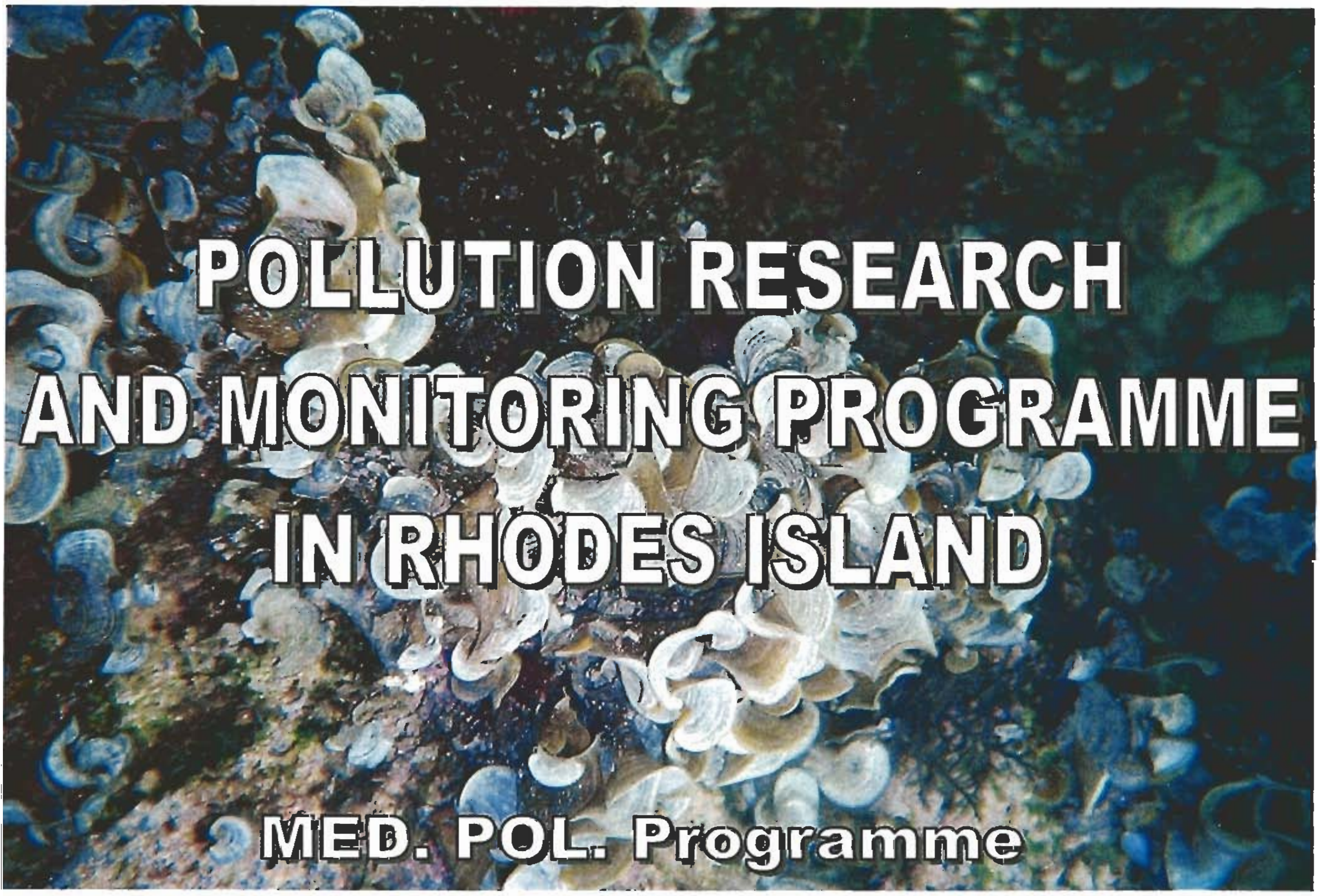
NATIONAL CENTRE FOR MARINE RESEARCH
HYDROBIOLOGICAL STATION OF RHODES



POLLUTION RESEARCH AND MONITORING PROGRAMME IN RHODES ISLAND

MED. POL. Programme

TECHNICAL REPORT 2000

Rhodes, 2002

Edited by: M. Corsini Foka

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CONTENTS

1. INTRODUCTION

1.1 Preface

The present work reports the results of the monitoring programme carried out in six sites selected along the NE coastal area of the Island of Rhodes during 2000. Samplings in this area are included in the National Mediterranean Pollution Programme of Greece.

Measurements of physical parameters (salinity, temperature, dissolved oxygen, turbidity), nutrients and Chlorophyll-a as well as determination of heavy metals in selected marine species were carried out during 2000.

1.2 Sampling stations and oceanographic cruises

According to the National monitoring programme, six sampling stations have been selected along the N.E. coastal area of the Island of Rhodes (Fig. 1.1), which coordinates and characteristics are presented on Table 1.1.

During 2000, three oceanographic cruises took place on June, September and December (Table 1.1). For the accuracy of coordinates, a Satellite Global Positioning System (Garmin 45 G.P.S. Locator) was used during the cruises.

The meteorological conditions and the parameters studied in each cruise are reported in Table 1.2.

Table 1.1. *Characteristics and coordinates of sampling stations.*

Area Code	Station Code	Station Location	Station Type	Latitude (DD, MM, SS, P)	Longitude (DD, MM, SS, P)	Bottom Depth (m)	Distance from shore (m)
GRE 6	1	Bay of Kalythies	Coastal General	36 21 30 N	28 14 00 E	40	800
	2	Cape Vodi (Koskinou)	Coastal General	36 23 21 N	28 15 06 E	65	425
	3	Koskinou	Coastal General	36 23 21 N	28 16 12 E	210	1700
	4	Rodos	Coastal General	36 27 01 N	28 14 09 E	15	400
	5	Aquarium	Coastal General	36 27 48 N	28 13 20 E	80	800
	6	Ladiko	Coastal General	36 19 30 N	28 12 08 E	Coastal	0

Mussels (*Patella sp.*) and brown algae (*Padina pavonica*) were collected from Station 6 on 10-06-00 and on 2-11-00.

Sediment samplings didn't take place due to technical problems.

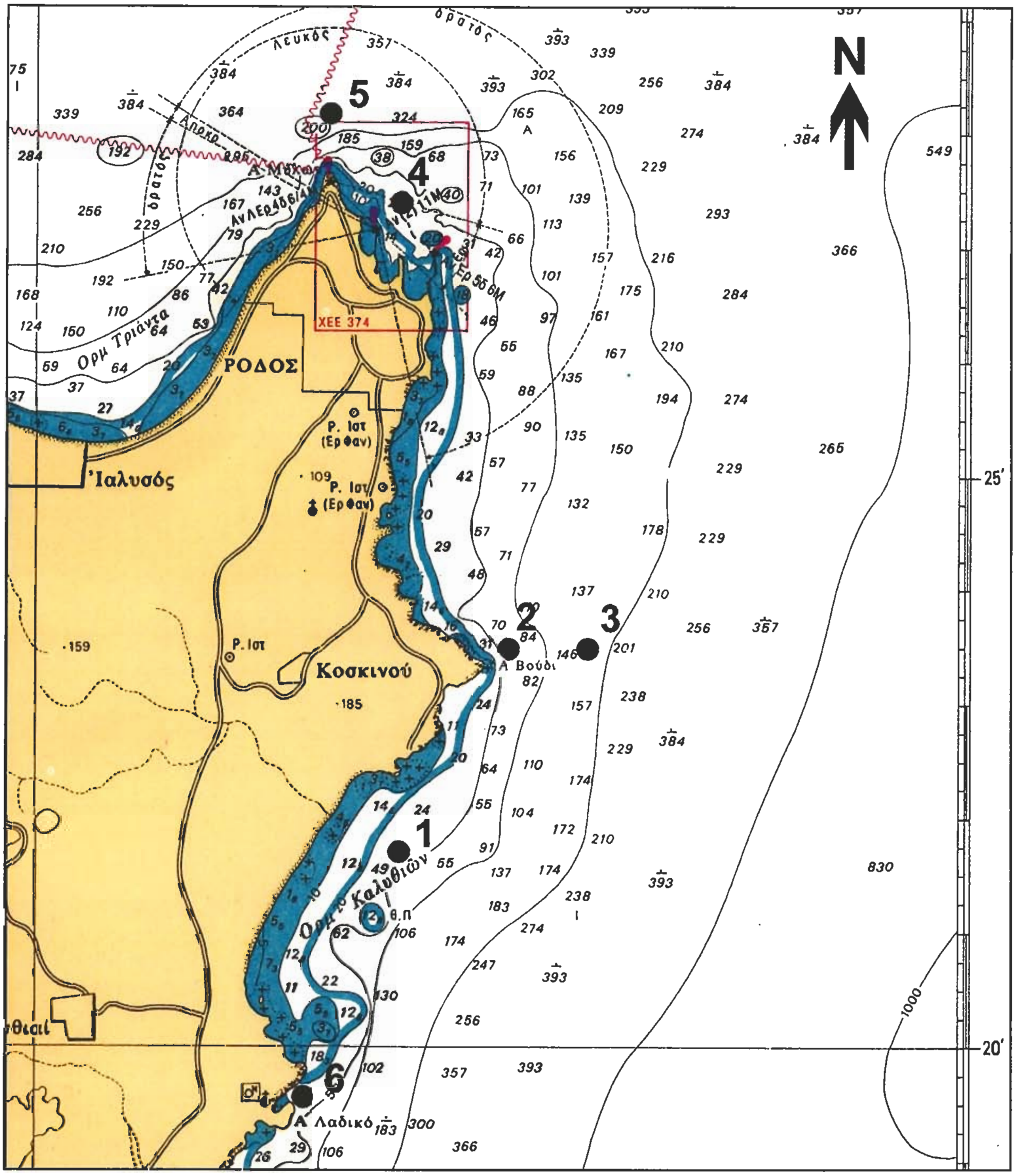


Fig. 1.1. Sampling Stations in Rhodes island.

Table 1.2. *Meteorological conditions and parameters studied during the oceanographic cruises.*

Cruise 02-06-00

	Station 1	Station 2	Station 3	Station 4	Station 5
Time	10^{00}	10^{30}	11^{30}	13^{30}	12^{30}
Air Temperature (°C)	24	24	23	23	23
Wind speed (miles/h)	8-12	19-24	25-31	13-18	25-31
Wind direction	N	N	N	N	N
Station depth (m)	40	65	210	15	80
T,S,DO	+	+	+	+	+
Turbidity	+	+	+	+	+
Nutrients	+	+	+	+	+
Chlorophyll	+	+	+	+	+

Cruise 05-09-00

	Station 1	Station 2	Station 3	Station 4	Station 5
Time	12^{00}	12^{45}	12^{30}	13^{45}	10^{00}
Air Temperature (°C)	30,5	30,5	30,5	30,0	27,6
Wind Velocity (miles/h)	4-7	4-7	4-7	8-12	13-18
Wind direction	N	N	N	N	N
Station Depth (m)	40	65	210	15	80
T,S,DO	+	+	+	+	+
Turbidity	+	+	+	+	+
Nutrients	+	+	+	+	+
Chlorophyll	+	+	+	+	+

Cruise 5-12-00

	Station 1	Station 2	Station 3	Station 4	Station 5
Time	12^{30}	12^{00}	11^{30}	10^{30}	10^{00}
Air Temperature (°C)	22	22	21	21	21
Wind Velocity (miles/h)	4-7	4-7	4-7	4-7	4-7
Wind direction	S	S	S	S	S
Station Depth (m)	40	65	210	15	80
T,S,O	+	+	+	+	+
Turbidity	+	+	+	+	+
Nutrients	+	+	+	+	+
Chlorophyll	+	+	+	+	+

1.3 Parameters

According to the contract (Table 1.3), the following parameters were measured:

a. Physical parameters:	
Temperature	°C
Salinity	psu (Practical Salinity Units)
Turbidity	FTU (Formazin Turbidity Units)
b. Chemical parameters:	
Phosphate	μg-at P/l
Silicate	μg-at Si/l
Nitrate	μg-at N/l
Nitrite	μg-at N/l
Ammonia	μg-at N/l
Chlorophyll-α	mgr/m^3 (μg/liter)
Dissolved oxygen	ml/l
c. Heavy metals in Biota	
Cu, Cr, Ni, Zn, Fe, Mn, Cd	μg/g dry weight

Table 1.3. *Parameters*

Area Code	No.of Stations	Location	Station Types	Parameter(s)/Group(s)	Sampling Frequency	Monitoring Institute
GRE6	5	1,2,3,4,5	Coastal general	MET+ in Air	Six-monthly	NCMR/ H.S.R.
				SP+, DOXY, NUT+ in Sea Water		
				CHLOR in Plankton		
				CU, HGT, CD, ZN, PB in Sediment	Yearly	
	1	6	Coastal general	HGT, CR, CD, ZN, CU, NI in Biota	Yearly	

1.4 Participants

The following members of the scientific and technical staff of the National Centre for Marine Research and the Hydrobiological Station of Rhodes were responsible for the field work, the sample analysis and the data processing:

M. CORSINI-FOKÀ / BIOLOGIST / SCIENTIST IN CHARGE
A. SIOULAS / GEOCHEMIST OCEANOGRAPHER
V. A. CATSIKI / BIOLOGIST
E. STROGYLOUDI / BIOLOGIST
G. A. HATIRIS / GEOLOGIST OCEANOGRAPHER
G. ALVANAKIS / CHEMIST
G. KONDYLATOS / ICHTHYOLOGIST TECHNICIAN

2. PHYSICAL PARAMETERS

Corsini-Foka M., Hatiris G. A., Sioulas A.

2.1 Methodology

- **Field work.** Three cruises were carried out on 02-06-00, 05-09-00 and 5-12-00, using a special equiped boat. During the cruises measurements were performed in all the stations, according to Table 1.1. Physical data (temperature, salinity) relative to all the sampling stations were obtained using a SEA CAT SBE 19-03 (Conductivity, temperature, depth recorder). The CTD recorder, supplied furthermore by a Seapoint Turbidity Meter, permitted to measure turbidity at all the sampling stations.
  Seawater samples were collected from the surface layers with a NIO sampler at standard depths from Stations 1, 2, 3, 4 and 5 for the determination of dissolved oxygen concentration, nutrients and Chlorophyll-α.
- For the processing of the raw data the software package Seabird & Seasoft Version 4.217 of SEABIRD Electronics was used.

2.2 Results and discussion

Temperature, salinity and turbidity values at standard depths are given per station on Tables 2.1 to Table 2.5.

The distribution of temperature and salinity obtained from CTD recorder for all sampling dates at each station (stations 1, 2, 3, 4, 5) are represented graphically in Fig. 2.1 to Fig. 2.5. Turbidity distributions given by the turbidity meter are represented graphically in Fig. 2.6 to Fig. 2.10.

2.2.1 Temperature and salinity

- During the cruise carried out on ***June*** the surface temperature values ranged from 20.5 to 20.8°C in stations 1, 2 and 3, while they were lightly higher in the stations 4 and 5 (21.2°C and 21.3°C respectively). In the stations 2 and 3 a thermocline was appearing from 10m depth (Figures 2.2a, 2.3a). The salinity was about 39.0 psu in the water column at all stations.
- During ***September***, high temperatures were measured in the surface layers. The temperature values ranged from the lower value of 26.6°C observed in station 5 to the higher value of 27°C measured in station 3. In station 2 a thermocline was observed between 25 and 30m depth, decreasing the temperature to 21°C (Fig. 2.2b), while in the deeper station 3 the temperature decreased from 27°C to 19.4°C in the layer from 25 to 35m depth (Fig. 2.3b). In station 5 the thermocline began at 30m depth, showing a decrease of the temperature from 26.6°C to 19.7°C at 40m depth. (Fig. 2.5b). During this cruise the salinity was high in the surface layers at all stations: it was about 39.3psu in station 2, 39.4psu in stations 4 and 5, 39.5psu in stations 1 and 3. An alocline was observed

in the deeper stations: at 25m depth in stations 2 and 3, at 30m depth in station 5. Under the alocline the salinity reached lower values of about 39.0psu (Fig. 2.2b, 2.3b, 2.5b).

- During the cruise of ***December*** temperature values ranged from 20.8°C to 21°C in the water column till 40-45m depth, being the termocline almost disappeared at all the deeper stations (Figures 2.1c to 2.5c). The salinity was about 39.3psu from the surface to the deeper layers.

2.2.2 Turbidity

In ***June*** the turbidity values were low, ranging from 0.01FTU in stations 1, 2 and 3 to 0.04 and 0.06FTU in stations 5 and 4 respectively. In ***September*** the turbidity ranged generally at low levels of 0.0-0.01FTU in stations 1, 3 and 5. Lightly higher values of about 0.04FTU were observed at 30m depth of station 2 as well as in station 4 (Figures 2.7b, 2.9b). During ***December*** the mean values of turbidity were very low ranging from 0.006 to 0.018FTU at all stations (Figures 2.6c to 2.10c).

Table 2.1. *T, S and Turbidity values in Station 1.*

Station 1	Depth (m)	T °C	S psu	Turbidity FTU
02/06/00	2	20,50	39,03	0,018
	10	20,29	39,01	0,012
05/09/00	2	26,86	39,45	0,000
	10	26,78	39,44	0,000
05/12/00	2	20,87	39,30	0,018
	10	20,84	39,30	0,012

Table 2.2. *T, S and Turbidity values in Station 2.*

Station 2	Depth (m)	T °C	S psu	Turbidity FTU
02/06/00	2	20,80	39,01	0,012
	10	20,75	39,00	0,012
	20	20,18	38,99	0,006
05/09/00	2	26,77	39,32	0,012
	10	26,67	39,34	0,012
	20	26,65	39,25	0,012
	30	21,52	38,75	0,049
	50	19,45	38,75	0,012
05/12/00	2	20,79	39,28	0,006
	10	20,78	39,28	0,012
	20	20,78	39,29	0,012
	30	20,75	39,29	0,006
	50	20,71	39,27	0,012

Table 2.3. *T, S and Turbidity values in Station 3.*

Station 3	Depth (m)	T °C	S psu	Turbidity FTU
02/06/00	2	20,70	39,01	0,012
	10	20,62	39,00	0,012
	20	20,03	39,03	0,006
05/09/00	2	26,94	39,46	0,000
	10	26,88	39,47	0,000
	20	26,87	39,48	0,000
	30	21,35	38,98	0,006
	50	19,44	38,96	0,000
05/12/00	2	20,87	39,29	0,012
	10	20,86	39,29	0,012
	20	20,85	39,29	0,012
	30	20,77	39,28	0,006
	50	20,74	39,27	0,006

Table 2.4. *T, S and Turbidity values in Station 4.*

Station 4	Depth (m)	T °C	S psu	Turbidity FTU
02/06/00	2	21,18	39,01	0,060
	10	21,13	39,01	0,050
05/09/00	2	26,77	39,39	0,037
	10	26,71	39,39	0,031
05/12/00	2	20,99	39,29	0,006
	10	20,69	39,25	0,031

Table 2.5 *T, S and Turbidity values in Station 5.*

Station 5	Depth (m)	T °C	S psu	Turbidity FTU
02/06/00	2	21,33	39,01	0,140
	10	21,23	39,02	0,037
	20	21,12	39,02	0,049
05/09/00	2	26,63	39,38	0,012
	10	26,61	39,36	0,018
	20	26,60	39,38	0,018
	30	23,20	38,84	0,012
	50	19,74	38,96	0,000
05/12/00	2	21,01	39,32	0,006
	10	20,98	39,32	0,006
	20	20,95	39,32	0,006
	30	20,94	39,32	0,006
	50	20,88	39,27	0,006

Table 2.6. *Summary statistics of physical data coming from all the sampling stations (CTD data, 2000).*

		June			September			December		
Station		T °C	S psu	Turb. FTU	T °C	S psu	Turb. FTU	T °C	S psu	Turb. FTU
1		0-9m			0-20m			0-20m		
	Avg	20,43	39,02	0,02	26,77	39,43	0,00	20,80	39,31	0,02
	Std	0,08	0,01	0,01	0,06	0,01	0,00	0,05	0,00	0,01
	Min	20,27	39,01	0,01	26,68	39,42	0,00	20,76	39,30	0,00
	Max	20,50	39,03	0,06	26,87	39,44	0,01	20,88	39,31	0,04
2		0-20m			0-30m			0-40m		
	Avg	20,61	39,01	0,01	25,16	39,18	0,02	20,76	39,28	0,01
	Std	0,22	0,01	0,00	2,11	0,26	0,01	0,03	0,01	0,01
	Min	20,17	38,99	0,00	21,15	37,81	0,00	20,71	39,27	0,01
	Max	20,81	39,02	0,02	26,86	39,47	0,06	20,79	39,29	0,06
3		0-20m			0-45m			0-40m		
	Avg	20,25	39,00	0,01	23,51	39,15	0,00	20,78	39,28	0,01
	Std	0,22	0,01	0,00	3,19	0,30	0,00	0,06	0,01	0,00
	Min	20,02	38,94	0,00	19,42	37,84	0,00	20,73	39,27	0,00
	Max	20,71	39,03	0,02	26,95	39,48	0,02	20,87	39,30	0,03
4		0-10m			0-10m			0-15m		
	Avg	21,15	39,01	0,05	26,73	39,38	0,03	20,80	39,27	0,02
	Std	0,02	0,01	0,01	0,03	0,01	0,01	0,16	0,03	0,01
	Min	21,12	38,98	0,04	26,70	39,37	0,02	20,53	39,23	0,00
	Max	21,19	39,02	0,07	26,82	39,39	0,05	21,00	39,31	0,06
5		0-20m			0-45m			0-40m		
	Avg	21,21	39,01	0,06	25,08	39,24	0,01	20,93	39,31	0,01
	Std	0,07	0,00	0,04	2,63	0,25	0,01	0,07	0,02	0,01
	Min	21,12	39,00	0,02	19,76	37,82	0,00	20,80	39,26	0,00
	Max	21,35	39,02	0,20	26,64	39,39	0,08	21,01	39,34	0,06

Fig. 2.1 *T, S profiles at St. 1 during June (a), September (b) and December (c).*

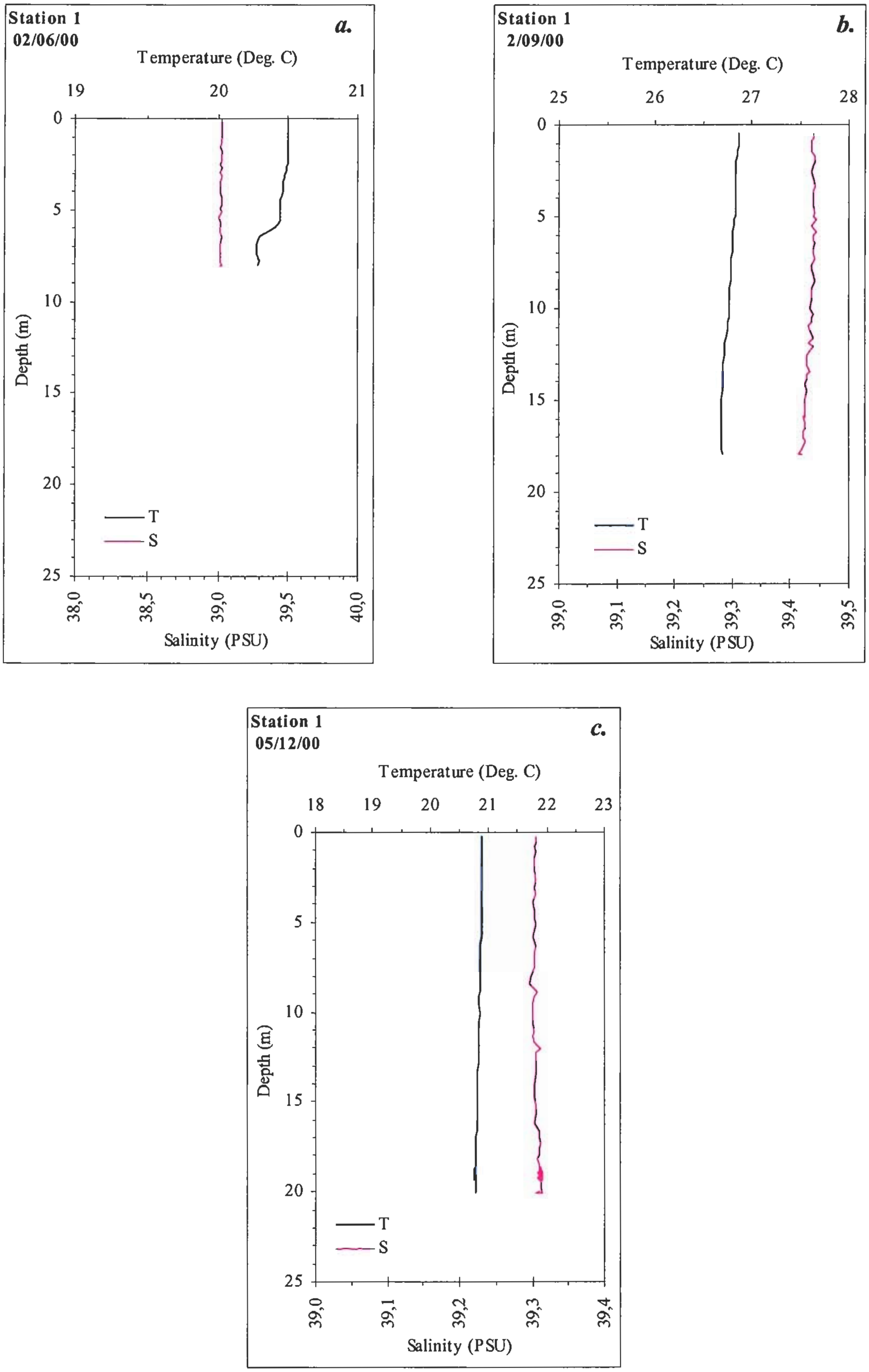


Fig. 2.2 *T, S profiles at St. 2 during June (a), September (b) and December (c).*

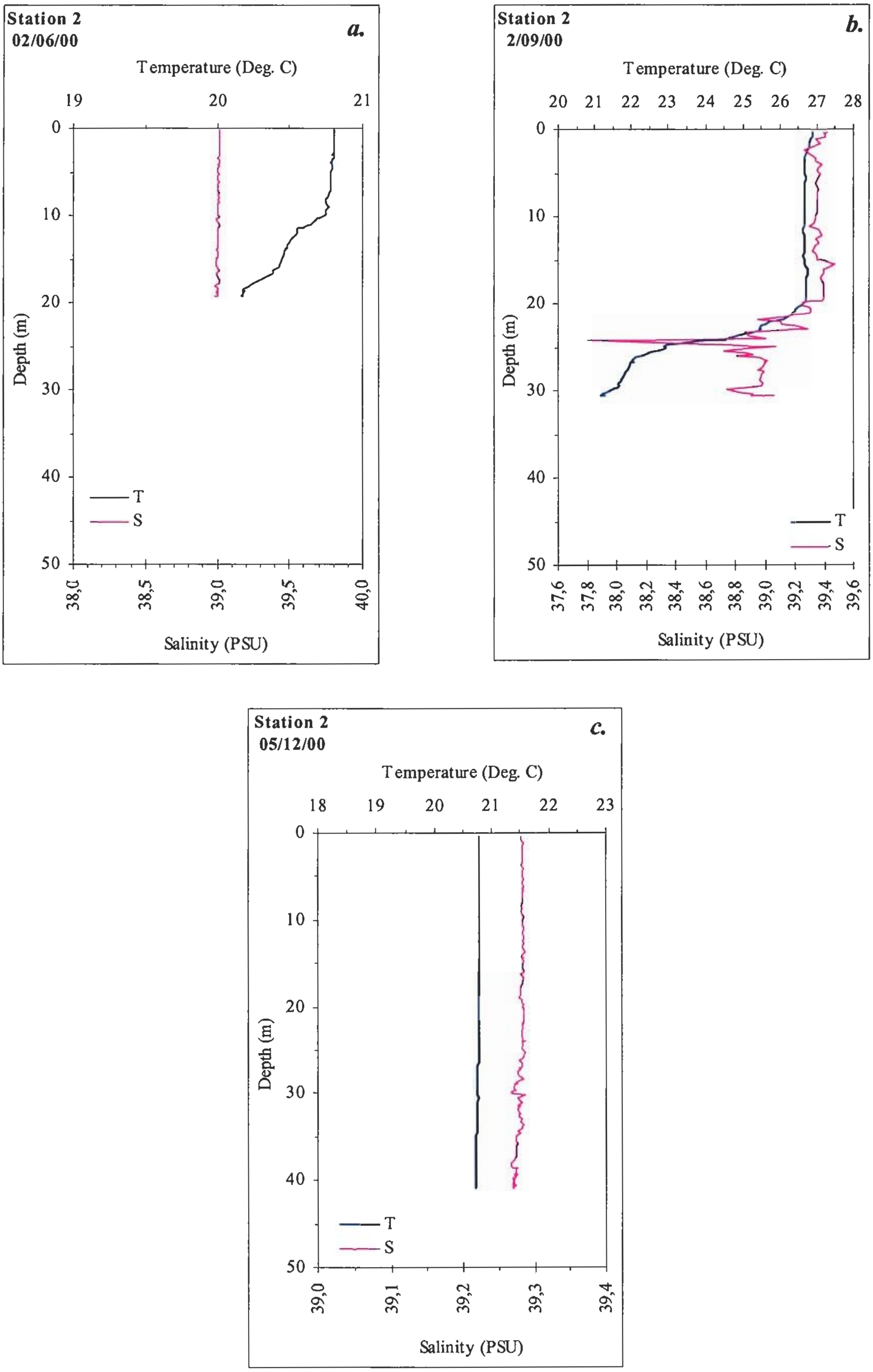


Fig. 2.3 *T, S profiles at St. 3 during June (a), September (b) and December (c).*

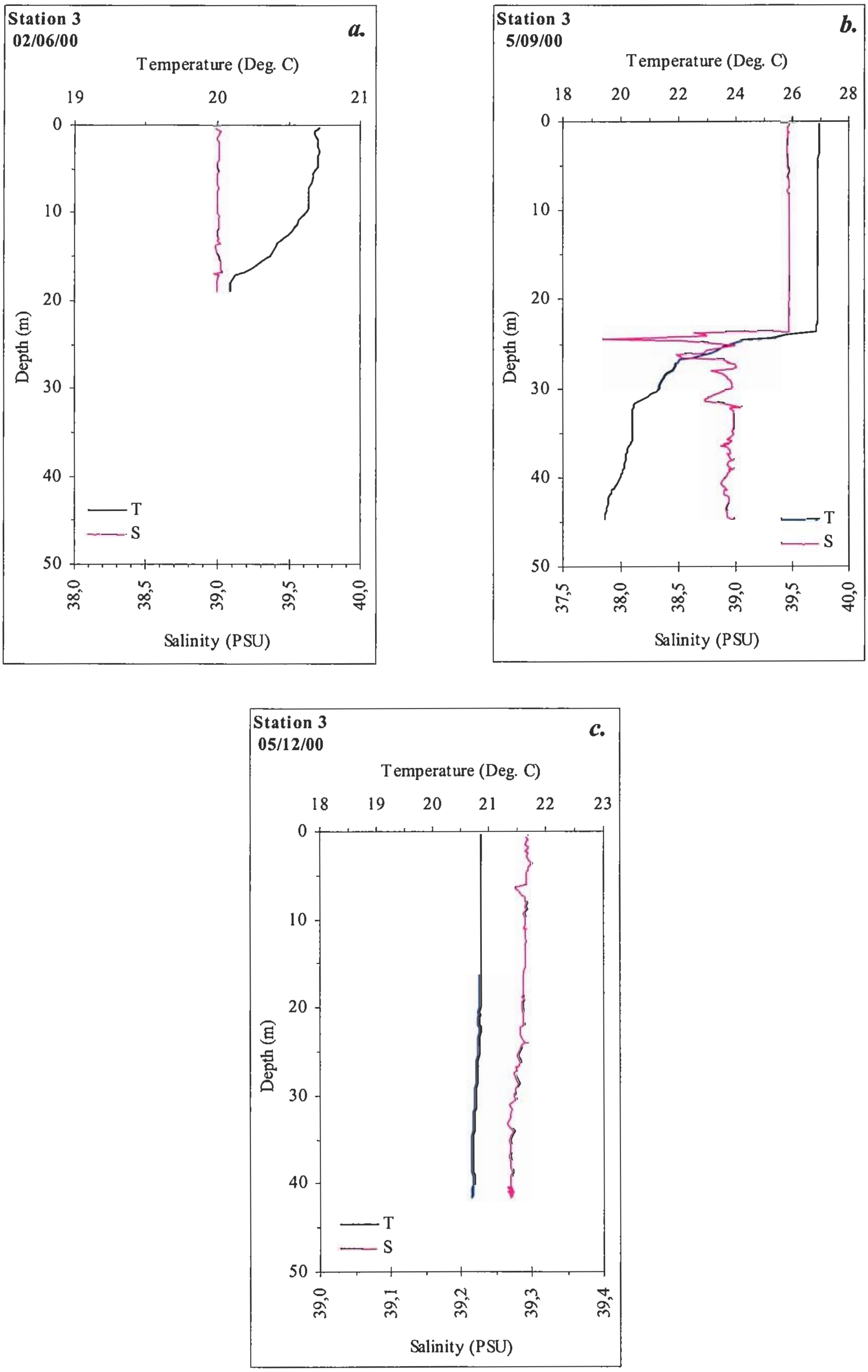


Fig. 2.4 *T, S profiles at St. 4 during June (a), September (b) and December (c).*

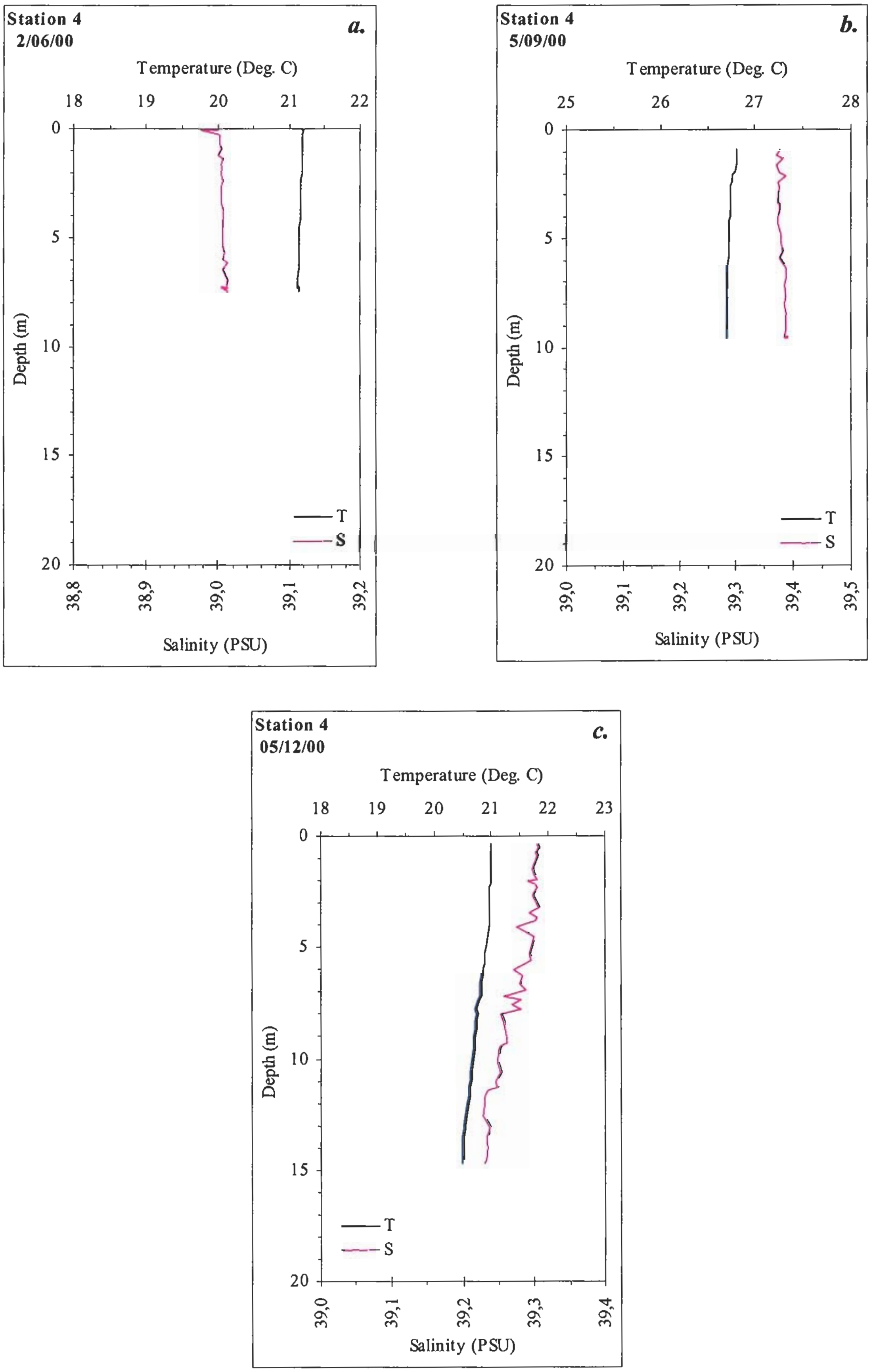


Fig. 2.5 *T, S profiles at St. 5 during June (a), September (b) and December (c).*

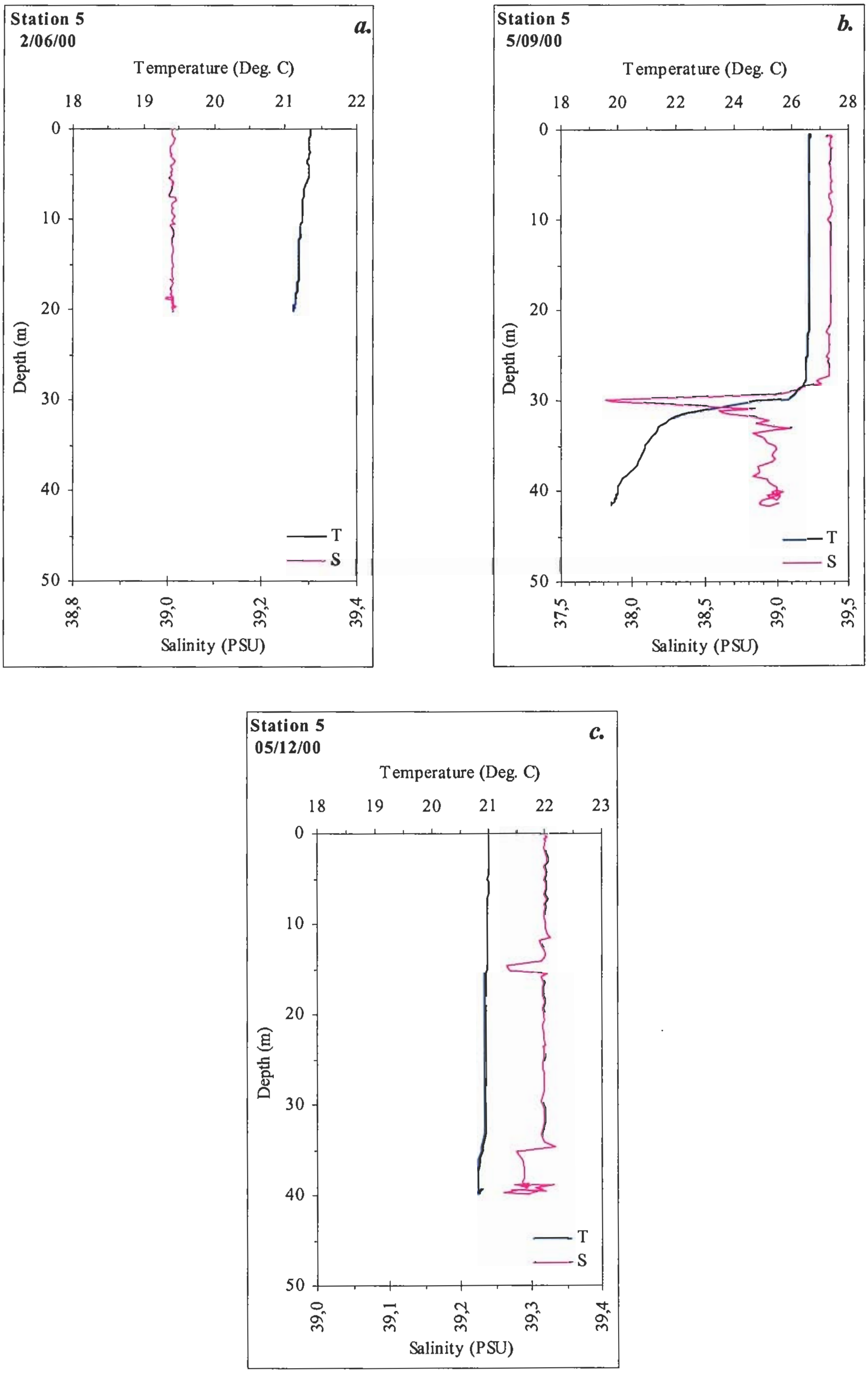


Fig. 2.6. *Turbidity profiles recorded at St. 1 during June (a), September (b) and Dec.(c).*

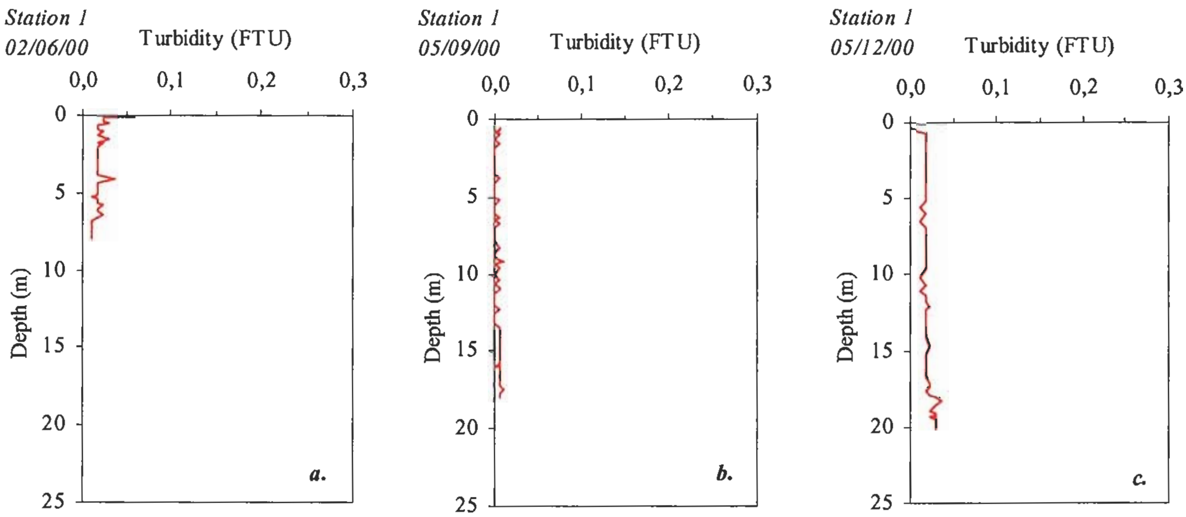


Fig. 2.7. *Turbidity profiles recorded at St. 2 during June (a), September (b) and Dec.(c).*

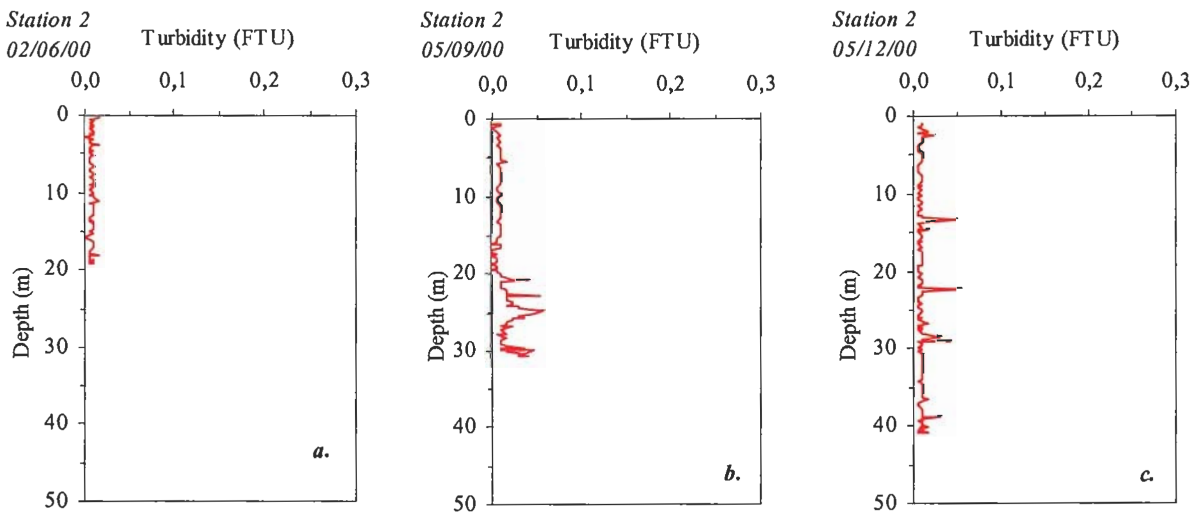


Fig. 2.8. *Turbidity profiles recorded at St. 3 during June (a), September (b) and Dec. (c).*

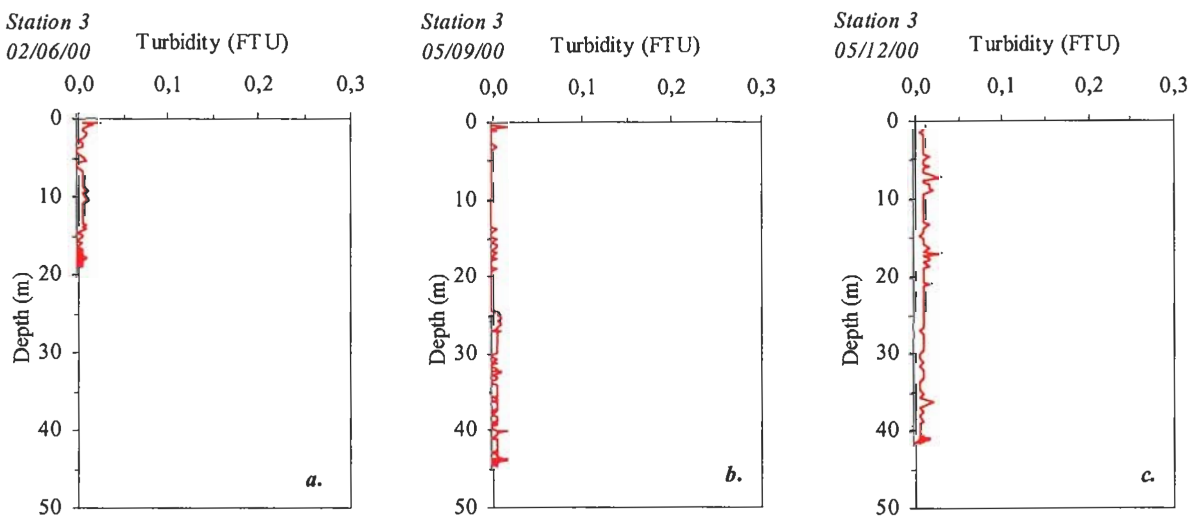


Fig. 2.9. *Turbidity profiles recorded at St. 4 during June (a), September (b) and Dec. (c).*

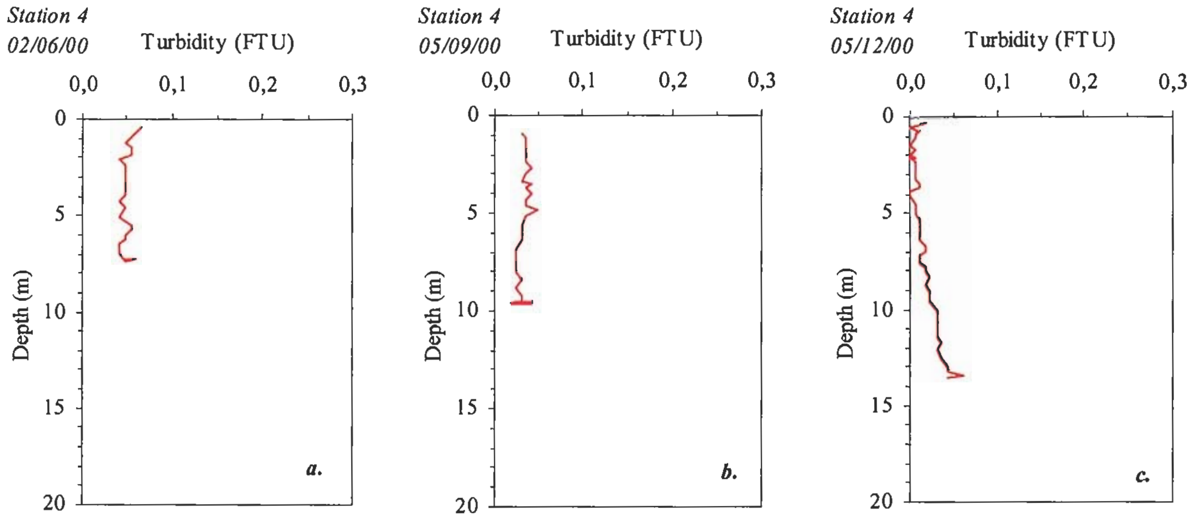
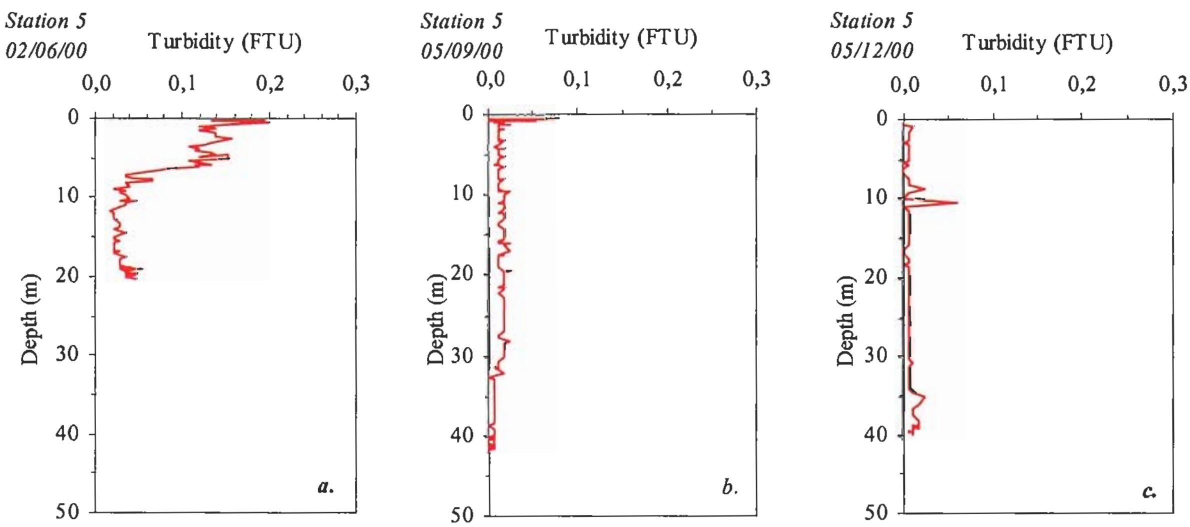


Fig. 2.10. *Turbidity profiles recorded at St. 5 during June (a), September (b) and Dec.(c).*



2.3 Conclusions

At the beginning of June the temperature and salinity results showed a good mixing in all the water column, while in September a thermocline and a alocline were clearly developed in the deeper stations 2, 3 and 5, as previously observed during August 1997, 1998 and July 1999. Temperature and salinity profiles obtained in December showed mixing of the water with values of about 21°C in the water column, one degree C higher than those described in the same period in previous reports (Corsini-Foka edit., 1998, 1999, 2000).

Turbidity values were always at very low levels at all stations and samplings.

3. CHEMICAL PARAMETERS

Corsini-Foka M., Alvanakis G., Hatiris G. A., Sioulas A.

3.1 Methodology

- **Field work**. Three cruises were carried out on 2-06-00, 5-09-00 and 5-12-00 using a special equiped boat. Seawater samples were collected from the surface layers with a NIO sampler at standard depths for the determination of dissolved oxygen, nutrients and Chl-α.
- **Analytical work**. The Winkler method (Strickland and Parsons, 1972) was used for oxygen determination.

  Samples for nutrients and Chl-α analysis were filtered immediately after sampling through GF/C Whatman glass fibers filters and kept at -20°C before analysis.

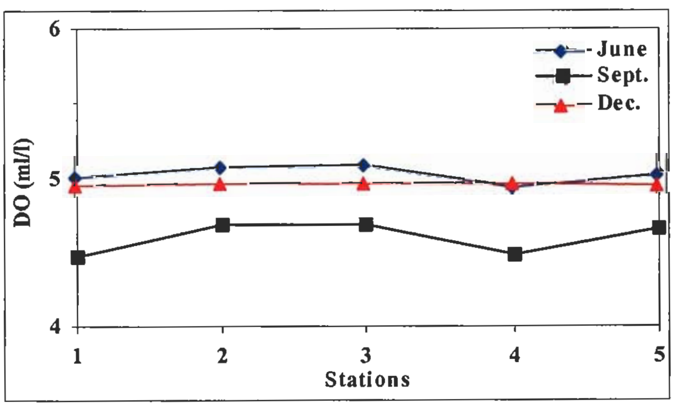
  Phosphate concentration was determined according to Strickland and Parsons (1972), while nitrate and nitrite concentrations were determined according to Greenberg et al. (Editors) (1992). Silicates were determined following Dasenakis and Skoullos (1989). The determination of ammonia was carried out according to Koroleff (1970). Photosynthetic pigments were measured spectrophotometrically after extraction with 90% acetone (SCOR-UNESCO, 1966). The above analysis were carried out at the Hydrobiological Station of Rhodes laboratory, using a Perkin Elmer UV/VIS Lambda 20 spectrometer.

3.2 Results and discussion

3.2.1 Dissolved oxygen

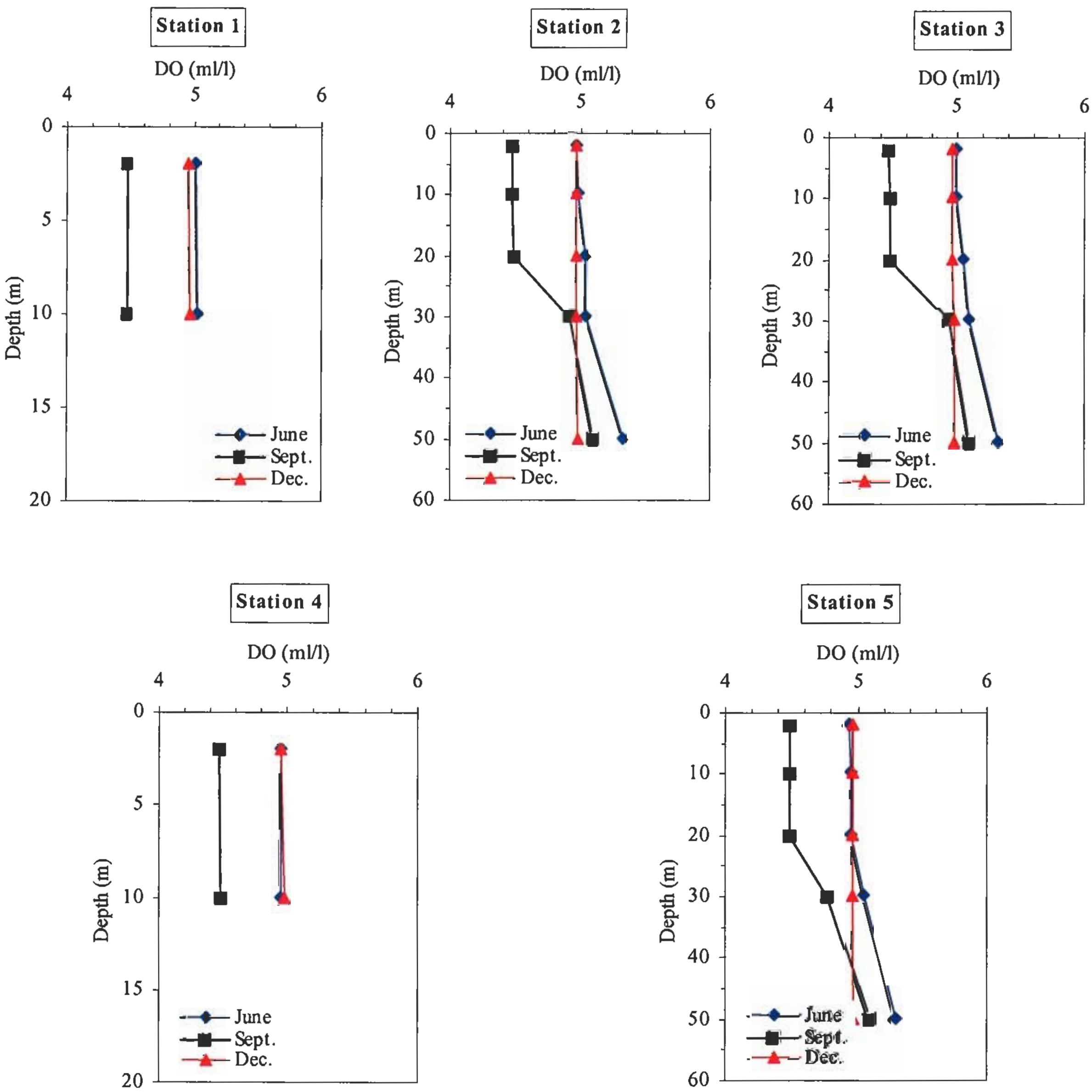
During ***June*** the concentration of dissolved oxygen ranged from 5,0 at surface to 5,3 ml/l at 50m depth, with a mean of about 5,0 ml/l, showing a good mixing of the water in this period in all stations (Table 3.6) (Fig. 3.1). In ***September*** the dissolved oxygen concentrations showed a surface stratification typical of summer months. In the surface layers the DO was lower than in June, being about 4.47ml/l at all the stations. Higher concentrations were measured at 30m depth (4.8-4.9ml/l) and at 50m depth (5.1ml/l) in the deeper stations 2, 3 and 5 (Tables 3.2, 3.3, 3.5) (Fig. 3.2). During ***December*** the DO stratification of the summer disappeared and the

Fig. 3.1. *Mean concentrations of DO during 2000.*



concentration of DO increased to 4.94-4.96ml/l, showing mixing of the water at all stations and depths (Fig. 3.2) (Table 3.6).

Fig. 3.2. *Vertical distribution of DO (ml/l) from all stations.*



3.2.2 Nutrients

The vertical distribution of nutrients at each station and sampling is given from Fig. 3.7 to Fig. 3.11, chemical data are given from Table 3.1 to Table 3.5, while summary statistics are presented in Table 3.6.

Nitrates. During June the mean nitrate concentration ranged from 0,1 to 0,2 µg-at/l in stations 1, 2 and 5, while it was 0,3 µg-at/l in stations 3 and 4 (Fig. 3.3), giving a mean of 0,2 µg-at/l among all the stations (Table 3.6). The mean concentration of nitrate during the cruise of September ranged from 0,1 to 0,2 µg-at/l in st. 1, 2, 3 and 5 (Tables 3.2, 3.3, 3.5) to 0,3 µg-at/l in station 4 (Tables 3.1, 3.4). In December the mean nitrate concentration was 0,1-0,2 µg-at/l in stations 1, 2 and 3, and about 0,3 µg-at/l in stations 4 and 5.

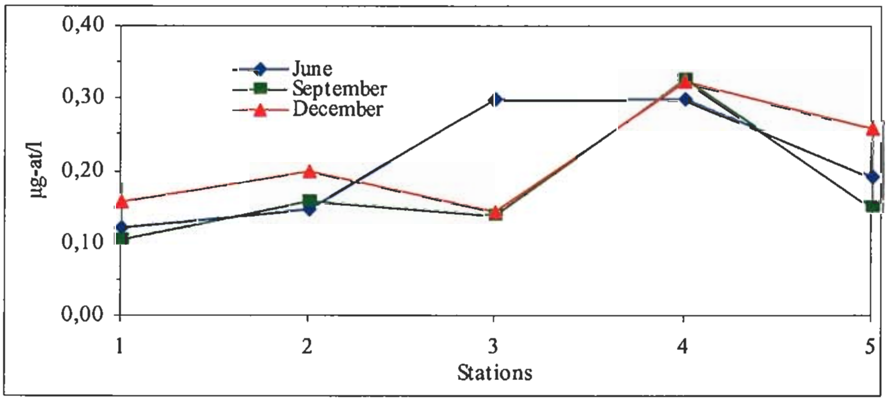


Fig. 3.3. *Mean concentrations of nitrate (µg-at/l) during 2000.*

Ammonia. The mean concentration of this salt in June ranged from 0,2 µg-at/l in station 4 to 0,4-0,5 µg-at/l in st. 1, 2 and 5, while it was slightly higher (0,85 µg-at/l) in station 3, where the concentration of ammonia reached the values of 1,4 and 1,2 µg-at/l at 2 and 10m depth respectively (Table 3.3). During summer the mean values NH_4 were uniformly distributed from 0,6 µg-at/l to 0,8 µg-at/l, but a high value of 2,4 µg-at/l was observed at 30m depth in st. 3 (Fig. 3.9b) and of 2 µg-at/l at 10m depth in st. 5 (Fig. 3.11b). In December the mean concentration of the salt showed very low values of 0,1-0,2 µg-at/l (Fig. 3.4).

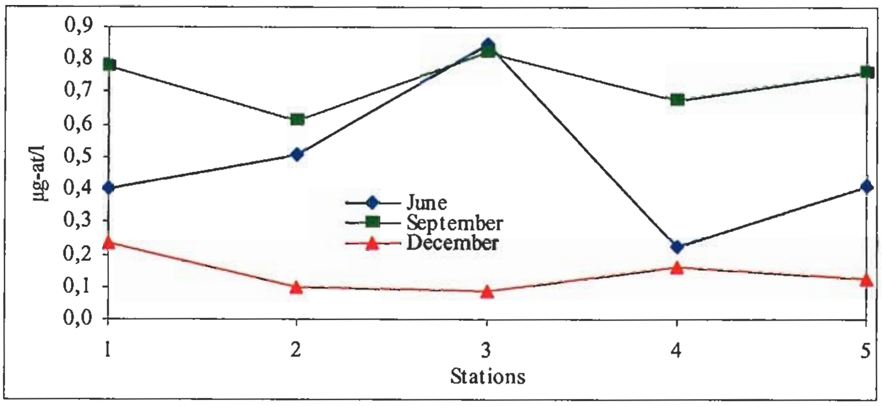


Fig. 3.4. *Mean concentrations of ammonia (µg-at/l) during 2000.*

Nitrites. The mean concentration of nitrites was at low levels of 0,01-0,02 µg-at/l at all sampling dates and stations, showing only a peak of about 0,06 µg-at/l in station 4 during summer (Fig. 3.5).

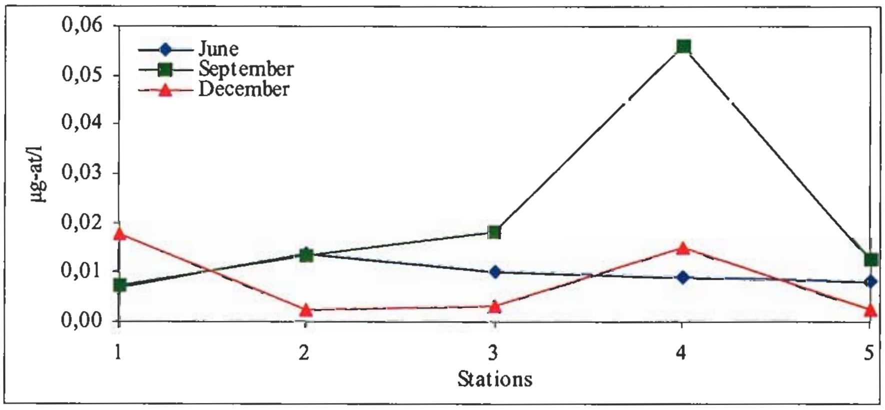


Fig. 3.5. *Mean concentrations of nitrites (µg-at/l) during 2000.*

Phosphates. The concentrations of phosphate was extremely low (0,0-0,1µg-at/l) at all sampling dates, stations and depths (Table 3.6), showing only a peak of 0,4 µg-at/l in station 2 at 20m depth, in December (Fig. 3.8c), which gave a slightly higher mean value of 0,08µg-at/l (Fig. 3.6).

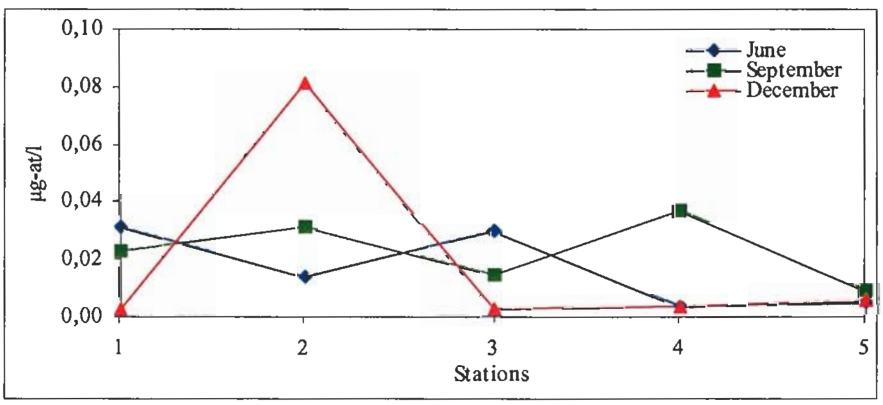


Fig. 3.6. *Mean concentrations of phosphate (µg-at/l) during 2000.*

Silicates. The mean concentration of this salt in June ranged from 1,1 μg-at/l in station 2 to 1,3, 1,6 and1,8 μg-at/l in station1, 5 and 4 respectively, while it was slightly higher (2,5 μg-at/l) in station 3. During September the mean concentration of silicates ranged from 1 μg-at/l in st. 1, 3 and 5 to 1,4 and 1,6 μg-at/l in stations 2 and 4. In December the mean concentration of silicate was at low levels of 0,6-0,7 μg-at/l at all stations (Fig. 3.7).

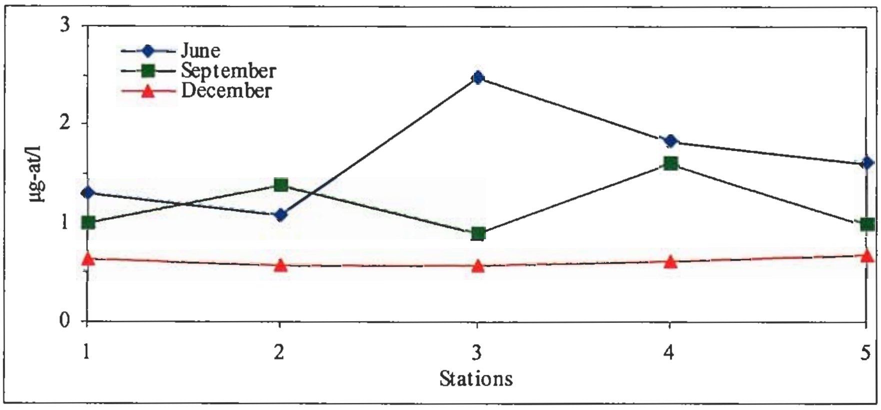


Fig. 3.7. *Mean concentrations of silicate (μg-at/l) during 2000.*

Table 3.1. *Concentrations of DO, nutrients and Chl-α obtained from St. 1*

Station 1	Depth (m)	DO ml/l	P-PO_4 µg-at/l	Si-SiO_4 µg-at/l	N-NO_3 µg-at/l	N-NO_2 µg-at/l	N-NH_4 µg-at/l	Chl-α µg/l
02/06/00	2	5,00	0,041	1,238	0,12	0,007	0,560	0,089
	10	5,02	0,021	1,353	0,12	0,007	0,240	0,065
	Mean	**5,01**	**0,03**	**1,30**	**0,12**	**0,01**	**0,40**	**0,08**
05/09/00	2	4,47	0,005	1,050	0,11	0,005	1,029	0,073
	10	4,47	0,041	0,926	0,10	0,010	0,521	0,063
	Mean	**4,47**	**0,02**	**0,99**	**0,11**	**0,01**	**0,77**	**0,07**
5/12/00	2	4,96	0,002	0,633	0,15	0,032	0,296	0,153
	10	4,96	0,003	0,607	0,16	0,004	0,168	0,151
	Mean	**4,96**	**0,00**	**0,62**	**0,16**	**0,02**	**0,23**	**0,15**

Table 3.2. *Concentrations of DO, nutrients and Chl-α obtained from St. 2.*

Station 2	Depth (m)	DO ml/l	P-PO_4 µg-at/l	Si-SiO_4 µg-at/l	N-NO_3 µg-at/l	N-NO_2 µg-at/l	N-NH_4 µg-at/l	Chl-α µg/l
02/06/00	2	4,97	0,037	1,184	0,22	0,026	0,790	0,055
	10	4,98	0,008	1,370	0,12	0,009	0,270	0,071
	20	5,03	0,012	1,167	0,15	0,014	0,620	0,287
	30	5,04	0,012	0,804	0,10	0,016	0,560	0,107
	50	5,33	0,000	0,848		0,004	0,300	0,055
	Mean	**5,07**	**0,01**	**1,07**	**0,15**	**0,01**	**0,51**	**0,12**
05/09/00	2	4,48	0,006	1,087	0,10	0,002	0,391	0,055
	10	4,48	0,017	1,102	0,10	0,017	0,510	0,070
	20	4,49	0,003	1,018	0,12	0,014	0,764	0,084
	30	4,92	0,052	2,253	0,21	0,012	0,717	0,050
	50	5,09	0,078	1,413	0,26	0,022	0,676	0,130
	Mean	**4,69**	**0,03**	**1,37**	**0,16**	**0,01**	**0,61**	**0,08**
5/12/00	2	4,97	0,001	0,502	0,15	0,001	0,070	0,136
	10	4,97	0,003	0,531	0,12	0,004	0,107	0,153
	20	4,97	0,401	0,583	0,28	0,006	0,104	0,108
	30	4,97	0,001	0,575	0,18	0,001	0,110	0,153
	50	4,97	0,001	0,613	0,27	0,001	0,106	0,153
	Mean	**4,97**	**0,08**	**0,56**	**0,20**	**0,00**	**0,10**	**0,14**

Table 3.3. *Concentrations of DO, nutrients and Chl-a obtained from St. 3.*

Station 3	Depth (m)	DO ml/l	P-PO_4 µg-at/l	Si-SiO_4 µg-at/l	N-NO_3 µg-at/l	N-NO_2 µg-at/l	N-NH_4 µg-at/l	Chl-α µg/l
02/06/00	2	4,98	0,009	2,317	0,47	0,011	1,350	0,066
	10	4,99	0,109	4,263	0,53	0,014	1,210	0,064
	20	5,04	0,018		0,13	0,009		0,046
	30	5,08	0,000	1,759	0,18	0,007	0,420	0,033
	50	5,32	0,014	1,521	0,18	0,009	0,400	0,091
	Mean	**5,08**	**0,03**	**2,47**	**0,30**	**0,01**	**0,85**	**0,06**
05/09/00	2	4,46	0,025	1,084	0,10	0,003	0,327	0,041
	10	4,47	0,025	0,954	0,14	0,023	0,505	0,056
	20	4,47	0,007	0,567	0,13	0,044	0,484	
	30	4,92	0,007	0,882	0,10	0,012	2,354	0,089
	50	5,09	0,007	1,007	0,22	0,010	0,431	0,089
	Mean	**4,68**	**0,01**	**0,90**	**0,14**	**0,02**	**0,82**	**0,07**
5/12/00	2	4,96	0,003	0,554	0,15	0,003	0,065	0,132
	10	4,96	0,002	0,588	0,11	0,006	0,170	0,152
	20	4,96	0,006	0,536	0,16	0,006	0,065	0,128
	30	4,97	0,001	0,600		0,000	0,068	0,131
	50	4,97	0,001	0,579	0,16	0,000	0,074	0,149
	Mean	**4,96**	**0,00**	**0,57**	**0,14**	**0,00**	**0,09**	**0,14**

Table 3.4. *Concentrations of DO, nutrients and Chl-a obtained from St. 4.*

Station 4	Depth (m)	DO ml/l	P-PO_4 µg-at/l	Si-SiO_4 µg-at/l	N-NO_3 µg-at/l	N-NO_2 µg-at/l	N-NH_4 µg-at/l	Chl-α µg/l
02/06/00	2	4,94	0,000	1,813	0,33	0,014	0,160	0,197
	10	4,94	0,006	1,848	0,27	0,004	0,280	0,153
	Mean	**4,94**	**0,00**	**1,83**	**0,30**	**0,01**	**0,22**	**0,18**
05/09/00	2	4,48	0,048	1,589	0,20	0,099	0,935	0,204
	10	4,48	0,026	1,605	0,45	0,013	0,408	0,199
	Mean	**4,48**	**0,04**	**1,60**	**0,33**	**0,06**	**0,67**	**0,20**
5/12/00	2	4,95	0,004	0,519	0,16	0,014	0,152	0,085
	10	4,97	0,003	0,706	0,48	0,016	0,163	0,155
	Mean	**4,96**	**0,00**	**0,61**	**0,32**	**0,02**	**0,16**	**0,12**

Table 3.5. *Concentrations of DO, nutrients and Chl-α obtained from St. 5.*

Station 5	Depth (m)	DO ml/l	$P\text{-}PO_4$ µg-at/l	$Si\text{-}SiO_4$ µg-at/l	$N\text{-}NO_3$ µg-at/l	$N\text{-}NO_2$ µg-at/l	$N\text{-}NH_4$ µg-at/l	Chl-α µg/l
02/06/00	2	4,93	0,000	1,742	0,15	0,004	0,210	0,067
	10	4,93	0,003	1,512	0,12	0,007	0,820	0,077
	20	4,94	0,011	1,768	0,10	0,009	0,370	0,066
	30	5,03	0,004	1,777	0,27	0,004	0,290	0,069
	50	5,27	0,005	1,167	0,30	0,016	0,350	0,170
	Mean	**5,02**	**0,00**	**1,59**	**0,19**	**0,01**	**0,41**	**0,09**
05/09/00	2	4,49	0,021	1,004	0,14	0,006	0,457	0,076
	10	4,49	0,001	1,077	0,15	0,015	1,915	0,058
	20	4,49	0,009	0,865	0,15	0,012	0,598	0,055
	30	4,77	0,011	0,935	0,11	0,015	0,352	0,065
	50	5,07	0,002	1,014	0,20	0,017	0,455	0,084
	Mean	**4,66**	**0,01**	**0,98**	**0,15**	**0,01**	**0,76**	**0,07**
5/12/00	2	4,94	0,005	0,498	0,20	0,001	0,114	0,084
	10	4,95	0,005	0,554	0,16	0,001	0,092	0,083
	20	4,95	0,002	0,525	0,13	0,001	0,141	0,110
	30	4,95	0,003	0,514	0,45	0,006	0,099	0,108
	50	4,96	0,013	1,217	0,34	0,003	0,170	0,149
	Mean	**4,95**	**0,01**	**0,66**	**0,26**	**0,00**	**0,12**	**0,11**

Table 3.6
Summary statistics of chemical data coming from all the sampling stations.

Date		DO ml/l	$P\text{-}PO_4$ µg-at/l	$Si\text{-}SiO_4$ µg-at/l	$N\text{-}NO_3$ µg-at/l	$N\text{-}NO_2$ µg-at/l	$N\text{-}NH_4$ µg-at/l	Chl-α µg/l
02/06/00	Avg	5,04	0,02	1,64	0,21	0,010	0,51	0,10
	Std	0,13	0,03	0,76	0,13	0,006	0,34	0,06
	Min	4,93	0,00	0,80	0,10	0,004	0,16	0,03
	Max	5,33	0,11	4,26	0,53	0,026	1,35	0,29
05/09/00	Avg	4,63	0,02	1,13	0,16	0,018	0,73	0,09
	Std	0,25	0,02	0,37	0,08	0,022	0,54	0,05
	Min	4,46	0,00	0,57	0,10	0,002	0,33	0,04
	Max	5,09	0,08	2,25	0,45	0,099	2,35	0,20
5/12/00	Avg	4,96	0,02	0,60	0,21	0,010	0,12	0,13
	Std	0,01	0,09	0,16	0,11	0,010	0,06	0,03
	Min	4,94	0,00	0,50	0,11	0,000	0,07	0,08
	Max	4,97	0,40	1,22	0,48	0,030	0,30	0,16

Fig. 3.7. *Vertical distribution of nutrients from St. 1 during June (a), Sept. (b) and Dec. (c).*

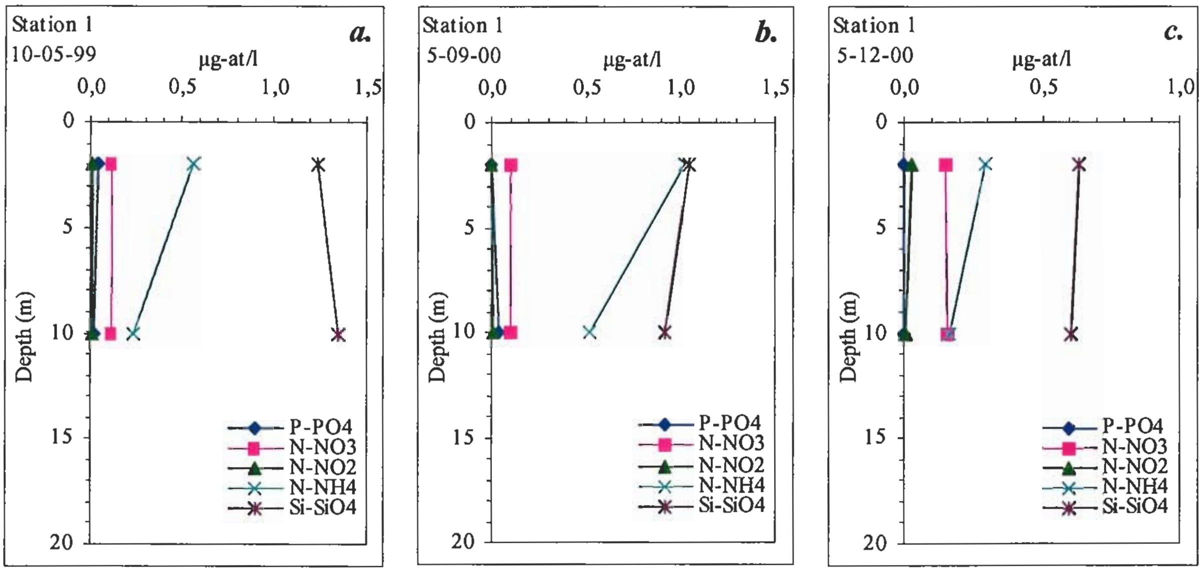


Fig. 3.8. *Vertical distribution of nutrients from St. 2 during June (a), Sept. (b) and Dec. (c).*

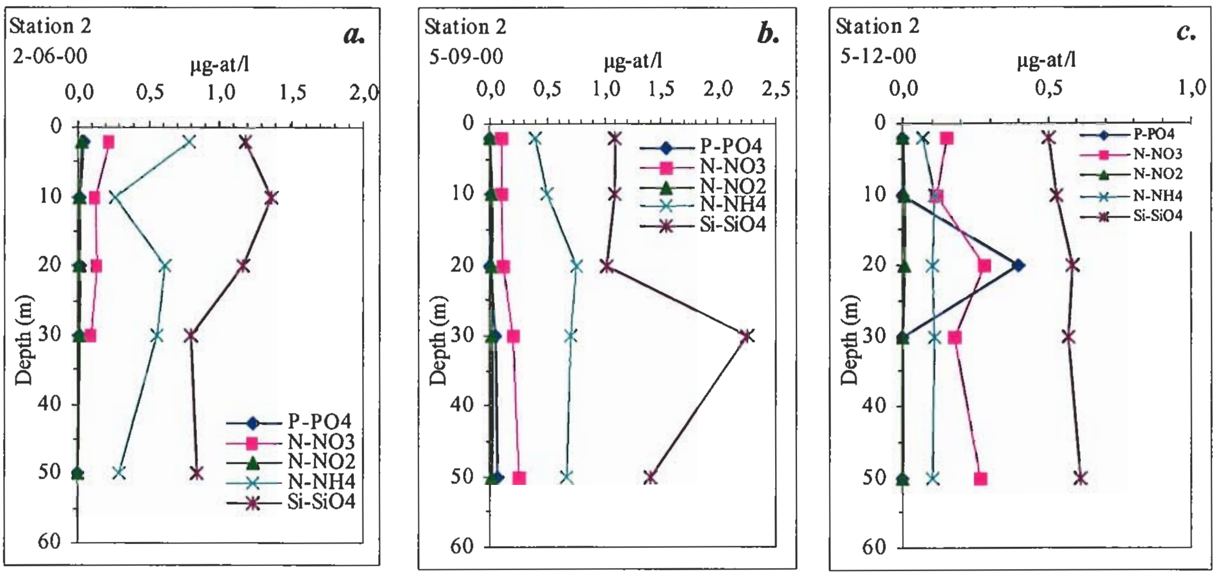


Fig. 3.9. *Vertical distribution of nutrients from St. 3 during June (a), Sept. (b) and Dec. (c).*

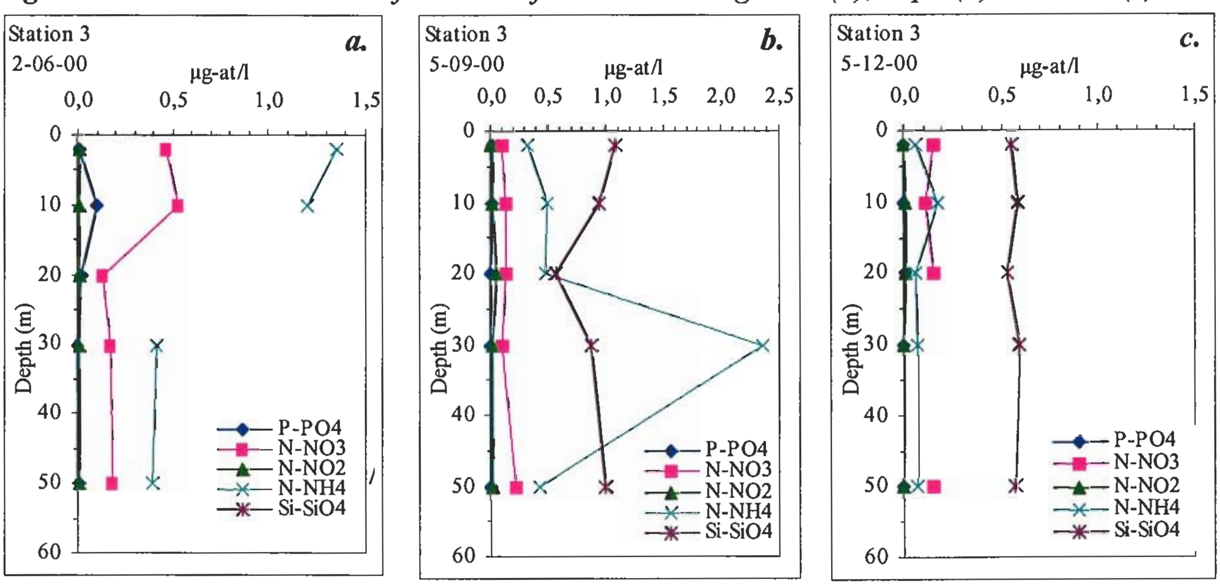


Fig. 3.10. *Vertical distribution of nutrients from St. 4 during June (a), Sept. (b) and Dec. (c).*

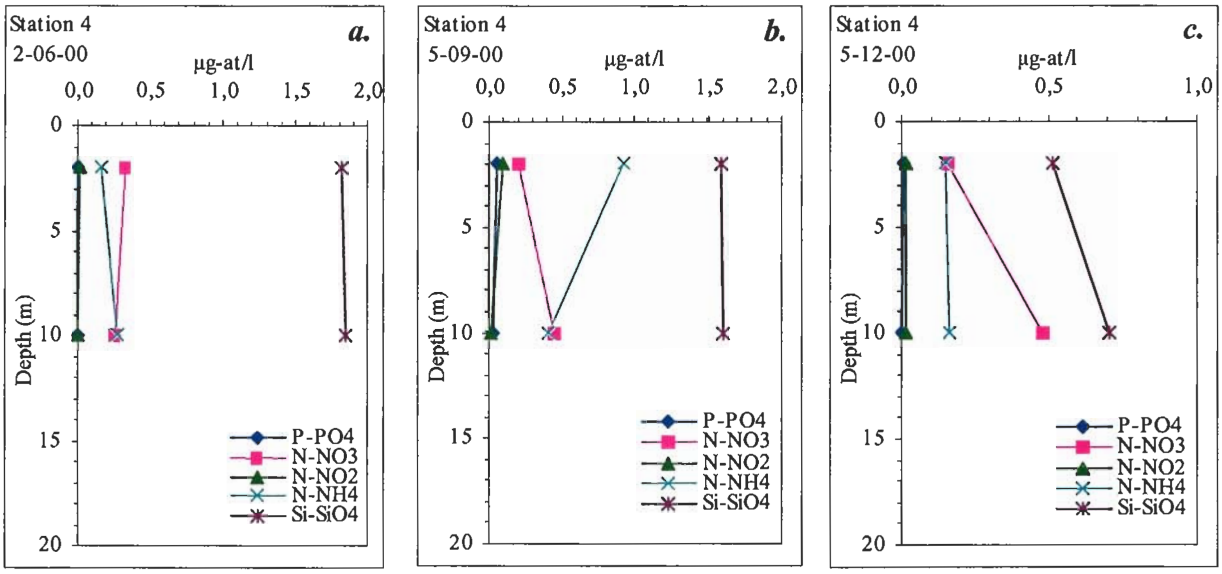
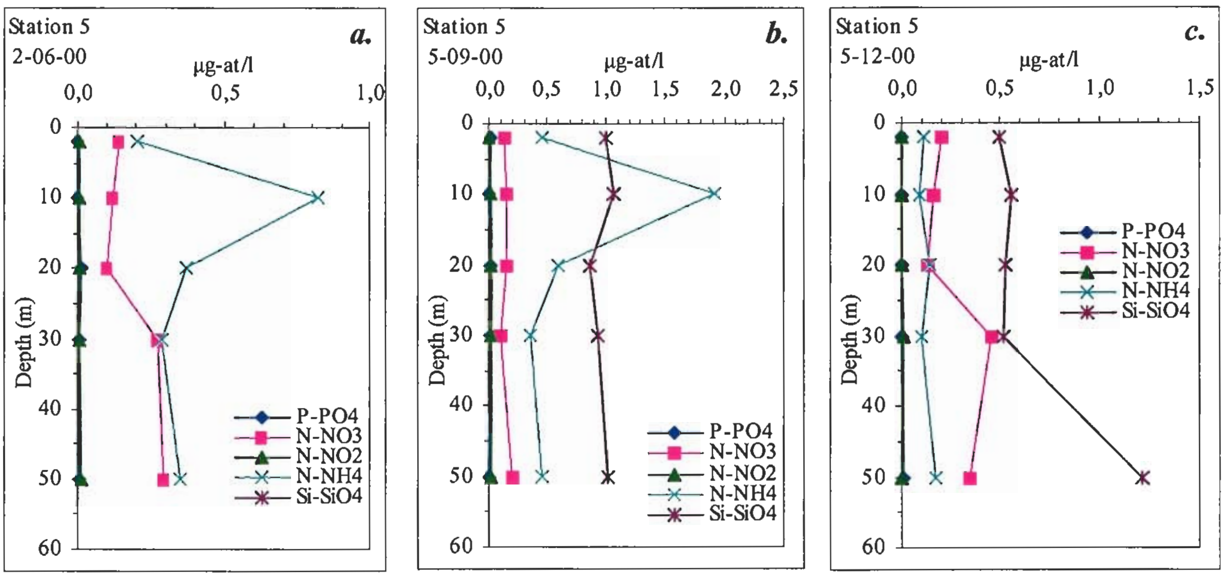


Fig. 3.11. *Vertical distribution of nutrients from St. 5 during June (a), Sept. (b) and Dec. (c).*

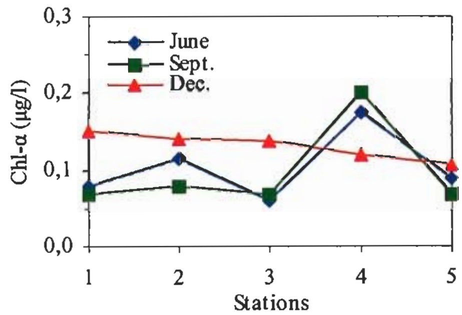


3.2.3 Chlorophyll-α

The concentration of Chl-α during ***June*** was generally distributed among the values of 0,3-0,9 μg/l. Slightly higher values of 0,15-0,2 μg/l appeared at station 4, while a concentration of 0,17μg/l was measured at 50m depth of station 5. In relation to the general profiles, a sensibly higher value of 0,29 μg/l was observed at 20m in station 2 (Fig. 3.13).

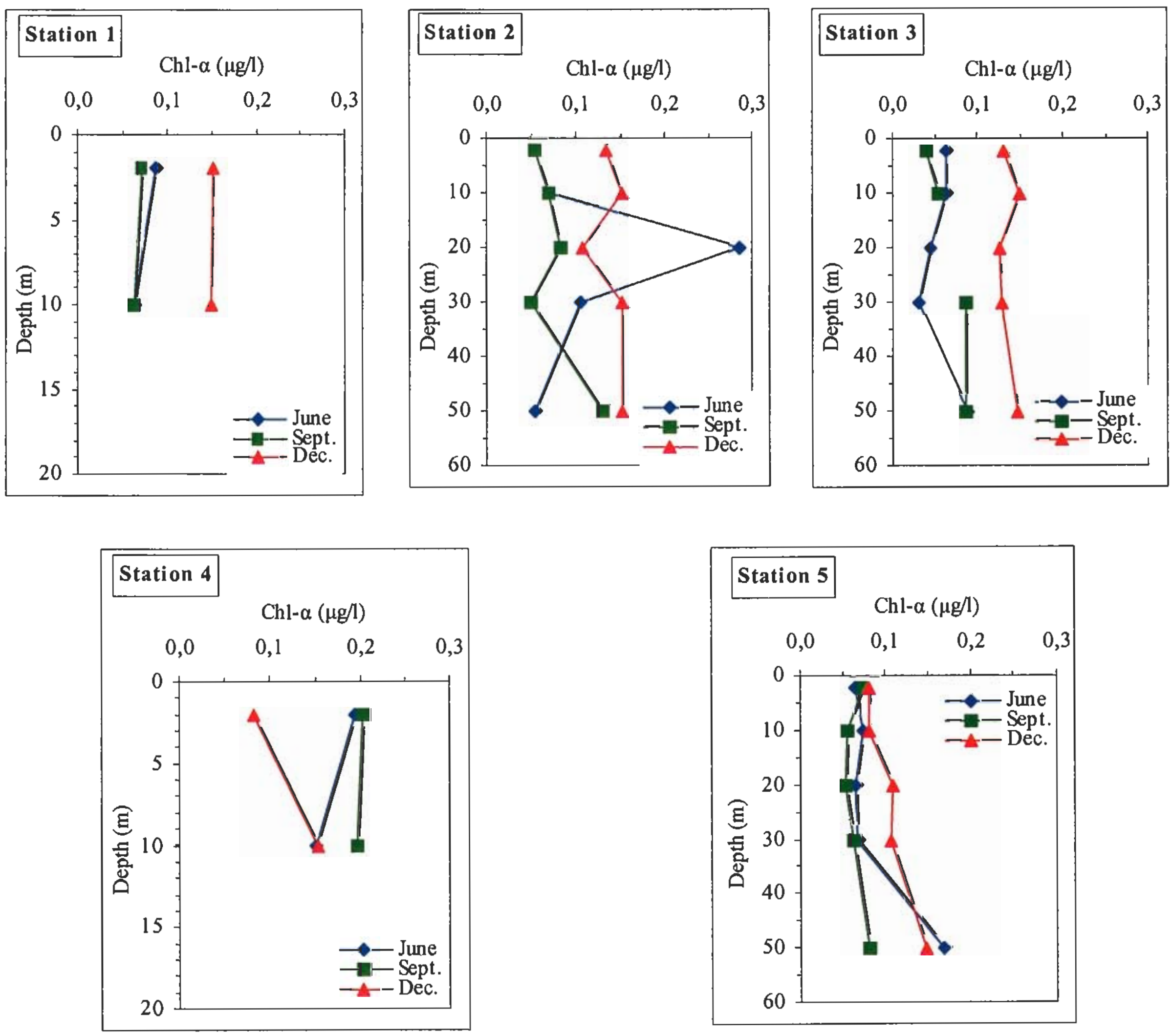
During ***September***, Chl-α ranged among low values of 0.04-0.13 μg/l in stations 1, 2, 3 and 5, while in station 4 slightly higher values of 0.2μg/l were determined at 2 and 10m depth (Fig. 3.12, 3.13).

Fig. 3.12. *Mean concentrations of Chl-α (μg/l) during 2000.*



The concentration of Chl-α during ***December*** was homogeneously distributed among 0,08-0.16 μg/l at all stations, with mean values among 0,1 and 0,15μg/l (Fig. 3.12).

Fig. 3.13. *Vertical distribution of Chl-α (μg/l) from all stations.*



3.3 Conclusions

Good mixing of the water was observed during June, with a mean concentration of dissolved oxygen of 5,0 ml/l, while a surface stratification typical of the summer months was noted in September with a mean value of 4.6ml/l. The mean value of dissolved oxygen concentration increased to 5 ml/l in autumn (Table 3.6) (Fig. 3.1), showing profiles similar to those previously observed (Corsini-Fokà, 1999, Corsini-Fokà et al., 2000).

The mean concentration of nutrients during 2000 resulted generally assessed to low values as observed during 1999 (Corsini-Fokà edit., 1999), especially in December (Fig. 3.14) (Table 3.7) (Karydis & Coccossis, 1989, Vounatsou P. & Karydis M., 1991, Karydis, 1995). Taking into account the limited number of samplings carried out each year and the lower number of sample depths taken in 1996 and 1997, the means of nutrient salts show a trend with values decreasing in the last three years (1998-2000) (Fig. 3.15). During 2000, very low values of nitrates and particularly of phosphates were noticed. Silicate concentration was at low levels as in 1999.

Fig. 3.14. *Mean values of nutrients in each station and sampling (2000).*

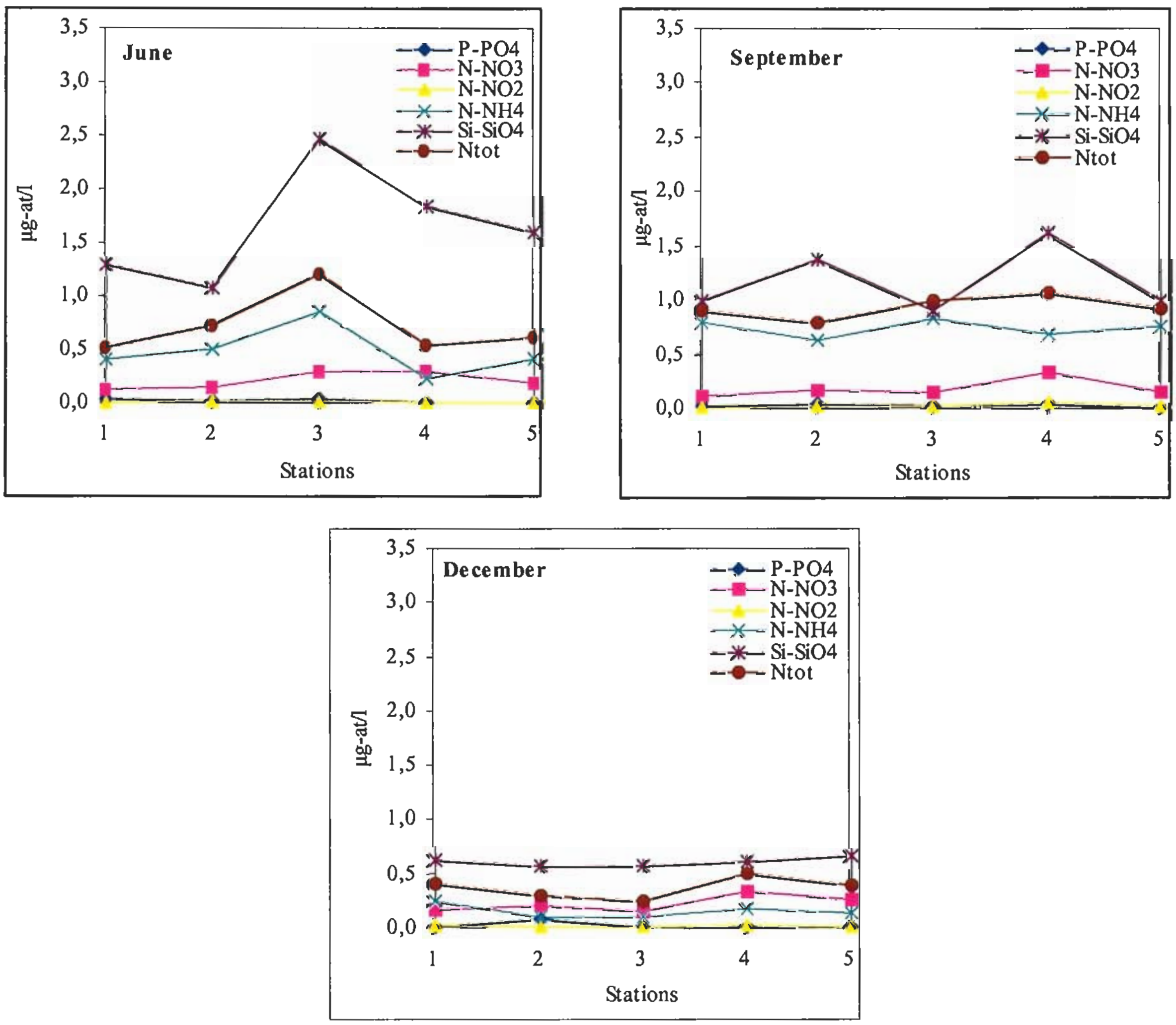


Table 3.7

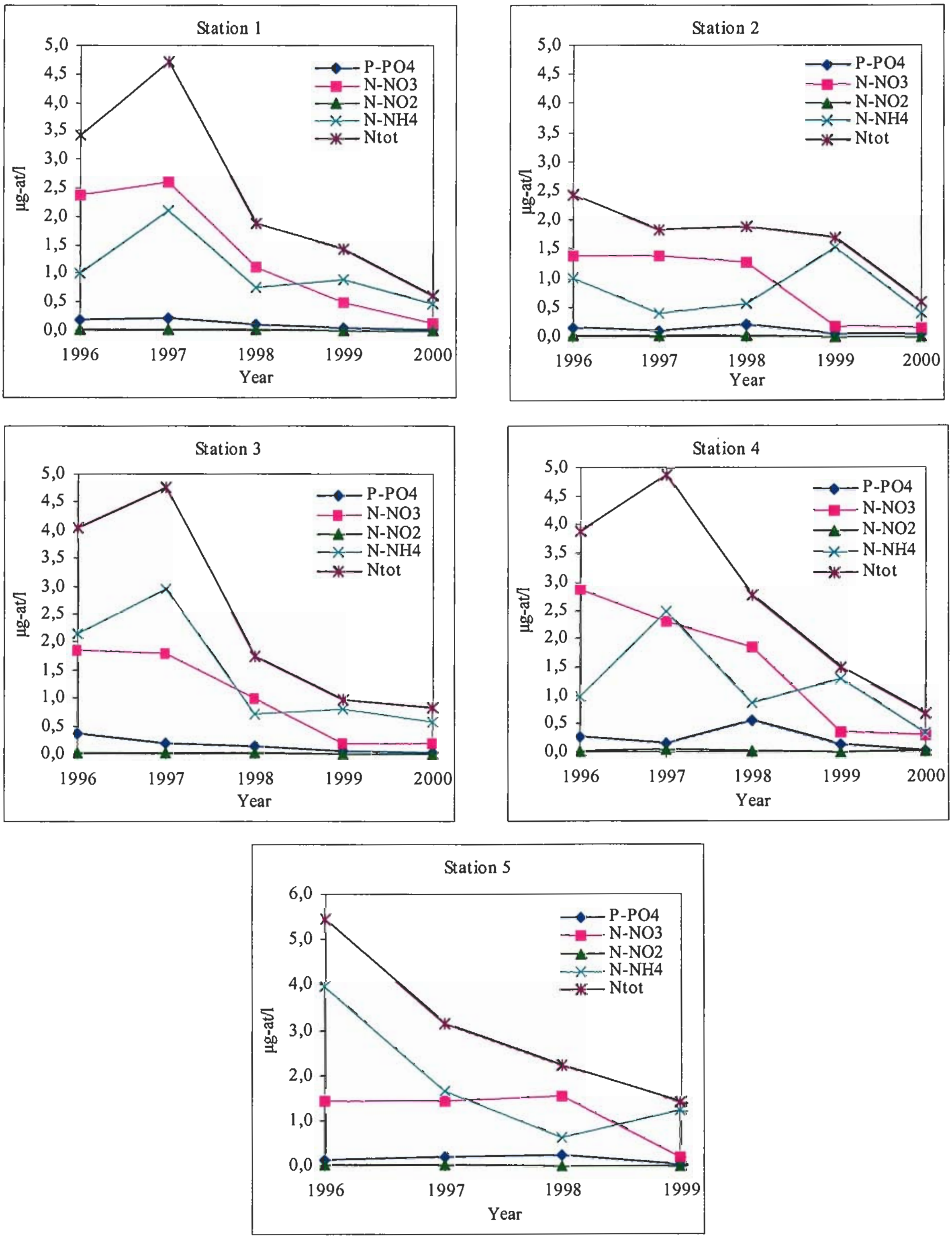
Summary statistics of chemical data for each sampling station (1998-2000).

Station 1		P-PO4 µg-at/l	N-NO3 µg-at/l	N-NO2 µg-at/l	N-NH4 µg-at/l	Chl-a µg/l	N/P	Ntot µg-at/l
1998	Avg	0,12	1,12	0,02	0,75	0,13	18,09	1,90
	Std	0,04	0,64	0,01	0,49	0,04	9,16	0,43
	Min	0,07	0,54	0,00	0,26	0,08	11,15	1,25
	Max	0,18	2,03	0,03	1,40	0,20	35,09	2,39
1999	Avg	0,07	0,52	0,00	0,90	0,11	21,04	1,42
	Std	0,03	0,21	0,00	0,38	0,02	3,56	0,56
	Min	0,03	0,27	0,00	0,36	0,09	17,97	0,65
	Max	0,11	0,73	0,00	1,34	0,15	28,01	2,07
2000	Avg	0,02	0,13	0,01	0,47	0,10	107,66	0,61
	Std	0,02	0,02	0,01	0,32	0,04	111,79	0,30
	Min	0,00	0,10	0,00	0,17	0,06	15,39	0,33
	Max	0,04	0,16	0,03	1,03	0,15	248,48	1,14
Station 2		P-PO4 µg-at/l	N-NO3 µg-at/l	N-NO2 µg-at/l	N-NH4 µg-at/l	Chl-a µg/l	N/P	Ntot µg-at/l
1998	Avg	0,21	1,29	0,02	0,59	0,13	15,18	1,91
	Std	0,26	1,32	0,02	0,23	0,02	16,80	1,42
	Min	0,07	0,19	0,00	0,38	0,10	3,63	0,67
	Max	1,07	4,17	0,08	1,14	0,17	64,24	5,32
1999	Avg	0,04	0,18	0,00	1,53	0,11	68,66	1,71
	Std	0,07	0,11	0,00	3,43	0,03	156,44	3,40
	Min	0,02	0,06	0,00	0,28	0,08	4,55	0,44
	Max	0,28	0,45	0,00	13,85	0,16	632,09	13,91
2000	Avg	0,04	0,17	0,01	0,41	0,11	116,54	0,59
	Std	0,10	0,07	0,01	0,27	0,06	129,27	0,29
	Min	0,00	0,10	0,00	0,07	0,05	0,98	0,22
	Max	0,40	0,28	0,03	0,79	0,29	375,60	1,04
Station 3		P-PO4 µg-at/l	N-NO3 µg-at/l	N-NO2 µg-at/l	N-NH4 µg-at/l	Chl-a µg/l	N/P	Ntot µg-at/l
1998	Avg	0,15	1,01	0,02	0,72	0,13	12,55	1,75
	Std	0,04	0,62	0,01	0,40	0,04	5,79	0,65
	Min	0,07	0,35	0,00	0,32	0,06	6,23	1,08
	Max	0,21	2,78	0,04	1,71	0,17	28,02	3,56
1999	Avg	0,07	0,19	0,00	0,79	0,10	33,04	0,98
	Std	0,14	0,08	0,00	0,47	0,03	19,75	0,47
	Min	0,02	0,09	0,00	0,27	0,06	1,26	0,42
	Max	0,56	0,41	0,00	1,95	0,17	83,48	2,16
2000	Avg	0,02	0,20	0,01	0,57	0,09	110,05	0,82
	Std	0,03	0,13	0,01	0,65	0,04	104,61	0,72
	Min	0,00	0,10	0,00	0,07	0,03	16,08	0,22
	Max	0,11	0,53	0,04	2,35	0,15	347,30	2,47

→ *Table 3.7*

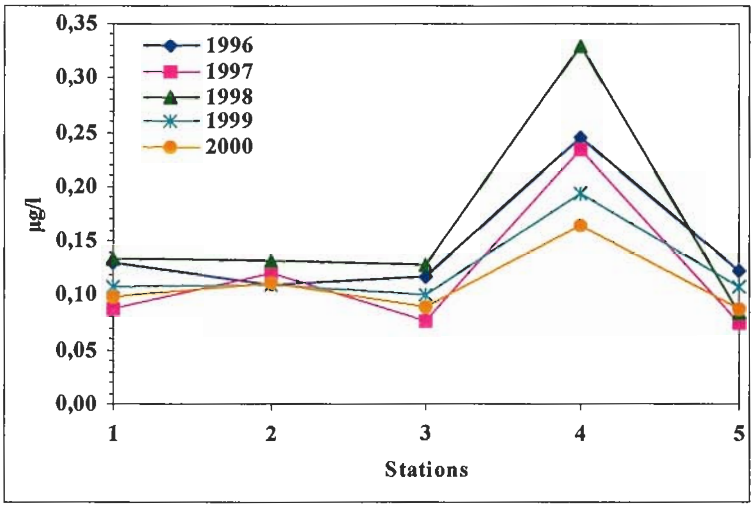
Station 4		P-PO4 µg-at/l	N-NO3 µg-at/l	N-NO2 µg-at/l	N-NH4 µg-at/l	Chl-a µg/l	N/P	Ntot µg-at/l
1998	Avg	0,56	1,85	0,03	0,88	0,33	16,27	2,76
	Std	0,74	2,14	0,01	0,44	0,25	17,88	1,99
	Min	0,11	0,16	0,02	0,53	0,11	0,48	0,90
	Max	2,00	5,34	0,05	1,68	0,75	39,02	5,89
1999	Avg	0,16	0,37	0,00	1,30	0,19	39,41	1,49
	Std	0,28	0,14	0,00	0,90	0,07	37,00	0,80
	Min	0,02	0,23	0,00	0,34	0,12	3,42	0,73
	Max	0,66	0,59	0,00	2,24	0,28	102,00	2,45
2000	Avg	0,01	0,32	0,03	0,35	0,17	90,12	0,69
	Std	0,02	0,13	0,04	0,30	0,05	78,22	0,32
	Min	0,00	0,16	0,00	0,15	0,09	25,71	0,33
	Max	0,05	0,48	0,10	0,94	0,20	220,93	1,23
Station 5		P-PO4 µg-at/l	N-NO3 µg-at/l	N-NO2 µg-at/l	N-NH4 µg-at/l	Chl-a µg/l	N/P	Ntot µg-at/l
1998	Avg	0,23	1,58	0,02	0,64	0,08	18,13	2,24
	Std	0,28	1,51	0,01	0,20	0,02	17,47	1,44
	Min	0,08	0,37	0,00	0,45	0,05	1,25	1,12
	Max	0,97	5,35	0,03	1,00	0,11	60,10	5,83
1999	Avg	0,03	0,21	0,00	1,23	0,11	56,97	1,43
	Std	0,01	0,07	0,00	1,65	0,05	79,45	1,63
	Min	0,02	0,13	0,00	0,36	0,03	12,84	0,55
	Max	0,04	0,38	0,00	6,26	0,21	304,29	6,39
2000	Avg	0,01	0,20	0,01	0,43	0,09	221,98	0,63
	Std	0,01	0,10	0,01	0,46	0,03	377,67	0,44
	Min	0,00	0,10	0,00	0,09	0,06	28,98	0,25
	Max	0,02	0,45	0,02	1,92	0,17	1485,57	2,08

Fig. 3. 15. *Mean values of nutrients at each sampling station (1996-00).*



During 2000 the mean concentration of Chl-α ranged among low levels (0,09-0,17μg/l) (Fig. 3.12). During the last five years of samplings a peak of Chl-α was constantly observed in station 4, the port of Rhodes (Fig. 3.16).

Fig. 3.16. *Mean values of Chl-a for each station (1996-00).*



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4. HEAVY METALS IN BIOTA FROM THE ISLAND OF RHODES

Strogyloudi Evangelia and Catsiki Vasiliki-Angeliki

4.1 Introduction

The determination of the metallic content in marine organisms is widely used both for the evaluation of the state of the marine environment and its impact on marine life. Aquatic organisms are naturally exposed to a variety of metals whose chemical forms and concentrations are governed by natural geochemical processes and anthropogenic activities. These metals include essential elements required to support biological processes; some of them being present in large amounts in the tissues (Na, K, Ca etc.), others only in trace amounts (Zn, Cu etc.). For other metals that are usually considered toxic for animals and plants (such as Cd), no biological function has been established.

The use of biological species in the monitoring of marine environment quality allows evaluating the biologically available levels of contaminants in the ecosystem or the effects of contaminants on living organisms. There is a need to identify widespread cosmopolitan bioindicators to allow intraspecific comparison of accumulated metal concentrations over large geographical areas (Campanella *et al.*, 2001).

In the framework of the MED-POL Programme, heavy metals were monitored since 1995 in phytobenthos and zoobenthos species from a coastal area of Rhodes island. The aim of this work was to provide information on heavy metals content in benthic organisms in an area, which is considered to be unpolluted.

4.2 Methodology

Benthic samples were collected at June (13/6/2000) and November (2/11/2000) from Ladiko coast (northeast of Rhodes island). The examined species were the algae *Padina pavonica* and the gastropod *Patella aspera.* The soft tissues of *P. aspera* and thallus of *P. pavonica* were analysed for metals. Pooled samples from 12 individuals (1,5-2,0 cm length) were prepared for the gastropods. On the whole 24 samples were prepared (10 for *P.pavonica* and 14 for *P.aspera*).

All samples were transported to the laboratory at -18°C, dried by lyophilisation and then homogenised. Approximately 1 gr of the tissue was digested with 12.5 ml of nitric acid into teflon vessels in a microwave device CEM MDS 2100. Determination of Cu, Cr, Ni, Zn, Fe and Mn was made using an air-acetylene flame spectrophotometer from Varian (AA 20 Plus) and for Cd a Perkin Elmer device with furnace (HGA 700) was used (UNEP, 1984).

The accuracy and precision of the analytical methodology was tested with the reference material Dorm-2 (Dogfish muscle). Results are presented in Table 4.1.

Table 4.1
Test of the analytical methodology with the reference material Dorm-2

Metal	Certified value	Value found
Cu	2.34±0.16	2.01±0.21
Cr	34.7±5.5	36.3±0.8
Ni	19.4±3.1	20.3±0.6
Zn	25.6±2.3	34.6±6.1
Fe	142±10	149±9
Mn	3.66±0.34	3.71±0.16

4.3 Results and Discussion

Summary statistics for the two studied species are presented in Table 4.2. Metal concentrations ranged between 3.21 to 7.20 ppm for Cu, 1.51 to 10.5 for Cr, 3.04 to 11.2 for Ni and 1.0 to 33.3 ppm for Mn. Levels of Zn and Fe are higher and ranged between 61 to 632 and 70 to 373 ppm respectively. Mean values for Cd were low and concentrations ranged between 0.14 to 7.37 ppm.

Generally, the measured metal values were higher in the herbivore gastropod (*P. aspera*) than in the primer producer (*P. pavonica)*. The opposite occurs only for Mn, this metal was accumulated in *P. pavonica* about 5 times more than in *P. aspera* (Table 4.2).

Table 4.2
Metal concentrations in Patella sp and P. pavonica from Ladiko (Rhodes island) during 2000, (μg/g dw)

	Cd	Cu	Cr	Ni	Zn	Fe	Mn
P.pavonica	1.07±0.92	4.72±0.61	3.12±1.53	5.10±1.80	192±106	108±36	21.9±11.1
N=10	0.20-2.17	3.21-5.25	1.51-5.18	3.04-7.76	84-362	70-168	0.99-33.3
P. aspera	3.61±2.68	5.01±1.00	5.27±3.46	7.10±2.59	255±228	255±78	3.98±1.67
N=14	0.14-7.37	3.72-7.20	2.39-10.5	4.49-11.2	61-632	136-373	1.77-5.77

Average, standard deviation, minimum and maximum values per species and season are presented in Table 4.3. Different environmental conditions at summer and autumn of 2000 seem to affect bioaccumulation of *Padina* and *Patella* populations located at Ladiko coast. Both species present higher metal concentrations at the warm period of the year for Cr, Ni, Zn and Fe. The opposite occurs for Cd and Mn.

Table 4.3
Metal concentrations in Patella sp and P. pavonica from Ladiko (Rhodes island) during 2000 (μg/g dw)

		Cd	Cu	Cr	Ni	Zn	Fe	Mn
P. pavonica	***Summer***	0.22±0.02	4.99±0.17	4.51±0.57	6.68±0.96	287±49	137±28	12.2±6.3
	N=5	0.20-0.25	4.84-5.19	3.84-5.18	5.41-7.76	245-362	104-168	1.0-16.1
	Autumn	1.93±0.27	4.46±0.80	1.73±0.30	3.52±0.37	97±16	80±8	31.6±1.6
	N=5	1.51-2.17	3.21-5.25	1.51-2.23	3.04-4.02	84-122	70-91	29.6-33.3
P. aspera	***Summer***	0.40±0.24	4.86±0.37	9.7±0.6	10.3±0.7	492±151	337±32	1.90±0.11
	N=5	0.14-0.74	4.55-5.48	9.0-10.5	9.5-11.2	261-632	296-373	1.77-2.04
	Autumn	5.39±1.27	5.10±1.24	2.81±0.30	5.31±0.74	86±15	210±53	5.14±0.52
	N=9	3.41-7.37	3.72-7.20	2.39-3.22	4.49-6.44	61-107	136-323	4.04-5.77

In order to find out if differences between seasons and species are statistically significant we performed analysis of variance. The results are presented in Table 4.4 and Figure 4.1. Metal levels for both species, remain stable during 2000 only for Cu: no statistical significant differences were recorded between summer and autumn. Seasonal variations in metal content are more obvious for the rest of the metals (Table 4.4 and Figure 4.1). Especially Cd and Mn had statistical significant higher concentrations during the cold period of the year. Additionally, only Cu and Zn concentrations did not present differences between species.

Table 4.4

Results of two factor analysis of variance (season and species). Values of the rate F.

factors	**Cd**^{L}	**Cu**^{L}	**Cr**^{L}	**Ni**^{L}	**Zn**^{L}	**Fe**^{L}	**Mn**^{L}
seasons	323***	0.48	495***	161***	206***	41***	24**
species	46***	0.43	162***	68***	3.82	133***	52***
season-species	23**	1.09	8*	0.13	10.3*	0.04	0.40

^{L} values were log-transformed (log_{10}) before statistical analysis

***P<0.001, **0.001≤P<0.01, *0.01≤P<0.05

Despite the existence of seasonal fluctuations in their metal load, both studied species can be used as bioindicators for the study of the quality of the marine environment and as alternative to the analysis of water and sediments (Catsiki *et al.,* 1991 & Nicolaidou and Nott, 1998 & Panayotidis and Florou, 1994). Gastropods collected from Ladiko coast had lower metal concentrations from industrialised marine areas and similar to other unpolluted areas (Nicolaidou and Nott, 1998 & Campanella *et al.*, 2001). The metal concentrations in the tissue of the organisms collected at the sampling station, may provide useful background levels for intraspecific comparison within the Mediterranean area.

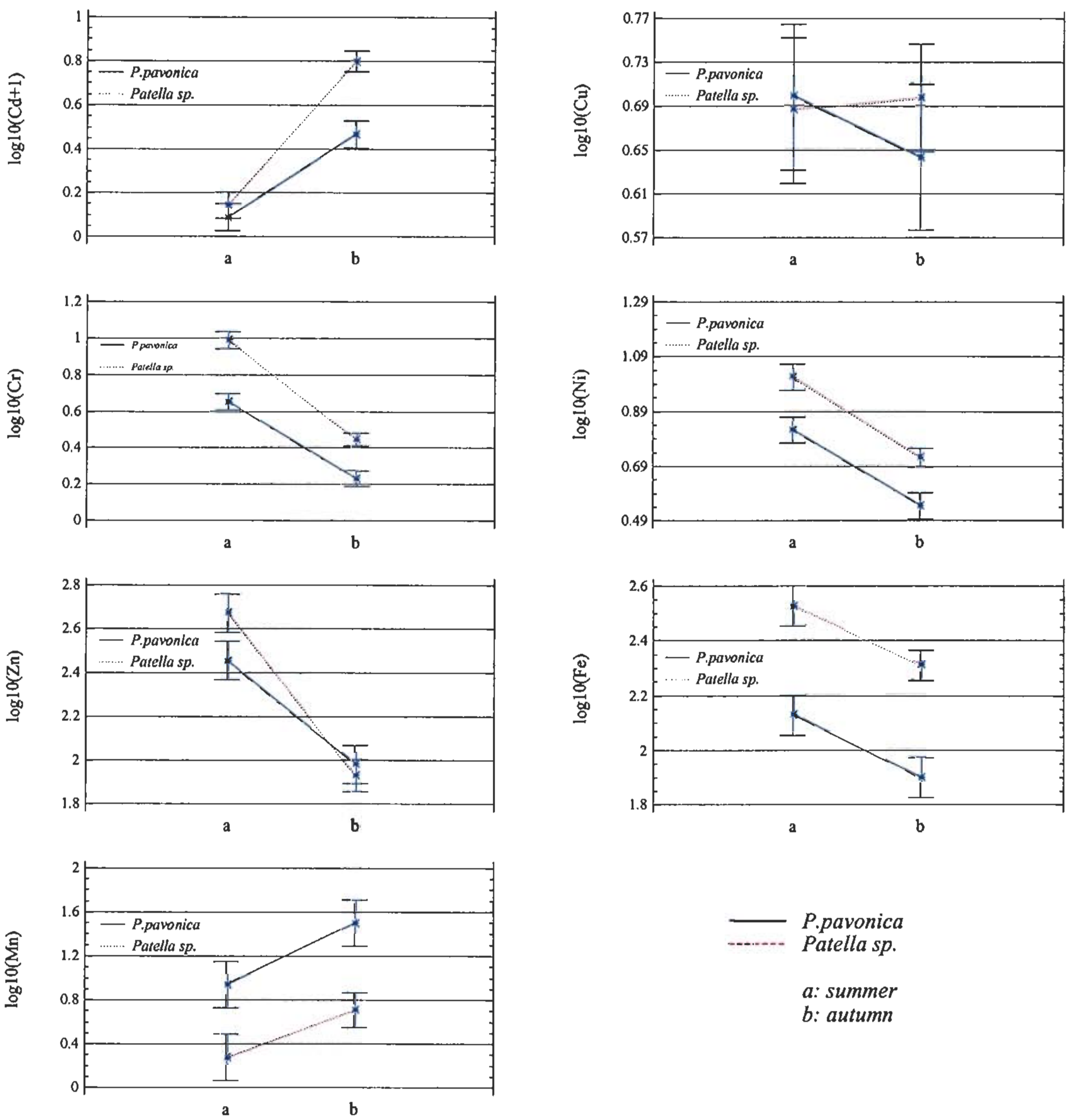

***Figure 4.1**: Average and 95% Tukey HSD intervals for metal concentrations in P. pavonica and P. aspera from the Island of Rhodes (Ladiko), during 2000*

4.4 Temporal evolution

In Figure 4.2 is presented the evolution of metal concentrations in the body of *Patella aspera* and in thallus *of Padina pavonica* through time (from 1995 to 2000). In order to reduce fluctuations in the data and make long-term trend more apparent, we used the Locally Weighted Regression smoothing technique.

Temporal evolution of Zn concentrations in *Patella* presented similar patterns with the respective of *Padina*. For both species an increasing trend has been observed especially for the last period of the study (1999-2000). For the rest of the elements, fluctuations of metal concentrations were more irregular and did not seem to follow any obvious or evident pattern (Figure 4.2).

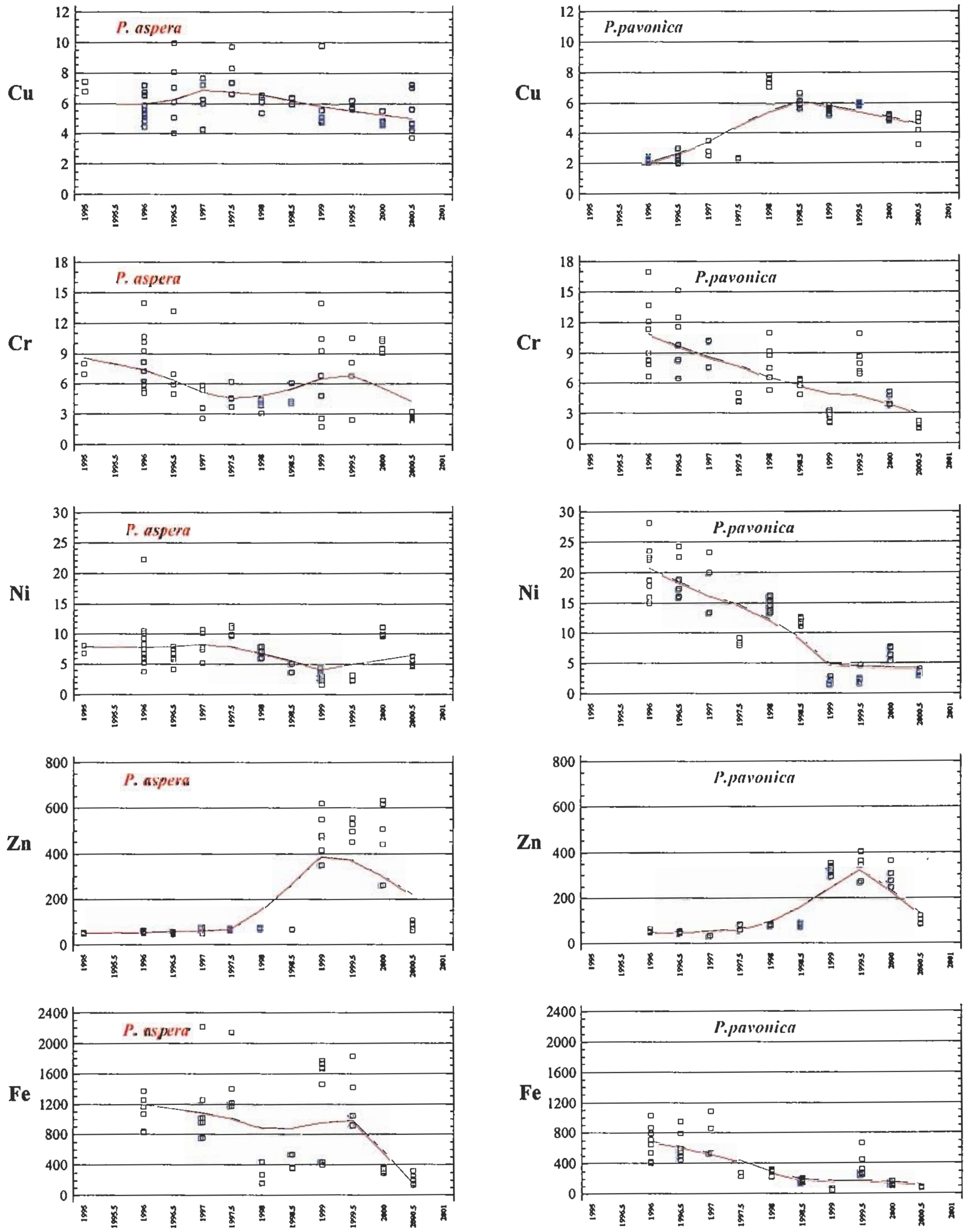

Figure 4.2: *Evolution of metal concentrations in P. aspera and P. pavonica during 1995-2000 from coastal areas of Rhodes island*

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