CHAPTER IV
RESULTS AND DISCUSSION

Seasonal variation of nutrients

There was no apparent stratification of salinity during dry season. Salinity of the Upper Gulf in this season were within range of 30 to 34 ppt. The surface salinity distribution were shown in Figure 4.1. The salinity in the central part of the Gulf was high during this period due to a very high evaporation in the area (evaporation rate ≈ 170 mm/month).

During wet season, the salinity increased gradually offshore. The salinity in the area were 26-32 ppt. Freshwater input from Chao Phraya and Bangpakong Rivers drained into the eastern part of the Gulf was higher than the western part (Mae Klong and Ta Chin Rives) which caused low salinity in the eastern part. For the first 20 km from the coast, there was some lateral effect of freshwater on salinity but beyond that area the water was vertically well mixed.

Phosphate and total phosphorus varied within the range of 0.07-2 and 0.2-5 $\mu mol\ l^{-1}$, respectively, in dry season. The distribution of phosphate and total phosphorus were not different for both vertical and horizontal line, while high concentration were near the coast especially in the eastern part of the Gulf and also in the central part of the Gulf when the evaporation was extremely high (Figure 4.2 and 4.3).

In the wet season, the nutrient concentrations of phosphate and total phosphorus were highest near the river mouths because of the terrestrial inputs effect. Concentrations of phosphate and total phophorus ranged in 0.05-3 and 0.1-7 $\mu mol\ l^{-1}$, respectively. A little difference of phosphate and total phosphorus were notified in the vertical line but there tend to decrease along the distance from the shoreline.

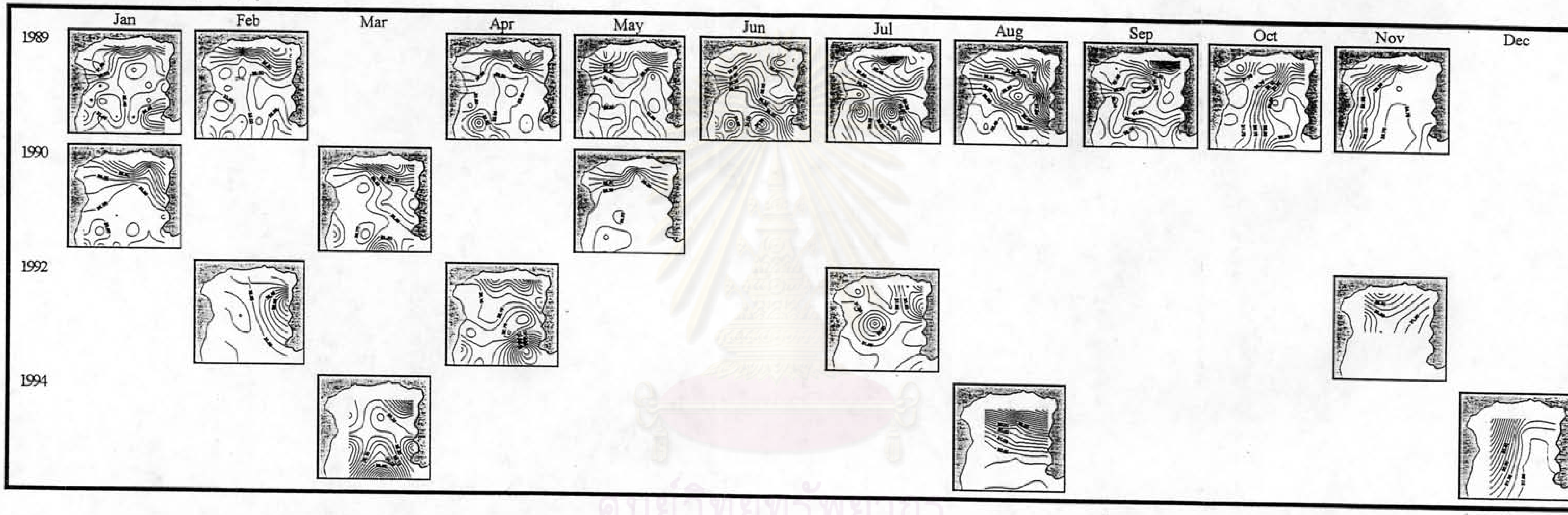

Figure 4.1 Surface salinity in the Upper Gulf of Thailand during 1989-1994

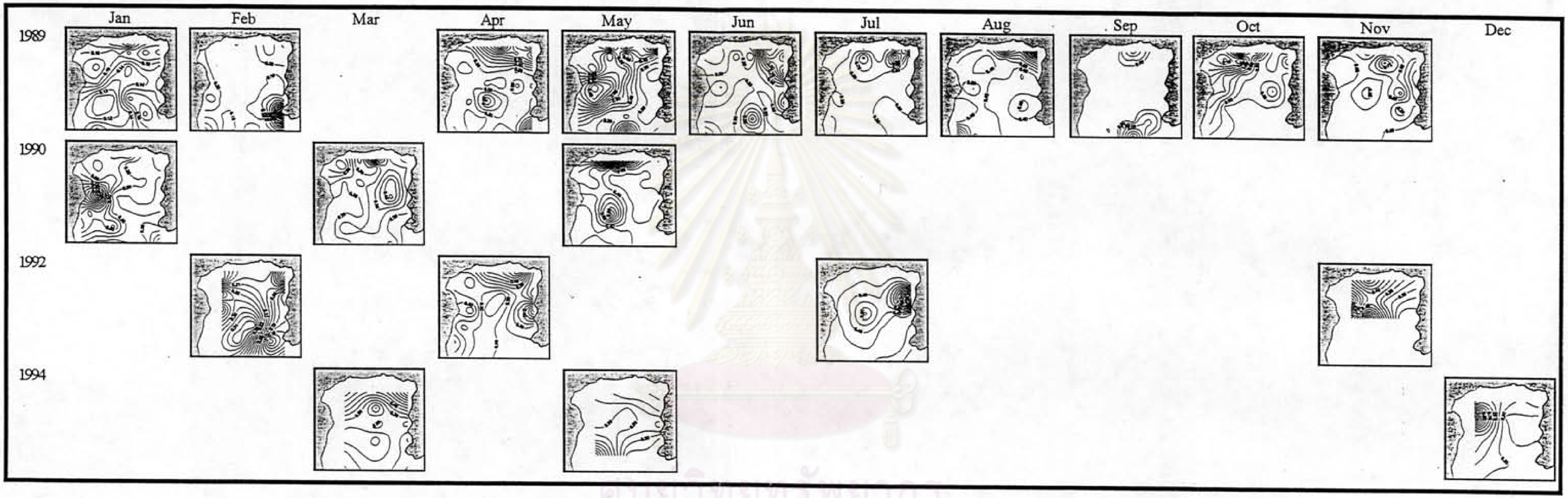

Figure 4.2 Surface concentrations of phosphate in the Upper Gulf of Thailand during 1989-1994

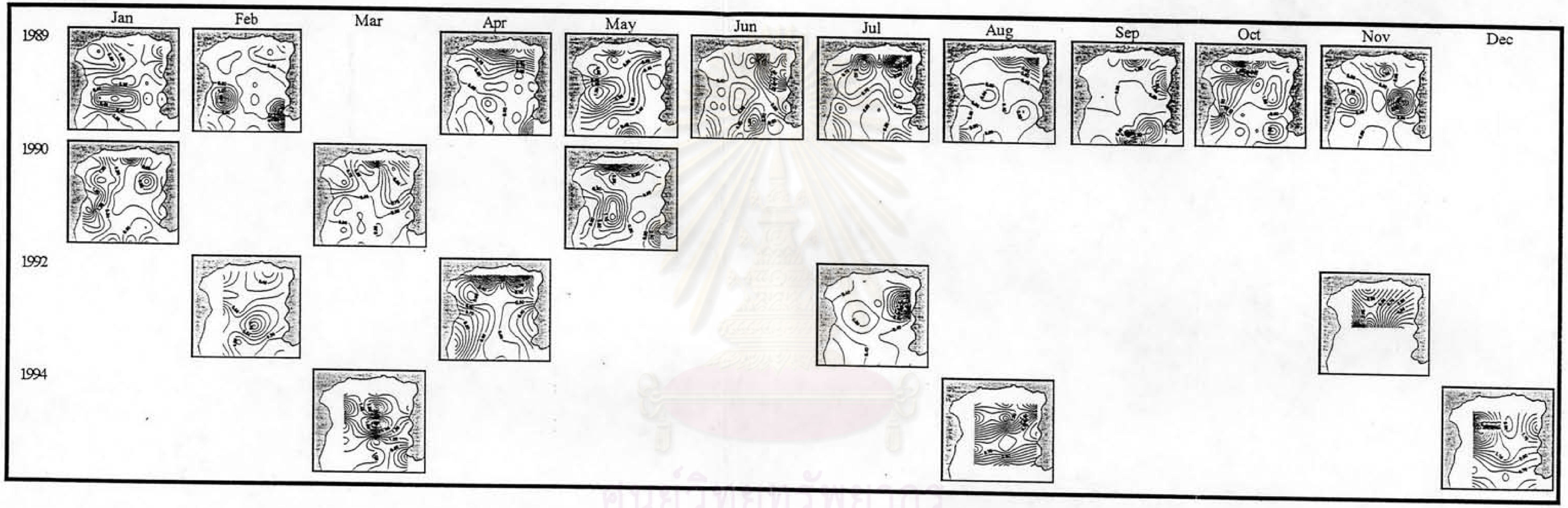

Figure 4.3 Surface concentrations of total phosphorus in the Upper Gulf of Thailand during 1989-1994

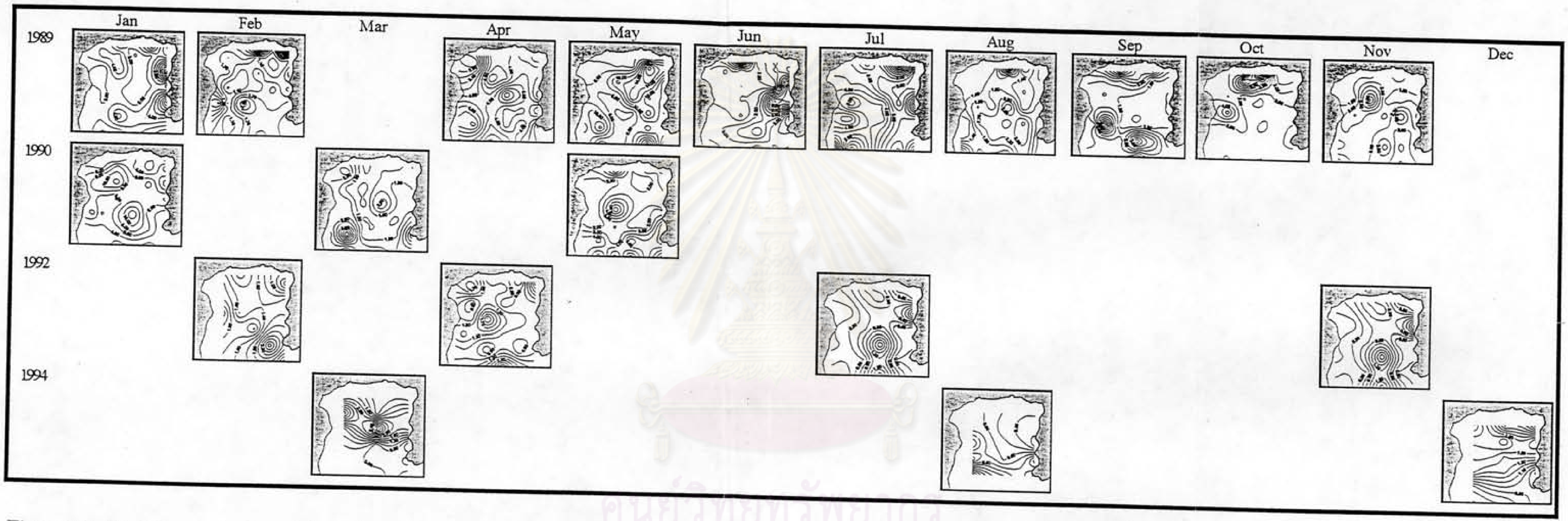

Figure 4.4 Surface concentrations of nitrate in the Upper Gulf of Thailand during 1989-1994

During dry period, nitrate and nitrite varied in 0.2-10 and 0.05-3 $\mu mol\ l^{-1}$, respectively. The general distribution of nitrate and nitrite were found that there tend to decrease along the distance from the coast both in the eastern and western parts but the highest concentrations were obviously observed in the central part of the Gulf when the evaporation was extremely high (Figure 4.4).

During wet season, large amount freshwater input into the Upper Gulf, and higher concentrations were observed. Nitrate and nitrite were 0.5-13 and 0.03-5 $\mu mol\ l^{-1}$, respectively. Some variation between surface and bottom layers were observed especially near the bay head. The distribution of nitrate was found to be decreased along the distance from bay head.

Long-term variations of nutrients

Long-term variations of nutrients were considered by using the secondary data from the Department of Fishery during 1987-1994.

By classified the study area into 3 parts (east, west and central part), long-term variation along the vertical profile of these parameters are shown in Figure 4.5 to 4.8. During this period, there was no obviously different in the concentration of nitrate, phosphate and total phosphorus along the vertical plain. These variations emphasized that there were vertically well mixed of the nutrients in the Upper Gulf.

The temporal variation patterns of these parameters can be illustrated in Figure 4.5 to 4.8 which show the surface long-term variation of salinity, nitrate, phosphate and total phosphate in the Upper Gulf of Thailand. The values of salinity were in the range of 26 to 34 ppt and altered due to the distance from the shoreline which lower in the east and along the coastline, while the central part of the gulf had higher concentration during these periods.

The concentration of nitrate and phosphate were high along the shoreline (particularly in the eastern part) and low in the central part. Long-term variations of these nutrient concentrations along the Upper Gulf show no significant fluctuate during these period.

(a)

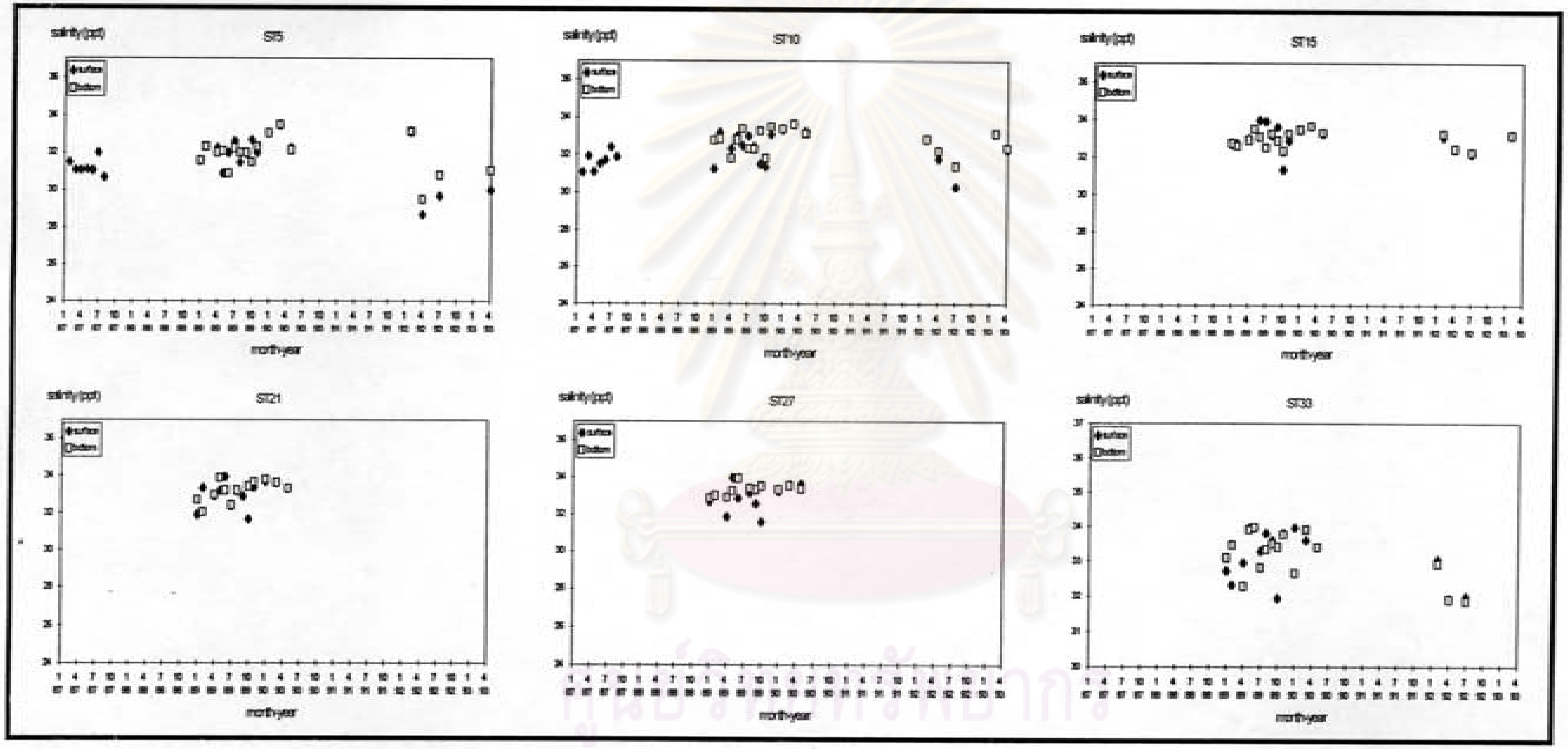

Figure 4.5 Long-term variation of salinity in the Upper Gulf of Thailand at stations along: (a) western part, (b) central part, and (c) eastern part during 1987-1994.

(b)

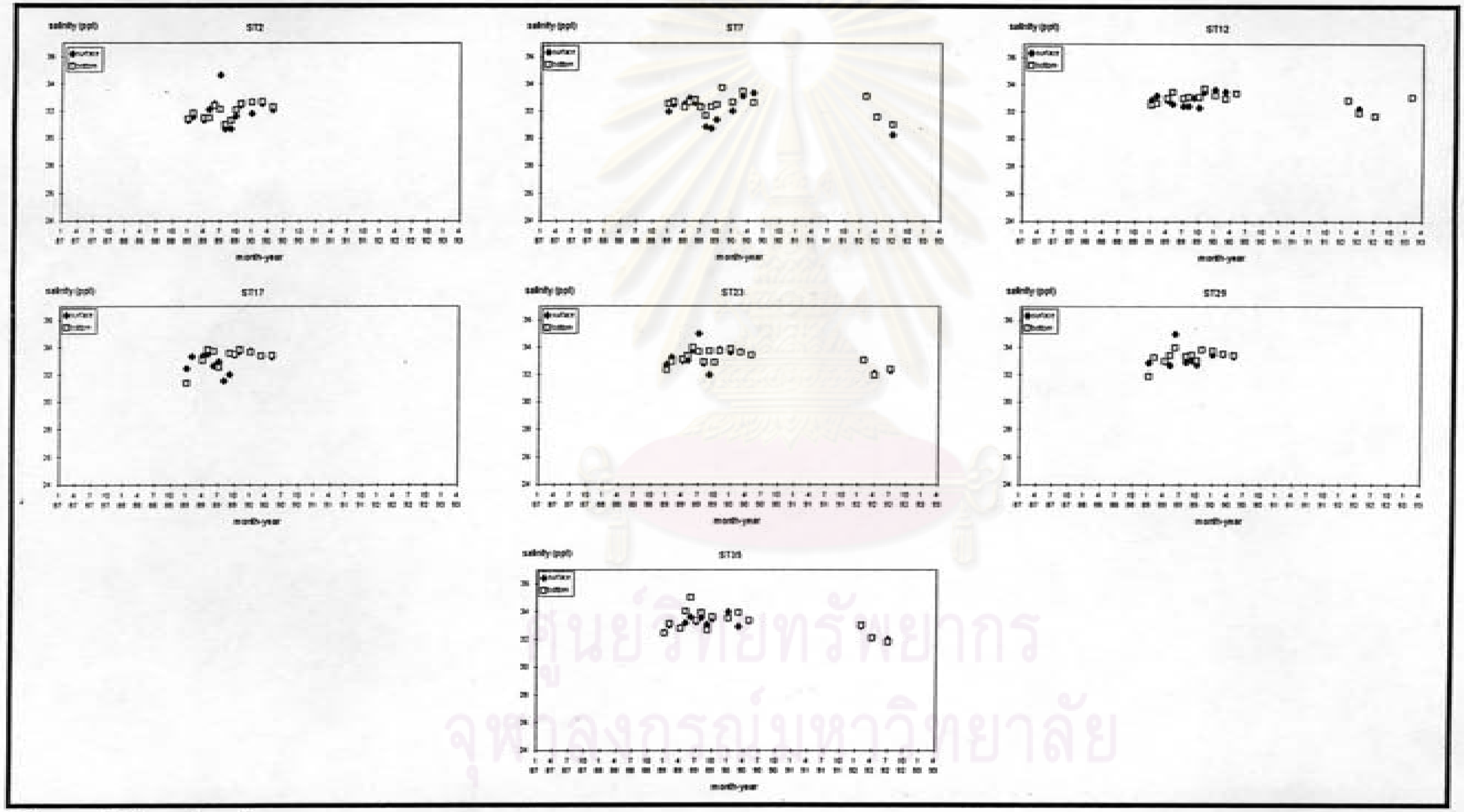

Figure 4.5 (continued)

(c)

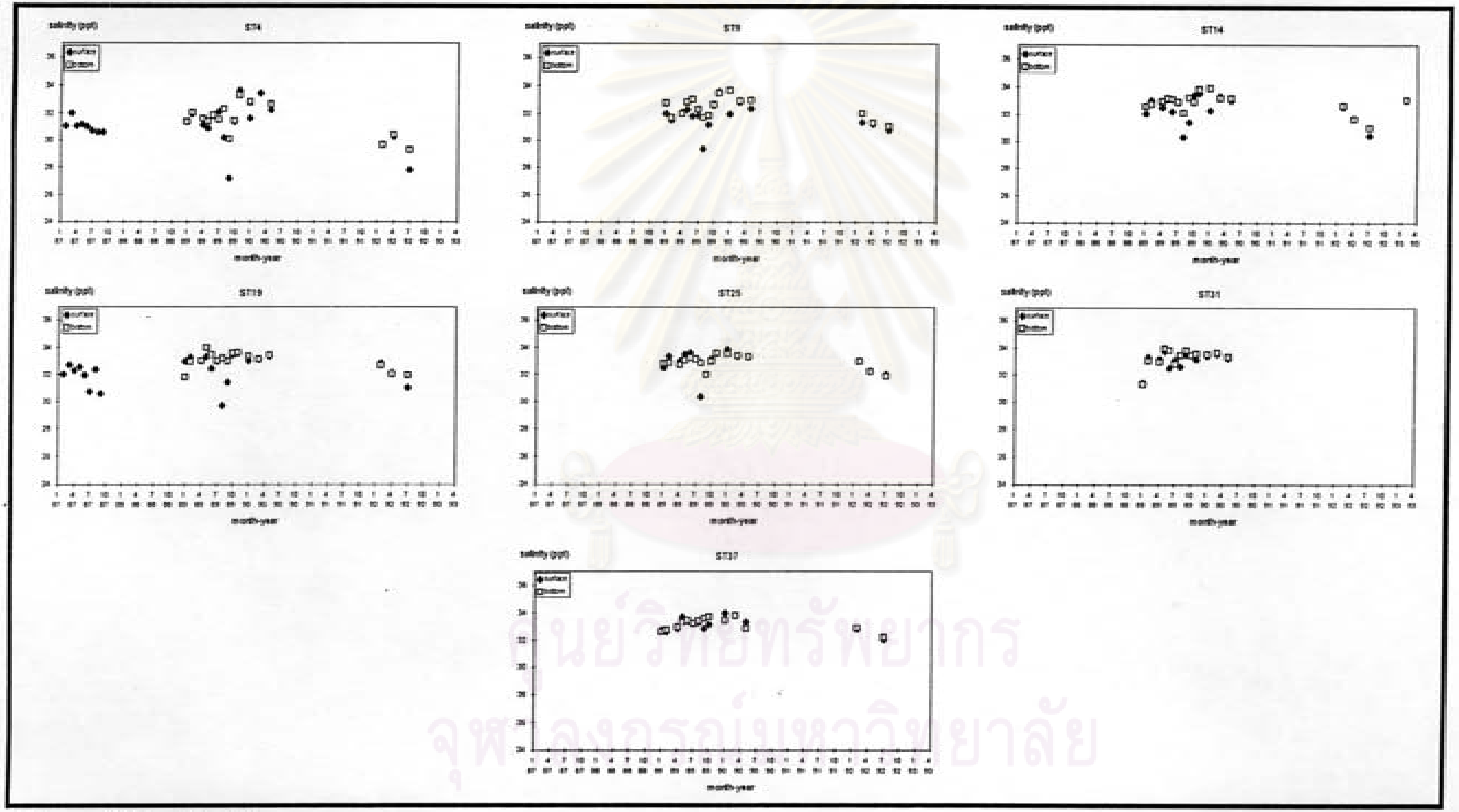

Figure 4.5 (continued)

(a)

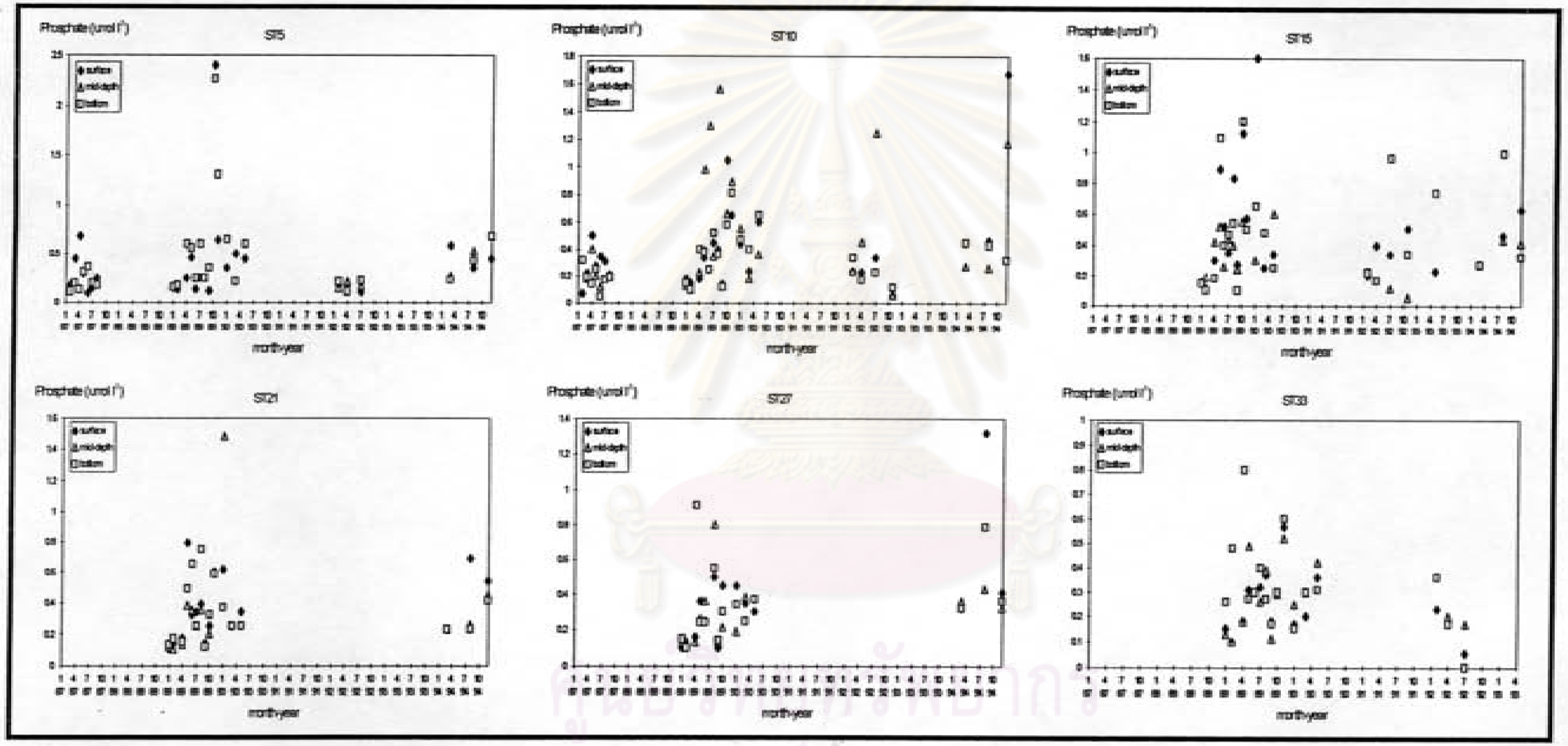

Figure 4.6 Long-term variation of phosphate concentrations in the Upper Gulf of Thailand at stations along: (a) western part, (b) central part, and (c) eastern part during 1987-1994.

(b)

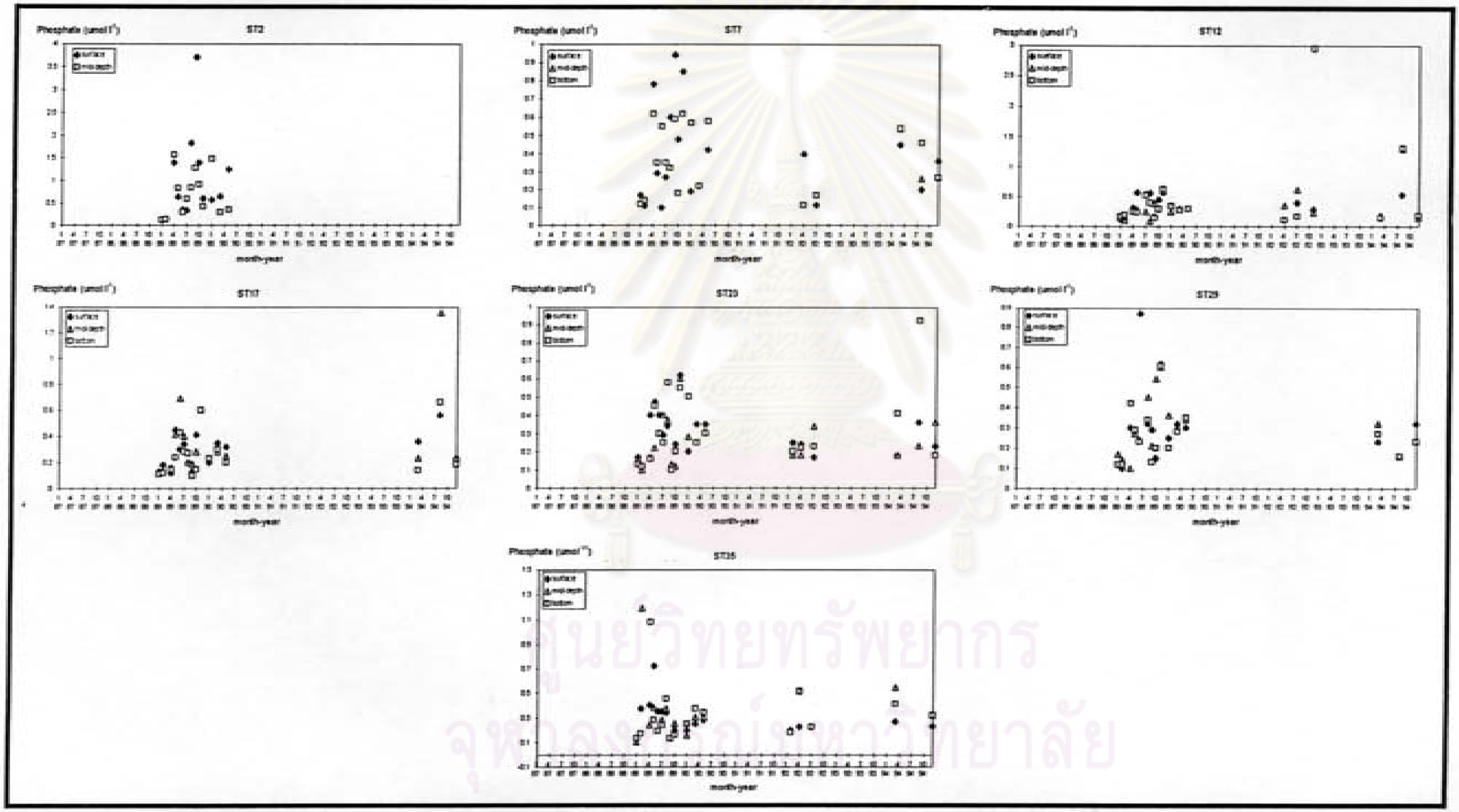

Figure 4.6 (continued)

(c)

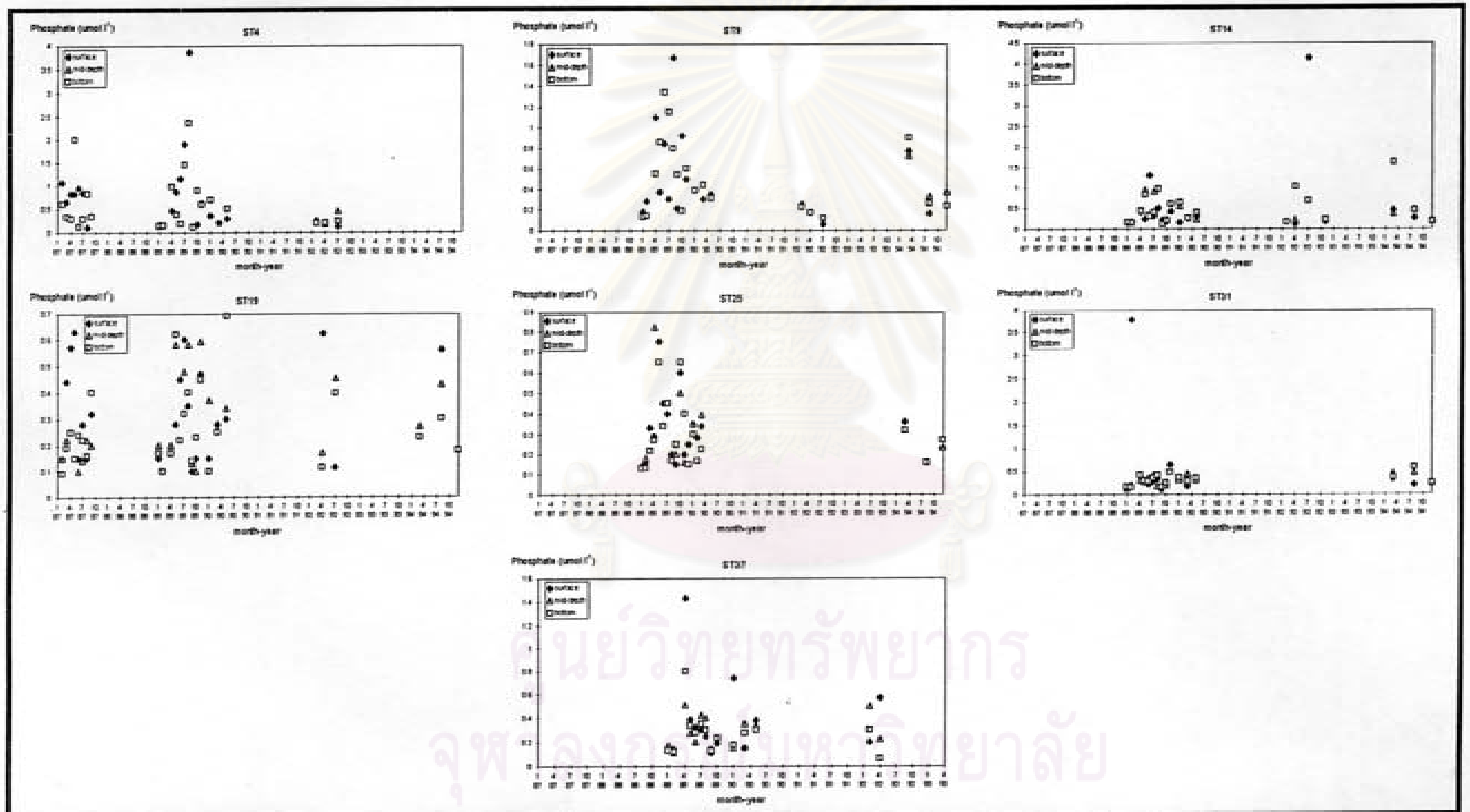

Figure 4.6 (continued)

(a)

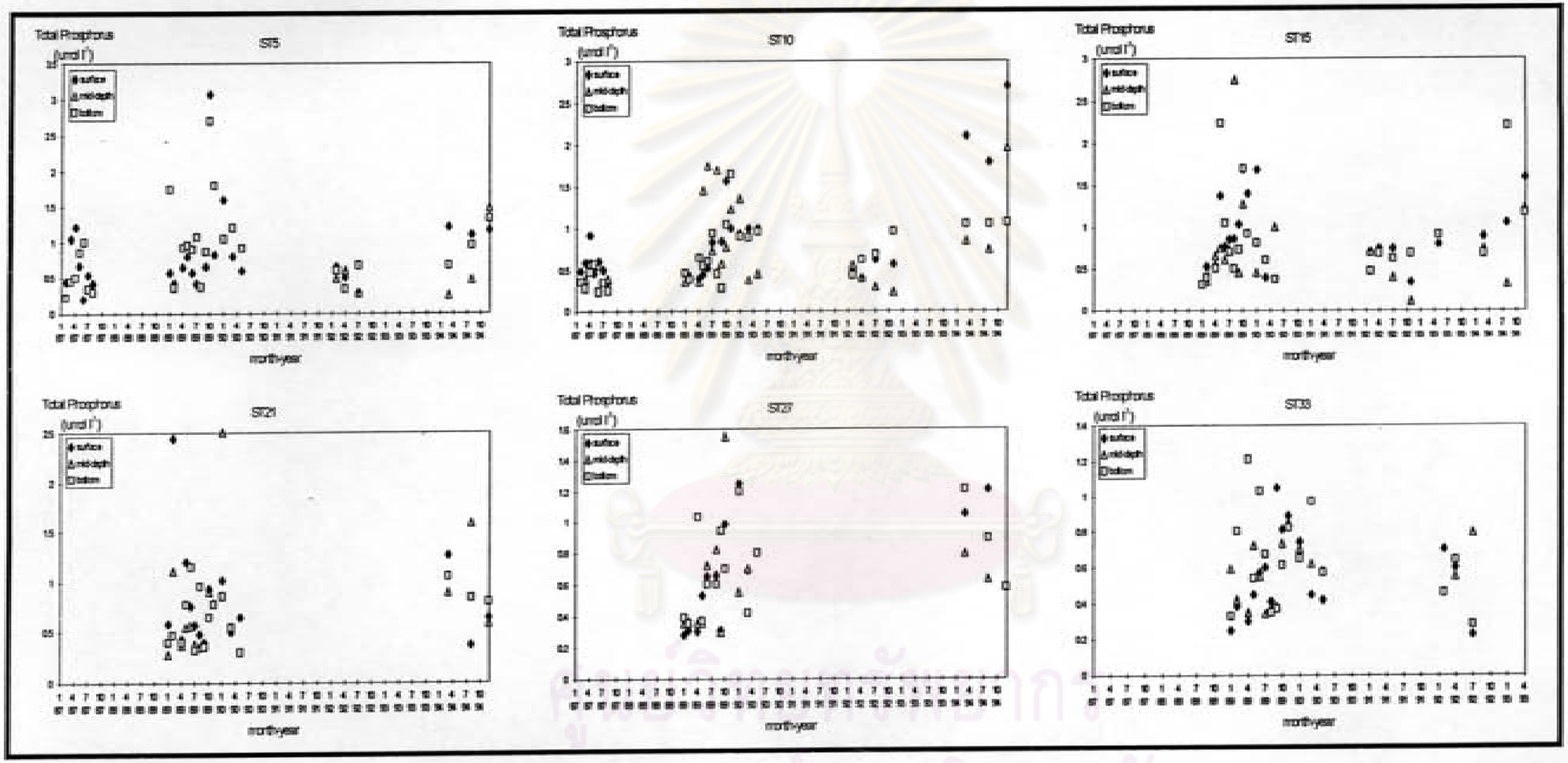

Figure 4.7 Long-term variation of total phosphorus concentrations in the Upper Gulf of Thailand at stations along: (a) western part, (b) central part, and (c) eastern part during 1987-1994.

(b)

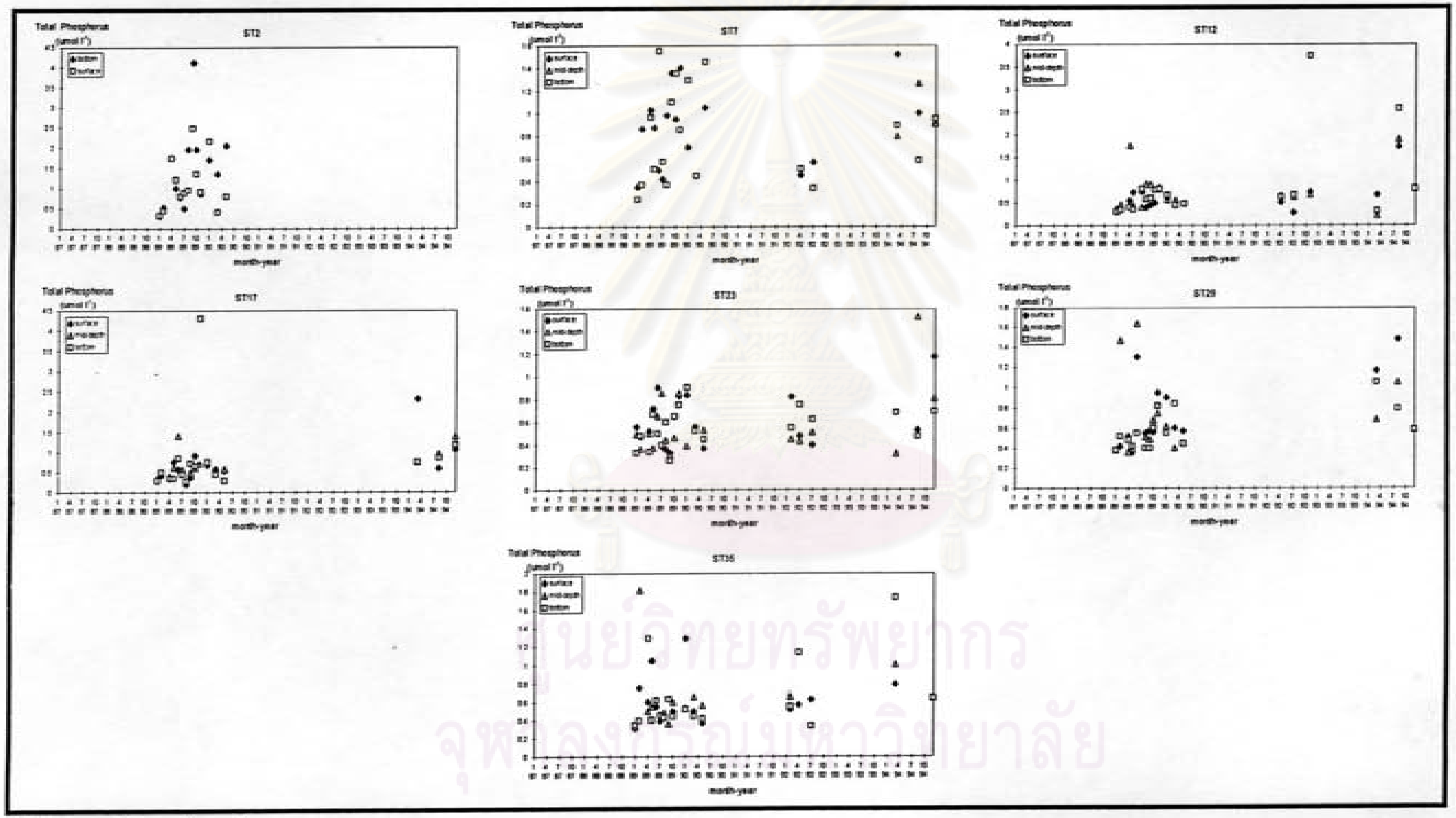

Figure 4.7 (continued)

(c)

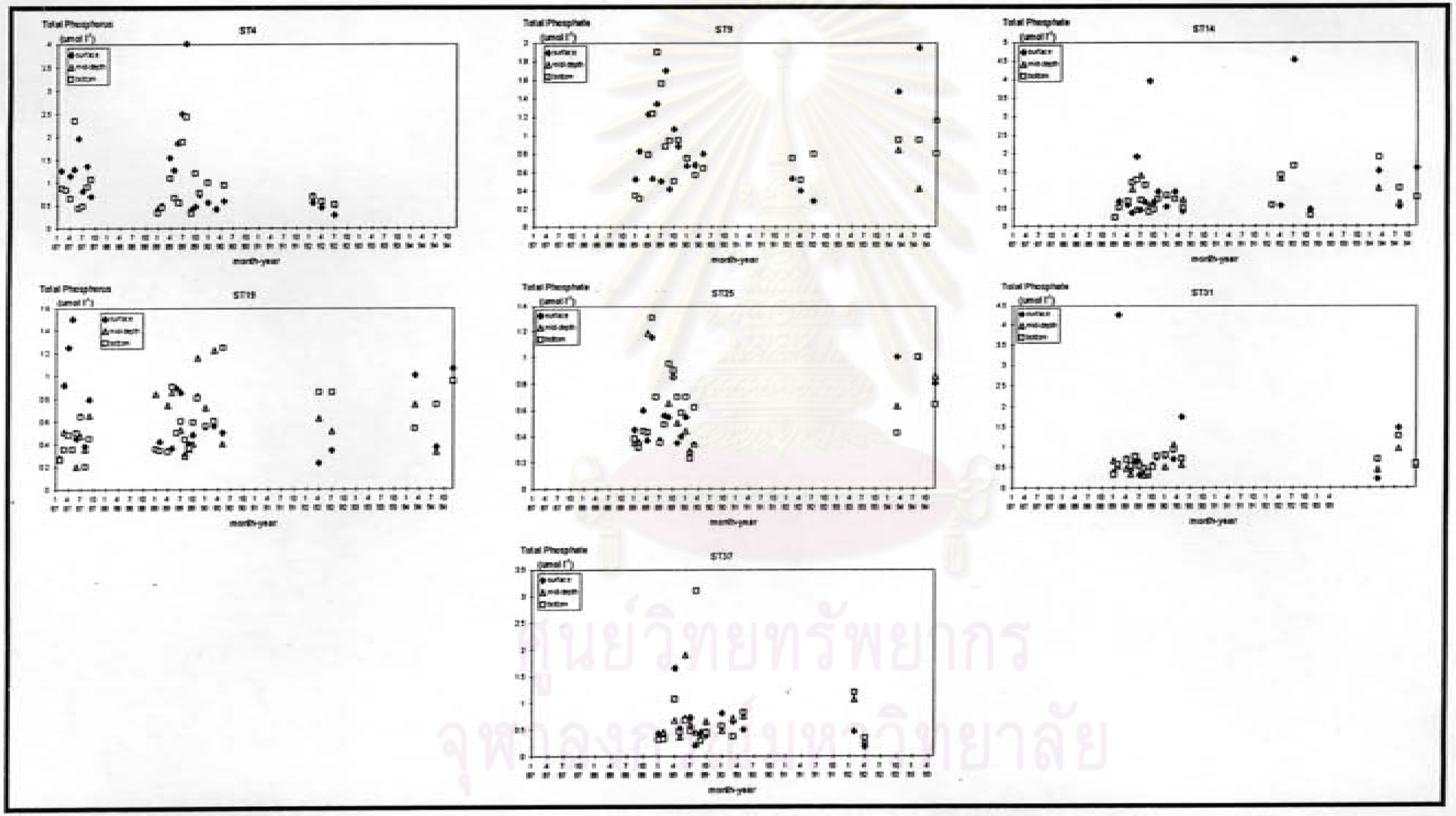

Figure 4.7 (continued)

(a)

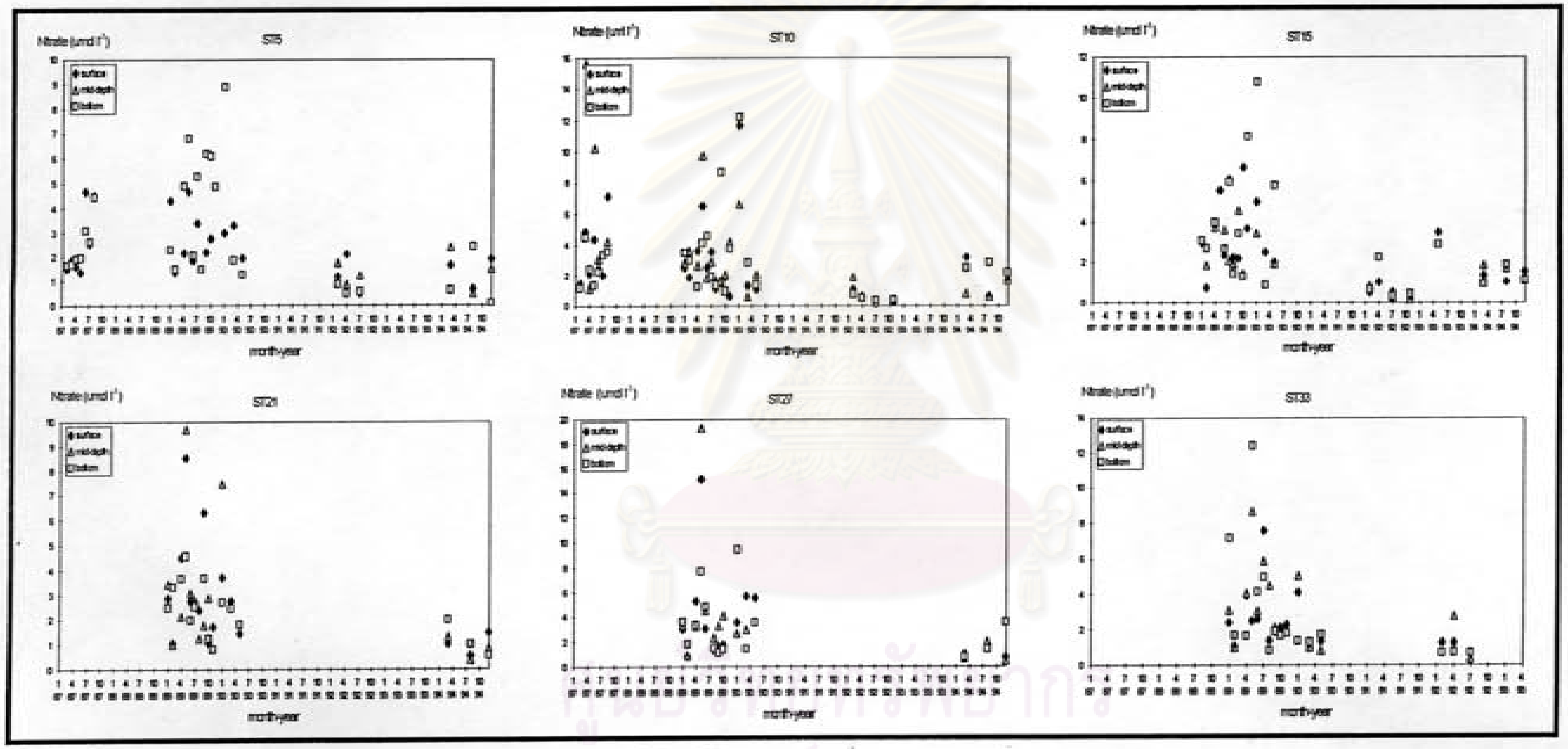

Figure 4.8 Long-term variation of nitrate concentrations in the Upper Gulf of Thailand at stations along: (a) western part, (b) central part, and (c) eastern part during 1987-1994.

(b)

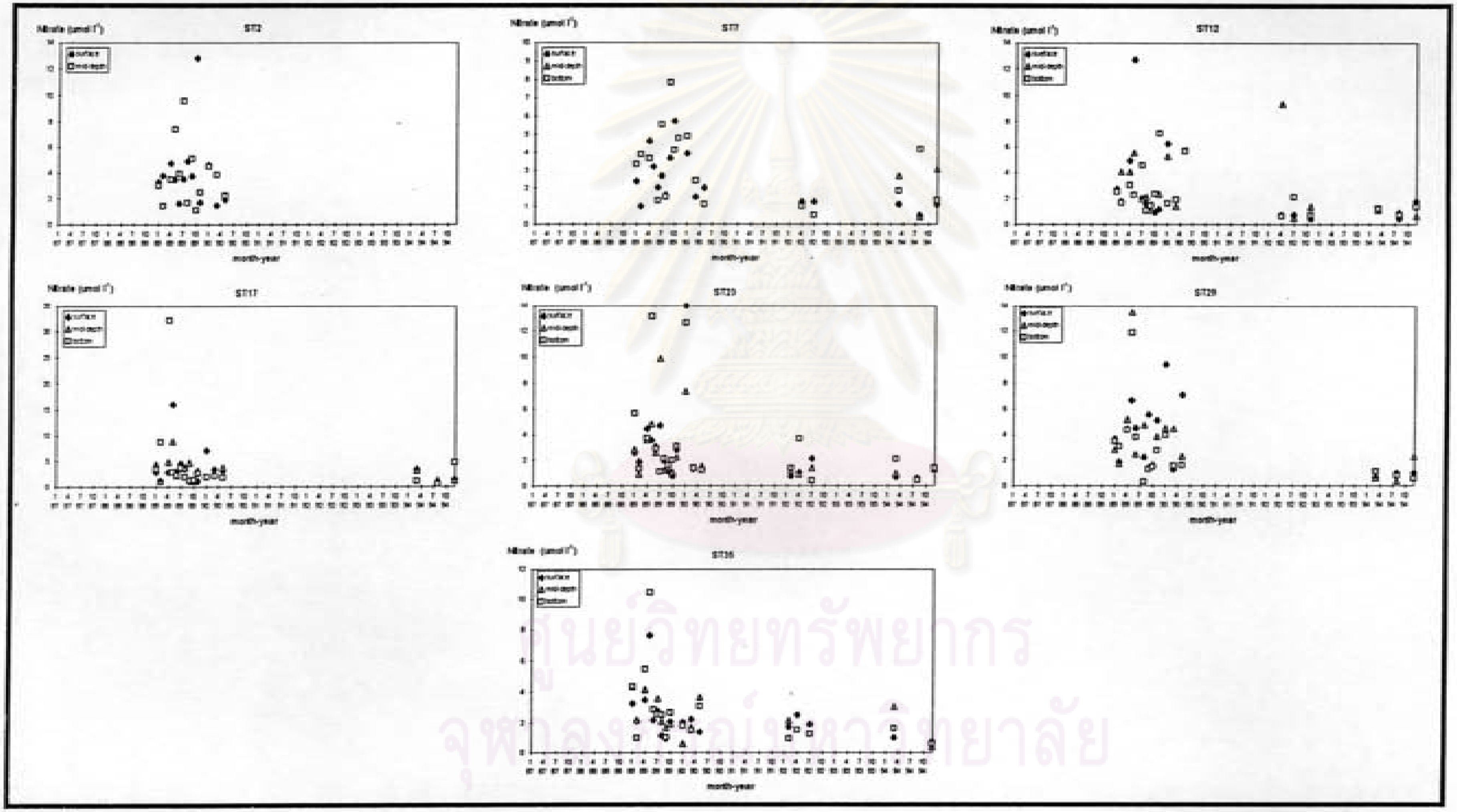

Figure 4.8 (continued)

(c)

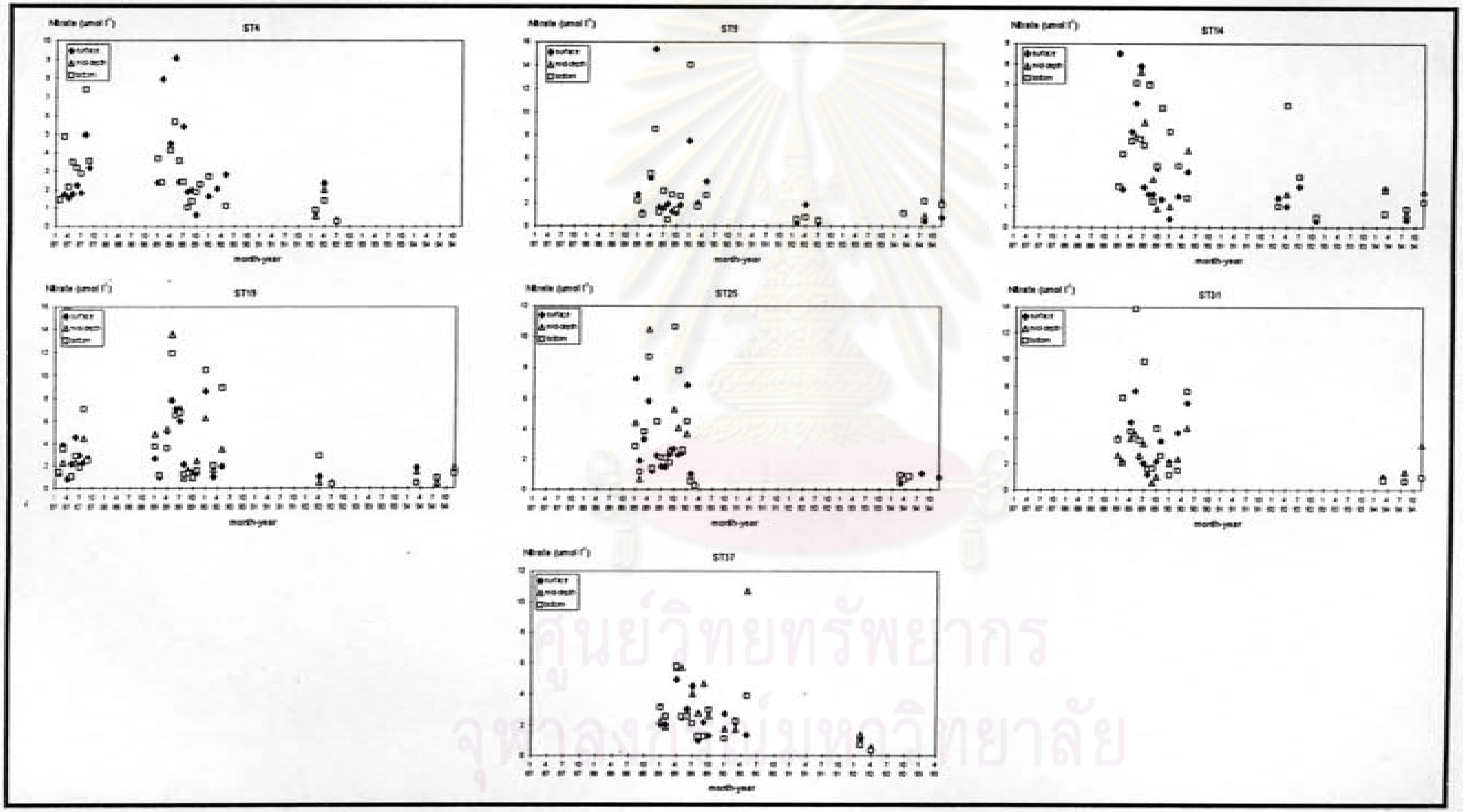

Figure 4.8 (continued)

During the study period, the amount of nutrients from major rivers increased due to the increasing of activities along the shoreline. The concentrations of nutrients in this area should be increased due to high loading of pollutants, but it was found that the concentrations of nutrients in the Upper Gulf of Thailand were quite consistent from time to time. This can be explained that the Upper Gulf of Thailand performed as the filtration area for such contaminants.

Nutrient Mass Balance in the Upper Gulf of Thailand

Single Longitudinal One Dimension Model

The study area was divided into 2 parts, coastal and offshore area, with a boundary at 20 km from the coast.Exchanges between coastal and offshore boxes were estimated from water and salt budget. Mixing coefficients for offshore box during January 1989-May 1990, were calculated from the salt and water budget according to equation (3.5). It was found that apparent (calculated) mixing coefficients were unrealistically high or less than zero for some months which is impossible (Figure 4.9). Thus some adjustments were applied in order to generate realistic results. By assuming that the longitudinal mixing is related to the advective outflows ($Q_{out} = Q_{river} - E + P$), the extrapolations of mixing coefficients for coastal and offshore areas were made using a log-log relationship between these two variables which salinity and freshwater (river runoff, precipitation and evaporation) data during 1979-1984 from the Department of Fishery, the Royal Irrigation Department and the Meteorological Department were added for helping to extrapolate (Figure 4.10). The long-term variation of the practical mixing coefficients for coastal($K_{x,a}$) and offshore ($K_{x,b}$) area during 1979-1994 varied within the range of 5×10^5-3×10^6 and 2×10^6-2×10^7 $cm^2 s^{-1}$, respectively (Figure 4.11). These practical mixing coefficients were used to estimate the nutrient exchange flux between coastal and offshore boxes and the nutrient exchange flux between the offshore box and the Lower Gulf.

The variation patterns of $K_{x,a}$ and $K_{x,b}$ demonstrated the effect of seasonal variation and freshwater exchange (river runoff, precipitation and evaporation) over

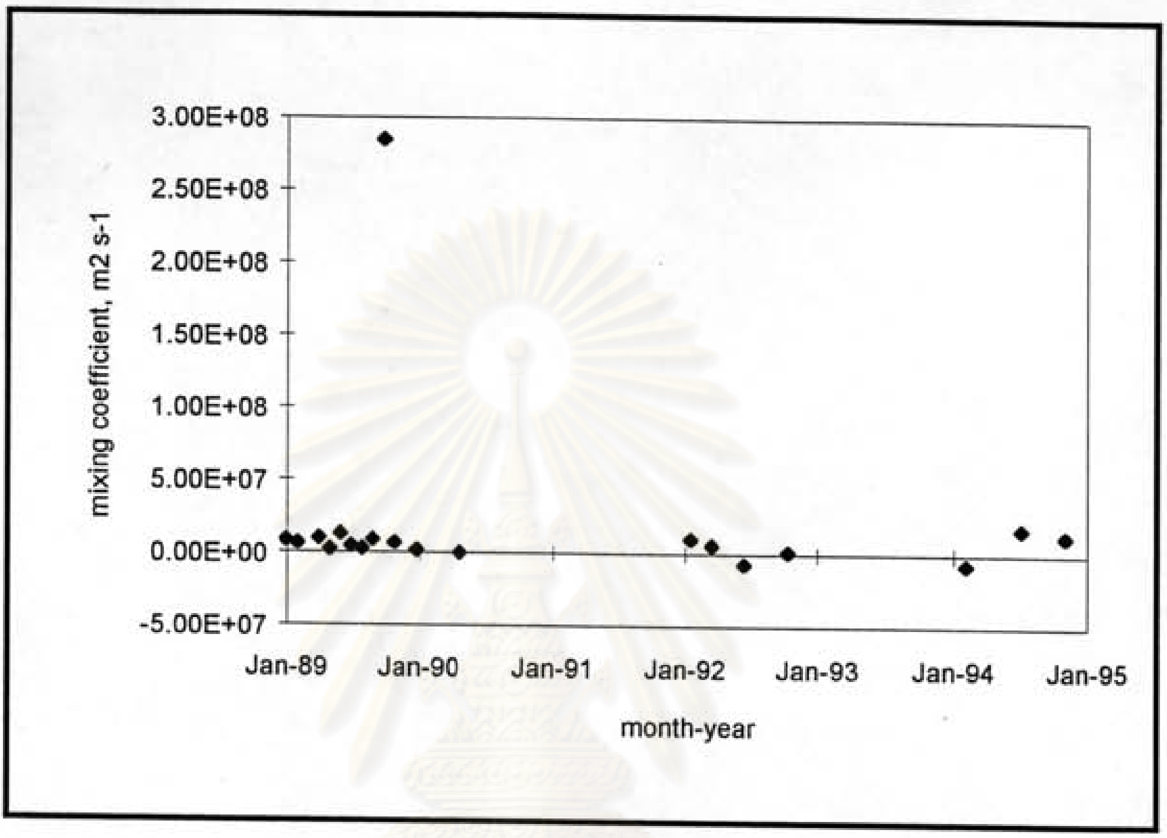

Figure 4.9 The Apparent mixing coefficients for offshore box during January 1989-May 1990

the Upper Gulf. Both $K_{x,a}$ and $K_{x,b}$ are high in wet season and low in dry season. Furthermore, it was found that longitudinal mixing coefficient of coastal area ($K_{x,a}$) was always lower than longitudinal mixing coefficient of offshore area ($K_{x,b}$). It can be applied to the determination of waste dumping into the Upper Gulf area. Lower mixing rate of the water mass between coastal and offshore areas compare to mixing rate of water mass between offshore area and the Lower Gulf caused the retaining of wastes in the coastal area particularly during dry season ($K_{x,a}$ in dry season was lower than in rainy season). It can be applied to explain the flushing of contaminant in the area. Any input of contaminant into the coastal area, < 20 km from the bay head, trends to take longer time to flush out of the area, while the input in the offshore area, > 20 km from the bay head, would gradually flush out to the Lower Gulf.

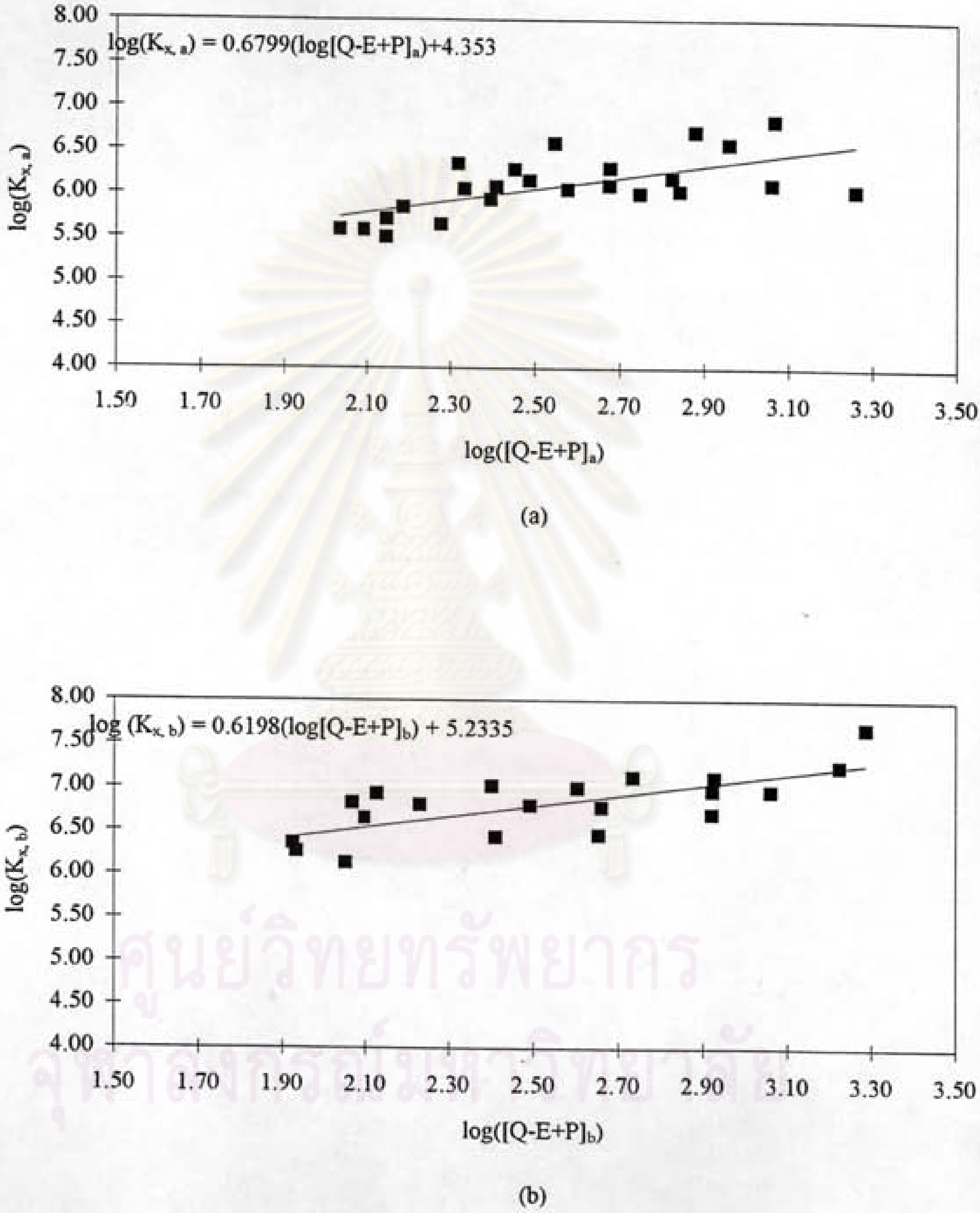

Figure 4.10 Log-log relationship for advective outflows (Q_{out}=Q_{river}-E+P) and apparent mixing coefficients (K_x) for (a) coastal area and (b) offshore area

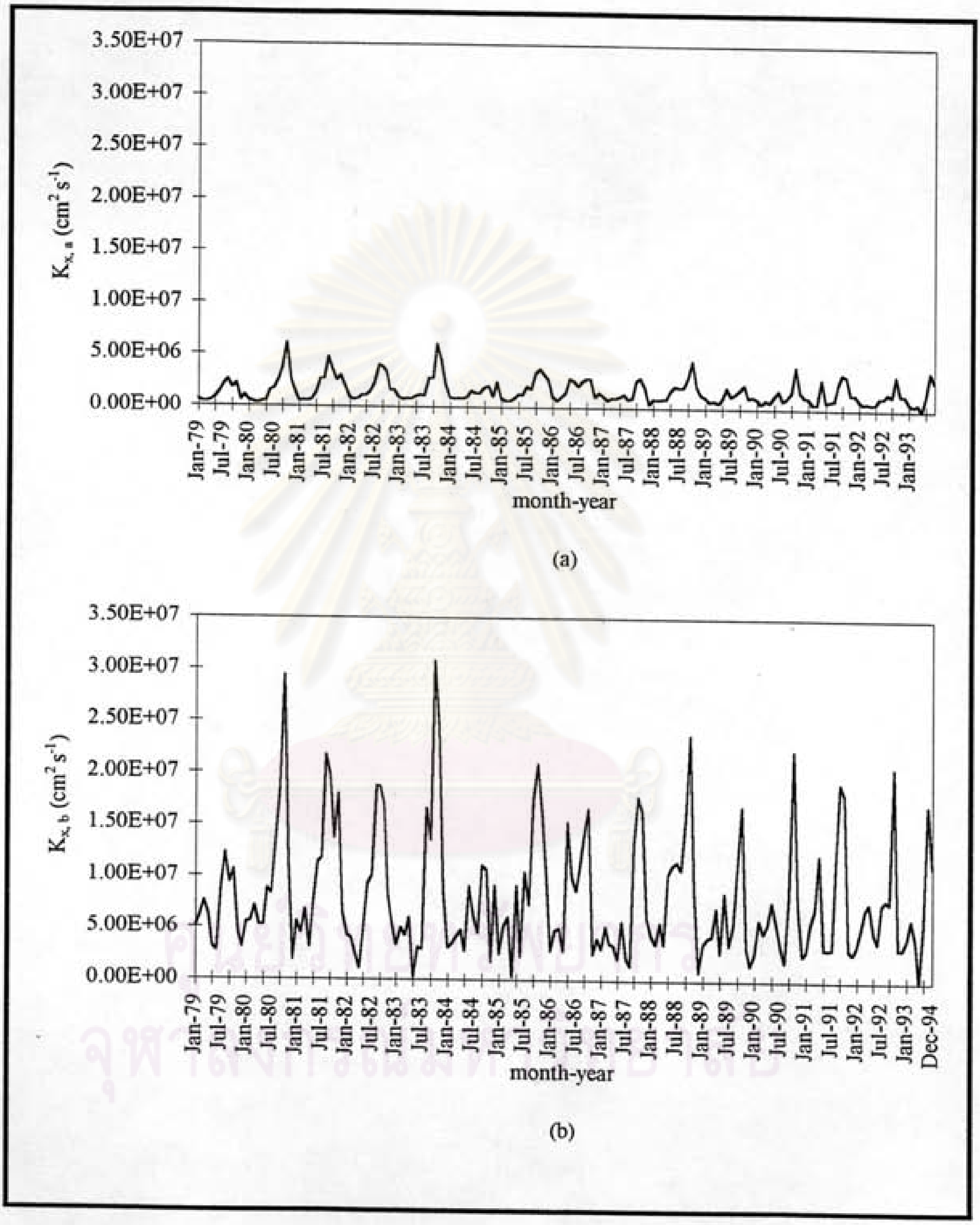

Figure 4.11 Long-term variation of practical mixing coefficients of (a) coastal area and (b) offshore area during 1979-1994

Figures 4.12 and 4.13 showed water advective transport and water mixing rates for coastal and offshore box, respectively. The Upper Gulf of Thailand are dominated with net freshwater inputs in both of coastal and offshore area, except in the offshore area during dry period. In wet period, it was clearly found that the freshwater runoff performed the extremely effect on the advective transport while high evaporation strongly affected over the Upper Gulf in dry period, particularly in the offshore area. Thus, during dry period, the Upper Gulf performed as the evaporative system (evaporation in excess of precipitation and river inflow; residual flow is into the system), especially in offshore area.

The continuous data for riverborne nutrients concentrations were needed to estimate the budgets of nutrients in the Upper Gulf during 1989, 1990 and 1994. According to equation (3.1), available data of river runoff and riverborne nutrient concentrations in 1978-1994 was used to interpolate the monthly concentrations of nutrients (Appendix C). The monthly interpolated nutrient concentrations of four major rivers during 1989, 1990 and 1994 are summarized in Table 4.1. Riverborne nutrient inputs into the Upper Gulf was estimated in the budget based on these interpolated concentrations.

Nutrient budgets (nitrate, nitrite plus nitrate, phosphate and total phosphate) in the water body for each box are modeled according to equation (3.6). Nonconservative fluxes of phosphate, total phosphorus, nitrate and nitrate plus nitrite in coastal and offshore box are shown in Figure 4.14-4.17 and the exchange flux of are summarized in Table 4.2 - 4.5.

Nonconservative fluxes of nutrients (both of phosphate and nitrate) indicated that these nutrients were removed from the water body (both of coastal and offshore box) in the dry season to the early of the wet season. However, the presence of nitrate+nitrite cannot be obviously explained because of the lack of ammonia measurement data. The removal pathways of phosphorus consists of two important processes (biological and sedimentation). Estuarine zone has the process which control

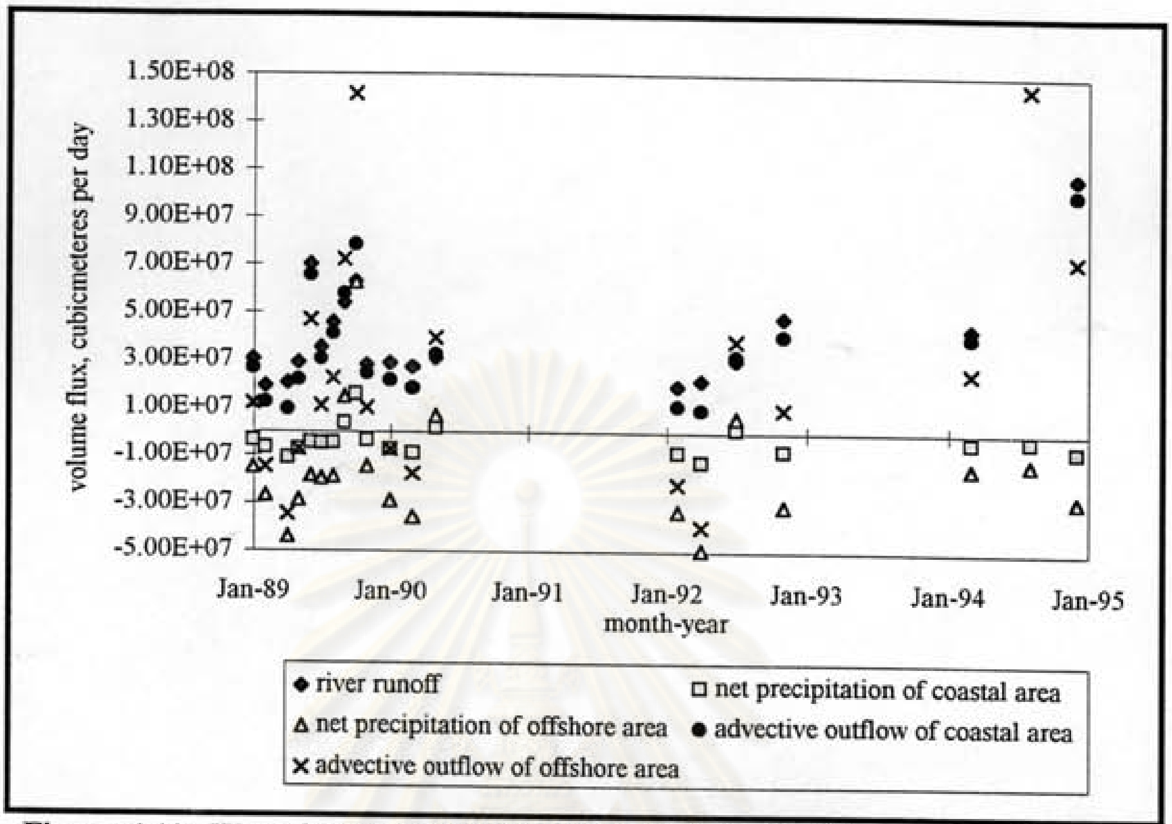

Figure 4.12 Water inflows and outflows for coastal and offshore area n the Upper Gulf of Thailand

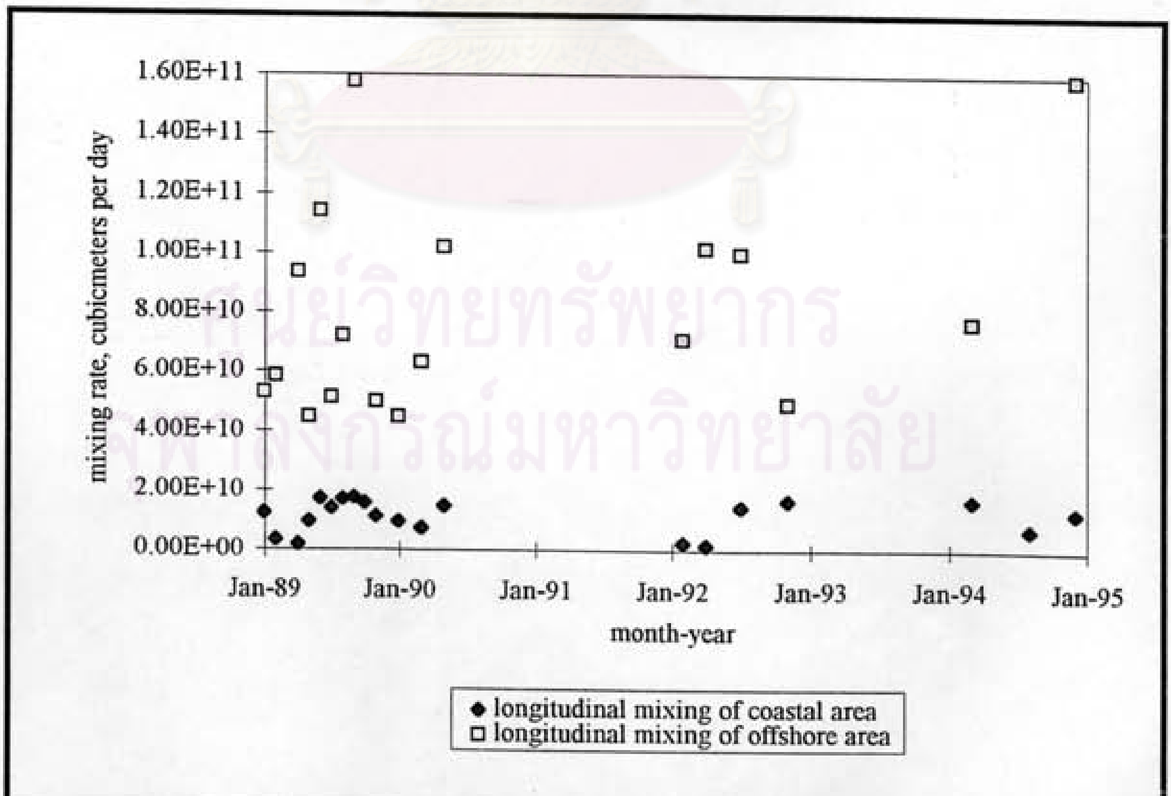

Figure 4.13 Water mixing rates for coastal and offshore area n the Upper Gulf of Thailand

Table 4.1 The monthly extrapolated nutrient concentrations of four major rivers in 1989, 1990 and 1994 (river runoff in m3 s-1, nutrient concentrations in umol l-1)

mth-yr	Chao Phraya River				Mae Klong River				Bangpakong River				Ta Chin River			
	runoff	NO_3^-	PO_4^{3-}	TP	runoff	NO_3^-	PO_4^{3-}	TP	runoff	NO_3^-	PO_4^{3-}	TP	runoff	NO_3^-	PO_4^{3-}	TP
Jan-89	176.70	2.39	2.17	1.40	165.51	3.20	0.37	1.31	7.64	0.79	1.13	0.51	1.97	11.10	2.25	0.66
Feb-89	116.90	1.92	1.59	1.08	96.06	2.71	0.58	1.25	4.31	0.51	0.97	0.32	1.62	10.15	2.38	0.89
Mar-89	129.63	2.03	1.72	1.15	147.38	3.09	0.41	1.30	3.18	0.40	0.89	0.25	1.45	9.63	2.46	1.05
Apr-89	107.25	1.84	1.49	1.03	125.00	2.94	0.47	1.28	3.25	0.40	0.90	0.25	0.58	6.28	3.20	4.28
May-89	106.48	1.83	1.48	1.02	199.85	3.39	0.32	1.34	24.42	1.98	1.55	1.33	2.62	12.69	2.07	0.43
Jun-89	348.38	3.43	3.61	2.13	390.05	4.15	0.18	1.41	72.94	4.68	2.09	3.29	2.10	11.44	2.21	0.60
Jul-89	128.86	2.03	1.71	1.15	178.24	3.27	0.35	1.32	101.39	6.07	2.28	4.31	0.93	7.83	2.79	2.08
Aug-89	107.25	1.84	1.49	1.03	103.40	2.77	0.55	1.26	319.29	14.96	3.12	11.12	1.30	9.17	2.53	1.24
Sep-89	203.32	2.58	2.41	1.53	161.65	3.18	0.38	1.31	257.37	12.62	2.94	9.31	4.75	16.73	1.75	0.17
Oct-89	387.35	3.63	3.91	2.28	176.31	3.26	0.35	1.32	152.24	8.35	2.55	6.03	13.46	27.20	1.30	0.04
Nov-89	180.56	2.42	2.20	1.42	107.25	2.80	0.53	1.27	35.91	2.68	1.72	1.83	2.96	13.44	2.00	0.35
Dec-89	317.90	3.27	3.37	2.02	108.02	2.81	0.53	1.27	16.76	1.47	1.40	0.98	1.10	8.47	2.66	1.61
Jan-90	153.16	2.22	1.94	1.28	175.93	3.26	0.35	1.32	6.62	0.71	1.09	0.45	0.55	6.12	3.25	4.66
Mar-90	135.42	2.08	1.77	1.19	171.68	3.24	0.36	1.32	8.92	0.90	1.18	0.58	0.19	3.75	4.39	23.02
May-90	195.22	2.52	2.33	1.49	147.38	3.09	0.41	1.30	14.96	1.35	1.36	0.89	1.00	8.08	2.74	1.87
Mar-94	341.00	3.39	3.55	2.11	144.00	3.07	0.42	1.30	20.00	1.69	1.47	1.13	2.12	11.49	2.20	0.59
Aug-94	335.86	3.36	3.51	2.09	1344.19	6.05	0.07	1.57	1007.97	36.97	4.26	28.75	1.00	8.08	2.74	1.87
Dec-94	226.00	2.73	2.61	1.63	1013.00	5.55	0.08	1.53	10.00	0.98	1.22	0.64	0.85	7.51	2.86	2.38

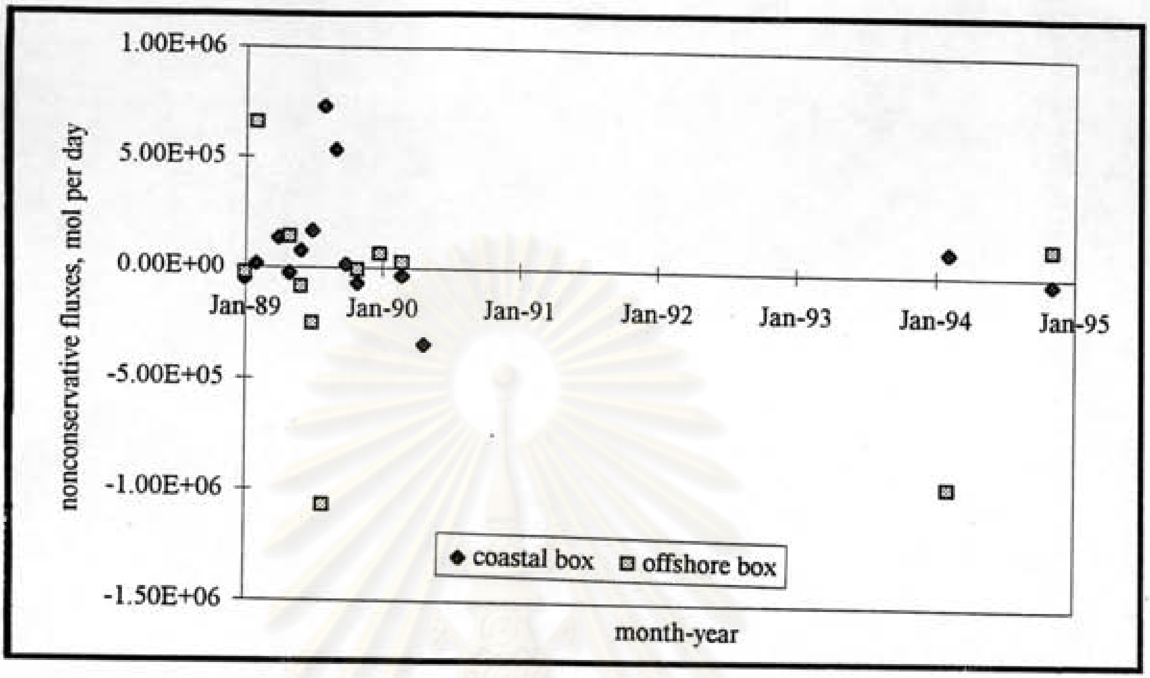

Figure 4.14 Nonconservative fluxes of phosphate for the coastal and offshore boxes in the Upper Gulf of Thailand

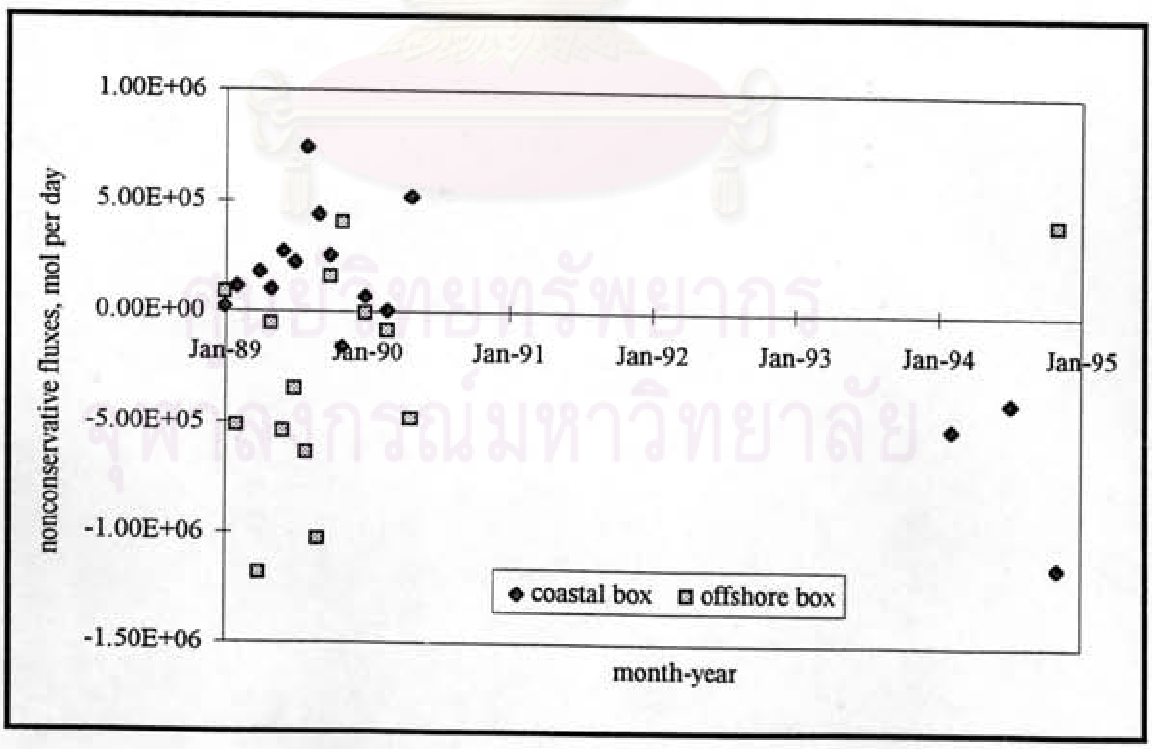

Figure 4.15 Nonconservative fluxes of total phosphorus for the coastal and offshore boxes in the Upper Gulf of Thailand

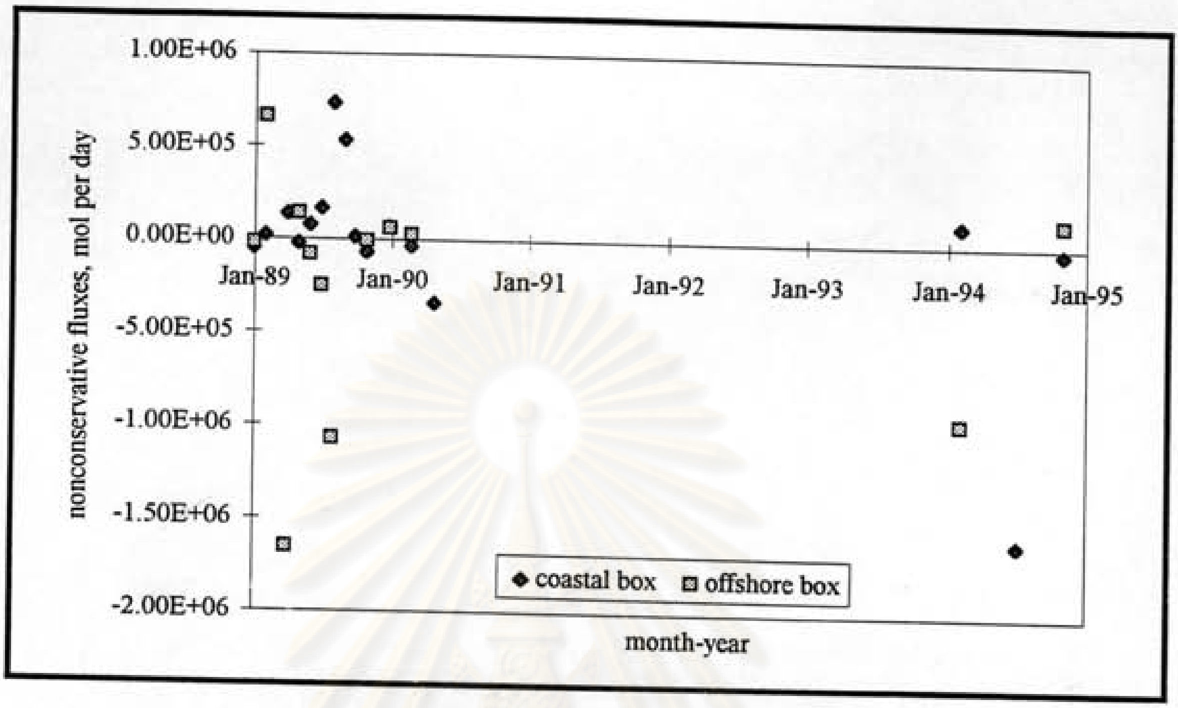

Figure 4.16 Nonconservatives fluxes of nitrate for the coastal and offshore boxes in the Upper Gulf of Thailand

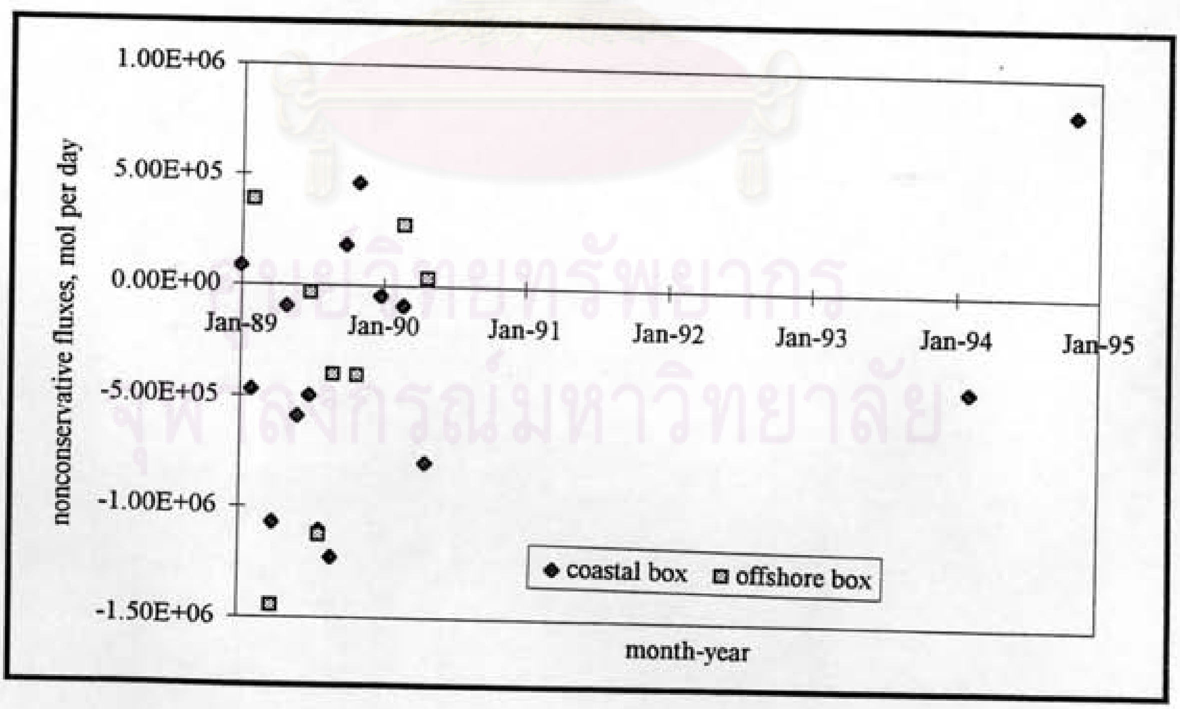

Figure 4.17 Nonconservatives fluxes of nitrate+nitrite for the coastal and offshore boxes in the Upper Gulf of Thailand

Table 4.2 Phosphate flux exchange for coastal and offshore box in the Upper gulf of Thailand

Month	River-load	Source/sink,a	Export,b	Source/sink,b	Net export
Jan-89	4.57E+02	-5.33E+04	-4.86E+03	-2.62E+04	-3.11E+04
Feb-89	2.50E+02	1.55E+04	5.03E+04	6.57E+05	7.07E+05
Apr-89	2.23E+02	1.33E+05	1.62E+05	-1.65E+06	-1.49E+06
May-89	2.64E+02	-2.54E+04	2.46E+04	1.38E+05	1.62E+05
Jun-89	1.49E+03	7.37E+04	2.29E+05	-8.55E+04	1.43E+05
Jul-89	5.16E+02	1.66E+05	2.25E+05	-2.52E+05	-2.69E+04
Aug-89	1.22E+03	7.32E+05	8.63E+05	-1.07E+06	-2.07E+05
Sep-89	1.32E+03	5.34E+05	6.90E+05	-2.90E+06	-2.21E+06
Oct-89	1.98E+03	1.39E+04	2.96E+05	2.96E+06	3.26E+06
Nov-89	5.22E+02	-7.04E+04	-3.74E+03	-8.35E+03	-1.21E+04
Jan-90	3.69E+02	6.69E+04	1.05E+05	6.25E+04	1.67E+05
Mar-90	3.13E+02	-3.45E+04	-5.08E+03	2.50E+04	1.99E+04
May-90	5.39E+02	-3.44E+05	-2.65E+05	1.37E+07	1.34E+07
Mar-94	1.31E+03	1.08E+05	-2.71E+05	-9.58E+05	-3.06E+05
Aug-94	5.57E+03	-1.60E+06	1.12E+06	1.25E+06	4.32E+05
Dec-94	6.88E+02	-2.82E+04	-3.10E+04	1.26E+05	1.67E+05

Table 4.3 Total phosphorus flux exchange for coastal and offshore box in the Upper gulf of Thailand

Month	River-load	Source/sink,a	Export,b	Source/sink,b	Net export
Jan-89	4.06E+04	9.63E+03	1.57E+04	8.66E+04	1.02E+05
Feb-89	2.16E+04	6.74E+03	1.35E+05	-5.15E+05	-3.80E+05
Apr-89	2.36E+04	8.53E+03	2.03E+05	-1.19E+06	-9.83E+05
May-89	3.54E+04	1.85E+04	1.34E+05	-5.48E+04	7.96E+04
Jun-89	1.33E+05	7.41E+04	3.94E+05	-5.41E+05	-1.47E+05
Jul-89	7.11E+04	2.77E+04	2.86E+05	-3.50E+05	-6.32E+04
Aug-89	3.28E+05	3.09E+04	8.83E+05	-6.35E+05	2.47E+05
Sep-89	2.52E+05	4.62E+04	7.31E+05	-1.03E+06	-2.97E+05
Oct-89	1.76E+05	1.21E+05	4.75E+05	1.60E+05	6.35E+05
Nov-89	3.96E+04	2.67E+04	-1.05E+05	4.05E+05	3.00E+05
Jan-90	6.88E+04	2.01E+04	1.39E+05	-4.70E+03	1.35E+05
Mar-90	3.43E+04	1.27E+04	4.29E+04	-8.32E+04	-4.04E+04
May-90	4.30E+04	2.58E+04	5.64E+05	-4.82E+05	8.24E+04
Mar-94	8.03E+04	3.84E+04	-1.16E+06	-6.52E+06	-7.68E+06
Aug-94	2.75E+06	1.52E+05	-2.20E+05	-6.60E+06	-6.82E+06
Dec-94	1.67E+05	1.11E+05	1.11E+05	4.17E+05	5.27E+05

Table 4.4 Nitrate flux exchange for coastal and offshore box in the Upper gulf of Thailand

Month	River-load	Source/sink,a	Export,b	Source/sink,b	Net export
Jan-89	8.47E+04	1.45E+05	-1.10E+04	-2.59E+05	-2.70E+05
Feb-89	4.36E+04	1.04E+05	1.47E+05	1.15E+06	1.30E+06
Apr-89	4.92E+04	1.79E+08	1.79E+08	2.80E+09	2.98E+09
May-89	8.24E+04	-2.39E+06	-2.32E+06	-1.06E+08	-1.09E+08
Jun-89	2.75E+05	4.10E+04	2.99E+05	-1.51E+05	1.47E+05
Jul-89	1.27E+05	1.62E+06	1.74E+06	2.61E+07	2.79E+07
Aug-89	4.56E+05	-4.51E+05	-2.41E+05	3.60E+06	3.36E+06
Sep-89	3.77E+05	9.42E+05	1.37E+06	-2.23E+05	1.15E+06
Oct-89	3.13E+05	1.69E+06	2.06E+06	-4.26E+06	-2.20E+06
Nov-89	7.55E+04	-2.28E+05	-1.35E+05	-1.38E+06	-1.52E+06
Jan-90	7.96E+04	-1.44E+06	-1.36E+06	7.24E+06	5.88E+06
Mar-90	7.31E+04	1.21E+05	1.94E+05	1.47E+05	3.42E+05
May-90	8.43E+04	-3.45E+05	-2.61E+05	-9.18E+05	-1.18E+06
Mar-94	1.43E+05	-1.09E+06	-9.51E+05	7.84E+05	-1.67E+05
Aug-94	4.02E+06	1.55E+06	2.50E+06	-4.40E+06	-1.90E+06
Dec-94	5.40E+05	-3.68E+05	2.04E+05	3.42E+06	3.62E+06

Table 4.5 Nitrate+nitrite flux exchange for coastal and offshore box in the Upper gulf of Thailand

Month	River-load	Source/sink,a	Export,b	Source/sink,b	Net export
Jan-89	8.47E+04	8.61E+04	1.69E+05	-1.64E+06	-1.47E+06
Feb-89	4.36E+04	2.23E+04	4.79E+04	3.84E+05	4.32E+05
Apr-89	4.92E+04	4.09E+04	2.86E+05	-1.45E+06	-1.16E+06
May-89	8.24E+04	2.06E+05	-1.99E+06	2.80E+06	8.10E+05
Jun-89	2.75E+05	1.82E+05	2.16E+06	-4.36E+06	-2.19E+06
Jul-89	1.27E+05	1.49E+05	1.29E+06	-3.45E+04	1.26E+06
Aug-89	4.56E+05	6.93E+04	3.39E+05	-1.13E+06	-7.87E+05
Sep-89	3.77E+05	1.82E+05	1.47E+06	-4.02E+05	1.07E+06
Oct-89	3.13E+05	3.09E+05	2.71E+06	-4.74E+06	-2.03E+06
Nov-89	7.55E+04	5.42E+04	-4.94E+05	-4.07E+05	-9.00E+05
Jan-90	7.96E+04	1.37E+05	-1.56E+06	5.76E+06	4.20E+06
Mar-90	7.31E+04	4.54E+04	1.16E+05	2.76E+05	3.92E+05
May-90	8.43E+04	7.86E+04	5.96E+05	3.70E+04	6.33E+05
Mar-94	1.43E+05	7.48E+04	-1.25E+08	6.70E+08	5.45E+08
Aug-94	4.02E+06	3.06E+05	2.61E+08	1.69E+09	1.95E+09
Dec-94	5.40E+05	1.91E+05	-2.63E+08	7.78E+08	5.16E+08

the concentration of phosphorus in water not to be fluctuated (Buffering Processes). These processes include the adsorption and desorption from the surface of particles which maintained the equilibrium of the concentration of sediment and saturated sediment water. The exchange of phosphorus at the surface of sediment was depended on several factors such as pH, salinity, temperature, redox potential value, phosphorus input rate into water body and bioproductivity in the water system. Adsorption of phosphate onto surface of clay minerals increased with the increase of and pH (highest at pH 3-7). In case of constant pH and temperature, higher salinity causes a decrease in the adsorption.

Box Model

Another approach was to establish nutrient budgets in order to estimate roughly internal transportation in the Upper Gulf of Thailand in addition to advective and longitudinal mixing. Since, in some periods particularly wet season, there were some difference between the river runoff which drained into the eastern and western part of the Upper Gulf and there were extreme variations on precipitation and evaporation over the Upper Gulf affected on the water exchange between eastern and western part of the Upper Gulf. The study area was divided (as mention above) into six boxes in order to construct the nutrient budgets and net transport between boxes.

Water and salt exchange fluxes between boxes were calculated using equation 3.8 and 3.9 to determine the water transportation (Figure 4.18). Figure 4.19-4.22 illustrated the nutrient budgets for phosphate, total phosphorus, nitrate and nitrate plus nitrite in each boxes. In this model there was clearly some exchange of water between the eastern and western part of the Gulf which was not takes into concentrations in the first approach. The result also showed that there were small scale circulations patterns in the Upper Gulf of Thailand. Most of the cases, the circulation pattern of the upper portion and the lower portion of the area were in opposite direction. Conversions of circulation pattern over the year were observed but no clear conclusion on the seasonal pattern can be made.

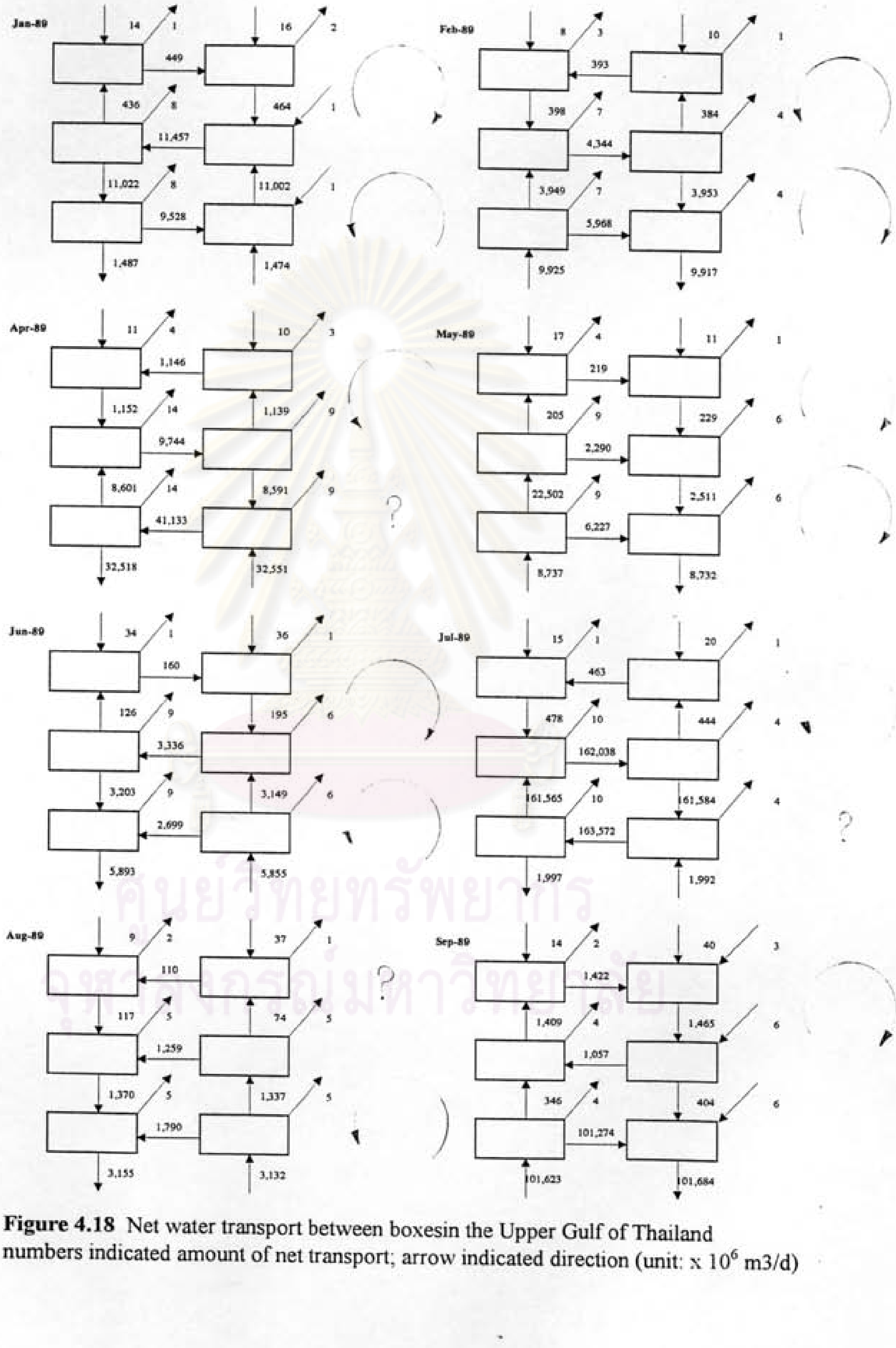

Figure 4.18 Net water transport between boxesin the Upper Gulf of Thailand numbers indicated amount of net transport; arrow indicated direction (unit: x 10^6 m3/d)

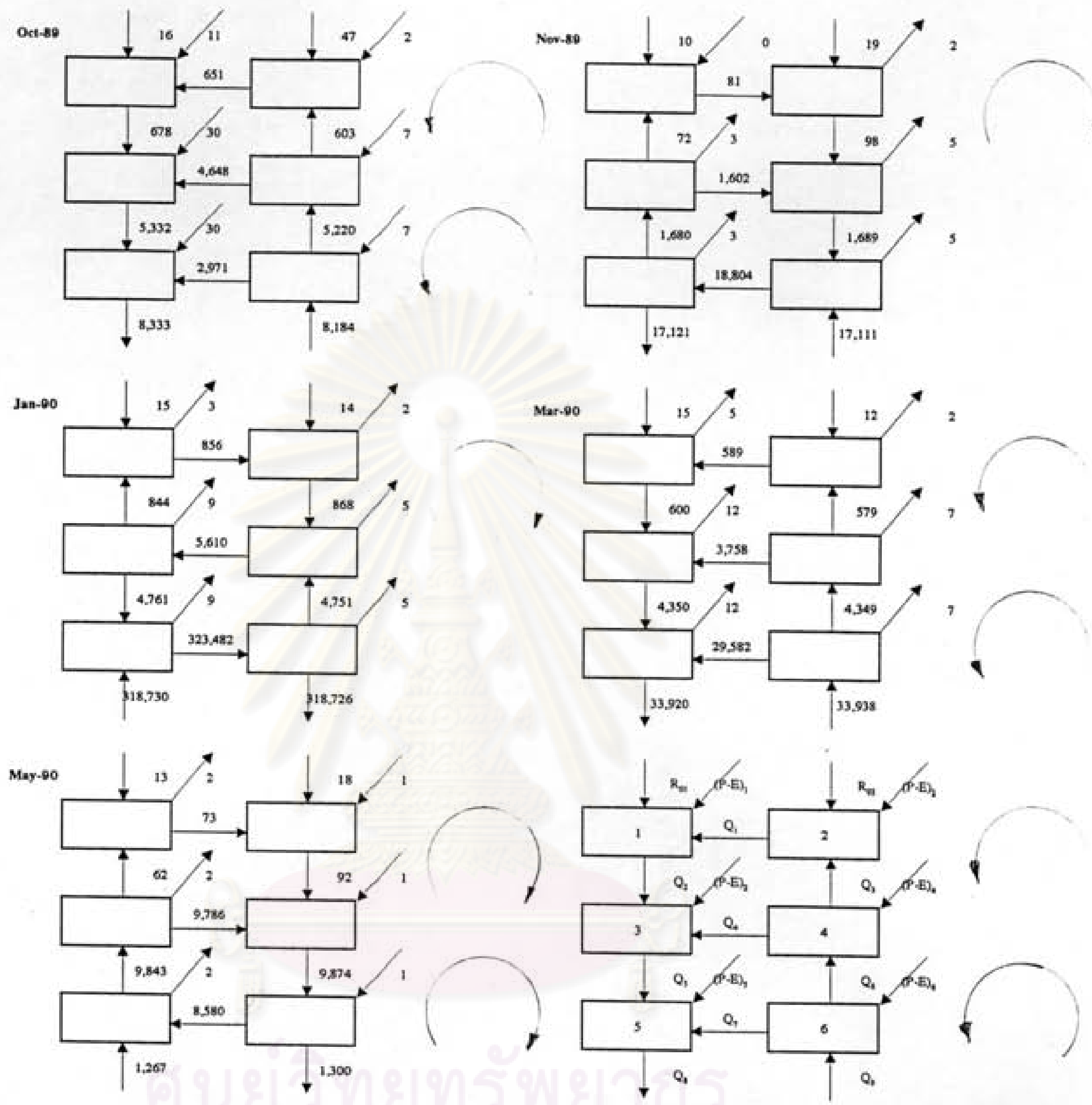

Figure 4.18 (continued)

R_{01}	: River runoff from Mae klong and Ta Chin Rivers
R_{02}	: River runoff from Chao Phraya and Bangpakong Rivers
Q_1-Q_9	: Net water transport between boxes
P	: Precipitation
E	: Evaporation

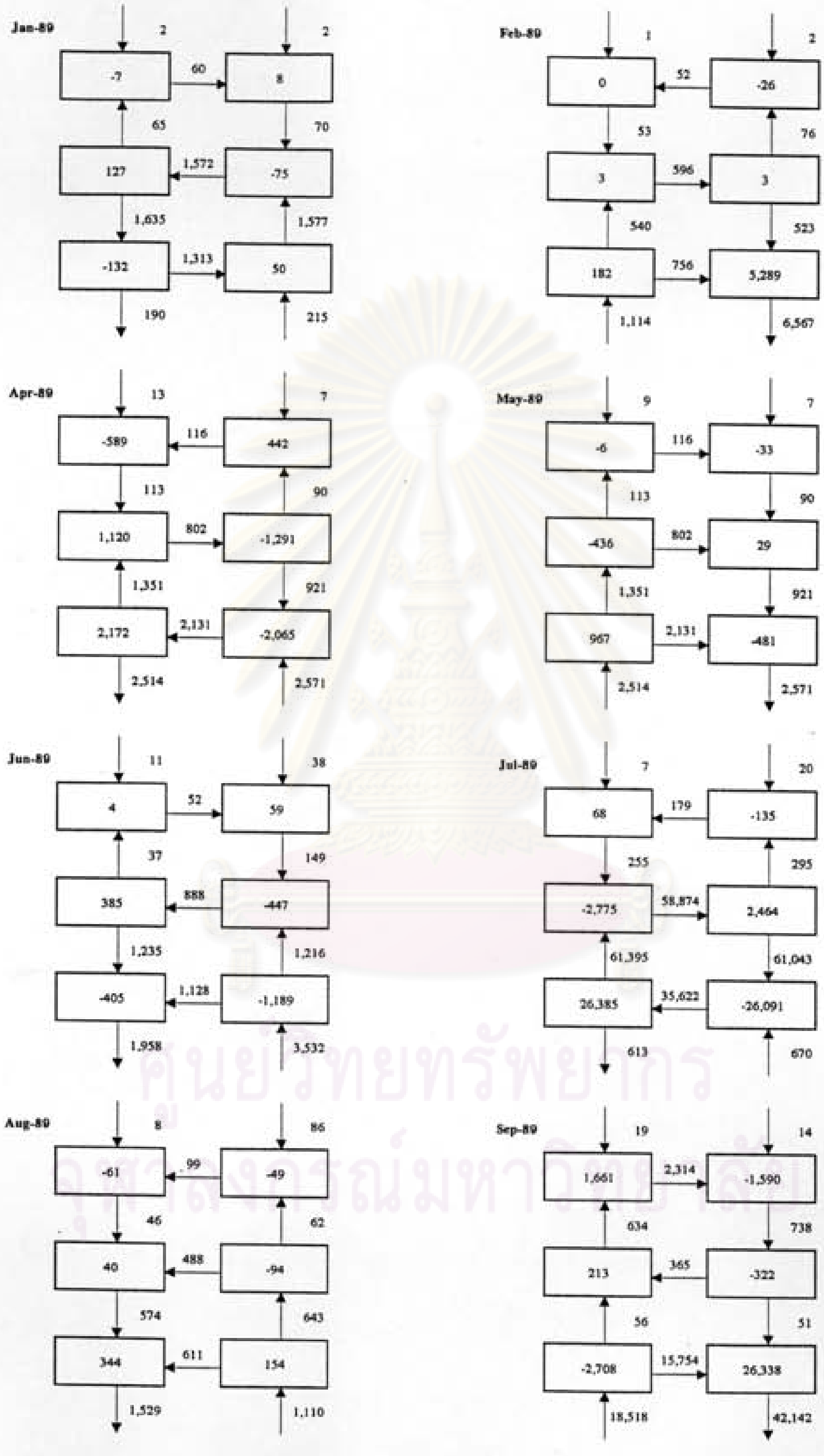

Figure 4.19 Phosphate budget for six boxes in the Upper Gulf of Thailand
numbers indicated amount of net transport; arrow indicated direction (unit: x 10^3 mol/d)
numbers in boxes indicated net budget of nutrient (negative: net sink; positive: net production)

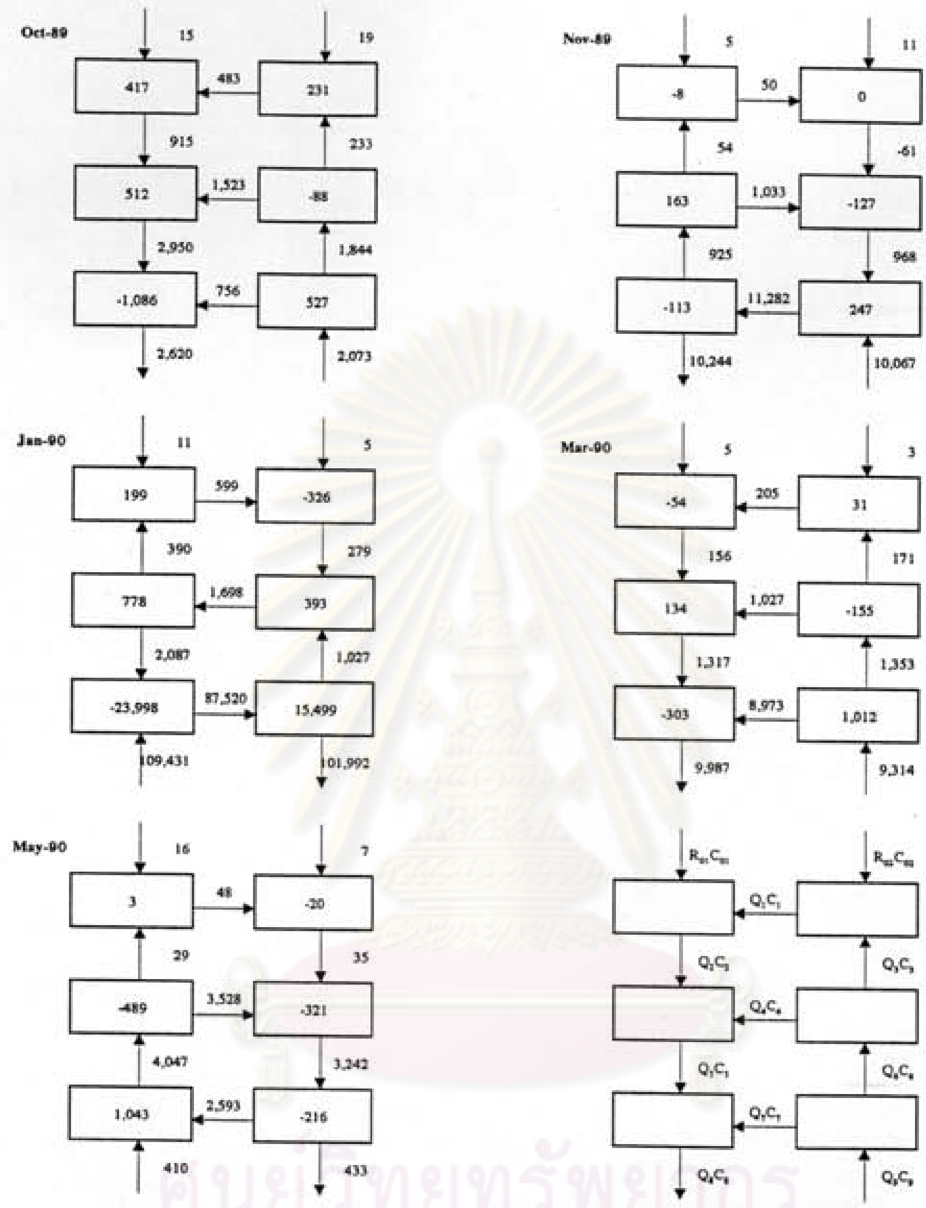

Figure 4.19 (continued)

R_{01}	: River runoff from Mae Klong and Ta Chin Rivers
R_{02}	: River runoff from Chao Phraya and Bangpakong Rivers
C_{01}	: Average nutrient concentrations at norhtern boundary of box 1
C_{02}	: Average nutrient concentrations at norhtern boundary of box 2
Q_1-Q_9	: Net water transport between boxes
C_1-C_9	: Average nutrient concentrations at boundary of each box
P	: Precipitation
E	: Evaporation

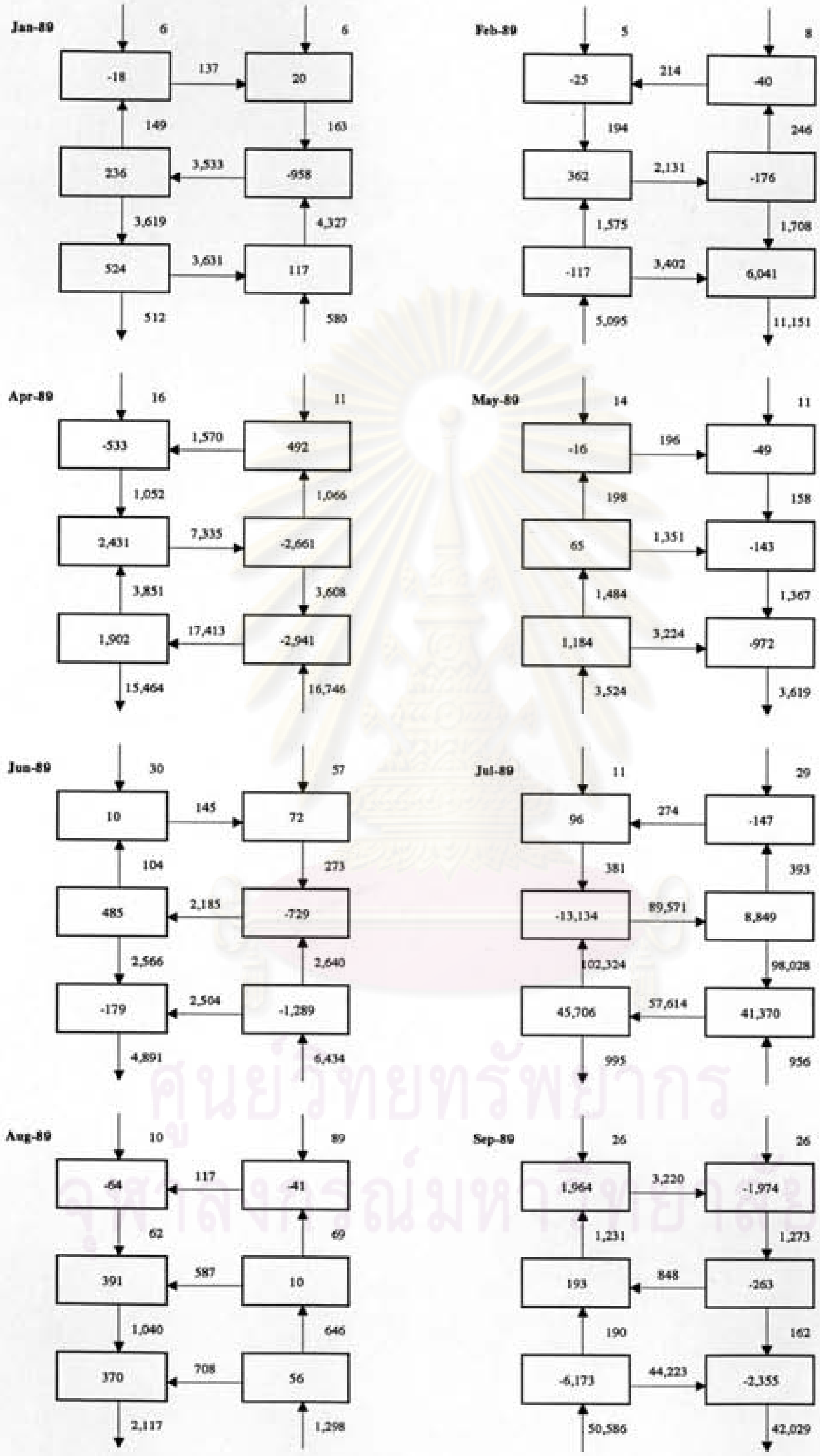

Figure 4.20 Total phophorus budget for six boxes in the Upper Gulf of Thailand numbers indicated amount of net transport; arrow indicated direction (unit: x 10^3 mol/d) numbers in boxes indicated net budget of nutrient (negative: net sink; positive: net production)

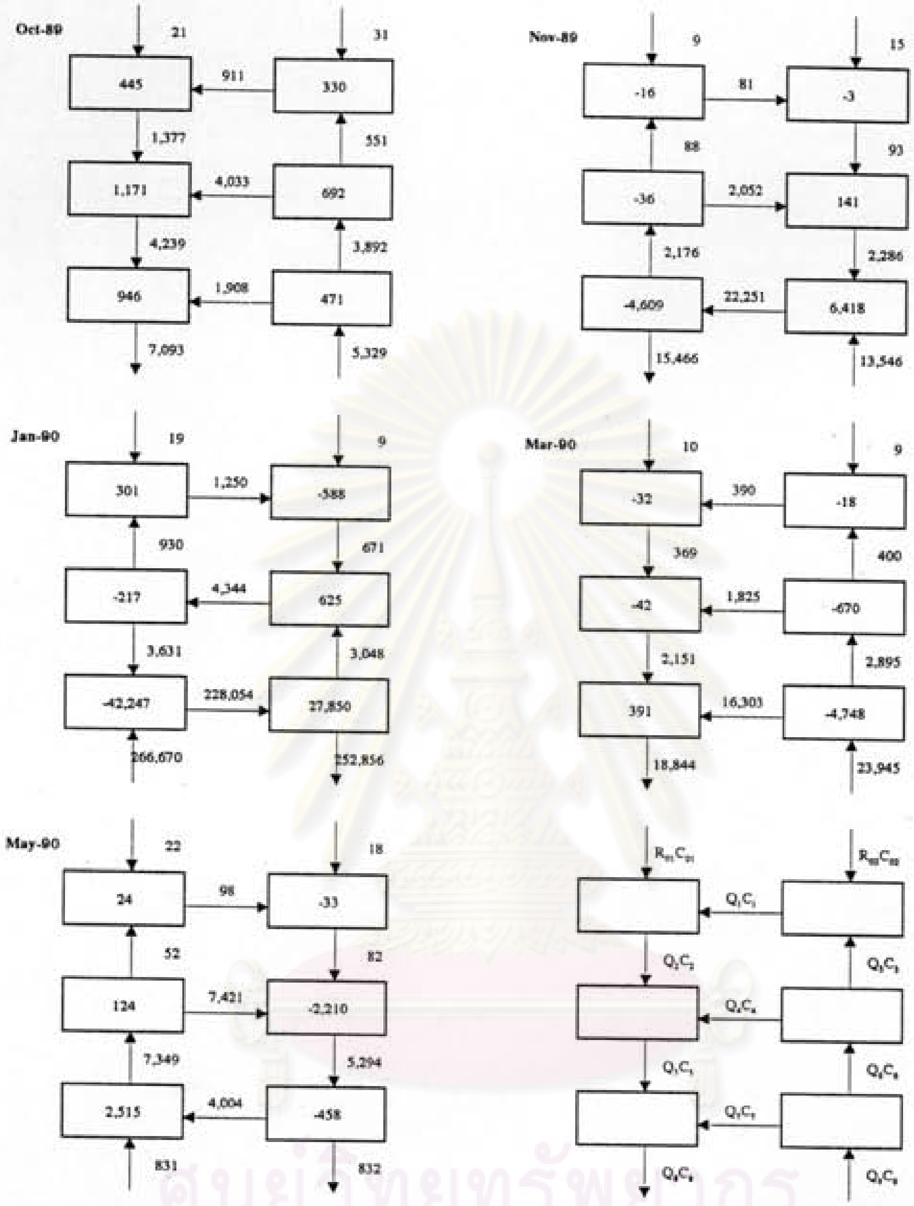

Figure 4.20 (continued)

R_{01}	: River runoff from Mae Klong and Ta Chin Rivers
R_{02}	: River runoff from Chao Phraya and Bangpakong Rivers
C_{01}	: Average nutrient concentrations at norhtern boundary of box 1
C_{02}	: Average nutrient concentrations at norhtern boundary of box 2
Q_1-Q_9	: Net water transport between boxes
C_1-C_9	: Average nutrient concentrations at boundary of each box
P	: Precipitation
E	: Evaporation

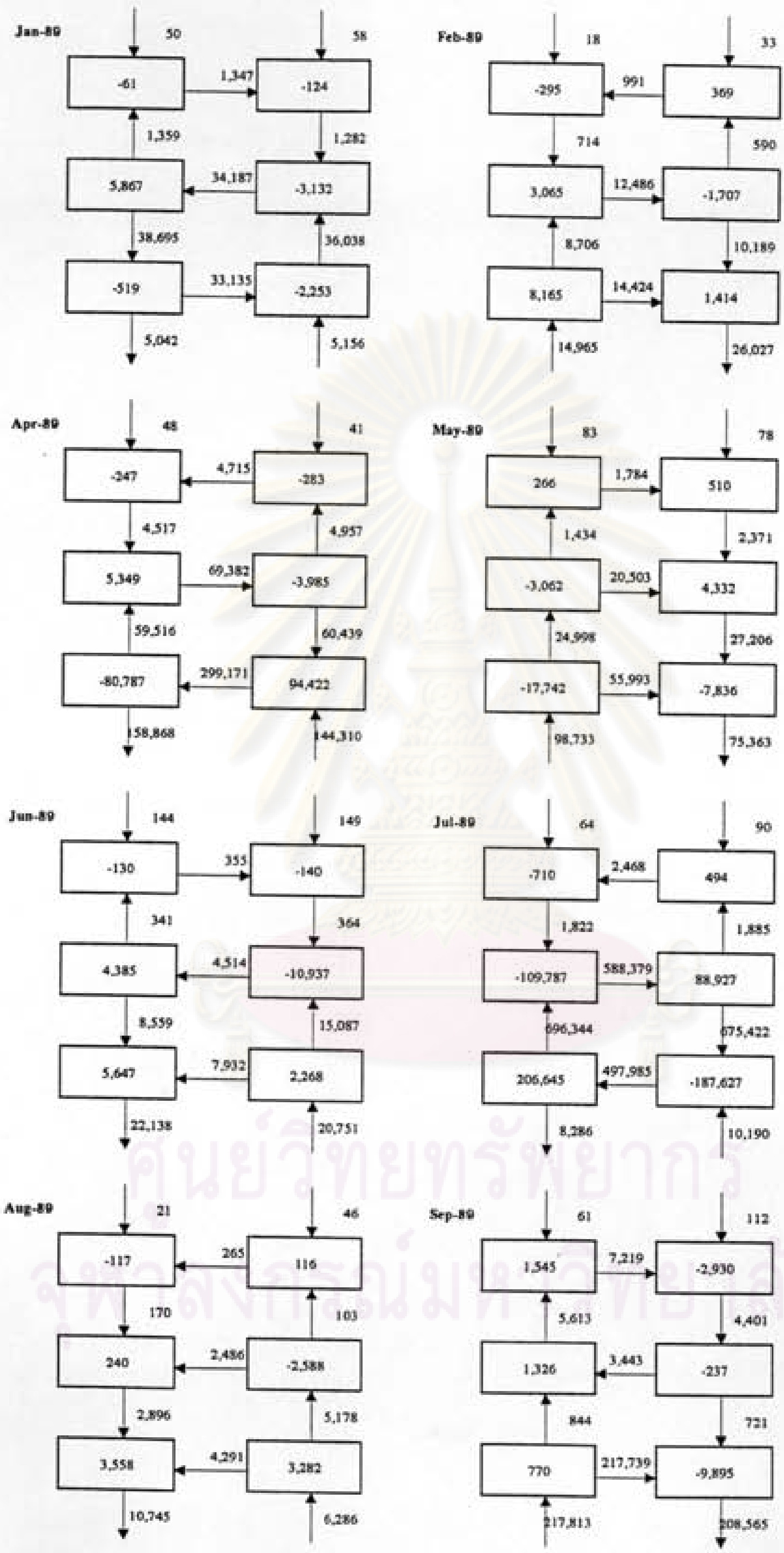

Figure 4.21 Nitrate budget for six boxes in the Upper Gulf of Thailand
numbers indicated amount of net transport; arrow indicated direction (unit: x 10^3 mol/d)
numbers in boxes indicated net budget of nutrient (negative: net sink; positive: net production)

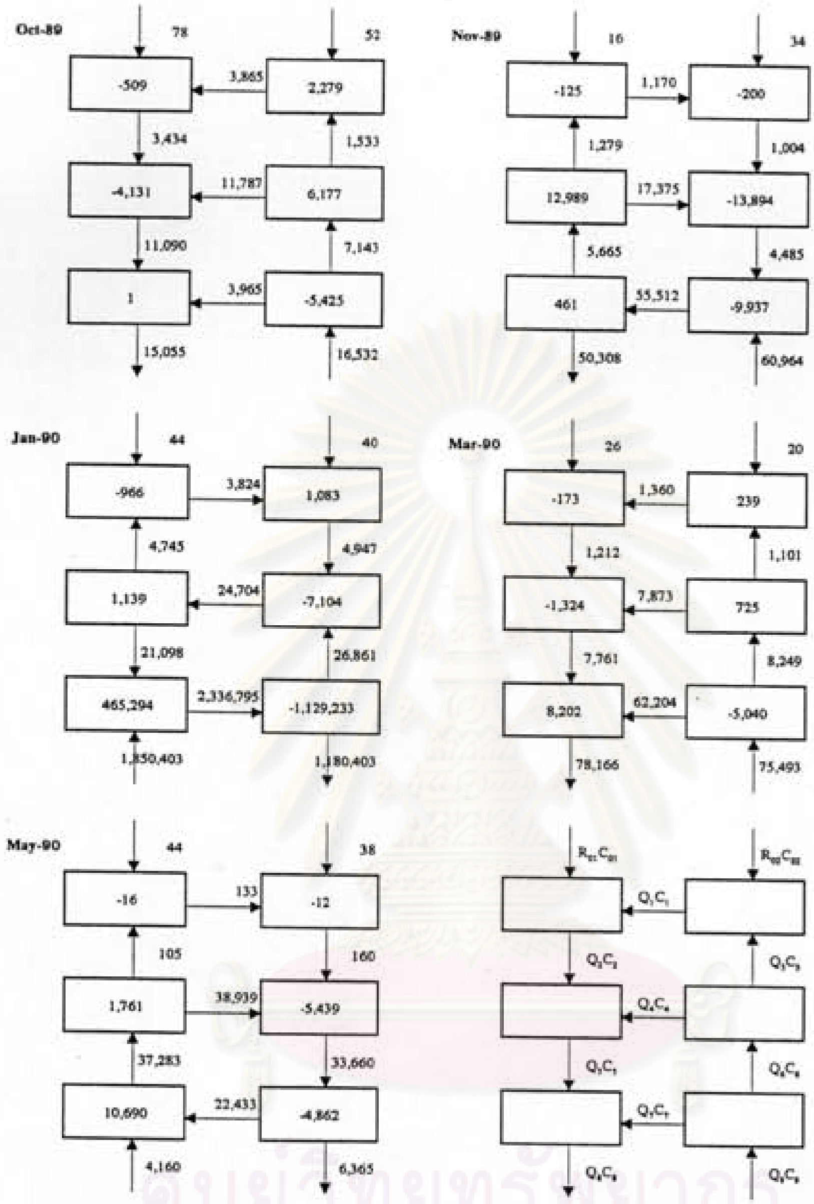

Figure 4.21 (continued)

R_{01}	: River runoff from Mae Klong and Ta Chin Rivers
R_{02}	: River runoff from Chao Phraya and Bangpakong Rivers
C_{01}	: Average nutrient concentrations at norhtern boundary of box 1
C_{02}	: Average nutrient concentrations at norhtern boundary of box 2
Q_1-Q_9	: Net water transport between boxes
C_1-C_9	: Average nutrient concentrations at boundary of each box
P	: Precipitation
E	: Evaporation

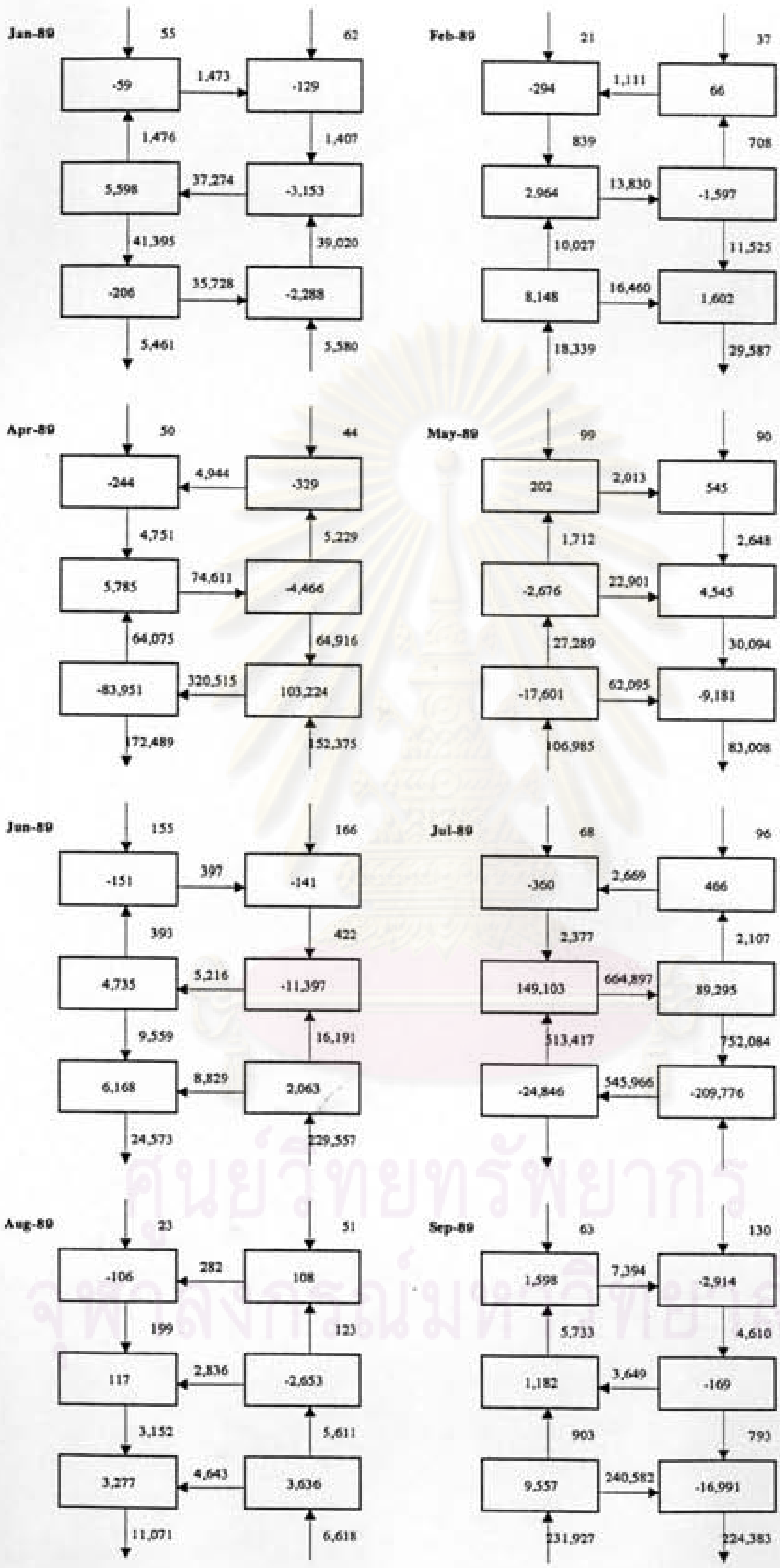

Figure 4.22 Nitrate+nitrite budget for six boxes in the Upper Gulf of Thailand
numbers indicated amount of net transport; arrow indicated direction (unit: x 10^3 mol/d)
numbers in boxes indicated net budget of nutrient (negative: net sink; positive: net production)

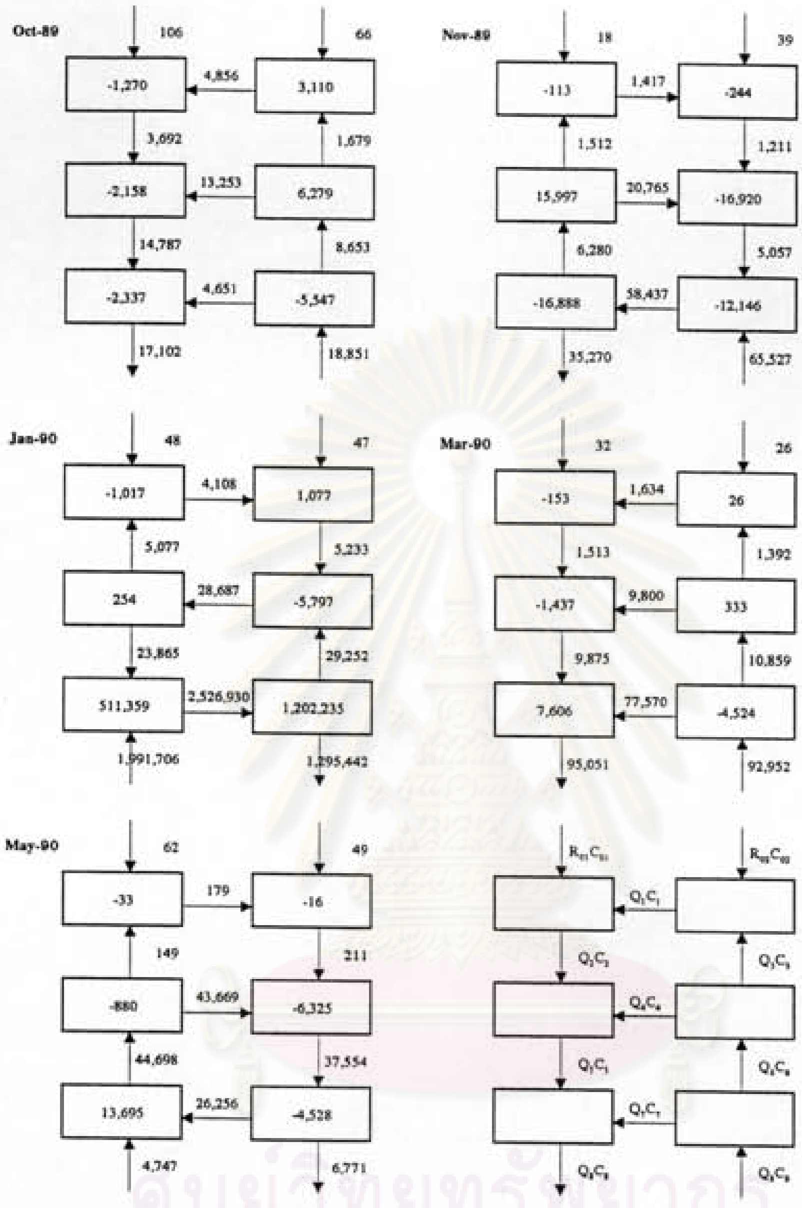

Figure 4.22 (continued)

R_{01}	: River runoff from Mae Klong and Ta Chin Rivers
R_{02}	: River runoff from Chao Phraya and Bangpakong Rivers
C_{01}	: Average nutrient concentrations at norhtern boundary of box 1
C_{02}	: Average nutrient concentrations at norhtern boundary of box 2
Q_1-Q_9	: Net water transport between boxes
C_1-C_9	: Average nutrient concentrations at boundary of each box
P	: Precipitation
E	: Evaporation

Net exchange fluxes of nutrients between boxes, both phosphorus and nitrogen, mostly related to net transportation of water while some seasonal variations of internal activities in each box were observed which were affected by the nutrient inputs into the box. The amount of nutrients exchanges between boxes mostly occurred in the eastern part of the Gulf particularly in the vicinity of the bay mouth.

The nutrient budgets were also showed high activities in the eastern part of the Gulf near the bay mouth. In this area, the anthropoginic source was found that became the major inputs of nutrients into the bay where high concentrations of phosphate and nitrate were obviously observed. The patterns of seasonal variations cannot be clearly summarized. It was also found some exchanges of phosphorus and nitrogen between the Upper Gulf and the Lower Gulf of Thailand.