorded in the first week of September. In the surface water the minimum recorded value was 0.005 μg at/l and the maximum was 0.243 μg at/l in the second week of September. In the bottom water the values ranged between

TABLE NO. 13. NITRITE (μg at/L) (MANGROVE)

	1	2	3	4	5	6	7	8	9	10	11	12
Surface	0.028	0.028	0.038	0.038	0.044	0.040	0.052	0.063	0.042	0.071	0.038	0.047
Bottom	0.028	0.027	0.030	0.032	0.036	0.048	0.063	0.082	0.041	0.068	0.049	0.052
0 - 5 cm	0.065	0.068	0.090	0.078	01083	0.043	0.053	0.056	0.078	0.092	0.082	0.081
5 - 10 cm	0.058	0.062	0.086	0.070	01071	0.048	0.062	0.042	0.072	0.098	0.099	0.094
10 - 15 cm	0.027	0.030	0.048	0.039	02047	01052	01071	01059	01051	01057	0.046	0.043
15 - 20 cm	0.029	0.034	0.042	0.052	0.051	0.057	0.079	0.062	0.058	0.051	0.037	0.045
20 - 25 cm	0.034	0.036	0.040	0.056	0.055	0.061	0.090	0.081	0.062	0.042	0.031	0.031

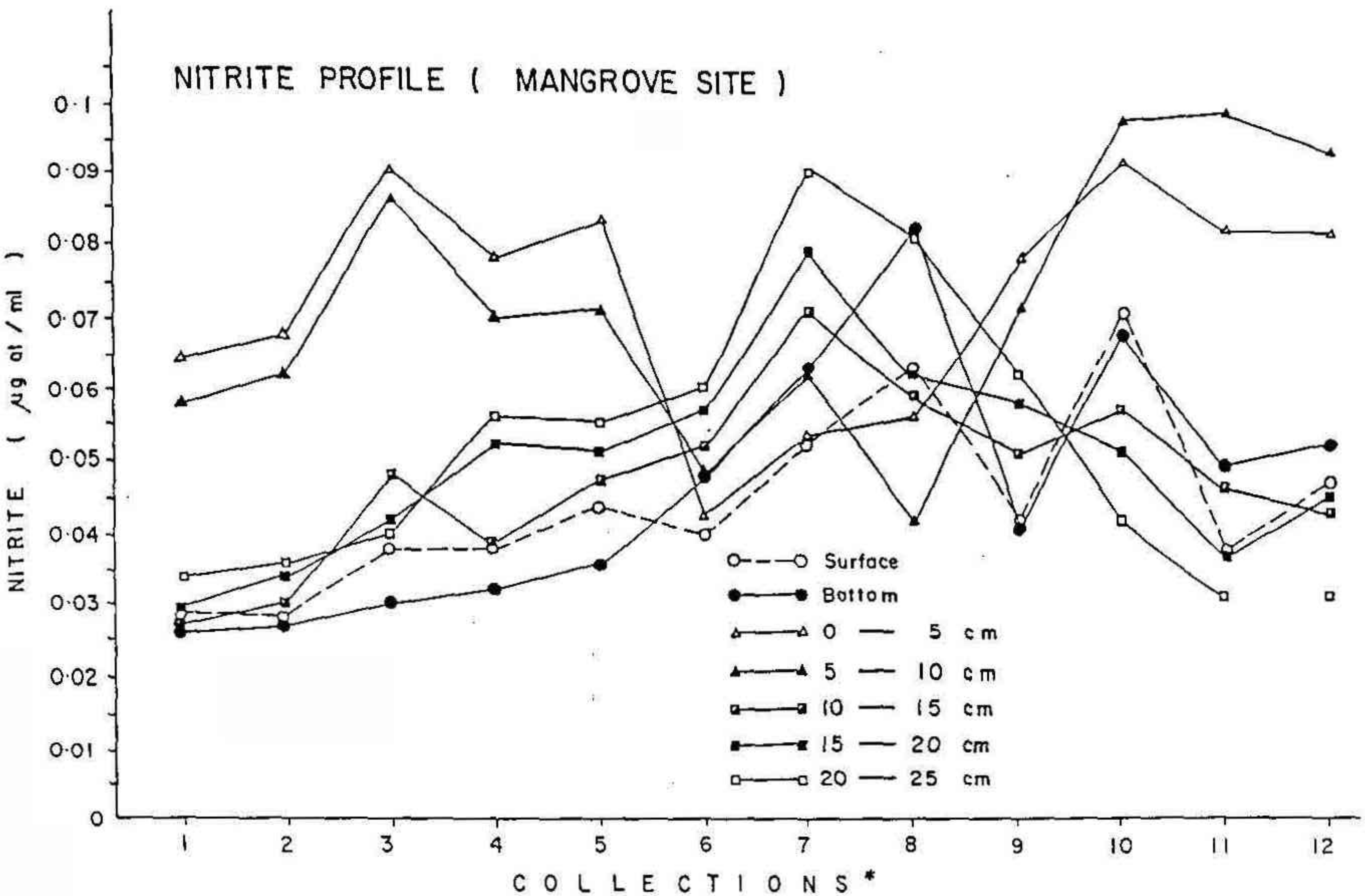


Fig. 13
(*Refer appendix 1)

TABLE NO. 14. NITRITE (μg at/L) (COCONUT GROVE)

	1	2	3	4	5	6	7	8	9	10	11	12
Surface	0.016	0.034	0.022	0.237	0.122	0.182	0.005	0.010	0.243	0.220	0.035	0.061
Bottom	0.022	0.035	0.029	0.289	0.167	0.203	0.007	0.014	0.287	0.276	0.042	0.088
0 - 5 cm	0.026	0.046	0.036	0.311	0.190	0.364	0.012	0.026	0.386	0.328	0.078	0.134
5 - 10 cm	0.125	0.053	0.051	0.364	0.223	0.411	0.016	0.043	0.422	0.513	0.117	0.201
10 - 15 cm	0.020	0.021	0.022	0.293	0.109	0.284	0.006	0.023	0.188	0.252	0.068	0.096
15 - 20 cm	0.021	0.028	0.029	0.300	0.146	0.337	0.007	0.027	0.239	0.276	0.084	0.114
20 - 25 cm	0.024	0.036	0.034	0.312	0.159	0.349	0.007	0.031	0.270	0.318	0.090	0.128

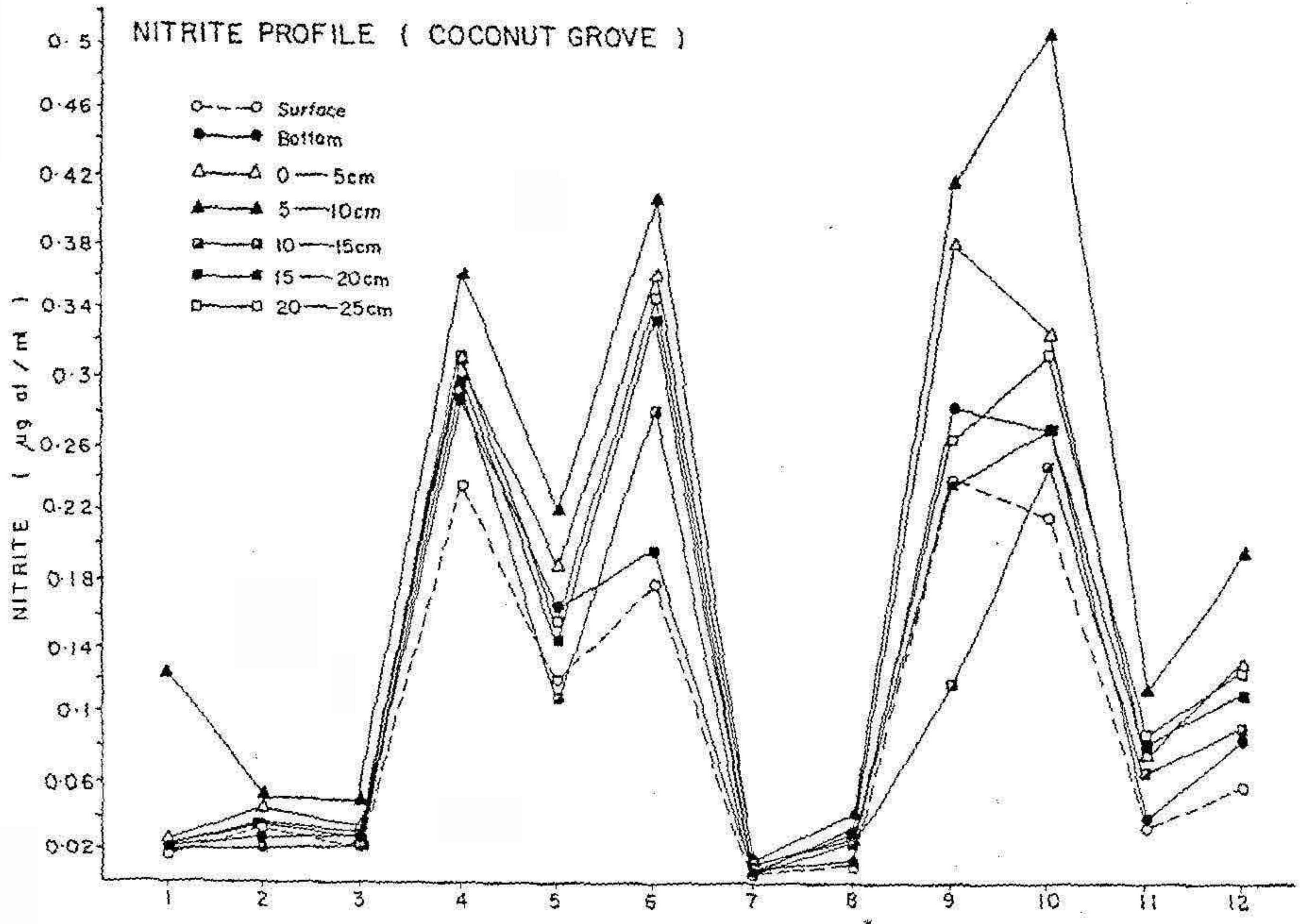


Fig. 14

(*Refer appendix 1)

TABLE NO. 15. NITRITE (μg at/L) (CULTURE POND)

	1	2	3	4	5	6	7	8	9	10	11	12
Surface	0.016	0.008	0.009	0.018	0.045	0.012	0.017	0.026	0.011	0.006	0.004	0.010
Bottom	0.020	0.009	0.013	0.024	0.057	0.024	0.029	0.042	0.019	0.011	0.009	0.025
0 - 5 cm	0.44	0.033	0.052	0.127	0.129	0.117	0.126	0.152	0.089	0.081	0.085	0.099
5 - 10 cm	0.048	0.040	0.063	0.212	0.256	0.225	0.174	0.252	0.157	0.155	0.125	0.234
10 - 15 cm	0.022	0.016	0.021	0.086	0.087	0.006	0.033	0.086	0.024	0.018	0.030	0.050
15 - 20 cm	0.028	0.018	0.025	0.092	0.092	0,018	0.041	0.099	0.036	0.024	0.036	0.074
20 - 25 cm	0.029	0.020	0.029	0.117	0.100	0.024	0.057	0.117	0.039	0.032	0.045	0.082

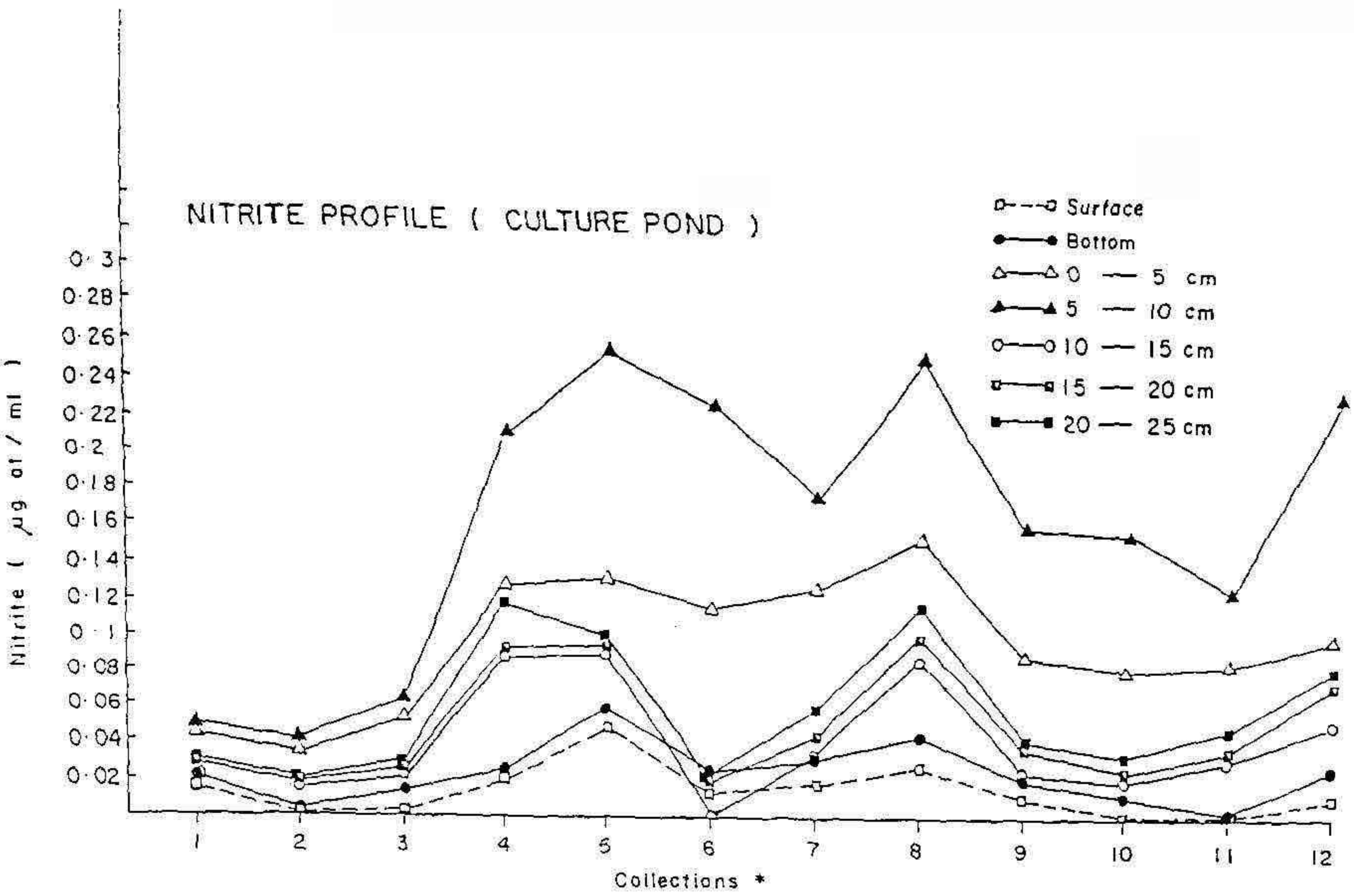


Fig. 15

(*Refer appendix 1)

0.007 /ug at/l and a maximum of 0.289 /ug at/l in the third week of August. In the 0-5 cm depth interstitial water sample the minimum was 0.012 /ug at/l while the maximum was 0.386 /ug at/l in the second week of September. The 5-10 m depth sample showed the widest range of values with a minimum of 0.016 /ug at/l and a maximum of 0.513 /ug at/l in the third week of September. 0.006 /ug at/l was the least value of nitrite in the 10-15 cm depth sample while the highest was 0.293 /ug at/l in the third week of August. In the 15-20 cm depth the minimum nitrite value was 0.007 /ug at/l while the maximum was 0.300 /ug at/l in the third week of August. In the lowest depth sampled viz. 20-25 cm the least nitrite value was 0.007 /ug at/l and the highest was 0.318 /ug at/l in the third week of September (Table 14, Fig. 14).

The culture pond had the least value of nitrite in the surface water at 0.004 /ug at/l in the third week of September while the highest was at 0.045 /ug at/l in the third week of August. In the bottom water the minimum value was 0.009 /ug at/l in the first week of August and third week of September to a maximum of 0.057 /ug at/l in the third week of August. In the 0-5 cm interstitial water sample nitrite values ranged between 0.033 /ug at/l in the first week of August to 0.152 /ug at/l in the first week of September. In the 5-10 cm sample the minimum value was 0.040 /ug at/l in the first week of August while the maximum value had moved upto 0.256 /ug at/l in the third week of August. 0.006 /ug at/l was the least value of nitrite in the 10-15 cm depth sample in the last week of August while 0.087 /ug at/l in the third week of August was the highest value. The minimum value in the 15-20 cm depth sample was 0.018 μg at/l in the first and last weeks of August while the maximum value was 0.099 μg at/l in the first week of September. The minimum had risen marginally to 0.020 μg at/l in the first week of August in the 20-25 cm depth sample while the maximum value had gone upto 0.117 μg at/l. (Table 15, Fig. 15).

Though the nitrite values from the mangrove station did not show any regular trend in the other 2 ecosystems nitrite generally increased from surface to bottom and in the interstitial water the increase was upto the 5-10 cm depth range from where a steep drop was observed in the next level (viz. 10-15 cm). Progressively lower values were recorded downwards. In general it was noticed that the nitrite values obtained were extremely low.

The two-way ANOVA showed that the nitrite values of the different depths and those from the different ecosystems were significant at 1% level (Appendix VI).

Growth data

The following was the length - weight data obtained from the growth studies conducted in the culture pond in the 60 day study period in the 4 pens of one square metre dimension where Penaeus indicus of 4-7 cm total length was stocked and cultured at a density of $25/m^2$. The salinity from the surface, bottom and the interstitial water from the 0-5 cm depth were also studied to observe its effect on the growth of the prawns. Of the four pens, one was kept as control while the other three were used as experimental pens and only the prawns in the experimental pens were fed at a rate of 12% of the body weight every day.

Length:

	Average Stocking length	Average length at Harvest (After 60 days)	Length gained	Average growth per day (mm)
Control	5.28 (± 0.462)	8.40 (± 0.1817)	3.12 cm	0.052
Experiment I	5.20 (± 0.3564)	9.78 (± 2653)	4.58 cm	0.076
Experiment II	5.26 (± 0.353)	9.96 (± 0.2821)	4.70 cm	0.078
Experiment III	5.34 (± 0.4946)	9.86 (± 0.2581)	4.52 cm	0.075

Generally a steeper increase in length was observed between the 10th day and the 35th day in the experimental pens while in the control it was more pronounced between the 20th and 35th day and later between the 45th day and 50th day.

Weight

	Average Stocking Weight	Average weight at Harvest (After 60 days)	Weight gained	Average Growth per day (g)
Control	1.3447 (± 0.1539)	3.5516 (± 0.1631)	2.2069 g	0.037 g
Experiment I	1.2883 (± 0.1093)	5.0478 (± 0.3217)	3.7595 g	0.063 g
Experiment II	1.2880 (± 0.0458)	5.296 (± 0.3002)	4.0081 g	0.067 g
Experiment III	1.4180 (± 0.1753)	5.0102 (± 0.2211)	3.5922 g	0.050 g

Table No.18

Salinity and Growth (Experiment II)

	Initial	1	2	3	4	5	6	7	8	9	10	11	12
LENGTH	5.26	5.28	5.46	6.2	6.36	7.9	8.62	9.1	9.38	9.44	9.48	9.6	9.96
WEIGHT	1.2880	1.2998	1.3961	1.6788	1.7207	3.2038	3.8736	4.3262	4.5537	4.5938	4.6768	4.7898	5.2961
SALINITY Surface		0.98	2.92	1.89	4.92	5.52	5.12	9.18	5.11	8.82	11.64	6.88	5.29
Bottom		1.20	3.06	2.03	5.09	5.67	5.65	9.84	5.48	8.97	11.90	7.14	5.61
0-5cm		1.07	3.78	2.78	5.87	6.47	6.88	10.90	6.77	10.80	13.64	8.97	6.70

Table No.19

Salinity and Growth (Experiment III)

	Initial	1	2	3	4	5	6	7	8	9	10	11	12
LENGTH	5.34	5.38	5.46	5.86	6.74	7.64	8.2	8.66	8.74	8.86	9.26	9.58	9.86
WEIGHT	1.4180	1.3554	1.3926	1.5406	1.9232	2.7953	3.4105	3.9112	3.9189	4.0613	4.4305	4.8446	5.0102
SALINITY Surface		0.82	2.72	1.54	4.78	5.64	5.09	9.06	5.19	8.41	11.39	6.39	5.68
Bottom		1.23	2.85	1.80	4.81	5.79	5.24	9.62	5.55	8.60	11.77	6.80	5.92
0-5cm		1.36	3.69	2.66	5.97	6.43	6.80	10.74	6.89	9.83	12.82	7.45	7.13

Table No.16

Salinity and Growth (Control)

	Initial	1	2	3	4	5	6	7	8	9	10	11	12
LENGTH	5.28	5.6	5.6	5.74	5.82	6.2	6.72	7.04	7.3	7.32	7.76	8.06	8.4
WEIGHT	1.3447	1.3724	1.3779	1.4335	1.4470	1.5826	1.9244	2.2844	2.5884	2.6510	3.0315	3.2353	3.5516
SALINITY Surface		1.29	2.86	1.75	4.89	5.62	4.96	8.98	4.90	8.23	11.27	6.23	5.06
Bottom		1.18	2.97	1.92	5.04	5.78	5.11	9.27	4.99	8.42	11.68	6.74	5.66
0-5cm		0.68	3.68	2.87	5.76	6.88	6.27	10.63	6.23	9.67	12.96	7.89	6.78

Table No.17

Salinity and Growth (Experiment I)

	Initial	1	2	3	4	5	6	7	8	9	10	11	12
LENGTH	5.2	5.48	5.66	6.54	7.14	7.36	8.6	8.8	9.06	9.18	9.54	9.54	9.78
WEIGHT	1.2883	1.4086	1.4854	1.7793	2.3961	2.4956	3.8495	4.0303	4.2724	4.3957	4.7267	4.9139	5.0478
SALINITY Surface		1.01	2.64	1.67	4.72	5.74	5.32	9.36	5.24	8.64	11.52	6.49	5.54
Bottom		1.16	2.89	1.72	4.88	5.93	5.62	9.78	5.62	8.88	11.85	6.91	5.89
0-5cm		0.88	3.42	2.38	5.72	7.26	6.04	10.79	6.87	10.32	13.32	8.32	6.64

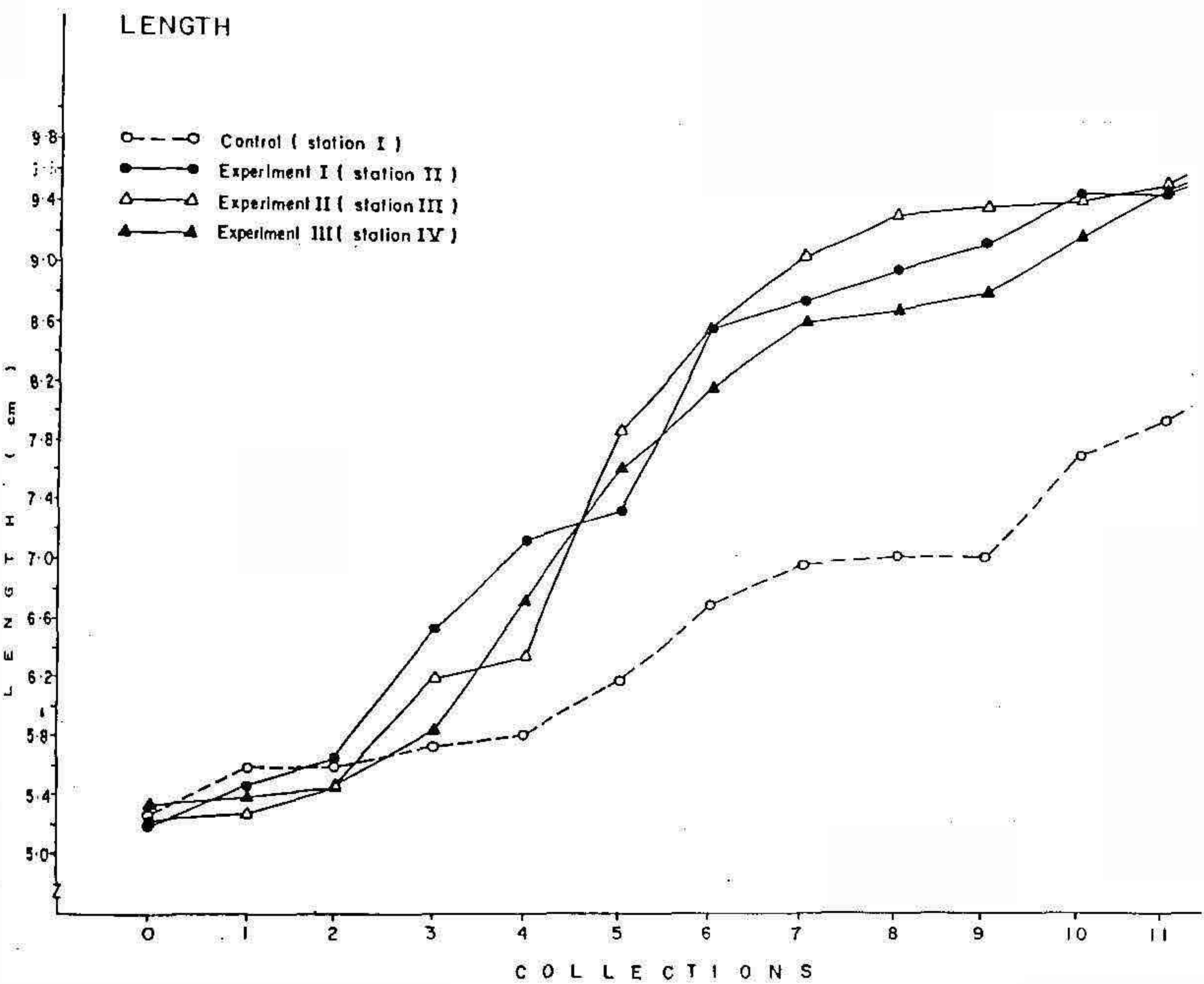

LENGTH
Control (station I)
Experiment I (station II)
Experiment II (station III)
Experiment III (station IV)
9·8
9·4
9·0
8·6
8·2
7·8
7·4
7·0
6·6
6·2
5·8
5·4
5·0
LENGTH (cm)
0
1
2
3
4
5
6
7
8
9
10
11
COLLECTIONS

Fig. 16

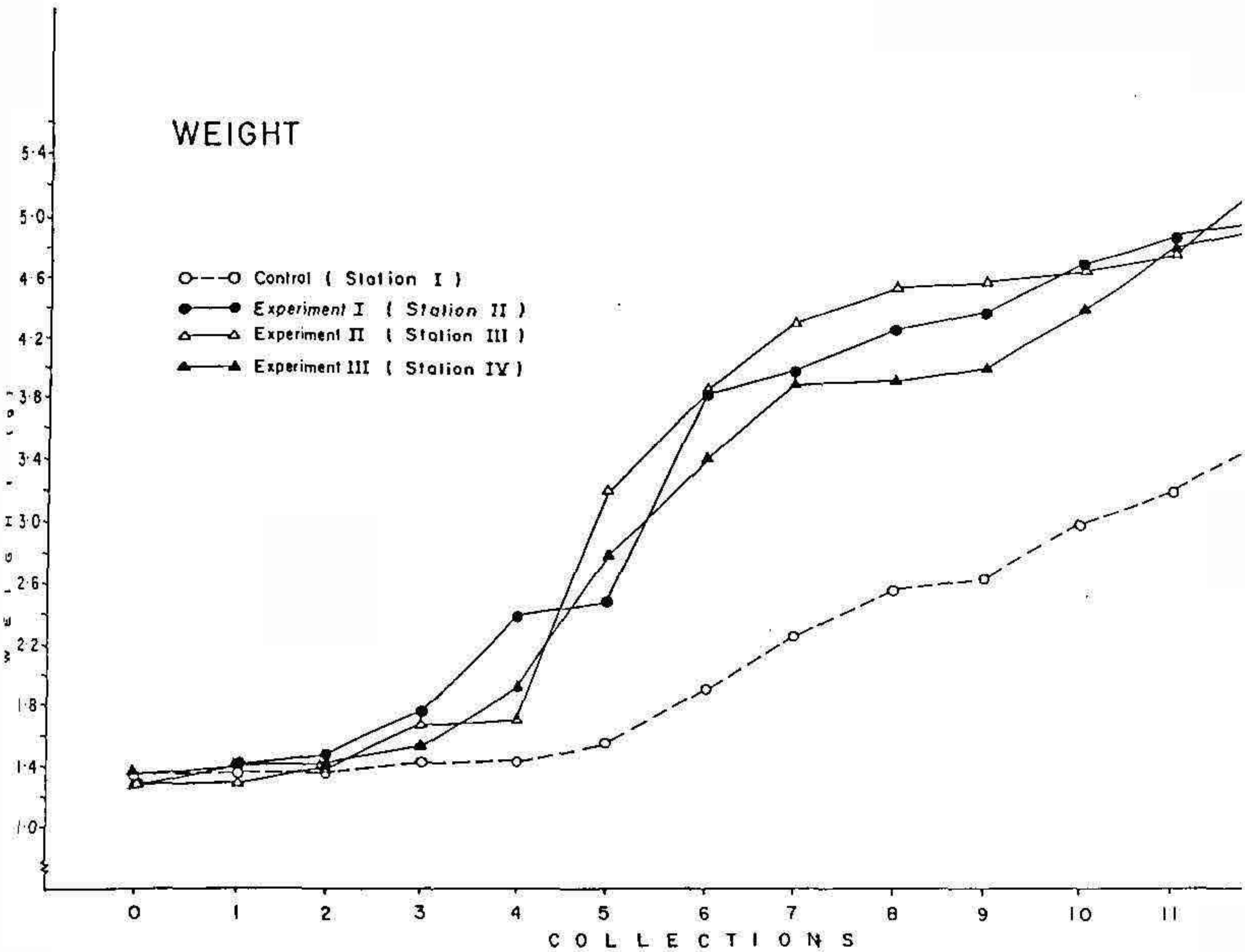

WEIGHT
Control (Station I)
Experiment I (Station II)
Experiment II (Station III)
Experiment III (Station IV)
5·4
5·0
4·6
4·2
3·8
3·4
3·0
2·6
2·2
1·8
1·4
1·0
0
1
2
3
4
5
6
7
8
9
10
11
COLLECTIONS

Fig. 17

In the case of experimental pens the weight data showed a steep increase between the 20th day and 35th day while the growth in weight was more pronounced in the control between the 25th day and 40th day and later beyond the 45th day.

Survival:

From an initial stocking density of 25 animals per square metre the final survival rate was as follows:-

	Stocking rate	Density at Harvest	Percentage Survival
Control	$25/m^2$	$16/m^2$	64%
Experiment I	$25/m^2$	$21/m^2$	84%
Experiment II	$25/m^2$	$18/m^2$	72%
Experiment III	$25/m^2$	$21/m^2$	84%

It can be noticed that the survival rate is higher in the experimental pens with fed prawns than in the control with the unfed prawns.

Salinity

The salinity in all the pens had their minimum values in the first week of August and the maximum values in the third week of September. The salinity in the surface water of the control varied from 1.29 ppt to 11.27 ppt. In the bottom the range was between 1.18 ppt and 11.68 ppt. In the interstitial water (0-5 cm) the minimum was 0.68 ppt and maximum 12.96 ppt.

In the experiment number I the surface salinity had the least value at 1.01 ppt and the highest at 11.52 ppt. In the bottom the variation was from 1.16 ppt to 11.85 ppt. The interstitial water from the 0-5 cm depth had the minimum at 0.88 ppt and maximum at 13.32 ppt.

The experiment number II had salinity in the surface water from 0.96 ppt to 11.64 ppt. In the bottom the least value was at 1.20 ppt and the highest at 11.90 ppt. The 0-5 cm depth sample of interstitial water had the minimum salinity of 1.07 ppt and the maximum of 13.64 ppt.

In the experiment number III the surface water had the lowest salinity of 0.82 ppt and the highest of 11.39 ppt. The bottom water salinity had a minimum of 1.23 ppt and a maximum of 11.77 ppt. The interstitial water from the 0-5 cm depth had the lowest salinity value of 1.36 ppt and the highest of 12.82 ppt.

According to the correlation matrix (Appendix VII) the length data and surface water salinity values were correlated with very high significance. The correlation between length data and bottom water salinity and that between length data and interstitial water salinity of 0-5 cm depth was found to be highly significant.

According to the correlation matrix (Appendix VII) the weight data and surface salinity values were correlated significantly at 1% level.

The correlation between weight data and bottom salinity was highly significant and that between weight data and interstitial salinity of the 0-5 cm depth was found to be significant at 1% level.

DISCUSSION

Among the three dilute salt water environments which are normally suitable for prawn culture practices chosen for the present study, the investigation carried out and data presented, the comparatively high salinity in the column and in the interstitial water in the mangrove station could be due to the direct connection that the tidal canal of the mangrove has with the sea. The coconut grove and culture pond stations have comparatively lower salinities as the back water system that feeds them is diluted by more freshwater inflows. The higher salinity in the culture pond than in the coconut grove could be due to the proximity of the former to the sea.

The salinity of the surface water is lower than the bottom marginally. This could be due to the high density of the higher saline waters.

It was observed in the three ecosystems that were studied that the salinity of the interstitial water was always higher than that of the column water. In the 0-5 cm zone the salinity is higher than the water immediately above it by 0.5 - 1.4 ppt though it is in direct contact with the low saline water above. But immediately below, in 5-10 cm depth, salinity lower than the strata above it is observed. This becomes significant when the 10-15 cm strata below shows an increase to that of the 5-10 cm. From this depth onwards increase of salinity coincided with the increase of depth upto 20-25 cm till which the present study was limited.

Mortimer (1941, 1942) while discussing chemical exchange in lakes between sediments and water has arrived at a general conclusion that various trapping mechanisms (eg. adsorption and complex formation) in the superficial oxidized sediments can prevent the transport of materials into the water. this could be the reason that there is a marked increase in the salinity of the first layer of interstitial water viz. 0-5 cm.

Lack of mixing in the interstitial waters causes the salts to concentrate with concentration increasing in the lower layers due to the increasing density. Ganapati et al. (1962) found a variation of 1 ppt between the interstitial and overlying waters on beaches on hot summer days. This is in accordance with the observations of this study where variations of upto 1 ppt are observed between the column water and the consecutive layers of the interstitial waters.

That the lowest of salinity values in all the sampled depths were found in one single sampling day during the first week of August and highest values during the third week of September is notable and clearly explains a limited and definite interaction between column and interstitial water.

The low salinity of the interstitial water between 5-10 cm compared to the 0-5 cm strata above and 10-15 cm strata below is intriguing and not explainable. Perhaps had the study been extended downwards upto 50 cm the finding would have thrown more light on the low saline 5-10 cm strata and most likely a cycling of salt water would have been understood.

The decrease in salinity in the 5-10 cm depth coincides with a marginally lower temperature in this depth.

The culture pond shows the highest temperature amongst the three ecosystems while the coconut grove shows the least.

In general like salinity, the temperature gradient in the interstitial waters shows a fall of 0.5 to 1°C in the 5-10 cm depth than in the 0-5 cm depth and gradually increased towards the lower layers.

The higher temperatures in the culture pond station could be due to the lower water depth and also because the pen is directly exposed to the sun. The lower temperature ranges in the coconut grove could be due to the canopy of trees preventing the direct heating of the water.

The higher temperature in the surface water samples compared to the bottom water samples could be due to the direct heating of the surface water by sunlight and that water at lower temperature is denser and hence sinks to the bottom. Ganapathi et al. (1962) noticed that temperature decreased with depth in the 15 cm depth range that they studied. This could explain the lower temperature of the 5-10 cm depth as compared to the 0-5 cm depth. The increase in temperature at the lower depths could be due to the slower loss of heat from these layers as we move away from the surface due to lack of any mixing forces.

The culture pond showed higher pH values than the other 2 ecosystems and there is only a very negligible difference between the coconut grove and culture pond.

The surface water, bottom water and the interstitial water from the 0-5 cm depth showed more or less the same pH in all the stations though an increase in pH was noticed in the lower layers.

The comparatively higher pH in the culture pond could be due to the higher photosynthetic activiy caused by the fertilising effects of the feed used and the closed nature of the pond with less water exchange acting as a nutrient sump. The low pH recorded in all the station in the first week of August could be caused due to the decomposition of organic matter carried in by the flood water of the rains (Subnash Chander (1986), Upadhayay (1988)). The increase in pH noticed in the later collections could be due to the photosynthetic activity of phytoplankton and aquatic vegetation which removes the CO_2 from the water column. Ganapathi et al. (1962) observed lower pH in interstitial waters than the overlying waters which they attributed to the low oxygen and high CO_2 in this zone. Prasad (1982), Srinivasan (1982), Sugunan (1983) and Singh (1987) while investigating the ecology of brackish water culture systems near Cochin, reported high values of pH for water and sediments during monsoon and post monsoon. But Ravindran (1983), Chandran and Ramamurthy (1984) Sheeba Susan Mathews (1992) reported that pH did not show any seasonal and tidal variations.

The nitrate and nitrate values in all the ecosystems showed a general increase in the column water from the surface to bottom and in the interstitial waters it incresed to a peak in the 5-10 cm beyond which low values were observed.

The higher values of nitrate and nitrite observed in the mangrove station could be due to its enrichment from the high amount of organic input from the human settlement around.

Lerman and Brunskill (1971) while studying the migration of major constituents from lake sediments to the lake water have suggested that the higher concentrations of dissolved components in interstitial water than in lake water indicate that there may be an upward flux across the sediment water interphase and this flux must account for some fraction of the chemical budget of the lakes. Components in the interstitial water in all approximation can be identified as those in sediments. Interruption of the flux from bottom se diments, however shall result in a decrease a concentration of dissolved components in the lake water compared to the sediments. Venugopalan et al. (1975) stated that in Vellar estuary monsoonal maximum of nitrogen compounds in water is found to be depleted during post monsoon season by post monsoon bloom of phytoplankton. This could explain the low values of nitrate and nitrite obtained in the present study. The nitrate concentration in the interstitial water increases to a maximum at the base of the zone of aerobic respiration and decreases in the zone of denitrifiation (Bender et al. (1977)) which is in accordance with the data observed in the present study where the depth upto 10 cm could be the zone of aerobic respiration. According to Malcolm and Stanley (1982) the concentration of factors like nitrate is much higher in the sediment interstitial water than in the overlying water and this leads to major fluxes across the sediment water interface. Mortimer (1941, 1942) says that under oxidising conditions the ions except nitrate and nitrite are adsorbed on soil colloids. The low retention capacity of the sediments with respect to nitrate and nitrite was also observed by Dinesh Babu (19850).

In the control pen the bottom salinity ranged between 1.18 ppt and 11.68 ppt. The recovery after 60 days growth was 64%. In experiments I,II & III,it is 84,72 & 84% respectively. The bottom salinity range in the 4 pens *did not vary much from one another and was between* 1.16 ppt to 11.90 ppt.

Shylaja (1989) indicated that the juvenile Penaeus indicus of 40-70 mm can tolerate a wide range of salinity varying from 3.9 - 40.7 ppt under environmental conditions. Kuttyamma (1980) noticed the extreme euryhaline nature of juvenile P. indicus obtained from wild and reported 5.35 ppt as the best survival limit. Based on laboratory rearing Nair and Krishnankutty (1975) noticed that the growth rate of P. indicus was significantly high in a salinity of 10 ppt for post larval stages and in a salinity of 30 ppt for juvenile prawns. Paul Raj and Sanjeeva Raj (1982) found better growth and survival rates at an optimum salinity range of 15-20 ppt levels. Kalyanaraman (1983) found that P. indicus of 26 to 32 mm size range have an optimum salinity preference of 20 ppt.

From the above referred facts maximum tolerable limit at the lower extreme is 3.9 ppt but the present study reveals that the juveniles of 40-70 mm size group tolerated a low salinity of 1.16 ppt. This could be due to the higher saline interstitial waters in the 0-5 cm depth and the burrowing habits of the particular species. Hindley's (1975) observation that most penaeids burrow or remain inactive during the day, supports this. The low survival in the control pen could be due to the lack of feed and cannibalism. The growth per day values in the experimental pens are comparable to those obtained by George (1975) in the Cochin backwaters, with the experimental pens showing higher values, possibly due to the feed given. The comparitively higher survival and growth rates of the experimental pens than the control indicate that the prawns in them have carried on the normal life activities like feeding and growth in the low salinities.

The higher correlation of the growth parameters viz., length and weight with the salinity of the interestitial water than that with the salinity of the bottom and surface samples of the column water strengthens the possibility of prawns seeking the sub-soil environment in adverse conditions (Appendix VII).

SUMMARY

The work was undertaken with an objective to study the salinity, temperature, pH, nitrate and nitrite of the interstitial water in comparison with the column water of three ecosystems viz. a mangrove, a coconut grove and a culture pond. All the ecosystems are situated on Vypeen island, Kochi.

As the sampling procedures and sampling devices used in sampling interstitial water in earlier studies were found unsuitable for the present study an interstitial water sampler was designed and fabricated. It consisted of four detachable parts (i) the basal cone, with threaded adaptors, (ii) an encasing GI pipe, (iii) a ventilated PVC pipe and (iv) a filter candle with string of which the filter candle was the actual filtering and collecting unit. The interstitial water was sampled from five different depths from the soil surface downwards viz. (i) 0-5 cm (ii) 5-10 cm (iii) 10-15 cm (iv) 15-20 cm and (v) 20-25 cm.

The salinity was found to be highest in the mangrove station among the ecosystems and least in the coconut grove. In the column water the bottom samples were more saline than the surface and the interstitial water was always more saline than the column water in all the ecosystems studied. In the interstitial water the salinity increased towards the lower depths with a maximum in the 20-25 cm depth, though the 5-10 cm depth was an exception showing lower salinity than the strata above and below it.

The culture pond showed the highest temperature amongst the ecosystems and the coconut grove, the least. Though in the column the temperature trend was opposite that of the salinity with the surface showing higher temperature, in the soil the trend was similar to the salinity with a general increase in the lower depths with the 5-10 cm layer being an exception showing lower temperature than the layers above and below it.

The pH values were highest in the culture pond while comparing the ecosystems with the other two systems showing more or less similar ranges. The column water and the 0-5 cm depth showed more or less the same pH with an increase in pH in the lower layers.

The nitrate and nitrite values showed a general increase in the column water from surface to bottom and in the interstitial water it reached a peak in the 5-10 cm layer beyond which low values were observed Generally the nitrite values obtained were very low. Among the ecosystems the mangrove showed the highest values.

Simultaneous to the above studies conducted in the months of August and September, a 60 day growth study was conducted in the culture pond alone by growing the juveniles of Penaeus indicus of the 4-7 cm size range in one square metre pens. One pen was maintained as control where no feed was given while in the other pens the animals were fed at 12% body weight every day. The animals were stocked at a density of 25 animals per square meter. Salinity from the surface water, bottom water and interstitial water from the the 0-5 m depth of all the pens were also studied regularly to correlate the same with growth. It was found that the growth rate of the animals in the experimental pens were significantly higher than the control though the salinity ranges were more or less the same.

Appendix I

Index of Collection dates

Collection Number	Date
1	03.08.92
2	07.08.92
3	12.08.92
4	17.08.92
5	22.08.92
6	27.08.92
7	01.09.92
8	07.09.92
9	11.09.92
10	16.09.92
11	21.09.92
12	26.09.92

All the collections were carried out between 8 hrs and 12 hrs.

Appendix II

Two way ANOVA (Salinity)

Means for first source (depths)

Depth	Means
Surface	5.716945
Bottom	6.002778
0 - 5 cm	6.790000
5 - 10 cm	6.529445
10 - 15 cm	7.714167
15 - 20 cm	8.660278
20 - 25 cm	9.543334

Means for second source (Ecosystems)

System	Mean
Mangrove	8.013097
Coconut grove	6.578453
Culture pond	7.247144

ANOVA

Source	df	SS	MS	F
First (depths)	6	435.386	72.564	7.923
Second (Ecosystems)	2	86.571	43.286	4.726
Interaction	12	6.817	0.568	0.062
Cell totals	20	528.774	26.439	2.887
Error	231	2115.749	9.159	1.000
Total	251	2644.523		

Appendix III

Two way ANOVA (Temperature)

Means for first source (depths)

Depth	Mean
Atm. Temperature	28.888889
Surface	29.777779
Bottom	28.819445
0 - 5 cm	29.569445
5 - 10 cm	29.111111
10 - 15 cm	30.069445
15 - 20 cm	30.861111
20 - 25 cm	31.583334

Means for second source (Ecosystems)

System	Mean
Mangrove	29.031250
Coconut grove	28.796875
Culture pond	31.677084

ANOVA

Source	df	SS	MS	F
First (depths)	6	240.797	34.400	8.351
Second (Ecosystems)	2	491.250	245.625	59.629
Interaction	14	10.906	0.779	0.189
Cell totals	23	742.953	32.302	7.842
Error	264	1087.469	4.119	1.000
Total	287	1830.422		

Appendix IV

Two way ANOVA (pH)

Means for first source (depths)

Depth	Mean
Surface	8.406945
Bottom	8.311111
0 - 5 cm	8.309722
5 - 10 cm	8.280556
10 - 15 cm	8.513889
15 - 20 cm	8.569446
20 - 25 cm	8.540278

Means for second source (Ecosystems)

System	Mean
Mangrove	8.226192
Coconut grove	8.310715
Culture pond	8.719644

ANOVA

Source	df	SS	SS	F
First (depth)	6	3.217	0.536	1.282
Second (Ecosystems)	2	11.707	5.854	13.992
Interaction	12	5.080	0.423	1.012
Cell totals	20	20.004	1.000	2.391
Error	231	96.637	0.418	1.000
Total	251	116.641		

Appendix V

Two way ANOVA (Nitrate)

Means for first source (depths)

Depth	Mean
Surface	0.202389
Bottom	0.243472
0 - 5 cm	0.439694
5 - 10 cm	1.108722
10 - 15 cm	0.528306
15 - 20 cm	0.451278
20 - 25 cm	0.407528

Means for second source (Ecosystems)

System	Mean
Mangrove	0.789250
Coconut grove	0.289917
Culture pond	0.370000

ANOVA

Source	df	SS	MS	F
First (depth)	6	19.378	3.230	16.612
Second (Ecosystems)	2	12.083	6.041	31.073
Interaction	12	3.704	0.309	1.588
Cell totals	20	35.164	1.758	9.043
Error	231	44.911	0.194	1.000
Total	251	80.076		

Appendix VI

Two way ANOVA (Nitrite)

Means for first source (depths)

Depth	Mean
Surface	0.052722
Bottom	0.063750
0 - 5 cm	0.109444
5 - 10 cm	0.148389
10 - 15 cm	0.067528
15 - 20 cm	0.077444
20 - 25 cm	0.085222

Means for second source (Ecosystems)

System	Mean
Mangrove	0.054762
Coconut grove	0.141310
Culture pond	0.0630000

ANOVA

Source	df	SS	MS	F
First (depth)	6	0.233	0.039	6.179
Second (Ecosystems)	2	0.383	0.192	30.561
Interaction	12	0.062	0.005	0.822
Cell totals	20	0.678	0.034	5.403
Error	231	1.449	0.006	1.000
Total	251	2.127		

Appendix VII

Correlation matrix : (Growth and salinity)

	Length	Weight	Surface Salinity	Bottom Salinity	Interstitial salinity
Length	1.000				
Weight	0.992	1.000			
Surface salinity	0.704	0.671	1.000		
Bottom salinity	0.715	0.684	0.999	1.000	
Interstitial Salinity	0.732	0.698	0.993	0.994	1.000

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