NATIONAL CENTRE OF MARINE RESEARCH

A. Kosmas, Hellinikon 16604

POLLUTION RESEARCH & MONITORING PROGRAMME IN AEGEAN & IONIAN SEAS

TECHNICAL REPORT 1996

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Programme financed by :

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Edited by : Dr N. Friligos
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CONTENTS

1. INTRODUCTION

1.1. PREFACE

For MED POL purposes the National Centre for Marine Research realises, since 1987, a research and monitoring Programme in the Aegean and Ionian Seas, areas that are considered as reference ones. The results of such studies provide an assessment of the state of pollution in the Greek Seas and consist an important tool for the decision makers.

The Programme is concentrated on the study of the more important pollutants in marine sediments and fish. However till 1991 the Programme comprised full oceanographic investigation: physical, chemical, biological and pollution parameters in a network of 38 stations, while contaminants in fish from different areas were also studied.

Because the monitoring Programme continues through several years the provided data can give information suitable to estimate possible trends of pollutants.

1.2 MONITORING PARAMETERS

The pollution parameters that are monitored are, according to the contract, heavy metals in superficial sediments and fish and chlorinated hydrocarbons in fish. However during 1996 additional parameters were studied :

Physical parameters

- Temperature
- Salinity
- Density

Pollution parameters:

- Heavy metals in sediments
- Organic carbon in sediments
- Heavy metals in fish
- Chlorinated hydrocarbons in fish

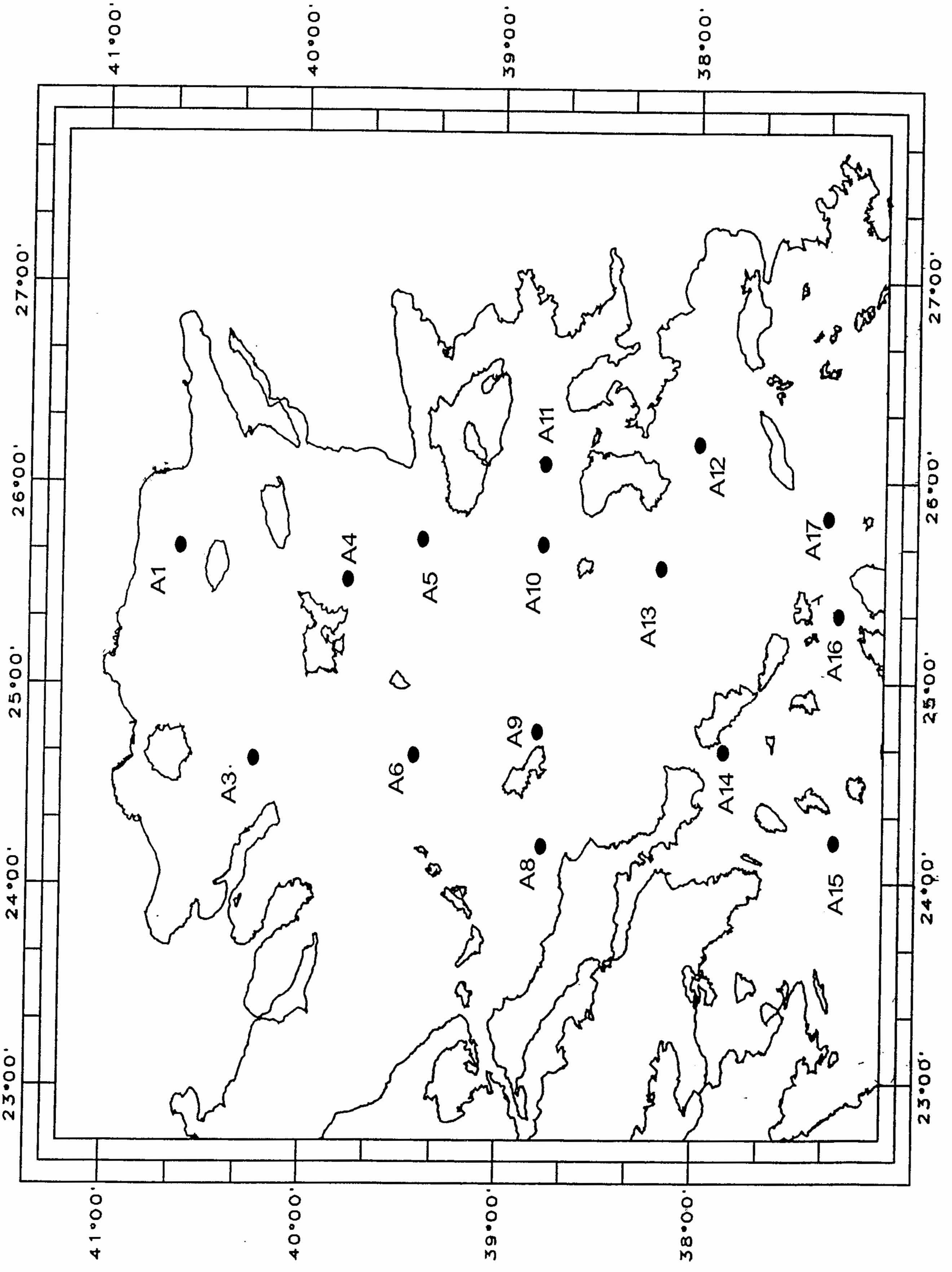

Figure 1.1 *: Location of oceanographic sampling stations in Aegean Sea during 1996.*

For the MED.POL purposes two fish species are studied belonging to two categories with different ecological niches: the demersal *Mullus barbatus* and the pelagic *Boops boops.* These species were chosen according to their commercial interest and their abundance throughout the Mediterranean. Further more these species are proposed by UNEP and are easy to identify and easily available in enough quantities.

There is an effort that, as much as possible, to choose individuals with the same age/size of about 15-17 cm.

1.3.- SAMPLING STATIONS AND OCEANOGRAPHIC CRUISES

During 1996 one oceanographic cruise took place during autumn. The network visited consisted of 15 sampling stations in the north Aegean Sea. In Figure 1.1 is shown the position of the sampling stations, while in Table 1.1 are presented their characteristics (co-ordinates and depth).

Table 1.1

Co-ordinates and depth of the sampling stations

stations	longitude	latitude	depth	sampling date
A8	24 11,90	38 47,20	365	17/10/1996
A9	24 46,00	38 48,00	254	17/10/1996
A6	24 38,30	39 26,90	358	17/10/1996
A3	24 38,00	40 14,00	814	18/10/1996
A1	25 42,00	40 38,00	45	18/10/1996
A4	25 30,00	39 46,00	93	19/10/1996
A5	25 42,60	39 24,50	300	19/10/1996
A10	25 42,00	38 48,00	375	19/10/1996
A11	26 06,00	38 48,00	284	19/10/1996
A13	25 36,00	38 10,50	427	20/10/1996
A12	26 12,00	38 00,00	770	20/10/1996
A17	25 48,80	37 19,00	325	20/10/1996

stations	**longitude**	**latitude**	**depth**	**sampling date**
A16	25 21,00	37 16,00	106	20/10/1996
A15	24 12,00	37 16,00	476	20/10/1996
A14	24 38,60	37 51,80	168	21/10/1996

Fish were collected once a year, before the reproduction period (April - May) from 7 marine areas throughout the Aegean and Ionian Seas. The dates of the collection of fish are presented in Table 1.2, while the sampling locations are shown in Figure 1.2.

Table 1.2

Dates of fish collection

station	**species**	**date**
Alexandroupolis	*B.boops* *M.barbatus*	24/5/1996
Hios	*B.boops* *M.barbatus*	19/4/1996
Rhodos	*B.boops* *M.barbatus*	14/5/1996
Hania	*B.boops* *M.barbatus*	28/5/1996
Parga	*B.boops* *M.barbatus*	4/5/1996
Kalamata	*B.boops* *M.barbatus*	17/6/1996
Volos	*B.boops* *M.barbatus*	25/5/1996

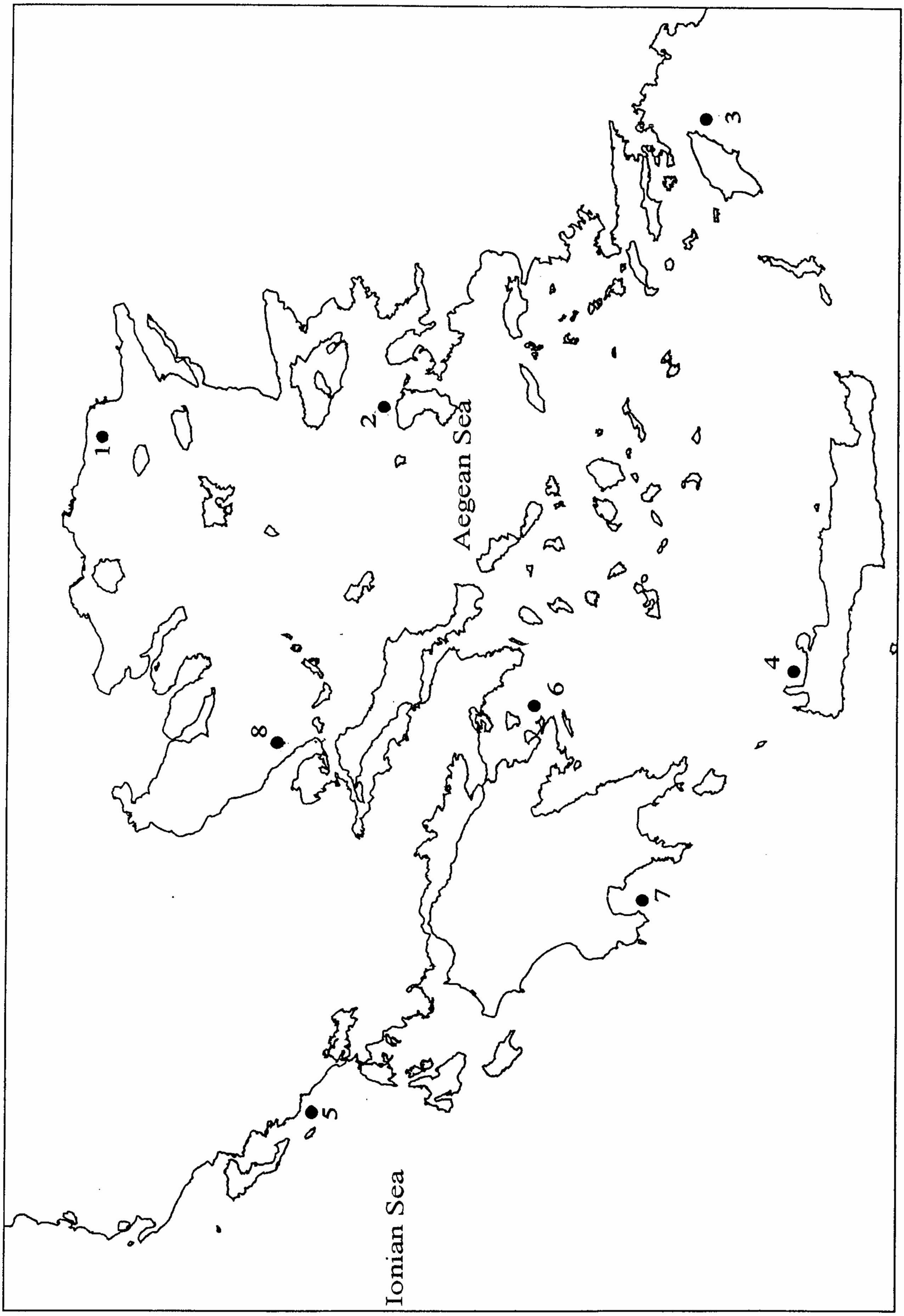

***Figure 1.2** : Areas of fish collection in the Aegean & Ionian Seas.*

1.4 PARTICIPANTS

The personnel, scientists and technicians, of the National Centre for Marine Research that participate to the Programme, or collaborated for its realisation, is listed below :

Friligos N.	COORDINATOR - Chemical Oceanography
Barbetseas S.	Physical Oceanography
Bei F.	Marine Biology -metals
Catsiki V.A.	Marine Biology -metals
Drakopoulou P.	Technician
Georgakopoulou E.	Chemical Oceanography- organochlorines
Hadjianestis J.	Chemical Oceanography- organochlorines,
Krasakopoulou E.	Chemical Oceanography - CHN analysis
Morfis A.	Technician
Moriki A.	Chemical Oceanography - Metals
Pappas G	Technician
Renieris P.	Technician
Samara P.	Technician
Satrogyloudi E.	Marine Biology -metals
Sklivagou E.	Chemical Oceanography- organochlorines, metals
Taxiarchi M.	Technician

The collection of fish was carried out with the help of:

Akepsimaidis C., Catsiki V.A., Christou E., Foka M., Pagou K., Samara P. and E. Strogyloudi.

The maps were drawn by G. Asimakopoulou.

Cover was designed by C. Manetas

2.-HYDROLOGICAL CHARACTERISTICS IN THE AEGEAN SEA, IN OCTOBER 1996.

2.1 INTRODUCTION

The National Centre for Marine Research (N.C.M.R),in Athens, has been studying the Aegean Sea since 1986. Information on the water masses exchange and circulation modes, have already been published by Greek and Foreign Scientists (Ref. 1-13).

The Aegean Sea, one of the four major Seas of the Eastern Mediterranean, is quite complicated in comparison to the other regions, with respect to the topography and the bathymetry. Its coastline is very irregular and, more than two thousand islands are scattered over the whole area. The three major basins divide the North Aegean Trough basin in the Northern part with a depth of about 1500m, the Chios basin in the Central part (1000m deep) and the Cretan Sea, the largest and deepest in the Southern Aegean (2500m deep). These complex features together with the variability of the Meteorological conditions (Ref. 4,5) result in a variety of space and time scale physical processes affecting the circulation in the area. The Aegean and the Ionian Seas communicate through the Kitherian straits (Elafonissos, Kythira, Antikythira), the monitoring of which contributes to the study of the exchange of the water masses between them. The Aegean communicates also with the Eastern Mediterranean (Levantin Basin) by the three eastern straits of the Cretan arc (Kassos, Karpathos, Rhodos).

The present chapter affords data collected during October 1996 and it aims at describing the Physical Characteristics of the above area during the sampling period.

2.2 METHODS

CTD casts were carried out in a network of 15 stations located in the Aegean Sea (Fig.2.1), using a Sea - Bird Electronics instrument (Model : SBE - 19), accurate to 0.1°C and 0.01psu. While the collected Meteorological data concerned the speed and the direction of the wind.

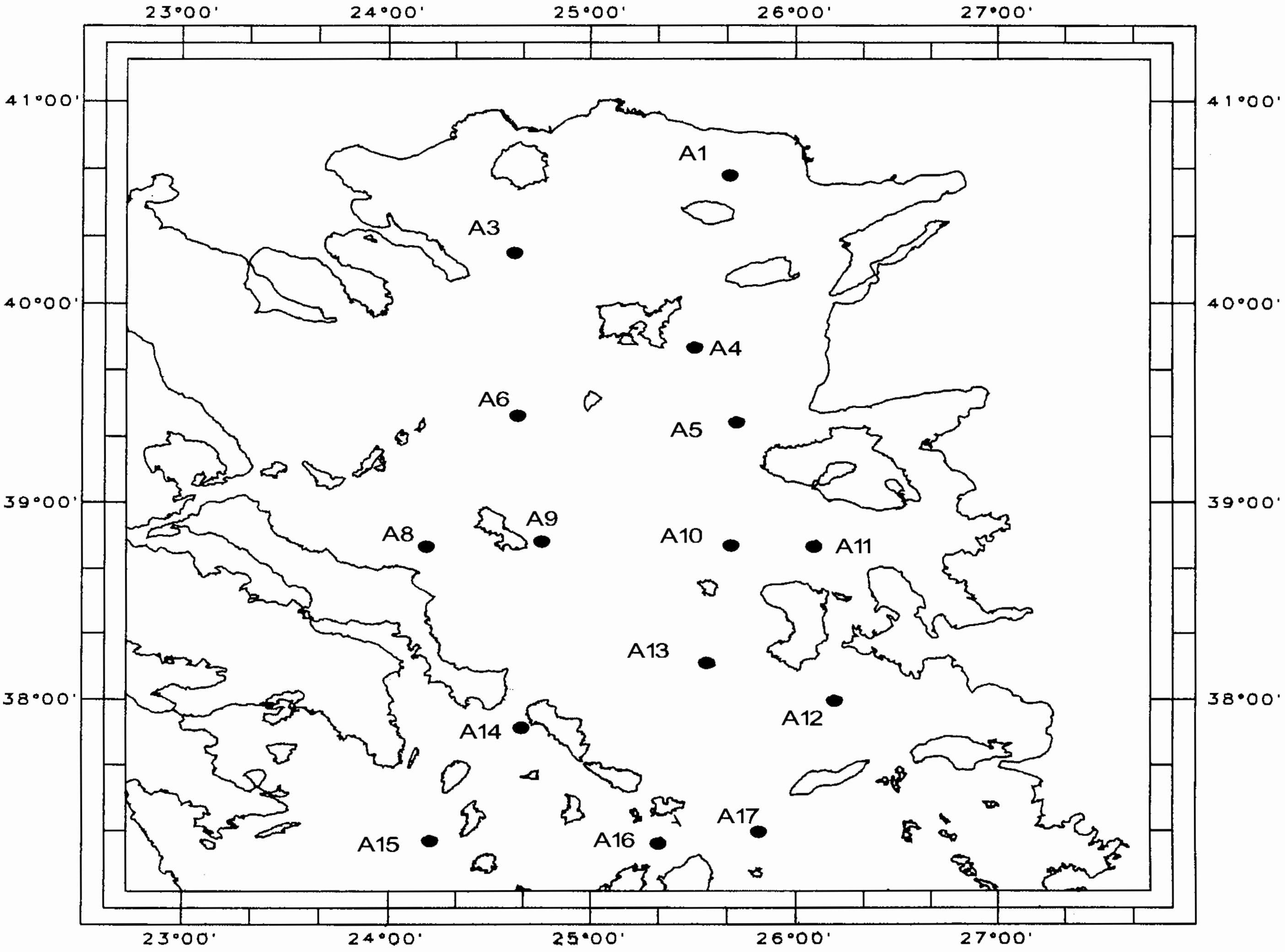

Figure 2.1: Map of the hydrological stations

2.3 PHYSICAL DATA EVALUATION

The wind data recorded during the Cruise are presented in Table 2.1. The data show that the local wind field during the period of the cruise was almost moderate, but variable. Temperature, salinity and density (sigma-t) vertical profiles were also plotted, shown in figures 2.2 -2.16. The temperature and salinity distributions within the surface layer, indicate three distinct areas covered by waters of different hydrological characteristics (Figs: 2.17, 2.18 and 2.19). These areas are the Northern and Western Aegean Sea (Stations: 1, 3, 4, 5, 6, 8, 9 and 14),

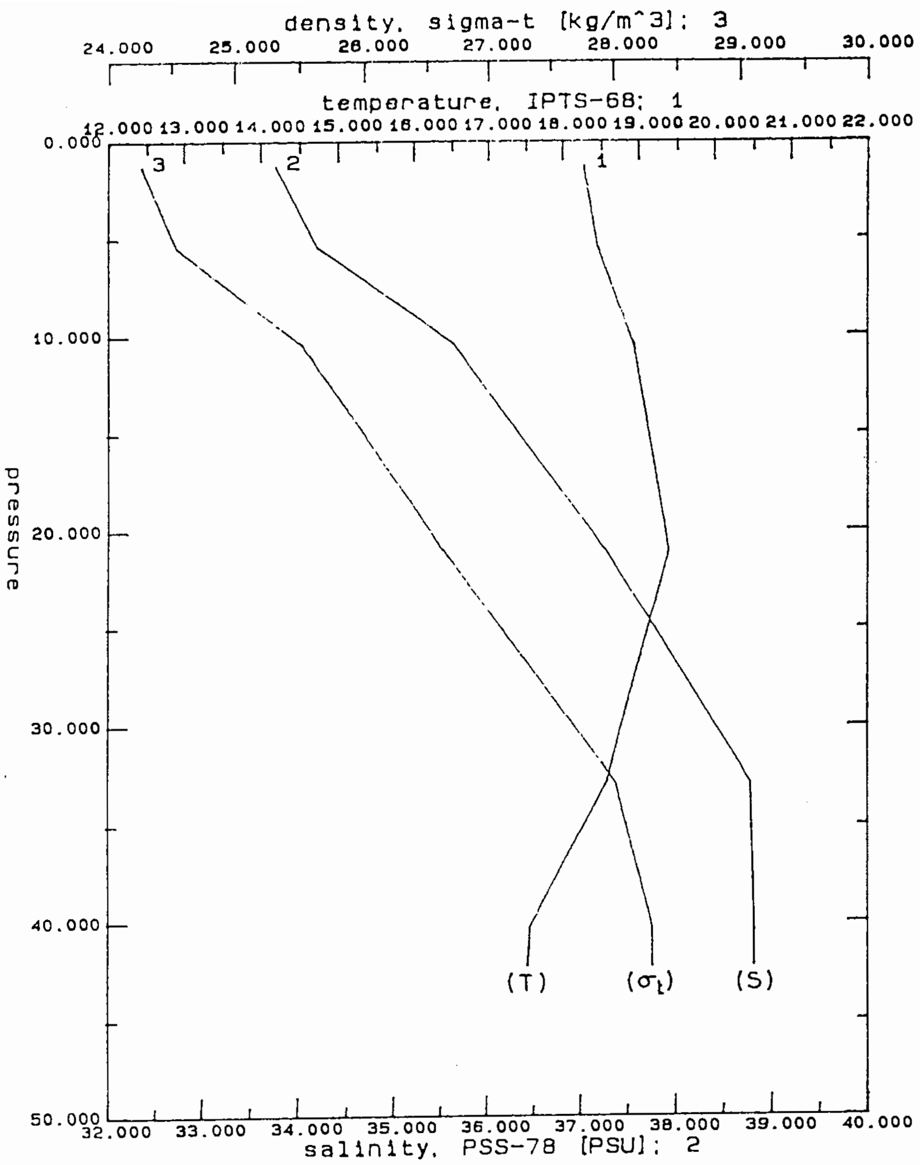

Figure 2.2: T, S and σ_t profiles recorded at St.1

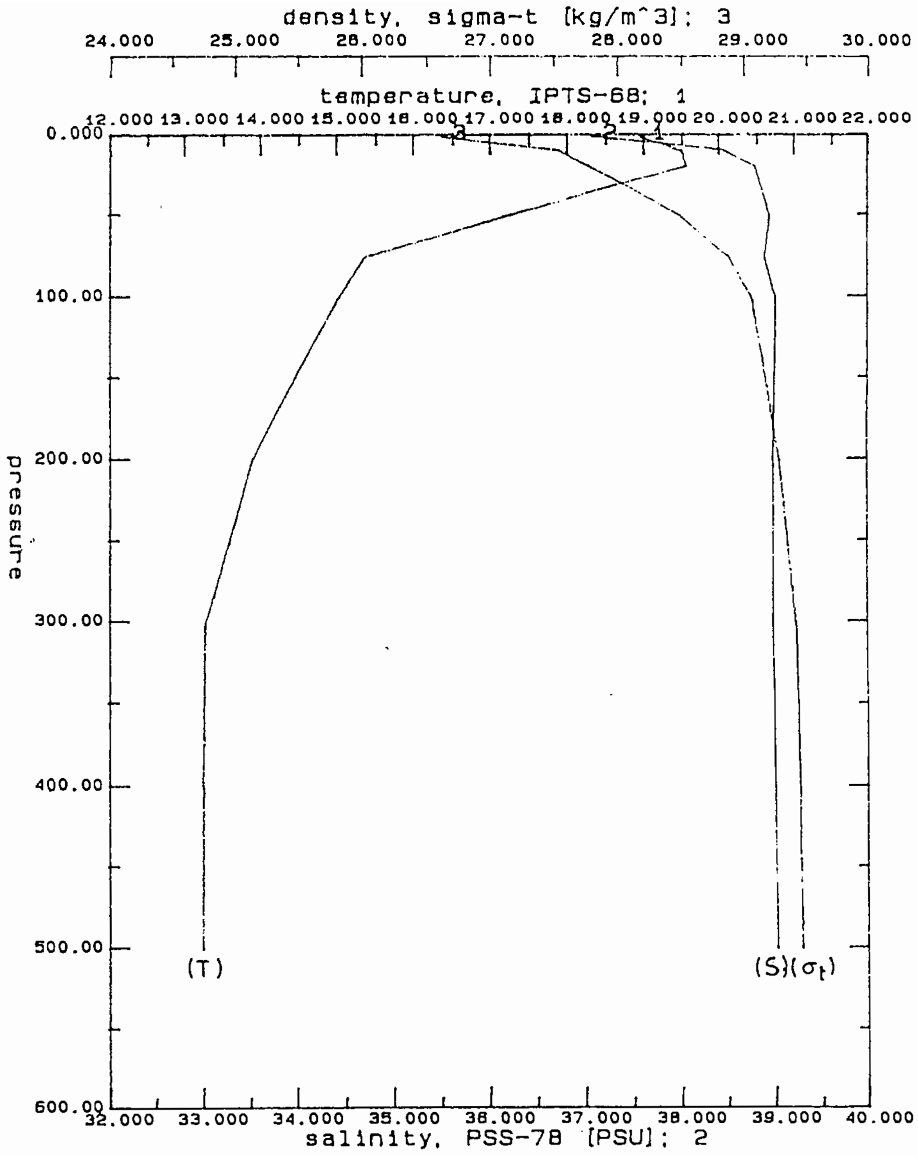

Figure 2.3: T, S and σ_t profiles recorded at St.3

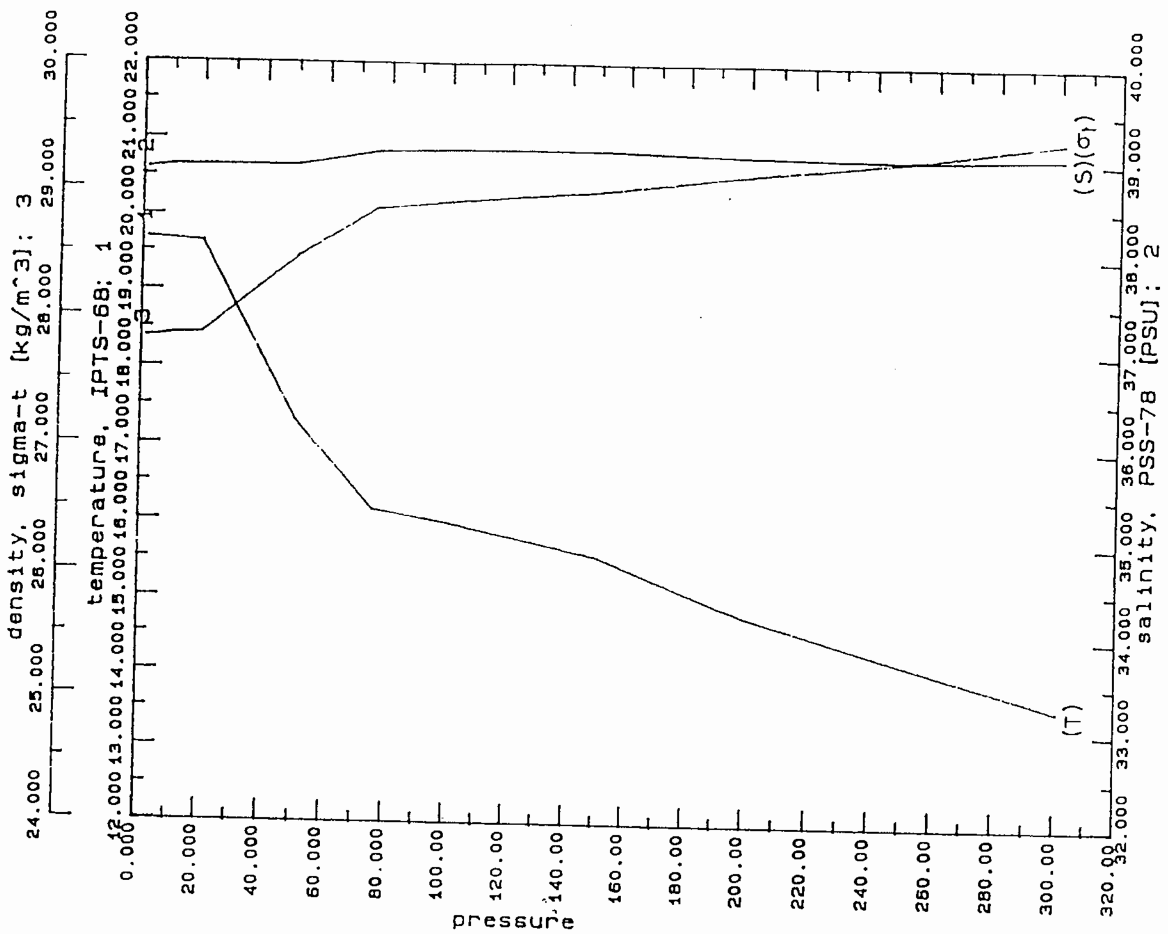

Figure 2.5: T, S and σ_t profiles recorded at St.5

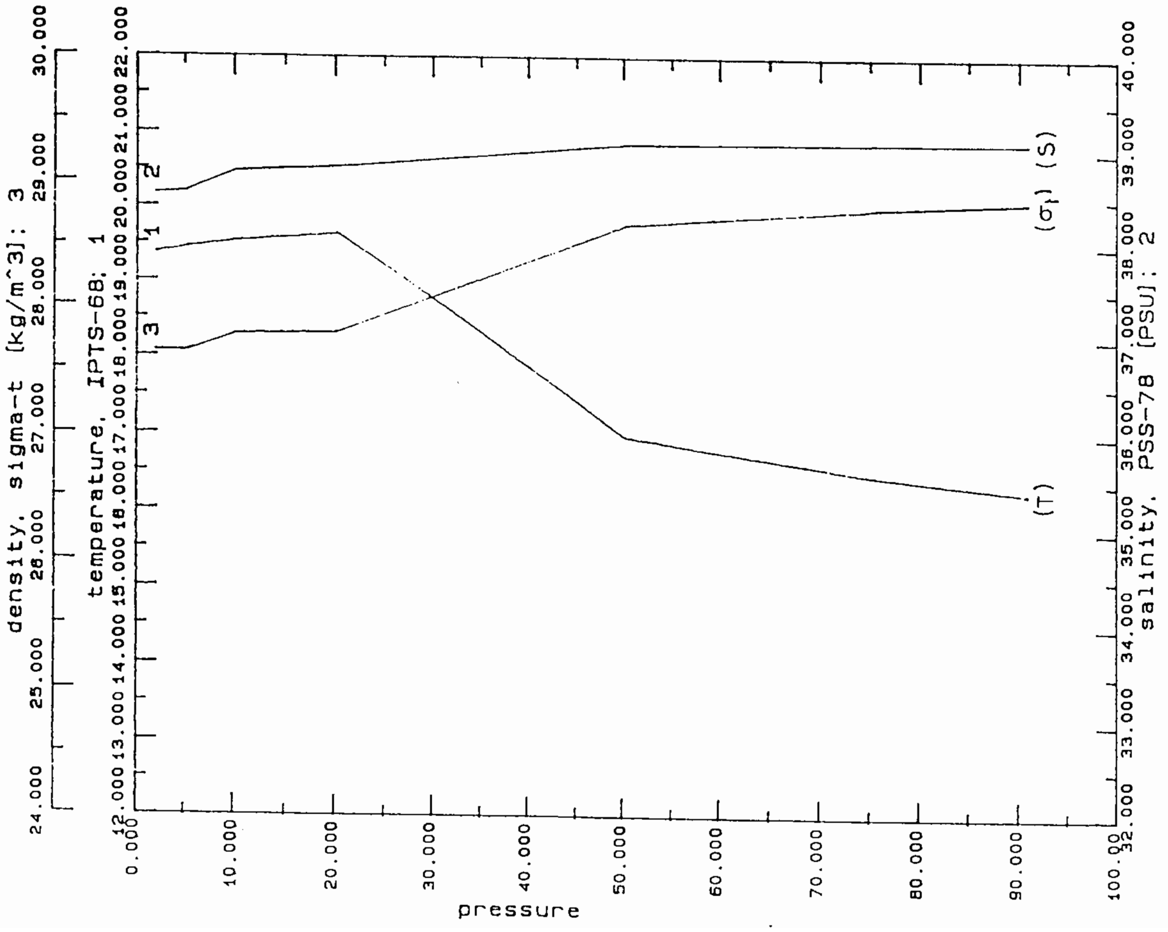

Figure 2.4: T, S and σ_t profiles recorded at St.4

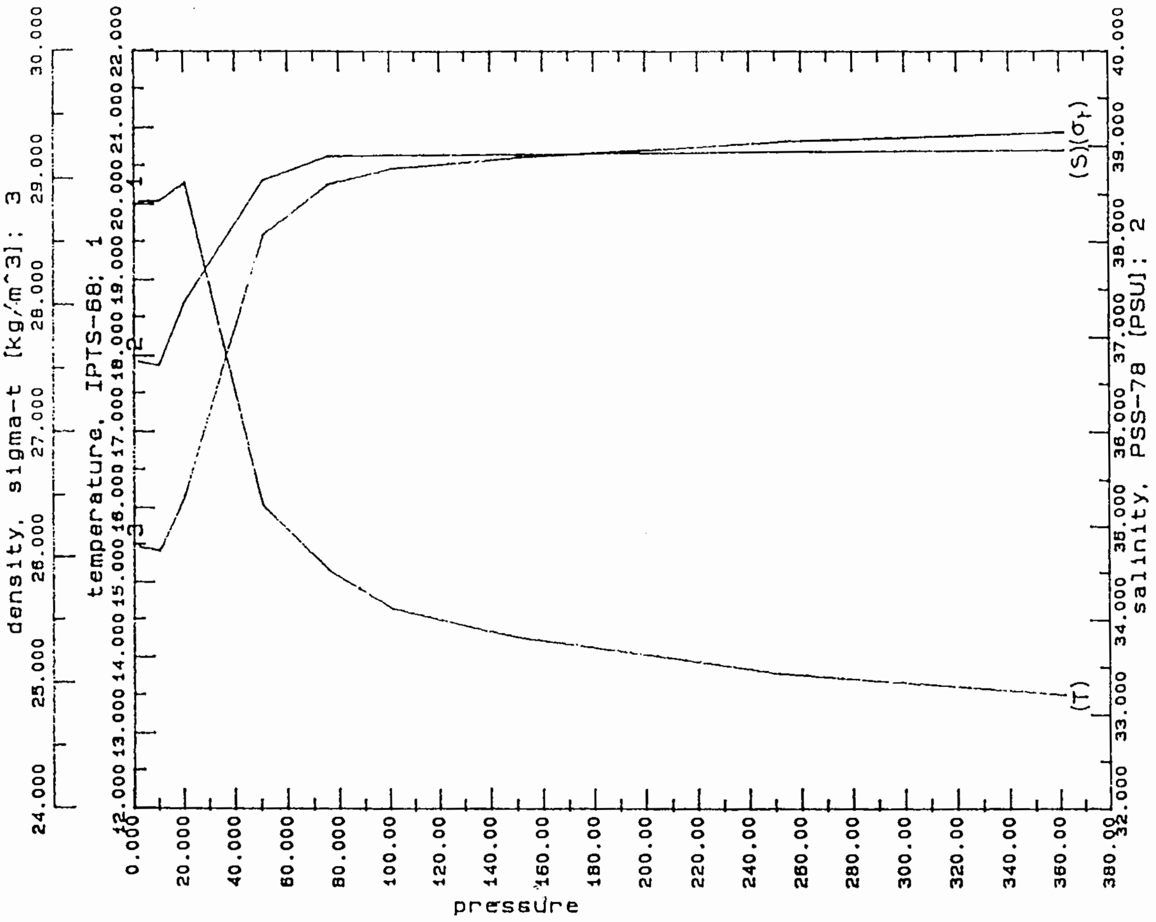

***Figure 2.7**: T, S and σ_t profiles recorded at St.8*

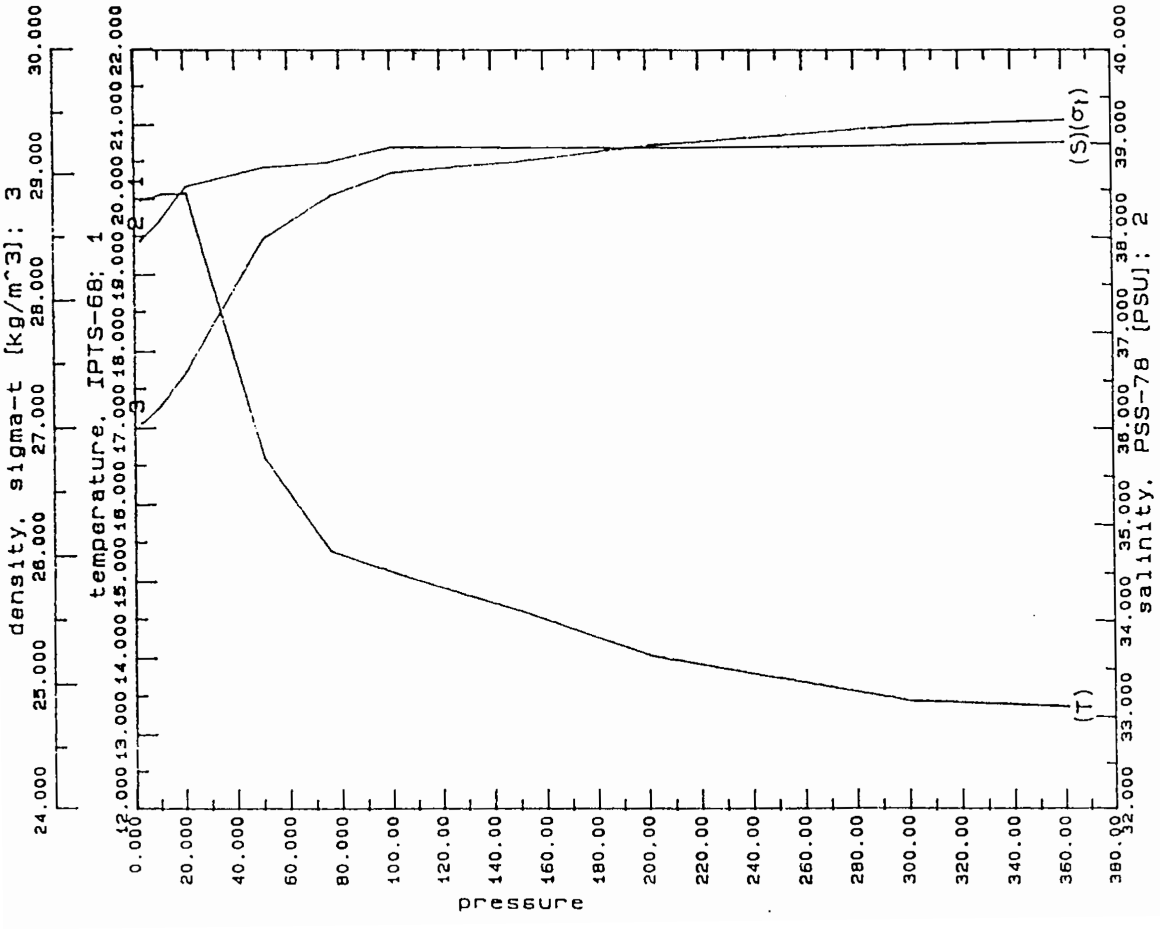

***Figure 2.6**: T, S and σ_t profiles recorded at St.6*

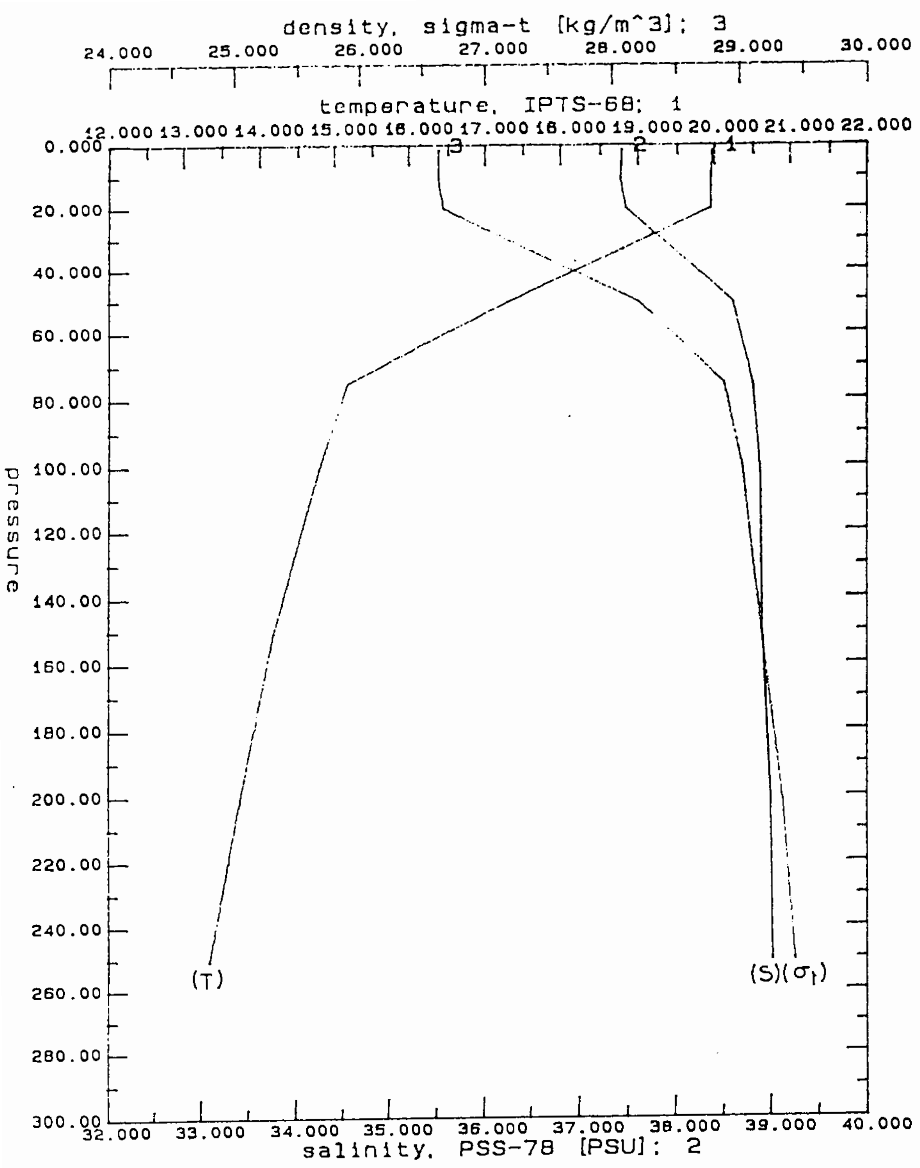

Figure 2.8: *T, S and σ_t profiles recorded at St.9*

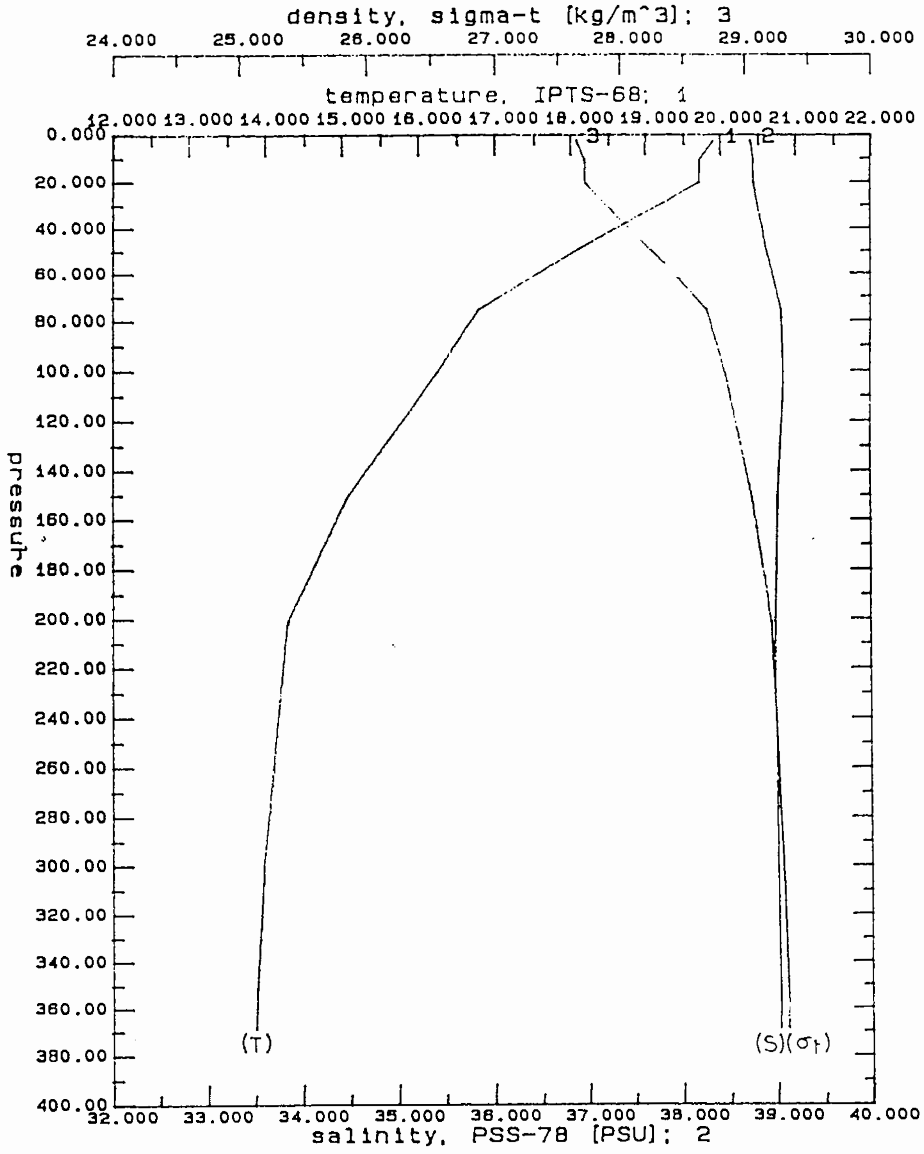

Figure 2.9: *T, S and σ_t profiles recorded at St.10*

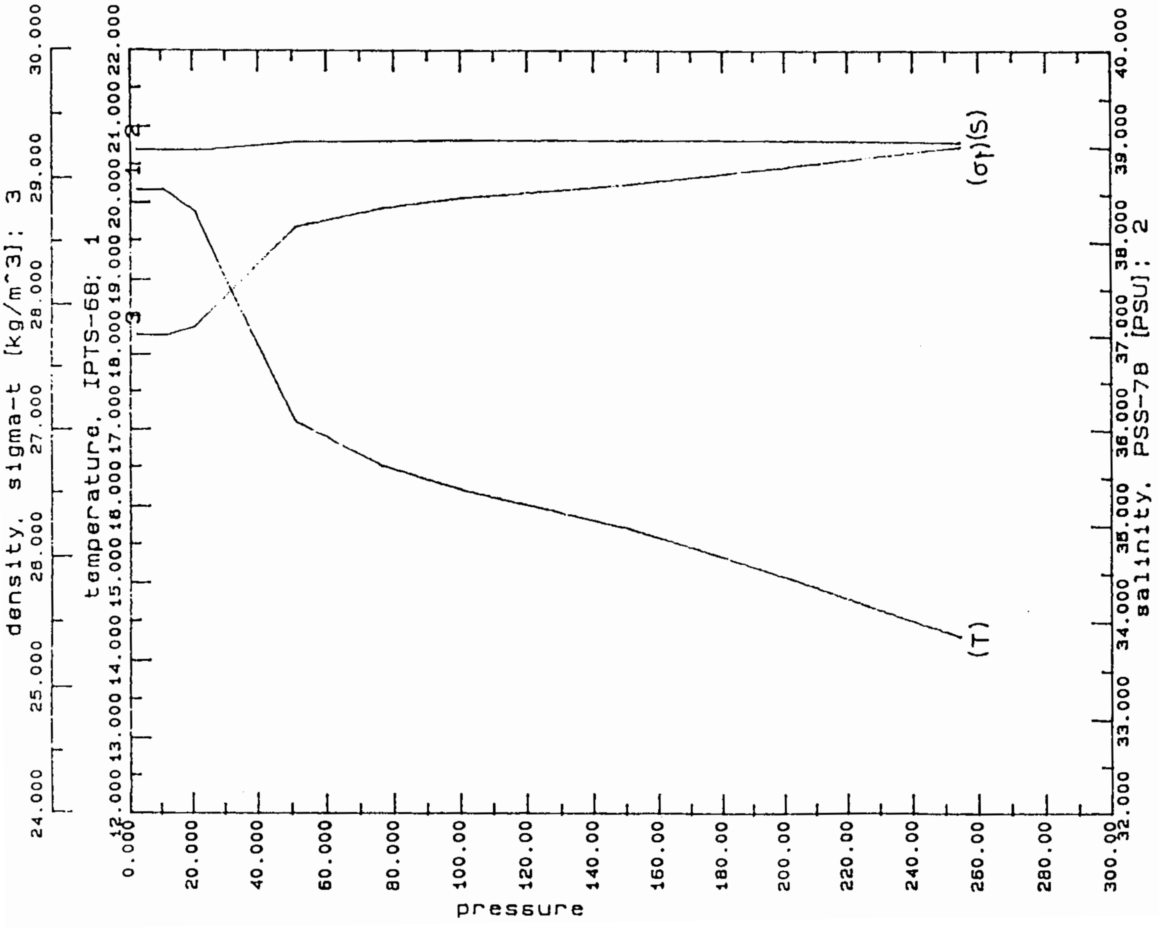

Figure 2.10: T, S and σ_t profiles recorded at St.11

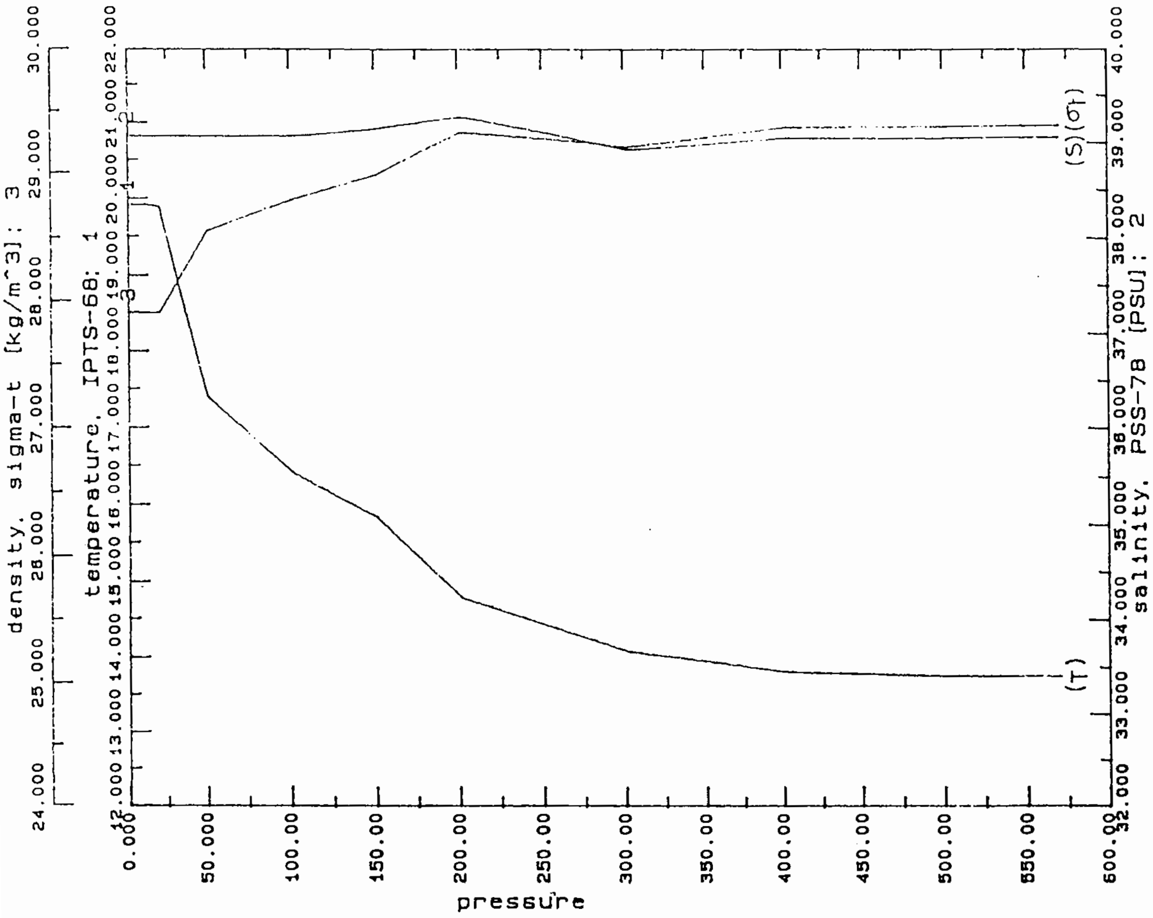

Figure 2.11: T, S and σ_t profiles recorded at St.12

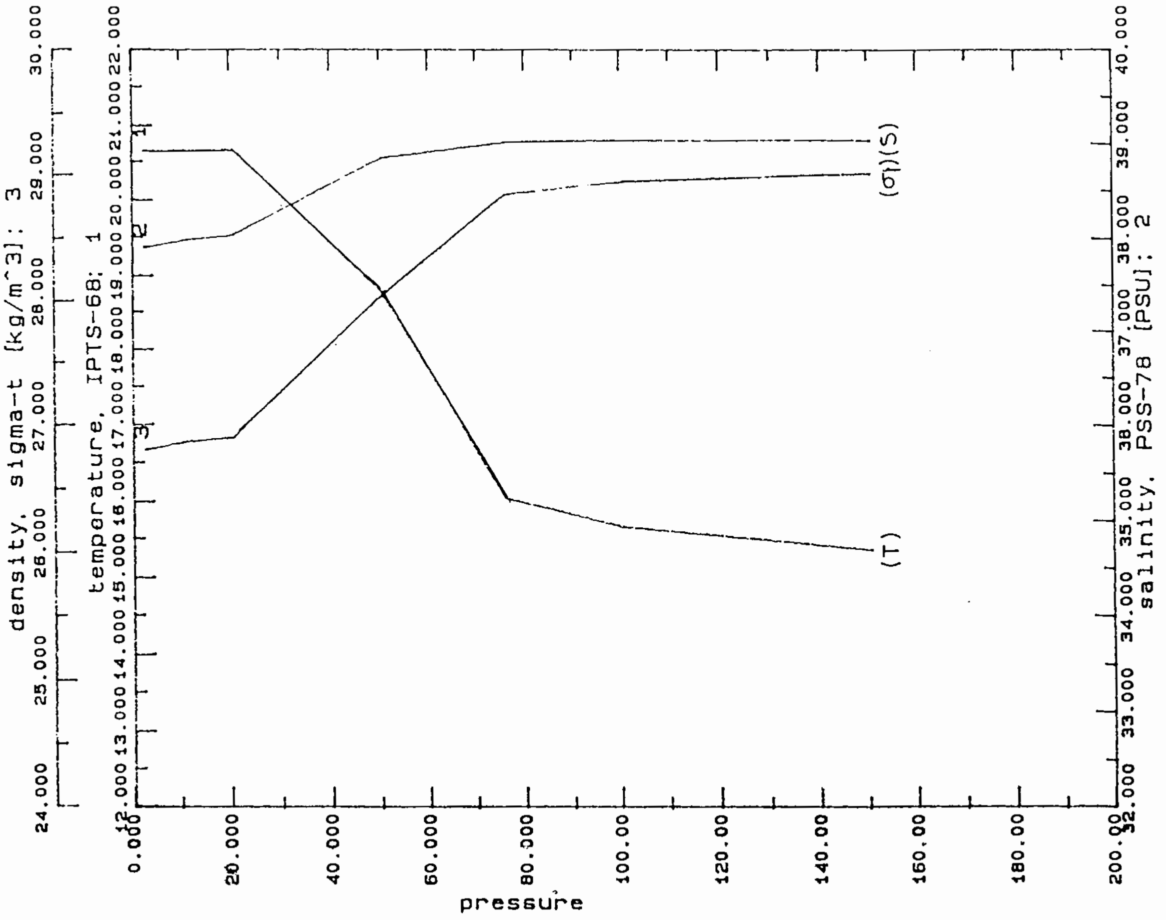

Figure 2.13: T, S and σ_t profiles recorded at St.14

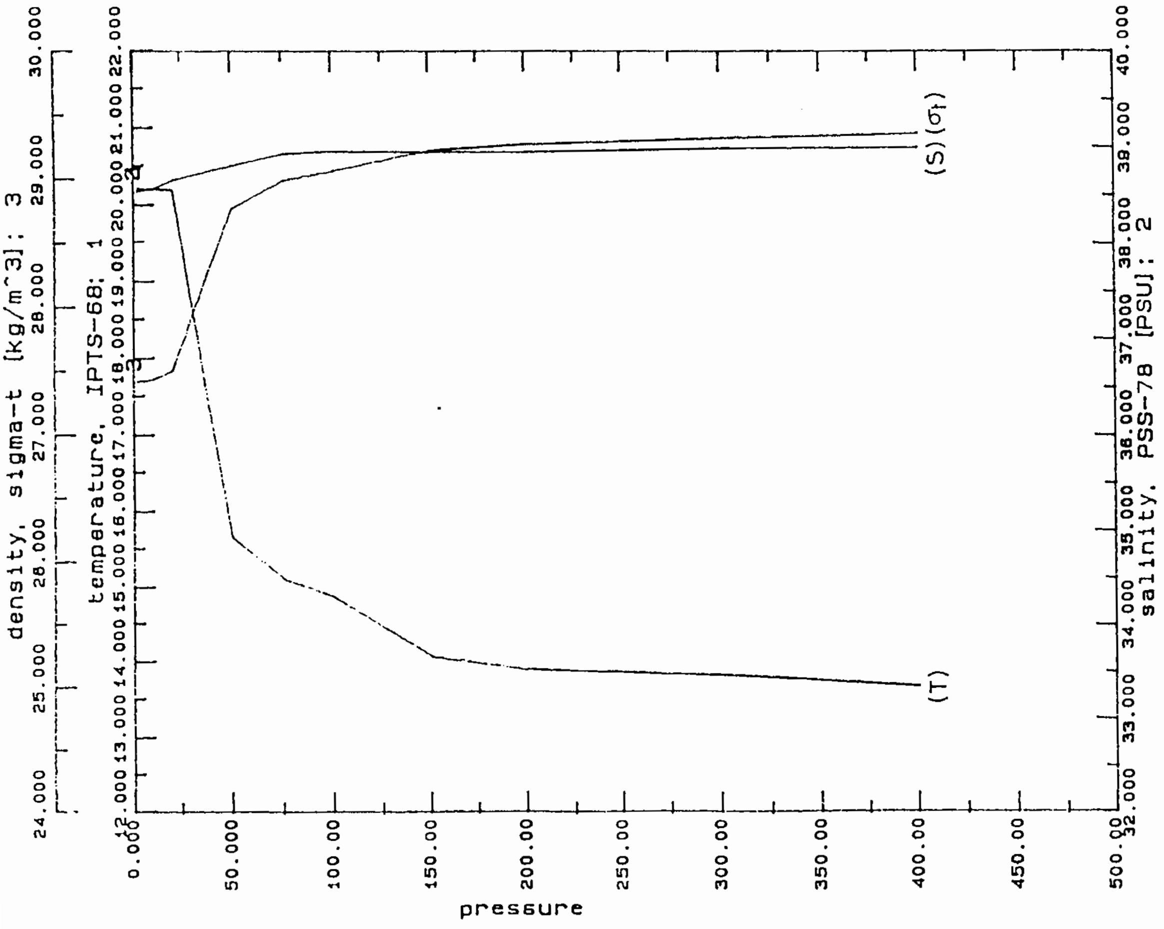

Figure 2.12: T, S and σ_t profiles recorded at St.13

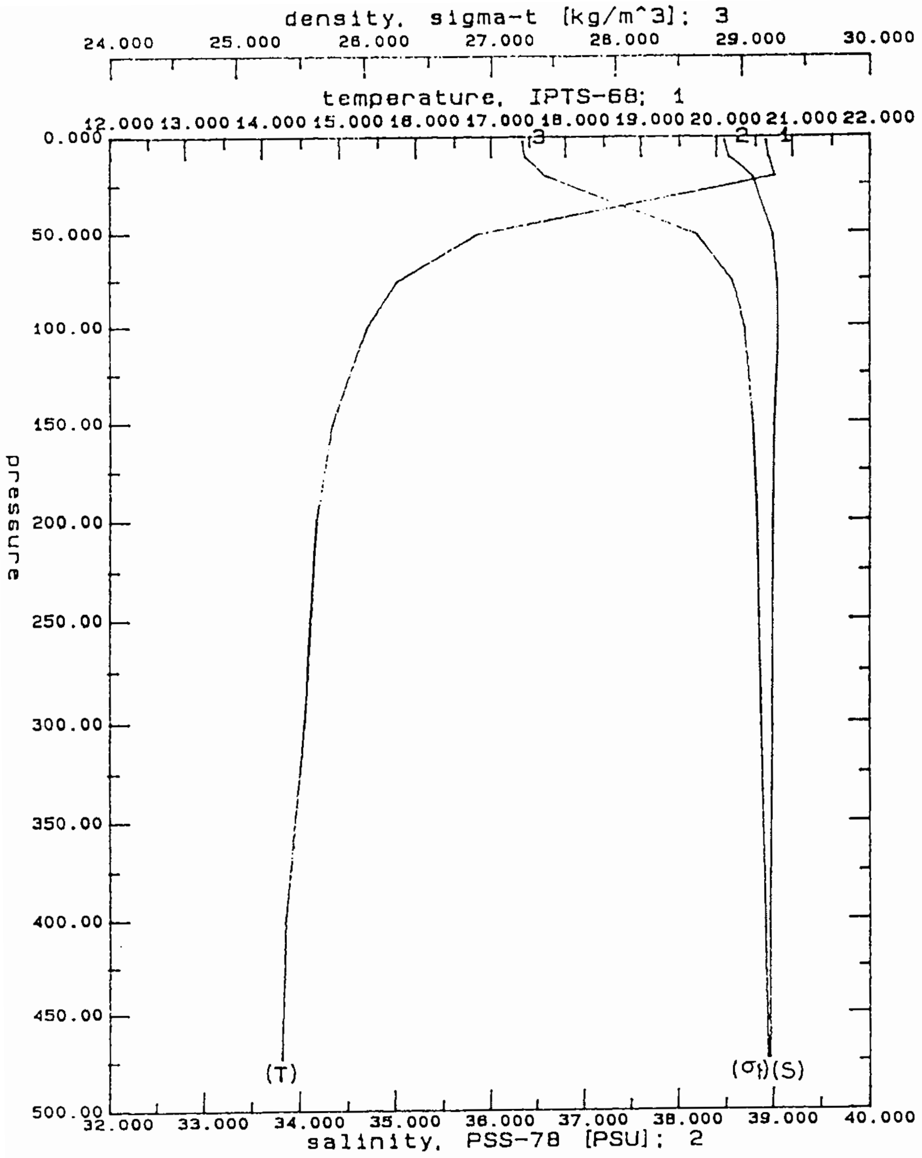

Figure 2.14: T, S and σ_t profiles recorded at St.15

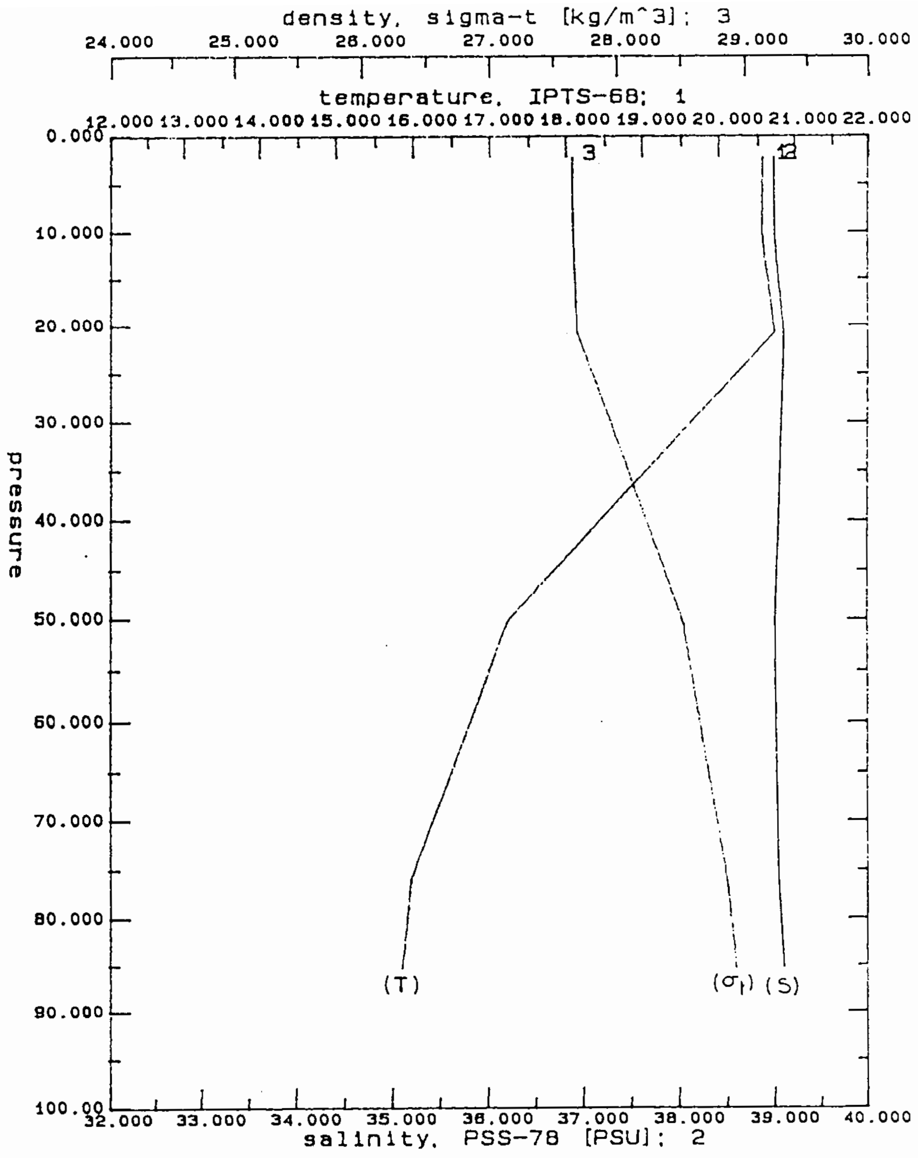

Figure 2.15: T, S and σ_t profiles recorded at St.16

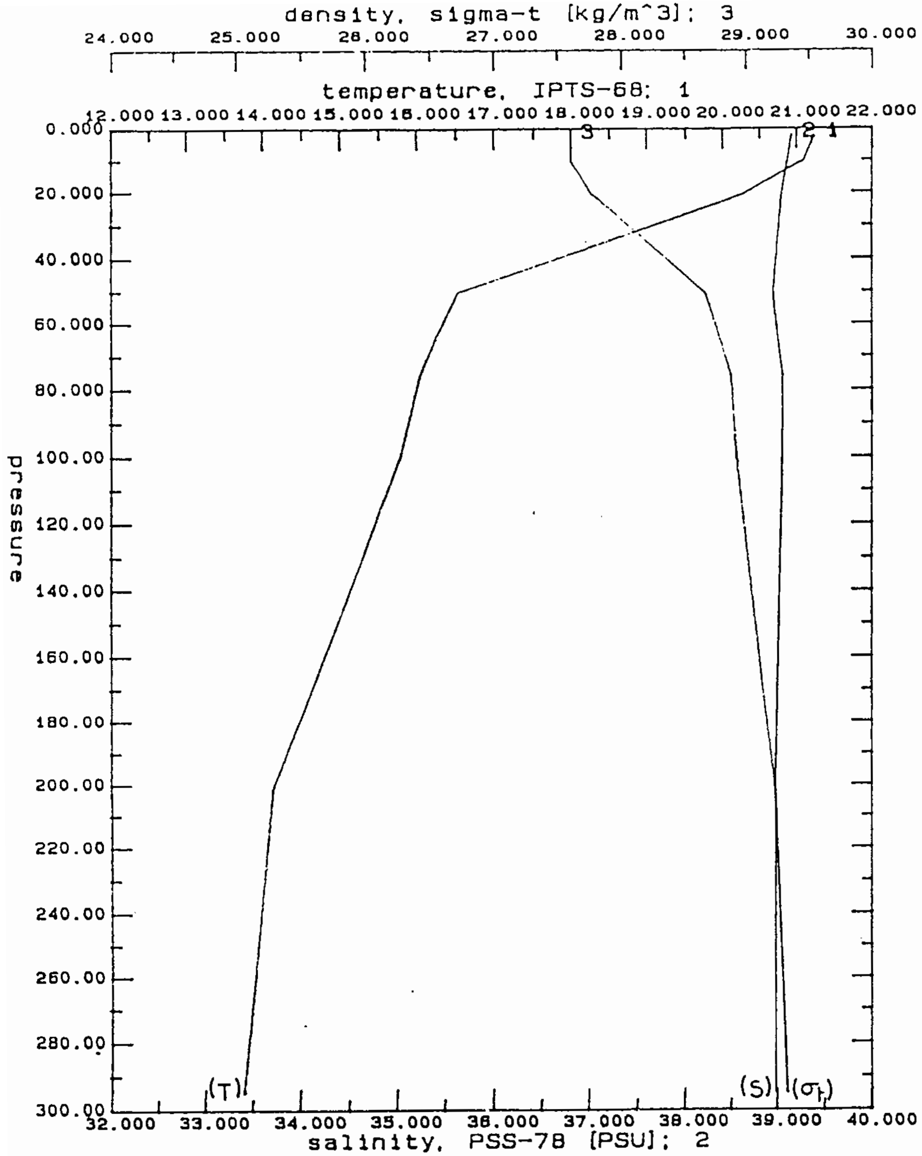

Figure 2.16: *T, S and σ_t profiles recorded at St.17*

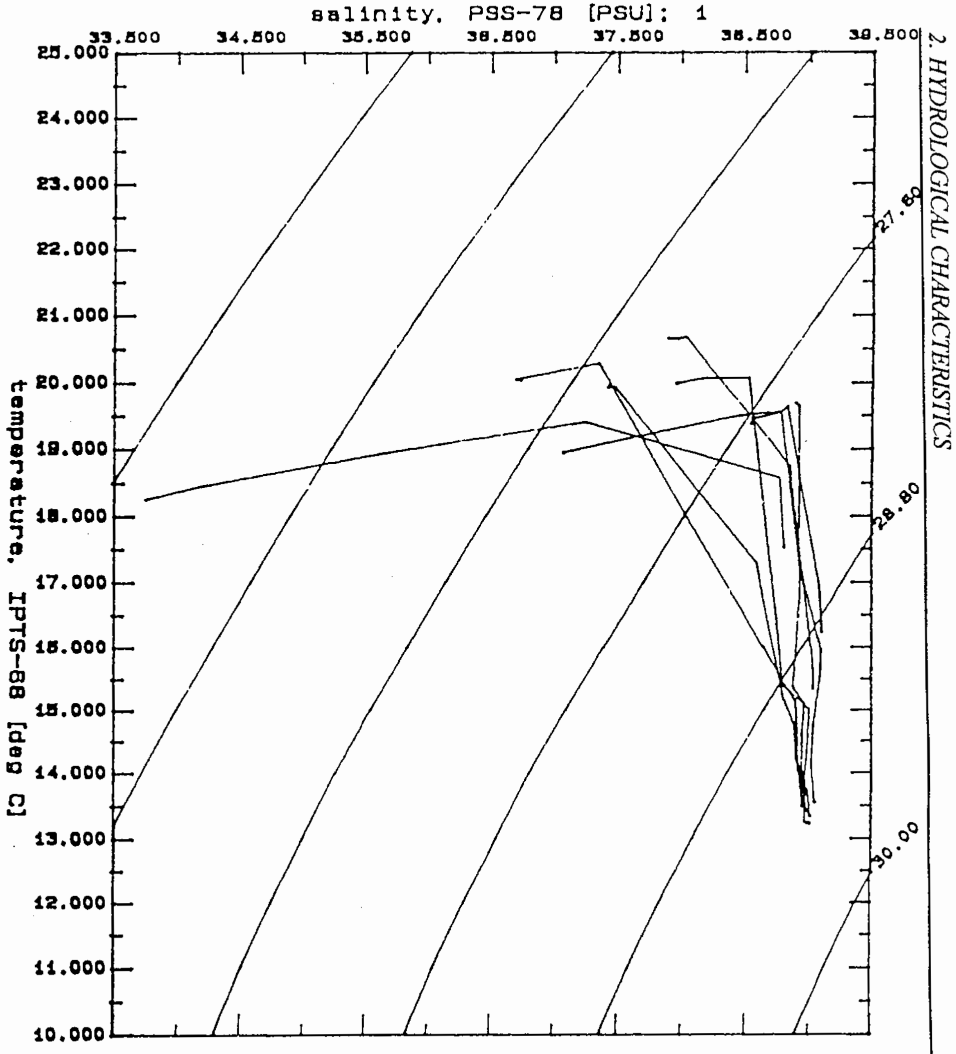

Figure 2.17: *T-S Diagram of the data collected in the Northern and Western Aegean Sea during the Cruise*

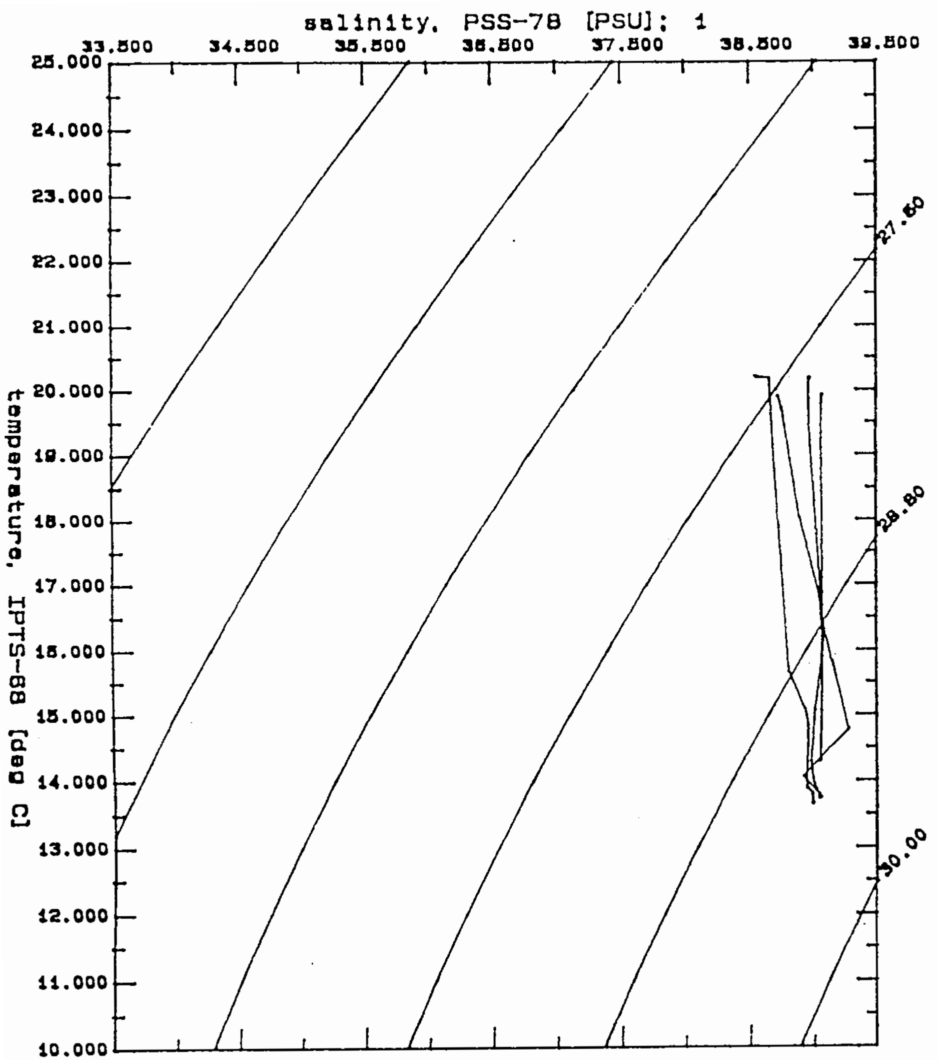

Figure 2.18: *T-S Diagram of the data collected in the Eastern Aegean Sea during the Cruise(17.10-21.10.96).*

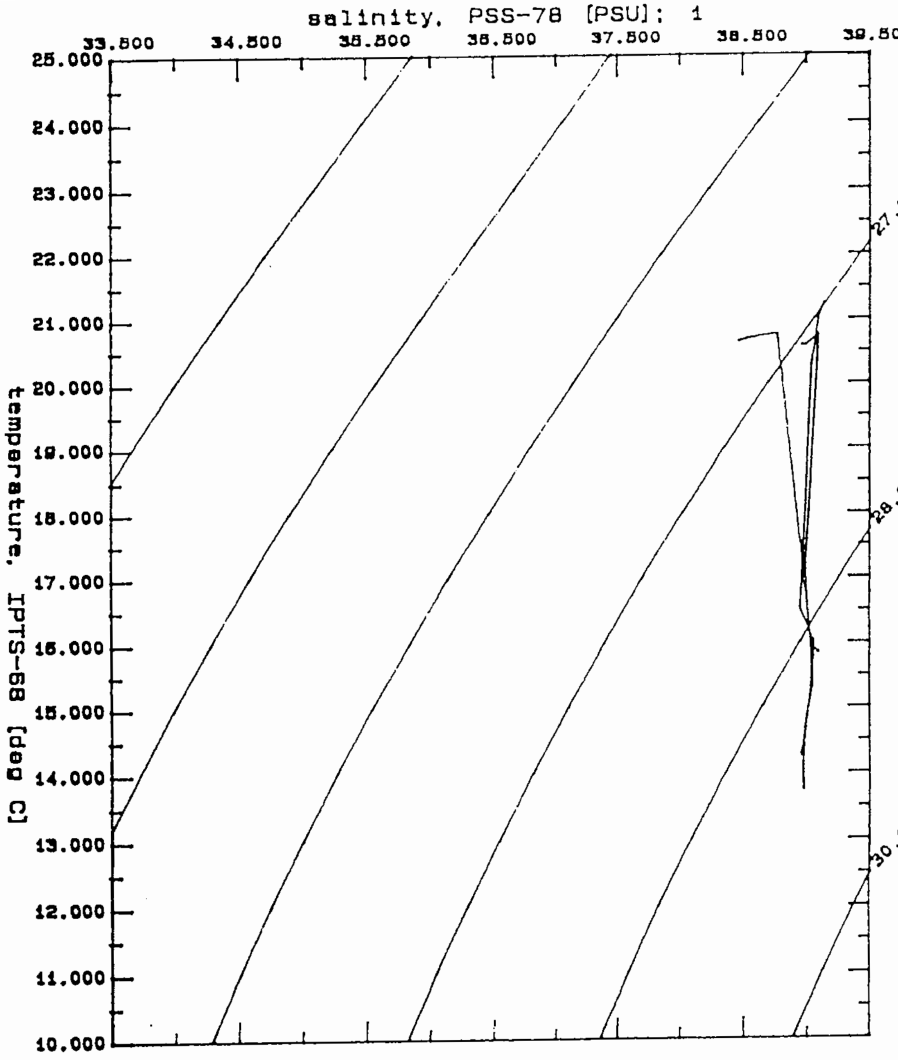

Figure 2.19: *T-S Diagram of the data collected in the Southern Aegean Sea during the Cruise(17.10-21.10.96).*

the Eastern Aegean Sea (Stations: 10, 11, 12, and 13) and the Southern Aegean Sea (Stations: 15,16 and 17).

Table 2.1
Meteorological Conditions during the Cruise.

Stations	Date and Time		AirTemp (°C)	Wind Speed (m/s)	Direction (Degrees)
1	18.10.96	10.15	19.0	6	210
3	18.10.96	14.45	19.0	4	210
4	19.10.96	07.40	17.3	4	360
5	19.10.96	11.00	19.0	5	300
6	17.10.96	20.00	19.0	2	270
8	17.10.96	10.10	20.0	4	270
9	17.10.96	14.15	21.0	7	160
10	19.10.96	16.20	21.0	5	270
11	19.10.96	18.50	20.0	4	270
12	20.10.96	05.5	19.0	4	090
13	20.10.96	01.20	19.0	5	110
14	21.10.96	06.10	18.0	11	220
15	20.10.96	23.10	19.0	1	220
16	20.10.96	6.05	20.5	4	090
17	20.10.96	13.10	22.0	5	140

2.3.1 THE NORTHERN AND WESTERN AEGEAN SEA:

The water column consisted of three main layers. In the upper layer, called also mixed layer, down to 20 to 25m, the ranges of temperature (T), salinity (S) and density (σ_t) were between 18.26 - 20.29°C, 33.74 - 38.78psu and 24.24 - 27.77 (σ_t) respectively. This layer reflects the effects of local surface heating and cooling and subsequent vertical mixing. The intermediate layer lay between approximately 25 and 75m. The respective limits of the T, S and σ_t variations were 15.35 - 19.65°C, 37.25 - 39.10psu and 26.63 - 28.88(σ_t). A third water layer, called deep layer, was observed below 75m, extended to the bottom. The T, S and σ_t variations in this layer were 13.22 - 16.46°C, 38.81 - 39.11psu and 28.82 -29.45(σ_t).

This area is spectacularly affected by the less saline waters coming from the Black Sea and the Sea of Marmara through the Dardanelles. Their influence is more evident in the Northern and Northeastern Aegean Sea, where the minimum salinity values (~ 33.74psu) were observed. The collected data show a rather cyclonic circulation within the surface layer. It seems that the less saline waters from the Black Sea, coming out from the Dardanelles, move northward and then westward and southward. Similar observations have been reported also by other Investigators (Ref: 1-13).

2.3.2 THE EASTERN AEGEAN SEA:

The surface waters (0 - 20m), are characterised by higher salinity values (38.53 - 39.07psu), the temperature ranges between 19.71 and 20.21°C and the density variations are 27.41 - 27.89σ_t . In the intermediate layer (20 - 100m), the same parameters fluctuate from 14.85 to 19.87°C, 38.65 - 39.07psu and 27.51 - 29.06σ_t. Below the depth of 100m, in the deep layer, the temperature vary from 13.65 to 16.41°C, the salinity from 38.91 to 39.07psu and the density from 28.79 to 29.38σ_t. Moreover, it seems that the water of lower salinity might disrupt between 200 and 300m , the general tendency of increased salinity with depth. In general, the Eastern Aegean is covered by waters of high salinity and lower temperature values, with an exception for the surface temperature for the waters of St.11. The lower temperatures and higher salinities prevailing at the surface of the area in question, may be due to the extended upwellings, occuring more during the warm period, under the influence of Etesians, blowing over the Aegean (Ref. 1-13).

2.3.3 THE SOUTHERN AEGEAN SEA:

The T, S and σ_t variations of the surface waters (0 - 20m), were found to be 20.28 - 21.24°C, 38.48 - 39.14psu and 27.24 - 27.76(σ_t). These waters coming from the Eastern Mediterranean through the eastern straits of the Cretan arc, loose heat and become less saline going westward(Ref.2,11,12). This can be due to the winds prevailed before the sampling period and to the mixing and spreading processes. In the intermediate water layer (20 - 75m), the corresponding ranges of the T, S and σ_t characteristics were found to be 15.75 - 20.77°C, 38.78 -

39.09psu and 27.44 - 28.92σ_t. The respective ranges of the same parameters in the deep water vary from 13.73 to 16.03°C, 38.95 - 39.09psu and 28.86 - 29.33σ_t. The stratification was due more to the strong thermocline, whereas, at the eastern region of the South Eagean a decrease in salinity below 180 m depth reaching the bottom, was observed.

2.4 CONCLUSIONS

- In the surface water of the investigated area, three distinct subregions of different hydrological characteristics were distinguished. The Northern and Western Aegean Sea, the Eastern Aegean and the Southern.
- The water column was essentially composed of three layers. The upper one or the so called mixed layer, between the surface and 20 to 25m, the intermediate, between 25 and 75 to 100m and the deep water below it, reaching the bottom.
- A cyclonic circulation within the surface layer was evident. It seems that the less saline waters from the Black Sea, entering through the Dardanelles, move Northward and consequently Westward and Southward.

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3. DISTRIBUTION OF HEAVY METALS AND ORGANIC MATTER IN THE SURFACE SEDIMENTS OF THE AEGEAN SEA

3.1 INTRODUCTION

Trace element concentrations in marine sediments is a result of both natural and anthropogenic processes. Monitoring of trace metals can therefore contribute not only to the understanding of the geochemical history of a certain area, but in the identification of anthropogenic enrichment as well. However, most of the studies on heavy metal pollution in the eastern Mediterranean sediments have been conducted in coastal areas and embayments [1-3], whereas only a single study has been performed around the Cyclades islands [4].

Geochemical Characteristics of the surface sediments were recorded for the first time in 15 stations in the Northern and Central Aegean Sea. Heavy metals, grain size parameters of the sediments, organic carbon, total carbon and nitrogen are the parameters that delineat the picture of the present situation of surface sediments of the Aegean Sea, in regard to heavy metal and organic mater content. The data obtained will form the baseline information for future pollution monitoring studies.

3.2 METHODOLOGY

Surface sediment samples (0-3 cm) were collected with a Smith-McIntyre type grab sampler from 15 stations in the Aegean Sea at depths ranging from 45 to 814 m. The cruise took place in October 1996 and the sampling locations are shown in Figure 3.1.

For trace metal analysis, about 20 g of undisturbed sediment was collected from the central part of the grab sample with a plastic tool and stored in a polyethylene bag. Grain size analysis was carried out by wet-seiving. The samples were dried at 60° C, the <63 μm fraction was estimated, ground in an agate mortar and a portion was analyzed for silt-clay content by X-ray analysis with Sedigraph (Micromeritics 5100).

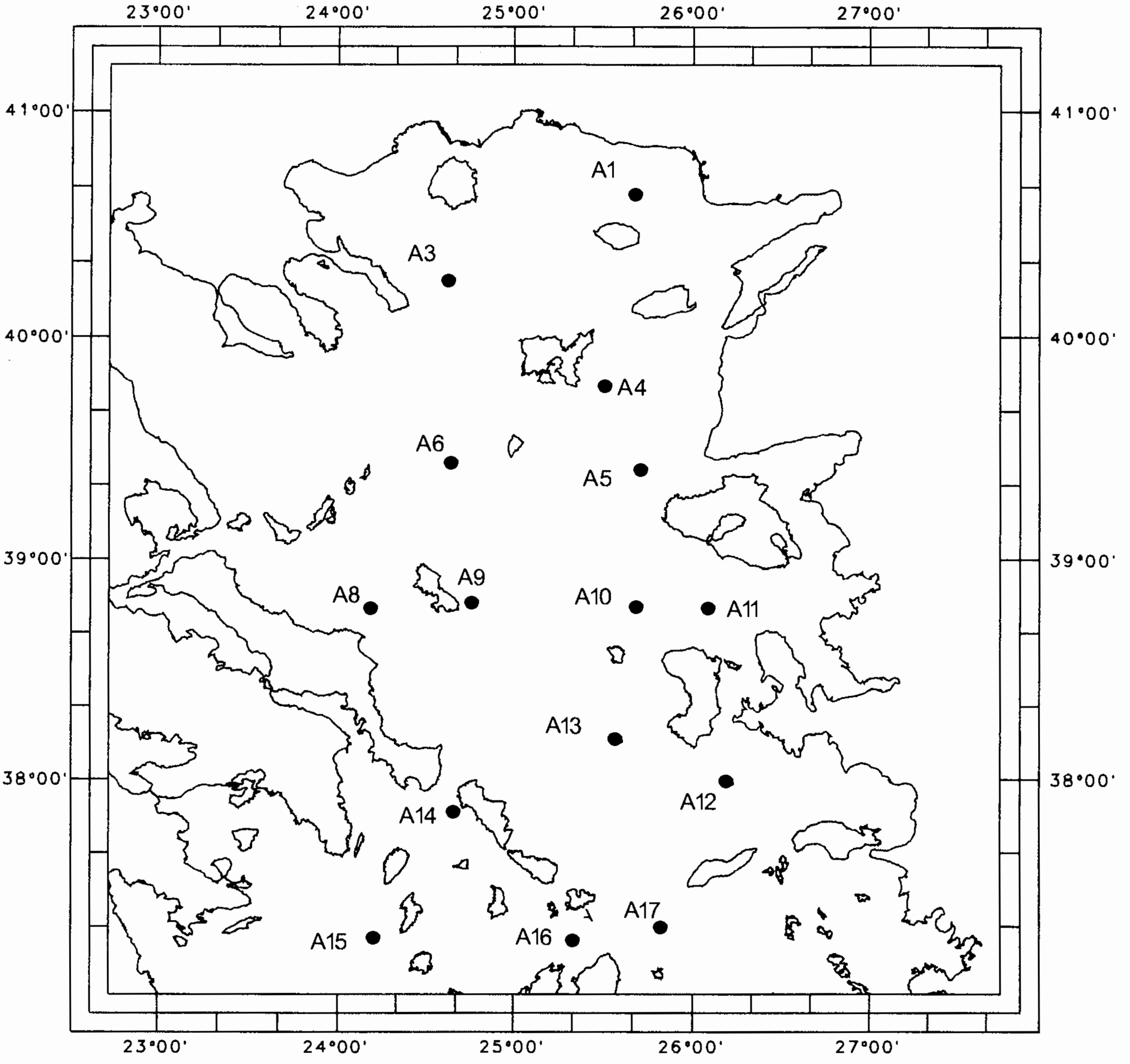

Figure 3.1: Map with the 15 sampling locations in the Aegean Sea.

Heavy metal analysis was performed after a complete digestion of the ground sample with subsequent addition of HNO_3, HF, aqua regia ($HCl:HNO_3$) and $HCLO_3$ [5,6]. The final sample was analyzed for Pb, Cu, Zn, Ni, Cr, Mn and Fe by flame atomic absorption spectrometry on a Varian SpectrAA 20 Plus. Cd determinations were performed on a Perkin-Elmer 4100 spectrophotometer with a HGA 100 Graphite Furnace. A reference material (SD-M-2/TM IAEA Monaco, No 182) of known concentrations was treated like the samples and analyzed in order to check the accuracy of the analyses.

Organic carbon, total carbon and nitrogen and carbonate content were determined in the bulk sample after oven drying the samples at 60° C and grinding in an agate mortar. The method is a modification of Nieuwenhuize *et al* [7]. Splits of 10-15 mg of powdered homogenized samples were accurately weighed into silver cups. Organic carbon was determined after the removal of inorganic carbon by *in situ* acidification of samples with hydrochloric acid 1:1 and drying the samples at 60° C. Silver cups were pinched closed, compacted and formed into a ball. The balls were transferred to the autosampler of the Fisons Instrumets CHN elemental analyzer type EA-1108. For total carbon analysis, carbon splits of 5-50 mg of dried samples were weighed into tin cups, sealed and analyzed without any pretreatment.

3.3 RESULTS AND DISCUSSION

Sampling locations, maximum water depth, geographical coordinates, carbonate content and sediment distribution are shown in Table 3.1. The grain size parameters fall among a wide range of values. Carbonate content follows the sand and total carbon distribution and presents the higher values at stations A8, A14, A16, A17 and A1.

Table 3.2 shows the concentrations of heavy metals in the surface sediments of the 15 stations. Pb and Cu were low among the stations and were similar to natural background values for the Mediterranean [8]. Zn concentrations reached 72 mg/kg at station A7 and 140 mg/kg (the highest value) at station A1. The highest value of Ni was observed at station A12 and the lowest at station A6. Cr concentrations followed the same pattern as Ni, a possible indication that these metals are weathering products. Cd concentrations were low and ranged between 0.13 and 0.22 mg/kg. Fe concentrations, given in percentage, ranged between 1.98-3.96 % and followed the same pattern as Ni and Cr. Mn values ranged between 400 and 2200 mg/kg and show a good correlation with the Fe levels.

Figure 3.2 presents the degree of correlation between (a) Cr and Ni, (b) Zn and Fe and (c) Cu-Fe, (d) Cu-Mn, respectively. Correlation coefficients are statistically significant at the 0.1 level of significance. Correlation between the rest of the metals was non significant.

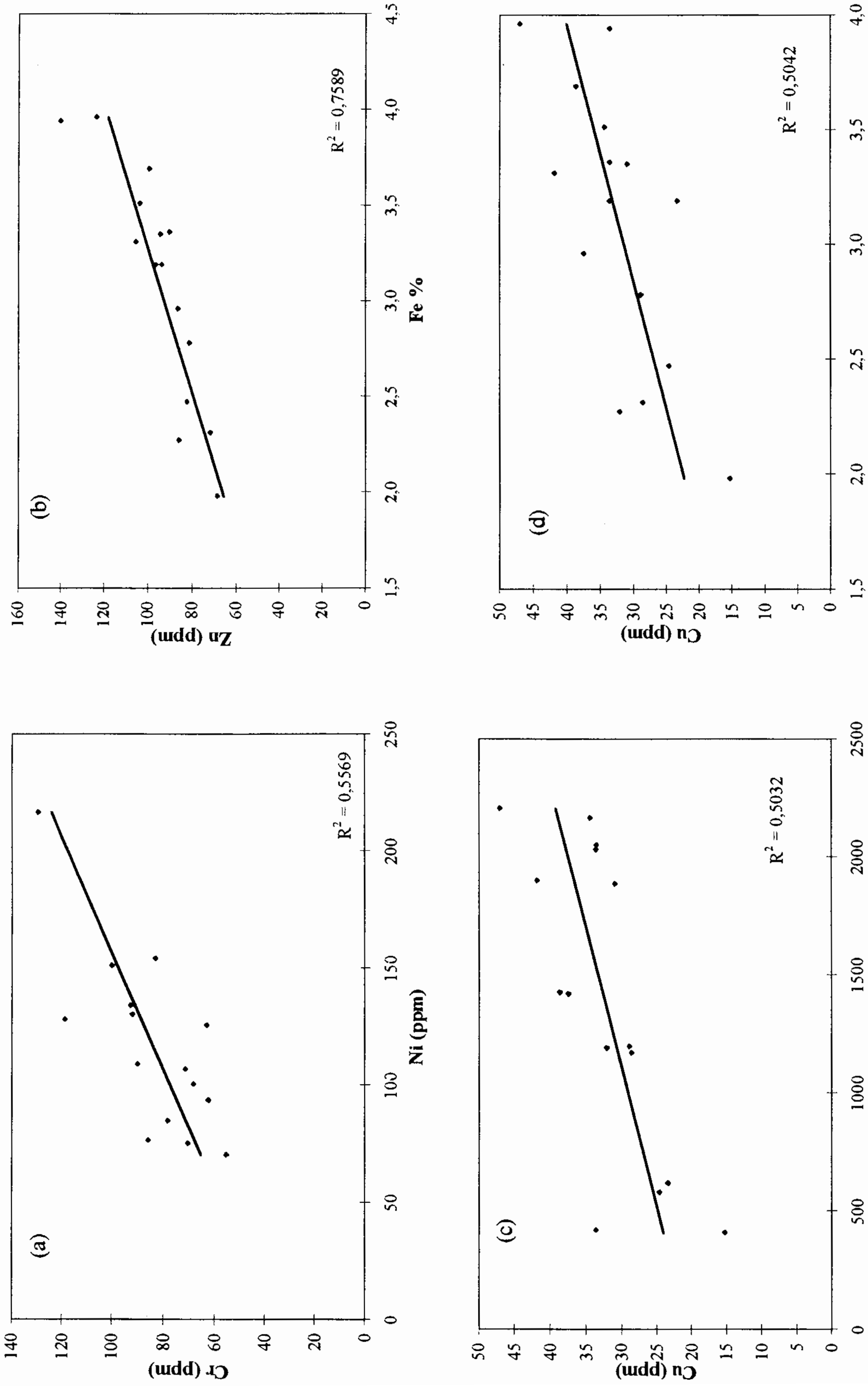

***Figure 3.2:** Correlation between (a) Cr-Ni, (b) Zn-Fe, (c) Cu-Mn and (d) Cu-Fe.*

Table 3.1

Grain size parameters of sediments.

Station	**Depth (m)**	**Longitude**	**Latitude**	**$CaCO_3$ %**	**Sand. %**	**Silt. %**	**Clay. %**
A1	45	25 42.00	40 38.00	65.46	70.56	12.71	16.73
A3	814	24 38.00	40 14.00	18.56	3.53	36.80	59.67
A4	93	25 30.00	39 46.00	22.00	85.00	10.52	4.48
A5	300	25 42.60	39 24.50	28.37	10.55	51.69	37.76
A6	358	24 38.30	39 26.90	35.84	23.23	39.00	37.80
A8	365	24 11.90	38 47.20	80.67	92.00	3.88	4.12
A9	254	24 46.00	38 48.00	53.55	45.36	32.90	21.74
A10	375	25 42.00	38 48.00	41.66	29.53	37.51	32.96
A11	284	26 06.00	38 48.00	36.78	15.85	51.31	32.84
A12	770	26 12.00	38 00.00	30.13	4.64	47.68	47.68
A13	427	25 36.00	38 10.50	71.35	70.22	16.85	12.93
A14	168	24 38.60	37 51.80	79.09	97.81	1.51	0.68
A15	476	24 12.00	37 16.00	57.59	18.38	47.34	34.28
A16	106	25 21.00	37 16.00	75.89	87.93	8.81	3.26
A17	325	25 48.80	37 19.00	68.53	68.23	19.32	12.45

Total and organic carbon concentrations in % and the C:N ratio are shown in Figures 3.3 and 3.4 respectively. Total carbon content ranged from 3 to about 10% with maximum values at stations A8, A14, A16, A13, A17 and A1. Organic carbon ranged from 0.20 to 0.77 % and presented a low degree of variability among the 15 stations.

The lowest content of nitrogen was observed at station A16 (0.008 %) and the highest at station A12 (0.056 %). The C:N ratio was high (more than 65) at stations A4, A8 and A1 and ranged between 40-55 at stations A14, A16 and A17, while it was about 15 at the rest of the stations. Stations A1, A4 and A8 had displayed the higher C/N values. Both carbon and nitrogen concentrations approached these which are considered the natural background levels [9]. A further evaluation of the results is required in order to obtain a better understanding of the distribution of trace metals and organic mater in the northern part of the Aegean Sea and to identify the main input sources of metal and organic mater enrichment of surface sediments.

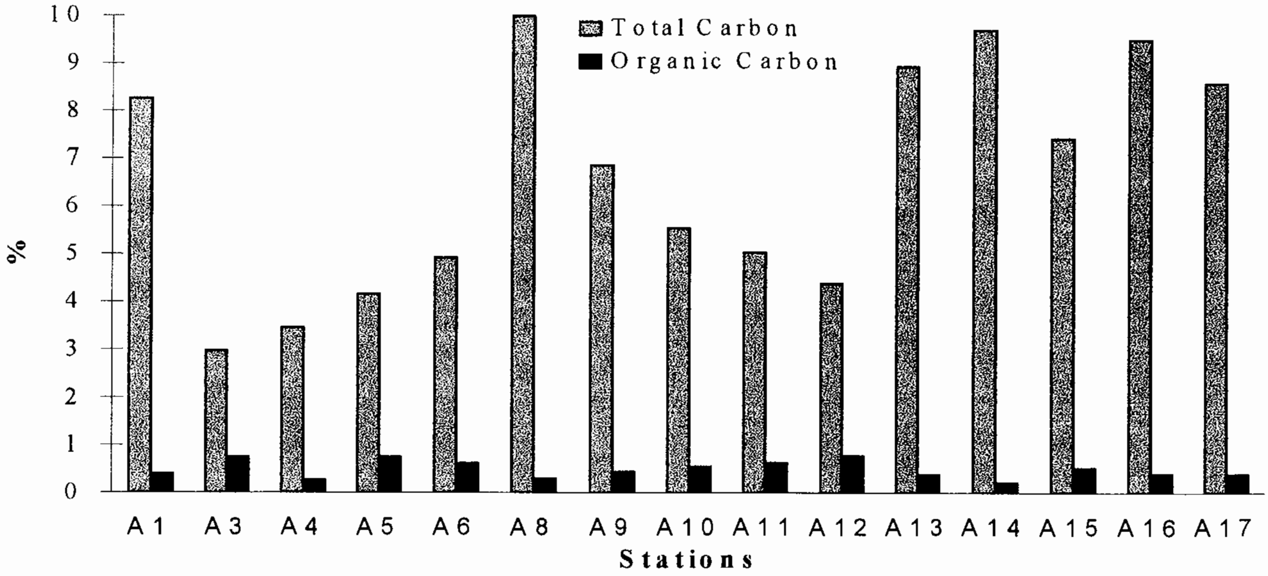

Figure 3.3*: Total and organic carbon distribution among the 15 stations.*

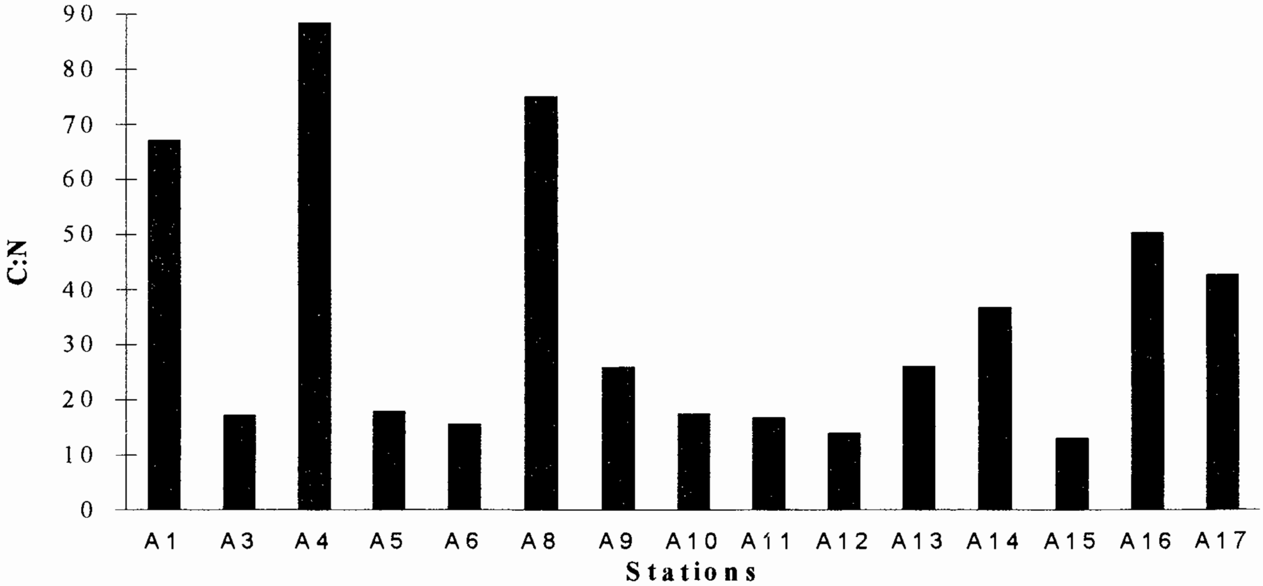

Figure 3.4: C:N ratio in the 15 stations.

Table 3.2

Heavy metal concentrations in the <63 μm fraction of surface sediments from the Aegean Sea. Results are expressed in mg/kg, except for Fe in %.

Stations	Pb	Cu	Zn	Ni	Cr	Cd	Mn	Fe%
A1	30.11	33.68	140.34	76.29	85.91	0.17	419.00	3.94
A3	30.36	47.06	123.72	108.71	89.95	0.16	2205.00	3.96
A4	24.34	23.40	96.71	75.02	70.50	0.14	618.00	3.19
A5	27.65	34.45	103.84	106.66	71.41	0.15	2164.00	3.51
A6	26.02	33.66	93.94	100.27	68.32	0.16	2031.00	3.19
A8	29.34	41.87	105.48	151.02	100.02	0.22	1899.00	3.31
A9	23.86	28.92	81.40	127.91	118.60	0.15	1196.00	2.78
A10	24.26	33.60	90.38	133.80	92.71	0.13	2050.00	3.36
A11	26.42	30.95	94.55	130.09	92.05	0.15	1884.00	3.35
A12	25.38	38.72	99.63	216.51	129.58	0.16	1427.00	3.69
A13	26.21	37.47	86.63	153.98	83.13	0.18	1420.00	2.96
A14	23.75	24.63	82.53	84.80	78.46	0.20	579.00	2.47
A15	28.61	32.15	86.14	93.53	62.48	0.17	1190.00	2.27
A16	22.72	15.25	68.76	70.18	55.43	0.14	406.00	1.98
A17	25.02	28.62	71.90	125.58	63.14	0.16	1170.00	2.31

3.4 REFERENCES

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4. PETROLEUM HYDROCARBONS IN SURFACE SEDIMENTS

4.1 INTRODUCTION

The main sources of hydrocarbons in marine sediments are the following [1]:

a) Petroleum inputs into the oceans

b) Polycyclic aromatic hydrocarbons, produced from the partial combustion of fuels can be introduced into the oceans by atmospheric fallout

c) Natural hydrocarbons derive from biosynthesis by marine or terrigenous organisms and from early diagenesis transformations in sediments.

In this work, the study of aliphatic and aromatic hydrocarbons in surface sediments of northern Aegean Sea was performed. In fact, no other references concerning hydrocarbon contents in the sediments of this area are available in the literature.

4.2 EXPERIMENTAL DETAILS

Surface sediment samples (the upper 2 cm) were collected from 15 stations in the northern Aegean during October 1996 using a Smith-McIntyre type grab sampler. The sampling locations are shown in Figure 4.1.

The analysis was performed according the methods suggested by IOC [2]. After oven drying at 40°C, the sediment samples were pulverized, spiked with internal standards (androstane and pyrene-D10) and extracted in a Soxhlet apparatus for 24 h with a mixture of dichloromethane - methanol 2:1. The extract was saponified with a methanolic solution of KOH and the hydrocarbons were extracted with hexane. The clean-up and fractionation step was performed by silica gel and alumina column chromatography and resulted in the collection of two hydrocarbon fractions. The first fraction contained the aliphatic compounds and the second the aromatic ones. The final determination was carried out by gas chromatography - mass spectrometry (Hewlett Packard 6890 GC-MS), on an HP-5 MS (30m X 0.25mm) analytical column.

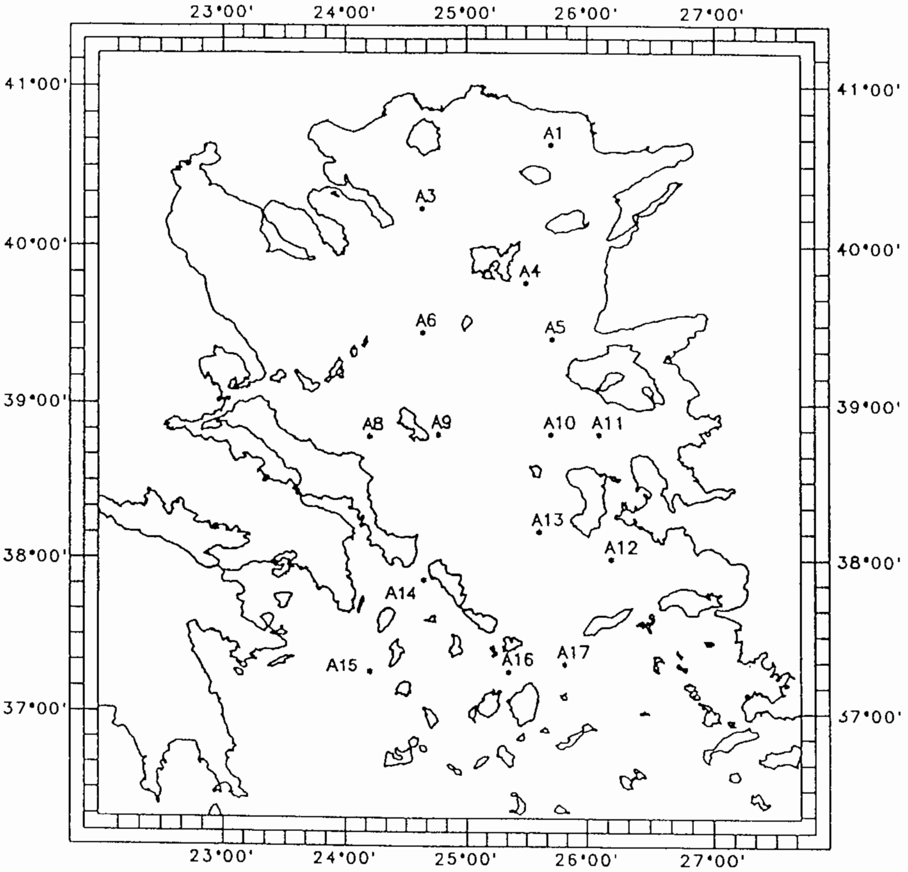

Figure 4.1. The sampling locations of surface sediments from the northern Aegean Sea.

4.3 RESULTS AND DISCUSSION.

The results of the hydrocarbon analysis and some other compositional parameters are given in Table 4.1. The total hydrocarbon concentrations found ranged between 10.7 and 57.5 μg/g dry sediment (average 25.6 μg/g). The highest concentrations were observed at stations A1 and A3, while the lowest values occur at stations A10, A14, A15. These concentrations are generally higher than those reported in unpolluted Mediterranean open sea sediments (<10 μg/g) [3].

Aliphatic hydrocarbons. Total aliphatic hydrocarbon concentrations varied from 10.6 to 57.3 μg/g dry weight and accounted for the 98.4-99.8 % of the total hydrocarbons. Fig. 4.2 shows their distribution in the study area. In all samples the gas chromatographic traces of the aliphatic fraction were characterized by two general features: resolved compounds and a unimodal hump corresponding to a mixture of unresolved compounds (UCM) with 15-34 carbon atoms. The UCM is considered as an elaborate mixture of branched and cyclic hydrocarbons and it is generally well correlated with degraded or weathered petroleum residues [4,5]. In the sediments analyzed the UCM was always the major component representing 72.3-87.4 % of the total aliphatics. The ratio unresolved/resolved compounds (U/R) is widely used to identify the origin of the hydrocarbons in marine sediments.

Table 4.1. *Organic carbon content (C_{org}), concentrations of total hydrocarbons (THC), unresolved complex mixture (UCM), total aliphatic hydrocarbons (ALIPH), total n-alkanes (n-ALK) and polycyclic aromatic hydrocarbons (PAH), the ratio unresolved/resolved compounds (U/R), the carbon preference index (CPI) calculated from C23 to C34 and the ratio pristane/phytane (Pr/Ph) in the sediments of the Aegean Sea.*

Stations	Depth (m)	C_{org} (%)	THC (μg/g)	UCM (μg/g)	ALIPH (μg/g)	n-ALK (μg/g)	PAH (ng/g)	U/R	CPI	Pr/Ph
A1	45	0.40	43.8	37.3	43.7	4.7	147.8	5.8	1.5	0.6
A3	814	0.75	57.5	45.3	57.3	8.6	159.8	3.7	1.9	0.8
A4	93	0.27	13.8	12.0	13.8	1.2	34.1	7.1	1.8	0.7
A5	300	0.75	32.3	26.2	32.2	4.3	155.7	4.4	2.5	0.9
A6	358	0.62	34.9	28.7	34.8	4.3	149.0	4.8	3.1	0.7
A8	365	0.30	33.5	27.1	33.4	4.2	145.2	4.3	1.7	0.8
A9	254	0.44	29.5	23.5	29.4	4.2	111.8	4.0	2.2	0.5
A10	375	0.56	10.7	7.6	10.6	2.3	176.3	2.6	4.5	1.0
A11	284	0.63	14.5	12.5	14.5	1.3	56.8	6.4	2.5	0.3
A12	770	0.78	20.0	15.8	19.9	3.2	118.7	3.7	2.4	0.6
A13	427	0.39	31.6	24.9	31.5	4.2	119.7	3.8	2.0	0.8
A14	168	0.22	12.1	10.5	12.1	1.1	30.9	6.9	1.5	0.5

Stations	Depth (m)	C_{org} (%)	THC (µg/g)	UCM (µg/g)	ALIPH (µg/g)	n-ALK (µg/g)	PAH (ng/g)	U/R	CPI	Pr/Ph
A15	476	0.52	12.4	10.3	12.4	1.3	47.9	5.2	2.2	0.8
A16	106	0.40	13.7	11.4	13.7	1.4	43.0	5.1	1.9	0.9
A17	325	0.39	18.2	15.2	18.1	1.9	52.5	5.3	2.4	0.6

Values U/R > 4 are considered as evidence of petroleum residues [6]. In the sediments of the Aegean Sea the U/R ranged between 2.6 and 7.1 (Table 4.1), indicating in most cases contamination by degraded petroleum. An additional index of contamination, the pristane/phytane ratio varied from 0.3 to 1.0 further demonstrating the presence of fossil fuel residues [7]. According to the above mentioned criteria stations A1, A14 and A11 appear to be the most petroleum contaminated although station A3 exhibits the highest hydrocarbon concentrations.

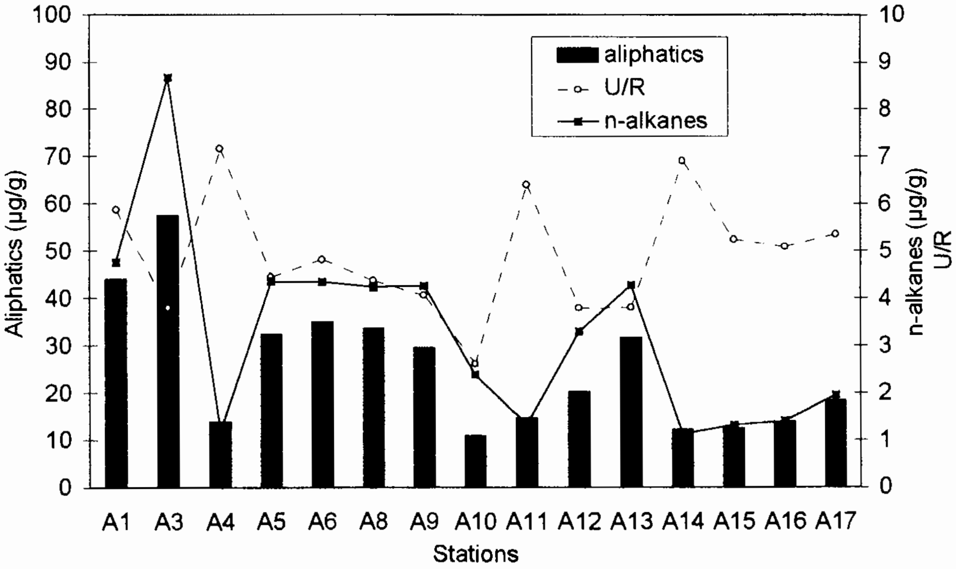

Figure 4.2. Distributions of total aliphatic hydrocarbons, n-alkanes and the U/R ratio in sediments of the Aegean sea.

N-alkane concentrations (C14-C34) ranged from 1.1 to 8.7 µg/g with a distribution similar to that of the total aliphatics (Fig. 4.2). They accounted for the 62-81 % of the total resolved compounds and for 9-16 % of the total aliphatics. The chromatograms of the aliphatic fraction revealed that the n-alkanes were typically characterized by odd-carbon predominance in the n-C23 to the n-C34 range, a feature indicative of terrigenous inputs originating from higher plant waxes. The CPI (Carbon Preference Index) calculated in the range C23-C34 varied between 1.5 and 4.5 (Table 4.1). These values are lower than those typically attributed to high terrigenous inputs (CPI >4-5) and they suggest the presence of fossil fuel inputs (CPI = 1) [7].

Polycyclic aromatic hydrocarbons (PAH). Total PAH concentration (the sum of two to six ring parent PAH, dibenzothiophene and methylated derivatives of naphthalene, phenanthrene and dibenzothiophene) ranged between 30.9 and 176.3 ng/g dry weight which accounted for the 0.2 - 1.6 % of the total hydrocarbons. Their distribution (Fig. 4.3) is generally similar with that of the aliphatics with the exception of the station A10 where the highest PAH concentrations were measured, although this station, according to the aliphatics values, appears as less contaminated. These concentrations are lower than those found in sediments from other Mediterranean regions [3]. The most abundant compounds were always two and three ring aromatics and mainly phenanthrene and its alkylated homologs, indicating rather a fossil fuel origin for the PAHs. Relatively high concentrations were also observed for naphthalenes (the parent compound and methyl-, dimethyl- and trimethyl- derivatives), while sulfur compounds such as dibenzothiophene and methyl dibenzothiophene were detected in all samples.

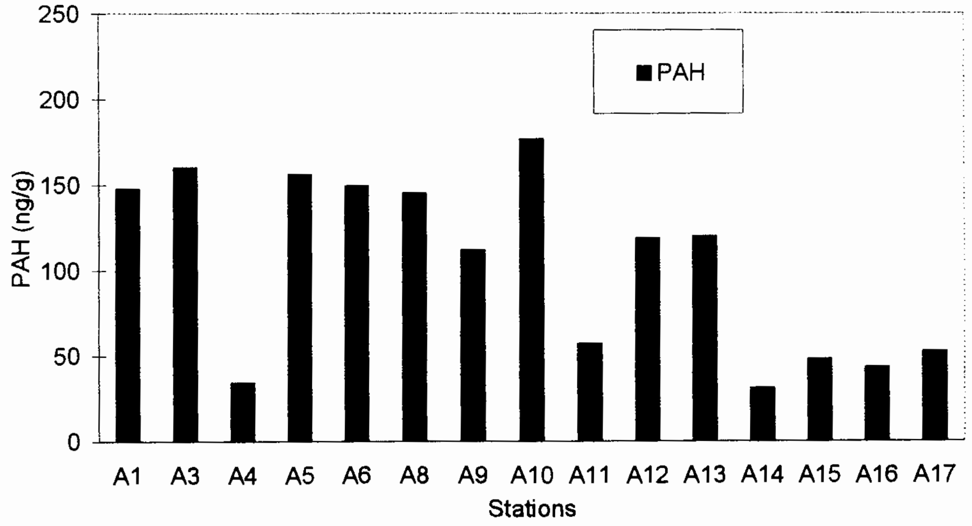

Figure 4.3. PAH distributions in sediments from the Aegean Sea.

4.4 CONCLUSIONS

Total aliphatic hydrocarbon concentrations were higher than those expected for typical unpolluted open sea sediments. The high absolute levels of UCM and the U/R ratio indicate in most cases petroleum inputs in the area.

Total PAH concentrations were low. However the dominance of low MW bi- and tri- cyclic aromatics along with the presence of their methylated derivatives and some characteristic sulfur compounds also support fossil fuel influence in the sediments.

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5. HEAVY METALS IN FISH

5.1.- INTRODUCTION

Metal pollution of the sea is less visible and direct than other types of marine pollution but its effects to human and marine ecosystems is of great extent and intensity. Trace metals are present in living organisms in limited amounts and most of them are "essential" for the correct functioning by biochemical processes. However most heavy metals, whether essential or not, are potentially toxic to living organisms.

Fish are widely used as sentinels of contamination in aquatic environments. Contaminant accumulation in various fish tissues is used as a measure of contaminant exposure and effects. According to the mechanisms of absorption, regulation, storage and excretion of trace metals, different tissues have different roles in these processes.

We are generally fortunated that muscle tissue, which accounts for much of the edible parts of fish, has usually low content of heavy metals compared with other tissues. (Bryan G.W., 1976 & 1987; Evans D.W. et al 1993).

For the purposes of the MED. POL. programme heavy metals were monitored in fish from Greek waters. Fish samples of *Mullus barbatus* (striped mullet) and *Boops boops* (bogue) were collected once a year (spring) from seven different areas along Aegean and Ionian Seas.

5.2.- METHODOLOGY

Fish samples, *Boops boops* (bogue) and *Mullus barbatus* (striped mullet) were collected during the period 19/4 to 17/6/1996 (Table 1.2 - page 4), from the following marine areas of Aegean and Ionian Seas: Alexandroupolis -station 1 in North Aegean, Hios -station 2 and Volos -station 8 in Central Aegean Sea, Rhodos -station 3 in South East Aegean, Hania -station 4 and Kalamata -station 7 in South West Aegean, Parga -station 5 in the Ionian Sea. The sampling areas (Figure 1.2 - page 5) were chosen so that a complete geographic coverage of the Aegean and Ionian Sea could be archieved as far as possible.

After their collection, fish samples were transported to the laboratory in deep freeze condition and their body parameters were measured (length and weight). For every station and species, ten different individuals were studied. From each fish the tissues flesh and gills were taken with P.V.C. utensils in order to prepare 20 individual samples (10 samples of flesh and 10 samples of gills). On the total 320 samples were analysed for the metals Cu, Cr, Ni, Zn, Fe, Mn and Cd.

The analysis of heavy metals was made by digesting approximately 0.5 gr of dried tissue with 5 ml nitric acid into teflon vessels under pressure at 120°C for 12 hours (UNEP, 1984). A VARIAN SPECTR AA 20 Plus Atomic Absorption Spectrophotometer was used for the determination of Cu, Cr, Ni, Zn, Fe and Mn (with flame). For the determination of Cd a PERKIN ELMER device equipped with a graphite furnace was used.

The accuracy and precision of the analytical methodology was tested with the reference material of BCR No 279 (*Ulva lactuca*) (Table 5.1).

Table 5.1

Test of the analytical methodology

Metal	Certified value	Value found
Cu	13.14±0.37	11.07±2.02
Cr	9.7-11.6±0.9	8.37±2.08
Cd	0.274±0.022	0.211±0.035
Ni	15.9±0.4	19.84±0.72
Zn	51.3±1.2	52.71±8.96
Fe	2300±100	2030±41.42
Mn	2030±30	1854.41±26.96

For the statistical analysis and analysis of variance, the software package STATGRAPHICS PLUS was used. Data were log transformed before statistical treatment.

5.3.- RESULTS- DISCUSSION

The results of the metal analysis and the body parameters are analytically presented in the Annex. The concentrations of all metals are expressed in μg of metal per g of dry weight of the tissue (ppm), the length in mm and the weight in gr. The average proportion of moisture per species and tissue presented in Table 5.2, can be used for the expression of the results in wet weight.

Table 5.2

Average proportion of moisture in fish samples

Species	Tissue	% water
B.boops	flesh	78
	gills	70
M.barbatus	flesh	76
	gills	75

The mean body parameters (length and weight) of the fish for each studied species are shown in Table 5.3. There was an effort to keep the size of the individuals quite stable from year to year in order to minimise the influence of this biological factor (size/age) on the bioaccumulation of metals and this way the results can be comparable through time. For this reason detectable differences in metal concentrations are considered not to be related to different body parameters of the fish.

Table 5.3

Mean length and weight of the analysed fish

a) B.boops

stations	length (mm)	weight (gr)
Alexandroupolis	173.1+10.0	90.11+15.46
	(150 - 185)	(57.07 - 108.35)
Hios	148.4±5.93	52.88±6.09
	(139 - 159)	(41.6 - 60.9)
Rhodos	147.2±11.37	53.39±12.30
	(131 - 161)	(37.8 - 73)
Hania	190.9±6.77	108.38±11.59
	(174 - 199)	(85.2 - 123.2)
Parga	149.8±4.49	46.14±4.30
	(140 - 155)	(38.6 - 51.4)
Kalamata	167±6.05	68.77±8.76

stations	length (mm)	weight (gr)
	(155 - 173)	(54.2 - 79.9)
Volos	163.5±13.77	80.0±10.43
	(145 - 185)	(65.4 - 98.7)

b) M.barbatus

Alexandroupolis	124±4.08	35.57±3.94
	(118 - 130)	(30 - 42.56)
Hios	120.9±5.44	37.35±6.59
	(113 - 131)	(30.9 - 51.9)
Rhodos	125.8±10.22	38.23±6.07
	(114 - 152)	(29.9 - 48.8)
Hania	144.5±8.01	59.22±9.62
	(130 - 155)	(43.9 - 71.4)
Parga	139.3±3.34	51.11±4.83
	(132 - 143)	(43.3 - 57.3)
Kalamata	128.8±5.62	39.45±5.98
	(119 - 140)	(31.1 - 48.7)
Volos	127.5±5.74	35.47±3.59
	(120 - 135)	(29.4 - 41.5)

The levels of the metals ranged for Cu between 0.90 and 13.55, for Cr between 0.34 and 22,56, for Ni values varied from 0.44 to 38.14 ppm and for Mn between 0.42 and 124.3. Levels of Fe and Zn are higher and ranged between 5.87 - 1047.9 and 12.85 - 162.99 ppm respectively. In the examined fish the concentrations of Cd are very low (some of them near the detection limit), (Table 5.4). The above ranges are presented graphically in the frequency histograms of Figures 5.1 & 5.2. The distribution of the determined concentrations is not symmetrical but rather follow the log-normal distribution. Generally for Cu, Cr, Ni and Mn the majority of the concentrations in flesh, were between 1 and 2 ppm, while in gills the values were not limited to a so strictly defined range.

Generally, the mean concentrations in flesh of both species, were for all metals (except for Cr) not significantly high enough to endanger public health. These levels are comparable to those reported in the literature for other areas in Greece and Mediterranean region (Grimanis et al 1980; Catsiki, et al 1996; Strogyloudi et al 1997, and 1997b, Panayotidis & Florou 1994, UNEP, 1996).

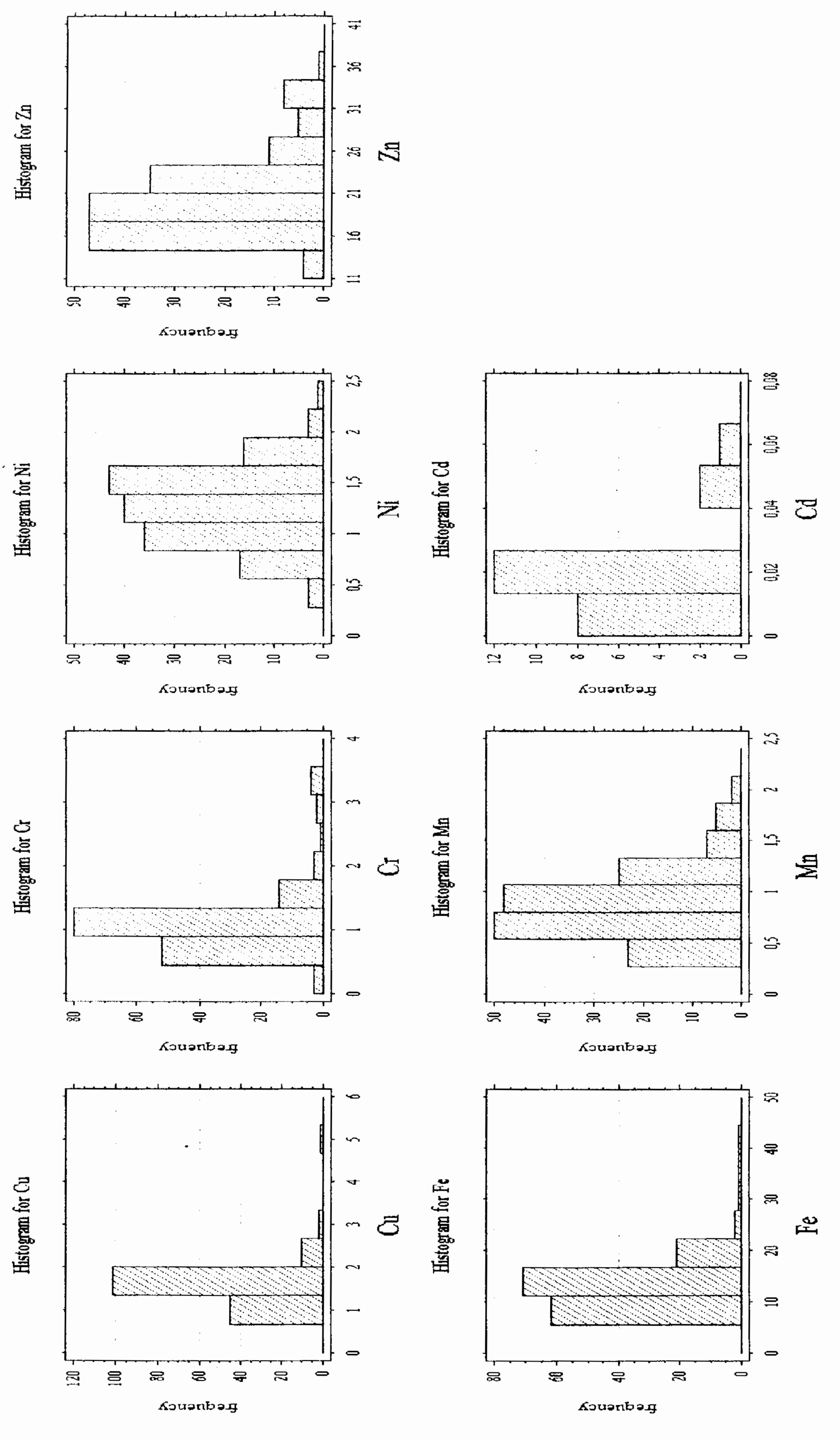


***Figure 5.1**: Frequency histograms of metal concentrations in flesh of B.boops and M.barbatus during 1996.*

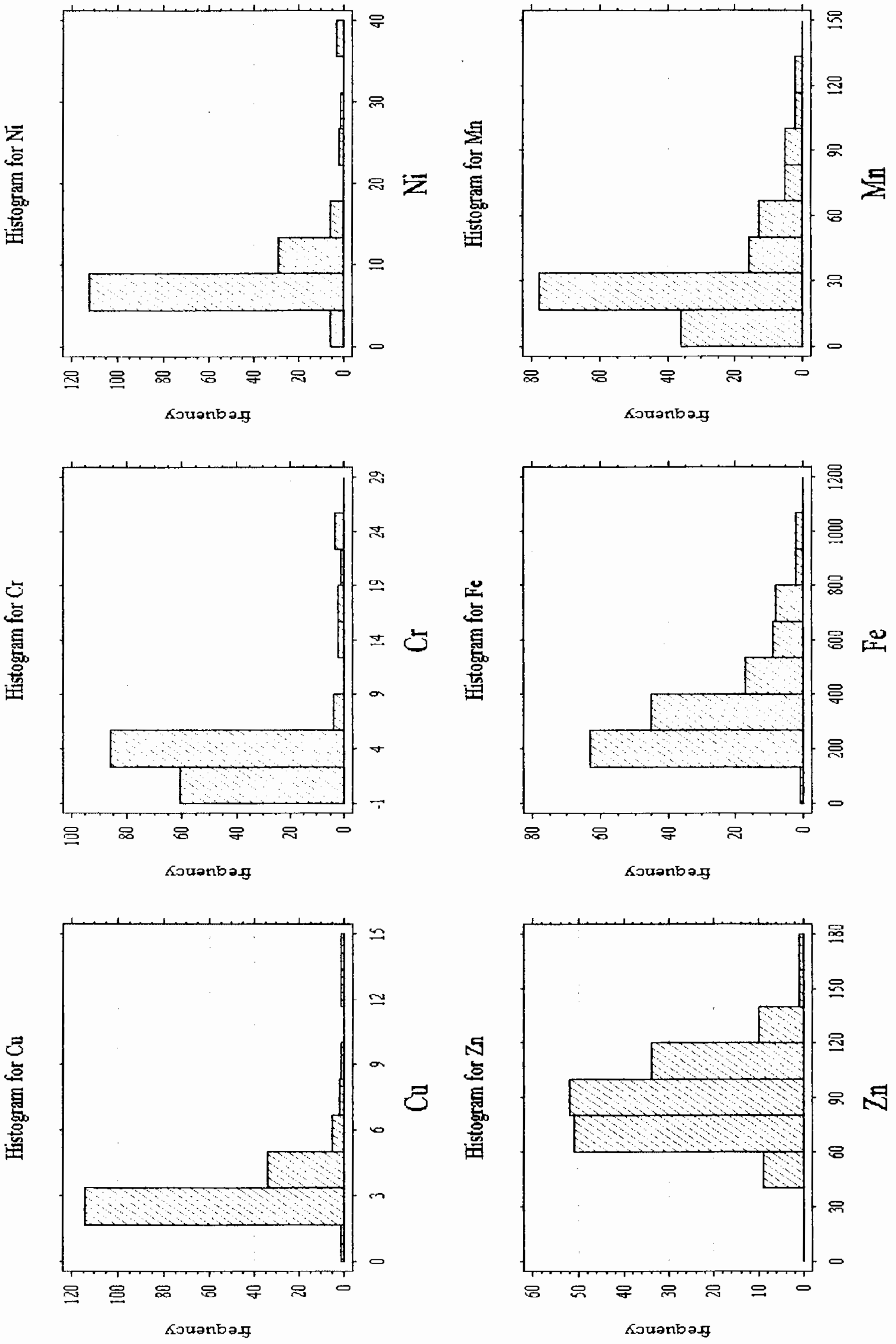


***Figure 5.2:** Frequency histograms of metal concentrations in gills of B.boops and M.barbatus during 1996*

Table 5.4

Metal concentrations in fish from Aegean and Ionian Seas, during 1996 (μg/g dry weight)

a) B.boops

tissue		Cu	Cr	Ni	Zn	Fe	Mn	Cd
flesh	N	80	79	80	79	79	80	32
	avg	1,52	1,11	1,27	21,84	11,22	0,77	0.020
	std	0,29	0,57	0,37	4,94	3,14	0,26	0.013
	min	0,94	0,46	0,44	14,59	6,28	0,42	0.010
	max	2,67	3,47	2,06	35,69	20,69	1,89	0.063
gills	N	79	78	79	79	78	78	
	avg	2,70	2,94	7,37	103,53	331,59	26,79	
	std	0,87	1,33	1,90	16,55	159,04	11,03	
	min	1,52	0,49	4,17	69,21	134,00	14,44	
	max	8,22	6,71	13,20	162,99	998,65	68,86	

b) M.barbatus

tissue		Cu	Cr	Ni	Zn	Fe	Mn	Cd
flesh	N	79	80	79	79	80	80	32
	avg	1,61	1,05	1,24	19,03	14,78	1,01	0.017
	std	0,55	0,47	0,38	3,88	5,77	0,32	0.006
	min	0,90	0,34	0,58	12,85	5,87	0,45	0.009
	max	5,14	3,19	2,38	31,33	39,20	1,96	0.034
gills	N	80	80	80	79	68	79	
	avg	3,70	3,85	9,47	75,54	351.07	36,02	
	std	1,95	4,87	6,98	14,59	207.73	29,79	
	min	1,92	0,43	3,74	52,76	125.75	7,91	
	max	13,55	22,56	38,14	142,97	1047.9	124,30	

Results showed that the two analysed tissues accumulate metals to a different degree: in all cases the ratio of the metal concentrations in gills and flesh is greater than 1 (concentrations of metals in gills/ concentrations of metals in flesh>1). It is known that the gills of the fish are a primary target for direct metal absorption from the external environment and thus they serve as a major route for metal uptake. Metal uptake by gills does not involve direct and rapid transfer from the water to the blood, but rather an intermediate step for metal transportation to the other tissues (Romeo et al 1994, Bryan 1987). Generally it seems that metal concentrations in gills are proportionally related to the amount of the metals imported through respiratory process and accumulated in flesh. This makes gills and flesh to follow common patterns.

Average, minimum, maximum values and standard deviation for each species of fish and different tissue for all metals given in Table 5.4 and Figures 5.3 & 5.4 show that the average concentrations of Zn and Cd are higher in flesh of pelagic fish than in demersal, while the opposite occurs for Fe. As concern Cu, Cr, Ni and Mn it seems that there are no differences in the bioaccumulation rate of the flesh, between the two categories of fish. In gills,

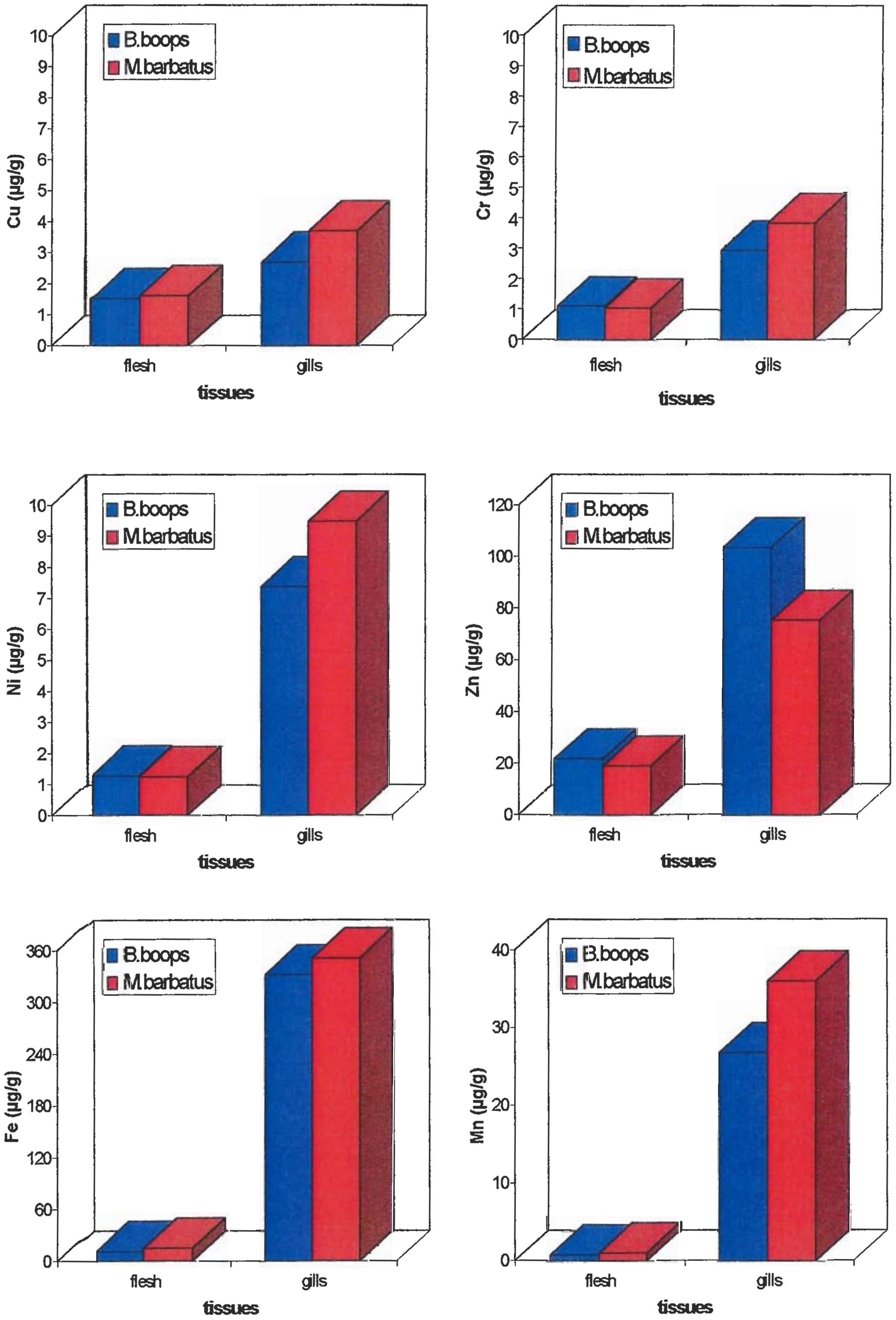


Figure 5. 3 : Average concentration of metals (µg/g dw) in flesh and gills of B.boops andM.barbatus from Aegean and Ionian Seas during 1996

Zn appear to be higher in pelagic than in demersal fishes but for the rest of the metals mean concentrations are higher in *M. barbatus* than in *B. boops.*

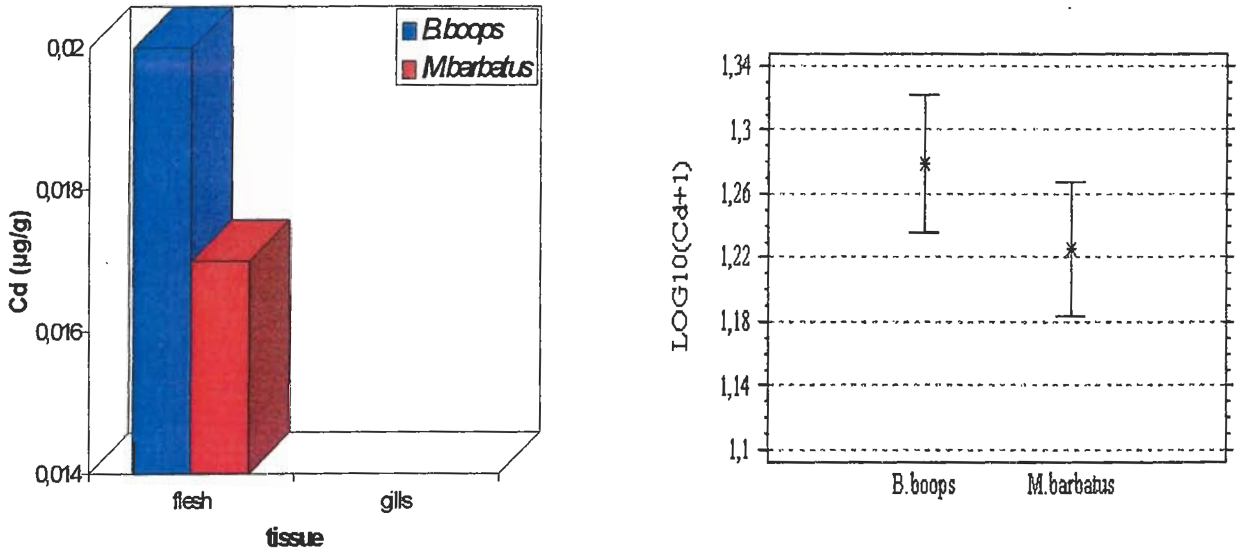


***Figure 5.4** : Average values of Cd in flesh and gills of B. boops and M. barbatus*

In order to find out if differences between species are statistically significant we performed analysis of variance. The results of the statistical analysis are presented in Table 5.5 and Figures 5.4 and 5.5. Different habitats and feeding habits of the examined fish species seem to affect the accumulation for most of the studied metals (Cu, Zn, Fe, Mn). This is especially marked in gills for Cu and Zn (Fig. 5.5).

Table 5.5

Results of the two factor statistical analysis of variance

factor		F	P		F	P
species	**Cu**	25.55	<0.05*	**Fe**	7.48	<0.05*
tissue		395.97	<0.05*		5037.93	<0.05*
species - tissue		14.93	<0.05**		7.92	<0.05**
species	**Cr**	0,05	0,83	**Mn**	4.30	<0.05*
tissue		220,71	<0.05*		3240.63	<0.05*
species - tissue		0,09	0,77		0.37	0.55
species	**Ni**	2.68	0.10	**Cd**	1.56	0.21
tissue		1829.61	<0.05*			
species - tissue		4.16	<0.05**			
species	**Zn**	114.66	<0.05*			
tissue		4871.13	<0.05*			
species - tissue		19.45	<0.05**			

*statistical significant difference

**statistical significant interaction

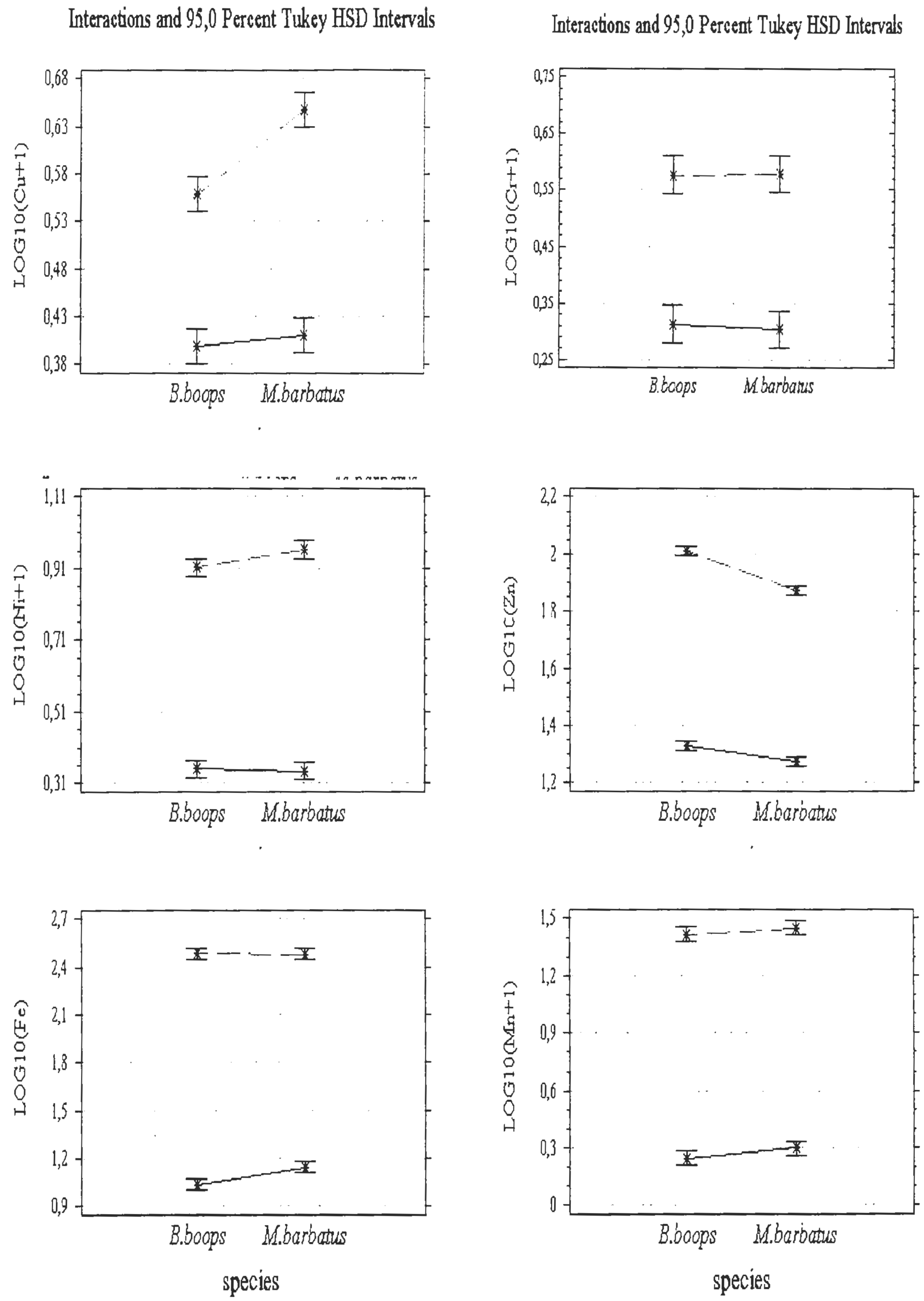


Figure 5.5: *Average metal concentrations in flesh and gills of B.boops and M.barbatus from Aegean and Ionian Seas during 1996. (solid line: flesh, dotted: gills).*

Table 5.6

Metal concentrations in fish from Alexandroupolis during 1996

a) B.boops

tissue		Cu	Cr	Ni	Zn	Fe	Mn	Cd
flesh	N	10	10	10	9	10	10	4
	avg	1.50	1.06	1.21	21.49	9.07	0.90	0.014
	std	.0.30	0.23	0.36	4.72	2.63	0.14	0.003
	min	1.22	0.81	0.65	15.03	6.28	0.65	0.011
	max	2.26	1.43	1.68	29.24	15.98	1.10	0.018
gills	N	10	10	10	10	10	10	
	avg	2.38	2.82	6.55	109.94	245.20	24.58	
	std	0.35	0.52	1.14	9.77	57.31	4.68	
	min	1.77	2.00	5.15	88.81	165.99	18.42	
	max	2.78	3.32	8.80	125.50	339.61	33.82	

b) M.barbatus

tissue		Cu	Cr	Ni	Zn	Fe	Mn	Cd
flesh	N	10	10	10	10	10	10	4
	avg	1.80	1.28	1.23	18.09	14.42	1.41	0.017
	std	0.23	0.74	0.37	2.64	3.09	0.26	0.005
	min	1.42	0.59	0.73	15.37	11.02	1.16	0.010
	max	2.21	2.70	1.99	23.84	19.66	1.96	0.020
gills	N	10	10	10	10	10	10	
	avg	3.47	1.80	7.32	67.91	246.09	35.15	
	std	3.19	0.72	1.67	7.71	102.60	16.46	
	min	2.05	0.72	5.70	58.26	144.53	19.31	
	max	12.50	2.69	10.90	86.81	431.89	72.23	

Table 5.7

Metal concentrations in fish from Hios during 1996

B.boops

tissue		Cu	Cr	Ni	Zn	Fe	Mn	Cd
flesh	N	10	10	10	10	10	10	4
	avg	1.71	1.61	1.56	23.68	12.53	0.80	0.014
	std	0.42	1.06	0.32	4.91	3.66	0.20	0.002
	min	1.20	0.46	0.89	15.02	6.90	0.67	0.012
	max	2.67	3.47	1.97	33.47	17.94	1.29	0.018
gills	N	10	10	10	10	10	10	
	avg	2.75	3.66	9.07	98.83	611.37	43.20	
	std	0.42	1.36	1.65	13.85	225.41	12.80	
	min	1.93	1.80	6.83	71.98	368.24	23.85	
	max	3.23	5.74	11.53	121.13	998.65	60.62	

M.barbatus

tissue		Cu	Cr	Ni	Zn	Fe	Mn	Cd
flesh	N	10	10	9	10	10	10	4
	avg	1.57	1.03	1.09	18.46	14.13	0.82	0.024
	std	0.18	0.43	0.38	2.14	3.50	0.18	0.010
	min	1.23	0.43	0.61	15.75	8.91	0.49	0.014
	max	1.81	1.79	1.89	21.35	20.15	1.04	0.034
gills	N	10	10	10	10	10	10	
	avg	3.15	1.33	6.66	70.65	273.79	19.52	
	std	0.45	1.00	1.20	9.26	118.86	12.26	
	min	1.92	0.43	4.76	54.84	188.87	8.84	
	max	3.63	4.02	8.59	81.88	594.94	50.94	

Table 4.8

Metal concentrations in fish from Rhodos during 1996

B.boops

tissue		Cu	Cr	Ni	Zn	Fe	Mn	Cd
flesh	N	10	10	10	10	10	10	4
	avg	1.71	0.96	1.16	19.60	11.49	0.75	0.014
	std	0.24	0.18	0.28	4.12	2.24	0.24	0.002
	min	1.30	0.52	0.85	14.59	8.97	0.43	0.011
	max	2.08	1.21	1.70	29.25	14.98	1.28	0.018
gills	N	10	10	10	10	10	10	
	avg	2.89	3.15	7.46	92.36	302.71	22.23	
	std	1.90	0.96	1.30	18.16	74.47	5.53	
	min	1.97	1.93	5.30	76.66	201.97	15.33	
	max	8.22	5.49	9.53	136.13	422.11	32.98	

M.barbatus

tissue		Cu	Cr	Ni	Zn	Fe	Mn	Cd
flesh	N	10	10	10	9	10	10	4
	avg	1.81	1.12	1.35	16.21	13.81	1.10	0.019
	std	0.34	0.75	0.27	2.43	3.70	0.25	0.006
	min	1.29	0.62	0.90	12.94	7.96	0.77	0.013
	max	2.33	3.19	1.66	20.01	18.27	1.46	0.025
gills	N	10	10	10	10	10	10	
	avg	3.02	2.90	12.05	85.35	464.95	59.38	
	std	0.51	1.37	2.93	21.26	153.50	22.66	
	min	2.26	0.84	7.56	70.98	275.30	27.83	
	max	3.86	4.85	15.28	142.97	755.91	93.15	

Table 5.9

Metal concentrations in fish from Hania during 1996

B.boops

tissue		Cu	Cr	Ni	Zn	Fe	Mn	Cd
flesh	N	10	9	10	10	10	10	4
	avg	1.37	0.88	1.18	20.05	11.12	0.56	0.025
	std	0.28	0.24	0.38	4.59	1.72	0.17	0.016
	min	0.94	0.51	0.47	15.44	9.10	0.42	0.014
	max	1.89	1.24	1.72	30.80	14.07	0.99	0.050
gills	N	10	10	10	10	10	10	
	avg	1.95	3.36	6.17	105.12	204.17	22.51	
	std	0.29	0.51	1.03	13.63	63.79	5.40	
	min	1.52	2.18	4.76	83.47	133.99	14.54	
	max	2.41	3.86	8.74	124.97	334.61	31.11	

M.barbatus

tissue		Cu	Cr	Ni	Zn	Fe	Mn	Cd
flesh	N	10	10	10	10	10	10	4
	avg	1.66	0.99	1.43	23.87	14.93	0.91	0.014
	std	0.63	0.16	0.50	4.62	3.75	0.21	0.001
	min	1.10	0.67	0.63	17.11	9.68	0.64	0.013
	max	3.21	1.20	2.38	31.33	22.61	1.32	0.016
gills	N	10	10	10	10	9	10	
	avg	3.75	2.74	6.33	79.15	418.56	17.83	
	std	0.81	0.56	1.67	7.09	145.46	5.88	
	min	2.68	1.81	4.59	68.24	262.72	12.54	
	max	5.06	3.46	9.11	88.63	717.15	29.36	

Table 5.10

Metal concentrations in fish from Parga during 1996

B. boops

tissue		Cu	Cr	Ni	Zn	Fe	Mn	Cd
flesh	N	10	10	10	10	10	10	4
	avg	1.43	1.22	1.56	25.24	13.94	0.97	0.035
	std	0.25	0.78	0.35	6.72	4.06	0.31	0.013
	min	0.94	0.68	0.91	16.70	8.21	0.65	0.020
	max	1.77	3.34	2.06	35.70	20.69	1.64	0.046
gills	N	10	10	10	10	10	10	
	avg	3.34	2.54	9.95	106.90	331.79	26.61	
	std	0.71	1.05	1.61	16.07	53.45	5.86	
	min	2.37	0.57	7.90	69.21	270.94	20.43	
	max	4.56	3.91	13.20	124.59	442.07	37.03	

M. barbatus

tissue		Cu	Cr	Ni	Zn	Fe	Mn	Cd
flesh	N	10	10	10	10	10	10	4
	avg	1.51	1.05	1.08	17.60	14.97	1.06	0.018
	std	0.44	0.30	0.35	1.45	3.98	0.14	0.007
	min	1.13	0.63	0.58	15.34	9.72	0.78	0.013
	max	2.64	1.49	1.56	19.81	20.86	1.23	0.027
gills	N	10	10	10	10	10	10	
	avg	3.75	3.00	6.02	60.13	322.12	21.69	
	std	2.14	1.31	1.08	7.93	246.49	13.36	
	min	2.40	1.80	4.43	52.76	163.99	10.91	
	max	9.61	6.21	8.37	76.83	880.05	56.40	

Table 5.11

Metal concentrations in fish from Kalamata during 1996

B. boops

tissue		Cu	Cr	Ni	Zn	Fe	Mn	Cd
flesh	N	10	10	10	10	9	10	4
	avg	1.52	1.00	1.29	22.97	13.51	0.84	0.021
	std	0.22	0.15	0.29	4.19	2.04	0.38	0.010
	min	1.22	0.78	0.88	16.02	10.09	0.61	0.013
	max	1.90	1.22	1.66	31.12	17.44	1.89	0.034
gills	N	10	10	10	10	9	9	
	avg	3.21	3.92	7.37	112.66	449.35	35.50	
	std	0.53	1.18	1.53	14.84	83.84	14.80	
	min	2.60	2.76	5.51	92.99	323.27	19.38	
	max	4.17	6.71	10.53	135.29	560.68	68.86	

M. barbatus

tissue		Cu	Cr	Ni	Zn	Fe	Mn	Cd
flesh	N	10	10	10	10	10	10	4
	avg	1.43	0.94	1.37	22.07	14.46	0.96	0.018
	std	0.23	0.34	0.35	3.53	4.07	0.15	0.007
	min	1.16	0.34	0.84	16.79	9.58	0.69	0.011
	max	1.78	1.52	1.89	28.42	21.76	1.17	0.027
gills	N	10	10	10	10	9	9	
	avg	3.96	2.99	8.15	78.54	587.96	41.62	
	std	0.81	1.04	1.95	7.31	266.17	22.43	
	min	2.93	1.24	5.00	70.21	215.22	15.29	
	max	5.74	4.38	11.46	88.23	1047.9	72.48	

Table 5.12

Metal concentrations in fish from Volos during 1996

B.boops

tissue		Cu	Cr	Ni	Zn	Fe	Mn	Cd
flesh	N	10	10	10	10	10	10	4
	avg	1.32	1.22	1.08	18.84	8.18	0.74	0.014
	std	0.13	0.62	0.34	1.63	1.28	0.20	0.005
	min	1.17	0.70	0.49	16.17	6.69	0.49	0.010
	max	1.56	2.90	1.60	21.60	10.92	1.26	0.021
gills	N	10	10	10	10	10	10	
	avg	2.51	1.78	6.14	108.07	281.35	19.20	
	std	0.41	0.68	1.45	22.71	35.51	3.27	
	min	2.02	0.49	4.17	83.24	229.81	14.89	
	max	3.13	2.75	8.83	162.99	335.73	24.46	

M.barbatus

tissue		Cu	Cr	Ni	Zn	Fe	Mn	Cd
flesh	N	9	10	10	10	10	10	4
	avg	1.86	1.22	1.29	19.68	22.30	1.27	0.013
	std	1.24	0.32	0.40	3.28	10.28	0.33	0.002
	min	1.19	0.81	0.63	15.42	11.30	0.86	0.010
	max	5.14	1.90	1.94	25.11	39.20	1.83	0.014
gills	N	10	10	10	9		10	
	avg	5.77	13.97	23.79	87.73		83.16	
	std	3.04	8.26	10.59	15.97		36.83	
	min	2.46	1.68	11.11	67.57		21.63	
	max	13.55-	22.56	38.14	117.39		124.30	

Summarised data of metal bioaccumulation in fish collected during 1996, comprising number of samples, average, minimum, maximum and standard deviation are given per sampling area in Tables 5.6 to 5.12. Figures 5.6 to 5.8 present the average concentrations of metals at the different stations. Generally there is no specific pattern of distribution of metals at stations.

In order to find out if differences between stations are statistically significant we performed analysis of variance. The results of this analysis are presented in Table 5.13 and in Figures 5.9 to 5.11.

The distribution of metals in gills of *M.barbatus* do not show any common pattern with those of *B.boops* (Figures 5.10 and 5.11), fact probably due to the different ecology of demersal and pelagic fish. There were important differences in spatial distribution of metal concentrations in fish during 1996.

The higher metallic values in gills of demersal fish. were met at samples from Volos (Station 8). Similarly high values occurred at stations 3 (Rhodos) and 7 (Kalamata) and in some cases at station 4 (Hania).

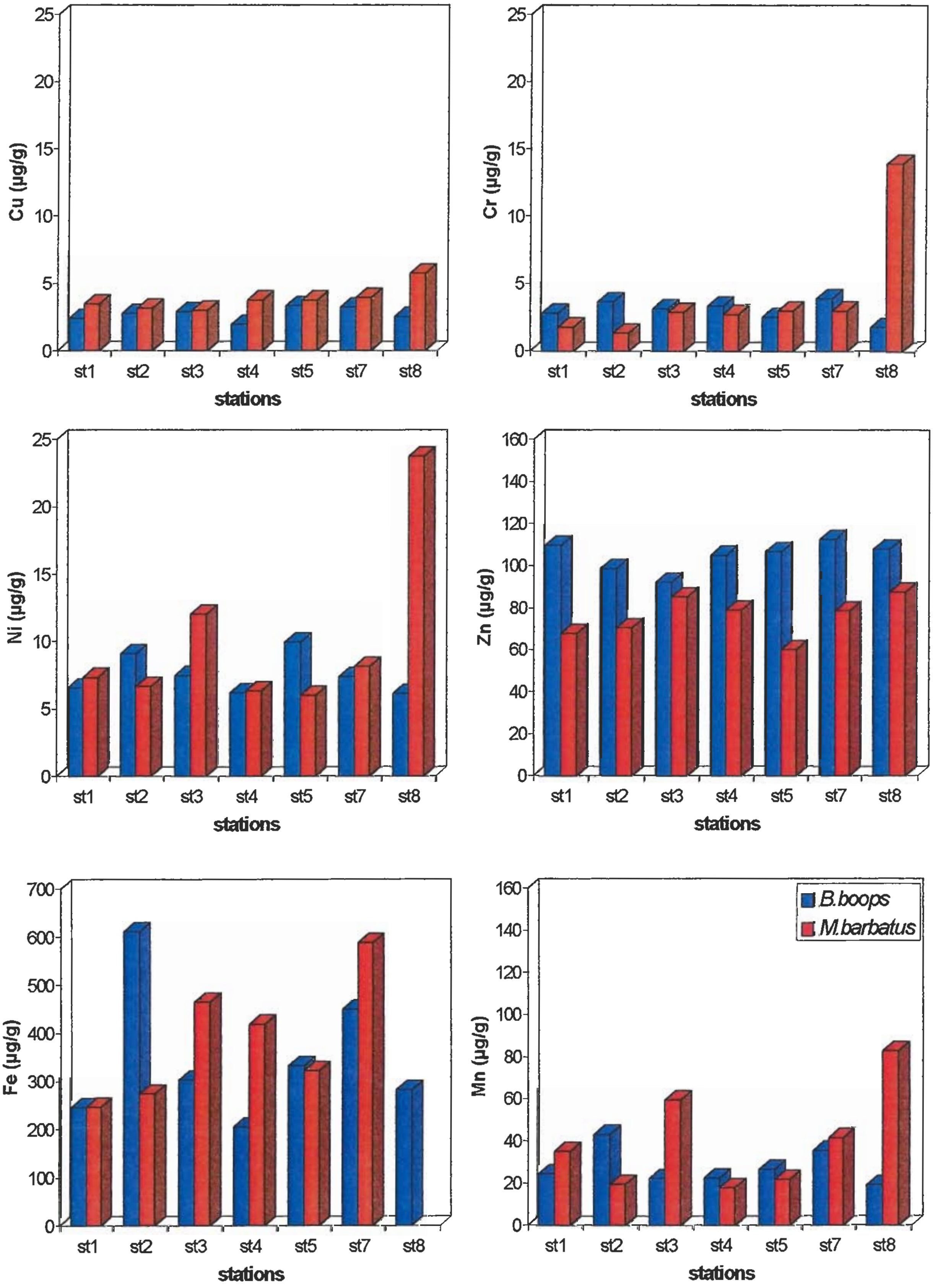


Figure 5.7: *Average values of metals in gills of B.boops and M.barbatus per sampling area (st1:Alexandroupolis, st2: Hios, st3: Rhodos, st4: Hania, st5: Parga, st7: Kalamata, st8: Volos)*

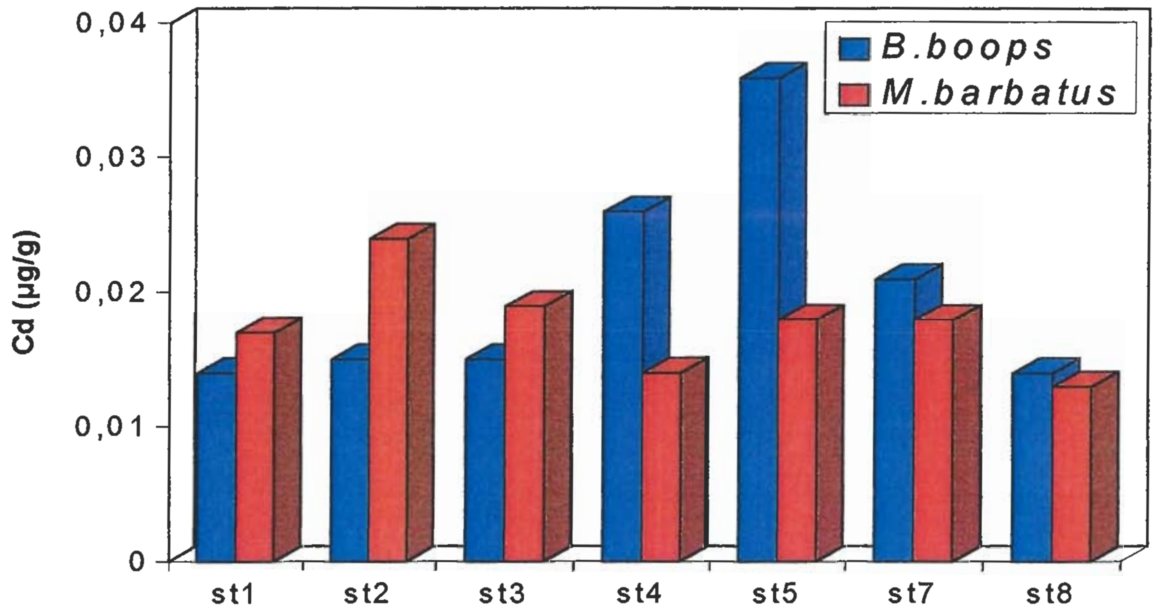


Figure 5.8 *: Average values of metals in flesh of B.boops and M.barbatus per station (st1:Alexandroupolis, st2: Hios, st3: Rhodos, st4: Hania, st5: Parga, st7: Kalamata, st8: Volos).*

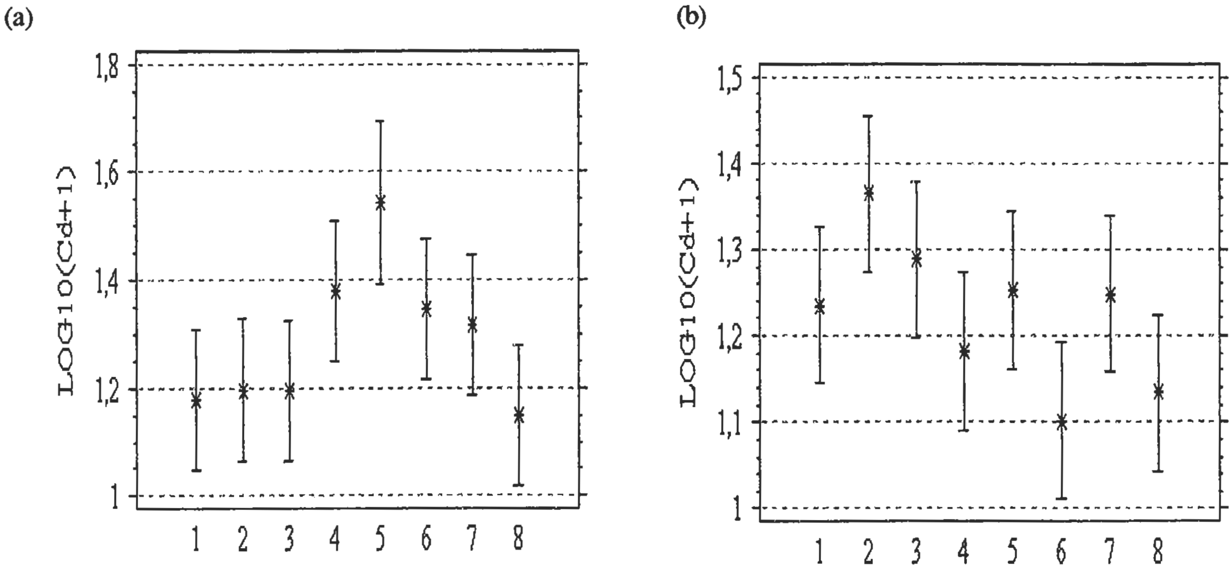


Figure 5.9*: Mean metal concentrations in flesh of B.boops (a) and M.barbatus (b) and confidence limits per station (st1:Alexandroupolis, st2: Hios, st3: Rhodos, st4: Hania, st5: Parga, st6: Aigina, st7: Kalamata, st8: Volos).*

Metals in gills of pelagic fish presented quite common spatial distribution patterns : the higher metal levels were observed in Hios (station 2), Parga (station 5) and Kalamata (station 7). However for Cr station 5 (Parga) presented also low values.

Table 5.13

Results of the two factor statistical analysis of variance (tissues and stations)

factors			F	P		F	P
station	**Cu**	***Boops boops***	5.67	<0.05*	***Mullus barbatus***	3.80	<0.05*
tissue			291.44	<0.05*		242.62	<0.05*
station-tissue			3.79	<0.05**		2.91	<0.05**
station	**Cr**		4,54	<0.05*		14.29	<0.05*
tissue			269,03	<0.05*		159.12	<0.05*
station-tissue			4,48	<0.05**		11.23	<0.05**
station	**Ni**		11.93	<0.05*		22.56	<0.05*
tissue			2622.13	<0.05*		1784.55	<0.05*
station-tissue			1.63	0.13		17.62	<0.05**
station	**Zn**		2.66	<0.05*		9.51	<0.05*
tissue			3054.88	<0.05*		3456.41	<0.05*
station-tissue			2.08	0.05		5.84	<0.05**
station	**Fe**		22.32	<0.05*		11.94	<0.05*
tissue			8528.31	<0.05*		3056.28	<0.05*
station-tissue			8.86	<0.05**		4.79	<0.05**
station	**Mn**		11.73	<0.05*		26.85	<0.05*
tissue			7597.46	<0.05*		2714.71	<0.05*
station-tissue			7.13	<0.05**		14.52	<0.05**
station	**Cd**		1.97	0.10		1.86	0.12

*statistical significant difference

** statistical significant interaction

Although we could not obtain a clear image of spatial metal distribution based on the metal bioaccumulation by the samples of flesh, we must mention that generally there was low variability between stations for most of the metals. This phenomenon was probably due to the low and stable metabolic rate of the flesh. Nevertheless it must be noticed that stations 5 (Parga), 7 (Kalamata) and partially 2 (Hios), for most of the metals tend to have higher concentrations in both examined fish.

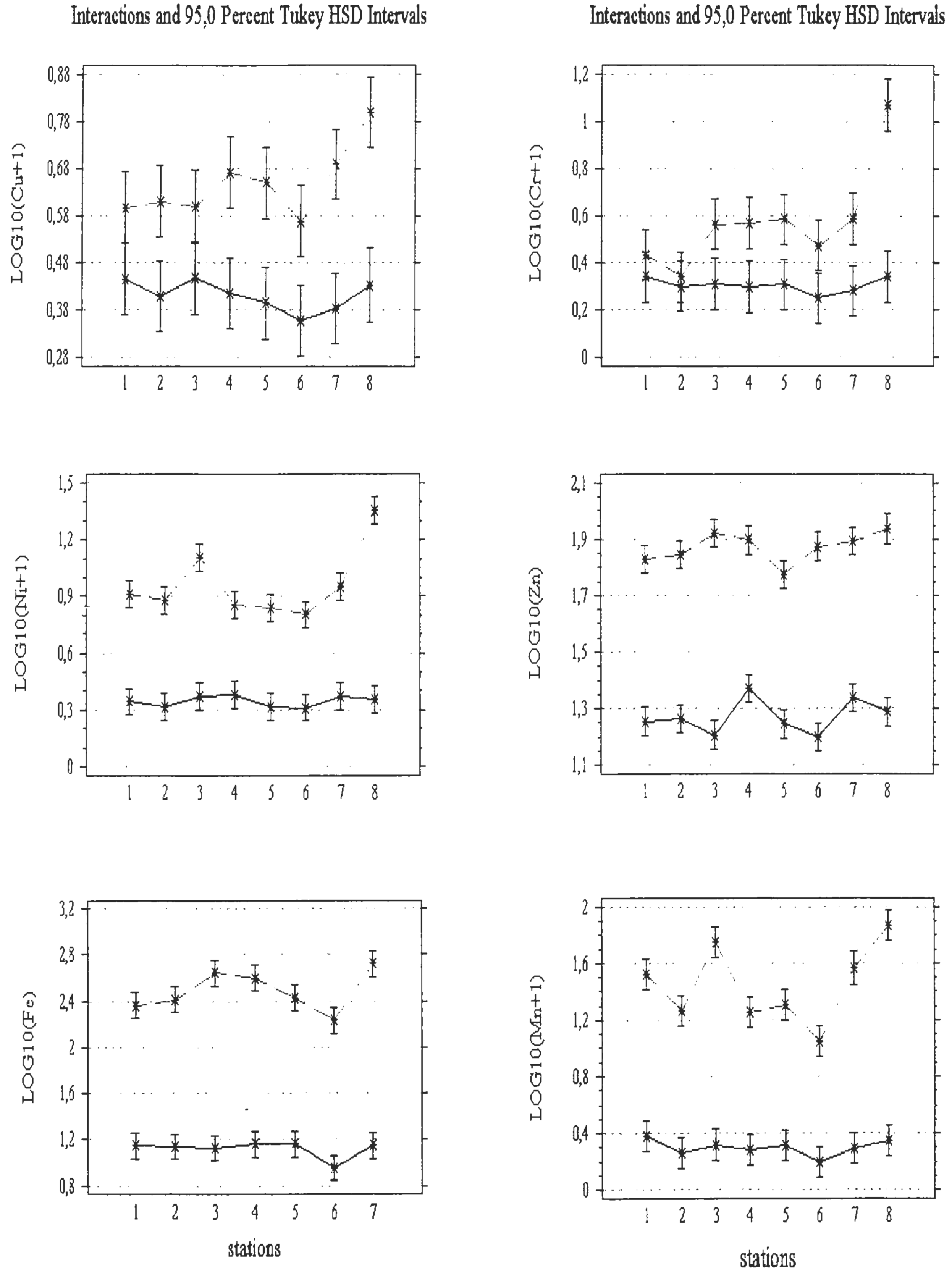
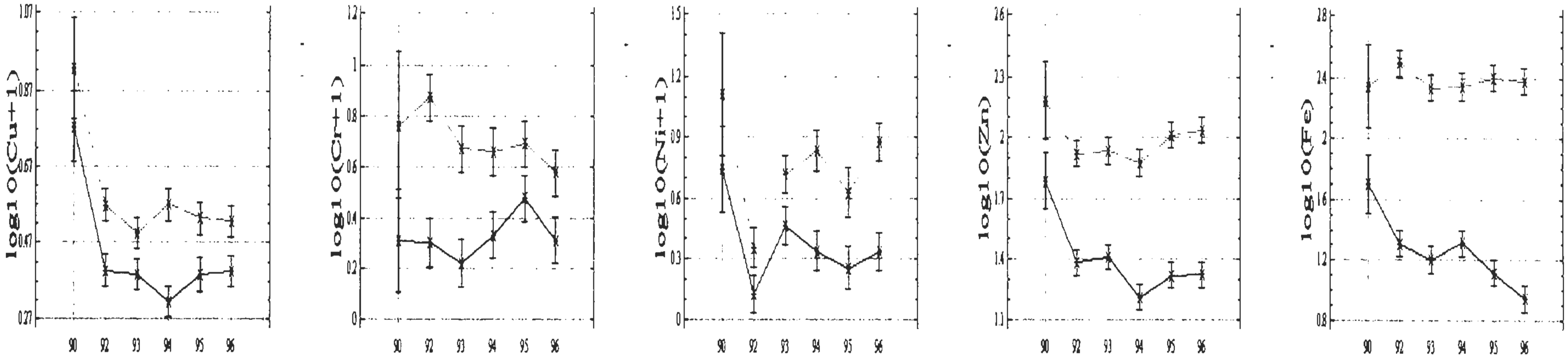


Figure 5.11: *Average values of metal concentrations in demesral fish, M.barbatus, for every station (st1: Alexandroupolis, st2: Hios, st3: Rhodos, st4: Hania, st5: Parga, st6: Aigina, st7: Kalamata, st8: Volos)*

a) pelagic fish



b) demersal fish

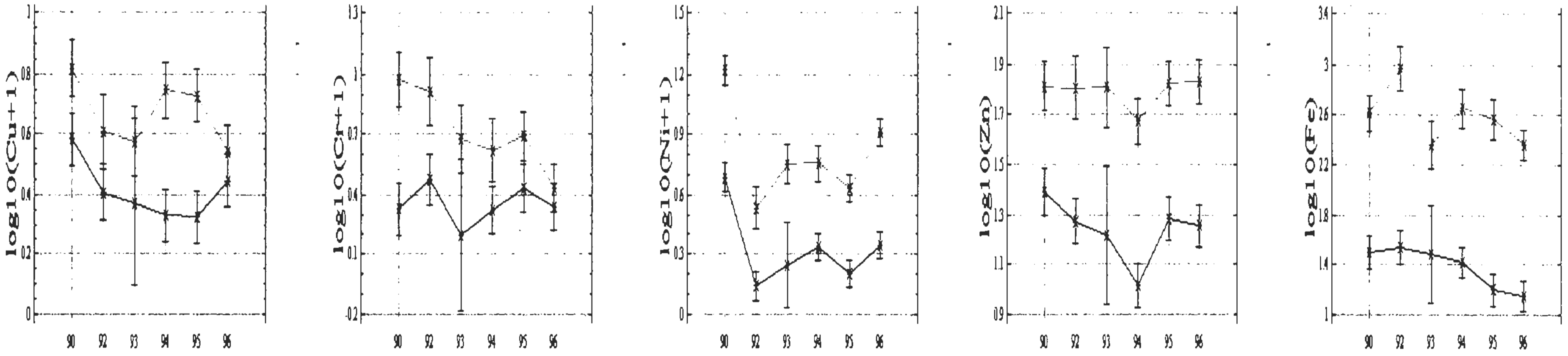
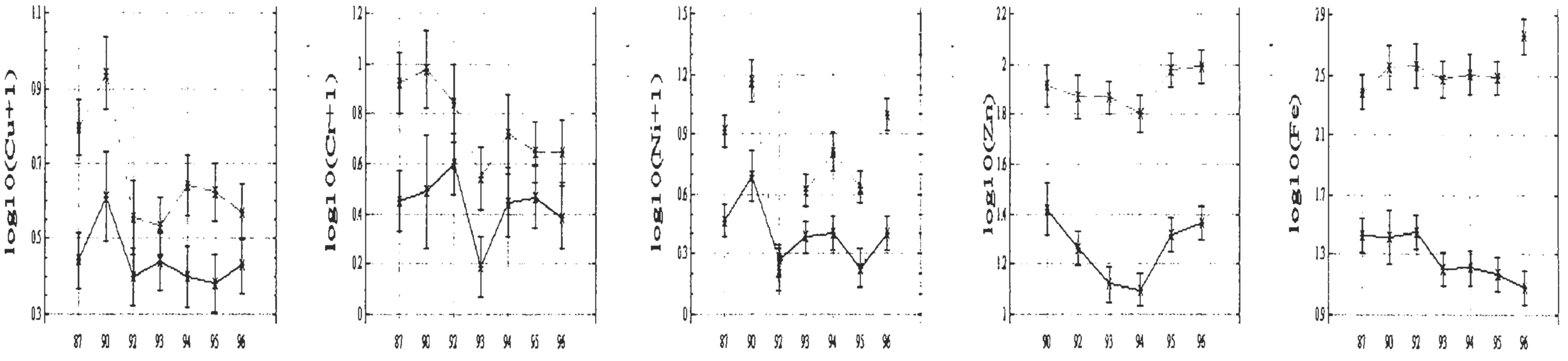


Figure 5.12 *: Evolution of metal concentrations in fish from Alexandroupolis (station 1) during 1990-96.*
(solid line: flesh, dotted line: gills)

a) pelagic fish



b) demersal fish

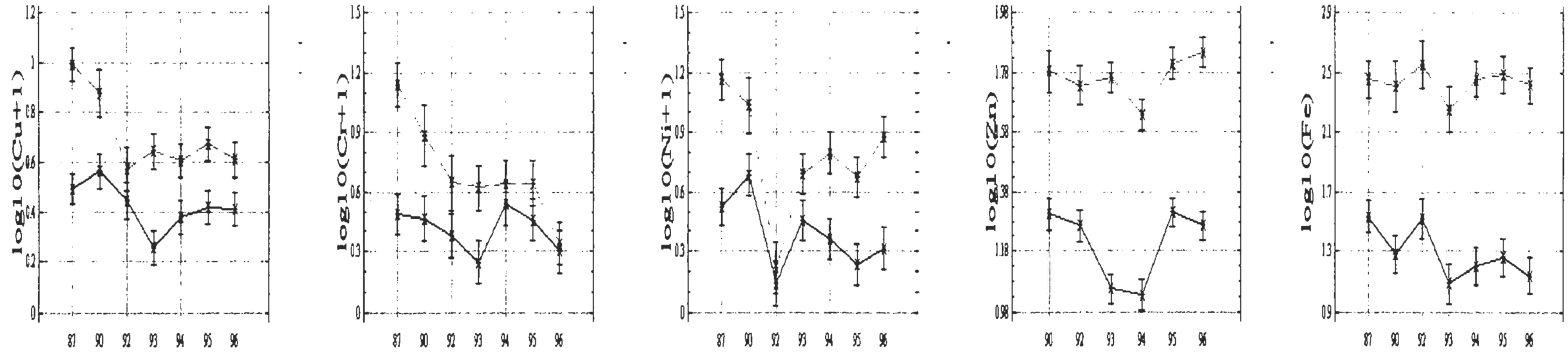
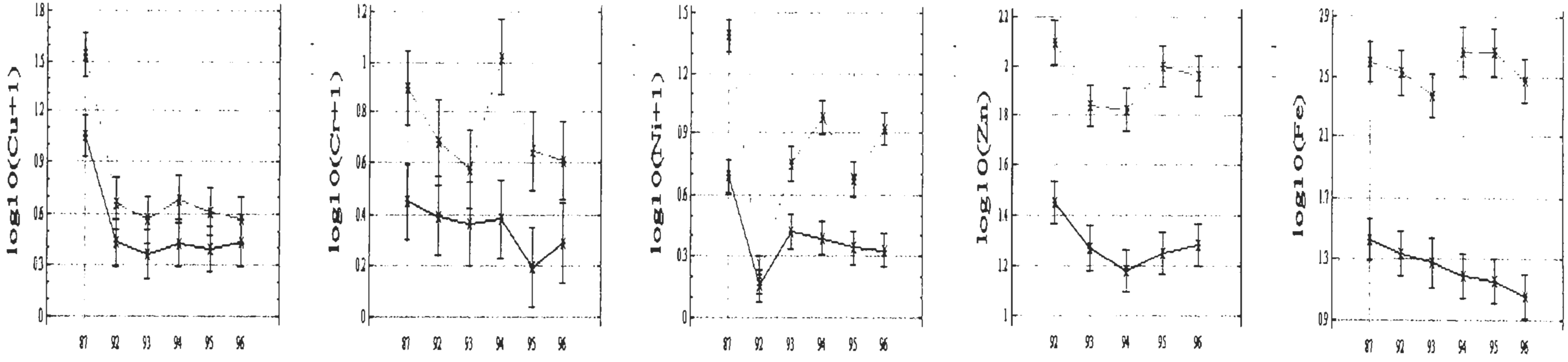


Figure 5.13 : *Evolution of metal concentrations in fish from Hios (station 2) during 1990-96.*
(solid line: flesh, dotted line: gills)

a) pelagic fish



b) demersal fish

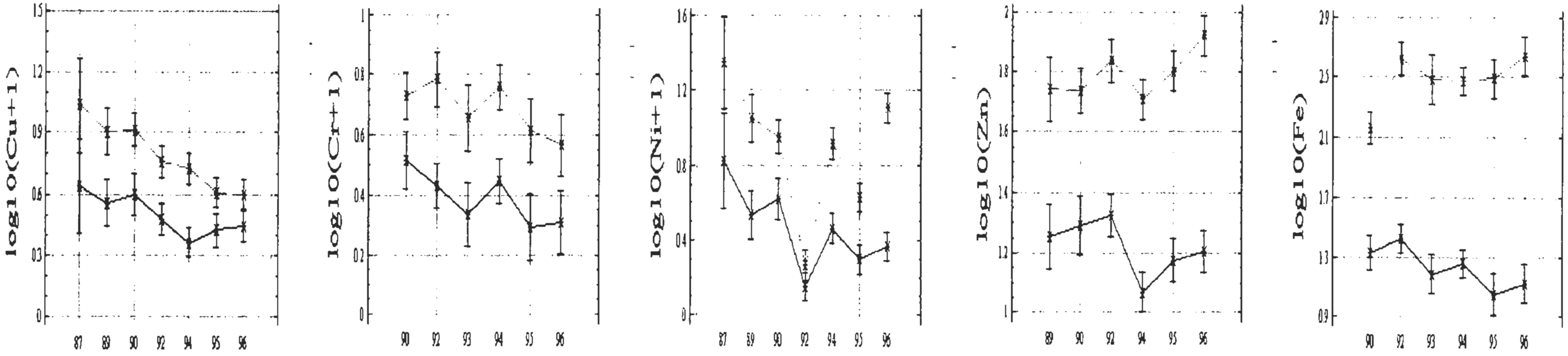
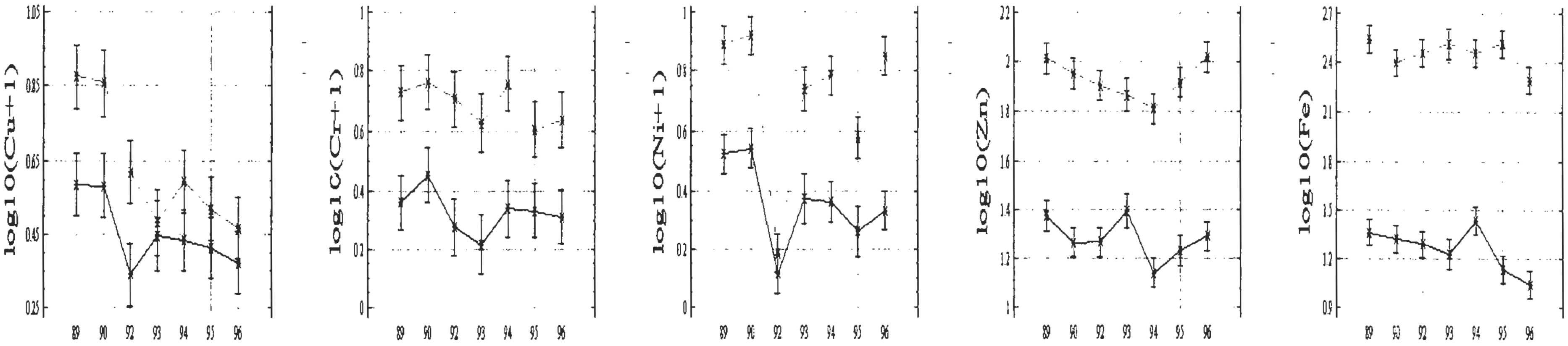


Figure 5.14 *: Evolution of metal concentrations in fish from Rhodos (station 3) during 1990-96.*
(solid line: flesh, dotted line: gills)

a) pelagic fish



b) demersal fish

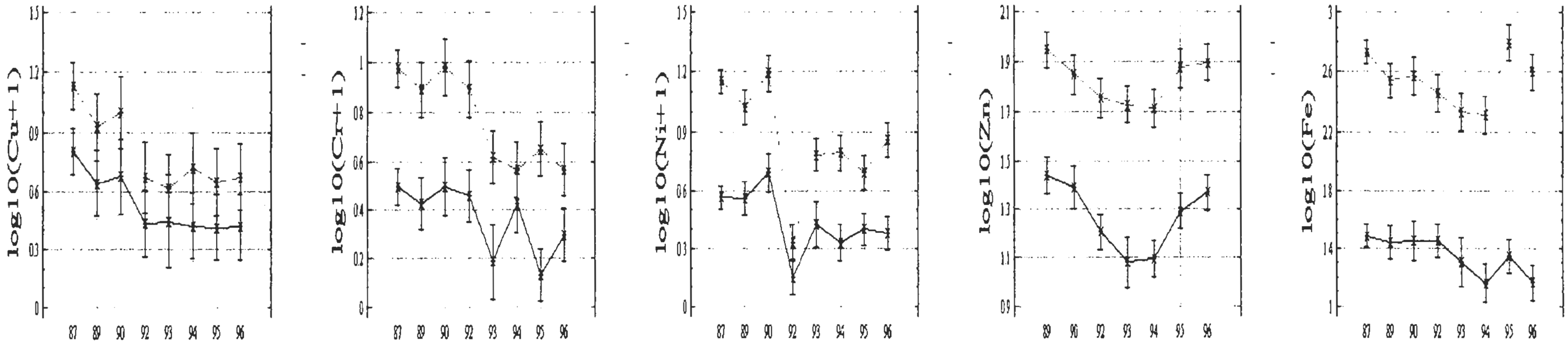


Figure 5.15 : *Evolution of metal concentrations in fish from Hania (station 4) during 1990-96.*
(solid line: flesh, dotted line: gills)

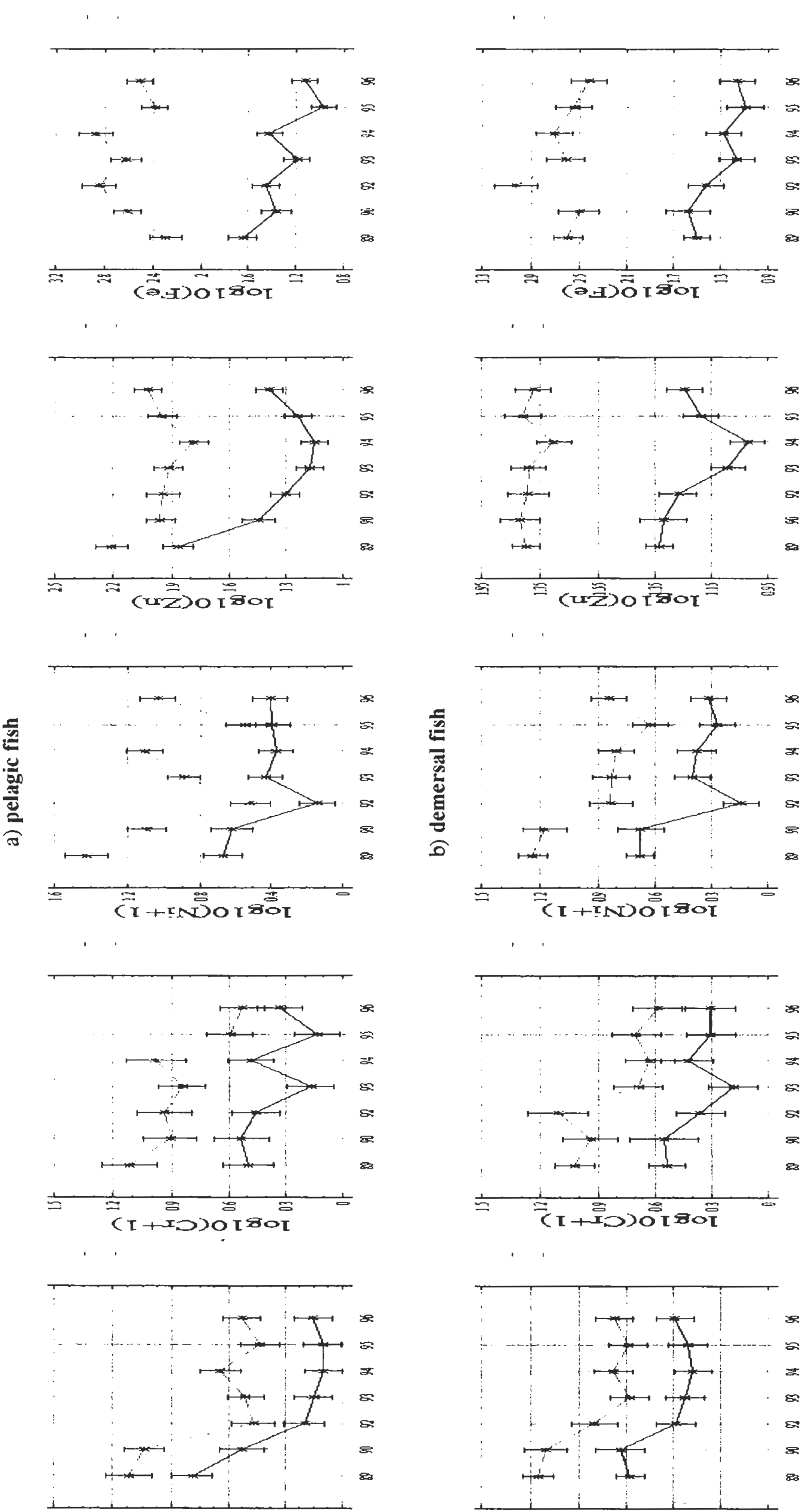
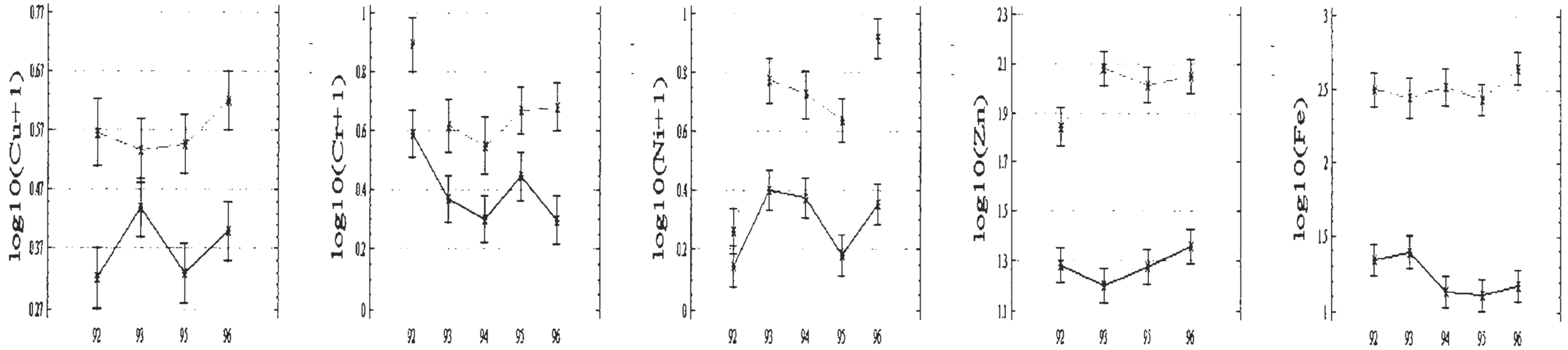


***Figure 5.16** : Evolution of metal concentrations in fish from Parga (station 5) during 1990-96.*
(solid line: flesh, dotted line: gills)

a)pelagic fish



b) demersal fish

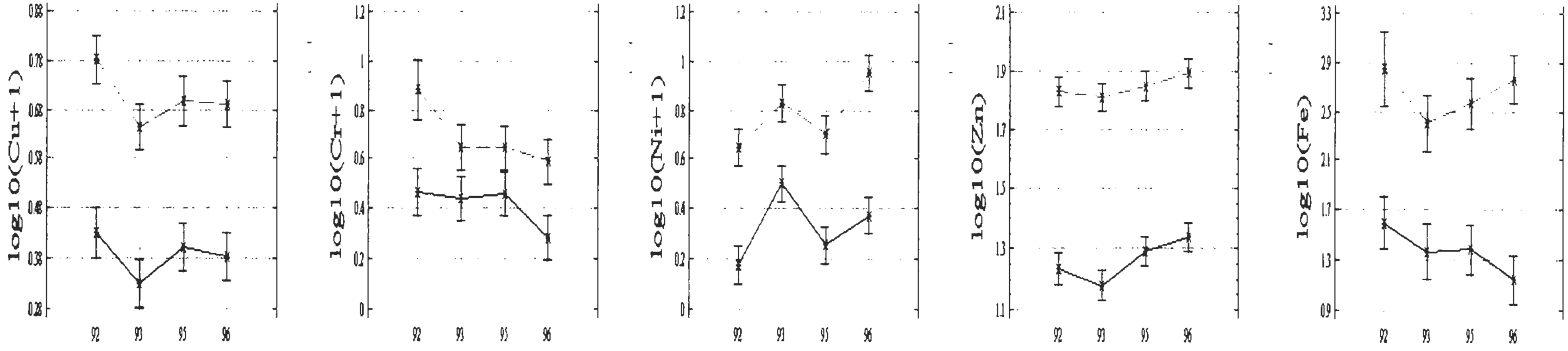


***Figure 5.17** : Evolution of metal concentrations in fish from Kalamata (station 7) during 1990-96.*
(solid line: flesh, dotted line: gills)

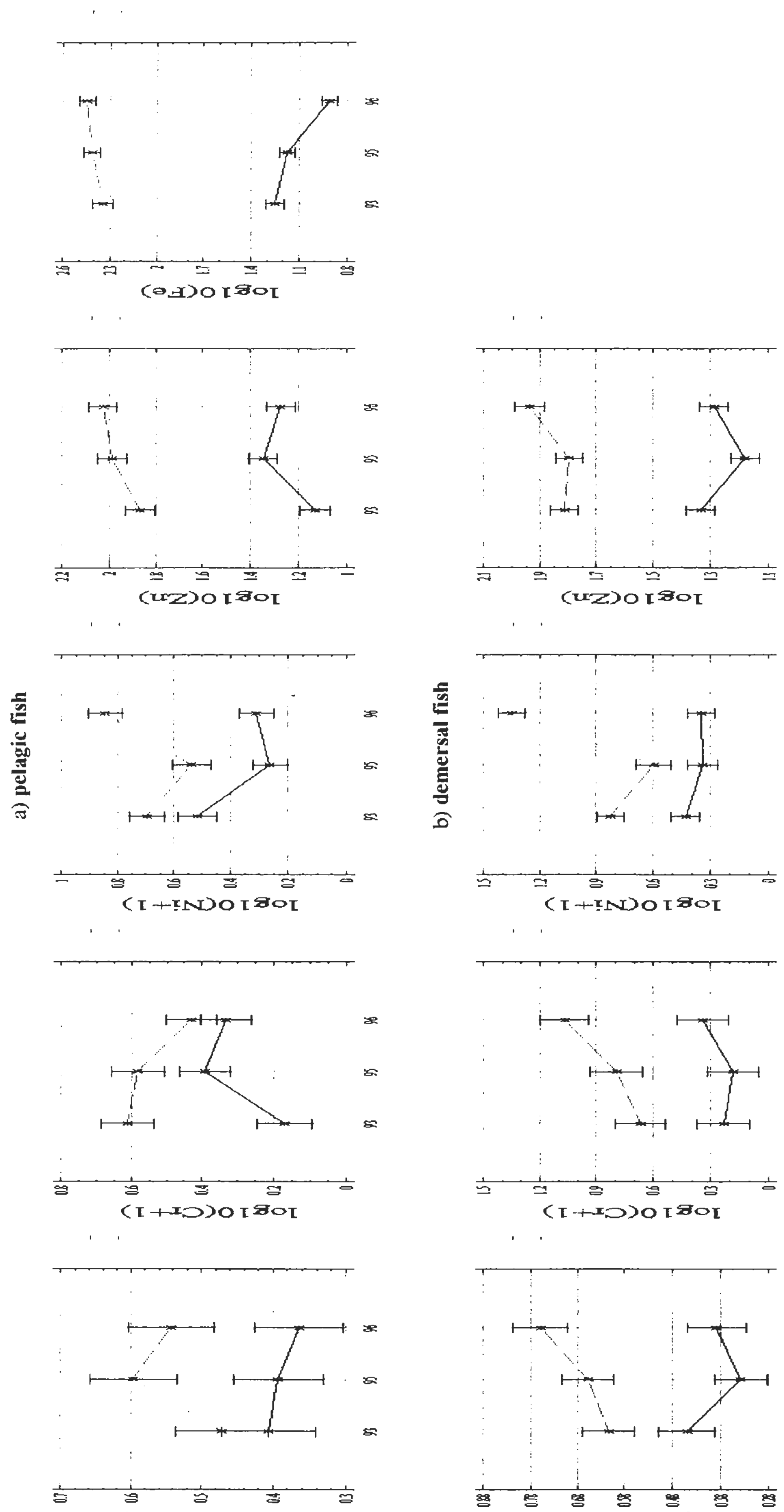


Figure 5.18 : Evolution of metal concentrations in fish from Volos (station 8) during 1990-96.
(solid line: flesh, dotted line: gills)

It is remarkable that for both species and tissues Aigina (station 6) presented low concentrations, and in some occasions the lowest values for all studied metals.

Temporal evolution of metals in fish

Temporal changes in the concentration of metals in flesh and gills of demersal and pelagic fish showed in general, a low degree of variation. However for most metals during the period 1988 to 1990 metal levels appeared to be higher. The following years, depending on the metal and the studied fish tissue, a slight decrease or increase was observed (Figures 5.12 to 5.18).

A general observation, that is very important, can be thrown from these Figures: the fact that each metal present similar temporal pattern at all the stations. This phenomenon can probably be attributed rather to climatic conditions during the periods previous to the fish collection, than to changes in the intensity of pollution.

Although there is not a clear trend on metal concentration in the two studied tissues of fish, we must mention that generally there was lower variability in flesh samples than in gills. This phenomenon is probably due to the more constant metabolic rate of the flesh.

5.4 CONCLUSIONS

- The determined concentration of metals in flesh samples of both studied species (*Mullus barbatus & Boops boops*), collected from the 6 greek marine areas during 1996 were not significantly high enough to endanger public health. Moreover these levels are comparable to those reported in the literature for other Greek and Mediterranean areas.
- Metal levels were higher in gill samples and thus the ratio of concentrations in gills and flesh was greater than 1.
- The flesh of demersal and pelagic fish presented similar concentrations for most metals (Cu, Cr, Ni and Mn). On the contrary, with the exception of Zn, the gills of demersal fish had higher metal levels than the pelagic
- Generally the spatial distribution of metals in fish collected in different marine areas followed no common pattern for both species or studied tissues. Concerning results from gills, the demersal the higher metallic values in demersal fish. were met at samples from Volos (Station 8). Similarly high values occurred at stations 3 (Rhodos) and 7 (Kalamata) and in some cases at station 4 (Hania). While in pelagic the higher metal levels were observed in Hios (station 2),

Parga (station 5) and Kalamata (station 7). Concerning results from flesh stations 5 (Parga), 7 (Kalamata) and partially 2 (Hios), for most of the metals tend to have higher concentrations in both examined fish..

- Concerning temporal changes in the concentration of metals in fish, for most metals during the period 1988 to 1990 metal levels appeared to be higher. The following years, depending on the metal and the studied fish tissue, a slight decrease or increase was observed.

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5. CHLORINATED HYDROCARBONS IN FISH DURING 1996

5.1.- INTRODUCTION

Man made chemicals such as PCBs (polychlorinated biphenyls) and chlorinated pesticides (DDT group, Lindane, Dieldrin) belong to the most persistent and toxic pollutants in aquatic and terrestrial ecosystems, because of their high toxicity in small quantities, strong resistance to physical, chemical and biological alterations and bioaccumulative capacity.

Through the food chain organochlorines accumulate in adipose tissues of organisms. Since fishes are lose chlorinated hydrocarbons slowly, if at all (Lieb et al.,1974), they consider excellent organisms for monitoring.

Although the use of chlorinated compounds has been restricted or discontinued in recent years, their residues remain in the environment and biota and continue to pose problems (Goldberg, 1991).

5.2.- SAMPLING AND METHODS

Fish samples of *Mullus barbatus* and *Boops boops*, abundant and commercially important fishes, were collected from seven different areas in Hellenic Waters during spring 1996, using commercial trawlers (Fig. 1.2, page 5).

In the laboratory their fork length and weight were recorded. The flesh of fishes was removed, lyophilized and extracted with pentane-dichloromethane on a soxhlet apparatus. The clean-up and fractionation took place on alumina columns. For the determination of chlorinated compounds a GC with 63Ni ECD was used equipped with a 30m Rtx-5 column, 0.32mm ID and 0.25μm df (EPA Manual for the Analysis of Pesticides, 1980, Satsmadjis et al., 1988).

5.3.- RESULTS AND DISCUSSION

In the past the laboratory used to study the PCBs content as mixture of Aroclors 1254 and 1260 and separately some congeners. Recent publications (Safe, 1990) have shown that the toxic nature of technical PCB mixtures is associated with the presence of a small group of

Table 5.1

Chlorinated hydrocarbons in fishes during 1996

Area	Date	Species	No Indiv.	Length mm	Weight g	EM % w.w	p,p'-DDE	p,p'-DDD	p,p'-DDT	DDTs	Lindane	Dieldrin	CB 101	CB 118	CB 153	CB 105	CB 138	CB 183	CB 128	CB 156	CB 180	CB 170	CB 194	CBs
ALEX	24/5/1996	MB	20	128	40	2,46	96,7	3,1	5,8	105,6	0,6	1,4	2,2	2,8	6,3	0,5	4,8	0,8	0,8	0,4	2,1	0,5	0,1	21,3
ALEX	24/5/1996	BB	12	205	138	1,52	24,3	1,0	1,2	26,5	0,1	0,4	1,2	0,7	1,9	0,1	1,4	0,6	0,2	0,1	0,6	0,3	0,1	7,2
HIOS	19/4/1996	MB	13	124	33	2,00	11,0	0,7	1,8	13,5	0,5	0,7	0,5	0,5	1,1	0,2	1,2	0,2	0,3	0,2	0,6	0,4	0,1	5,3
HIOS	19/4/1996	BB	8	166	67	2,38	2,0	0,4	0,5	2,9	0,5	0,3	0,3	0,2	0,5	0,1	0,7	0,2	0,1	0,1	0,4	0,1	0,1	2,8
RHODOS	21/6/1996	MB	20	155	46	1,17	16,1	1,0	0,6	17,7	0,3	0,3	0,6	0,8	2,3	0,2	2,1	0,2	0,3	0,3	1,3	0,4	0,1	8,6
RHODOS	21/6/1996	BB	20	150	44	2,21	9,2	0,8	0,5	10,5	0,1	0,3	1,0	0,6	1,5	0,3	1,5	0,3	0,2	0,2	0,7	0,6	0,2	7,1
HANIA	19/6/1996	MB	20	152	61	2,54	4,6	0,3	1,0	5,9	0,2	0,4	0,4	0,3	0,9	0,1	1,0	0,6	0,3	0,2	0,6	0,5	0,1	5,0
HANIA	19/6/1996	BB	14	190	102	1,35	3,4	0,4	0,9	4,7	0,3	0,3	0,3	0,3	0,5	0,1	0,7	0,1	0,2	0,1	0,4	0,3	0,1	3,1
PARGA	4/5/1996	MB	10	137	51	4,05	56,6	1,9	2,0	60,5	0,6	1,2	3,1	1,7	3,9	0,1	2,9	0,4	0,4	0,2	1,3	0,7	0,1	14,8
PARGA	4/5/1996	BB	20	150	45	1,98	26,6	0,2	0,2	27,0	0,2	0,3	2,6	1,2	3,8	0,3	3,1	0,1	0,3	0,4	1,9	0,9	0,3	14,9
KALAM	17/6/1996	MB	20	140	55	2,18	27,0	1,4	1,7	30,1	0,1	0,3	0,9	0,9	3,5	0,4	3,2	0,4	0,6	0,4	1,6	1,5	0,3	13,7
KALAM	17/6/1996	BB	17	165	69	1,67	5,3	0,6	0,4	6,3	0,1	0,2	0,6	0,7	1,4	0,3	1,2	0,1	0,2	0,3	0,8	0,5	0,2	6,3
VOLOS	25/5/1996	MB	17	127	38	2,78	94,4	2,9	4,7	102,0	0,3	1,1	2,1	2,2	5,5	0,3	4,4	0,6	0,7	0,3	1,9	0,9	0,2	19,1

Concentration: ng/g wet weight
MB: Mullus barbatus BB: Boops boops

chlorobiphenyls congeners. PCBs are theoretically composed of 209 congeners about 50 of which are found in the environment. So, in this work, we quantified PCBs as sum of eleven congeners, namely CB No 101, 118, 153, 105, 138, 128, 183, 156, 180, 170, 194 according to the usual nomenclature.

The above mentioned congeners were chosen for the following reasons:

- they occur in relatively high concentrations in the technical PCB mixtures,
- they cover the chlorination range from penta to octa- chlorines,
- some of them are toxic and
- they have been recommended for pollution monitoring studies (Kramer et al, 1994).

Dieldrin, Lindane, p,p'-DDT and its metabolites p,p'-DDE, p,p'-DDD were also measured. In an aliquot of the extract, lipid content was determined as the pentane-dichloromethane extractable material (E.M). Data on sampling and analysis are presented in Table 5.1.

a) Mullus barbatus

A total of 120 individuals were selected and analyzed. Their fork lengths, weights and E.M ranged between 127-155mm, 33-61g and 1.70-4.05% w.wt. respectively. The sum of CBs analyzed (Fig. 5.1a) varied from 5.0 ng/g w.wt. off Hania to 21.3 ng/g w.wt. off Alexandroupolis (mean value 12.5). CBs No 153 and 138 both hexachlorobiphenyls, were predominant (Fig. 5.2a), because of their resistance to enzymatic metabolic processes (Boon & Eijgenraam, 1988).

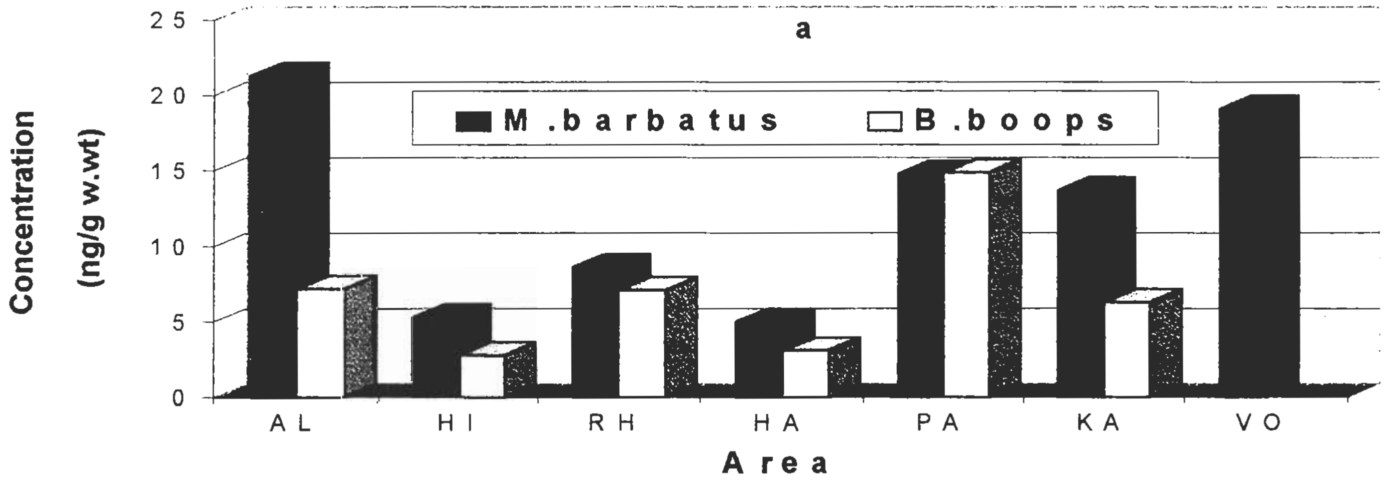

Figure 5.1a : CBs levels in Mullus barbatus and Boops boops (AL:Alexandroupolis, HI:Xios, RH:Rhodos, HA:Xania, PA:Parga, KA:Kalamata, VO:Volos)

fishes (Aly & Radaway, 1984), and its concentration was determined in relatively high values for the samples from Alexandroupolis, Volos and Parga. About 78-93.6% of total DDT was composed of DDE, while only 2.8-5.6 % of DDD.

Dieldrin, and Lindane were detected in low concentrations below 2ng/g w.wt.

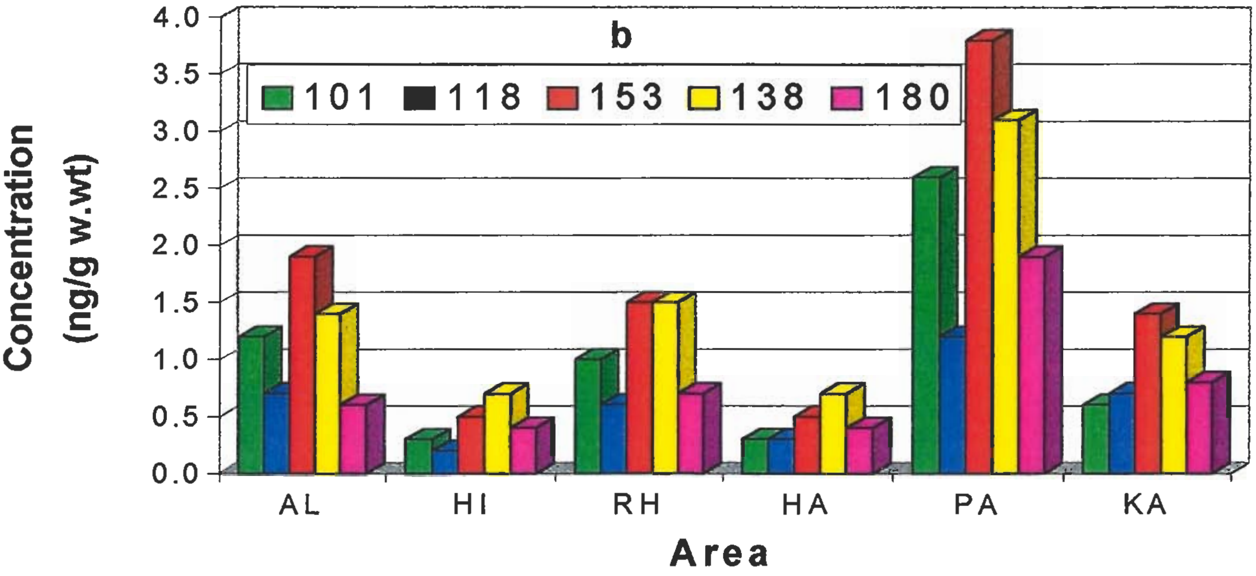

Figure 5.2b. Congener's composition in Boops boops (b). (AL:Alexandroupolis, HI:Xios, RH:Rhodos, HA:Xania, PA:Parga, KA:Kalamata, VO:Volos)

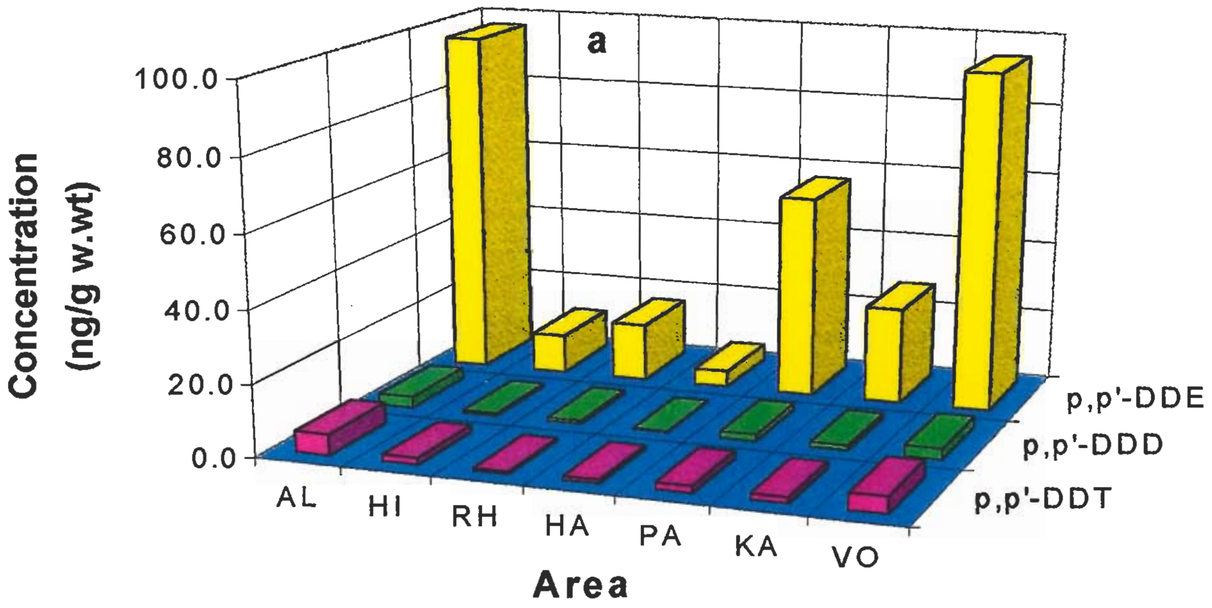

Figure 5.3a. DDT and its metabolites in Mullus barbatus (a) (AL:Alexandroupolis, HI:Xios, RH:Rhodos, HA:Xania, PA:Parga, KA:Kalamata, VO:Volos)

b) Boops-boops

About 100 individuals (fork length 150-205 mm, weight 44-138 g) were selected, and analyzed. The E.M was found between 1.35-2.38 % w.wt.

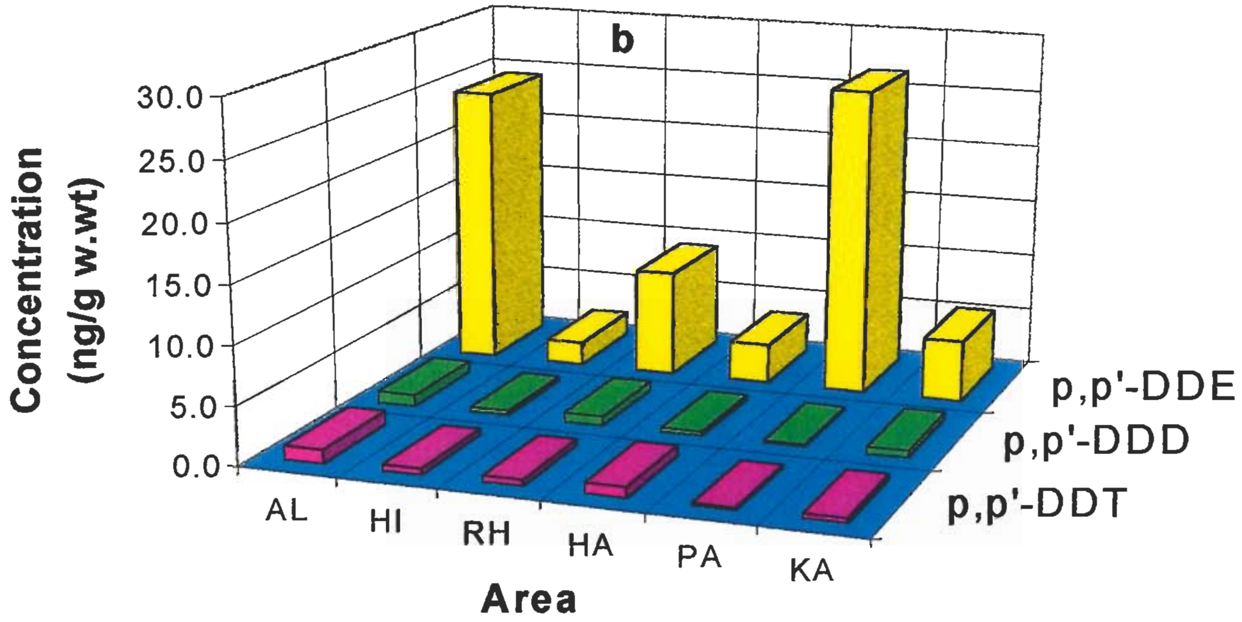

Figure 5.3b. *DDT and its metabolites in Boops boops (AL:Alexandroupolis, HI:Xios, RH:Rhodos, HA:Xania, PA:Parga, KA:Kalamata, VO:Volos)*

The concentration of organochlorines in all samples were lower than in *Mullus barbatus* (Fig. 5.1 a,b). So the CBs didn't exceed the 15 ng/g w.wt. (mean value 6.9) and No 138 and 153 were the predominant (Fig. 3b). DDTs levels varied from 3 to 27 ng/g w.wt. (mean value 13.0), while the other compounds were found below 0.5 ng/g w.wt. Among DDTs (Fig. 5.3b), the main metabolite was the DDE (69-98.5% of total DDT) and as in *Mullus barbatus,* the DDE presented relatively high values in the samples collected from Alexandroupolis and Parga. The same phenomenon has also been observed in mussel and fish samples collected in spring from Saronikos Gulf. However further studies are required in order to estimate these results.

Temporal evolution of Chlorinated hydrocarbons in fish

Mean concentrations of PCBs and DDTs in the flesh of Mullus barbatus during the period 1986-95 are presented in Figures 5.4 and 5.5.

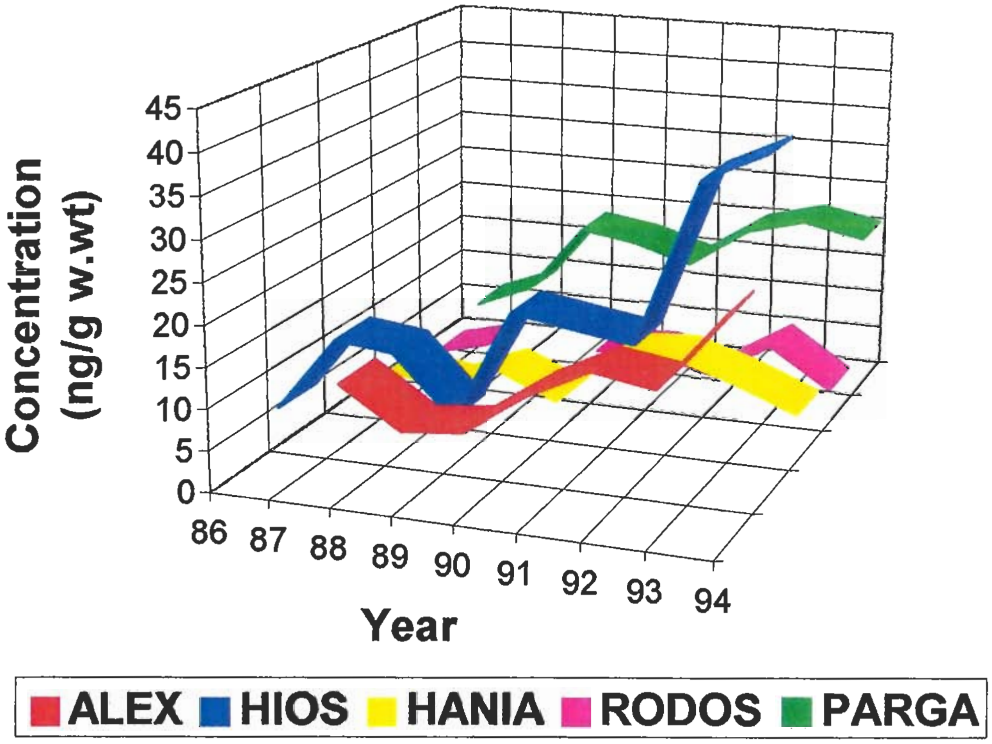

Figure 5.4 Temporal evolution of PCBs in Mullus barbatus during 1986-1994.

We can observe that the concentration of PCBs had slightly increased in the areas of Alexandroupolis and Hios after 1992, while in the other areas the levels of PCBs did not exhibit significant variations over the study period.

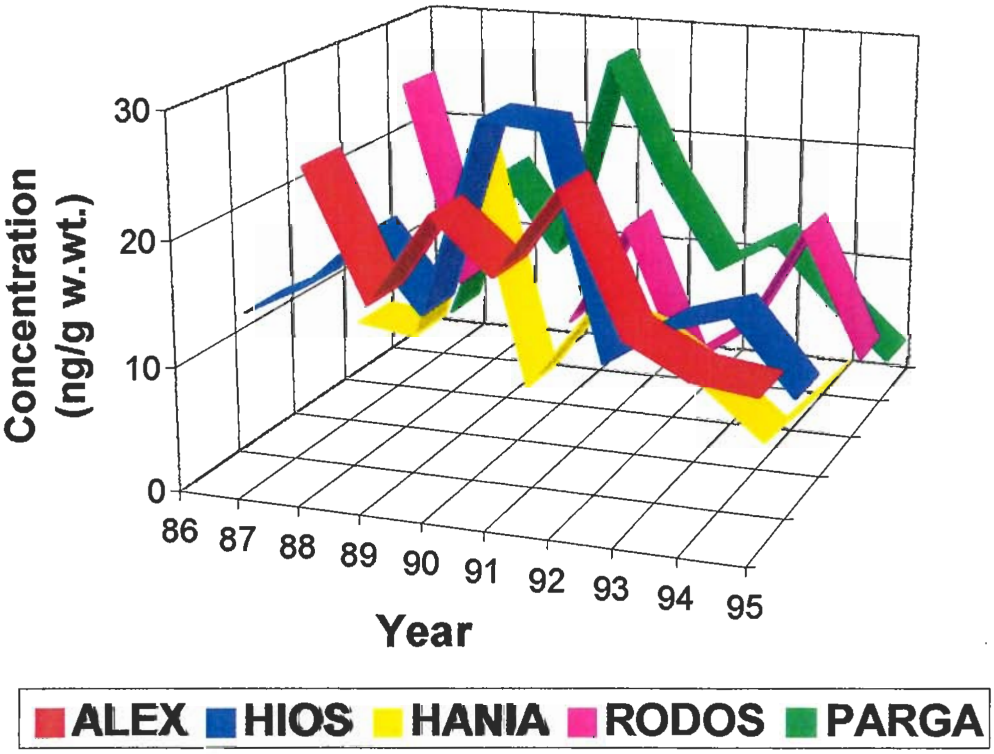

Figure 5.5. Temporal evolution of DDTs in Mullus barbatus during 1986-1995.

We can also observe that no clear trend can be discerned in the DDTs levels, although slightly increased values were met in all areas from 1989 till 1992.

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7. GENERAL CONCLUSIONS

- The water column in the examined area of the Aegean Sea was composed of three layers. The upper one between the surface and 20 to 25m, the intermediate between 25 and 75m to 100m and the deep water below it.
- A cyclonic circulation within the surface layer as evident. It seems that the less saline waters from the Black Sea, entering through the Dardanelles move northward and consequently westward and southward.
- The metal concentrations in the surface sediments of the Aegean Sea fall among the natural levels. The correlation coefficients calculated showed strong correlation between Cr and Ni and among Zn, Fe, Cu and Mn.
- C:N ratios in surface sediments presented high values in stations A_1, A_4 and A_8 suggesting an enrichment in organic carbon.
- Total aliphatic hydrocarbon concentrations were higher than those expected for typical unpolluted open sea sediments. The high absolute levels of UCM and the U/R ratio indicate in most cases petroleum inputs in the area.
- Total PAH concentrations were low. However the dominance of low MW bi- and tri- cyclic aromatics along with the presence of their methylated derivatives and some characteristic sulfur compounds also support fossil fuel influence in the sediments.
- Metal levels, in both fish species, were low and comparable to those reported from other areas in the Mediterranean region. Furthermore metal concentrations were not high enough to endanger public health. In addition, there was low variation through time on metal concentrations during the period of the study.
- The organochlorine concentrations (such as DDT group, Lindane, Dieldrin and PCBs) in fish samples were lower than those found in other Mediterranean regions and their levels were well below the health hazard limits.

8. ANNEX

Metal concentrations in fish from Greek waters during 1996
(metal concentration in μg/g, length in mm and weight in gr)

	station	No	species	tissue	length	weight	Zn	Cu	Fe	Mn	Cr	Ni	Cd
1	Parga	1	*B.boops*	gills	151	44,2	124,59	3,36	366,44	37,03	2,34	11,81	
2	Parga	1	*B.boops*	flesh	151	44,2	32,53	1,24	16,28	0,91	1,14	0,91	0,05
3	Parga	2	*B.boops*	gills	152	51,4	108,86	2,90	285,58	24,65	3,70	7,90	
4	Parga	2	*B.boops*	flesh	152	51,4	24,66	1,28	12,21	1,02	1,33	1,55	
5	Parga	3	*B.boops*	gills	149	49,3	122,96	4,56	343,99	29,06	2,65	9,10	
6	Parga	3	*B.boops*	flesh	149	49,3	24,51	1,77	14,58	0,65	0,78	1,80	0,04
7	Parga	4	*B.boops*	gills	148	45,2	102,68	3,85	282,14	20,43	2,64	10,39	
8	Parga	4	*B.boops*	flesh	148	45,2	35,69	1,45	11,10	0,73	0,68	1,57	0,02
9	Parga	5	*B.boops*	gills	154	50,3	96,91	2,76	282,91	21,94	3,29	8,96	
10	Parga	5	*B.boops*	flesh	154	50,3	16,70	0,94	11,33	0,69	0,75	1,61	
11	Parga	6	*B.boops*	gills	155	46,1	109,79	3,72	331,36	24,08	2,64	9,27	
12	Parga	6	*B.boops*	flesh	155	46,1	23,20	1,59	11,94	0,99	0,89	1,79	
13	Parga	7	*B.boops*	gills	150	44,2	101,93	3,94	442,07	23,55	2,58	8,43	
14	Parga	7	*B.boops*	flesh	150	44,2	23,32	1,54	20,34	1,35	1,37	2,06	
15	Parga	8	*B.boops*	gills	140	38,6	69,21	2,37	343,61	35,78	0,57	13,20	
16	Parga	8	*B.boops*	flesh	140	38,6	34,08	1,69	20,69	1,64	3,34	1,40	
17	Parga	9	*B.boops*	gills	145	40,8	113,74	3,43	368,84	21,34	1,08	10,67	
18	Parga	9	*B.boops*	flesh	145	40,8	19,88	1,30	12,69	0,89	0,83	1,84	
19	Parga	10	*B.boops*	gills	154	51,3	118,36	2,48	270,94	28,20	3,91	9,79	
20	Parga	10	*B.boops*	flesh	154	51,3	17,81	1,50	8,21	0,82	1,09	1,07	
21	Alex/poli	1	*M.barbatus*	gills	119	30	62,10	2,12	241,65	26,69	1,25	8,08	
22	Alex/poli	1	*M.barbatus*	flesh	119	30	16,42	1,65	16,93	1,96	0,59	0,92	0,02
23	Alex/poli	2	*M.barbatus*	gills	125	42,56	58,26	2,22	313,22	55,74	2,58	5,69	
24	Alex/poli	2	*M.barbatus*	flesh	125	42,56	15,87	2,21	11,02	1,48	0,84	0,73	0,01
25	Alex/poli	3	*M.barbatus*	gills	129	40,82	68,96	12,50	148,12	28,83	1,25	5,92	
26	Alex/poli	3	*M.barbatus*	flesh	129	40,82	18,37	1,78	12,26	1,17	0,82	0,88	0,02
27	Alex/poli	4	*M.barbatus*	gills	118	30,24	70,70	2,28	228,20	35,20	2,19	8,87	
28	Alex/poli	4	*M.barbatus*	flesh	118	30,24	17,30	1,42	17,21	1,32	1,19	1,00	0,02
29	Alex/poli	5	*M.barbatus*	gills	130	37,5	64,49	2,85	431,89	72,23	2,69	7,21	
30	Alex/poli	5	*M.barbatus*	flesh	130	37,5	19,20	1,77	14,70	1,41	0,75	1,15	
31	Alex/poli	6	*M.barbatus*	gills	125	35,31	70,25	2,33	177,50	20,71	2,10	6,60	
32	Alex/poli	6	*M.barbatus*	flesh	125	35,31	20,97	2,06	16,77	1,20	1,17	1,31	
33	Alex/poli	7	*M.barbatus*	gills	123	33,77	67,20	2,41	178,52	19,31	0,72	5,93	
34	Alex/poli	7	*M.barbatus*	flesh	123	33,77	15,37	1,71	19,66	1,26	1,23	1,55	
35	Alex/poli	8	*M.barbatus*	gills	120	33,53	67,38	3,07	144,53	27,69	1,42	8,04	
36	Alex/poli	8	*M.barbatus*	flesh	120	33,53	17,56	1,90	11,07	1,40	0,98	1,41	
37	Alex/poli	9	*M.barbatus*	gills	128	36,34	62,97	2,05	400,29	32,88	1,16	5,97	
38	Alex/poli	9	*M.barbatus*	flesh	128	36,34	16,03	1,59	13,23	1,16	2,55	1,99	
39	Alex/poli	10	*M.barbatus*	gills	123	35,64	86,81	2,87	196,95	32,19	2,62	10,90	
40	Alex/poli	10	*M.barbatus*	flesh	123	35,64	23,84	1,92	11,32	1,72	2,70	1,37	
41	Alex/poli	1	*B.boops*	gills	180	101,18	115,67	2,12	201,79	33,82	3,22	6,49	
42	Alex/poli	1	*B.boops*	flesh	180	101,18	17,70	1,35	8,17	0,79	1,33	1,39	0,01
43	Alex/poli	2	*B.boops*	gills	170	90,72	100,68	2,51	228,59	26,15	3,12	6,22	
44	Alex/poli	2	*B.boops*	flesh	170	90,72	29,24	1,59	7,28	0,94	0,94	0,81	0,02
45	Alex/poli	3	*B.boops*	gills	180	103,3	112,61	2,78	211,98	18,98	2,25	6,21	
46	Alex/poli	3	*B.boops*	flesh	180	103,3	23,52	1,58	7,98	0,65	0,81	1,29	0,01
47	Alex/poli	4	*B.boops*	gills	150	57,07	88,81	2,77	219,05	26,27	2,03	6,75	
48	Alex/poli	4	*B.boops*	flesh	150	57,07	22,78	1,52	8,56	0,93	1,39	0,65	0,01
49	Alex/poli	5	*B.boops*	gills	185	108,35	125,50	2,62	245,55	18,42	3,32	5,15	
50	Alex/poli	5	*B.boops*	flesh	185	108,35	19,98	1,45	9,03	0,95	0,88	1,52	

	station	No	species	tissue	length	weight	Zn	Cu	Fe	Mn	Cr	Ni	Cd
51	Alex/poli	6	*B.boops*	gills	167	77,57	115,67	1,94	165,99	28,15	3,09	8,09	
52	Alex/poli	6	*B.boops*	flesh	167	77,57	19,88	1,29	6,28	1,00	0,90	1,68	
53	Alex/poli	7	*B.boops*	gills	173	84,6	108,62	2,21	325,90	23,47	3,20	5,71	
54	Alex/poli	7	*B.boops*	flesh	173	84,6		1,30	8,25	0,73	0,90	1,13	
55	Alex/poli	8	*B.boops*	gills	184	107,85	108,32	2,45	299,49	24,81	3,03	5,40	
56	Alex/poli	8	*B.boops*	flesh	184	107,85	15,03	1,43	9,82	1,10	0,94	1,11	
57	Alex/poli	9	*B.boops*	gills	172	84,86	111,21	1,77	214,10	25,76	2,00	8,80	
58	Alex/poli	9	*B.boops*	flesh	172	84,86	17,71	1,22	9,38	0,85	1,04	0,84	
59	Alex/poli	10	*B.boops*	gills	170	85,58	112,32	2,60	339,61	19,92	2,96	6,70	
60	Alex/poli	10	*B.boops*	flesh	170	85,58	27,57	2,26	15,98	1,02	1,43	1,64	
61	Volos	1	*B.boops*	gills	160	77,3	105,57	2,42	256,91	14,89	1,70	5,74	
62	Volos	1	*B.boops*	flesh	160	77,3	20,47	1,44	8,30	0,64	1,12	0,66	0,01
63	Volos	2	*B.boops*	gills	185	84,6	108,86	2,72	297,05	16,97	2,25	8,83	
64	Volos	2	*B.boops*	flesh	185	84,6	18,57	1,17	7,68	0,73	1,41	1,29	0,01
65	Volos	3	*B.boops*	gills	185	98,7	83,24	2,02	236,20	20,99	0,49	7,26	
66	Volos	3	*B.boops*	flesh	185	98,7	17,84	1,23	6,69	0,70	1,03	1,60	0,01
67	Volos	4	*B.boops*	gills	170	87,2	162,99	2,94	283,91	20,53	2,01	5,31	
68	Volos	4	*B.boops*	flesh	170	87,2	19,05	1,17	7,42	1,26	1,11	1,47	0,02
69	Volos	5	*B.boops*	gills	170	90,8	99,65	3,01	282,75	15,72	1,54	7,58	
70	Volos	5	*B.boops*	flesh	170	90,8	16,17	1,36	7,73	0,64	2,90	0,98	
71	Volos	6	*B.boops*	gills	165	83,8	107,20	2,26	229,81	19,36	1,92	4,86	
72	Volos	6	*B.boops*	flesh	165	83,8	17,09	1,23	7,61	0,49	1,00	0,49	
73	Volos	7	*B.boops*	gills	150	70,6	90,30	2,30	335,73	23,82	0,88	6,29	
74	Volos	7	*B.boops*	flesh	150	70,6	18,23	1,22	6,97	0,69	0,70	1,17	
75	Volos	8	*B.boops*	gills	155	71,6	87,52	2,14	320,58	24,46	1,93	6,53	
76	Volos	8	*B.boops*	flesh	155	71,6	19,23	1,39	9,11	0,69	0,87	0,91	
77	Volos	9	*B.boops*	gills	150	70	115,88	2,15	310,57	18,46	2,33	4,17	
78	Volos	9	*B.boops*	flesh	150	70	21,60	1,56	10,91	0,85	1,11	1,21	
79	Volos	10	*B.boops*	gills	145	65,4	119,54	3,13	260,03	16,76	2,75	4,83	
80	Volos	10	*B.boops*	flesh	145	65,4	20,17	1,40	9,34	0,72	0,93	1,02	
81	Volos	1	*M.barbatus*	gills	125	35,7	67,57	5,83	432,00	87,77	18,13	28,05	
82	Volos	1	*M.barbatus*	flesh	125	35,7	17,67	1,37	11,30	1,06	1,09	0,92	0,01
83	Volos	2	*M.barbatus*	gills	125	34	96,03	2,45		35,02	1,82	11,85	
84	Volos	2	*M.barbatus*	flesh	125	34	21,39	5,14	12,40	0,95	1,89	1,04	0,01
85	Volos	3	*M.barbatus*	gills	135	34,8	76,33	5,76		124,29	22,56	36,02	
86	Volos	3	*M.barbatus*	flesh	135	34,8	19,52	1,25	17,79	1,29	0,94	1,02	
87	Volos	4	*M.barbatus*	gills	120	29,4	79,95	6,72		109,01	22,03	38,14	
88	Volos	4	*M.barbatus*	flesh	120	29,4	15,42	1,46	39,20	1,63	1,28	1,94	0,01
89	Volos	5	*M.barbatus*	gills	130	39,5	82,91	4,07		86,42	13,26	24,33	
90	Volos	5	*M.barbatus*	flesh	130	39,5	19,96	1,75	36,19	1,66	1,03	1,76	0,01
91	Volos	6	*M.barbatus*	gills	125	34,7		4,96		45,84	12,56	17,42	
92	Volos	6	*M.barbatus*	flesh	125	34,7	15,89	1,19	13,30	1,05	0,81	1,31	
93	Volos	7	*M.barbatus*	gills	135	41,5	107,23	13,55		113,50	18,91	23,25	
94	Volos	7	*M.barbatus*	flesh	135	41,5	23,98	1,65	31,63	1,18	1,36	1,30	
95	Volos	8	*M.barbatus*	gills	135	39	79,80	4,43		87,90	6,25	11,81	
96	Volos	8	*M.barbatus*	flesh	135	39	20,95	1,36	19,01	1,17	1,45	1,54	
97	Volos	9	*M.barbatus*	gills	120	31,4	117,39	3,55		21,63	1,68	11,11	
98	Volos	9	*M.barbatus*	flesh	120	31,4	16,92	1,57	16,07	0,86	1,39	1,39	
99	Volos	10	*M.barbatus*	gills	125	34,7	82,38	6,33		120,22	22,53	35,92	
100	Volos	10	*M.barbatus*	flesh	125	34,7	25,11		26,11	1,83	0,97	0,63	
101	Aigina	1	*B.boops*	gills	137	44,6	88,30	2,46	255,04	16,98	23,94	6,29	
102	Aigina	1	*B.boops*	flesh	137	44,6	19,09	1,38	7,73	0,46	0,73	1,12	0,02
103	Aigina	2	*B.boops*	gills	142	50,5	82,29	2,86	212,08	17,84	2,21	6,54	
104	Aigina	2	*B.boops*	flesh	142	50,5	17,87	1,53	11,57	0,45	0,61	1,43	0,01
105	Aigina	3	*B.boops*	gills	154	66,1	99,75	2,11	248,74	34,36	3,17	5,26	

	station	No	species	tissue	length	weight	Zn	Cu	Fe	Mn	Cr	Ni	Cd
106	Aigina	3	*B.boops*	flesh	154	66,1	24,66	1,60	10,81	0,46	1,37	0,44	0,06
107	Aigina	4	*B.boops*	gills	130	41	87,49	2,37	227,56	15,92	3,05	4,63	
108	Aigina	4	*B.boops*	flesh	130	41	19,31	1,66	11,08	0,50	0,85	1,56	0,01
110	Aigina	5	*B.boops*	flesh	145	52,7	21,57	1,80	12,94	0,93	1,24	0,96	
111	Aigina	6	*B.boops*	gills	148	62,5	81,44	2,35	273,62	25,05	2,85	5,92	
112	Aigina	6	*B.boops*	flesh	148	62,5	21,42	1,97	8,39	0,73	0,49	0,81	
113	Aigina	7	*B.boops*	gills	140	49,5	93,10	2,49	235,90	14,44	1,32	8,11	
114	Aigina	7	*B.boops*	flesh	140	49,5	17,41	1,30	8,09	0,44	1,23	1,16	
115	Aigina	8	*B.boops*	gills	158	63,5	96,42	3,04	216,07	20,81	2,00	7,32	
116	Aigina	8	*B.boops*	flesh	158	63,5	31,23	1,79	8,80	0,73	0,76	1,53	
117	Aigina	9	*B.boops*	gills	150	59,7	121,60	2,92	181,35	20,65	0,97	5,19	
118	Aigina	9	*B.boops*	flesh	150	59,7	31,42	1,26	10,65	0,44	0,99	1,43	
119	Aigina	10	*B.boops*	gills	138	47,6	89,20	2,24	203,31	21,34	1,40	5,65	
120	Aigina	10	*B.boops*	flesh	138	47,6	24,01	1,72	11,40	0,95	0,81	0,71	
121	Aigina	1	*M.barbatus*	gills	129	41,2	71,46	1,92	176,14	7,91	1,71	5,99	
122	Aigina	1	*M.barbatus*	flesh	129	41,2	17,17	1,86	14,82	0,69	0,72	0,77	0,01
123	Aigina	2	*M.barbatus*	gills	112	33,6	93,78	2,48	197,03	9,10	2,88	6,71	
124	Aigina	2	*M.barbatus*	flesh	112	33,6	16,77	1,36	9,78	0,49	1,75	1,39	0,01
125	Aigina	3	*M.barbatus*	gills	120	36,2	98,02	3,63	210,30	11,15	1,07	8,41	
126	Aigina	3	*M.barbatus*	flesh	120	36,2	18,46	1,43	8,36	0,90	0,59	1,22	0,01
127	Aigina	4	*M.barbatus*	gills	125	48,2	57,59	2,43	125,75	8,87	2,80	4,29	
128	Aigina	4	*M.barbatus*	flesh	125	48,2	12,85	1,22	8,81	0,50	1,22	1,29	0,01
129	Aigina	5	*M.barbatus*	gills	132	50,9	66,05	3,03	172,63	9,39	2,66	3,74	
130	Aigina	5	*M.barbatus*	flesh	132	50,9	14,84	0,89	5,87	0,48	0,53	1,14	
131	Aigina	6	*M.barbatus*	gills	122	44,6	74,53	2,99	150,80	9,98	2,03	4,31	
132	Aigina	6	*M.barbatus*	flesh	122	44,6	14,77	1,17	7,95	0,46	0,48	0,60	
133	Aigina	7	*M.barbatus*	gills	132	42,6	73,16	2,57	163,95	10,63	2,83	5,61	
134	Aigina	7	*M.barbatus*	flesh	132	42,6	22,56	1,11	10,14	0,46	0,58	1,49	
135	Aigina	8	*M.barbatus*	gills	122	40,5	69,99	2,78	135,37	16,66	1,71	5,32	
136	Aigina	8	*M.barbatus*	flesh	122	40,5	14,39	1,43	8,41	0,89	0,60	0,88	
137	Aigina	9	*M.barbatus*	gills	110	33	96,09	2,57	203,89	9,35	1,17	5,96	
138	Aigina	9	*M.barbatus*	flesh	110	33	14,98	1,45	10,48	0,45	1,05	0,68	
139	Aigina	10	*M.barbatus*	gills	113	35,7	60,03	2,84	208,74	10,84	1,62	4,40	
140	Aigina	10	*M.barbatus*	flesh	113	35,7	13,35	1,01	7,71	0,54	0,59	1,16	
141	Kalamata	1	*B.boops*	gills	168	65,9	127,36	2,95	452,36	36,47	3,37	5,51	
142	Kalamata	1	*B.boops*	flesh	168	65,9	26,55	1,77	13,60	0,90	1,22	1,62	0,02
143	Kalamata	2	*B.boops*	gills	170	66,4	115,53	3,93			6,71	10,53	
144	Kalamata	2	*B.boops*	flesh	170	66,4	31,12	1,49		1,89	0,78	0,88	0,03
145	Kalamata	3	*B.boops*	gills	156	54,2	119,67	2,91	374,46	19,38	2,91	5,88	
146	Kalamata	3	*B.boops*	flesh	156	54,2	23,99	1,38	13,00	0,68	0,86	0,93	0,01
147	Kalamata	4	*B.boops*	gills	170	78,5	92,99	2,74	560,68	45,68	3,84	8,07	
148	Kalamata	4	*B.boops*	flesh	170	78,5	16,02	1,33	13,50	0,76	0,99	0,95	0,01
149	Kalamata	5	*B.boops*	gills	170	67,3	98,79	3,47	383,76	23,08	2,91	6,87	
150	Kalamata	5	*B.boops*	flesh	170	67,3	22,08	1,73	14,87	0,72	0,91	1,33	
151	Kalamata	6	*B.boops*	gills	170	72,8	99,46	2,89	512,88	68,86	4,26	7,61	
152	Kalamata	6	*B.boops*	flesh	170	72,8	21,13	1,58	14,23	0,74	1,14	1,31	
153	Kalamata	7	*B.boops*	gills	168	71,5	124,40	3,48	502,24	35,76	4,62	7,00	
154	Kalamata	7	*B.boops*	flesh	168	71,5	22,14	1,22	11,71	0,65	0,83	1,66	
155	Kalamata	8	*B.boops*	gills	155	54,7	95,84	2,97	394,62	29,63	2,76	6,95	
156	Kalamata	8	*B.boops*	flesh	155	54,7	18,92	1,46	10,09	0,72	0,99	1,32	
157	Kalamata	9	*B.boops*	gills	170	76,5	117,31	4,17	539,91	34,30	4,41	6,15	
158	Kalamata	9	*B.boops*	flesh	170	76,5	25,64	1,90	13,18	0,61	1,16	1,26	
159	Kalamata	10	*B.boops*	gills	173	79,9	135,29	2,60	323,27	26,32	3,42	9,07	
160	Kalamata	10	*B.boops*	flesh	173	79,9	22,08	1,36	17,44	0,78	1,09	1,60	
161	Kalamata	1	*M.barbatus*	gills	128	31,9	88,18	4,19		51,41	4,37	7,55	

	station	No	species	tissue	length	weight	Zn	Cu	Fe	Mn	Cr	Ni	Cd
162	Kalamata	1	*M.barbatus*	flesh	128	31,9	16,79	1,18	10,38	0,69	0,88	1,30	0,03
163	Kalamata	2	*M.barbatus*	gills	132	46,7	72,67	3,76	305,73	18,79	2,15	5,00	
164	Kalamata	2	*M.barbatus*	flesh	132	46,7	18,65	1,35	9,58	0,75	1,20	1,78	0,01
165	Kalamata	3	*M.barbatus*	gills	128	39,1	84,65	3,33	322,26	15,29	1,24	7,80	
166	Kalamata	3	*M.barbatus*	flesh	128	39,1	23,46	1,16	13,70	0,93	0,97	1,47	0,01
167	Kalamata	4	*M.barbatus*	gills	140	48,7	74,67	4,45	750,67	62,07	3,49	6,31	
168	Kalamata	4	*M.barbatus*	flesh	140	48,7	25,93	1,21	13,92	1,01	1,52	0,84	0,02
169	Kalamata	5	*M.barbatus*	gills	128	37	88,23	5,74	1047,90		4,02	9,57	
170	Kalamata	5	*M.barbatus*	flesh	128	37	28,42	1,75	21,76	1,17	1,07	1,59	
171	Kalamata	6	*M.barbatus*	gills	128	35,7	71,12	2,93	616,09	45,36	2,36	9,31	
172	Kalamata	6	*M.barbatus*	flesh	128	35,7	23,15	1,48	13,25	1,03	0,96	1,89	
173	Kalamata	7	*M.barbatus*	gills	133	44,3	70,20	3,50	215,22	18,35	2,66	6,31	
174	Kalamata	7	*M.barbatus*	flesh	133	44,3	19,75	1,36	11,76	0,89	0,44	1,07	
175	Kalamata	8	*M.barbatus*	gills	130	43,9	71,15	3,30	579,64	25,90	2,71	9,81	
176	Kalamata	8	*M.barbatus*	flesh	130	43,9	19,56	1,68	15,23	0,96	0,34	1,44	
177	Kalamata	9	*M.barbatus*	gills	119	31,1	82,20	3,81	729,57	64,91	2,51	11,46	
178	Kalamata	9	*M.barbatus*	flesh	119	31,1	21,45	1,36	13,89	1,14	1,04	1,42	
179	Kalamata	10	*M.barbatus*	gills	122	36,1	82,32	4,54	724,52	72,48	4,38	8,43	
180	Kalamata	10	*M.barbatus*	flesh	122	36,1	23,55	1,78	21,14	1,02	0,99	0,91	
181	Hania	1	*B.boops*	gills	189	85,2	98,74	1,92	205,60	14,54	2,90	6,25	
182	Hania	1	*B.boops*	flesh	189	85,2	19,39	1,26	10,81	0,69	1,13	1,33	
183	Hania	2	*B.boops*	gills	195	104,5	107,27	2,37	271,05	23,35	3,24	4,76	
184	Hania	2	*B.boops*	flesh	195	104,5	30,80	1,33	11,18	0,99	1,24	1,72	
185	Hania	3	*B.boops*	gills	197	123,2	91,83	2,00	225,29	16,57	3,77	5,38	
186	Hania	3	*B.boops*	flesh	197	123,2	17,50	1,89	14,07	0,48	0,94	0,99	
187	Hania	4	*B.boops*	gills	174	92,3	83,47	2,10	171,42	16,86	3,86	6,34	
188	Hania	4	*B.boops*	flesh	174	92,3	15,44	1,34	9,32	0,48	0,79	1,31	
189	Hania	5	*B.boops*	gills	190	106,2	118,55	1,68	203,24	23,39	3,73	6,06	
190	Hania	5	*B.boops*	flesh	190	106,2	21,90	1,26	9,10	0,42	0,51	1,41	
191	Hania	6	*B.boops*	gills	193	117	117,32	1,75	143,73	21,48	2,18	6,04	
192	Hania	6	*B.boops*	flesh	193	117	21,27	1,80	13,07	0,51	1,00	1,54	0,02
193	Hania	7	*B.boops*	gills	187	109,7	114,12	2,41	334,61	31,11	3,53	8,74	
194	Hania	7	*B.boops*	flesh	187	109,7	17,91	1,44	12,59	0,61	0,66	1,24	0,01
195	Hania	8	*B.boops*	gills	193	111,3	102,94	1,72	133,99	22,59	3,58	6,40	
196	Hania	8	*B.boops*	flesh	193	111,3	23,27	0,94	9,65	0,52	0,96	0,70	0,02
197	Hania	9	*B.boops*	gills	199	116,8	124,97	2,05	218,17	28,93	3,61	6,04	
198	Hania	9	*B.boops*	flesh	199	116,8	17,13	1,17	11,68	0,45	0,69	0,47	0,05
199	Hania	10	*B.boops*	gills	192	117,6	92,00	1,52	134,57	26,24	3,16	5,67	
200	Hania	10	*B.boops*	flesh	192	117,6	15,88	1,29	9,69	0,47		1,07	
201	Hania	1	*M.barbatus*	gills	155	71,4	86,27	4,54	282,99	24,01	3,10	5,43	
202	Hania	1	*M.barbatus*	flesh	155	71,4	22,07	1,10	12,95	0,88	1,16	1,46	0,01
203	Hania	2	*M.barbatus*	gills	141	51,6	88,63	4,32	418,57	14,55	3,46	9,11	
204	Hania	2	*M.barbatus*	flesh	141	51,6	26,48	1,34	11,89	0,98	1,10	0,90	0,01
205	Hania	3	*M.barbatus*	gills	140	55,6	86,97	5,06	717,15	13,09	2,97	8,33	
206	Hania	3	*M.barbatus*	flesh	140	55,6	24,11	1,46	14,00	0,64	1,11	1,70	0,01
207	Hania	4	*M.barbatus*	gills	133	43,9	68,24	3,44	526,50	24,10	3,21	7,73	
208	Hania	4	*M.barbatus*	flesh	133	43,9	21,64	1,33	16,03	1,32	0,93	2,38	0,02
209	Hania	5	*M.barbatus*	gills	151	58,9	74,33	3,33	330,16	12,97	2,17	4,72	
210	Hania	5	*M.barbatus*	flesh	151	58,9	22,43	1,90	15,73	0,70	1,20	1,74	
211	Hania	6	*M.barbatus*	gills	150	69	70,87	2,88	262,72	12,54	3,32	4,77	
212	Hania	6	*M.barbatus*	flesh	150	69	17,11	1,15	9,68	0,74	0,96	1,37	
213	Hania	7	*M.barbatus*	gills	130	45,4	77,73	3,17		29,36	1,81	6,89	
214	Hania	7	*M.barbatus*	flesh	130	45,4	31,33	3,21	22,61	0,84	0,67	1,49	
215	Hania	8	*M.barbatus*	gills	150	61,8	84,13	3,52	511,75	17,64	2,67	4,96	
216	Hania	8	*M.barbatus*	flesh	150	61,8	31,09	2,10	14,17	0,95	0,88	1,67	

	station	No	species	tissue	length	weight	Zn	Cu	Fe	Mn	Cr	Ni	Cd
272	Parga	6	*M.barbatus*	flesh	132	46,5	16,97	1,41	15,22	1,23	1,06	1,46	
273	Parga	7	*M.barbatus*	gills	142	57,3	53,40	2,40	188,17	16,16	3,47	4,99	
274	Parga	7	*M.barbatus*	flesh	142	57,3	16,93	1,26	19,03	1,12	0,83	1,14	
275	Parga	8	*M.barbatus*	gills	143	54,3	76,83	3,35	222,06	24,02	2,10	5,99	
276	Parga	8	*M.barbatus*	flesh	143	54,3	19,28	1,40	9,72	0,78	1,28	1,22	
277	Parga	9	*M.barbatus*	gills	138	43,3	60,06	2,94	217,93	16,88	2,63	6,80	
278	Parga	9	*M.barbatus*	flesh	138	43,3	17,62	1,45	15,54	1,14	0,72	0,59	
279	Parga	10	*M.barbatus*	gills	137	47,1	52,76	3,28	880,05	56,40	6,21	8,37	
280	Parga	10	*M.barbatus*	flesh	137	47,1	16,06	1,13	20,48	1,18	1,47	0,81	
281	Hios	1	*M.barbatus*	gills	125	46,5	79,43	2,62	242,48	8,84	1,17	6,23	
282	Hios	1	*M.barbatus*	flesh	125	46,5	15,75	1,51	13,51	0,68	1,71	0,86	0,03
283	Hios	2	*M.barbatus*	gills	115	32,7	56,24	2,60	196,81	12,93	1,05	4,76	
284	Hios	2	*M.barbatus*	flesh	115	32,7	20,80	1,23	16,09	0,75	0,85	1,20	0,02
285	Hios	3	*M.barbatus*	gills	126	36,9	54,84	3,61	284,85	11,58	1,13	5,37	
286	Hios	3	*M.barbatus*	flesh	126	36,9	15,84	1,76	12,12	0,72	1,79	1,30	0,01
287	Hios	4	*M.barbatus*	gills	131	51,9	74,21	4,75	188,87	16,00	1,24	6,27	
288	Hios	4	*M.barbatus*	flesh	131	51,9	16,22	1,44	11,02	0,49	1,01	1,15	0,03
289	Hios	5	*M.barbatus*	gills	122	35,7	68,62	2,90	217,55	15,45	1,65	6,22	
290	Hios	5	*M.barbatus*	flesh	122	35,7	21,35	1,42	14,93	0,71	1,15	1,05	
291	Hios	6	*M.barbatus*	gills	120	36,3	67,62	2,79	248,88	13,92	0,60	7,57	
292	Hios	6	*M.barbatus*	flesh	120	36,3	17,11	1,52	8,91	1,04	0,63	1,08	
293	Hios	7	*M.barbatus*	gills	122	37,9	69,59	2,65	221,65	50,94	0,84	8,59	
294	Hios	7	*M.barbatus*	flesh	122	37,9	18,74	1,59	18,81	0,96	0,86	1,89	
295	Hios	8	*M.barbatus*	gills	113	30,9	75,65	2,34	230,57	21,61	1,15	6,53	
296	Hios	8	*M.barbatus*	flesh	113	30,9	18,65	1,81	11,61	0,95	0,43	0,71	
297	Hios	9	*M.barbatus*	gills	115	32,5	78,37	4,51	311,25	16,14	0,43	6,78	
298	Hios	9	*M.barbatus*	flesh	115	32,5	20,77	1,73	14,13	0,91	0,92		
299	Hios	10	*M.barbatus*	gills	120	32,2	81,88	2,70	594,94	27,83	4,02	8,26	
300	Hios	10	*M.barbatus*	flesh	120	32,2	19,38	1,67	20,15	0,99	0,96	0,61	
301	Hios	1	*B.boops*	gills	150	55,4	114,56	3,20	998,65	45,00	5,74	11,53	
302	Hios	1	*B.boops*	flesh	150	55,4	25,66	1,88	14,58	0,67	3,45	1,55	0,01
303	Hios	2	*B.boops*	gills	159	60,9	100,24	3,23	571,86	23,85	3,35	7,05	
304	Hios	2	*B.boops*	flesh	159	60,9	22,22	1,42	13,18	0,70	1,17	0,89	0,02
305	Hios	3	*B.boops*	gills	155	57,2	121,13	2,52	521,38	37,39	4,41	8,19	
306	Hios	3	*B.boops*	flesh	155	57,2	33,47	1,63	13,48	0,70	1,16	1,90	0,01
307	Hios	4	*B.boops*	gills	140	44,3	98,24	2,66	463,78	56,24	1,86	10,13	
308	Hios	4	*B.boops*	flesh	140	44,3	22,50	1,86	7,24	0,85	0,74	1,44	
309	Hios	5	*B.boops*	gills	145	60,1	71,98	1,93	676,91	58,17	3,47	9,47	
310	Hios	5	*B.boops*	flesh	145	60,1	22,18	1,20	6,90	0,68	3,47	1,59	0,01
311	Hios	6	*B.boops*	gills	148	52,6	87,55	2,89	369,30	37,47	1,80	6,83	
312	Hios	6	*B.boops*	flesh	148	52,6	22,48	2,67	12,97	1,29	1,11	1,89	
313	Hios	7	*B.boops*	gills	148	53,1	90,46	2,84	932,11	60,62	5,25	8,89	
314	Hios	7	*B.boops*	flesh	148	53,1	24,71	2,00	16,74	0,70	0,46	1,55	
315	Hios	8	*B.boops*	gills	150	53,8	103,66	2,80	446,17	32,91	4,19	8,05	
316	Hios	8	*B.boops*	flesh	150	53,8	20,19	1,32	12,58	0,77	0,90	1,35	
317	Hios	9	*B.boops*	gills	150	49,8	104,36	3,15	368,24	29,96	2,30	9,07	
318	Hios	9	*B.boops*	flesh	150	49,8	28,34	1,57	17,94	0,70	1,69	1,97	
319	Hios	10	*B.boops*	gills	139	41,6	96,10	2,31	765,31	50,36	4,24	11,53	
320	Hios	10	*B.boops*	flesh	139	41,6	15,02	1,49	9,66	0,98	1,92	1,44	