

**Ortho-phosphate in the Sea Water of the South China Sea.
Area II : Sabah, Sarawak and Brunei Darussalam.**

Tengku Rozaina bt. Tengku Mohamad¹
and Mohd. Shukri b. Yusoff²

¹Marine Fishery Resources Development and Management Department
Southeast Asian Fisheries Development Center, Chendering, 21080 Kuala Terengganu, Malaysia.

²Fish Health and Quarantine Office, Department of Fisheries, Johor Bahru, Malaysia.

ABSTRACT

The distribution of ortho-phosphate in the South China Sea off Sarawak, Sabah and Brunei Darussalam waters was studied in the SEAFDEC Interdepartmental Collaborative Research Survey : Area II. The samples were collected by M.V. SEAFDEC on 8 July to 3 August 1996 (pre monsoon period) and 1 to 24 May 1997 (post monsoon period). Seventy-nine stations were established in this study. The average concentration of ortho-phosphate of the pre monsoon period at 0-1 meter, 10 meter, 20 meter, 50 meter, 100 meter and 200 meter, 500 meter, 1000 meter and 1500 meter depth of the third survey cruise were 0.14 μM , 0.09 μM , 0.10 μM , 0.09 μM , 0.50 μM , 0.90 μM , 1.94 μM , 2.59 μM and 3.10 μM respectively. The average concentration of ortho-phosphate of the post monsoon period at 0-1 meter, 10 meter, 20 meter, 50 meter, 100 meter, 200 meter, 500 meter, 1000 meter and 1500 meter depth were 0.24 μM , 0.28 μM , 0.20 μM , 0.25 μM , 1.15 μM and 2.27 μM , 4.13 μM , 5.19 μM and 5.41 μM respectively. The ortho-phosphate levels were low in the surface water and increase with depth. The results indicated that the deep water of the study area is very rich in phosphate.

Introduction

Information on dissolved inorganic nutrients distribution such as phosphorus and nitrogen in the South China Sea is limited. Some studies of nutrients in the coastal waters off Peninsular Malaysia, Sabah and Sarawak were conducted by Lim (1978), Law and Kamil (1986), Law and Rahman (1987), Ichikawa *et. al* (1987), Law and Zawawi (1988), Saleh *et. al* (1988), Law (1990) and Mohd. Shukri *et al.* (1997). These nutrients are essential for primary productivity that are required for maintaining our fisheries resources.

Phytoplanktons are primary producer in the sea. They require dissolved inorganic nutrients for their growth. Through photosynthesis, they produce food for supporting all trophic levels in the sea. Phytoplanktons provide food for zooplanktons which are then consumed by organisms higher up in the food chain. Phosphorus such as ortho-phosphate can be considered as a primary nutrient for phytoplankton. (Horne, 1969). Pojed and Kveder (1977) believed that phosphorus was the limiting nutrient in the growth of phytoplankton in the northern Adriatic Sea. Dissolved inorganic phosphate is utilized by all species of phytoplankton (Riley, 1981). Phosphate is taken up by phytoplankton during active photosynthetic activities in the surface water. The objective of this study is to determine ortho-phosphate distribution in the South China Sea off Sabah, Sarawak and Brunei Darussalam waters. Previous studies by Law and Zawawi (1988) and Law (1990) indicated that some of the study area was very rich in ortho-phosphate in the deep water.

Materials and Methods

The third and fourth survey cruises of M.V. SEAFDEC were conducted from 8 July to 3 August 1996 and 1 to 24 May 1997 respectively. This study is one of the projects under SEAFDEC Interdepart-

mental Collaborative Research Program: Area II. Seventy-nine (79) stations were established in this study, which cover the Sabah, Sarawak and Brunei Darussalam waters. The locations of the sampling stations are shown in Figure 1. Water for ortho-phosphate analysis was obtained at different levels using a Rosette Water Sampler with twelve Niskin (PVC) bottles attached. The water sample was then filtered through a meshed syringe (1.0 μm) into acid washed plastic bottles.

Analysis was done on board for the third survey cruise samples using an Autoanalyzer TRAACS 2000. Samples for the fourth survey cruise were kept frozen in freezer at -20°C . These samples were analysed in the MFRDMD Laboratory using the Autoanalyzer. Determination of phosphate by the Autoanalyzer was based on colorimetric method. A blue colour was formed by the reaction of phosphate, molybdate ion and antimony ion followed by reduction with ascorbic acid. The reduced blue phosphomolybdenum complex was read at 880 nm. Since the water sample was not preserved with acid or digested with strong oxidizing agent prior to analysis, the phosphate analysed in this study was the ortho-phosphate.

Results and Discussion

The concentration of ortho-phosphate of the third and fourth survey cruises at various depths of the sampling stations are presented in Table 1 and Table 2. The average concentration of ortho-phosphate at 0-1 meter, 10 meter, 20 meter, 50 meter, 100 meter and 200 meter, 500 meter, 1000 meter and 1500 meter depth of the third survey cruise were 0.14 μM , 0.09 μM , 0.10 μM , 0.09 μM , 0.50 μM , 0.90 μM , 1.94 μM , 2.59 μM and 3.10 μM respectively. The average concentration of ortho-phosphate for the fourth survey cruise at 0-1 meter, 10 meter, 20 meter, 50 meter, 100 meter, 500 meter, 1000 meter and 1500 meter were 0.24 μM , 0.28 μM , 0.20 μM , 0.25 μM , 1.15 μM and 2.27 μM , 4.13 μM , 5.19 μM and 5.41 μM respectively. The depth profiles of ortho-phosphate at each sampling station of the third and fourth survey cruises are presented in Figure 2. The results showed that ortho-phosphate concentrations were lower in the surface and upper layer of water and increase with depth. Similar patterns were found by Law and Zawawi (1988) in the Sarawak waters and Law (1990) in the Sabah waters.

The topographies of the ortho-phosphate distribution in the upper water layer of the study area taken during the third and fourth survey cruise are shown in Figure 3 and 4 respectively. While for the bottom water, the distributions are shown in Figure 5 and 6. The phosphate concentration in surface water is usually low due to uptake by phytoplankton for the active primary productivity which resulted in lowering the phosphate in the water (Law and Zawawi, 1988).

Higher ortho-phosphate concentration was found in the bottom waters as shown in Figure 5 and 6. The high level of phosphate in the bottom water may indicate that active mineralization processes are occurring at these depths (Law and Zawawi, 1988). As phytoplankton and other organisms die, phosphate is regenerated in the water column (Millero, 1996). The organic phosphorus in their tissue is rapidly converted to phosphate (Riley, 1981; Chester, 1990).

A comparison of ortho-phosphate concentration in the surface waters between the present study area and other seas especially in the South China Sea is given in Table 3. Ortho-phosphate concentration in the surface layer of the present study area is much lower than those detected in the Japan Sea (Anon, 1985), Gulf of Thailand (Kaewsripraky & Chantarasakul, 1985), Southern South China Sea off Malaysian coast, cruise 1972 and cruise 1973 (Lim, 1978) and Sabah coastal waters (Law, 1990). The ortho-phosphate concentration is much higher than those found in the coastal waters off Kuala Terengganu (Law & Kamil, 1986) and Western English Channel (Wafar *et al.* 1983). The concentration of ortho-phosphate in the present study is comparable to that reported by Law & Zawawi (1988) for coastal waters off Sarawak. Average concentration of ortho-phosphate in the third survey cruise and fourth survey cruise at various depths is shown in Table 4. The ortho-phosphate concentration were higher in the fourth survey cruise.

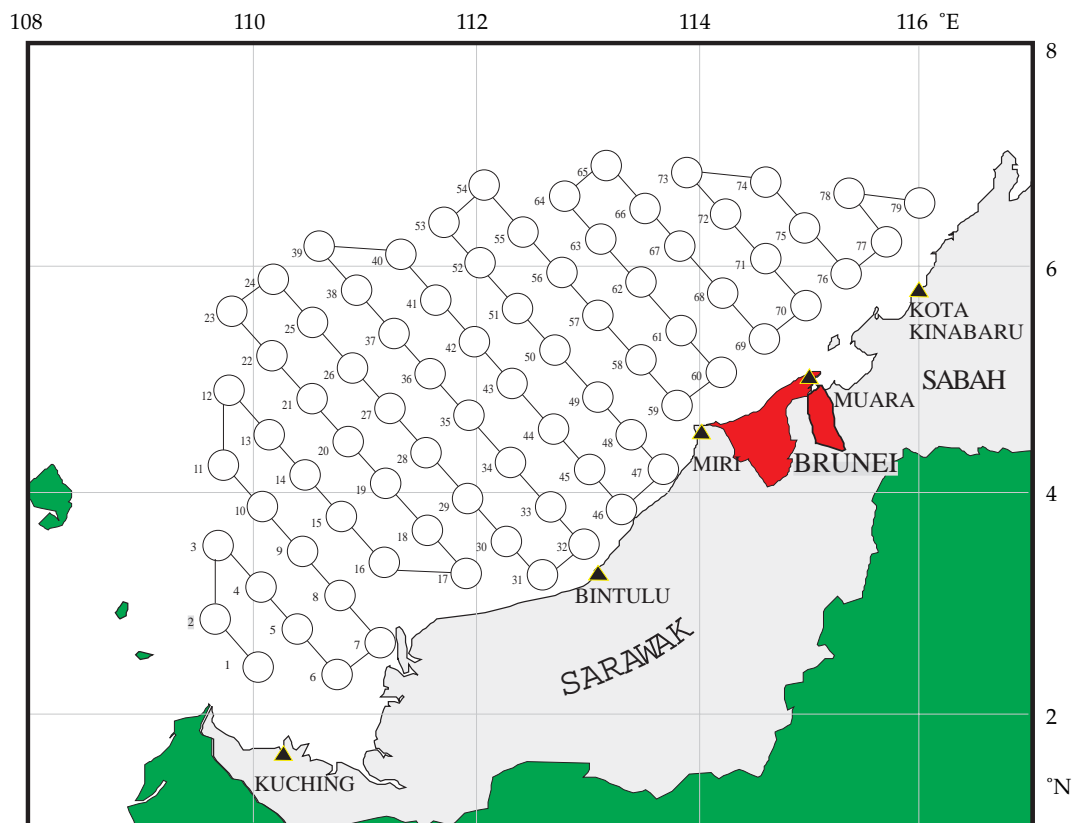


Fig. 1 Locations of the survey stations

Conclusion

The results of this study showed that the Sabah, Sarawak and Brunei Darussalam waters are rich in phosphate. Higher ortho-phosphate concentrations are found in deeper water than surface water. This high concentration in deeper water can be brought to the surface water by upwelling process. Studies on the relationship between nutrients concentration and other oceanographic parameters and then the fisheries resources in this study area are needed.

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Table 1. Ortho-phosphate concentration in the Sabah, Sarawak and Brunei Darussalam waters during July-August 1996 (third cruise).

Station	Depth(m)	Ortho-phosphate(mM)
1	0 - 1	0.05
	10	0.09
	20	0.06
	30	0.09
	35	0.15
2	0 - 1	0.07
	10	0.08
	20	0.01
	30	0.02
	40	0.03
3	0 - 1	0.20
	20	0.14
	40	0.09
	50	0.15
	60	0.26
4	0 - 1	0.18
	10	0.12
	20	0.14
	30	0.13
	40	0.14
5	0 - 1	0.20
	15	0.17
	30	0.14
	40	0.16
	45	0.16
6	0 - 1	0.23
	10	0.17
	20	0.23
	40	0.22
	7	0 - 1
10		0.15
20		0.16
29		0.17
8		0 - 1
	10	0.18
	20	0.13
	30	0.13
	37	0.14
9	0 - 1	0.13
	20	0.14
	30	0.09
	40	0.18
	50	0.16
9	60	0.40
	67	0.45

Station	Depth(m)	Ortho-phosphate(mM)	
10	0 - 1	0.13	
	30	n.d	
	40	n.d	
	50	n.d	
	60	n.d	
	70	0.53	
	84	0.57	
11	0 - 1	0.47	
	30	0.06	
	50	0.06	
	60	0.03	
	70	0.38	
	80	0.74	
11	96	0.93	
	12	0 - 1	0.06
		20	0.01
		40	0.08
		60	0.02
70		0.13	
80		0.04	
90		0.31	
100		0.40	
13	0 - 1	0.09	
	10	0.03	
	20	0.05	
	40	0.08	
	60	0.13	
	70	0.52	
	80	0.29	
	90	0.45	
	100	0.87	
	111	0.87	
	14	0 - 1	0.09
10		0.02	
30		0.02	
40		0.00	
50		0.04	
60		0.03	
70		0.33	
80		0.79	
90		0.89	
15	0 - 1	0.03	
	20	0.04	
	30	0.02	
	35	0.11	
	40	0.04	
	50	0.14	
15	55	0.22	
	63	0.22	
	16	0 - 1	0.13
10		0.03	
20		0.05	

Table 1. Continue

Station	Depth(m)	Ortho-phosphate(mM)	Station	Depth(m)	Ortho-phosphate(mM)
16	30	0.05	23	0 - 1	0.15
	40	0.05		20	0.10
	50	0.09		40	0.07
	59	0.16		58	0.24
17	5	0.07		70	0.35
	10	0.05		100	0.68
	20	0.06		120	1.04
	27	0.04		141	1.00
18	0 - 1	0.05	24	10	0.14
	10	0.04		20	0.07
	20	0.04		40	0.10
	30	0.04		60	0.11
	35	0.04		80	0.21
	40	0.04		100	0.39
	46	0.13		120	0.89
19	0 - 1	0.14		150	1.15
	10	0.08	300	1.85	
	20	0.07	500	2.19	
	30	0.04	25	0 - 1	n.d
	40	0.06		20	n.d
	50	0.05		40	n.d
	53	0.11		55	0.02
65	0.33	65		0.12	
20	0 - 1	0.08		90	0.39
	10	0.06		140	1.12
	20	0.03	196	1.63	
	30	0.03	26	0 - 1	0.14
	40	0.04		20	0.04
	50	0.06		30	0.01
	60	0.09		50	0.02
	70	0.30		65	0.25
	80	0.60		80	0.35
85	0.93	100		0.06	
21	0 - 1	0.13	119	0.96	
	10	0.07	27	0 - 1	0.07
	30	0.06		20	0.03
	40	0.05		40	0.00
	50	0.08		50	0.01
	60	0.11		62	0.15
	70	0.23		70	0.52
	80	0.42		80	0.78
	90	0.52		89	0.83
	100	0.72	28	0 - 1	0.26
	110	0.81		10	0.10
116	0.86	20		0.10	
22	0 - 1	0.14		30	0.07
	20	0.08		40	0.09
	40	0.10		50	0.06
	60	0.23		60	0.19
	70	0.25	70	0.41	
	80	0.30	75	0.42	
	100	0.69	29	0 - 1	0.13
	120	0.96		10	0.12
141	1.12	20		0.14	

Table 1. Continue

Station	Depth(m)	Ortho-phosphate(mM)
29	30	0.14
	45	0.16
	52	0.24
30	0 - 1	0.13
	10	0.13
	20	0.14
	29	0.14
31	0 - 1	0.14
	10	0.15
	20	0.14
	15	0.14
32	0 - 1	0.16
	10	0.16
	20	0.15
	31	0.21
33	0 - 1	0.15
	10	0.14
	20	0.14
	30	0.13
34	0 - 1	0.12
	10	0.13
	20	0.13
	45	0.14
	55	0.18
35	0 - 1	0.21
	20	0.14
	30	0.15
	40	0.14
	70	0.21
36	0 - 1	0.16
	10	0.14
	20	0.14
	30	0.14
	40	0.15
	61	0.18
37	0 - 1	0.14
	20	0.13
	39	0.14
	180	1.42
	254	1.74
	300	1.92
	378	1.40
38	0 - 1	0.22
	20	0.14
	30	0.15
	40	0.13
	65	0.17
	80	0.16
	200	1.40
	300	1.88
	500	2.50
950	1.76	
39	0	0.13
	20	0.11

Station	Depth(m)	Ortho-phosphate(mM)
39	40	0.13
	55	0.16
	70	0.13
	150	1.05
	200	1.39
	300	1.88
	500	2.45
	800	2.79
	1100	2.85
40	0 - 1	0.13
	15	0.13
	31	0.12
	50	0.24
	67	0.21
	150	1.15
	300	1.84
	600	2.67
	950	2.94
41	0 - 1	0.15
	20	0.14
	40	0.14
	140	1.12
	300	1.84
42	0 - 1	0.07
	20	n.d
	40	n.d
	50	n.d
	63	0.06
	80	0.32
	100	0.72
43	0 - 1	0.18
	10	0.02
	20	0.03
	30	0.02
	40	n.d
	50	0.02
	62	0.12
	75	0.37
	85	0.66
	95	0.87
44	0 - 1	0.17
	10	0.04
	20	0.06
	40	n.d
	50	0.07
	57	0.11
	70	0.52
	80	0.85
45	10	0.15
	20	0.05
	30	n.d
45	40	0.01

Table 1. Continue

Station	Depth(m)	Ortho-phosphate(mM)	Station	Depth(m)	Ortho-phosphate(mM)
45	45	0.02	52	500	2.55
	53	0.11		1000	2.44
	63	0.39		1500	3.50
46	0 - 1	0.07	53	0 - 1	0.23
	10	0.04		10	0.10
	18	0.03		20	0.07
47	0 - 1	0.02		50	0.04
	10	0.02		70	0.06
	20	0.01		500	2.80
	27	0.05		1000	2.47
48	0 - 1	0.07	1600	1.78	
	10	0.06	54	0 - 1	0.07
	20	0.05		10	0.04
	30	0.06		20	n.d
	40	0.06		30	n.d
	50	0.08		40	n.d
	60	0.08		60	n.d
72	0.30	80		0.26	
49	0 - 1	0.15	100	0.21	
	10	0.08	200	1.13	
	20	0.05	500	0.87	
	30	0.02	1000	3.30	
	40	0.04	1700	1.37	
	50	0.03	55	20	0.10
	60	0.07		61	0.06
	67	0.15		150	2.33
	80	0.30		400	2.02
100	0.14	600		1.01	
50	0 - 1	0.20		800	3.03
	20	0.05		1000	2.77
	30	0.08	1200	1.61	
	40	0.01	56	20	0.18
	50	0.04		50	0.10
	58	0.09		71	0.10
	100	0.58		100	0.42
	200	0.70		300	0.80
300	0.82	500		1.83	
400	0.89	700		1.02	
51	0 - 1	0.11	1000	2.61	
	20	0.04	57	20	0.15
	40	0.05		50	0.13
	50	0.05		75	0.18
	62	0.17		100	0.35
	80	0.46		500	2.52
	90	0.39		800	1.96
	100	0.64		1000	1.42
	140	0.58	1800	2.81	
185	****	58	0 - 1	0.24	
52	0 - 1		0.14	20	0.16
	10		0.16	40	0.13
	20		0.05	70	0.11
	40		0.05	100	0.18
	60		0.08	150	0.65
	79		0.38	200	0.31
	300	1.93	300	1.48	

Table 1. Continue

Station	Depth(m)	Ortho-phosphate(mM)	Station	Depth(m)	Ortho-phosphate(mM)
58	500	0.67	64	100	0.36
	700	2.21		200	0.97
	1000	2.67		300	1.49
	1500	2.71		500	1.82
59	0 - 1	0.06		800	2.87
	10	0.03		1000	2.60
	20	0.02	1200	2.11	
	30	0.02	65	0 - 1	0.16
	45	0.01		20	0.08
	60	0.01		40	0.08
	70	0.25		60	0.10
	80	0.21		70	0.21
	93	0.22		80	0.35
60	0 - 1	0.02		100	0.55
	10	0.00		200	0.90
	30	n.d		300	****
	47	n.d		500	0.77
	80	0.27	1000	2.69	
	100	0.57	1400	2.76	
	130	0.90	66	0 - 1	0.12
	170	0.81		20	0.10
61	10	0.06		40	0.05
	50	0.01		60	0.06
	63	0.01		80	0.15
	200	0.15		100	0.29
	600	1.41		200	0.96
	1000	2.58		300	1.29
	1500	2.77		500	1.44
	1800	2.93		1000	2.62
62	20	0.26	1400	2.30	
	30	0.11	1800	2.47	
	50	0.04	67	0 - 1	0.21
	70	0.14		20	0.13
	100	0.50		40	0.10
	200	0.97		60	0.68
	500	2.15		80	0.36
	1000	2.77		100	1.02
1850	2.04	200		0.54	
63	0 - 1	0.12		500	2.22
	20	0.02		800	0.95
	40	0.02		1000	2.68
	60	0.02	1500	2.80	
	80	0.19	2000	3.11	
	100	0.68	68	0 - 1	0.24
	200	1.12		20	0.13
	300	1.46		40	0.10
	500	2.38		60	0.10
	800	2.69		80	0.28
	1000	2.47		100	0.51
	1500	3.72		200	1.10
64	0 - 1	0.22		400	2.03
	20	0.11		600	2.44
	40	0.08		800	2.65
	60	0.09	1000	2.80	
	74	0.15	1700	2.25	

Table 2. Ortho-phosphate concentration in the Sabah, Sarawak and Brunei Darussalam waters during May 1997 (fourth cruise).

Station	Depth (m)	Ortho-phosphate(mM)	Station	Depth (m)	Ortho-phosphate(mM)
1	0 - 1	0.12	8	0 - 1	0.11
	6	0.13		5	0.09
	10	0.11		10	0.06
	20	0.10		20	0.14
	27	0.03		30	0.10
	33	0.11		40	0.08
2	0 - 1	0.11	9	0 - 1	0.11
	10	0.10		10	0.08
	20	0.04		30	0.12
	25	0.10		40	0.14
	30	0.08		45	0.22
	35	0.04		50	0.25
	40	0.12		60	0.31
	51	0.16		65	0.35
3	10	0.08	10	0 - 1	0.13
	20	0.04		10	0.12
	25	0.08		30	0.15
	30	0.06		40	0.15
	40	0.08		50	0.15
	50	0.15		60	0.46
	60	0.44		70	0.70
	70	0.65		80	0.97
4	0 - 1	0.16	11	0 - 1	0.15
	10	0.14		10	0.19
	20	0.11		30	0.15
	30	0.12		50	0.28
	40	0.12		60	0.23
	50	0.25		70	0.28
	60	0.24		80	0.76
	67	0.33		90	1.16
5	0 - 1	0.15	12	0 - 1	0.31
	10	0.14		10	0.17
	20	0.10		30	0.24
	30	0.14		40	0.27
	40	0.22		50	0.31
	50	0.28		60	0.66
	60	0.25		70	0.60
	74	0.11		80	0.58
6	0 - 1	0.10	13	0 - 1	0.33
	10	0.13		10	0.16
	15	0.10		30	0.29
	20	0.10		50	0.19
	30	0.06		70	0.32
	35	0.11		80	0.55
7	0 - 1	0.12	14	0 - 1	0.17
	10	0.12		10	0.14
	20	0.17		20	0.14
	25	0.29		30	0.14
	33	0.26		40	0.11

Table 2. continue

Station	Depth (m)	Ortho-phosphate(mM)
14	50	0.13
	65	0.30
	80	0.85
	88	0.93
15	0 - 1	0.15
	10	0.70
	20	0.70
	30	0.63
	40	0.62
	50	0.68
	64	0.67
16	0 - 1	0.60
	10	0.57
	20	0.58
	30	0.60
	40	0.58
	50	0.66
	63	0.66
17	0 - 1	0.57
	10	0.57
	18	0.51
	25	0.55
	28	0.61
18	0 - 1	0.50
	10	0.46
	20	0.48
	30	0.50
	35	0.50
	45	0.49
19	0 - 1	0.44
	10	0.43
	30	0.45
	40	0.45
	50	0.43
	60	0.49
	68	0.48
20	0 - 1	0.44
	10	0.42
	20	0.38
	30	0.43
	40	0.39
	50	0.43
	60	0.51
	70	0.66
	80	1.16
85	1.14	
21	0 - 1	0.42
	20	0.33
	30	0.35
	40	0.41

Station	Depth (m)	Ortho-phosphate(mM)
21	50	0.43
	60	0.49
	70	0.57
	80	0.67
	90	1.15
	100	1.12
	116	1.20
22	0 - 1	0.39
	20	0.36
	40	0.30
	50	0.29
	60	0.28
	70	0.48
	80	0.57
	90	0.82
	100	1.08
23	0 - 1	0.33
	20	0.29
	40	0.18
	60	0.27
	80	0.70
	100	1.20
	120	1.57
	144	1.64
24	0 - 1	0.32
	20	0.20
	40	0.22
	60	0.22
	70	0.30
	80	0.66
	100	0.95
	120	1.26
	150	1.59
	200	2.17
25	0 - 1	0.46
	10	0.30
	30	0.18
	50	0.22
	70	0.44
	80	0.66
	100	0.57
	197	1.23
27	0 - 1	0.15
	10	0.14
	30	0.10
	50	0.08

Table 2. continue

Station	Depth (m)	Ortho-phosphate(mM)	Station	Depth (m)	Ortho-phosphate(mM)
27	60	0.25	35	30	0.04
	70	0.27		40	0.05
	80	0.31		50	0.08
	93	0.58		60	0.19
28	0 - 1	0.15		70	0.49
	20	0.07		80	0.55
	30	0.17	85	0.61	
	40	0.17	36	0 - 1	0.13
	50	0.19		10	0.13
	65	****		30	0.10
	77	0.42		40	0.12
29	0 - 1	0.12		50	0.12
	10	0.11		60	0.33
	20	0.17		70	0.48
	30	0.19	80	0.63	
	40	0.13	100	0.92	
	50	0.22	108	0.95	
30	0 - 1	0.07	37	0 - 1	0.20
	10	0.09		20	0.12
	20	0.12		40	0.13
	25	0.06		50	0.20
	33	0.11		60	0.48
31	0 - 1	0.05		70	0.62
	5	0.09		80	0.70
	10	0.02		100	1.23
	15	0.14		150	1.75
	19	0.16		200	2.18
32	0 - 1	0.09		300	2.95
	10	0.09	409	****	
	15	0.07	38	0 - 1	0.36
	20	0.06		20	0.21
	25	0.12		40	0.21
31	0.19	50		0.23	
33	0 - 1	0.04		60	0.18
	10	0.05		80	0.37
	15	0.04		100	0.96
	20	0.07		200	2.22
	30	0.06		300	3.04
	40	0.07		500	****
	50	0.10		700	****
34	0 - 1	0.05	1006	****	
	10	0.04	39	0 - 1	0.51
	20	0.03		20	0.30
	30	0.06		40	0.26
	35	0.09		60	0.23
	50	0.10		80	0.58
	60	0.24		100	1.10
71	0.32	150		1.80	
35	0 - 1	0.03		200	2.25
	10	0.05		300	3.03
	20	0.07		500	****

Table 2. continue

Station	Depth (m)	Ortho-phosphate(mM)
39	700	****
	1100	****
40	0 - 1	0.14
	20	0.11
	40	0.10
	60	0.09
	80	0.49
	100	0.87
	150	1.66
	200	2.63
	300	3.53
	500	****
	700	****
1000	****	
41	0 - 1	0.56
	20	0.32
	40	0.23
	60	0.48
	80	0.98
	100	1.58
	150	1.98
	200	2.66
	300	3.58
	500	****
750	****	
1100	****	
42	0 - 1	0.54
	20	0.41
	40	0.34
	50	0.34
	60	0.31
	70	0.55
	80	0.98
	100	1.27
	120	1.23
	131	1.69
43	0 - 1	0.19
	20	0.26
	30	0.25
	40	0.25
	50	0.35
	60	0.32
	70	0.75
	80	0.85
	90	0.98
	100	1.19
44	0 - 1	0.24
	20	0.17
	30	0.13
	40	0.12
	50	0.13

Station	Depth (m)	Ortho-phosphate(mM)
44	60	0.32
	70	0.23
	80	0.55
	86	0.73
45	0 - 1	0.16
	20	0.09
	30	0.09
	40	0.16
	50	0.19
	63	0.27
46	0 - 1	0.10
	10	0.09
	15	0.09
	19	0.08
47	0 - 1	0.04
	10	0.07
	15	0.07
	20	0.04
	26	0.10
48	0 - 1	0.06
	10	0.05
	20	0.03
	30	0.05
	40	n.d
	50	0.07
	70	0.46
	75	0.59
49	0 - 1	0.08
	20	0.09
	30	0.56
	40	0.14
	50	0.14
	60	0.15
	70	0.35
	80	0.64
	90	0.96
	101	1.50
50	10	0.18
	30	0.13
	50	0.19
	60	0.31
	70	0.74
	80	0.90
	100	1.44
	150	1.91
200	2.12	
300	3.39	
500	****	
700	****	
51	10	0.45
	30	0.31

Table 2. continue

Station	Depth (m)	Ortho-phosphate(mM)	Station	Depth (m)	Ortho-phosphate(mM)
51	50	0.30	55	1200	****
	60	0.33	56	10	0.44
	70	0.49		30	0.32
	80	0.93		50	0.62
	100	1.26		70	1.01
	120	1.68		100	1.61
	150	1.80		200	2.12
	180	2.21		285	3.03
52	10	0.13		465	****
	40	0.17	685	****	
	70	0.83	950	****	
	100	1.47	57	10	0.46
	150	1.78		30	0.29
	200	2.56		60	0.52
	300	3.34		100	1.56
	500	****		200	2.34
	1000	****		300	3.34
1450	****	500		****	
53	10	0.52		1000	****
	40	0.29		1500	****
	60	0.56	2000	****	
	80	1.09	58	10	0.48
	100	1.16		30	0.31
	150	1.83		50	0.28
	200	2.59		60	0.29
	500	****		70	0.38
	1000	****		100	0.83
1840	****	150		1.30	
54	10	0.37		200	1.74
	30	0.33		300	3.04
	50	0.29	500	****	
	60	0.54	990	****	
	80	0.93	1500	****	
	100	1.42	59	0 - 1	0.19
	150	1.72		10	0.13
	200	2.47		20	0.13
	300	3.46		30	0.08
	500	****		40	0.21
	1000	****		50	0.16
	1900	****		60	0.16
	55	10		0.43	70
30		0.31		80	0.19
50		0.19	86	0.20	
60		0.53	60	10	0.43
80		1.06		20	0.25
100		1.29		40	0.20
150		1.91		50	0.16
200		2.28		60	0.13
300		3.25		80	0.50
500		****		100	0.90
1000	****	150		1.67	

Table 2. continue

Station	Depth (m)	Ortho-phosphate(mM)	Station	Depth (m)	Ortho-phosphate(mM)	
60	195	2.06	65	150	1.63	
61	10	0.25		200	2.08	
	50	0.18		300	3.14	
	80	0.76		500	4.13	
	100	1.32		700	4.90	
	200	2.05		1000	5.48	
	300	3.11		1500	5.20	
	500	****	66	10	0.75	
	1000	****		30	0.36	
	1500	****		50	0.38	
	2000	****		70	0.90	
		100		1.25		
62	10	0.12		150	1.70	
	20	0.11		200	2.24	
	50	0.13		300	2.88	
	70	0.83		500	3.66	
	100	1.19		1000	5.22	
	150	1.92		1500	4.68	
	200	2.37		1800	5.20	
	300	3.03	67	10	0.51	
	500	4.35		30	0.36	
	1000	5.22		50	0.44	
1500	5.58	70		0.92		
1995	5.57	100		1.38		
63	10	0.49			180	1.90
	30	0.38			200	2.45
	50	0.18			300	3.48
	70	1.09			500	4.35
	100	1.39			1000	5.15
	150	1.39		1500	5.47	
	200	2.08		2000	4.73	
	300	2.71	68	10	0.51	
	500	3.79		30	0.30	
	700	3.29		50	0.34	
1000	5.13	70		0.85		
1500	3.35	100		1.37		
64	10	0.17			150	1.74
	30	0.14			200	2.24
	70	0.85			250	2.72
	100	0.18			500	4.17
	150	1.31			1000	5.24
	200	1.39		1500	5.49	
	300	2.38		1700	5.45	
	500	2.77	69	0 - 1	0.59	
	700	3.56		10	0.16	
	1000	2.86		20	0.24	
1250	4.88	30		0.18		
65	10	0.40		40	0.25	
	30	0.31		50	0.18	
	50	0.30		60	0.13	
	70	0.85	70	0.22		
	100	1.13				

Table 2. continue

Station	Depth (m)	Ortho-phosphate(mM)	Station	Depth (m)	Ortho-phosphate(mM)
69	80	0.37	74	200	2.68
	90	0.82		300	3.50
70	10	0.18		500	4.90
	20	0.15		1000	5.94
	40	0.09		1500	6.24
	50	0.18		2000	6.30
	60	0.14	75	10	0.58
	80	0.61		30	0.34
	100	1.12		50	0.25
	120	1.59		70	0.40
130	1.50	100		0.97	
71	10	0.16		200	2.60
	30	0.16		300	3.66
	50	0.12		500	4.81
	70	0.47	1000	6.17	
	100	1.23	1700	6.45	
	150	2.02	76	10	0.58
	200	2.16		20	0.27
	300	3.31		40	0.19
	1000	5.33		50	0.22
	1500	5.86		60	0.15
1900	5.74	70		0.27	
72	10	0.61	90	1.15	
	30	0.32	77	0 - 1	0.25
	50	0.37		10	0.15
	70	0.66		20	0.10
	100	1.16		40	0.03
	150	1.93		50	0.04
	200	2.41		60	0.12
	300	3.54		70	0.30
	500	4.82		80	0.42
	1000	5.62	78	0 - 1	0.45
	1500	6.09		20	0.22
	2000	6.22		30	0.11
73	10	0.57		50	0.14
	30	0.31		70	0.11
	50	0.39		100	0.42
	70	0.84		150	1.11
	100	1.44		200	1.89
	150	2.13		300	2.75
	200	2.64		500	3.66
	300	3.64	1000	4.25	
	1000	5.90	1450	6.19	
	1500	6.16	79	10	0.51
1750	6.23	20		0.39	
74	10	0.75		30	0.18
	50	0.50		35	0.17
	70	0.74	50	0.20	
	100	1.23			

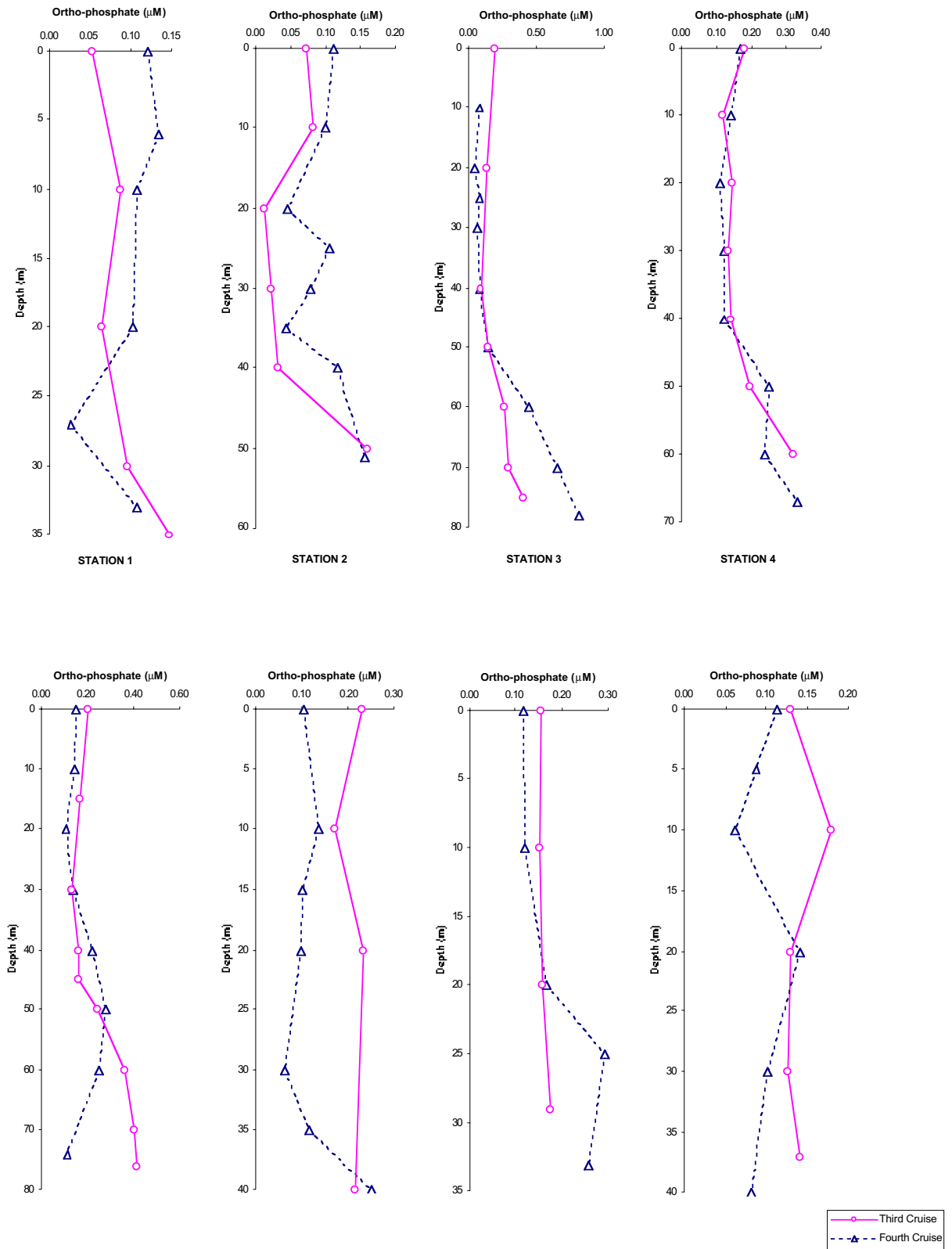


Fig. 2 Depth profiles of ortho-phosphate at the sampling stations during the third and fourth cruises

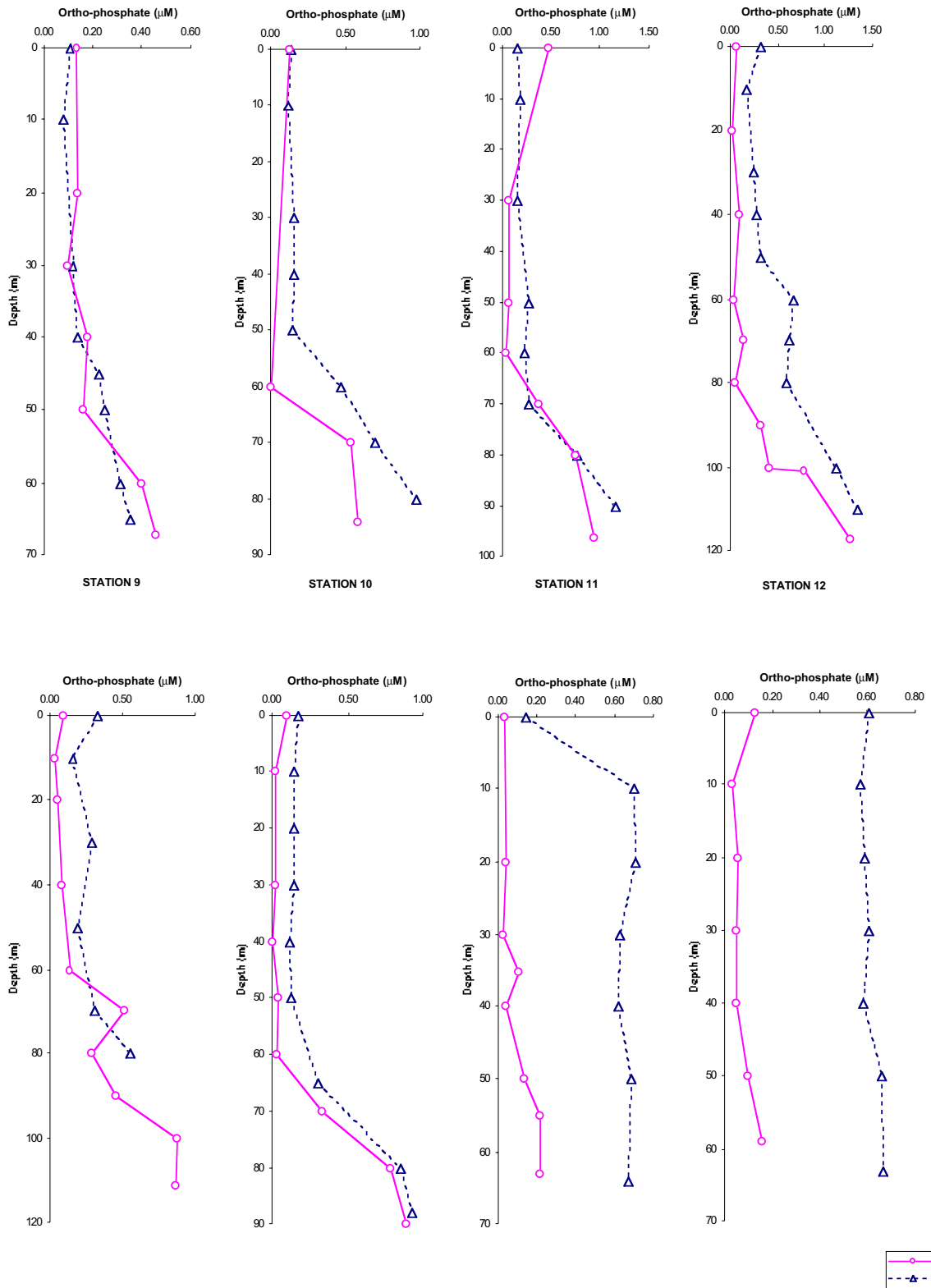


Fig. 2 Continue

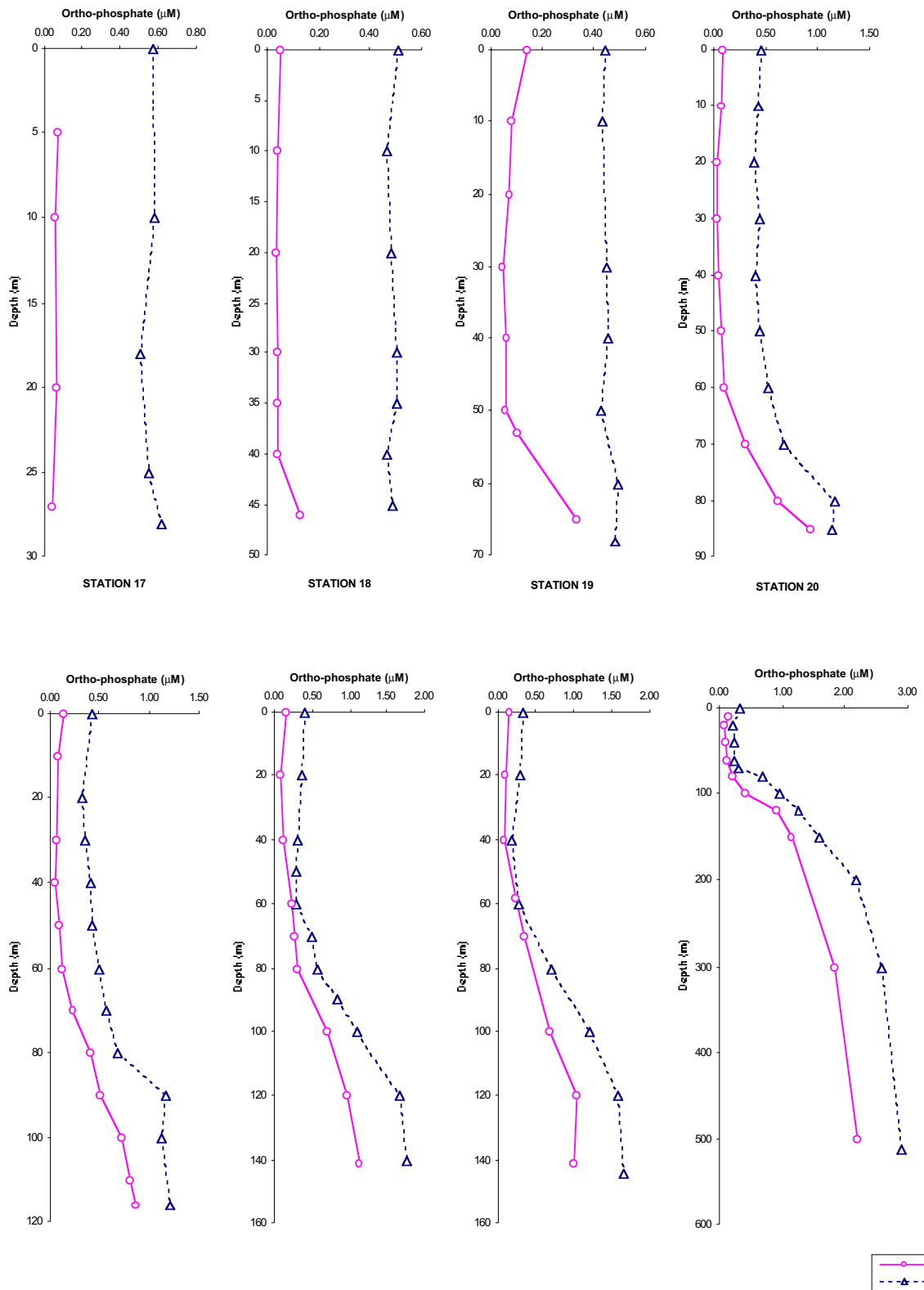


Fig. 2 Continue

S1/OG3<ROZAINA>

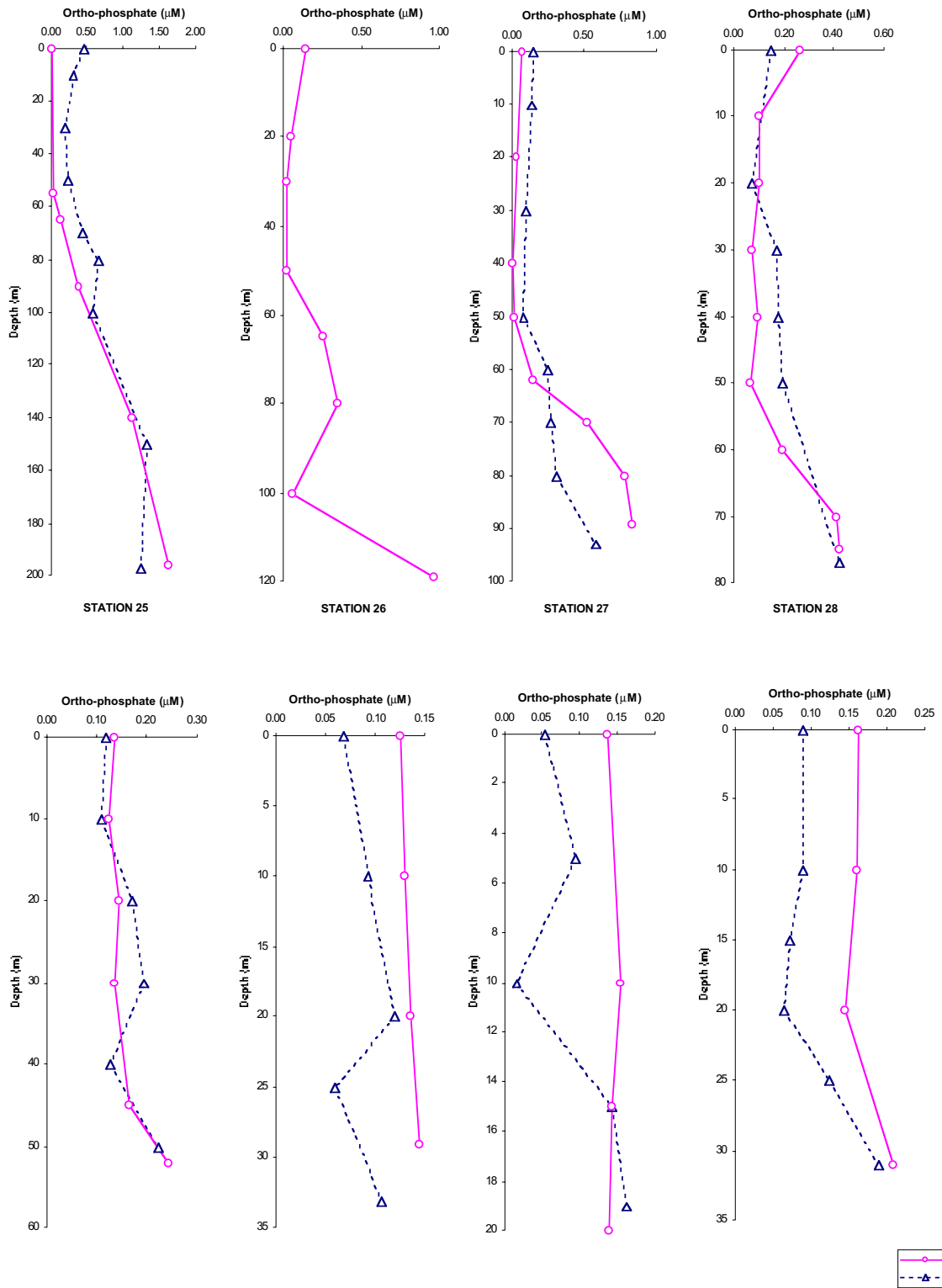


Fig. 2 Continue

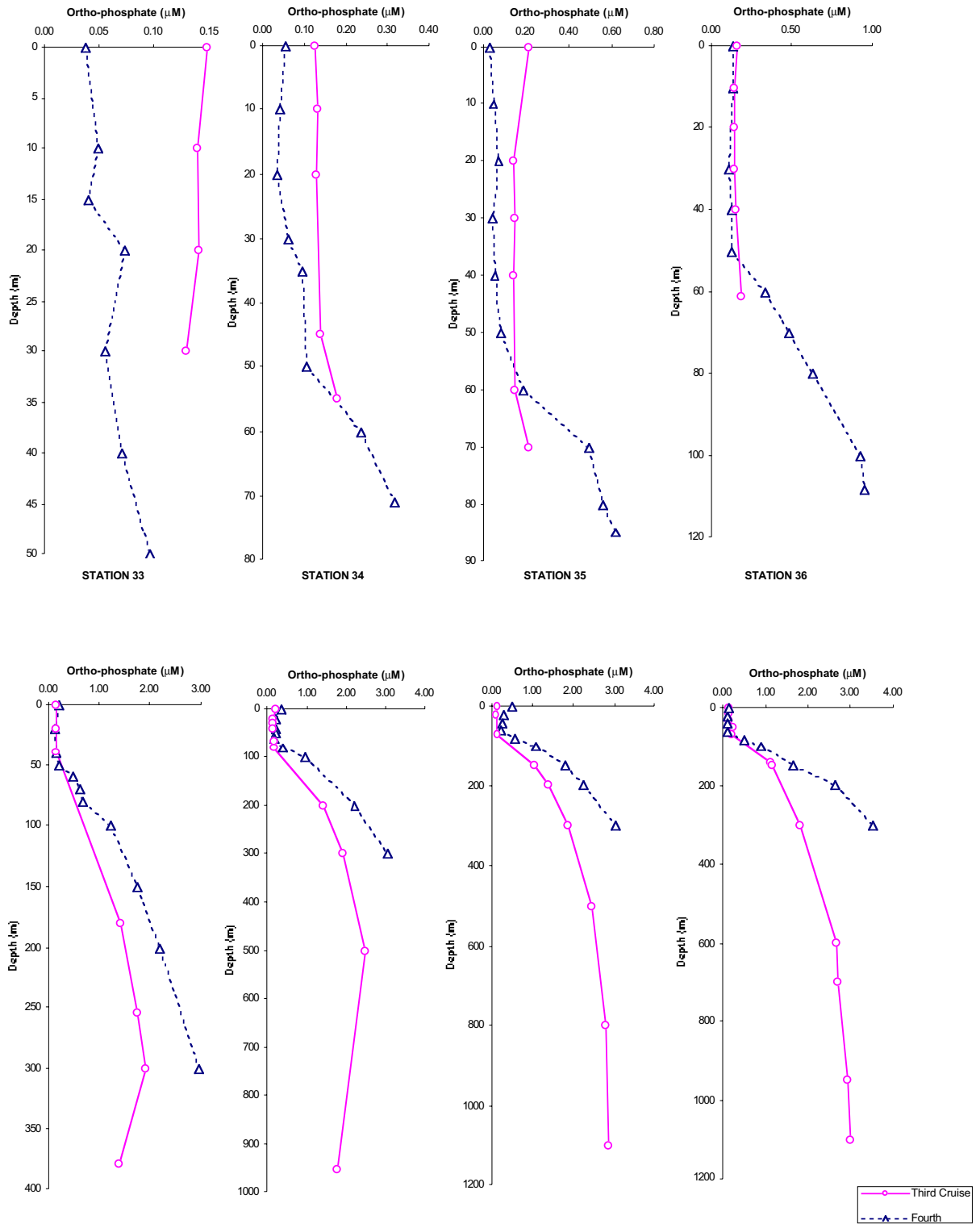


Fig. 2 Continue

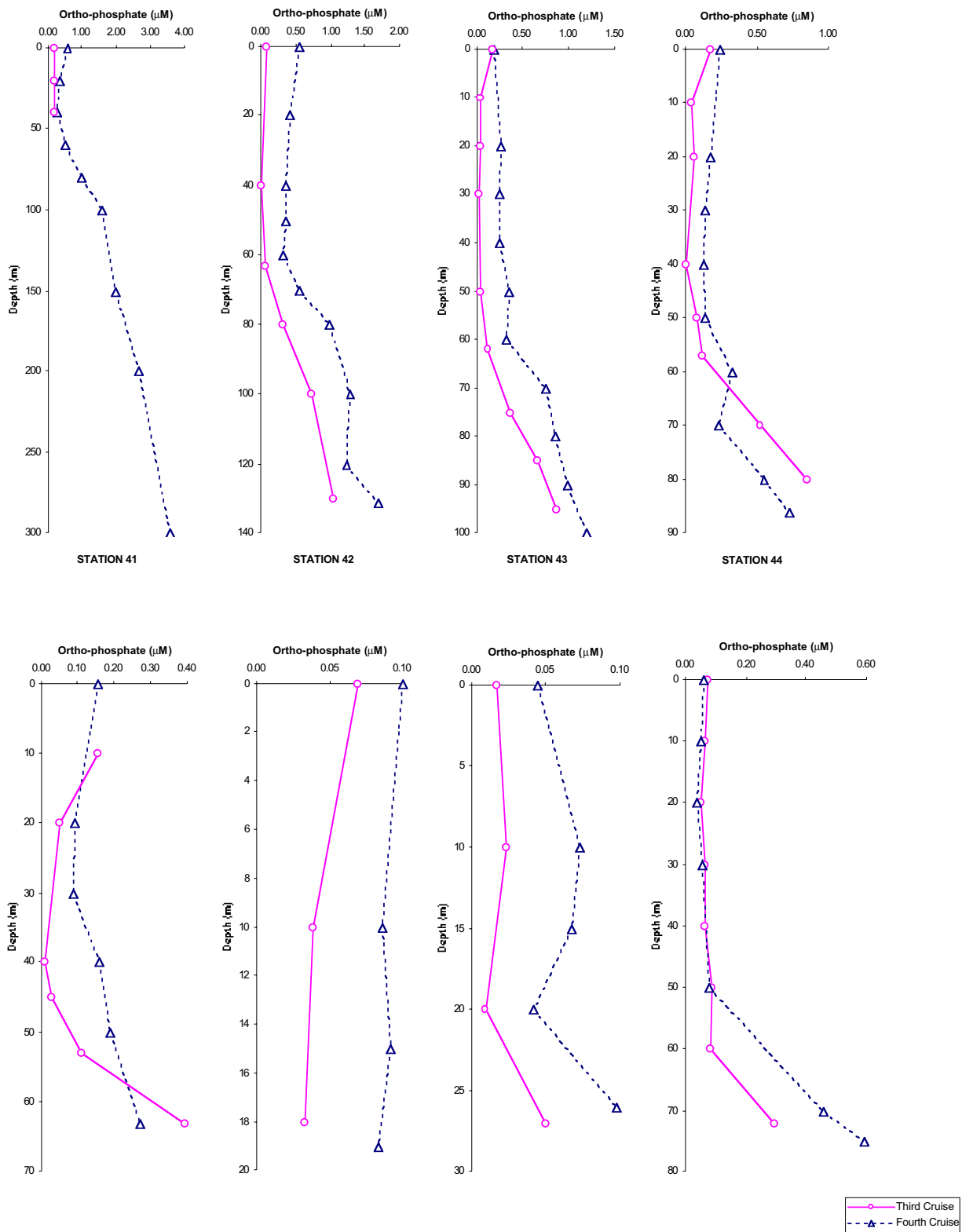


Fig. 2 Continue

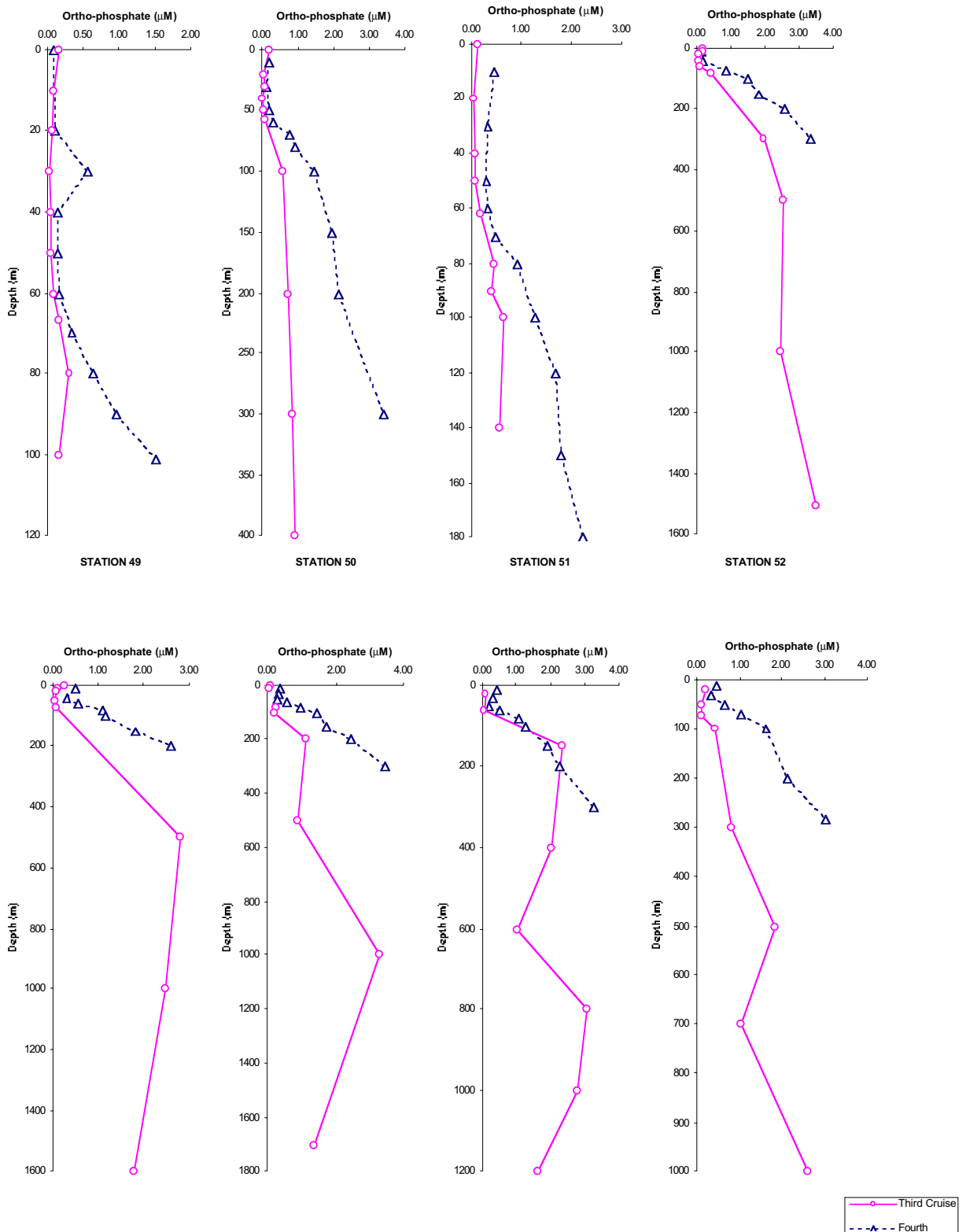


Fig. 2 Continue

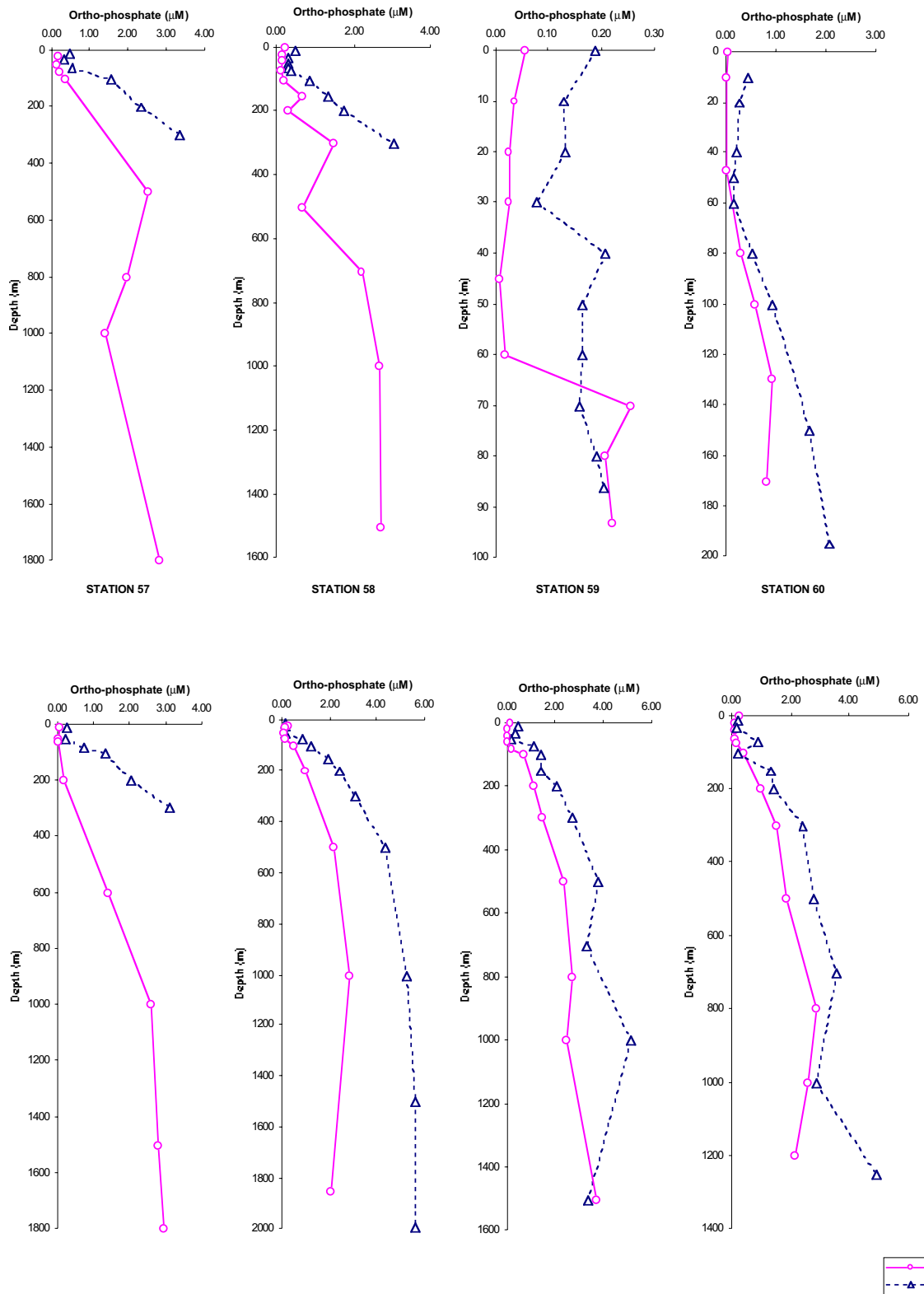


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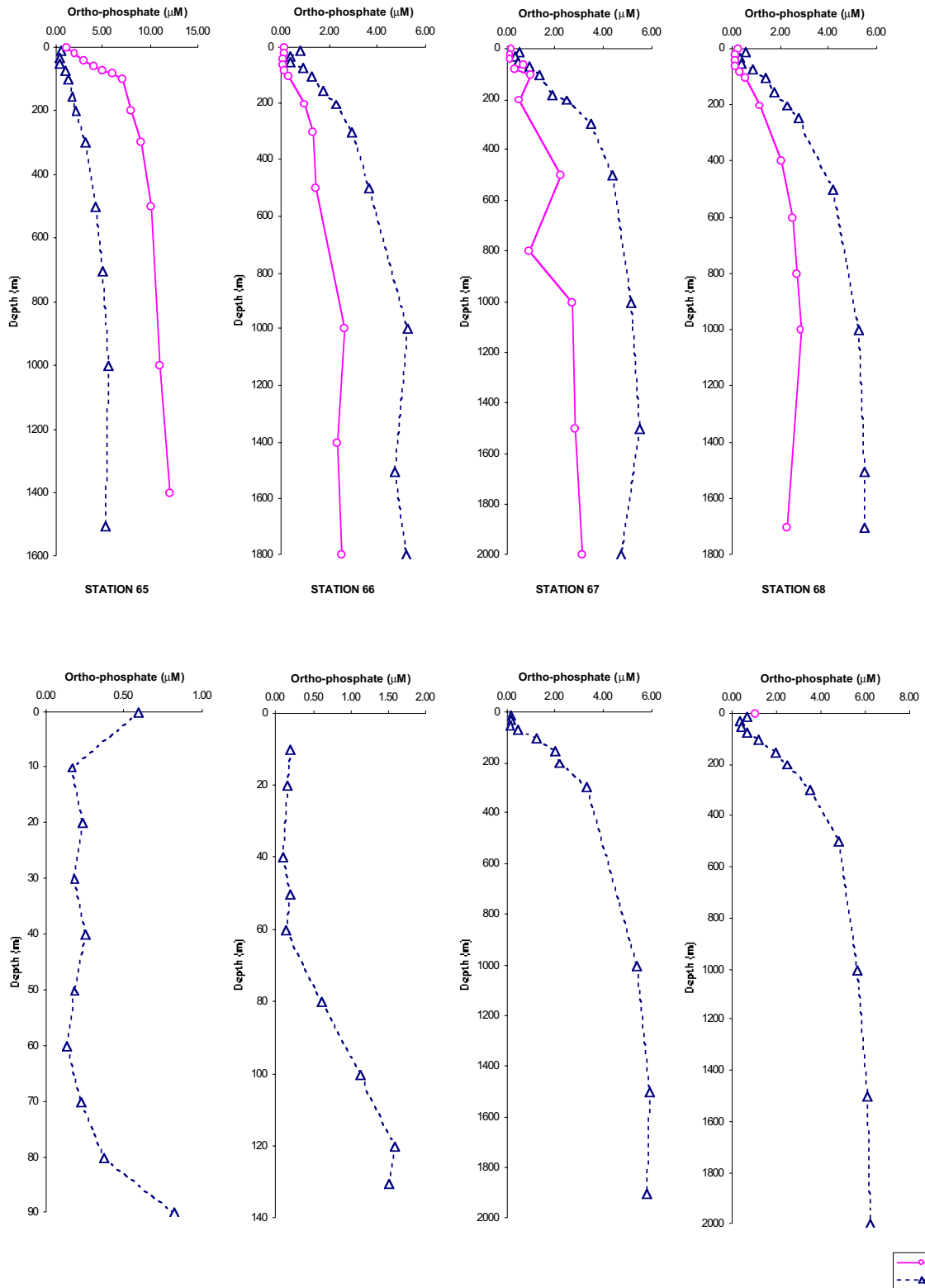


Fig. 2 Continue

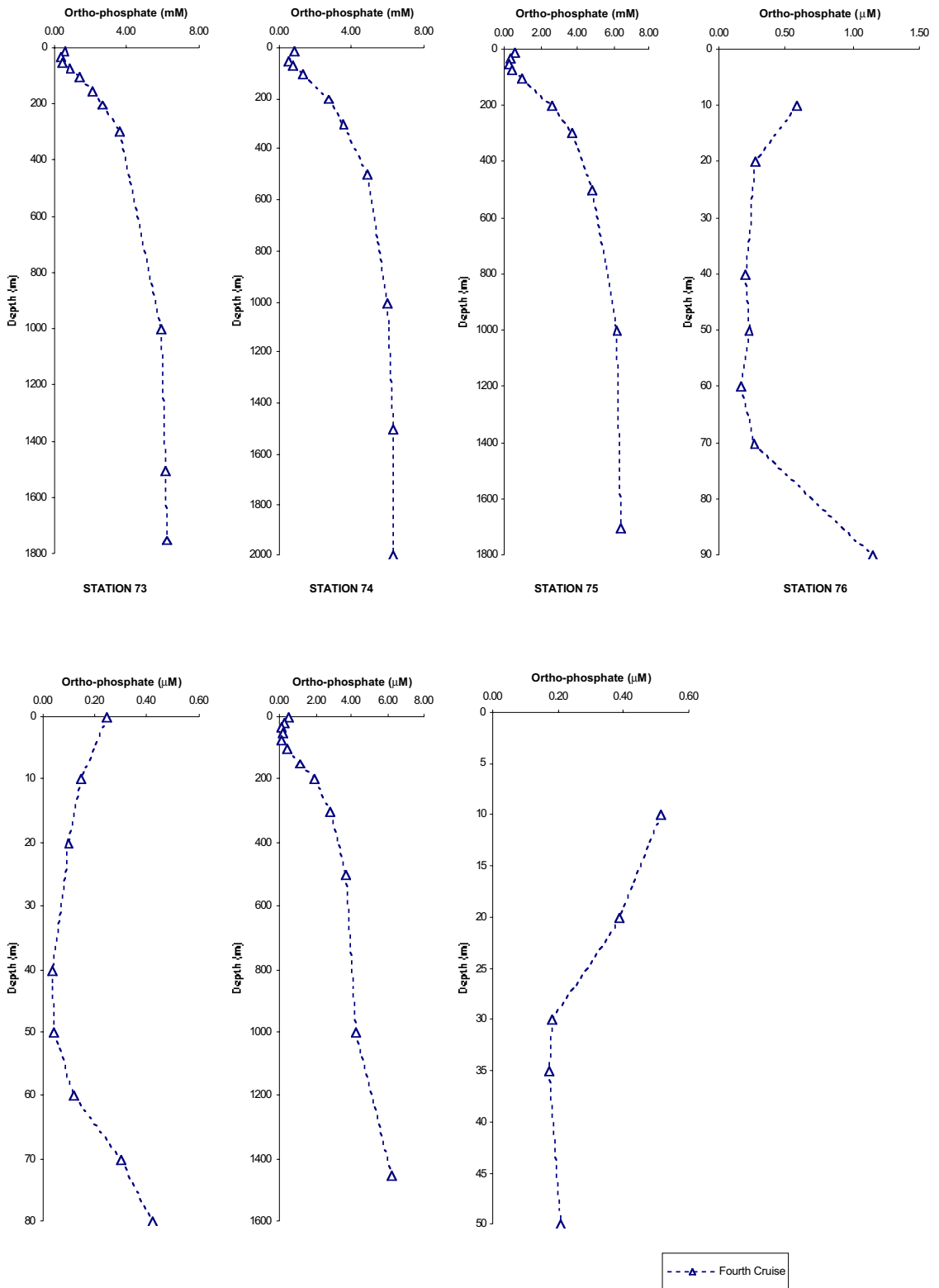


Fig. 2 Continue

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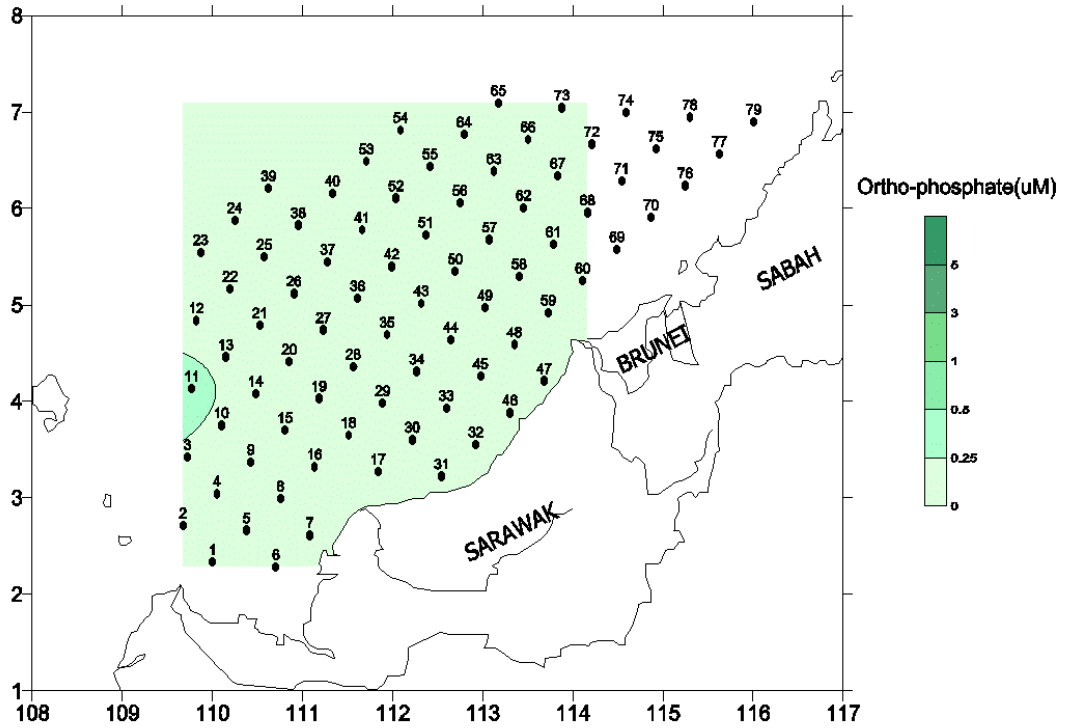


Fig. 3 Ortho-phosphate concentration in the upper layer of the sampling stations during July- August 1996 (third cruise).

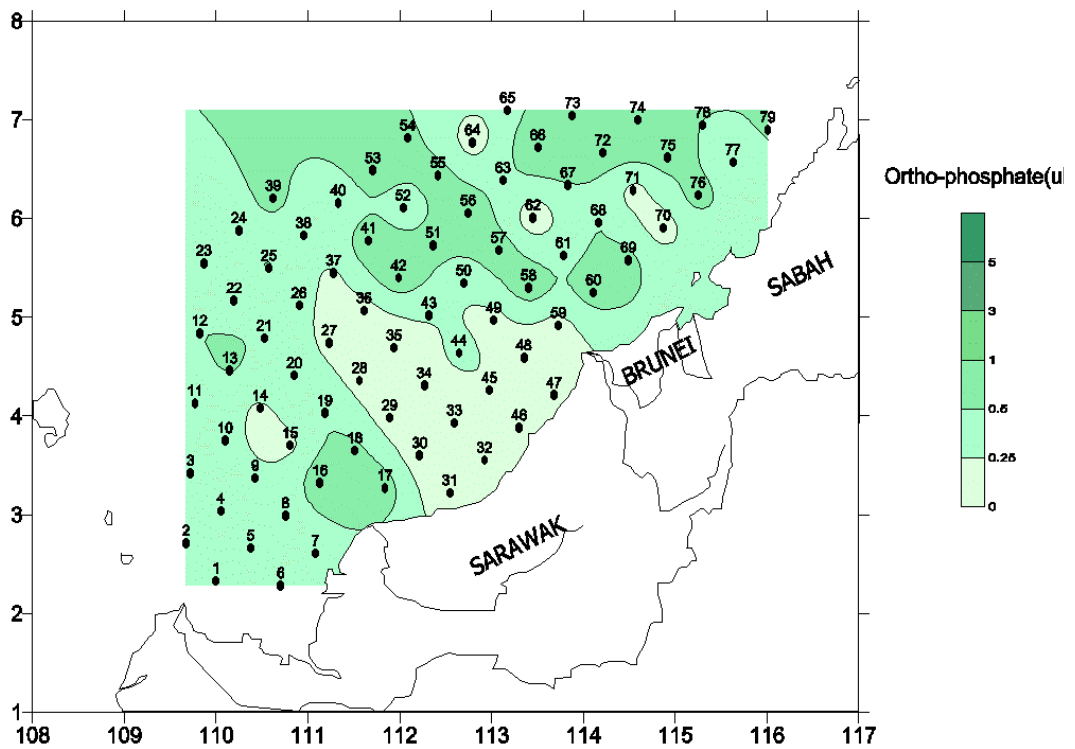


Fig. 4 Ortho-phosphate concentration in the upper layer of the sampling stations during May 1997 (fourth cruise).

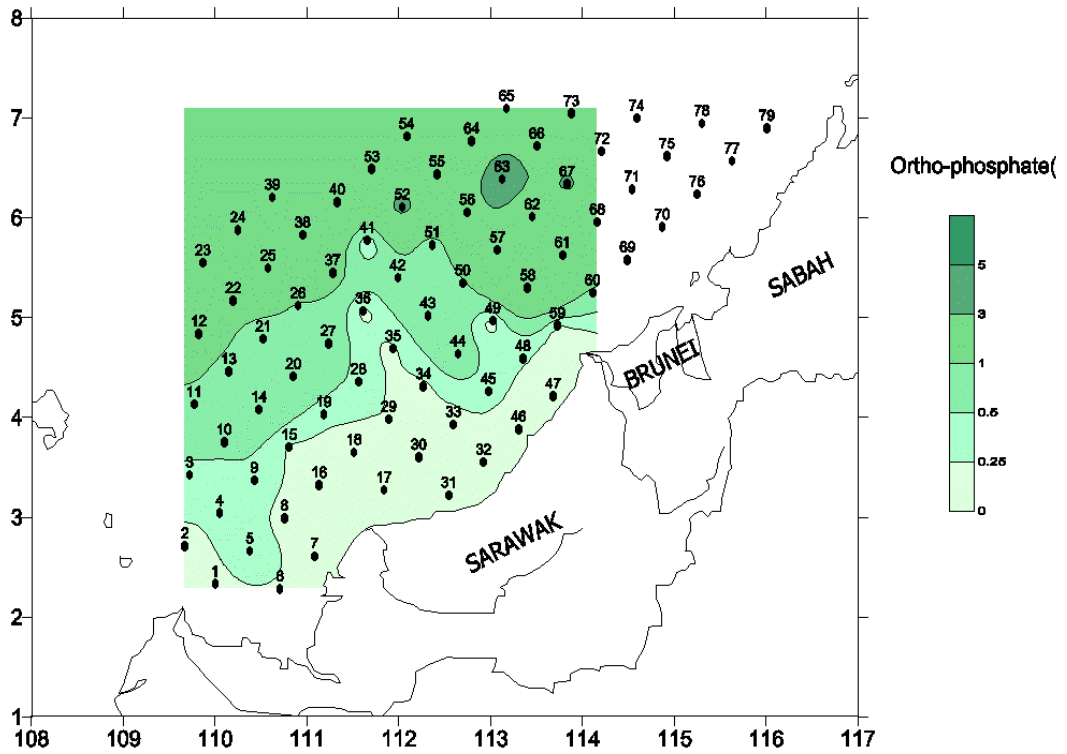


Fig. 5 Ortho-phosphate concentration in the bottom layer of the sampling stations during July-August 1996 (third cruise).

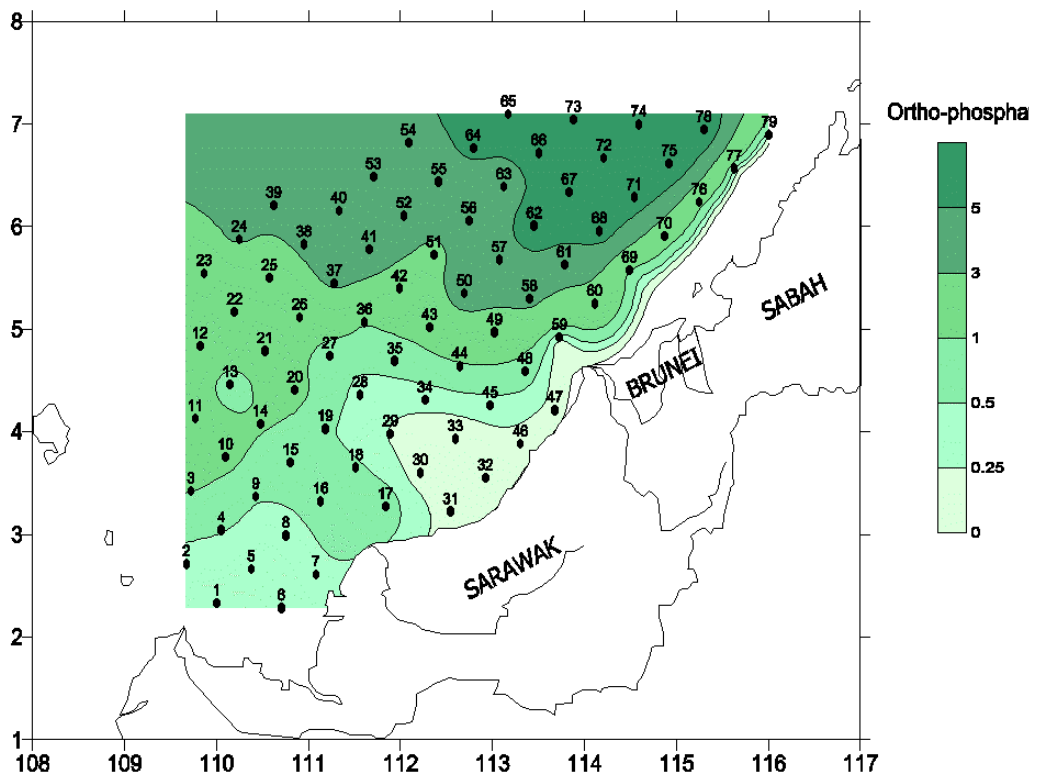


Fig. 6 Ortho-phosphate concentration in the bottom layer of the sampling stations during May 1997 (fourth cruise).

Table 3 Comparison of phosphate concentration (μM) in the world ocean and seas

Author(s)	Location	Surface layer
Kaewsripraky & Chantarasakul 1985*	Gulf of Thailand	0.88
Anon 1985*	Japan Sea Pacific Waters off Japan	0.55 0.22
Wafar <i>et al.</i> 1983*	Western English Channel	0.11
Law & Kamil 1986*	Malaysian EEZ off Kuala Terengganu, South China Sea	0.07
Lim 1978*	Southern South China Sea, off Malaysian coast 1971 cruise 1972 cruise 1973 cruise	0.26 0.38 0.68
Hirata <i>et al.</i> 1983*	Oceanic Region, North Solomon Island, South Pacific Ocean	0.21
Makita <i>et al.</i> 1984*	Oceanic Region between Gilbert and the Fiji Islands, South Pacific Ocean	0.20
Hirata <i>et al.</i> 1984*	Oceanic Region, North of Solomon Island, South Pacific Ocean	0.21
Law & Rahman 1987*	Malaysian EEZ Coastal waters off Kuantan to Pulau Tioman	0.18
Law & Zawawi 1988*	Malaysian EEZ Coastal waters off Sarawak, South China Sea	0.32
Law 1989*	Malaysian EEZ off Sabah, South China Sea	0.62
Law & Chu 1990	Coastal waters off Port Dickson, Straits of Malacca	0.18
Mohd. Shukri <i>et al.</i> 1997	Gulf of Thailand and East Coast of Peninsular Malaysia	0.14
Present study	Sabah, Sarawak and Brunei Darussalam waters, South China Sea Third Cruise (1996) Fourth Cruise (1997)	0.14 0.31

Note : * Source from Table 3 in Law and Rahman (1987)

Table 4 Comparison of average concentration of Ortho-phosphate in the third cruise and fourth cruise

Depth (m)	Ortho-phosphate (μM)	
	Third cruise	Fourth cruise
0-1	0.14	0.24
10	0.09	0.28
20	0.1	0.2
50	0.09	0.25
100	0.5	1.15
200	0.9	2.27
500	1.94	4.13
1000	2.59	5.19
1500	3.1	5.41

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