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Primary Productivity and Mineral Nutrient Status of some Estuarine and Coastal Waters along the East Coast of Peninsular Malaysia during the off Monsoon Period.

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Key words: **Mineral nutrients; primary productivity; estuaries; coastal waters.**

RINGKASAN

Satu penyelidikan tentang kedudukan organik dan bukan organik, produktiviti utama dan setengah setengah parameter alam sekitar bagi peraliran muaran dan tepian pantai di sepanjang kawasan tepian pantai Semenanjung Malaysia, menunjukkan bahawa muara memainkan peranan sebagai tempat punca pembahagian nutrien ke kawasan tepian pantai yang berhampiran. Kandungan fotosintesis net bagi stesyen-stesyen di muara adalah di antara 82.0-125.4 dan 104.0-257.9 μg C/1/h manakala untuk stesyen-stesyen tepi pantai pula masing-masing di antara 42.0-164.5 dan 66.0-192.2 μg C/1/h masa air pasang dan surut. Semasa air surut di kedua-dua stesyen muara dan tepi pantai, nitrogen organik terlarut, partikulat fosforus organik dan nitrogen ammonia bukan organik adalah berkadar tinggi manakala oksigen terlarut, nitrogen nitrat bukan organik dan nitrogen nitrit adalah berkadar rendah sewaktu penyelidikan dilakukan.

SUMMARY

A study of the organic and inorganic mineral status, primary productivity and related environmental parameters of some estuarine and coastal waters along the east coast of Peninsular Malaysia indicates that the estuarine waters act as nutrient sources for the adjacent coastal waters. The net photosynthetic values at the estuarine stations ranged from 82.0-125.4 and 104.0-257.9 μg C/1/h while that of coastal stations ranged from 42.0-164.5 and 66.0-198.2 μg C/1/h during the high and low tides respectively. During the low tides, at both the estuarine and coastal stations, the dissolved organic nitrogen, particulate organic phosphorus and inorganic ammonium nitrogen were present in high concentrations while that of dissolved oxygen, inorganic nitrate nitrogen and nitrite nitrogen were low throughout the study period.

INTRODUCTION

There are few studies on nutrient contents or other related productivity parameters in tropical aquatic environments, especially estuarine or mangrove ecosystems along the coast of Peninsular Malaysia. Many of these water bodies have been reported to be polluted by agrobased effluents, untreated human and animal wastes, and siltation due to erosion from land development (Bishop 1973, Law *et al.*, 1980; Shamsudin *et al.*, 1982).

Unfortunately many of these investigations were not related to the organic content of the system. Ong *et al. (1980)* working on tropical mangrove ecosystems, calculated the net aquatic community productivity and found it to be low. This could be due to various factors, viz. high turbidity of the water and its consequent low light penetration and high organic load leading to a high biological oxygen demand. Lee *et al.* (1980) carried out a study on the effect of oil palm effluents on nutrient status and planktonic primary production of a Malaysian mangrove inlet. They found that the polluted inlet had elevated nutrient levels but nevertheless primary production was higher in the unpolluted inlet. They also found that the toxic nature of the effluent overrode any eutrophication effect.

The present investigation is a study of the nutrient status, both organic and inorganic, and the related productivity parameters of various estuarine and coastal waters along the east coast of Peninsular Malaysia, especially the coast of Kelantan and Trengganu.

METHODS AND MATERIALS

Six estuarine stations (namely, D1, P1, C1, K1, T1 and TP1) and six coastal stations (namely, D2, P2, C2, K2, T2 and TP2) were selected along the coast of Kelantan and Trengganu and the research was carried out between April to May 1983 (the off-monsoon period) during two mean tidal ranges, viz. a mean low tidal range of 0.7 ± 0.5 m and a mean high tidal range of 1.2 ± 0.5 m referring to a tide table). The estuarine station is situated in the middle of the given river estuary itself while the coastal station is situated approximately 100 m offshore adjacent to the given estuarine river mouth. The areas under study include those estuaries of sungei Dungun, Sungei Paka, Sungai Cukai, Sungai Kerteh, Sungai Golak or Taba and Sungai Tumpat as shown in Figures 1 (Station names derived from their respective first alphabetical letter).

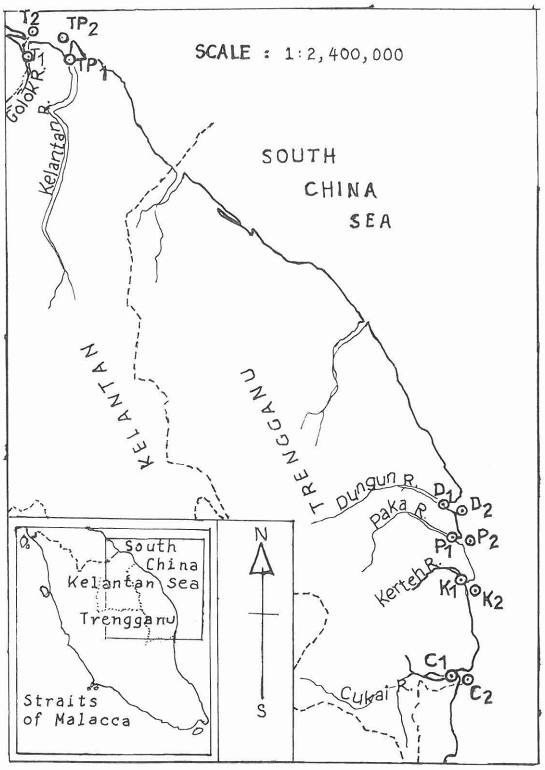

Fig. 1. Map showing sampling stations along the coast of Kelantan and Trengganu.

With the help of a Kemmerer water sampler (capacity 1.75l), 5-7 subsurface samples (at depth .5m) at each of the sampling stations were taken to the laboratory for analysis immediately, ie, analysis was done 2 to 3 hours after sampling. Altogether, at least 10 duplicated samples were carried out for each of the various determinations at any one given time and the volume of the sample used is in accordance with their respective mentioned methods. Pretreatment filteration of the sample was carried out to separate particulate matter in water for analysis or to obtain a particle free sample of water for the analysis of soluble material. Whatman GF/C (Glass Filter) grade filter papers (47mm diam discs with a pore size of $2\text{-}3\mu$) were employed and the filteration was done at a suction pressure of less than 15 p.s.i. Photosynthetic measurements were carrried out according to the modified method of Bryan *et al.*, (1976) This gives a Winkler titration coefficent variation of 0.1%.

A modification of Solarzano's method (1969) by Shamsudin (1979) was used to determine ammonium in order to eliminate the high blank values, which is basically a colorimetric phenolhypochlorite method. In this modified method, one of the reagents, phenol in methanol, is used in preference to phenol in ethanol as it will give a lower value for the blank (Shamsudin, 1979). Flasks used during the analysis were covered with aluminium foil to minimise light interference. The water solvent used for reagent preparations, blanks and glassware washing is first distilled followed by a deionisation process by passing through a cation exchange resin to remove the last traces of ammonium ions. This method requires careful attention to light interference as well as contamination and has a precision of ± 10% on a routine basis.

Nitrate nitrogen was determined by the colorimetric cadmium copper amalgam reduction method (Strickland and Parsons, 1972); the reactive phosphorus was carried out by the colorimetric ascorbic molybdate method (Strickland & Parsons, 1972). Salinity and temperature at the sampling stations were measured in situ with a portable battery-operated SCT meter (YSI model 3). The pH was measured in situ using a portable battery operated pH meter (Schott Gerate pH meter Cg 817) which provides accurate digital reading over its 0-14 range with a resolution of 0.1 pH units, reproducible to ± 0.05 pH.

Determination of total dissolved phosphorus and particulate phosphorus in natural waters was carried out according to the method of Solorzano and Sharp (1980b), which gives 100% recovery with refractory phosphorus compounds and has a precision of ± 10%. This method involves drying a sample with magnesium sulphate and baking the residue at a high temperature to decompose organic phosphorus compounds. The residue is then treated with hydrochloric acid to hydrolyse polyphosphates and the orthophosphates and this is followed by the molybdate method.

Total dissolved nitrogen in natural waters was determined according to the method of Solorzano and Sharp (1980a), which has a maximum capability of 40 HM nitrogen in undiluted samples and a precision of ± 2%. This method requires careful attention to pH, alkalinity, the neutralising buffer, reaction vessels and dilution factors.

RESULTS

High ammonium nitrogen concentrations were generally present at all estuarine stations, namely, stations D1, P1, C1, K1, T1 and TP1 especially during the low tides throughout the study period. These ranged from 0.28–4.4μg at NH_4^+–N/1 and 0.22–3.10 μg at NH_4^+–N/1 during the low and high tides respectively at the estuarine stations (Tables 1 – 2). Similar tendencies for ammonium nitrogen concentrations were also observed at coastal stations, namely station D2, P2, C2, K2, T2 and TP2, during both the high and low tides. These ranged from 0.11 –2.80 μg at NH_4^+–N/1 and from 0.44 – 3.30 μg at NH_4^+–N/1 during the high and low tides respectively at the coast stations (Table 3 – 4). However, the ammonium nitrogen values for the coastal stations were relatively lower than their respective estuarine stations throughout the study period. The nitrate nitrogen contents at the estuarine stations ranged from 0.32 – 1.80 and 0.16 – 1.30 μg at NO_3^-–N/1 during the high and low tides respectively. At the coastal stations the values ranged from 0.29–1.60 and 0.20–1.48 μg at NO_3^-N/1 during the high and low tides respectively. The reactive phosphorus and nitrite nitrogen contents at the estuarine and coastal stations did not show any definite trend and their contents were less than 0.02 and 0.08 μg at N/1 respectively.

Relatively high disolved organic nitrogen contents were observed at both the estuarine and coastal stations during the low tides and vice versa during the high tides, indicating similarity to those of ammonium nitrogen contents. These ranged from 3.81 – 10.20 and 9.26 – 11.23 μg at N/1 at estuarine stations during the high and low tides respectively while the values at the coastal stations ranged from 0.84 – 3.20 and 0.96 – 3.60 μg at N/1 at coastal stations during the high and low tides respectively. The particulate organic phosphorus ranged from 0.12 – 0.72 and 0.43 – 1 02 μg at P/1 at estuarine stations during the high and low tides respectively while the values ranged from 0.22 – 0.67 and 0.25 – 0.35 – 1.95 μg at P/1 at coastal stations during the high and low tides respectively. Generally, the dissolved organic phosphorus contents at both the estuarine and coastal stations were found to be significantly lower as compared to that of particulate organic phosphorus and dissolved organic nitrogen throughout the study period.

The net photosynethetic values at the estuarine stations ranged from 82.0–125.4 and 104–257.9 μg C/1/h during the high and low tides respectively while the values at the coastal stations ranged from 42.0 – 164.5 and 66.0 – 198.2 μg C/1/h during the high and low tides respectively. High net photosynthetic values were observed at all stations during the low tide throughout the study period. Station TP1 had the highest primary productivity, nitrate nitrogen and ammonium nitrogen values especially during low tides throughout the study period.

The temperature values were relatively constant at all stations throughout the study period (Tables 1 – 4). At all stations, the pH and the salinity values were low during the low tides and *vice versa* during high tide. The salinity ranged between 19 – 29 and 18 – 24 p.p.t. at estuarine stations during the high and low tides respectively while the salinity was constant (32 p.p.t) at coastal stations throughout the study period. The dissolved oxygen contents at estuarine station ranged from 5.10 – 5.87 and 4.95 – 5.71 mg O_2/1 during the high and low tides respectively. At the coastal stations, the values ranged from 5.90 – 6.68 and 5.18 – 6.06 mg O_2/1 during the high and low tides respectively.

DISCUSSION AND CONCLUSION

The investigation which was carried out at various estuarine and coastal waters along the east coast of Peninsular Malaysia indicated that the estuarine waters were more productive then the coastal waters especially during the low tides. It was also observed that the net photosynthetic values and the nutrient contents, especially ammonium nitrogen and dissolved organic nitrogen, were significantly higher during low tide than high tide at both estuarine and coastal waters. During the low tides, dissolved oxygen and nitrate nitrogen contents were observed to have dropped considerably while inorganic and organic ammonium rose at all stations. This was

TABLE 1
Productivity of various estuaries along the east coast of
Peninsular Malaysia during the off – monsoon period at high tide in April – May 1983.
(Sampling depth 0.5 m, Time 0830 – 0930 h, Tide 1.2 ± 0.5 m).

YR 83 DATE	ST	T	pH	S%	NH_4^+ µgat/l	NO_3^- µgat/l	NO_2^- µgat/l	PO_4^- µgat/l	O_2 mg/l	DON µgat/l	DOP µgat/l	POP µgat P/l	NET PS µgC/l/h
25.4	D1	30 ±.5	7.97 ±.05	29 ±.5	2.09 ± .23	.32 ± .04	.02 ± .001	.02 ± .001	5.82 ± .63	7.05 ± .35	ND	.12 ± .04	104.1 ± 16.3
26.4	P1	30 ±.5	8.15 ±.05	26 ±.5	0.96 ± .09	.74 ± .08	.01 ± 002	.01 ± .002	5.80 ± .64	10.20 ± .94	.01 ± .002	.67 ± .08	92.3 ± 13.9
27.4	C1	30 ±.5	8.30 ±.28	25 ±.5	.22 ± .02	.42 ± .05	.06 ± .004	.01 ± .002	5.87 ± .51	9.53 ± .97	.11 ± .02	.72 ± .09	88.0 ± 15.8
29.4	K1	30 ±.5	8.33 ±.35	19 ±.5	2.56 ± .21	.45 ± .06	.04 ± .008	.01 ± .003	5.60 ± .56	9.12 ± .92	ND	.45 ± .05	125.4 ± 25.9
17.5	T1	30 ±.5	8.24 ±.30	29 ±.5	.98 ± .08	.74 ± .08	.04 + .006	.01 ± .004	5.40 ± .56	7.61 ±.45	.01 ± .004	.39 ± .04	82.0 ± 18.3
18.5	TP1	30 ±.5	8.16 ±.08	27 ± .5	3.10 ± .39	1.80 ± .19	.02 ± .004	ND	5.10 ± .52	3.81 ± .17	.01 ± .002	.69 ± .09	114.5 ± 14.2

Note: ND-Not detectable, DON-Dissolved organic nitrogen, DOP-Dissolved organic phosphorus, POP-Particulate organic phosphorus, ST-Station, T-Temperature C, + denotes Standard deviation

TABLE 2

Productivity of various estuaries along the east coast of Peninsular Malaysia during the off monsoon period at low tide in April – May 1983. (Sampling depth 0.5m, Time 1430 – 1530 h, Tide 0.7+ 0.5 m)

YR' 84 DATE	ST	T	pH	S%	$NH_4^+ \mu gat/1$	$NO_3 \mu gat/1$	$NO_2^- \mu gat/1$	$PO_4^- \mu gat/1$	$O_2 mg/l$	DONμgat/1	DOPμgat/1	POPμgat/1	NET PSμgc/l/h
25.4	D1	30 ±.5	7.85 ±.15	24 ±.5	2.92 ± .36	.15 ± .03	.02 ± .004	.01 ± .002	5.56 ± .58	9.26 ± .48	.06 ± .002	.43 ± .04	192.0 ± 25.3
26.4	P1	30 ±.5	7.85 ±.05	22 ±.5	1.47 ± .18	.48 ± .08	.01 ± .005	.01 ± .003	4.95 ± .83	9.54 ± .58	.17 ± .02	1.02 ± 0.23	118.3 ± 11.3
27.4	C1	30 ±.5	7.96 ±.08	24 ±.5	.28 ± .04	.35 ± .05	.07 ± .009	.02 ± .004	5.71 ± .43	10.29 ± .93	.01 ± .002	.44 ± .04	125.0 ± 12.9
29.4	K1	30 ±.5	7.90 ±.16	18 ±.5	2.67 ± .28	.16 ± .02	.06 ± .008	.01 ± .004	5.50 ± .38	10.94 ± 1.2	.05 ± .008	.61 ± .88	224.4 ± 22.5
17.5	T1	30 ±.5	7.86 ±.18	22 ±.5	1.20 ± .15	.42 ± .06	.03 ± .004	.01 ± .002	5.20 ± .29	11.23 ± 1.8	.02 ± .006	.60 ± .07	104.0 ± 15.3
18.5	.TP	30 ±.5	7.75 ±.24	22 ±.5	4.40 ± .49	1.30 ± .16	.02 ± .003	.01 ± .002	5.00 ± .73	10.67 ± 1.3	.01 ± .002	.98 ± .08	257.9 ± 30.3

Note ND-Not detectable, DON-Dissolved organic nitrogen, DOP-Dissolved organic phosphorus, POP-Particulate organic phosphorus, ST-Stations, T-Temperature C, ± denotes Standard deviation

TABLE 3

Productivity of Coastal waters around the vicinity of their respective river mouths along the east coast of Peninsular Malaysia during the off-monsoon period at high tide in May – April 1983. (Sampling depth 0.5 m, Time 0830-0930 h. Tide 1.2 + 0.5 m).

YR 83 DATE	ST	T	pH	S%	NH_4^+ μgat/1	NO_3^- μgat/1	NO_2^- μgat/1	PO_4^- μgat/1	O_2 mg/1	DONμgat/1	DOPμgat/1	POPμgat/1	NET PSμc/l/h
25.4	D2	30 ±.5	8.1 ±.8	32 ±.5	1.70 ± .25	.29 ± .03	.03 ± .004	.02 ± .004	5.90 ± .58	.84 ± .05	ND	.22 ± .04	68.0 ± 7.2
26.4	P2	30 ±.5	8.3 ±.4	32 ±.5	1.31 ± .21	.42 ± .05	.02 ± .005	.02 ± .006	6.58 ± .74	1.59 ± .18	.03 ± .006	.28 ± .06	81.3 ± 8.9
27.4	C2	30 ±.5	8.2 ±.5	32 ±.5	.11 ± .03	.91 ± .08	.05 ± .006	.02 ± .008	6.21 ± .83	2.67 ± .22	.11 ± .012	.67 ± .08	62.0 ± 7.4
29.4	K2	30 ±.5	8.3 ±.4	32 ±.5	1.91 ± .24	.94 ± .07	.05 ± .007	.02 ± .008	6.04 ± .95	2.25 ± .24	.03 ± 004	.44 ± .06	151.2 ± 20.4
17.5	T2	30 ±.5	8.2 ±.3	32 ±.5	1.11 ± .18	.53 ± .86	.05 ± .008	.02 ± .006	6.05 ± .78	.96 ± .08	.02 ± 005	.50 ± .08	42.0 ± 5.8
18.5	TP2	30 ±.5	8.1 ±.5	32 ±.5	2.80 ± .30	1.60 ± .18	.02 ± .004	ND	6.30 ± .74	3.20 ± .35	.01 ± .008	.50 ± .06	164.5 ± 20.7

Note: ND-Not detectable, DON-Dissolved organic nitrogen, DOP-Dissolved organic phosphorus, POP-Particulate organic phosphorus, ST-Stations, T-Temperature°C, + denotes Standard deviation

TABLE 2

Productivity of various estuaries along the east coast of Peninsular Malaysia during the off monsoon period at low tide in April – May 1983. (Sampling depth 0.5m, Time 1430 – 1530 h, Tide 0.7+ 0.5 m)

YR' 84 DATE	ST	T	pH	S%	NH_4^+ μgat/1	NO_3^- μgat/1	NO_2^- μgat/1	PO_4^- μgat/1	O_2 mg/l	DON μgat/1	DOP μgat/1	POP μgat/1	NET PS μgc/l/h
25.4	D1	30 ±.5	7.85 ±.15	24 ±.5	2.92 ± .36	.15 ± .03	.02 ± .004	.01 ± .002	5.56 ± .58	9.26 ± .48	.06 ± .002	.43 ± .04	192.0 ± 25.3
26.4	P1	30 ±.5	7.85 ±.05	22 ±.5	1.47 ± .18	.48 ± .08	.01 ± .005	.01 ± .003	4.95 ± .83	9.54 ± .58	.17 ± .02	1.02 ± 0.23	118.3 ± 11.3
27.4	C1	30 ±.5	7.96 ±.08	24 ±.5	.28 ± .04	.35 ± .05	.07 ± .009	.02 ± .004	5.71 ± .43	10.29 ± .93	.01 ± .002	.44 ± .04	125.0 ± 12.9
29.4	K1	30 ±.5	7.90 ±.16	18 ±.5	2.67 ± .28	.16 ± .02	.06 ± .008	.01 ± .004	5.50 ± .38	10.94 ± 1.2	.05 ± .008	.61 ± .88	224.4 ± 22.5
17.5	T1	30 ±.5	7.86 ±.18	22 ±.5	1.20 ± .15	.42 ± .06	.03 ± .004	.01 ± .002	5.20 ± .29	11.23 ± 1.8	.02 ± .006	.60 ± .07	104.0 ± 15.3
18.5	TP	30 ±.5	7.75 ±.24	22 ±.5	4.40 ± .49	1.30 ± .16	.02 ± .003	.01 ± .002	5.00 ± .73	10.67 ± 1.3	.01 ± .002	.98 ± .08	257.9 ± 30.3

Note ND-Not detectable, DON-Dissolved organic nitrogen, DOP-Dissolved organic phosphorus, POP-Particulate organic phosphorus, ST-Stations, T-Temperature C, ± denotes Standard deviation probably due to the decrease in activities of the nitrification bacteria in the system, culminating in the accumulation of ammonia derived from microbial organic nitrogen mineralisation or decomposition. Law *et al.*, (1980) suggested that the increased dissolved oxygen content during the high tide enhances the biodegradation of nitrogenous organic matter, and facilitates the oxidation of ammonium by nitrification bacteria.

The particulate organic phosphorus contents at all stations were relatively higher than that of dissolved organic phosphorus, especially during the low tides. It was also noted that the reactive phosphorus contents at all stations were significantly low. The ammonium content exceeds that of nitrate at all sampling stations throughout the study. In contrast Raine (1972) working on a temperate estuary found the indigenous content of nitrate to be much higher than that of ammonium by a factor of 5 (i.e. indigenous nitrate as 20 μg at N/1 and that of ammonium as 4.5 μg at 11/1). Comparing the photosynthetic values obtained by Raine (1972) and those obtained in the present study, it would appear that a temperate estuary is more productive than a tropical one.

During the high tide, it had been observed that the nutrient contents were observed to be relatively low as a result of a gradual dilution effect due to increased seawater volume entering the study area from the surrounding South China sea. This probably led to low primary productivity. Consequently, the increase in sea water volume entering the estuaries during high tide followed by its withdrawal during low tide, would inevitably bring about leaching of nutrients to the surrounding coastal water from the estuaries.

Strickland and Austin, 1960, carried out a study on annual variations in the presence of three forms of phosphorus in a temperate coastal environment, and found that there was an inverse relationship between organic and inorganic content over a peirod of one year. Law *et al.* (1980) suggested that the occurrence of high ammonium nitrogen contents could be attributed to increased bacterial mineralisation or decomposition processes while that of nitrate nitrogen to nitrification. Shamsudin *et al.* (1982) carried out a study on photosynthetic rates and nutrient contents of Sungai Ibaf, Terengganu and found that the wet monsoon period lowers the values of the former while increasing the ammonium nitrogen, nitrate nitrogen and dissolved oxygen contents. They also found that the North-east Monsoon (Nov. Feb.) and the South-west Monsoon (Mar. – Aug.), which cover the rainy and dry periods respectively, bring about a seasonal variation in net photosynthetic values at various predetermined stations of the river under study. During the dry season the values were high while during the wet season they were low.

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