CALCIUM EXCHANGES BETWEEN SEDIMENTS AND WATER IN SOME CULTURE PONDS WITH STRESS ON CARBONATE AND BICARBONATE ALKALINITIES

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To my parents

CERTIFICATE

This is to certify that this Dissertation is a bonafide record of work carried out by Shri A.P. Dinesh Babu, under my supervision and that no part thereof has been presented before for any other degree.

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PREFACE

In any aquaculture programme, the limnological studies are of great significance and in latter studies the practical value of preparing ponds for fish culture is of great importance. The importance lies in the capacity of pond to sustain high productivity which largely depends on the exchange of nutrients that takes place between the water and the soil. The soil plays several important roles such as in the storage and release of nutrients. In shallow water bodies such as culture ponds there is an intense interchange of organic and mineral compounds between the soil and the water. The soil profits more as it is constantly enriched by organic matter. The main processes taking place at the bottom of the pond are accumulation and decomposition of organic matter. As a result of this accumulation of organic matter, important macro elements are eliminated from the pond water and immobilized on the bottom, while the decomposition of organic matter not only release minerals but contribute also to the dissolution of available phosphate and carbonate.

As a developing country, for aquaculture practices, India is still depending only on natural source of water. So a sound knowledge about conservative and non conservative properties of water is very essential, for proper management of riverfed farms and tide fed farms. For increasing fish production, quality of water is very important, with periodical monitoring of various factors and the study of interaction of those factors with the soil and the water. With increase in population, the human intefference with culture systems is increasing which in turn increases the pollution problems, such as Industrial pollution and pesticidal pollution. Considering these factors the water quality is given prime importance while doing microlevel survey for pond construction for fish culture.

Calcium which lies fifth among the elements inorder of abundance plays an important role in water alkalinity, hardness, buffering capacity, limestone formation, and also in the formation of skeletal parts of animals. For living organisms especially for crustaceans, molluscs and fin-fishes the calcium content in the water is very important. Most of the animals accumulate calcium in the body from the water surrounding it and calcium can form complex with carbonate and phosphate which cause precipitation of the calcarious complex in animal tissue thus hardening the skeleton. Animals are supposed to be controlling the precipitation of calcium carbonate in their body by withdrawal of phosphate from the calcium-carbonate-phosphate complex. A drop in this element concentration will affect the living organism.

Water is an universal solvent and it has a capacity to hold substances in solutions and enter into chemical reaction. A number of gases are also found to be dissolved in natural waters. The composition and regulation of abundance of elements such as Oxygen, Nitrogen, Phosphorous, Calcium, Potassium etc. are dramatically changed by the activities of living organisms and replinished by the exchange process between hydrosphere and sediment. In upper layers the elements are withdrawn in higher proportion when compared to regeneration which occur at depths. The distribution of major components are to be accounted on physical and geochemical principles. The dissolved components are transported from place to place by advection and more from one place to other by eddy diffusion.

The higher temperature increases the rate of biochemical activity of microbiota so that the release of nutrients by decomposition of organic matters at the bottom is more at higher temperature with subsequent increase in the nutrient status of water. Compared to the yield of fish in ponds in temperate zones, the natural waters of the tropical areas generally show higher production due to more heat budget in ecosystem. For the growth of fish, a combination of solar energy and inorganic nutrients in closed systems called 'food chain' is essential. In primary production stage, the first link of 'food chain', the nutrients are usually dissolved in water. Further on they may be also bound to organic substances in the particulate matter.

Chemical environment is important for many of the processes that take place, both biotic and abiotic in the environment. Based on known concentration of various chemical constituents such as nutrients and trace elements, the energy conversion level from phase to phase and also the production of organic material for direct utilisation by organism can be found out. To keep aquatic habitat favourable for existence, physical and chemical factors like turbidity, colour, odour, pH, dissolved gases like Oxygen, Carbondioxide, and also reducing gases like hydrogen sulphide and methane, working lethal on fish life, will exercise their influence individually and synergetically while the nutrient status of water and soil plays an important role in governing the production of plankton organism or primary production in fish pond. The major abiogenic factors influencing the pond productivity are tidal inflow, land influence, precipitation and run off during heavy monsoon.

Alkalinity of water is its quantiative capacity to neutralize a strong acid to a designated pH. It is a measure of gross property of water and can be interpreted in terms of specific substances present in the water. The alkalinity of many surface waters is primarily a function of carbonate, bicarbonate and hydroxide content of calcium and magnesium, and alkalinity is taken as an indication of these constituents. The alkalinity is contributed by borate, phosphate and silicate to a lesser extend. In establishing water quality criteria of culture water, acidity and alkalinity are of great importance because the aquatic productivity will get reduced to minimum when pH drops below seven and with alkalinity below 10 ppm.

It has been inferred that buffering capacity of seawater is maintained by the balancing mechanism between factors that tend to increase alkalinity and pH. The carbondioxide dissolution and precipitation of carbonates are also controlled by alkalinity and CO_2 content of water by a chain of reactions. Nitrifying and denitrifying bacteria also play a role.

The better production of algae is found to occurs in ponds having bottom of peaty clay than those having sand, especially when water is stagnant. The pond fertility of tide fed farms depends on the fertility of the estuarine surroundings. The main function of pond soil of these type of ponds seems to be the accumulation of nutrients brought in by tides and provision of living place for benthic algae and other organisms.

This type of study is one of the pioneer works in brackishwater aquaculture systems of south India. I hope this study will be helpful for evaluating fertility of pond and also for understanding the limiting factors of nutrient availability.

I express my deep sense of gratitude to my supervising teacher Mr.C.P.Ramamritham, Scientist for his constant encouragement and guidance without whose help this work could not have been materialised.

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INTRODUCTION

In aquaculture, the success of the practice depends upon the productivity of watermass. The capacity of a pond to sustain it s high productivity depends largely upon the exchange of nutrients that takes place between water and the soil. The soil plays several important roles such as storage of nutrients and its release acc rding to the composition of watermass. Mortimer (1941, 1942) opined that the mechanism of turnover of nutrients between soil and water follows a definite pattern. Hepher(1958) also by his experiments found the opinion is correct and suggested that the mechanism of turnover is influenced by the activity of fish and organisms in the watermass. Hickling(1962) stated that nutrients brought about with the inflow of water are insignificant as compared to those supplied from the bottom, in static ponds. Barret(1953) studied the exchange of nutrients in a pond in relation to alkalinity. Hepher(1958) studies the precipitation and dissolution of calcium and its relationship with phosphate. Ohle(1938) from his studies found that the release of nutrients is more in more alkaline water and Shiori and Aomine(1940) also arrived at a similar conclusion. Golterman(1967) reviewed the work done on the phosphorous exchange and its complex formation with Calcium, Sulpher, Iron and Carbonate. He opined that while adding lime to increase the pH values about 8, certain optimum Calcium concentration may probably not to be surpassed because of the danger of formation of insoluble compounds. Yoshihiro(1967) also reviewed works done on the exchange of nutrients between soil and water both in aquaculture farms and rice field. Mollah _et al._(1964) found an inverse relationship between calcium in water and soil in one of the ponds he worked, and in some others correlation was not so clear. Sumitra(1973) in her studies got different types of relationship in different ponds in their Calcium, Phosphorus and Nitrogen level between soil and water. In most of the ponds, nitrogen and phosphate content of water, showed inverse relationship to that of soil. Welaver _et al._(1983) found that the tidal exchange of nutrients is occurring more in marshy soil. Rowe, Clifford and Smith (1977) also studied the exchange of nitrate between soil and water. Stangerberg(1949) stated that in shallow water bodies the exchange of nutrients is intense and soil profits more as it is enriched in organic matter, phosphate and carbonates. Wrobel (1967) opined that the Calcium, Phosphorous, Nitrogen, Iron and other nutrient cycles are dependent, in a direct or indirect way, mainly on Carbon cycle, so the investigation should embrace the accumulation and decomposition of organic matter in the pond bottom, as well as the primary production of phytoplankton and oxygen consumption in the pond water.

Among workers who did works on exchange of nutrients the names of McPherson, Sinclair and Hayes(1958); Hayes and Phillips (1958); Einsele(1936, 1937, 1938); Duke _et al._(1968); Banerjea (1967); Zapher(1964); Venkateswaran(1969) are worth mentioning.

Calcium is an essential element which should be present in the environment for the life activities of organisms. Greenway peter(1983) stated that marine decapods lose their 90% of body calcium during 'ecdysis', and calcification of new exoskeleton is achieved predominantly with the calcium absorbed from sea water. Dall(1964) also stressed the importance of calcium content in the surrounding water by the results he got from his studies on integuments of marine brachuras. Huner et al.(1976)stated that the calcium content in the integument of crustaceans is found to be decreased appreciably with drops in Calcium content in the surroundings. Banarjea(1967) opined that the pond with less concentration of available calcium both in soil and water will be less productive than others where calcium is abundant.

Estimation of calcium is also described by different authors with some modification for more accuracy. Ellis et al.(1948) suggested that Calcium estimation is done by oxalate method in which Calcium Oxalate is found to be more stable than other compounds of Calcium. EGTA Complexometric titration is discribed by Lakhin(1970). Krumgalz et al.(1980) developed and used Calcium sensitive electrode in end point determination of EGTA titration, where as Knight(1951) used EDTA titration, Suchdev and West(1970) described the estimation of Calcium by Flamephoto meter. Tragnanza et al.(1967)formulated a method of calculation of calcium from alkalinity and chlorinity data. Iswaran(1980) described a modified method of Ellis by titrating Calcium oxalate with standard Permanganate.

Brunskill and Ludlam(1969) estimated Ca^{++} and HCO_3^{-} in Green lake and Round lake near New York. Clair *et al.*(1983) studied the calcium content of rivers of atlantic Canada in relation with pH values. Eville Gorham(1983) studied the distribution of Calcium and its relationship with nutrients in lakes of United States. Kestar *et al.*(1969); Culkin and Cox(1966); Kosov(1983); Krumgalz *et al.*(1980) determined amount of Calcium along with Mg, Na and in the seawater at different areas and stated that it is very much related to the salinity. Horibe *et al.*(1979) stated that calcium distribution in South pacific is very much related to alkalinity. Among other workers of the study of Calcium dissolution and precipitation and its relationship to other parameters, the names of Mizuno and Yoshim (1983); Shiller and Geiskes(1980); Smith(1972) are worth mentioning.

In India Guptha and Naik(1981) has done work on Calcium along with other parameters in the Mandovi and Zuari tide dominated river system and they observed that calcium along with magnesium appeared to take some part in the biogeochemical cycles of the river and behave as semi conservative parameters. Shetty and Rao(1972) studied the Ca^{++} and CO_3^{--} distribution and its relationship with phosphate and organic matter in the core sample from the shelf region in North western Coast of India. Marching(1975) also did studies on the distribution of $CaCO_3$, Mg, and Ca in the same region. Rao(1978) studied the nature and distribution $CaCO_3$, Mg, and Ca in the same region. Sreedharan

Manikkoth(1975) conducted a preliminary study of the distribution of Calcium in Cochin backwaters.

Calcium in pond water and soil, in relation to fish production is studied by Banarjee(1967). Naqvi and Reddi(1975) found that the degree of saturation of Calcium is related to the Alkalinity and pH of the water mass.

The alkalinity of water is very important factor which influence the exchange of nutrients between the sediment and the water. The determination of alkalinity by potentiometric titration is discribed by John and Edmond(1970). Lazer _et al._(1983) studied the alkalinity and $CaCO_3$ solubility in evoporated seawater. Haapala and Stark(1983) also did work on alkalinity of water with less buffering capacity and opined that the buffering capacity of seawater is influenced by the alkalinity. Hillborn _et al._ (1983) developed a probe for direct determination of alkalinity _in situ_ so as to avoid sampling error. Lim(1982) studied the alkalinity condition of Tasekbera Lake. Park _et al._ (1969) studied the alkalinity budjet of Columbia river and stated that in Columbia river alkalinity is mostly due to carbonates and some part of the alkalinity is due to silicate content.

Pytkowicz(1973, 1975) studied the carbonate and bicarbonate content and their pairing in seawater. Shiller and Gieskes(1980) showed that the distribution of calcium is very much related to alkalinity. Joris(1974) also studied the alkalinity and total carbon dioxide system of sea water. Banarjee(1967) opined that the water with more than 50 ppt alkalinity is more productive than others by his studies of fish production and water quality relationship. Saha and Ramakrishna(1967) also found out relationship in their studies in paddy fields fish culture centres.

The distribution of chemical components such as phosphate, nitrate, nitrite and dissolved oxygen is essential for the understanding of bio-geo chemical cycles in the ecosystem. Temperature acts a double role in dissolution of gases in water and also influencing the metabolism of the organisms inside it. High temperature lead to high metabolic rate and less gas dissolution in water, thus making hypoxia condition leading to mortality of fishes. The availability of nutrients in water and soil and other hydrological parameters like salinity, dissolved oxygen, were studied extensively by various authors.

Ramamritham and Jayaraman(1960) worked on the hydrological parameters of contenantal shelf water off Cochin. They stated that South West monsoon have a profound influence on hydrographical parameters. Jayaraman(1954) studied the seasonal variation in salinity, dissolved oxygen and nutrients in inshore waters of Gulf of Mannar and Palk Bay. Ramamritham and Jayraman(1963) studied the hydrographical conditions of backwater around Willington Island. Similar works have conducted by Murthy(1963) in North Canara Coastal waters, Annigery(1968) alòng Karwar Bay Nagvi _et al._(1978) in western bay of Bengal, Suresh, Reddy and Kurian(1978) along Mangalore coast, Singbal and Reddy(1976) in

Velsao Bay, Khatri(1984) in Lakhotia estuary; Benoy B. Bose (1956) in Hoogly estuary; Venugopalan and Rajendran(1975) in Vellar estuary; Sankaranarayanan and Quasim(1969) in Cochin backwater; Banarjee and Choudhury(1966) in Chilka lake.

In the fish ponds the availability of nutrients is studied by Banarjea(1967) and opined that the fertility of water very much depends on the soil characteristic of the ponds. Mollah(1979) also agreed with this opinion from the result obtained from his studies. Varma, Tampi and George(1963) showed the relationship between plankton production and nutrient availability in Marine fish pond. Similar works were conducted by Chattopadhyay and Mandal(1980, 1982) Saha and Ramakrishna(1962) Ravindran(1983) and Anne Mathew(1984) in fish culture ponds.

Nitrate in the soil is exchanged very easily with the upper water column than phosphate. Venugopalan and Rajendran(1975) found wide variations in nitrate and nitrite content of water and soil with seasons. Banerjea(1967) opined that the deficiency of the nitrate in the soil is counter balanced by the nitrogen fixation by bacteria from atmosphere. Mollah(1979) stated that during summer the nitrate is supplied mainly by soil for the plankton growth.

Phosphate is the one of the essential element which cannot be provided from the atmosphere so its availability in soil is very important. Wrobel(1967) stated that phosphate is one of the element that is easily subject to retrogradation in acid medium as well as in the basic one. When compared to other metallic elements the geochemistry of phosphate in sedimentary cycle has been more thoroughly studied and much better understood. Naidu and Dora(1967) opined that in a pond system the phosphorous is released by decay of terrigenous matter. Among other workers, Hayes(1952) studied the kinetics of phosphorous exchange in lake while Heartner(1968) studied the absorption of phosphate in lake mud. Boaj(1978) also critically studied the phosphorous adsorption and release characteristics of sediments in the lakes in Victoria. Golterman(1967) opined that phosphorous is forming complexes in the soil as (1) Iron-Sulphur-Phosphorus system and (2) Calcium-Carbonate-Phosphorus systems. Hickling(1962) also studied the retrention of phosphorus in pond soil and its residual effect on fishes.

Among Indian workers, Murthy and Veerayya(1972); Banarjea and Ghosh(1976); Naidu and Dora(1967); Ramamoorthy et al.(1973); Ansari and Rajagopal(1974); and Banarjee and Choudhuri(1966), studied the availability of phosphorous in pond system.

MATERIALS AND METHODS

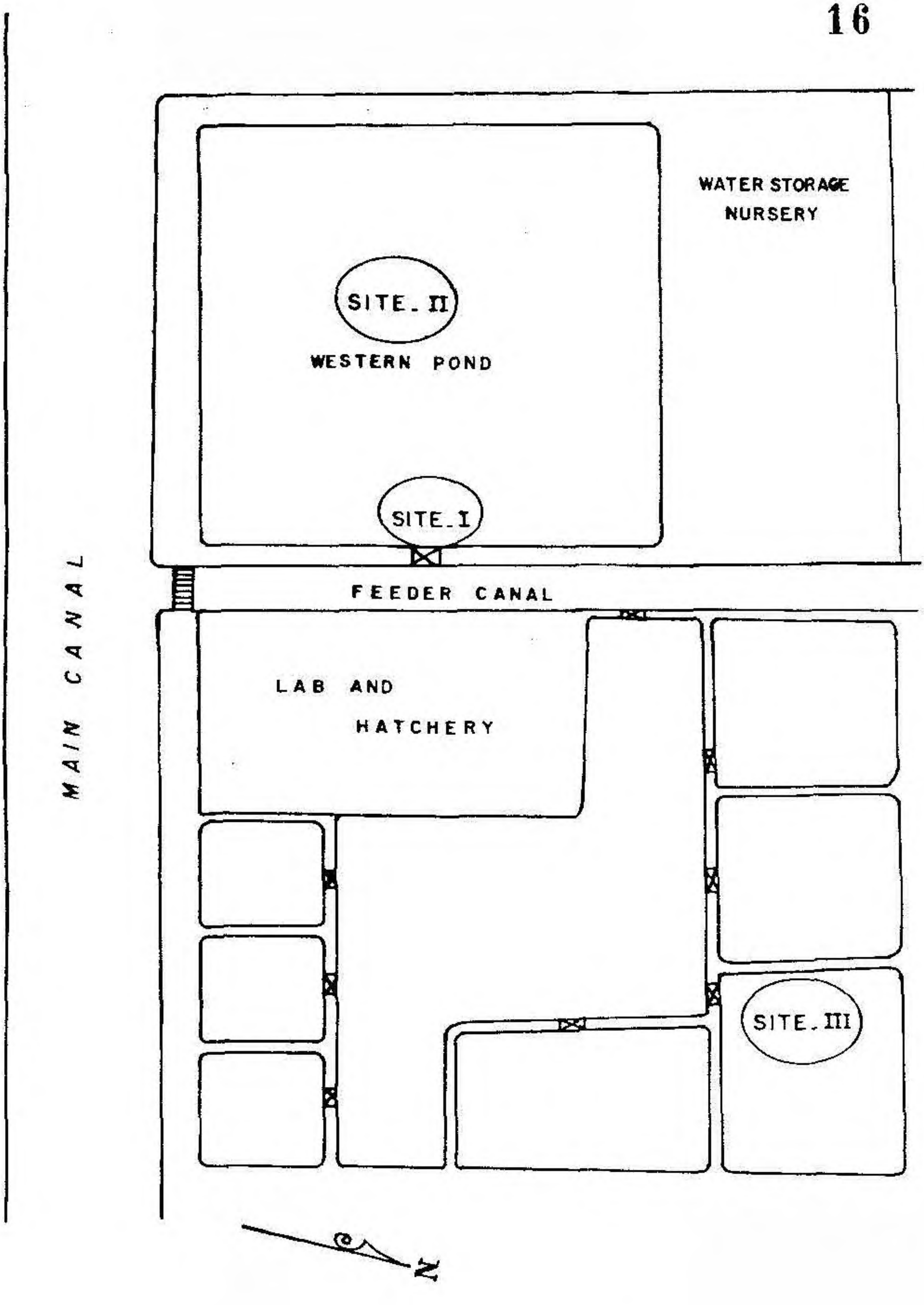
Study Area

A short term study during monsoon and post monsoon season from end of May to middle of September is carried out in the brackish water ponds at Narakkal. Narakkal(10.01°N --75.16°E) is a fisheries centre in Vypeen island about 11 Km. North West of Cochin. The land strip is bordered by the Arabian sea on the western side and by Vypeen Channel a branch of Cochin backwater on the eastern side.

Two ponds at Narakkal were selected as regular collection sites for the entire study period. The ponds belong to Marine Prawn Hatchery Laboratory of Central Marine Fisheries Research Institute. The ponds are at a distance of approximately 250 meters from the sea.

Description of Pond

Pond A: It is a large pond having an area of 0.6 ha. and an average depth of 75 cm. Bottom of the pond is mainly sandy. The pond is directly fed with water from main channel by an open type wooden sluice gate. Bunds of pond is strengthened by Granite stones. This pond is found to be highly productive and in this, Mixed culture of Chanos chanos, Tilapia, Prawns such as Penaeus indicus, P. monodon, Metapenaeus dobsoni were cultured.


WATER STORAGE
NURSERY
SITE_II
WESTERN POND
SITE_I
FEEDER CANAL
MAIN CANAL
LAB AND
HATCHERY
SITE_III
N

STUDY AREA

For better understanding of water exchange, two sites were selected from this large pond.

Site-I. The site is very near to the sluice gate so that it is very much influenced by the tidal exchange. Here the bottom soil is found to be constituted by 86% sand 8% silt and 6% of clay.

Site-II. This site is taken at about ¼th distance of the length of the pond, it is almost 30 meters away from the sluice and the exchange of water in each tide is considered to be very slow. Here also the bottom is found to be predominantly sandy ie. 85% of sand 5% silt and 10% of clay.

Pond B: (Site-III) The third site of collection is from a comparative small pond of an area of 0.1 ha. and an average depth of 0.75 meter. Here the water exchange is indirect ie. the water from a feeder canal enter into a large pond and this small pond is connected with the large one with an open type wooden sluice gate. The bund is made of sand and clay and the soil constituted by 79% of sand 7% of silt and 14% of clay. Here the prawns *Penaeus indicus* and *P. Monodon* are cultured. During monsoon period the prawns are found to be effected by 'soft prawn' disease.

Sampling method:

The water samples from surface and bottom are collected in plastic and glass bottles from three regular sites. The sample for oxygen estimation was taken in 125 ml. glass bottles. The water for analysis of Calcium and other nutrients are collected in 500 ml. plastic bottles.

The soil samples were collected using plastic corer and it is transferred to a polythene bag. A part of the soil is allowed to air dry and rest of the soil is kept in oven at 70°C. The air dried soil is used for phosphate determination.

The Oven dried soil is weighed and distilled water is added in a ratio of 1:5. The mixture is then transferred to mechanical shaker and shaken for an hour. This is kept over night for settling of the soil. The sample is filtered through a buchner funnal using a high vaccum pump. This extract is used for calcium estimation and Nitrate estimation.

A representative sample of the soil from these sites during different periods are taken and analysed for the grain size determination.

The following parameters were collected during the studies.

1. Water temperature
2. Water pH
3. Water salinity
4. Dissolved oxygen
5. Nitrite nitrogen in water
6. Nitrate nitrogen in water
7. Reactive phosphorous in water
8. Carbonate and bicarbonated alkalinity and Total alkalinity of water
9. Dissolved calcium in water
10. Available phosphorous in soil.

11. Available nitrate in soil
12. Exchangeable calcium in soil
13. Grain size of soil.

Temperature

Temperature was measure with ordinary thermometer of range 0-50°C each division being 0.1°C.

pH:

pH was measured using digital 'century' pH meter within an hour of collection.

Sanility

Salinity was estimated by Mohr's titration method (Strickland and Parson 1968).

Dissolved Oxygen

The dissolved oxygen content was estimated by Winkler's method.

Nitrite Nitrogen:

Nitrite nitrogen is found out by Shinh method modified by Bendsneider and Robinson(Strickland and Parson 1968). The reagents used were acidic sulphanilamide and NNED. The absorbance was measured in a Colorimeter at 530nm using ERMA photo electric colorimeter - Model A.E. II N Japan.

Nitrate nitrogen:

For determining nitrate nitrogen Morris and Reley method (Strickland and Parson 1968) is used. Water samples after keeping for reduction using Copper sulphate and hydrazine sulphate for 20 hours in darkness, is treated with the sulphanilamide and NNED and the absorbance was measured at 530 nm using ERMA photoelectric colorimeter.

Reactive Phosphorus

Reactive phosphorus was determined by Murphy and Reley method(Strickland and Parson 1968). Water is allowed to react with ammonium molybdate and potassium antimony tartrate in an acid medium (Sulphuric acid and Ascorbic acid). A blue complex is formed. The absorbance is measured in a calorimeter using red filter of 620 nm, using ERMA photoelectric calorimeter.

Carbonate and bicarbonate alkalinity and Total alkalinity:

The alkalinity was determined by titrating 100 ml of the sample with 0.02 N.H_2SO_4. The phenolpththa1ein end point determines the carbonate alkalinity and Methyl-orange--Bromocresol green end point is used to determine bicarbonate alkalinity. Total alkalinity (ppm $CaCo_3$) is determined by multiplying the total ml of acid with 10. Let 'p' be the ml. of acid used for titration with phenopththalein and 'T' the ml. of the acid used for the total titration.

Alakalnity due to CO_3 = 2p X 10 ppm
Alkalinity due to HCO_3 = (T-2p) x 10 ppm.

Dissolved calcium in water

The dissolved calcium in water is determined by precipitating Calcium as Calcium oxalate and titrating the Calcium oxalate with 0.1 N. Potassium Permanganate. This is a modified method of Calcium estimation discribed by Eillis. This modified method is described by Iswaran(1980).

Available phosphorous in Soil:

Available phosphorus in air dried soil is extracted using sodium bicarbonate of 8.5 pH. This extract is treated with acidic Ammonium molybdate, Potassium antimony tart rate and freshly weighed Ascorbic acid(Olsen 1954). The blue colour developed between 30 and 40 minutes is measured by using red filter of 620 nm in ERMA photoelectric Colorimeter.

Available nitrate in soil:

Available nitrate was estimated from the extract of soil prepared with distilled water. The extract is evaporated and treated with phenol-disulphonic acid and ammonium hydroxide (Mackereth, 1957). The yellow colour developed is measured as absorbance using 420 nm in ERMA photoelectric Colorimeter.

Exchangeable Calcium:

Exchangeable calcium was estimated from soil extract prepared in distilled water. The method of estimation is described by Ellis et al.(1948). The titration of the precipitated calcium oxalate is done with 0.1 N.$KMnO_4$ and the Calcium is estimated from titre values.

Grain size analysis:

The representative samples of air dried soil is taken and analysed for grain size by the seive and pippette method of Krumbein and Pettijohn(1938). This method was quoted by Buchanan and Kain(1971) in Marine Benthos edited by Holmes and McIntyre(1971).

RESULTS

The seasonal distribution of temperature is presented in Figures 1, 2 and 3. The maximum surface temperature is observed during September which is not the usual case. The minimum is observed during the middle of South West monsoon. The surface to bottom difference were negligible showing thorough vertical mixing in the pond which were uniformly shallow(Depth 0.75 to 1.25 meter) A uniform decrease or increase in the temperature was not conspicous because of the abrupt fluctuations in the monsoon rainfalls during this period.

But at surface the abrupt decrease in Salinity was quite conspicuous by the onset of monsoon (Fig.4). As can be seen, the salinity dropped from 10.5 ppt during May to about 1.75 ppt by late June. There after uniformity was observed till the middle of September. More or less same features prevailed in the bottom (Fig.5). In all the three sites similar condition could be observed (Fig.6 to 9) as far as the salinity is concerned. The site I, where the water exchange is more, the bottom and surface temperature and salinity showed close relations. Dissolved oxygen contents were uniformly high in the sites at the surface and bottom except for late September. Two conspicuous maxima could be observed during July and August in all sites, which are highly well defined at site III at surface. In the latter case super saturation could be inferred during July and August and minimum is observed during September, which was absent at site III (Fig.8 and 9).

The seasonal distribution of carbonate and bicarbonate alkalinities in conjunction with pH values are presented in Fig. 10 to 15. In site I at surface the maximum bicarbonate alkalinity is observed during late postmonsoon and minimum during the peak monsoon period. The pH values were mostly on alkaline side. As can be seen from the figure (Fig.10) the carbonate alkalinity values were much lower, the maximum being during monsoon. More or less same features prevailed at bottom except that the high peak during July was more well defined in the case of pH, the values being nearly 8.6. Surface at site II during late monsoon the bicarbonate alkalinity was lower than Site I and much higher pH values are encountered with.(Fig.12). This could be correlated with the higher carbonate alkalinity values during late monsoon. Comparable features prevailed in the bottom (Fig.13). The seasonal distribution of carbonate alkalinity at surface at site III, varies from the other site, in the sense that it is uniformly much higher than the other two sites (Fig.4). It can be remembered that the site is having minimum tidal influence compared to the others and as such the pH values are also much higher especially during monsoon and post monsoon. The bicarbonate alkalinities are also low. These characteristics are more well defined in the bottom layers at site III, where a high peak in carbonate alkalinity occured, the value being 35 ppm, the maximum during the period of investigation(Fig.15). This high peak again corresponded with high peak in pH(Value 8.8) and with a minimum peak in bicarbonate alkalinity. The usual trend, namely increase in carbonate alkalinity and decrease in bicarbonate alkalinity with increase in pH, could be observed in the distribution patterns. The total alkalinity values also showed similar trend.

The distribution of calcium content in the bottom sediments in three sites is presented in figures 16 to 18 along with dissolved calcium in overlying water. It has been pointed out that the clay content of sediment is maximum in site III and it is observed that maximum soil calcium is again in site III, which is minimum influenced by water from the feeder canal. In site I and III, high values are observed during the monsoon and these high values are maintained with lesser intensity in site II. But in site I the values are much lower during the progressing monsoon. In Site II also higher values are maintained during progressing monsoon. During monsoon the calcium content of the bottom water more or less maintained a steady concentration throughout. There is observed a drastic decrease from the pre-monsoon values in both soil and water calcium contents during monsoon. The fluctuating nature in the soil calcium is not so closely exhibited in the water calcium content. The fluctuating nature is not well defined in site I which has maximum effect of tidal action.

The nutrient content in the bottom sediments and overlying waters show conspicuous fluctuations during the investigational period namely monsoon and post monsoon. In site I, where the tidal influences are high, maximum phosphate content of 9 µg at PO_4 P/g occures during the end of monsoon. It can be noticed that when phosphate content of water is high, the soil phosphorus on the corresponding date is low and vice versa. This appears to be a regular trend in site I, but the case is little different in site II, especially during early monsoon. But in site III, a more or less direct relationship exist between the water and the soil phosphorus content. But unlike site I and II, the soil phosphorus content is uniformly high in Site III, maximum of 10.5µg at PO_4 -P/g occuring during August. It can be pointed out that this maximum in soil phosphorus content during August, is invariably present in all three sites which corresponds to minimum water phosphorus.

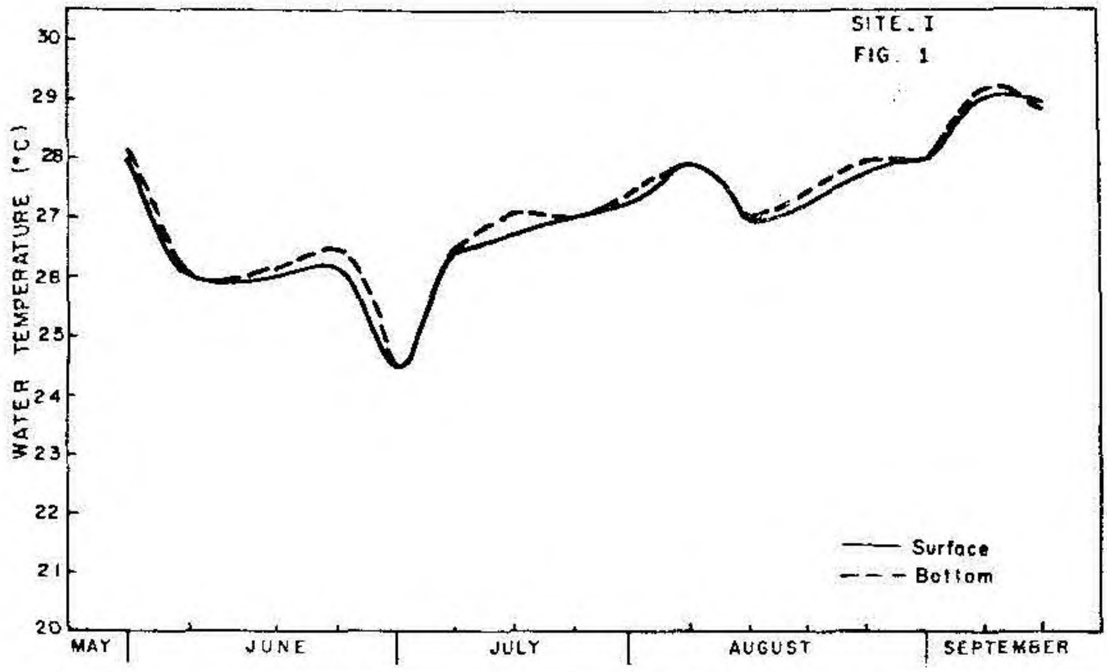
Unlike the phosphorus content, the nitrate in the bottom sediments in all the three sites are very low, values being less than 5 µg at NO_3-NO_3- N/g soil. But overlying water contains good amount of this nutrients the maximum occuring during the pre-monsoon period (Fig. 22-24). Another maximum, although not very high is observed during peak monsoon period but the over all trend is towards a decrease by the progress of the season, the minimum value being during late monsoon and post monsoon. One remarkable feature is the steady nature of the soil nitrogen content through out the period of investigation. Nitrite nitrogen content of water is also found to be very low which showed maximum during pre-monsoon, maximum value being

8.3 μg at NO_2- N/L and at the middle of monsoon it showed minimum, the value being less than 1 ug at NO_2-N/L in all the three sites (Fig. 25, 26 and 27).

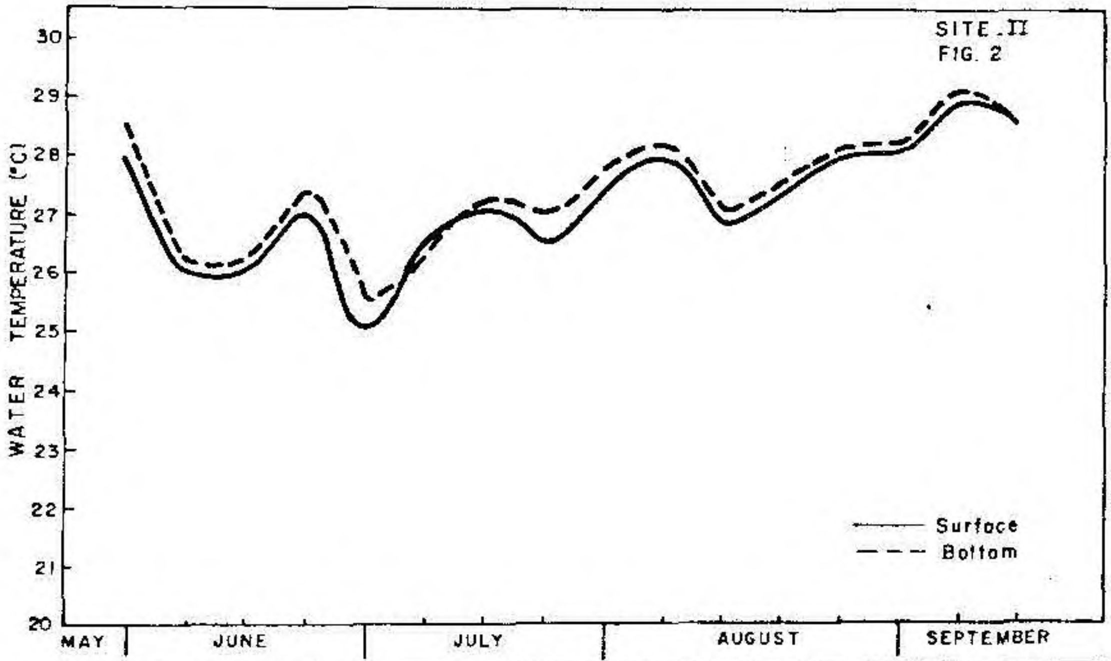
The grain size of the soil is found to be predominantly constituted by sand with a decreasing proportion from Site I to site III. The soil at site III is found to be more clayey than those of others (Fig.28).

Figures 1, 2 & 3

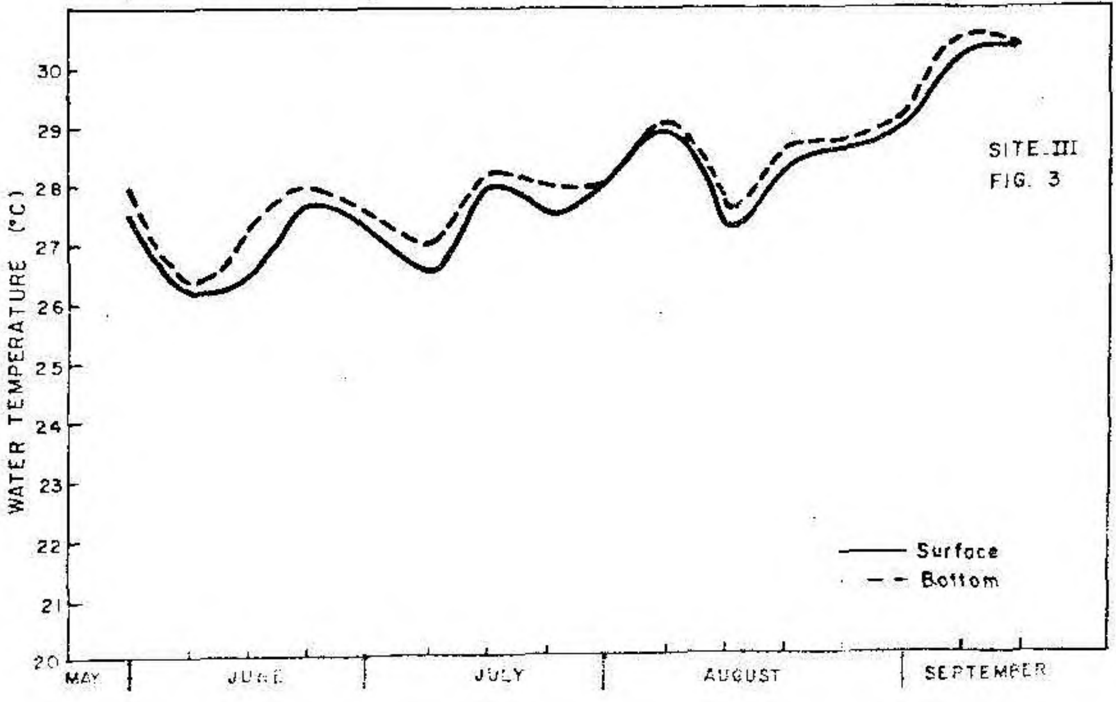
Variation in water temperature at the three sites during the study period.



SITE. I
FIG. 1



SITE. II
FIG. 2

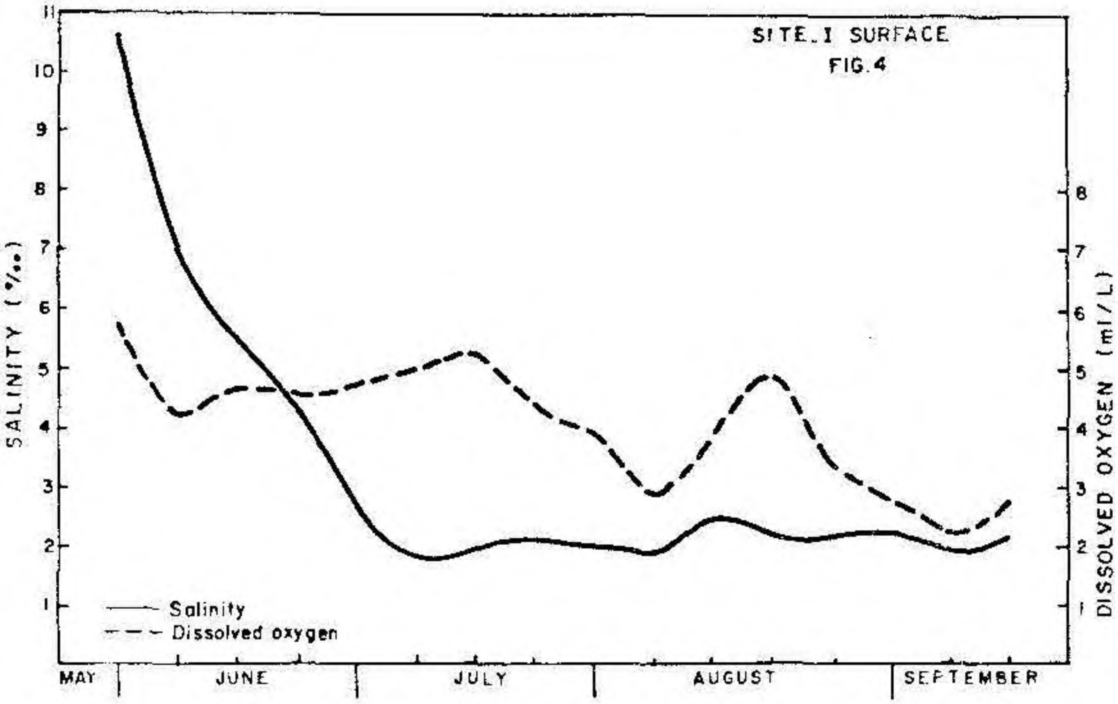


SITE. III
FIG. 3

Figures 4 & 5

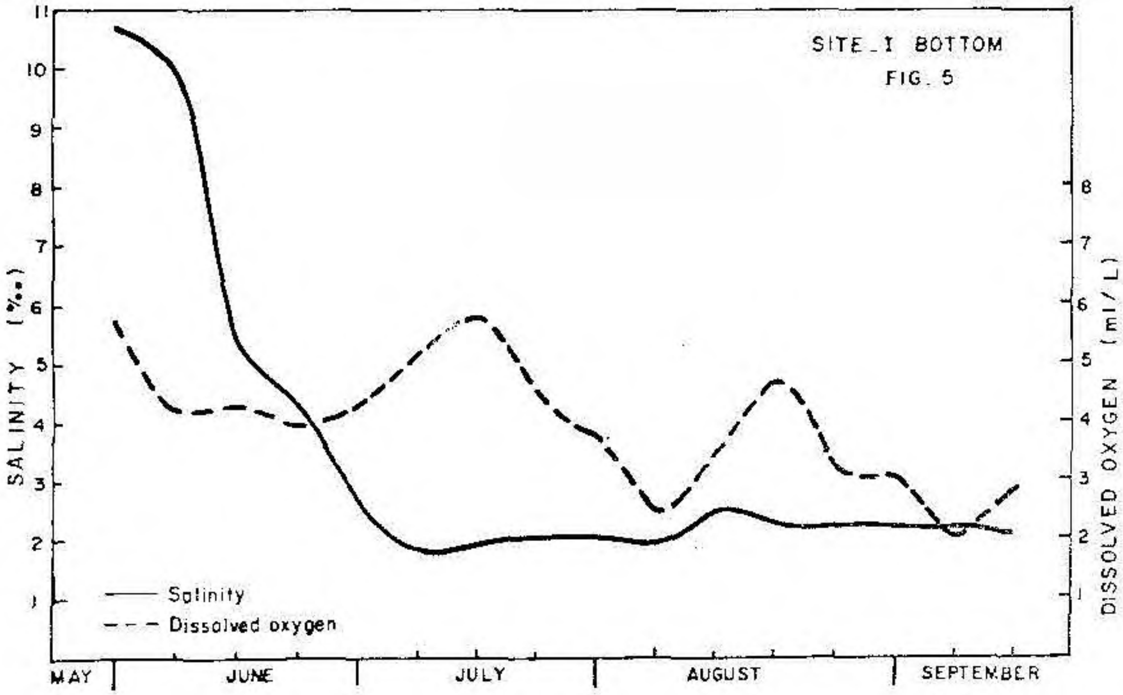
Variation in the salinity and dissolved oxygen content in the surface and the bottom water at Site I during the study period.

C



SITE_I SURFACE

FIG.4

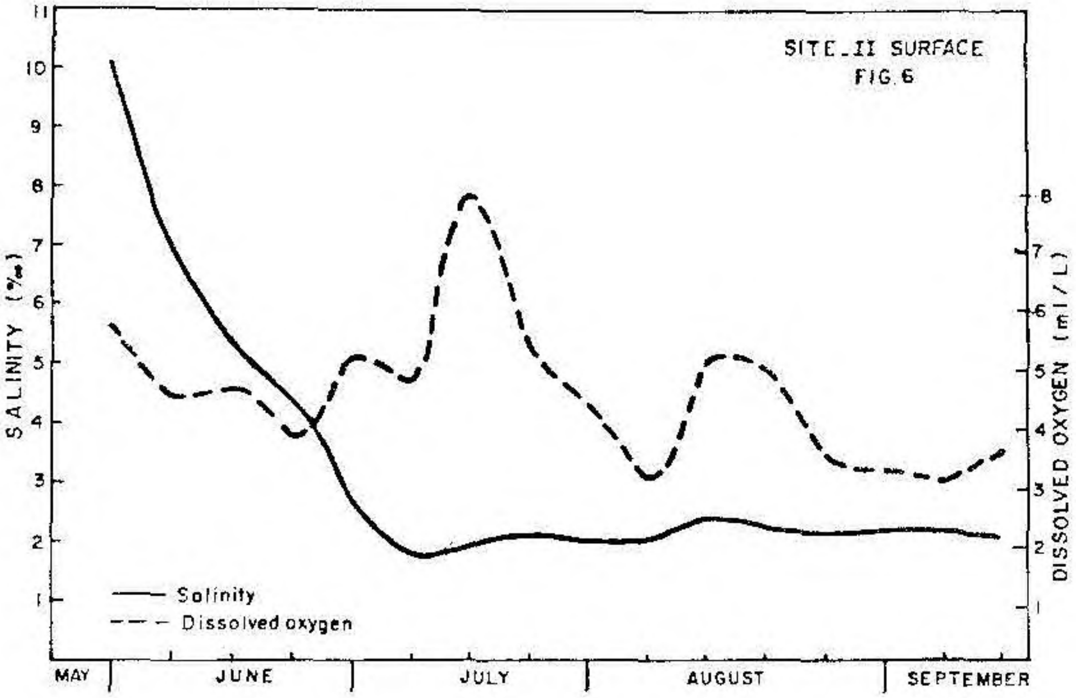


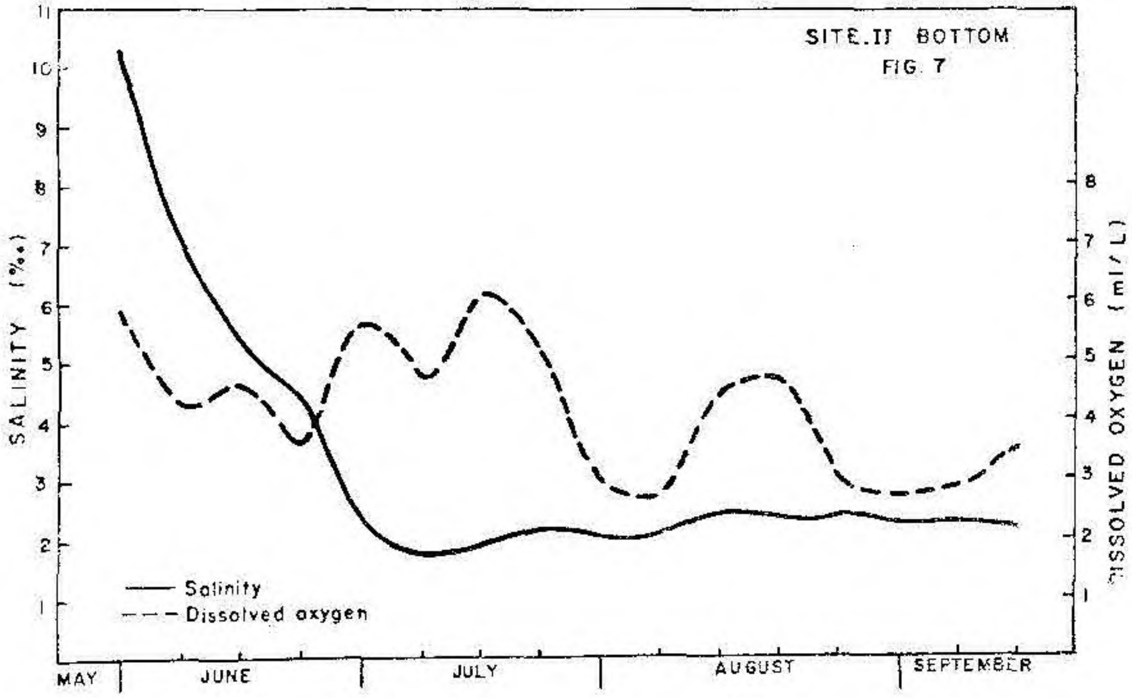
SITE_I BOTTOM

FIG. 5

Figures 6 & 7

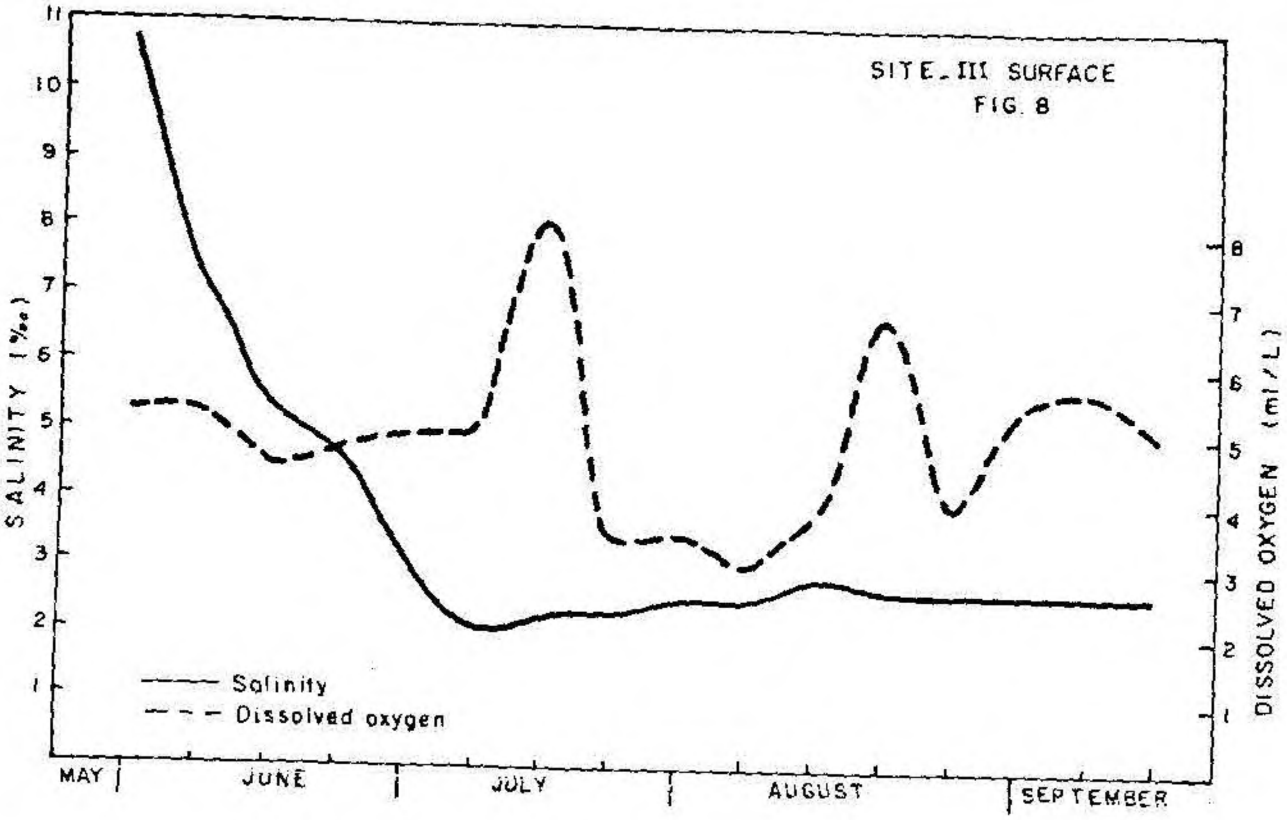
Variation in the salinity and dissolved oxygen content in the surface and the bottom water at Site II during the study period.


SITE.II SURFACE
FIG. 6

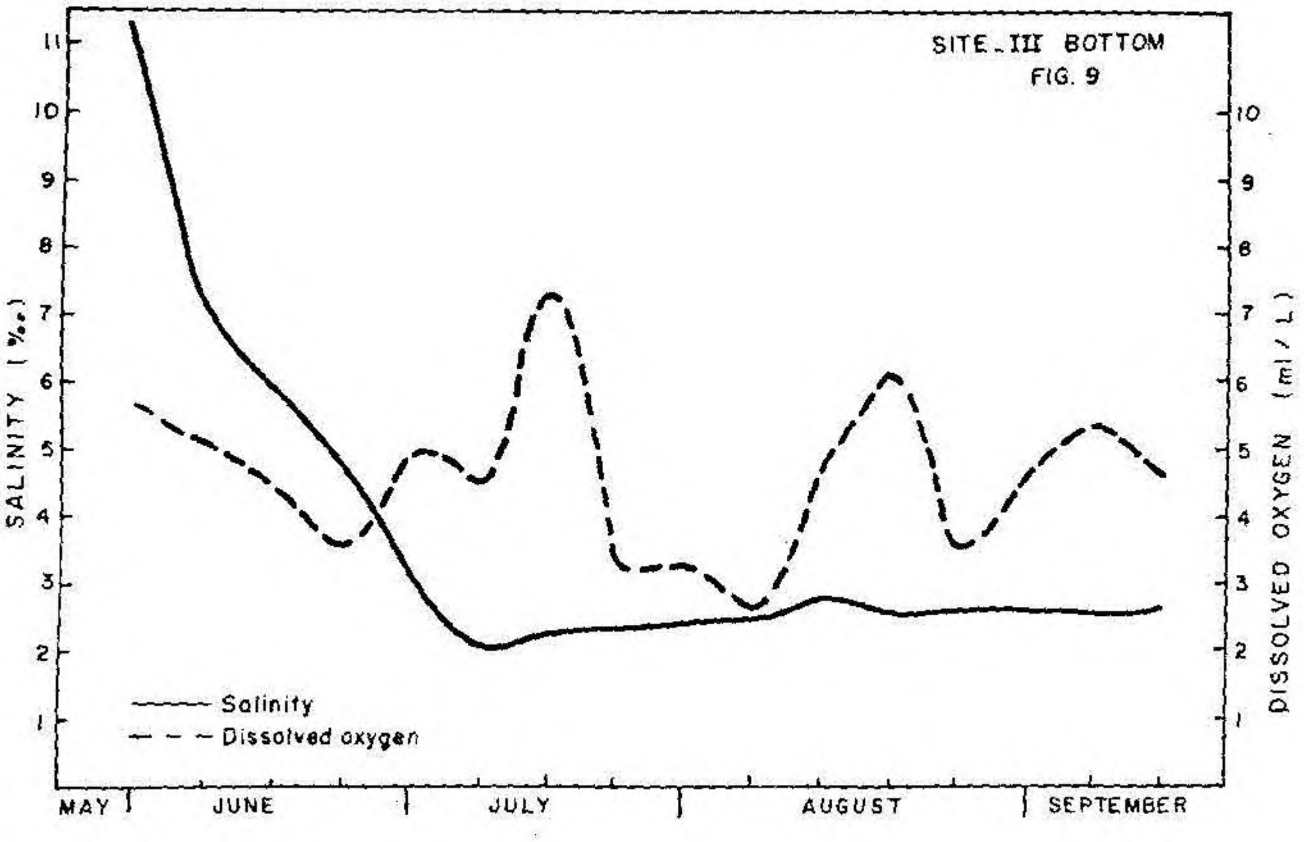

SITE.II BOTTOM
FIG. 7

Figures 8 & 9

Variation in the salinity and dissolved oxygen content in the surface and the bottom water at Site III.



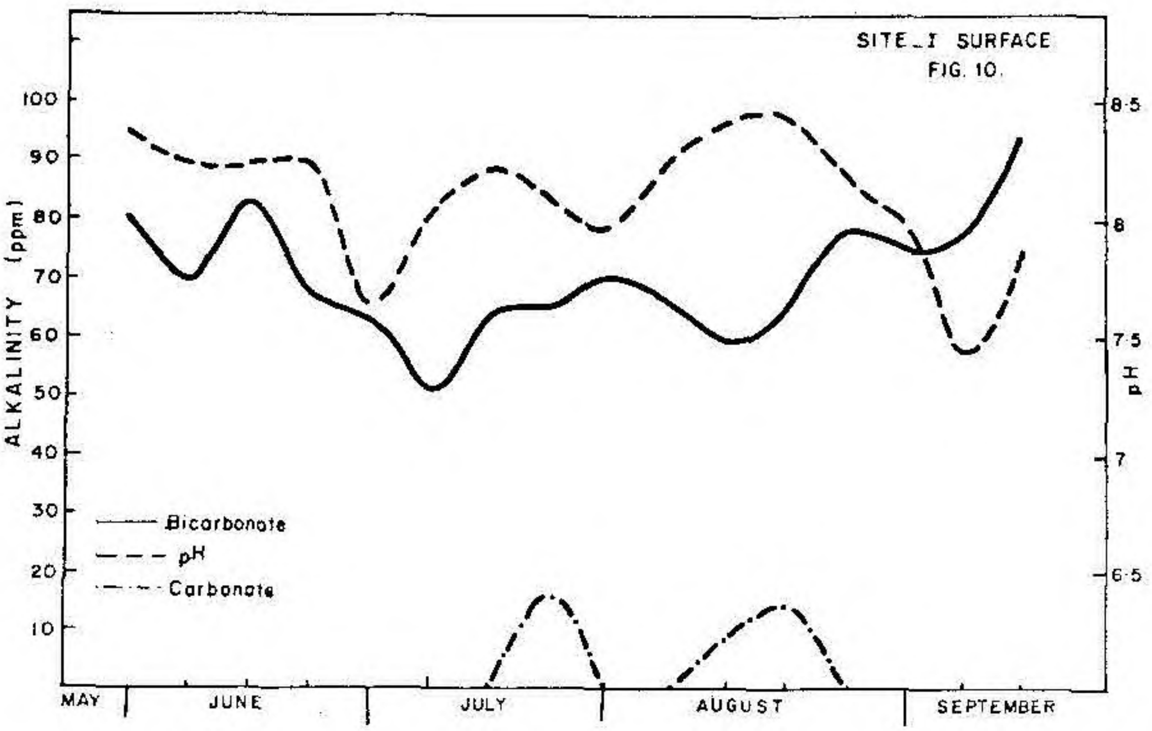
SITE-III SURFACE
FIG. 8



SITE-III BOTTOM
FIG. 9

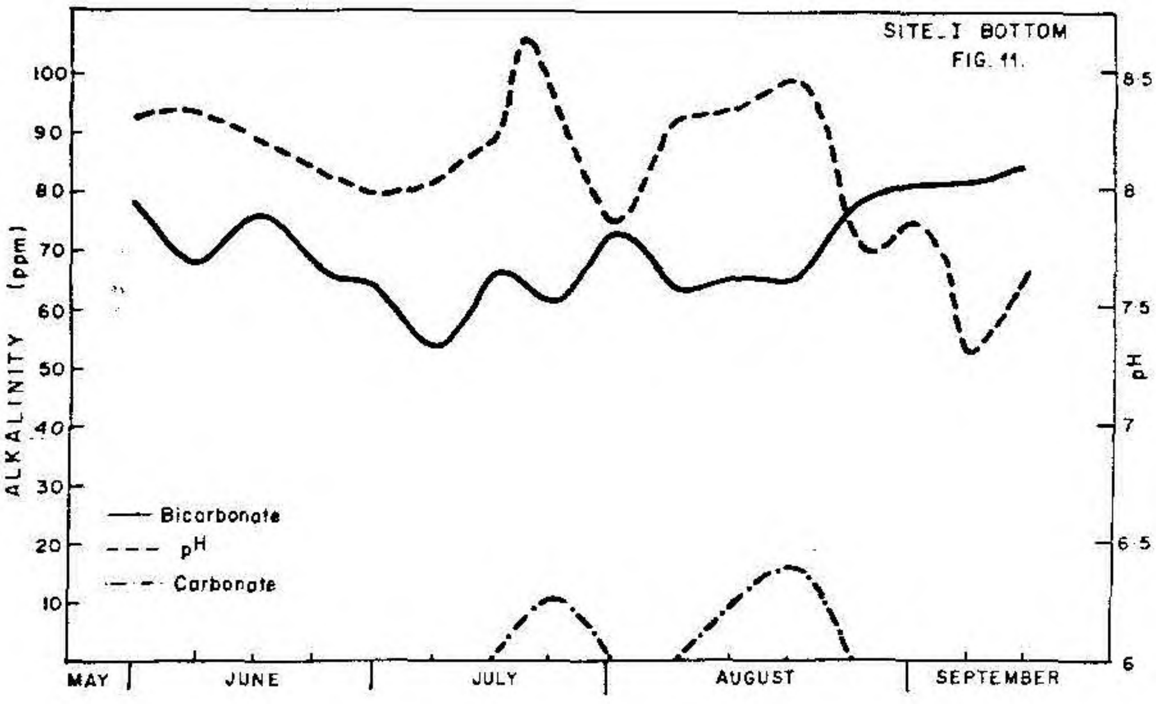
<u>Figures 10 & 11</u>

Variation in the carbonate and bicarbonate alkalinity and pH during the period of study in the surface and the bottom water at Site I.



SITE_I SURFACE

FIG. 10.

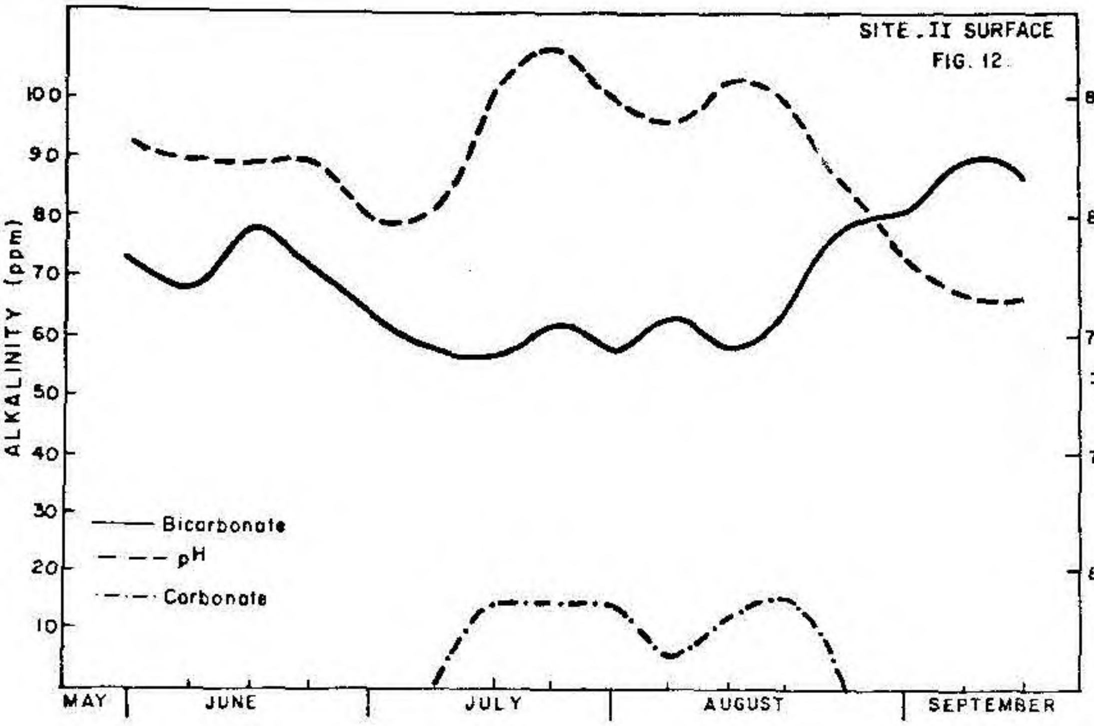


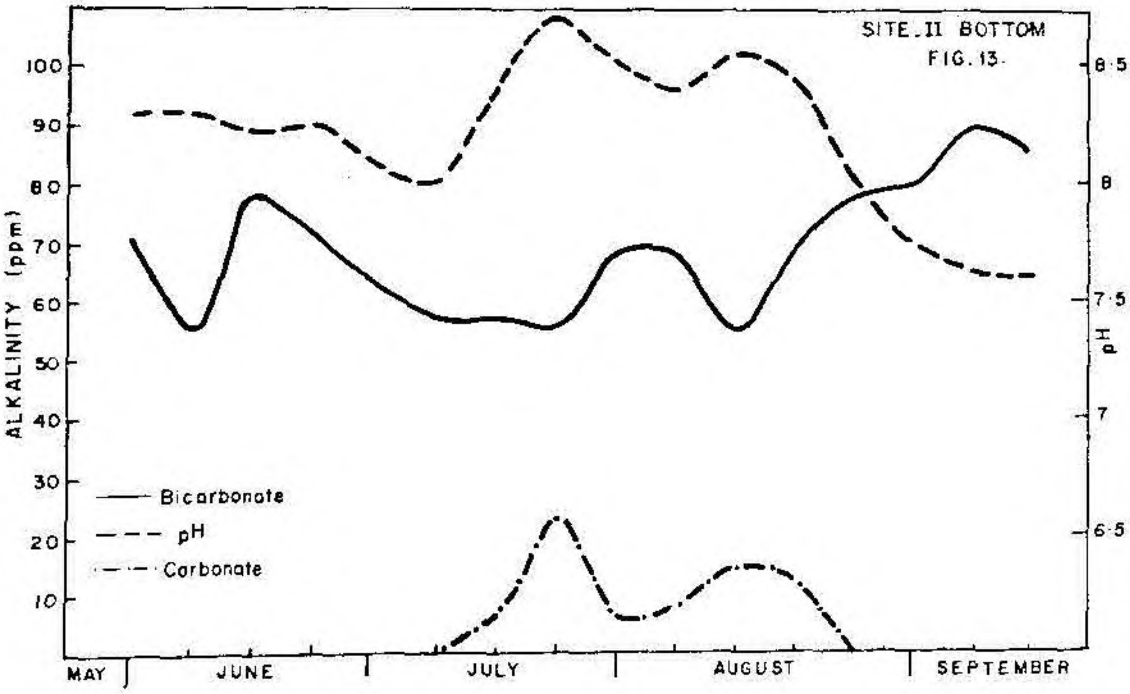
SITE_I BOTTOM

FIG. 11.

<u>Figures 12 & 13</u>

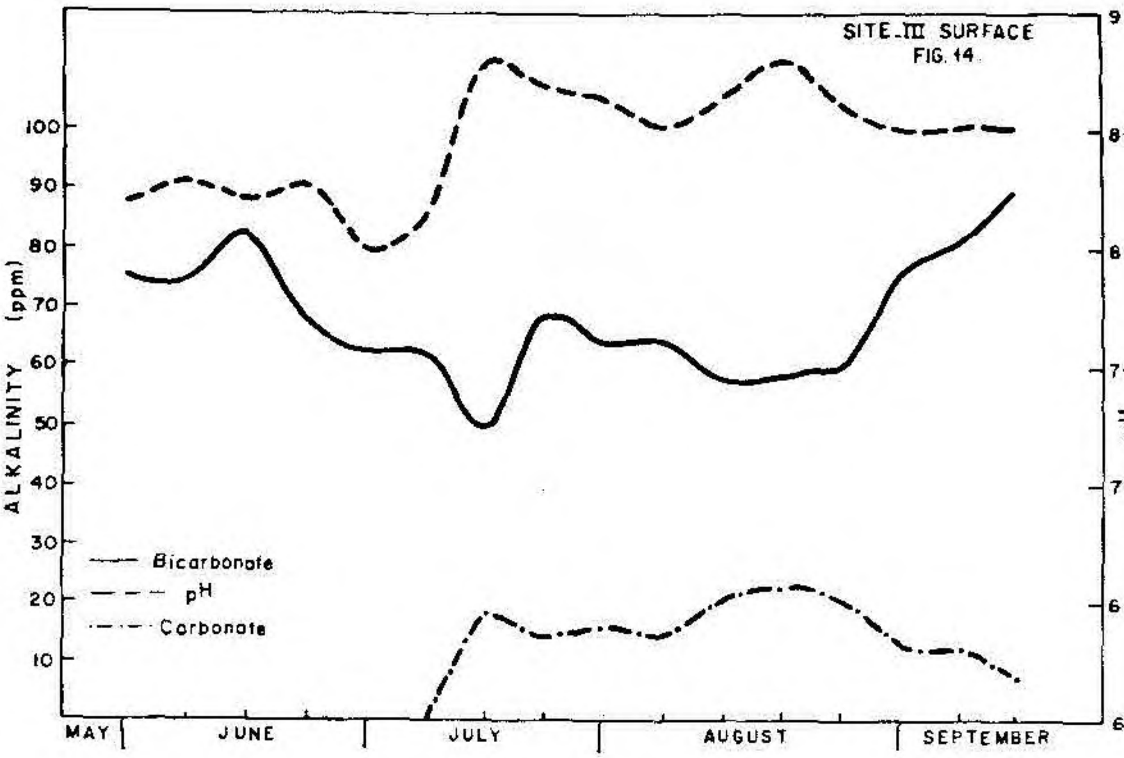
Variation in the carbonate and bicarbonate alkalinity and pH during the period of study in the surface and the bottom water at Site II.

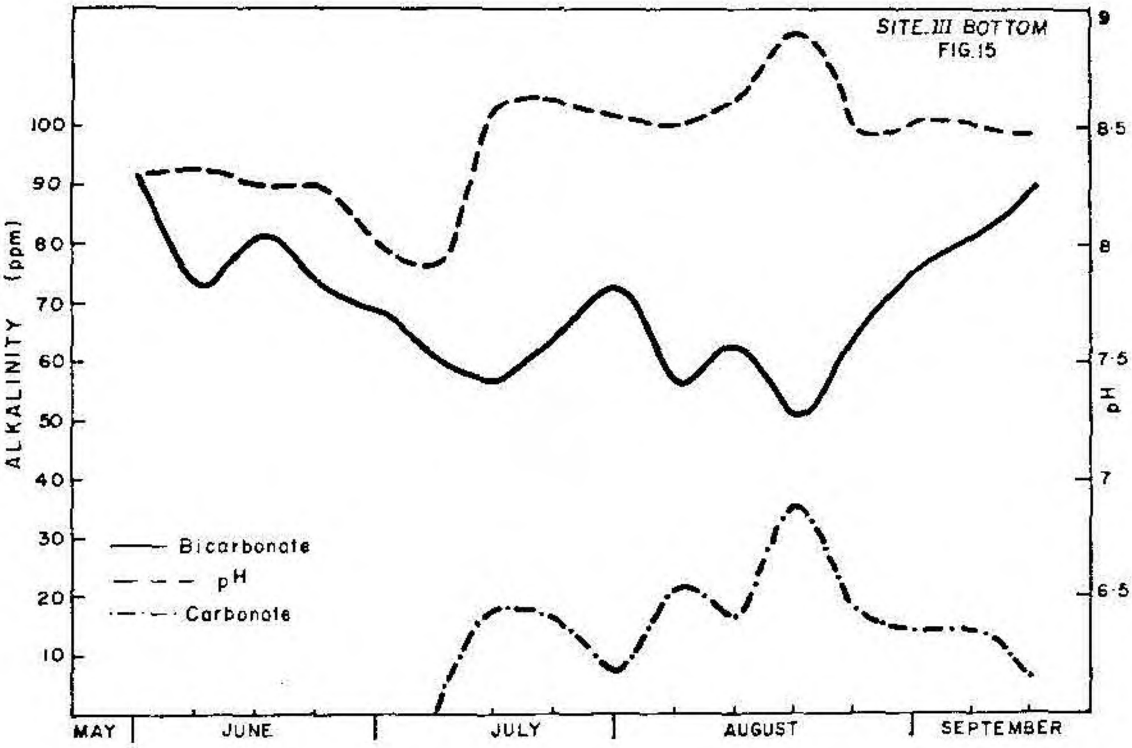

SITE. II SURFACE
FIG. 12.


SITE. II BOTTOM
FIG. 13.

Figures 14 & 15

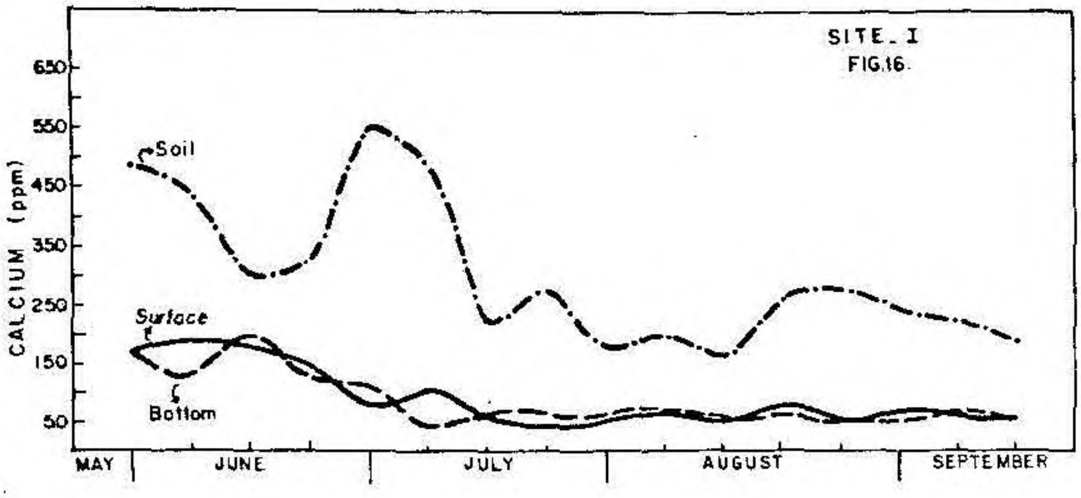
Variation in the carbonate and bicarbonate alkalinity and pH during the period of study in the surface and the bottom water at Site III.

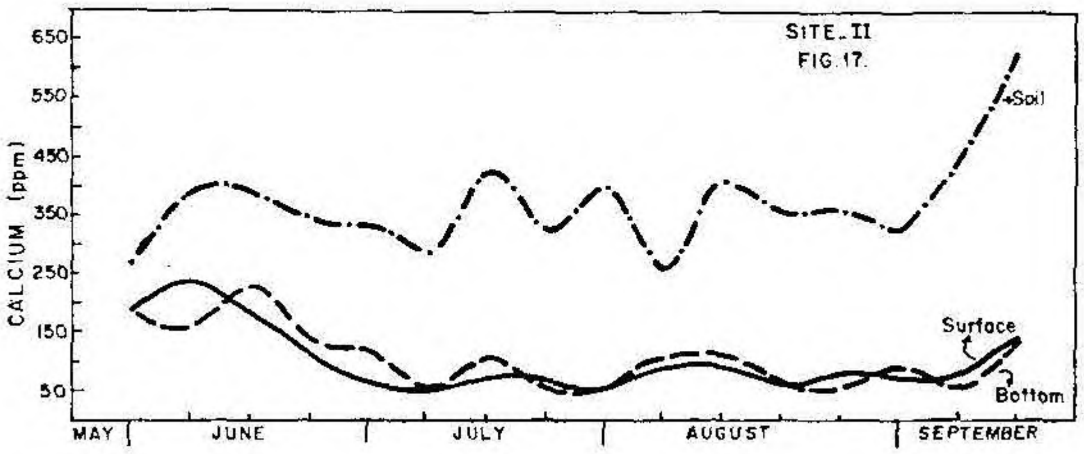

SITE-III SURFACE
FIG. 14

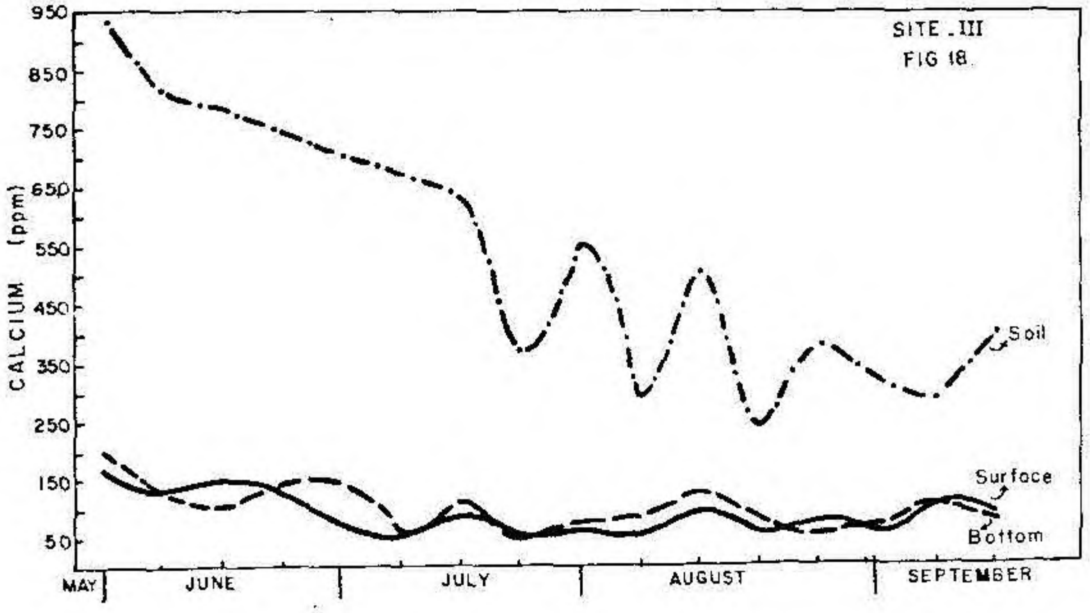

SITE-III BOTTOM
FIG. 15

Figures 16, 17 & 18

Variation in the Calcium content of the surface water, bottom water and of the soil at the three sites during the period of study.

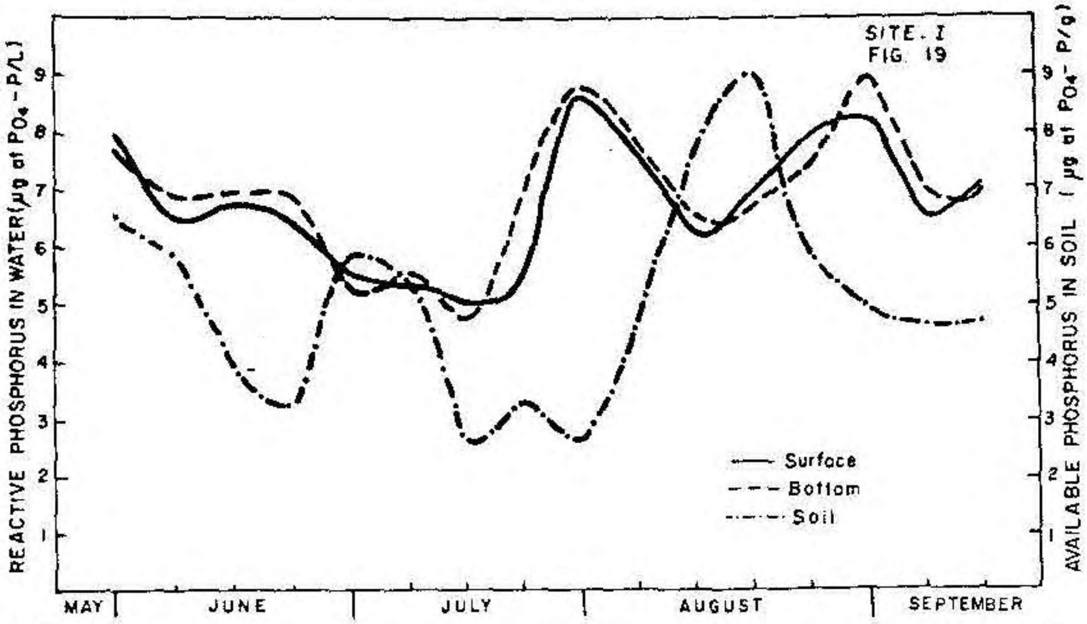

SITE_I
FIG.16.

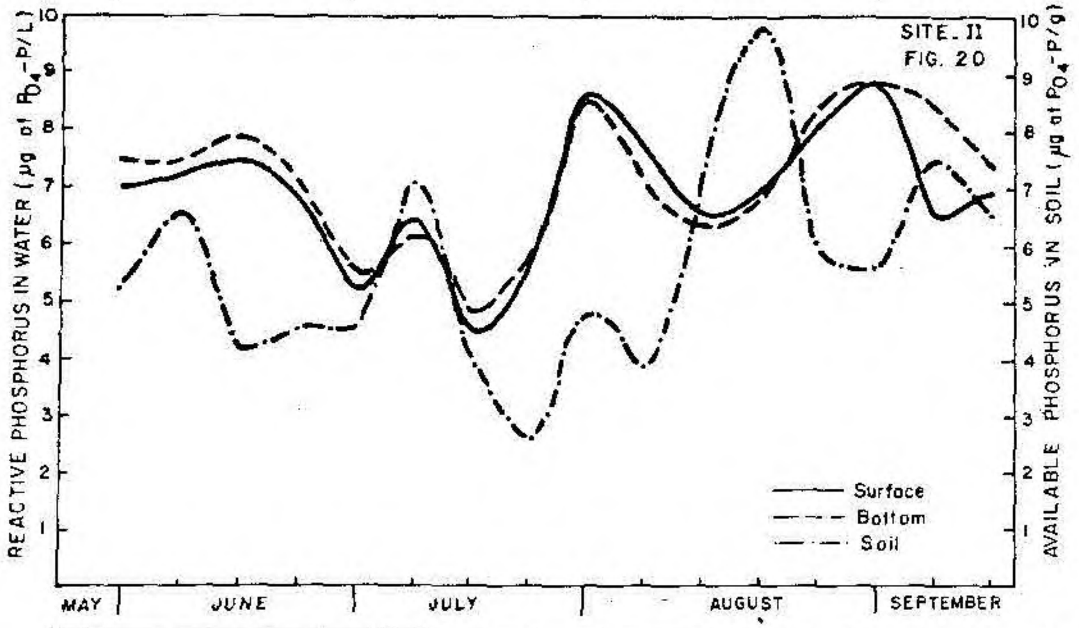

SITE_II
FIG.17.

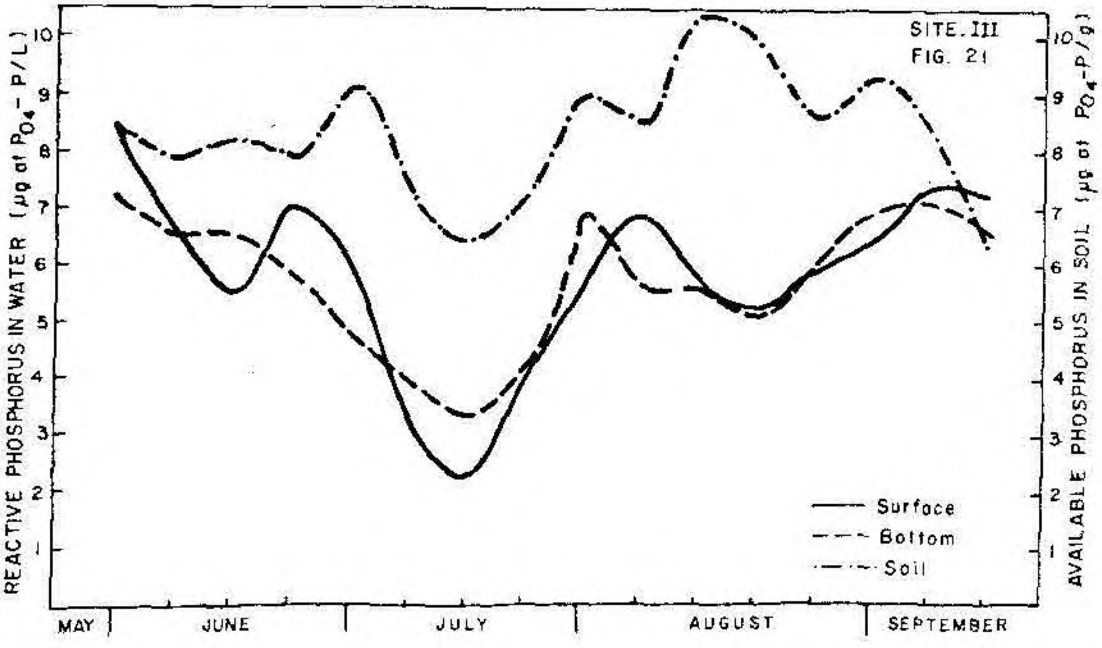

SITE_III
FIG 18.

Figures 19, 20 & 21.

Variation in the reactive Phosphorus of the surface and the bottom water and available Phosphorus of the soil at the three sites during the period of study.

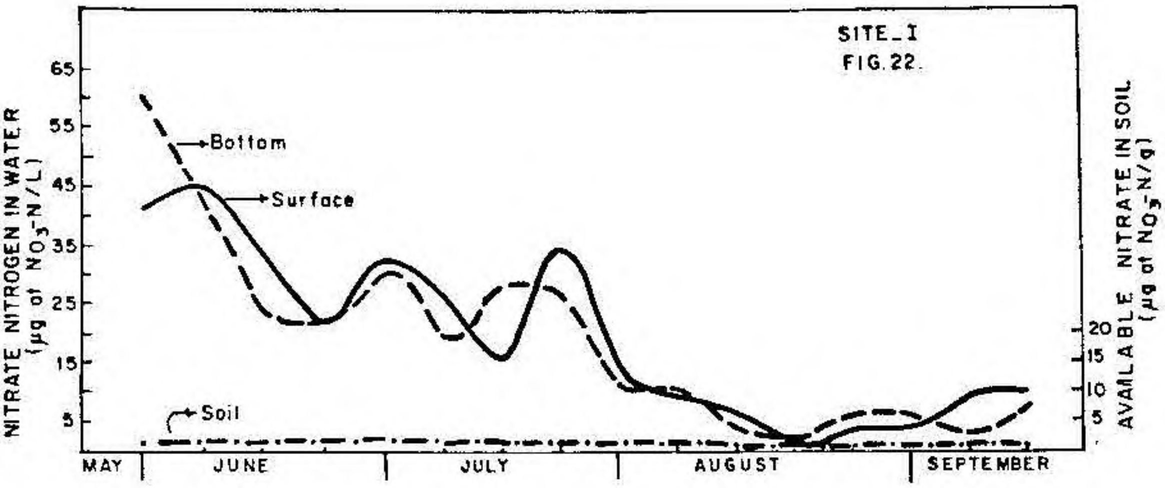

SITE. I
FIG. 19


SITE. II
FIG. 20

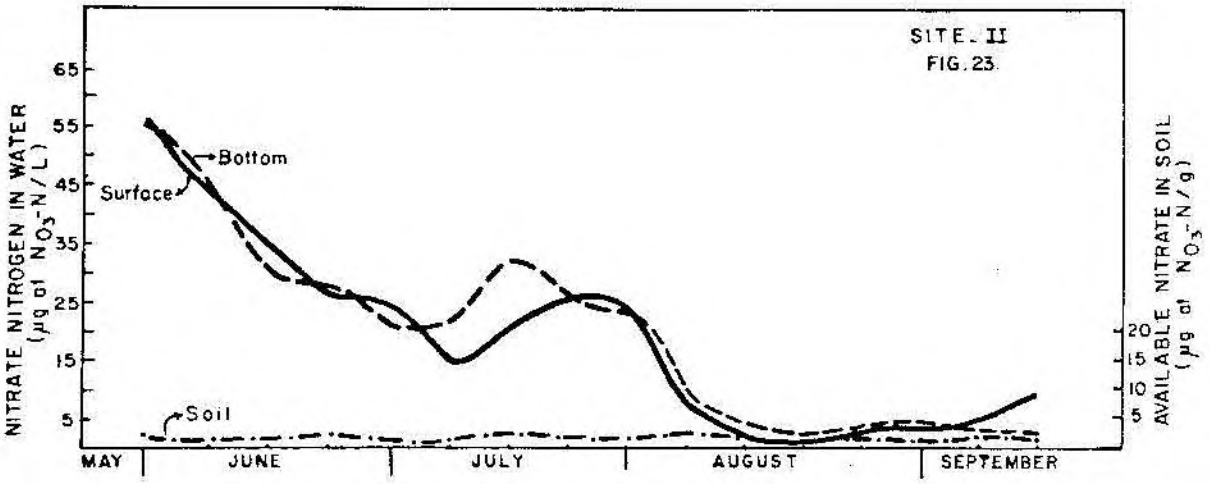

SITE. III
FIG. 21

Figures 22, 23 & 24

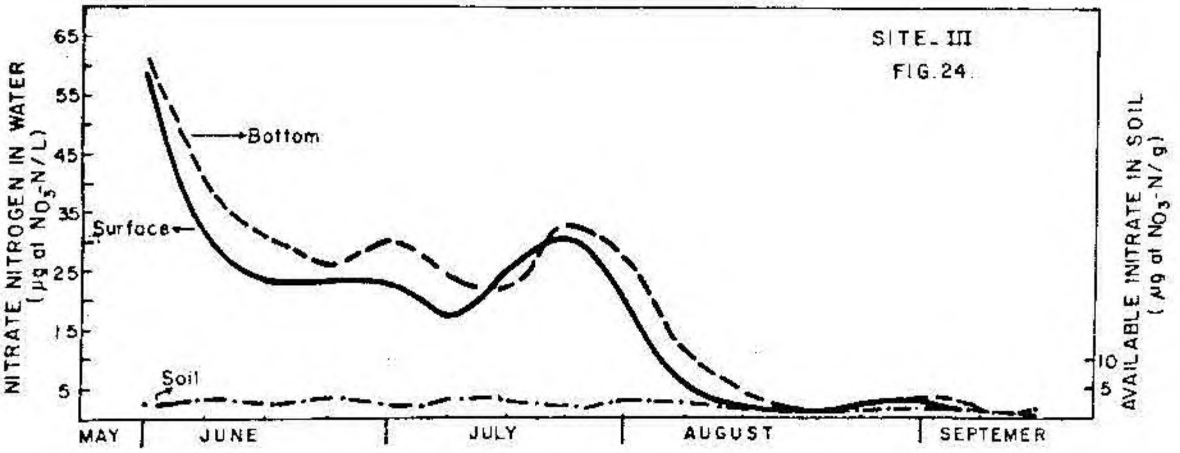
Variation in the nitrate Nitrogen of the surface water and the bottom water and available nitrate Nitrogen of the soil at the three sites during the period of study.



SITE_I
FIG.22.



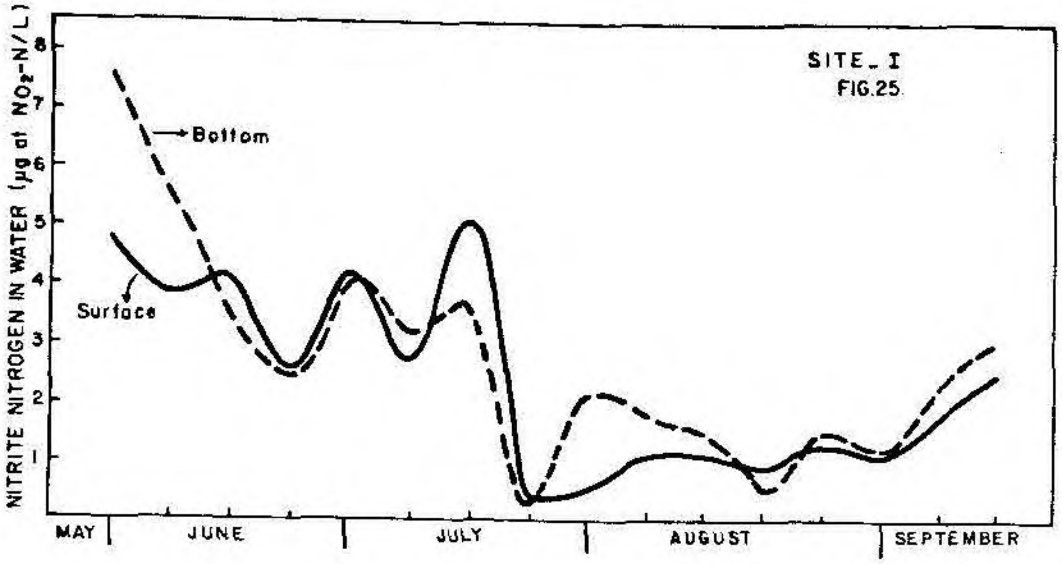
SITE_ II
FIG. 23.



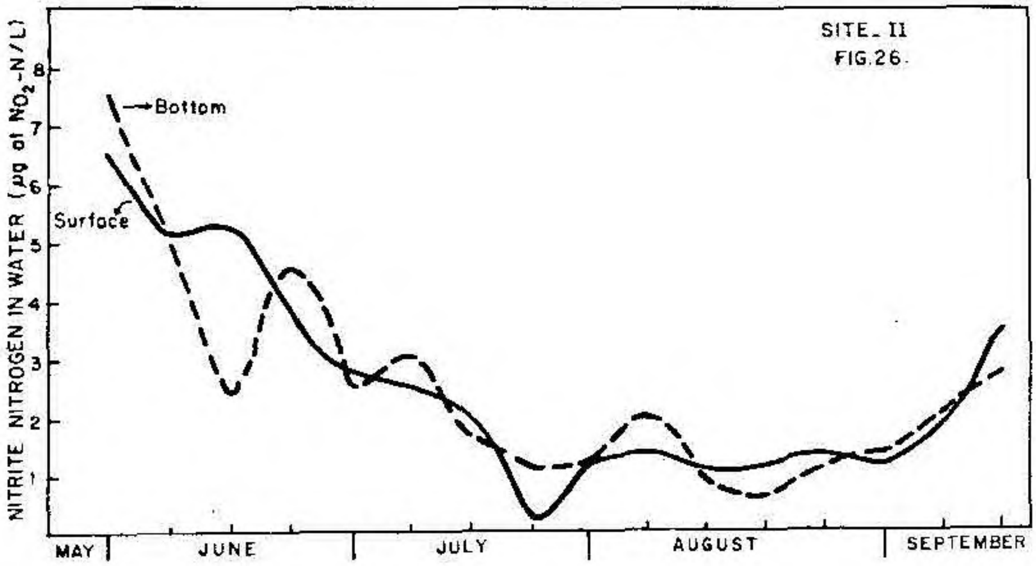
SITE_ III
FIG.24.

Figures 25, 26 & 27

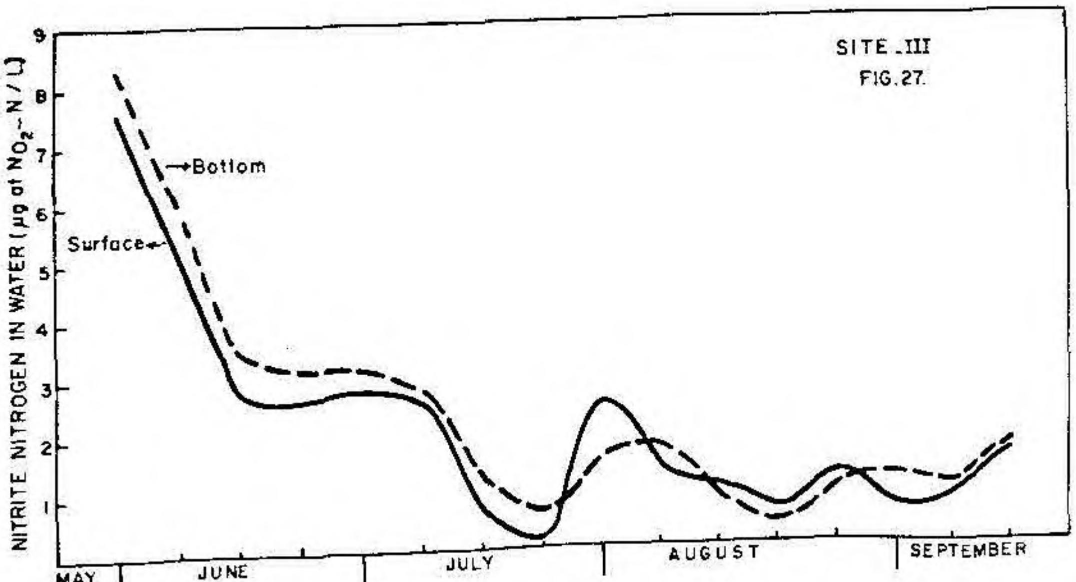
Variation in the nitrite Nitrogen content of the surface and the bottom water at the three sites during the period of study.



SITE_I
FIG.25.



SITE_II
FIG.26.



SITE_III
FIG.27.

<u>Figure 28</u>

Triangular graphs showing the soil composition at the three sites where studies were conducted.

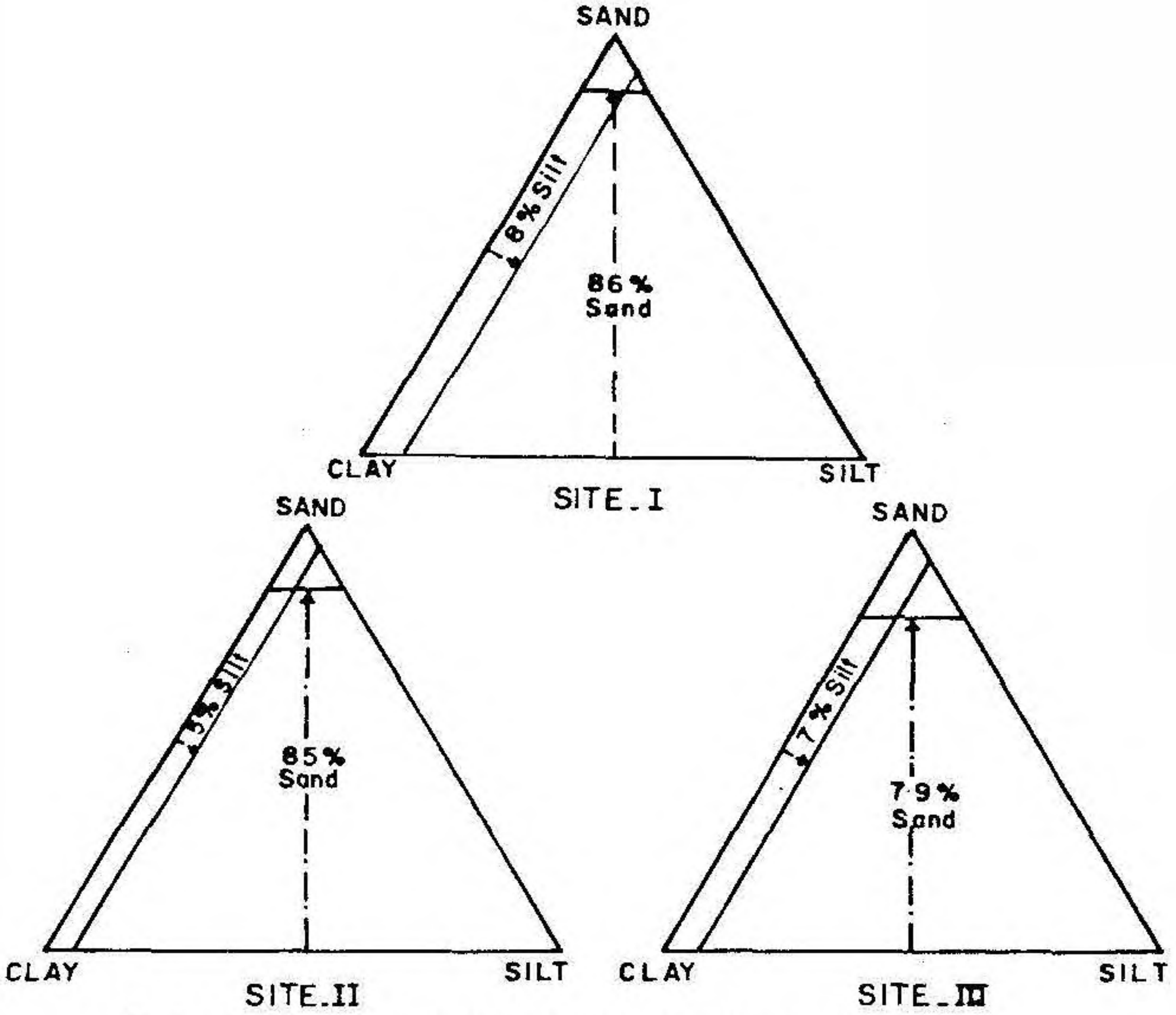


FIG. 28. SOIL COMPOSITION OF THE SITES

Characteristics of Surface water at Site I

Date	Water Temperature (°C)	Salinity (‰)	D.O. (ml/l)	NO_2^- (ug at/l)	NO_3^- (ug at/l)	PO_4^{---} (ug at/l)	Calcium (ppm)	Carbonate alk. (ppm)	Bicarbonate Alk. (ppm)	Total Alk. (ppm)	pH
31-05-1985	28.0	10.62	5.71	4.83	41.75	8.0	168.6	0	80.1	80.10	8.25
07-06-1985	26.0	6.93	4.23	3.79	45.26	6.5	190.3	0	69.42	69.42	8.24
14-06-1985	26.0	5.45	4.71	4.14	33.62	7.0	185.9	0	78.32	78.32	8.23
21-06-1985	26.2	4.35	4.53	2.41	21.58	6.5	149.1	0	67.64	67.64	8.25
28-06-1985	24.5	2.67	4.74	4.14	32.92	5.5	79.9	0	63.19	63.19	7.64
05-07-1985	26.5	1.77	4.98	3.28	25.66	5.4	114.5	0	52.51	52.51	8.04
12-07-1985	26.7	1.93	5.25	3.79	25.15	5.0	62.7	0	64.80	64.80	8.22
19-07-1985	27.0	2.09	4.35	0.34	34.95	5.5	46.2	10.68	65.86	76.54	8.72
26-07-1985	27.3	2.01	3.92	0.48	13.64	8.5	57.2	0	71.2	71.20	7.96
02-08-1985	28.0	1.93	2.85	1.03	9.38	7.0	66.0	0	65.86	65.86	8.25
09-08-1985	27.0	2.53	3.85	1.03	5.85	6.3	55.0	8.90	59.63	68.53	8.36
16-08-1985	27.3	2.24	4.84	0.88	0.84	7.0	81.4	14.24	65.86	80.10	8.45
23-08-1985	27.8	2.24	3.35	1.31	3.25	8.0	57.2	0	78.32	78.32	8.20
30-08-1985	28.0	2.24	2.78	1.03	3.35	8.3	70.4	0	75.65	75.65	8.03
06-09-1985	29.2	1.94	2.21	1.72	9.04	6.5	68.2	0	77.4	77.4	7.35
13-09-1985	29.0	2.05	2.78	2.41	9.06	7.0	63.8	0	89.99	80.99	7.85

Characteristics of Bottom water at Site I

Date	Water Temperature (°C)	Salinity (%.)	D.O. (ml/l)	NO_2^- (µg at/l)	NO_3^- (µg at/l)	PO_4^{---} (µg at/l)	Calcium (ppm)	Carbonate alk. (ppm)	Bicarbonate Alk. (ppm)	Total Alk. (ppm)	pH
31-05-1985	28.1	10.71	5.77	7.58	60.18	7.8	172.9	0	78.32	78.32	8.22
07-06-1985	26.0	6.93	4.32	5.52	43.89	6.9	129.7	0	67.64	67.64	8.23
14-06-1985	26.1	5.45	4.29	3.48	23.34	7.0	201.1	0	76.54	76.54	8.25
21-06-1985	27.0	4.35	3.90	2.45	21.85	7.0	125.4	0	67.64	67.64	8.23
28-06-1985	24.5	2.67	4.50	4.31	33.80	5.3	116.7	0	63.19	63.19	7.98
05-07-85	26.5	1.77	5.11	2.76	19.83	5.6	41.0	0	53.4	53.4	8.10
12-07-1985	27.1	1.93	5.76	5.17	28.35	4.8	69.1	0	66.76	66.76	8.25
19-07-1985	27.0	2.09	4.49	0.38	29.61	5.7	66.0	16.02	60.52	76.54	8.67
26-07-1985	27.5	2.01	3.77	2.27	10.79	8.7	61.6	0	73.86	73.86	7.85
02-08-1985	28.0	2.01	2.47	1.90	10.09	7.8	68.2	0	63.17	63.17	8.24
09-08-1985	27.0	2.53	3.49	1.38	3.91	6.5	57.2	3.56	64.97	69.53	8.32
16-08-1985	27.5	2.24	4.70	0.69	1.22	6.8	68.2	16.02	64.08	80.10	8.41
23-08-85	28.0	2.24	3.21	1.66	5.34	7.4	55.0	0	78.32	78.32	7.75
30-08-1985	28.0	2.24	3.01	1.07	3.53	9.0	59.4	0	80.10	80.10	7.86
06-09-1985	29.2	1.94	2.01	2.24	6.74	7.0	63.8	0	80.99	80.99	7.53
13-09-1985	28.9	2.05	2.78	3.10	7.39	7.0	70.4	0	83.66	83.66	7.65

Characteristics of Surface water at Site II

Date	Water Temperature (°C)	Salinity (‰)	D.O. (ml/l)	NO_2 (µg at/l)	NO_3 (µg at/l)	PO_4 (µg at/l)	Calcium (ppm)	Carbonate Alk. (ppm)	Bicarbonate Alk. (ppm)	Total Alk. (ppm)	pH
31-05-1985	28.0	10.15	5.68	6.55	56.27	7.0	190.3	0	72.98	72.98	8.28
07-06-1985	26.0	6.93	4.47	5.13	44.63	7.3	237.8	0	65.86	65.86	8.24
14-06-1985	26.0	6.93	4.65	5.17	34.64	7.5	185.9	0	78.32	78.32	8.28
21-06-1985	27.1	4.43	3.75	3.48	26.51	6.9	114.6	0	71.20	71.20	8.25
28-06-1985	24.5	2.66	5.13	2.76	24.41	5.3	71.3	0	63.19	63.19	8.00
05-07-1985	26.5	1.77	4.69	2.58	15.24	6.5	51.9	0	57.85	57.85	8.05
12-07-1985	27.1	1.93	7.83	2.07	22.64	4.0	75.7	14.24	56.96	71.20	8.53
19-07-1985	26.6	2.17	5.27	0.21	25.99	5.5	66.0	14.24	62.30	76.54	8.71
26-07-1985	27.5	2.09	4.35	1.21	23.49	8.7	52.8	14.24	57.85	72.09	8.65
02-08-1985	28.0	2.01	3.06	1.65	7.17	7.6	94.6	5.34	58.74	64.08	8.40
09-08-1985	26.8	2.44	5.13	1.02	1.44	6.8	90.2	12.46	57.85	70.31	8.59
16-08-1985	27.4	2.33	4.99	1.03	0.66	6.9	59.4	16.02	65.02	81.88	8.50
23-08-1985	28.0	2.33	3.42	1.31	2.64	8.1	77.0	0	79.21	79.21	8.01
30-08-1985	28.1	2.24	3.21	1.17	3.34	8.9	72.6	0	76.54	76.54	7.83
06-09-1985	29.0	2.24	3.01	1.79	3.79	6.5	74.8	0	89.00	89.00	7.67
13-09-1985	28.6	2.16	3.57	3.44	8.91	6.9	149.6	0	87.22	87.22	7.65

Characteristics of Bottom water at Site II

Date	Water Temperature (°C)	Salinity (‰)	D.O. (ml/1)	NO_2^- (µg at/1)	NO_3^- (µg at/1)	PO_4^{---} (µg at/1)	Calcium (ppm)	Carbonate alk. (ppm)	Bicarbonate Alk. (ppm)	Total Alk. (ppm)	pH
31-05-1985	28.3	10.34	5.85	7.24	55.76	7.5	185.9	0	71.2	71.2	8.27
07-06-1985	26.2	7.11	4.29	5.17	45.3	7.5	156.6	0	65.86	65.86	8.26
14-06-1985	26.2	5.36	4.65	2.41	29.36	7.9	231.3	0	74.76	74.76	8.22
21-06-1985	27.4	4.43	3.61	4.14	27.62	7.1	140.5	0	68.53	68.53	8.23
28-06-1985	25.0	2.74	5.65	2.58	15.06	5.5	142.7	0	63.19	63.19	8.18
05-07-1985	26.3	1.77	4.73	3.10	26.89	6.3	51.9	0	56.96	56.96	8.02
12-07-1985	27.2	1.93	6.18	1.72	31.80	4.3	108.1	5.34	56.96	62.3	8.42
19-07-1985	27.0	2.17	5.06	1.21	25.61	5.8	63.8	23.14	55.18	78.32	8.72
26-07-1985	27.8	2.09	2.99	1.21	23.14	8.6	52.8	5.34	68.53	73.87	8.51
02-08-1985	28.2	2.01	2.70	2.06	7.29	7.0	96.8	7.12	57.85	64.97	8.40
09-08-1985	27.0	2.44	4.49	0.87	4.08	6.4	116.6	14.74	54.29	68.53	8.56
16-08-1985	27.5	2.33	4.70	0.69	1.25	6.9	61.6	12.46	68.53	80.99	8.45
23-08-1985	28.1	2.33	2.92	1.22	2.71	8.5	55.0	0	77.43	77.43	8.05
30-08-1985	28.2	2.24	2.70	1.21	3.52	8.9	88.6	0	79.21	79.21	7.76
06-09-1985	29.1	2.34	2.85	2.14	2.62	8.5	55.0	0	89.89	89.89	7.64
13-09-1985	28.6	2.16	3.50	2.75	1.44	7.4	145.2	0	85.44	85.44	7.61

Characteristics of Surface water at Site III

Date	Water Temper-ature (°C)	Sali-nity (‰)	D.O. (ml/l)	NO_2^- (μg at/l)	NO_3^- (μg at/l)	PO_4^{---} (μg at/l)	Cal-cium (ppm)	Carbo-nate Alk. (ppm)	Bicar-bonate Alk. (ppm)	Total Alk. (ppm)	pH
31-05-1985	27.5	10.8	5.34	7.59	59.91	8.5	168.6	0	75.65	75.65	8.20
07-06-1985	26.2	7.30	5.31	5.11	31.94	6.5	129.7	0	74.76	74.76	8.28
14-06-1985	26.5	5.82	4.50	2.75	23.72	5.5	149.2	0	83.66	83.66	8.28
21-06-1985	27.7	4.75	4.77	2.58	23.72	7.1	129.7	0	67.64	67 .64	8.21
28-06-1985	25.2	2.97	4.95	2.76	23.71	6.0	71.4	0	62.30	62.30	7.99
05-07-1985	26.5	2.09	4.98	2.58	16.83	3.7	51.9	0	82.30	62.30	8.06
12-07-1985	28.0	2.17	8.10	1.20	24.56	2.8	90.8	17.8	49.84	67.64	8.70
19-07-1985	27.5	2.25	3.42	0.17	31.94	4.2	55.0	14.24	69.42	83.66	8.71
26-07-1985	28.0	2.41	3.49	2.55	22.39	5.7	63.8	16.02	64.08	80.10	8.64
02-08-1985	28.9	2.41	2.99	1.31	5.04	6.9	572	14.24	64.08	78.32	8.51
09-08-1985	27.2	2.83	3.78	1.04	2.14	5.8	96.8	21.36	57.85	79.21	8.65
16-08-1985	28.3	2.63	6.77	0.69	1.22	5.3	61.6	23.14	63.19	86.33	8.81
23-08-1985	28.5	2.63	3.85	1.21	2.42	6.0	77.0	21.36	59.63	80.99	8.60
30-08-1985	29.0	2.63	4.92	0.62	2.33	6.4	57 .2	12.46	76.84	89.00	8.50
06-09-1985	29.7	2.63	5.63	0.86	1.79	7.4	114.4	12.46	80.10	92.16	8.54
13-09-1985	29.8	2.65	4.99	1.55	1.48	7.3	92.4	7.12	89.00	96.12	8.51

Characteristics of Bottom water at Site III

Date	Water Temperature (°C)	Salinity (‰)	D.O (ml/l)	NO_2^- (µg at/l)	NO_3^- (µg at/l)	PO_4^{---} (µg at/l)	Calcium (ppm)	Carbonate Alk. (ppm)	Bicarbonate alk. (ppm)	Total alk. (ppm)	pH
31-05-1985	28.0	11.35	5.86	8.27	60.73	7.3	205.4	0	93.45	93.45	8.27
07-06-1985	26.0	7.29	5.10	5.86	36.50	6.6	125.4	0	73.87	73.87	8.22
14-06-1985	27.3	5.91	4.57	3.48	31.10	6.6	103.8	0	81.88	81.88	8.25
21-06-1985	28.0	4.75	3.54	3.10	26.01	5.8	149.2	0	73.87	73.87	8.24
28-06-1985	25.5	3.14	4.95	3.10	40.04	6.0	149.2	0	66.7	66.7	7.94
05-07-1985	27.0	2.09	4.51	2.76	24.06	4.0	54.1	0	60.52	60.52	7.90
12-07-1985	28.2	2.25	7.32	1.72	22.17	3.4	112.4	10.68	56.96	67.64	8.60
19-07-1985	28.0	2.25	3.28	0.69	33.58	4.0	48.4	16.02	64.08	80.1	8.62
26-07-1985	28.0	2.41	3.28	1.51	27.78	6.9	68.2	7.12	72.98	80.1	8.56
02-08-1985	29.0	2.41	2.83	1.72	12.39	5.6	85.8	21.36	56.07	77.43	8.54
09-08-1985	27.5	2.83	4.77	0.86	4.43	5.6	132.0	16.02	63.19	79.21	8.62
16-08-1985	28.5	2.63	6.13	0.34	1.63	5.1	77.0	35.60	50.73	86.33	8.88
23-08-1985	28.7	2.63	3.50	1.03	2.24	6.0	59.4	17.8	64.97	82.77	8.48
30-08-1985	29.1	2.63	4.71	1.21	2.62	6.5	63.8	14.24	75.65	89.89	8.54
06-09-1985	29.9	2.63	5.35	0.97	1.92	7.1	110.0	14.24	80.10	94.34	8.51
13-09-1985	29.8	2.65	4.64	1.72	1.46	7.6	83.6	5.34	89.00	94.34	8.47

SOIL CONDITION

Date	SITE I			SITE II			SITE III		
	Available Nitrate (µg at/g)	Available Phosphorus (µg at/g)	Exchangeable Calcium (ppm)	Available Nitrate (µg at/g)	Available Phosphorus (µg at/g)	Exchangeable Calcium (ppm)	Available Nitrate (µg at/g)	Available Phosphorus (µg at/g)	Exchangeable Calcium (ppm)
31-05-1985	1.06	6.52	486.5	2.19	5.22	259.4	2.58	8.48	940.5
07-06-1985	1.44	5.86	443.2	1.63	6.52	389.2	3.13	7.83	813.5
14-06-1985	1.44	3.91	302.6	1.56	4.24	389.2	2.50	8.16	786.5
21-06-1985	1.56	3.26	324.3	1.75	4.57	345.9	3.44	7.83	745.9
28-06-1985	1.75	5.87	551.3	0.94	4.57	335.1	1.88	9.13	702.7
05-07-1985	1.50	5.54	497.3	1.31	7.17	281.3	2.88	7.25	670.2
12-07-1985	1.44	2.61	220.0	2.32	4.13	429.0	2.81	6.39	627.0
19-07-1985	1.38	3.39	275.0	1.25	2.61	319.0	1.56	7.17	440.0
26-07-1985	1.25	2.61	176.0	1.88	5.34	396.0	2.56	8.99	550.0
02-08-1985	1.56	4.89	198.0	2.06	3.91	253.0	2.38	8.48	341.0
09-08-1985	0.63	7.70	165.0	1.25	7.83	407.0	1.75	10.36	506.0
16-08-1985	0.71	9.07	264.0	1.02	7.17	352.0	1.65	9.85	231.0
23-08-1985	0.94	5.80	285.0	0.88	5.90	360.0	1.56	8.60	380.0
30-08-1985	0-56	4.89	246.0	0.94	5.61	324.0	1.63	9.26	320.0
06-09-1985	1.57	4.70	225.0	1.31	7.50	450.0	1.88	8.40	280.0
13-09-1985	0-88	4.70	187.0	1.63	6.58	627.0	1.13	6.19	396.0

DISCUSSION

While discussing the interdependence of soil and water in ponds, Stangenberg(1943) has stated that, the soil profits more as it is constantly enriched in organic matter, phosphates and carbonates. In such shallow water bodies as ponds there is an intense interchange of organic and mineral compounds between the soil and the water. Enrichment with carbonates occurs only when the inflowing water is rich in carbonates. In the present case it was observed that the tidal influence is maximum in site I and the carbonate dissolution is more here. Site III is more or less of a stagnated nature and the maximum amount of carbonates are present here and minimium of bicarbonates also. The maximum pH also is observed in this region. Except for the post-monsoon, the maximum amount of soil calcium is again in Site III. The conditions of exchange of various ions between soil and water are not so simple, as their passing from soil to water is mainly dependent on the amount of clay minerals. Lyzymetric investigation of ponds(Wrobel 1959) proved that calcium is the most easily washed out factor. In the present investigation it has been observed that maximum clay content is in site III where the Soil calcium contents are also maximum. During monsoon in Site-III the water calcium content is more than the other two sites and the exchange between soil and water also appears to be more. It may also be remembered that tidal influences are minimum in this site.

The relationship between the calcium content of the soil and the water has been investigated in some tropical ponds previously also(Sumitra Vijayraghavan 1973). The author has stated that the relation was almost direct in one pond whereas it was inverse for most of the year in the second pond. No relationship could be established between calcium content of the water and of the soil in the third pond. Soil calcium is much more abundant than the water calcium content in all the present three sites. Mollah _et al._(1979) while investigating in some fresh water ponds have stated that the calcium content of water showed an inverse relationship with that of the soil in one of the two ponds they worked, and in the second pond correlation was not clear. Such an inverse relationship is observed by the onset of monsoon in site I, whereas during peak monsoon a more or less direct one is conspicuous. In site III the relation between soil and water calcium content showed fluctuations during peak monsoon and the relation was inverse during late July and more or less direct during the fag end of monsoon.

Banarjea(1967) has stated that the availability of calcium from soil to water is likely to be influenced more by exchangeable calcium and he attempted a correlation between exchangeable calcium and productivity in ponds and has inferred that there is no marked influence of exchangeable calcium upon productivity. Hence it can be said that the nutrient exchange is more significant, as far as the plankton bloom and productivity are concerned.

Phosphorus is one of the elements easily subject to retrogradation in an acid medium as well as in a basic one. The retrogradation of phosphorus and the accumulation of insoluble calcium phosphate in soil causes a rapid decrease of phosphate supplied by fertilization. Golterman(1967) while discussing calcium-carbonate-phosphorus system has stated that the water of fish ponds generally has a high calcium content, as lime is used widely as a fertilizer.

Osugi _et_ _al_.(1932), (Sited in Kawaguchi,1950) and Lu and Chung(1964) have studied the solubilities of various phosphate minerals under different pH values and they observed that solubilities of most phosphates increased under alkaline condition. Such a correlation in the present case was observed at Site II and Site III especially during the peak monsoon period. But in Site I this relationship was not so clear.

Mollah _et_ _al_.(1975) in an investigation of soil and water phosphorus content in the ponds have stated that available phosphorus of water and soil in certain ponds showed an inverse relationship while in certain other ponds such a relationship was not observed. Considering Site I where the tidal influence is more, such an inverse relationship is observed during monsoon and post-monsoon seasons. This is not so well defined in site II and III, but in site III soil phosphorus was always higher than that contained in water and more or less a direct relationship was observed during monsoon.

This could be due to the adsorbing capacity of the pond sediment which is not releasing the nutrients to the overlying water. Such an adsorbing capacity can be visualised in the case of calcium also where the sediment always contained much higher amounts of calcium than the overlying water and a noticeable exchange could be observed during late monsoon and post-monsoon only, that too maximum in site I where the tidal influence is high. 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 oxidised sediments can prevent the transport of materials into the water, while scavenging of materials from the water (Eg. adsorption of phosphate) can usually proceed unchecked. It appears in the present case that vertical turbulence plays an important role in the exchange mechanism. Lerman and Brunskil(1971) while studying the migration of major constituents from lake sediments to the lake water has suggested that the higher concentration of dissolved components in interstitial water than in lake water indicate that there may be flux upward across the sediment water interphase and this flux accounts 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 sediments, however should result in a decrease in concentration of dissolved components in the lake water compared to the sediments. The flux rate in the present contest seems to be small except for monsoon and post-monsoon.

The water of fish pond generally has a high calcium content as lime is used widely as a fertilizer(Golterman H.L. 1967). From solubility-product consideration it has been calculated that a concentration of more than 10 mg/L of calcium causes the precipitation of calcium. This is the case with fresh water ponds. But in salt water ponds as in the present case concentrations of calcium were never below 200 ppm. Chattopadhyaya and Mandal(1983) has stated that the chemical properties in soil and water of a brackish water pond where artificial fertilization was introduced showed that, the behaviour of different nutrient elements in soil and water of the pond is largely influenced by prevailing water salinity levels. The seasonal salinity distribution patterns at surface and bottom in the present investigational sites are more or less the same and as such the salinity influence over the changes in properties of the sediment and soil phases will be more or less the same. So the exchange process between sediments and water are inferred to be controlled by other criteria. Mortimer(1941, 1942) while discussing diurnal and seasonal fluctuations of dissolved oxygen have observed that nutrient ions are produced by the decomposition of precipitated organic matter. Under oxidising conditions the ions except nitrite and nitrate are adsorbed on soil colloids. Thus the retention capacity of the sediments with respect to nitrite and nitrate seems to be small which is observed in the present case also. Throughout the investigational period the nitrate content of the bottom sediment were below 5 µg. at of NO_3-N/g whereas in the overlying water a maximum of 60 µg at of NO_3-N/l during premonsoon and another high peak during the monsoon period, were observed. The nitrite contents also were high during this period. Venugopalan et al. (1975) stated that in Vellar Estuary the monsoonal maximum of nitrogen compounds in water is found to be depleted during post-monsoon season by the post-monsoon bloom of phytoplankton. Such a bloom can be inferred in the present case also since minimum values for nitrogen nutrients are observed during the post-monsoon where as during the monsoon are pre-monsoon values were quite high.

Stevenson(1951) found that phosphate was given off rapidly from surface layers of estuarim mud when the supernatent water becomes deoxygenated. In all the three sites minimum values of oxygen where observed during peak monsoon and this correspond to maximum amount of phosphate in the pond water which observation agrees to a good extent with the previous one.

SUMMARY

The investigations pertain to a short term study of the calcium and nutrient contents in the bottom sediments and overlying water in three sites where fish culture operations are usually carried out. The tidal influences are maximum in Site I and II and minimum at Site III. The ponds are of shallow depths and more or less vertically homogenous waters are present. The period of investigation was from late premonsoon to late postmonsoon and monsoon effects were maximum in Site I and II. From the observed values of the various parameters in the soil and overlying water, general conclusions as to the degree of exchange between the soil and overlying water are drawn. The calcium exchanges between the soil and overlying water seems to be maximum during monsoon and that too especially in Site I and II where turbulance is a high degree due to tidal influence. Site III is a bit isolated from the main stream and as such retention of calcium in the bottom sediments appears to be high, values during early monsoon also being nearly 650 ppm. This is reflected in the distribution pattern of carbonate alkalinity which is highest in Site-III at surface and bottom wat ers. The inverse relationship between carbonate and bicarbonate alkalinities is observed. Carbonate alkalinity is observed invariably when exchange processes are in vouge between the sediments and the overlying water. During early monsoon and pre-monsoon seasons carbonate alkalinity is absent and this the vertical turbulence during the peak monsoon and post-monsoon are inferred to have

noticeable influence over the mixing and exchange processes in the ponds. With good amounts of bottom oxygen values and thus at oxidising conditions the nitrate retention capacity of the pond bottom sediment is observed to be very feeble, as usual. The release of phosphorus by the sediments to overlying water under low oxigenated conditions is observed.

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