DISTRIBUTION OF MOLLUSC ASSEMBLAGES IN THE SURFACE SEDIMENTS OF THE BLACK SEA, MARMARA SEA AND AEGEAN SEA

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DISTRIBUTION OF MOLLUSC ASSEMBLAGES IN THE SURFACE SEDIMENTS OF THE BLACK SEA, MARMARA SEA AND AEGEAN SEA

by

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This thesis is dedicated to my sister Şirincan Çakıroğlu who has survived cancer and my aunt Gülçin Anter who is still battling cancer.

ABSTRACT

The Marmara Sea Gateway connects the hypersaline (<36 ‰) Aegean Sea and the low-salinity (~17–22 ‰) Black Sea through the Straits of Bosphorus and Dardanelles and the landlocked Marmara Sea. This gateway forms a natural laboratory in which to study the effects of climate change, sea-level fluctuations and water-mass exchange between small basins.

Surface sediment samples were collected from 137 stations across six transects in the Black Sea, the Marmara Sea and the Aegean Sea. At each station grab samples and CTD (conductivity, temperature, depth) measurements were also collected.

In the Marmara Sea, CTD data revealed the presence of a low salinity surface water mass representing Black Sea outflow and a high salinity deeper water mass, separated by a sharp mixing zone. Across the Southwestern Black Sea shelf the CTD data showed the presence of 3 water masses: 1) a low salinity surface water mass extended down to 10 m; 2) a low salinity, but colder water mass occupies water depth below 40 m; 3) and a higher salinity Mediterranean water occurs between these two water masses. In the Aegean Sea CTD data revealed a relatively low salinity Black Sea outflow water mass at the surface, and high salinity water mass at the bottom separated by a mixing zone.

The mollusc shells from grab samples were identified using a number of taxonomic keys and analyzed qualitatively and quantitatively in order to investigate the relationship between the community structure and the environment. The mollusc absence and presence data in quadrats was used to delineate seven different mollusc assemblages, with each assemblage representing a distinct set of environmental conditions. Principal component analysis was used to constrain mollusc faunal assemblages and their relationship to environmental variables. Seven hypothetical faunal assemblages and three hypothetical environmental variables were extracted, explaining 73.9 % and 73.8 % of the variance in the faunal and environmental data, respectively. Cross-plots of scores for the major faunal and environmental components revealed empirical relationships between the three oceanographically different seas. The separation of the Black Sea from the Marmara Sea and the Aegean Sea assemblages was found in the cross-plot of Faunal Component 1 versus Environmental Component 1. The separation from the Marmara Sea to the Aegean Sea was found in the cross-plots of Faunal Component 1 versus Environmental Component 3 and Faunal Component 4 versus Environmental Component 3.

Mollusc shells were also identified and counted in a ~8 m long piston core recovered from the SW Black Sea shelf. Visual inspection of the data revealed four distinct faunal assemblages in the core. To test the validity of using the principal components determined from the surface samples to deduce past environments in a core, the same mollusc species found both in the surface samples and core units/subunits were used to calculate faunal scores for each unit/subunit. Principal components scores for units/subunits provided little basis for making strong interpretations about the changing paleoenvironment. Because only five species that were used in the principal component analysis on surface samples were present in the core MAR 02–45P.

Acknowledgements

I extend my sincere gratitude and appreciation to many people who made this masters thesis possible.

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CHAPTER 1

INTRODUCTION

The Aegean Sea, the Marmara Sea and the Black Sea are located in the eastern Mediterranean region between 34.5° and 46°N latitude (Figure 1.1). Today, the Marmara Sea and the Straits of Dardanelles and Bosphorus form an oceanographic gateway connecting the hypersaline (<36 ‰) Aegean Sea and the low-salinity (~17–22 ‰) Black Sea. This gateway functions as the only link between the world's largest anoxic basin, the Black Sea, and the eastern Mediterranean Sea. The straits are narrow and have shallow sills (40–70 m deep). This gateway forms a natural laboratory in which to study the effects of climate change, sea-level fluctuations and water-mass exchange between small basins during the Quaternary paleoceanographic evolution of the eastern Mediterranean. In this thesis, ecological characteristics are delineated by comparison between the present-day oceanographic parameters (such as temperature, salinity, dissolved oxygen, etc.) and the mollusc assemblages found in surface sediments.

1.1. Physical Oceanography of the Study Area

1.1.1. Black Sea Bathymetry

The Black Sea covers an area of ~423 000 km^2 and has a volume of ~530 000 km^3 (Figure 1.2). It is connected to the Azov Sea via the <5 m deep Kerch Strait, and to the Marmara Sea via the <40 m deep Strait of Bosphorus. The continental shelf in the northwestern Black Sea is very broad (190 km wide) but narrows to <20 km along the

Figure 1.1. Map of Mediterranean region, showing the location of study area (large box).

Turkish coast, and southeast of the Crimean Peninsula. The shelf-slope break occurs at ~100 m, and steep slopes, excluding the gentle slopes near the Danube and Kerch fans, lead to abyssal depth of ~2000 m. The continental slope is dissected by several submarine canyons (Ross et al., 1974), including the prominent canyons north of the Strait of Bosphorus, and those related to the mouths of major rivers such as the Danube, Dnieper, Dniester, Sakarya, and Kızılırmak. A broad bathymetric high, the Arkhangelsky (Yeşilırmak) Ridge, extends northward off the mouth of the Yeşilırmak River, and divides the Black Sea into western and eastern basins (Figure 1.2; Oğuz et al., 1991). The Danube fan is a prominent feature of the basin apron (200–2000 m depth), extending from the Romanian shelf into the abyssal depths (Oğuz and Beşiktepe, 1999). The center of the Black Sea basin is called the Euxine Abyssal Plain, which reaches a maximum depth of 2206 m.

1.1.2. Black Sea Oceanography

"The Black Sea is a 'miniature ocean' complete with intermediate layer ventilation and deepwater formation" (Murray, 1991). It has a two-layer system with a low density surface layer and a higher density deep layer.

1.1.2.1. River Input

Large rivers discharge into the Black Sea from the northwest, the Caucasus, and the coasts of Turkey, Bulgaria and Romania (Figure 1.3). They play an important role in the water balance. The total fresh-water discharge into the Black Sea ranges between 294

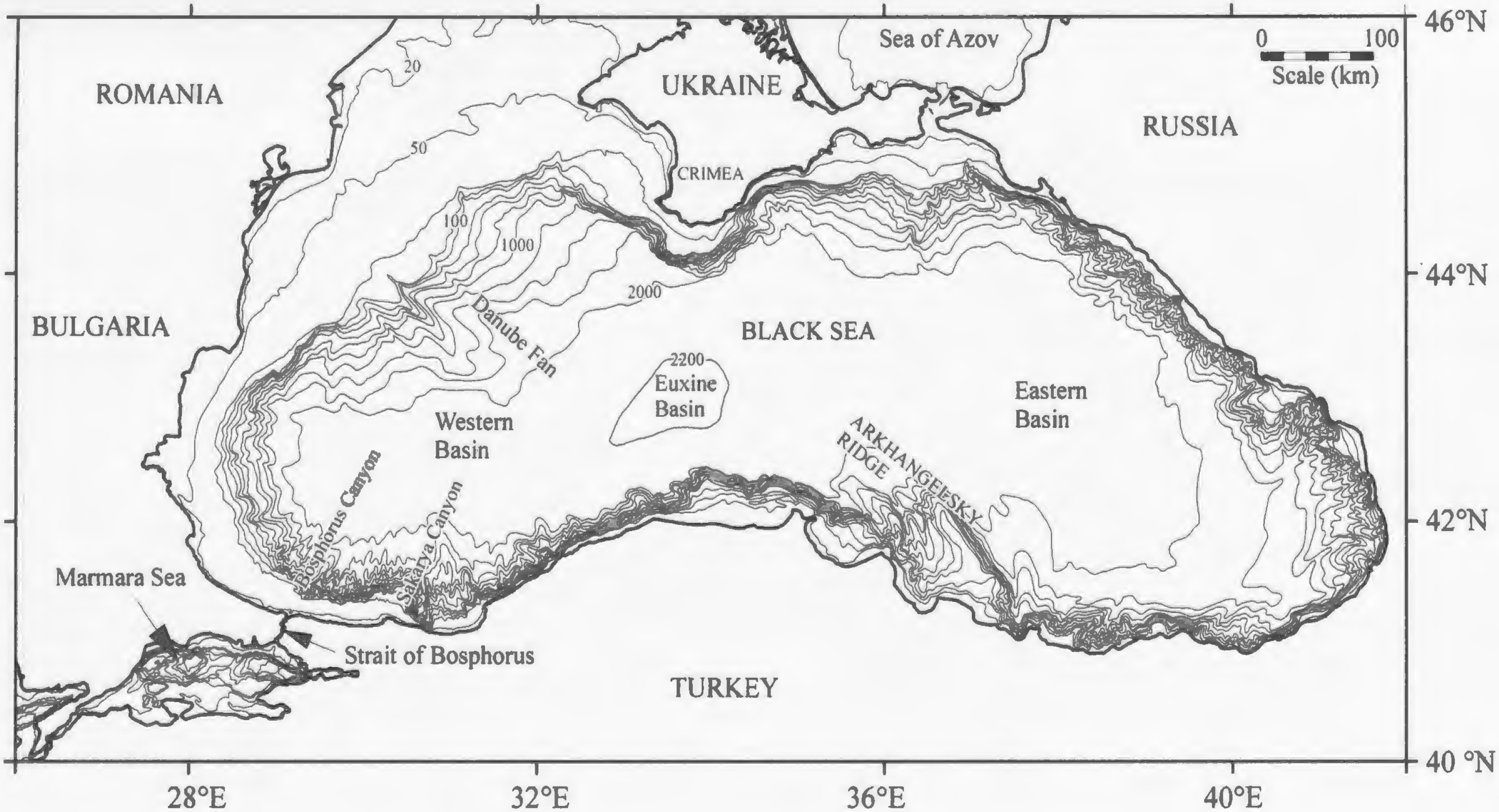


Figure 1.2. Bathymetry of the Black Sea basin. Depth contours are labelled in meters.

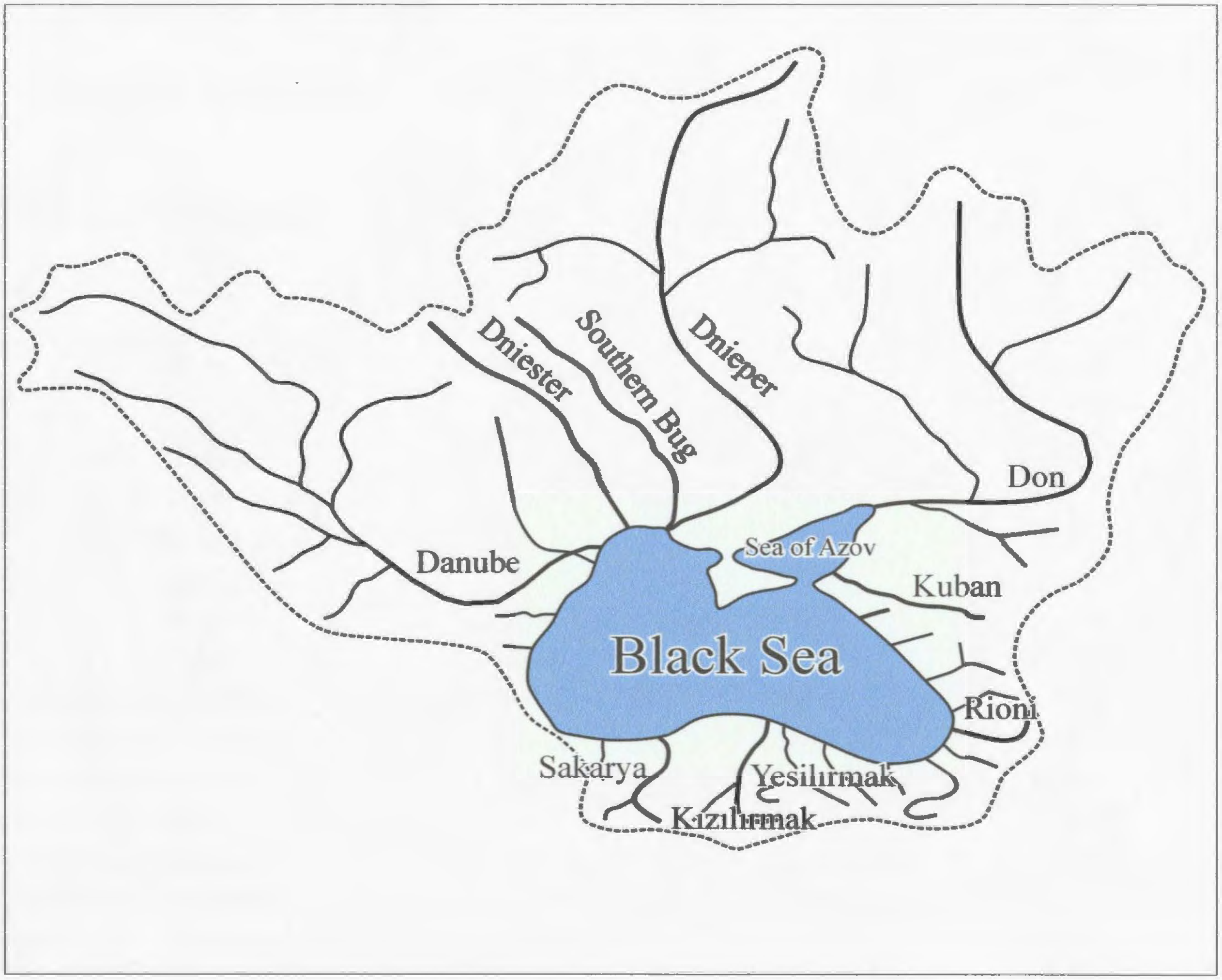


Figure 1.3. Large rivers discharging into the Black Sea, after Jaoshvili, 2002.

$km^3 year^{-1}$ and 474 $km^3 year^{-1}$ (Table 1.1; Jaoshvili, 2002). The largest discharges of freshwater into the Black Sea occur in April and May.

Table 1.1. The drainage area and annual discharge rates of major rivers draining to the Black Sea, from Jaoshvili (2002).

River	Drain area (km^2)	Mean annual discharge ($m^3 s^{-1}$)	Mean annual volume (km^3)
Mzymta (Russia)	885	49.50	1.562
Rioni (Georgia)	13400	119.00	3.773
Chorokhi (Georgia)	22100	276.00	8.710
Bzyb (Georgia)	1510	120.00	3.790
Kodori (Georgia)	2030	132.00	4.170
Inguri (Georgia)	4060	165.00	5.232
Yeşilırmak (Turkey)	36100	183.00	5.300
Kızılırmak (Turkey)	78600	184.00	5.900
Sakarya (Turkey)	56500	182.00	5.600
Filyos (Turkey)	13100	134.00	2.900
Veleka (Bulgaria)	995	9.41	0.025
Kamchea (Bulgaria)	5358	27.70	0.873
Danube (Romania-Ukraine)	817000	6300.00	200.000
Dniester (Ukraine)	72100	320.00	10.200
Southern Bug (Ukraine)	63700	69.00	2.200
Dnieper (Ukraine)	503000	1683.00	53.367

The biggest river entering the Black Sea basin is the Danube with a total annual discharge of 200 $km^3 year^{-1}$. In addition to the Danube, the Dniester (10.2 $km^3 year^{-1}$), the Rioni (13.37 $km^3 year^{-1}$), the Chorokhi (8.71 $km^3 year^{-1}$), and the Dnieper (53 $km^3 year^{-1}$) feed the Black Sea with a total volume of 285.2 $km^3 year^{-1}$. These rivers constitute ~72 % of the fresh water discharge into Black Sea; the remaining small rivers do not play an important role in the water balance.

1.1.2.2. Evaporation and Precipitation

Precipitation and evaporation over the water surface play an important role in the Black Sea water balance with an annual average of ~300 km^3year^{-1} (Table 1.2). Highest precipitation occurs during the winters. In general, the east and the southeast regions receive the largest amount of precipitation. All data indicate that evaporation significantly exceeds precipitation.

Table 1.2. Precipitation and evaporation values in the Black Sea from various authors (Jaoshvili, 2002).

Author	Atmospheric Precipitation (km^3year^{-1})	Evaporation (km^3year^{-1})
Leonov (1960)	230	365
Solyankin (1963)	129	332
Özturgut (1971)	300	353
Serpoianu (1973)	120	340
Fonselius (1974)	230	350
Bondar (1986)	119	332
Ünlüata (1990)	300	353
Altman (1991)	238	396
Reshetnikov (1992)	225	370

1.1.2.3. Water Masses

The surface water mass is 150–200 m thick and includes a surface mixed layer, a cold intermediate layer, and a permanent pycnocline-halocline-thermocline system at the lower boundary (Figure 1.4; Özsoy and Ünlüata, 1997). The surface mixed layer (0–30 m) has a salinity of ~17–18.5 ‰, but the salinity decreases to ~14 ‰ near the mouths of large rivers in the western Black Sea. In April, this surface mixed layer extends to ~40 m depth. By the end of June, the water mass becomes thinner (~10 m) and warmer (~21 °C)

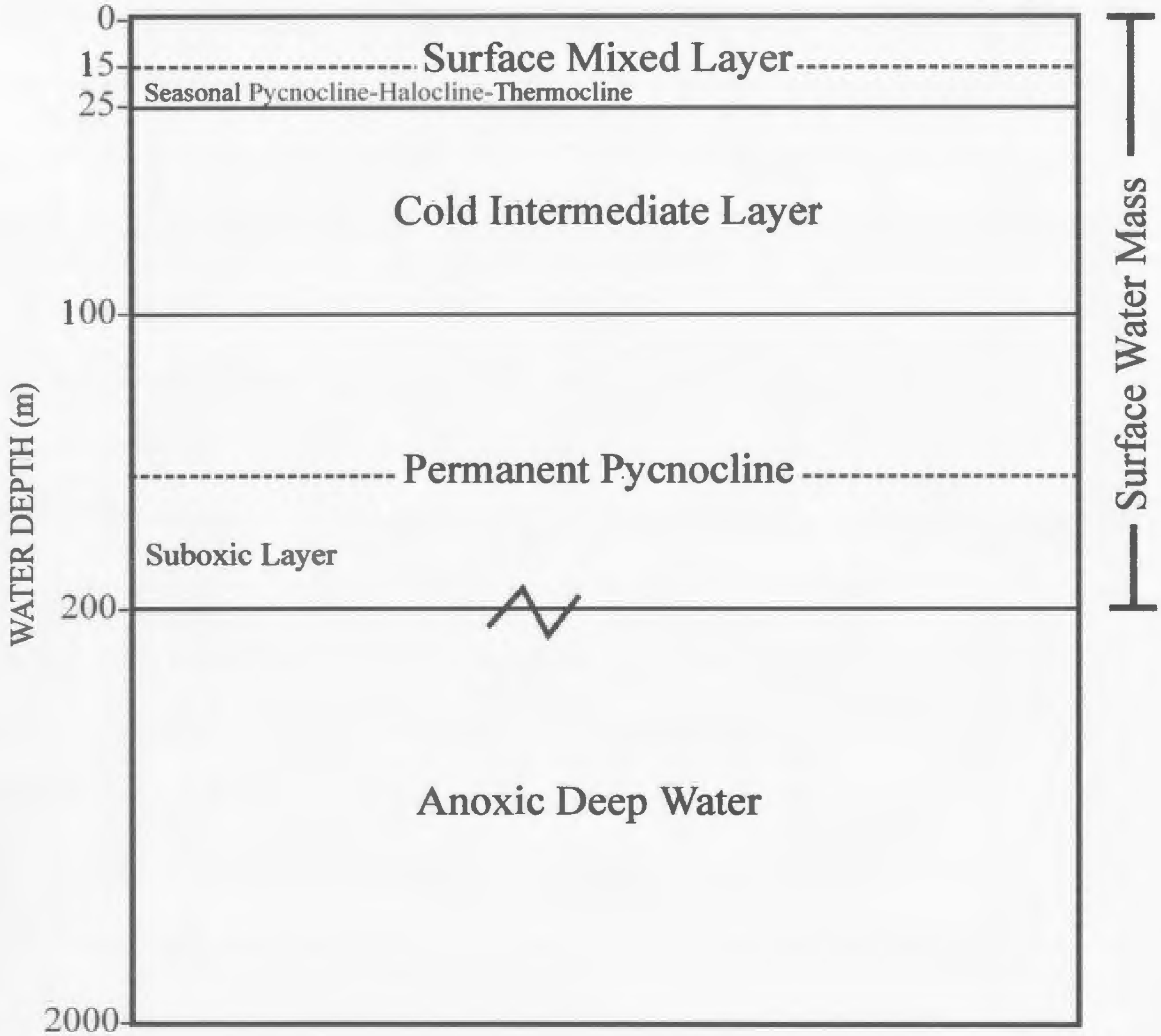


Figure 1.4. An overview of water masses in the Black Sea. Water depths are approximate values.

(Murray, 1991). In the winter, surface temperatures range between 0 °C and 8 °C, whereas in the summer temperature reaches 23 °C to 27 °C. A seasonal pycnocline 5 m thick occurs at ~15–25 m depth. In this zone, salinity increases downward from 17.9 ‰ to 18.3 ‰ and temperature decreases from ~22 °C to 10 °C (Oğuz and Beşiktepe, 1999).

The minimum temperature in the coastal areas occurs at ~50 m in the water column and in the basin it occurs deeper than 100 m (Beşiktepe et al., 2001). This relatively cold and oxygen-rich water is called the Cold Intermediate Layer. In winter, the Cold Intermediate Layer forms in the northwestern shelf area and in the centers of the cyclonic eddies (discussed below). The newly formed Cold Intermediate Layer extends from 25 m to 150 m and can be readily identified by its temperature of 6.5–7 °C in the western basin and ~7.5 °C in the eastern basin. In the spring and summer, this water mass spreads over the entire basin and becomes thinner (40–100 m thick) and warmer (8 °C) (Oğuz et al., 1991; Eremeev, 1995; Beşiktepe et al., 2001).

Below the Cold Intermediate Layer, a strong pycnocline separates the high-density bottom waters (σ_T=~17 kgm^{-3}) from the lower density upper waters (σ_T=~11 kgm^{-3}) (Beşiktepe et al., 2001), preventing vertical mixing and ventilation. At the base of the pycnocline a suboxic layer (a transition layer between the oxic and anoxic domains) occurs. The suboxic layer has a mean salinity of 20.8 ‰, temperature of 8.5 °C and corresponding density of σ_T=16.2 kgm^{-3}. It extends downward to a depth of 105–115 m within the central Black Sea Basin, 140 m within the Rim Current system, and ~190 m within the centers of the Batumi and Kaliakra Eddies (Figure 1.5; Oğuz and Beşiktepe, 1999). This layer is known for its very low concentration of both dissolved oxygen and low hydrogen sulphide. The suboxic layer is situated beneath the highly productive surface water and above the sulfidic subsurface waters (Oğuz et al., 2005). It acts as a "buffer layer" that confines highly efficient biological production and material recycling near the surface without much loss to the deep anoxic water mass. It also blocks the ascent of the highly concentrated sulfidic water mass.

Anoxic deep water lies below the Suboxic Layer. The variability of temperature and salinity in the waters from ~200–500 m depth is much smaller than in the near surface waters. Below 500 m, deep waters show no changes in these properties (Özsoy and Ünlüata, 1997). Below 1700 m, a bottom convection layer ~400 m thick has a uniform potential temperature of 8.8 °C and salinity of 22.32 ‰ (Özsoy and Ünlüata, 1997).

1.1.2.4. Water circulation

Surface circulation above the permanent pycnocline (~200 m) consists of a cyclonically meandering peripheral current system called the Rim Current or Main Black Sea Current (Figure 1.5). This counterclockwise-rotating peripheral Rim Current is dominated by a series of anticyclonic coastal eddies, such as the Crimea Eddy, Sevastopol Eddy, Kaliakra Eddy, Bosphorus Eddy, Sakarya Eddy, Sinop Eddy, Kızılırmak Eddy, Batumi Eddy, Caucasus Eddy, and two cyclonic eddies over the eastern and western parts of the basin. During the summer, the circulation is dominated by the central cyclonic eddies, whereas during the winter the Rim Current becomes stronger and

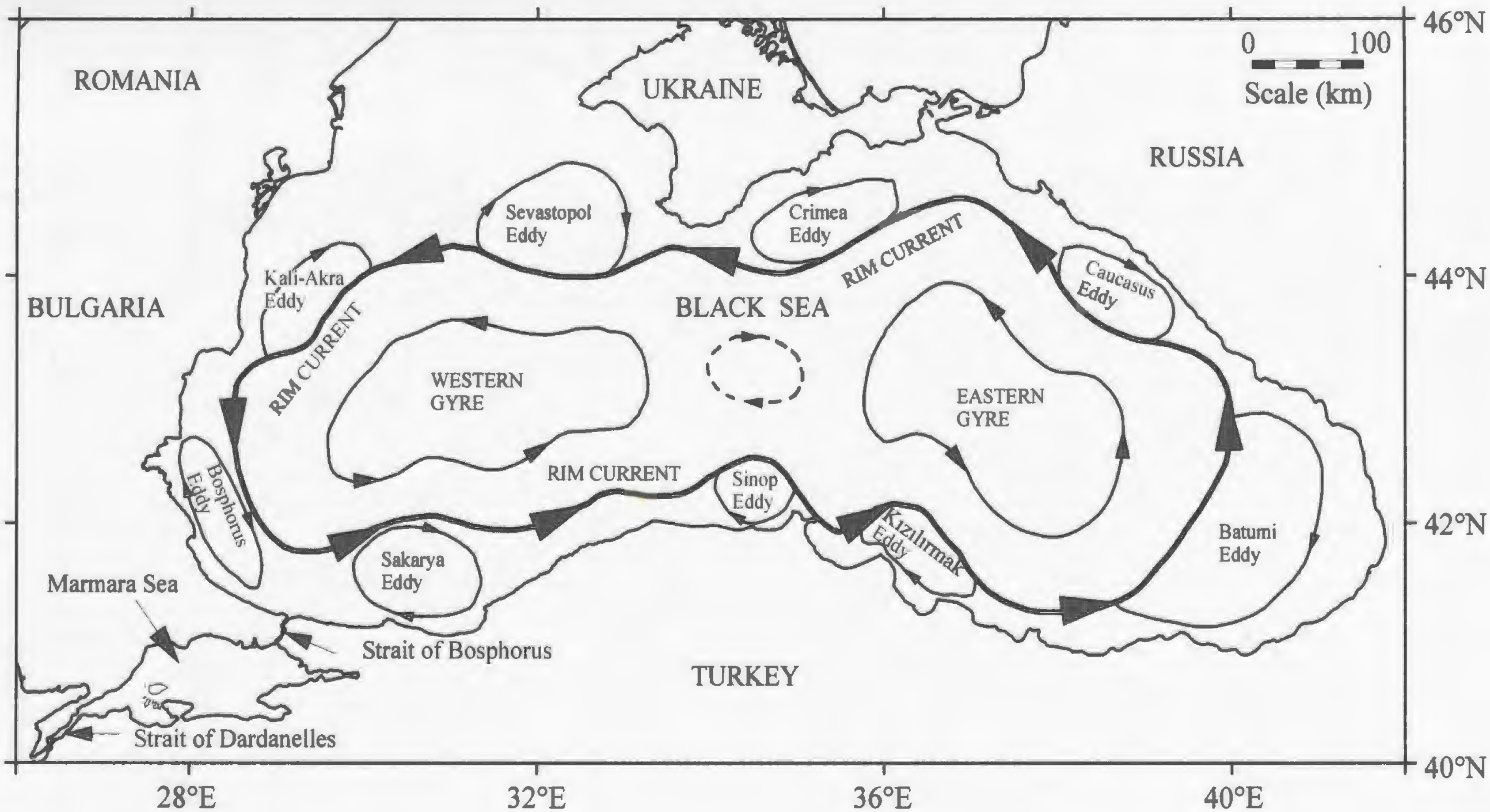


Figure 1.5. The surface water circulation of the Black Sea, from Oğuz et al, (1993).

the anticyclonic coastal eddies weaker (Oğuz et al., 1991). The Rim Current separates the coastal zone from the central basin (Oğuz et al., 1993). In the summer, salinity variations control the thermohaline structure; in the winter, temperature effects dominate and are associated with the formation of a cold-water mass toward the northwest (Oğuz and Beşiktepe, 1999).

The intensity of the Rim Current below the permanent pycnocline (>200 m) is reduced considerably as the current weakens and decelerates. However, the anticyclonic eddies along the Turkish coast and the Caucasus and Crimea eddies become more pronounced at these depths. Below 400 m along the upper slope the Rim Current gives way to the weaker and narrower Mid-Basin Current.

1.1.3. Marmara Sea Bathymetry

The Marmara Sea is a small (~11500 km^2) enclosed sea lying between the Black Sea and the Aegean Sea (Figure 1.6). It is bordered to the south by an ~30 km-wide and shallow (~100 m) shelf, and to the north by a narrower (5–10 km) shelf. The shelf break occurs at ~100 m. The southern slope has an average gradient of ~7°–9°, except ~15°–20° just beyond the shelf edge. The northern slope is very steep, ~6°–10°, and the grade reaching ~30° at the top of the slope (Aksu et al., 1999). Three 1000–1300 m-deep basins are separated by two 800–400 m-deep saddles. These basins create the east-west-trending Marmara Trough. The easternmost Çınarcık Basin is also referred to as the Istanbul Basin (Ergin and Bodur, 1999) and has a maximum depth of 1240 m. The westernmost Tekirdağ Basin and Central Marmara Basin have maximum depths of 1097

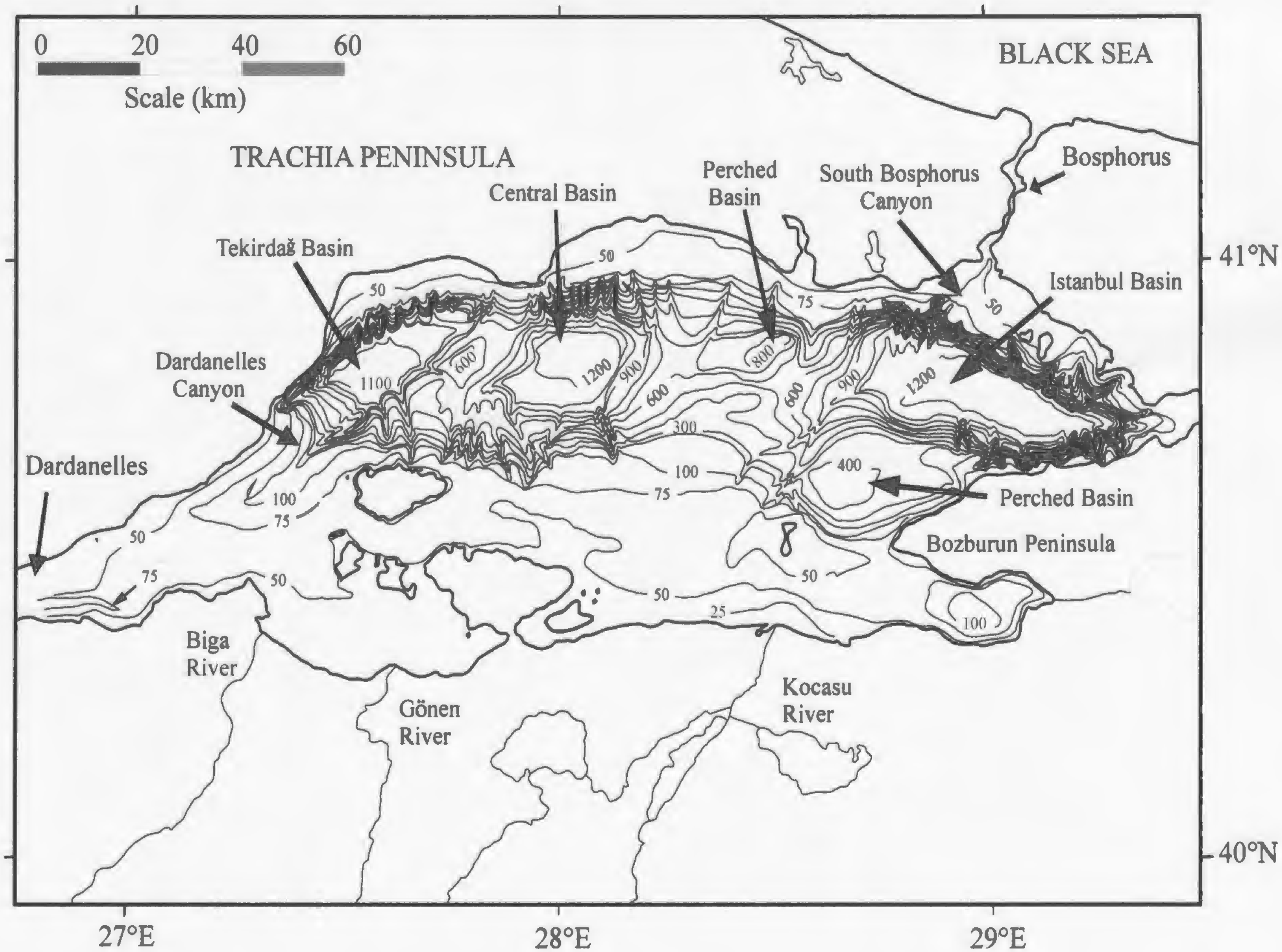


Figure 1.6. Bathymetry of the Marmara Sea basin, from Aksu et al. (1999). Depth contours are in meters.

m and 1389 m, respectively, are elongate, southwest-trending rhombohedral depressions (Aksu et al., 2000). A ~800 m-deep shallow basin is perched on the broad eastern ridge, whereas a ~400 m-deep crescent-shaped depression is perched high on the southern slope of the Çınarcık Basin (Aksu et al., 2000). The Çınarcık Basin and this 400 m-deep perched basin are separated by a west-trending ridge ~100 m shallower than floor of the shallow perched basin (Aksu et al., 2000).

Two canyons, the Dardanelles Canyon and South Bosphorus Canyon, extend basinward from the straits of Dardanelles and Bosphorus, respectively (Figure 1.6). The Dardanelles Canyon extends to a depth of 1000 m. The head of the canyon lies at ~80 m depth and the canyon broadens eastward. The South Bosphorus Canyon heads in ~100 m of water off the southern exit of the Bosphorus Strait and extends to 1000 m depth (Figure 1.6).

1.1.4. Marmara Sea Oceanography

1.1.4.1. River Input

The volume of river discharge from the north is minor (Ergin et al., 1997). To the south, three small rivers enter the Marmara Sea of which the Kocasu (or Simav) River is the largest. The Biga and Gönen Rivers are of secondary importance (Figure 1.6; Table 1.3).

Table 1.3. The drainage area and annual discharge rates of major rivers draining to the Marmara Sea, from Ergin et al. (1991).

Rivers	Drain area (km^2)	Mean annual discharge (m^3s^{-1})	Mean annual volume (km^3)
Simav	21611.2	171	5.422
Biga	2095.6	3.4	0.107
Gönen	1192.8	5.6	0.177

1.1.4.2. Water Masses

A permanent two-layer water flow characterizes the hydrography of the Marmara Sea: (1) a surface outflow from the Black Sea toward the Aegean Sea via the straits, and (2) a reverse subsurface inflow from the Aegean Sea to the Black Sea via the straits (Ergin and Bodur, 1999). Surface and subsurface water masses are separated by a permanent pycnocline at a depth of ~50 m at the southern end of the Strait of Bosphorus and ~10 m at the eastern end of the Strait of Dardanelles, with a depth of 20–25 m within the Marmara Sea. The surface water mass shows the seasonal characteristics of Black Sea water (Beşiktepe et al., 1994). The surface Black Sea water entering the Marmara Sea has a salinity of 19–21 ‰, which increases to 22–25 ‰ by the time the water mass reaches the Dardanelles entrance (Beşiktepe et al., 1994). In winter, surface salinity reaches a maximum value of ~27 ‰, owing to increased wind mixing in the Marmara Sea and a reduction in the influx from the Black Sea. The salinity values decrease during the summer when the inflow of brackish water from the Black Sea increases. Winter surface temperatures range from 7–15 °C, increasing to 22–25 °C in the summer (Beşiktepe et al., 1994).

Cold Intermediate Water forms in the spring at the halocline. The upper 15 m-thick layer becomes warmer than below 15 m because of solar warming. Cold Intermediate Water is identified by its constant temperature of 8 °C throughout the year (Beşiktepe et al., 1994).

The bottom water mass of the Marmara Sea is supplied by inflow of Aegean Sea water via the Dardanelles Strait. This water mass can be distinguished by its high salinity (~38.6 ‰) and high temperature (14–15 °C) at water depths greater than 150 m. The distribution of the bottom water of the Marmara Sea is determined by the bottom topography (Beşiktepe et al., 1994).

1.1.4.3. Water Circulation

The overall water circulation of the Marmara Sea is mostly driven by prevailing winds and by the seasonal variations of the Black Sea surface-water inflow from the Bosphorus Strait. The prevailing circulation in the Marmara Sea is a jet flow from the Bosphorus flowing southwards to the Bozburun Peninsula (Figure 1.7a). This flow turns west and then northwest, defining an anticyclonic eddy attached to the Trachian coast (Figure 1.7a). From the Trachian coast the surface flow follows the northwestern coastline and exits through the Dardanelles Strait (Figure 1.7a; Beşiktepe et al., 1994). At the beginning of autumn, the anticyclonic circulation becomes strong and moves to the west. In autumn, summer circulation changes significantly to a winter pattern that lasts until the early spring because of a change in the prevailing winds. There is a cyclonic eddy in the eastern basin and an anticyclonic eddy in the central basin (Beşiktepe et al., 1994).

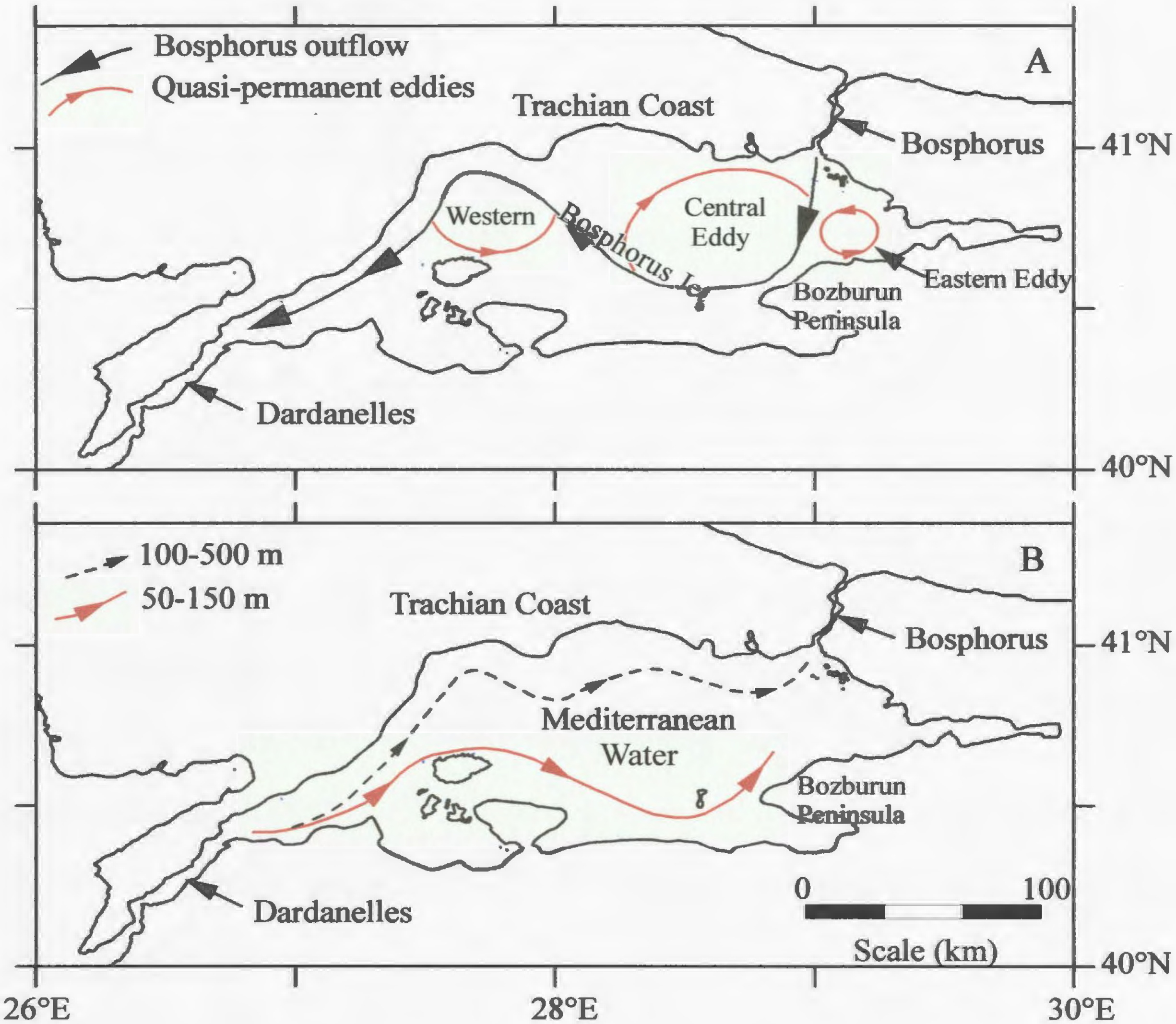


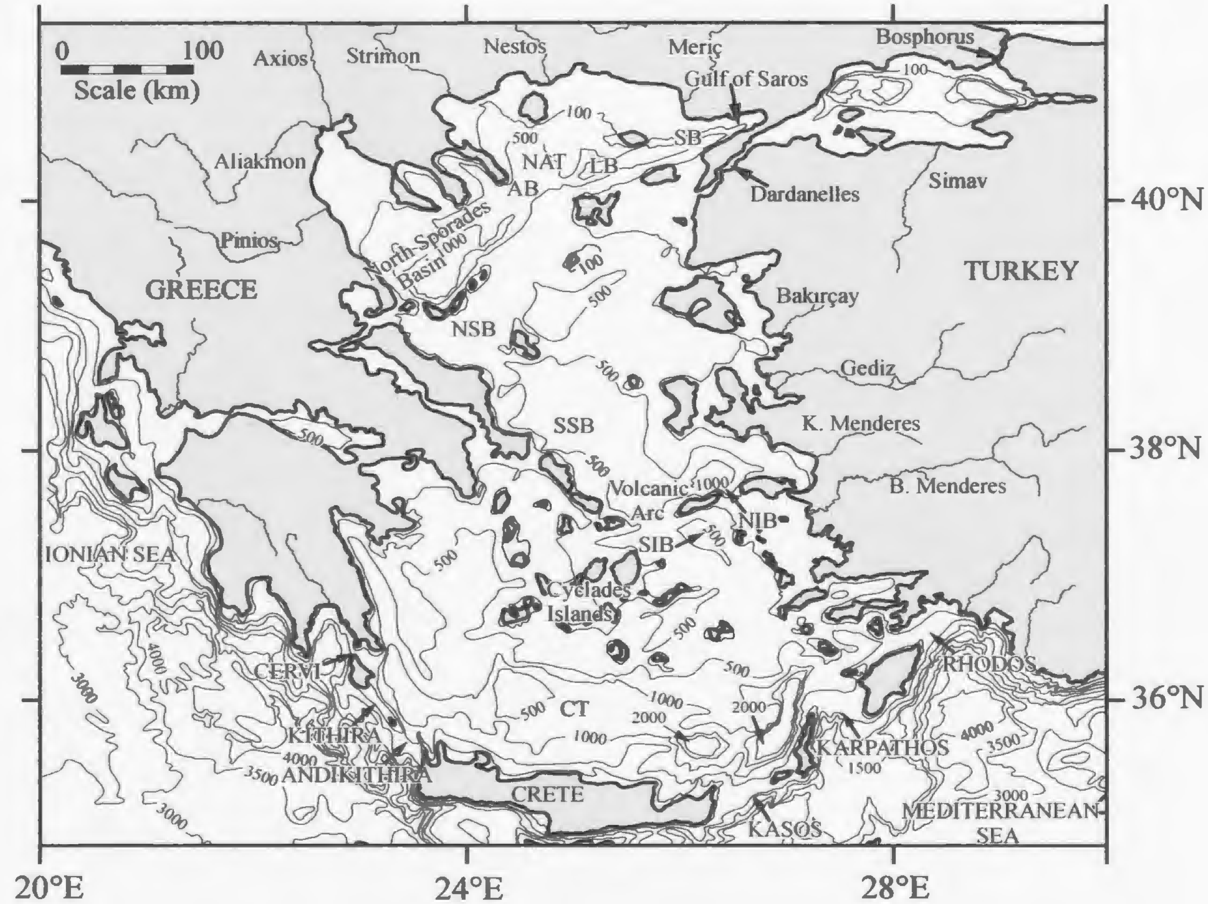
Figure 1.7. The overall water circulation of the Marmara Sea: (A) upper layer; (B) bottom layer after, Besiktepe et al. (1994).

Denser Mediterranean waters enter the Marmara Sea through the Dardanelles Strait and form the bottom water in the Marmara Sea. The bottom water flows eastward, following the bottom topography (Figure 1.7b; Beşiktepe et al., 1994), then travels northeast across the Strait of Bosphorus and penetrates into the Black Sea.

1.1.5. Aegean Sea Bathymetry

The Aegean Sea is one of the major basins of the Eastern Mediterranean and is situated between Turkey and Greece (Figure 1.8). It is connected to the Marmara Sea via the Dardanelles Strait in the northeast, to the Mediterranean Sea by the Rhodos, Karpathos, and Kasos straits, and to the Ionian Sea by the Cervi, Kithira, and Andikithira straits. It has a surface area of ~200 000 km^2 which is approximately 10 % of the whole Mediterranean Sea (Yüce, 1992). An arcuate volcanic arc at latitude of 37°–38° N divides the Aegean Sea into two physiographic provinces: the North Aegean Basin and the South Aegean Basin. The deepest area (~2500 m) is located in the Southern Aegean Basin whereas in the Northern Aegean Basin the deepest areas are 1200 m and 1400 m. The mean water depth is ~362 m, and ~33.6 % of the Aegean Basin is <200 m deep (Yaşar, 1994; Figure 1.8).

The Northern Aegean Basin is composed of the North Aegean Trough, the North Skiros Basin (~500 m deep), the South Skiros Basin, and the North Ikaria Basin (Figure 1.8). A <200 m-deep shelf encircles it. The widest part of the shelf is located at the exit of the Strait of Dardanelles around the islands of Limnos, Gökçeada, and Bozcaada. This shelf is dissected by the North Aegean Trough, which extends from the Gulf of Saros to



NAT: North Aegean Trough
NSB: North Skiros Basin
SIB: South Ikaria Basin
SSB: South Skiros Basin
NIB: North Ikaria Basin
CT: Crete Trough

AB: Athos Basin
LB: Lemnos Basin
SB: Saros Basin

Figure 1.8. Bathymetry of the Aegean Basin. Depth contours are labelled in meters.

the Greek coastline. Four sub-basins are located along the North Aegean Trough including the North Sporades (~1470 m deep), Athos (~1150 m deep), Lemnos (~1550 m deep), and Saros basins. These sub-basins are separated from each other by sills at depths of ~500 m (Zervakis and Georgopoulos, 2002). The deepest part of the North Aegean Trough (North Sporades Basin) is situated at the western end of the trough.

The South Ikaria Basin and the Cretan Trough comprise the Southern Aegean Basin. The South Ikaria Basin is situated on the Aegean Volcanic Arc. To its east is a wide <200 m-deep shelf, and to its west the Cyclades Islands. The Cretan Trough is situated between the Cyclades Islands and Crete. It is generally ~1000 m deep but has two deep basins to the east, both deeper than 2000 m (Figure 1.8).

The Aegean Sea Basin is surrounded by narrow (1–10 km) and broad (25–95 km) continental shelves. Narrow shelves leading to steep 1:20 slopes are generally found in the west and around islands. Broad shelves are generally found to the east and north, especially seaward of major deltas (Figure 1.8).

1.1.6. Aegean Sea Oceanography

1.1.6.1. River input

Several rivers drain into the Aegean Sea mostly from the east and north (Figure 1.8, Table 1.4). River discharges show seasonal variations: rivers from Greece show maximum discharge from December to April, whereas rivers from Turkey show maximum discharge between October and March (Poulos et al., 1997).

Table 1.4. Drainage areas and annual discharge rates of major rivers draining into the Aegean Sea, from Yaşar (1994).

Rivers	Drainage area (km^2)	Mean annual discharge (m^3s^{-1})	Mean annual volume (km^3)
Bakırçay (Turkey)	2888	19.8	0.624
Gediz (Turkey)	15617	85.1	2.684
Küçük Menderes (Turkey)	3255	25.8	0.814
Büyük Menderes (Turkey)	23889	154.5	4.872
Meriç (Turkey)	45374	298.8	9.423
Strimon (Greece)	10937	110.0	3.440
Axios (Greece)	22450	159.0	5.031
Aliakmon (Greece)	6075	73.0	2.292
Pinios (Greece)	7081	81.0	2.529
Sperchios (Greece)	1158	62.0	1.966

1.1.6.2. Precipitation and Evaporation

The water budget in the Aegean Sea is mostly driven by the outflow from the Dardanelles (300 km^3yr^{-1}, Ünlüata et al., 1990) in the north, precipitation (400–700 mm yr^{-1}; Poulos et al., 1997), and evaporation (~1460 mm yr; Poulos et al., 1997). Rainfall is more pronounced over the eastern part with its 65–75 % relative humidity (Poulos et al., 1997). Evaporation is at a minimum (730 mm yr^{-1}) in late spring and autumn, but at a maximum (1825–2555 mm yr^{-1}) in February and July/August (Poulos et al., 1997). The maximum and minimum values of evaporation rate are related to seasonal variations in the prevailing winds and to air-sea temperature differences (Jakovides et al., 1989).

1.1.6.3. Water Masses

Three different water masses occupy the Aegean Sea: surface, intermediate, and bottom. The surface water mass in the north originates in the Black Sea and forms a 40–50 m-thick layer in the Northern Aegean Sea. The surface water mass in the south originates in the Mediterranean Sea and forms a <50 m-thick layer in the Southern Aegean Sea. During the winter, surface water temperatures range between 10 ˚C in the north and 16 ˚C in the south. During the summer, surface temperatures range from 20 ˚C in the north to 25.5 ˚C in the south (Yüce, 1991). Salinity distribution in the surface water has a similar gradient to surface temperature because of the Black Sea inflow. Summer salinity values range from 27 ‰ in the northeast and 30 ‰ in the northwest, to 39 ‰ in the south. Winter salinity values range from 36 ‰ in the north to 39 ‰ in the south (Yüce, 1991).

The Aegean Sea Intermediate Water originates in the Levantine Sea Intermediate Water and occupies water depths between ~50 m and 200–300 m (Zervakis and Georgopoulos, 2002). The temperature difference from north to south is less marked than for the surface water mass. During the winter, intermediate water temperatures range from 11˚C in the north to 16 ˚C in the south, and during the summer they range from 15 ˚C in the north to 18 ˚C in the south. Salinity values of this water mass have small seasonal variations, ranging from 39 ‰ to 39.1 ‰ (Yaşar, 1994). In the Gulf of Saros there is a maximum salinity of ~38 ‰ at a depth of 250–350 m (Yüce, 1991).

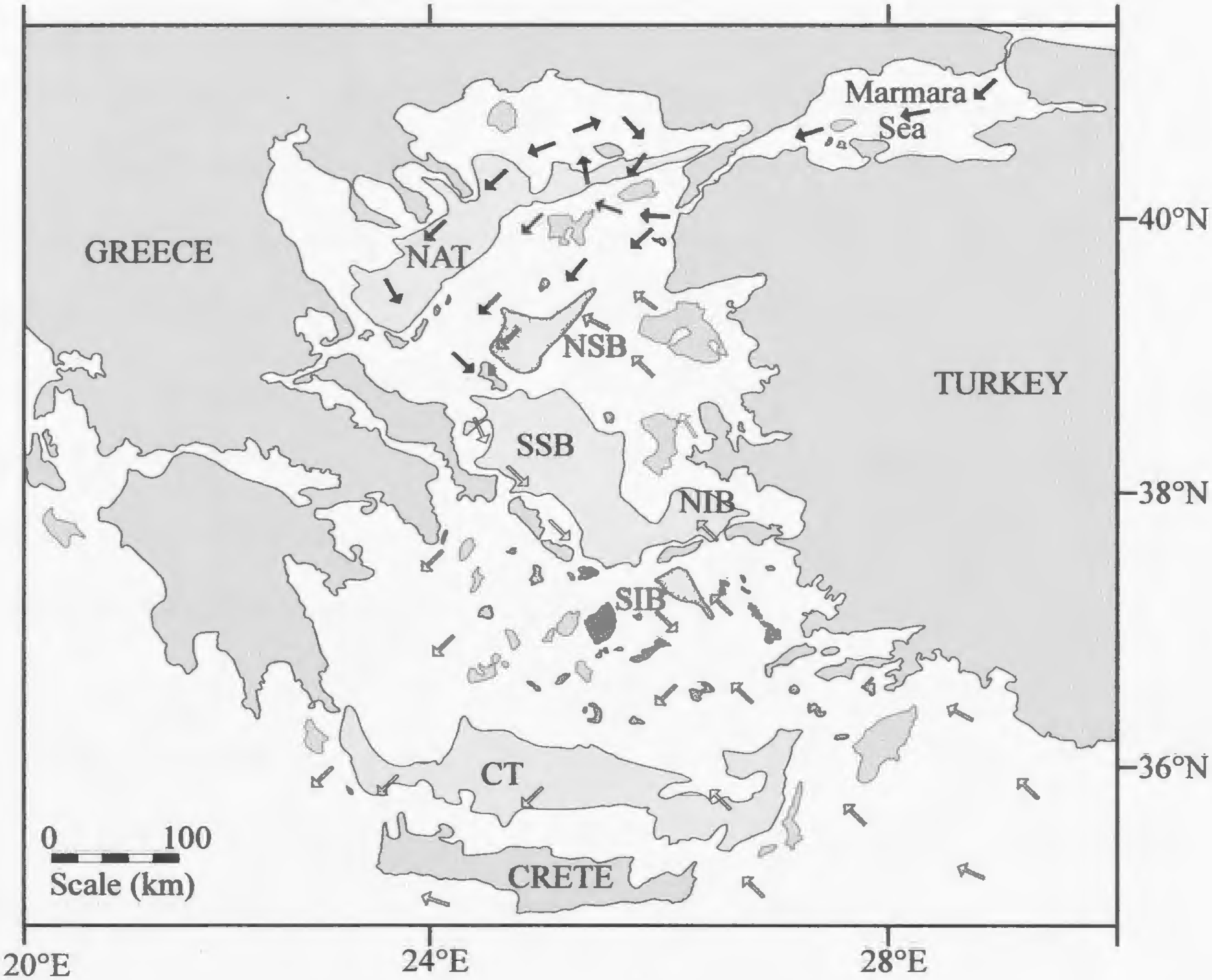
The Aegean Sea Bottom Water is found in water depths >300 m. This water mass exhibits nearly constant salinity and temperature and shows very little seasonal variation.

Salinity ranges between 38.7 ‰ and 39 ‰ and temperature range between 12.70 ˚C and 14.6 ˚C (Yüce, 1992).

1.1.6.4. Water Circulation

Water circulation in the Aegean Sea is driven by the inflow from the Black Sea, river discharge, meteorological conditions (mostly prevailing winds), bottom topography, and the geographical distribution of island chains (Poulos et al., 1997).

The most pronounced characteristic of the circulation in the North Aegean Sea is the spreading of the Black Sea water (Poulos et al., 1997). In general, the brackish surface water leaving the Strait of Dardanelles follows a cyclonic (counterclockwise) path towards the southwest and south (Figure 1.9). In summer, after entering the Aegean Sea, one branch of the Black Sea water flows anticyclonically to the north and joins an anticyclone to the northeast (Zervakis and Georgopoulos, 2002; Figure 1.9). In winter, surface waters are divided into two branches: one flows north and circulates in the northeast as an anticyclone, and the other moves southwest forming a cyclonic gyre in the south. Poulos et al. (1997) noted that the southerly flow of surface waters in summer is driven by northerly winds, called Etesian winds, which also generate coastal upwelling along the Turkish coast and downwelling along the Greek coast. In the southern part of the Aegean Sea, summer circulation is mostly an east - northeast movement of



NAT: North Aegean Trough
NSB: North Skiros Basin
SIB: South Ikaria Basin
SSB: South Skiros Basin
NIB: North Ikaria Basin
CT: Crete Trough

Low salinity Black Sea water
High salinity Mediterranean water
Land area
Basins

Figure 1.9. Present-day sea surface water circulation in the Aegean Sea.

Mediterranean Water (Poulos et al., 1997). In winter, two small cyclonic gyres are active in the southern Aegean, fed by inflow from the Levantine Sea.

The circulation of the bottom water mass is predominantly a cyclonic gyre. Zervakis and Georgopoulos (2002) suggested that, in May a tongue of water with salinity 38.6 ‰ from the northwest traces a cyclonic route, although in September this circulation is reversed. The overall cyclonic circulation brings the saline Mediterranean water to the north where it is diluted by mixing with low salinity waters from the Dardanelles. Thus, the subsurface water returning towards the south has a lower salinity than the Mediterranean inflow (Zervakis and Georgopoulos, 2002).

1.2. Water Exchange Between the Aegean Sea and the Black Sea

The Marmara Sea Gateway regulates the water exchange between the Aegean Sea and the Black Sea (Ünlüata et al., 1990). Low salinity water (~18 ‰) from the Black Sea moves to the Mediterranean as a surface current; conversely, the more saline (~40 ‰) Mediterranean water flows into the Marmara and the Black seas as an undercurrent.

1.2.1. Physiography and Physical Oceanography of the Straits

1.2.1.1. Bathymetry of the Straits

The Bosphorus Strait is 31 km long and 0.7–1.3 km wide, with a mean depth of 35 m (Ünlüata et. al, 1990). There are two sills: one is located ~4 km north of the northern exit at a depth of 59 m, and the other is located ~3 km north of the southern exit at a depth of 35 m (Ünlüata et al., 1990, Algan et al., 2001).

The Strait of Dardanelles is 62 km long with widths varying from 1.3–7 km. The strait extends into the Marmara Sea, creating the Dardanelles Canyon, which reaches ~1000 m water depth (Ünlüata et al., 1990). Although the average depth is 55 m and the maximum depth is 100 m, several 60–70 m-deep sills are present in the Strait of Dardanelles.

1.2.1.2. Water Exchange

Water exchange through the Straits of Bosphorus and Dardanelles is partly driven by the density difference between the low density (σ_T= 14–18; Beşiktepe et al., 1994) Black Sea and the high density (σ_T= 29–29.5; Beşiktepe, 2003) Aegean Sea. Based on data from Beşiktepe et al. (1994), satellite altimetry shows that the mean sea-level drop from the Black Sea to the Marmara Sea is 30 cm with smaller seasonal differences (±10 cm), and from the Marmara Sea to the Aegean Sea the drop is a minimum of 5 cm in October and a maximum of 17 cm in June. This sea-level difference is the second main cause of water exchange.

The relatively dense Aegean Sea water enters the Strait of Dardanelles below a depth of 15–25 m (Figure 1.10). It continues to flow at ~30 cm s^{-1} by following the bottom topography without much change in water characteristics. The Aegean waters enter the Dardanelles Canyon at the entrance of the Marmara Sea and follow the canyon axis before spreading horizontally into the Marmara Sea subsurface waters (Ünlüata et al., 1990), finally joining the bottom water circulation of the Marmara Sea. In the northeastern Marmara Sea, the bottom waters follow the topography of the South

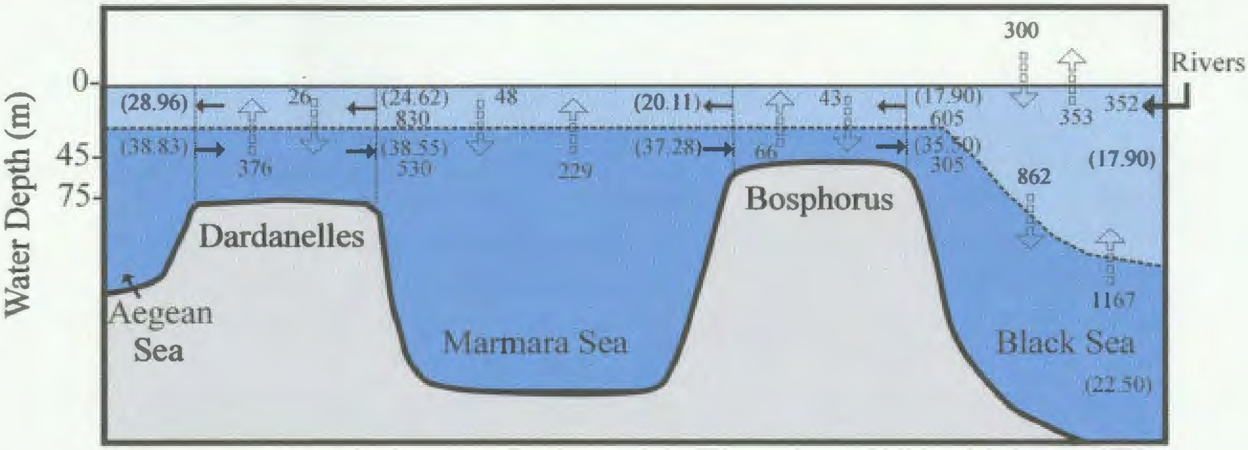


Figure 1.10. Water circulation across the Marmara Sea Gateway, after Özsoy et al. (1995). Flow directions and water exchange are shown with arrows; average salinity values are in parentheses; mean annual volume fluxes are given in units of km^3/yr and salinity in units of ppt.

Bosphorus Canyon and enter the Strait of Bosphorus. The ~30 m southern sill does not prevent the entrance of Aegean water because the top of this water mass occurs at ~20 m depth (Yüce, 1991). The bottom water in the Strait of Bosphorus flows at a speed of ~40 cm/s in the south, decreasing to ~20 cm/s towards the north (Ünlüata et al., 1990). After crossing the Strait of Bosphorus, the Aegean waters enter the contiguous shelf-crossing channel north of the Strait of Bosphorus, flow 8 km towards the northeast, turn northwest across the shelf break, and eventually join the Black Sea deep water (Yüce, 1991).

The low density Black Sea water enters the Bosphorus Strait as a surface outflow. The low salinity (~17 ‰) surface layer within the confines of the strait increases its salinity to ~19 ‰ at the southern exit. The upper layer average current speed is 50 cm s^{-1} in the north and 20 cm s^{-1} in the south of the Strait of Bosphorus (Ünlüata et al., 1990). This strong outflow enters the Marmara Sea as a thin surface jet, which bifurcates and circulates within the surface layer of the Marmara Sea (Ünlüata et al., 1990). The surface layer salinity has increased by nearly 6 ‰ by the time it enters the Dardanelles Strait with 25 ‰ salinity. By the time this water reaches the Aegean Sea, it has an even higher salinity of ~29 ‰ (Ünlüata et al., 1990).

1.3. Biological Oceanography of the Study Area

The Marmara Sea Gateway plays an important role in the biology of the Black Sea and the Aegean Sea. It is a transitional zone and it constitutes either a barrier, a corridor or an acclimatization zone for different organisms (Zaitsev et al., 2002). The Strait of Dardanelles serves as a barrier between the Aegean Sea and the Marmara Sea and the Strait of Bosphorus as a barrier between the Marmara Sea and the Black Sea. For instance, a Mediterranean endemic seagrass, *Posidonia oceanica*, is limited by the Dardanelles Strait. Some Mediterranean zooplankton and phytoplankton species penetrate through the Marmara Sea Gateway into the Black Sea. In contrast, several endemic elements of the Black Sea zooplankton are also found in the Aegean Sea. The Bosphorus Strait also acts as an acclimatization zone for some Mediterranean species, such as decapod crustaceans, anthozoans and sponges that expand their distribution to the

Black Sea via the Bosphorus Strait thus, they are gradually acclimatized to the environmental conditions of the Black Sea (Öztürk and Öztürk, 1996).

1.3.1. The Black Sea

Because of its high degree of isolation from the world ocean, its depth (maximum 2212 m), its large catchment area and the large number of discharging rivers, nearly 87 % of the Black Sea volume is entirely anoxic and contains high levels of hydrogen sulphide (Zaitsev et al., 2002). Thus, deep pelagic and benthic organisms are largely absent in the Black Sea.

The number of species in the Black Sea is around one third of that found in the Mediterranean Sea. However, the total biomass, abundance and productivity of the Black Sea are much higher than in the Mediterranean Sea (Zaitsev et al., 2002). This difference is explained by the eutrophic characteristics of the Black Sea, mainly from anthropogenic influence (Siokou-Frangou et al., 2004). The greatest part of the Black Sea coastal waters and continental shelf are eutrophic, the central part is mesotrophic and the northwestern part, which is influenced by inflow from large rivers (Danube, Dniester and Dnieper), is hypertrophic (Zaitsev et al., 2002).

The phytoplankton, as primary producers, have an important place in the Black Sea ecosystem. Their abundance and biomass increase with increasing nutrient concentrations. Thus, in the Black Sea, phytoplankton become the first target of anthropogenically-induced stress, resulting in alterations in species composition, abundance and biomass (Moncheva et al., 2001). The dominant species at the surface are dinoflagellates in March-April and diatoms and coccolithophores in October (Eker et al., 1999). The Black Sea shows two phytoplankton blooms, one during winter-early spring, the other during autumn. Phytoplankton abundance is on annual average around 7 million individuals/litre but in cases of phytoplankton blooms may reach extreme values of 800 million individuals/litre (Zaitsev et al., 2002). Abundance and biomass of phytoplankton at the surface in spring are higher in the western Black Sea than in the eastern region due to the outflow of large rivers from the northwestern Black Sea (Eker et al., 1999).

The zooplankton community of the Black Sea is influenced by seasonal dynamics that control the species assemblage, and the biology and seasonal variability of its component organisms (Siokou-Frangou et al., 2004). In coastal waters, cold-water copepods and some eurythermal species are dominant in winter, and in late spring-early summer meroplankton such as the larvae of some bivalves, polychaetes and gastropods are dominant. The community structure of the Black Sea offshore waters is dominated by some copepod species and some cladoceran species. During the annual cycle, there are two peaks of zooplankton abundance and biomass. The first occurs in spring following the phytoplankton bloom, and the second towards the end of summer-early autumn resulting from the bloom of warm-water species during summer (Siokou-Frangou et al., 2004). Maximal concentrations of zooplankton are found in the coastal waters of the northwestern part of the Black Sea and the average biomass falls from west to east (Zaitsev et al., 2002).

The macrophytobenthic community of the Black Sea is mostly represented by red algae, (e.g. *Phyllophora*), brown algae, (e.g. *Cystoseira*), and the sea grass *Zostera* (Zaitsev et al., 2002). During the last three decades, increasing eutrophication has considerably changed the ecology of the Black Sea (Bologa et al., 1995). The most diverse group, red algae, was extensive in shallow waters up to 60 m depth and was an important source of oxygen. After habitat destruction due to human activity, especially in the northwest Black Sea, the area covered by eelgrass (*Zostera*) has decreased tenfold and the *Phyllophora* habitat has declined from 10,000 km^2 to 50 km^2 (Bologa et al., 1995; Zaitsev et al., 2002). The present day benthic flora is dominated by several species of *Enteromorpha* and the red alga *Ceramium* (Bologa et al., 1995).

The Black Sea zoobenthos is composed of 29–35 % Mollusca, 25–33 % Polychaets, ~27 % Crustacea and only four species of Echinodermata (Zenetos et al., 2000). The composition of the zoobenthos in the Black Sea has changed during recent decades because of very intense algal blooms, that leave large amounts of decaying organic material in the water column and trigger an oxygen shortage. This has resulted in the gradual decrease in biodiversity, mainly affecting the benthos (Bologa et al., 1995). For example, some mollusc species such as *Corbula mediterranea* and *Hydrobia ventrosa,* which accounted for 96 % of the benthic biomass in the fine sands biocoenosis, are about to disappear (Bologa et al., 1995). The populations of *Mytilus galloprovincialis* and *Modiolus phaseolius* have also decreased, but they still form an important part of the silt biocoenosis. However, some opportunistic species such as *Mya arenaria* and

Scapharca inaequivalvis have increased in diversity and become dominant (Bologa et al., 1995).

As a result of increasing hydrogen sulfide concentration and anoxia under the thermocline, the number of macrobenthic species decreases rapidly with increasing depth. The only macrobenthic species found below 120 m is the polychaete worm *Notomastus profundus* (Zaitsev et al., 2002). Because of decreasing oxygen content with increasing depth along the Turkish coast of the Black Sea, the larvae of aerobic benthic organisms tend to settle to the seabed only in depths less than 70 m (Mutlu et al., 1993).

1.3.2. The Marmara Sea

The Marmara Sea forms a transition between the Black Sea and the Aegean Sea. Thus, its biological properties as well as its oceanographic properties are influenced by the two neighboring seas (Ergin et al., 1993b). The oxygen-rich (~9 ml l^{-1} O_2) waters from the Aegean Sea enter the Marmara Sea below 20–30 m. Because of the oxygen demand of the vertically sinking organic matter, the Marmara Sea deep water loses a large proportion of its oxygen and becomes hypoxic (0.1–1.0 ml l^{-2} O_2) (Ergin et al., 1993b). The continuous supply of oxygen from the Aegean Sea prevents the development of anoxic conditions below the halocline (25–30 m depth), as in the Black Sea (Beşiktepe et al., 1994).

Primary production occurs only in the upper layer. The main sources of organic matter for this primary production are natural input to the subhalocline waters by vertical mixing and Black Sea inflow, along with land-based sources such as domestic/industrial waste, especially from the city of Istanbul (Polat et al., 1998). Primary production in the Marmara Sea is controlled by diatom and dinoflagellate blooms during the winter-spring and summer periods (Ergin et al., 1993b). The most abundant dinoflagellate is *Noctiluca scintillans,* and at the beginning of the spring and summer this species sometimes produces a 3–5 cm-thick surface layer of bloom called "red tide" (Baykut et al., 1987).

There is a spatial distribution to the primary productivity in the Marmara Sea. Average annual primary production rates based on chlorophyll-a data are higher (161 g C m^{-2} $year^{-1}$) on the southern shelf of the Marmara Sea and lower (83 g C m^{-2} $year^{-1}$) on the northern shelf Ergin et al., 1993b). The higher productivity on the southern shelf is attributed to nutrient supply from major rivers in this area and an organic-rich surface outflow from the Black Sea. The low productivity on the northern shelf is attributable to the lack of rivers.

Uysal et al. (2002) reported that the dominant zoobenthic groups in the Marmara Sea are the Polychaeta, Echinodermata and Crustacea. The polychaete *Mellina palmata* is the most common macrobenthic species. As in the Black Sea, the bivalve mollusc species *Mytilus galloprovincialis* and *Modiolus phaseolinus* have the greatest abundance and biomass in the Marmara Sea. Mollusc species, especially the bivalves *Mysella bidendata*, *Cingula* sp. and *Myrtea spinifera,* are abundant in the northeastern region of the Marmara Sea (the Bosphorus entrance) (Ergin et al., 1991).

1.3.3. The Aegean Sea

Owing to the geographic position of the Aegean Sea within the eastern Mediterranean Sea, the Black Sea to the northeast and the Levantine Sea to the southeast directly influence its biological oceanography. In general, the Aegean Sea can be characterized as being oligotrophic. Because of the influx of eutrophic Black Sea water, the northeast Aegean Sea is less oligotrophic than the southern Aegean Sea (Sempéré et al., 2002; Siokou-Frangou et al., 2004). Phytoplankton concentration and chlorophyll a concentration are both higher in the northern Aegean Sea; the lowest values of phytoplankton abundance (<14000 cell l^{-1}) are reported in the eastern part of the central Aegean Sea. Consistent with its oligotrophic character, annual primary productivity in the Aegean Sea is low, especially in the southern basin (30 g C m^{-2}) (Stergiou et al., 1997).

Diatoms such as *Nitzschia closterium* and *Rhizosolenia stolterfothii* generally dominate coastal phytoplankton assemblages in winter and spring, but in summer and autumn dinoflagellates such as *Cryptomonas* sp., *Prorocentrum mican* and *Gymnodinium* sp. are dominant (Stergiou et al., 1997). The species dominating the offshore phytoplankton assemblages are similar to those of the coastal phytoplankton assemblages (Stergiou et al., 1997). In addition, coccolithophores such as *Coccolithus pelagicus* and *Coccolithus fragilis* constitute a very important element of the winter and summer offshore phytoplankton assemblages, especially in the central and southern Aegean Sea (Stergiou et al., 1997).

Zooplankton abundance and biomass generally parallel phytoplankton abundance (Stergiou et al., 1997). In May, very high values of zooplankton abundance (>11732 individuals m^{-3}) are observed in the 0–20 m layer in the northeastern Aegean Sea, with decreasing numbers westwards and southwards (to 12–536 individuals m^{-3}; Siokou-Frangou et al., 2004). Zooplankton abundance declines rapidly with increasing depth. At depths from 500 m to 1000 m, zooplankton abundance is <1–10 individuals m^{-3} (Stergiou et al., 1997).

Copepods such as *Paracalanus parvus, Oithona plumifera* and *Acartia clausi* dominate the zooplankton communities of the offshore and coastal surface waters (Stergiou et al., 1997). In summer and autumn, cladocerans represent 50 % of the total zooplankton in the 0–50 m layer of coastal surface waters, and in late winter to early spring, as well as in summer, appendicularians constitute ~17 % of the total zooplankton in the 0–50 m layer (Siokou-Frangou et al., 2004).

Among the phytobenthic communities of the Aegean Sea, Stergiou et al. (1997) reported 452 species of *Chlorophyceae, Phodophyceae* and *Phaeophyceae,* and four species of phanerogram: *Posidonia oceanica* (1 m to 30 m), *Zostera noltii* (few cm to 2 m), *Halophila stipulacea* and *Cymodocea nodosa*.

The zoobenthic community of the Aegean Sea is dominated by polychaetes (48 %) such as *Avicidea claudiae* and *Chaetozone setosa*, followed by molluscs (15–25 %; Zenetos et al., 2000). The most important mollusc species are *Abra alba, Nucula nucleus, Timoclea ovata* and *Gouldia minima* (Stergiou et al., 1997). The rest of the benthic fauna includes 5–10 % Crustacea and 5–8 % Echinodermata (Stergiou et al., 1997).

1.4. Grain Size of the Sediment in the Study Area

The type of sediment found in the Black Sea, the Marmara Sea and the Aegean Sea is determined by climate, geological source, organic productivity, environmental conditions, and depositional setting.

1.4.1. The Black Sea

The source of sediment in the Black Sea is mainly rivers or erosion of coastal rocks. On average of 52.2 million m^3 of sediment reaches the Black Sea every year as river load (Jaoshvili, 2002). The Danube River is the most important sediment supplier of the Black Sea. Its influence extends to the deep sea floor (Panin et al., 1999). Although there is a relatively high supply of terrigenous sediment input into the Black Sea, pelagic sedimentation plays the major role in the deepest parts of the basin (Çiftçi et al., 2002). Surface sediments (0–5 cm) of the Black Sea, shallow-water deposits of the northwestern shelf consist of coarse-grained biogenic and terrigenous limey sediments (mostly 30–50 % $CaCO_3$) and gravely-sand (Mitropolsky and Olshtynsky, 1999). However deep-water deposits consist of fine-grained terrigenous and biogenic limey sediments (mostly 10–30 % $CaCO_3$ and silt).

1.4.2. The Marmara Sea

Several rivers release their fine-grained terrigenous loads into the Marmara Sea (Figure 1.6). The largest, the Simav (Kocasu) River, supplies a mean annual suspended load of approximately 6.5×10^5 tons; the smaller Gönen and Biga Rivers provide 5000 and 7800 tons $year^{-1}$ suspended solids, respectively (Ergin et al., 1997). In addition, the inflows from the straits of Bosphorus and Dardanelles transport suspended solids to the Marmara Sea with an annual discharge of 12.5×10^5 tons and 9.0×10^5 tons, respectively (Ergin and Bodur, 1999).

The surficial sediments of the Marmara Sea show a wide range of grain size composition from clay to sandy gravel, whereas the sediments of the southern shelf of the Marmara Sea show three distinct coarse-grained zones: west of the Bozburun Peninsula, southeast of Marmara Island and southwest of Marmara Island. Total sand and gravel comprise 30–90 % of total sediment in three zones, which are all surrounded by fine-grained sediment (Ergin et al., 1997). Away from the coarser-grained substrates, silt percentages are mostly around 50 % and clay content is around 90 %, especially on the southwestern shelf (Ergin and Bodur, 1999). The sediments of the northeastern shelf of the Marmara Sea are mostly composed of clay (up to 90 %) and silt, and small amounts of sand and gravel (Ergin and Bodur, 1999). In the upper South Bosphorus Canyon, higher level of coarse-grained sediments occur (70–90 %), whereas there is an increase of fine material (17 % to 88 %) in the down-canyon direction (Ergin et al., 1991). The deep-water sediments of the Marmara Sea generally constitute 70–90 % clay and 30–50 % silt with very small amounts of sand and gravel (Ergin and Bodur, 1999).

1.4.3. The Aegean Sea

The main source of fluvial detritus to the eastern Aegean Sea is from the Meriç, Gediz, Büyük Menderes, Küçük Menderes, Bakırçay and Dalaman rivers. Bottom sediments of the eastern Aegean Sea show a wide-range of grain-sizes, from silty clay to sandy gravel (Ergin et al., 1993a). High percentages of silt and clay characterize the areas of high terrigenous input (off the Meriç, Gediz and Küçük Menderes rivers) and areas of low energy conditions (Ergin et al., 1993a). The coarse sediment fractions (sand and gravel) are composed of bioclasts derived from bivalves, gastropods, foraminiferas, ostracods, algae and echinoids, and occur in high energy coastal environments. For instance, at the western entrance of the Strait of Dardanelles sediments contain little mud but higher amounts of sand and gravel because of the high current velocities and the low fluvial discharge from the adjacent land masses (Bayhan et al., 2001).

1.5. Previous Studies

Previous investigations of benthic community structure in the Black Sea, the Marmara Sea and the Aegean Sea were largely confined to nearshore areas such as gulfs or islands. The very few studies dealing with mollusc assemblages in surface sediments and their relationships with the physical oceanographic parameters in these seas were mostly written in Russian, Bulgarian, Turkish or Romanian and this literature is not easily accessible.

Zenetos et al. (2000) determined the composition of the coastal macrobenthic communities in the Black Sea and Aegean Sea. They compared species diversity, population abundance (individuals m^{-2}) and community diversity (Shannon Index (H')) with the anthropogenic input into these seas, and found that benthic faunal diversity in the Black Sea is about 1/3 of that in the Aegean Sea, although the total population abundance is greater in the Black Sea than in the Aegean Sea.

Moncheva et al. (2001) carried out a comparative study of the western Black Sea and the Aegean Sea, focusing on the responses of the phytoplankton to anthropogenic nutrient enrichment. They discussed environmental factors, such as temperature, salinity and nutrient ratios, to determine the difference between the two basins using cluster analysis and principal components analysis. They found that temperature and salinity are key factors accounting for the differences between the Aegean Sea and the Black Sea ecosystems. In addition, nutrients and their ratios locally are significant factors in explaining differences between sites.

Uysal et al. (2002) studied the distribution of macrobenthic communities around the Strait of Bosphorus with additional stations in the Marmara Sea and the Black Sea. They were particularly interested in the effects of lower-layer saline flow on these communities. Univariate measures, such as population abundance (individuals m^{-2}) and Shannon Index (H'), and multivariate methods such as cluster analysis were utilized to characterize community structure. There were significant differences among stations in species composition and diversity and these differences reflect hydrodynamic processes as well as anthropogenic impact.

Demir (2003) determined the occurrence and abundance of mollusc species in the eastern Aegean Sea, the Marmara Sea and the southern Black Sea. He examined a total of 610 mollusc species and many varieties belonging to various classes, subclasses, families and subfamilies of the Mollusca.

Siokou-Frangou et al. (2004) carried out a comparative study of the mesozooplankton communities of the Aegean Sea and the Black Sea. They found dissimilarities in species composition and abundance of zooplankton between these seas. Although most of the Black Sea zooplankton species are of Mediterranean origin, Siokou-Frangou et al. (2004) found that the great majority of Mediterranean species are absent in the Black Sea, including number of common eurytherm and/or euryhaline Aegean copepod species form the bulk of the zooplankton. They suggested that the link between the species composition of the northern Aegean Sea and the Black Sea is related to water exchange between the Black Sea and the Aegean Sea, and viewed the northern Aegean Sea as a transitional zone between the Black Sea and the eastern Mediterranean Sea.

1.6. Objectives of the Thesis

In this thesis, the ecological characteristics of mollusc assemblages in the Black Sea, Marmara Sea and Aegean Sea are outlined by comparison of the present-day oceanographic variables (such as temperature, salinity, dissolved oxygen) with the distribution of mollusc assemblages found in surface sediments. Sampling was not restricted to coastal areas, but was undertaken along a number of transects at water depths ranging from 13 m to 500 m.

The objectives of this thesis are:

1. to characterize the occurrence and abundance of mollusc species in surface sediment samples;

2. to determine the relationship between the distribution of mollusc species and environmental variables including the composition of the substrate;

3. to delineate assemblages that can be used in the identification of discrete water masses; and

4. to develop a tool to read environmental history from a sediment core by comparing present day mollusc assemblages to buried mollusc assemblages.

CHAPTER 2

METHODS

The data for this thesis were collected during two research cruises to the Black Sea, the Marmara Sea and the Aegean Sea on the RV Koca Piri Reis of the Institute of Marine Science and Technology (IMST), Dokuz Eylül University, in 2002 and 2003. During these cruises 137 grab samples and CTD (conductivity, temperature, depth) measurements were collected along six transects. Navigational fixes were obtained using a ship-based GPS (global positioning system).

2.1. Field Methods

2.1.1. Collection of Sediments and Shells

Sediment samples were collected at approximately 10 m water-depth increments from ~13 m to ~501 m using a Shipek grab. A ~100–150 cm^3 sub-sample was extracted from the grab sample and sieved through a 2 mm screen. All shells were separated, stored in plastic bags, and shipped to Memorial University of Newfoundland for analysis.

A Shipek grab consists of a half cylinder sampling scoop of ~3000 ml volume, ~25 cm length and ~10 cm diameter. The Shipek grab is deployed with a 50 kg weight by a winch. When the open grab touches the bottom, inertia from the weight releases a catch; helical springs then rotate an inner half cylinder by 180°. After this rotation, the spring keeps the scoop closed like a clam shell. Because the rotation of the inner half cylinder is extremely rapid, the sediment is cut cleanly, particularly soft clays, silts, and sands. The grab sampler is then retrieved from the sea floor. On the deck of the ship, the scoop is quickly removed from the frame by releasing two retaining latches, one at each side of the sampler, and sediment samples are then removed.

2.1.2. CTD (Conductivity-Temperature-Density) Measurements

The CTD probe used in this survey was a SEACAT SBE 19plus profiler, which collects real-time data through a conductor cable, connected from the base of the probe to a computer on board the ship. The sampling is conducted via a pump-controlled influx of water through the water intake cell located at the base of the probe.

The primary function of the CTD device is to record conductivity, temperature and pressure of the water column of a function of depth. Conductivity (Siemens/m) measures how easily electric currents pass through the water sample being tested. By measuring conductivity, a measurement of salinity can be obtained. Salinity is measured in psu (practical salinity units), equivalent to parts per thousand by weight (‰). A CTD probe also measures the temperature (°C) of the water. Finally, a probe measures pressure. Pressure is recorded in decibars. Since depth (meters) and pressure are directly related, a measurement in decibars can be converted to depth in meters. Conveniently, the pressure at x meters of depth is almost exactly equal to the pressure in x decibars. The density of the water can be calculated from the measurements of conductivity (salinity), temperature and pressure. The CTD probe was equipped to provide data on pH, dissolved oxygen (ml l^{-1}), chlorophyll concentration (μ/l), and light transmission (%). Chlorophyll concentration is measured by using a fluorometer probe. The fluorometer emits specific color wavelengths and simultaneously reads the wavelength that travel through the water column. The amount of green light that is recorded is an indirect measure of the amount of chlorophyll a, and therefore the biomass of phytoplankton.

2.2. Laboratory Methods

2.2.1. Identification of shells

The mollusc shells separated by sieving on board ship were individually cleaned with distilled water, placed in foil dishes dried in an oven at 40 °C and then placed in glass or plastic vials and labeled. The shells were examined using a 10× hand lens and identified using a number of taxonomic keys, descriptions and illustrations (Abbott and Dance, 1998; Demir, 2003; Graham, 1971; Grossu, 1995; Müller, 1995; Poppe and Goto, 1991; Tebble, 1966). Primary taxonomy was completed using specific features such as dentition, color, presence of pallial line, pallial sinus and muscle scars. Other attributes used in identification were ratios of shell dimensions and the habitat and depth range of each species.

2.2.2. Grain Size Analysis

Grain size distribution in sediment samples from six transects was determined using a standard sieve technique for the >63 μm fraction for all transects, a Sedigraph 5100 particle size analyzer for the <63 μm fraction for Transects 1, 3, 5, and pipette analysis of total silt and total clay for Transects 2, 4, 7, 8.

Approximately 15 g of sediment were placed in a beaker with 100 ml 10 % hydrogen peroxide. Approximately 400 ml distilled water was added and the suspension brought to a boil in order to remove the organic matter. The excess hydrogen peroxide was removed and the wet sample passed through a 63 μm sieve. The fraction passing the sieve was kept for Sedigraph or pipette analysis.

The >63 μm fractions were dried, then passed through a stack of 14 sieves grades from -3 ϕ to 4 ϕ on a Ro-Tap mechanical shaker for 15 minutes ($\phi = -\log_2$ size in milimeters). After 15 minutes, the sediment retained by each sieve was transferred to a large sheet of paper and weighed.

The <63 μm fractions were suspended in 1 % sodium hexametaphosphate (Calgon) as a dispersant, poured into a small beaker and stirred as a 50 ml aliquot was pipetted off for Sedigraph analysis. The Sedigraph 5100 uses Stokes's Law of settling to determine the grain size. According to Stokes's Law, three forces act upon a particle falling through a viscous liquid:

1. gravitational force, acting downward,
2. buoyant force, acting upward,
3. drag force (friction), acting upward.

Knowing the gravitational acceleration, the density of the particle, the density and viscosity of the distilled water, and the time it takes for the particle to settle, the equivalent spherical diameter of that particle can be calculated (Sedigraph 5100 Operator's manual, 1989). The Sedigraph 5100 uses these parameters and collects data on sedimentation velocity of settling particles by measuring the concentration of particles, using attenuation of an X-ray beam remaining in suspension as a function of time (Sedigraph 5100 Operator's Manual, 1989).

The remaining <63 μm fractions were transferred into 1000 ml cylinders and suspended in distilled water and 20 ml stock 1 % Calgon solution for pipette analysis. Cylinders were stirred for 2 minutes and a reference sample was extracted and transferred to an evaporating dish. After a 15 minute settling period, a sample was removed by pipette from 20 cm depth and transferred to an evaporating dish. According to pipette withdrawal times calculated from Stokes's Law this sample contained only particles finer than 4 ϕ. After a settlement period of 2 hours and 1 minute, a sample was withdrawn from 10 cm depth and placed in an evaporating dish. This last sample contained only particles finer than 8 ϕ. All pipetted volumes were the same. After evaporation and weighing, the weight of t=0 sediment (wt_0) gives a reference concentration of the entire <63 μm fraction, the weight at 15 minutes divided by wt_0 gives the wt % for particles finer than 4 ϕ, and the weight at 121 minutes divided by wt_0 gives the wt % for those finer than 8 ϕ. From these values, the wt % of silt (4–8 ϕ) and clay (8 ϕ) can be determined.

2.2.3. Carbon element and isotope analysis

Approximately 2 g of sediment sample was treated with 30% HCl and distilled for one day until effervescence stopped. During the dissolving reaction, all calcium carbonate ($CaCO_3$) in the sample was removed. Samples were cleaned, centrifuged with distilled water and dried at 40 °C. Subsequently, $CaCO_3$-free samples were ground in a mortar. 15 mg sample and >0.2 mg vanadium pentoxide (V_2O_5) were weighed and put into 4×6-mm-thin aluminum capsule for analysis with a Carlo-Erba NA 1500 Elemental Analyzer coupled to a Finnigan MAT 252 isotope ratio mass spectrometer (IRMS). Total organic carbon (TOC) was converted to CO_2, H_2O and other gaseous oxidation products in the oxidation chamber and then passed through a reduction reagent, a $Mg(ClO_4)_2$ water trap and 1.2-m Poropak QS 50/80 chromatographic column at 70 °C for final isolation. TOC in generated CO_2 was determined using an external standard (sulfanilamide, $C_6H_8N_2O_2S$) and a thermal conductivity detector. From the thermal conductivity detector, the CO_2 was transported by He to a ConFloII interface, which allowed a portion of the He and combustion gases to enter directly the ion source of the IRMS for carbon isotopic measurement. The TOC concentration in the sample was back-calculated as a weight percentage of sediment dry weight. All isotopic analyses are reported in standard δ notation referenced to Pee Dee Belemnite (PDB).

2.3. Data Analysis

2.3.1. Qualitative Analysis

An assemblage is defined as a unique community that reflects the associated characteristics of the environment. Assemblages were identified after considering the relationships between stations and oceanographic parameters from all transects. Each assemblage reflects a distinct set of environmental conditions. Some species are only present in one assemblage, although others are more cosmopolitan and can be found in more than one assemblage. Qualitative analysis was done by using absence and presence of mollusc species. Abundance of species was calculated as a percentage contribution to each assemblage, using the following equation:

$$\text{Species A percentage} = 100 \times (\text{number of shells species A}) / (\text{total number of shells})$$

2.3.2. Quantitative Analysis

The counts of dead molluscs were converted to percent occurrence data and analyzed using the computer software package MINITAB 14. Ordination techniques such as Principal Component Analysis were used to describe relationships between variables (mollusc species), and to identify variables significant to the identification of particular assemblages.

An ordination is a map of samples, which reflects the similarities of biological assemblages. For example, nearby samples on the ordination show similar assemblages, and samples that are far from each other reflect different assemblages (Clarke and Warwick, 2001).

Principal Component Analysis is used to reduce the number of variables (in this thesis 12 species), while accounting for a majority of the total variance in the data set. Principal Component Analysis also constructs new axes so that a maximum of variation is explained on the first axis; second most variation is represented on the second axis and so on.

CHAPTER 3

PHYSICAL OCEANOGRAPHIC DATA

3.1. The Marmara Sea

3.1.1. Transect 1

Transect 1 was run in the southwest Marmara Sea, east of the Dardanelles Canyon (Figure 3.1, Figure 3.2). Summer CTD measurements along transect 1 revealed the presence of two different water masses separated by a mixing zone (Figure 3.3). The upper water mass is characterized by low salinity (~22 ‰) and density (σ_t: 12–13), and by high temperature (26–27 ˚C) (Figure 3.4, 3.5, 3.6). It occupied the upper 10 m of the water column and represents the Black Sea outflow into the Marmara Sea. Below the surface water mass, a mixing layer was identified through which there is a temperature drop of 14 ˚C and a salinity increase of 16 ‰. This layer forms a thermocline-halocline-pycnocline at ~10 – ~32 m depth across transect 1. Below the pycnocline, a second water mass characterized by high salinity (37–41 ‰) and low temperature (15–18 ˚C) (Figure 3.4, 3.5). This water mass generally occupies depths below ~30 m and forms the bottom water mass in transect 1. It defines the intermediate waters of the Marmara Sea and is interpreted as the Mediterranean water intrusion into the southwest shelf of the Marmara Sea (Beşiktepe et al., 1994). Because this water mass is significantly denser than the surface water mass, it is intruded presumably beneath the surface layer and lies below the pycnocline.

The dissolved oxygen concentration in the upper water mass is generally low (0–3 ml/l; Figure 3.7). Low dissolved oxygen values probably represent high secondary

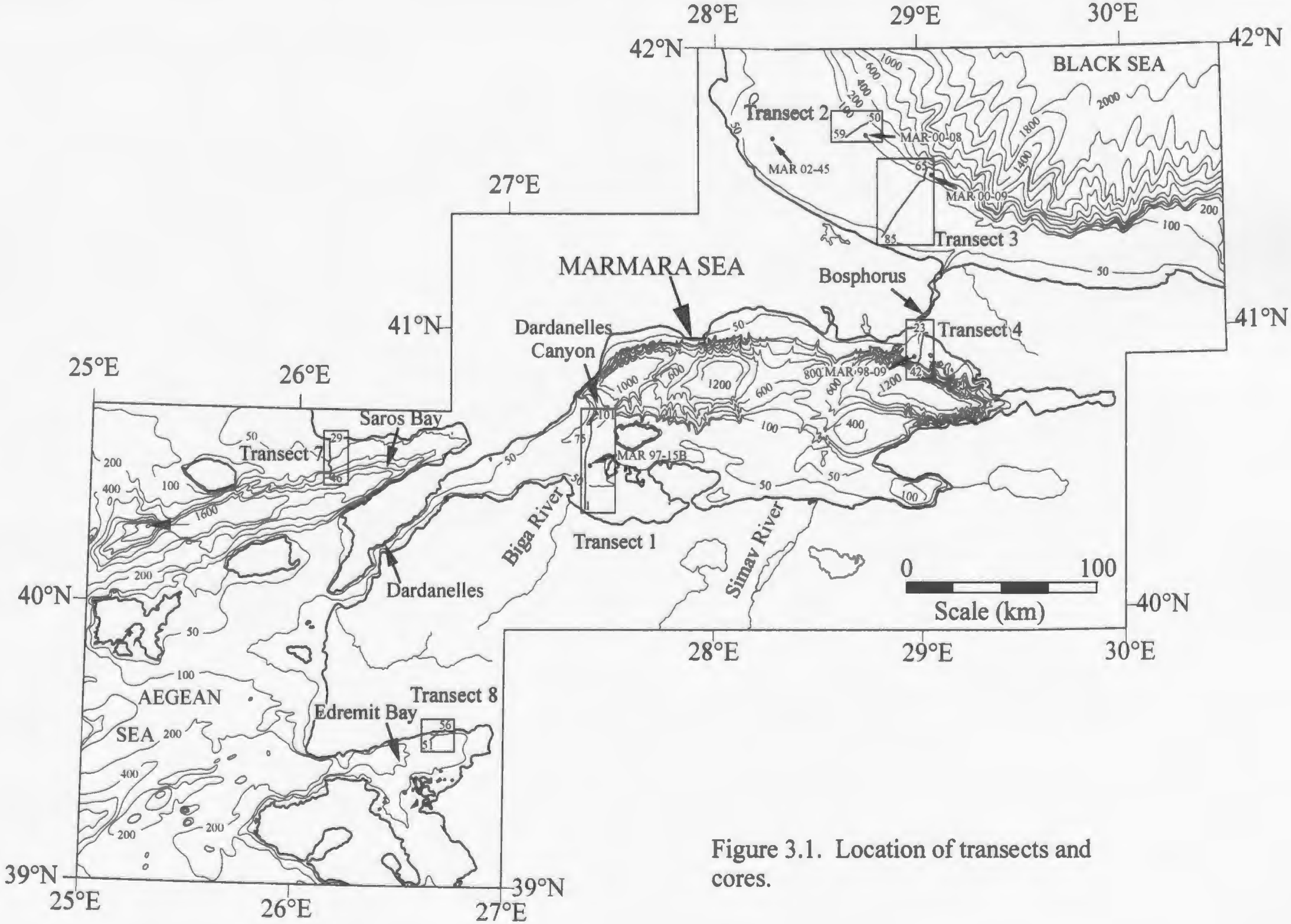


Figure 3.1. Location of transects and cores.

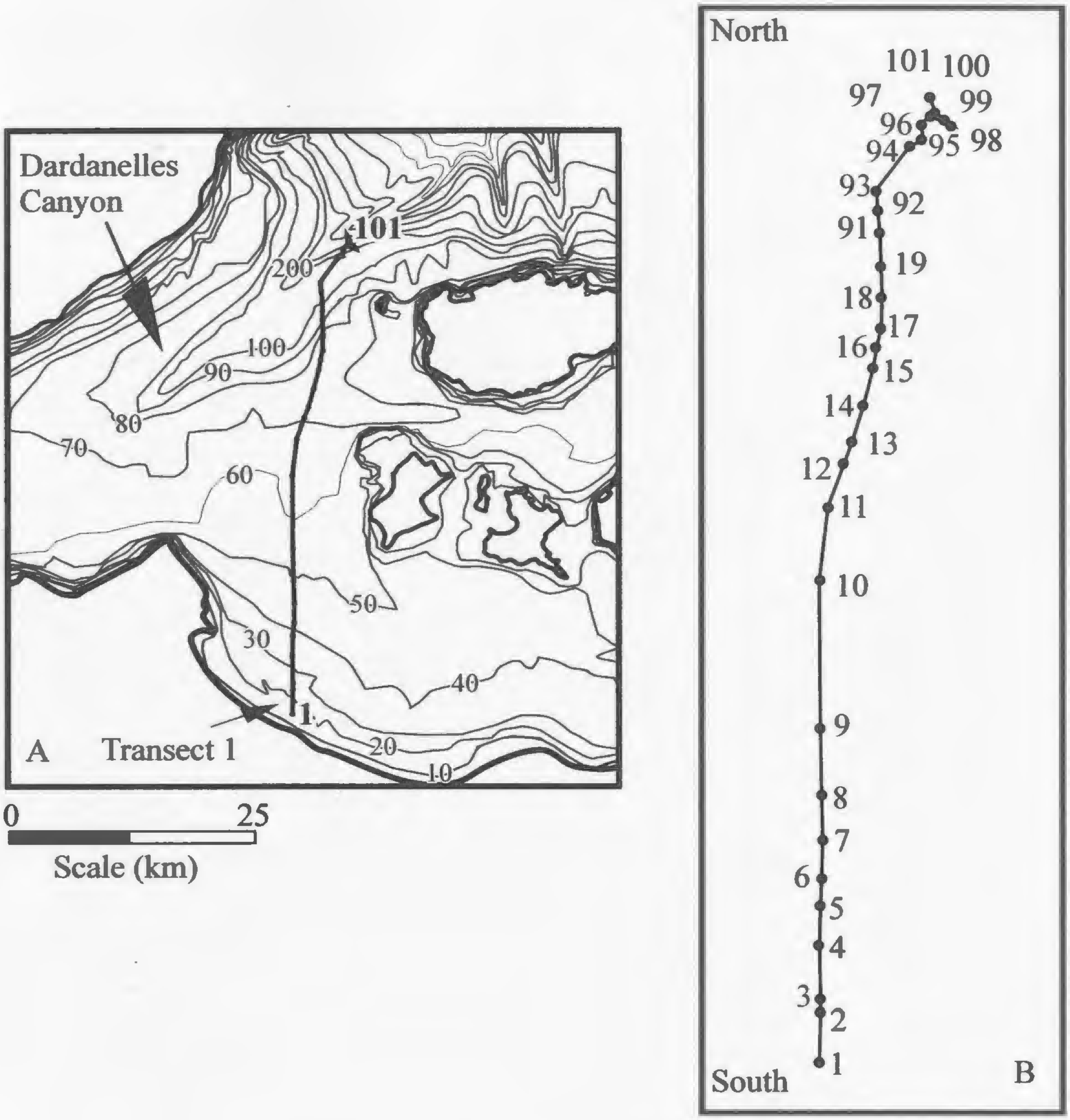


Figure 3.2. Bathymetry of the transect 1(A), modified from Yaltirak, 2002 and station numbers across transect (B). Contours are in meters.

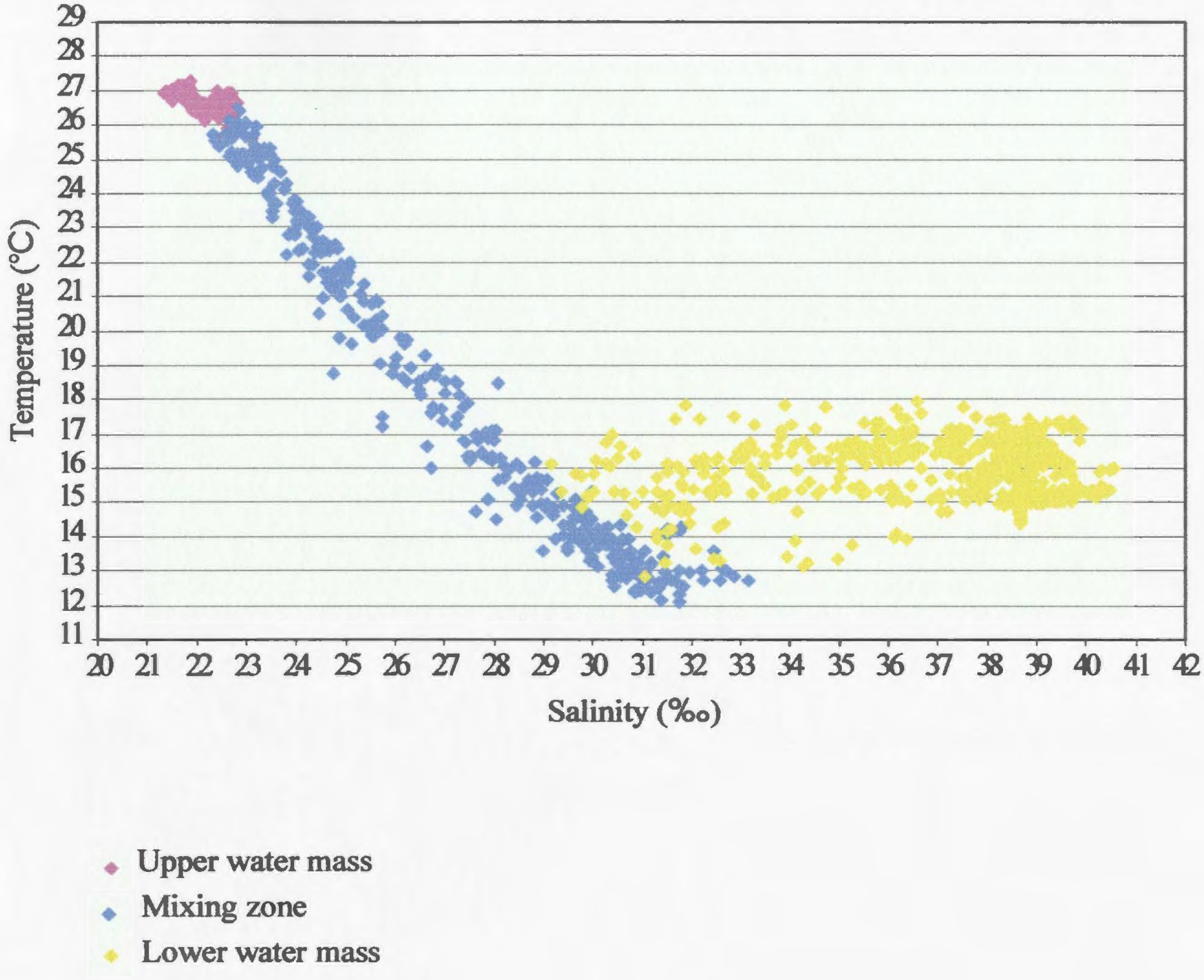


Figure 3.3. Temperature (°C)-Salinity (‰) diagram of transect 1.

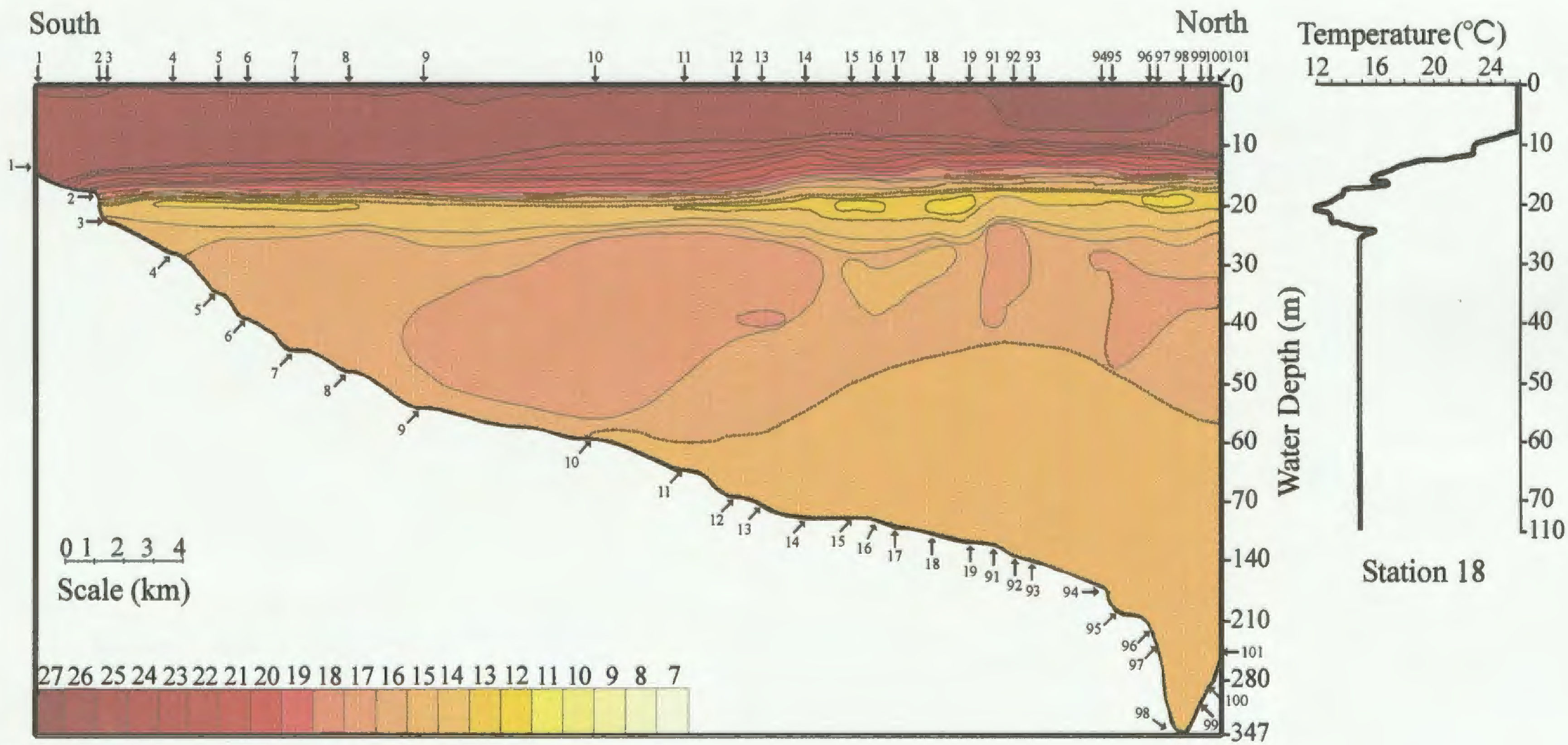


Figure3.4. Temperature (°C) distribution across transect 1. Note the change in depth scale (to one division = 70 m) below 70 m.

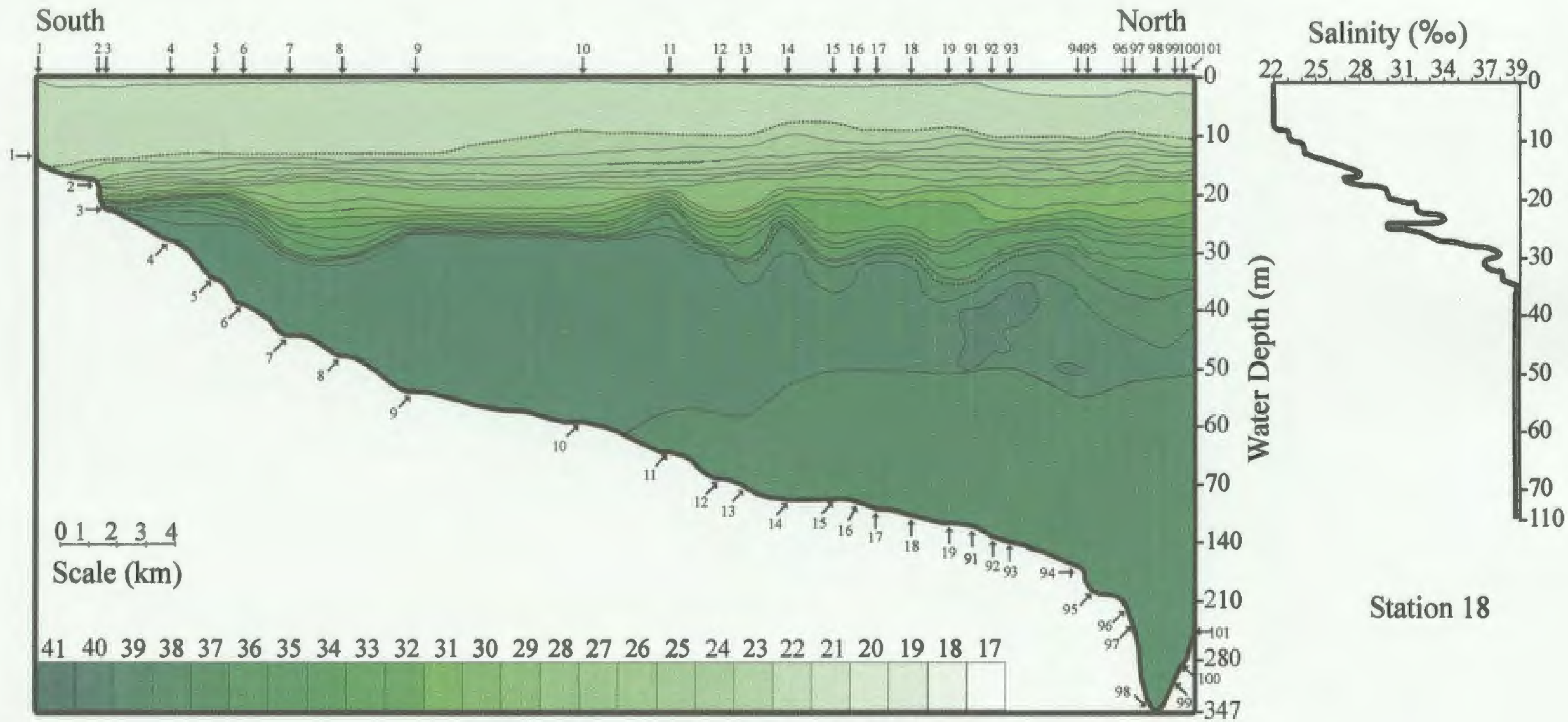


Figure 3.5. Salinity (‰) distribution across transect 1. Note the change in depth scale (to one division = 70 m) below 70 m.

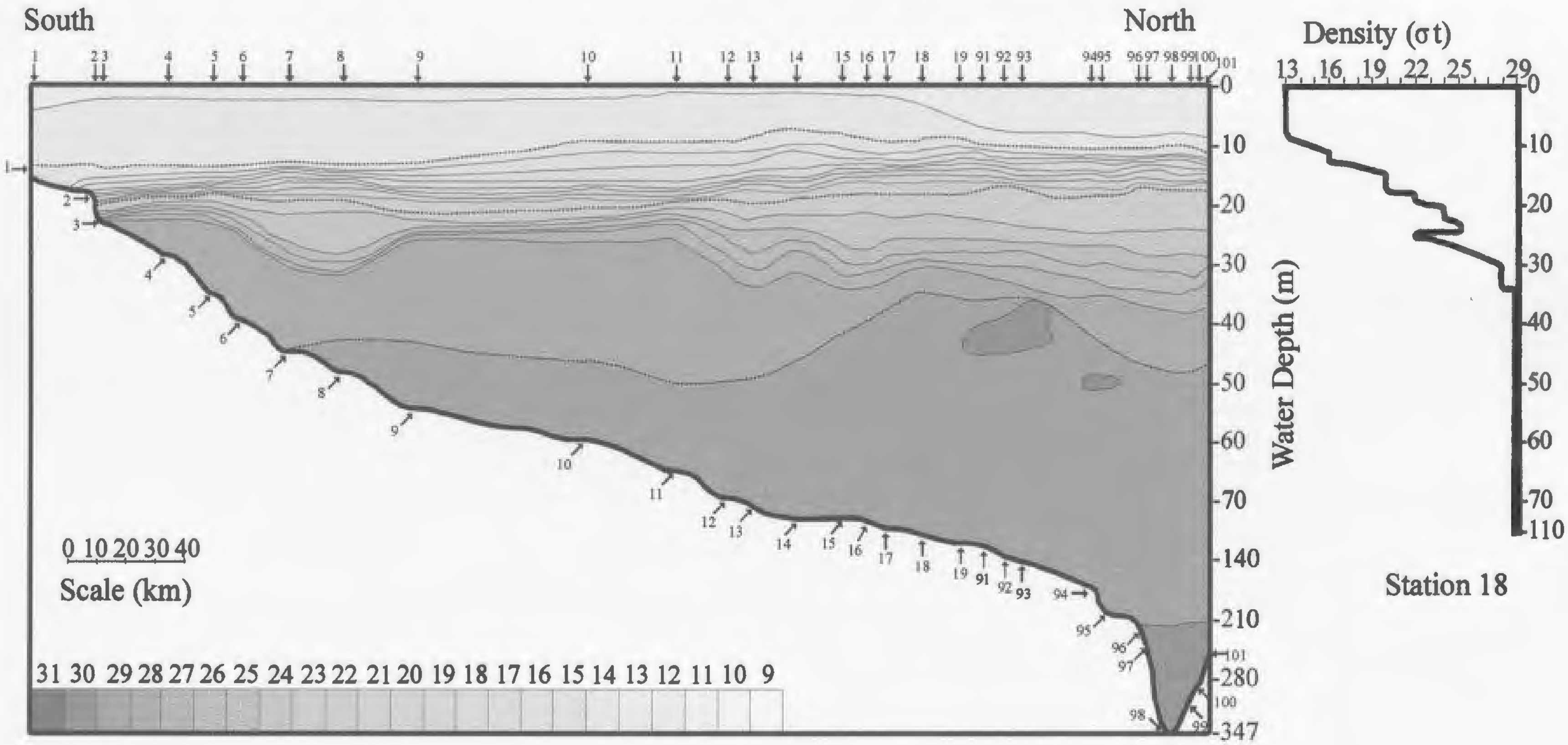


Figure 3.6. Density (σt) distribution along transect 1. Note the change in depth scale (to one division = 70 m) below 70 m.

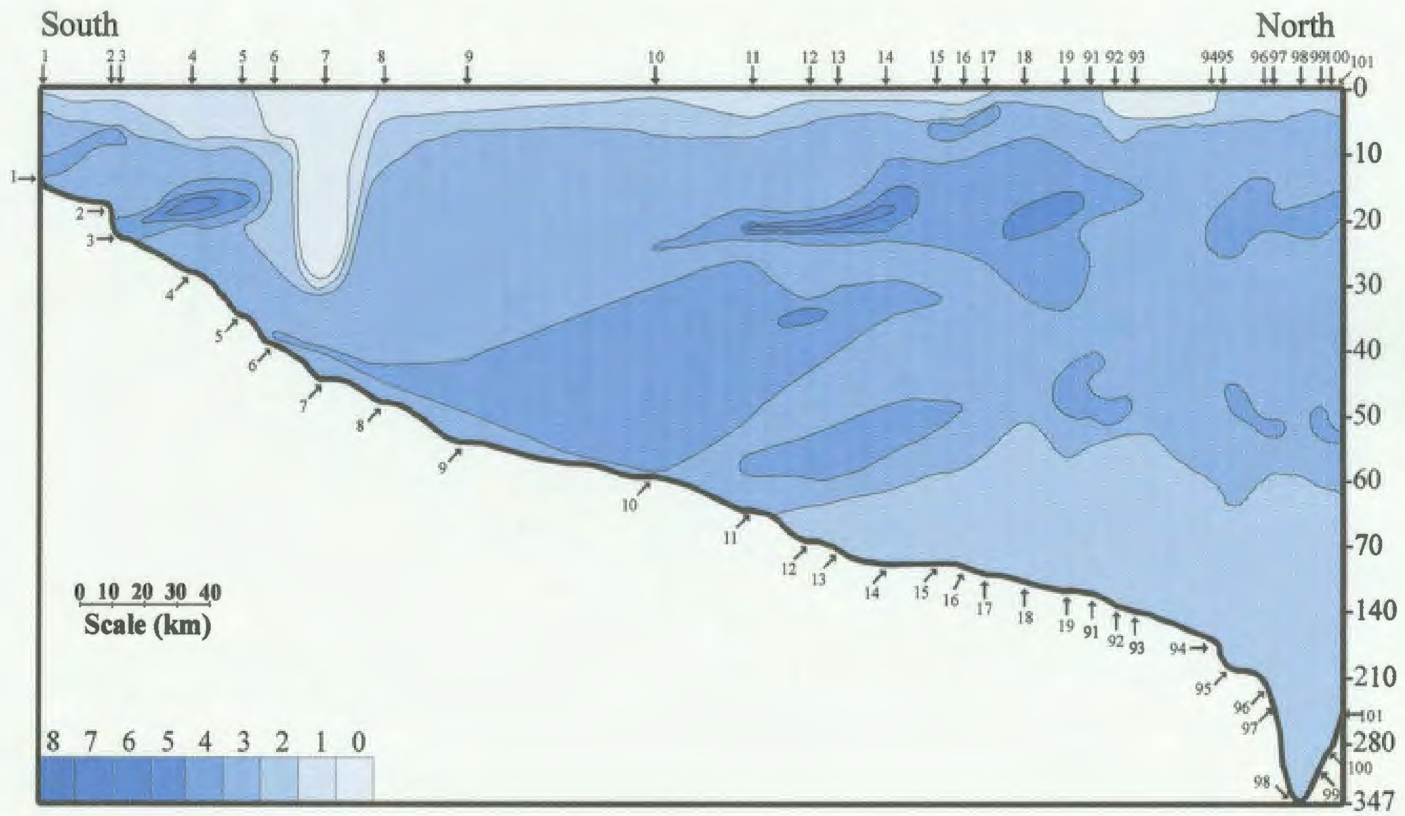


Figure 3.7. Dissolved oxygen (ml/l) distribution across transect 1. Note the change in depth scale (to one division = 70 m) below 70 m.

production in the surface waters. Dissolved oxygen in the bottom water mass show a decline from 5–6 ml/l to 2 ml/l as water depth increase. The low (2 ml/l) oxygen concentrations below ~60 m are ascribed to oxidation of the sinking particulate organic matter in a strongly stratified water column. The stratification prevents vertical mixing and ventilation (e.g. Beşiktepe et al., 1994).

Surface sediments across the transect consisted primarily of a mixture of clayey-silt, silty-clay, sandy-silt and sandy-silty-clay (Figure 3.8). There is a general trend towards finer sediment from the shore into the deeper water. For example, bottom sediments at stations 1 (13 m) and 2 (17 m) reflect their proximity to the Biga River as well as higher energy conditions in shallower depths. Conversely, the deepest station (98) is clayey-silt, associated with low energy conditions in deep water.

Total organic carbon (TOC) in surface sediments is a function of (i) preservation of organic matter in sediments as a consequence of sub-floor oxygen levels (ii) productivity in surface waters and (iii) input of terrigenous organic carbon into a basin. Total organic carbon (TOC) content of the surface sediments across transect 1 vary between 0.50 and 1.81 %. TOC values generally higher (1.20–1.80 %) in shallow water sediments than in those from deep waters (>100 m), especially deep stations 98, 99, 100, and 101 where TOC values ranged between 0.60 % and 0.80 % (Figure 3.9).

The $\delta^{13}C_{org}$ values ranged from -26.05 ‰ near the coast to -23.02 ‰ in the deepest stations. Using $\delta^{13}C_{org}$ data and the following mixing equations, the origin of the TOC in sediments can be estimated:

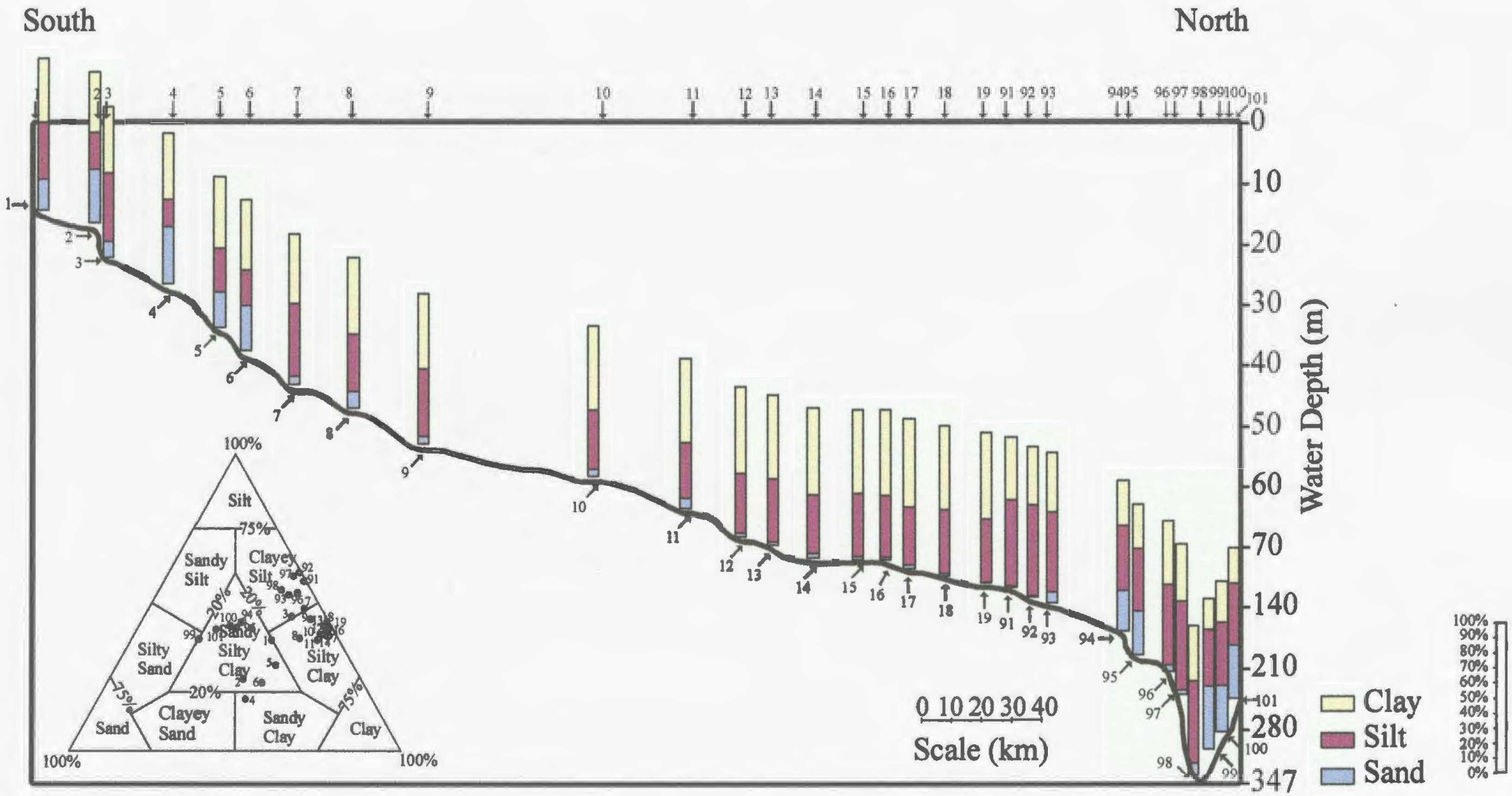


Figure 3.8. Grain size data of surface sediments along transect 1. Note the change in depth scale (to one division = 70 m) below 70 m. The classification triangle is from Shepard (1954).

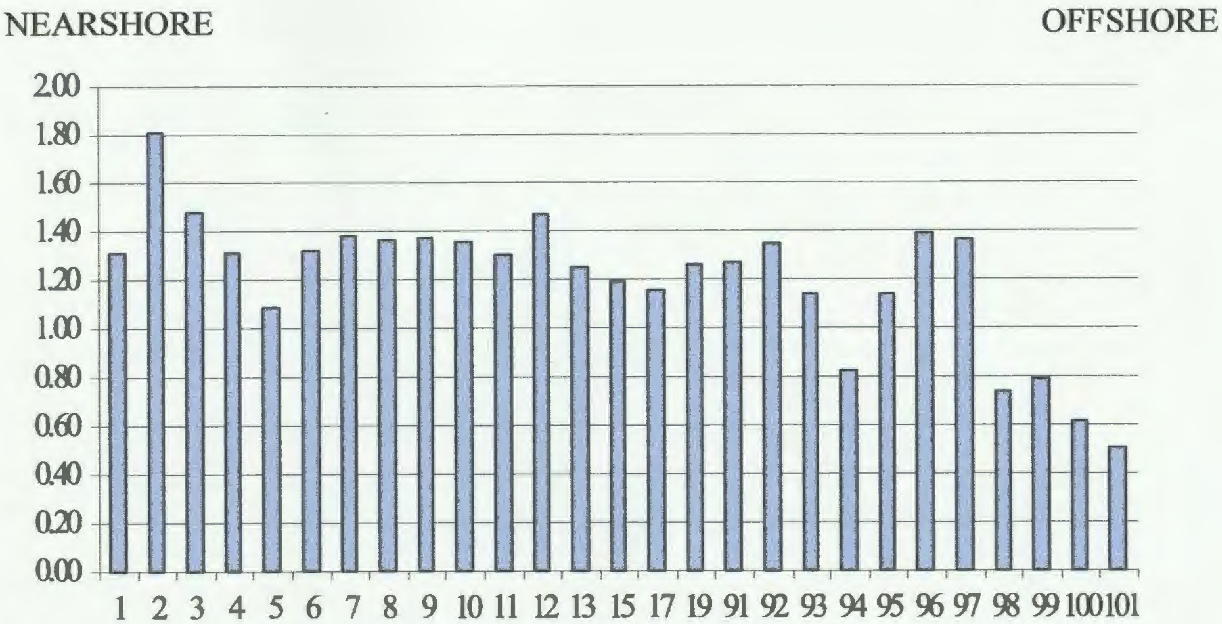


Figure 3.9. Total organic carbon (%) in sediments along transect 1.

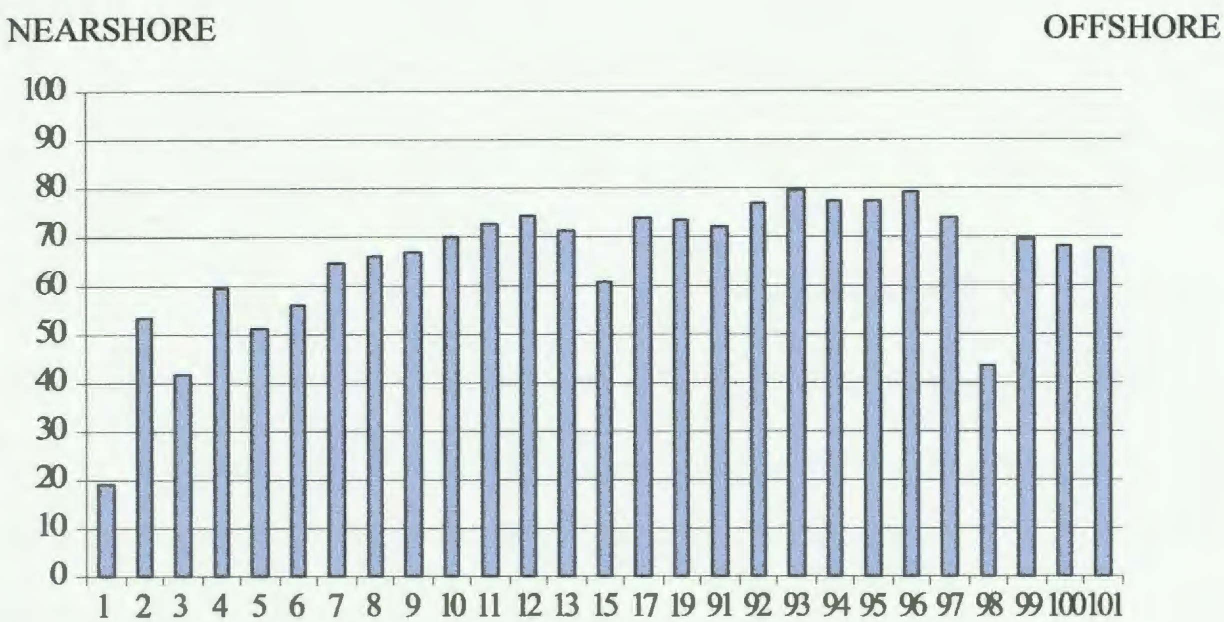


Figure 3.10. Percentages of marine organic carbon along transect 1.

$$\delta^{13}C_{org} = F_t \times \delta^{13}C_t + F_m \times \delta^{13}C_m \quad \text{and} \quad F_t + F_m = 1$$

where F_t and F_m are the fractions of terrestrial and marine organic carbon, and $\delta^{13}C_t$ and $\delta^{13}C_m$ are the carbon isotopic composition of terrestrial and marine source end-members, which are estimated to be -27 ‰ and -22 ‰, respectively (Aksu et al., 1999). According to this equation, the percentage of marine organic carbon ranges between 19.1 % and 79.4 % along transect 1. For example, the ~1.3 % TOC at station 1 consisted of 19.1 % marine organic carbon and 80.9 % terrestrial, suggesting a large terrigenous input from the Biga River. There is a gradual seaward increase in the fraction of marine organic carbon (Figure 3.10). In transect 1, the distribution of organic carbon in the sediments can be related to the dissolved oxygen concentration in the water column. Due to high oxygen (5–6 ml/l) in the shallow waters, TOC values are high as a result of the high rate of organic influx caused by increased primary productivity.

3.1.2. Transect 4

Transect 4 was run in the Marmara Sea immediately south of the Bosphorus Strait (Figure 3.1, 3.11). The CTD data revealed the presence of three water masses (Figure 3.12). A mixing zone present, corresponding to a thermocline-halocline-pycnocline layer between ~10 m and ~20 m depth across which there is an approximately 11 ˚C decrease in temperature and 7 ‰ increase in salinity (Figure 3.13, 3.14). The upper water mass is characterized by its seasonally high temperature (24–27 ˚C) and low salinity (21–24 ‰) values. It occupies the upper 10 m of the water column and represents the surface water mass in the Marmara Sea (Beşiktepe et al., 1994). The water mass below the

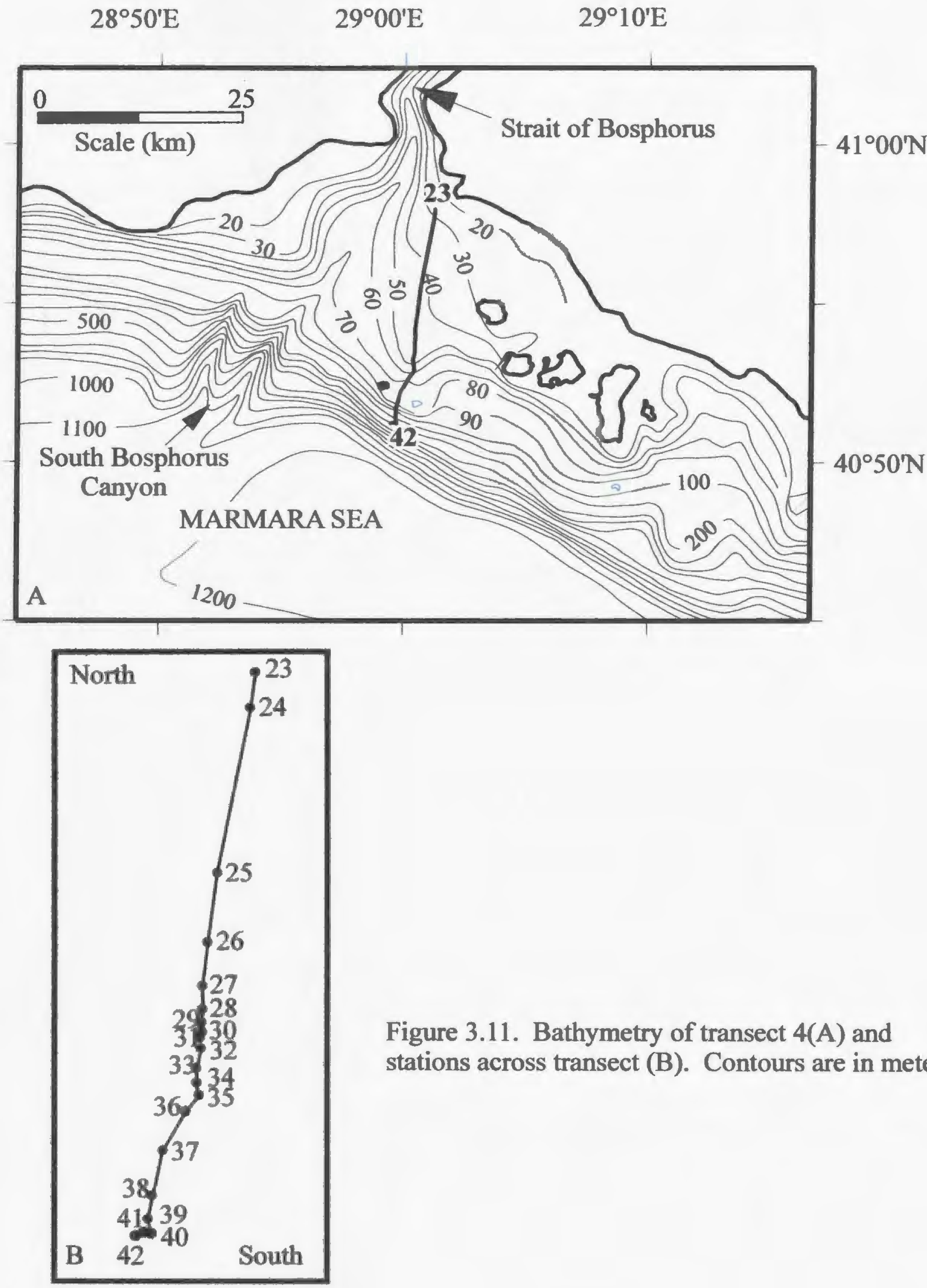


Figure 3.11. Bathymetry of transect 4(A) and stations across transect (B). Contours are in meters.

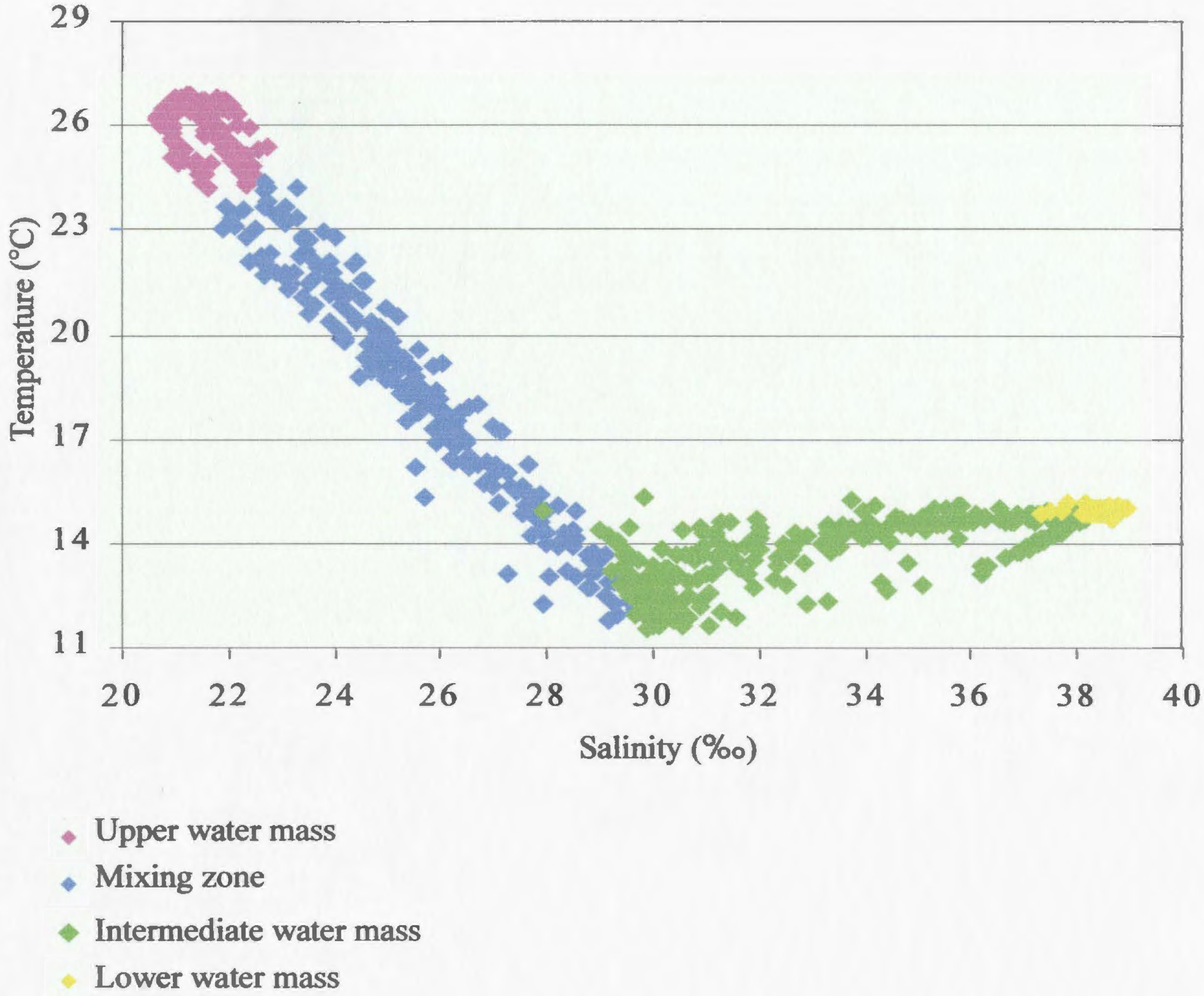


Figure 3.12. Temperature (°C)-Salinity (‰) diagram of transect 4.

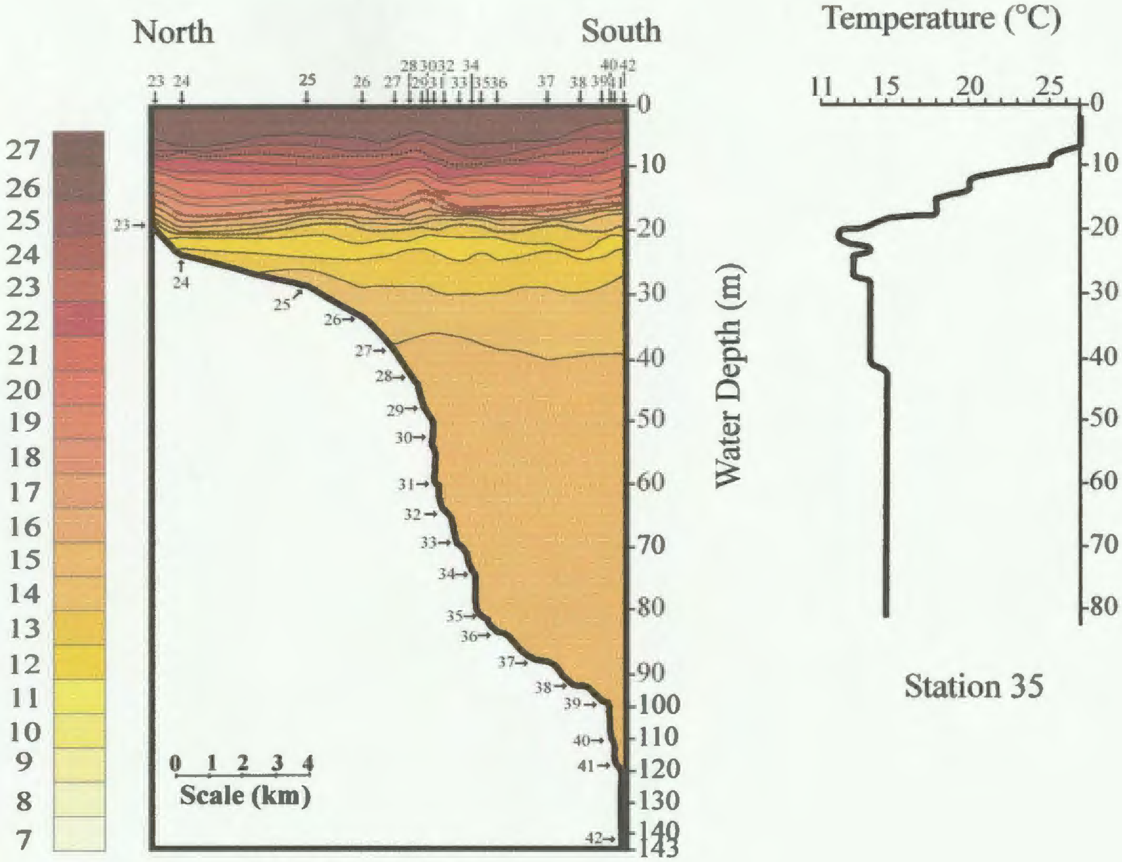


Figure3.13. Temperature (°C) distribution across transect 4. Note the change in depth scale below 90 m.

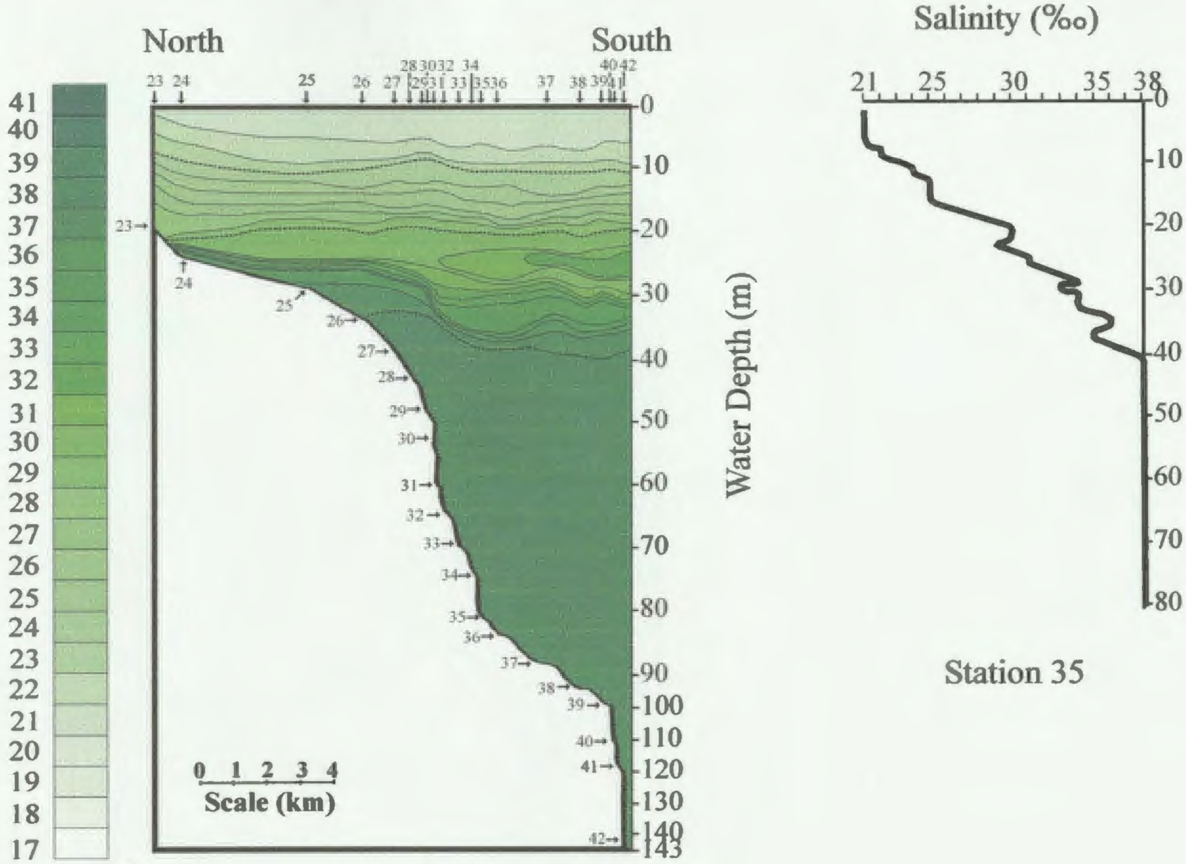


Figure 3.14. Salinity (‰) distribution across transect 4. Note the change in depth scale below 90 m.

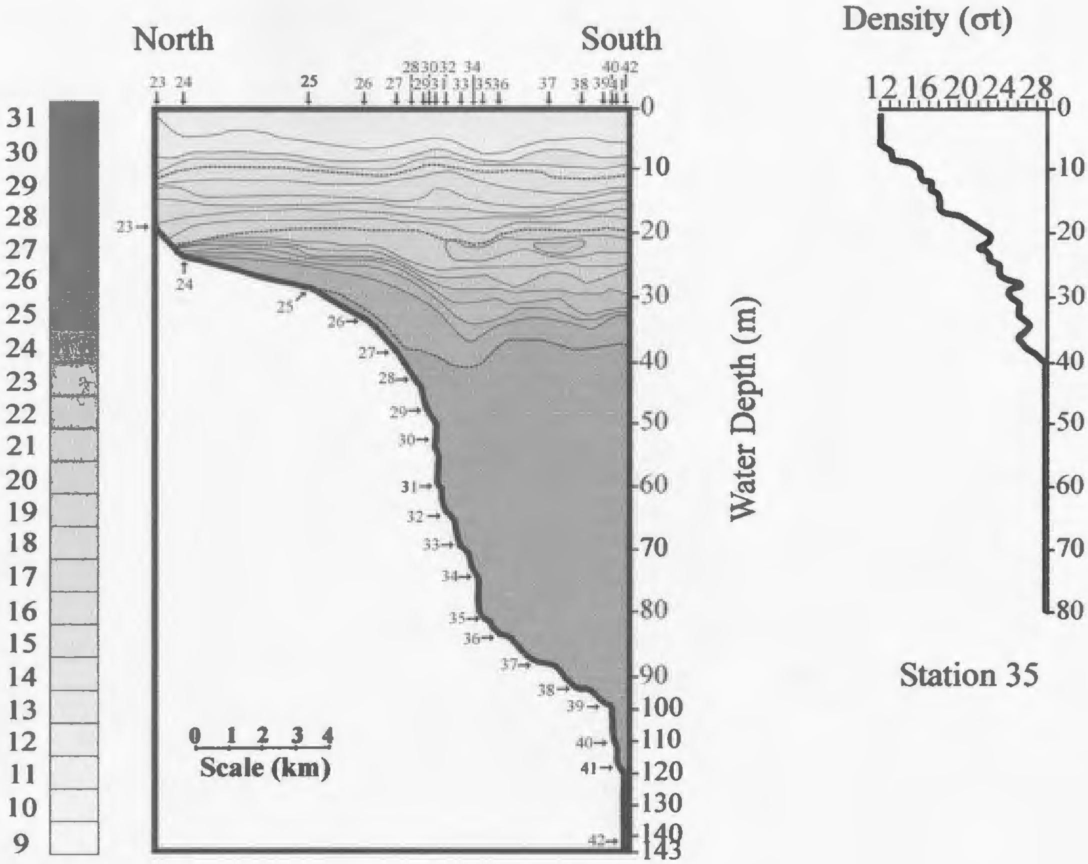


Figure 3.15. Density (σt) distribution along transect 4.

thermocline-halocline a temperature of 13–14 °C and a salinity of 29–37 ‰. It lay between 20 m and 40 m, and corresponding to the intermediate water mass of the Marmara Sea (Beşiktepe et al., 1994). However, along transect 4 this intermediate water mass has a higher temperature (14 °C) than reported elsewhere in the Marmara Sea (cf. Beşiktepe et al., 1994), possibly because of the high summer temperatures of the surface waters when the transect was run and an unusual amount of vertical mixing of this surface water with subsurface waters. The deepest water mass on transect 4 has a high salinity (38 ‰) and a constant temperature of 15 °C (Figure 3.13, 3.14), and lay below 40 m. It represents the bottom water mass of the Marmara Sea, which is supplied by the Mediterranean Sea inflow into the Marmara Sea (Beşiktepe et al., 1994).

The dissolved oxygen concentration along transect 4 varied in complex ways from 0–5 ml/l (Figure 3.16). Low dissolved oxygen values (0–3 ml/l) are generally found in the surface layer. At the pycnocline, high dissolved oxygen concentrations (4–5 ml/l) occur especially at the seaward stations; however, at station 25, the dissolved oxygen value is ~0 ml/l in the same layer. This difference might result from high primary productivity at seaward stations or oxygenation by wave action. Dissolved oxygen concentration near the bottom is very low (~1 ml/l) as a result of the oxidation of sinking particulate organic matter from the surface waters.

The surface sediments composed of silty-sand, sandy-silt, clayey-silt, and sandy-silty-clay (Figure 3.17).

Most stations are characterized by sapropelic (0.5–2% organic carbon in sediment) sediments having a TOC of 1.01–1.87 ‰. Two stations at the landward end of the

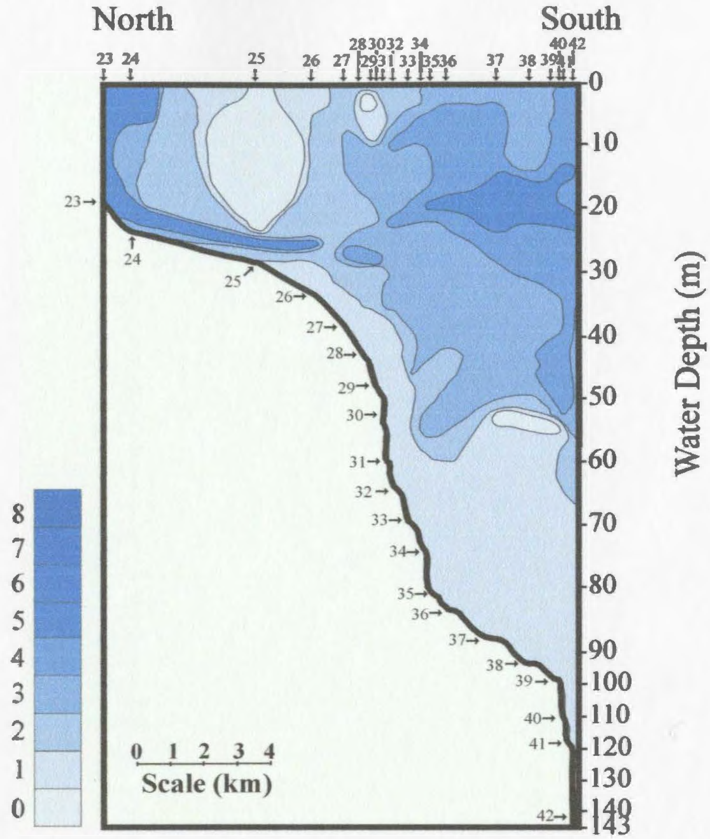


Figure 3.16. Dissolved oxygen (ml/l) distribution across transect 4. Note the change in depth scale below 90 m.

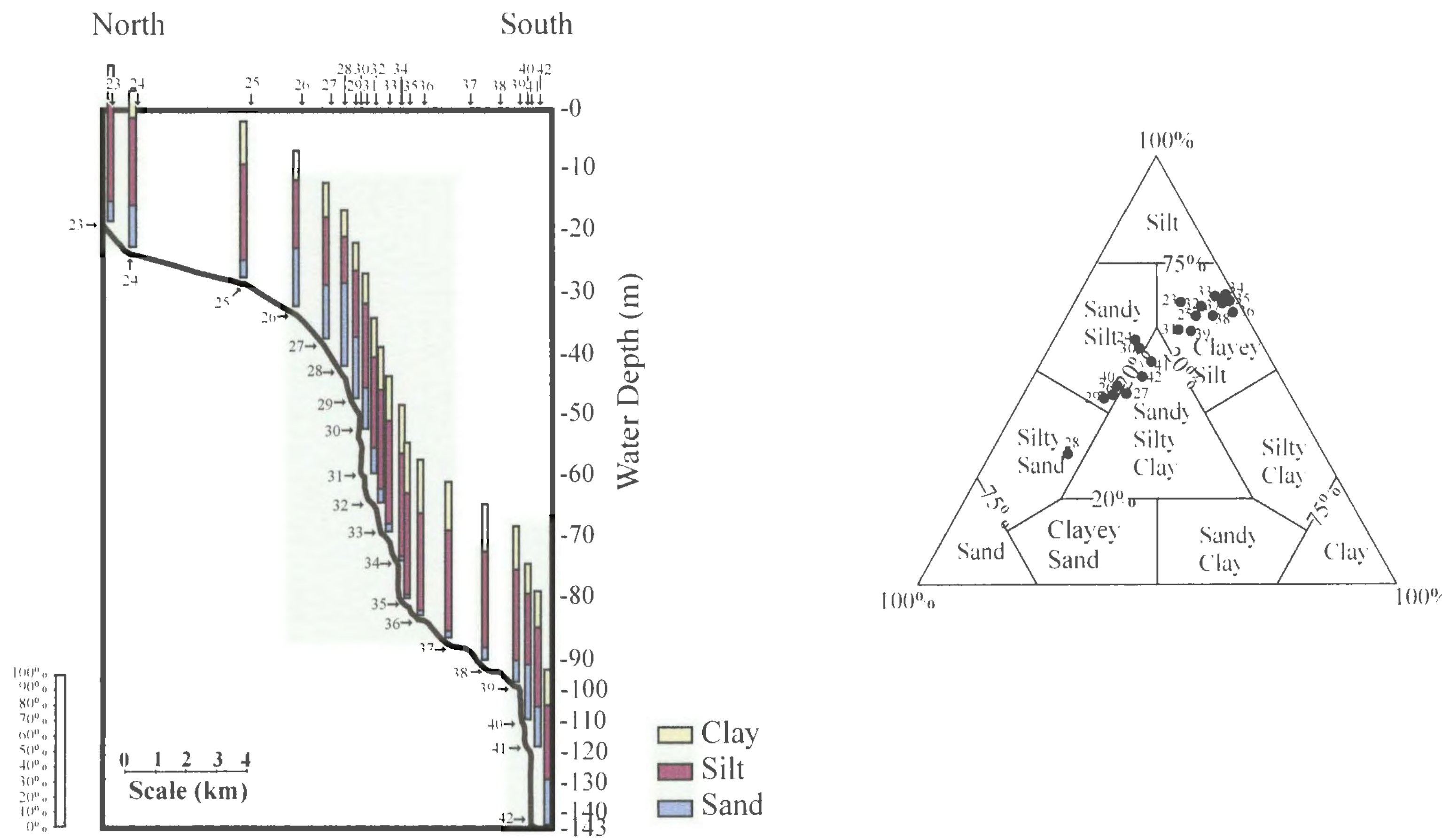


Figure 3.17. Grain size data of surface sediments along transect 4. The classification triangle is from Shepard (1954).

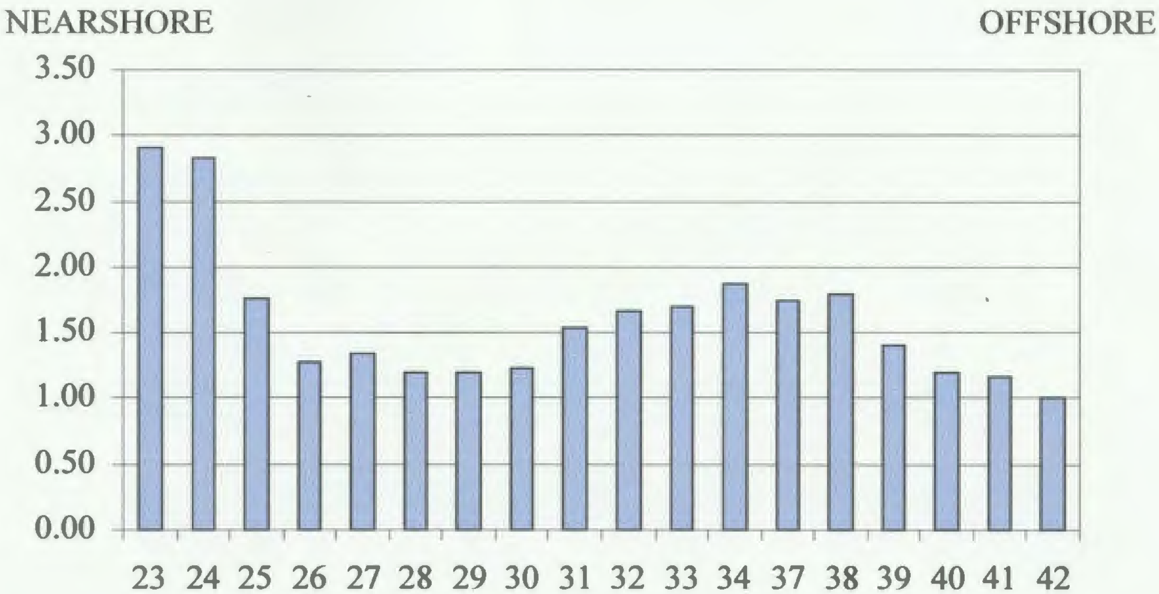


Figure 3.18. Total organic carbon (%) in sediments along transect 4.

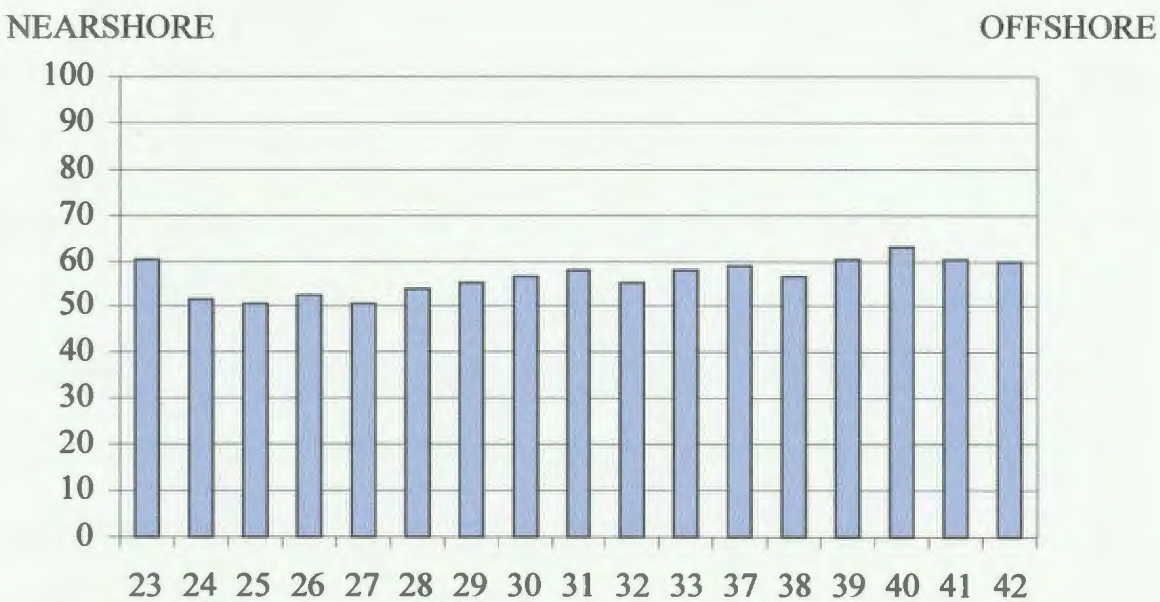


Figure 3.19. Percentages of marine organic carbon along transect 4.

transect (23 and 24) have sapropel (≥2 % organic carbon) with 2.82 ‰ and 2.91 % TOC (Figure 3.18). The $\delta^{13}C_{org}$ of the TOC ranged between -23.86 ‰ and -24.47 ‰. The mixing equation suggests that ~55 % of the TOC was of marine origin (Figure 3.19).

3.2. The Black Sea

3.2.1. Transect 2

Transect 2 was completed on the southwestern Black Sea shelf (Figure 3.1, 3.20). There three different water masses (Figure 3.21). The upper water mass has a low salinity (17–18 ‰) and seasonally high temperature (26–27 ˚C), and extended from the surface to a depth of ~10 m (Figure 3.22). This water mass represents the surface mixed layer of the Black Sea (Murray, 1991), beneath which lies, a thermocline-halocline-pycnocline (~15–22 m); this layer exhibited a 8 ˚C decline of water temperature and 3 ‰ downward increase of salinity and so is the typical seasonal pycnocline of the Black Sea (Oğuz et al., 1994; Figure 3.22, 3.23). Below the pycnocline, a distinct water mass occurred between ~22 m and ~40 m with salinity of 20–23 ‰ and temperature of 10–12 ˚C (Figure 3.22), representing the penetration of Mediterranean water into the Black Sea (Ünlüata et al., 1990). The lowest water mass on transect 2 occurred below ~40 m depth and it was characterized by low temperature (7–8 ˚C) and salinity (18–20 ‰) (Figure 3.22). Between 60 m and 100–120 m depth (Figure 3.22), the temperature was nearly constant at 7˚C, which is typical of the Cold Intermediate Water of the Black Sea (Oğuz et al., 1991).

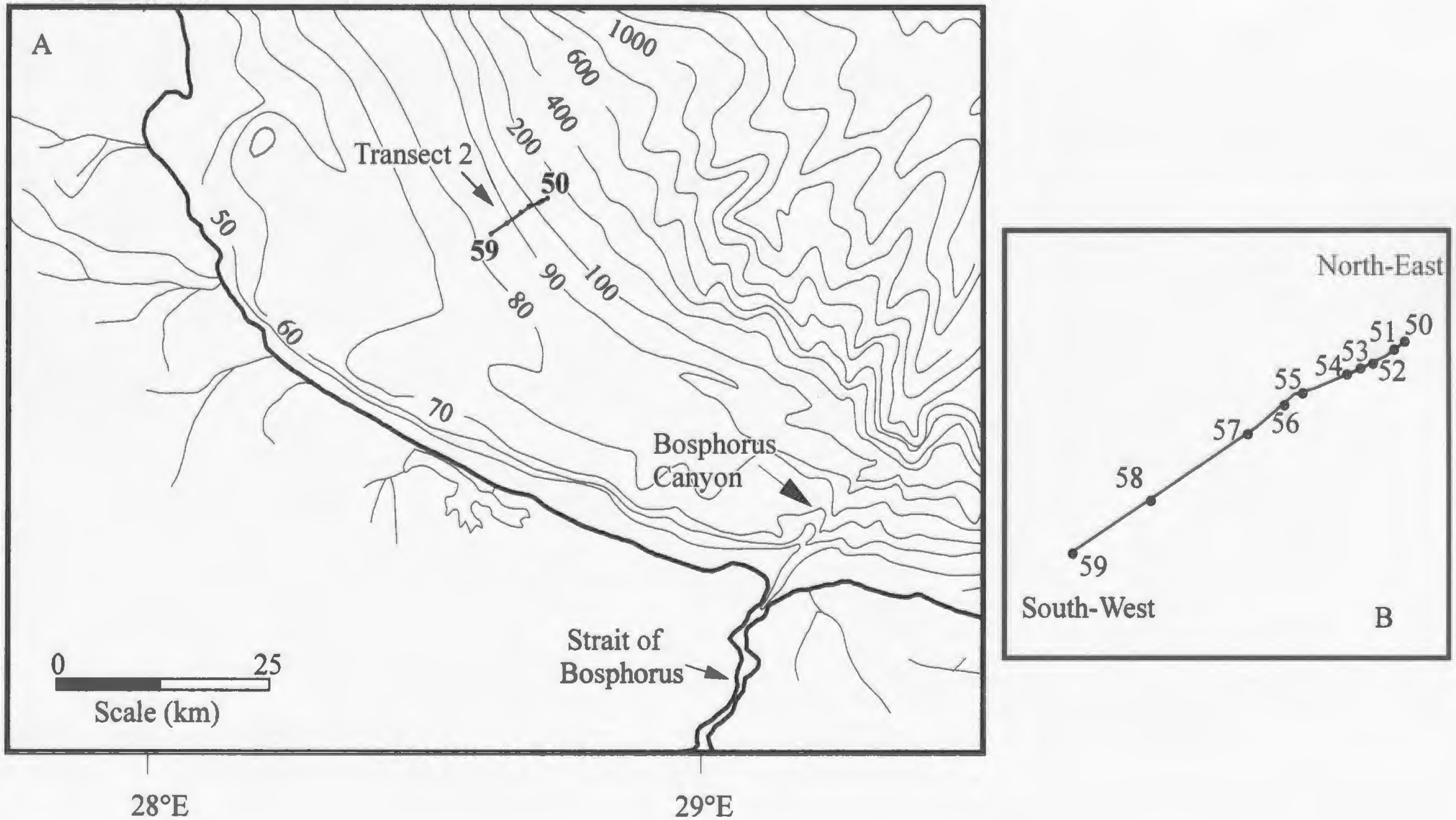


Figure 3.20. Bathymetry of transect 2 (A) and station numbers across transect (B). Contours are in meters.

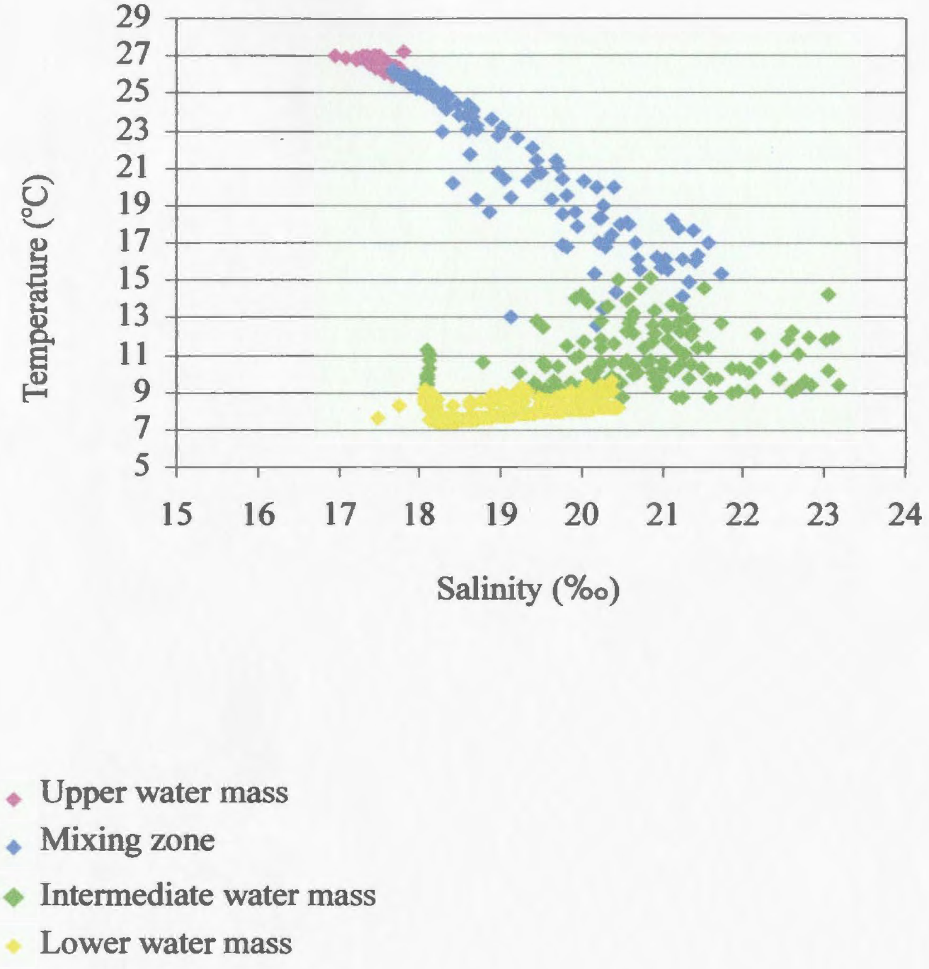


Figure 3.21. Temperature (°C)-Salinity (‰) diagram of transect 2.

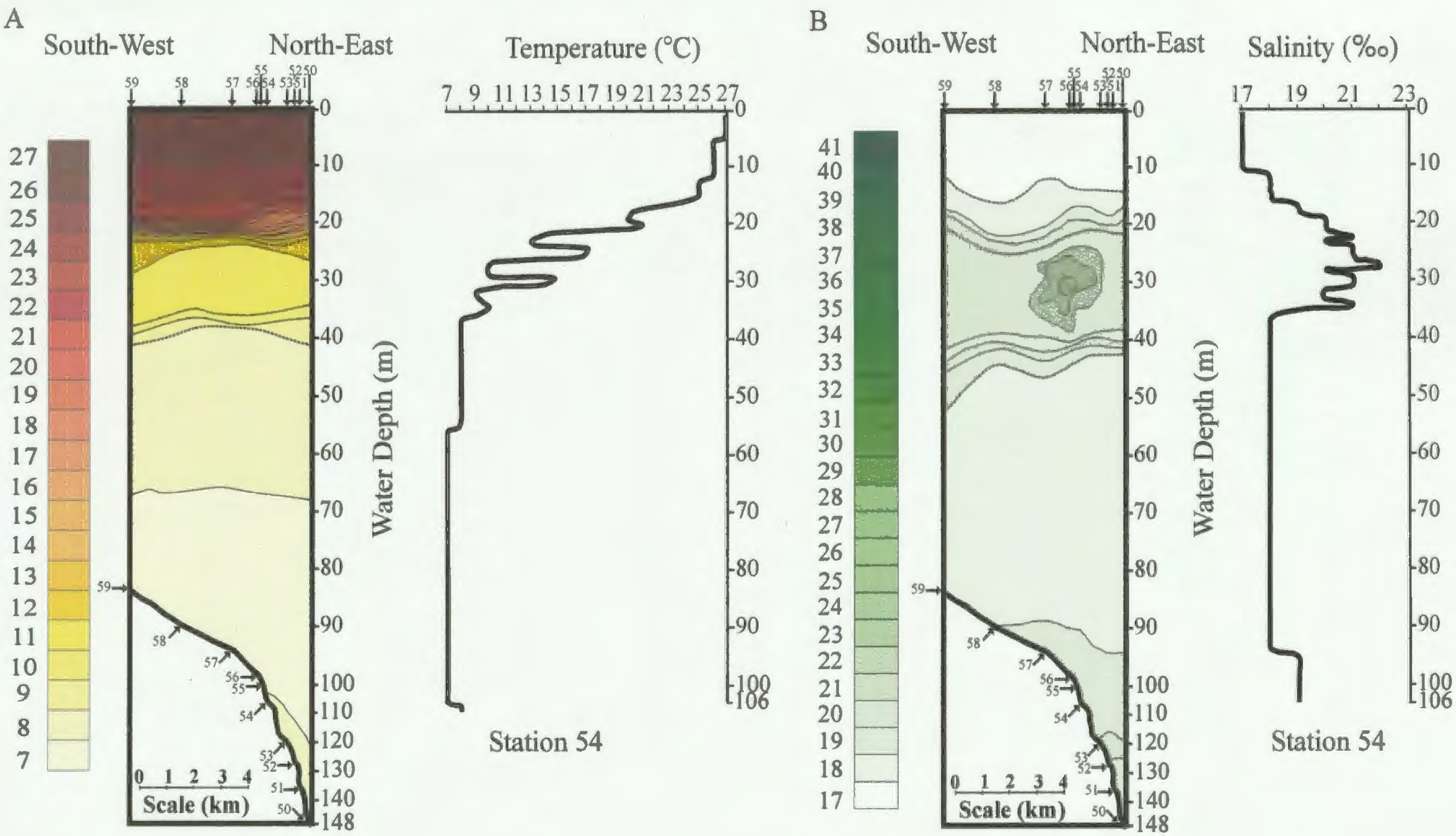


Figure 3.22. A- Temperature (°C) and B- salinity (‰) distribution across transect 2. Note the change in the depth scale below 100 m.

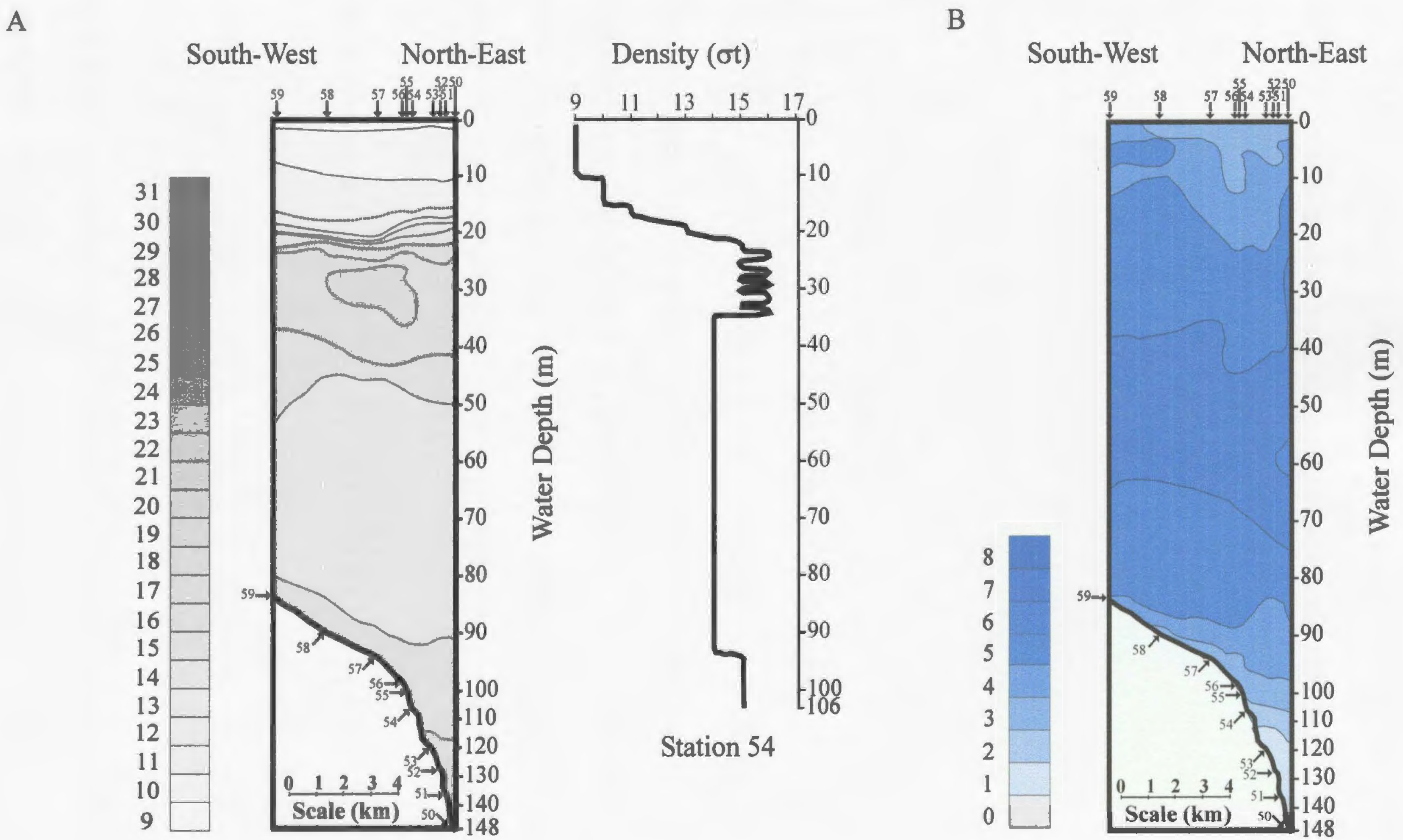


Figure 3.23. A- Density (σt) and B- Dissolved oxygen (ml/l) distributions across transect 2. Note the change in the depth scale below 100 m.

Oxygen concentrations were high (4–6 ml/l) above ~90 m throughout the transect, and are typical of the well-oxygenated Black Sea surface waters, reflecting the lack of vertical mixing (Yılmaz, 2002). However, at depths <10 m there were isolated lower values of 2–3 ml/l, probably as a result of a seasonal zooplankton bloom following a phytoplankton bloom. Below ~90 m depth, the dissolved oxygen values felt rapidly to 1 ml/l by 115 m depth, forming the oxycline layer. According to Yılmaz (2002), this rapid drop in dissolved oxygen concentration is a result of oxidation of particulate organic matter settling through the water column.

Surface sediments along transect 2 were clayey-silts, except those at station 55, which sandy-silt (Figure 3.24). Total organic carbon content in the surface sediment ranged from 1.87–3.59 % (Figure 3.25). These high TOC values suggest either a higher flux of sinking organic matter caused by increased primary productivity, or increased preservation of organic carbon in surface sediments due to low dissolved oxygen concentrations in the overlying bottom waters, or both. The mixing equation discussed in section 3.1.1. suggests that 65%–68% of the TOC is of marine origin (Figure 3.26).

3.2.2. Transect 3

Transect 3 was run across the southwestern shelf of the Black Sea (Figure 3.1, 3.27). There were three distinct water masses (Figure 3.28). The upper water mass is identified by seasonally high temperature values (25–27 °C) and low salinity values (17–18 ‰). It occupied the upper ~12 m of the water column (Figure 3.29, 3.30). Below the upper water mass, a thermocline-halocline-pycnocline between ~10 – ~20 m was

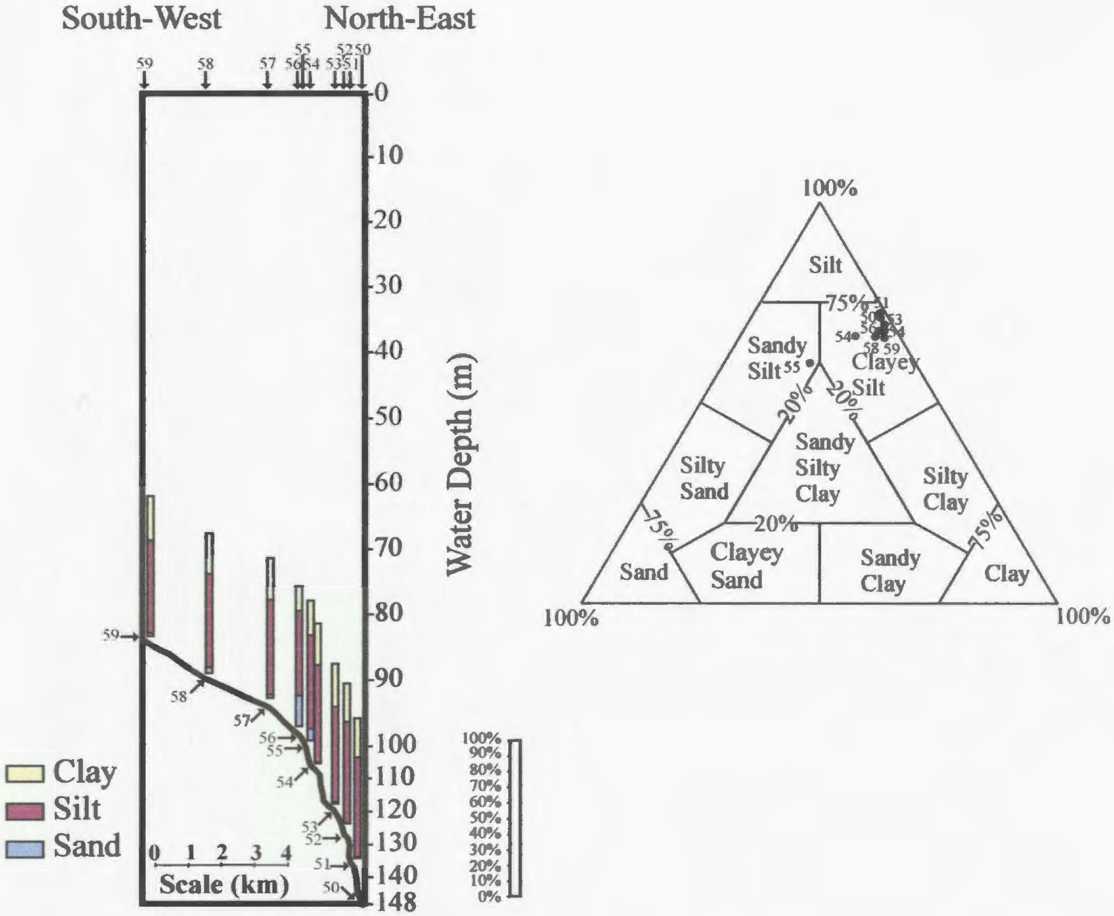


Figure 3.24. Grain size data of surface sediments along transect 2. Note the change in depth scale below 100 m. The classification triangle is from Shepard (1954).

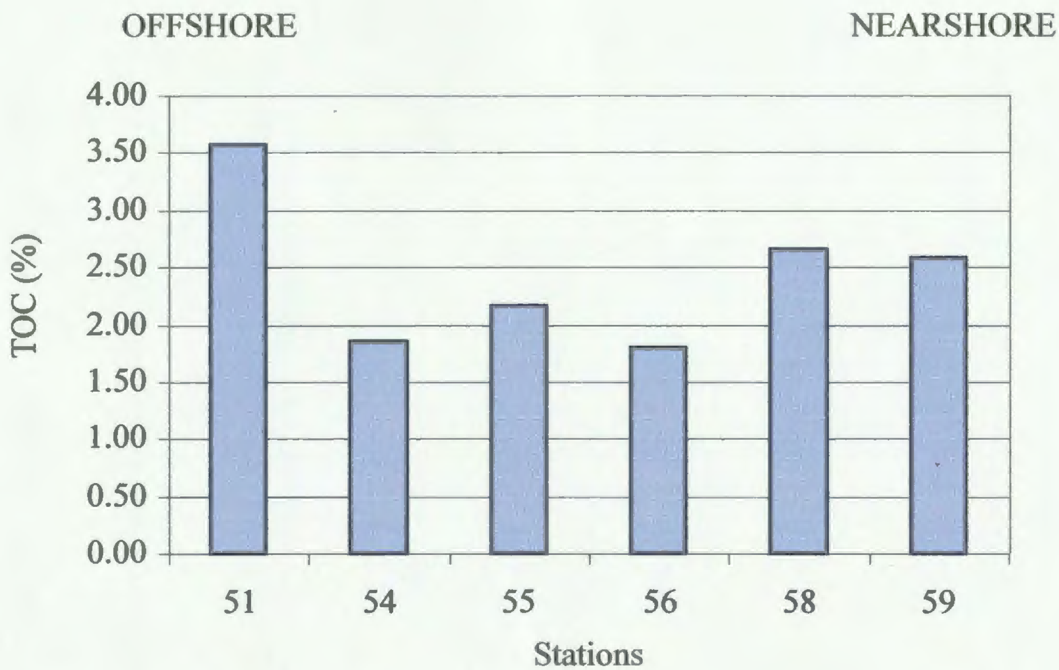


Figure 3.25. Total organic carbon (%) in sediments along transect 2.

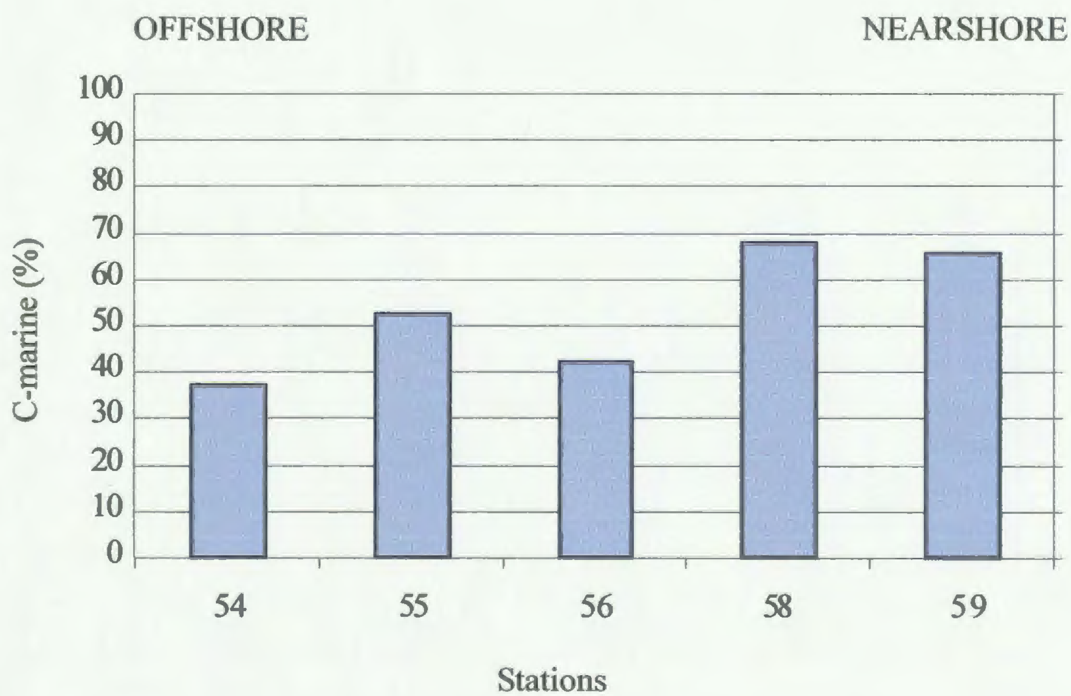


Figure 3.26. Percentages of marine organic carbon along transect 2.

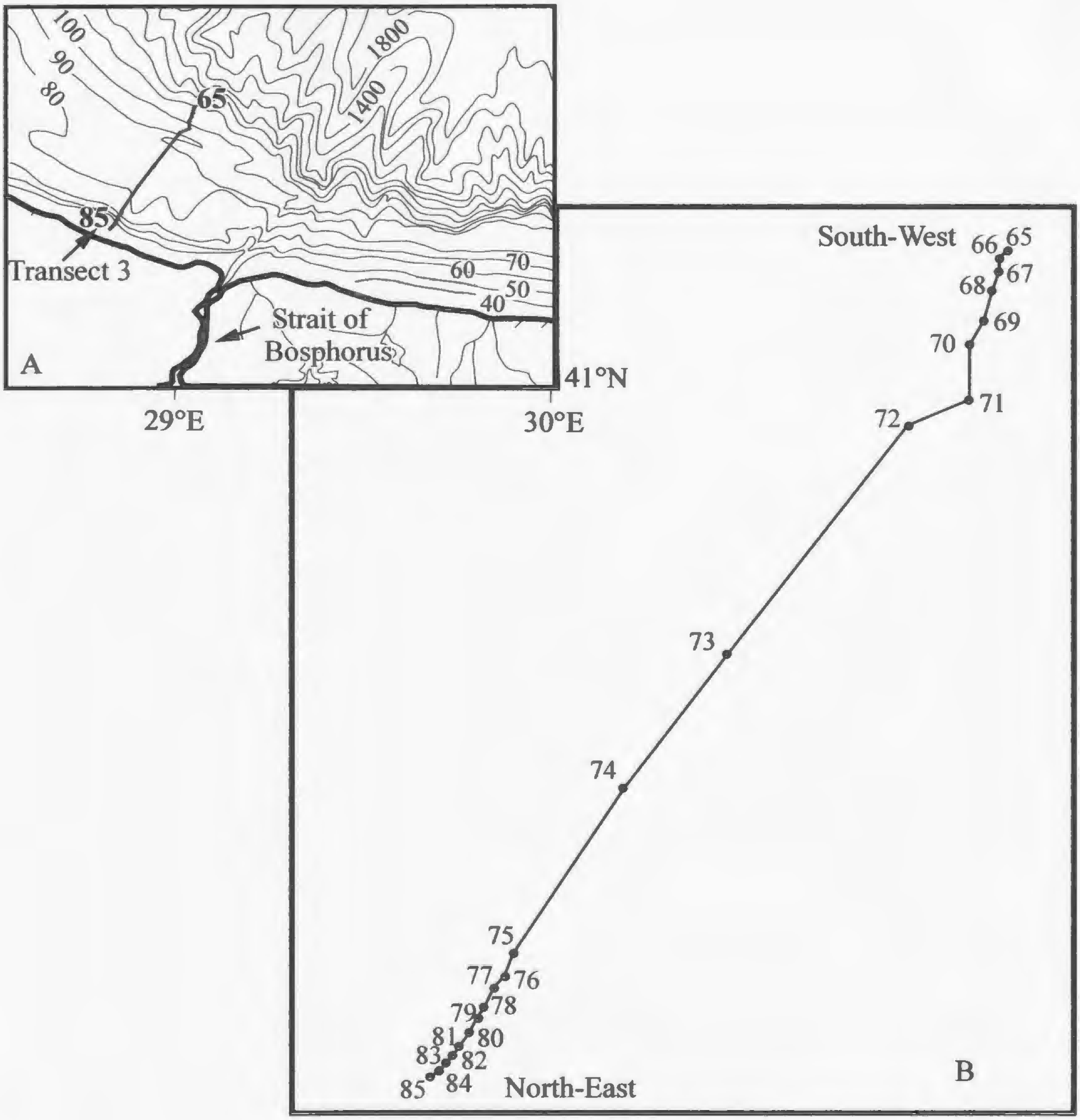


Figure 3.27. Bathymetry of transect 3 (A) and station numbers across transect (B). Contours are in meters. .

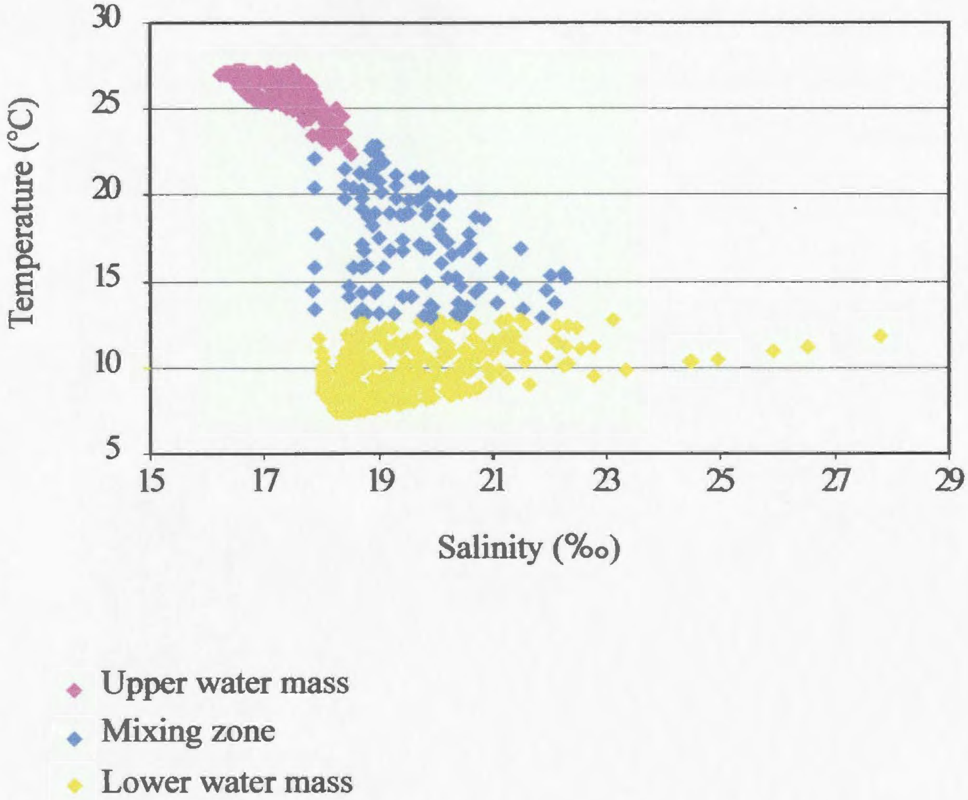


Figure 3.28. Temperature (°C)-Salinity (‰) diagram of transect 3.

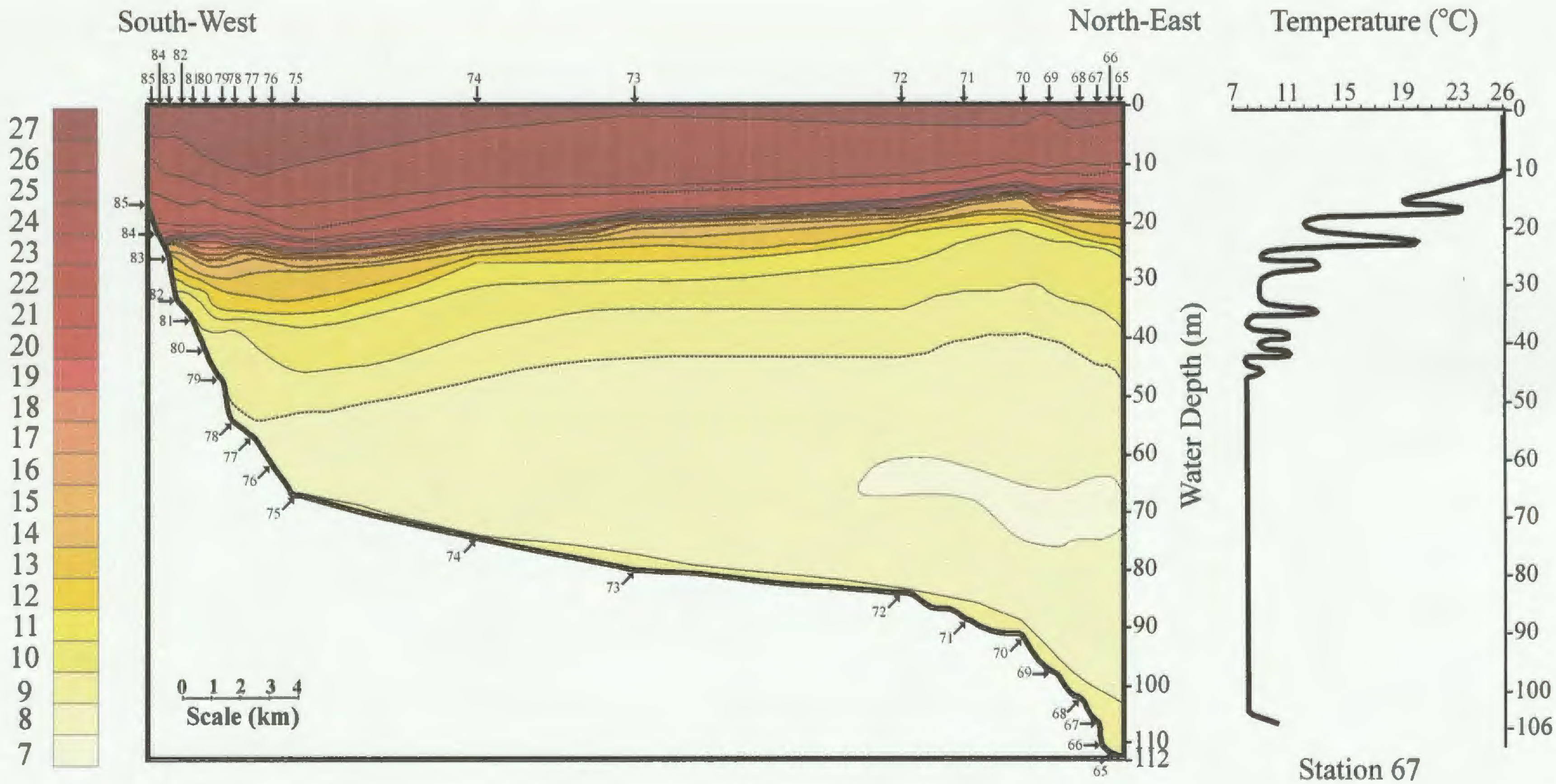


Figure3.29. Temperature (°C) distribution across transect 3.

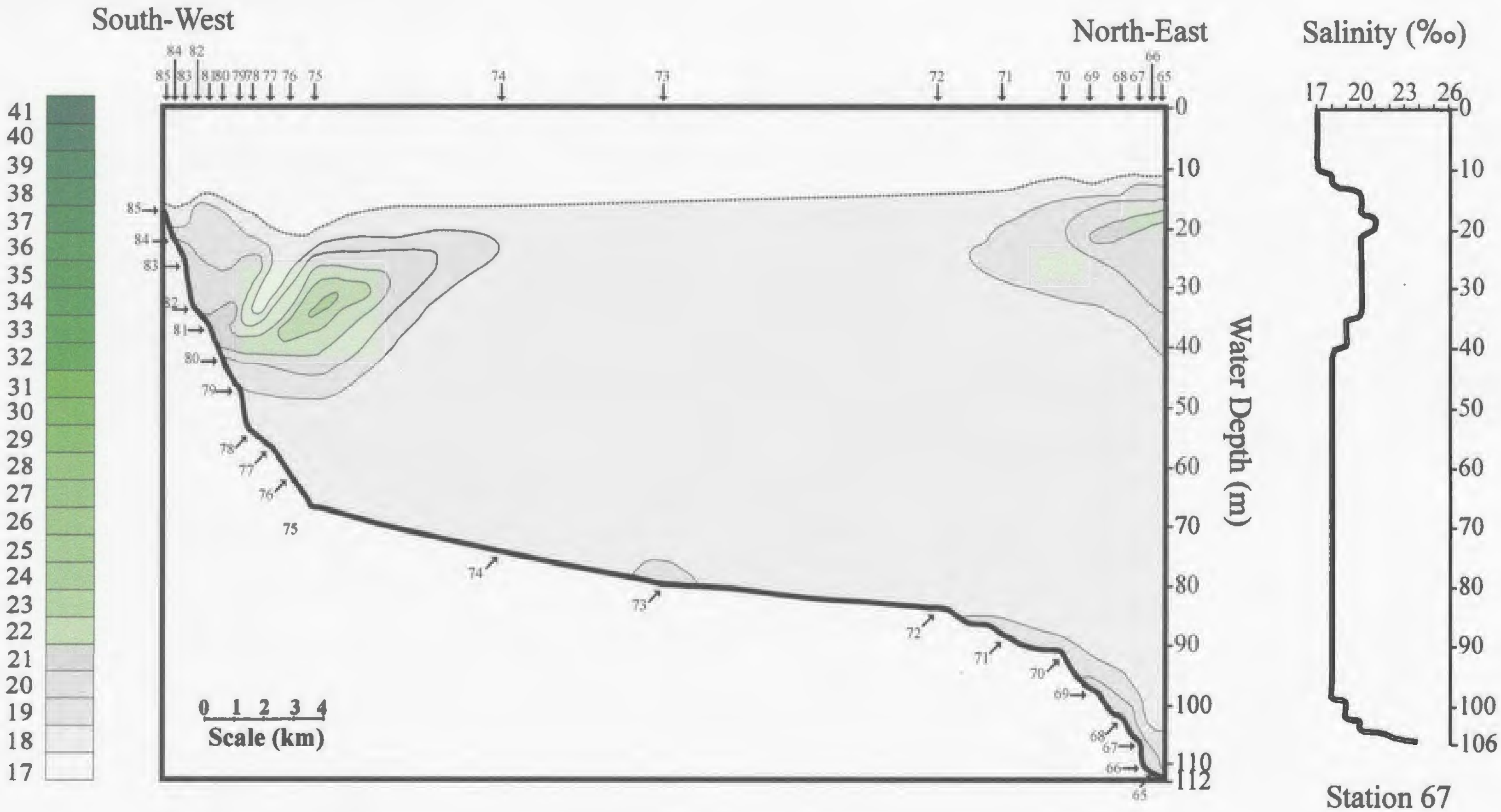


Figure 3.30. Salinity (‰) distribution across transect 3.

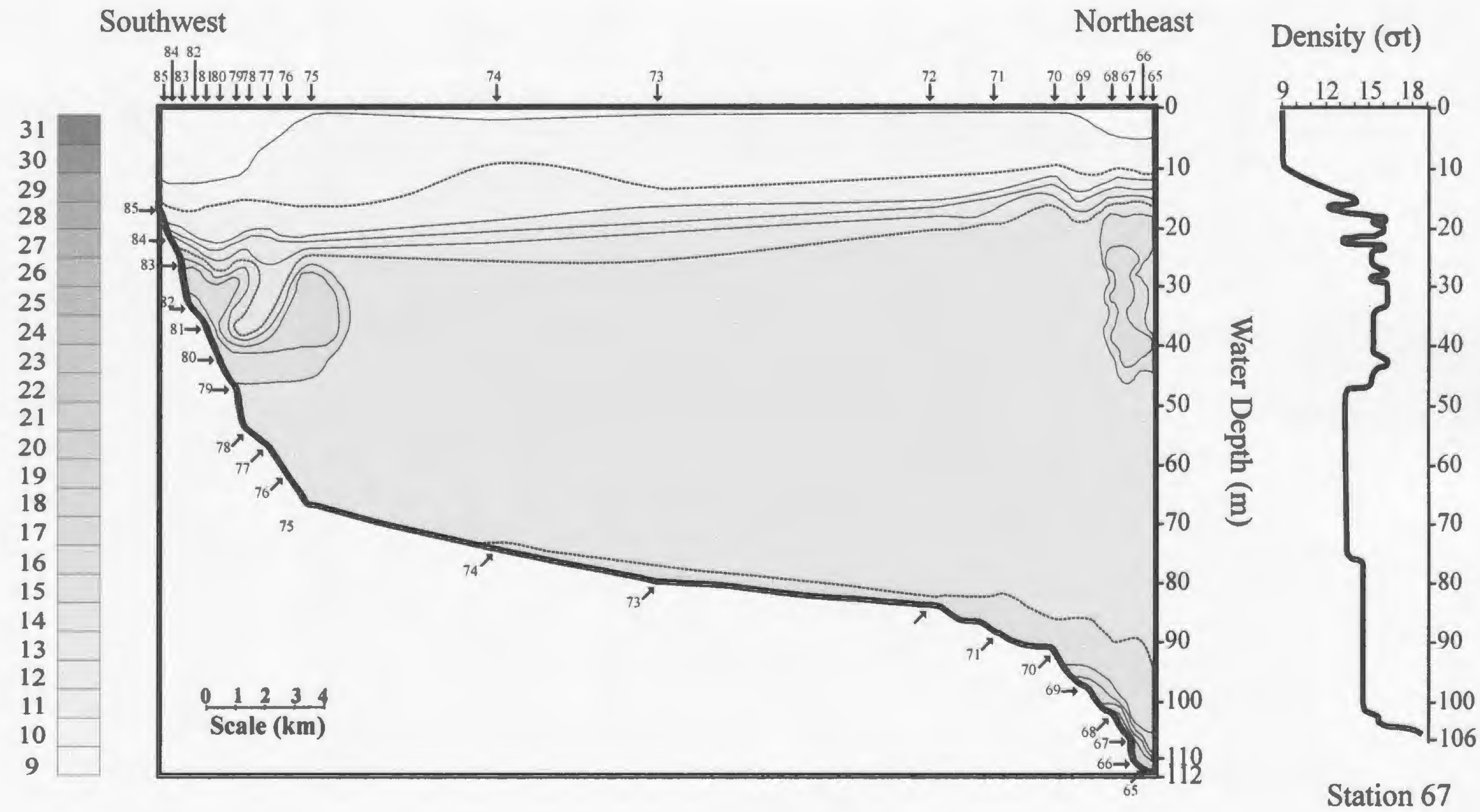


Figure 3.31: Density (σt) distribution across transect 3.

characterized by a 12 °C decrease in temperature and 1 ‰ increase in salinity with increasing depth (Figure 3.31). The upper water mass and the thermocline-halocline-pycnocline layer represent the surface mixed layer and the seasonal pycnocline of the Black Sea (Murray, 1991). The water mass below the thermocline-halocline-pycnocline was characterized by low temperature (7–10 °C) and low salinity (18 ‰) and lies between 22 m and 100 m. In the nearshore area between stations 81 and 74, there a tongue of higher salinity water (~23 ‰), which occupied the 25–40 m depth zone; this represents Mediterranean Water inflow from the Bosphorus Strait (Figure 3.29, 3.30). The lowest water mass on transect 3 was found at the seabed beyond station 70, in water depths greater than 100 m. It characterized by low-intermediate salinity (25–27 ‰) and temperature (9–11 °C) (Figure 3.29, 3.30). This water mass represents another plume of Mediterranean Sea inflow which reaches the Black Sea via the Bosphorus Strait (Ünlüata et al., 1990). The size and location of the tongues of higher salinity Mediterranean water would be expected to vary from week to week, or certainly whenever shelf currents fluctuate. Therefore, a re-survey of transect 3 in another year would be expected to reveal a different pattern of salinity variation with depth for many stations. However, the bulk of the water from ~22–100 m should have temperature of 7–10 °C and salinity of ~18 ‰.

The dissolved oxygen concentrations generally high, ranging between 2 and 7 ml/l (Figure 3.32), its highest values being at station 65 (8–11 ml/l). These very high concentrations are typical of the eutrophic Black Sea waters, reflecting the excess

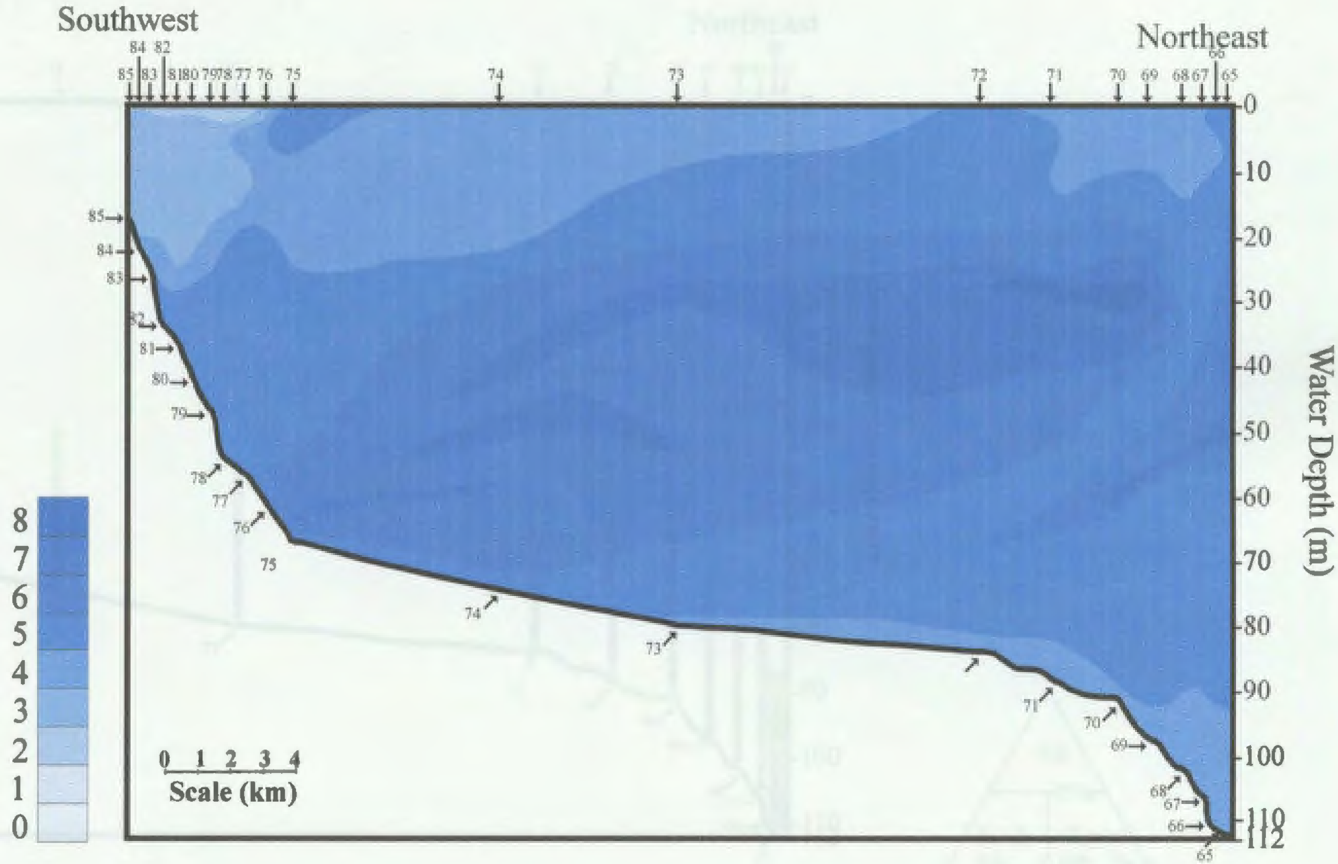


Figure 3.32. Dissolved oxygen (ml/l) distribution across transect 3.

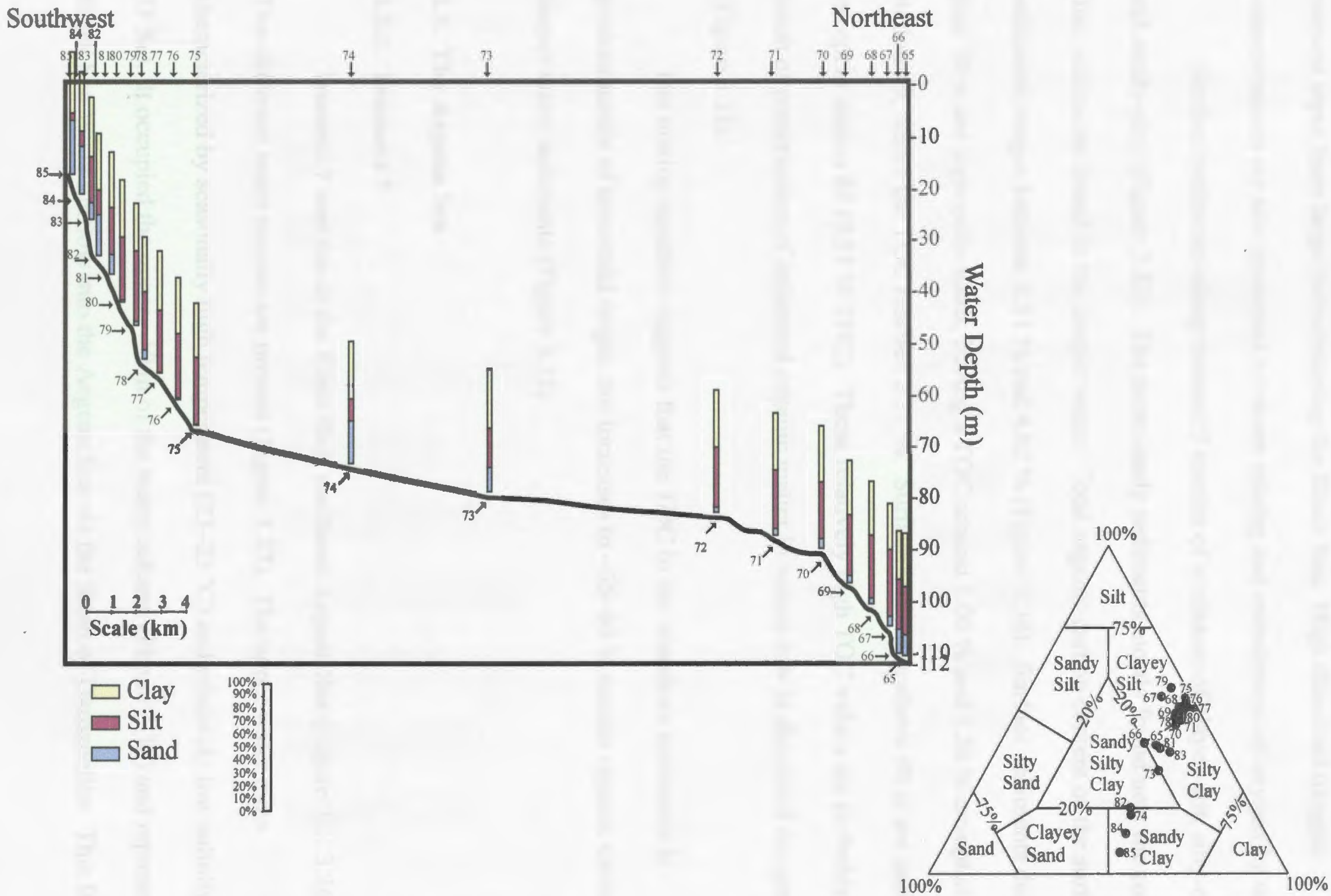


Figure 3.33. Grain size data of surface sediments along transect 3. The classification triangle is from Shepard (1954).

nutrient input from large rivers entering the Black Sea. High dissolved oxygen concentrations are also promoted by storm mixing and entrainment of oxygen by waves.

Surface sediments along transect 3 consist of a mixture of clayey-silt, silty-clay and sandy-clay (Figure 3.33). The more sandy sediments mostly found near the coast and finer sediments found in the deeper water. Total organic carbon content of the surface sediments ranges between 0.51 % and 4.62 % (Figure 3.34). Surface sediments deeper than 70 m are sapropelic muds, having a TOC around 1.00 % and 1.50 % except at station 69, where the TOC reached 2.31 %. Surface sediments above 40 m are sapropel, except at station 84 (0.51 % TOC). These relatively high TOC values are probably the result of preservation of enhanced organic matter in waters low in dissolved oxygen (Figure 3.32).

The mixing equation suggests that the TOC in the nearshore sediments is predominantly of terrestrial origin, but increases to ~55–60 % marine organic carbon in deeper water sediments (Figure 3.35).

3.3. The Aegean Sea

3.3.1. Transect 7

Transect 7 was run in the Saros Bay, northeast Aegean Sea (Figure 3.1, 3.36). Two different water masses are present (Figure 3.37). The upper water mass characterized by seasonally high temperature (23–25 ˚C) and relatively low salinity (32–35 ‰). It occupied the upper ~10 m of the water column (Figure 3.38) and represents the Black Sea Water outflow into the Aegean Sea via the Strait of Dardanelles. This Black

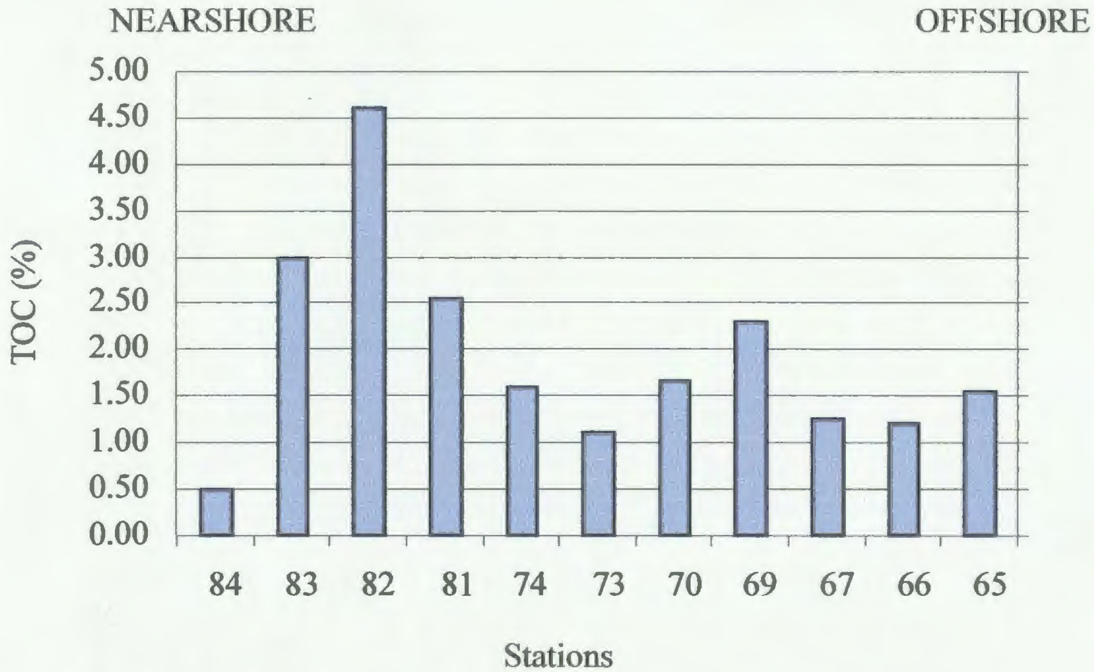


Figure 3.34. Total organic carbon (%) in sediments along transect 3.

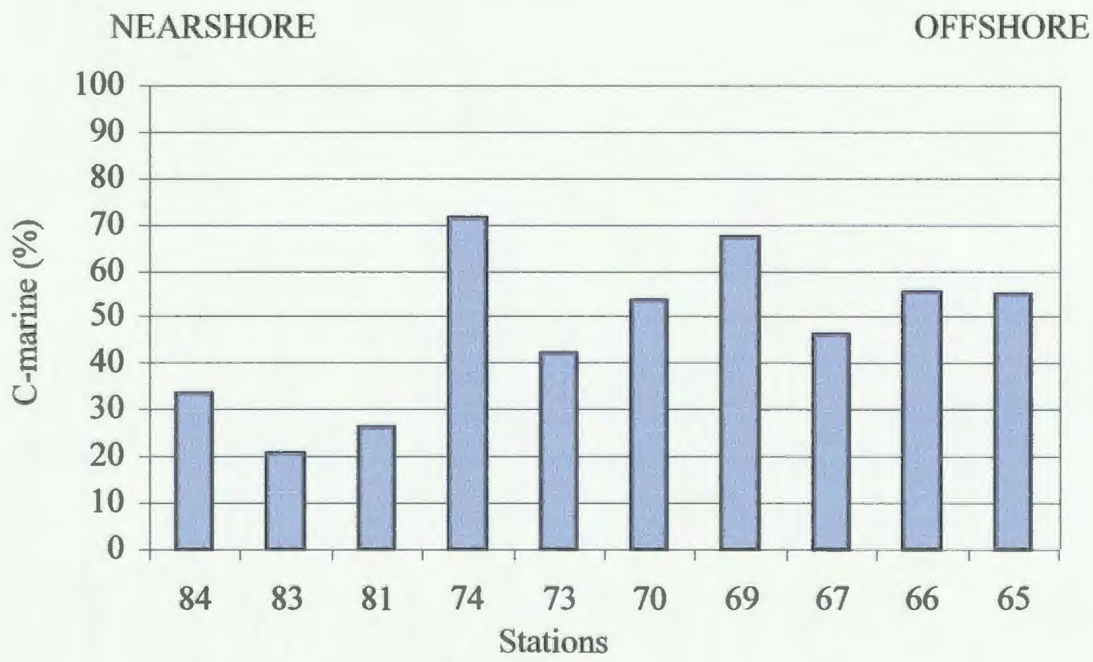


Figure 3.35. Percentages of marine organic carbon along transect 3.

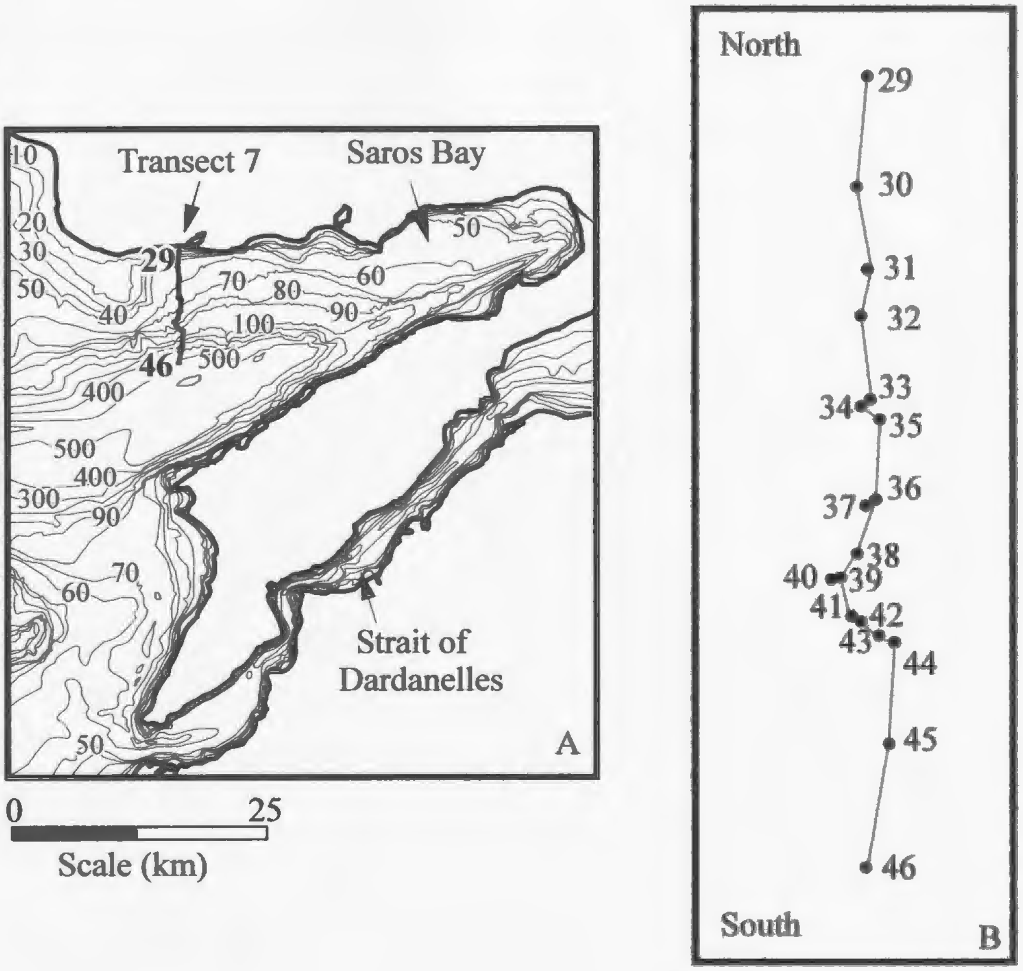


Figure 3.36. Bathymetry of transect 7 (A), modified from Yaltırak and Alpar, 2002 and station number across transect (B). Contours are in meters.

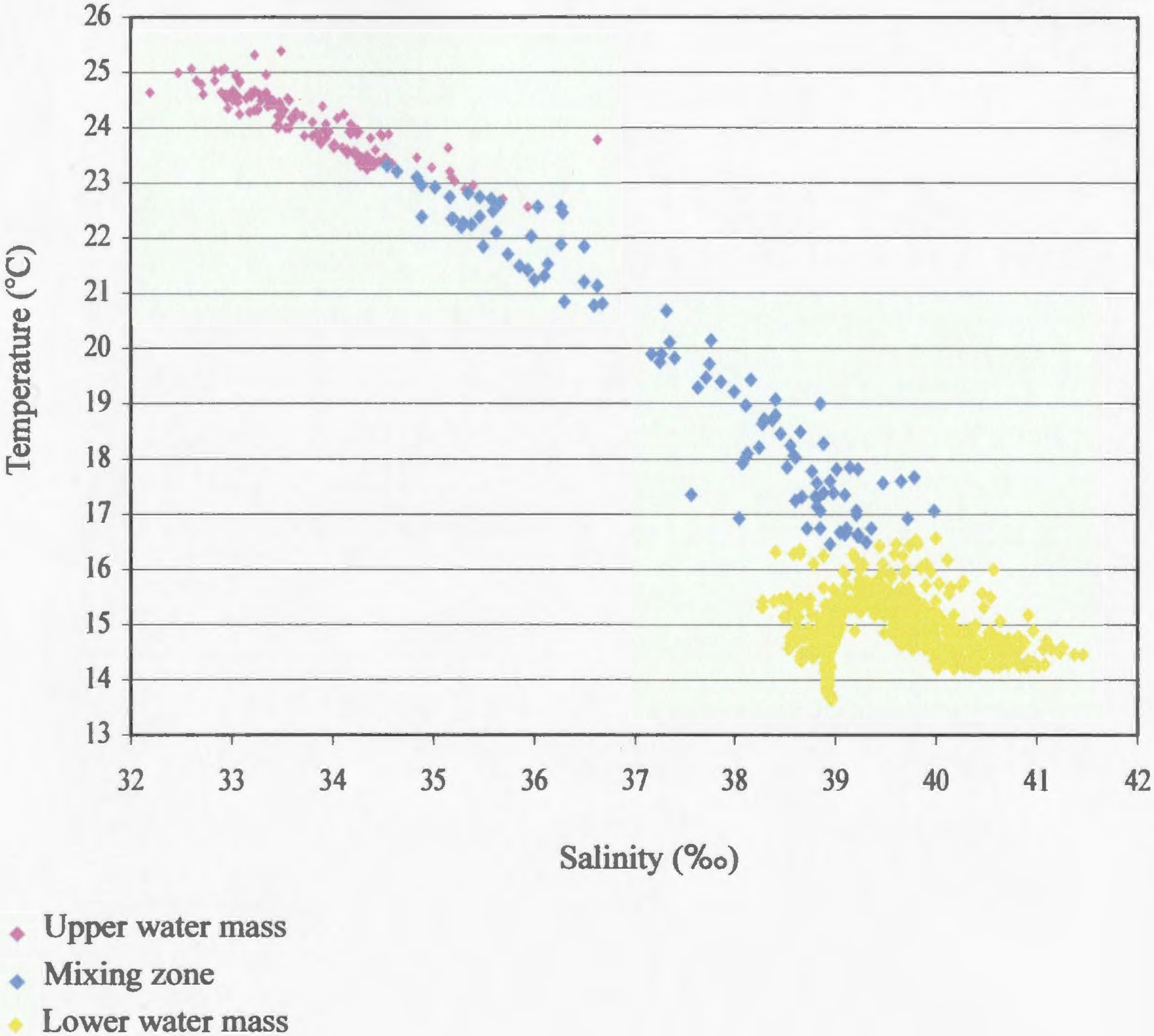


Figure 3.37. Temperature (°C)-Salinity (‰) diagram of transect 7.

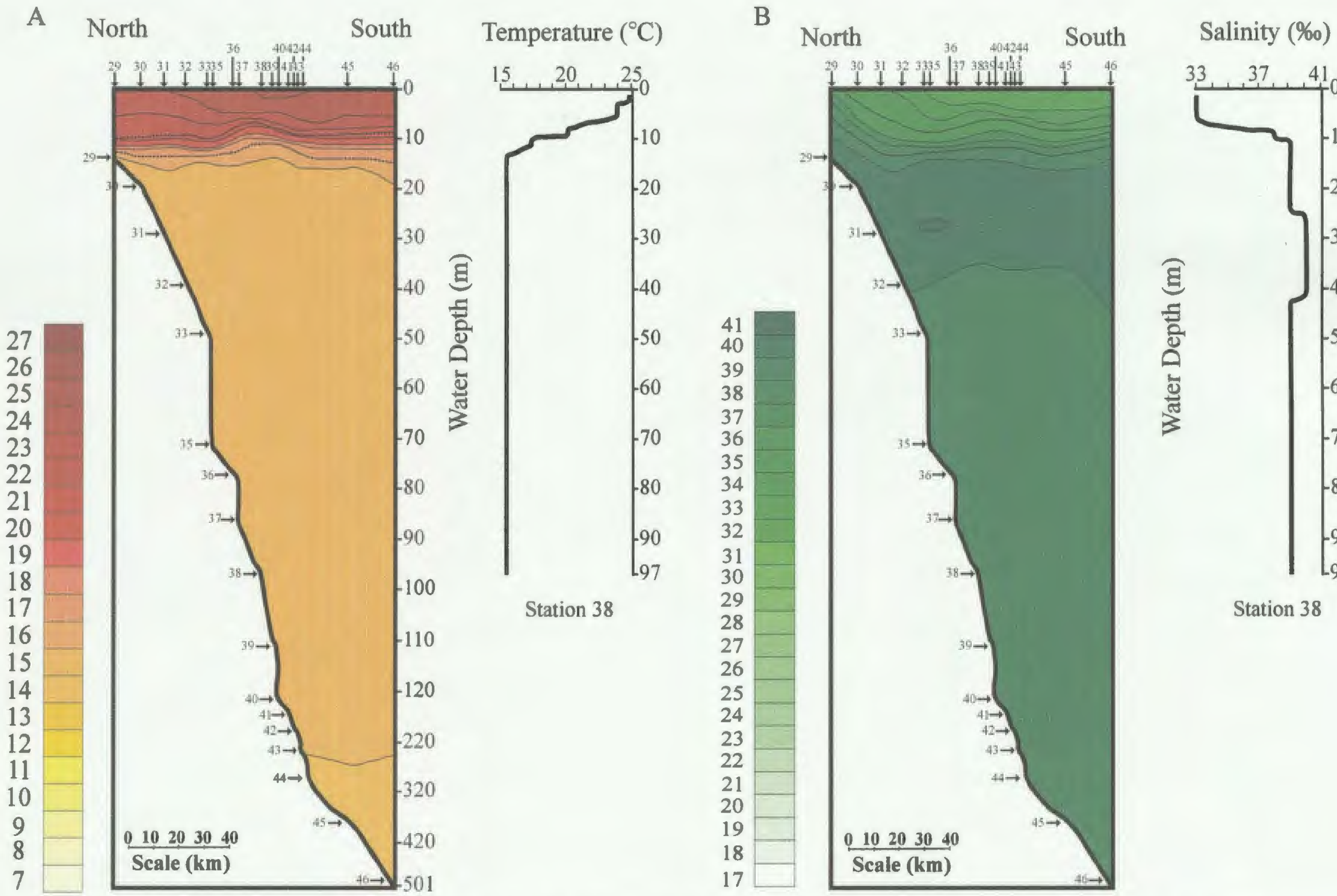


Figure 3.38. A- Temperature (°C) and B- salinity (‰) contours of transect 7. Note the change in the depth scale (to one division = 100 m) below 120 m.

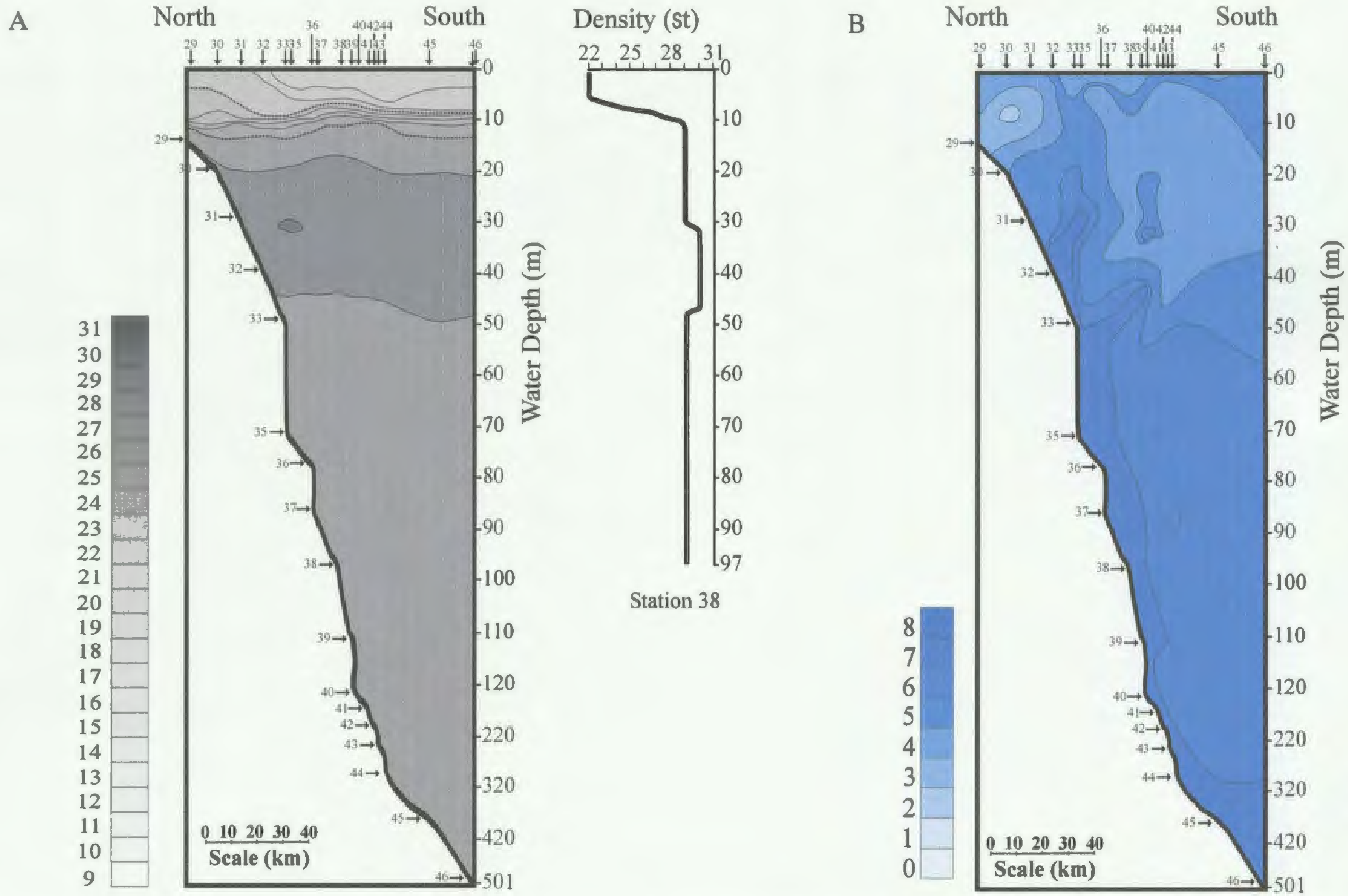


Figure 3.39. A- Density (St) and B- dissolved oxygen (ml/l) distributions along Transect 7. Note the change in the depth scale (to one division = 100 m) below 120 m.

Sea influenced water mass forms the 40 m-deep surface water in the Aegean Sea (Zodiatis, 1994), but in transect 7 only occupied 5 m of the water column. A mixing zone forms the thermocline-halocline-pycnocline between ~10 m and ~15 m and marks a 9 °C decrease in temperature and 7 ‰ increase in salinity with increasing water depth (Figure 3.38, 3.39). The water mass below the thermocline is characterized by low temperature (14–15 °C) and high salinity (39–40 ‰) (Figure 3.38), corresponding to the Intermediate Water Mass of the North Aegean Sea (Yaşar, 1994).

High dissolved oxygen concentrations across the profile, ranging between 4 and 7 ml/l, probably represent entrainment of atmospheric oxygen through wind mixing or wave breaking. The lowest value was 2 ml/l at ~10 m depth at landward station 30 (Figure 3.39).

Surface sediments along transect 7 consisted primarily of silty-sand, sand, clayey-sand, and clayey-silt (Figure 3.40). The sandier sediments occurred in depths <90 m, the more muddy sediments farther offshore. Total organic carbon content in the surface sediments is generally between 0.05 and 1.85 % (Figure 3.41). The $\delta^{13}C_{org}$ values ranged from -18.11 ‰ to -22.56 ‰. According to the mixing equation, surface sediments contain almost exclusively marine organic carbon (Figure 3.42).

3.3.2. Transect 8

Transect 8 was run on at the north side of Edremit Bay in the Aegean Sea (Figure 3.1, 3.43). Three different water masses present (Figure 3.44). The upper water mass identified by high salinity (39–40 ‰) and temperature (22–24 °C), and occupied the

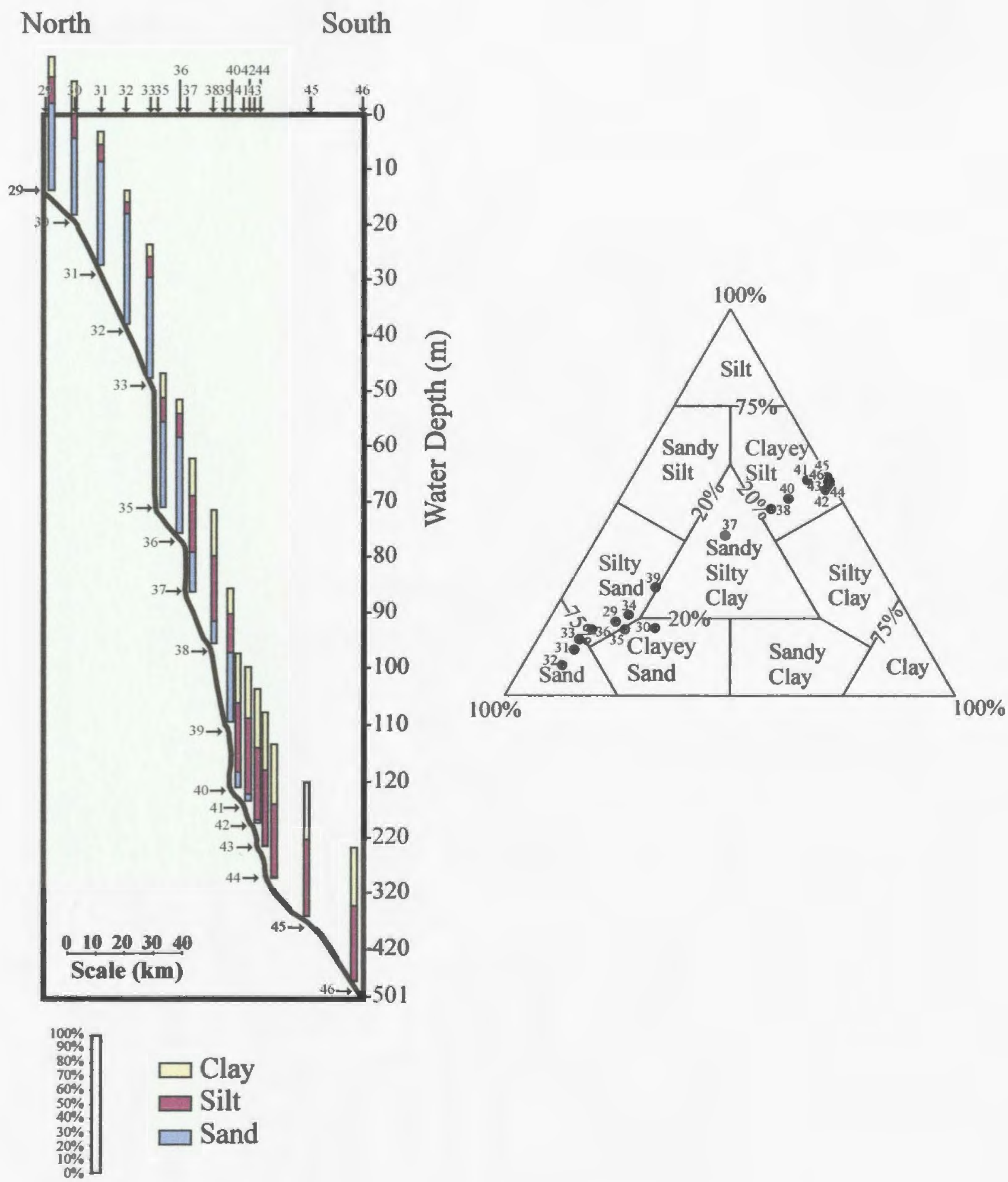


Figure 3.40. Grain size data of surface sediments along transect 7. The classification triangle is from Shepard (1954). Note the change in the depth scale (to one division = 100 m) below 120 m..

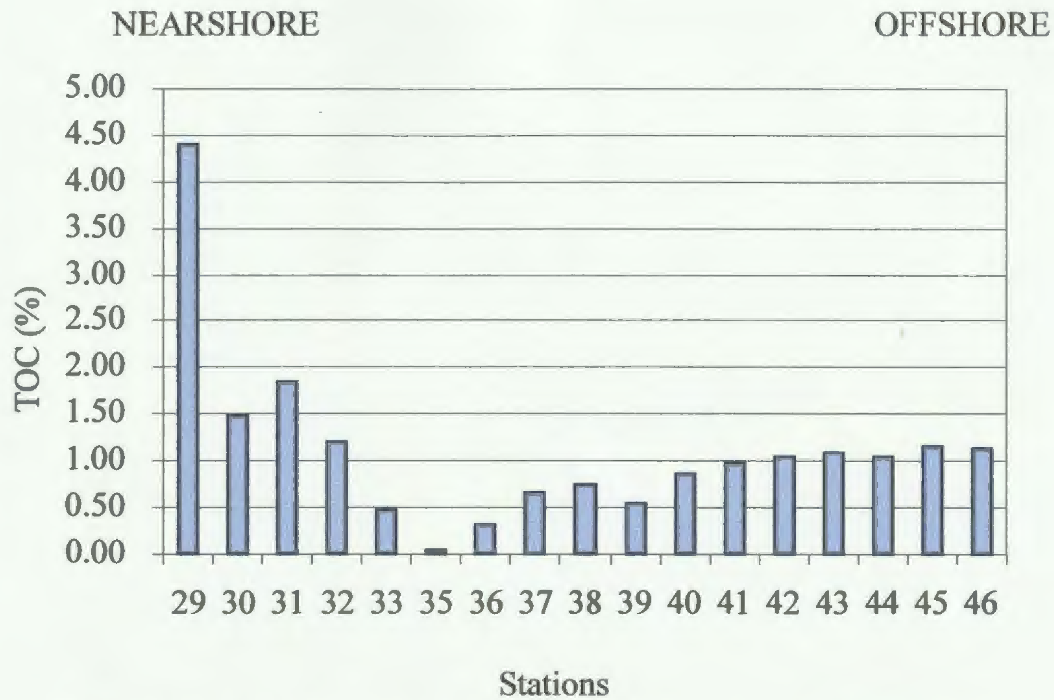


Figure 3.41. Total organic carbon (%) in sediments along transect 7.

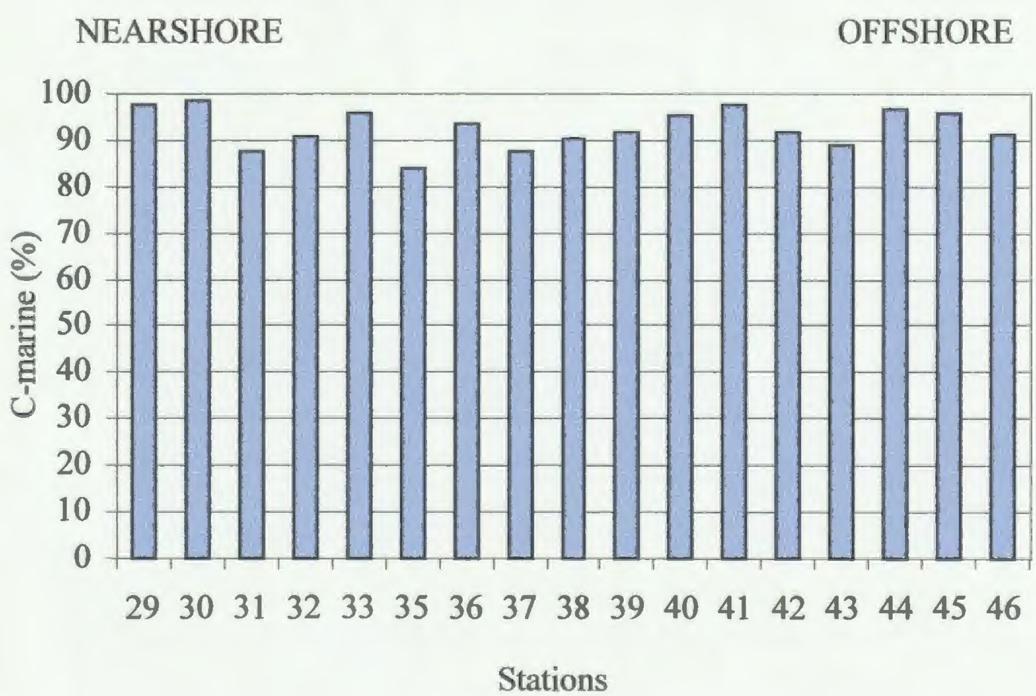


Figure 3.42. Percentages of marine organic carbon along transect 7.

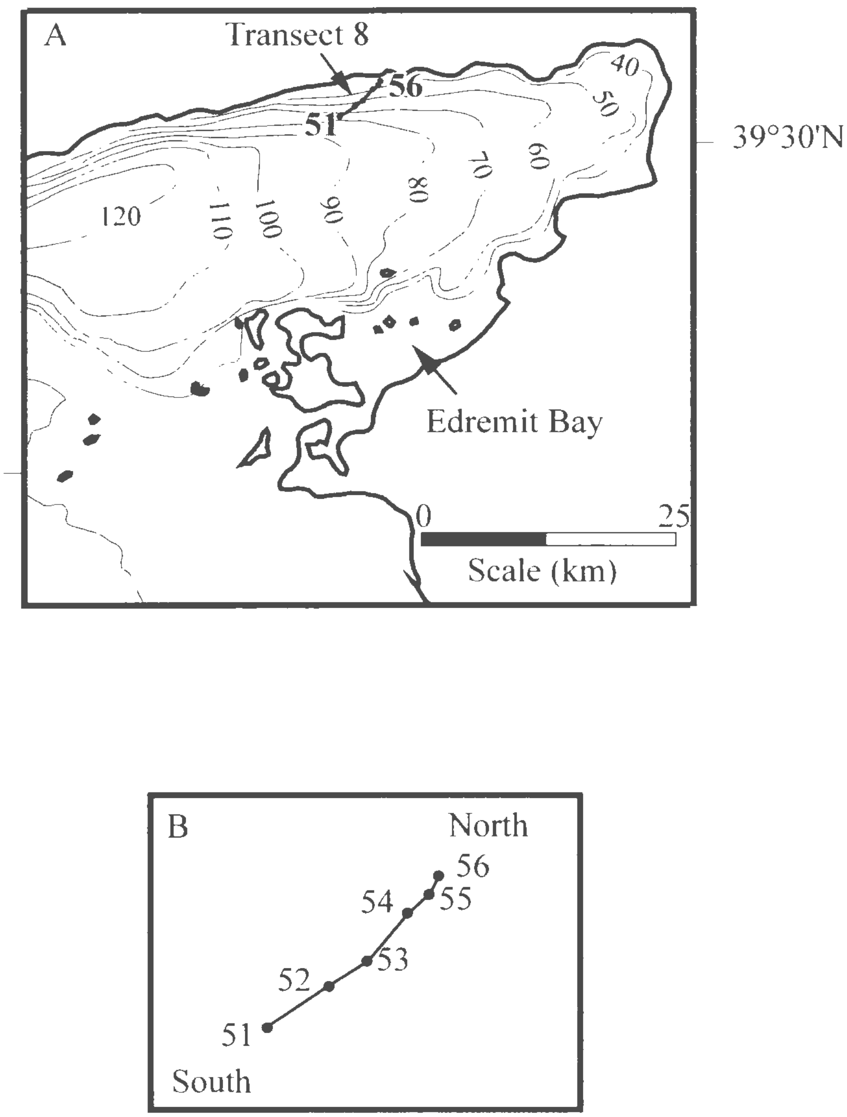


Figure 3.43. Bathymetry of transect 8 (A) and station numbers across transect (B), modified from Yaltırak, 2003. Contours are in meters.

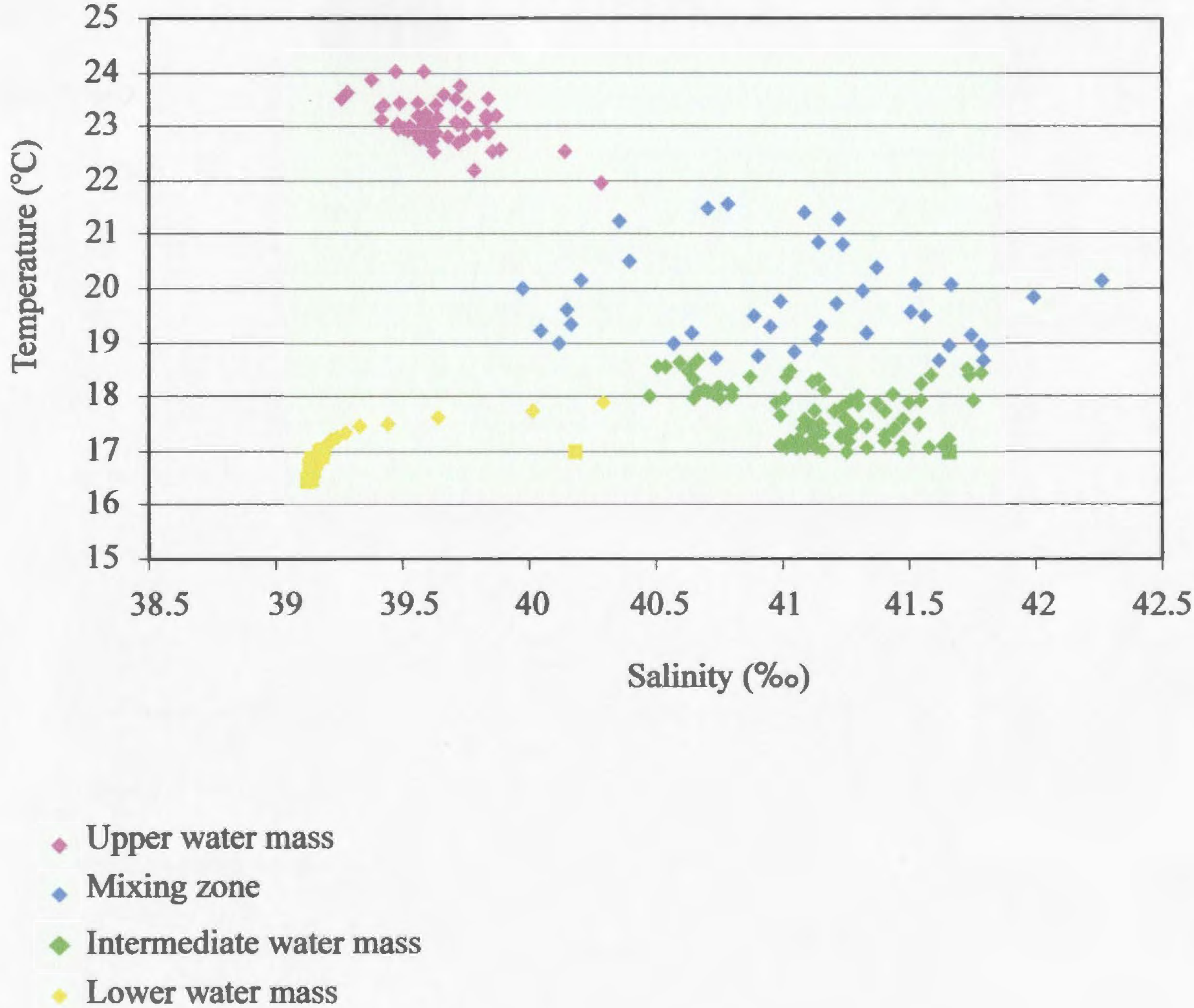


Figure 3.44. Temperature (°C)-Salinity (‰) diagram of transect 8.

upper ~10 m of the water column (Figure 3.45). The next water mass characterized by high salinity (41–42 ‰) and low temperature (17–18 °C), and extended from ~15 m to ~30 m depth. These two water masses were separated by a thermocline-halocline-pycnocline between ~10 m and ~15 m. The third water mass had a salinity similar to that of the surface waters (39–40 ‰), but colder (16–17 °C). It situated below ~40 m depth. The deepest part of transect 8 was only at 67 m. The three water masses described above are still within what is traditionally recognized as the surface waters of the Aegean Sea (Yüce, 1991).

The dissolved oxygen profiles generally showed high values (4–8 ml/l), which is attributed to wind mixing and wave activity (Figure 3.45). However, surface measurements at stations 54, 52 and 51 had lower values of 2–3 ml/l dissolved oxygen.

The surface sediments of transect 8 consisted of clayey-silt and silty-sand (Figure 3.46). The total organic carbon content is moderate, ranging between 0.54 % and 1.81 % (Figure 3.47). The $\delta^{13}C_{org}$ values ranged between -23.34 and -24.89 ‰. According to the mixing equation, stations 56, 55 and 54 have ~70 % marine organic carbon and stations 53, 52 and 51 had almost equal amounts of marine and terrestrial organic carbon (Figure 3.47).

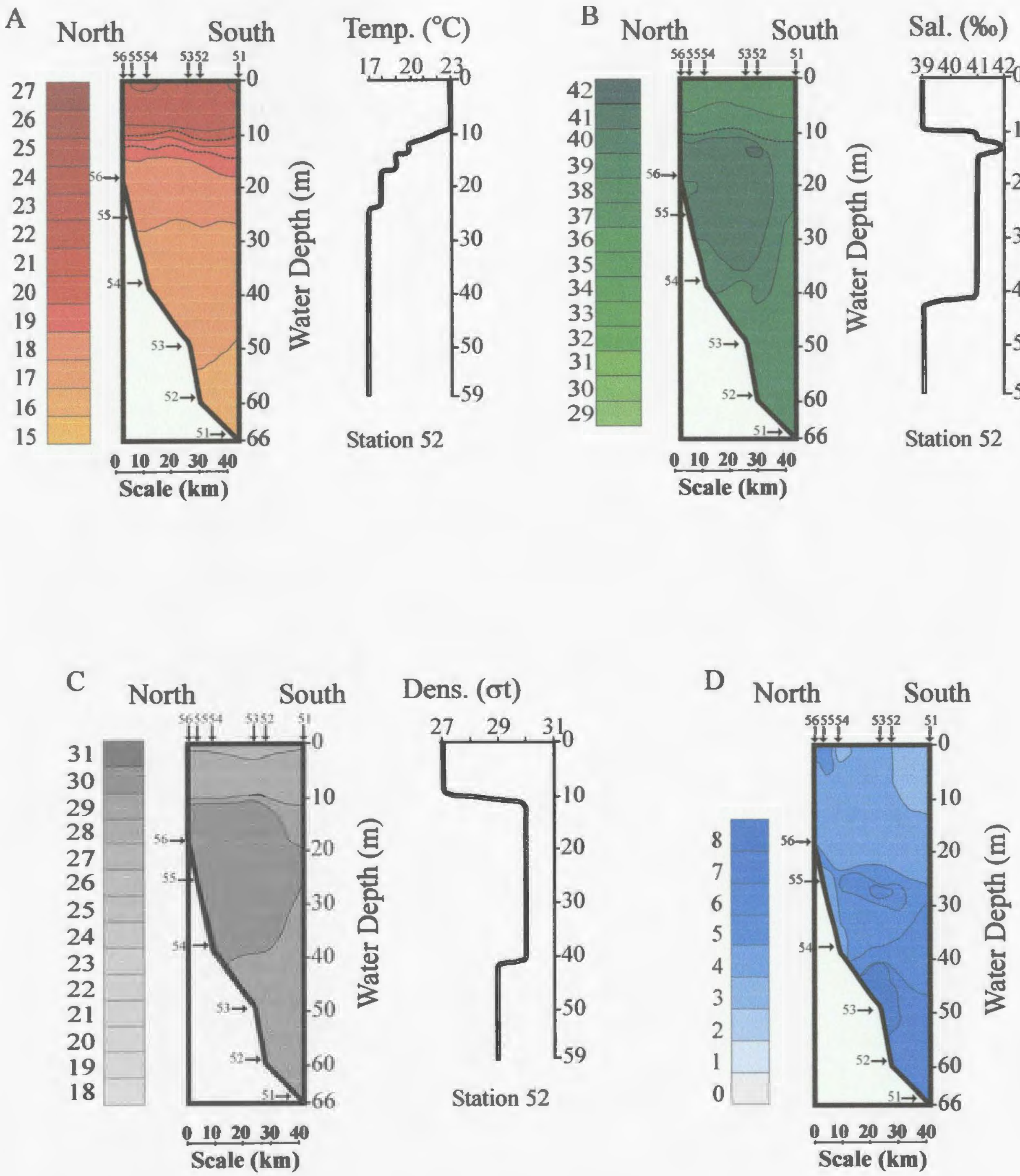


Figure 3.45. A- Temperature (°C), B- Salinity (‰), C- Density (σt) and D- Dissolved Oxygen (ml/l) distributions across transect 8.

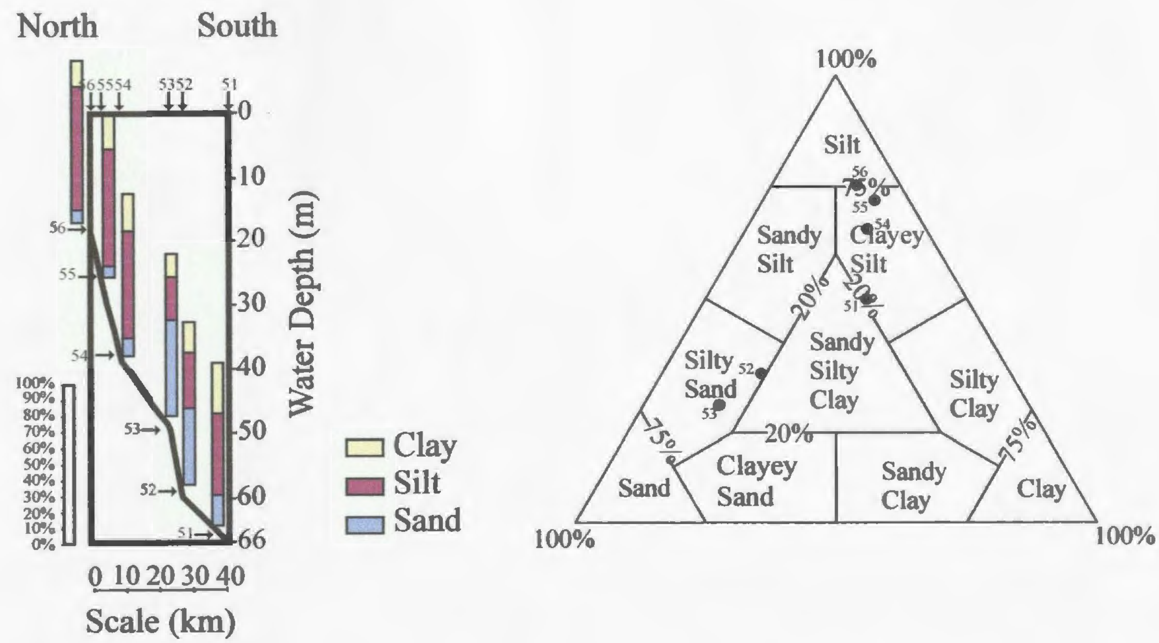


Figure 3.46. Grain size data of surface sediments along transect 8. The classification triangle is from Shepard (1954).

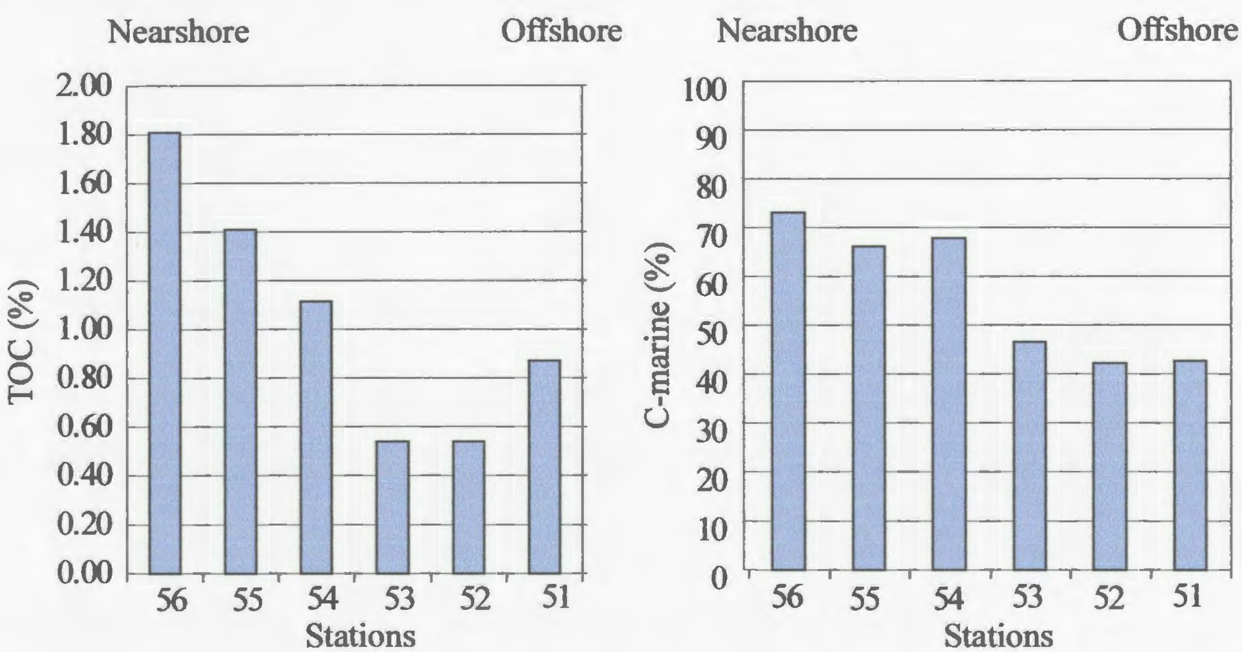


Figure 3.47. Total organic carbon (%) and the percentage that is marine organic carbon in sediments along transect 8.

CHAPTER 4

TAXONOMY

The phylum Mollusca is one of the largest, most diverse groups in the animal kingdom. There are six major classes of molluscs: Monoplacophora, Polyplacophora, Gastropoda, Cephalopoda, Scaphopoda, and Bivalvia. In this thesis only three classes of Mollusca and 77 species were collected and identified from the grab samples.

Class: GASTROPODA

Family: Fissurellidae

Emarginula rosea (Bell, 1824) (Plate 1-a)

Remarks: This species is found from the low tide line to 90 m deep in the Mediterranean Sea (Poppe and Goto, 1991). It lives under pitted rocks, often where there is a fine silt sediment (Graham, 1971), and was only found in samples collected at 33 m in the Marmara Sea, transect 4 and at 50 m in the Aegean Sea, transect 7.

Family: Trochidae

Calliostoma conulus (Linnaeus, 1758) (Plate 1-b)

Remarks: This species is found in the Mediterranean Sea but is not present in the Black Sea. It lives at water depths between 20 and 200 m (Poppe and Goto, 1991), and prefers a sandy gravel substrate. It was collected at 17 m depth in the Marmara Sea transect 1 and at water depths of 14 m, 20 m, and 39 m in the Aegean Sea, transect 7.

Gibbula leucophaea (Philippi, 1836) (Plate1-c)

Remarks: This species prefers shallow water on rocky shores in the Mediterranean Sea (Poppe and Goto, 1991). It was only obtained from water depths of 14 m and 59 m in the Aegean Sea, transect 7 and transect 8, respectively.

Family: Tricollidae

Tricolia tenuis (Michaud, 1828) (Plate 1-d)

Remarks: This gastropod lives in *Posidonia* fields in shallow waters in the Mediterranean Sea (Poppe and Goto, 1991), and was only found at a water depth of 14 m in the Aegean Sea, transect 7.

Family: Cerithiidae

Cerithium rupestre (Risso, 1826) (Plate 1-e)

Remarks: According to Poppe and Goto (1991), this species prefers rock and sand bottoms, and can be found from the intertidal (<1 m) to a few meters deep in the Mediterranean Sea. It was only collected at 20 m in the Aegean Sea, transect 7.

Bittium latreilli (Payraudeau, 1826) (Plate 1-f)

Remarks: This species is found in the Mediterranean Sea (Poppe and Goto, 1991). It lives under stones or rocky shores or in sandy mud at around the spring low tidal mark (Graham, 1971). The species was collected at 17 m and 109 m in the Marmara Sea, transect 1 and transect 4, respectively and at 14 m, 20 m, 50 m in the Aegean Sea, transect 7 and 49 m from transect 8.

Bittium reticulatum (da Costa, 1778) (Plate 1-g)

Remarks: This species is found from the intertidal zone down to about 250 m deep and it lives on seaweed such as *Posidonia* in the Mediterranean Sea (Poppe and Goto, 1991).

This species was collected at 79 m and from 106 m to 112 m in the Black Sea, transect 3; at 18 m and at 43 m in the Marmara Sea, transect 4; at 14 m in the Aegean Sea, transect 7.

Family: Turritellidae

Turritella communis (Risso, 1826) (Plate 1-h)

Remarks: This species is abundant in muddy sediments and lives in colonies partly buried in the sediment at water depths between 10 and 200 m (Graham, 1971). It is found in the Mediterranean Sea, the Aegean Sea and the Marmara Sea and Bosphorus district in the Black Sea (Zapevalin, 1998). This species was collected from 23 m to 74m deep at the Marmara Sea transects 1 and 4; from 14 m to 112 m deep at the Aegean Sea transects 7 and 8.

Family: Rissoidae

Rissoa auriscalpium (Linnaeus, 1758) (Plate 1-i)

Remarks: This species is found from mean tide level to 15 m water depth in the Mediterranean. It lives under rocks or on algae. Species was only collected from a single sample at 14 m depth in the Aegean Sea, transect 7.

Rissoa splendida (Eichwald, 1830) (Plate 1-j)

Remarks: This species lives in the shallow waters of open bays with algae and it is found in the eastern Mediterranean and the Black Sea (Zapevalin, 1998). This species was only found in samples collected at 14 m and 20 m in the Aegean Sea, on transect 7.

Rissoa lineolata (Michaud, 1832) (Plate 1-k)

Remarks: This species is found on all hard substrates but especilly on weeds in the Mediterranean Sea (Poppe and Goto, 1991). *Rissoa lineolata* was collected at 26 m from the Aegean Sea, transect 8.

Alvania cancellata (da Costa, 1778) (Plate 1-l)

Remarks: This species is common under stones from the low tide line down to 90 m deep in the Mediterranean Sea (Poppe and Goto, 1991). This species was only collected at water depths of 14 m, 20 m, and 39 m in the Aegean Sea, transect 7.

Alvania cimex (Linnaeus, 1758) (Plate 2-a)

Remarks: This species lives under stones in shallow waters of the Mediterranean Sea, the Aegean Sea, the Marmara Sea and Bosphorus district in the Black Sea (Zapevalin, 1998). *Alvania* species was collected at 111 m in the Black Sea, on transect 3 and at 14 m and 20 m in the Aegean Sea, on transect 7.

Family: Tornidae

Tornus subcarinatus (Montagu, 1803) (Plate 2-b)

Remarks: This species found in the lower intertidal zone down to 3 m deep or deeper water into the Mediterranean Sea and the Black Sea (Poppe and Goto, 1991). It prefers to live under big stones and rocks laying on well oxygenated sand (Poppe and Goto, 1991). This species was only found at 39 m and 59 m in samples collected in the Aegean Sea, transects 7 and 8.

Family: Truncatellidae

Truncatella subcylindirica (Linnaeus, 1767) (Plate 2-c)

Remarks: This species lives at lower to upper littoral zone in the Mediterranean Sea and the Black Sea. It is found in the upper intertidal zone under stones, wood and plants and it prefers gravely or muddy bottoms (Graham, 1971; Poppe and Goto, 1991). It can tolerate salinity between 18 and 40 ‰. *Truncatella* species was only collected at 74 m and 79 m in the Black Sea, transect 3.

Family: Aporrhaidae

Aporrhais pespelecani (Linneaeus, 1758) (Plate 2-d)

Remarks: This species lives in colonies between 10 and 180 m deep on muddy sand or mud bottoms. It can be found from northern Norway and Iceland to Morocco and into the Mediterranean Sea and the Black Sea (Poppe and Goto, 1991). Species was only collected at 60 m in the Aegean Sea, on transect 7 and at 49 m and 59 m in the Aegean Sea, on transect 8.

Family: Calyptraeidae

Calyptraea chinensis (Linnaeus, 1758) (Plate 2-e)

Remarks: This species is found from the intertidal to 70 m water depth, where it lives on shells or under stones. *C. chinensis* is common in the Mediterranean sea and in the Black Sea. This species was found from 17 m to 39 m deep in the Marmara Sea, on transect 1; at 79 m deep in the Black Sea, on transect 3; from 14m to 59 m in the Aegean Sea, on transects 7 and 8.

Family: Naticidae

Lunatia pulchella (Risso, 1826) (Plate 2-f)

Remarks: This species lives infaunally in sand-rich substrates from the intertidal zone down to 200 m deep and has also been recorded at 2000 m deep from northern Norway to the Mediterranean (Poppe and Goto, 1991). It can be found in the Mediterranean Sea, the Aegean Sea and the Marmara Sea (Zapevalin, 1998). This species was collected at 69 m and 109 m in the Marmara Sea, on transect 4 and at 14 m and 18 m in the Aegean Sea, on transects 7 and 8, respectively.

Family: Muricidae

Trophon breviatus (Jeffreys,1882)

Remarks: This species was recorded from dredge samples of muddy sand between 10 m and 100 m in the Marmara Sea and in the Bosphorus district of the Black Sea (Zapevalin, 1998). *Trophon breviatus* was collected at 17 m and 28 m in the Marmara Sea, on transect 1 and at 71 m in the Aegean Sea, on transect 7.

Trophon muricatus (Montagu, 1803) (Plate 2-g)

Remarks: This species can be found all European coasts including the Black Sea. It is common between 10 and 200 m deep and in the Mediterranean Sea it lives on coral bottoms or muddy sand (Poppe and Goto, 1991). This species was found at 89 m and 106 m in the Black Sea, transect 2; 74 m, 79 m, 106 m, 111 m, and 112m in the Black Sea, transect 3; 112 m in the Aegean Sea, transect 7 and 59 m and 66 m in the Aegean Sea, transect 8.

Family: Nassaridae

Cyclope donovania (Risso, 1826) (Plate 2-h)

Remarks: This species lives on fine sand bottoms in shallow waters in the Mediterranean Sea including the Black Sea. They also prefer brackish water (Poppe and Goto, 1991). This species was collected at 17 m in the Marmara Sea, transect 1 and at 74 m, 79 m, 92 m, 106 m, 111 m in the Black Sea, on transect 3.

Family: Turridae

Mangelia attenuata (Montagu, 1803) (Plate 2-i)

Remarks: This species lives in the muddy gravel bottoms in the Mediterranean Sea (Graham, 1971). This species was only found in sample collected at the water depth of 17 m in the Marmara Sea, on transect 1.

Class: BIVALVIA

Depending on environmental factors such as temperature, salinity, water depth or oxygenation, bivalves show different modes of life. Shallow infaunal bivalves live just in the sediment on the sea or river floor. Deep infaunal bivalves live deep within the sediment on the sea or river floor. Epifaunal bivalves secrete their sticky threads known as byssal threads and attach themselves to the sediment surface or rocks. Some bivalves (oysters) are able to physically cement themselves to hard surfaces. Pectinids lie on the sea floor but they can perform a swimming function over short distances to escape their predators. Boring bivalves tend to have a very thin soft shell with a hard tip able to bore into surfaces such as wood or rock.

Family: Nuculidae

Nucula nucleus (Linnaeus, 1758) (Plate 3-a)

Remarks: This species lives on gravel and mud bottoms from below the low tide line down to 150 m deep (Poppe and Goto, 1993). It is widely distributed, ranging from Norwegian Sea, into the Mediterranean Sea and the Black Sea (Tebble, 1966). This species was collected from transects 1, 3, 4, 7, 8 in the Black Sea, the Marmara Sea and the Aegean Sea. It was found from 21 Marmara Sea stations with lowest depth of 13 m and highest depth of 312 m and one Black Sea station at the depth of 111 m. In the Aegean Sea specimens were collected from 14 stations with lowest depth of 18 m and highest depth of 298 m.

Nucula sulcata (Bronn, 1831) (Plate 3-b)

Remarks: This species lives on mud or clay bottoms between 10 and 400 m deep. It can be found in the Mediterranean and in the Black Sea. Specimens were collected from the Marmara Sea and the Aegean Sea in three transects (transect 4, transect 7 and transect 8) and 14 stations. In the Marmara Sea, specimens were collected at 18 m, 23 m and 60 m. In the Aegean Sea, the lowest depth between the stations is 18 m and the highest depth is 97 m.

Family: Nuculanidae

Nuculana commutata (Philippi, 1844) (Plate 3-c)

Remarks: This species lives on mud between 40 and 200 m deep. It is found in the Mediterranean Sea, the Aegean Sea, the Marmara Sea and the Bosphorus district of the Black Sea. This species was found in samples collected between 28 m and 171 m from transect 1 and between 43 m and 118 m from transect 4, in the Marmara Sea. It was also found in samples collected between 78 m and 173 m from transect 7 and between 49 m and 66 m from transect 8, in the Aegean Sea.

Nuculana (Lembulus) pella (Linnaeus, 1758)

Remarks: This species lives on mud and muddy sand bottoms between 4 and 180 m deep (Poppe and Goto, 1993). It is found in the Mediterranean Sea, the Aegean Sea, the Marmara Sea and the Black Sea. This species was found only in the Marmara Sea transect 1 at water depths of 28 m, 34 m and 171 m.

Family: Archidae

Arca noae (Linnaeus, 1758) (Plate 3-d)

Remarks: This species lives attached with its byssus on rocks or shells and it can be found on all kinds of hard substrates, from low tide zone down to 120 m (Poppe and Goto, 1991). It is distributed to Atlantic Ocean and in the Mediterranean Sea. It was only found in sample collected at 20 m depth in the Aegean Sea, on transect 7.

Arca tetragona (Poli, 1795)

Remarks: This species lives from the extreme low tide line down to 120 m with attaching to all kinds of hard substrate such as, dead mollusc shells, stones, rock cervices with its massive green byssus from Norway into the Mediterranean Sea (Tebble, 1966; Poppe and Goto, 1993). This species were collected at the water depths of 14 m, 50 m, 60 m and 112 m in the Aegean Sea, on transect 7.

Anadara diluvii (Lamarck, 1805) (Plate 3-e)

Remarks: This species lives on muddy bottoms over 30 m deep in the Mediterranean. This species were collected from the Aegean Sea transect 8 (59 m) and the Marmara Sea transect 4 at 43 m and 98 m.

Bathyarca philippiana (Nyst, 1848) (Plate 3-f)

Remarks: This species lives at depths around 150 m deep on muddy bottoms in the Mediterranean Sea (Poope and Goto, 1991). *Bathyarca philippiana* was collected at 112 m in the Aegean Sea, on transect 7.

Scapharca inaequivalvis (Bruguière, 1789) (Plate 3-g)

Remarks: This species lives from inshore brackish waters down to 30 m on sand, on rocks; mud and sand is associated with *Zostera nana* and *Cymodocea nodosa* (CIESM, 2004). It is distributed in the Mediterranean Sea. This species were collected in the Marmara Sea at 146 m and 171 m in the transect 1.

Family: Noetidae

Striarca lactea (Linneaus, 1758) (Plate 3-h)

Remarks: This species is found in the Mediterranean and in the Black Sea. It lives with algae or under stones from the intertidal zone to 130 m (Poppe and Goto, 1993). This species was only collected in the Aegean Sea at water depths of 20 m, 50 m and 49 m.

Family: Glycymerididae

Glycymeris insubrica (Brocchi, 1814) (Plate 3-i)

Remarks: This species is a Mediterranean species and it lives on muddy, sandy, or shelly gravely bottoms with burrowing its muscular foot in the infralittoral zone (Tebble, 1966). This species was only collected in the Aegean Sea at 14 m and 29 m.

Family: Mytilidae

Mytilus galloprovincialis (Linnaeus,1758) (Plate 3-j)

Remarks: This species is very common in Atlantic and all coasts of Europe that have hard substrates. They live from intertidal zone to 40 m deep, attached by byssus threads to rocks (Tebble, 1966). This species was collected in the Black Sea, on transects 2 and 3 at water depths between 36 m and 111 m.

Mytilaster lineatus (Gmelin, 1791)

Remarks: This species is found in the Mediterranean Sea, including the Black Sea. It lives attached to the rocks (Poppe and Goto, 1993). Specimens were collected in the Marmara Sea, on transect 1 at the water depth from 187 m to 347 m.

Modiolula phaseolina (Philippi, 1844) (Plate 4-a)

Remarks: This species is found in the Mediterranean Sea and the Black Sea. It lives from the low tide line down to 160 m, attached by byssus to rocks or in the base of the larger algae such as *Laminaria* (Poppe and Goto, 1993). This species was collected in the Black Sea and in the Aegean Sea. The Black Sea stations had the greatest abundance of *Modiolula* which were found at the water depths from 74 m to 112 m. In the Aegean Sea they were found between 20 m and 49 m.

Family: Pteriidae

Pteria hirundo (Linneaeus, 1758) (Plate 4-b)

Remarks: This species is common in the Mediterranean. They live in all types of bottom especially, mud, sandy mud or gravel attached by their byssus threads between 10 m and considerable water depths (Tebble, 1966; Poppe and Goto, 1993). This species was only collected from the Marmara Sea on transect 1, at 146 m depth.

Family: Pectinidae

Pseudamussium clavatum (Poli, 1795) (Plate 4-c)

Remarks: This species lives between 5 and 1400 m deep on mud bottoms in the Mediterranean Sea, Marmara Sea and the Bosphorus district of the Black Sea. Specimens were collected in the Marmara Sea, transect 4 at the water depth of 74 m and in the Aegean Sea, transect 7 at the water depths of 71 m and 78 m.

Palliolum incomparabile (Risso, 1826) (Plate 4-d)

Remarks: This species is common in the Mediterranean and it is also found in the Marmara Sea. It lives on all types of bottoms between 10 and 250 m deep (Poppe and Goto, 1993). Specimens were collected in the Marmara Sea transect 1 at 146 m and in the Aegean Sea transect 7 at water depths from 20 m and 60 m.

Chlamys varia (Linnaeus, 1758) (Plate 4-e)

Remarks: This species is found in the Mediterranean Sea, the Aegean Sea, the Marmara Sea and the Bosphorus district of the Black Sea. It lives from the intertidal zone to 83 m deep, attached by its byssus, especially under rocks (Poppe and Goto, 1993). Specimens were collected from the Aegean Sea, on transects 7 and 8 with the lowest depth of 39 m and the highest depth of 97 m.

Chlamys glabra (Linnaeus, 1758) (Plate 4-f)

Remarks: This species is a Mediterranean species and it is also found in the Black Sea. It lives in the infralittoral zone, from 6 m down to 900 m. It prefers sandy, muddy, and rocky bottoms (Poppe and Goto, 1993). This species collected in the Aegean Sea at 59 m and 112 m.

Family: Ostreidae

Ostrea edulis (Linnaeus, 1758) (Plate 4-g)

Remarks: This species is distributed from the Norwegian Sea and into the Mediterranean Sea, including the Black Sea. It lives in shallow water down to 90 m on all types of bottoms, especially cemented to rocks. This species was found in the Marmara Sea and in the Aegean Sea in the deep water from 103m to 146 m, except 17 m in the Marmara Sea.

Family: Lucinidae

Loripes lucinalis (Lamarck, 1818) (Plate 5-c)

Remarks: This species is found in the Mediterranean Sea and in the Black Sea. It burrows into fine mud, clay and gravel bottoms, from the intertidal zone down to 150 m (Poppe and Goto, 1993). This species was only collected in the Aegean Sea, on transect 7 at water depths of 14m, 78 m, 97 m, 142 m and 201 m.

Lucinella divaricata (Linnaeus, 1758) (Plate 5-d)

Remarks: This species is distributed to the Mediterranean Sea and in the Black Sea (Tebble, 1966). It lives in fine sand and mud from below the low tide line to a depth of 60 m (Poppe and Goto, 1993). This species was collected only from the Aegean Sea at water depths of 49 m and 59 m in the transect 8 and water depth of 60 m in transect 7.

Myrtea spinifera (Montagu, 1803) (Plate 5-e)

Remarks: This species is found in the Mediterranean Sea, the Aegean Sea, the Marmara Sea and the Bosphorus district of the Black Sea (Demir, 2003). It lives on sand, mud and gravel bottoms between 7 and 250 m deep (Poppe and Goto, 1993). This species was collected from the Marmara Sea and the Aegean Sea at water depths ranging between 18 m and 247 m and between 18 m and 59 m, respectively.

Family: Thyasiridae

Thyasira flexuosa (Montagu, 1803) (Plate 5-f)

Remarks: This species is found in the Mediterranean Sea but not in the Black Sea. It lives on sand or mud bottoms between 10 and 2000 m deep (Poppe and Goto, 1993). This species was collected in the Marmara Sea, transect 1 and transect 4 at 54 m and 28 m, respectively, and in the Aegean Sea, transect 8 at 59 m and 66 m.

Family: Carditidae

Cardites antiquata (Linnaeus, 1758) (Plate 5-g)

Remarks: This species is distributed to the Mediterranean Sea and Atlantic Ocean, where it lives from the intertidal zone to a depth of 40 m (Poppe and Goto, 1993). This species was only collected in the Aegean Sea, on transcet 7 at 20 m.

Glans trapezia (Linnaeus, 1767) (Plate 5-h)

Remarks: This species lives on all kinds of hard substrates from the intertidal zone to 73 m deep (Poppe and Goto, 1993). Specimens were collected in the Aegean Sea, transect 7 at 20 m.

Glans aculeata (Poli, 1795) (Plate 5-i)

Remarks: This species is found in the Mediterranean Sea, the Aegean Sea and in the Marmara Sea (Demir, 2003). It lives in fine sand and gravel bottoms, often mixed with other small shells or attached by its byssus to the macrophytic algal holdfast between 10 and 200 m deep (Poppe and Goto, 1993). Specimens were found in the Marmara Sea (transect 1) and in the Aegean Sea (transects 7 and 8) at the highest water depth of 112 m and the lowest water depth of 39 m.

Family: Astartidae

Gonilia calliglypta (Dall, 1903) (Plate 5-j)

Remarks: This species common on gravel bottoms between 10 and 200 m depth and it is distributed into the Atlantic Ocean and the Mediterranean Sea. Specimens were collected in the Aegean Sea, on transect 7, at 50 m water depth.

Family: Cardiidae

Acanthocardia paucicostata (Sowerby, 1834) (Plate 5-k)

Remarks: This species is found in the Mediterranean Sea including the Black Sea. It lives from the low tide line down to 250 m, especially on muddy bottoms (Poppe and Goto, 1993). Specimens were collected from the Black Sea and the Aegean Sea at 93 m in transect 2; 79 m in transect 3; 97 m in transect 7 and from 18 m to 59 m in transect 8.

Parvicardium exiguum (Gmelin, 1791) (Plate 5-l)

Remarks: This species ranges from the Mediterranean Sea to the Black Sea. It lives on mud, sand and gravel bottoms from the extreme low tide to about 55 m deep and it also prefers calm waters (Poppe and Goto, 1993). Collected specimens were found in all six transects. The deepest station was in transect 1, the Marmara Sea with 146 m and the shallowest station was in transect 7 at 14 m depth.

Parvicardium minimum (Philippi, 1836)

Remarks: This species is found in the Mediterranean Sea, but it is absent in the Black Sea. It lives on mud, sand and gravel bottoms between 4 and 161 m water depth (Poppe and Goto, 1993). Specimens were collected in the Marmara Sea (transect 1 and transect 4) and in the Aegean Sea (transect 7 and transect 8) with depths between 26 and 112 m.

Parvicardium scabrum (Philippi, 1844)

Remarks: This species is found in the Mediterranean but not in the Marmara Sea and the Black Sea. It lives on sand, mud and gravel bottoms from the intertidal zone to several hundered meters deep (Poppe and Goto, 1993). Specimens were only collected in the Aegean Sea with water depths of 39 m and 60 m in transect 7 and at 49 m in transect 8.

Parvicardium papillosum (Poli, 1795)

Remarks: This species is found in the Mediterranean Sea and in the Black Sea. It prefers coarse grained sand and gravel bottoms between 1 and 60 m deep and it is attached by its byssus (Poppe and Goto, 1993). Specimens were only collected in the Aegean Sea from transect 7 (20 m and 112 m) and transect 8 (49 m).

Family: Dreissenidae

Dreissena polymorpha (Pallas, 1771) (Plate 5-b)

Remarks: This species originated in the Black Sea and the Caspian Sea and has expanded its range westward to Europe and America. It lives in the littoral and sublittoral zone as well as rivers, lakes and the less saline parts of inland seas (Zhadin, 1965). Specimens were collected in the Black Sea at the depths of 74 m and 79 m.

Family: Mactridae

Spisula subtruncata (da Costa, 1778) (Plate 5-n)

Remarks: This species is found in the Mediterranean and in the Black Sea (Tebble, 1966). It lives from the intertidal zone down to 200 m in silty and fine sand (Poppe and Goto, 1993). Specimens were collected from the Black Sea (transect 3) and the Marmara Sea (transect 1 and 4). The deepest station was in the Black Sea with 106 m and the shallowest station was in the Marmara Sea at 13 m water depth.

Family: Solenidae

Solen marginatus (Pulteney, 1799) (Plate 5-o)

Remarks: This species is distributed from the Norwegian Sea, into the Mediterranean Sea and Black Sea. It burrows into sand or muddy sand from intertidal zone to a depth of 20 m (Poppe and Goto, 1993). Specimens were collected from the Marmara Sea, on transect 1, at 13 m depth.

Family: Tellinidae

Tellina (Arcopagia) balaustina (Linnaeus, 1758) (Plate 6-a)

Remarks: This species is found in the Mediterranean Sea, the Aegean Sea and the Marmara Sea. It lives from below the low tide line to a depth of 750 m in sand, mud and gravel bottoms (Poppe and Goto, 1993). This species was collected from the transect 4 in the Marmara Sea at 43 m and from the transect 7 in the Aegean Sea at 14 m.

Tellina donacina (Linnaeus, 1758) (Plate 6-b)

Remarks: This species ranges from the Mediterranean Sea to the Black Sea. It lives in coarse sand and shell-gravel bottoms from the intertidal zone to 85 m deep (Tebble, 1966; Poppe and Goto, 1993). Specimens were collected in three transects (1, 7 and 8) from the Marmara Sea and the Black Sea. The deepest station was at 50 m and in transect 7 and the shallowest station was at 13 m in transect 1.

Family: Semelidae

Abra nitida (O. F. Müller, 1776) (Plate 6-c)

Remarks: This species is found in the Mediterranean Sea, the Aegean Sea, the Marmara Sea, and in the Black Sea (Demir, 2003). It lives on mud, sandy mud or gravel bottoms, mainly offshore to depths of 200 m (Poppe and Goto, 1993). Specimens were collected only one station (43 m deep) from transect 1 in the Marmara Sea and five stations with depths ranges from 18 m to 142 m from transects 7 and 8 in the Aegean Sea.

Abra prismatica (Montagu, 1808) (Plate 6-d)

Remarks: This species can be found in the Mediterranean Sea but not the Black Sea. It prefers to live in sand or muddy sand bottoms from the infralittoral zone to 400 m deep (Poppe and Goto, 1993). This species was found in the Marmara Sea, transect 1 at 13 m and in the Aegean Sea at 50 m and 71 m.

Abra alba (W. Wood, 1802) (Plate 6-e)

Remarks: This species is found in the Mediterranean Sea and in the Black Sea. It lives in sand, mud or muddy gravel from the infralittoral zone to a depth of 65 m (Poppe and Goto, 1993). Specimens were collected from all three seas in five transects. The Black Sea has the highest density and the Marmara Sea has the lowest density. The deepest station was 501 m in the Aegean Sea, transect 7 and the shallowest station was 33 m in the both in the Marmara Sea (transect 4) and in the Black Sea (transect 3).

Family: Solecurtidae

Azorinus chamasolen (da Costa, 1778) (Plate 6-f)

Remarks: This species is found in the Mediterranean Sea, the Aegean Sea and the Marmara Sea. It lives in all types of muddy bottoms, offshore from 5 to 400 m deep (Poppe and Goto, 1993). Specimens were collected from the Marmara Sea on transect 1, at water depths of 13 m and 34 m and from the Aegean Sea on transect 7 at 112 m.

Family: Veneridae

Venus casina (Linnaeus, 1758) (Plate 6-g)

Remarks: This species is found in the Mediterranean Sea but not the Black Sea. It lives on sand, mud and gravel bottoms with algae and shell debris, between 5 and 200 m deep (Poppe and Goto, 1993). This species was collected from only one station at 79 m on transect 3 in the Marmara Sea.

Claussinella brongniartii (Payraudeau, 1826) (Plate 6-h)

Remarks: This species is found in the Mediterranean Sea, including the Black Sea. It prefers relatively deep water: from the infralittoral zone down to the continental shelf (Poppe and Goto, 1993). This species was collected from the Aegean Sea at the six stations with depth ranges between 14 m and 112 m and from the Marmara Sea at one station at 39 m water depth.

Timoclea ovata (Pennant, 1777) (Plate 6-i)

Remarks: This species ranges from the Mediterranean Sea to the Black Sea. It lives on all types of bottoms between 4 and 200 m deep (Poppe and Goto, 1993). Specimens were collected from 21 stations from the Marmara Sea and the Aegean Sea. The deepest station was in transect 4 (the Marmara Sea) at 109 m and the shallowest station was on transect 7 (the Aegean Sea) at 14 m.

Gouldia minima (Montagu, 1803) (Plate 6-j)

Remarks: This species is found in the Mediterranean Sea, and is abundant in the Aegean Sea and the Marmara Sea. It lives on sand, mud and fine gravel bottoms from below the low tide zone to more than 200 m deep (Poppe and Goto, 1993). Specimens were collected from the Marmara Sea and from the Aegean Sea with water depths range between 17m and 60 m.

Dosinia lupinus (Linnaeus, 1758) (Plate 6-k)

Remarks: This species is found in the Mediterranean Sea and Black Sea. It prefers clean sand and fine gravel bottoms from the intertidal zone to 200 m deep (Poppe and Goto, 1993). Specimens were only collected from the Black Sea transect 3 at 74 m and 79 m.

Pitar rudis (Poli, 1795) (Plate 6-l)

Remarks: This species ranges from the Mediterranean Sea to the Black Sea. It lives from the intertidal zone to 80 m deep on sand and gravel bottoms (Poppe and Goto, 1993). Specimens were collected from the Marmara Sea, transect 1 and from the Aegean Sea, on transect 7. The stations in the Marmara Sea were shallower (13 m) than the stations in the Aegean Sea (20- 147 m).

Family: Petricolidae

Mysia undata (Pennant, 1777) (Plate 6-m)

Remarks: This species is distributed from the Norwegian Sea into the Mediterranean Sea and it burrows in muddy sand, gravel, muddy shell-gravel from below the low tide line to 55m deep (Tebble, 1966; Poppe and Goto, 1993). Specimens were collected from the Aegean Sea, on transect 8, at 26 m depth.

Family: Corbulidae

Corbula gibba (Olivi, 1792) (Plate 6-n)

Remarks: This species is found in the Mediterranean Sea, in the Aegean Sea, in the Marmara Sea and in the Bosphorus district of the Black Sea (Demir, 2003). It lives anchored by a byssus on silty sand and muddy-gravel bottoms from the low intertidal zone to 250 m deep (Poppe and Goto, 1993). According to Diaz and Rosenberg (1995), this species is the most tolerant form of oxygen depletion and, as a filter-feeder, it can also tolerate large quantities of suspended matter.

Specimens were collected from 26 stations primarily in the Marmara Sea (15 stations) and in the Aegean Sea (10 stations). The deepest and lowest stations were on transect 1, the Marmara Sea with 312 m and 13 m, respectively. In the Aegean Sea depth ranged between 39 m and 142 m.

Family: Cuspidariidae

Cuspidaria rostrata (Spengler, 1793) (Plate 6-o)

Remarks: This species is found in muddy sand and gravel from 20 m to considerable depth (Tebble, 1966). It is widely distributed from Atlantic to the Mediterranean Sea.

This species was collected from transect 4 (93 m deep) in the Marmara Sea and transect 7 (142 m and 173 m deep) in the Aegean Sea.

Cardiomya costellata (Deshayes, 1835) (Plate 6-p)

Remarks: This species is found in the Mediterranean Sea, the Aegean Sea and the Marmara Sea (Demir, 2002). It lives in muddy-sand and gravel bottoms between 18 and 200 m deep (Poppe and Goto, 1993). Specimens were found in the Marmara Sea and in the Aegean Sea. They were found at the shallow stations (26 m and 38 m) in the Aegean Sea; however, they were found at the deep stations (98 m, 109 m, 118 m, 143 m, and 187 m) in the Marmara Sea.

Class: SCAPHOPODA

Family: Dentaliidae

Dentalium dentalis (Linnaeus, 1758) (Plate 2-k)

Remarks: This species is found in the Mediterranean Sea, and most commonly in the Aegean Sea. It prefers mud and sandy bottoms at depths between 1 and 164 m (Poppe and Goto, 1993). Specimens were collected from the Marmara Sea and the Aegean Sea, transects 1, 4, 7 and 8. Transects water depth ranged from 23 m (transects 1) to 501 m (transect 7).

Family: Siphonodentaliidae

Gadulus politus (Wood, 1842) (Plate 2-l)

Remarks: This species is found in the Aegean Sea. It prefers to live on mud bottoms. Specimens were collected from the Marmara Sea (transect 1) and the Aegean Sea (transects 7 and 8). The sample stations in these three transects had similar water depth range from 28 m to 78 m.

Entalina tetragona (Brocchi, 1814) (Plate 2-m)

Remarks: This species is found in the Mediterranean Sea, in the Aegean Sea and in the Marmara Sea. It lives on mud bottoms. Specimens were collected from the Marmara Sea (transect 4) and the Aegean Sea (transects 7 and 8). The shallowest stations were on transect 8 (26 m, 38 m, 49 m) and the deepest stations were on transect 4 (88 m, 98 m, 143 m).

CHAPTER 5

INTERPRETATION

5.1. Current and Taphonomic Faunal Assemblages in Relation to the Environment

The present-day geographic distribution of live molluscs in surface sediments depends on a number of factors; such as, their power of dispersal, their adaptability to environmental factors (i.e. temperature, salinity, dissolved oxygen), their mobility, the degree of dispersal at the larval stage, the effects of geographic isolation, and the amount of passive dispersal resulting from the activities of man (Purchon, 1977).

In general, organisms are not distributed uniformly in space. Heterogeneous distribution occurs at all spatial scales; this concept is known as patchiness (Valiela, 1995). Patchiness can be described in terms of the distances that separate individuals of a population over a continuous space, or by assessing the occurrence of individuals at discrete spatial scales such as in quadrats, tidal pools, or samples (Valiela, 1995). Detection and analysis of patchiness depend on sampling strategy and sampling equipment (Peres, 1982). The size of the sample or quadrat needs to be considered, because the choice of sample size can artificially create or obscure patchiness. For instance, Figure 5.1 displays a hypothetical distribution of a population and three different sizes of quadrats. The largest quadrat in the figure shows a more-or-less uniform number of individuals and misses the smaller-scale patchy nature of the distribution. Using an intermediate quadrat size reveals the aggregated (non-random) distribution. Small-scale quadrats show a very uniform distribution and may either miss

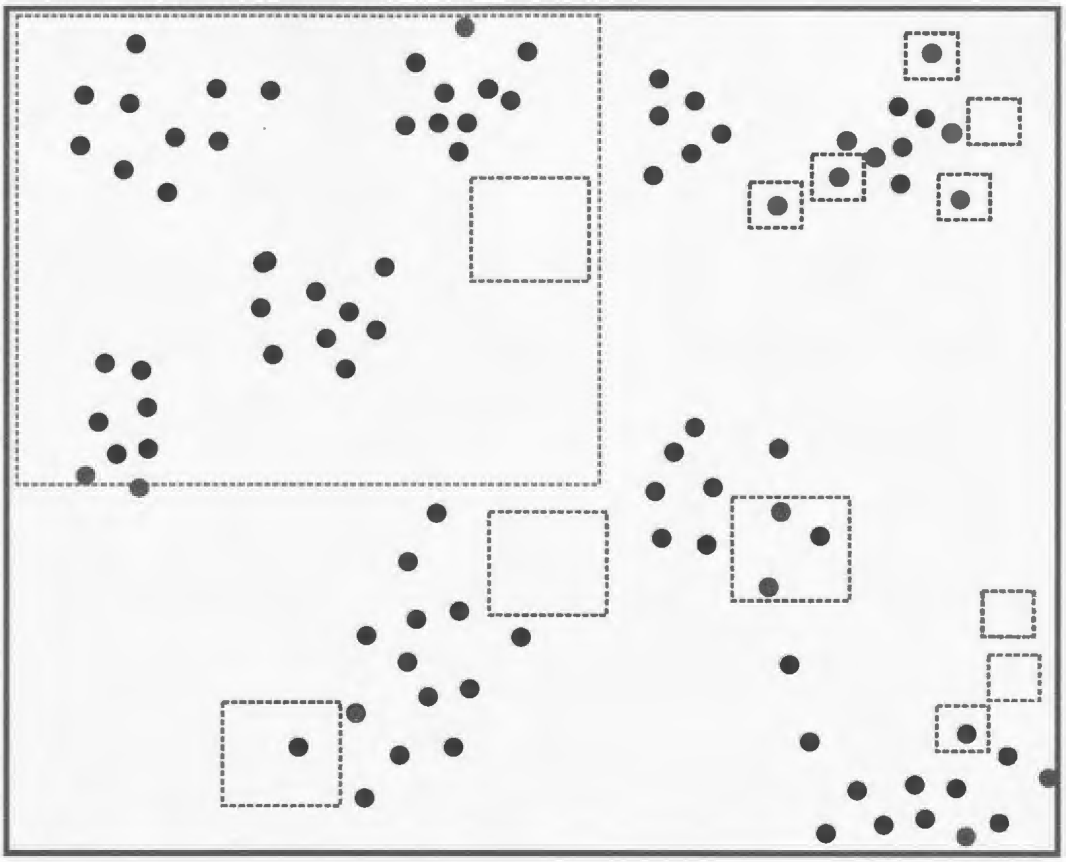


Figure 5.1. Hypothetical distribution of a population over space. The dashed squares indicate the different sample sizes, discussed in the text. Adapted from Valiela (1995).

or over sample species that are very rare, depending on where the quadrats are placed (Valiela, 1995).

In this thesis, dead mollusc shells were collected from six transects at approximately 10 m water-depth increments from ~13 m to ~501 m using a Shipek grab sampler. A Shipek grab sampler consists of a half-cylinder sampling scoop of 3000 ml volume, 25 cm length and 10 cm diameter. When the open grab touches the bottom, the rapid 180° rotation of an inner half cylinder collects sediments from approximately the upper 10 cm of the seabed. The depth averaging effect on shelly fauna by the sampling tool is controlled by the age of the sediments recovered in the grab, which is largely controlled by the sedimentation rate in a region. Sedimentation rates vary widely in the marine environment, ranging from 1–3 mm/1000 yrs in the Arctic Ocean (e.g. Aksu and Mudie, 1985) to 40–60 cm/1000 yrs in modern turbidite fans (e.g. Piper et al., 1999). In the Black Sea, Aegean Sea and Marmara Sea shelf regions, bulk sedimentation rates are 10–30 cm/1000 yrs (e.g. Hiscott and Aksu, 2002); therefore, the grab samples should contain an approximately 300–1000 year average of the shelly fauna.

In order to correctly interpret the field data, there must be good reason to believe that the shells found in each sample, or quadrat, faithfully reflect the modern environmental conditions at the sampling stations. Three pivotal questions can be posed to evaluate weather shells found in the surface 10 cm reflect current environmental conditions. The first question is: are the dead shells *in situ* or transported from elsewhere? Transported shells would have the same age as the enclosing sediments, but would give false environmental information. When transported, the protective calcium carbonate and proteinaceous layer (periostracum) of mollusc shells is easily abraded. Alteration of the morphology of shell structure reveals itself as rounded edges or smoothed surfaces. Moreover, depending on the amount of dissolved CO_2 in bottom waters and water temperature, dissolution of the shell calcite or aragonite material in transported shells can degrade the periostracum, resulting in a chalky white appearance. According to Table 5.1, most of the sampling stations are away from the coast and therefore away from where waves and currents are strongest. These sediments are mostly muds; thus, these stations are below fair-weather wave base and in a calm environment.

The absence of large percentages of shell fragments and the good preservation state of the shells suggest that the large majority of the mollusc shells in the surface samples did not experience prolonged reworking or long distance transport. Moreover, in order to eliminate possible reworked shells, all fragments were discarded during sieving operations. Based on these procedures, whole dead mollusc shells from surface sediments of the Black Sea, the Marmara Sea and the Aegean Sea were assumed to have experienced no significant post mortem transport.

A second, somewhat different question is whether the recovered shells might be *in situ* but reworked from older deposits, which formed when the environment was different. Mollusc shells collected for this thesis were found in the upper 10 cm of sediment. Examination of high-resolution seismic-reflection profiles in the vicinity of the transects clearly shows the presence of >100 cm of Holocene deposits. There is no indication of pre-Holocene strata exposed at the sea floor. Therefore, little chance exists for reworking of molluscs from older strata in the Black Sea and the Marmara Sea

Table 5.1. Distribution of stations along each transects showing the percentage that each depth range forms of the entire transect. Approximate water depth ranges are: nearshore, 13–35 m; openshelf, 30–70 m; deep water, 70–500 m.

Transect		Nearshore	Open Shelf	Deep Water
1	Station number	1, 2, 3, 4, 5	6, 7, 8, 9, 10, 11, 12, 13	14, 15, 16, 17, 18, 19, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101
	Area (%)	20%	30%	50%
2	Station number			59, 58, 57, 56, 55, 54, 53, 52, 51, 50
	Area (%)			100%
3	Station number	85, 84, 83, 82	81, 80, 79, 78, 77, 76, 75, 74	73, 72, 71, 70, 69, 68, 67, 66, 65
	Area (%)	20%	40%	40%
4	Station number	23, 24	25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36	39, 40, 41, 42
	Area (%)	10%	70%	20%
7	Station number	29, 30, 31	32, 33, 35	36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46
	Area (%)	10%	20%	70%
8	Station number	56, 55	54, 53, 52, 51	
	Area (%)	10%	90%	

transects. In the Aegean Sea, only the nearshore stations of transect 7 and transect 8 consist of coarse-grained sediments supplied from the shore; fine-grained sediments characterize the rest of these transects. Thus, except for the possibility of input from land, the chance of reworking from older underlying deposits is low. Instead, the mollusc shells collected from the muddy seabed are likely both *in situ* and as young as the enclosing sediments.

A third and the final question concerns temporal environmental changes. Specifically, is the time represented by each sample smaller than the time over which environmental change might have occurred? If the answer is no, then some of shells might be *in situ* with the same age as enclosing sediments, but would yield environmental information at odds with modern conditions. Linear interpolation of radiocarbon dates in cores near transect routes (Figure 3.1) shows that none of the recovered material is demonstrably older than ~1500 years (Table 5.2).

Table 5.2. Interpolated ages anticipated in grab samples.

Transect No.	Nearest Core	Reference	Age at 10 cm depth
1	MAR97-15B	Hiscott and Aksu (2002)	~600 years
2	MAR00-08	Aksu et al. (2002)	~1000 years
3	MAR00-09	Aksu et al. (2002)	~480 years
4	MAR98-09	Hiscott et al. (2002)	~1500 years

Vertical reworking by bioturbation might have introduced some older shells, so a conservative estimate of the maximum range of shell age in each sample is given that intact shells were counted only vertebrate or decapod bioturbation would be capable of introducing older shells from below. Global sea level has been within 5 m of the modern value since ~4000 yr BP (Fairbanks, 1989), so all recovered shells must have lived at essentially the present water depth and therefore should have experienced near-modern conditions. For example, the shallowest sampling station is at 13 m and would have been only slightly shallower at ~2000 yr BP. There have been important climatic changes over the last few millennia, but these would likely have had a very subdued effect in the marine realm. Two examples are the Medieval Warm Period (10^{th} to 14^{th} centuries) and Little Ice Age (15^{th} to 19^{th} centuries), reported by several authors. As examples of the types of changes encountered by others, Thorndycraft et al. (2005) reported large palaeoflood events in northeast Spain (AD1500–1700). Abrantes et al. (2005) detected 2 °C variability of the sea surface temperature between the Medieval Warm Period and the Little Ice Age from a multi-proxy study of sediments deposited by the Tagus River, Lisbon, over the last 2000 years. González-Álvarez et al. (2004) reported a change to cold water planktonic foraminifera species at 1420 AD related to an intense upwelling pulse reinforced by colder atmospheric temperatures during the Little Ice Age, from a gravity core retrieved from the outer Galician shelf, Spain. Climate change is also recorded in Turkish written archives as freezing of the Bosphorus and some parts of the Black Sea (Erinç, 1978).

Some of the mollusc shells collected for this thesis probably lived during these climatic swings of the last millennium. However, the large water masses likely buffered any temperature changes, particularly at the seabed in shelf and deep-water sites (e.g. Beşiktepe et al., 1994). It is therefore assumed that the Little Ice Age and Medieval Warm Period did not affect the water masses and thus the mollusc community structure in a significant way in the Black Sea, the Marmara Sea and the Aegean Sea.

Taking the essential points from the preceding discussion leads to the following assumptions that will be applied in this thesis:

1. whole, dead mollusc shells are *in situ*, and have not been transported from other environments;
2. whole, dead mollusc shells have not been locally reworked from older deposits;
3. each sample only contains shells which formed in an environment indistinguishable from the modern environment at the site of collection, because shells older than ~2000 years are assumed not to have been reworked upwards.

With these assumptions, the reworked shells can be treated as if the molluscs had died very recently, under modern conditions. The spatial distribution of shells following the death of an organism is expected to be as patchy as the aggregated distribution of live specimens if no transport or reworking (Schneider and Haedrich, 1991). Hence, the segment approach to assessing spatial distribution can be applied. Each sample along a transect is considered to be a small-scale quadrat (Figure 5.1). Because smaller quadrats either suggest a very uniform distribution, or give results that depend on where the samples are taken for very rare species, transect segments will be used to interpret the thesis data. The size of the segment is set so as to group samples which developed under similar environmental conditions into a single segment. Similar conditions might include similar temperature and salinity. This approach leads to a smaller number of segments per transect than the number of samples. In the qualitative analysis which follows, all stations in the Aegean Sea are considered. In the Black Sea, only 11 of 16 stations are considered because the other five included mostly common stations. In the Marmara Sea, only 5 of 38 stations are considered because the others are either characterized by an Aegean Sea water mass (intermediate depths) or a Black Sea water mass (0–13 m) and show the same mollusc faunal as these other areas. For this reduced set of stations, Table 5.3 shows the even smaller number of distinct segments that are recognized.

Table 5.3. Comparison of number of sample stations and segments between each sea.

Transects	Sample Stations	Quadrats
2, 3 (Black Sea)	11	2
1, 4 (Marmara Sea)	5	1
7, 8 (Aegean Sea)	23	4

5.2. Qualitative Analysis: Assemblages and relationships between environmental parameters

Assemblages were identified after considering the relationships between and within large quadrats from all transects. Each assemblage reflects a distinct set of environmental conditions. Some species are only present in one assemblage, although others are more cosmopolitan and can be found in more than one assemblage. These cosmopolitan species are not useful for interpreting environmental conditions except at scales large relative to transects.

Qualitative analysis was done by using absence and presence of mollusc species in quadrats. Seven assemblages were identified. Abundance of species was calculated as a percentage contribution to each assemblage, using the following equation:

Species A percentage = 100 × (number of shells of species A) / Total number of shells in each transect).

Percentage data are listed in Appendix A.

Assemblage 1

Assemblage 1 was dominated by the high occurrence of two gastropods which prefer sandy-mud bottoms: *Calliostoma conulus* and *Bittium reticulatum* (Figure 5.2). *Timoclea ovata, Gouldia minima* and *Pitar rudis* were the dominant bivalves of this assemblage. Finally, a scaphopod, *Gadulus politus,* occured in moderate abundance. Eighteen very minor species are noted in Figure 5.2. Assemblage 1 was found at water depths between 14 m and 50 m along Aegean Sea transect 7 where surface sediments are composed of silty-sand, clayey-sand and sand (57–82 % sand), where bottom water temperatures range between 14–15 °C, and where salinity is 40 ‰ (Figure 5.3). On the basis of its high salinity, this bottom water mass is interpreted as the Mediterranean water mass. *Timoclea ovata* can live on every type of bottom; however, *Pitar rudis* and *Gouldia minima* are diagnostic of sandy mud or gravelly sediments. The most abundant species, excluding the euryhaline species *Bittium reticulatum*, prefer high salinities. Hence, assemblage 1 is interpreted as an indicator of high salinity and a sandy-mud substrate.

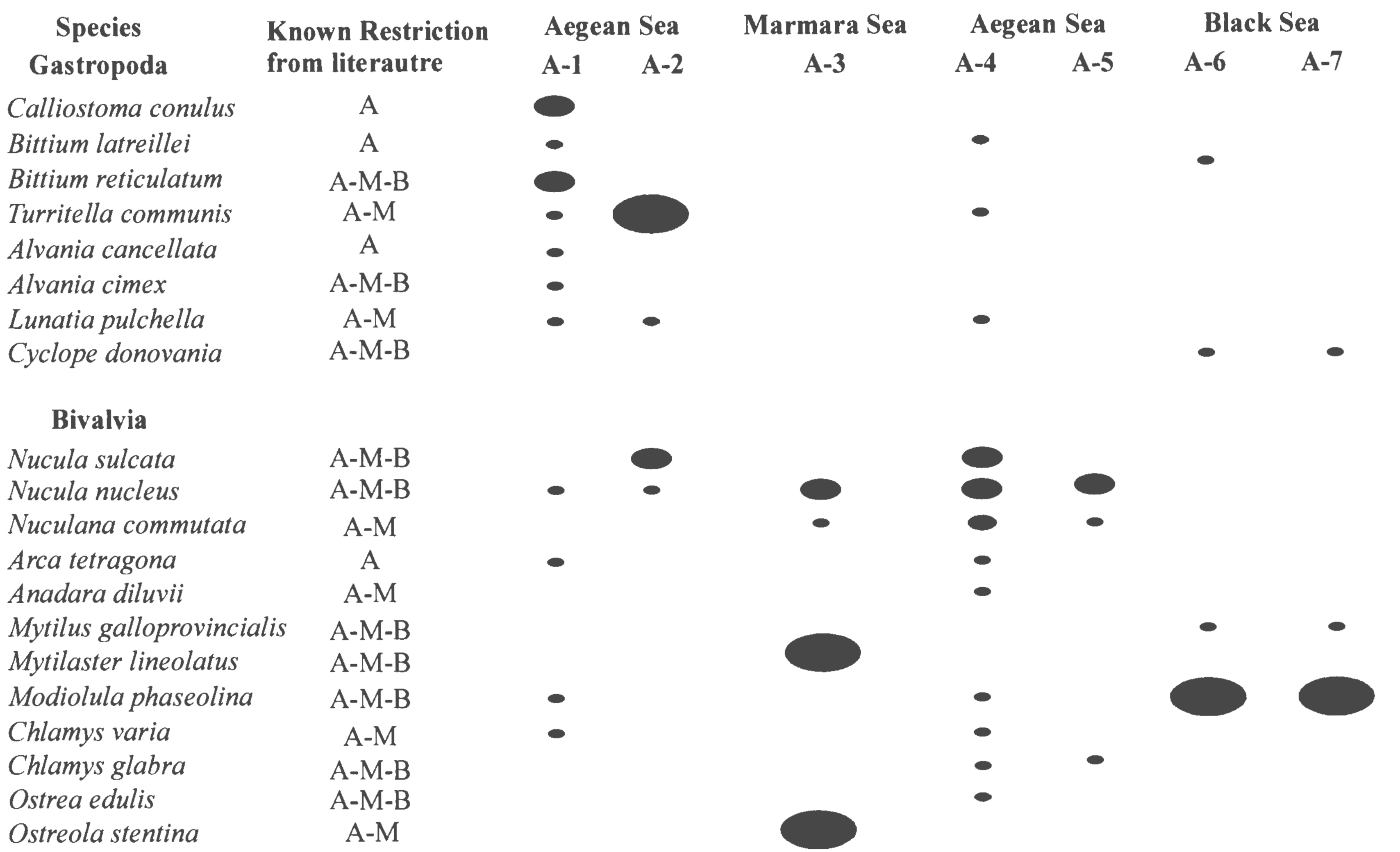
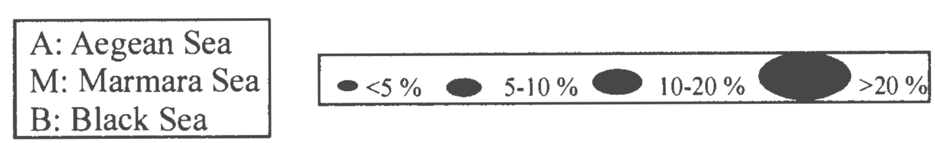


Figure 5.2. Abundance data of assemblages A-1 through A-7.



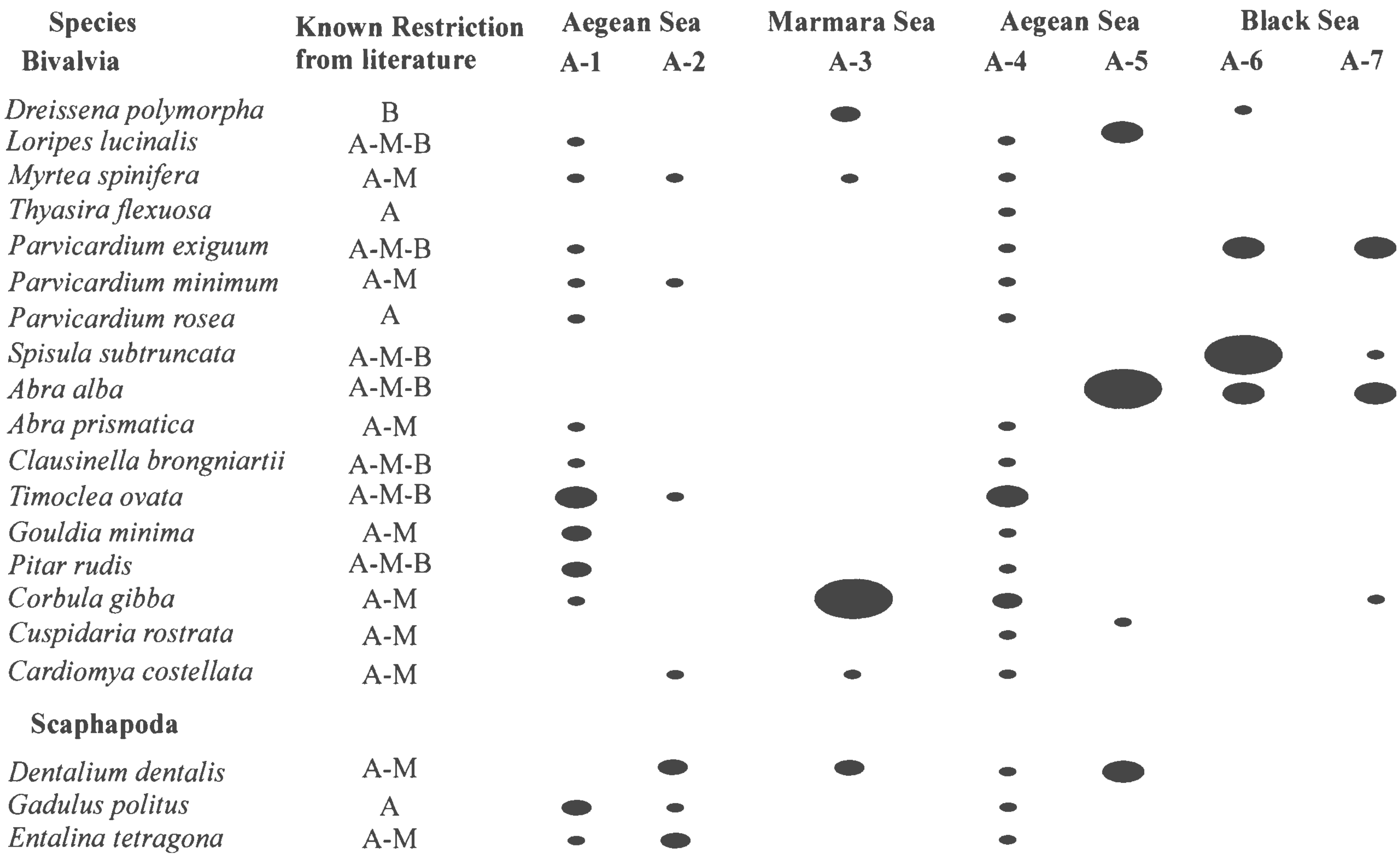
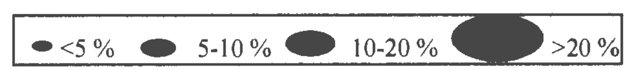


Figure 5.2 Cont'd. Abundance data of assemblages A-1 through A-7.

A: Aegean Sea
M: Marmara Sea
B: Black Sea



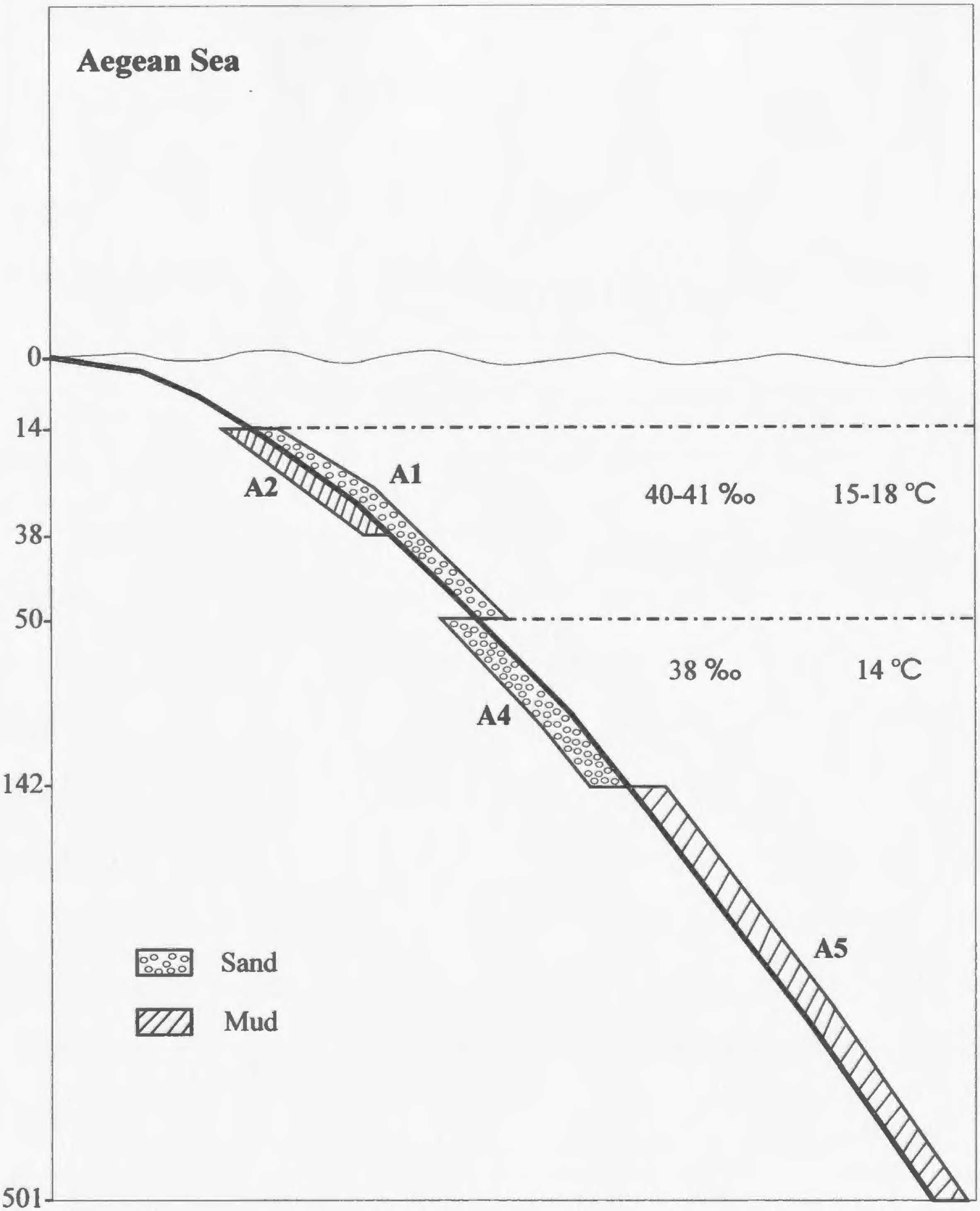


Figure 5.3. Schematic diagram of the distribution of the Aegean Sea assemblages.

Assemblage 2

Assemblage 2 was found at shallow water depths ranging between 18 m and 38 m along Aegean Sea transect 8 with bottom temperature of 17 °C, salinity of 41 ‰, and clayey-silt bottom sediments (Figure 5.3). *Turritella communis*, *Nucula sulcata* and the scaphapods *Dentalium dentalis* and *Entalina tetragona* showed highest abundances (Figure 5.2). This assemblage is interpreted to indicate high salinity and muddy conditions.

Assemblage 3

Assemblage 3 was found on transect 1 in the Marmara Sea at water depths from 171 m to 312 m where bottom sediments consist of sandy-silty-clay. Here, a water temperature of 14 °C, salinity of 38 ‰, and dissolved oxygen concentration of ~1.5 ml/l represent the Mediterranean water mass (Figure 5.4). This Marmara Sea assemblage is characterized by high abundances of *Nucula nucleus, Mytilaster lineolatus,* and *Corbula gibba* (Figure 5.2). Among these species, *Nucula nucleus* and *Corbula gibba* are cosmopolitan species with euryhaline and eurytherm preferences. However, *Mytilaster lineolatus* and *Myrtea spinifera* are less tolerant to environmental fluctuations and signify Mediterranean environmental characteristics. *Mytilaster lineolatus* is only found in the Marmara Sea.

Assemblage 4

Assemblage 4 was dominated by the high occurrence of *Nucula nucleus*, *Nucula sulcata*, *Nuculana commutata, Timoclea ovata,* and *Corbula gibba* (Figure 5.2). It was found in water depths between 49 m and 142 m in the Aegean Sea transects 7 and 8

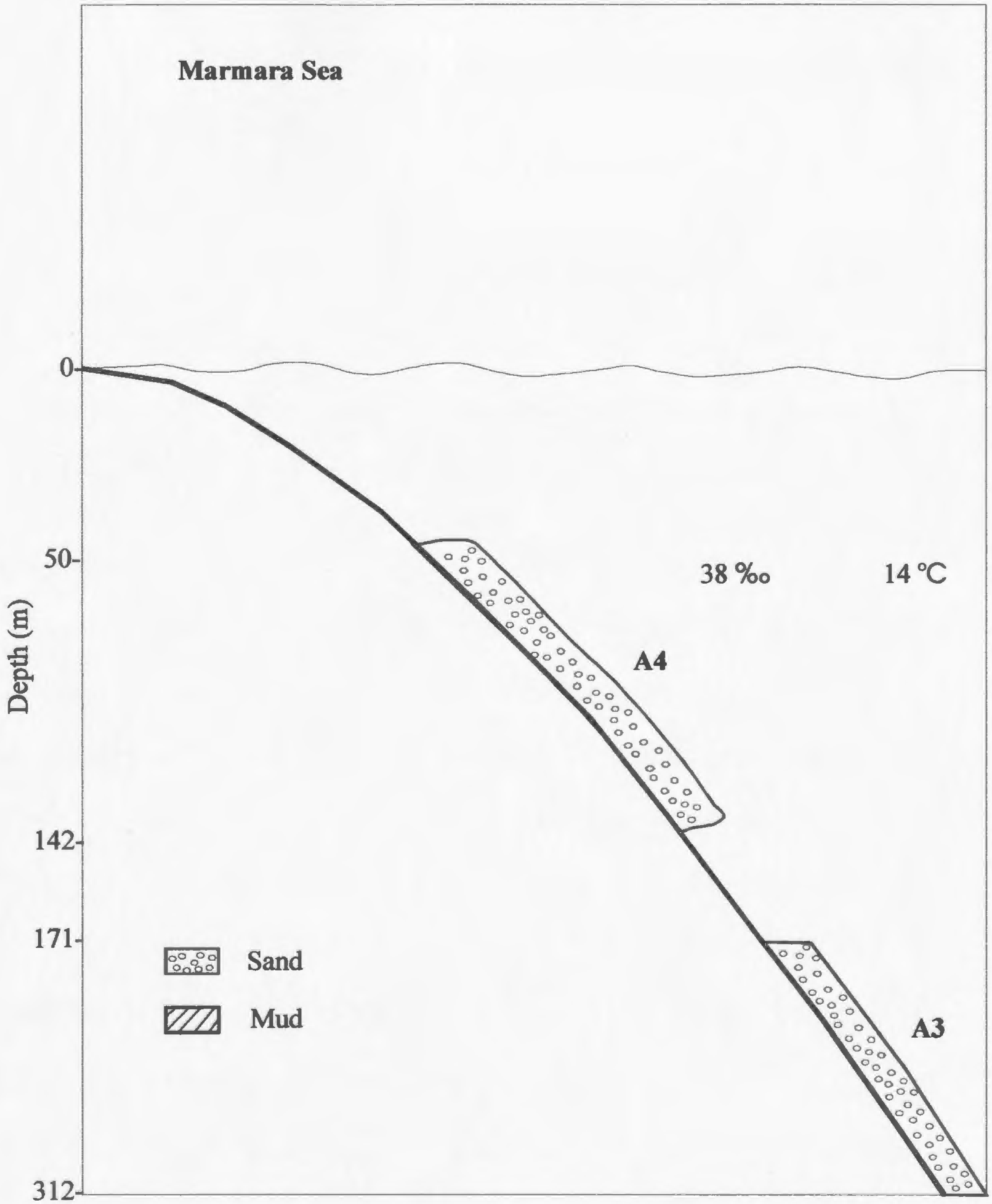


Figure 5.4. Schematic diagram showing the distribution of the Marmara Sea assemblages.

where surface sediments are composed of silty-sand and sandy-silty-clay (Figure 5.3). Temperature and salinity are 14–16 °C and 38 ‰, respectively. Dissolved oxygen concentration was high (5.8–8.4 ml/l).

Assemblage 5

Assemblage 5 is found at water depths between 173 m and 501 m in the Aegean Sea, along transect 7 (Figure 5.3). Temperatures and salinity are 14–16 °C and 38 ‰, respectively. This assemblage prefers a clayey-silt substrate. *Abra alba*, *Loripes lucinalis* and *Dentalium dentalis* were abundant in these muddy bottoms (Figure 5.2).

Assemblage 6

Assemblage 6 was found at water depths between 22 m and 102 m in the Black Sea transects 2 and 3 where bottom sediments are characterized by a mixture of sandy-clay and sandy-silt (Figure 5.5). It was associated with a low temperature (7–8 °C), low salinity (18–19 ‰) water mass, and moderate dissolved oxygen concentration (4–5 ml/l). The two most abundant bivalve species are *Modiolula phaseolina* and *Spisula subtruncata* (Figure 5.2). Both species prefer low salinity waters and best reflect the Black Sea conditions. They were only rarely found in the other two seas (Figure 5.2). *Bittium reticulatum*, although minor, only lives under gravel, rocks or on seaweed (i.e. *Zostera*).

Assemblage 7

Assemblage 7 was found in water depths between 83 m and 106 m in the Black Sea transects 2 and 3 (Figure 5.5). Temperature (7–8 °C) and salinity (18–19 ‰) were similar to assemblage 6 but assemblage 7 was found on clayey silt bottoms (Figure 5.5). The absence of *Bittium reticulatum* in this assemblage is attributed to the fine grain size of the substrate. The only other difference from assemblage 6 was the far lesser abundance in assemblage 7 of *Spisula subtruncata*.

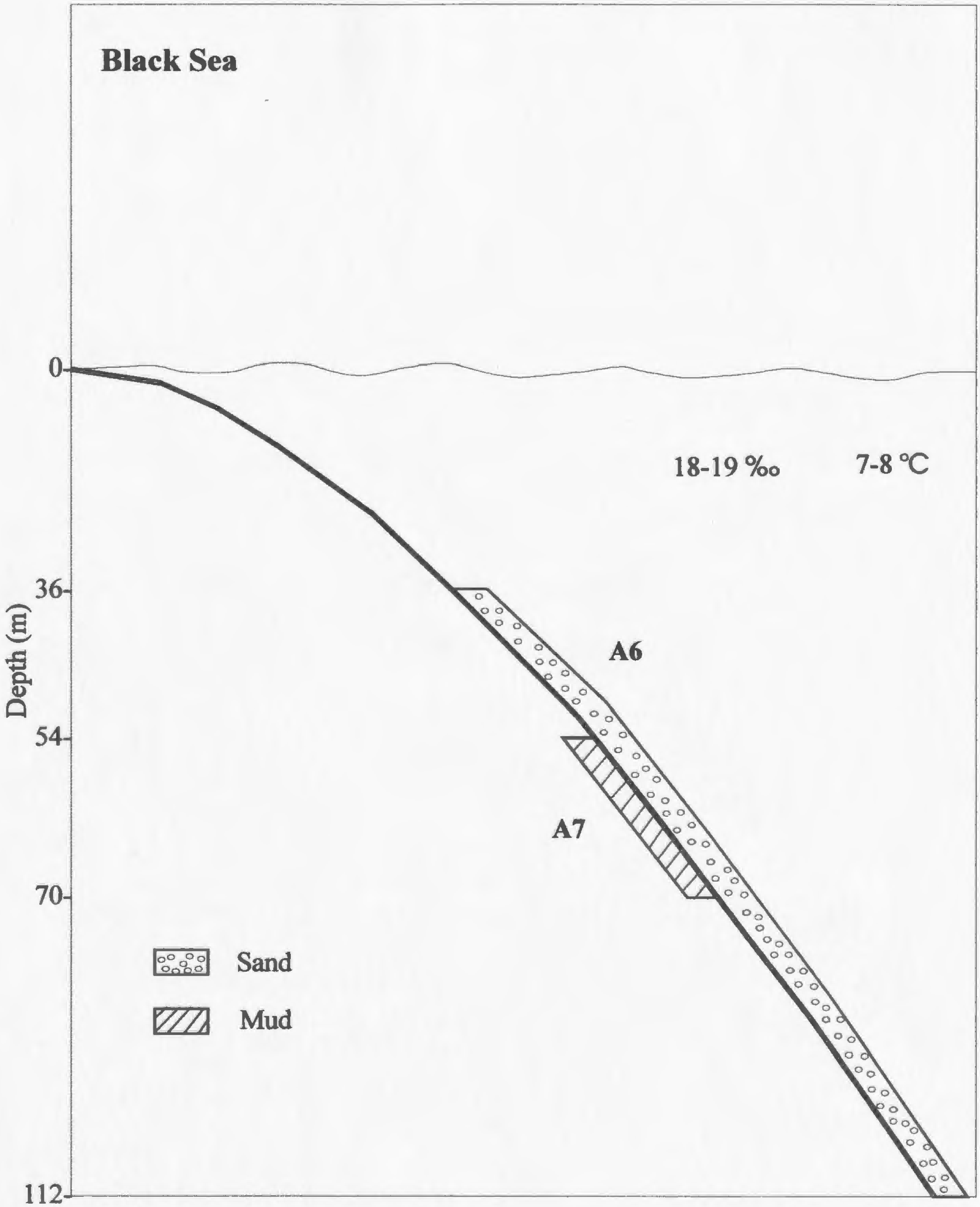


Figure 5.5. Schematic diagram showing the distribution of the Black Sea assemblages.

5.3. Quantitative Analysis: Statistical Treatment of Data

5.3.1. Ordination of data by principal component analysis (PCA)

Principal component analysis was used to determine associations of species that are distinct from one another and that account for the largest amount of the total variance in the data. Analysis was performed on a reduced data set, which consisted of 12 species and 77 stations, to diminish the effects of less-common species as recommended by Imbrie and Kipp (1971). Only the 12 species that represent ≥ 2 % of the total fauna and which are present in at least 10 stations were considered. The abundances of the 12 species were recalculated so as to sum to 100 % and this data was used without standardization (Davis, 1973). Ten principal components were extracted, accounting for 94.2 % of the total variance in the reduced data set (Table 5.4).

Based on the Kaiser criterion (Kaiser, 1960), only those components with eigenvalues greater than 1 are significant and should be retained for interpretation. Seven principal components with eigenvalues >1 are considered further. These principal

Table 5.4. Eigenvalues for faunal principal component (FC) analysis. The first seven principal components are considered significant using the Kaiser criterion.

FC	Eigenvalues	%Variation	Cum.%Variation
1	1.87	15.60	15.60
2	1.33	11.10	26.70
3	1.28	10.70	37.40
4	1.16	9.70	47.00
5	1.11	9.20	56.30
6	1.09	9.00	65.30
7	1.03	8.60	73.90
8	0.89	7.50	81.30
9	0.84	7.00	88.30
10	0.71	5.90	94.20

components explain 73.9 % of the total variance (Table 5.4). Results of this analysis and loadings associated with each principal component are listed in Table 5.5. These loadings are coefficients, which indicate the relative weight of each variable in the component. The bigger the coefficient, the more important the corresponding variable is in explaining the component. High negative and positive loadings (>±0.3) of key species on the seven principal components identify the faunal constituents of each principal component. If a loading is positive, then the occurrence of that species is positively correlated with the principal component; if it is negative, then the reverse is true. The seven principal components can be considered as seven different hypothetical assemblages, which explain, from 1 to 7, decreasing amounts of the total variance.

Table 5.5. Coefficients (loadings) of mollusc species on the seven significant components. Significant loadings are shown in bold characters.

Species	FC1	FC2	FC3	FC4	FC5	FC6	FC7
T. communis	0.143	**-0.593**	0.134	0.269	**0.519**	-0.007	0.068
N. nucleus	0.077	**0.596**	**0.465**	0.005	**0.341**	0.014	-0.109
N. sulcata	**0.333**	-0.137	**-0.373**	-0.230	0.122	**-0.390**	-0.072
N. commutata	**0.333**	0.212	-0.065	**-0.364**	0.125	**-0.402**	-0.074
M. phaseolina	**-0.432**	0.060	**-0.372**	0.093	0.165	0.078	0.111
M. spinifera	0.237	0.146	-0.128	0.064	-0.278	0.041	**0.836**
P. exiguum	**-0.331**	0.126	**-0.349**	-0.060	0.184	0.252	-0.121
S. subtruncata	-0.135	0.013	0.062	**0.547**	**-0.477**	**-0.495**	-0.266
A. alba	**-0.414**	-0.028	0.046	**-0.517**	-0.200	-0.144	-0.008
T. ovata	0.285	-0.091	**-0.368**	-0.095	-0.214	0.236	**-0.351**
C. gibba	**0.342**	0.054	0.071	0.029	-0.279	**0.537**	-0.226
D. dentalis	-0.106	**-0.419**	**0.446**	**-0.387**	-0.235	0.068	0.045

The principal component coefficients are used to calculate the principal component scores. Scores are listed in Tables 5.6, 5.7, and 5.8. For each station and the 12 species in Table 5.5, scores of FC 1 are calculated as;

Score = (percent abundance of *T.communis*) (0.143) + (percent abundance of *N. nucleus*)(0.077) + ….. + (normalized abundance of *D.dentalis*) (-0.106)

The principal component scores for FC2–FC7 are calculated in the same way, but with the correspondingly different coefficients (loadings) from Table 5.5. In the following summaries and interpretations, stations and transects with the highest scores for each faunal component are emphasized because they are inferred to have environmental conditions (e.g. salinity, substrate type) most amenable to the survival and well-being of the species with high positive loadings, and most detrimental to the survival and reproduction of species with high negative loadings. In many cases, the highest scores are confined to only one or two of the Aegean Sea, the Marmara Sea, and the Black Sea, or to particular water masses in cases where the water column is stratified. For ease in recognizing higher and lower scores, calculated values were normalized across all stations and all seas on a scale from 0 to 100, one component at a time (Tables 5.6, 5.7, 5.8). In order to concentrate the discussion on the most significant data, only those scores that are higher than 70 are considered dominant scores. Dominant scores for faunal components and environmental components account for 19.6 % and 41.1 % of all faunal scores and environmental scores, respectively. These dominant scores characterize stations which best exemplify the defining characteristics of each component. Appendix B shows the transect-by-transect distributions of dominant scores for each component.

Table 5.6. Scores for faunal components at Marmara Sea stations. Separate transects are alternatively shaded and unshaded. Scores are normalized between 0 and 100, component by component. Bold scores are higher than 70. See Table 5.7 for a key to the main environmental implications of each faunal component.

					SCORES			
Station	**Depth (m)**	**FC1**	**FC2**	**FC3**	**FC4**	**FC5**	**FC6**	**FC7**
1-1	13.89	57.63	68.46	57.62	**79.08**	33.02	60.25	18.89
2-1	17.86	19.40	66.28	21.29	46.37	85.99	**83.51**	21.66
3-1	23.81	54.80	16.38	62.70	59.16	85.27	**77.29**	36.10
4-1	28.77	66.10	46.98	33.01	50.38	51.54	**73.15**	30.11
5-1	34.73	**73.82**	43.37	52.93	50.38	26.84	**100.00**	22.89
6-1	39.69	**72.51**	50.65	44.53	49.05	28.98	**96.62**	20.89
7-1	44.65	58.95	10.00	52.54	61.76	**100.00**	55.60	37.33
8-1	48.61	**87.38**	34.90	43.95	33.97	**74.35**	39.75	25.35
9-1	54.57	63.65	10.88	51.95	68.51	**83.37**	67.65	32.87
10-1	59.53	58.95	0.00	52.54	61.76	**100.00**	55.60	37.33
11-1	64.49	**70.62**	27.21	51.17	63.36	58.67	**85.84**	26.27
12-1	69.45	47.27	7.32	**76.37**	37.60	57.72	60.68	37.63
13-1	74.41	56.31	**70.00**	64.06	62.02	**90.74**	56.45	32.41
15-1	84.32	53.86	**100.00**	**75.39**	52.29	**81.47**	57.29	27.34
17-1	103.17	53.86	**100.00**	**75.39**	52.29	**81.47**	57.29	27.34
19-1	121.02	53.86	**100.00**	**75.39**	52.29	**81.47**	57.29	27.34
93-1	146.80	**76.27**	61.23	49.41	46.95	32.07	**86.47**	31.18
94-1	171.59	**71.19**	65.30	58.59	51.53	35.15	**93.66**	24.42
95-1	187.45	**78.15**	65.36	52.15	43.89	38.72	**78.01**	29.34
96-1	225.12	35.41	14.63	**100.00**	3.24	15.44	65.75	37.94
97-1	247.91	68.74	**74.20**	55.86	54.58	43.23	**81.40**	37.02
99-1	312.32	57.82	47.62	**75.00**	33.78	29.45	**84.14**	26.73
100-1	293.50	**72.88**	69.61	58.20	54.01	38.96	**96.41**	19.20
101-1	255.84	53.86	**100.00**	**75.39**	52.29	**81.47**	57.29	27.34
23-4	18.85	67.23	56.16	18.75	44.85	43.94	**75.48**	34.41
24-4	23.81	**77.40**	54.78	19.14	36.26	38.72	45.24	48.23
25-4	28.77	**70.81**	55.21	45.90	53.63	37.06	**79.07**	42.55
26-4	33.73	**72.88**	64.70	37.50	51.53	33.97	**80.76**	35.18
27-4	39.69	47.65	64.83	28.13	38.17	40.38	**86.47**	16.90
28-4	43.65	67.80	**70.97**	32.23	45.04	42.04	60.89	25.65
29-4	49.61	**70.81**	50.97	46.88	62.41	50.59	**80.76**	41.01
30-4	55.56	**78.72**	60.40	35.35	32.25	40.38	59.41	29.19
31-4	60.52	**77.97**	60.97	20.51	47.90	65.08	33.62	53.76
32-4	64.49	**71.75**	55.09	29.49	58.40	18.05	60.68	**100.00**
39-4	98.21	**71.75**	62.52	29.49	58.40	18.05	60.68	**100.00**
40-4	109.12	**84.18**	62.73	23.05	38.36	30.64	45.24	69.28
41-4	118.04	**76.08**	**74.25**	46.29	12.60	65.80	15.86	37.17
42-4	143.83	62.71	**75.52**	52.34	55.34	49.88	58.99	63.59

Table 5.7. Scores for faunal components at Black Sea stations. Separate transects are alternatively shaded and unshaded. Scores are normalized between 0 and 100, component by component. Bold scores are higher than 70.

					SCORES			
Station	**Depth(m)**	**FC1**	**FC2**	**FC3**	**FC4**	**FC5**	**FC6**	**FC7**
59-2	83.33	0.00	54.02	6.06	28.24	68.41	**80.55**	22.73
58-2	89.28	14.69	54.31	14.65	53.05	66.03	63.85	37.63
56-2	98.21	13.18	53.96	12.50	51.72	67.70	66.81	35.95
55-2	104.16	15.63	**70.88**	15.23	54.39	66.03	62.79	38.56
54-2	106.14	12.81	**79.19**	14.06	49.24	65.80	65.33	35.79
84-3	22.82	36.72	64.70	48.05	**100.00**	0.00	8.03	14.44
83-3	25.80	36.72	56.37	48.05	**100.00**	0.00	8.03	14.44
82-3	33.73	31.83	61.55	47.85	**83.40**	4.51	13.32	17.51
81-3	36.71	36.72	34.20	48.05	**100.00**	0.00	8.03	14.44
74-3	74.41	7.91	40.48	12.70	40.46	62.95	69.13	28.57
73-3	79.36	9.42	33.50	25.20	31.30	48.93	56.87	29.49
70-3	92.26	31.64	62.15	33.20	49.43	39.91	63.43	29.95
69-3	97.22	16.20	62.15	17.38	53.44	63.90	60.47	39.32
67-3	106.14	15.25	59.76	12.31	59.54	65.32	64.48	34.10
66-3	111.10	15.25	64.18	22.27	45.23	58.91	58.14	37.79
65-3	112.09	16.01	61.08	17.19	53.44	64.13	60.89	39.17

Key to interpret environmental preference of each faunal component

Faunal Component 1: High salinity water masses and sandy sediments.

Faunal Component 2: Poorly oxygenated waters.

Faunal Component 3: Sediments with low total organic carbon and water temperature <14 °C.

Faunal Component 4: Low salinity water masses.

Faunal Component 5: High salinity water masses.

Faunal Component 6: Mixed water masses.

Faunal Component 7: Poorly oxygenated deep-water masses.

Table 5.8. Scores for faunal component at Aegean Sea stations. Separate transects are alternatively shaded and unshaded. Scores are normalized between 0 and 100, component by component. Bold scores are higher than 70. See Table 5.7 for a key to the main environmental implications of each faunal component.

					SCORES			
Station	**Depth(m)**	**FC1**	**FC2**	**FC3**	**FC4**	**FC5**	**FC6**	**FC7**
29-7	14.11	51.41	20.54	27.73	59.54	**81.47**	**71.25**	25.65
30-7	20.16	33.52	65.65	38.48	55.92	**79.57**	64.48	32.10
31-7	29.23	**83.43**	43.57	1.56	41.79	19.00	**91.97**	0.00
32-7	39.31	**79.28**	42.46	17.77	49.05	27.55	**88.16**	17.51
33-7	50.40	53.86	0.00	**75.39**	52.29	**81.47**	57.29	27.34
35-7	71.57	**81.73**	45.44	16.80	42.18	44.66	67.02	13.52
36-7	78.62	**93.41**	52.70	9.77	23.28	57.72	30.44	15.98
37-7	86.69	**95.48**	59.77	21.68	18.32	69.36	16.28	21.51
38-7	97.78	**87.38**	44.89	4.49	28.44	39.67	53.49	11.06
39-7	112.91	**73.45**	67.17	61.52	28.05	**71.73**	38.48	26.11
40-7	142.15	**71.75**	59.67	56.06	22.14	69.60	32.98	24.12
41-7	173.42	52.73	67.52	65.63	34.16	**72.68**	43.55	27.34
42-7	201.66	7.35	47.52	47.27	0.00	27.32	40.17	32.72
43-7	246.05	21.47	31.08	**73.63**	1.53	21.38	52.85	35.33
44-7	298.53	30.70	63.76	61.33	26.15	54.39	48.63	29.95
45-7	353.04	18.64	34.37	68.36	1.15	22.57	50.32	34.72
46-7	501.49	11.49	42.82	54.69	0.38	25.65	43.76	33.49
56-8	18.14	64.97	10.68	42.97	58.40	**89.07**	46.51	35.02
55-8	26.21	66.48	13.73	40.63	60.12	**88.60**	44.82	39.48
54-8	38.30	59.32	11.27	53.52	54.77	**81.00**	52.43	36.41
53-8	49.39	**70.25**	54.54	23.44	38.93	50.83	63.85	18.28
52-8	59.47	**82.11**	39.26	20.51	37.98	58.91	49.68	22.27
51-8	66.53	**100.00**	41.19	0.00	16.79	**73.40**	0.00	26.58

Faunal component 1 is characterized by positive loadings for *Nucula sulcata, Nuculana commutata,* and *Corbula gibba* and negative loadings for *Modiolula phaseolina, Abra alba,* and *Parvicardium exiguum*. *M. phaseolina* and *P. exiguum* generally prefer low salinity (<30 ‰) waters and sandy sediments. *A. alba* is a common species lives under a variety of conditions. *C. gibba, N. sulcata* and *N. commutata* all live in muddy environments and prefer high salinity waters. Clearly, faunal component 1 is defined by above average proportions of Mediterranean species and below average proportions of Black Sea species. This is most easily appreciated by inspection of the above equation. A normalized abundance will be positive if larger than the global mean, and negative if less than the mean. A species with a negative coefficient (loading) will only contribute to a higher score if its normalized abundance is also negative, because the product of two negative numbers is positive. Faunal component 1 is interpreted as an indicator of highly saline waters and sandy bottoms. Scores for this component are highest in the Aegean Sea, moderate in the Marmara Sea, and lowest in the Black Sea (Tables 5.6, 5.7, 5.8). Station 51 in transect 8 (Aegean Sea) was the best representative of this component, having a salinity of 39.13 ‰ and a substrate with 19.00 % sand. In contrast, station 59 in transect 2 (Black Sea) had a salinity of 18.96 ‰ and 2.23 % sand. All other stations with low scores are located in the Black Sea.

The positive loading of *Nucula nucleus* and negative loadings of *Turritella communis* and *Dentalium dentalis* characterize faunal component 2. *N. nucleus* is found in the Aegean Sea and the Marmara Sea; it is a common species that is distributed widely in normal marine environments. In addition, *N. nucleus* can tolerate very low dissolved oxygen concentrations. *T. communis* and *D. dentalis* are mostly common in highly-oxygenated marine environments; however, in this thesis research, they were never found in the shallow shelf depth in the Black Sea, which is a highly-oxygenated brackish environment. Taking all these preferences together, faunal component 2 can be interpreted to indicate poorly oxygenated marine water masses. High scores in the Marmara Sea and moderate scores at only two stations in the Black Sea highlight the geographic control on the strength of this component (Table 5.6, 5.7, 5.8). The most typical stations for this component are stations 15, 17, 19, and 101 in the Marmara Sea, all having very low dissolved oxygen (1.18–1.76 ml/l). This component is not representative of the Aegean Sea water mass where dissolved oxygen concentrations are very high (4–9 ml/l).

Faunal component 3 is characterized by the high positive loadings of *Nucula nucleus* and *Dentalium dentalis* and high negative loadings of *Nucula sulcata, Modiolula phaseolina, Parvicardium exiguum* and *Timoclea ovata*. *N. nucleus* and *D. dentalis* are found in sediments with low total organic carbon content, and where water temperature is higher than 14 °C. *N. sulcata, T. ovata, P. exiguum* and *M. phaseolina* are found in sapropels, beneath water colder than 14 °C. Therefore, this component is interpreted as an indicator of sediments with low (<1.5 %) total organic carbon and bottom waters warmer than 14 °C. Tables 5.6, 5.7 and 5.8 show that faunal component 3 has high scores only in the Marmara Sea and at two stations of the Aegean Sea (i.e, stations 43 and 33). The station most typical of this component is station 96 in the Marmara Sea. This component is not representative of the Black Sea water mass and sediments because of the high total organic carbon percentage and cold bottom water in that area. Station 51 in the Aegean Sea has no relationship with faunal component 3 because none of the highly loaded mollusc species are found at that station (Table 5.8).

Faunal component 4 has a high positive loading with only *Spisula subtruncata,* and high negative loadings for *Nuculana commutata, Abra alba,* and *Dentalium dentalis.* These latter species prefer mostly high salinity (>30 ‰) waters; however, *A.alba* can tolerate low salinity waters. *S. subtruncata* prefers low salinity. Faunal component 4 is therefore attributed to the presence of a low salinity water mass. High scores in the Black Sea and moderate scores at only one shallow station (13 m) in the Marmara Sea highlight the geographic control on the strength of this component (Table 5.6, 5.7, 5.8). This component has low scores at stations in the Aegean Sea because of its high salinity water mass. Because of the pycnocline in the Marmara Sea, the water has Aegean Sea characteristics so scores are also low (Figures 3.5, 3.14).

Faunal component 5 shows high positive loadings for *Turritella communis* and *Nucula nucleus* and a high negative loading for *Spisula subtruncata. N. nucleus* and *T. communis* prefer high salinity waters; however, *S. subtruncata* prefers low salinity waters such as in the Black Sea. In this thesis research, *S. subtruncata* was not found outside the Black Sea. Based on these opposed preferences, faunal component 5 is interpreted as an indicator of highly saline waters. Geographically, this component had its highest scores in the Aegean Sea and in the Marmara Sea and its lowest scores in the Black Sea (Table 5.6, 5.7, 5.8). If faunal component 5 represents highly saline water masses, why do some stations have low scores in the Aegean Sea and in the Marmara Sea? If the abundance of one species is particularly low at one station, that will affect the score for this particular station because station-by-station scores are calculated by using abundance of species at each station. *T. communis* and *N. nucleus* do not always show high percentages along the Maramara Sea and the Aegean Sea transects (Appendix A). This might be result from patchy distribution of individuals. In addition, faunal component 5 corresponds to only 9.20 % of the cumulative variance. Considering the irregular abundance data and the small contribution to total variance, a few high salinity stations with low scores are acceptable.

A high positive loading for *Corbula gibba* and high negative loadings for *Nucula sulcata, Nuculana commutata*, and *Spisula subtruncata* characterize faunal component 6. *C. gibba* was associated with moderately to highly saline environments and *S. subtruncata* prefers low salinity waters. *N. sulcata* and *N. commutata* both prefer high salinity waters even though they show an inverse relationship with *C. gibba* in this faunal component. Thus, this component is interpreted to result from the mixing of two water masses. Component scores also show that this component is represented highly in the Marmara Sea, moderate in the Aegean Sea, and low in the Black Sea (Tables 5.6, 5.7, 5.8). This is believed to reflect the fact that the Marmara Sea is transitional between the Aegean Sea and the Black Sea, having a mixture of the Aegean Sea and the Black Sea water mass characteristics at the thermocline-halocline-pycnocline. Therefore, scores of faunal component 6 are high between water depth of ~17 and ~40 m (thermocline-halocline-pycnocline) in the Marmara Sea transects 1 and 4 (Table 5.6).

Faunal component 7 has only a single high positive loading with *Myrtea spinifera* and a single high negative loading with *Timoclea ovata*. *M. spinifera* prefers high salinity, mostly poorly oxygenated (<2 ml/l) and deep (>60 m) waters. *T. ovata* prefers high salinity and high oxygen contents. Hence, this component is identified with sites deeper than 60 m, having low dissolved oxygen in the bottom water. Based on station-by-station scores, this component is strongest in the poorly oxygenated waters of transect 4, Marmara Sea (Table 5.6); and has very low scores in the well oxygenated waters of the Black Sea and the Aegean Sea (Table 5.7, 5.8). The reason for not finding high faunal scores in all poorly oxygenated deep-water stations in the Marmara Sea is the low abundance of *Myrtea spinifera* in these stations.

5.3.2. Comparison with environmental data

Based on inferences made to explain the faunal components, water salinity is the most important variable explaining the distribution of molluscs between the Marmara Sea, the Black Sea and the Aegean Sea. Dissolved oxygen in the bottom water and water depth has secondary importance; sediment type and total organic content in the sediment are of less importance.

In order to more fully interpret the species data in relation to environmental data, such as salinity (‰), temperature (°C), depth (m), dissolved oxygen (ml/l), and proportion of sand (%), another principal component analysis was run using the oceanographic data. Three principal components, explaining 73.8 % of the cumulative variance, have eigenvalues >1 (Table 5.9). Results of this analysis and loadings for each

Table 5.9. Eigenvalues of the environmental Principal Component Analysis. The first three environmental components (EC) are considered significant using the Kaiser criterion.

EC	Eigenvalues	%Variation	Cum.%Variation
1	1.86	31.00	31.00
2	1.47	24.40	55.40
3	1.11	18.40	73.80
4	0.67	11.10	84.90
5	0.57	9.50	94.40

component are listed in Table 5.10. The most positive (>0.3) and the most negative (< -0.3) loadings associated with each component show the relationships of the components to the physical oceanographic variables. The meaning of each component can be interpreted using these relationships.

Table 5.10. Coefficients (loadings) for the six environmental variables on the three environmental principal components. Significant loadings are shown in bold type.

Variables	EC1	EC2	EC3
Depth (m)	0.108	**-0.712**	-0.214
Temperature (˚C)	**0.527**	0.247	**0.320**
Salinity (‰)	**0.609**	-0.063	0.207
Oxygen (ml/l)	0.172	0.089	**-0.835**
Sand (%)	0.238	**0.562**	**-0.317**
Total organic carbon (%)	**-0.503**	**0.325**	0.105

To assist interpretation, scores were calculated for each station using the environmental component coefficients (loadings) and the normalized values of the environmental variables. Scores are listed in Table 5.11, 5.12 and 5.13. As before, scores are normalized between 0 and 100, component by component. This facilitates the recognition of stations with particularly high scores. As for the faunal scores, environmental scores higher than 70 are considered to be dominant. Scores are normalized between 0 and 100, component by component. This facilitates the recognition of stations with particularly high scores. As for the faunal scores, environmental scores higher than 70 are considered to be dominant.

Environmental component 1 is characterized by high (>0.3) positive loadings on temperature and salinity, and a high (<-0.3) negative loading on total organic carbon (%) (Table 5.10). This component can be interpreted as a high-salinity and warm-water component in association with sediments having low total organic carbon. Environmental component 1 had high scores at almost all stations in the Aegean Sea, moderate scores in the Marmara Sea, and low scores in the Black Sea (Tables 5.11, 5.12, 5.13). In the Aegean Sea, this component represented salinity of 38–41 ‰, temperature of14–18 ˚C and <1.8 % total organic carbon in sediments. Only at station 29 in the Aegean Sea transect 7 did environmental component 1 show a very low score because of high (4.40 %) total organic carbon content (Table 5.13). The typical station for this component is station 33 in transect 7 with salinity of 40.49 ‰, temperature of 14.33 ˚C, and sediments having total organic carbon percentage of 0.47 % (Table 5.13). The moderate scores characteristic of the Marmara Sea are found at stations with temperature

Table 5.11. Environmental scores for stations in the Black Sea. Separate transects are alternatively shaded or unshaded. Scores are normalized between 0 and 100, component by component across all seas. Bold scores are higher than 70.

Station	Depth	Temp.	Salinity	Oxygen	Sand	TOC	SCORES EC1	EC2	EC3
59-2	83.33	7.74	18.96	4.14	2.23	2.59	2.26	50.95	45.23
58-2	89.28	7.77	19.02	2.53	4.10	2.66	0.00	50.51	58.19
56-2	98.21	7.88	19.35	2.59	2.34	1.80	10.19	44.07	55.75
55-2	104.16	7.99	19.68	1.65	21.84	2.18	9.81	52.86	57.95
54-2	106.14	8.01	19.74	1.11	8.43	1.87	10.00	45.24	66.50
84-3	22.82	20.60	19.05	3.91	39.03	0.51	**72.64**	**75.55**	63.08
83-3	25.80	17.61	20.62	4.23	13.95	2.99	33.02	**75.70**	**70.42**
82-3	33.73	11.43	21.05	5.51	33.65	4.62	1.89	**85.07**	41.32
81-3	36.71	9.10	18.03	5.08	15.99	2.55	8.87	63.69	37.41
74-3	74.41	8.01	18.68	5.55	34.83	1.59	22.45	60.32	19.07
73-3	79.36	9.15	18.66	4.60	19.88	1.12	26.98	51.98	33.74
70-3	92.26	8.78	19.07	4.32	7.97	1.66	17.74	48.32	40.83
69-3	97.22	10.49	22.54	3.89	6.14	2.31	20.00	51.98	53.30
67-3	106.14	10.31	24.47	3.74	7.58	1.25	34.53	45.10	51.35
66-3	111.10	11.78	27.81	3.55	19.85	1.22	46.79	50.37	53.79
65-3	112.09	8.06	19.63	3.93	16.80	1.56	19.06	47.73	38.14

Key to the meaning of each Environmental Component

Environmental component 1: High salinity and warm water mass with low total organic carbon.

Environmental component 2: Shallow water and sandy sediments.

Environmental component 3: Shallow water depth, warm and poorly oxygenated water mass.

Table 5.12. Environmental scores for stations in the Marmara Sea. Separate transects are alternatively shaded or unshaded. Scores are normalized between 0 and 100, component by component across all seas. Bold scores are higher than 70. See Table 5.11 for a key to the meaning of each environmental component.

Station	Depth	Temp.	Salinity	Oxygen	Sand	TOC	SCORES EC1	EC2	EC3
1-1	13.89	25.82	22.84	3.96	20.37	1.31	**81.89**	**79.36**	**88.02**
2-1	17.86	21.02	24.90	4.67	35.40	1.81	68.30	**82.14**	66.99
3-1	23.81	15.22	37.95	2.88	10.36	1.48	64.72	60.62	**84.11**
4-1	28.77	15.65	38.05	2.72	38.08	1.32	**73.77**	**70.43**	**75.55**
5-1	34.73	16.11	38.49	3.49	23.31	1.09	**76.60**	63.54	**74.82**
6-1	39.69	16.38	38.71	3.76	30.35	1.32	**77.17**	67.50	**71.15**
7-1	44.65	16.49	38.83	3.87	5.55	1.39	**71.89**	57.69	**79.46**
8-1	48.61	16.68	38.93	4.09	11.56	1.36	**74.53**	59.74	**75.80**
9-1	54.57	16.30	38.89	3.31	5.12	1.38	**70.76**	55.78	**83.37**
10-1	59.53	16.25	38.97	3.94	4.87	1.35	**72.08**	55.20	**77.75**
11-1	64.49	15.65	38.85	2.46	6.49	1.31	68.87	53.59	**87.78**
12-1	69.45	15.37	38.79	2.32	2.40	1.47	65.09	51.98	**89.98**
13-1	74.41	15.00	38.71	1.84	2.17	1.25	65.66	49.34	**92.18**
15-1	84.32	14.88	38.68	1.76	1.97	1.19	66.04	47.58	**91.93**
17-1	103.17	14.89	38.68	1.75	2.41	1.15	66.98	45.39	**90.71**
19-1	121.02	14.82	38.67	1.70	0.76	1.26	65.47	43.19	**90.95**
93-1	146.80	14.62	38.65	1.66	7.56	1.14	68.11	41.87	**86.31**
94-1	171.59	14.47	38.66	1.39	26.56	0.83	**75.28**	44.51	**78.73**
95-1	187.45	14.46	38.66	1.29	28.93	1.14	**72.64**	45.24	**78.73**
96-1	225.12	14.45	38.66	1.23	4.58	1.39	65.28	32.65	**86.80**
97-1	247.91	14.44	38.67	1.20	3.04	1.36	65.85	29.28	**86.31**
99-1	312.32	14.41	38.67	1.42	42.09	0.79	**82.08**	33.97	64.30
100-1	293.50	14.42	38.66	1.62	30.47	0.62	**81.51**	30.75	67.48
101-1	255.84	14.44	38.66	1.18	35.25	0.50	**82.45**	36.16	**71.39**
23-4	18.85	14.21	26.49	4.92	12.68	2.91	32.08	**71.30**	60.39
24-4	23.81	13.09	33.05	4.32	26.42	2.82	41.32	**73.21**	61.37
25-4	28.77	14.10	37.33	0.68	11.14	1.76	54.34	59.44	**100.00**
26-4	33.73	14.51	37.80	0.72	37.26	1.28	67.55	66.91	**89.49**
27-4	39.69	14.87	38.23	1.10	34.38	1.34	68.68	66.03	**88.51**
28-4	43.65	14.89	38.26	0.88	53.43	1.19	**74.34**	**72.04**	**82.64**
29-4	49.61	14.97	38.38	0.91	39.49	4.40	36.04	**83.90**	**97.07**
30-4	55.56	14.99	38.45	0.86	26.50	1.48	66.04	61.79	**93.40**
31-4	60.52	15.01	38.47	0.81	16.34	1.85	60.00	59.30	**98.29**
32-4	64.49	15.01	38.49	0.83	8.84	1.21	65.66	52.42	**98.78**
39-4	98.21	14.77	38.64	0.64	13.94	0.54	**74.15**	46.27	**94.13**
40-4	109.12	14.76	38.64	0.65	35.34	1.20	**71.51**	57.10	**87.53**
41-4	118.04	14.74	38.64	0.65	25.67	1.17	**70.00**	52.12	**90.22**
42-4	143.83	14.68	38.65	0.64	29.27	1.01	**73.02**	49.49	**87.04**

Table 5.13. Environmental scores for stations in the Aegean Sea. Separate transects are alternatively shaded or unshaded. Scores re normalized between 0 and 100, component by component across all seas. Bold scores are higher than 70. See Table 5.11 for a key to the meaning of each environmental component.

Station	Depth	Temp.	Salinity	Oxygen	Sand	TOC	SCORES EC1	EC2	EC3
29-7	14.11	15.58	40.13	3.48	65.17	4.40	48.68	**100.00**	**70.17**
30-7	20.16	14.44	40.77	3.82	57.26	1.48	**77.55**	**78.62**	58.68
31-7	29.23	14.29	40.60	4.27	77.66	1.85	**77.93**	**87.70**	47.43
32-7	39.31	14.27	40.72	7.32	82.35	1.21	**90.57**	**86.53**	16.87
33-7	50.40	14.33	40.49	9.25	75.37	0.47	**100.00**	**79.50**	0.00
35-7	71.57	14.56	38.78	7.18	64.07	0.05	**98.11**	69.55	19.07
36-7	78.62	14.55	38.81	6.65	71.39	0.32	**96.23**	**72.91**	21.27
37-7	86.69	14.48	38.79	7.05	30.00	0.65	**84.15**	57.69	33.50
38-7	97.78	14.67	38.88	6.91	16.67	0.74	**81.13**	51.83	39.85
39-7	112.91	14.81	38.95	6.63	51.91	0.54	**91.32**	62.81	28.12
40-7	142.15	14.66	38.97	7.26	11.58	0.87	**80.19**	45.53	36.43
41-7	173.42	14.38	38.92	7.54	5.15	0.98	**77.55**	39.97	34.23
42-7	201.66	14.26	38.92	7.17	2.34	1.05	**76.04**	35.58	36.68
43-7	246.05	14.07	38.92	7.23	0.61	1.11	**75.47**	29.87	33.99
44-7	298.53	13.83	38.91	7.33	0.89	1.06	**76.60**	23.43	29.10
45-7	353.04	13.79	38.92	7.21	0.45	1.17	**76.23**	17.42	27.38
46-7	501.49	13.66	38.97	7.19	0.46	1.15	**79.43**	0.00	18.58
56-8	18.14	18.40	41.74	4.44	8.00	0.87	**88.68**	61.05	**80.44**
55-8	26.21	17.88	40.98	4.67	7.00	0.54	**89.81**	57.39	**75.55**
54-8	38.30	17.06	41.58	4.76	11.00	0.54	**89.43**	56.66	**70.91**
53-8	49.39	16.87	39.14	8.42	59.00	1.11	**94.34**	**79.36**	20.78
52-8	59.47	16.60	39.14	8.40	47.00	1.41	**87.74**	**74.96**	24.94
51-8	66.53	16.46	39.13	5.80	19.00	1.81	**73.40**	63.84	58.19

of ~16 °C, salinity of ~38 ‰, and sediments with total organic carbon percentage of ~1.30 % (Table 5.12).

Environmental component 2 has a high positive loading for sand (%), a moderate positive loading for total organic carbon (%), and a very high negative loading for water depth (Table 5.10). This is a sandy shallow-water component with highest scores found in shallow waters (< 75 m) and sandy bottom sediments (Tables 5.11, 5.12, 5.13). A typical station for this component is station 29 in transect 7 with water depth of 14 m and 65.17 % sand. In contrast, station 46 in transect 7 had the lowest score because this station is the deepest station (501 m) and it had a very low percentage (0.46 %) of sand. The moderate loading on total organic carbon gives this variable less influence on individual scores. Thus, high component scores can be found at stations with low total organic carbon, for example station 84 in transect 3, and stations 33 and 36 in transect 7 (Tables 5.11, 5.13).

Environmental component 3 has a significant positive loading for temperature (°C), a negative loading for depth (m), and a very high negative loading for dissolved oxygen concentration (ml/l) (Table 5.10). This component signifies warm, shallower conditions with very low (< 2 ml/l) dissolved oxygen concentrations. Highest scores were found mostly in the Marmara Sea (Tables 5.11, 5.12, 5.13). A typical station for this component is at 28 m in station 25, transect 4, with very low dissolved oxygen concentration (0.68 ml/l). The lowest score was in the Aegean Sea, station 33, with very high dissolved oxygen concentration of 9.25 ml/l. Temperature seems to have little influence on the distribution of the higher scores; for example, in the Marmara Sea the highest scores are found at stations with water temperature between 14 °C and 15 °C. The reason might be the over-riding influence of the high negative loading of dissolved oxygen on environmental component 3.

In an attempt to clarify the relationship between environmental components and physical oceanographic data along each transect, cross-plots were made of environmental scores and variables, transect by transect. Significant correlations between scores and variables from regression analysis were selected using the 5 % criteria for significance. These significant correlations are thrown graphically in Appendix C, and consistent with the interpretations given above. For instance, environmental score 1 showed a highly correlated reverse relationship with total organic carbon in transects 1, 4, 7 and 8 with correlation coefficients $R^2 = 0.62, 0.84, 0.90$, and 0.83, respectively. Moreover, transect 7 exhibited the reverse relationship between depth and environmental component 2, which reveals highest scores of environmental component 2, with correlation coefficient ($R^2= 0.87$). As an example for environmental component 3, dissolved oxygen and sand percentage showed very high negative correlation with this component in transect 8 ($R^2= 0.98$ and $R^2=0.96$).

CHAPTER 6

DISCUSSION

6.1. Assemblages and correlations with environmental data

The study of faunal assemblages is important for marine geological studies because these assemblages can contain the naturally archived record of habitats and changing ecosystems. In this thesis, the faunal assemblages collected from the surface sediments are considered younger than ~2000 years and are assumed to have lived beneath the present-day water masses. The data presented in this thesis show that seven different qualitative mollusc assemblages reflect seven different sets of environmental parameters. Because a particular assemblage has specific environmental preferences, its presence in any given sample should help distinguish a particular water mass. For instance, assemblage 6 is dominated by *Spisula subtruncata*, which prefers a low-temperature (7–8 °C), low-salinity (18–19 ‰) water mass and sediments formed of a mixture of sandy-clay and sandy-silt. Similarly, the presence of species of assemblage 3 in any sample would suggest a paleoenvironment defined by high salinity (38 ‰) shelf depths and sandy-silty-clay bottom sediments. To quantify such relationships, however, an appropriate statistical method must be employed, such as principal component analysis.

6.2. Regional distribution of faunal and environmental components, and procedures for predicting one from the other

Principal component analyses showed that seven different faunal and three different environmental components explain 73.9 % and 73.8 % of the variance in the faunal and environmental data, respectively. Cross-plots of scores for the major faunal and environmental components revealed clear empirical relationships between data from the three oceanographically different seas.

The aim of this section is to discuss clear correspondences between faunal and environmental components where they are both dominant (i.e. scaled score ≥ 70). In cases where these criteria are satisfied, the data are said to have a high positive covariance (e.g. shaded area in Figure 6.1). The primary objective is to establish criteria to predict the environmental setting for the fauna in at a station or along a transect (or *vice versa*). If such clear relationships exist, then shells collected from marine cores, where the fauna but not environment is known, might be used to reconstruct past environments.

To begin, the faunal and environmental scores from the two separate principal component analyses were cross-plotted. All of these plots are presented in Appendix D, and those which provide the ability to predict the environment from the fauna are discussed more fully here.

The score plot for faunal component 1 (FC 1) versus environmental component 1 (EC 1) effectively separates the Marmara Sea and the Aegean Sea stations from the Black Sea stations (Figure 6.1). The Aegean Sea stations show the highest scores and the Black

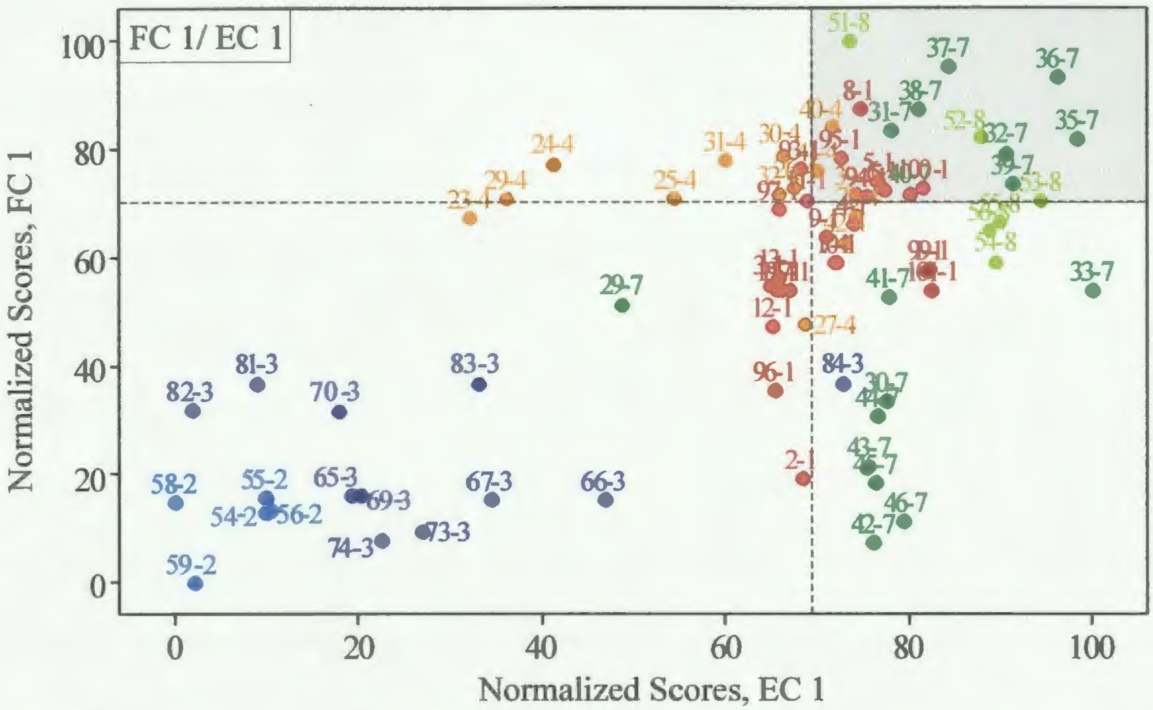
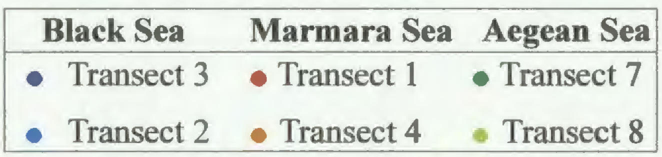


Figure 6.1. Score plot for faunal component 1 versus environmental component 1.



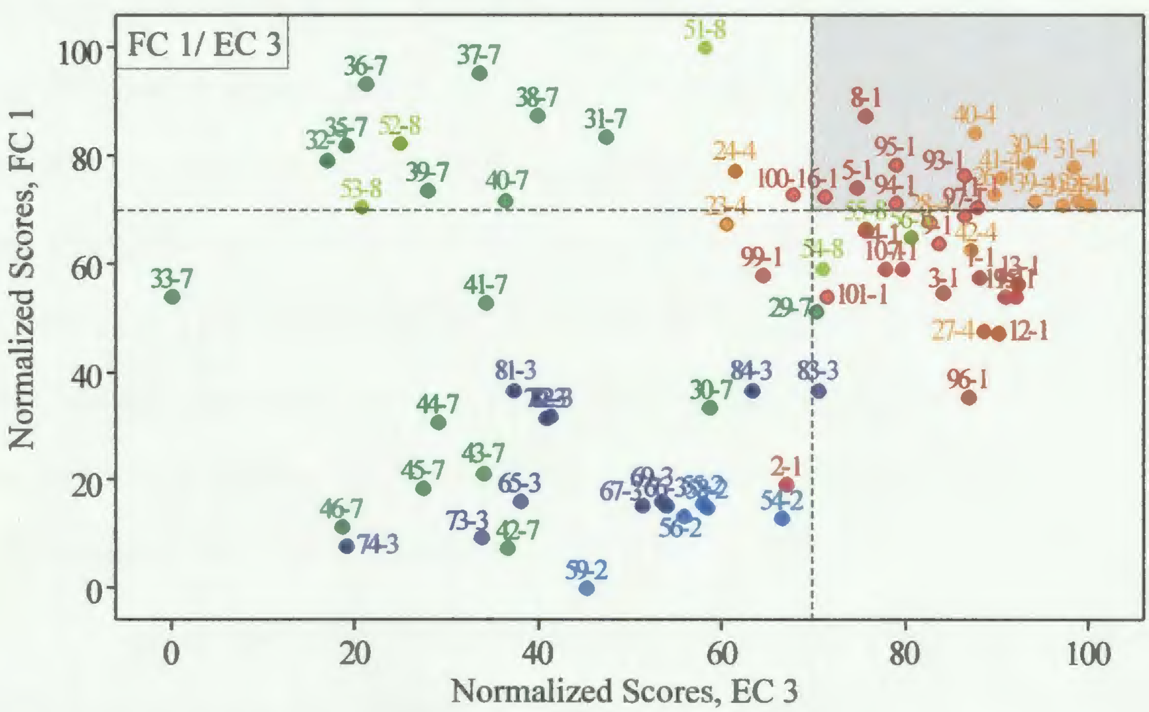


Figure 6.2. Score plot for faunal component 1 versus environmental component 3.

Sea stations show the lowest scores. The high salinity of the Aegean Sea and low salinity of the Black Sea drive EC 1 and have a clear correlation with FC 1. The score plot for FC 1 versus EC 2 does not show good separation between the three seas because EC 2 (see Appendix D) is mostly related to sediment types. Instead, the high scores of environmental and faunal components reflect sandy shallow stations with high salinities (shaded area in the plot). The score plot for FC 1 versus EC 3 does not reveal a good separation between data from the Black Sea and the Aegean Sea, but the Marmara Sea is well separated (Figure 6.2). The data points in the shaded area are mostly from the high salinity, warm and poorly oxygenated Marmara Sea stations (Figure 6.2).

The score plot for faunal component 2 (FC 2) versus environmental component 1 (EC 1) clearly separates the Aegean Sea and the Marmara Sea stations from the Black Sea stations (Figure 6.3). The shaded area in this cross-plot corresponds to high salinity, poorly oxygenated conditions, and sediments with low total organic carbon. Stations are the Marmara Sea stations and the Black Sea stations scatter separately to them. Black Sea stations scatter separately because they possess moderately oxygenated water masses and high total organic carbon in the sediments. The scatter plot of FC 2 versus EC 2 does not show any significant clustering. The scatter plot of FC 2 versus EC 3 shows a subset of the samples from the poorly oxygenated shallow Marmara Sea in the shaded area (Figure 6.4). In contrast, samples from the well-oxygenated Aegean Sea have low faunal and environmental scores in this plot.

The score plot for faunal component 3 (FC 3) versus environmental component 1 (EC 1) separates the Black Sea stations with low scores from the Aegean Sea and the

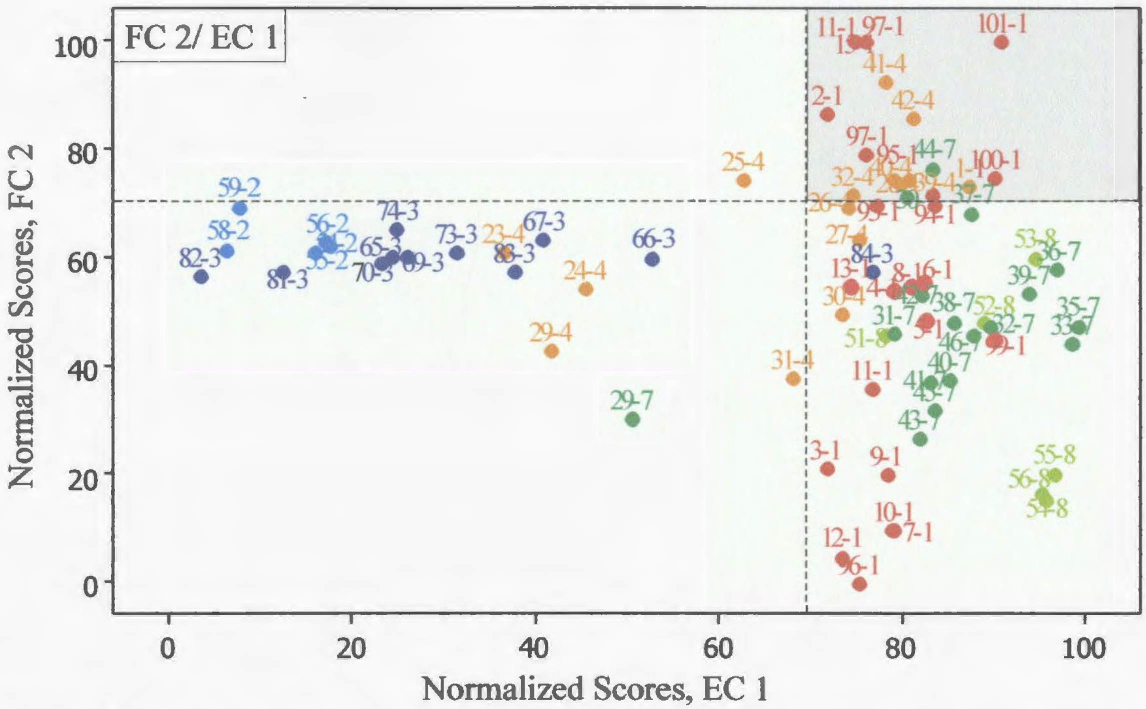


Figure 6.3. Score plot for faunal component 2 versus environmental component 1.

Black Sea	Marmara Sea	Aegean Sea
• Transect 3	• Transect 1	• Transect 7
• Transect 2	• Transect 4	• Transect 8

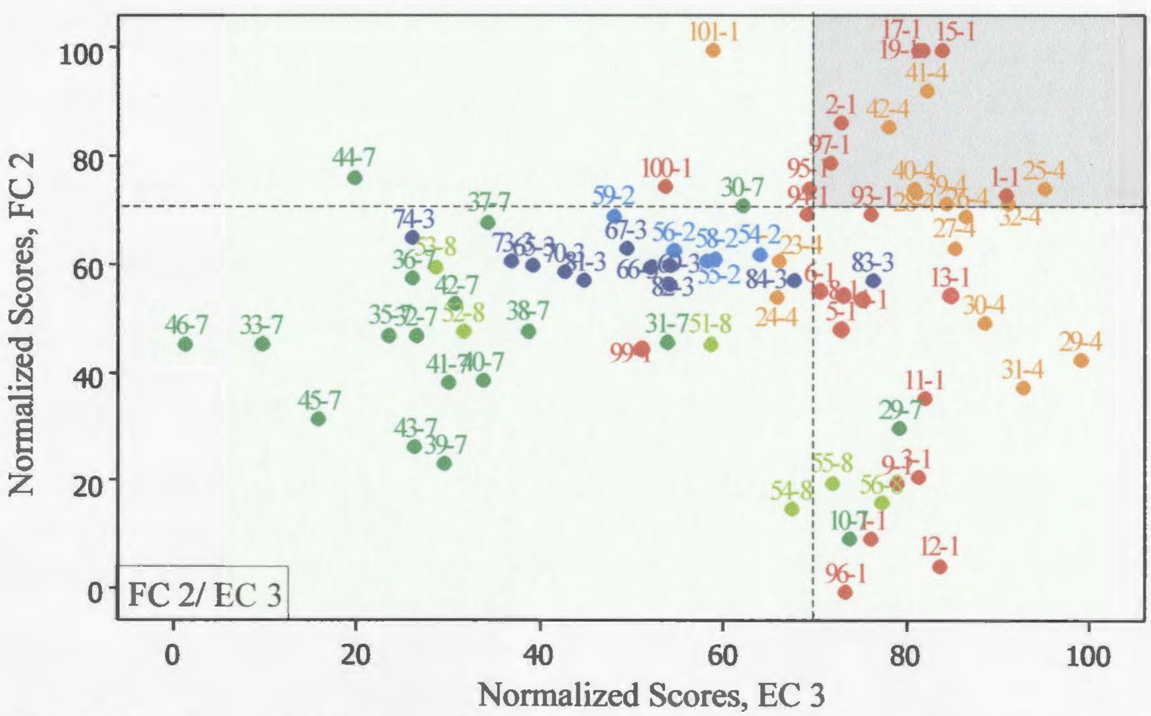


Figure 6.4. Score plot for faunal component 2 versus environmental component 3.

Marmara Sea stations (Figure 6.5). The shaded area in the lower left of the plot corresponds to Black Sea sediments with high total organic content. The rest of the plot in Figure 6.5 does not show any distinct separation. The scatter plot of FC 3 and EC 2 does not any specific clusters. The reason for this might be that environmental component 2 only reflects sediment type not water mass difference. The scatter plot of FC 3 versus EC 3 does not show a good separation of data from the different seas.

The cross plots for faunal component 4 (FC 4) versus environmental components 1 to 3 also do not show clear relationships between faunal and environmental components (Appendix D). A potential reason is the low percentage (9.70 %) of the variance that is explained by faunal component 4. It might, indeed, be expected that the more minor principal components (those accounting for less variance) would be less likely to provide good separation between clusters of data. Only the cross plot for FC 4 versus EC 2 clearly distinguishes the low-salinity, shallow and sandy Black Sea stations from the high-salinity, deeper-water Aegean Sea stations (shaded areas in Figure 6.6).

The cross plots of faunal components 5 to 7 versus environmental components 1 to 3 do not reveal any evident correspondences between faunal and environmental components (Appendix D). This is again attributed to the low amount of the population variance accounted for by these faunal components.

According to Figures 6.1-6.6 very few of the faunal and environmental score cross-plots separate various datasets. Cross-plots of FC 1/EC 1, FC 2/EC 1, and FC 3/EC 1 nicely separate the Black Sea from the Marmara Sea and the Aegean Sea. Because EC 1 is a highly saline, warm water mass with low total organic carbon sediment

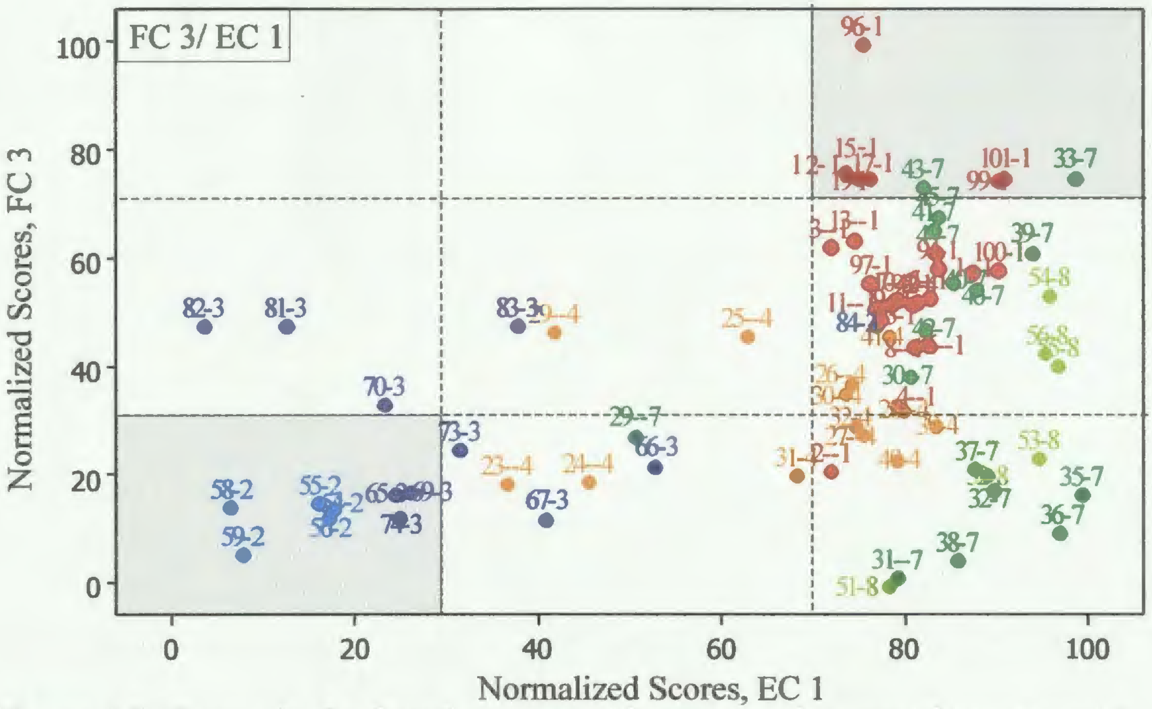
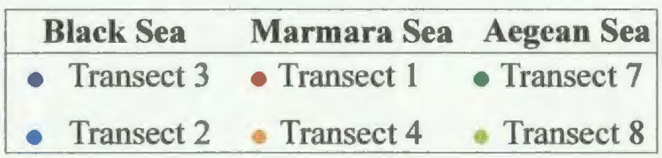


Figure 6.5. Score plot for faunal component 3 versus environmental component 1.



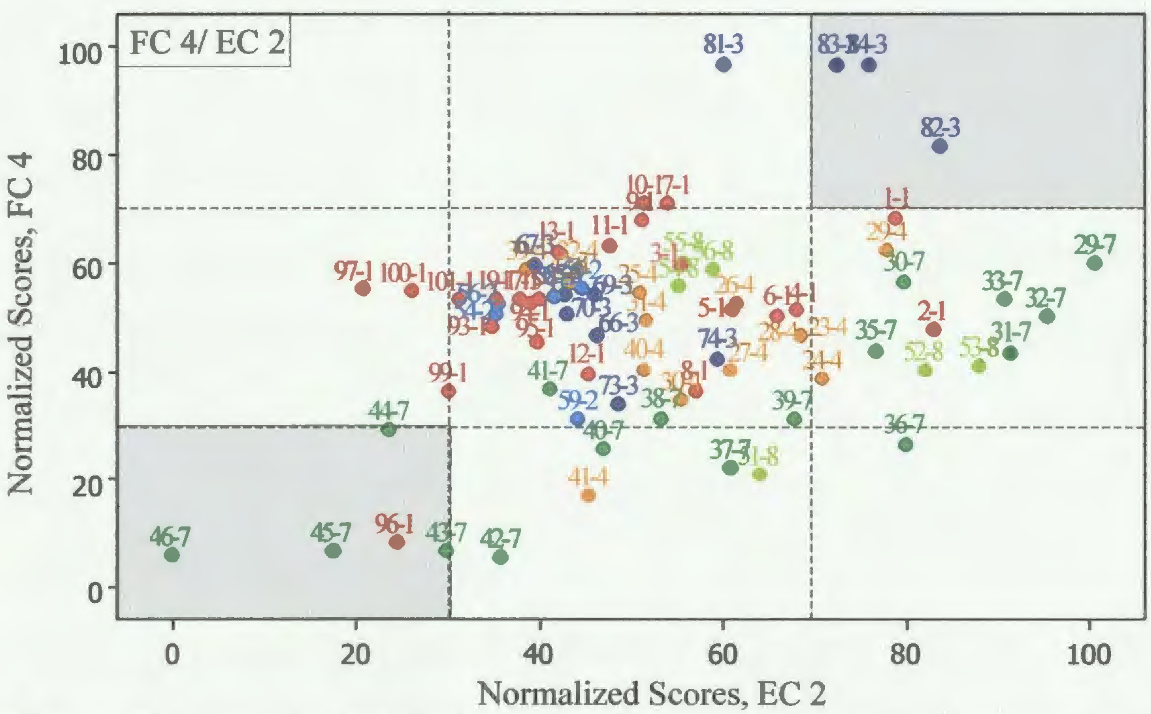


Figure 6.6. Score plot for faunal component 4 versus environmental component 2.

the Black Sea samples can easily be separated. In order to be able to see the difference between the Marmara Sea and the Aegean Sea, another cross-plot needs to be checked. For example, the FC 1/EC 3 cross-plot can be used. In this plot EC 3, which is a shallow water depth, warm and poorly oxygenated water mass indicator that helps to distinguish the Marmara Sea stations from the Aegean Sea stations.

6.3. A practical application of the quantitative results

The assemblages (faunal components) identified by PCA have potential value as predictive tools for the evaluation of past paleoceanographic parameters in core samples, or in other samples with unknown environmental affinities. In this section, a procedure will be set out for application of the quantitative results to interpretation of faunal assemblages in cores. In order to be able to reliably use these faunal components to interpret core data, however, some possible complications, such as time averaging, and physical and bioturbational reworking must be taken into account. Each of the possible complicating factors will be briefly discussed.

Time averaging is the stratigraphic mixing of non-contemporaneous individuals in single samples. This is a function of sedimentation rate, the rate of sediment reworking by bioturbational and physical processes, and the burrowing depths of infaunal molluscs (Powell et al., 1989). It is important to understand sources of variation in taphonomic rates and processes over time and their influence on the vertical distribution of species in cores, because time averaging also increases the chance of preservation of a species by input from many generations. Although the preservation potential of an individual specimen is low, the chance of preservation of any species through time averaging is high. As a result, most preservable species found in the living community are ultimately preserved in the geological record. In other words, at least some individuals are present in the death assemblage. In addition, the death assemblage in a core potentially contains many species which might not be found in surface-sediment samples due to rarity of the organism. The counterpoint to these arguments, however, is that core samples are necessarily small, and rare genera might not be captured in the limited amount of material available for study.

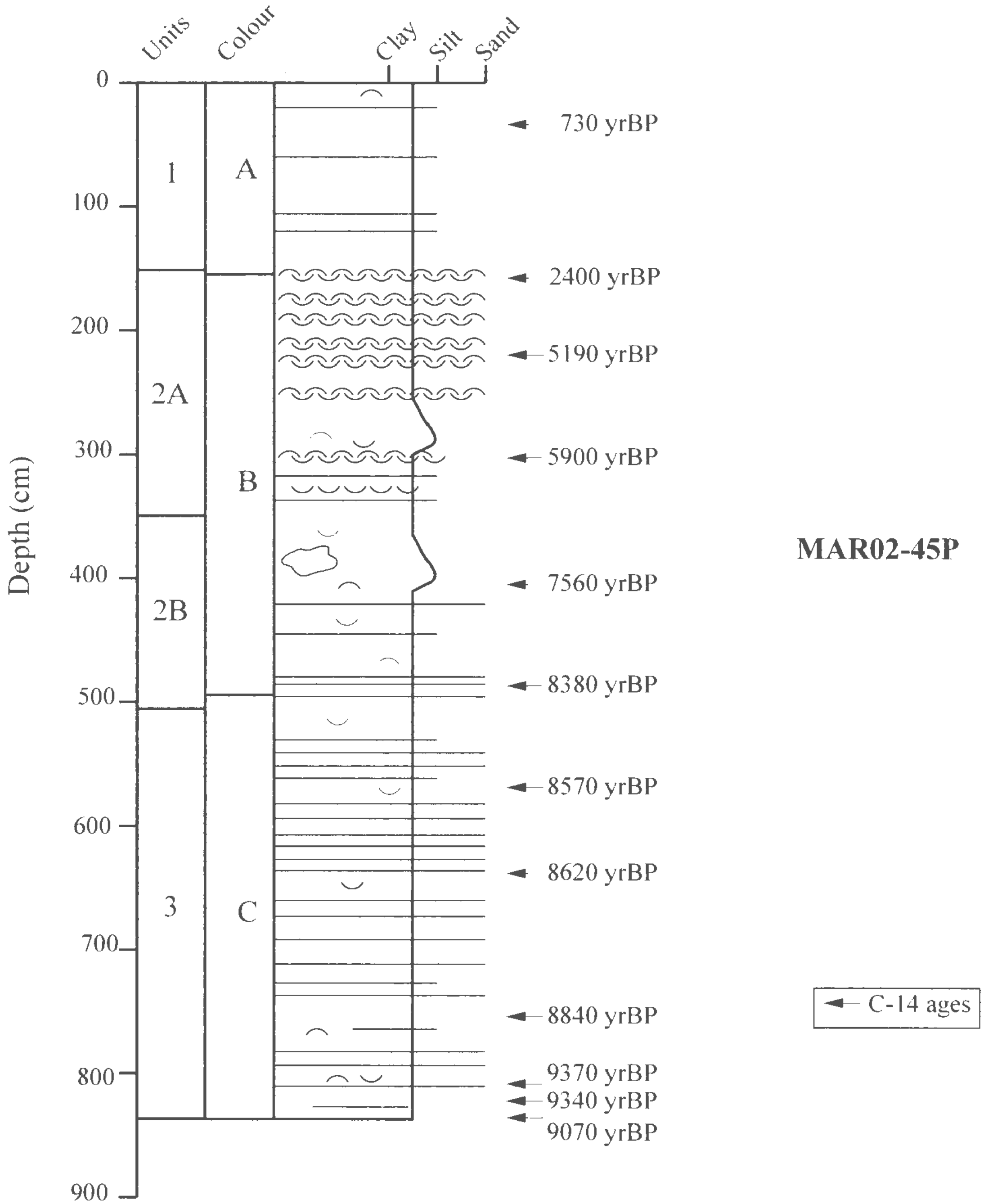
Allochthonous shells are shells which have undergone lateral transport between habitats. Although most shells are moved from the actual site of death, most post-mortem transport is within the habitat rather than over long distances (Powell et al., 1989). Reworked (parautochthonous) shells are shells which have been relocated by bioturbation or predation. Bioturbation is an important process during burial but bioturbational reworking rates are usually slow relative to most taphonomic processes (Powell et al., 1989). There is often an inverse relationship between bioturbation and preservation, so that preservation is generally better in less bioturbated sediments. In a core sample, the effect of bioturbation can most easily be evaluated where there is lithologic contrast. Bioturbation might be less evident in the rest of the core.

Each specific environment is represented by different physical, chemical, and biological processes; these processes leave a unique and predictable signature on a faunal assemblage forming under these conditions (Powell et al., 1989). For mollusc assemblages from present-day sediments, the shells were treated as if the molluscs had died very recently, under modern conditions, and these assemblages were used to characterize environmental parameters. Minor reworking was assumed to not affect these results. In a core study, if the effects of time-averaging, transportation within the habitat, and bioturbation are minimal, then it is believed to be valid to use the mollusc assemblages as paleoenvironmental indicators for the succession of past environments that existed during accumulation of the cored sediment.

In order to check the validity of using principal components as a tool to reconstruct the history of Marmara Sea Gateway from mollusc assemblages, a core (MAR 02–45P) from the Black Sea was chosen and its mollusc assemblages were used to calculate scores for the same faunal principal components which had been developed using the modern seabed samples. In effect, the ancient core samples were treated as "unknowns" to see if they could be correctly classified and interpreted in the context of modern faunal communities and modern environmental parameters. As will be seen, the different species assemblage found in parts of the core, as compared to the surface grab samples, restricts the application of this test. Nevertheless, the procedure itself is advocated here as an approach to the evaluation of past environments using the quantitative surface data gathered for this thesis.

6.4. The Black Sea core, MAR 02–45P

MAR 02–45P is a 850 cm piston core which was raised from the mid-shelf setting (69 m) in the southwestern Black Sea (Figure 3.1, 6.7). The location is 41°41.17' N latitude and 28°19.08' E longitude. MAR 02–45P can be divided into four units and



Colour A: N3-Dark gray, N2- Grayish black, 5GY4/1-Dark greenish gray, 5Y4/1-Olive gray mottled and banded

Colour B: 5Y4/1- Olive gray

Colour C: N3-Dark gray, N2-Grayish black and 5Y4/1-Olive gray colour banded

Unit 1: Burrowed colour-mottled silty mud

Unit 2: Burrowed colour-mottled silty mud, shell beds, high total sulphur

Unit 3: Colour banded and mottled silty mud with common silt-fine sand laminae

Figure 6.7. Description of core MAR 02-45 (R. Hiscott, pers. comm. 2005). The subdivision of Unit 2 is based on the frequency of shelly interbeds.

subunits (Hiscott et al., 2005; pers. comm.). Unit 1 is a burrowed, colour-mottled silty mud. Unit 2 is a burrowed, colour-mottled silty mud with shell beds and high total sulphur content. It can be divided into an upper subunit 2A with common shell beds and a lower subunit 2B with thin sand beds only. Unit 3 is a colour-banded and mottled silty mud with common silt to fine sand laminae (Figure 6.7). Several uncalibrated ^{14}C dates obtained from mollusc shells constrain the ages of Units 1, 2A, 2B and 3 to ~0–2400 yrBP, ~2400–6500 yrBP, ~6500–8400 yrBP, and ~8400–9350 yrBP, respectively (Table 6.1).

Mollusc shells are present throughout the core, and 12 species were identified in the same way as the modern molluscs were identified in chapter 4. Only five of these species are also present in significant numbers in the surface samples (Table 5.5). This fact alone limits the effectiveness of using the surface assemblages to interpret the core assemblages. Ideally, the core and the surface samples would contain the same complement of organisms, so that each core assemblage would have a counterpart in the modern environments of the gateway.

Table 6.1. Radiocarbon ages for core MAR 02–45P reported as uncalibrated conventional ^{14}C dates in yrBP (half-life of 5568 years; errors represents 68.3% confidence limits).

Depth	Dated material	^{14}C date
33 cm	*Spisula subtruncata*	730±40
158 cm	*Mytilus edulis*	2400±60
220 cm	*Mytilus edulis*	5190±50
302 cm	*Mytilus galloprovincialis*	5900±60
406 cm	*Anadara spp.*	7560±60
495 cm	*Truncatella subcylindrica*	8380±70
569 cm	*Anadara spp.*	8570±70
639 cm	*Anadara spp.*	8620±70
754 cm	*Dreissena polymorpha*	8840±70
810 cm	*Mytilus edulis*	9370±70
822 cm	*Dreissena polymorpha*	9340±70
835 cm	*Cyclope donovani*	9070±70

Abundances of species were calculated as a percentage for each unit and subunit of the core, using the following equation, modified for the various species encountered:

Species A percentage = 100 × (number of shells of species A in a unit) / Total number of shells in that unit)

Percentage data are listed in Table 6.2.

In the surface transects, quadrats were defined to include geographically adjacent samples confined to the same water mass, and with similar sediment textures. In core MAR 02–45P, the conceptual equivalent of a surface quadrat is taken to be a relatively homogeneous facies that presumably formed under a distinct set of hydrodynamic conditions. Such facies have stratigraphic thickness, so formed over a significant interval of time. Walther's law (Middleton, 1973) describes how facies belts shift through time to produce a stratigraphic record. Hence, a facies in a core can be thought of as the record of deposition beneath spatially separated sites passing sequentially over the core site as, for example, the shoreline and isobaths shift landward during a transgression. Viewed in this way, it is logical to associate seabed quadrats of a single age (e.g. the present) with facies of finite thickness in a core. The simplest facies subdivision of core MAR 02–45P is at the level of lithologic Units 1 to 3.

Table 6.2. The percentage distribution of mollusc species within each unit. The most abundant key species are shown in bold characters.

Species	Unit 1	Unit 2A	Unit 2B	Unit 3	In grabs
Bittium reticulatum	**30.56**	1.68	0.00	0.00	–
Spisula subtruncata	**27.78**	1.67	0.00	0.00	+
Acanthocardi paucicostata	**12.22**	0.00	1.10	0.00	–
Abra alba	8.33	0.00	0.00	0.00	+
Turritella communis	3.70	0.00	0.00	0.00	+
Mytilus galloprovincialis	9.26	**50.58**	3.46	0.00	–
Modiolula phaseolina	0.00	5.35	0.00	0.00	+
Retusa truncata	0.00	4.78	0.00	0.00	–
Truncatella subcylindrica	4.44	**23.73**	**38.00**	16.27	–
Parvicardium exiguum	0.00	6.65	**52.31**	**53.34**	+
Dreissena polymorpha	3.70	0.00	5.13	**24.14**	–
Rissoa spp.	0.00	5.56	0.00	6.25	–

Inspection of Table 6.2 shows that each unit and subunit in core MAR 02–45P had different fauna. Mostly Mediterranean immigrant molluscs, such as *Bittium reticulatum, Spisula subtruncata, Acanthocardia paucicostata, Abra alba, Mytilus galloprovincialis, Turritella communis*, *Truncatella subcylindrica* and *Dreissena polymorpha* characterize Unit 1. The high frequency occurrence of *Spisula subtruncata* and *Bittium reticulatum* suggests that Unit 1 formed under conditions similar to the present-day Black Sea oceanography, because on the transects *Spisula subtruncata* is only found in the Black Sea grab samples.

Unit 2A is characterized by *Mytilus galloprovincialis*, *Modiolula phaseolina, Truncatella subcylindrica*, *Retusa truncata, Parvicardium exiguum* and *Rissoa spp.* Among these species, *Mytilus galloprovincialis* and *Truncatella subcylindrica* have the highest abundance. These two species have euryhaline and eurytherm preference; thus, they are not good environmental indicators. However, the occurrence of *Modiolula phaseolina* suggests that Unit 2A formed in a low salinity (~18 ‰) environment such as that of the present-day Black Sea.

Unit 2B is characterized by the highest abundances of *Truncatella subcylindrica,* and *Parvicardium exiguum*. These are Mediterranean species which live today in the Black Sea and have a wide range of salinity preference. Low abundances of *Acanthocardia paucicostata, Mytilus galloprovincialis* and *Dreissena polymorpha* are also characteristic of Unit 2B. Although it is very minor in abundance, the occurrence of bivalve *Dreissena polymorpha,* which is an endemic species of the Pontic-Caspian Basin, indicates a brackish (<15 ‰) water mass during the accumulation of Unit 2B.

Unit 3 is characterized by high abundances of *Truncatella subcylindrica, Parvicardium exiguum*, *Dreissena polymorpha* and *Rissoa* spp. As noted for Unit 2B, the species *Truncatella subcylindrica, Parvicardium exiguum* and, in addition, *Rissoa spp.* are Mediterranean species that live in the Black Sea. However the occurrence of the Pontic-Caspian species *Dreissena polymorpha* indicates brackish to fresh water conditions.

The Unit 2B and Unit 3 molluscan assemblages were not encountered in any of the surface grab samples, where the brackish water bivalve *Dreissena polymorpha* was never found. *Mytilus galloprovincialis, Retusa truncata, Truncatella subcylindrica* and *Rissoa spp.* were also not encountered in surface samples.

The four units and subunits can be readily distinguished based on fauna alone in down-core plots of the abundances of the key species for Units 1, 2A, 2B, and 3 (Figure 6.8).

Core MAR 02–45P includes a nearly continuous succession dating from ~10000 yrBP, and thus provides a unique opportunity to test the validity of using the principal components determined from the surface samples to deduce past environments in a core. Only five mollusc species were found both in the core and in surface samples: *Spisula subtruncata, Modiolula phaseolina, Turritella communis, Abra alba,* and *Parvicardium exiguum.* The surface grabs lack 2 of 3 key species for Unit 1; 2 of 2 key species for Subunit 2A; 1 of 2 key species for Subunit 2B, and 1 of 2 key species for Unit 3 (Table 6.2, bold entries).

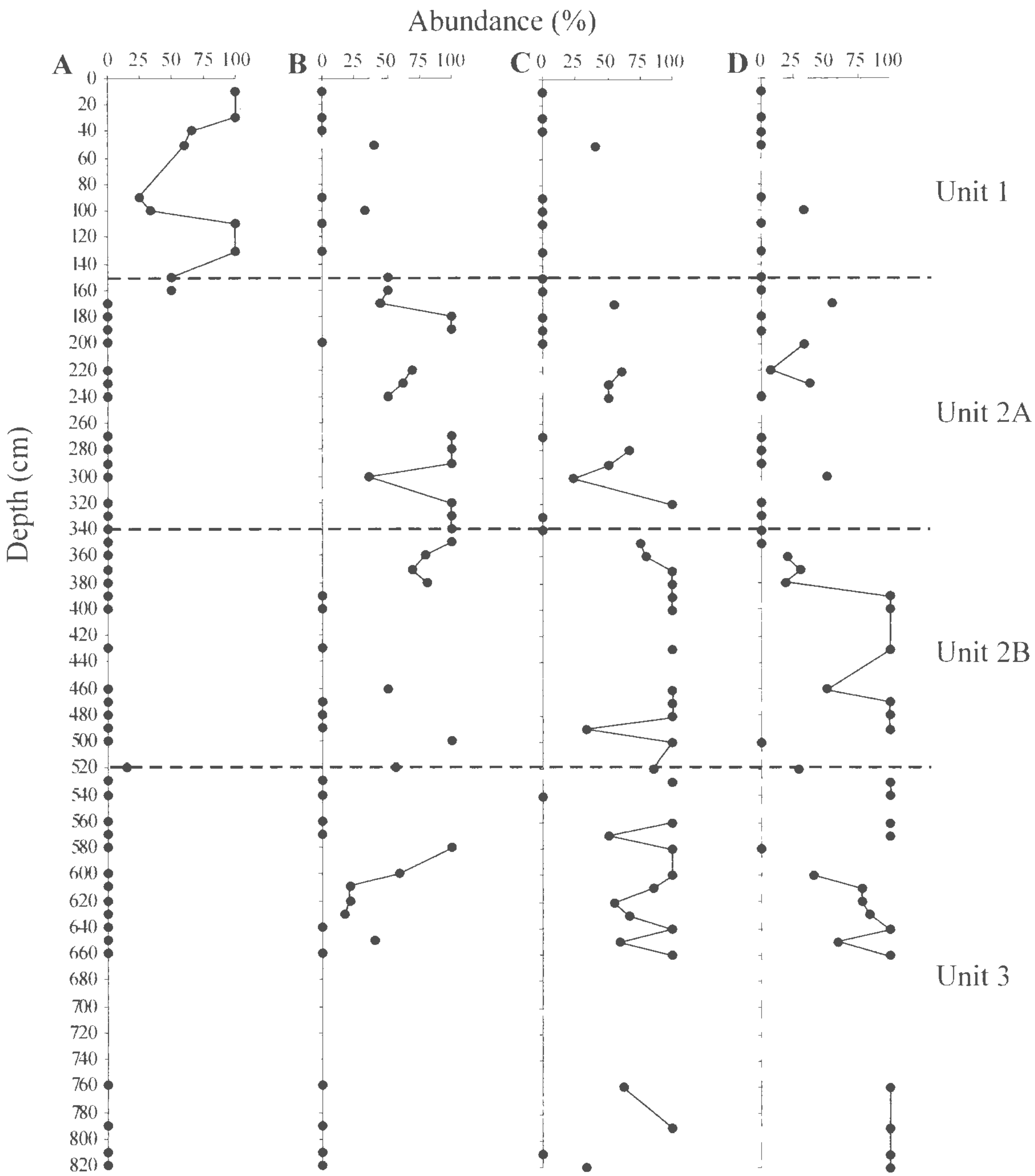


Figure 6.8. Sample-by-sample downcore plots of the sum of the percent abundances of the key species for each unit (bold taxa in Table 6.2) in core MAR 02-45P. Although small numbers are present outside the unit where the particular species are abundant (Table 6.2), there is a sharp difference in abundance with depth. "A" indicates three key species; "B" indicates two key species; "C" indicates two key species; "D" indicates three key species.

The first step in testing the principal component method was to recalculate the five mollusc species listed above to 100 % (Table 6.3). This is effectively the same as performing the recalculation on the same 12 species used for determining the scores for surface samples, because seven of these surface species = 0 % in the core. Then, these recalculated data were standardized by subtracting the mean percentage for the surface samples and then dividing the result by the standard deviation for surface samples. This effectively scaled the standardized core data in a manner identical to the way that individual surface samples had been treated. Next, faunal scores were calculated for each of the four units/subunits using the standardized abundances (now dimensionless) and the principal component coefficients from the surface mollusc data (i.e. Table 5.5. values). This procedure effectively treats the core data for the four units/subunits as if they are "unknown" surface samples. The aim is to attempt to correctly classify the core samples in the context of what has been learned about surface assemblages. The aim here is not to come to definitive conclusions about the origin of the facies in core MAR02-45P, but rather to demonstrate a method which can later be applied to a number of cores in the gateway area, or which can be modified as the quantity of modern grab samples from a wider range of, in particular, brackish-water settings is augmented.

Table 6.3. Percentages of core species also found in the surface samples.

Species	Unit 1	Unit 2a	Unit 2b	Unit 3
Spisula subtruncata	4.76	33.33	0.00	0.00
Modiolula phaseolina	0.00	33.33	0.00	0.00
Turritella communis	23.81	0.00	0.00	0.00
Abra alba	71.43	0.00	0.00	0.00
Parvicardium exiguum	0.00	33.33	100.00	100.00

Finally, the scores for the core units were scaled using the minimum and maximum scores, which themselves had been assigned values of 0 and 100. This was done by applying the same spreadsheet equations to the scores for the core units/subunits that had been used to scale all of the scores for the surface samples. After completion of all these steps, the faunal data for a core unit would have a score of 50 (on a scale of 0–100 for surface samples) if it had the same raw mollusc percentages as a surface sample with a score of 50. Normalized scores are listed in Table 6.4. The highest scores for each unit/subunit identify the modern faunal components which are most strongly represented in the data. The environmental implications of those dominant components can then be used to assess the likely paleoenvironments.

In order to be able to make some arguments about the faunal affinities of each unit/subunit in core MAR 02–45P, histograms were first plotted for surface faunal component scores (Figure 6.9). Normalized faunal scores for each core unit were then superimposed in these histograms to discover the closest correspondence between the ancient units/subunits and the modern faunal assemblages.

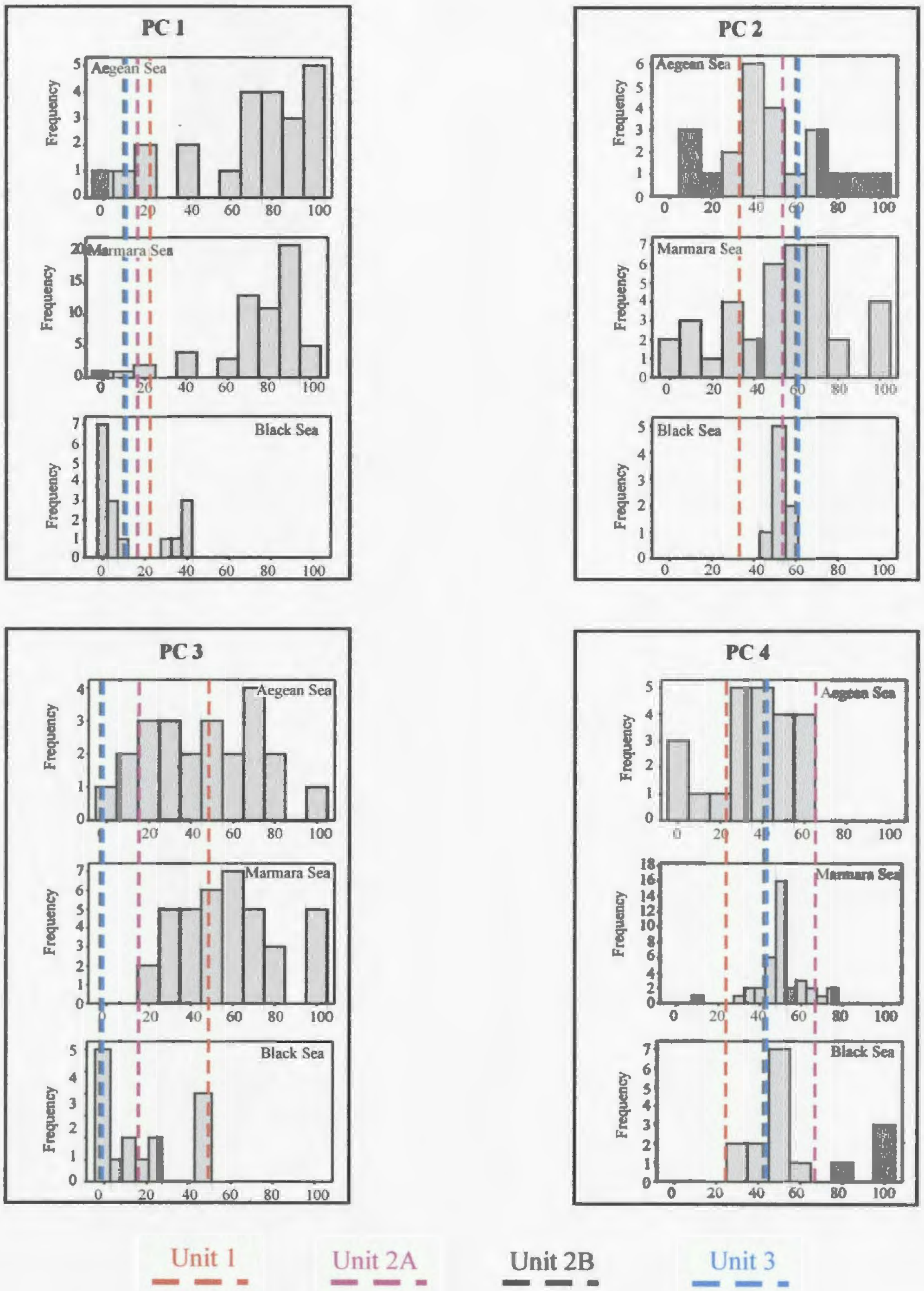
Table 6.4. Normalized faunal scores for mollusc species in each core unit. Bold values are considered as the more significant scores.

Units	Score 1	Score 2	Score 3	Score 4	Score 5	Score 6	Score 7
Unit 1	22.90	36.64	51.07	22.00	43.51	41.69	28.50
Unit 2A	18.69	55.73	15.58	66.41	43.44	49.96	20.85
Unit 2B	14.41	60.75	-0.39	42.61	66.20	**84.67**	18.37
Unit 3	14.41	60.75	-0.39	42.61	66.20	**84.67**	18.37

Histograms for faunal component 1 (supported by Table 6.4) show that all units in core MAR 02–45P have low scores for this component. Normalized scores decrease from the top of the core downward. All units/subunits resemble the Black Sea FC 1 scores (i.e. they are very low).

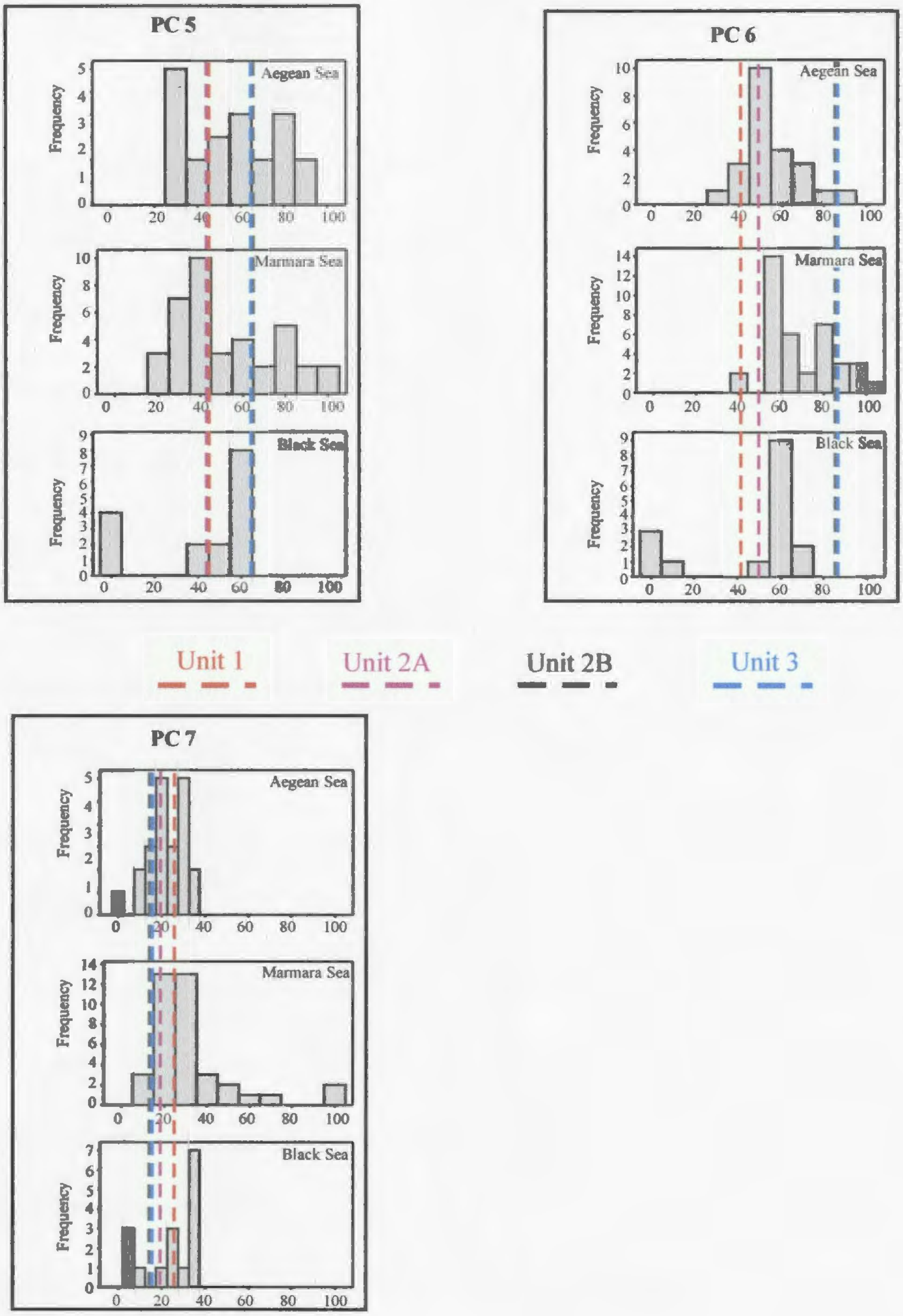
Principal component 2 signifies a poorly oxygenated water mass; Marmara Sea has the highest scores and the Aegean Sea has the lowest scores for this component. In core MAR 02–45P, this component increases with increasing depth. Unit 1 appears to have formed under an oxygenated water mass similar to the Aegean Sea, whereas the environmental setting of Units 2A, 2B and 3 more closely resembles the Marmara Sea with its poorly oxygenated water mass.

Unit 1 shows moderate scores for faunal component 3 (low TOC and cold water (<14 °C) component). Units 2A, 2B and 3 show scores lower than 20, typical of modern Black Sea scores. Hiscott et al. (2005) reported TOC values are as follows: Unit 1 ~1 % TOC, Unit 2A ~2 % TOC, Unit 2B 1–2 % TOC and Unit 3 less than 1 % TOC. Thus, except for Unit 2A all units should have had high scores for faunal component 3 if TOC



PC 1: High salinity water masses and sandy sediments.
PC 2: Poorly oxygenated waters.
PC 3: Sediments with low total organic carbon and water temperature <14 °C
PC 4: Low salinity water masses.

Figure 6.9. Histograms of surface faunal component scores sea-by-sea, showing normalized faunal scores for each unit in core MAR 02-45.



PC 5: High salinity water masses.
PC 6: Mixed water masses.
PC 7: Poorly oxygenated deep water masses.

Figure 6.9 Cont'd. Histograms of surface faunal component scores sea-by-sea, showing normalized faunal score for each unit in core MAR 02-45.

were the primary control. On the other hand, temperature also controls this component. The low scores can also be explained by high temperature or poor match between the species in the core and the species in the grab samples.

Principal component 4 is a low-salinity water mass component and has its highest scores in the Black Sea grab samples and moderate scores for surface samples from the Aegean Sea and the Marmara Sea. The scores for the MAR 02–45P units/subunits are between 20 and 70 so do not resemble scores for a specific sea.

Histograms for principal component 5, a high-salinity water mass indicator, show high scores for the Aegean Sea and the Marmara Sea and low scores for the Black Sea. Unit/subunit scores are uniformly moderate for this component, and are thus not particularly diagnostic.

Principal component 6 reflects mixing of high- and low-salinity water masses; thus, the Marmara Sea has some high scores. Overall except for a few low values in the Black Sea, all three seas have similar scores at about 50–60. Core Units 1 and 2A have low scores, suggesting no correlation with this component. Units 2B and 3 show high scores resembling those in the modern Marmara Sea.

Faunal component 7 only shows a few higher scores in the Marmara Sea, and is otherwise quite low in all seas. Hence, it is a poor discriminator. None of the units/subunits in core MAR 02–45P have high scores.

In summary, the faunal component scores for the four units/subunits in core MAR 02-45P, when compared to the histograms derived from surface samples, provide little basis for making strong interpretations about the changing paleoenvironment. The most that can be said is that Unit 1 (based on FC 1 scores) likely accumulated under conditions like those in the modern Black Sea. Unit 3 also shows some faunal similarities with the Black Sea (based on FC 3 scores), but is unlike typical samples from any modern sea when FC 6 is considered.

The ability to assign an environmental interpretation to each core unit is dramatically weakened for the following four reasons:

1. Only five species that were used in the principal component analysis on surface samples are present in the core MAR 02–45P;
2. Among the seven key species that are abundant in the core units/subunits, only two are present in the surface samples (Table 6.2);
3. The other three species which are common to the core and the surface study are very low in abundance in the core units/subunits;
4. Moreover, there was a sample size difference between the core samples and the grab samples i.e. core width is 67 mm however grab sampler width is 25 cm.

In hindsight, these results suggest that core MAR 02–45P was a poor candidate to test the efficiency of applying the results of the principal component analysis on the modern fauna to ancient mollusc communities. This is because the mollusc assemblage in this core is too different from the assemblage in the surface samples. In particular, the species in Units 2B and 3 are outside the boundary parameters of the grab-sample transects because their mollusc assemblages are even different from the present-day Black Sea faunal assemblages where they were studied for this thesis.

In order to increase the number of overlapping species between the surface and core samples, one approach might be to designate proxy species (in the core) for surface species that contribute to the calculation of faunal scores. For example, *Bittium reticulatum, Acantocardia paucicostata* and *Mytilus galloprovincialis* are not present in the surface samples so do not contribute to the calculation of principal-component scores. These species have euryhaline and eurytherm preferences similar to *Turritella communis* and *Modiolula phaseolina.* Instead of taking the abundance of the gastropod *Bittium reticulatum* to be zero, the percentage of gastropod *Bittium reticulatum* might be substituted, and multiplied by the coefficient for *Turritella communis* when calculating the scores for FC1 to FC 7. Similarly, *Mytilus galloprovincialis* might be paired with *Modiolula phaseolina* because of their similar environmental preferences. However, this approach might not work well, even if the paired species prefer similar oceanographic conditions, because they might have different substrate preferences. Ideally, the better solution would be to broaden the spectrum of modern environments and mollusc assemblages, in order to develop a more powerful set of faunal components which have greater species overlap with the assemblages in the core(s).

In order to take the suggestion in the preceding paragraph one step further, the scores for FC 1 were recalculated with the two proposed proxy substitutions (*Bittium reticulatum* for *Turritella communis; Mytilus galloprovincialis* for *Nucula nucleus*). The scores for Units 1, 2A, 2B and 3 are then 54.30, 49.87, 14.41 and 14.41, respectively. This approach increased the scores for Units 1 and 2A and can be changed the interpretation of Units 1 and 2A as more saline waters and sandy sediments but still resembling the Black Sea waters.

Because of too small an overlap between the species in the core and the species in surface samples, the application of the results of the principal component analyses to the interpretation of the past environments was not a success. In order to overcome this data deficiency and to be able to more profitably apply results from the principal component analysis, different sampling strategies and sampling densities will be required in future work. This is true for both surface samples and core samples. For surface sample collection, longer depth transects should be sampled at 5 m depth increments from ~10 m water depth to the shelf edge, and then at 10 m depth increments from the shelf edge to significantly greater depths in the Marmara Sea, the Black Sea and the Aegean Sea. More importantly, transects must be completed in extreme marginal environments like the low-salinity estuaries at the mouths of major rivers entering the Black Sea, and in the Sea of Azov. It is in these settings that various species of *Dreissena* live today. Cores should be collected from many different subbasins in the Black Sea or in the Marmara Sea to be able to see different ecological settings. Moreover, in order to do quantitative environment estimates, a more traditional approach of developing a transfer function should be undertaken. With a new and more comprehensive set of data, a transfer function could be derived using factor analysis and multiple regression analysis (Kipp, 1976).

CHAPTER 7

CONCLUSION

The main objective of this thesis was to determine the ecological characteristics of mollusc assemblages in the Black Sea, the Marmara Sea and the Aegean Sea surface sediments and their relations with present day physical oceanographic parameters such as temperature, salinity, dissolved oxygen. The following salient conclusions summarize the findings in this thesis:

1. Summer CTD measurements along transects 1 and 4 in the Marmara Sea revealed the presence of two water masses separated by a mixing zone. The upper 10 m of the water column is characterized by the low (21–24 ‰) salinity and seasonally high (24–27 ˚C) temperature, representing the Black Sea outflow into the Marmara Sea. The mixing zone (thermocline-halocline-pycnocline layer) occupies between ~10 m and ~30 m and is identified by a temperature decrease and a salinity increase with depth. The deeper water mass occupies depths below ~30 m and is characterized by high (37–41 ‰) salinity and low (15–18 ˚C) temperature: it represents the Aegean Sea intrusion into the Marmara Sea. Dissolved oxygen concentration values are generally low in the upper water mass, high in the mixing zone and low in the bottom water mass, depending on seasonally high secondary production, high primary production and oxidation of sinking particulate organic matter from the surface water mass, respectively. Grain-size analyses showed that in the Marmara Sea, there is a general trend towards finer sediment from the shore into the deeper water. The TOC data showed that the organic content of the surface sediments are generally higher (1.20–1.80 %) in shallower depths than in those found in from deep water sediments (>100 m) where TOC values range between 0.60 % and 0.80 %. The isotopic data showed that the $\delta^{13}C$ of the TOC is predominantly marine in origin.

2. Summer CTD measurements along transects 2 and 3 reveal the presence of three water masses and a mixing zone. The surface water mass occupies the upper ~10 m of the water column, and is identified by seasonally high (25–27 ˚C) temperatures and low (17–18 ‰) salinity values. The mixing zone delineated by the combination of the thermocline-halocline-pycnocline occupies depths between ~10 m and ~20 m, and shows ~2 ‰ increase in salinity and ~10 ˚C decrease in temperature. Below this layer extending down to ~40 m deep, a water mass with salinity of 20–23 ‰ and temperatures of 10–12 ˚C is distinguished: this water mass represents the penetration of Mediterranean waters into the Black Sea. The lowest water mass is characterized by low temperature (7–8 ˚C) and salinity (18–20 ‰). Dissolved oxygen concentrations are generally high (6–8 ml/l), reflecting the excess nutrient input from the large rivers such as, Danube, Don, Dnieper, Dniester. Grain size analyses show that surface sediments generally consist of a mixture of clayey-silt, silty-clay and sandy-clay. Total organic carbon content of the surface sediments ranges between 0.51 % and 4.62 % with ~55–60 % TOC being of marine origin.

3. Summer CTD measurements along transects 7 and 8 reveal the presence of two water masses and a mixing zone in the Aegean Sea. The surface water mass occupies at upper 10 m of the water column and is identified by seasonally high temperature (23–25 ˚C) and relatively low salinity (32–35 ‰), representing the Black Sea water outflow into the Aegean Sea. A ~10 ˚C decrease in temperature and ~7 ‰ increase in salinity with increasing water depth characterize the mixing zone. The lower water mass is identified by relatively cold (14–16 ˚C) and high salinity (39–40 ‰) conditions. The dissolved oxygen profiles are generally high (4–8 ml/l) because of wind mixing and wave activity. Grain size analyses show that surface sediments consist of sand in depths <90 m and muddy sediments found farther offshore. Total organic carbon content in the surface sediments is generally between 0.05 and containing 1.85 % organic carbon of marine origin.

4. Three classes of Mollusca (Gastropoda, Bivalvia, Scaphopoda) and 77 species were identified in the grab samples. The absence and presence data in quadrats delineated seven different mollusc assemblages, with each assemblage representing a distinct set of environment. Assemblage 1 (A 1) is dominated by *Calliostoma conulus, Bittium reticulatum*, *Timoclea ovata, Gouldia minima*, *Pitar rudis* and *Gadulus politus* and it is interpreted as an indicator of high salinity and a sandy-mud substrate. Assemblage 2 (A 2) is dominated by *Turritella communis*, *Nucula sulcata*, *Dentalium dentalis* and *Entalina tetragona* and is interpreted as an indicator of high salinity and muddy conditions. The high abundances of *Nucula nucleus, Mytilaster lineolatus,* and *Corbula gibba* characterize Assemblage 3 (A 3) and it represents Mediterranean environmental characteristics in the Marmara Sea. The occurrence of *Nucula nucleus*, *Nucula sulcata*, *Nuculana commutata, Timoclea ovata,* and *Corbula gibba* characterized the Assemblage 4 (A 4) and it is representative of high (5.8–8.4 ml/l) dissolved oxygen concentrations in the Aegean Sea. Assemblage 5 (A 5) is dominated by *Abra alba*, *Loripes lucinalis* and *Dentalium dentalis* and it represents a clayey-silt substrate.

Assemblage 6 (A 6) is dominated by *Modiolula phaseolina, Spisula subtruncata* and *Bittium reticulatum* and it is interpreted as an indicator of low temperature (7–8 °C) and low salinity (18–19 ‰) water masses of the Black Sea.

5. Principal component analysis was used to determine mollusc faunal assemblages and their relationship with the environmental variables. Seven hypothetical faunal assemblages were extracted. Faunal component 1 is interpreted as an indicator of high salinity waters and sandy bottoms and scores because this component are highest in the Aegean Sea, moderate in the Marmara Sea, and lowest in the Black Sea. Faunal component 2 is interpreted to indicate poorly oxygenated marine water masses and high scores occur in the Marmara Sea, whereas moderate scores occur only in two stations in the Black Sea. Faunal component 3 is interpreted as an indicator of sediments with low (<1.5 %) total organic carbon and warmer bottom waters temperatures and high scores occur only in the Marmara Sea and at two stations of the Aegean Sea. Faunal component 4 is interpreted as an indicator of low salinity water mass and high scores occur in the Black Sea, whereas moderate scores are characteristic of the Marmara Sea. Faunal component 5 is interpreted as an indicator of high salinity waters and this component has its highest scores in the Aegean Sea and in the Marmara Sea and lowest scores in the Black Sea. Faunal component 6 is interpreted as an indicator of the mixing of two high salinity and low salinity water masses. Component scores also show that this component is represented abundantly in the Marmara Sea, moderate in the Aegean Sea, and low in the Black Sea. Faunal component 7 represents low dissolved oxygen waters and has very low scores in the well-oxygenated waters of the Black Sea and the Aegean Sea, whereas high scores characterized the Marmara Sea.

6. Three hypothetical environmental variables were extracted from the principal component analysis. Environmental component 1 indicates a high-salinity and warm-water component in association with sediments having low total organic carbon, explaining 31 % of the total variation. High scores for this component occur in the Aegean Sea, moderate scores occur in the Marmara Sea, and low scores occur in the Black Sea. Environmental component 2 is a sandy shallow-water component, explaining 24.40 % of the total variation. High scores occur in shallow waters of all transects. Environmental component 3 signifies warm, shallower conditions with very low (< 2 ml/l) dissolved oxygen concentrations and highest scores are found mostly in the Marmara Sea. This component explains 18.40 % of the total variation.

7. The cross plots of the faunal and environmental component scores reveal clear relationship between the three oceanographically different seas. The most effective separation is found in the FC 1 versus EC 1 cross-plot. In this plot, the Black Sea is clearly separated from the Marmara Sea and the Aegean Sea. The separation from the Marmara Sea to the Aegean Sea is found in the cross-plots of FC 1 versus EC 3 and FC 4 versus EC 3.

8. In order to check the validity of using mollusc assemblages as a tool to reconstruct the paleoenvironment, core MAR 02–45P was raised from the Black Sea. It was divided into 4 units and subunits and each unit/subunit was considered as quadrats in the surface samples. Unit 1 is dominated by *Bittium reticulatum, Spisula subtruncata,* *Acanthocardia paucicostata, Abra alba, Mytilus galloprovincialis, Turritella communis*, *Truncatella subcylindrica* and *Dreissena polymorpha*. The highest occurrence of *Spisula subtruncata* and *Bittium reticulatum* suggested that Unit 1 formed under conditions similar to the present-day Black Sea environment. Unit 2A is characterized by *Mytilus galloprovincialis*, *Modiolula phaseolina, Truncatella subcylindrica, Retusa truncata, Parvicardium exiguum* and *Rissoa* spp. The occurrence of *Modiolula phaseolina* suggests that Unit 2A formed in a low salinity (~18 ‰) environment such as that of the present-day Black Sea. Unit 2B is dominated by *Truncatella subcylindrica, Parvicardium exiguum, Acanthocardia paucicostata, Mytilus galloprovincialis* and *Dreissena polymorpha*. The occurrence of bivalve *Dreissena polymorpha,* which is an endemic species of the Pontic-Caspian basin, indicates a brackish (<15 ‰) water mass during the accumulation of Unit 2B. Unit 3 is characterized by *Truncatella subcylindrica, Parvicardium exiguum*, *Dreissena polymorpha* and *Rissoa* spp. The occurrence of the Pontic-Caspian species *Dreissena polymorpha* indicates brackish to fresh water conditions.

9. In order to test the validity of using the principal components determined from the surface samples to deduce past environments in a core, same mollusc species found both in the surface samples and core units/subunits were used to calculate faunal scores for each unit/subunit. Normalized faunal scores for each core unit/subunit were then superimposed in these histograms to discover the closest correspondence between the ancient units/subunits and the modern faunal assemblages. All units/subunits resemble the Black Sea FC 1 scores. According to FC 2 scores, Unit 1 appears to have formed under an oxygenated water mass similar to the Aegean Sea, whereas the environmental setting of Units 2A, 2B and 3 more closely resembles the Marmara Sea with its poorly oxygenated water mass. FC 3 scores showed that Units 2A, 2B and 3 had high TOC and warm water environment. MAR 02–45 scores did not resemble any surface FC 4 and FC 5 scores. For FC 6, Units 1 and 2A have low scores, suggesting no correlation with this component. Units 2B and 3 showed high scores resembling those in the modern Marmara Sea. FC 7 was also a poor discriminator, none of the units/subunits in core MAR 02–45P have high scores.

10. The faunal component scores for the four units/subunits in core MAR 02-45P, when compared to the histograms derived from surface samples, provided little basis for making strong interpretations about the changing paleoenvironment. Because only five species that were used in the principal component analysis on surface samples were present in the core MAR 02–45P. Among the seven key species that were abundant in the core units/subunits, only two were present in the surface samples. The other three species which were common to the core and the surface study were very low in abundance in the core units/subunits. These results suggested that core MAR 02–45P was a poor candidate to test the efficiency of applying the results of the principal component analysis on the modern fauna to ancient mollusc communities.

11. Too small overlap between the species in the core and the species in surface samples, the application of the results of the principal component analyses to the interpretation of the past environments was not a success. In order to overcome this data deficiency and to be able to more profitably apply results from the principal component analysis, different sampling strategies and sampling densities for both surface and core samples will be required in future work.

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APPENDIX A. CTD and mollusc species data in each of the sampling stations.

Key for the Appendix A:

Variables

Samples			
	A1	A2	A3
	B1	B2	B3

A1

Station	Depth(m)	Temperature(C)	Salinity(‰)	Density(kg/m3)	Dissolved Oxygen(ml/l)	Sand(%)	Silt(%)	Clay(%)	TOC (%)	d13C (%)	*Emarginula rosea*	*Calliostoma conulus*	*Gibbula leucophaea*	*Tricolia tenuis*	*Cerithium rupestre*	*Bittium latreillei*	*Bittium reticulatum*	*Turritella communis*	*Rissoa auriscalpum*	*Rissoa splendida*	*Rissoa lineolata*	*Alvania cancellata*	*Alvania cimex*	*Tornus subcarinatus*	*Truncatella subcylindrica*	*Aporrhais pespelecani*	*Calyptraea chinensis*	*Natica spp.*	*Lunatia pulchella*	*Payraudeautia intricata*	*Epitonium pulchellum*	*Trophon breviatus*	*Trophon muricatus*
1-1	13.89	25.82	22.84	14.00	3.96	20.37	37.48	42.15	1.31	-26.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2-1	17.86	21.02	24.90	17.21	4.67	35.40	24.26	40.34	1.81	-24.33	0.00	4.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.00	0.00	0.00	0.00	0.00	2.00	0.00
3-1	23.81	15.22	37.95	28.31	2.88	10.36	45.34	44.30	1.48	-24.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4-1	28.77	15.65	38.05	28.19	2.72	38.08	17.53	44.39	1.32	-24.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	1.00	0.00
5-1	34.73	16.11	38.49	28.56	3.49	23.31	29.05	47.64	1.09	-24.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
6-1	39.69	16.38	38.71	28.69	3.76	30.35	23.08	46.57	1.32	-24.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00
7-1	44.65	16.49	38.83	28.78	3.87	5.55	48.04	46.41	1.39	-23.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8-1	48.61	16.68	38.93	28.83	4.09	11.56	38.00	50.44	1.36	-23.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9-1	54.57	16.30	38.89	28.92	3.31	5.12	44.56	50.32	1.38	-23.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10-1	59.53	16.25	38.97	29.01	3.94	4.87	39.22	55.92	1.35	-23.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11-1	64.49	15.65	38.85	29.09	2.46	6.49	37.50	56.01	1.31	-23.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12-1	69.45	15.37	38.79	29.12	2.32	2.40	40.21	57.39	1.47	-23.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13-1	74.41	15.00	38.71	29.17	1.84	2.17	42.07	55.76	1.25	-23.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15-1	84.32	14.88	38.68	29.22	1.76	1.97	42.07	55.95	1.19	-23.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17-1	103.17	14.89	38.68	29.30	1.75	2.41	38.72	58.87	1.15	-23.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19-1	121.02	14.82	38.67	29.38	1.70	0.76	41.65	57.59	1.26	-23.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
91-1	123.00	14.88	38.69	29.39	1.76	0.75	57.31	41.93	1.27	-23.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
92-1	138.87	14.64	38.65	29.49	1.66	0.72	60.17	39.11	1.34	-23.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93-1	146.80	14.62	38.65	29.53	1.66	7.56	52.66	39.78	1.14	-23.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
94-1	171.59	14.47	38.66	29.68	1.39	26.56	43.34	30.10	0.83	-23.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
95-1	187.45	14.46	38.66	29.76	1.29	28.93	41.55	29.52	1.14	-23.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
96-1	225.12	14.45	38.66	29.93	1.23	4.58	53.44	41.98	1.39	-23.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
97-1	247.91	14.44	38.67	30.03	1.20	3.04	59.02	37.94	1.36	-23.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
98-1	347.98	14.40	38.67	30.48	1.23	9.04	54.28	36.68	0.74	-24.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
99-1	312.32	14.41	38.67	30.32	1.42	42.09	37.76	20.14	0.79	-23.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100-1	293.50	14.42	38.66	30.24	1.62	30.47	42.32	27.21	0.62	-23.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
101-1	255.84	14.44	38.66	30.06	1.18	35.25	41.06	23.69	0.50	-23.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
59-2	83.33	7.74	18.96	15.13	4.14	2.23	66.34	31.42	2.59	-23.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
58-2	89.28	7.77	19.02	15.21	2.53	4.10	66.60	29.30	2.66	-23.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
56-2	98.21	7.88	19.35	15.49	2.59	2.34	67.94	29.72	1.80	-24.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
55-2	104.16	7.99	19.68	15.77	1.65	21.84	60.51	17.65	2.18	-24.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
54-2	106.14	8.01	19.74	15.81	1.11	8.43	66.77	24.80	1.87	-25.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00
84-3	22.82	20.60	19.05	12.60	3.91	39.03	12.19	48.78	0.51	-25.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
83-3	25.80	17.61	20.62	15.65	4.23	13.95	37.45	48.59	2.99	-25.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
82-3	33.73	11.43	21.05	16.86	5.51	33.65	20.24	46.10	4.62	-65.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
81-3	36.71	9.10	18.03	14.03	5.08	15.99	38.66	45.35	2.55	-25.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
74-3	74.41	8.01	18.68	14.84	5.55	34.83	17.75	47.42	1.59	-23.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00
73-3	79.36	9.15	18.66	14.57	4.60	19.88	31.85	48.27	1.12	-24.87	0.00	0.00	0.00	0.00	0.00	0.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	3.00	0.00	0.00	0.00	0.00	0.00	5.00
70-3	92.26	8.78	19.07	14.87	4.32	7.97	46.06	45.97	1.66	-24.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
69-3	97.22	10.49	22.54	17.53	3.89	6.14	49.46	44.40	2.31	-23.63	0.00	0.00	0.00	0.00	0.00	0.00	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
67-3	106.14	10.31	24.47	19.20	3.74	7.58	54.84	37.58	1.25	-24.66	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
66-3	111.10	11.78	27.81	21.56	3.55	19.85	40.48	39.67	1.22	-24.22	0.00	0.00	0.00	0.00	0.00	0.00	3.00	0.00	0.00	0.00	0.00	0.00	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00
65-3	112.09	8.06	19.63	15.76	3.93	16.80	39.68	43.53	1.56	-24.25	0.00	0.00	0.00	0.00	0.00	0.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00

A2

Station	*Cyclope donovania*	*Mangelia attenuata*	*Nucula nucleus*	*Nucula sulcata*	*Nuculana commutata*	*Arca noae*	*Arca tetragona*	*Anadara diluvii*	*Bathyarca philippiana*	*Scapharca inaequivalvis*	*Striarca lactea*	*Glycymeris insubrica*	*Mytilus galloprovincialis*	*Mytilaster lineatus*	*Modiolula phaseolina*	*Pteria hirunda*	*Pseudamussium clavatum*	*Palliolum incomparabile*	*Chlamys varia*	*Chlamys glabra*	*Limatula subauriculata*	*Ostrea edulis*	*Ostreola stentina*	*Dreissena polymorpha*	*Loripes lucinalis*	*Lucinella divaricata*	*Myrtea spinifera*	*Thyasira flexuosa*	*Cardites antiquata*	*Glans trapezia*	*Glans aculeata*	*Gonilia calliglypta*	*Acanthocardia paucicostata*
1-1	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2-1	1.00	6.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3-1	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4-1	0.00	0.00	6.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.00	0.00	0.00	0.00	0.00	0.00	0.00
5-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
6-1	0.00	0.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	1.00	0.00	0.00
7-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8-1	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
10-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13-1	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15-1	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17-1	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19-1	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
91-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
92-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93-1	0.00	0.00	7.00	0.00	3.00	0.00	0.00	0.00	0.00	3.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00	7.00	0.00	0.00	0.00	0.00	8.00	0.00	0.00	0.00	0.00	0.00	0.00
94-1	0.00	0.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
95-1	0.00	0.00	7.00	0.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00	0.00	0.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00
96-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
97-1	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
98-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
99-1	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100-1	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
101-1	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
59-2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
58-2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
56-2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	50.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
55-2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
54-2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	30.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
84-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
83-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
82-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
81-3	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
74-3	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00	0.00	70.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
73-3	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00	0.00	30.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
70-3	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
69-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
67-3	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
66-3	2.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	50.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
65-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

A3

Station	*Parvicardium exiguum*	*Parvicardium minimum*	*Parvicardium rosea*	*Laevicardium crassum*	*Spisula subtruncata*	*Solen marginatus*	*Tellina balaustina*	*Tellina donacina*	*Abra nitida*	*Abra prismatica*	*Abra alba*	*Azorinus chamasolen*	*Venus casina*	*Clausinella brongniartii*	*Timoclea ovata*	*Gouldia minima*	*Dosinia lupinus*	*Pitar rudis*	*Mysia undata*	*Corbula gibba*	*Cuspidaria rostrata*	*Cardiomya costellata*	*Dentalium dentalis*	*Gadulus politus*	*Entalina tetragona*
1-1	0.00	0.00	0.00	0.00	1.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	10.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
2-1	6.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00
4-1	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.00	0.00	0.00	0.00	0.00	5.00	0.00	0.00	1.00	2.00	0.00
5-1	0.00	2.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	18.00	0.00	0.00	3.00	1.00	0.00
6-1	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	6.00	0.00	0.00	0.00	0.00	21.00	0.00	0.00	3.00	1.00	0.00
7-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00
9-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
10-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00
12-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00
13-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
17-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
91-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
92-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93-1	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	30.00	0.00	0.00	2.00	0.00	0.00
94-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.00	0.00	0.00	1.00	0.00	0.00
95-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	17.00	0.00	1.00	1.00	0.00	0.00
96-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00
97-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00
98-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
99-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	2.00	0.00	0.00
100-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00
101-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
59-	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
58-	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
56-	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
55-	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
54-	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
84-	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
83-	0.00	0.00	0.00	0.00	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
82-	0.00	0.00	0.00	0.00	5.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
81-	0.00	0.00	0.00	0.00	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
74-	80.00	0.00	0.00	0.00	10.00	0.00	0.00	0.00	0.00	0.00	50.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
73-	30.00	0.00	0.00	0.00	10.00	0.00	0.00	0.00	0.00	0.00	59.00	0.00	5.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
70-	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00
69-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
67-	4.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
66-	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
65-	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

B1

Station	Depth(m)	Temperature(C)	Salinity(‰)	Density(kg/m3)	Dissolved Oxygen(ml/l)	Sand(%)	Silt(%)	Clay(%)	TOC (%)	d13C (‰)	*Emarginula rosea*	*Calliostoma conulus*	*Gibbula leucophaea*	*Tricolia tenuis*	*Cerithium rupestre*	*Bittium latreillei*	*Bittium reticulatum*	*Turritella communis*	*Rissoa auriscalpium*	*Rissoa splendida*	*Rissoa lineolata*	*Alvania cancellata*	*Alvania cimex*	*Tornus subcarinatus*	*Truncatella subcylindrica*	*Aporrhais pespelecani*	*Calyptraea chinensis*	*Natica spp.*	*Lunatia pulchella*	*Payraudeautia intricata*	*Epitonium pulchellum*	*Trophon brevitus*	*Trophon muricatus*
23-4	18.85	14.21	26.49	19.66	4.92	12.68	64.79	22.54	2.91	-23.99	0.00	2.00	0.00	0.00	0.00	0.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24-4	23.81	13.09	33.05	25.10	4.32	26.42	56.06	17.52	2.82	-24.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25-4	28.77	14.10	37.33	28.10	0.68	11.14	61.52	27.34	1.76	-24.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26-4	33.73	14.51	37.80	28.40	0.72	37.26	43.44	19.31	1.28	-24.38	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
27-4	39.69	14.87	38.23	28.67	1.10	34.38	43.74	21.87	1.34	-24.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28-4	43.65	14.89	38.26	28.71	0.88	53.43	29.81	16.77	1.19	-24.30	0.00	0.00	0.00	0.00	0.00	0.00	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29-4	49.61	14.97	38.38	28.81	0.91	39.49	42.58	17.93	4.40	-95.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30-4	55.56	14.99	38.45	28.89	0.86	26.50	54.16	19.34	1.48	-18.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31-4	60.52	15.01	38.47	28.92	0.81	16.34	58.37	25.29	1.85	-19.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32-4	64.49	15.01	38.49	28.95	0.83	8.84	63.81	27.35	1.21	-20.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
33-4	69.45	14.97	38.56	29.04	0.66	4.87	66.11	29.02	0.47	-21.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
37-4	88.29	14.86	38.62	29.19	0.72	4.21	64.56	31.24	0.65	-21.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38-4	93.25	14.84	38.62	29.22	0.66	7.63	61.58	30.79	0.74	-21.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
39-4	98.21	14.77	38.64	29.27	0.64	13.94	58.09	27.97	0.54	-21.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40-4	109.12	14.76	38.64	29.32	0.65	35.34	45.50	19.16	1.20	-23.86	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
41-4	118.04	14.74	38.64	29.37	0.65	25.67	51.10	23.23	1.17	-23.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
42-4	143.83	14.68	38.65	29.50	0.64	29.27	47.66	23.06	1.01	-24.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29-7	14.11	15.58	40.13	29.80	3.48	65.17	19.90	14.93	4.40	-95.45	0.00	27.00	3.00	7.00	0.00	16.00	3.00	6.00	6.00	5.00	0.00	2.00	2.00	0.00	0.00	0.00	1.00	3.00	5.00	0.00	0.00	0.00	0.00
30-7	20.16	14.44	40.77	30.56	3.82	57.26	18.32	24.42	1.48	-18.11	0.00	4.00	0.00	0.00	1.00	4.00	0.00	1.00	0.00	1.00	0.00	1.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31-7	29.23	14.29	40.60	30.46	4.27	77.66	12.76	9.57	1.85	-19.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32-7	39.31	14.27	40.72	30.55	7.32	82.35	8.82	8.82	1.21	-20.63	0.00	2.00	0.00	0.00	0.00	3.00	0.00	1.00	0.00	0.00	0.00	4.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
33-7	50.40	14.33	40.49	30.36	9.25	75.37	15.39	9.24	0.47	-21.24	2.00	0.00	0.00	0.00	0.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
35-7	71.57	14.56	38.78	28.99	7.18	64.07	17.96	17.96	0.05	-21.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
36-7	78.62	14.55	38.81	29.02	6.65	71.39	17.88	10.73	0.32	-22.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
37-7	86.69	14.48	38.79	29.02	7.05	30.00	42.00	28.00	0.65	-21.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38-7	97.78	14.67	38.88	29.05	6.91	16.67	48.78	34.55	0.74	-21.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
39-7	112.91	14.81	38.95	29.07	6.63	51.91	28.86	19.24	0.54	-21.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
40-7	142.15	14.66	38.97	29.12	7.26	11.58	51.45	36.98	0.87	-22.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
41-7	173.42	14.38	38.92	29.14	7.54	5.15	56.14	38.71	0.98	-22.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
42-7	201.66	14.26	38.92	29.17	7.17	2.34	53.71	43.95	1.05	-22.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
43-7	246.05	14.07	38.92	29.21	7.23	0.61	56.07	43.32	1.11	-22.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
44-7	298.53	13.83	38.91	29.26	7.33	0.89	54.83	44.29	1.06	-22.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
45-7	353.04	13.79	38.92	29.28	7.21	0.45	56.89	42.67	1.17	-22.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
46-7	501.49	13.66	38.97	29.35	7.19	0.46	55.99	43.55	1.15	-22.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
56-8	18.14	18.40	41.74	30.34	4.44	8.00	76.00	16.00	0.87	-23.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	60.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
55-8	26.21	17.88	40.98	29.89	4.67	7.00	72.00	21.00	0.54	-23.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	50.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00
54-8	38.30	17.06	41.58	30.56	4.76	11.00	66.00	23.00	0.54	-23.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	35.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
53-8	49.39	16.87	39.14	28.73	8.42	59.00	27.00	14.00	1.11	-24.67	0.00	0.00	0.00	0.00	0.00	1.00	0.00	20.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	7.00	0.00	3.00	0.00	0.00	0.00	0.00
52-8	59.47	16.60	39.14	28.79	8.40	47.00	34.00	19.00	1.41	-24.89	0.00	0.00	1.00	0.00	0.00	0.00	0.00	50.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	2.00	1.00	0.00	2.00	0.00	0.00	0.00	2.00
51-8	66.53	16.46	39.13	28.82	5.80	19.00	50.00	31.00	1.81	-24.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00

B2

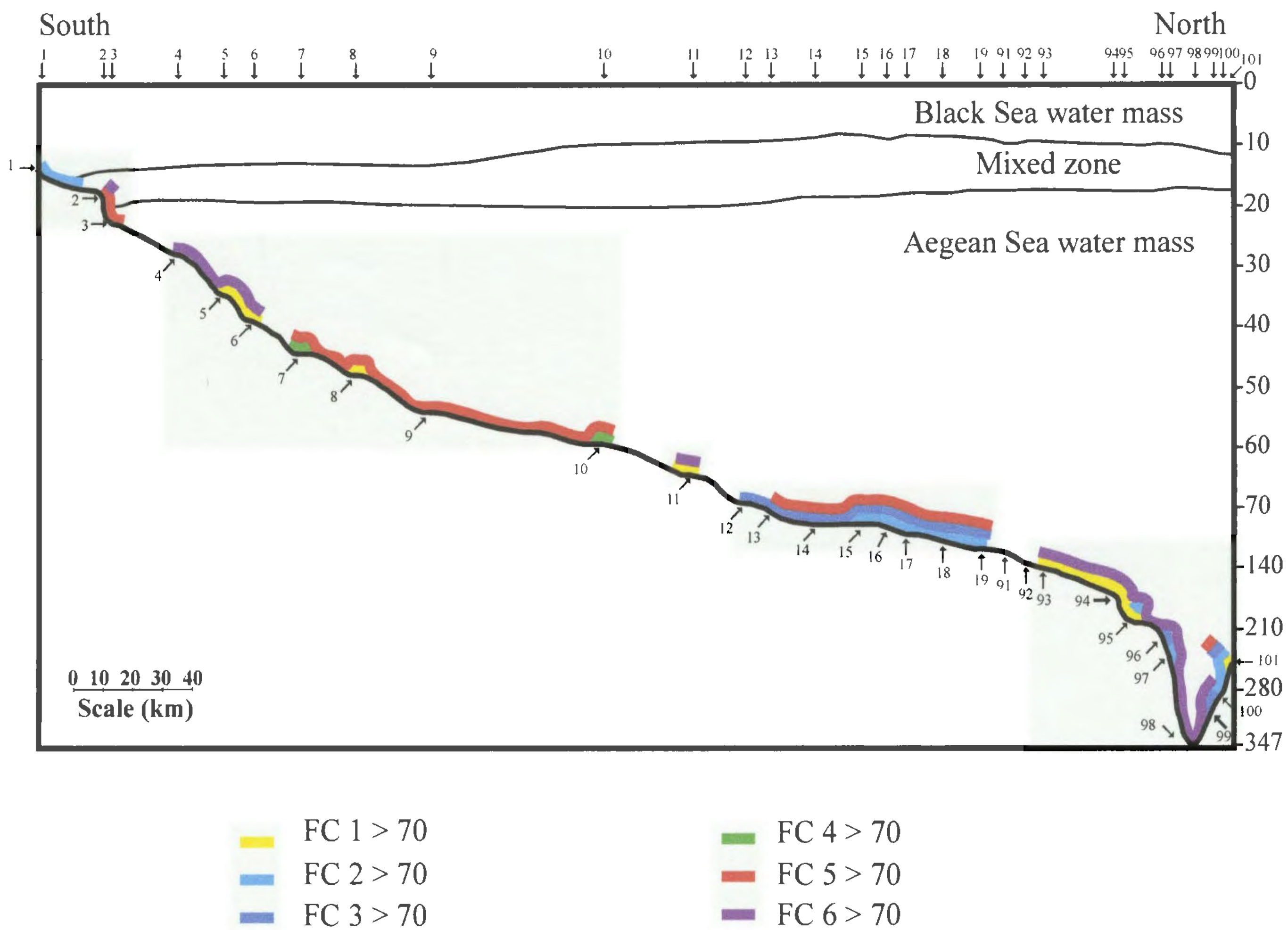
Station	Cyclope donovania	Mangelia attenuata	Nucula nucleus	Nucula sulcata	Nuculana commutata	Arca noae	Arca tetragona	Anadara diluvii	Bathyarca philippiana	Scapharca inaequivalvis	Striarca lactea	Glycymeris insubrica	Mytilus galloprovincialis	Mytilaster lineatus	Modiolula phaseolina	Pteria hirundo	Pseudamussium clavatum	Palliolum incomparabile	Chlamys varia	Chlamys glabra	Limatula subauriculata	Ostrea edulis	Ostreola stentina	Dreissena polymorpha	Loripes lacteus	Lucinella divaricata	Myrtea spinifera	Thyasira flexuosa	Cardites antiquata	Glans trapezia	Glans aculeata	Gonilia calliglypta	Acanthocardia paucicostata
23-4	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
24-4	0.00	0.00	0.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00
25-4	0.00	0.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00	1.00	0.00	0.00	0.00	0.00	0.00
26-4	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00
27-4	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28-4	0.00	0.00	1.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
29-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
30-4	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
31-4	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
32-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
33-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
37-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
39-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
40-4	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00
41-4	0.00	0.00	2.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
42-4	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00
29-7	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	4.00	0.00	0.00	2.00	0.00	0.00	0.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30-7	0.00	0.00	3.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	3.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	2.00	0.00	0.00	0.00
31-7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32-7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
33-7	0.00	0.00	1.00	0.00	0.00	0.00	3.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
35-7	0.00	0.00	1.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36-7	0.00	0.00	1.00	3.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
37-7	0.00	0.00	1.00	2.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38-7	0.00	0.00	0.00	5.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
39-7	0.00	0.00	4.00	0.00	2.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	7.00	0.00	14.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00
40-7	0.00	0.00	4.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
41-7	0.00	0.00	8.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
42-7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
43-7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
44-7	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
45-7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
46-7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
56-8	0.00	0.00	2.00	12.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	1.00
55-8	0.00	0.00	2.00	11.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00	0.00	0.00	0.00	0.00	0.00	2.00
54-8	0.00	0.00	2.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	1.00
53-8	0.00	0.00	55.00	23.00	14.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	12.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00	11.00	0.00	0.00	0.00	0.00	0.00	0.00
52-8	0.00	0.00	9.00	30.00	22.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	8.00	0.00	0.00	0.00	0.00	0.00	5.00	11.00	1.00	0.00	0.00	1.00	0.00	1.00
51-8	0.00	0.00	0.00	27.00	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	1.00	0.00	0.00	0.00	0.00	0.00

B3

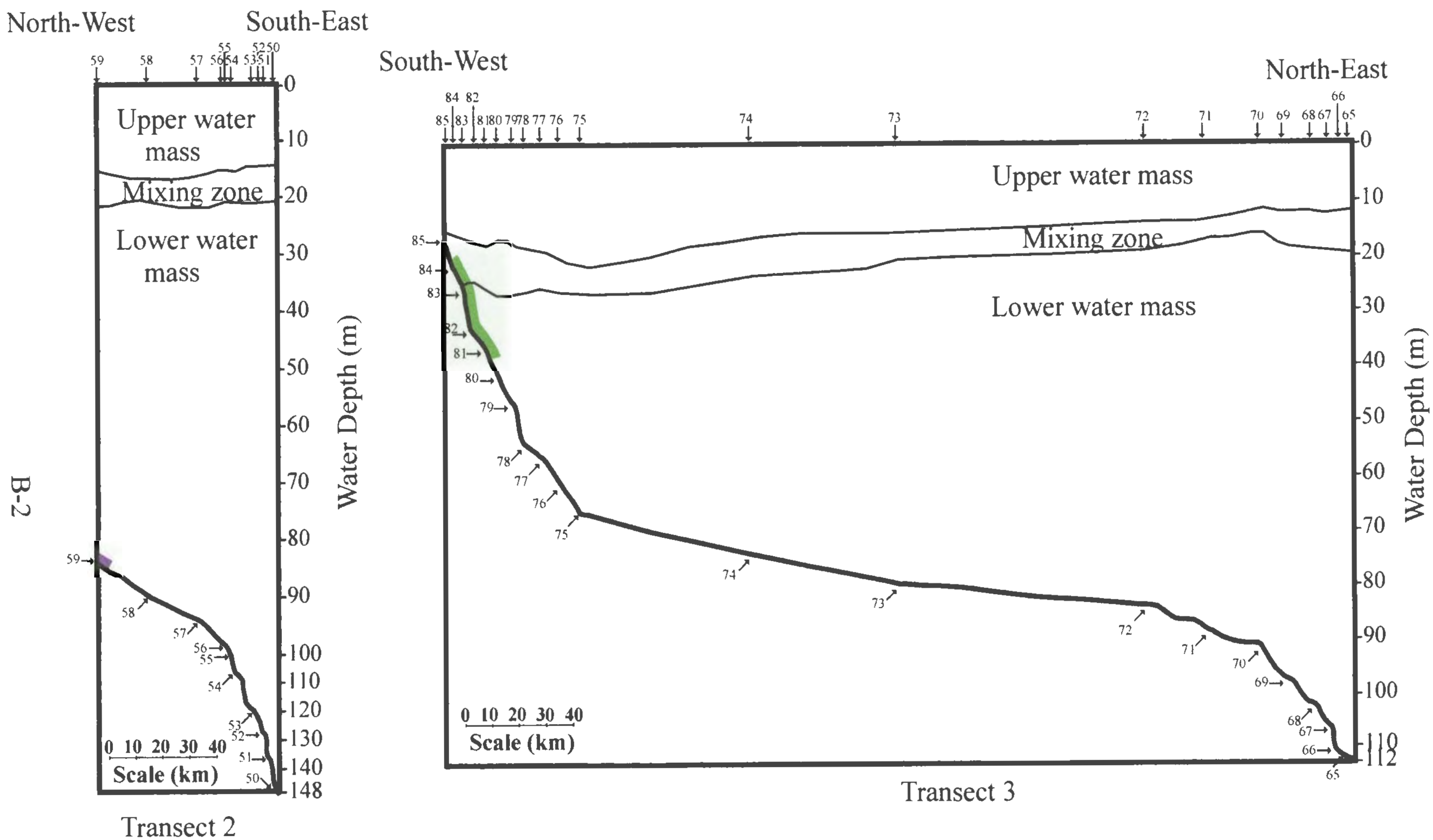
Station	*Parvicardium exiguum*	*Parvicardium minimum*	*Parvicardium rosea*	*Laevicardium crassum*	*Spisula subtruncata*	*Solen marginatus*	*Tellina balaustina*	*Tellina donacina*	*Abra nitida*	*Abra prismatica*	*Abra alba*	*Azorinus chamasolen*	*Venus casina*	*Clausinella brongniartii*	*Timoclea ovata*	*Gouldia minima*	*Dosinia lupinus*	*Pitar rudis*	*Mysia undata*	*Corbula gibba*	*Cuspidaria rostrata*	*Cardiomya costellata*	*Dentalium dentalis*	*Gadulus politus*	*Entalina tetragona*
23-4	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00
24-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00
25-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	3.00	0.00	0.00	0.00	0.00	0.00
26-4	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00
27-4	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	3.00	0.00	0.00	0.00	0.00	0.00
28-4	1.00	2.00	0.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00
29-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00
30-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00
31-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
33-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
37-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
38-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
39-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	1.00
40-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
41-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
42-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	3.00
29-7	2.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00	2.00	18.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30-7	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31-7	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	8.00	0.00	0.00	2.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
32-7	0.00	1.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00	0.00	0.00	2.00	0.00	2.00	0.00	0.00	0.00	3.00	0.00
33-7	0.00	2.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	2.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	1.00
35-7	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	4.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	2.00	0.00
36-7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	3.00	0.00
37-7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
38-7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	8.00	0.00	0.00	1.00	0.00	3.00	0.00	0.00	0.00	0.00	1.00
39-7	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00	12.00	0.00	1.00	0.00	0.00	1.00	0.00	1.00
40-7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	1.00	3.00	0.00	0.00	0.00	0.00
41-7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00
42-7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
43-7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00
44-7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
45-7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00
46-7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00
56-8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00	1.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00	0.00	0.00
55-8	0.00	1.00	0.00	0.00	0.00	0.00	0.00	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	2.00
54-8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	8.00	5.00	20.00
53-8	19.00	1.00	16.00	0.00	0.00	0.00	0.00	6.00	14.00	0.00	9.00	0.00	0.00	2.00	100.00	1.00	0.00	0.00	0.00	22.00	0.00	2.00	3.00	0.00	40.00
52-8	4.00	12.00	0.00	0.00	0.00	0.00	0.00	8.00	5.00	0.00	0.00	0.00	0.00	0.00	60.00	0.00	0.00	0.00	0.00	20.00	0.00	0.00	0.00	0.00	0.00
51-8	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	3.00	0.00	0.00	0.00	0.00	0.00

APPENDIX B. Transect-by-transect distributions of dominant principal component scores.

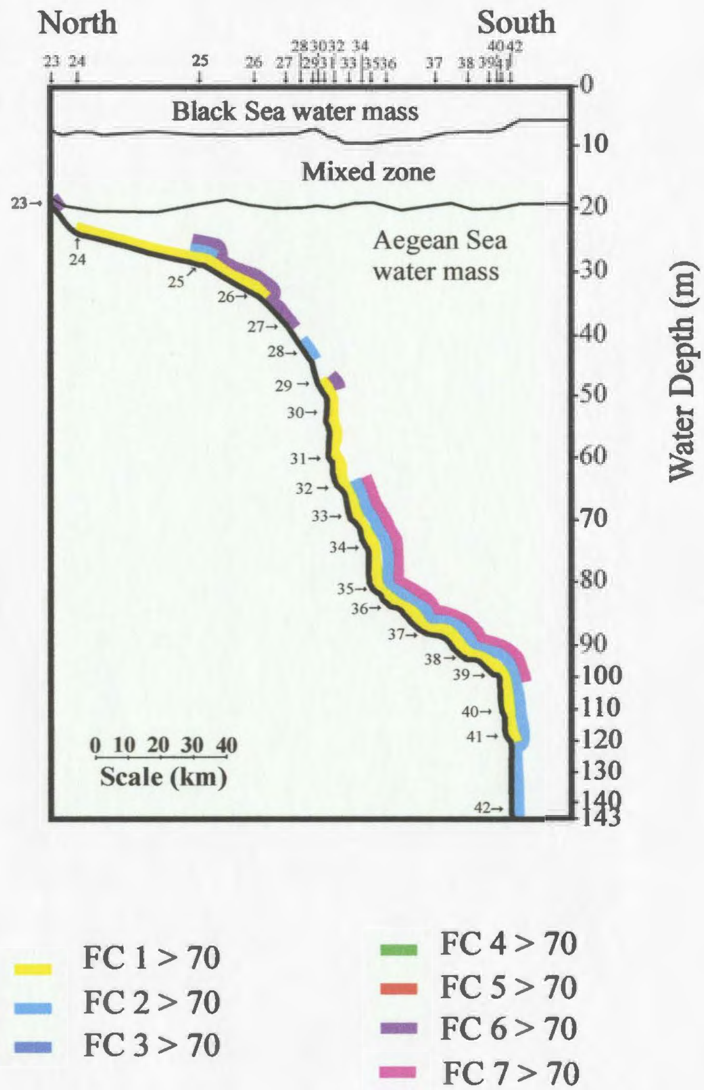
Appendix B. Schematic diagrams showing the distribution along each transect of normalized scores >70 for all faunal components.



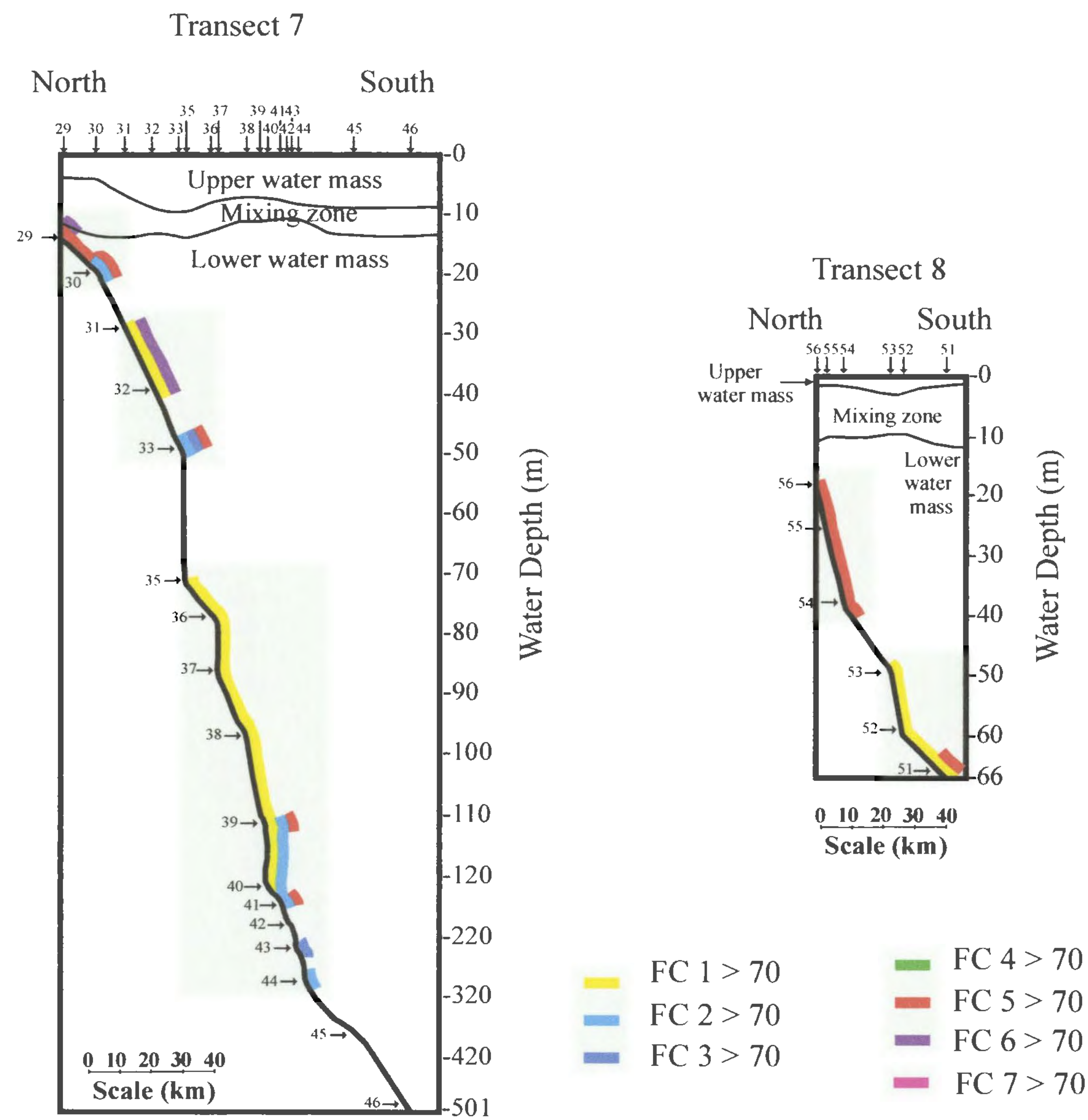
Faunal component dominant scores across transect 1. Note the change in depth scale below 70 m.



Faunal component dominant scores across transect 2 and transect 3.



Faunal component dominant scores across transect 4. Note the change in depth scale below 90 m.

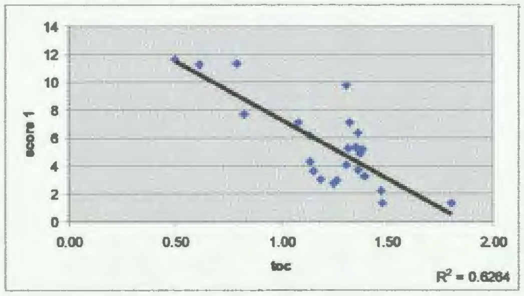


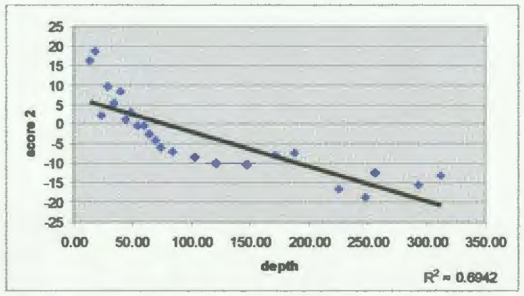
Faunal component dominant scores across transect 7 and transect 8.

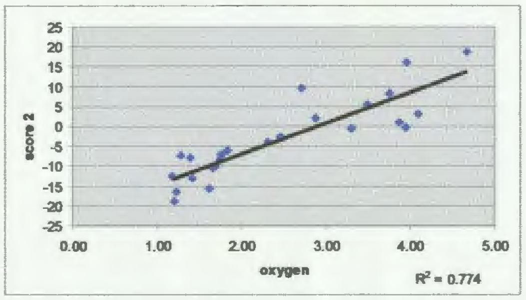
APPENDIX C. Cross-plots of environmental components and physical oceanographic data.

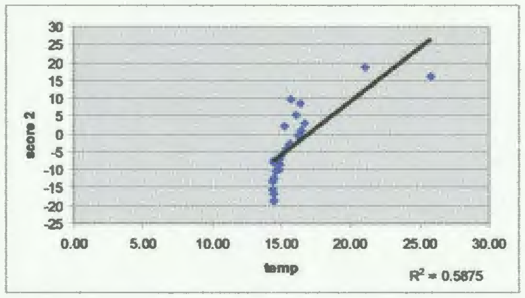
Appendix C.

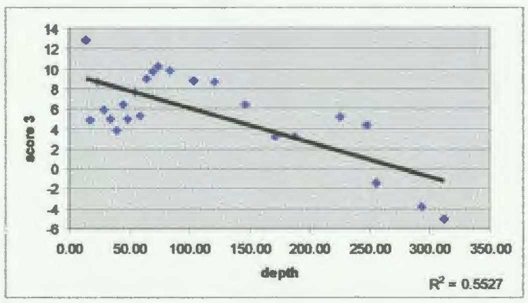
Transect 1. Relationship of environmental data and environmental principal component scores.



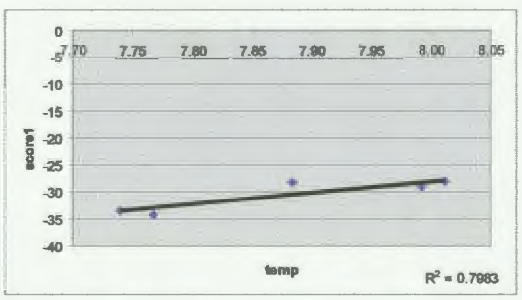


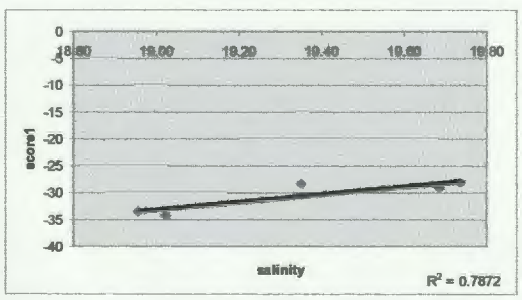


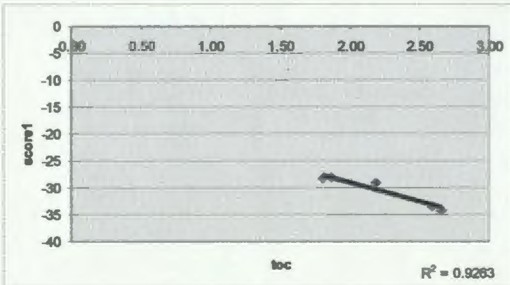


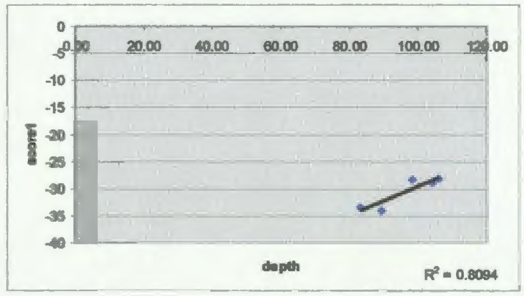


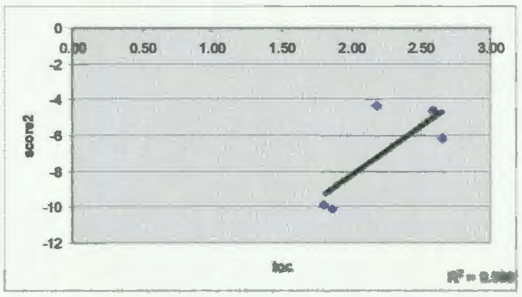
Transect2. Relationship of environmental data and environmental principal component scores.

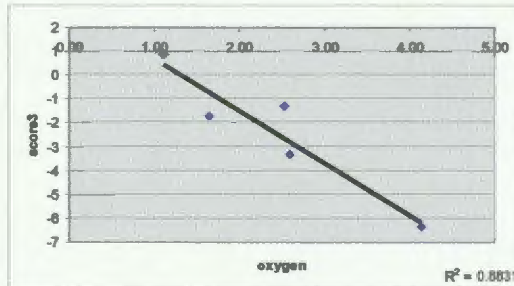




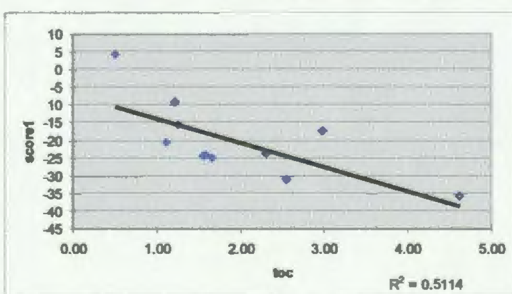


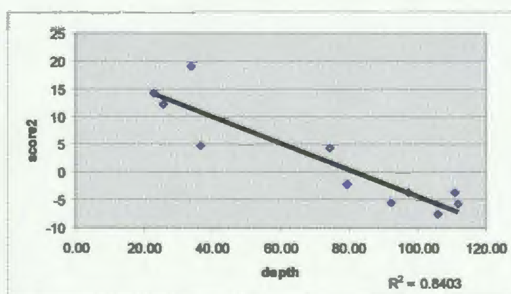


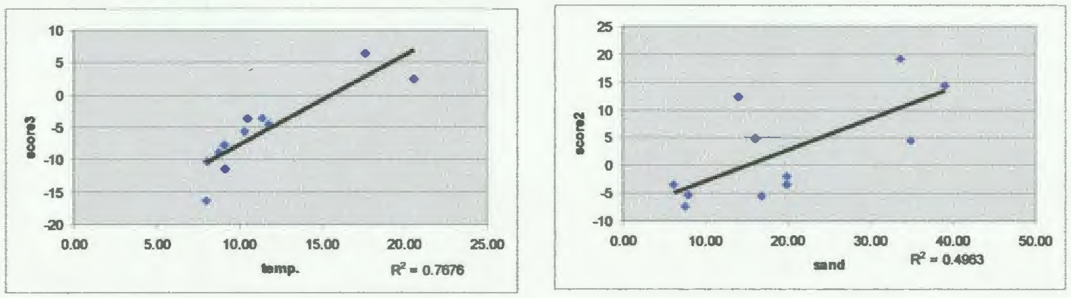




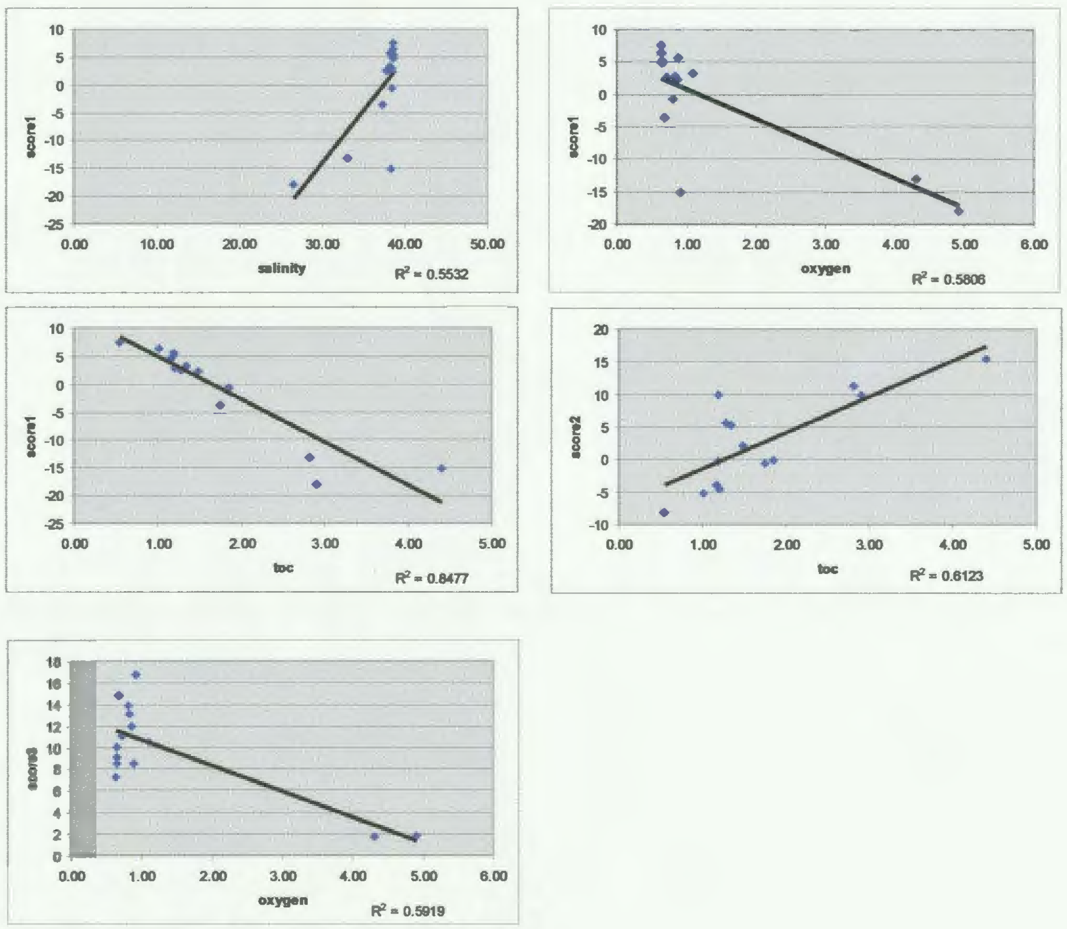
Transect3. Relationship of environmental data and environmental principal component scores.



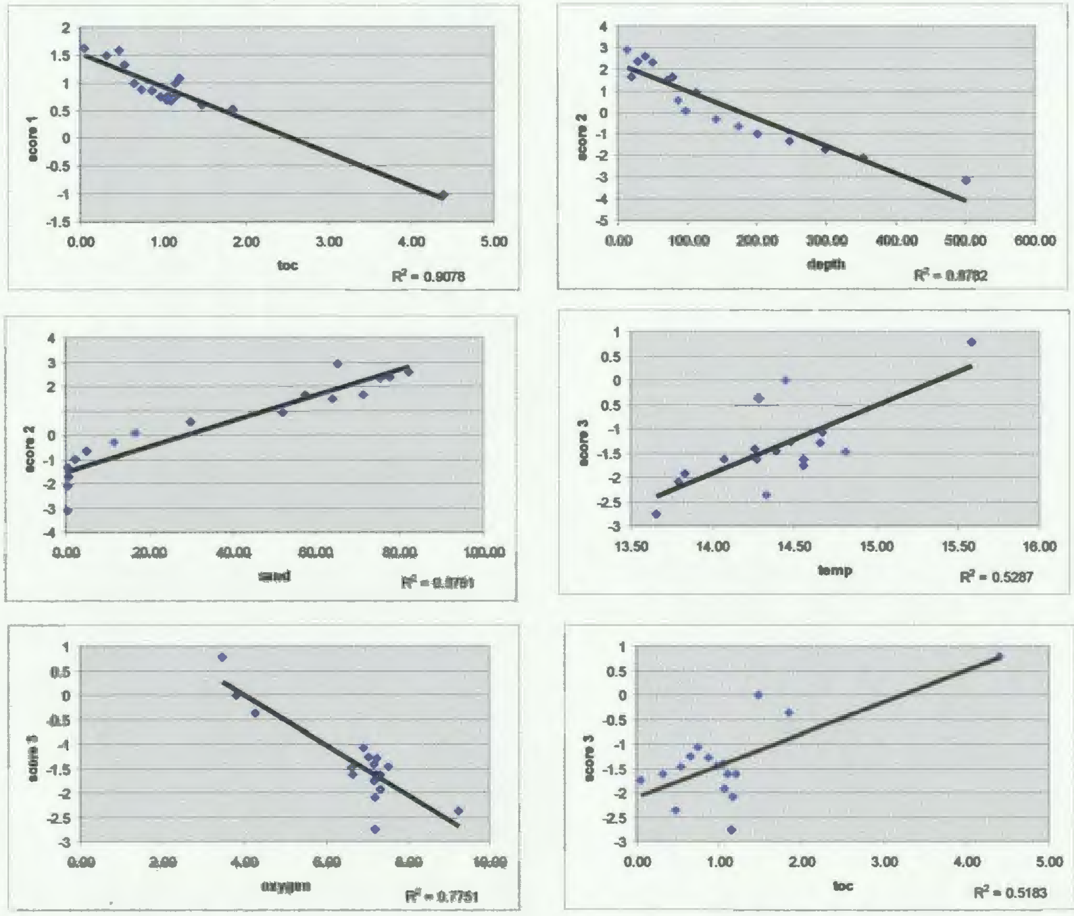




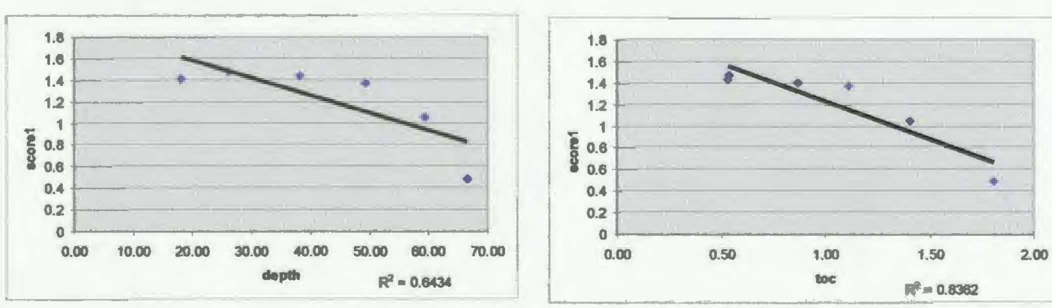
Transect4. Relationship of environmental data and environmental principal component scores.

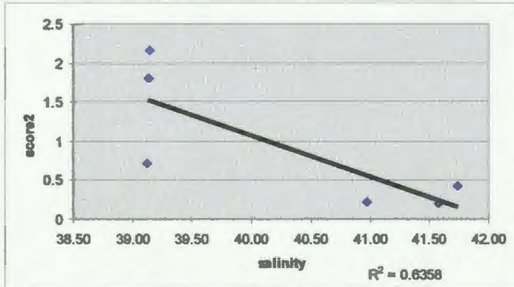


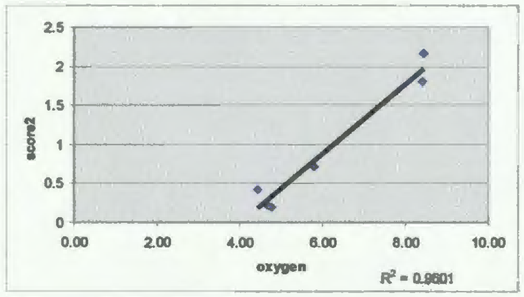
Transect7. Relationship of environmental data and environmental principal component scores.

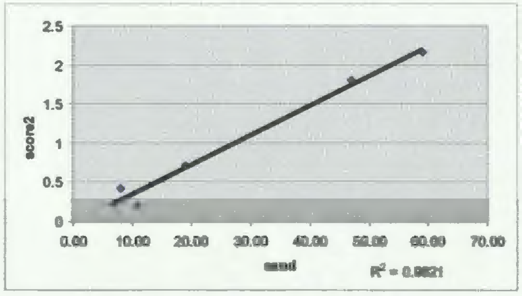


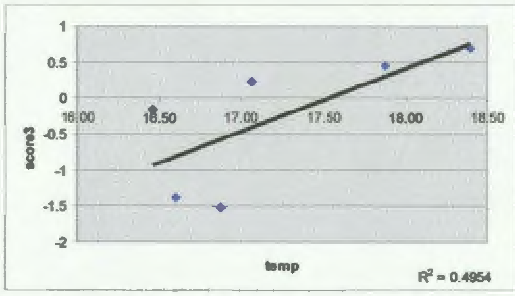
Transect8.Relationship of environmental data and environmental principal component scores.

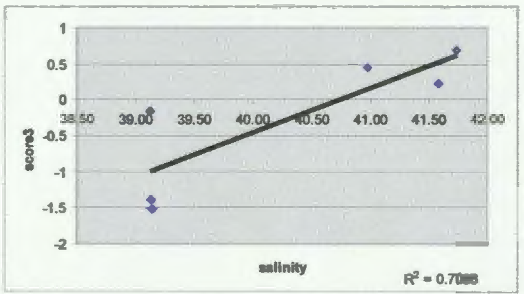


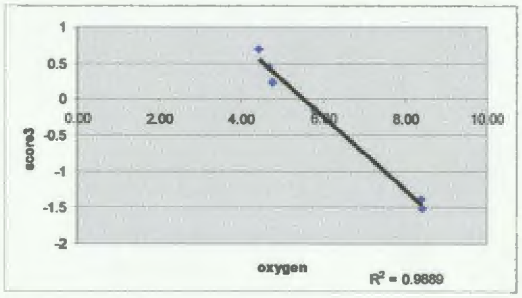

score2
salinity
R² = 0.6358

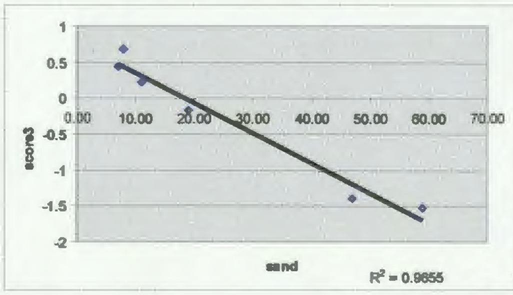

score2
oxygen
R² = 0.9601


score2
sand


score3
temp
R² = 0.4954

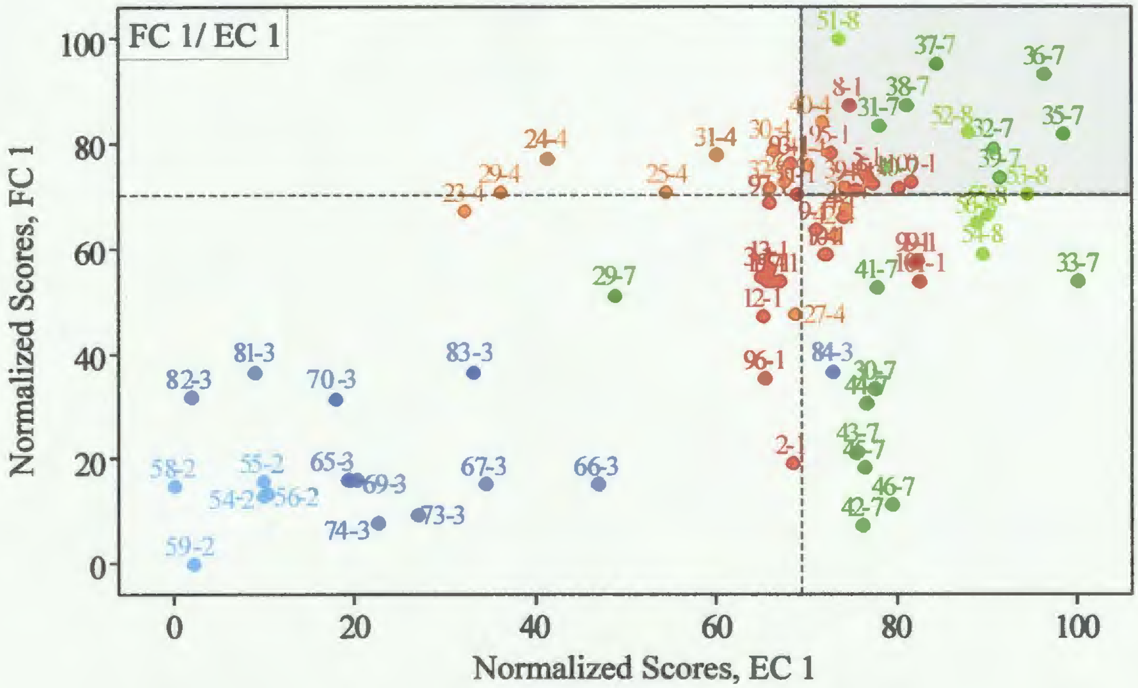

score3
salinity

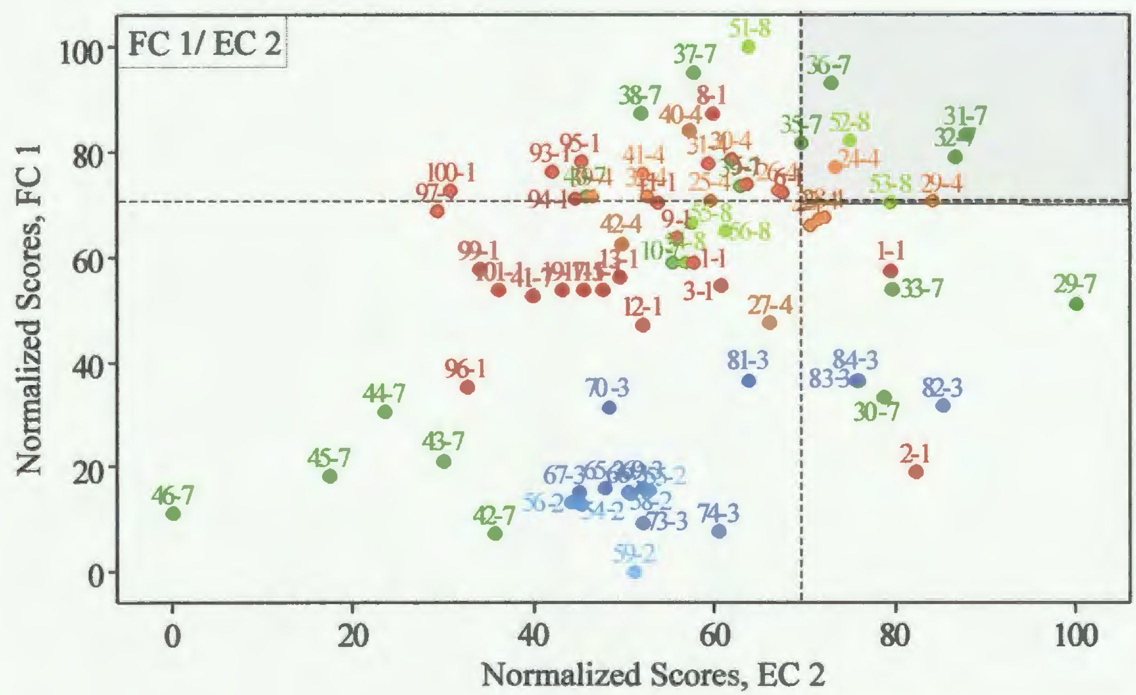

score3
oxygen
R² = 0.9889


score3
sand
R² = 0.9655

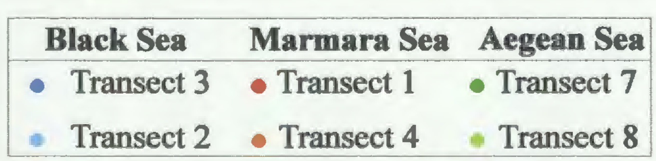
APPENDIX D. Cross-plots of environmental components versus faunal components.

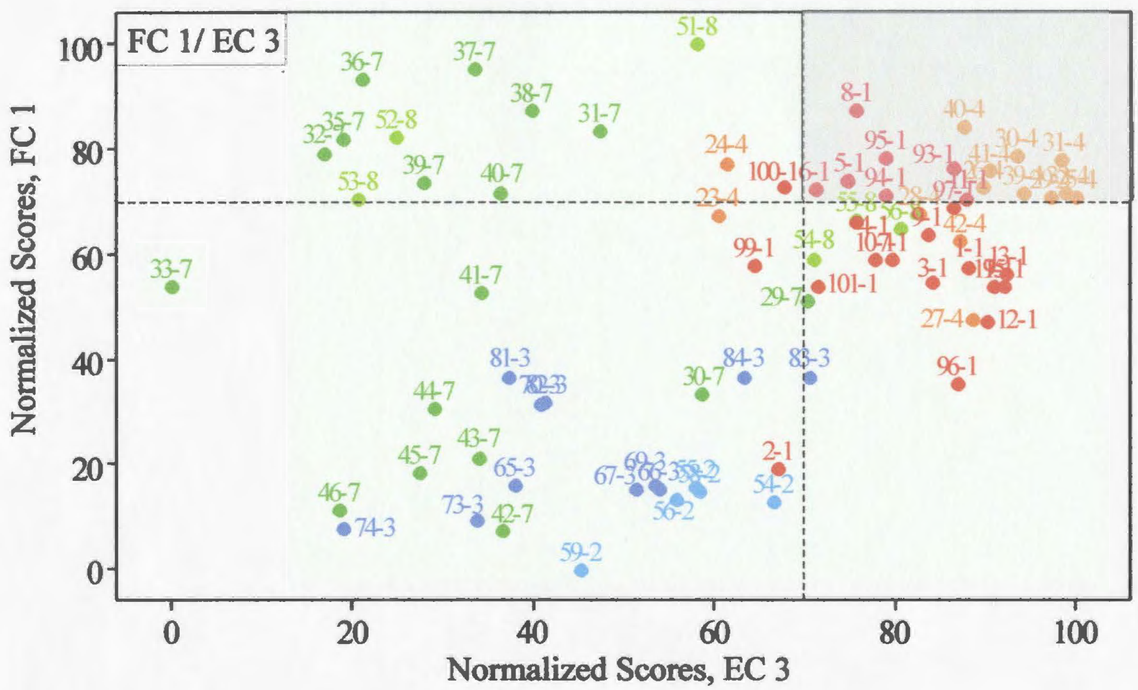
Appendix D. Cross-plots of faunal scores 1 to 7 versus environmental scores 1 to 3.





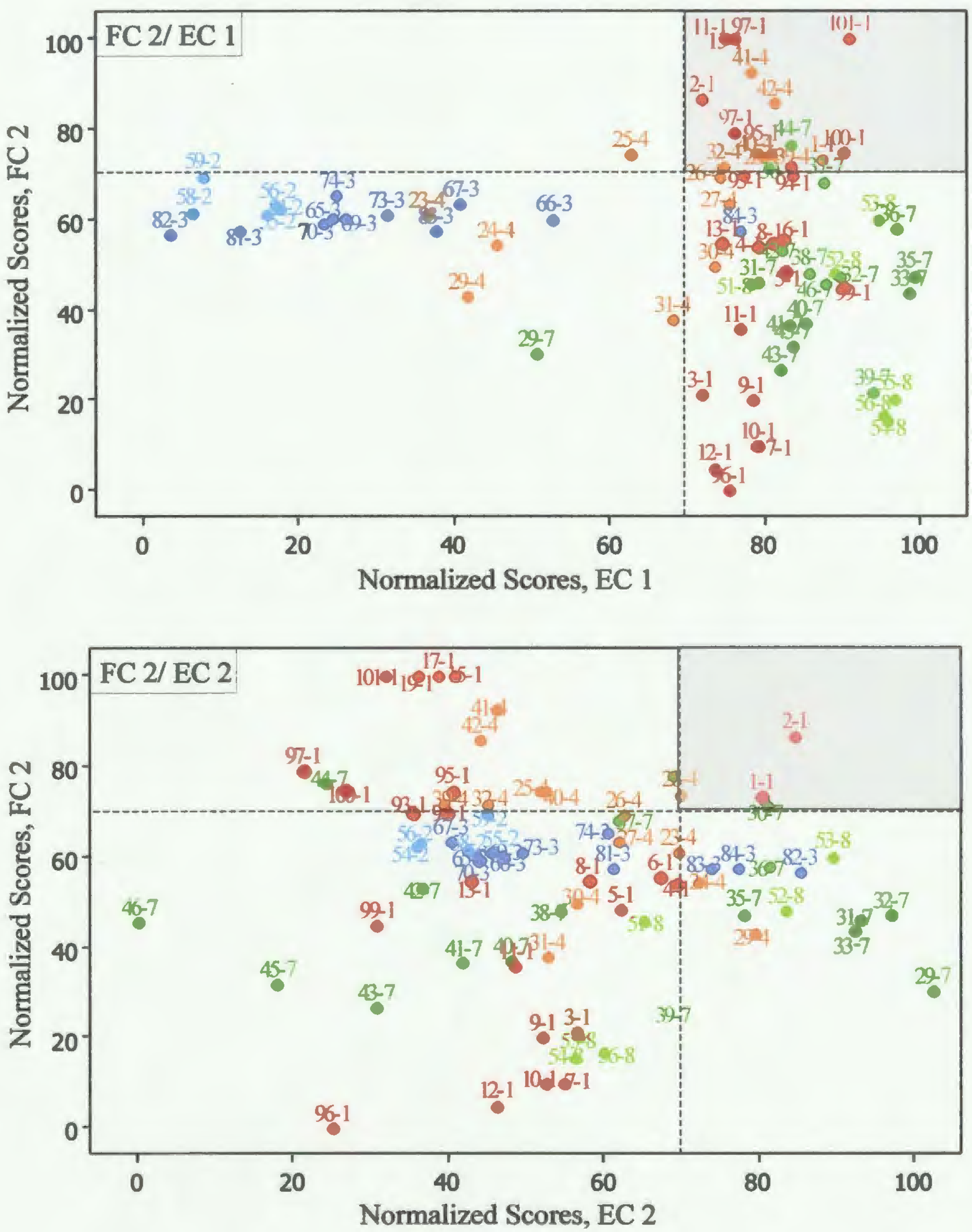
Scatterplots of normalized faunal score 1 versus normalized environmental scores 1, 2 and 3.





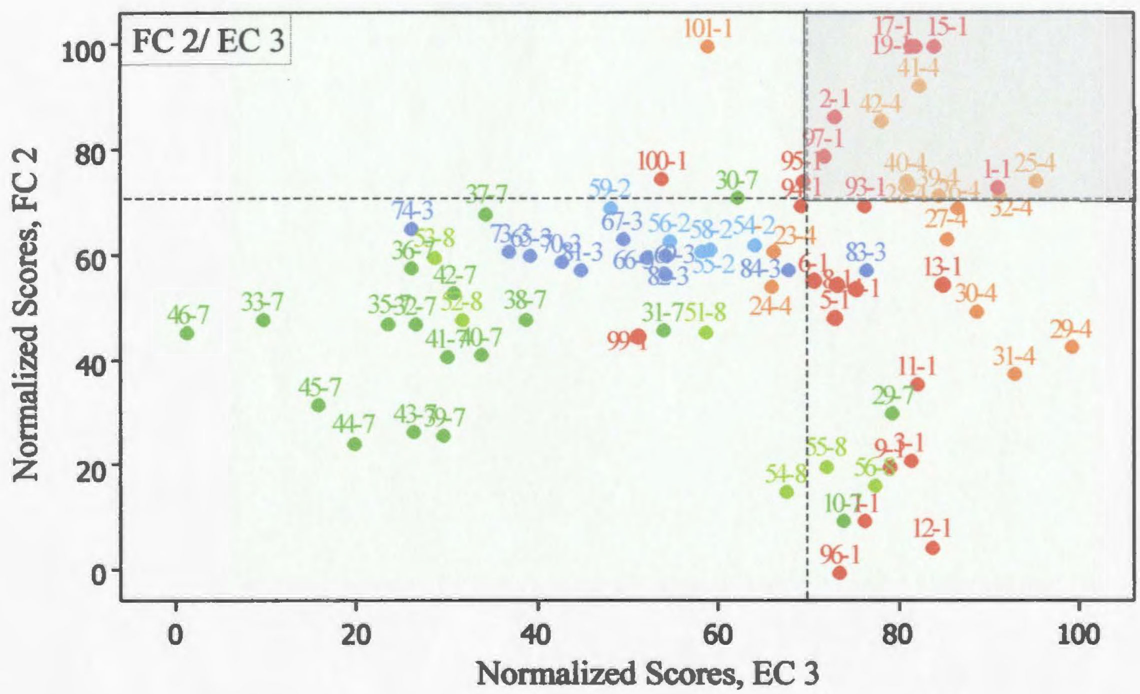
Scatterplots of normalized faunal score 1 versus normalized environmental scores 1, 2 and 3.

Black Sea	**Marmara Sea**	**Aegean Sea**
• Transect 3	• Transect 1	• Transect 7
• Transect 2	• Transect 4	• Transect 8



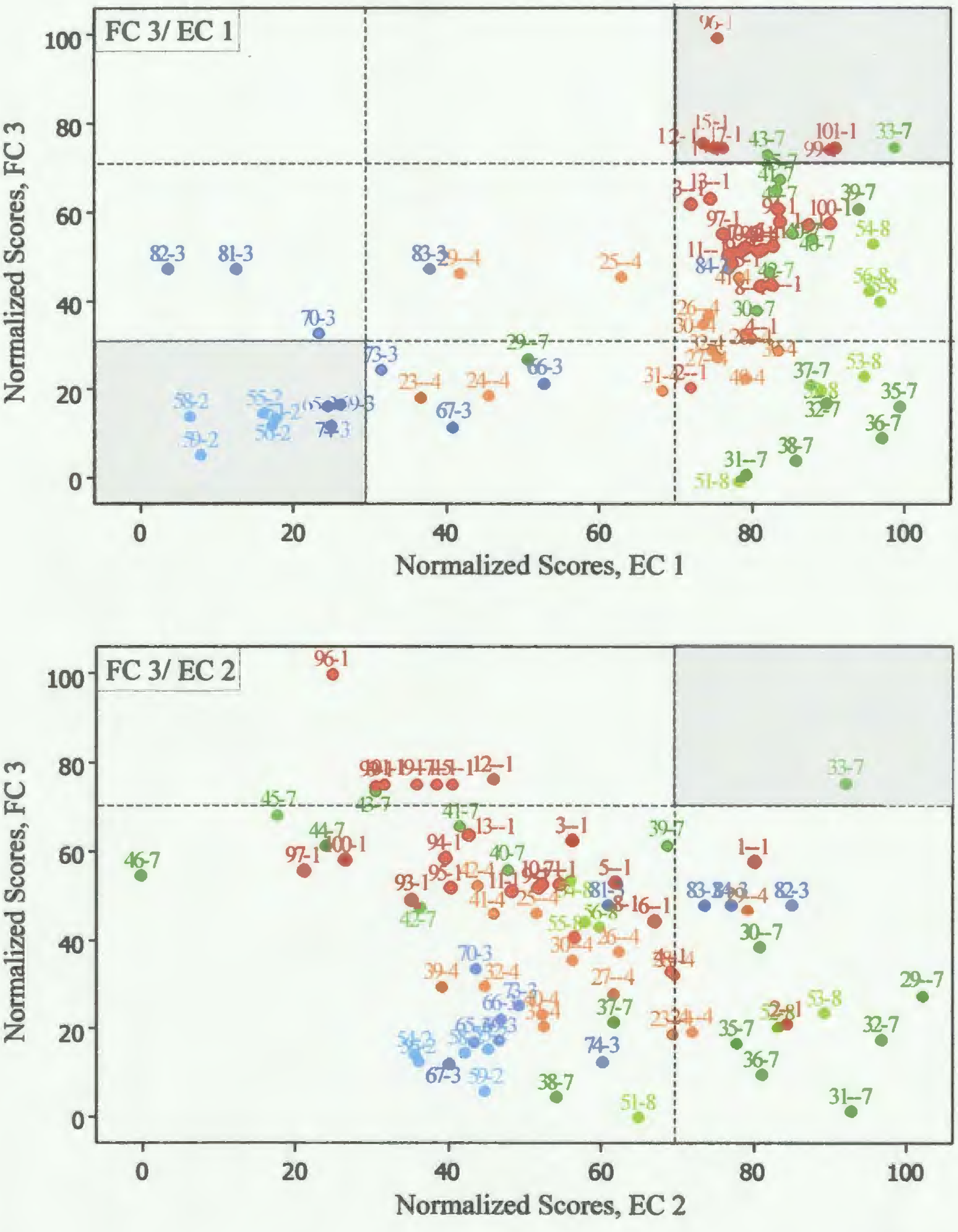
Scatterplots of normalized faunal score 2 versus normalized environmental scores 1, 2 and 3.

Black Sea	Marmara Sea	Aegean Sea
Transect 3	Transect 1	Transect 7
Transect 2	Transect 4	Transect 8



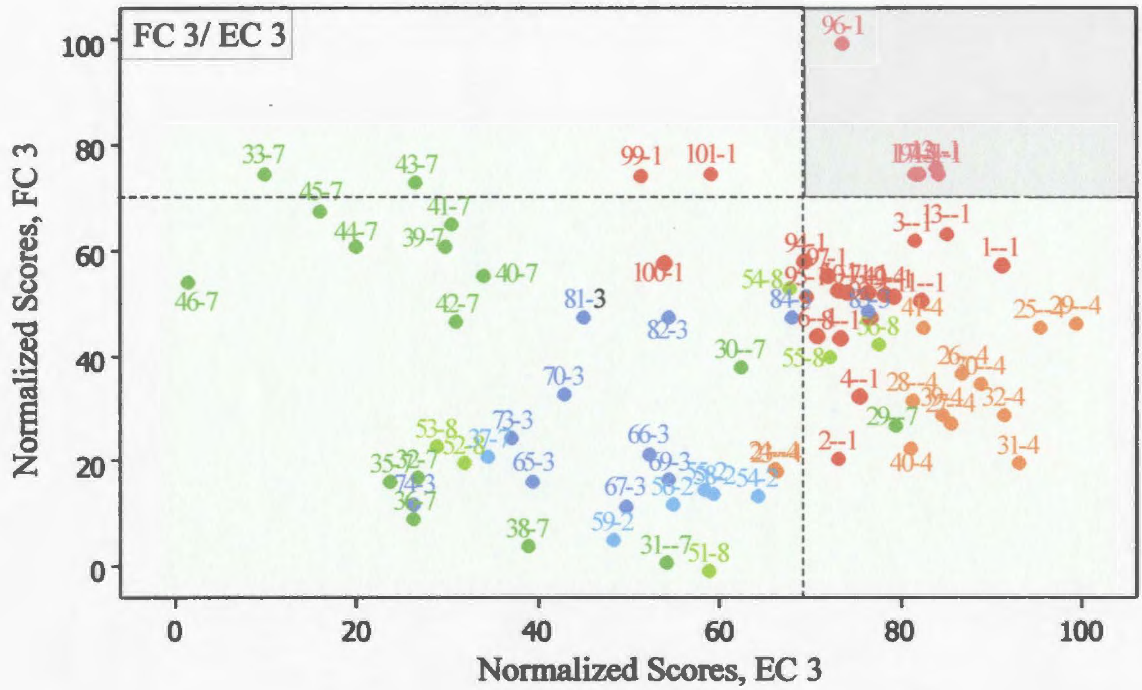
Scatterplots of normalized faunal score 2 versus normalized environmental scores 1, 2 and 3.

Black Sea	Marmara Sea	Aegean Sea
Transect 3	Transect 1	Transect 7
Transect 2	Transect 4	Transect 8



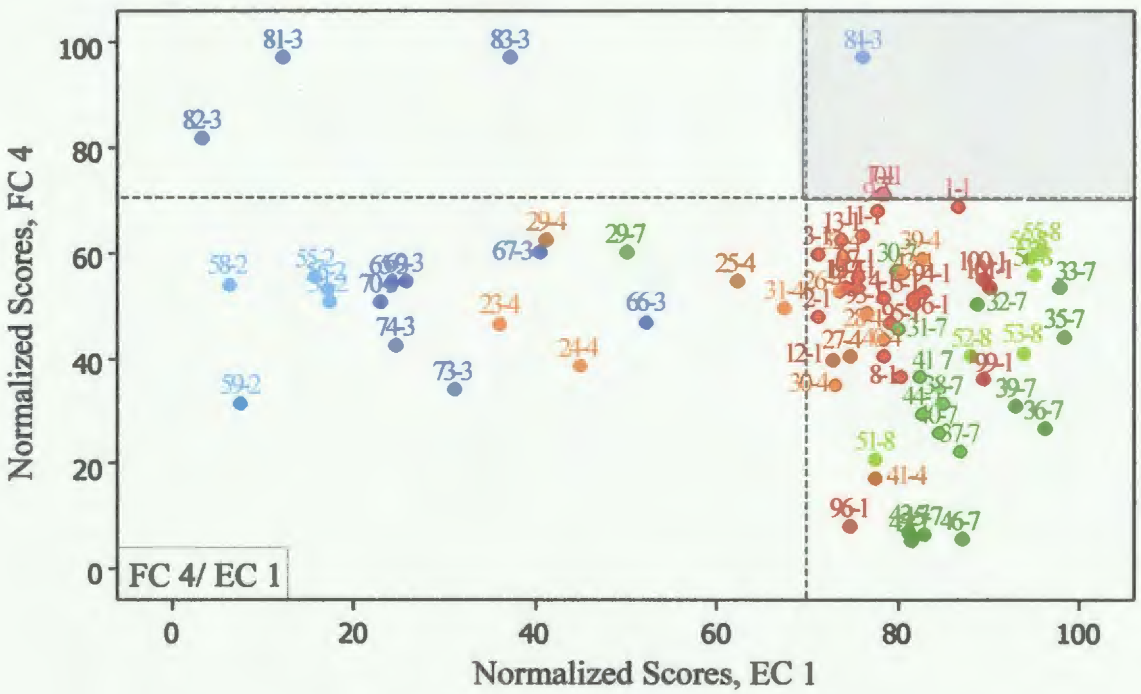
Scatterplots of normalized faunal score 3 versus normalized environmental scores 1, 2 and 3.

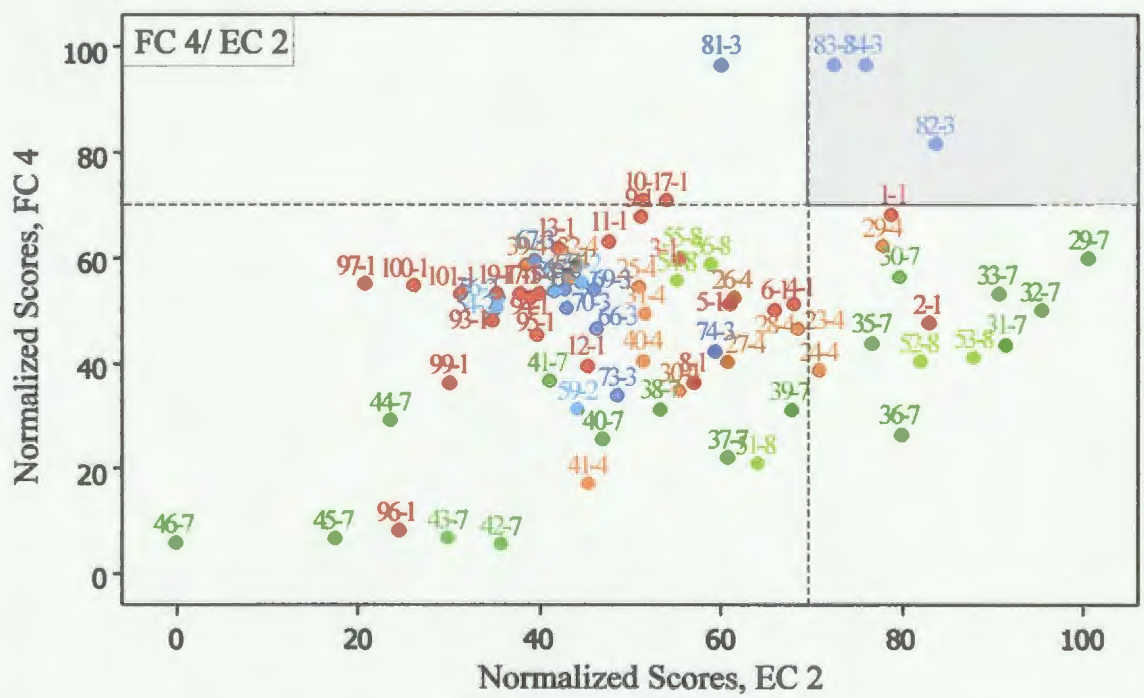
Black Sea	Marmara Sea	Aegean Sea
Transect 3	Transect 1	Transect 7
Transect 2	Transect 4	Transect 8



Scatterplots of normalized faunal score 3 versus normalized environmental scores 1, 2 and 3.

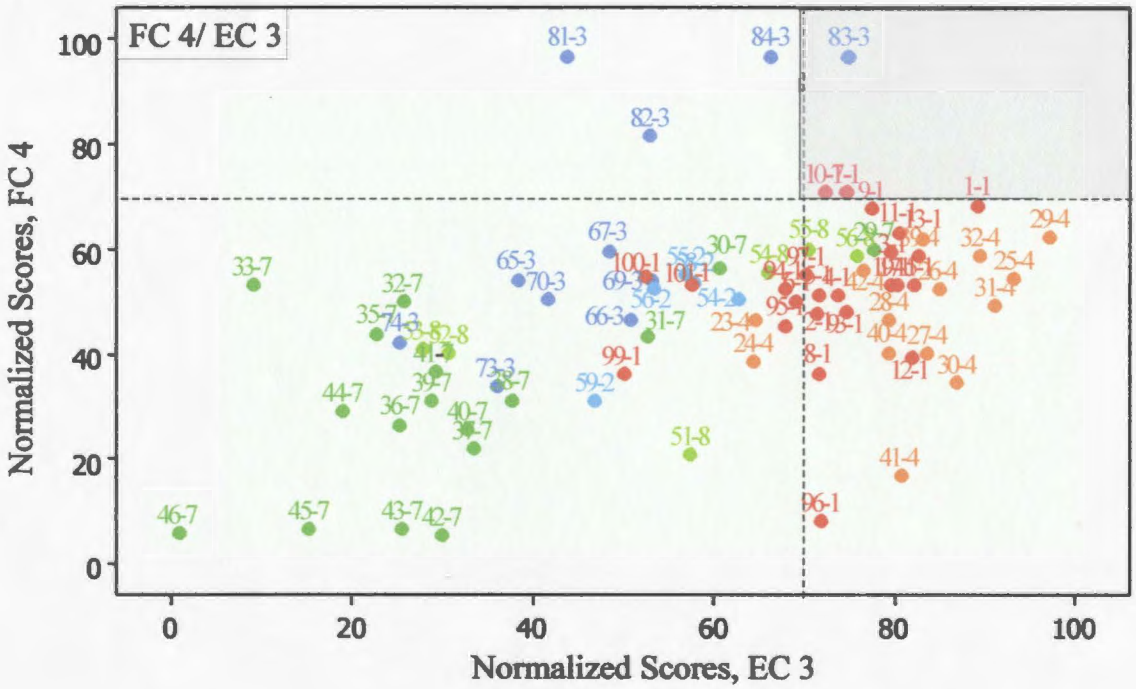
Black Sea	Marmara Sea	Aegean Sea
Transect 3	Transect 1	Transect 7
Transect 2	Transect 4	Transect 8





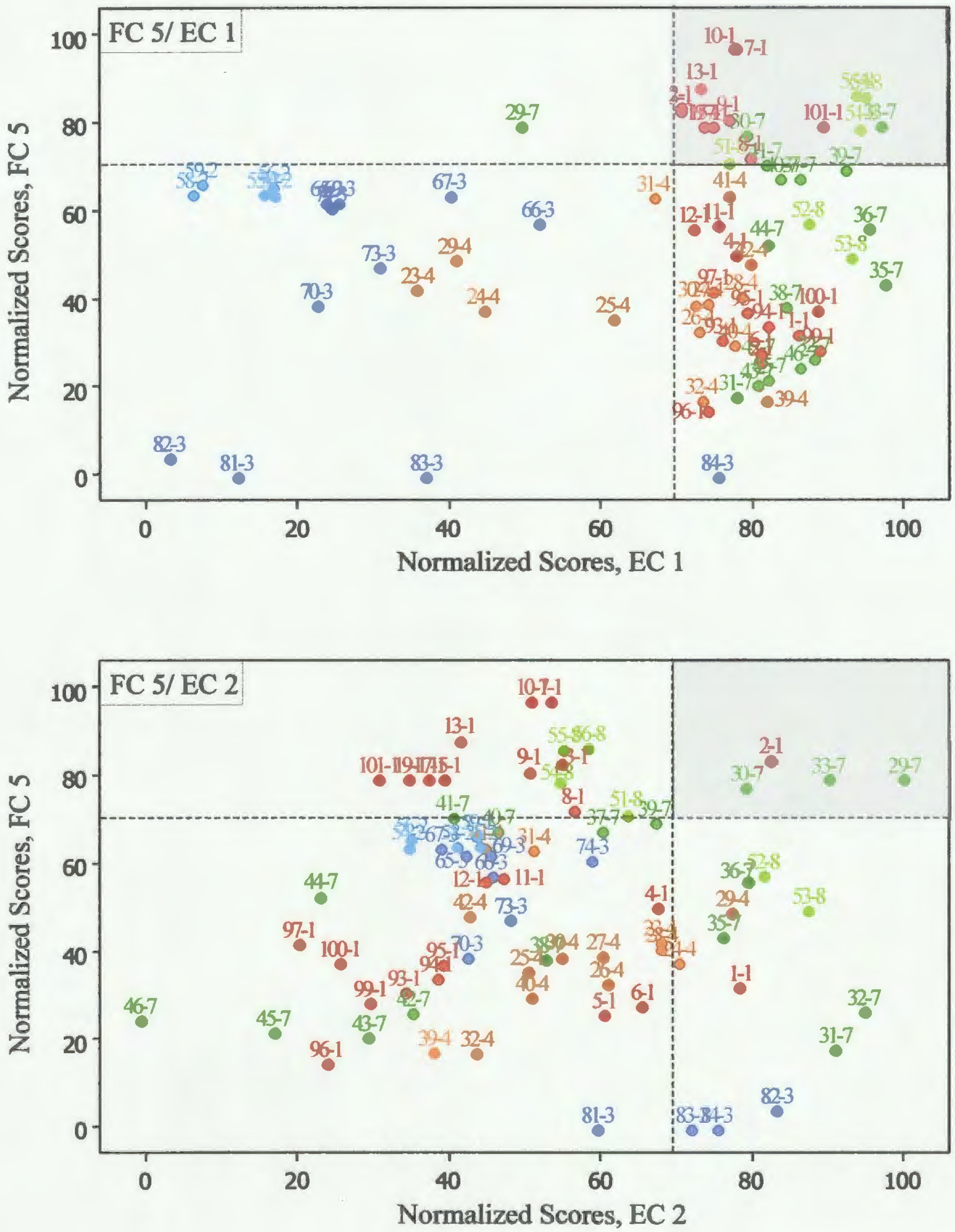
Scatterplots of normalized faunal score 3 versus normalized environmental scores 1, 2 and 3.

Black Sea	Marmara Sea	Aegean Sea
Transect 3	Transect 1	Transect 7
Transect 2	Transect 4	Transect 8



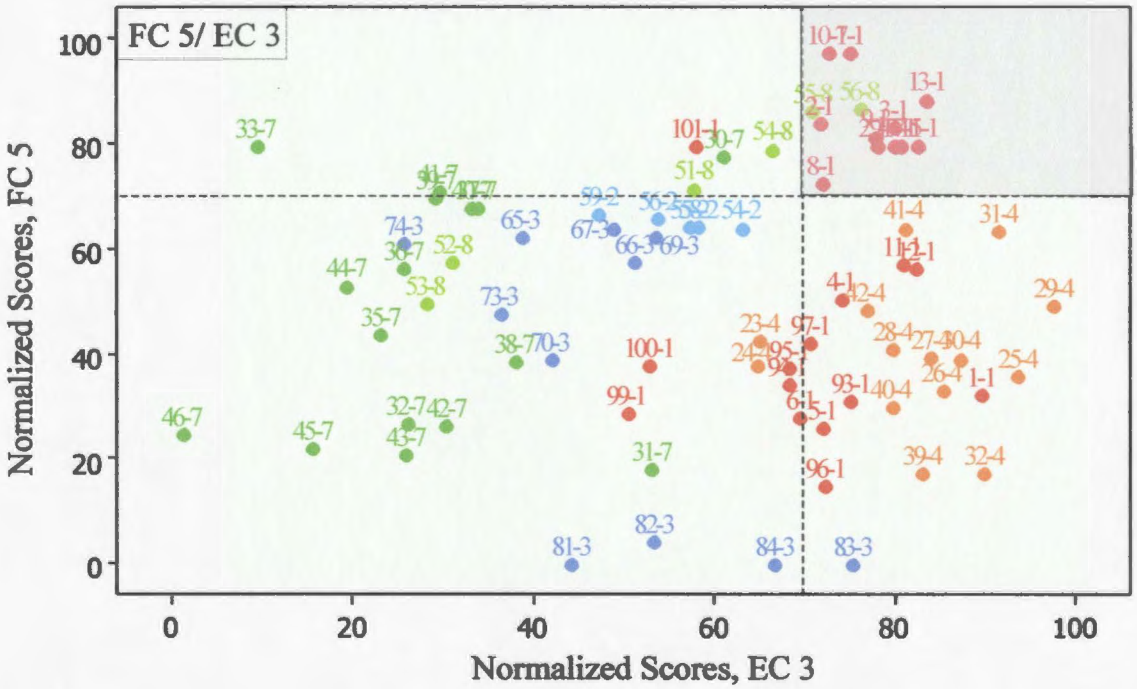
Scatterplots of normalized faunal score 3 versus normalized environmental scores 1, 2 and 3.

Black Sea	Marmara Sea	Aegean Sea
Transect 3	Transect 1	Transect 7
Transect 2	Transect 4	Transect 8



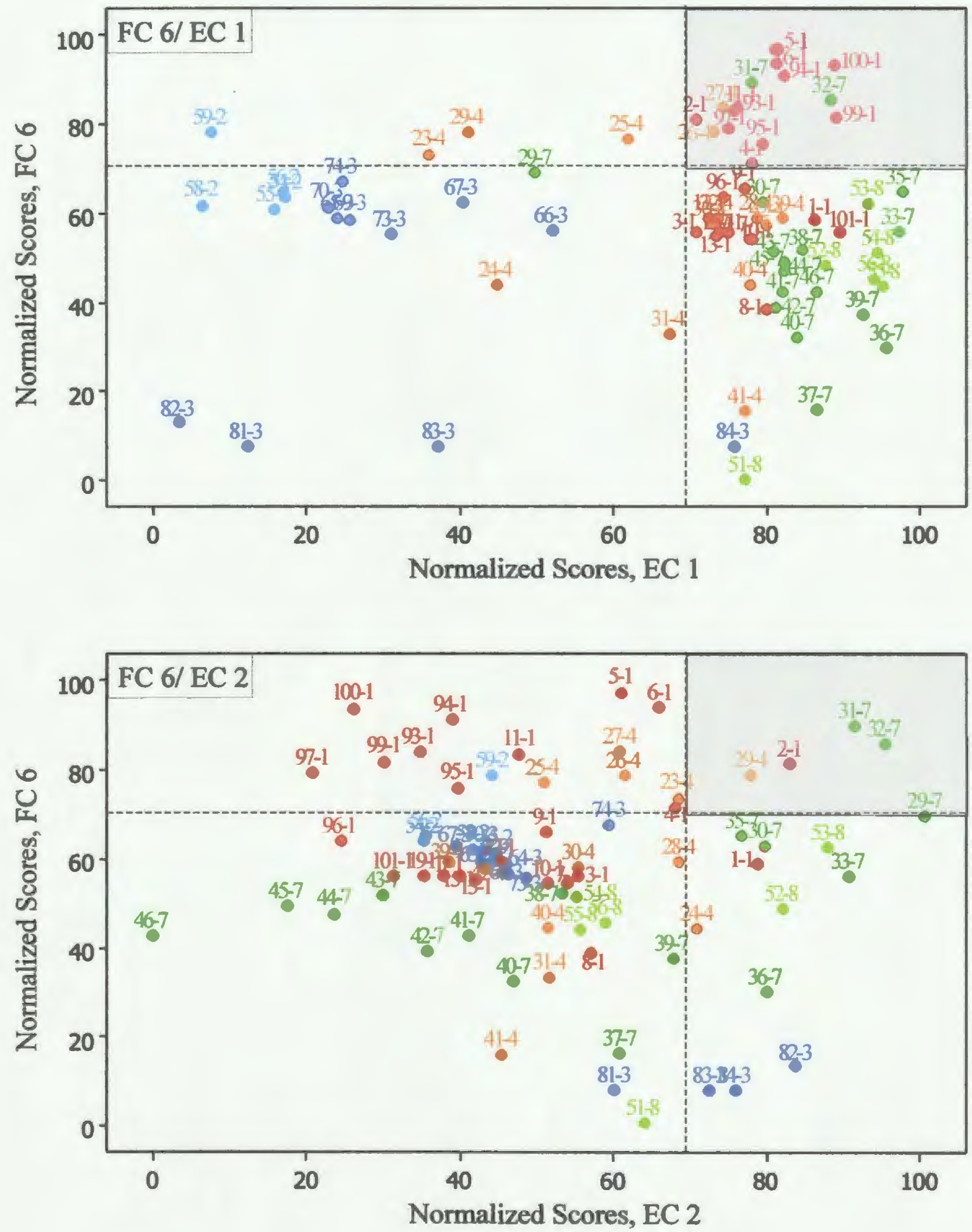
Scatterplots of normalized faunal score 5 versus normalized environmental scores 1, 2 and 3.

Black Sea	**Marmara Sea**	**Aegean Sea**
• Transect 3	• Transect 1	• Transect 7
• Transect 2	• Transect 4	• Transect 8



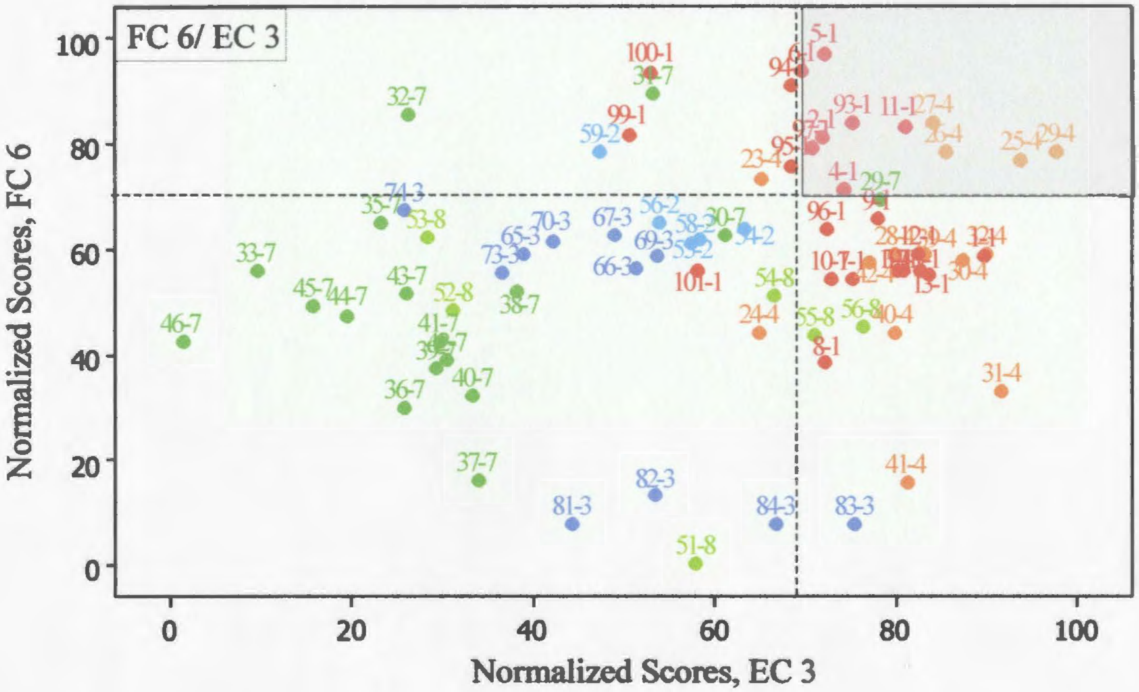
Scatterplots of normalized faunal score 5 versus normalized environmental scores 1, 2 and 3.

Black Sea	Marmara Sea	Aegean Sea
Transect 3	Transect 1	Transect 7
Transect 2	Transect 4	Transect 8



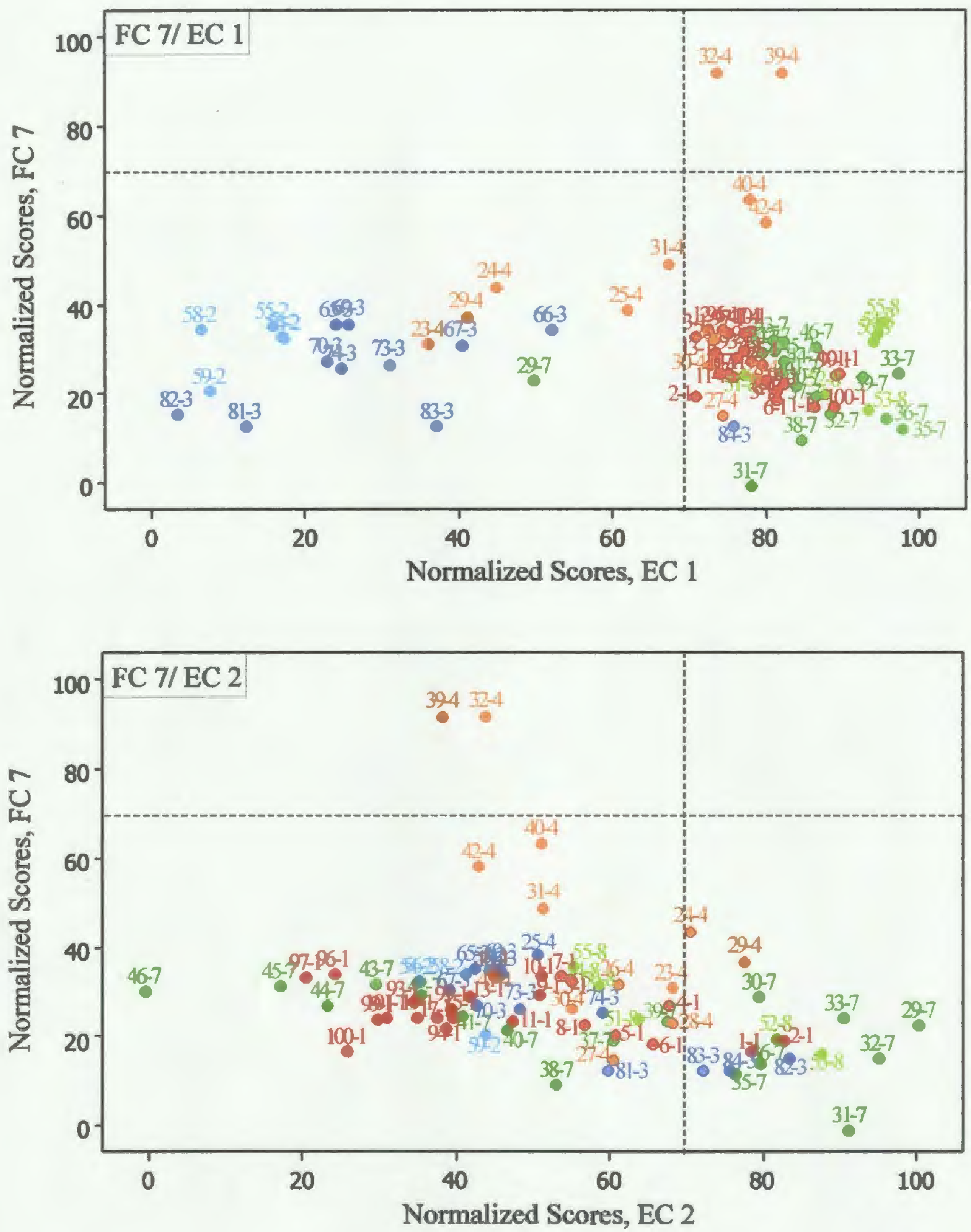
Scatterplots of normalized faunal score 6 versus normalized environmental scores 1, 2 and 3.

Black Sea	Marmara Sea	Aegean Sea
Transect 3	Transect 1	Transect 7
Transect 2	Transect 4	Transect 8



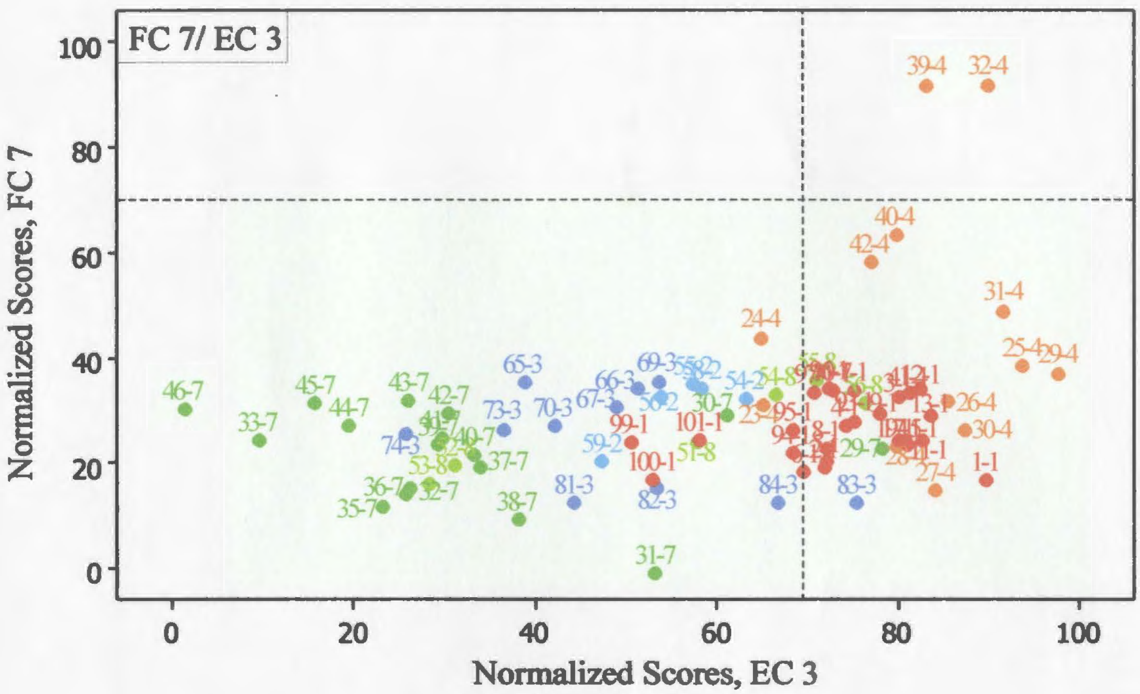
Scatterplots of normalized faunal score 6 versus normalized environmental scores 1, 2 and 3.

Black Sea	Marmara Sea	Aegean Sea
• Transect 3	• Transect 1	• Transect 7
• Transect 2	• Transect 4	• Transect 8



Scatterplots of normalized faunal score 7 versus normalized environmental scores 1, 2 and 3.

Black Sea	Marmara Sea	Aegean Sea
Transect 3	Transect 1	Transect 7
Transect 2	Transect 4	Transect 8



Scatterplots of normalized faunal score 7 versus normalized environmental scores 1, 2 and 3.

Black Sea	Marmara Sea	Aegean Sea
Transect 3	Transect 1	Transect 7
Transect 2	Transect 4	Transect 8

PLATES

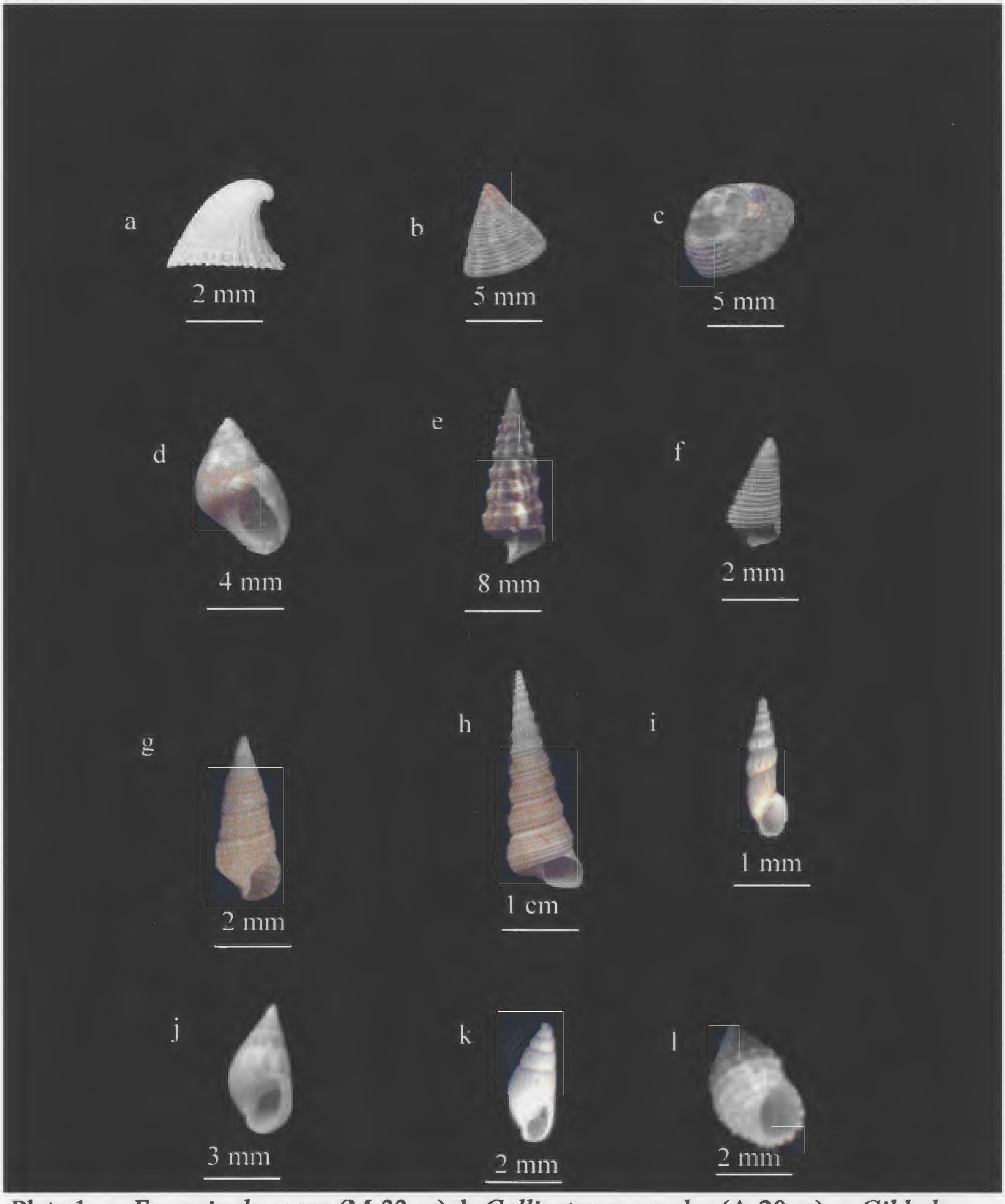


Plate 1: a-*Emarginula rosea* (M-33 m), b-*Calliostoma conulus* (A-20 m), c-*Gibbula leucophaea* (A-14 m), d-*Tricolia tenuis* (A-14 m), e-*Cerithium rupestre* (A-20 m), f-*Bittium latreillei* (A-49 m), g-*Bittium reticulatum* (B-79 m), h-*Turritella communis* (M-23 m), i-*Rissoa auriscalpum* (A-14 m), j-*Rissoa splendida* (A-20 m), k-*Rissoa lineolata* (A-28 m), l-*Alvania cancellata* (A-20 m).
A: Aegean Sea; B: Black Sea; M: Marmara Sea

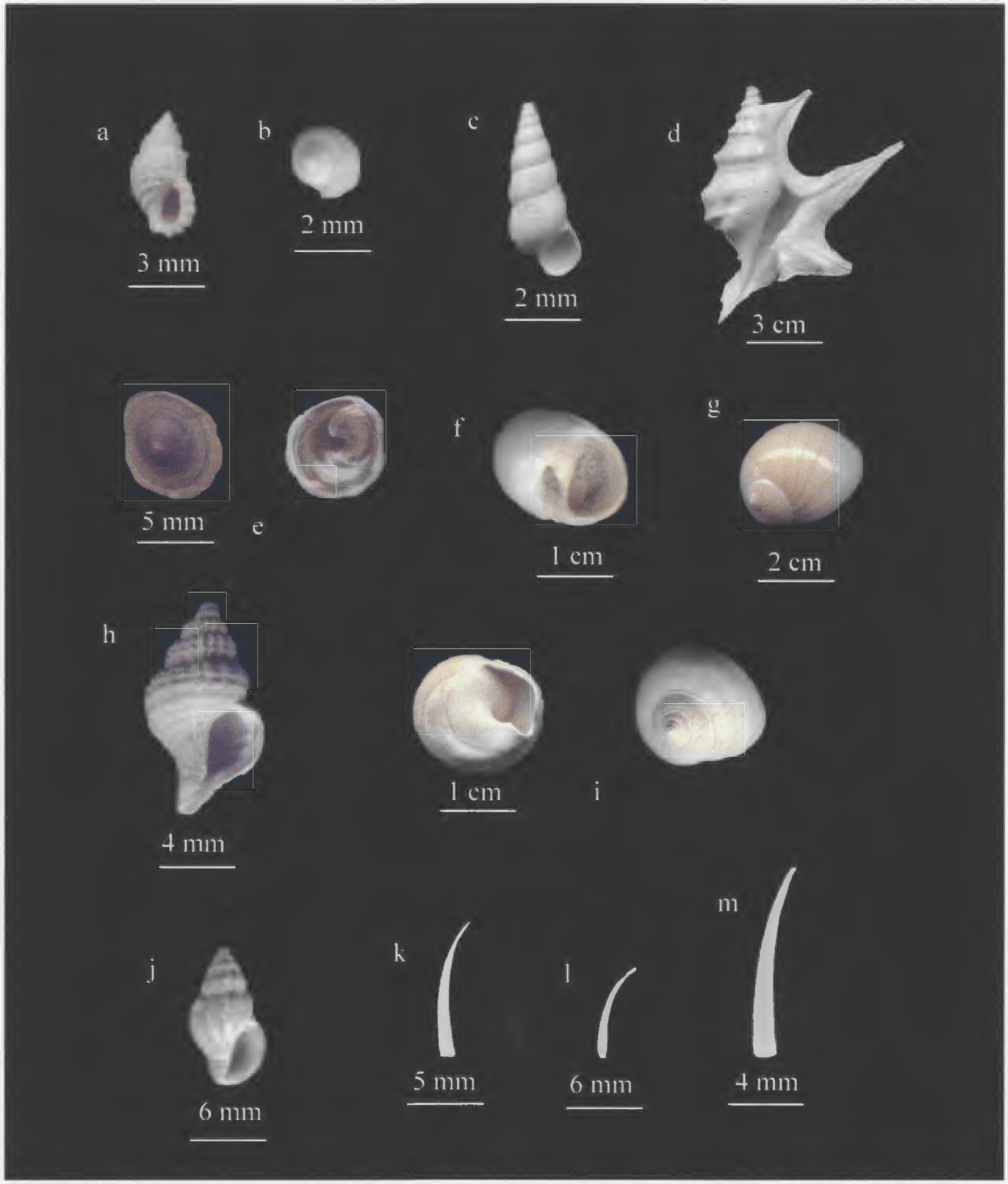


Plate 2: a- *Alvania cimex* (BS-111 m), b-*Tornus subcarinatus* (AS-39 m), c- *Truncatella subcylindrica* (BS-74 m), d-*Aporrhais pespelacani* (AS-60 m), e-*Calyptrea chinensis* (MS-39 m), f- *Lunatia pulchella* (AS-18 m), g- *Payraudeautia intricata*, h- *Trophon muricatus* (BS-106 m), i- *Cyclope donovania* (MS-17 m), j- *Mangelia attenuata* (MS-17 m), k- *Dentalium dentalis* (MS-28 m), l- *Gadulus politus* (AS-78 m), m- *Entalina tetragona* (AS-88 m). A: The Aegean Sea; B: The Black Sea; M: The Marmara Sea.

Plate 3: a- *Nucula nucleus* (A-18 m), b- *Nucula sulcata* (M-23 m), c- *Nuculana commutata* (M-43 m), d- *Arca noae* (A-20 m), *e- Anadara diluvii* (A-59 m), *f- Bathyarca philippiana* (A-112 m), *g- Scapharca inaequivalvis* (M-146 m), *h- Striarca lactea* (A-20 m) *i- Glycymeris insubrica* (A-14 m), *j- Mytilus galloprovincialis* (B-36 m).
A: The Aegean Sea; B: The Black Sea; M: The Marmara Sea.

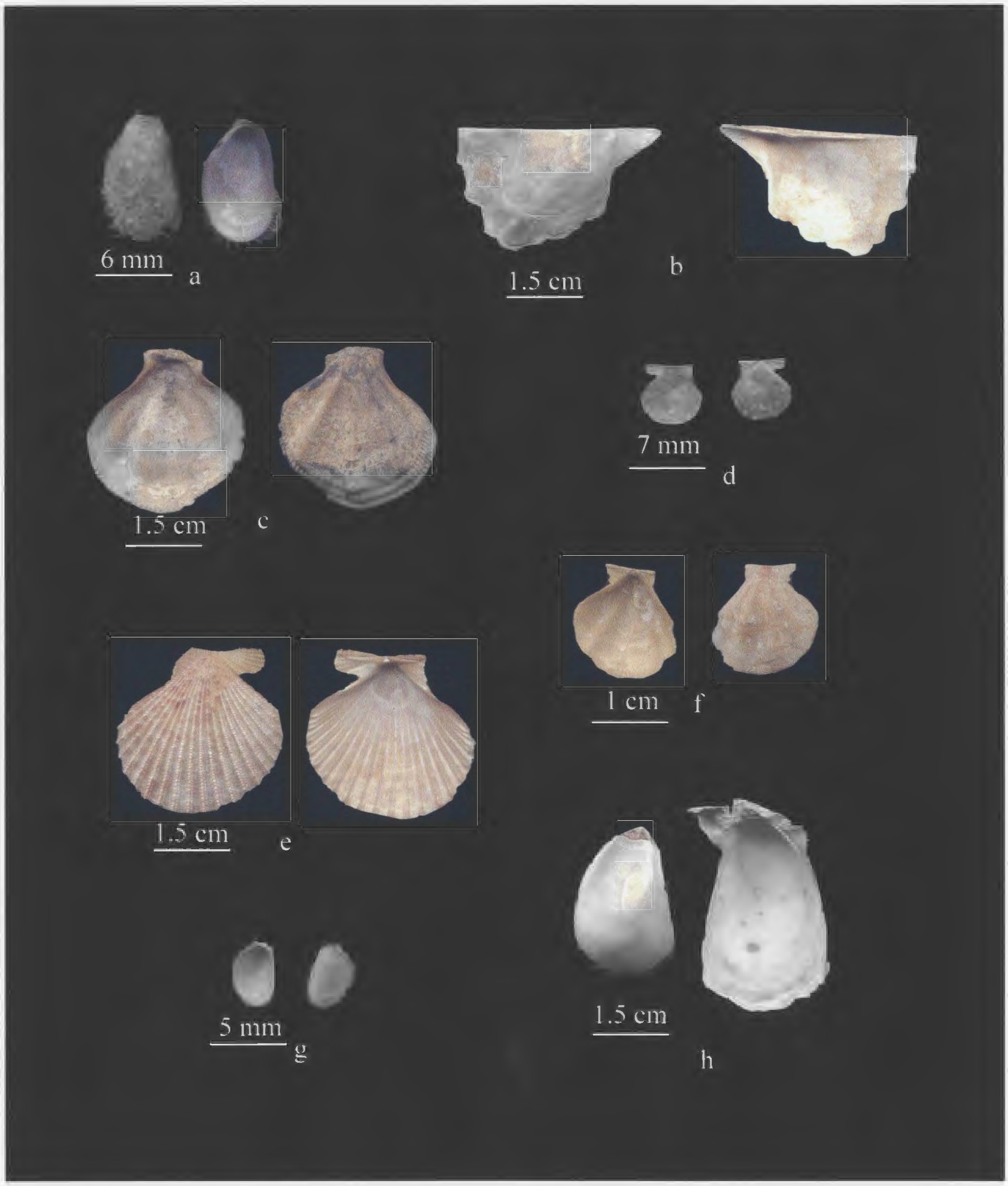


Plate 4: a-*Modiolula phaseolina* (B-74 m) , b-*Pteria hirunda* (M-146 m), c-*Pseudamussium clavatum* (M-74 m), d-*Palliolum incomparabile* (M-146 m), e-*Chlamys varia* (A-97 m), f-*Chlamys glabra* (A-112 m), g-*Limatula subauriculata*, h-*Ostrea edulis* (M-103 m).
A: Aegean Sea; B: Black Sea; M: Marmara Sea

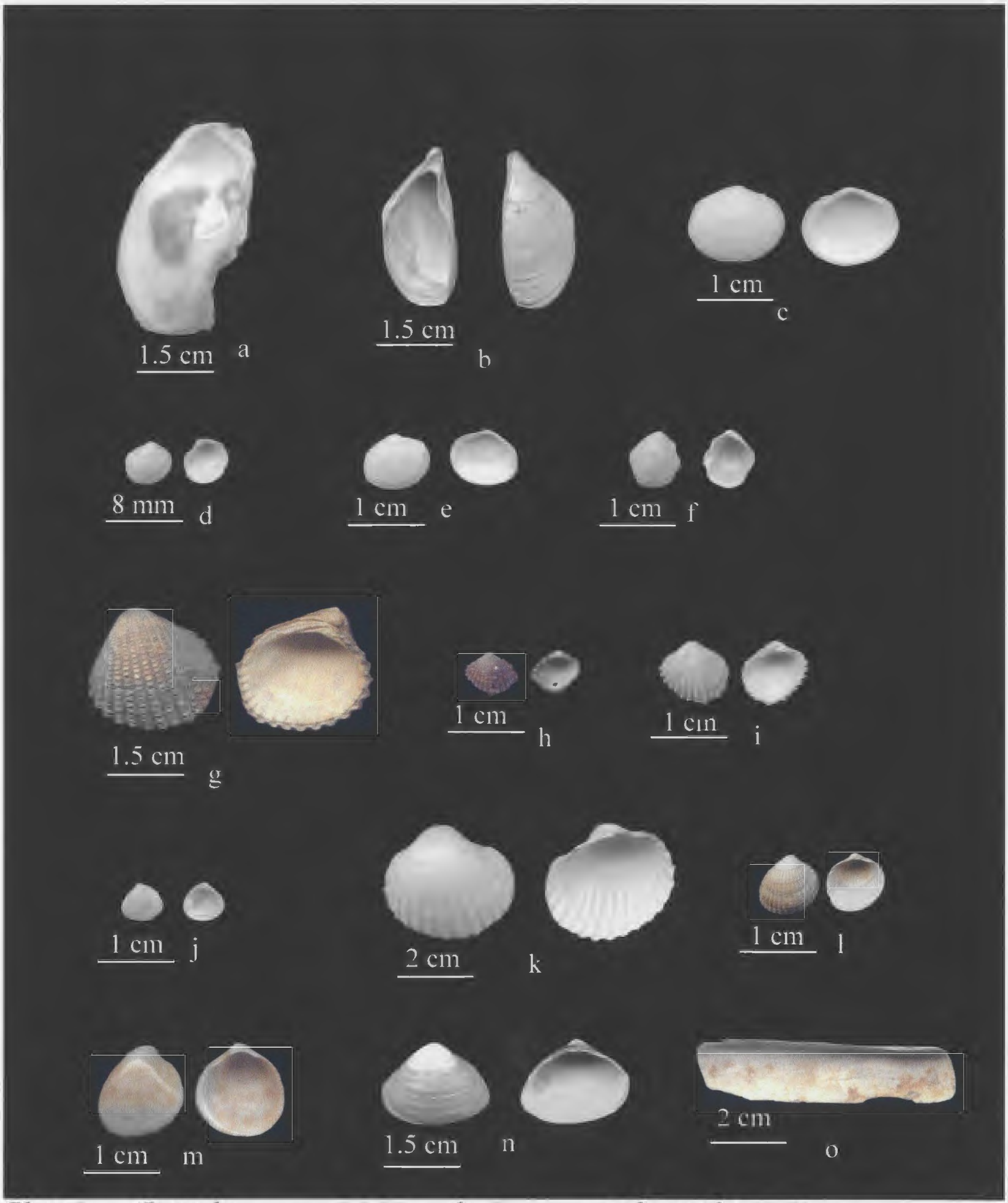


Plate 5: a- *Ostreola stentina* (M-90 m), b- *Dreissena polymorpha* (B-79 m), c- *Loripes lucinalis* (A-14 m), d- *Lucinella divaricata* (A-60 m), e- *Myrtea spinifera* (A-18 m), f- *Thyasira flexuosa* (M-54 m), g- *Cardites antiquata* (A-20 m), h- *Glans trapezia* (A-20 m), i- *Glans aculeata* (M-112 m), j- *Gonilia calliglypta* (A-70 m), k- *Acanthocardia paucicostata* (B-92 m), l- *Parvicardium exiguum* (A-14 m), m- *Laevicardium crassum* (A-39 m), n- *Spisula subtruncata* (B-33 m), o-*Solen marginatus* (M-13 m).

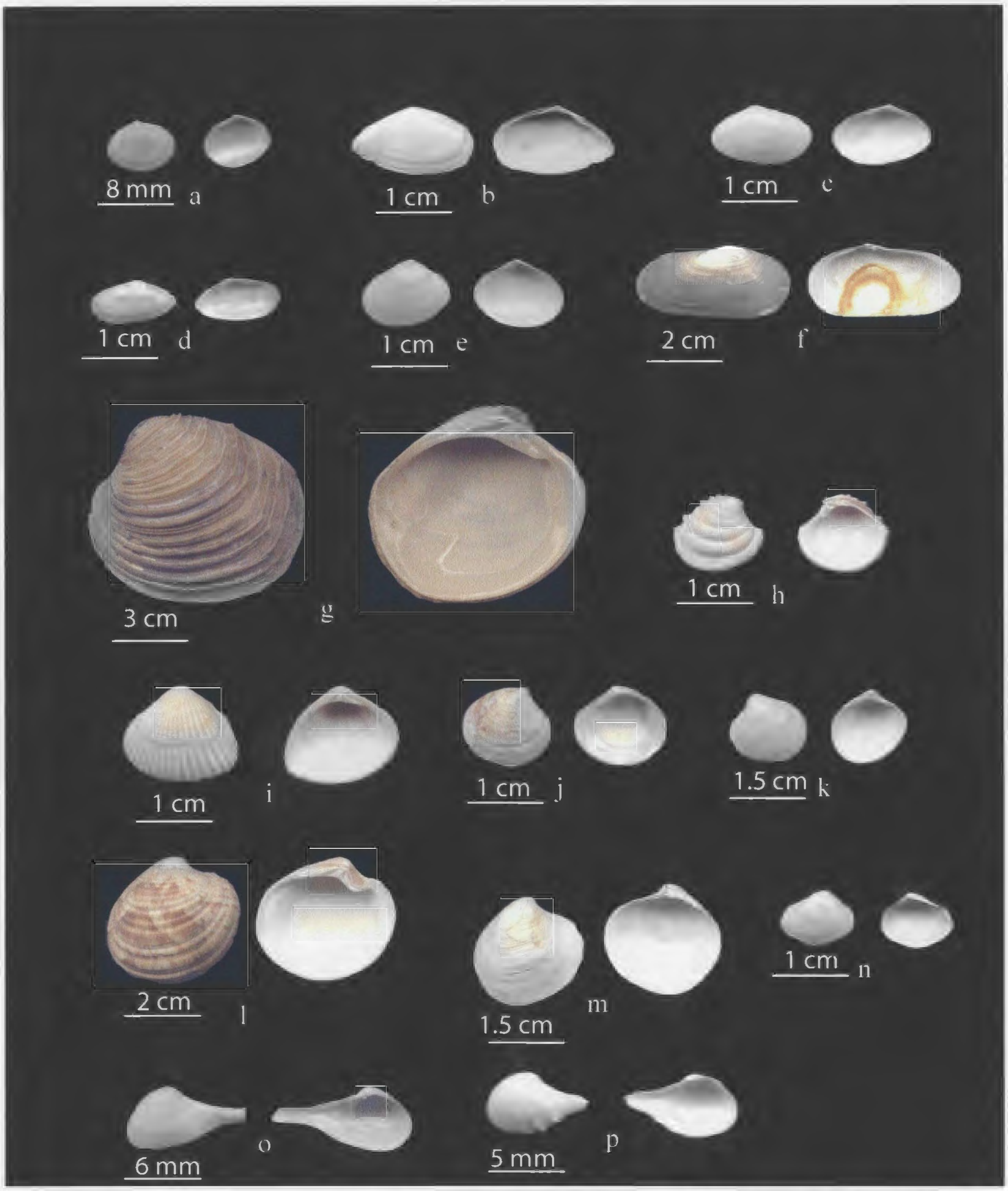


Plate 6: a- *Tellina balaustina* (A-14 m), b- *Tellina donacina* (M-13 m), c- *Abra nitida* (A-18 m), d-*Abra prismatica* (M-13 m), e- *Abra alba* (B-33 m), f- *Azorinus chamasolen* (M-34 m), g- *Venus casina* (M-79 m), h- *Clausinella brongniartii* (M-39 m), i- *Timoclea ovata* (M-109 m), j- *Gouldia minima* (A-17 m), k- *Dosinia lupinus* (B-74 m), l- *Pitar rudis* (A-20 m), m- *Mysia undata* (A-26 m), n- *Corbula gibba* (A-39 m), o-*Cuspidaria rostrata* (M-93 m), p- *Cardiomya costellata* (M-98 m).