CMFRI
bulletin 39

JANUARY 1987

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(Indian Council of Agricultural Research)
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ECOLOGY OF PEARL CULTURE GROUNDS

A. C. C. VICTOR[1] AND T. S. VELAYUDHAN[1]

INTRODUCTION

The growth of pearl oysters either in the natural beds or in the culture farms is strongly influenced by the oceanographical conditions of the ground, the chemical substances present in the sea water, particularly some of the salt and trace elements, the quality of the plankton taken by the oysters, hydrogen-ion concentration etc. The kind and quantity of the minute amount of the chemical substances and metal ions might affect the quality of the cultured pearls (Matsui, 1958). He also pointed out that the difference in the water temperature and nutritional conditions of the grounds strongly affect the growth of the oysters, especially a conspicuous variation occurs in the thickness of the shell which in turn influence the lustre, colour, shape, degree of scratches and size and weight. Besides growth, the propagation of the oysters depend greatly on the quality of the water and the currents prevailing from time to time. Alagarswami (1970) has drawn attention to the necessity of hanging pearl oyster nets and cages at such depths where optimum temperature conditions prevail and also the importance of altering the depths of nets and cages when the hydrological conditions change according to the seasons of the year. A good current is also found to be necessary not only as a source of oxygen but also to bring in planktonic organisms on which the pearl oysters feed.

PHYSIOGRAPHY OF INDIAN COAST

The configuration of Indian coasts is of a straight stretch of exposed sandy beaches without any sheltered bays and rocky coves except the shore line from Bombay upto Karwar and that of Andaman and Nicobar Islands where the coast line is irregular and crenulate (Easterson and Mahadevan, 1980). The major interruptions are the numerous rivers and rivulets which open into the Arabian sea and the Bay of Bengal. These rivers discharge into the sea every year immense volumes of water which bring along large quantities of organic and inorganic substances. The shore line between Mandapam and Kanyakumari is mainly sandy but here and there the coast is indented and rocky with some cliffs.

In Japan pearl culture farms are located in enclosed bays which have connections with open sea. Areas with minimal tidal effect are preferred for establishing pearl culture farms. In places where bays are absent, farming is done in open sea, such as the Seto Inland Sea. Areas bordered by chains of Islands are desired (Alagarswami, 1970).

TOPOGRAPHY

The pearl oyster *Pinctada fucata* lives attached to rocks or any other hard substratum with the byssus threads on the bottom of the sea. In the Gulf of Mannar it inhabits depths from 10—20 m. The same species occupies the intertidal habitat in the Gulf of Kutch. Thus the species can adapt itself to varying depth conditions within the above range. *P. margaritifera* occurs in the intertidal flats of the Andaman and Nicobar Islands. In the Gulf of Mannar farming of pearl oyster is being done at Veppalodai and at Tuticorin Harbour basin. At Veppalodai the farm was in the open sea located 1.5 km away from the shore where the depth of the water is 4.5 m. It is bounded on the east by two small Islands and on the west by the mainland coast. These two islands give some protection

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to the farm from winds and waves. In spite of the presence of the two islands, the farm is exposed to prevailing winds and some swells and therefore the area is subjected to vigorous wave action. The farm at Tuticorin Harbour is located within the two arms of the breakwater and hence is protected from winds and swells. The depth ranges between 5.75 and 6.5 m. It is well known that the benthic ecology of the pearl oyster grounds play a vital role in the rate of production as well as the quality of pearls. Rocky and gravelly bottom is more suitable. Matsui (1958) is of opinion that culturing pearl oysters in the same ground often causes serious decline in the rate of production as well as in the quality of pearls. The fouling organisms which settle on the oysters and culture materials discharge enormous quantity of organic matter which get deposited on the sea bottom. The sea bottom of Veppalodai farm is hard and devoid of mud but with a thin layer of shells and coral fragments. In the Tuticorin Harbour the sea bottom is predominantly muddy and devoid of weeds and sandy patches. The accumulation of mud on the bottom of Harbour enclosure is mainly due to the blasting of rocks at the Harbour entrance.

WIND

Climatically, Tuticorin has four distinct periods in the year. November to February is the characteristic north-east monsoon season, with the mean monthly surface wind velocity of 22.45 km per hour. There is heavy rainfall especially in November. The annual rainfall in the Tuticorin Harbour basin varies from 345 mm to 863 mm and the maximum precipitation occurs during November (221 mm) and December (108 mm). With the onset of winter, local heat and moisture give rise to tropical cyclones, most of which originate near Andaman Islands and move in westerly or north westerly direction towards the east coast of India. The rains lash along with wind the Circar and Coromandal coasts and the southern districts during October to December (Easterson and Mahadevan, 1980). March to May is the period of premonsoon or summer and the prevalent wind is south east, south south west and west with its mean velocity ranging between 19.96 and 25.91 km per hour. Next comes the south west monsoon period from June to the beginning of September. The west coast of India receives heavy rainfall. But, for the Gulf of Mannar coast the period June-August is the period of least or no rainfall. The direction of the prevalent wind is towards west and its mean velocity is increased to 29.52 km per hour. September and October constitute a transitional period with a fairly dry weather with occasional rains in October. In October the wind velocity is decreased to 20.61 km per hour. A maximum speed of 104 km per hour was recorded during June 1975 and a minimum of 10 km per hour during March and October 1979.

WAVES

In the Veppalodai and Harbour basin, the predominant wave generating wind is north east monsoon, in directions of north north east, north east, east north east and east. The size of the wave is due to the velocity and the distance travelled (fetch) by the wave generating wind. The north east monsoon is powerful on the coast of Tuticorin and the water becomes clear from mid October to mid April. During this period survey of pearl oyster beds is possible by direct under water observations by SCUBA. At the entrance of the Harbour basin a maximum of 1.78 m wave height was recorded during the years 1974-1980 and the monthly mean wave height ranges from 0.10 to 1.10 m. Inside the Harbour basin, where the pearl culture rafts are moored, the wave height ranges upto 0.90 m. At the entrance of the Harbour basin, the duration between the successive waves is 2.90-5.41 seconds whereas inside the Harbour basin and at the farm site it is between 9 and 11 seconds.

CURRENTS

A good current is necessary not only as a source of oxygen but also to bring in the planktonic organisms on which the pearl oysters feed. The current also helps in removing the deposited silt on the oysters as it flows through the farm. The water current to a larger extent influences the propagation and dispersal of pearl oyster.

The current system in this area is generated by the south-west and north-east monsoons and is of low velocity. At the entrance of Tuticorin Harbour basin the current velocity ranged from 0.047 knots (March 1980) to 1.15 knots (December 1979). The current velocity is high during the period of north-east monsoon, the velocity being 0.65, 0.69, 0.48 and 0.50 knots during November, December, January and February respectively.

TIDES

Next to waves and currents, tides are the most striking movements of sea water. The vertical movements of sea water can be transformed into tidal currents of high speed in narrow inlets, river mouths, small bays or entrances to inland seas. The tides are semidiurnal in east coast of India. The strength of the tide both at Veppalodai and Tuticorin Harbour is extremely weak. The tidal amplitude is 0.16 m at neap tide and 0.70 m at spring tide.

Turbidity

In order to measure the rate of siltation, plankton bottles of 270 ml volume with a mouth diameter of 2.54 cm are attached to nylon twins and suspended from the raft to a depth of 2 metres for a period of six days. In the laboratory the sediment was allowed to settle in a measuring cylinder and the volume measured. The rate of silt deposition at Veppalodai varies between 0.87 ml day and (March 1976) to 3.13 ml day and (December 1975). Visual observations were made to measure the transparency of water using a sechhi disc. At Veppalodai the transparency of water was very poor during most part of the year. At a depth of 2.00-2.75 m in the farm, the light penetration was confined to 1.5 m. At Tuticorin Harbour farm the light penetration was confined to 1.00-4.5 m at a depth of 5.75-6.50 m. The south-West and north-east monsoons are active in the south-east coast of India resulting in large quantities of suspended matter in the water. This accounted for high turbidity at both the farms.

Temperature

Temperature plays a vital role in the reproductive activities of marine benthic molluscs of inshore waters. The oceanographical data collected during the period 1980 to 1985 show that the monthly mean atmospheric temperature exhibits, a clear double oscillation with a single peak in July (31.5°C for 1980) and a depression in December-January (25.9°C for 1982-83). April and May are the months of high atmospheric temperature, the highest individual value being in May 1983 (33.5°C). The monsoon months are colder, the lowest individual value being in January 1982 (23.8°C). At Veppalodai the annual temperature fluctuation in the surface sea water is from 25.5°C in winter (December 1974) to 32.1;C in summer (May 1978). At the Harbour basin farm the monthly mean surface temperature fluctuates between 25.2°C (December 1984) and 31.6°C (May 1982). Similarly the bottom temperature ranges between 25.2°C (December 1984) and 31.6°C (April 1985) (Fig. 1). The lowest individual surface temperature recorded during the present study was 24.3°C for January 1978 and the highest was 32.5°C in May 1978. The surface and bottom water temperatures have three distinct periods in the year. The first, extending from January to April is the period of temperature rise in which the surface temperature is invariably low in January, increases steadily and reaches the maximum in April-May. The gradual increase in the surface temperature is due to the reversal in the direction of currents (Ganapathy and Murthy, 1955) which brings highly saline water from the equitorial region. The second, extending from June to October is the period of temperature fluctuations in which the temperature begins to fall in June until the minimum is reached in July-August which coincides with the period of south-west monsoon. The third extending from November to December is the period of temperature decrease in which the temperature begins to fall in November until the minimum is reached in December. The steep fall in the surface temperature was primarily due to the onset of the rain bearing north-east monsoon and the influx of freshets into the sea from the numerous rivers and rivulets. In all these years, the coincidence between atmospheric temperature and surface temperature is not continuous, although the air temperature was higher than the surface temperature. The air and sea temperature appear to be correlated with rainfall. The air temperature is as low as that of surface temperature during peak rainfall period. During non-rainy or least rainy periods in June-August the air temperature is higher than that of the sea temperature.

Salinity

The pearl oysters are stenohaline and prefer high salinities and when reared in such waters produce pearls with golden tint. The monthly mean salinity in the Harbour farm varies from 30.5‰ (December, 1983) to 35.75‰ (September 1983). The highest individual salinity value of 36.68‰ was recorded in September 1983 and the lowest value of 26.27‰ was recorded in December, 1983. The salinity shows a single peak in July-August preceded by a gradual rise from January and followed by a gradual decline to December. High saline conditions prevail over a period of six months from May to October and low saline from November to April. The period of high values and low values coincide with south-west and north-east monsoons respectively. The salinity is lowest during January-February which is the result of rainfall in October-November (Fig. 1).

Dissolved oxygen

The surface waters of Tuticorin coast are rich in dissolved oxygen throughout the year. Jayaraman (1954) opined that high oxygen values for surface

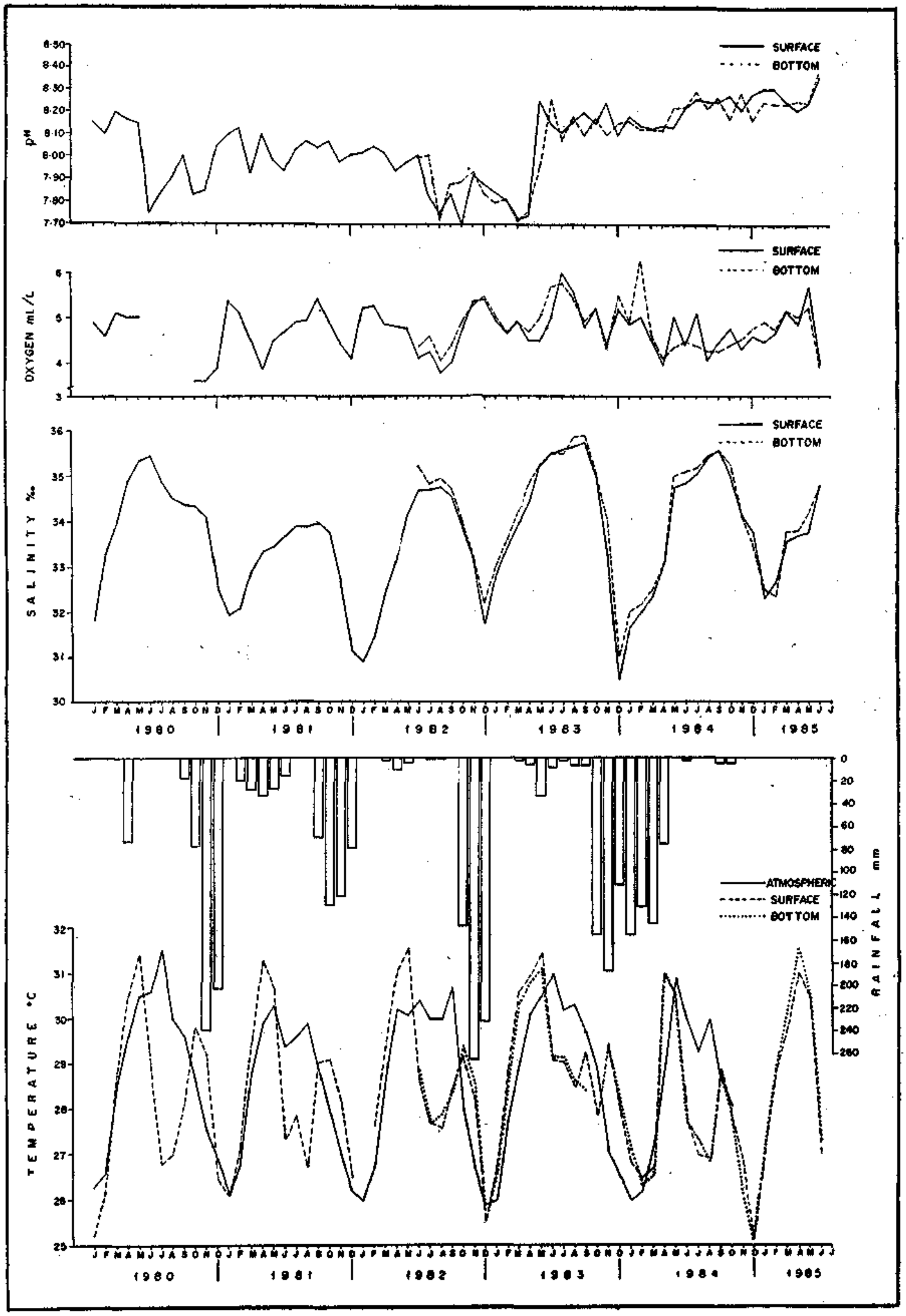

FIG. 1. Monthly variations in the mean values of temperature, rainfall, salinity, dissolved oxygen, pH at Tuticorin Harbour basin from January 1980 to July 1985.

waters could indicate increased photo-synthetic activity. The monthly mean dissolved oxygen at Veppalodai ranges from 4.4 ml/l (November 1978) to 6.4 ml/l (August 1978). The monthly mean dissolved oxygen in the surface waters of Tuticorin Harbour farm varies from 3.2 ml/l (November 1980) to a maximum of 6.0 ml/l in July 1983, while the bottom water dissolved oxygen content fluctuates between 4.0 ml/l (August 1982) and 6.5 ml/l (February 1984). There is no perceptible seasonal variation in the dissolved oxygen (Fig. 1).

pH

The monthly mean pH values at the Veppalodai farm varies from 7.96 (February 1974) to 8.42 (November 1974). In the Harbour farm the monthly mean surface water pH and bottom water pH ranges were 7.7 (October 1982) to 8.30 (January 1985) and 7.73 (August 1983) to 8.30 (July 1984) respectively (Fig. 1).

Phosphate

The inorganic phosphate of Tuticorin waters does not show any perceptible seasonal variation. The monthly mean surface water inorganic phosphate fluctuates between 0.16μg at P/1 (October 1980) and 1.66 μg at P/1 (August 1984) while in the bottom waters it varies from 0.11 μg at P/1 (May, 1983) to 2.06μg at P/1 (December 1983) (Fig. 2).

Silicate

The silicate content in the Tuticorin waters exhibit wide fluctuations. The monthly mean silicate values from surface waters ranges from 0.001 μg at Si/1 (January 1983) to 9.872 μg at Si/1 (June 1984). Similarly in the bottom water the silicate values fluctuates between 0.001 μg at Si/1 (January 1983) and 10.975 μg at Si/1 (April 1982) (Table 1).

Calcium

The monthly mean calcium content varies between 0.316 g/l to 0.454 g/l. The individual lowest value is 0.311 g/l in January 1982 and the highest 0.466 g/l in January 1985. The monthly average in the bottom

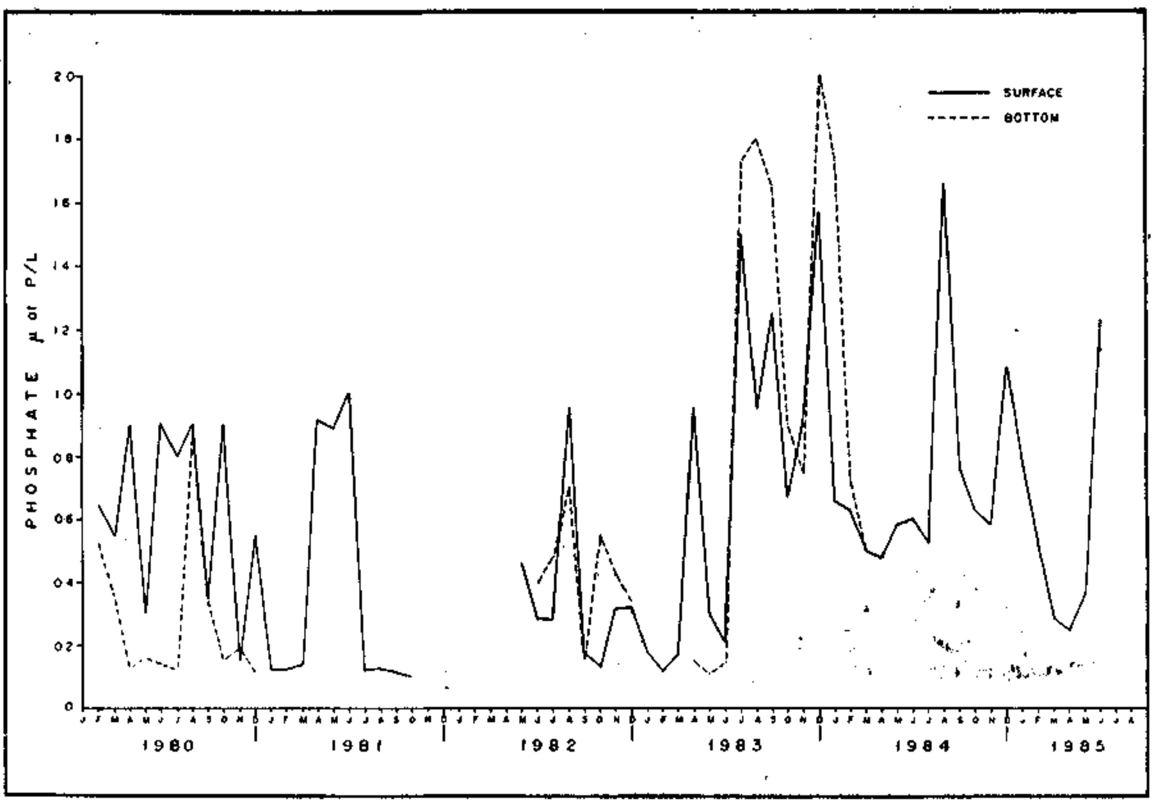

Fig. 2. Monthy variations in the mean values of phosphate at Tuticorin Harbour basin from January 1980 to July 1985.

water indicate a maximum of 0.447 g/l in August 1982 and a minimum of 0.350 g/l in June 1984 (Fig. 3).

Magnesium

The monthly mean magnesium values for the surface water of Tuticorin Harbour varies from 1.229 g/l (December 1982) to 1.406 g/l (June 1980), while the bottom water varies between 1.229 g/l (September 1983) and 1.445 g/l (June 1980) (Fig. 3).

in the surface waters. In the case of bottom waters he values vary from 0.067 g/m^3 (March 1984) to 6.592t g/m^3 (June 1983) (Table 1).

Primary Production

The mean monthly values of gross production at Veppalodai farm vary between 196 mgC/m^3/12 hours day (March 1978) and 377 mgC/m^3/12 hours day (September 1978). There are two peaks of production,

Table 1. *Monthly mean values of gross productivity, chlorophyll and silicate at Tuticorin Harbour farm for the period January* 1983 *to September* 1985

Month		Gross productivity mg/Cm^3/day		Chlorophyll (a) g/m^3		Silicate µg at-Si/l	
		Surface	Bottom	Surface	Bottom	Surface	Bottom
Jan 1983	..					0.001	0.001
Feb	..					0.001	0.001
Mar	..					0.001	0.001
Apr	..			1.068		0.073	0.165
May	..			0.935	1.341	0.189	0.295
Jun	..			5.140	6.592	7.200	0.098
Jul	..			0.935	0.948	0.102	0.034
Aug	..			1.600	0.534	0.038	0.032
Sep	..			1.202	1.335	0.029	0.030
Oct	..			1.869	0.668	1.000	1.008
Nov	..			6.140	2.003	5.833	5.649
Dec	..			1.469	2.136	5.583	9.895
Jan 1984	..	1029	772	6.942	2.759	7.508	9.895
Feb	..	2240	2153	1.739	0.267	3.276	3.740
Mar	..	257	103	1.335	0.067	6.143	6.552
Apr	..	—	—	0.801	0.623	1.151	1.638
May	..	876	—	0.701	0.173	1.549	1.646
Jun	..	382	283	0.801	0.468	9.872	8.875
Jul	..	1167	176	2.136	1.335	3.057	6.170
Aug	..	652	1869	3.115	0.801	5.460	4.313
Sep	..	1244	517	0.623	0.712	2.948	1.420
Oct	..	558	—	2.670	0.801	2.851	7.340
Nov	..	132	127	0.670	—	3.822	9.719
Dec	..	415	313	0.890	0.178	5.667	1.751
Jan 1985	..	200	243	0.267	1.060	0.601	0.601
Feb	..	47	329	0.359	0.801	2.949	2.211
Mar	..	315	176	1.268	0.312	6.552	6.279
Apr	..	165	457	0.935	0.267	6.552	10.975
May	..	256	325	1.424	1.938	3.929	6.279
Jun	..	282	9	3.393	1.157	2.184	3.822
Jul	..	188	795			3.325	2.719
Aug	..	141	24			2.858	3.112
Sep	..	12				2.498	1.532

Chlorophyll

The chlorophyll values indicate a high seasonal variability in Gulf of Mannar. Values ranging from a minimum of 0.267 g/m^3 (January 1985) to a maximum of 6.942 g/m^3 (January 1984) have been observed

one in May (345 mgC/m^3/12 hours day) and another in September (377 mgC/m^3/12 hours day). Two depressions noticed are in March (196 mgC/m^3/12 hours day) and in October (212 mgC/m^3/12 hours day).

Table 1 illustrates the mean monthly values of gross

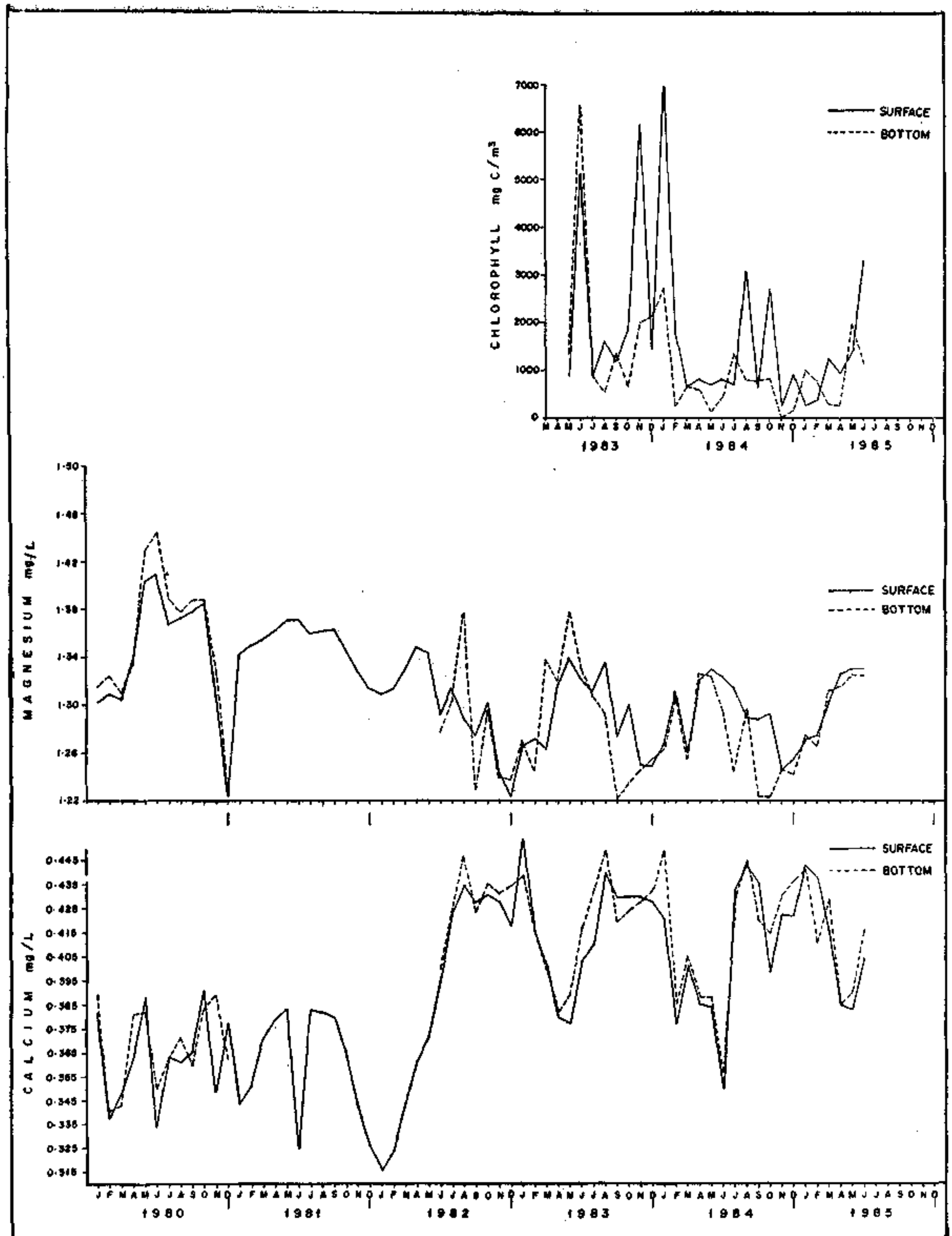

Fig. 3. Monthly variations in the mean values of calcium, magnesium and chlorophyll at Tuticorin Harbour basin from January 1980 to July 1985.

productivity at Tuticorin Harbour farm. The results indicate that there is considerable variation in unit volume production $mgC/m^3/day$. In the surface waters, the production rate ranges from 12 $mgC/m^3/day$ (Spe. tember 1985) to 2240 $mgC/m^3/day$ (February 1984). In the bottom waters the production rate varies from 9 $mgC/m^3/day$ (June 1985) to 2153 $mgC/m^3/day$ (February 1984).

Growth of Pearl Oysters

The pearl oyster *Pinctada fucata* under conditions of raft culture at Veppalodai and Tuticorin Harbour exhibits differential growth rate. The progress of growth is better in younger size groups than in the older groups. Growth is relatively faster during September-January (Chellam, 1978). Comparative growth studies reveal that the Harbour farm oysters grow faster and could attain a size as large as 70 mm DVM whereas the Veppalodai farm oysters grow to a maximum of 60 mm DVM. The large difference in the growth rate and attainment of maximum size is attributable to differences in the habitat namely greater depth, low silting, lesser fouling and calm sea conditions prevailing in the Harbour farm. Strong coastal current is also responsible for erosion of growth shoots along the margin of the shells and thereby causing retardation of growth of Veppalodai oysters.

Studies on the maturity and spawning of *P. fucata* indicate that it spawns intensly during July-September. The average condition index of oysters is 50.5 at Veppalodai farm, 52.3 at Harbour farm and 61.5 in the natural beds. The flesh weight constitute 21.4% of total weight at Veppalodai, 22.9% at Harbour and 30.4% in the natural beds. These data would broadly indicate that the ecological conditions at the three different locations play a key role in the well-being of the oysters.

Larval Life

Like many benthic invertebrates with a sedentary adult life and a dispersive larval stage, *P. fucata* larvae settle and establish in new areas by larval drift. The planktonic larval life span under laboratory condition lasts about 18-20 days at the end of which it attaches to the substratum by means of byssus. During larval life, the free swimming larvae are being carried away from the parental site by currents. Therefore, the larvae which settle on a particular paar need not necessarily be from the same area whereby mass spawning in one area could result in dense settlement in another area. This could be the reason for the wider annual fluctuation in the density of colonisation of *P. fucata* in different paars.

Pearl Production

Despite the various ecological factors that affect the growth of Veppalodai oysters, pearl-sac formation proceeds normally and production of cultured pearls has been equally good at Veppalodai farm and Harbour basin. The average success in production of cultured pearls through single implantation was 60%. In some batches, even 100% success could be achieved. In multiple implantation, pearl production with reference to the number of nuclei was 68.3% and with reference to the number of oysters was 180.6%. The quality of pearls produced ranged from dull prismatic to bright nacreous pearls. Pearls of different colours have also been produced. The more common colours are silver white, cream and golden yellow; less so is pink and rarely steel grey.

Discussion

The present study has concentrated on some of the ecological parameters of the pearl culture farms at Veppalodai and Tuticorin Harbour. Compared to the environmental conditions of pearl culture farms in Japan (Matsui, 1958; Alagarswami, 1970) and Australia, (Hancock, 1973) those at Veppalodai and Harbour farms are far different in regard to many factors. The pearl oyster *P. fucata* whose natural habitat in the Gulf of Mannar is in the deep water of 15-20 m can be successfully farmed in the shallow waters of 4-8 m. At Veppalodai rough sea conditions prevail during most part of the year while Tuticorin Harbour is almost calm throughout the year. Silt load and fouling is relatively heavier in the Veppalodai area than in the Harbour basin and these factors adversely affect the growth of the oysters. At the Harbour basin the oysters grow faster and attain a greater size than it does at Veppalodai. Despite the fact that good quality pearls were produced at the Veppalodai farm, Harbour basin has been found to give better results on the well being of the oysters and production of cultured pearls.

In Japan, pearl oyster inhabits calm and serene bays which have connections with the open sea. The salinity in the bays is not appreciably decreased by the river water flowing in. As these bays are under the influence of warm currents the temperature does not fall below 10°C. These bays have either rock or gravel bottom (Matsui, 1958). Pearl oysters are cultured in shallow waters of about 5 to 10 m deep where a large number of organisms attach to culture rafts, cages and on pearl oysters themselves (Matsui, 1958). Pearl culture is also being practised in open seas such as the Seto Inland sea and in areas bordered by chains of small islands (Alagarswami, 1970).

A comparison of ecological conditions prevailing in the pearl culture farms at Tuticorin and Japan show more dissimilarity than similarity, especially in regard to some factors—protection from winds and waves, depth and turbidity and temperature. According to Victor (1983), in the absence of suitable bays in the Indian mainland the shallow open coastal areas could be considered for establishing pearl culture farms.

The Andaman and Nicobar group of islands have many protected bays with clear water more similar to that of Japan (Mahadevan and Easterson, 1983). In Andaman group of islands pearl culture could be very succesfully carried out in Port Cornwalis area, in the bays of Ritchie's Archipelago, around Shoal Bay, and in the enclosed waters of Port Blair. The sheltered waters of Expedition Bay and Nancowry harbour in the Nicobars are also highly deserving for locating pearl culture farms. In Lakshadweep the pearl oysters are collected by hand picking from the lagoons. The Lakshadweep Fisheries Department has started a pearl culture unit at Bangaram in the year 1982. On the north-east side of the island the farm is located at 5-10 m deep. The bottom is sandy and the water is fairly clear with very little wave action. This area may be considered ideal for establishing pearl culture farm.

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