CHAPTER 3

RESULTS

1. Nutrients

Coastal sea water from three depths: surface, 3 m, and 6 m, were used to measure gross primary production with no addition of nutrient. The maximum gross primary production mostly occured from the natural phytoplankton population at 3 m depth. Only one time the highest gross primary production was obtained in the surface sample (Figure 6). Figure 6 also shows that phytoplankton photosynthesis, when incubated in the constant climate chamber, is higher than in situ (at the pier); probably due to the optimum factors of light and temperature.

The variation of micronutrients in sea water (phosphate, nitrate and nitrite), temperature, pH and salinity were measured at monthly intervals (Table 6) to demonstrate the change in certain chemical and physical properties in the study area as control of sea water samples.

Bioassay of sea water after addition of nitrogen, of phosphorous seperately, and combination of nitrogen and phosphorous, show increasing gross primary production of the natural phytoplankton population (Figure 7). The data show that both P and N stimulate phytoplankton growth. P alone, at the concentration of 0.5 ug - at/l., nearly equal to normal $PO_4^{\equiv}$ - P. Reference sea water (Table 6), displayed low gross premary production when

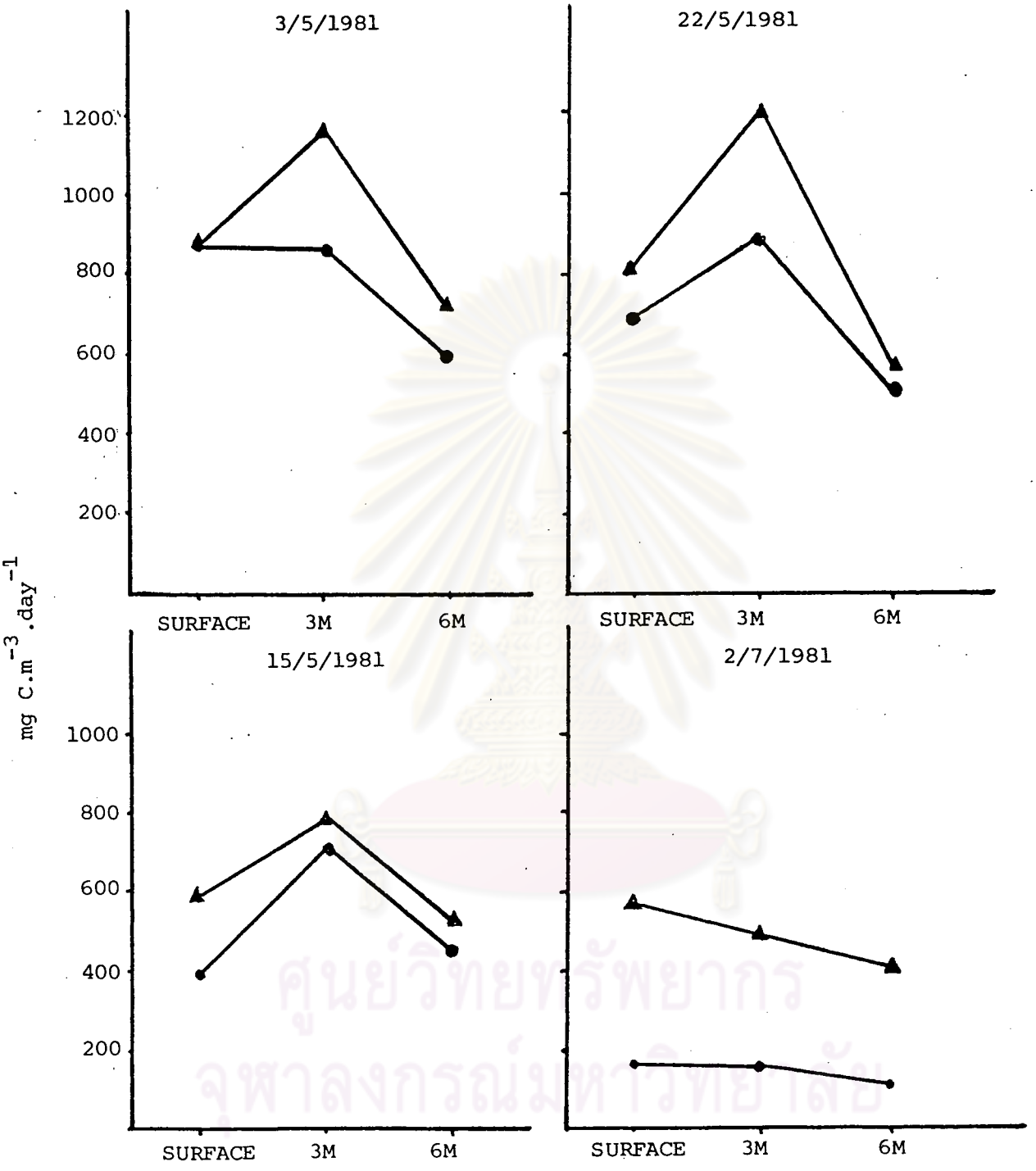

Figure 6 Comparison between gross primary productivity of sea water incubated in situ at the pier (●——●) of PMBC (Surface, 3M and 6M depth) and incubated in constant climate chamber (▲——▲).

Table 6 The range of variations of $PO_4^{\equiv}$ - P, NO_3^- - N, NO_2^- - N, temperature, pH, and salinity, of the sea water at the PMBC pier at monthly intervals from May 1981 to March 1982 to be used as reference for all bioassay. The pH values for February and March 1982 were not recorded dued to the fact that the pH meter was out of order).

Month	$PO_4^{\equiv}$ - P (ug-at/L)	NO_3^- - N (ug-at/L)	NO_2^- - N (ug-at/L)	T ^oC	pH	Salinity (%.)
May 1981	.15 - .30	.32 - .49	.13 - .16	28.6-30.0	8.21-8.23	31.5
Jun 1981	.15 - .30	.06 - .50	.05 - .29	26.9-29.0	8.06-8.21	32
Jul. 1981	.43 - .59	.16 - .64	.03 - .11	27.0-28.2	0.04-8.27	32 - 33
Aug. 1981	.10 - .30	.11 - .29	.03 - .13	27.8-28.9	8.15-8.22	33
Sep. 1981	.43 - .50	.30 - .50	.05 - .09	27.2-28.7	8.02-8.22	33
Oct. 1981	.19 - .30	.24 -1.6	.07 - .20	26.6-28.3	8.01-8.20	32 - 33
Nov. 1981	.15 - .39	.21 - .61	.05 - .20	26.7-27.6	8.10-8.21	32 - 33
Dec. 1981	.47 - .72	.22 - .41	.07 - .11	25.0-26.7	8.02-8.24	32 - 33
Jan. 1982	.10 - .22	.10 - .21	.00 - .03	26.0-26.5	8.15	33
Feb. 1982	.22 - .35	.21 - .22	.00 - .03	26.0-26.7	-	33
Mar. 1982	.39 - .48	.46 - .19	.00 - .03	27.5-27.7	-	33

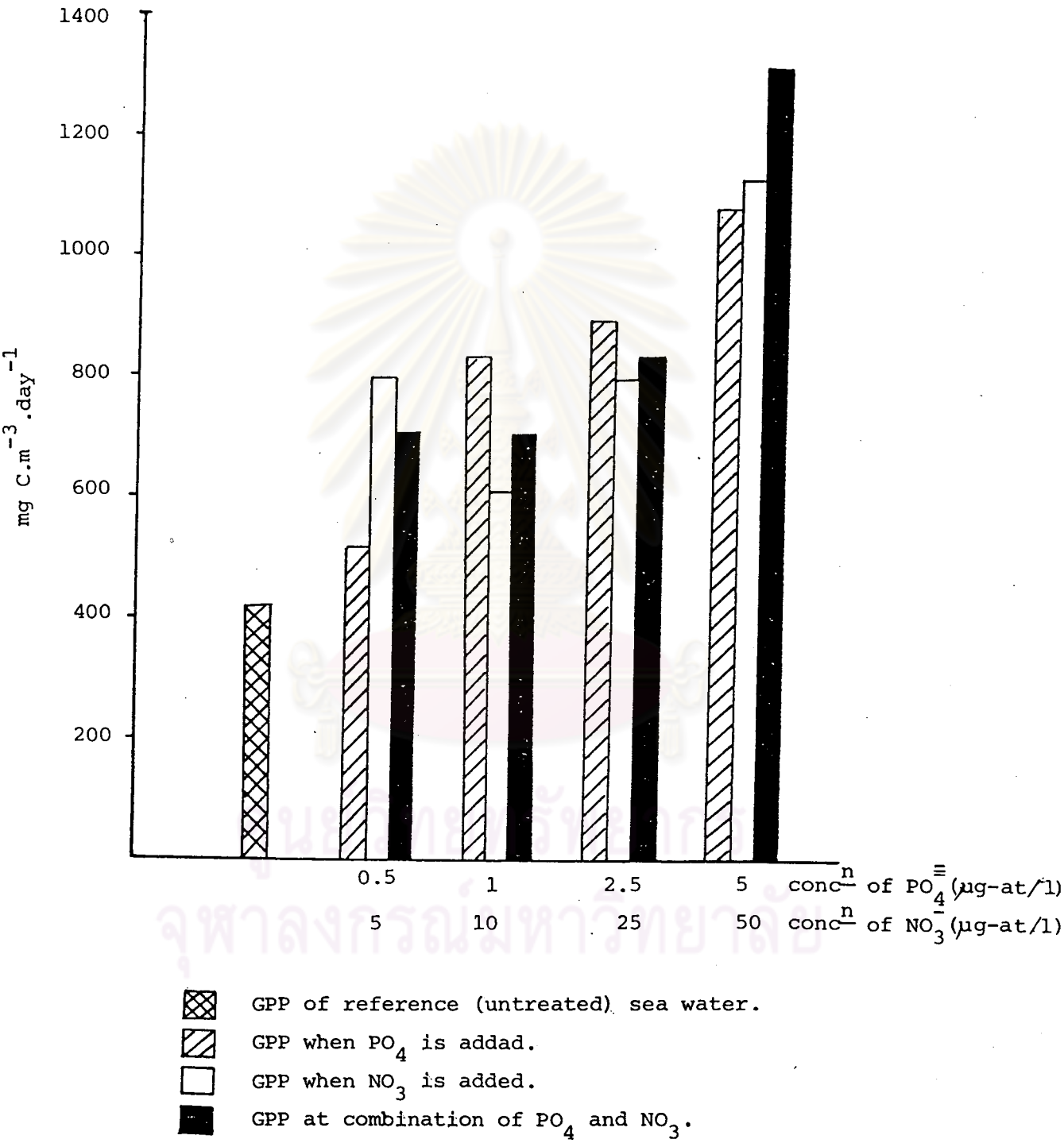

Figure 7 Gross primary production (GPP) with addition of different concentrations of N and P seperately and in combination. The proportion of N: P = 10 : 1

concentrations of nutrients were low. Higher concentration of nutrients were more effective in stimulating phytoplankton of the reference, and gross primary production increased significantly (Figure 7). Nitrogen alone was also strongly stimulating phytoplankton activities, as clearly shown in the dilution of 5 ug-at/l and 50 ug-at/l. Table 6 shows that the maximum concentration of NO_3^- - N of the reference water was only 1.6 ug-at/l. With the combination of N and P in the ratio of N:P = 10:1 the result (Figure 7) indicates that the rate of gross primary production was between the addition of P or N alone at the dilution of 0.5 & 5, 1 & 10 and 2.5 & 25 ug-at/l of phosphate nitrate, respectively. The highest concentration of N and P in combination resulted in the highest growth rate. Thus from these data the result shows that not only nitrogen was found to be a limiting nutrient, like in other experiments, but also phosphorous as well.

In this case, substantial growth occurred when both phosphorous and nitrogen were added in high concentration. Natural water contains very small amount of these nutrients so by increasing the amount of nutrients, the productivity of phytoplankton will increase according to the law of Liebig. When the concentration of N is increased P becomes limiting and vice versa. Liebig's law cannot be used quantitatively. There will always be a difference among conditions and species composition, thus the variation of gross primary production in different ways.

NH_4 was used as N-source and added in order to compare with nitrate nitrogen (Figure 8). Ammonia also increased the gross primary production to a level similar to what obtained with phosphorous in this experiment. Eventhough, the result shows that nitrate is a better nitrogen source for phytoplankton than ammonia, it is to be noted that ammonia turned out to be a reasonably good N-source as well.

The natural phytoplankton populations are composed of many types of organisms, such as flagellates and diatoms, but in fact not so many diatoms are found in this coastal sea water found (at the pier). An experiment was carried out in order to show the effect of silicon on production of phytoplankton (Figure 9). Silicon did not have much effect on photosynthesis, although important for the formation of the theca of diatoms. The natural concentration of silicon is apparently so high that this nutrient cannot be considered limiting. By the comparison of Figures 8 and 9 it indicates that P, N or NH_4 can increase gross primary production to such a level that added silicon did not seem to have additional effection on the production.

The last part of the experiment was to enrich the natural phytoplankton population by additions of phosphorous, nitrogen, trace element (Fe), organic chelator (EDTA), seperately and in combination (Figure 10). This part of the experiment was conducted in September 1981 when the natural nutrients in the water were rather high (Table 6). Among all nutrients seperately added, organic chelator (EDTA) showed the weakest stimulation to gross primary production. Combination of all nutrients used in

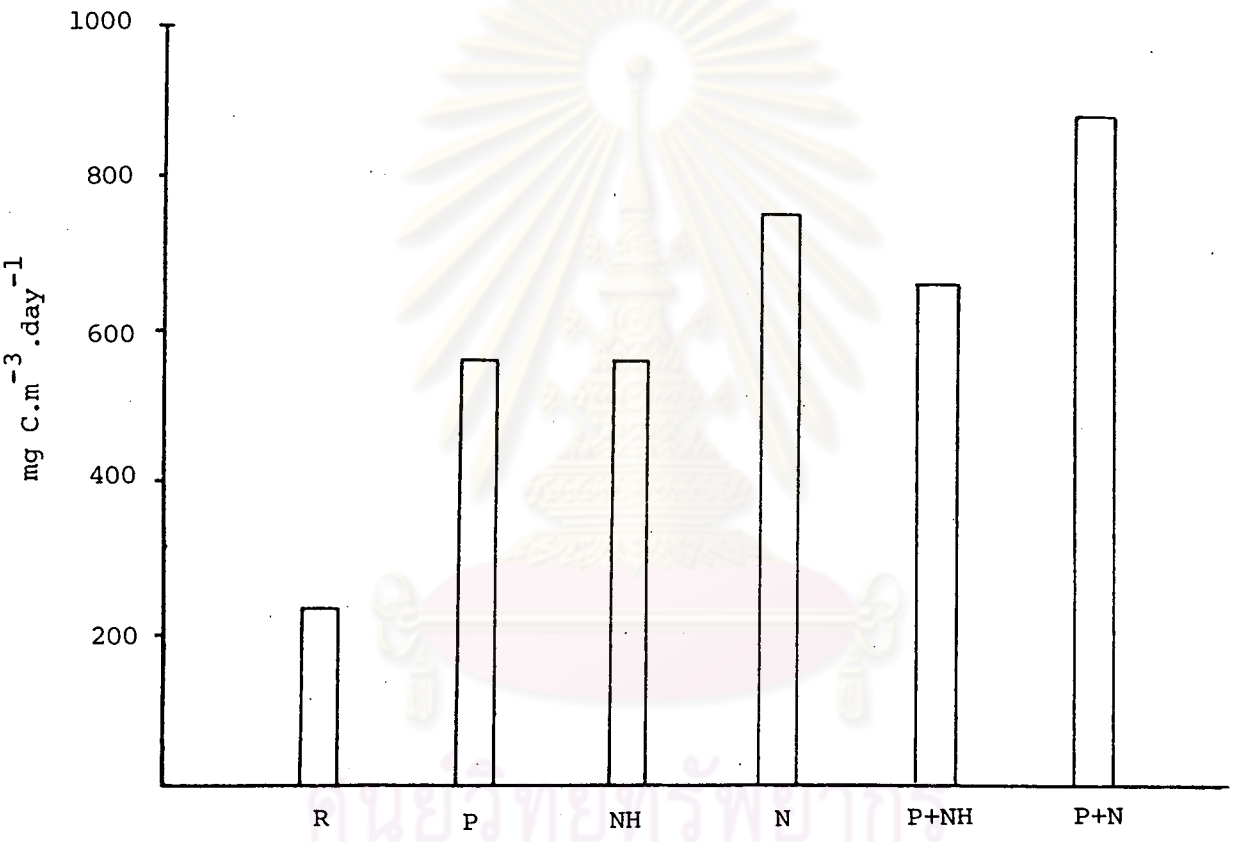

Figure 8 NH_4 - N was used as nitrogen nutrient in comparison with NO_3 - N. Addition of each nutrient seperately and in combination. (R = Reference, P = PO_4, N = NO_3, NH = NH_4).

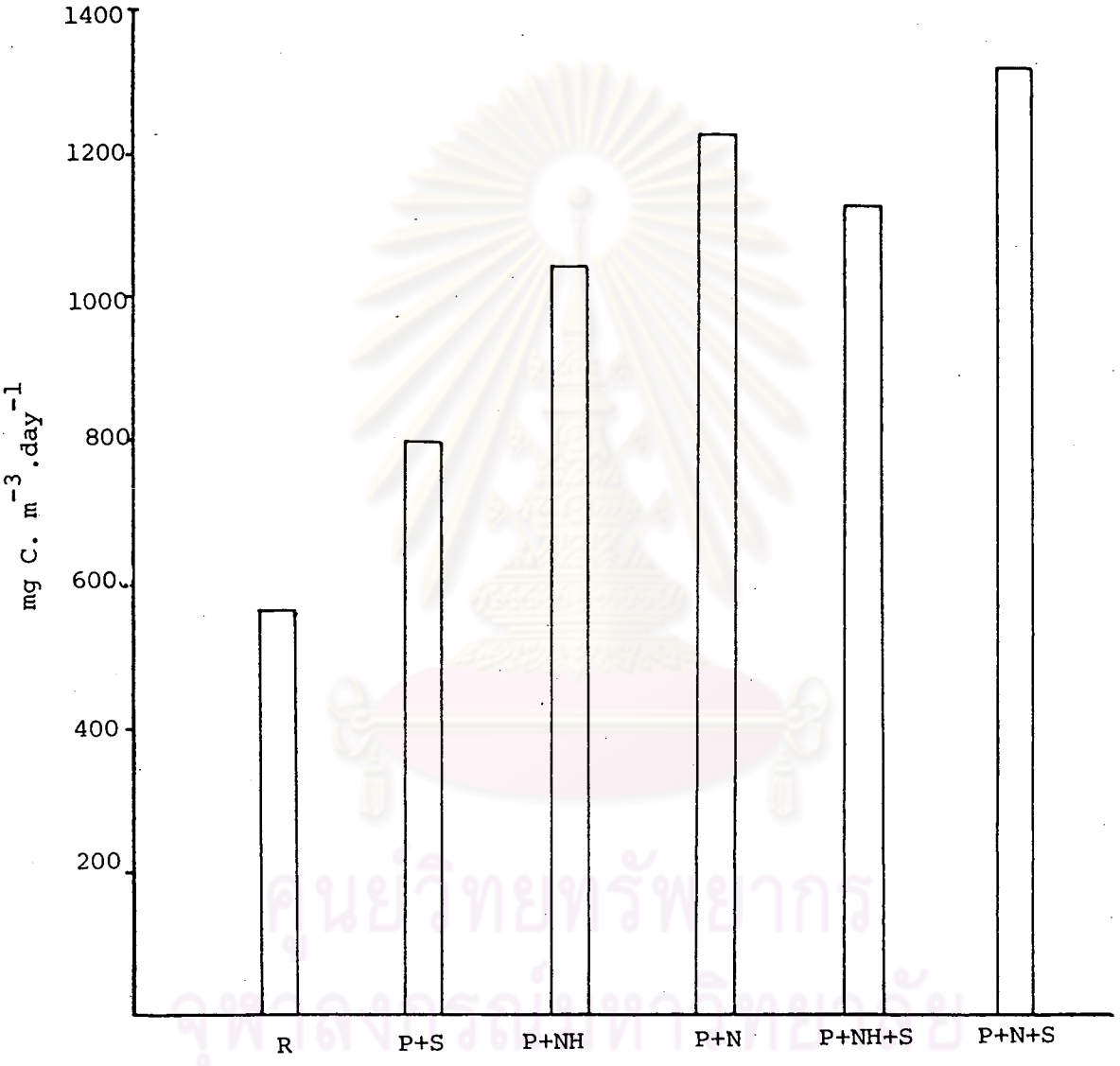

Figure 9 Comparison of addition of combination of P + S, P + NH, P + N, P + NH + S, P + N + S into sea water in order to see the effect of Silicon. (S = Silicon).

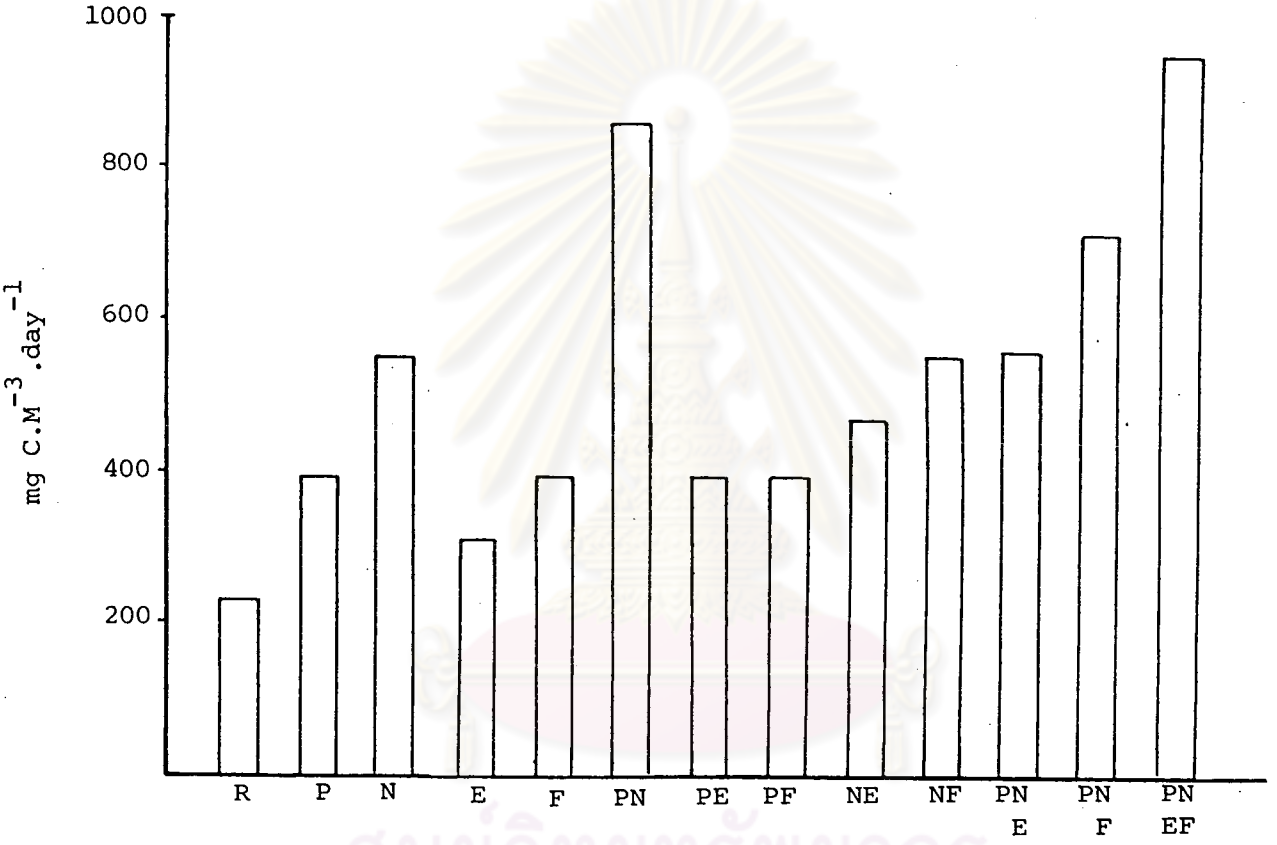

Figure 10 Gross primary production as the result of different nutrient added, seperately and in combination.
(R = Reference, P = PO_4, N = NO_3, E = EDTA, F = Fe)

this experiment, phosphorus, nitrogen, Fe as trace clement, and organic chelator EDTA, resulted in the highest gross primary production. It is to be noted that, eventhough the combination of phosphorus and nitrogen gave almost as high a production as the combination of all nutrients, but when the trace clement (FE) was added to form the combination of 3 types of nutrient, the production was not as high.

2. Coral Water

Figure 11 and Figure 12 show that dissolved oxygen in the coral water reached highest concentration after 4 hours of incubation which was both in the early afternoon and decreased when incubated further which indicated that the rate of oxygen consumption was higher than the rate of procution from zooxanthellae and phytoplankton in both of these experimental systems. This drop in oxygen concentration was caused by a number of factors. Falling light intensity and changing in the quality of coral water in the bag, i.e., increasing pH, were probably among the main reasons for the observed decrease in dissolved oxygen.

On the basis of these data, coral water was pumped up from the plastic bag after 4 hours of setting up the bag, and used for the following bioassay experiments. Data shown in Figures 12 and 13 were obtained on the same day, 11th. February, 1982. The experimental bag coutains a multiplicity of organisms producing and consuming oxygen. Furthermore, the bag represents in situ measurements of coral reef respiration and production while the

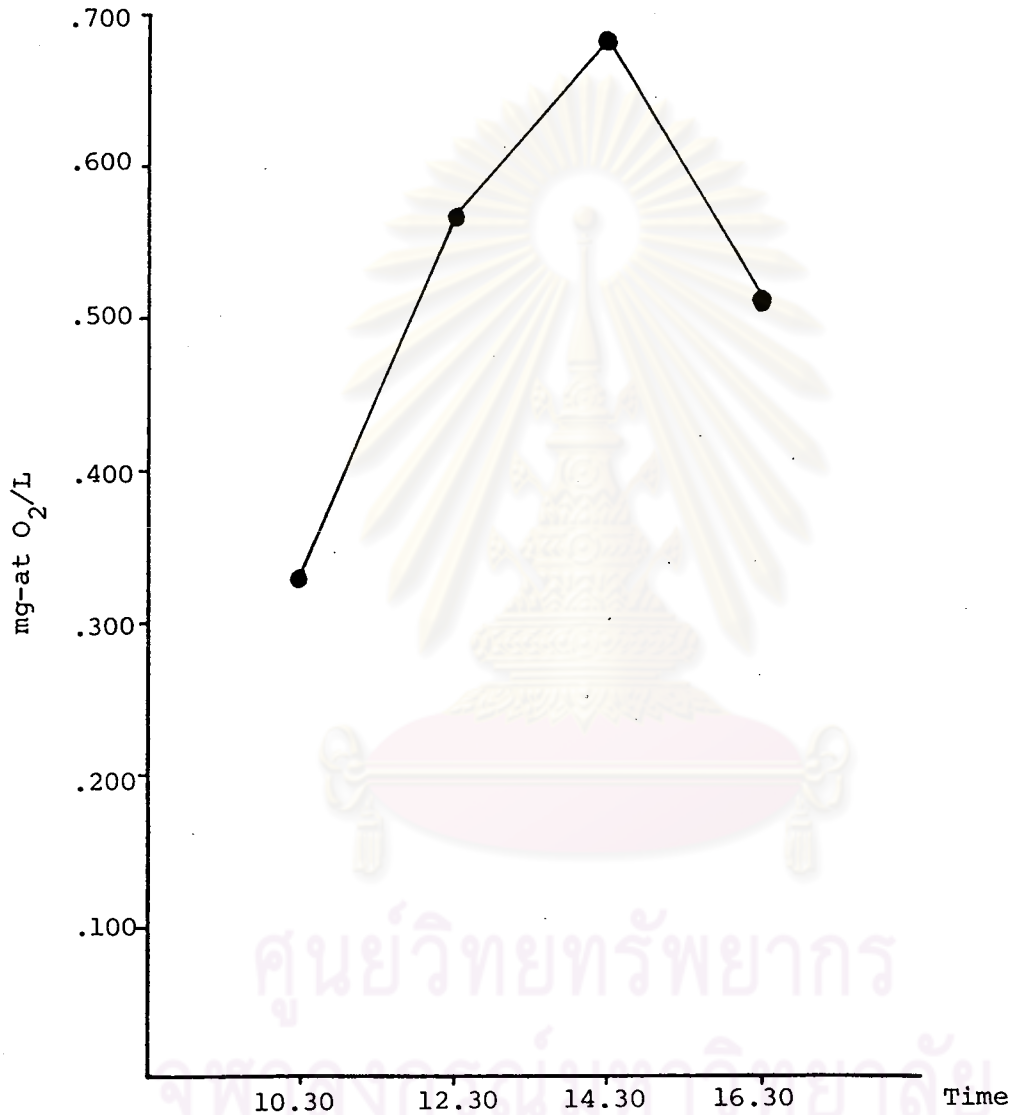

Figure 11 Dissolved oxygen in coral water inside the experimental bag. Oxygen was measured every 2 hours during 6 hours incubations. Time period: 10.30 - 16.30. Date : 15/1/1982.

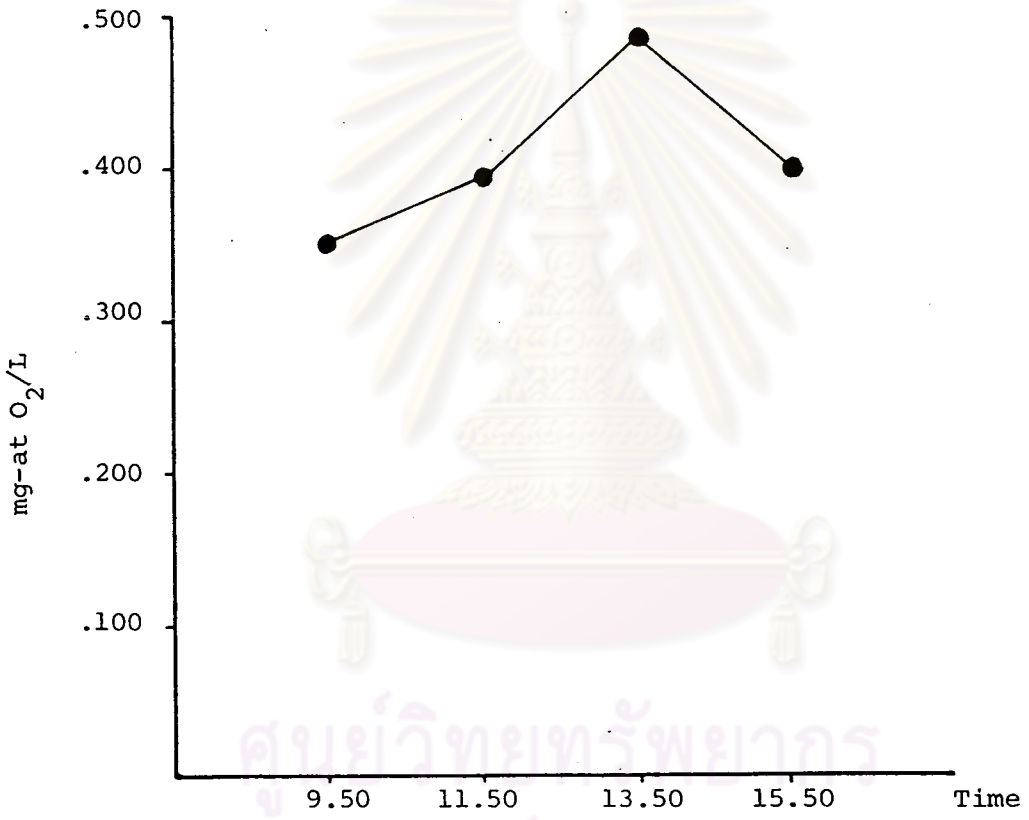

Figure 12 Dissolved oxygen in coral water inside the experimental bag. Oxygen was measured every 2 hours during 6 hours incubations. Time period: 9.50 - 15.50. Date : 11/2/1982.

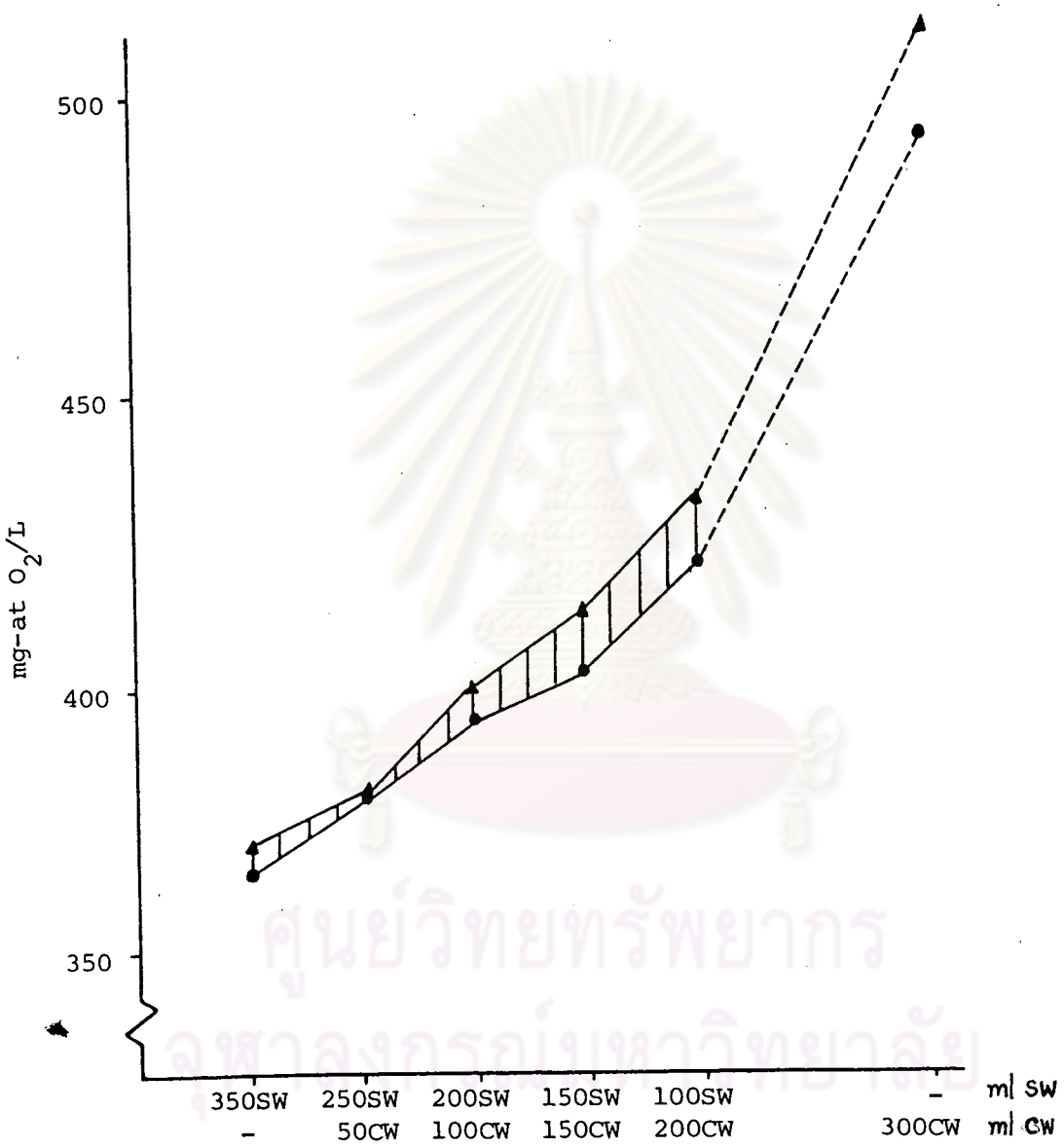

Figure 13 Dissolved oxygen in light (▲) and dark (●) bottles in different dilutions of mixed coral and sea water. Date: 11/2/1982. (SW = Sea water, CW = coral water within the bag).

light and dark bottles are laboratory measurements of the planktonic community. Therefore, it is not possible to calculate production form the coral head itself in any detail. However, a crude idea can be obtained if we consider Figure 12 and Figure 13 and Figure 17 together.

The actual amount of oxygen produced in the light bottle is a measure of net photosynthesis. The amount of oxygen consumed in a parallel dark bottle may be added to the amount produced in the light bottle to give an estimate of gross photosynthesis in the following way:

I	=	initial concentration of dissolved O_2
D	=	O_2 in dark bottle at the end of the experiment
L	=	O_2 in light bottle at the end of the experiment
(I-D)	=	respiration per unit volume and time
(L-I)	=	production: net photosynthetic activity (net primary production)
(I-D) + (L-I)	=	gross photosynthesis (gross primary production)

Figure 12 shows a difference in thiosulphate consumption ($I_{9.50}$-$L_{13.50}$) of 1.30 ml, corresponding to a net primary production of 2039 mg C/m^3/day.

The planktonic gross primary productivity of coral bag water as estimated with the light and dark bottles in the laboratory was 259 mg C/m^3/day (Figure 17). The amount of oxygen

consumed by phytoplankton varies within wide limits. Values of 10 - 50% oxygen consumption of gross primary production have been recorded. If 30% was used as a mean value, the gross primary production (Figure 17) can be converted to net primary production by subtraction of oxygen consumed by the phytoplankton. This gives a net primary production of (259-78) = 181 mg $C/m^3/day$. If this crude estimate of planktonic net primary production is subtracted from the net primary production of the total bag system (Figure 12), the production from the coral head itself is about 2039 - 181 = 1858 mg $C/m^3/day$. In other words, the production from the planktonic community surrounding the coral head may be half an order of magnitude of the produciton from the coral head itself.

Figure 13 and Figure 14 show that dissolved oxygen in the light and dark bottles increased with increasing amounts of coral water in the mixture. In the two experiments carried out, pure coral water from the bag showed a higher value of gross primary production than gross primary production of the sea water collected at PMBC pier (Figure 17). Similarly, Figure 16 shows that ambient water collected outside the bag had a singificantly higher gross primary production than water from the PMBC pier on the 11th. February 1982, but almost the same when measured carlier on 5th. February 1982 (Figure 15).

The effect of mixing phytoplankton populations of each water type is shown in Figure 17. When a small amount (50 ml.) of coral water was mixed with the large volume of sea water (250 ml.), the gross primary production decreased. When more

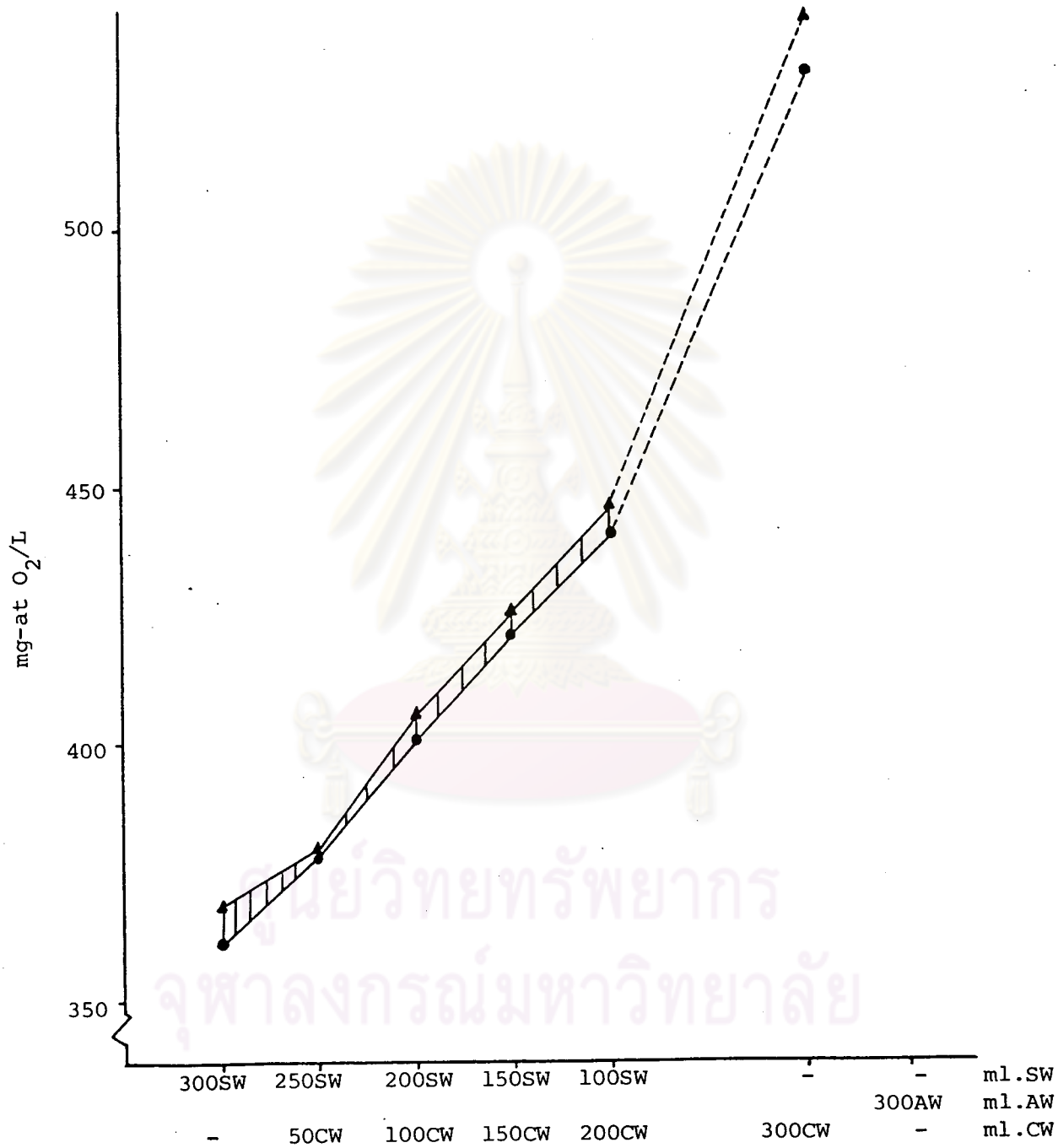

Figure 14 Dissolved oxygen in light (▲) and dark (●) bottles in different dilutions of mixed coral and sea water. Date : 5/2/1982. (SW = Sea water, CW = Coral water within the bag, AW = ambient water outside the bag.)

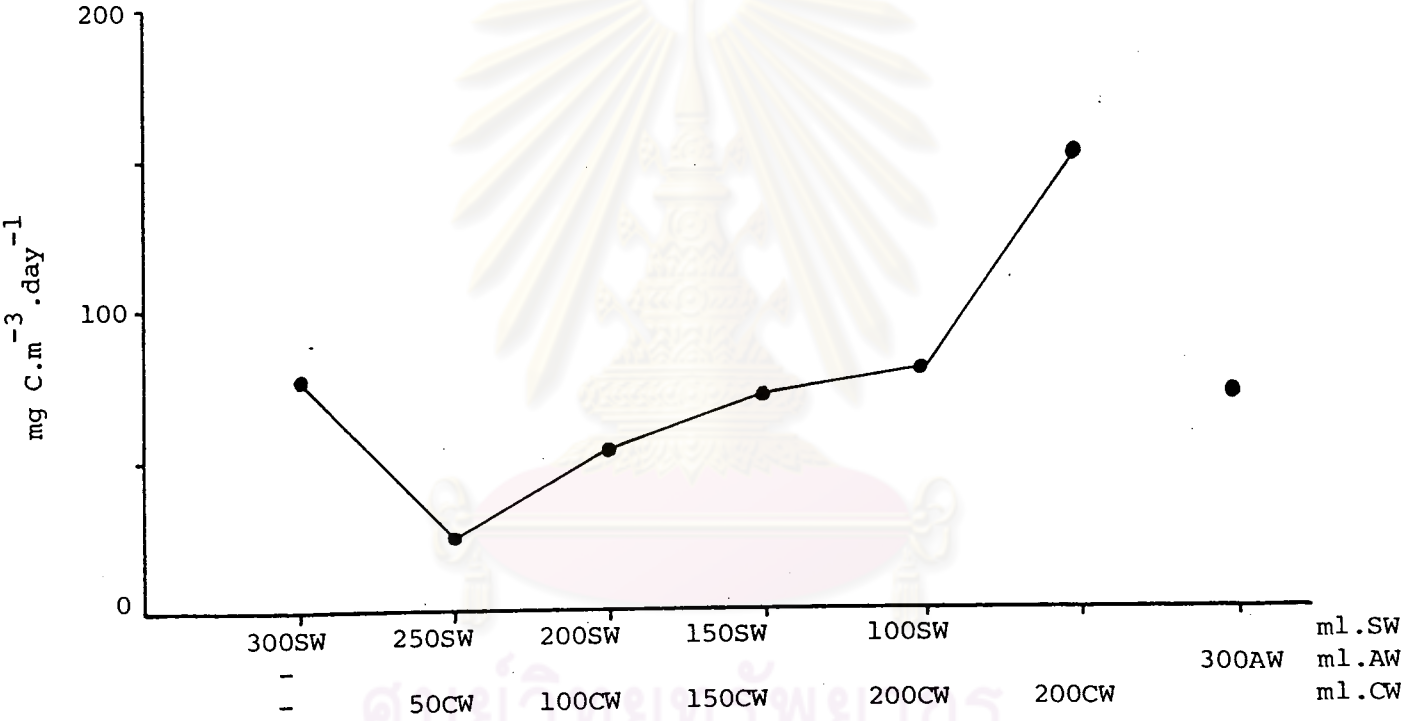

Figure 15 The gross primary production of each dilution of mixed coral and sea water. Date: 5/2/1982. (SW - Sea water, CW = Coral water within the bag, AW = ambient water outside the bag).

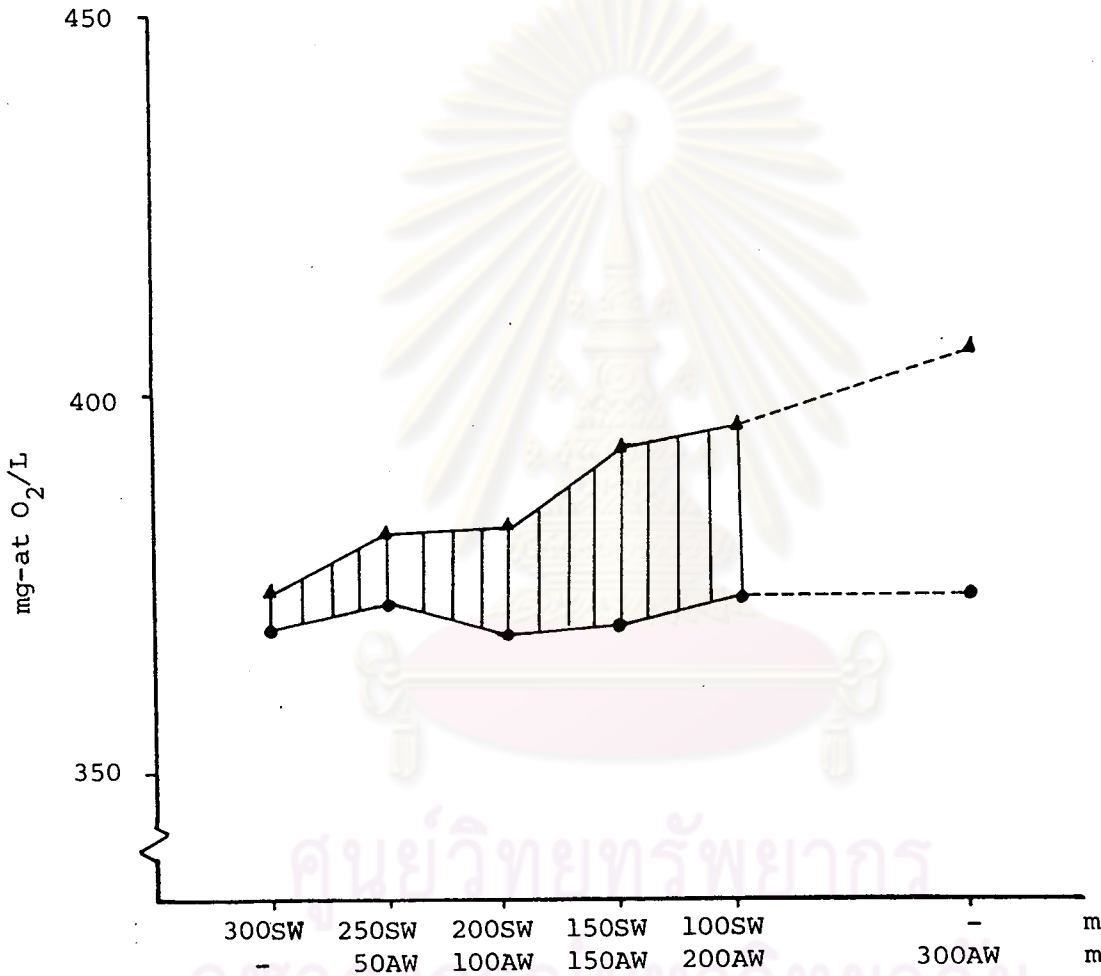

Figure 16 Dissolved oxygen in light (▲) and dark (●) bottles in different dilutions of mixed sea water (SW) and ambient water (AW). Date: 11/2/1982.

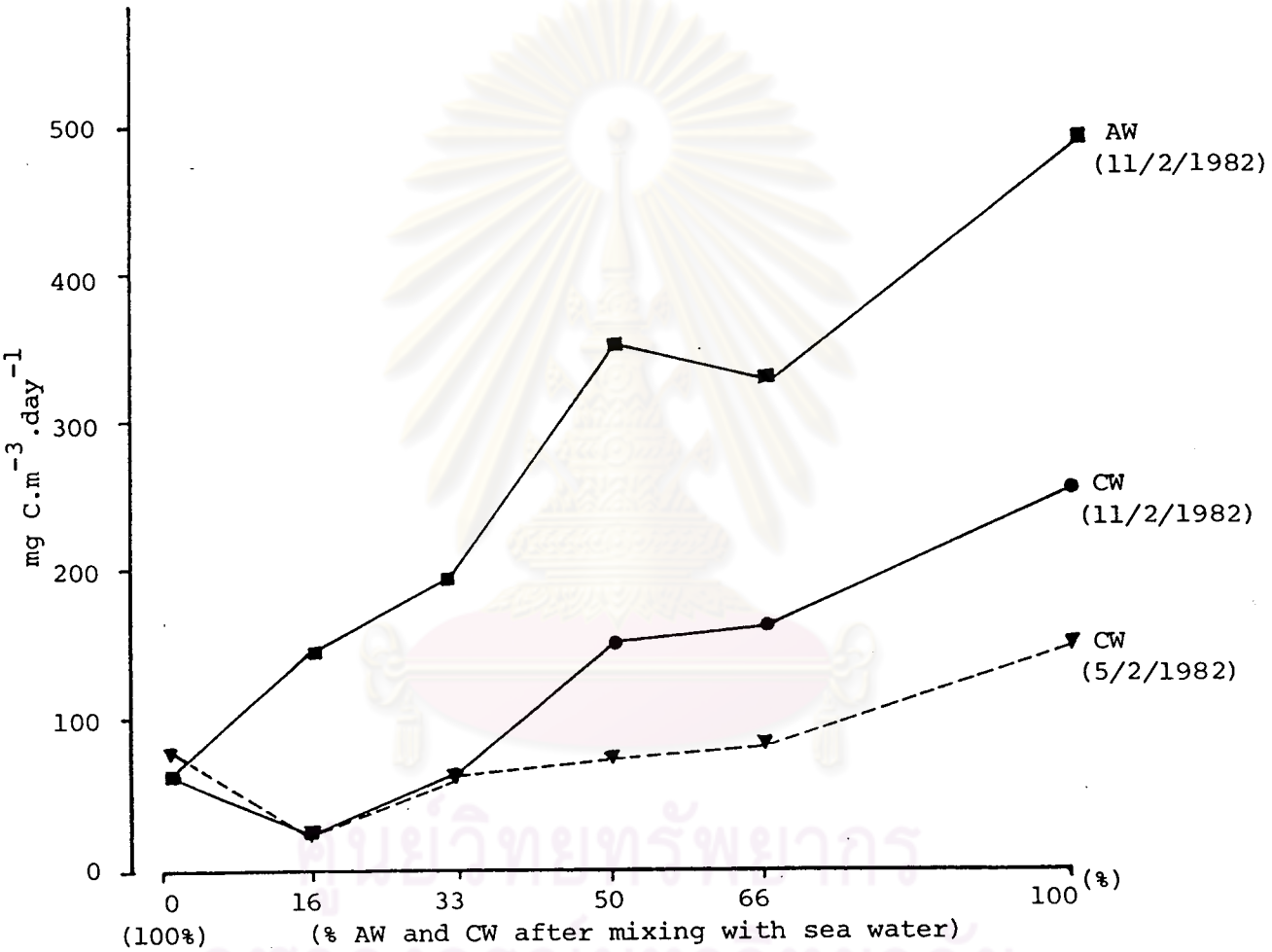

Figure 17 Comparison of gross primary production when coral (CW)and ambient water (AW) are mixed with sea water. DAta from Figure 13, 14 and 15.

coral water was mixed with sea water the gross primary production increased gradually. However, pure coral water had the highest gross primary production, indicating an interesting adaptation of coral water organisms to the special environmental conditions inside the plastic bag. If these organisms were exposed to water from the sea at large the effect was negative in terms of gross primary production. Even more so than inside the experimental bag, ambient water from the outside of the bag, had much higher rates of production. Any way, the sea water showed a low gross primary production when compared with the two catagories stated.

Figures 13 & 16 show the differences of dissolved oxygen in the dark and light bottles when sea water was mined with ambient water or coral water. From these data the gross primary production had been calculated. Figure 17 shows the results on both days of the experiment that the gross primary production increased when the amount of coral water increased. In other words, the experiments agree in principle.

Since there are three parameters in the experiment, namely coral water from the bag, ambient water, and pure sea water, the effect of mixing these waters can be looked from both ends. From Figure 17, one could either say that coral water and ambient water increase gross primary production of the sea water, or on the other hand, the present coral water is very productive, so when more low productive sea water is added, gross primary production decreases more.

To check on the major nutrients which effect the primary production, the amount of phosphate, nitrate and nitrite of sea water, initial coral water befor being covered with plastic bag, pure coral water and ambient water were recorded. Table 7 shows the high concentration of phophate near the coral but low in nitrate as compare to sea water at large.

Table 7 The amount of phosphate, nitrate and nitrite in ug-at/L of sea water, initial coral water before being covered with plastic bag, pure coral water and ambient water.

Type of water	$PO_4^{\equiv}$ ug-at P/l	NO_3^- ug-at N/l	NO_2^- ug-at N/l
1. Sea water	2.09	2.0	-
2. Coral water before cover with plastic bag	>10	1.5	-
3. Coral water (in plastic bag)	>10	0.75	>10
4. Ambient water	>10	0.90	5.50

3. Mangrove water

Since there are tidal effects in the mangrove area which may cause fluctuation of salinity, therefore the variation of salinity at each station at each level of tidal water height were recorded (Table 8)

Table 8 The salinity of sea water and mangrove water of 3 station at 4 different height of waters above the lowest low water

Height of water above the lowest low water (dm.)	Salinity (‰.)			
	sea water	station I	station M	station O
15 - 16	31	33	33	32
18 - 18	31.5	32	29	29
21 - 27	32.5	34	36	35
31 - 32	32	34	32	32

Gross primary production at each station with various dilutions and at different depth were studied. (Table 9). At a water height of 15 - 16 decimeters the gross primary productivity of pure mangrove water at the inner station (I) was very high (443.04 mg C/m^3/hr) compared to that of the sea water (74.84 mg C/m^3/hr). Except when a small amount of mangrove water was mixed with sea water, in the ratio 50 ml. the gross primary production of the sea water increased with increasing concentration of mangrove water (Table 10 and Figure 18).

Table 9 Gross primary production at different dilutions of mangrove and sea water at each station.

Height of water above the lowest low water	Dilution of the mixtures (ml.)			Gross Productivity ($mg\ C.m^{3}.hr^{-1}$)		
	sea water	man-grove	sea water	station 1	station M	station O
15 - 16 dm	300	0	74.84		50.89	59.87
	250	50		41.91	98.81	44.90
	200	100		131.71	38.92	50.89
	150	150		155.66	5.99	50.89
	100	200		140.69	14.97	47.90
	0	300		443.04		
18 - 18 dm	300	0	92.80			
	250	50		83.82	53.88	92.80
	200	100		118.75	35.92	53.88
	150	150		170.63	47.89	80.82
	100	200		191.58	23.95	77.83
	0	300		511.89	26.94	62.86
21 - 27 dm	300	0	89.80			
	250	50		80.82	41.91	68.85
	200	100		62.26	110.76	61.92
	150	150		71.84	86.81	50.89
	100	200		137.70	50.89	59.87
	0	300		116.75	59.87	41.91
31 - 32 dm	300	0	74.84			
	250	50		77.80	59.87	68.85
	200	100		50.89	26.94	74.84
	150	200		53.88	8.98	77.83
	100	300		59.87	35.92	80.82
	0			80.82	0	89.80

\+ (dissolved oxygen in dark and light bottle are equal)

\- Height of water predicted in decimeters above the lowest low water.

Table 10 Relative differences in gross primary production calculated for mixtures of sea water (SW) and mangrove water (MW) in relation to pure sea water. The % increase (+) or % decrease (-) of GPP is calculated according to the formula:

$$\% \text{ GPP} = \frac{\text{GPP (MW)} \cdot 100}{\text{GPP (SW)}} - 100$$ (Data from Table 9.)

Heigth of water	% SW	% MW	Gross primary production compare to pure sea water (100%)			
			sea water	I	M	O
15 - 16 dm	100	0	100%			
	83	17		- 44	- 32	- 20
	67	33		+ 76	+ 32	- 40
	50	50		+ 108	- 48	- 32
	33	67		+ 88	- 92	- 32
	0	100		+ 492	- 80	- 36
18 - 18 dm	100	0	100%			
	83	17		- 10	- 42	0
	67	33		+ 22	- 61	- 42
	50	50		- 84	- 48	- 13
	33	67		+ 106	- 74	- 16
	0	100		+ 452	- 71	- 32
21 - 27 dm	100	0	100%			
	83	17		- 10	- 53	- 23
	67	33		- 31	+ 23	- 31
	50	50		- 20	- 3	- 43
	33	67		+ 53	- 43	- 33
	0	100		+ 30	- 33	- 53
31 - 32 dm	100	0	100%			
	83	17		+ 4	- 20	- 8
	67	33		- 32	- 64	0
	50	50		- 28	- 88	+ 4
	33	67		- 20	- 52	+ 8
	0	100		+ 8	- 100	+ 20

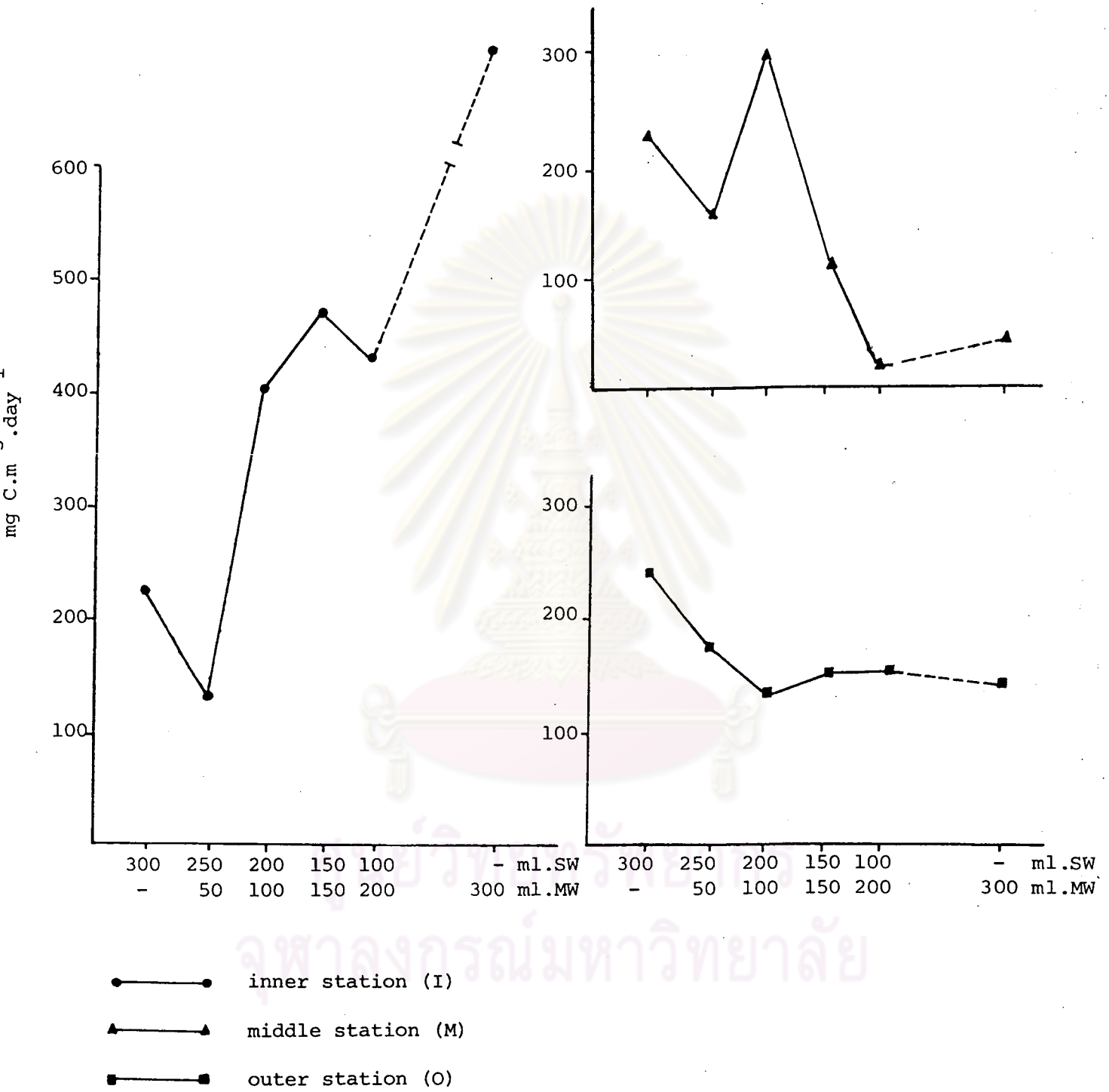

Figure 18 The gross primary production of mangrove water (MW) and sea water (SW) mixtures in different dilutions (height of water 15 - 16 dm above the lowest low water).

The result is similar at 18 - 18 dm. of station I (Table 9 and Figure 19), the gross primary production of pure mangrove water is 511.89 mg $C/m^3/hr$ while that of sea water is only 92.80 mg $C/m^3/hr$. The data obtained from the middle part of the mangrove (Station M) and the outer part (Station O) for the gross primary production of the pure mangrove from these two levels (15 - 16 dm, 18 - 18 dm) were very low, lower than that of sea water (Table 10). At these levels (15 - 16 dm, 18 - 18 dm) when the tide was low the water in the inner part of the mangrove was cut off from the sea water. Phytoplankton from the inner part of the mangrove probably consised of local species which evolved to suit the special condition of this part. When sea water enters the mangrove at high tide, the outer and the middle parts will recieve species of phytoplankton from sea water before the inner part (Station I). Generally the gross primary production decreased compared to pure sea water when mangrove water was mixed with sea water. May be because the phytoplankton transported into the outer and middle parts met with unfamiliar condition.

At the height of 21 - 27 dm of station I sea water gradually mixed with mangrove water, phytoplankton species also mixed. Gross primary productions were slightly less than that of the pure sea water when mangrove water were mixed less than half in the mixtures (Figure 20). Over than half of mangrove water in the mixture, gross primary production become more than that of the sea water. When water runs off from the mangrove during low tide, station I becomes the first one to become a "pure" mangrove water station. It is also the last station

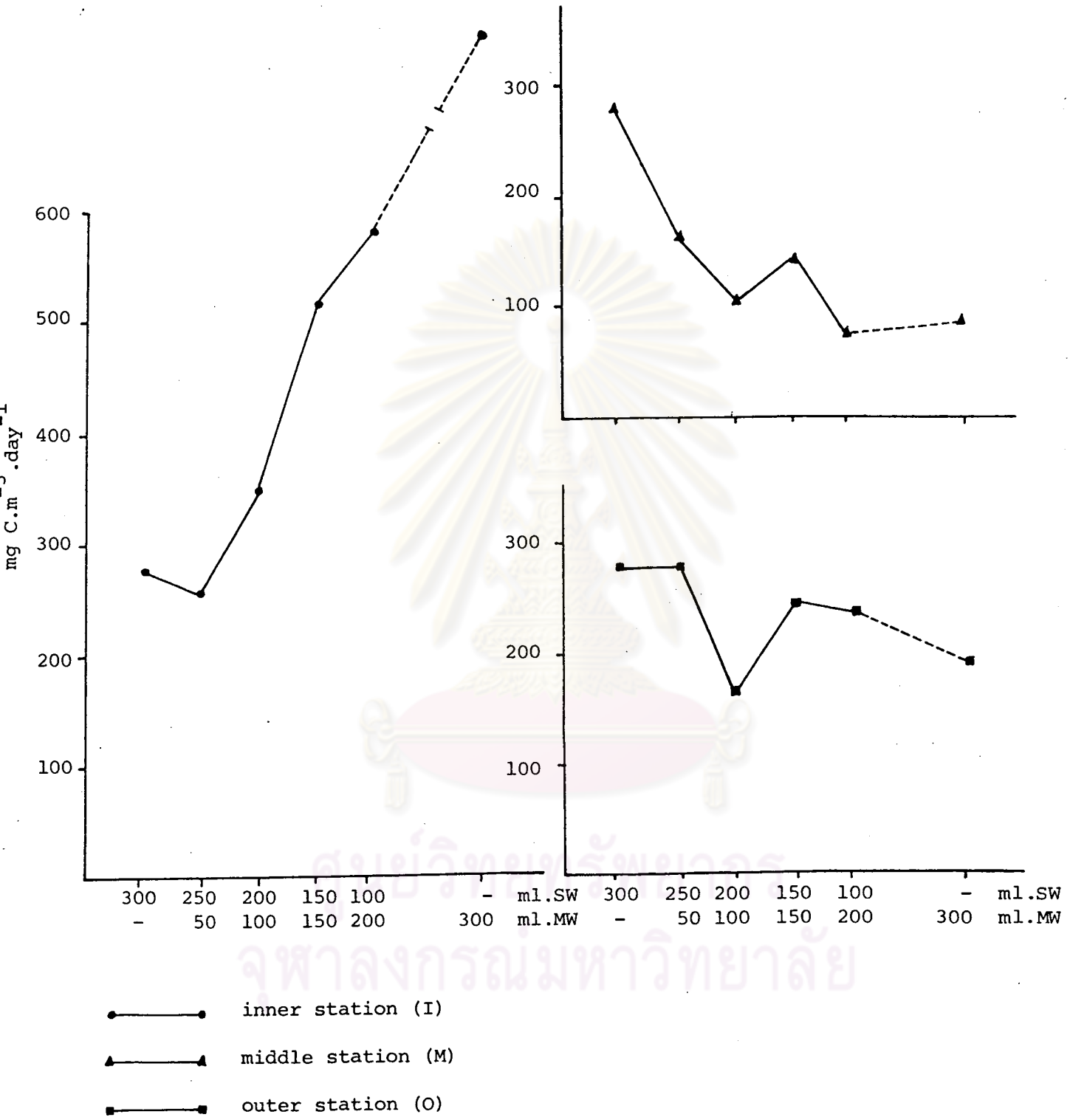

Figure 19 The gross primary production of mangrove water (MW) and sea water (SW) mixtures in different dilutions (height of water 18 - 18 dm above the lowest low water).

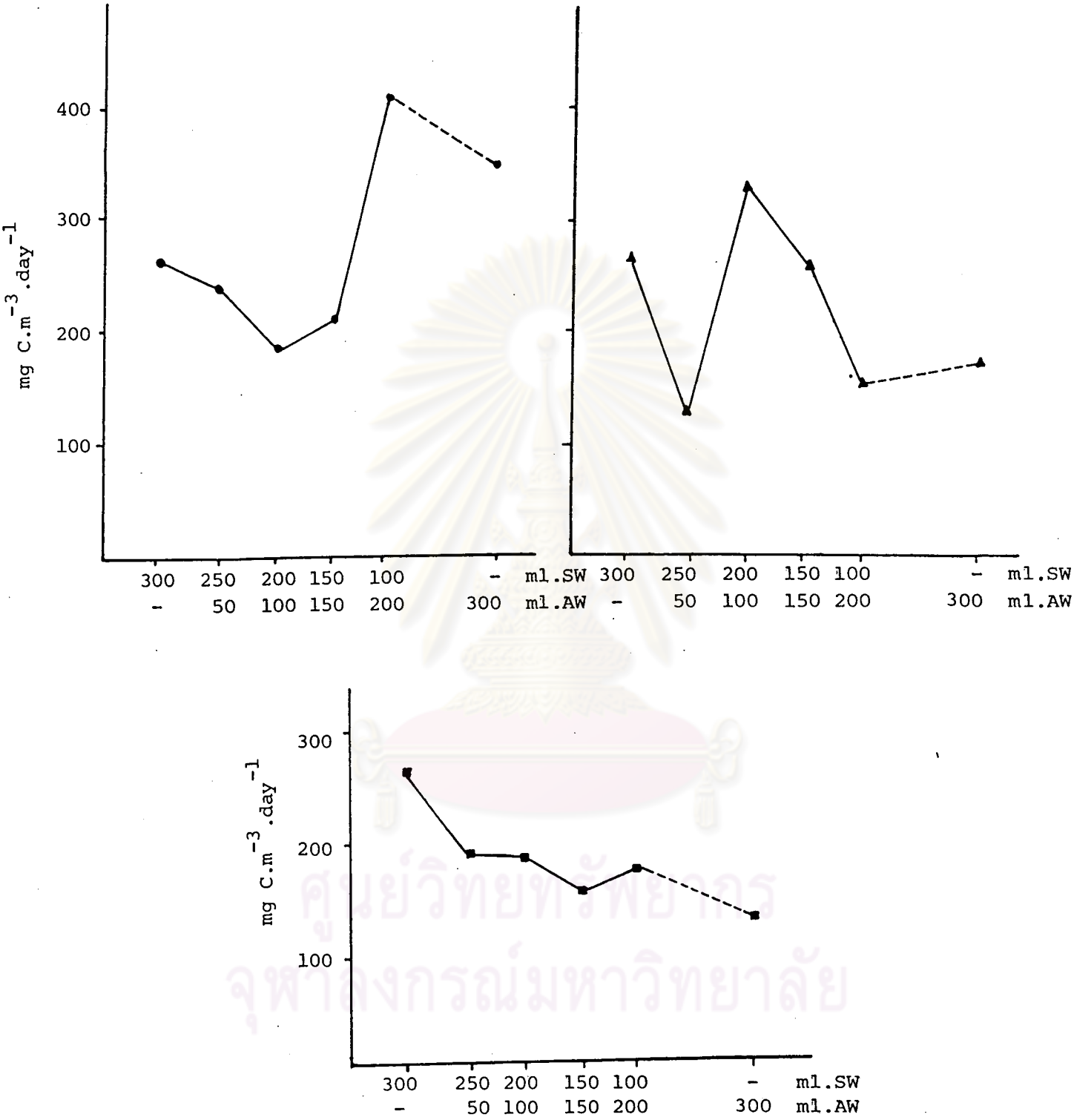

Figure 20 The gross primary production of mangrove water (MW) and sea water (SW) mixtures in different dilutions (height of water 21 - 27 dm above the lowest low water).

to be covered with sea water during high tide. However, the mangrove influences were also obvious at station M and station O although phytoplankton's activities in some cases were rather similar to pure sea water. Gross primary production of station O in particular, at this height (21 - 27 dm) showed reduction when compared to station I.

At the height of 31 - 32 dm the sea water and mangrove water mixed rather homogenously, but still some effects appeared from the mangrove. Station M, pure mangrove water, showed no gross primary production (Table 9, Figure 21).

4. Domestic sewage

When sea water mixed with sewage in various dilution (Table 4) the resulf of gross primary production came out in four patterns referred to as type 1 - 4 in the fallowing.

Type - 1

This type, pure sewage, had the highest gross primary production which decreased with increasing admixture of sea water. This situation was the most common and was observed in 8 out of the 18 incubations (Figure 22). The gross primary production of pure sewage was rather high, up to 128 times higher, compared to sea water without addition of sewage, obviously, the nutrient rich conditions in the sewage (Table 11) caused this high gross primary production. If the control of pure sewage had not been included in the bioassays the interpretation of the experiment would have been that sewage stimulated the gross

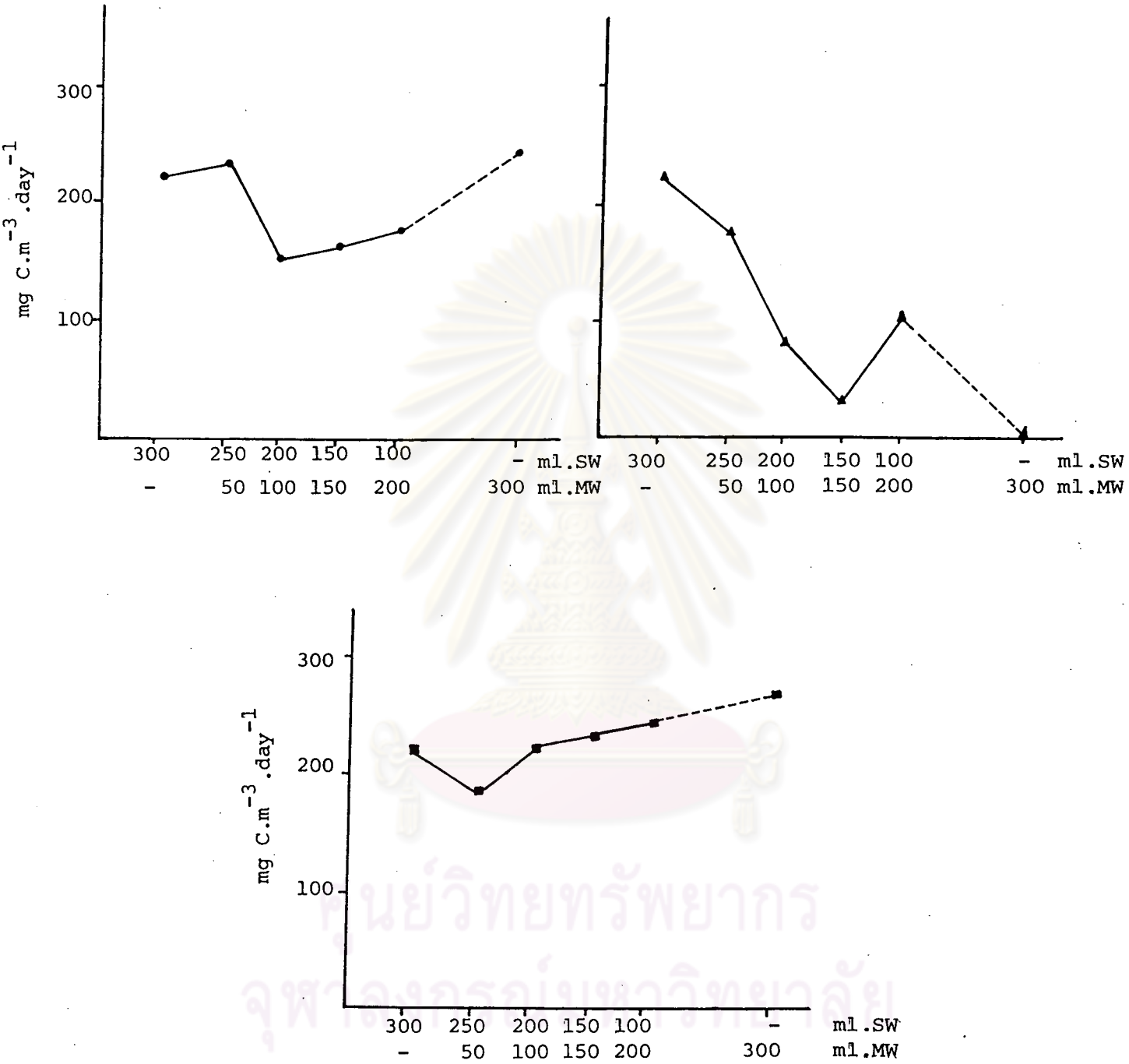

Figure 21 The gross primary production of mangrove water (MW) and sea water (SW) mixtures in different dilutions (height of water 31 - 32 dm above the lowest low water).

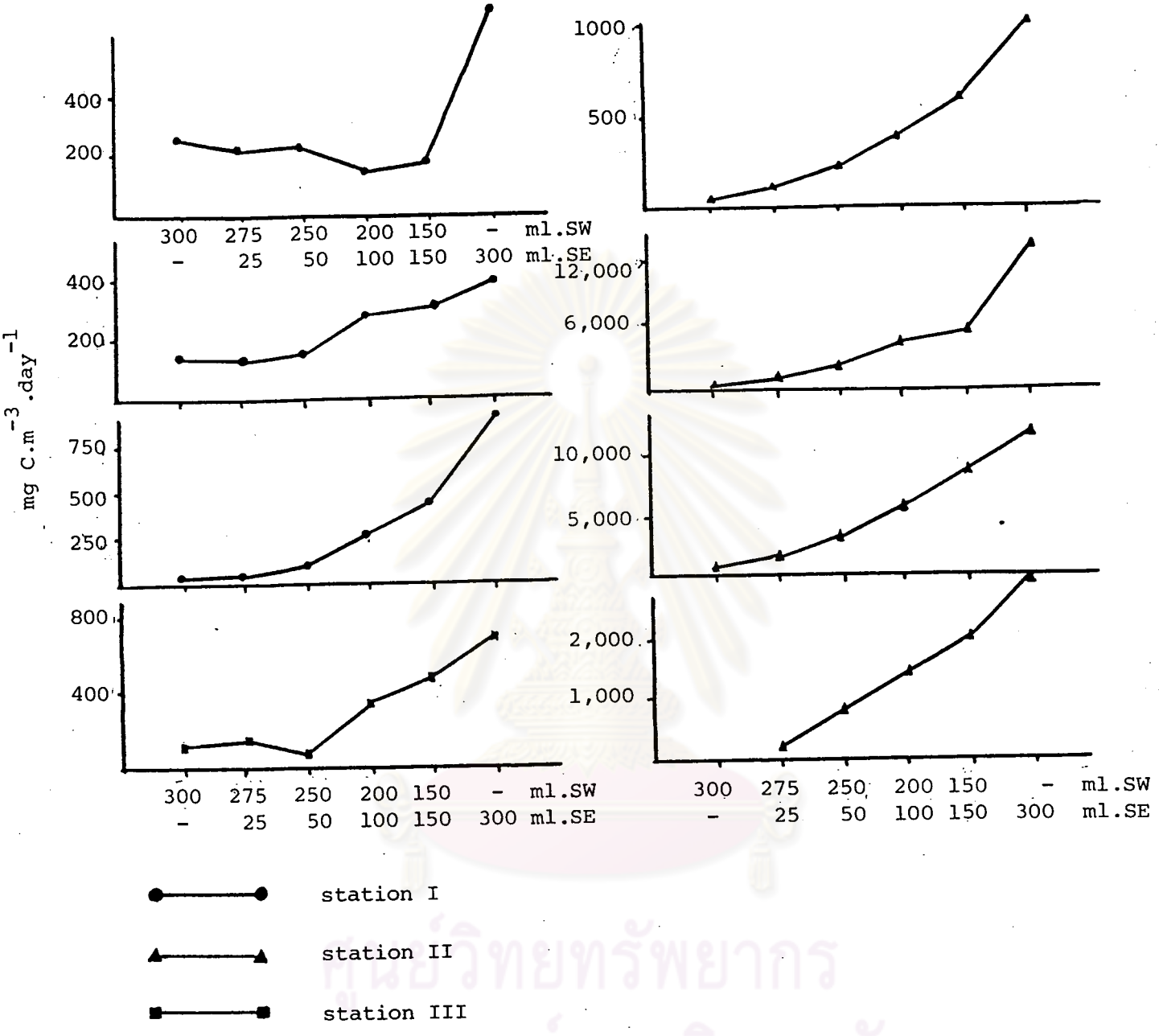

Figure 22 The gross primary production of domestic sewage (SE) and sea water (SW) in different dilutions. Type - 1

Table 11 Environmental factors measured in Klong Bang Yai (St. I - III) on five sampling occasions during the month of April 1982.

Date	station	salinity (‰)	$PO_4^{\equiv}$ - P (ug-at/l)	NO_3^- - N (ug-at/l)	NO_2^- - N (ug-at/l)
10.4.1982	sea water	30.5	0.20	0.42	-
	St. I	6	0.28	0.53	-
	St. II	14	0.25	8.80	0.001
	St. III	3	57.1	0.68	-
14.4.1982	sea water	32	-	0.47	-
	St. I	2	18.0	0.24	-
	St. II	7	lost	lost	lost
	St. III	2	43.0	0.59	-
16.4.1982	sea water	31	0.05	0.40	-
	St. I	0	21.6	0.41	-
	St. II	4	43.0	1.20	-
	St. III	0	46.1	0.82	-
23.4.1982	sea water	30.5	0.09	0.2	0.35
	St. I	2	14.4	0.35	2.65
	St. II	6	18.8	0.6	2.1
	St. III	2	9.4	1.0	66.0
28.4.1982	sea water	31.5	0.7	0.5	0.05
	St. I	2	20.5	0.45	0.75
	St. II	9	12.2	0.2	0.70
	St. III	2	18.0	1.0	11.1
3. 5.1982	sea water	32	0.5	0.1	0.3
	St. I	0	4.5	8.2	2.15
	St. II	1	3.9	6.4	2.1
	St. III	0	21.0	6.5	16.0

primary production of the sea water. However the results of gross primary production at different dilutions of sewage and sea water should be explained by the combined effects of dilution upon pH, salinity, nutrients and the organisms in the experimental bottles. The data showed that, at the time of incubation, the sewage was rich in fresh water primary producers, but when sea water was added the optimum conditions was lost and gross primary production decreased.

Type - 2

This type showed various optima of gross primary production at different dilutions of sewage. Type - 2 was found in 5 of the 18 incubations (Figure 23). Gross primary production of pure sewage was very low in these occasions. Some unknown substances blocked or masked the primary production. However, when diluted with sea water, the nutrients of sewage apparently stimulated primary production. Of course, it is impossible from this kind of experiment to state whether the increase in gross primary production was due to stimulation of sea water phytoplankton utilizing the increased supply of nutrients, or due to primary producers in the sewage itself. In the latter case, the sewage organisms produced oxygen because the harmful factors blocking photosynthesis in the pure sewage were diluted to nontoxic levels. In both cases the different salinities at different dilutions of sewage and sea water were tolerated by the marine plankton and or the freshwater plankton.

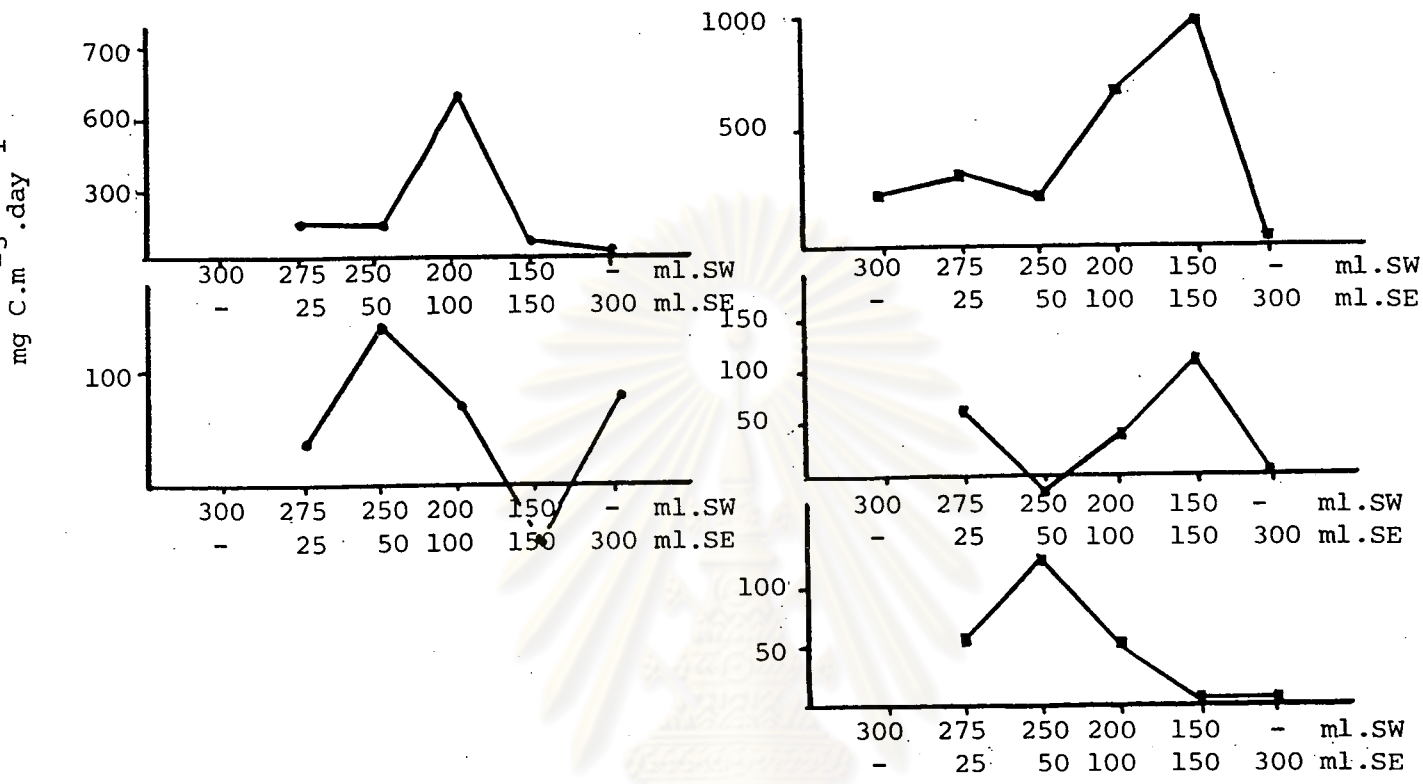

Figure 23 The gross primary production of domestic sewage (SE) and sea water (SW) in different dilutions. Type - 2

Type - 3

This third type was observed in 2 of the 18 incubations. This type showed a decreasing in gross primary production with increasing amounts of sewage added to the sea water (Figure 24 a). From this case, it is suggested that the sewage water was very polluted and toxic. Photosynthesis was blocked by some unknown substances in the water. The type - 3 results are in accordance with bioassays carried out by Goldman et al. (1973) and Ryther & Dunstan (1971). In those bioassys secondary treated waste water was added to sea water in various dilutions with the result that gross primary production of sea water decreased with increasing amounts of waste water. The precise nature of the toxic substance is not known, but as previously mentioned heavy metals and certain organic wastes may be harmful. Too much nutrients can also turned to be an inhibited factor for primary production. Metabolites from bacteria may also play a role since domestic sewage is particularly rich in bacteria derived from faeces, remains of food, etc. These bacteria would attack organic matters and may be able to use up dissolved oxygen, thereby creating anaerobic conditions in the klong water.

Type - 4

Three of the 18 incubations showed the puzzling result that the dark bottle values were higher than that of the light bottle values, especially in the experiment performed on 28 April 1982. This abnormal result was found in both station I and III (Figure 24 b).

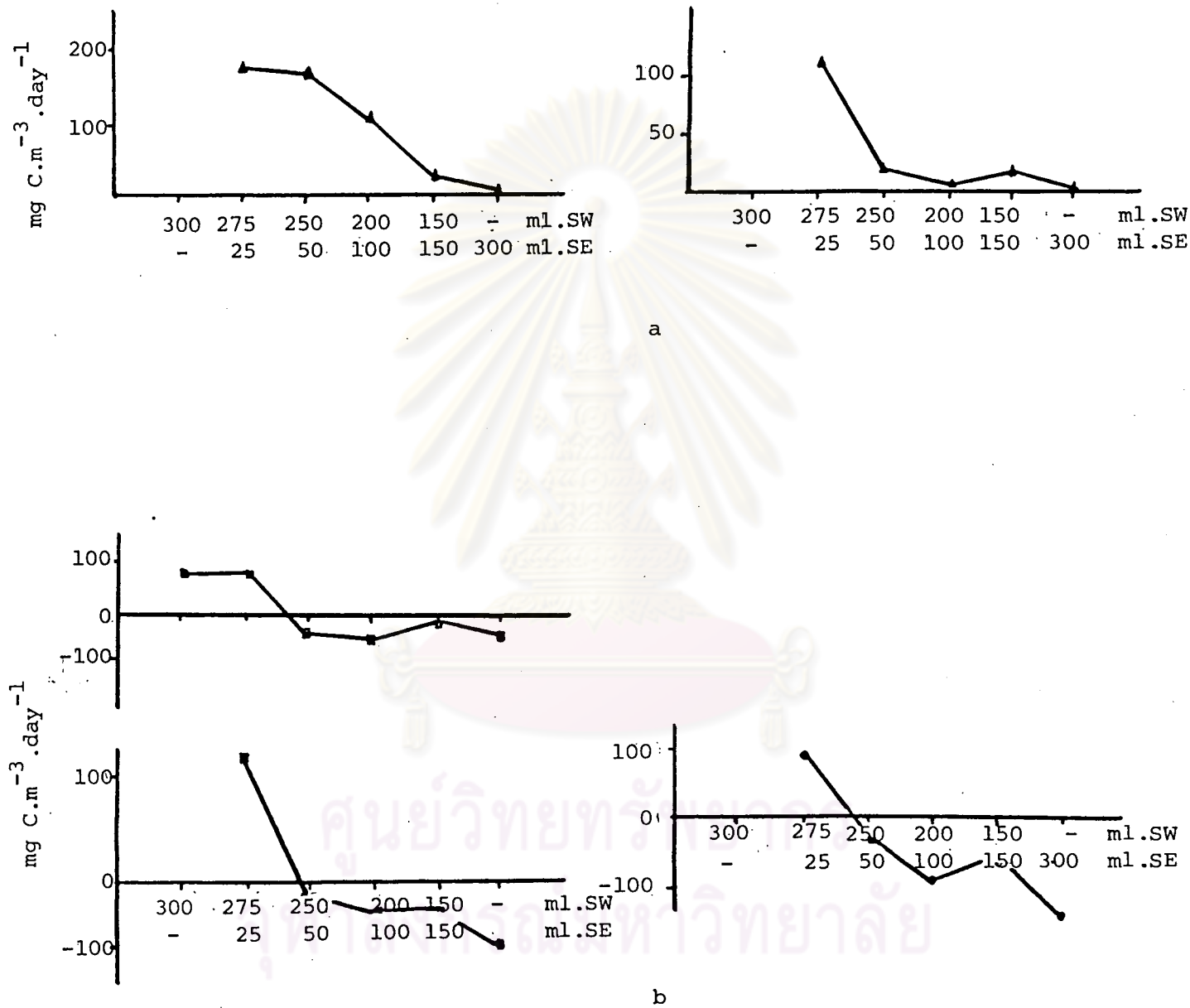

Figure 24 The gross primary production of domestic sewage (SE) and sea water (SW) in different dilutions.

5. Tin mine water

Water from tin mine area I at station 4 seemed to increase phytoplankton growth in sea water when the amount of tin mine water was increased (Figure 25). There were some variations in the gross primary production on different day because of variation in the natural phytoplankton populations in each bottle and diferent in the amount of nutrients. When distilled water was mixed with sea water in the equal amount (50% each) the production showed negative value (light bottle < dark bottle). Obviously, distilled water can block photosynthesis of phytoplankton because of the reduced salinity and lowered the concration of nutrients in the bottle.

Tin mine water from stations 3 and 4, were rich in nutrient, as shown in table 12. Therefore, mixing these tin mine waters with sea water, were like adding nutrients to stimulate phytoplankton growth but also the effects of dilution upon pH and salinity had to be considered. This stimulated was found in both tin mining areas, although water from tin mine area II, station 3 A, had lower gross primary production compared to station 4 A when 50% tin mine water was mixed with sea water (Figure 26).

When Fe and EDTA were added into there mixtures of 50% tin mine water and 50% sea water, the results came out that Fe stimulated phytoplankton growth more than EDTA and the mixing of Fe and EDTA was better than adding the compounds seperately (Figure 27, 28). These data indicate the possibility that some trace metals, such as Fe, were present in the tin mine water and

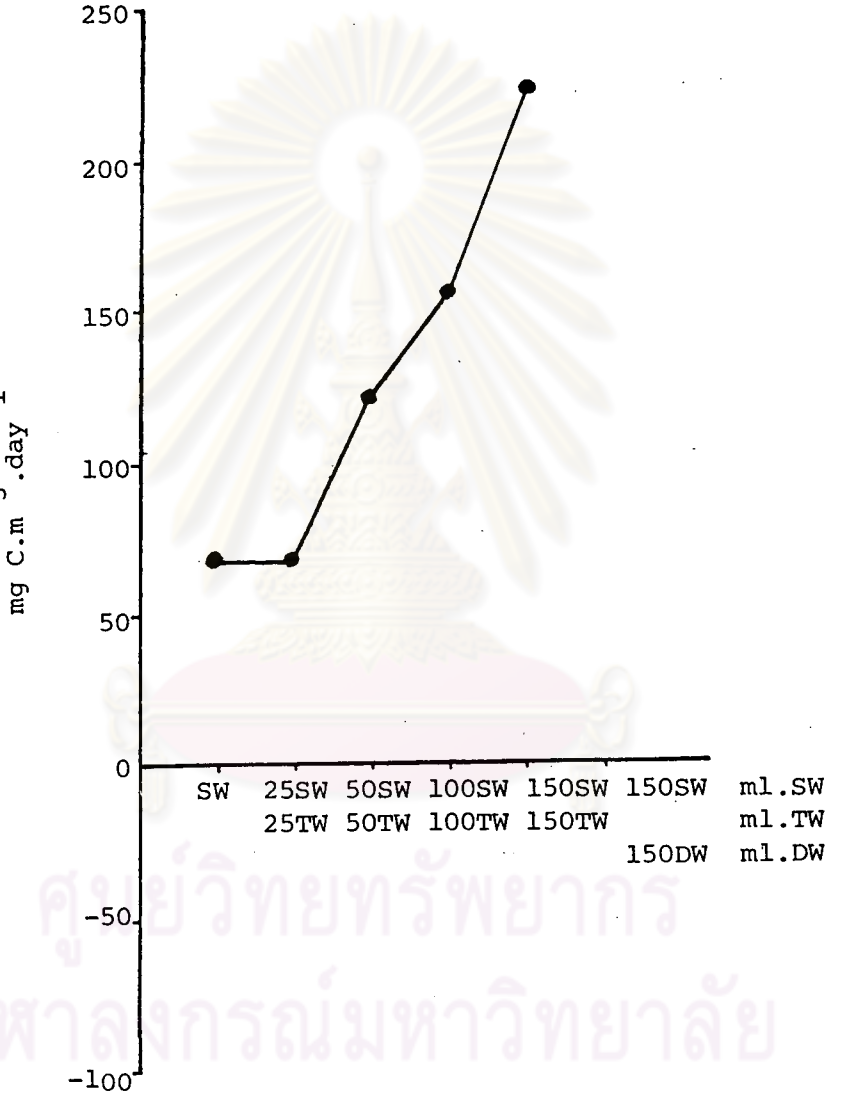

Figure 25 The gross primary production of tin mine water (TW) or distilled water (DW) and sea water (SW) in different dilutions. Tin mine area I, station 4. Date: 1/12/1982.

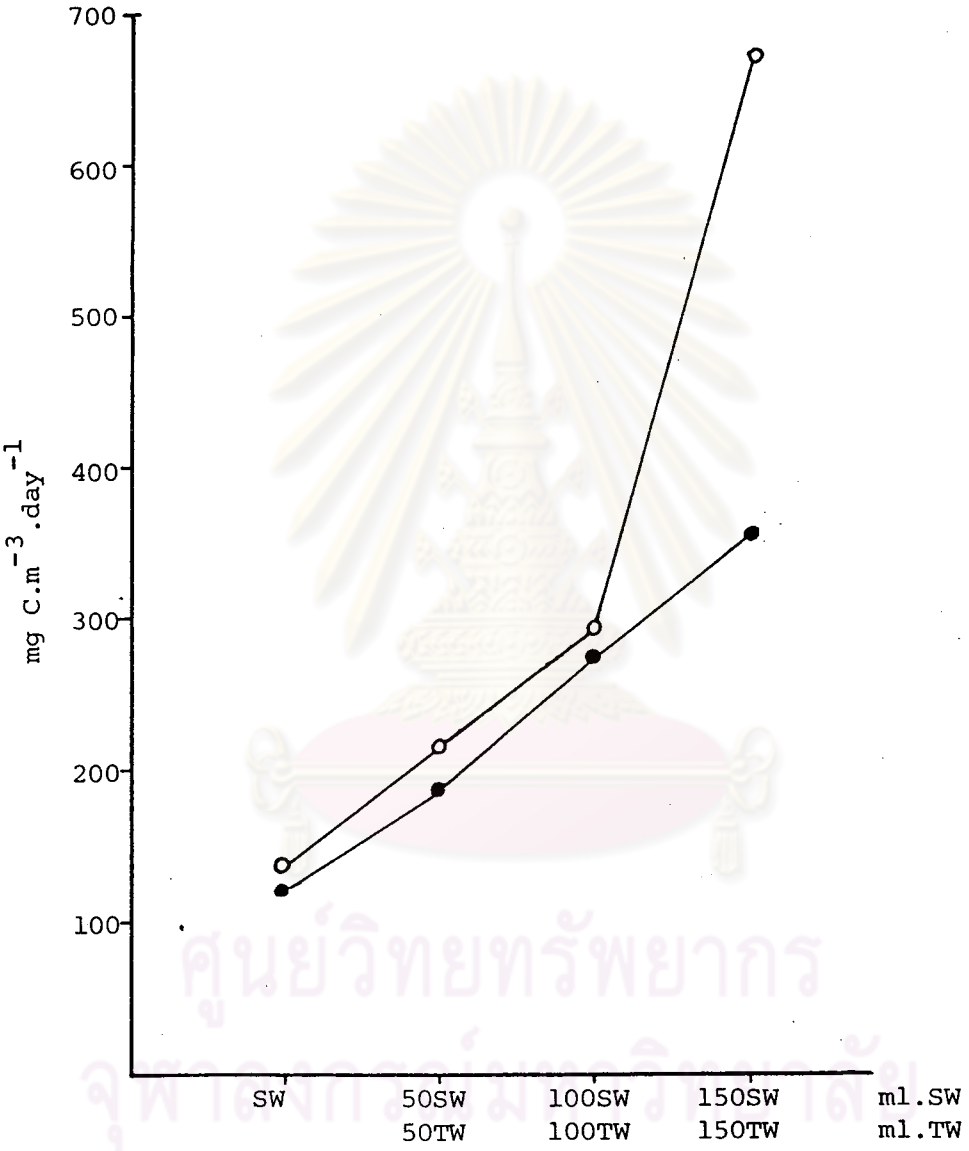

Figure 26 Comparison of the gross primary production of tin mine water (TW) and sea water (SW) in different dilutions between station 4A (o) and station 3A (●) tin mining area II.

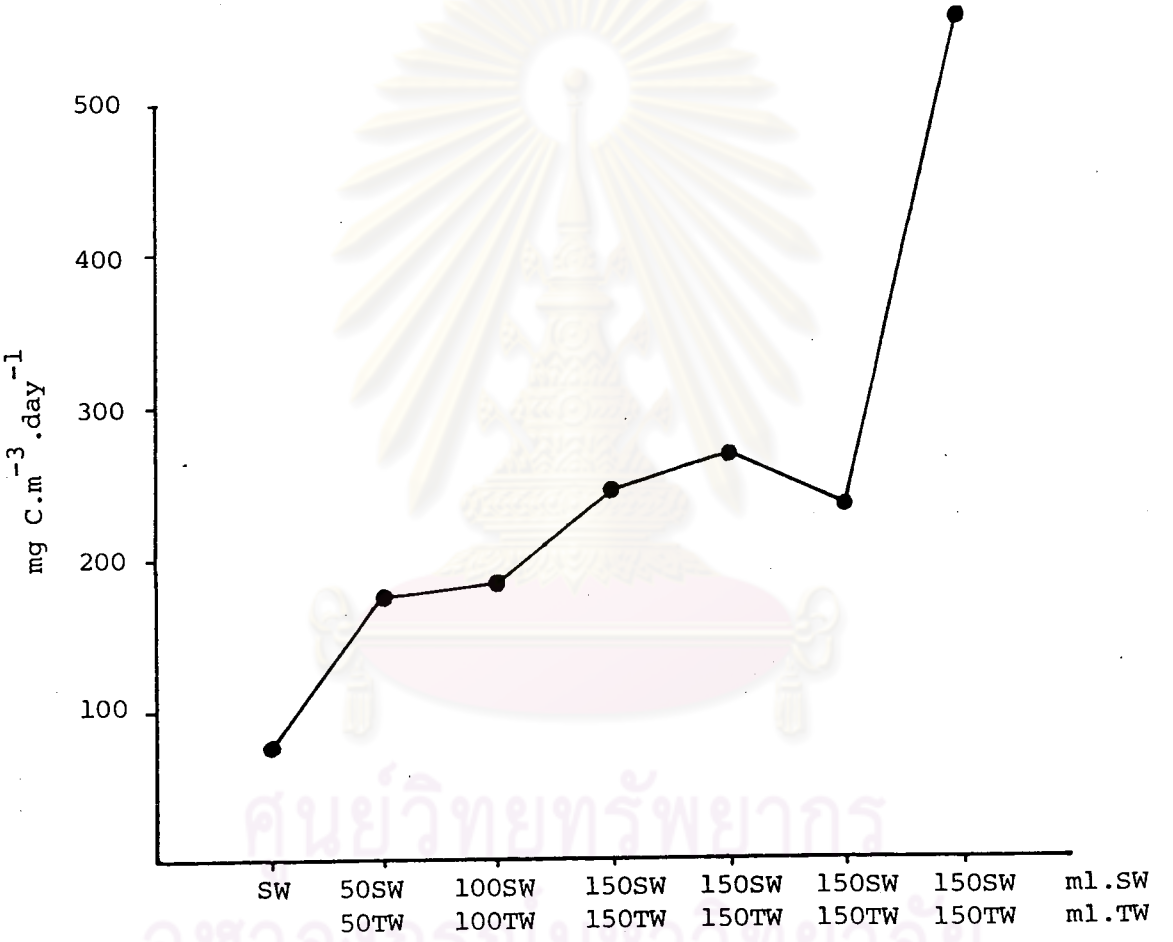

Figure 27 Variations of the gross primary production of tin mine water (TW) and sea water (SW) in different dilutions. Fe (F) and EDTA (E) were added seperately or in combination to the mixtures of equal dilution of both water. Tin mine area II, station 3; date: 14/2/1981.

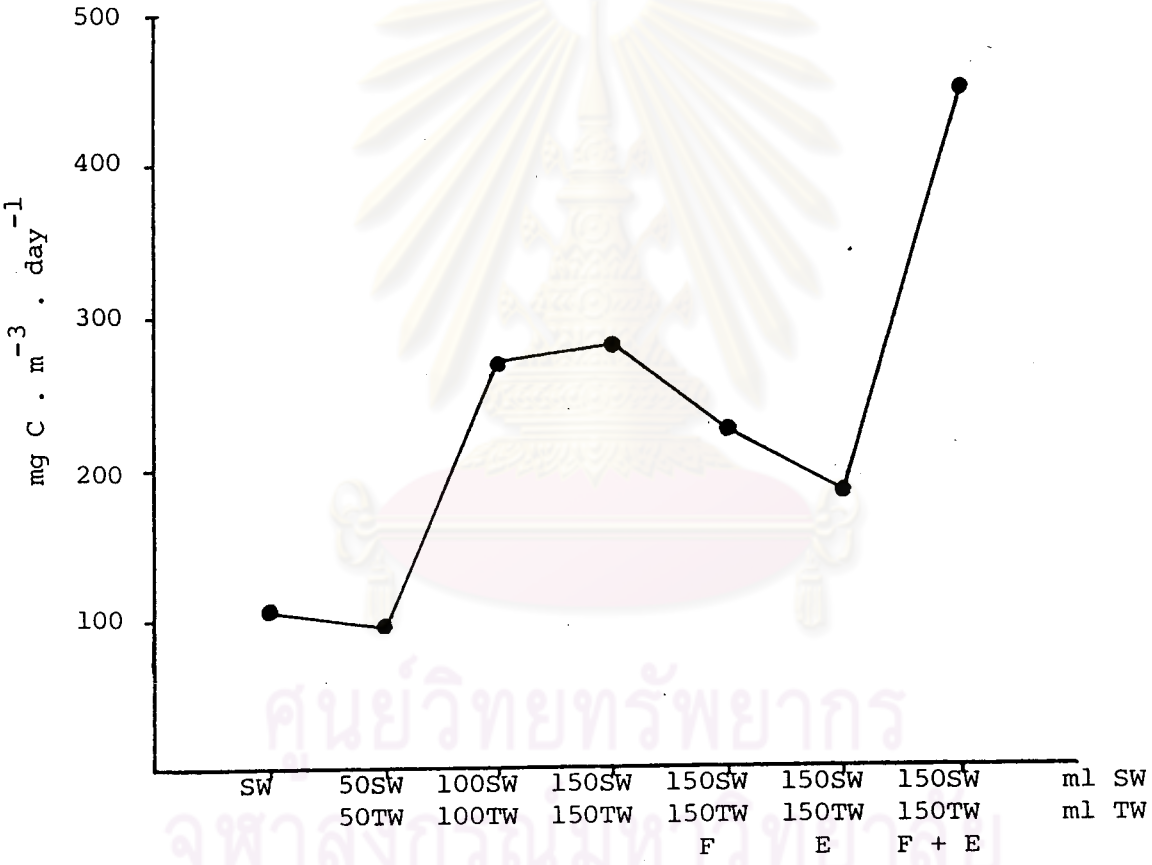

Figure 28 Variations of the gross primary production of tin mine water (TW) and sea water (SW) in different dilutions when Fe (F) and EDTA (E) were added. Tin mine area II, station 4; date; 14/12/1981.

Table 12 Environmental foctors at station 1 - 4 in the Phuket tin mining area (I)

Station	Salinity (‰)	pH	PO_4^{-3} - P µg-at/l	NO_3^- - N µg-at/l	NO_2^- - N µg-at/l
1	1.3	6.85	0.67	57.5	2.42
2	1.4	6.30	0.75	52.3	8.50
3	1.25	4.80	0.92	40.0	0.80
4	0.45	3.85	1.25	68.4	2.80

stimulated phytoplankton growth to some extent. Comparison of gross primary productions when nutrients were added seperately or in combination to different dilutions of the mixtures, the results indicated that EDTA alone can inhibit phytoplankton growth (Figure 29). Figure 29 shows that mixing of all the nutrients, N + P + Fe + EDTA, was the best combination yielding the highest gross primary production. However, the experiments showed that P + N were more necessary than Fe + EDTA for phytoplankton production.

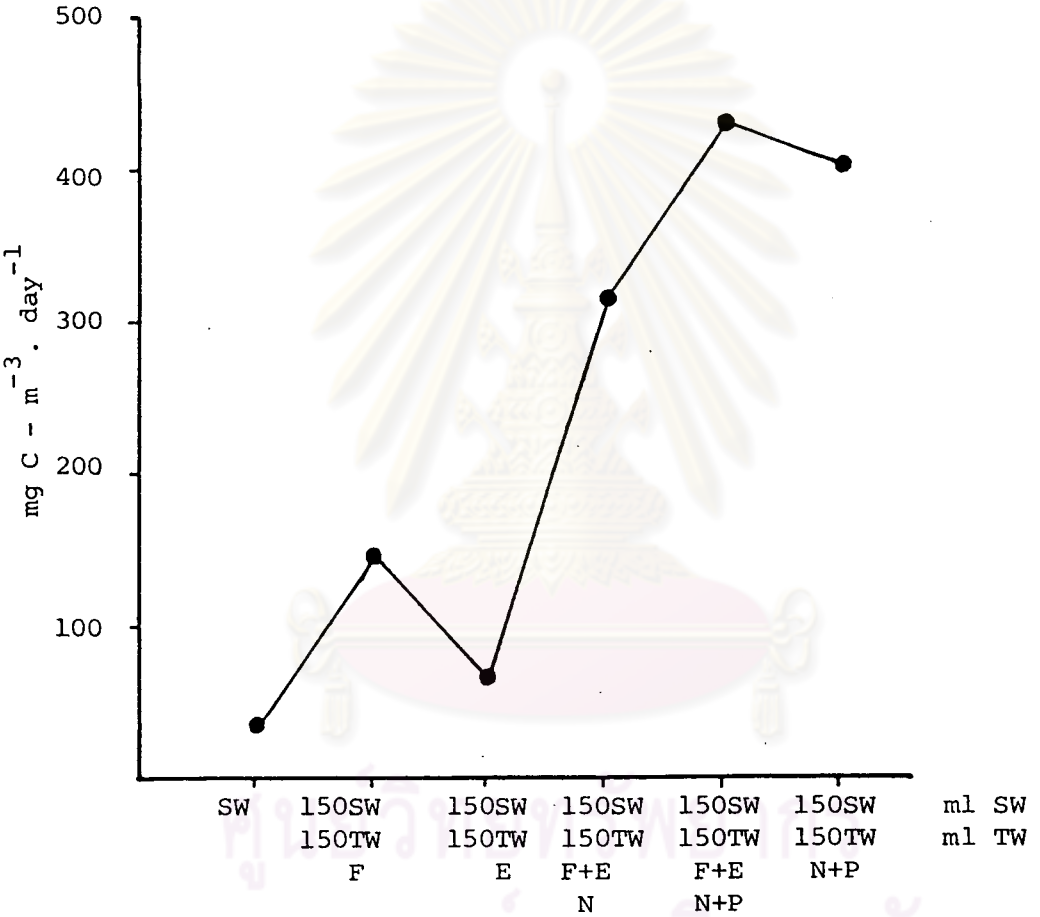

Figure 29 Variations of the cross primary production of the mixtures of 1:1 ratio between tin mine water (TW) and sea water (SW) when nutrients were mixed seperetely and in cambination. Tin mine area II, station 4; date 7/1/1981 (F = Fe^{+} - F, E = EDTA, N = NO_3^-, P = $PO_4^{\equiv}$ - P)