United Nations
Environment
Programme

UNEP(OCA)/WG.2/9
August 1988

Original: ENGLISH

Joint Meeting of the Task Team on Implications of Climatic Changes in the Mediterranean and the Co-ordinators of Task Teams for the Caribbean, South-East Pacific, South Pacific, East Asian Seas and South Asian Seas regions

Split, 3-8 October 1988

IMPLICATION OF FUTURE CLIMATIC CHANGES ON THE INNER THERMAIKOS GULF

D. Georgas[1] and C. Perissoratis[2]

[1] Spata, Greece and Athens, Greece

[2] Institute of Geology and Mineral Exploration,

F I R S T   D R A F T

N O T   T O   B E   C I T E D

UNEP
Athens, 1988

pages

PREFACE

Earth's climate has been subject to continuous natural changes throughout its existence. These changes were associated with significant impacts on all life forms of the planet. Temperature and sea level variations appear to play a critical role on these changes especially during the Ice Ages. Today, due to the expanding human activities, climate seems to be changing in a faster rate than before. This became obvious in the last 300 years when agricultural and industrial revolutions reached their peak. The continuous increase of the atmospheric concentration in gases, absorb some of the radiation emitted by the Earth, which will consequently lead to a warmer and probably, in some cases, wetter planet. This phenomenon has been studied recently and is broadly known as the "greenhouse effect".

It is known that the Earth's average temperature has very rarely varied by more than 1° or 2°C over the past 1000 years, whereas in the most recent Ice Age it was only about 5°C colder that its now. Apparently a global warming of only a few degrees would have a profound effect on climate.

Although future forecasts tend to be uncertain, attempts have been made to estimate the scale of the induced climatic changes, based on our current knowledge. Starting from a given scenario, which is the approach to the implications on the Mediterranean region, the change is considered within two time periods in the future. These are 25 and 50 years from now, when impacts would be noticeable and catastrophic respectively.

The present study concerns the implications on a specific area of the Eastern Mediterranean, the Inner Thermaikos Gulf, northern Greece.

1. INTRODUCTION

At the inner Thermaikos area, northern Greece, three interrelated important parameters make this sector the second socio-economic center of the country, after Athens. These are, to the east a large urban center, the city of Thessaloniki; to the west a 24.000 acres fertile low lying plain formed recently by the sediment brought by four rivers, two of them among the largest in Greece; and finally between them the gulf, rich in fishes and intensively used by marin traffic. Today in the greater area more than 1 million people live. The adjacent plain contributes the major part of the corps produced at the whole perfecture, and the port is used for 80% of Greece's imports and 30% of its exports.

Going back in the past, Thessaloniki was one of the main cities built during the time of Alexander the Great, but also one of the few which not only survived but also developed and constituted in the major part of its 2300 yr history, the capital of northern Greece. Built in 316 B.C. by Kassandros after his wife Thessaloniki, the sister of Alexander, lying at the northwesternmost corner of the Aegean Sea, overlooking land and sea, it soon became an important urban and social center. At the time of its built the today's plain was not existed because the sea was extended more than 30 km to the west, where the city of Pella was lying; then the capital of Macedonia. Up to the time of the Roman occupation (136 B.C.), Thessaloniki was a prosperous city due to the gold and silver mines and to the agricultural production from the areas around. Meanwhile the sediments deposited to the west by the rivers had make unoperational the port of Pella, which was finally abandoned since many parts of the sea were transformed into swamps and marshes.

During the Roman occupation there was a relative social and economic stability (Pax Romana) a situation which helped city's progress. The people were dealing with trading, agriculture and mining while an important contribution to the local economy came from the construction by the Roman's of the famous "Egnatia Road" which connected the Adriatic and black seas and passed through the city. At the same period the marshes had covered great part of the area to the west, leaving a lagoon at the center, which had an outlet connection with the open sea to the east. At the succeeding Greek-Byzantine period (4th to 15th century) and especially between the 9th and 11th century, the city was the economic center of the whole Balkan peninsula and the second important city of the empire. The population many times exceeded 100.000 while marine trade and industry were greatly advanced, along with agriculture. A big fortress built around Thessaloniki was extended all along the seashore protecting the city from the pirates and offering a shelter to the population around and to the ships sailing at the northern Aegean. At the adjacent plain the deposited sediments were transforming many parts of the swamps into land which, however, due to the primitive drainage methods, were not yet available for agriculture.

Gradually though, especially at the Otoman occupation period (15th to 19th century) agriculture developed more rapidly. Cotton and smoke were cultivated at the area which was also used for hunting and fishing. Mining of silver, lead and iron contributed to the prosperity of the Thessaloniki. By the end of the 19th century the whole plain was land with occasional marshes and a small lake at its center, where the lagoon existed before. The coastline was similar to that of today and the continuous sediment deposition was threatening the cut-off of Thessaloniki port, as it happened before with the port of Pella.

The first decades of the 20th century are characterized by the great increase in population, by the radical agricultural transformations and by the large technical works carried out. Thus between the years 1928 and 1939 Axios river's course was distructed, the lake and the swamps were drained and the whole plain area was given to agriculture. The former peasants became land owners and the productivity rose sharply as the new farmers were particularly interested for higher yields from their farms. At the same time the divertion of the river's route to a more southward course saved the port from cut-off. As a result by 1951 the total population of the Thessaloniki perfecture reached 450.000 with the city itself having more than 300.000 habitants.

From the begining of the 50's up to now the area has experienced a booming unparallel to any other during its history. Indicative of the city's growth is that from 1967 to 1971 about 50.000 new apartment houses were built. In 1981 the population of the Thessaloniki perfecture was over 850.000 while the city had about 700.000 people. Today there are more than 1 million people living in and around Thessaloniki with 10.000 small and large industries and a total cargo traffic of 10.4 million tonnes/year.

This "anarchic" development and growth, however, had the relevant consequences such as the severe pollution of the gulf due to the domestic and industrial sewages and the agricultural fertilizers, which downgraded considerably the whole natural environment. The city is already feeling the results as swimming is prohibited in extensive coastal areas of the Inner Gulf and generally the living standards in many parts is low.

Today the question arises: what will be the impacts of a future temperature and sea level rise in the inner Thermaikos gulf and its surroundings? Will the bay become a sluggish lagoon with stratified water layers and sapropel formation due to excessive pollution? How will precipitation changes affect warm and cold season's duration? Will there be an excessive need of water for agricultural and other uses? Is there a possibility of the plain becoming a swamp again? Which will be the effects on infrastruture, industry, housing, tourism etc.? And, finally, how could the battle be gained against the consequences of human violation on natural settins? This paper, using data from various researches carried out at the area, is an attempt to answer the above questions. More than than, though, it is an effort to make people, and especially decision makers, sensitive and to urge them to plan as early as possible how and which measures to take. The full verification of the climatic changes will be too late for effective action.

2. THE COASTAL ENVIRONMENT

2.1. Geomorphology

The area under study is located in Macedonia, Northern Greece between longitude 22°30' and 23°00' and latitude 40°20' and 40°45'. However, our study is occasionally extended to the adjacent areas when additional data are necessary for the understanding of several interrelated mechanisms (geology, geomorphology, hydrology, etc.). The inner Thermaikos Gulf, a shallow embayment having an areal extent of 470 km^2, is limited by a 160 km long coast line, stretched from Kitros saltmarshes up to the Epanomi Cape (fig. 1). Three geographically distinct basins are considered, the semi-enclosed Inner Thessaloniki Bay (maximum depth 26 m), the outer Thessaloniki Bay (maximum depth 30 m) and the inner Thermaikos Bay (maximum depth 40 m). The gulf is characterised by a uniform bathymetry. The western coast is gently sloping due to the estuarine discharges, whereas the eastern is slightly steeper (fig. 1).

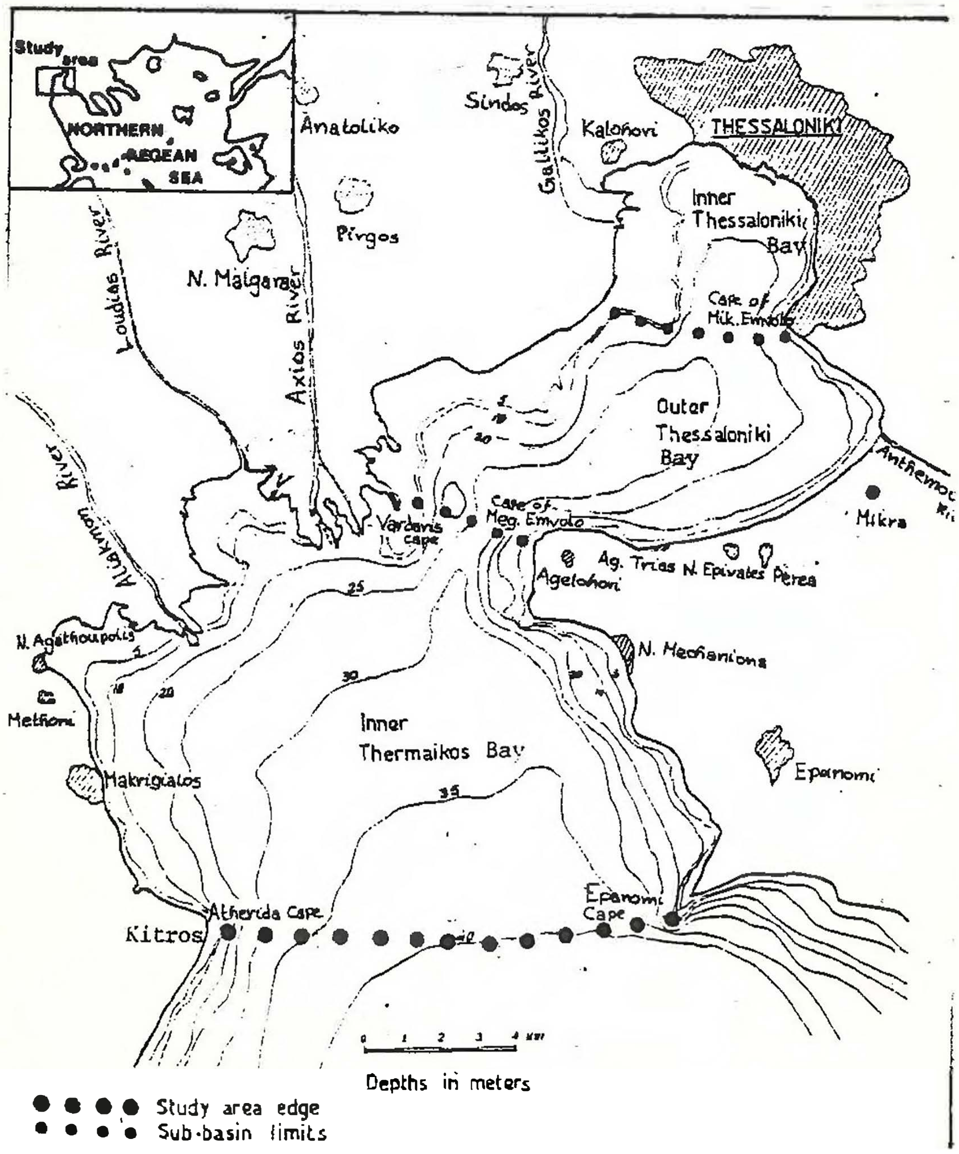


Fig. 1 - The study area
Index map shows its location

The topographic relief of the adjacent land is generally smooth, surrounded everywhere, except to the NW, by hills and mountains. The land sector to the NW is occupied by the broad alluvial Thessaloniki plain, which meets the sea in a series of deltas.

The plain itself is also bounded by the mountain chain of Paiko (1650 m) to the NW and Vermio (2050 m) to the West. The Pieria hills, the northern foothills of the Olympus massif which streches eastwards to the sea, are the southeastern boundary of Thessaloniki plain. Mount Chortiatis (1200 m) lies almost behind the city of Thessaloniki to the SE (fig. 2).

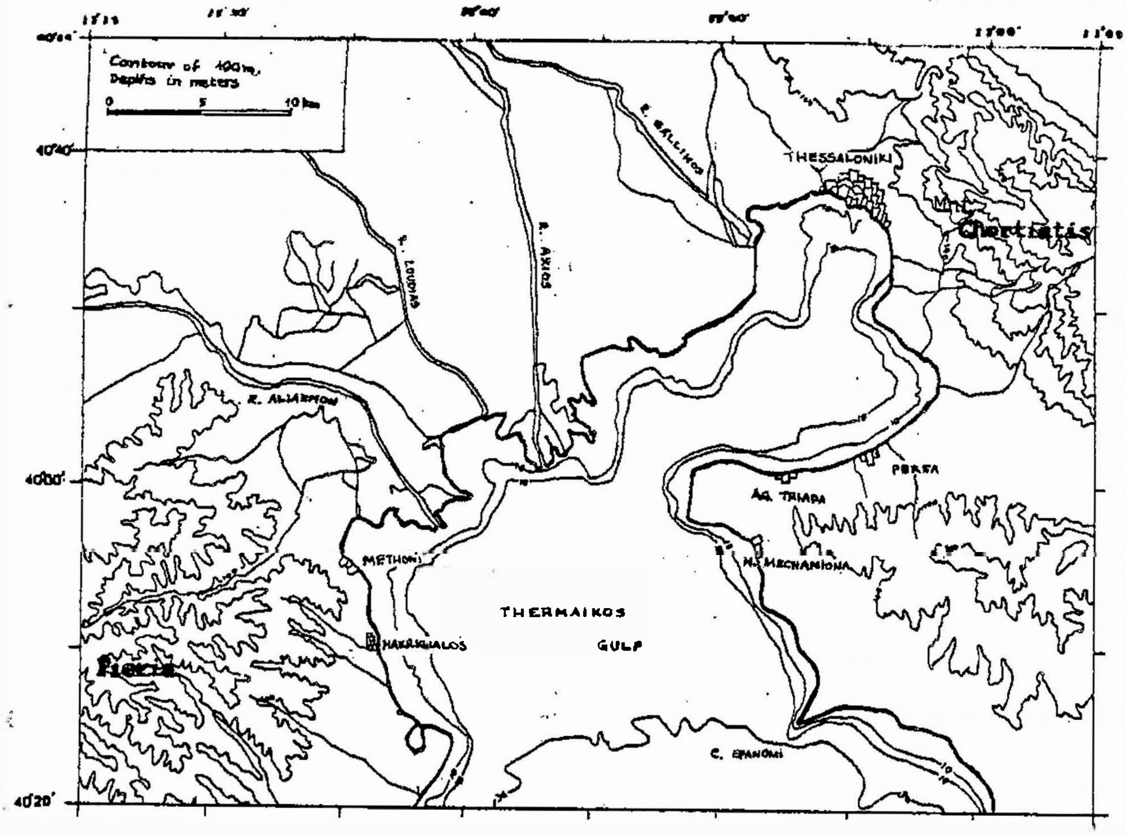


Fig. 2 - Topography of the area (after Chronis, 1986)

Four rivers discharge in the three bays, the Gallikos, Axios, Loudias and Aliakmon rivers. The Axios River owever is the largest river and is mainly responsible for the geomorphology of the area. It drains a basin of 23.000 km^2 and has a route of 380 km from which 300 km in Yugoslavia and only the last 80 km in Greece (fig. 3). The 350 km long Aliakmon River, the longest river flowing entirely in Greece, drains a basin of 11.000 km^2. Loudias River runs between the two major rivers above and is a 38 km long draining channel with a 1250 km^2 basin (fig. 3a). Finally Gallikos River is now only a seasonal stream.

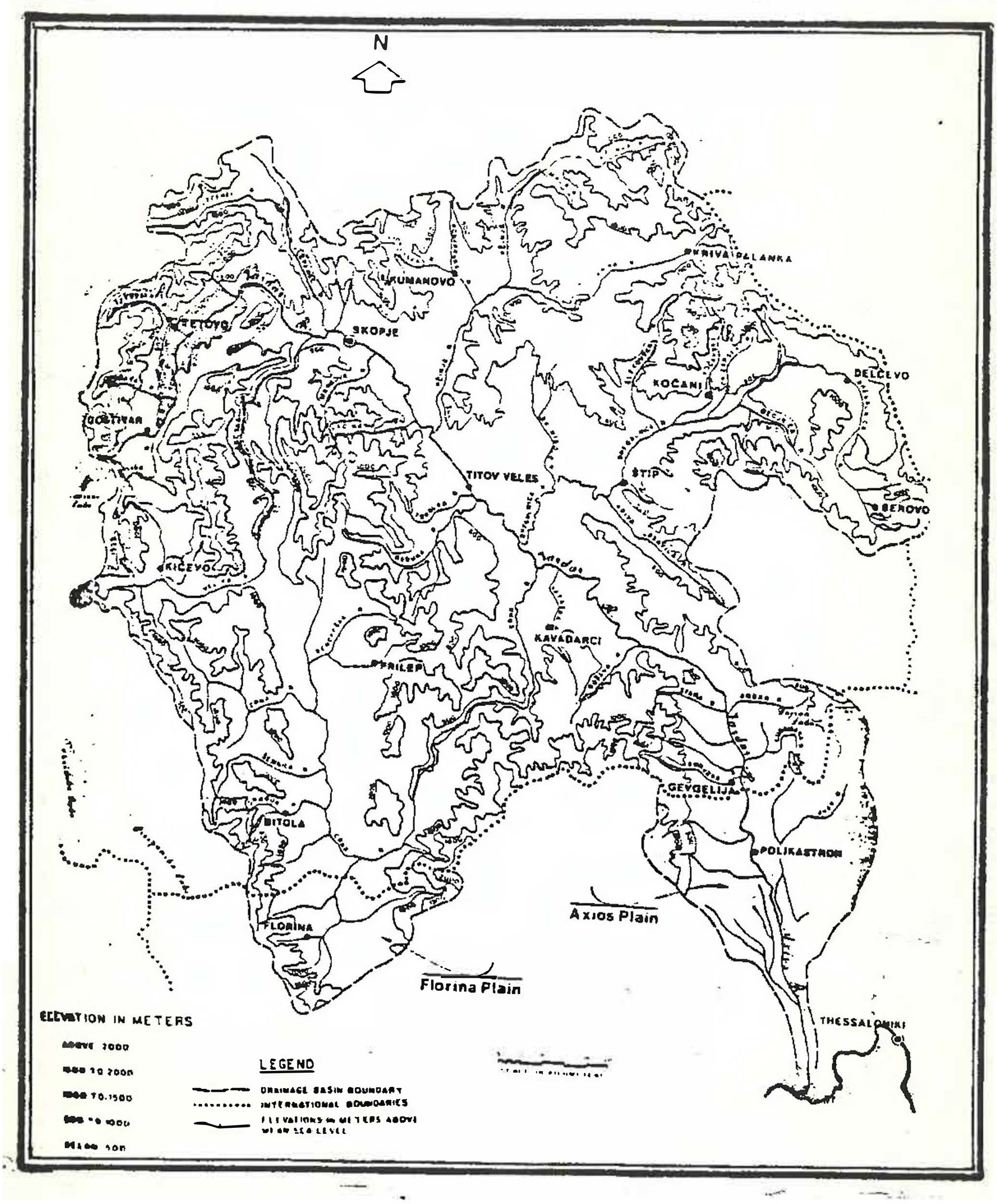


Fig. 3 - Axios drainage basin (after Ganoulis et al., 1988)

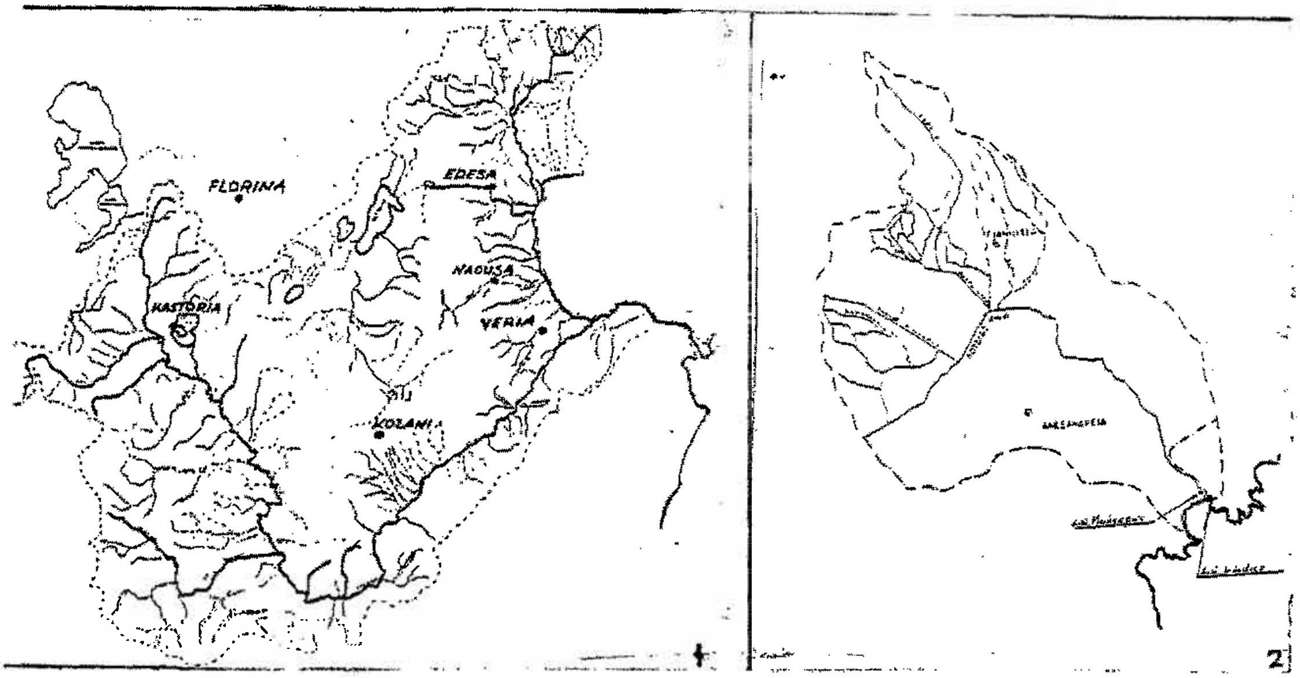


Fig. 3a - Aliakmon[1] and Loudias[2] draining basin
(after Ganoulis, 1987)

The study area belongs geologically to the Axios/Vardar zone which represents the last stage in the infilling of a subsiding basin. This alpine orogenic basin has experienced intense tectonic stresses and has been infilled by debris and volcanic tuffs from the surrounding mountains. The principal factors in transporting the excessive sediment, particularly during the Quarternary, are Axios and Aliakmon rivers (Zimerman, 1971).

The sediments of the basin reflect the time variability of two major contrasting environments, that is sediment of terrestrial origin brought down by rivers, and marine sediments consisted mainly of shell fragments. The interbedded marine and terrestrial facies are particularly evident in the Quaternary deposits of the Thessaloniki plain reflecting the sea level changes (Nedeco and Grontmy, 1970).

2.2. Evolution

As said above, Axios and Aliakmon rivers have been the major controlling factors in the evolution of the progressively expanding Thessaloniki plain, especially since Holocene time, when the sea was close to the alpine marginal boundary (Chronis, 1985).

Historic evidence from the 5th Century B.C. indicate that the city of Pella, the capital of Macedonia at the reign of Alexander the Great was by the sea. The ruins of the city have been located now about 30 km inland (fig. 4). During the 2nd and 1st Century B.C. only an artificial channel existed for the communication to the sea. Struck (1908, fig. 4) believed that from approximately the 5th Century A.D. the progressive filling of the estuary of the Western Gulf resulted in the cut off and final isolation of the shrinking lake of Giannitsa. The lake was connected to the open sea by Loudias river.

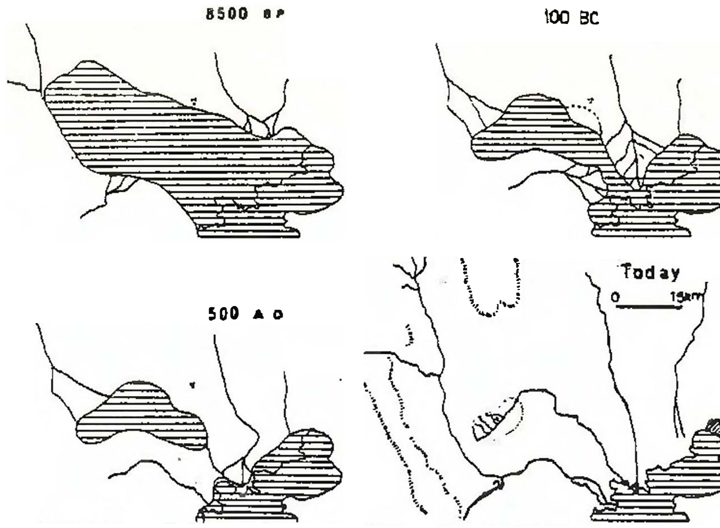


Fig. 4 - The evolution of Thessaloniki plain (after Struck, 1908)

Increased sedimentation gradually drifted Axios delta to gradual westward where the river was discharging either to Loudias River and down to the sea or to the adjacent Gianitsa lake. At the 16th Century A.D., floods turned the lake into a huge swamp, which periodically received the water of Aliakmon River. Although the 19th Century damming of Aliakmon diverted the river course back to the old bank, when the dam broke, it caused catastrophic floodings and malaria became a significant local health problem.

The projects of 1925-1935 diverted the Axios River and bunded the downstream part of it in order to avoid the cut-off of Thessaloniki Bay into a lake. Additionally, the complete drain of Gianitsa lake, the reclamation of the adjacent swamp, and other works, prevented the plain from innundation and malaria. Later, reclamation and irrigation projects converted the area into a highly productive agricultural plain of major economical importance (Evmorphopoulos, 1961).

2.3. Rivers run-off, sedimentation rates

The sediment contribution from the major rivers and the stream system discharging in the Thermaikos Bay is influenced by climate and especially by the precipitation rates. The local precipitation pattern (see chapter 3) has the character of the Eastern Mediterranean region: high during the winter and low during summer (fig. 5).

The observed shallow and deep water circulation is given at fig. 6 (Ganoulis, 1987). A first water management to the upstream Axios/Vardar river in Yugoslavia is undertaken through several small scale water management constructions, whereas in the Greek part, only one irrigational diversion exists. However the present daming is insufficient to prevent flooding. Thus Axios has a very high mud load transport capability with an annual deposition rate of 8.4×10^6 m^3/y in the delta and a lateral of 0.9×10^6 m^3/y on its way downstream (Therianos, 1974).

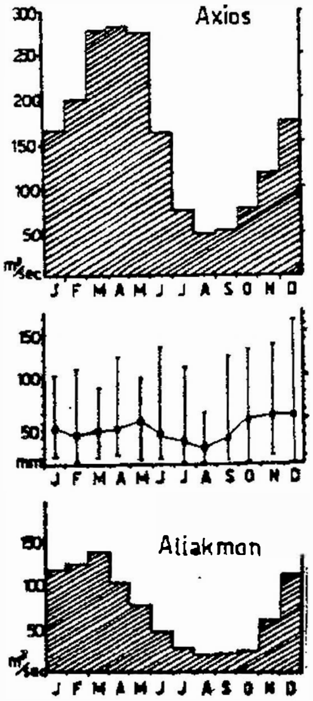


Fig. 5 - Mean annual variation of the runoff of Axios and Aliakmon rivers (Therianos, 1974) and mean annual variation of precipitation (1930 to 1972) (Angouridakis and Machairas, 1973)

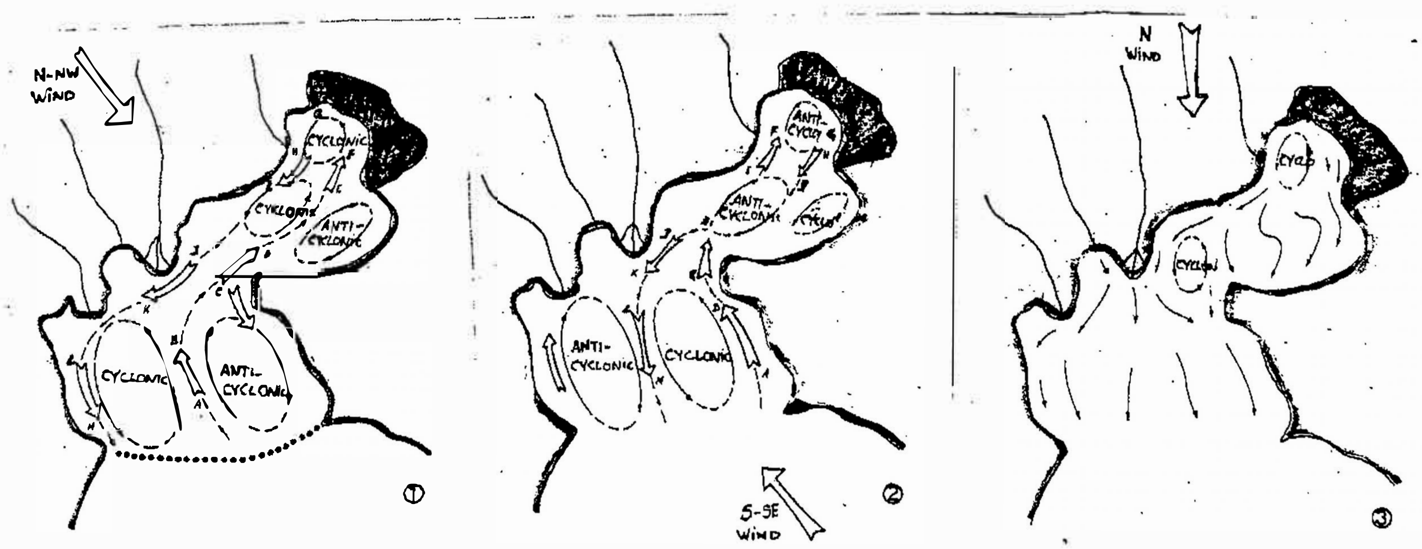


Fig. 6 - Shallow and deep sea water mass circulation models for N-NW (1), S-SE (2) and surface circulation for N wind (3) (Ganoulis, 1987)

On the other hand Aliakmon River has an almost entirely controlled flow through three hydroelectrical dams across its course. Thus in addition to the downstream vegetation, the sand transport load is relatively low with an annual rate of deposition in the delta of 5.6×10^6 m^3/y and a latteral 0.6×10^6 m^3/y (Therianos, 1974). Loudias is rather a draining channel with a very low annual flow of 2-3 $m^3/sec.$, reduced during summer sometimes into nil values under the tidal influence of the sea.

Gallikos River finally has a stream like annual deposition of 0.16×10^3 m^3/y in the delta and 0.04×10^3 m^3/y laterally.

2.4. Circulation patterns, sediment deposition, marine dynamics

The main factors controlling the local circulation in the gulf are winds, tides and density currents. The circulation is different in the three sub-basins, the inner and outer Thessaloniki Bay and the Inner Thermaikos Gulf, which is are considered as one enclosed basin. The prevailing winds are the "Vardaris" N-NW winter wind and the summer S-SE etesian winds (see chapter 3).

Tides are low ranging from 5 cm to 30 cm mean during spring, and following a semi diurnal cycle. Short and long periods of sea level oscillation corresponding to SW sea breezes and barometric pressures are also low (Wilding et al., 1980). There are no significant tidal and density currents in Thermaikos Gulf except during the intensive summer stratification of the sea water masses. The schematic circulation for N-NW and S-SE winds is given at fig. 6.

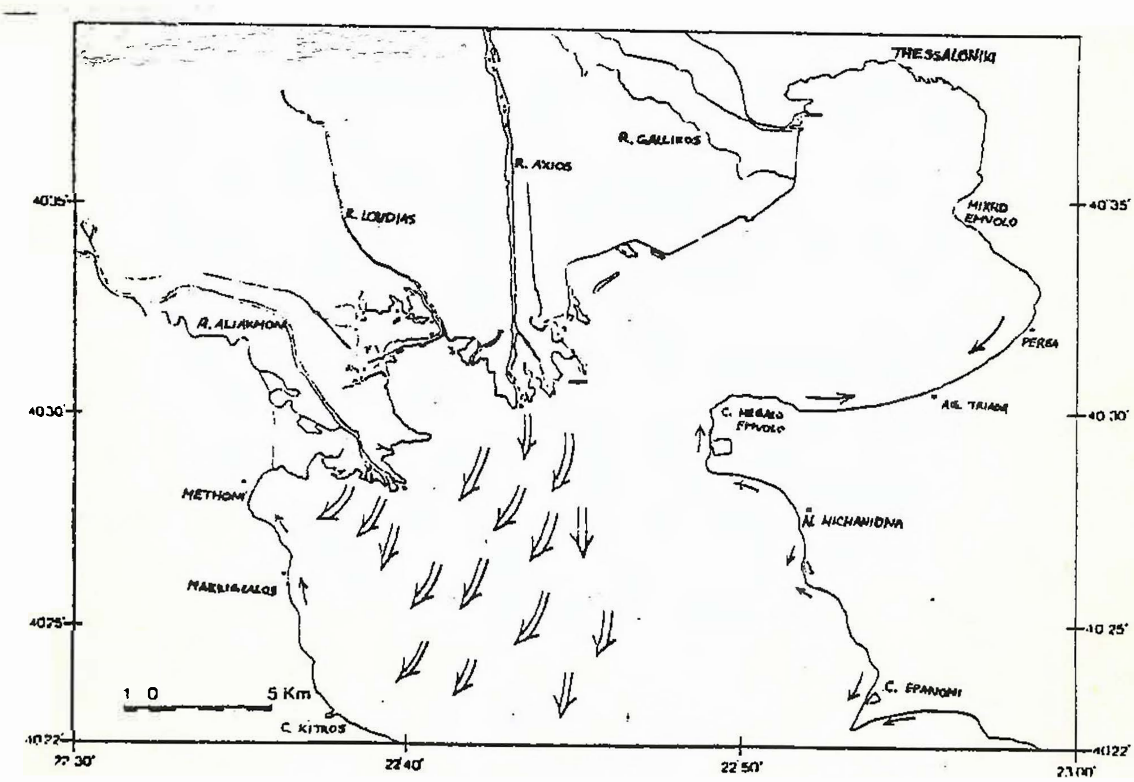


Fig. 7 - River and coastal sediment movement.
Large arrows depict river sediment dispersal
while small black arrows indicate coastal erosion (Chronis, 1986).

Sedimentation at the Gulf is controlled by the quantity and the grain size of the discharged sediment in combination with the oceanographic conditions. Thus, the low amplitude wave energy in the Inner Thermaikos leads to a deposition of the coarser sediments in front of the estuaries. "Bird-foot" delta formation types characterize Axios and Aliakmon estuaries. This caused a fast extension of Thessaloniki plain during the last 1000 years and contributed to the reduction of the width of the Thessaloniki Bay entrance. Thus the present distance between the cape of M. Emvolo (or M. Karabournou) and Axios delta, which is the limit of outer Thessaloniki basin, is only 4.5 km (fig. 7). The limited input of coarse sediment toward the east causes the erosion and retreat of the eastern coasts. Therefore, the only coarse debris which are subject to shorting and reworking from the wave action are these from the erosion of the older steep quaternary sediments at the coast of Emvolo and Mechaniona to the east, and Makrigialos and Methoni to the west of the bay. The erosion takes place under the strong wave action of SE and NW winds for the western and eastern coasts respectively (Chronis, 1986) (figs. 7, 8).

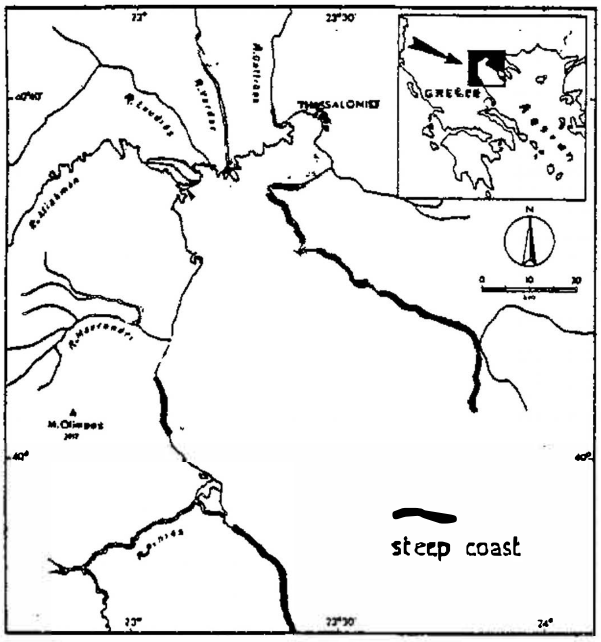


Fig. 8 - Steep coast of high erosion
(abstracted from Branbati and Stefanini, 1970)

The suspended fine material of the river discharges is "sliding" with its fresh water carrier on the top of the stratified saline wedge. It is deposited off the western coast, where suspended particles flocculate to form larger grains. Changes in this depositional regime usually reflect climatic disturbances.

2.5. Impacts

Sea level changes and river transported debris have been the major factors throughout the evolution of the study area. Since any natural environment is subject to a continuous change, one way to outline the expected future climatic changes is monitoring the lesser amplitude mechanisms of the sea level changes.

According to the climatic changes scenario proposed so far, the expected 1°-2°C temperature rise will be followed by a gradual mean sea level rise of 20-30 cm in the next 50 years, as a consequence of the thermal expansion of the seawater column and the partial melting of the polar icecap. In such a case the excessive sea water masses might slowly flood the low lying unprotected coastal and estuarine areas, as well as the lowlands and the reclaimed areas of Thessaloniki plain (fig. 9). This will not be pronounced in the next 50 years, but storm surges will gradually become more intense, causing significant catastrophic events. The intrusion of salt water in the low flow river mouths of Loudias and Gallikos but also at those of Aliakmon and Axios, is expected to take place, especially during high water spring tides reinforced by SW winds. This could possibly lead to a lesser sediment deposition at the upper delta, causing reshaping of todays actual lower deltas. Also lagoons with direct access to the sea will be subject to flooding, while marshes will be converted to lagoons. In 75 years from now, when mean sea level could rise by 0.8-1.0 m. this effect would become noticeable and catastrophic with major economical impacts as the coastline will shift landwards (fig. 9). Most of the coastal areas of the reclaimed agricultural Thessaloniki plain are today defended by a 1.5-2.0 m high dyke along the sea, and at the city of Thessaloniki by a 1-1.5 m high concrete seawall. In this case, the height of the constructions will have to be readjusted.

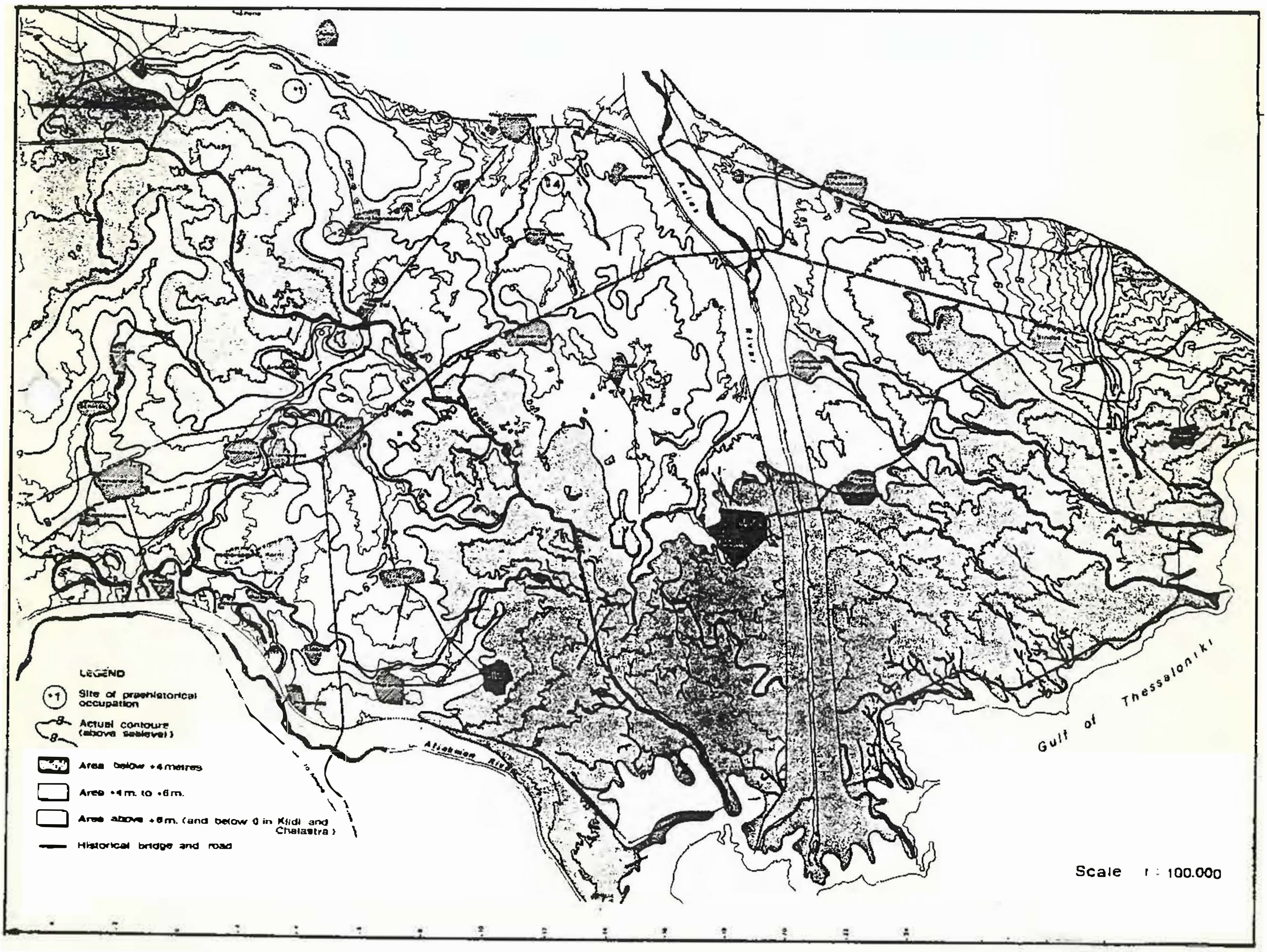


Fig. 9 - The Axios plain landscape showing the lowlying areas of high flood risk (Nedeco and Grontmy, 1970)

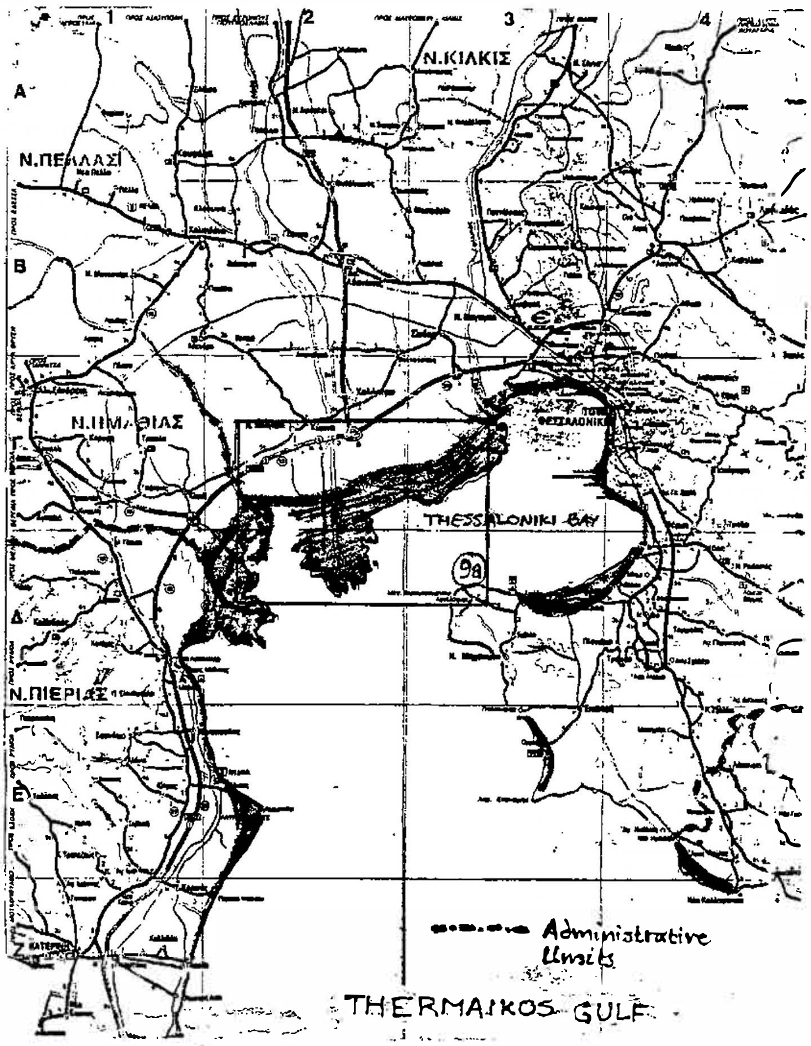


Fig. 9a. - Map of the possible submerged coastal areas at a 3 m. sea level rise
The total area to be covered is approximately 152 km^2

Lowlying sensitive areas such as the industrial zone of Sindos (from the port to Kalohori) (fig. 1), the Mikra airport as well as the area next to Aliakmon River and the east coast are totally exposed to any sea level rise. Therefore, it is urgent to identify and monitor the present coastal lowlands which are vulnerable to flooding, and maps of high flood risk areas have to be drawn.

However, it must be noted that no significant changes are expected in the circulation and the tidal regime of the studied area. Thus, due to the added watermass, short period mean sea level oscillations caused by SW sea breezes may slightly exceed the present tide value of 10-15 cm.

A temperature rise will result in a warmer sea, reinforcing the sea water stratification. This will help the fine sediment transport mechanism, as the suspended matter and the river water will be transported further away. The oxygen depletion and the reduction of the eutrophic zone is expected to cause severe consequences to marine biota (see chapter 4). This might establish bottom anaerobic conditions, especially in the presence of excessive organic carbon environment in the sluggish and polluted waters of Inner Thessaloniki bay. Thus under a reduced sediment input regime, the deposition of sapropelic black mud will begin.

High evaporation due to the warmer climate, will increase the future needs in fresh water and the prevailing hydrological balance will be affected. Axios and Aliakmon river's runoff is expected to decrease due to the greater water used for irrigation and hydroelectric energy.

Faster sediment filling rates at the water reservoirs, the dams and the irrigation channels of Aliakmon river could result from a higher temporal sediment load, due to a more "stormy" type of rainfall onto the drier desertified slopes. The lack of coarse sediment will increase the erosion of the already eroded Eastern and SWestern coasts. In other words the touristic beaches of Emvolo, Mechaniona, Macrigialos and Methoni might eventually be destroyed.

Loudias river is expected to become a polluted stream draining part of Thessaloniki plain during winter. Gallikos river on the other hand, will become a drier highly polluted stream with temporal run, as the precipitation might be reduced into fewer but heavier storms.

3. WATER CYCLE

3.1. Meteorological setting

The greater Thessaloniki area is characterized by a Meso-Mediterranean semi-arid climate with cold winter (min 0°-3°C, Mavromatis, 1980). However, the local climate of the region does not appear to be typical of its latitude and Mediterranean setting. The elongated N-S Axios valley plays an important role in the weather of Thessaloniki plain as it introduces the Eastern European and Balkan peninsula anticyclones to the Eastern Mediterranean. The prevailing N-NW winds frequently blow throughout the year and are enhanced during the winter. During the summer the characteristic southerly Etesian winds of the Eastern Mediterranean region are common but are weak in the Thessaloniki Bay. They follow a diurnal cycle blowing strongly during the day and abating at night. Other winds of smaller scale, like the daily sea-breezes, are generated by the different land-sea temperature. The annual variation of the mean wind speed exhibits a primary maximum in the main winter season (December - February) and a secondary during the main summer season (June - August) (fig. 10, Livadas & Sahsamanoglou, 1973).

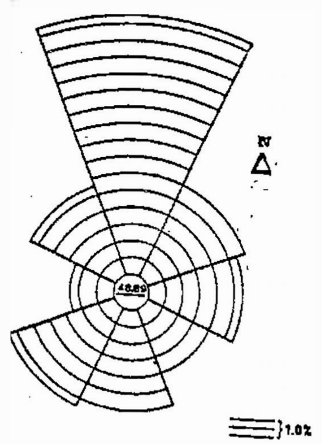


Fig. 10 - Mean annual frequency of wind direction in Thessaloniki (1930 to 1971), abstracted from Livadas and Sahsamanoglou (1973)

In spite of the above, the weather of Thessaloniki is characterized by considerable and rapid variability of all its parameters. Sudden summer thunderstorms occur, possibly caused by the annual frontal cool displacement of the warm and dry southerly winds. The annual precipitation average is 480 mm, being variant during the year. Although precipitation is higher during winter, mean monthly values do not appear significantly higher than those of summer season (fig. 11a,b,c). Air temperature ranges around 0° - 38° C over the year. Therefore sea-water is subjected to a strong cycle of summer heating and winter cooling (Angouridakis and Maheras, 1973).

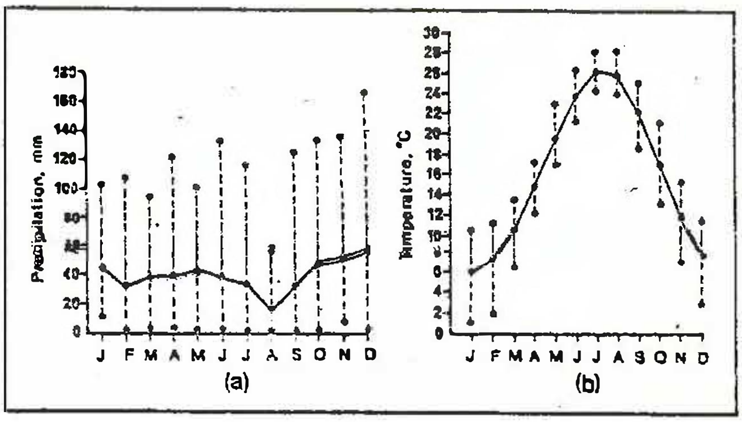


Fig. 11a - Meteorological conditions over Thermaikos Bay:
a) mean annual variation of precipitation (1930 to 1972, abstracted from Angouridakis and Machairas, 1973), and
b) mean annual variation of air temperature (1892 to 1973, from Flocas and Papadimitriou, 1974)

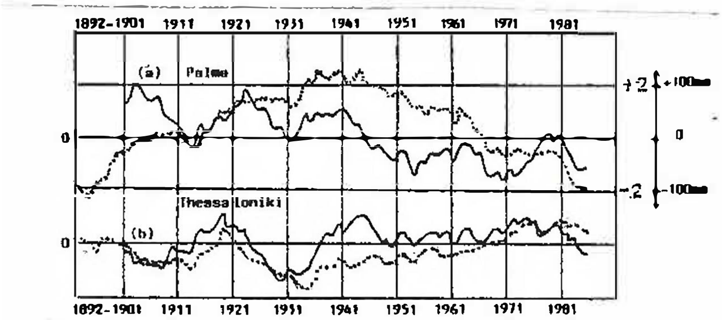
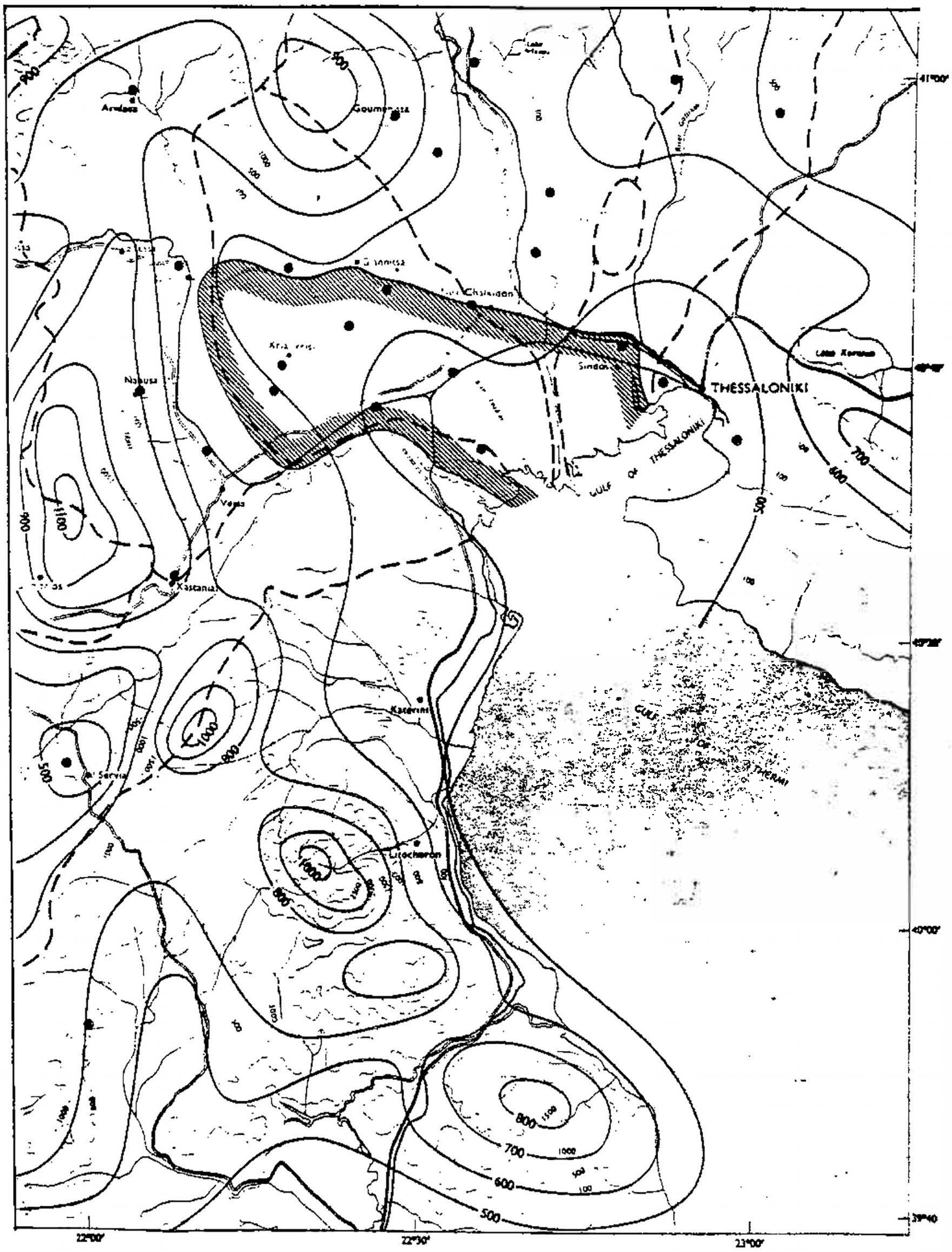


Fig. 11b - Palma (a) and Thessaloniki (b) annual precipitations values smoothed with a 10-year running mean (——) (the values for each ten-year period have been given at its end), and time-series (Palma and Thessaloniki), of annual cumulative deviation from the mean (....) (Maheras, 1987)



----------	Watershed limits
500	Mean annual Isohyet (mm)
o	Rain fall station
//////////	approx. boundary of Thessaloniki Plain

Fig. 11c - Precipitation catchments of the area
(Nedeco and Grontmy, 1970)

3.2 Sewage and industrial output

Industrial wastes, domestic sewage and river discharged pollutants drained from the adjacent agricultural plain and urban areas are the polluting constituents of the inner Thermaikos collector. The inner Thessaloniki Bay mainly receives the inputs of the Sindos drainage channel, of the mentioned north industrial zone, as well as the minor industrial sites in the eastern part, and from the domestic sewages (fig. 12).

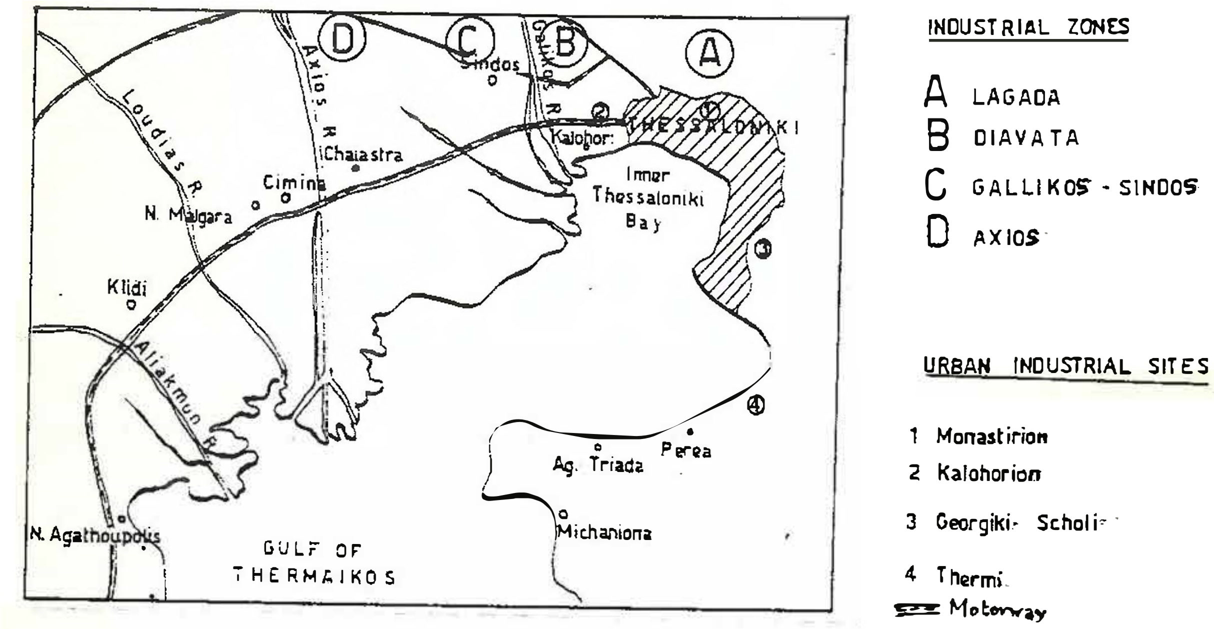
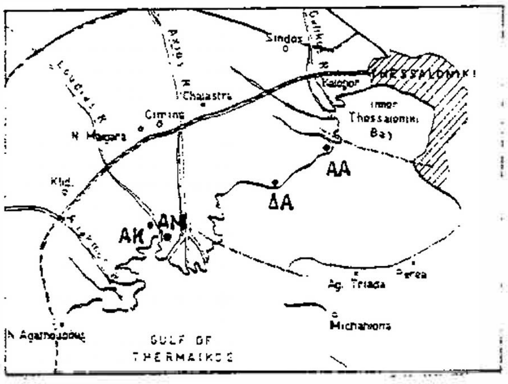


Fig. 12 - Industrial activities

A total of over 10,000 industries are distributed along the greater Thessaloniki industrial zone. Of them, 300 are large establishments. Among the 35 largests are a refinery and a steel mill, papermills, a canning factory and others. They are primarily responsible for the wastes discharged into the inner bay. However, the industrial plants near Axios and Gallikos rivers have waste processing units that discharge either directly in the Bay or to the highly polluted Sindos Channel. Additionally, the domestic wastes of one million habitants of Thessaloniki city are directly discharged unprocessed in the Bay. This sewage input is estimated to amount approximately 130,000 m^3/day of 36,000 kg/day BOD_5 (Ganoulis, 1987). The new sewage disposal project, which is under construction, will provide a main waste collector, treatment plant and finally discharging off the Axios estuary.

The pollutants drained from the plain between Gallikos and Axios delta are derived from the intense agricultural sector and from several industries. At the growing periods, during irrigation "washes", the excessive fertilizer and the other additives (pesticides, etc.) which are carried through the draining channels and the pumping stations and finally are shed into the sea. Consequently, during spring and summer months, the waters of the east and west Chalastra pumping stations are rich in PO_4, NH_4, NO_2, NO_3, NO_3 ions (fig. 13).



AA. Eastern station
ΔA. Western station
AM. Malgara station
AK. Klidi station

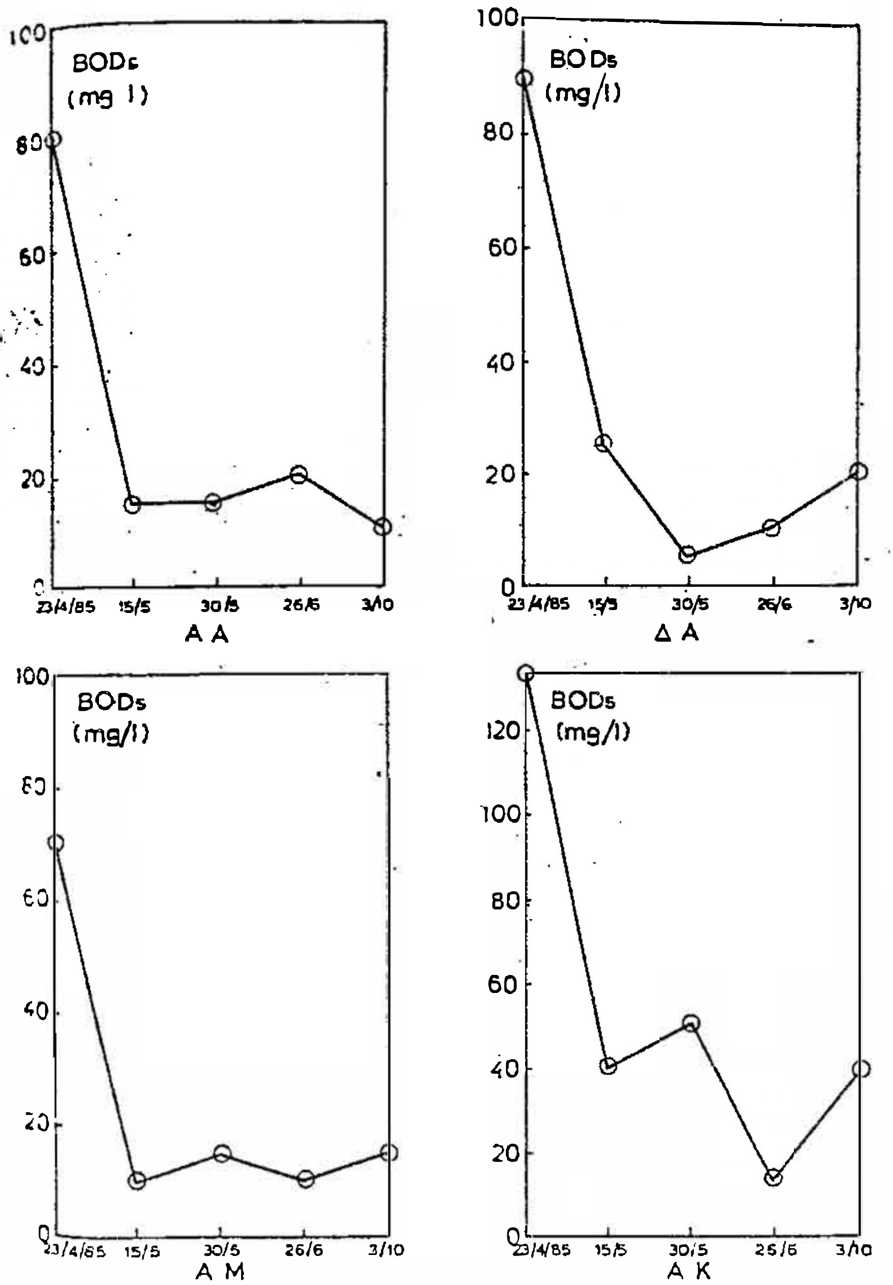
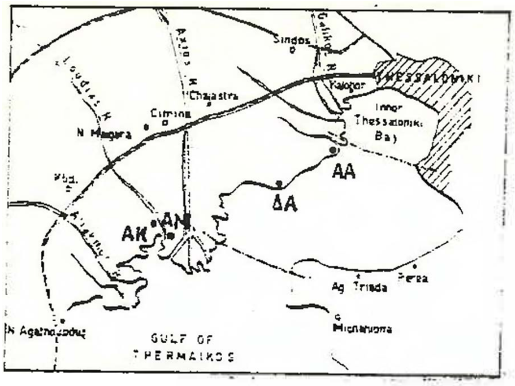


Fig. 13.1 - BOD5 load rates (mg/l)
of the Pumping station discharges (Ganoulis, 1987)



AA. Eastern station
ΔA. Western station
AM. Malgara station
AK. Klidi station

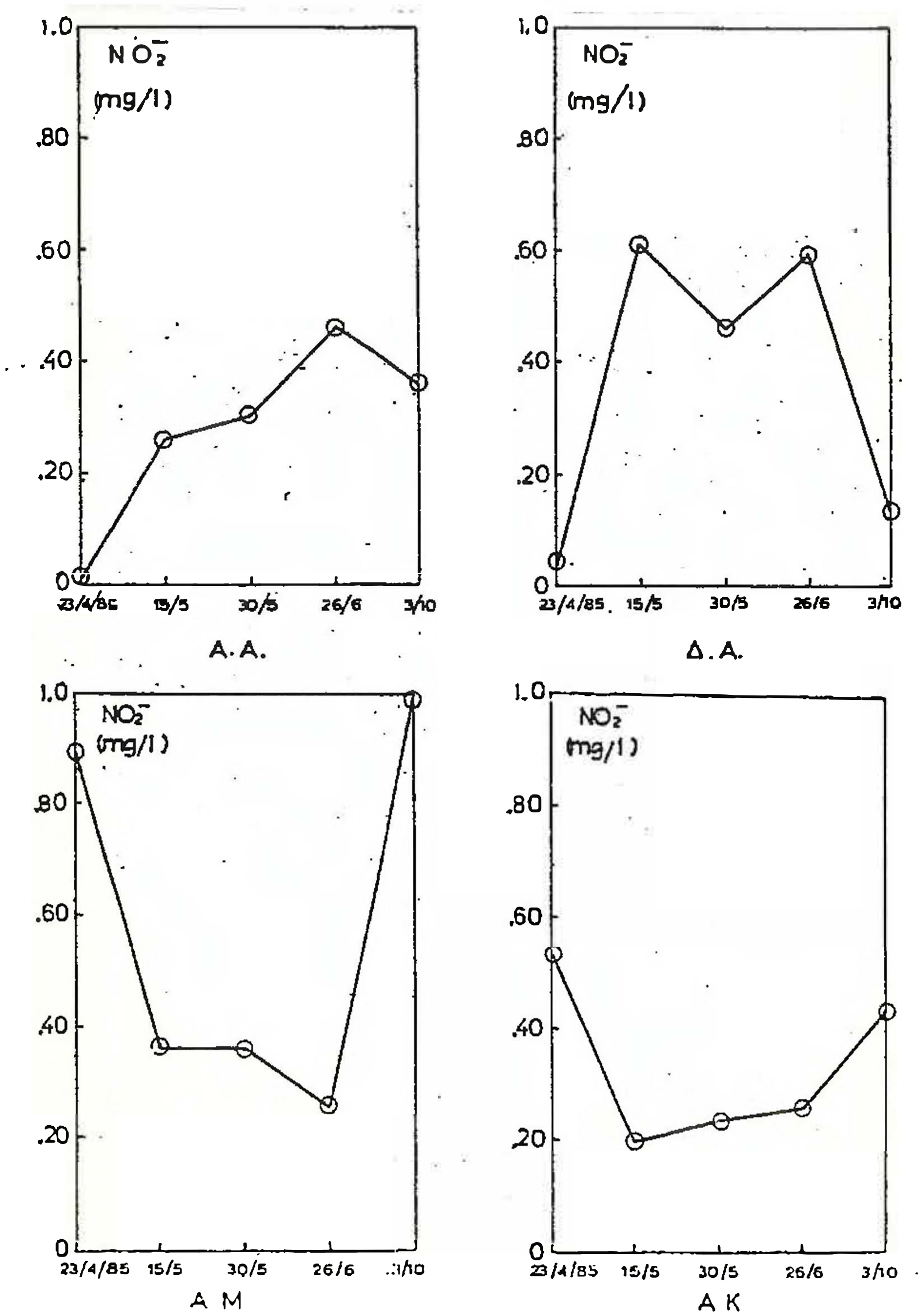
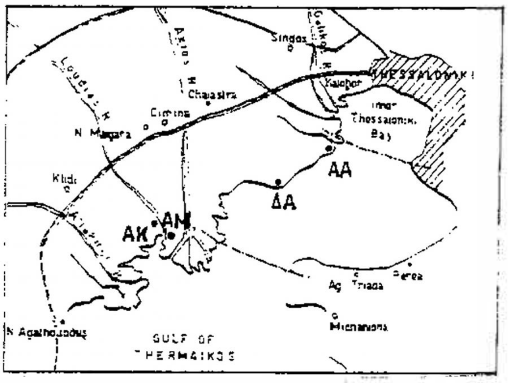


Fig. 13.2 - NO_2^- rates (mg/l)
of the Pumping station discharges (Ganoulis, 1987)



AA. Eastern station
ΔA. Western station
AM. Malgara station
AK. Klidi station

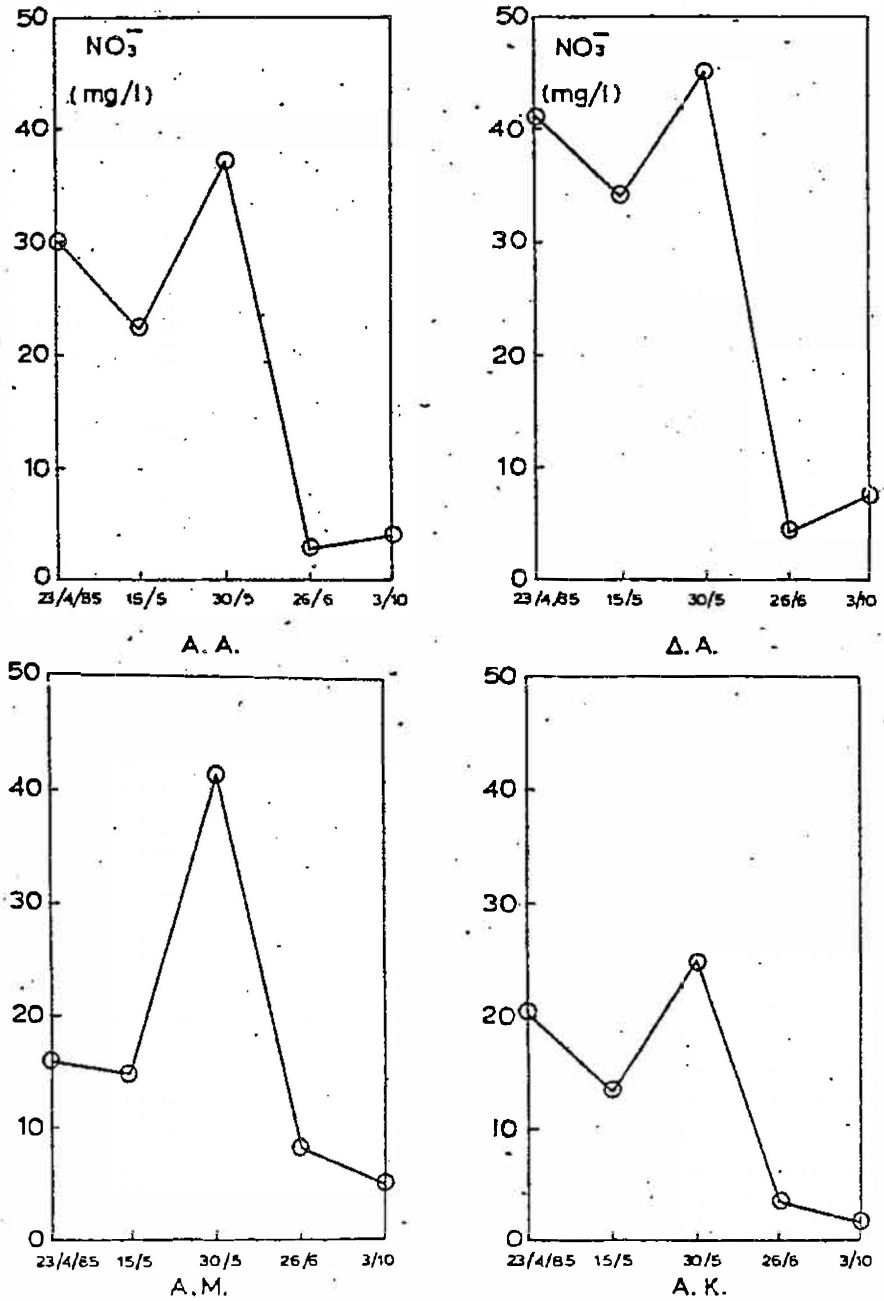
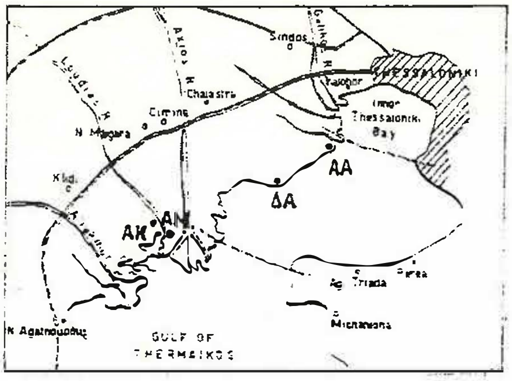


Fig. 13.3 - NO_3^- rates (mg/l)
of the Pumping station discharges (Ganoulis, 1987)



AA. Eastern station
ΔA. Western station
AM. Malgara station
AK. Klidi station

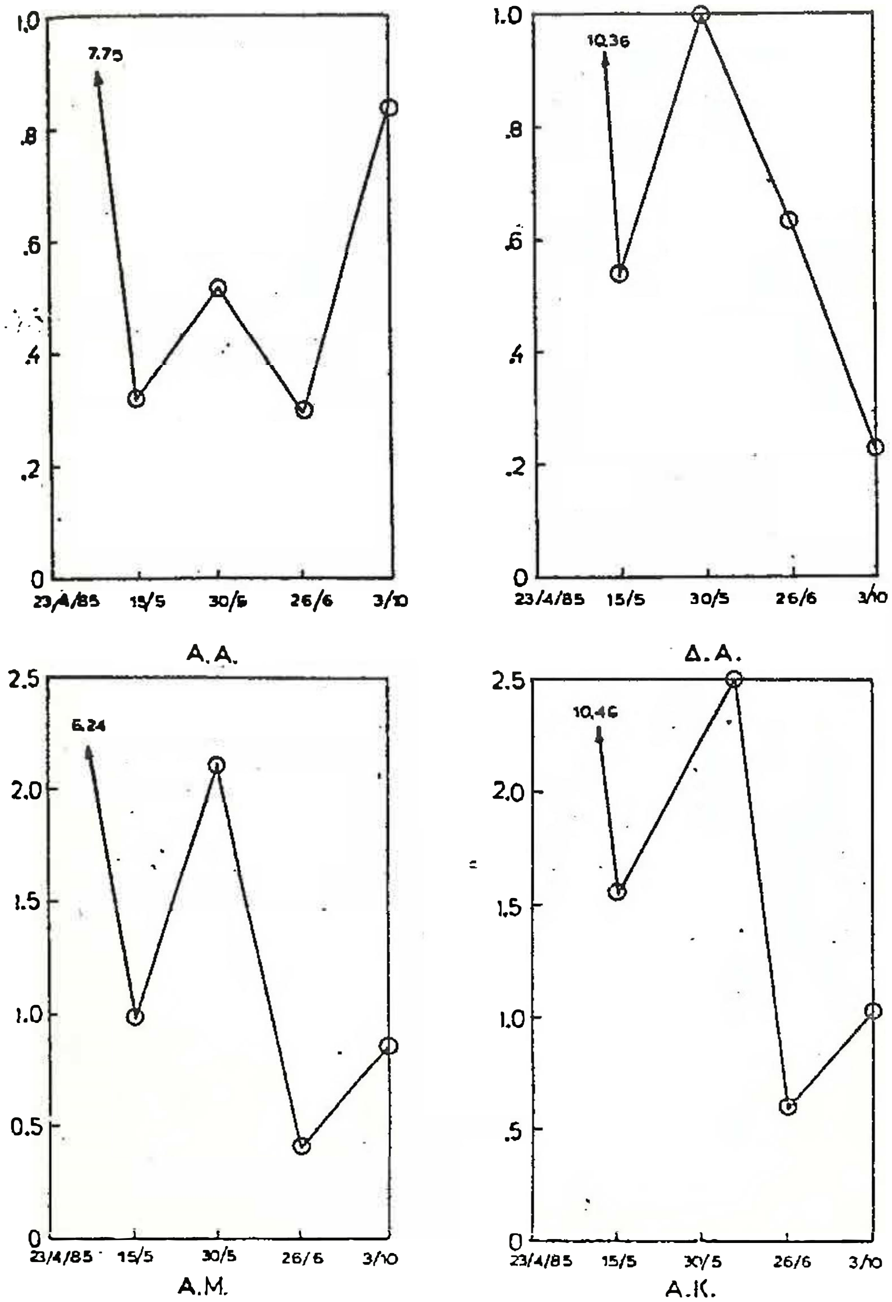
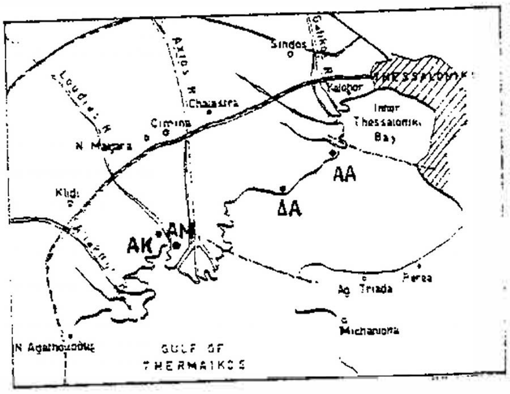


Fig. 13.4 - NH_4^+ rates (mg/l)
of the Pumping station discharges (Ganoulis, 1987)



AA. Eastern station
ΔA. Western station
AM. Malgara station
AK. Klidi station

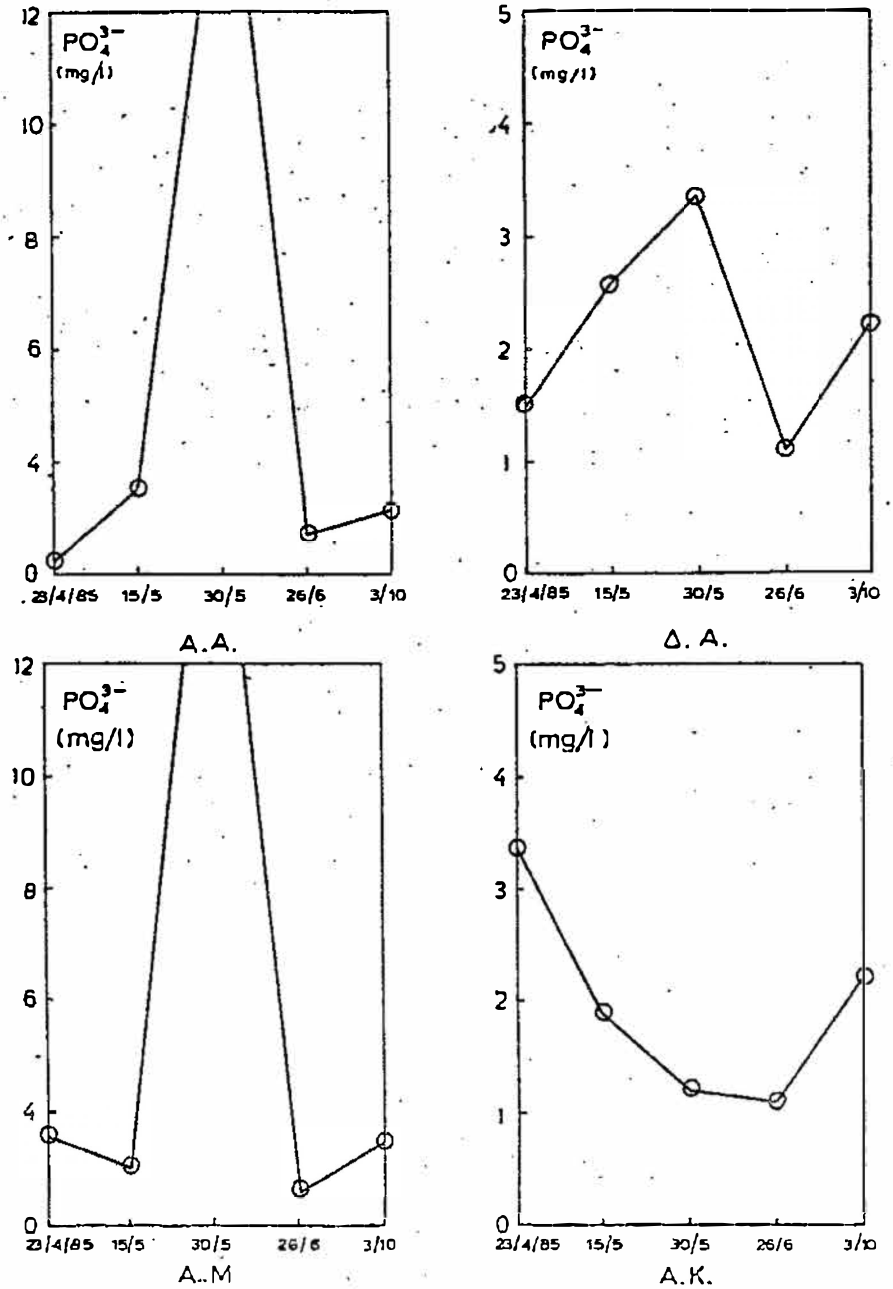


Fig. 13.5 - PO_4^{3-} rates (mg/l)
of the Pumping station discharges (Ganoulis, 1987)

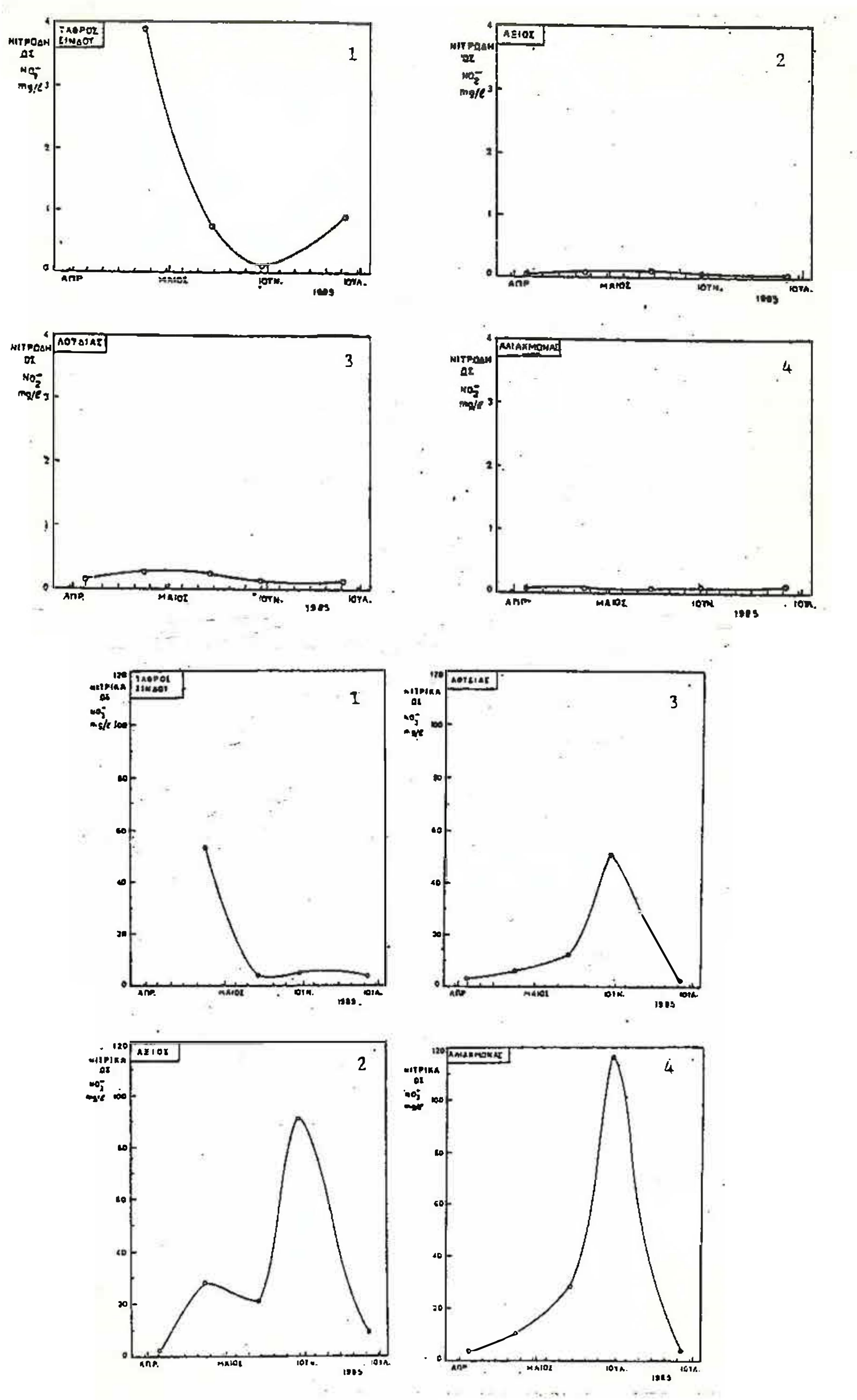


Fig. 13.6 - NO_2^- (higher) and NO_3^- (lower) rates (mg/l) of the Sindos channel, Axios[2], Loundias[3] and Aliakmon[4] rivers (Ganoulis, 1987)

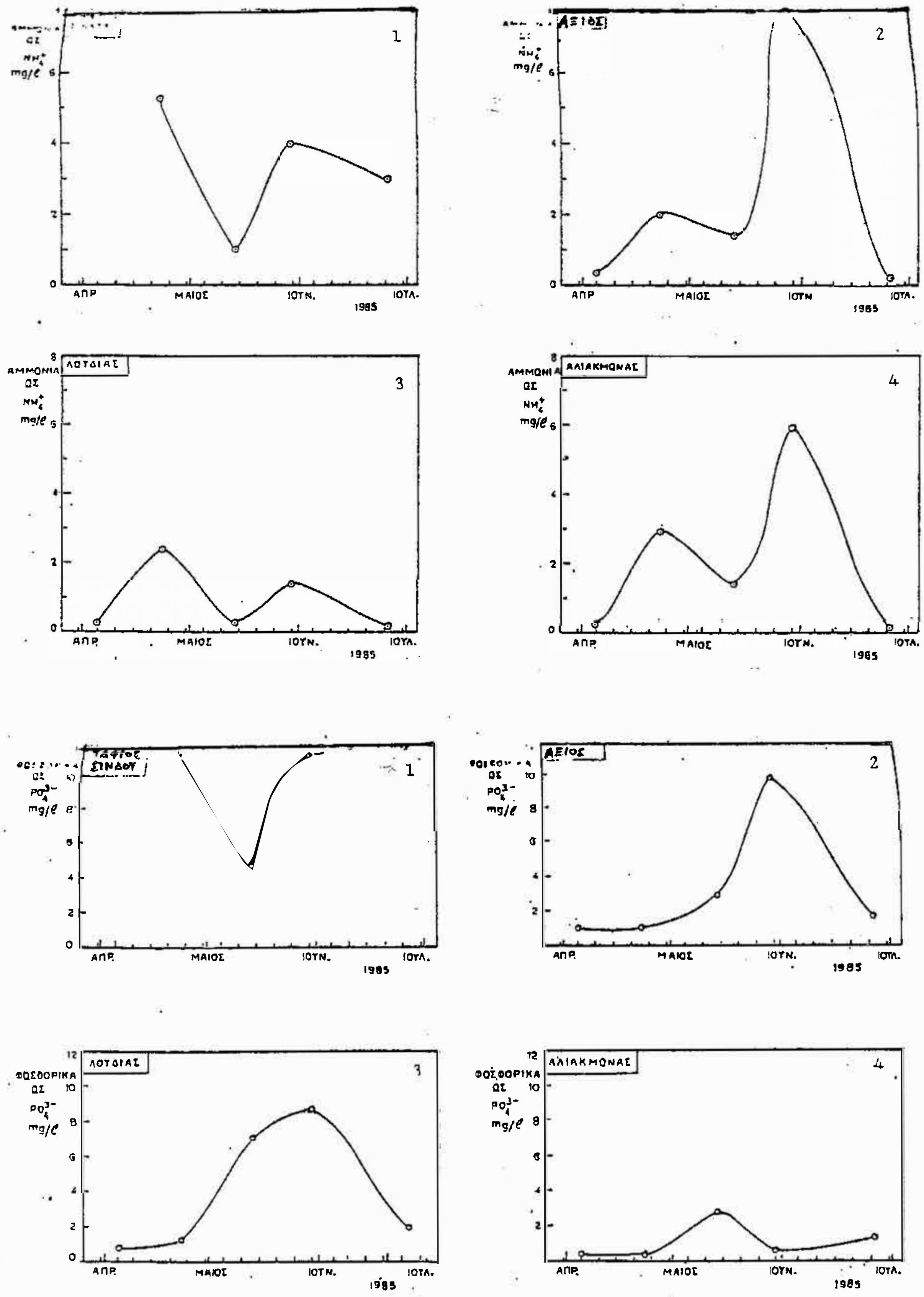


Fig. 13.7 - NH_4^+ (higher) and PO_4^{-3} (lower) rates (mg/l) of the Sindos trench[1], Axios[2], Loundias[3] and Aliakmon[4] rivers (Ganoulis, 1987)

Domestic wastes of the coastal and adjacent villages does not affect the outer Thessaloniki Bay, but Axios, Loudias and Aliakmon rivers as well as the two pumping stations of N. Malgara and Klidi discharge into the outer bay (fig. 12).

Loudias, which is considered one of the highly polluted rivers in Northern Greece, is the main drainage outlet for the greater part of the irrigated Thessaloniki plain area, especially during summer irrigation. It receives additionally a 50,000 m^3/day industrial waste load, rich in organic material, from the milk and sugar plants. It is noticeable that during the growing season months, the values of several pollutants (BOD, COD, PO^{-2}, NO^{-2}) exceed several times the EEC's higher limits (Min. of Environment, 1986). Thus, fishes have disappeared due to the anaerobic conditions formed.

Concerning the other rivers, there are no data available for the Yugoslavian part of Axios/Vardar river, although it runs through large industrial towns (Skopje, Titov Veles). However, Axios and Aliakmon waters are rich in $CaCO_3$, and $CaMnCO_3$ due to the karstic limestone and ophiolithic origin of their drained basins respectively. Finally, Aliakmon is the cleanest river that discharges in the gulf (figs. 13.6, 13.7).

3.3 Fresh water resources and ground water management

Considering the hydrology of the SEastern part of Thessaloniki plain, the surface inflow consists entirely of the irrigational diversion of Aliakmon and Axios rivers. Further inflows, such as rainfall and ground water pumped from artesian wells are added to the water balance of the area. The outflow drain is managed through a channel network where the drained water is pumped via several stations and Loudias channel, described earlier (Nedeco and Grontmy, 1970).

The hydrogeologically important upper sedimentary strata at the whole plain consist of inderbedded marine and lagoonal facies represented by clays, sands and gravels. Thus, the 80 m top-most sediment are of terrestrial origin and are gradually changing seaward into marine, consisting predominantly of clayey and a few thin sandy horizons (fig. 14).

Ground watertables can be distinguished into a shallow phreatic water level (at about 10m depth and a thickness of 6 to 8 m), an intermediate and a deep aquifer.

The shallow phreatic one is supported mainly from the lateral infiltration of the main rivers and other streams, the rainfall and the irrigation. It is largely controlled, however, by the extensive artificial drainage network. Watertable rises and falls within a moving range of 0.30 - 0.50 m in response to infiltration from rainfall. Furthermore it is affected by the summer irrigation and mainly by the lateral subsurface drainage and evapotranspiration.

The artesian intermediate aquifer lies at 40 to 60 m (locally 30 to 80 m) depth and is fed from the same as above phreatic catchments. Also it receives water from the flushing out process of the lateral water movement and from the intake marginal areas in the highlands surrounding the plain. The subsurface main flow direction follows the old riverbed course.

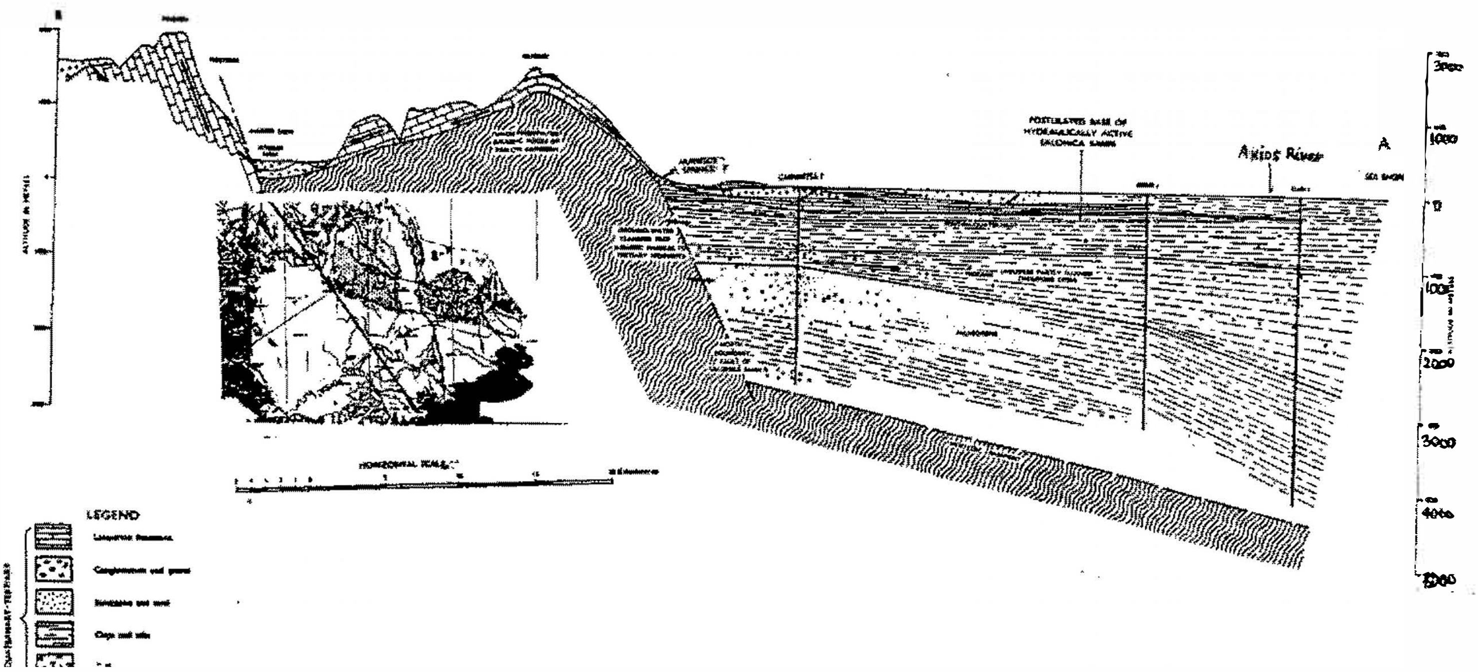


Fig. 14 - Hydrogeological cross section across Thessaloniki plain (Nedeco and Grontmy, 1970)

The deep artesian aquifer lying at a 100-200 m depth, is fed by the same as intake sources above (Knithakis and Tzimourtas, 1987). The marine origin of the sediments produces high salinization-alkalization of the phreatic ground water, as the infiltrating surface water flushes sodium chlorate to phreatic and artesian acquifers. As a result, the phreatic water is subject to high salinization and alkanization while the underlying intermediate artesian aquifer, due to bad water quality is not suitable for drinking. Mean annual fluctuation of the water table is 0.5 - 4 m. Finally the deep artesian ground water finally exhibits satisfactory quality mainly used by the water authority of the city of Thessaloniki and its suburbs. Water table fluctuation in the order of 7 m is common there due to the intensive use of the aquifer.

3.4 Impacts

At present time it is rather difficult to outline the impacts on the water cycle due to climatic changes induced by the greenhouse effect. However, in order to evaluate impacts in the area, the spatial model for doubled green house gases concentration (2 x CO_2) for whole Europe was applied, monitored onto selective local scale (fig. 15). This way we can plausibly assess the bulk climatic changes which are essential for monitoring these impacts.

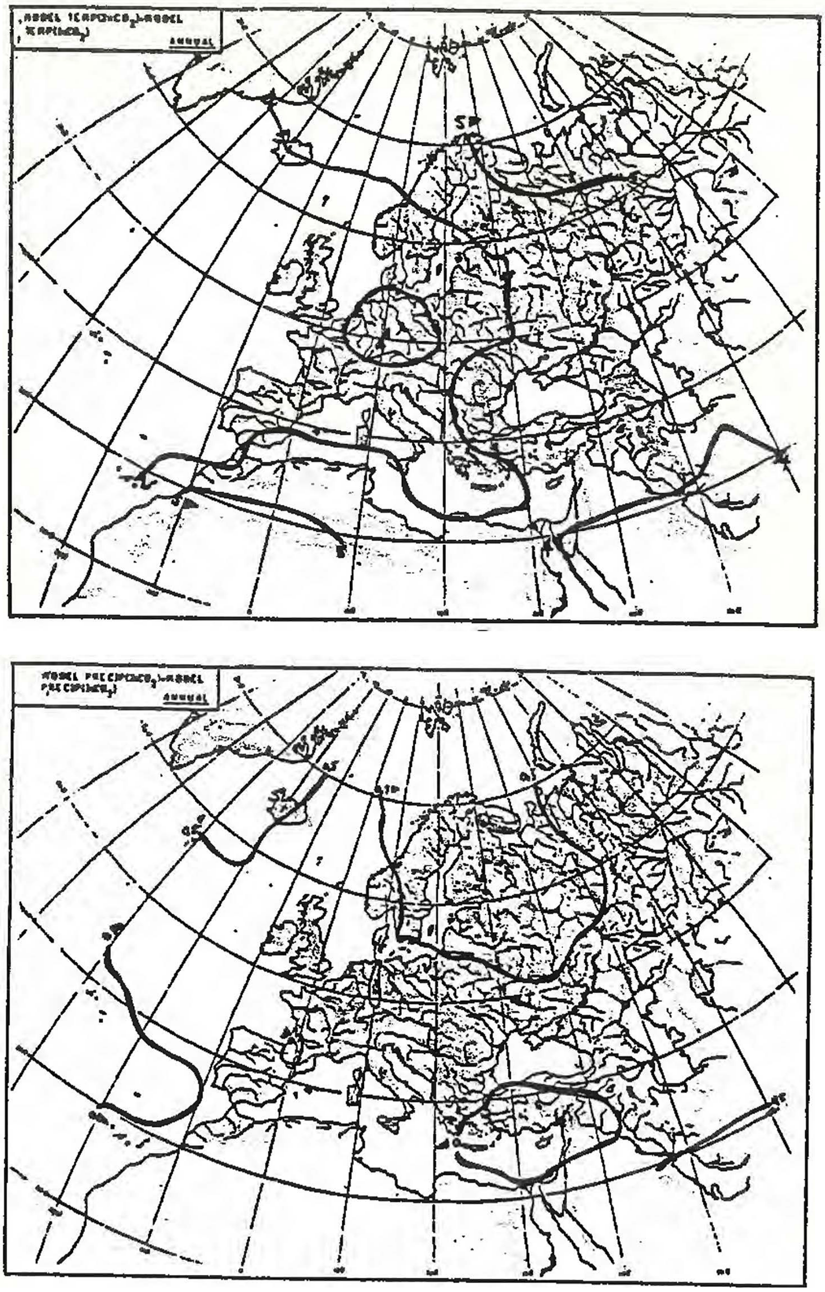


Fig. 15 - The climate scenario as it introduced by the models of the temperature increase annual (a) and the precipitation isoyets (annual) for whole Europe, at a possible doubling of CO_2 concentration (Wigley, 1987).
The values of the study area are: +4°C and 0-0,5 mm/day

Based on the scenario of Wigley and Pitovranov,introduced during the European Workshop on interrelated bioclimatic and land use changes (vol. A, 1987) a future northwards climatic shift is expected. According to this, the autumn and spring seasons will be shortened in length, whereas winter will be gently mild and rather moist.

Although the local cyclonic future regime of the southern end of Balkan peninsular is unpredictable, Vardaris, the highly important prevailing north wind, is expected not to be affected. Summer Etesian winds, on the contrary, might be increased due to the temperature rise.

The above Mediterranean precipitation pattern will be subject to slight change. Local annual precipitation will rather be reduced, characterized by increased variability and patchiness of the rainfall, while warm season rainfall will almost disappear, transferred to winter. In the meanwhile, aridity will be increased as a result not only of the decrease of the annual amount of precipitation but also due to the change in frequency and magnitude of the rainfall events. Also due to the temperature rise, a higher evapotranspiration regime will be established. On the other hand, a chain of impacts associated with the probable deterioration of soil properties and structure will take place, which might influence the balance between infiltration and runoff especially at the reclaimed areas. The benefited overland flow, in contrast to the infiltration, could result in excessive erosion and flooding of the whole drainage basins and the lower plain, causing also hydrological disturbances. Therefore, a general decline in percolation and eventually in the ground water supply must be expected.

Saline water will intrude further landward into the plain's subsurface, overcoming the present limits which are roughly estimated up to the height of Athens-Thessaloniki motorway (fig. 12), thus deteriorating the phreatic water and soil quality. On the other hand, there will be no direct impact of this to the phreatic intermediate and deep artesian water. There is also no evidence that coastal artesian aquifers have direct access to the sea, as they exhibit almost constant annual salt variations throughout the year, which is due to its mainly marine sedimentary strata. However, quality might be influenced by the fact that the overlying phreatic water will be deteriorated due to lateral percolation.

Under a rising sealevel the irrigation and drinkable freshwater needs will be risen, especially during the summer. Thus the intensive use of the artesian water might gradually result in seawater intrusion. In this case first the intermediate first and then the deep coastal aquifer, will be subjected to salinization, deteriorating the quality of drinkable water sources (Kalohori, Axios) which are used by the city population.

Lower discharges of surface flow will reduce the river's ability to dilute waste materials brought into them. Sea and water pollution is therefore likely to increase unless effluents are properly treated. Firstly the already highly polluted Sindos drainage channel and later Loudias river, as well as the other minor draining channels have to be incorporated into a central cleaning sewage system of the whole Thessaloniki area.

Finally bacterial growth will be stimulated by high temperature and water born health risk will agrevate. Additionally, wa. rmanoxic stagnant waters and sediments, mainly during long warm periods will present ideal growing conditions for seveal pathogens, increasing the risk of infections, especially malaria, in "swampy" areas. Diseases which are now either absent or exceptional might become recurrent and significant, possibly in epidemic form, unless hygiene standards be readjusted.

4. ECOSYSTEMS

4.1. Soils

The pedological features of the area under study are characterized by interbedded marine and lagoonal formations and river deposits. The first are classified as entisols, whereas the second are classified as inceptisols. The high mica and the relatively low quartz content is typical of the soils occurring in the area. The poor clay crystallization and the sand disintegration exhibited, is also typical of young soils, in which processes are still under development. According to the silt content, several soil families are distinguished ranging from fine coarse silty soils along the coast, into more clayey types landwards. Permeability depends largely on the top soil structure and tends to increase with depth. The silty soil families exhibit high drainability and are usually used for rice growth. The construction of the drainage and irrigation systems at Axios and Aliakmon rivers carrying water rich in Ca^{++}, led to a decrease of the soil salinity and alkalinity. The application of gypsum based techniques were also beneficial to the desalinitation of the reclaimed plain soils. Although de-alkalinization is a slower process than desalinization the occurrence of non-saline/alkaline soils indicates a high improvement of the reclaimed soils. The persisting salinity in a few spotted areas is due either to the insufficient irrigation and drainage conditions or to upward seepage and concentration of saline ground water in conjuction to a locally high watertable (mainly along Loudias and South of Aliakmon Rivers). In general, salinity increases with depth, indicating a leaching process. (Nedeco and Grontmy, 1970).

4.2 Biota

4.2.1. Flora

Terrestial vegetation of the coastal environment is characterized by the following vegetation types: sandy beaches; rice fields; saline soils; marginal saline soils; lagoonal; and river forest. The river drained basins exhibits broad bioclimatic zonation. Following is a brief examination of these types:

- Vegetation of the sandy beaches

Along the W-SW coast, between N. Agathoupolis and Aliakmon (fig. 17), as well as at several sites on the estuary of Axios, the loose sand and sedimentary zone has an extent of 3-6 m from the sea, and is colonized by nitric, nitrophile and sandy type vegetation. On the intertidal zone, especially in places where organic detritus is accumulated, the Salsola kali-Xanthium strumarium plant communities are growing, typical and exclusive species in all Greek coasts. On the coasts with lesser slope, such as south of Aliakmon and between Axios river bank and Kalohori (fig. 17), the area is occupied by the Antipicethum Tatarici community (see appendix I). Although it doesn't appear to be any typical "sand dune" plant community, a few data are available (appendix I, Ministry of Environment Report, 1986). In the densily habited and highly populated eastern coasts and beaches, chlorophycaea and phenophycaea species are spread characterizing the aggrevated marine environment and all biotopes of the eastern coasts of the Inner Bay. Consequently, there is negative evolution of the benthic flora which is contaminated from the industrial and domestic wastes (Nicolaides 1985).

- Vegetation of rice paddyfields

Rice fields are man-made temporal wetlands, characterized by shallow stagnant water, more like an artificial lake environment. The rich algal floor, mainly due to high eutrophic level of the water, plays an ecologically important role for the rice growth. Several nitrogen blocking blue algae species, appeared on alkaline cultivated soils, supply nutrients and oxygen to the rice. On the other hand, several fishes living at the rice paddies (i.e. Tilapia nitolica) feed on blue algae. The seasonal micro- and macro-flora of the rice paddyfield and the adjacent irrigation and drainage channels are listed in Appendix I.

- Saline soils vegetation

Where cultivation was established after reclamation, marine soils predominate. Typical Mediterranean communities are locally found, the dominant of which are:

- the coastal Salicomiethum european, spreading in the extended submerged areas, which are flooded most of the time (lagoons, saltmarshes);
- Salsola soda-Sueda splendens on limited humid areas at the estuaries;
- Halocnemum strobicei occurs at the recently reclaimed areas between the rivers;
- Juncetum maritimi, at the areas very close to the sea;
- Hallmionetum portulacoides, occurs near channels and creeks on saline soils.

- Vegetation of the marginal saline soils.

Estuarine places, which are not under the direct influence of seawater, are considered marginal. Although most of these marginal areas are now cultivated, locally the dominant species is Juncus acuctus which grows in huge communities, especially between Loudias and Aliakmon Rivers. High growing shrubs (Tamarix hampeana) are met on elongated strips along the banks of downstream Axios and Aliakmon rivers. Tamarix shrub grows better in humid conditions while in saline places its growth is limited. These species are considered an ideal biotope along both rivers, and are protected by the Ramsar contract.

- Vegetation of the lagoons

Reed families find favorable growing conditions in lagoons and swamps forming two communities, Bolboschoenetum maritimi on saline fresh water and Phragniterum in small channels with direct access to the sea.

- River forests vegetation

Relict river forest vegetation is present along the downstream banks of Axios and Aliakmon rivers, where dominant species are Salix pedicellata, Salix alba, Populus alba and Alnus glutinosa.

4.2.2. Fauna

It is rather impossible to mention here all the individuals of the whole food web present in the lively estuaries of Axios and Aliakmon. Table II gives the dominant species of microorganisms, bacteria, microfauna, benthos and downstream fishes of Axios and Aliakmon rivers. Additionally a list of amphibians, reptiles, mammals and birds provide a rough idea of the wildlife of the area.

Although land reclamation in addition to the recent projects, have limited the natural biotopes, the deltas of Axios and Aliakmon Rivers are still considered as wetlands of major importance. The Ramsar contract protect the forests along the downstream banks of Axios and Aliakmon, at the small sandy river islands and the salt marshes and lagoons. The summer rice paddyfields are all ideal places for birds which nest or temporarily rest at the estuaries.

Most of these significant bird colonies, unique in Greece, are of the biggest in Europe (except USSR). Birds are spread from Aliki lagoon (20 km south of the study area) up to Gallikos river and from the coast to the marginal cultivated land. The wetland is characterized by the widespread salt marshes lagoons and swamps, with abundant mudflats. The low tidal range and the low amplitude seasonal prevailing north wind (Vardaris) permit a great deal of the coastal zone to be a host environment available to thousands migration birds (Ministry of Environment Rep. 1986).

A significant number of eagles, herons, and cormorants nest along the banks of downstream Axios between the main motorway and the railroad, as well as into the reed beds along the channels of Loudias. Also a big commmunity of avocets rests on Aliki (near Kitros) and pelicans were seen in the mouth of Aliakmon Riveeeer. Marsh harriers are often fed from the rice fields, whereas knots, plovers, avocets and curleens are met at the mudflats during winter. Gulls seem to be benefited from the developing pollution in the deltas while the limited number of duck and geese are seriously reduced due to hunting.

4.3 Agriculture

The productive estuarine area as well as the rest of the plain were formed after reclamation and subsequent soil improvements. When the area was given to cultivation, the complex ecosystem was benefited from irrigation, and was soon developed into a more simple one with high fertility and productivity. Thus, by enhancing nutrients and by adding fertilizers, better yields were achieved. The action of soil bacteria however, was critically reduced, thus introducing the use of insecticides, which are essential to reinforce the reduced resistance of the plants. Although, the link of the ecosystem was already broken as a result of the agricultural development, all crop cultivations are characterized by the extremely high use of fertilizers which then increase the eutrophic level of the main collector. Also insecticides and pesticides negatively affect the marine ecosystem.

Today the highly productive Thessaloniki plain is of major agricultural and economical importance. In an area of about 24,000 acres, the sector between the rivers is cultivated mainly with maize, rice, cotton, cereals and sugar beets. The rest of the lowland is used for pasturage and animal breeding (fig. 16).

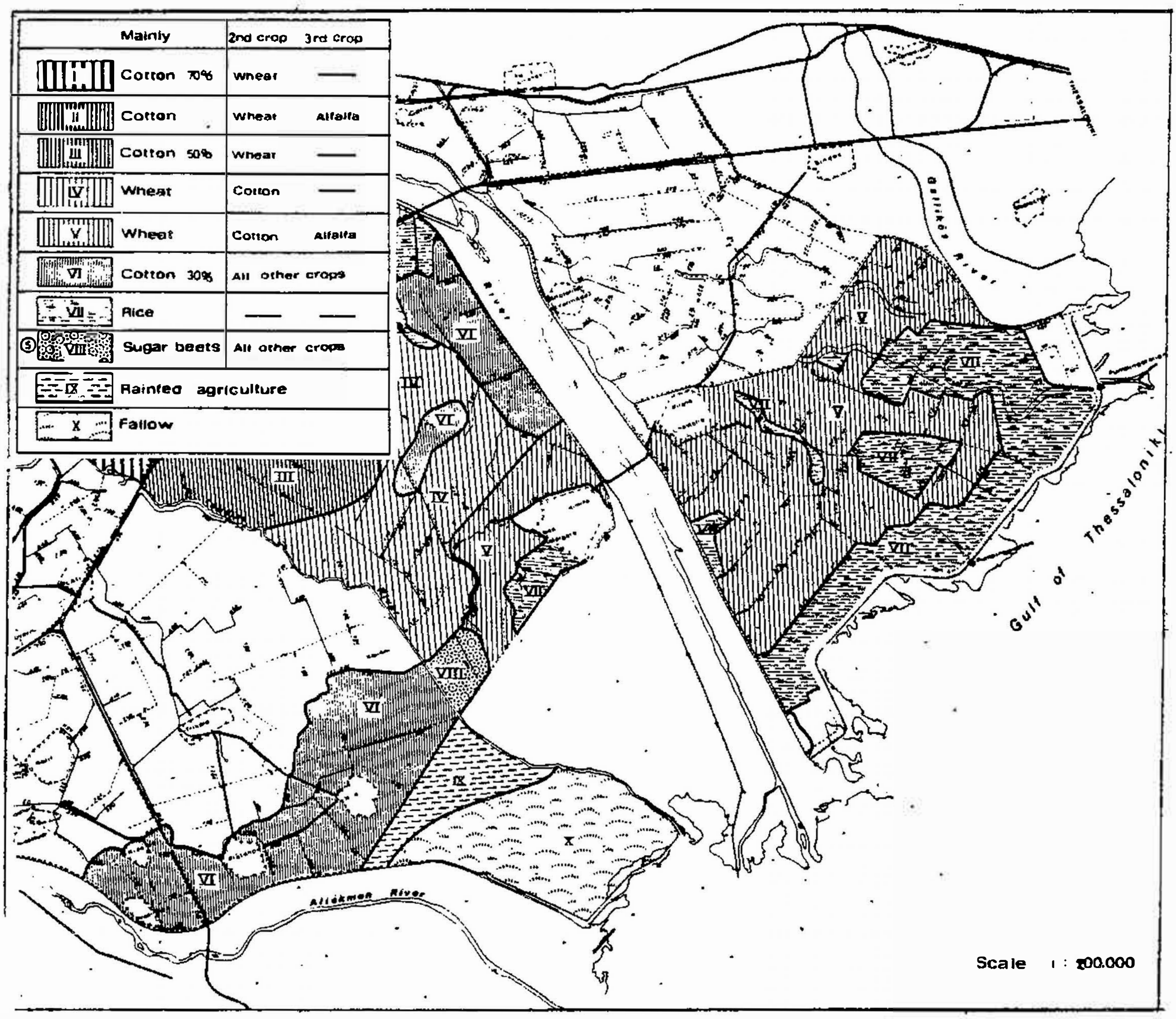


Fig. 16 - Crop distribution on the coastal Thessaloniki plain
(Nedeco and Grontmy, 1970)

Corn is considered one of the most valuable mechanical crops, easily grown in a wide variety of soils, ranging from sandy to clayey silts. Yields are around 800-1200 kgr per 1000 m^2. Saline coastal areas between rivers having high a watertable of ground water are the host environment for intense rice growth. This fully mechanized crop with high needs in water (3 m^3 water per m^2 area) yields 600-8300 kgr per 1000 m^2. Cotton is mainly cultivated between Loudias and Aliakmon Rivers, yielding 300-400 kgr per 1000 m2. Sugar beets are cultivated to the NW plains end in close distance to the sugar factory, yielding 5,000-7,000 kgr/1000 m^2. Cereals are mainly bewteen the Aliakmon and N. Agathoupolis (fig. 16). The 1986's agricultural production of the coastal plain area and its percentage conbribution to the total production of Thessaloniki district (in brackets) for the various crops was: cereals: 48,400 t (21%); corn: 61,000 t (75%); rice: 76,000 t (100%); cotton: 31,600 t (80%), sugarbeet: 27,400 t (81%) (Prefecture of Thessaloniki, 1986).

4.4. Aquaculture

The Gulf of Thessaloniki has been known widely for the excellent quality of its fish, but pollution has gradually downdegraded the marine environment. Fish farming was known in the area since the last decade, while between Loudias and Aliakmon a big fish hatchery was employed. Today the inner Thesssaloniki Bay is seriously polluted, by the industrial and domestic sewage and, as a consequence, fishing activities were banned. However, due to high eutrophicity, estuaries are still attracting fish, especially at the Loudias and Axios estuaries.

At the outer Thessaloniki Gulf, in the estuaries of Axios River and at the opposing eastern coast, there is a number of primitively equiped oyster and mollusc farms (fig. 17) with a total production of 1000-2000 t/year.

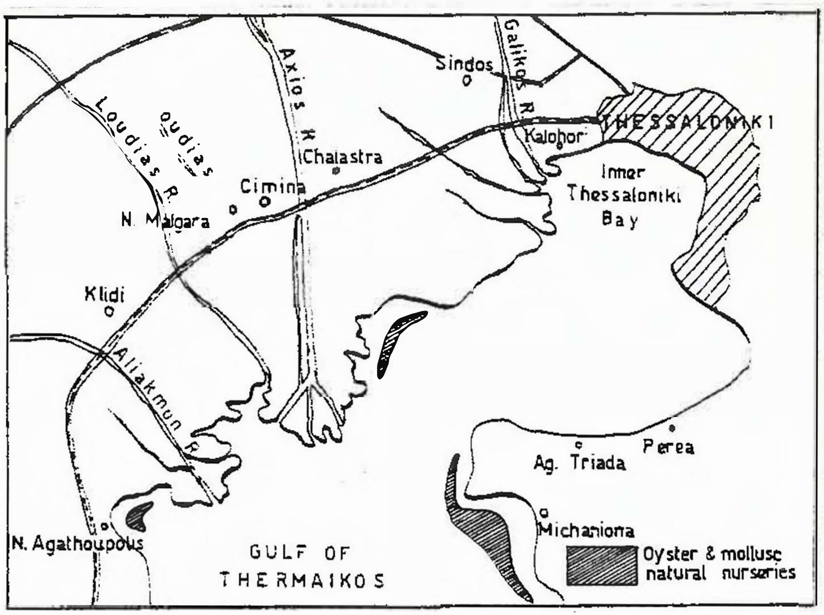


Fig. 17 - Sites of natural nurseries of oysters <u>(Ostria edulis)</u> and molluscs <u>(Mytilus galloprovincialis)</u>

4.5 Impacts

Soil, considered as an open system, will respond immediately to the dynamic processes which might be induced by a warmer and rather dryer environment. These processes will include the subsurface hydrology and soil chemistry as well as the nutrient balance of the soil.

Small changes in terms of rainfall, frequency and magnitude, in combination to increased evapotranspiration might lead to intensification of certain pedological processes. Under a soil moisture deficiency regime, porosity and permeability will be reduced, thus degrading soil structure and texture. Particularly, the Aliakmon karstic surroundings may exhibit a tendency of crust formation which will gradually lead to surface pore sealing and consequently to lower infiltration rates, especially where higher runoff and erodibility could be critical for the cultivated areas. Therefore, irrigation would become difficult, requiring better soil drainage.

In addition, the problem of top soil seasonal salt accumulation in the reclaimed plain could seriously appear again. This is because salts would not be sufficiently flushed from the soil, but would increase its residual salt content affecting soil fertility and productivity at the crop fields. On the other hand, the onset of sea level rise and the subsequent rise of the saline phreatic watertable could produce a secondary partial salinization of the plain. Therefore the recently vanished local ponding in several places might take place again.

In the estuarine evironment, organic matter plays a vital role in soil fertility because it retains nutrients and moisture favourable for soil microfauna. Forest fires in contrast, are leading to a loss of the upper soil horizon which is rich in organic matter. High temperature could cause soil degradation, reinforced, in the cultivated lands, by the increased mineralisation of the organic matter, essentially where organic input is high. At places where the high temperature in combination with drought could result in a greater susceptibility to slaking, there will also be a negative effect on soil microfauna, especially when the soil will eventually be moistenend by rain.

The induced Mediterranean climate, as far as the impacts on plants and the agricultural production is concerned, will be characterized by a general water shortage, particularly evident during the prolonged dry seasons. Occurrence of extreme weather phenomena and accelerated plant-growing cycles will also be stimulated by CO_2 emission. A combination of these factors in conjunction to soil degradation could modify plant growing periods. Net biomass, especially weeds, would rather be benefited in favour of grass in grazing fields. Weather variabilities could also be critical for other field crops on Thessaloniki plain. Although cotton grows quickly under enriched CO_2 environment (fig. 18), its industrially importance fibre quality is vulnerable to warm summer winds and heat-stress conditions during late growing harvesting season. Precipitation decrease and patchiness will negatively affect hard wheat production, which is highly depended on spring time rainfall and also on the prevailing weather conditions during harvest. In addition, the supplementary irrigation for the excessive water needs of rice and other crops would lead to salinization, negatively affecting maize production. On the other hand, for the other adaptable crops like sugarbeets, earlier planting methods could be used avoiding extreme summer events.

Thus, the remaining crop cultures will gradually be replaced by new developed varieties which will exhibit better adaptation to the changed environment, or by new subtropical crops, as bioclimatic zonation will probably be shifted to higher latitudes.

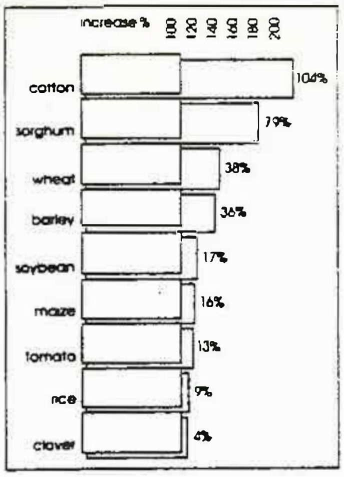


Fig. 18 - Predicted increase in yields (left) in nine major crops that would be caused by a doubling of carbon dioxide concentration (UNEP/GEMS, 1987)

Early warm and moist springs can favour high level of fungus and bacterial diseases, in spite of the prolonged dry seasons in a CO_2 rich environments. Increased temperatures will selectively benefit insects. Two or more generations could multiply the population. In addition to this, other insects will probably visit the area by wind migration from the subtropics. Under the gradually changing climate, plant protection practices and technologies for agricultural pests have to be adapted to new conditions, in order to meet future requirements. Finally, it is believed that temperature rise might be the major controlling factor which will allow extensive migration of air- and water-born species from southern environments.

Due to a rising sea level, marshes will change to lagoons. Also the most sensitive lagoonial organism of the lower food web will be easily adapted, as they exhibit a high salt tolerance to increased saline environments. Thus, temperature in the closed marsh systems will possibly control the growing cycles, especially where higher temperatures could lead to subtropic conditions and finally to thermal pollution.

Benthic biomass will also exhibit a seasonal diferentiation. Certain species will be particularly benefited from the climatic changes such as the epiphytic algal flora and the sea grasses. Increased organic input will lead to higher eutrophic level and consequently to increased primary production on estuaries. But the well stratified marine environment in the inner gulf will subsequently result in oxygen depletion which may lead to botton anaerobic conditions especially where sewage inputs is high.

It is known that the birds and a few other animals have shown a high degree of adaptability to the changing terrestrial environment during the reclamation projects at the estuaries. Thus, although the projected climatic changes would force small populations of rare protected species to disappear, most of them will probably continue to live there, as long as their biotops are well protected.

5. COASTAL ACTIVITIES

5.1. Industry

Thessaloniki is the second economically important city of Greece. The fast growing industrial activity of the area (see chapter 3.2) is distributed along into four major industrial zones at the NNW suburbs and also along four minor urban industrial sites at the edge of the city (fig. 12). Some of the largest industries in a total of 10.000 are a brewery and a bottling plant (Gallikos); paper mills and canning factories (Monastirion and Axios); a chemical and a steel industry and a refinery (Diavata). Some of them are quite close to the coastline and are developed down to the shore, especially east of Kalohori, where there is a refinery (expanded down to the jeties), a cement industry, and slaughter houses, as well as Kitros saltmarshes and the whole of the eastern coastal site.

5.2. Infrastructure

Due to its geographical setting, the city of Thessaloniki exhibits a well developped transportation network. Railroad and motorways running across the upper estuaries link Thessaloniki with Athens (520 km) with Yugoslavian borders (70 km), and with central and eastern Macedonia and Thraki. It is also the nearest European approach to the Eastern Mediterranean. The port of Thessaloniki has a total cargo maritime traffic of 10,4 million tonnes/year (Thess. port authorities, 1986). The direct airlink to some main European capitals and domestic airlink is done through Mikra Airport which is also used for the summer tourist charter flights. Most of the lowlands of the reclaimed estuarine area is protected by a 1-1.50 m high dyke along the sea, whereas a cement seawall of similar height protects the city of Thessaloniki.

5.3. Tourist facilities

Increased pollution from the city's unprocessed domestic discharges tends to become the dominant problem for the recreationally used eastern coast of the inner and central Thessaloniki Bay. Once, walking at the city along the sea was pleasant and enjoyable. Now a repulsive odor carried by sea breezes drives people away. The situation is better however at Agia Triada beach in central Thessaloniki Bay, and further in the outer Bay, where the beaches of Nea Michaniona and Epanomi are still attracting a number of tourists during the summer. These are the nearest beaches to the city, just 30 km away, highly populated at seasons. Camping facilities are organized in two sites, at Agia Triada and at Epanomi, run by National Tourist Organization (NTO). Additionally Methoni, Nea Agathoupolis and Makrigiakos are camping beaches at the west coast, south of the Aliakmon estuary (fig. 19).

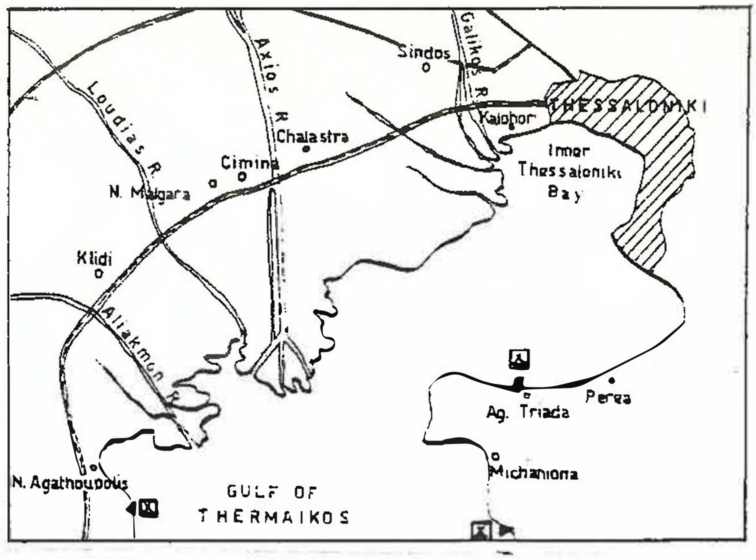


Fig. 19 - Camping sites

5.4. Population distribution

The over 2200 year old city of Thessaloniki is also the second largest city in Greece and capital of Macedonia, Northern Greece. Growing fast, from 320,000 habitants in 1951 to 702,000 in 1981; it now has reached 850,000 habitants, 1 million with the surrounding suburbs. It is a densely populated coastal city which is expanded southward to the coastal suburbs and villages. Touristic villages at the eastern and western coasts exhibit a summer seasonal population of over 45,000 people.

5.5. Economical impacts

Man and his constructions exhibit a high adaptation and tolerance to temperature variations. Thus, the effects of sea level rise seems to be the major thread of a possible climatic change. These impacts are not expected to be noticeable during the first 10-20 cm rise, when sea will gradually cover the intertidal zone. In the enclosed gulf regime this could be manifested during seasurges, reinforced by strong south winds where waves will be prolongated, washing the city's exposed seawall pavement.

However, the effects would become significant under a 30-50 cm or higher sea level rise, with important economical repercussions on land and property. Seawater will cover broad coastal areas, especially at sites of high vulnerability, such as:

- between the Aliakmon down stream estuary and New Agathoupolis, which is not considered an economically important area (mudflats - swamp);
- between Kalohori and the port where sea could easily reach the nearby lying coastal industries;

- the steeper eastern beaches where, under prolongated wave action, they will be seriously eroded. Therefore beaches as well as other recreational coastal constructions might be destroyed;

- at the area of Mikra airport, seasurges could seriously damage the low lying port ground, with serious economical impacts;

- most of the 1-1.5 m high protection constructions, like dykes and seawalls, can be easily overflowed during seasurges, unless no other actions will be taken;

- motorways and railroads are expected to be unaffected because they are lying quite above the sensitive lowlying plain areas.

6. CONCLUSIONS - SUGGESTED ACTIONS

The preceeding chapters were an attempt to describe the inner Thermaikos gulf environment and to define the potential effects of the climatic changes on it. However nature has the ability to "digest" and smoothly incorporate its own changes under certain conditions. It is very difficult however to estimate the nature's reaction to the new climatic conditions induced by the "greenhouse effect" and therefore the attempt for a progonosis is rather qualitative than quantitative.

Impacts will be first sensed at year 2030-40 when a 1°-2°C rise to the average temperature is expected and might be accompanied by a 20-30 cm rise of the mean sea level. However, later impacts of a 2°-3°C and of a 0.5-1.0 m gradual sea level rise might be catastrophic, if no action will be taken.

The coastal environment of the semienclosed embayment of the inner Thermaikos Gulf will accept the excessive water masses which will first gradually flood the intertidal zone and then part of the unprotected lowland (east of Kalohori, north of Agathoupolis). As a consequence, properties and lowlying industries might be damaged. Seasurges will also cause gradually significant damages along the whole coastline, as waves will easily overcome the present sea barriers, along the reclaimed agricultural, and the cement seawall along the city of Thessaloniki. The coast at the eastern touristic area might be gradually disappeared because of the high erosion, producing significant economical effects to the touristic and recreational land use.

The lowlying Mikra airport will be seriously threatened if no action will be taken. The sea-walls built for the port and other offshore port constructions have to readjusted to meet future conditions. The seasonal reduction of both Axios and Aliakmon river flows, due to the limited temporal rainfall, will cause problems to the irrigation regime of the agricultural plain and to the hydroelectrical power stations along Aliakmon river.

Temperature rise will establish a well formed stratification of the seawater masses, especially during the summer period months, which will affect the sediment depositional regime in and out of the bays. Fine suspended sediment load will be deposited further away from its sources causing the shallowing of the navigation channels. Also stratification would negatively effect the prime producers of the eutrophic zone, which at the beginning might be benefited from the warmer environment but lately will be vulnerably affected because of the oxygen depletion and the peak summer temperatures.

There will possibly be a northward shift of climatic zone, and thus autumn and spring might be shortened in length. Additionally an increased variability and patchiness of the rainfall might extend summer aridity. The scattered rainfalls will probably be totally disappeared from the warm season and might be transferred to winter. Thus, under the induced aridity the irrigation needs of Thessaloniki agricultural plain, in combination with the lower infiltration will cause critical fall of the ground water table and will finally lead to the salinization of the ground water. Seawater will progressively intrude the watertable landward thus deteriorating the quality of the phreatic and intermediate ground water. On the other hand, there will be a possible high risk on the hygiene of the drinkable water, as conditions will be ideal for several waterborn pathogens and bacterias, which can easily cause widespread infection and diseases.

Reduction of rainfall during hot summer period might cause deficiency in the soil moisture, thus degrading soil structure and agricultural fertility. Moreover, the reduced wash-off could possibly cause seasonal salt-accumulation on the top soil at several reclaimed lowlands. As a result better draining of the plain will be required.

Water shortage during the growing season could diminish agricultural production, especially for several field crops which depend on spring rainfall (i.e. wheat). Also, salinization of the irrigation water would have negative consequence on sensitive grain yield. Consequently new varieties of crops have to be introduced, adapted to the new natural setting and yielding standards. On the other hand, fast growing plant cycles, due to the CO_2 emission and the temperature rise, might increase fertilizer consumption, as the needs in NO_3 will be higher. Generally marine and land weds are expected to be benefited from the induced conditions. Flora and fauna of the wetlands will be forced to gradual adaptation to induced conditions which might be crucial for the protection of the sensitive species with low adaptability. As bioclimatic zonation will gradually shift northwards, several species will migrate to the north.

Finally, there will be favorable conditions for an increasing risk of agricultural pests, insect populations, bacterias and diseases, especially in the swamps.

The action which have to be taken in view of the forthcoming climatic changes should be the careful monitoring of the local long-term changes in the following fields:

- weather pattern and seasonability;
- underground water quality and water table movements;
- soil quality and insalinization of the coastal reclaimed areas;
- soil fertility and agricultural yields;
- insect population and movements; pests; bacterias; diseases;
- forest fires;
- floods.

The policy which has to be followed in order to prevent possible catastrophic impacts could be:

- mappping of the high risk coastal sites vulnerable to flooding;
- readjustment of the present flood defensive constructions (dykes, seabound seawalls);
- careful protection design of the coastal sites and of the instrastructure of higher economic importance (airport, port, industrial zone, city);
- readjustment of the building standards on the lowlying construction.

From the above mentioned data and estimations it is obvious that if the future scenario of the climatic changes will become real, large scale radical consequences could affect the greater Thessaloniki area. These enormous changes require equally remarkable and daring future steps. Such a step might be the damming and isolation of the Thermaikos Bay and its use as a "buffer zone" in order to diminish or remove the impacts of a sea level rise on the lowlying coastal area. Therefore the construction of the barrier across the 4,5 km long NE of Axios delta and M. Envolo cape (max. depth of 27 m) depth will be within the capabilities of tomorrow's technology (see the great dam in Holland, which tackled efficiently the flood problems in this country). The proposed idea of the damming of the Thessaloniki Bay and its transformation into a controlled lagoon, with the essential navigational outlets, will not negatively affect the greater Thermaikos Gulf marine environment, as seawater ciruclation and sewage output regime will remain almost unaffected.

APPENDIX

The main algae species met at the E-SE coast of Thessaloniki Bay
(Nicolaidis, 1985)

Ulva lactuca ((L) Le Jol
Enteromorpha linza (L) J. Ag.
Cystoseira barbata (Good. et Woodw) C. Ag
Cystoseira crinita (Dest.) Bory
Cystoseira fibriata (Dest.) Bory
Gracilaria verrucosa (Huds) Parens.
Punctaria latifolia Grev.
Scytosiphon lomentaria (Lyngb.) Endl.
Polysiphonia (Roth.) Grev.
Laurancia obtusa (Huds) Asa Hauck.
Dictyota dichottoma (Huds) Lamour
Ectocarpus arctus Kütz.
Cladophora cericea (Huds.) Kütz
Cladophora prolifera (Roth) Kütz.
Cladophora pellucida (Huds.) Kütz.
Gelidium crinale (Turn.) Lamour
Ceramium diapharu, (Zoth.) Hary.
Ceramium rubrum (Huds.) C. Ag.
Ceramium strictum (Kütz.) Harv.
Ceramium ciliatum (Ell.) Ducl.
Gigartina teedii (Roth.) Lamour
Gracilaria dura (Ag.) J. Ag.
Chaetomorpha linum (O.F. Müller) Kütz.
Eryopsis disticha (J. Ag.) Kütz
Hypnaea musciformis (Wulf.) Lamour
Jania rubens (L.) Lamour
Corallina officinalis (L.)
Padina pavonica (L.) Gaill.
Polysiphonia variegata (Ag.) Zanard.
Cladophora albida (Huds.) Kütz.
Halopteris scoparia (L.) Saur.
Porphyra leucosticta Thur.
Antithamnium cruciatum (C. Ag.) Naeg.
Champia parvula (C. Ag.) Harv.
Polysiphonia pennata (C. Ag.) Ambr.
Schacelaria tribuloides (Menegh.)
Taonia atomaria (Woodw.) J. Ag.
Dictyota linearis (C. Ag.) Crov.
Acetabularia acetabulum (L.) Silv.
Liagora viscida (Fors.) C. Ag.
Callithamnium acetabulum (Schmith.) Lyngb.
Anadyomene stellata (Wulf.) Ag.
Dasycladus vermicularis (Scop.) Krasser
Halimeda tuna (Ellis and Soland.) Lamour
Udotea petiolata (Turn.) Borg.
Cystoseira discors (L.) C. Ag.
Dilophus spiralis (Mont.) Hamel

Sphacelaria cirrosa (Roth.) C. Ag.
Sphacelaria plumola Zanard.
Corallina mediterranea Aresch.
Wrangelia penicillata C. Ag.
Dictyopteris membranacea (Stack.) Batt.
Valonia macrophysa (Kütz.)
Spyridia filamentosa (Wult.) Harv.
Cladostephus verticillatus (Light.) Prud Home van Reine
Sargassum vulgare C. Ag.
Dasya pedisellata VC. Ag.
Laurencia papillosa (Forsk.) Grev.
Peysonnelia squamaria (Gmel.) Decaisne
Rhodymenia ardossonei J. Feldmann
Alcidium corallium C. Ag.
Rhizoclonium riparium (Roth. Harv.
Enteromorpha compressa (L) Grev.

The dominant marine benthic fauna (central and NW coast)
Cattoula M. and Frangouli A. (after Ganoulis, 1987)

Harmothôe lunulata
Leanira yhleni
Nephthys hystricis
Diopatra neapolitana
Glycera Rouxii
Poecolochaetus serpens
Clymene gracilis
Maldane Sarsi
Sternaspis scutata
Pectinaria koreni
Melinna palmata
Lanice conchilega
Terebellides stroemi

Cirolana borealis

Turritella communis
Corbula gibba
Angulus planatus
Tellina pulchela
Nucula sulcata

Amphiura chiajei
Labidoplax digitata

Aspidosiphon mulleli

BIRDS FAUNA OF THE "RAMSAR" AND THE ADJACENT ESTUARINE WETLANDS

Specie	Common name	Nestling	Passing	Resting	Red list	Protected under rules B.C. ANNEX I, II, 1, II, 2	
Anser albifrons	White-fronted goose		C		+	-	+
Anser anser	Greylag goose		?		+	-	+
- *Tadorna tadorna*		20-30	C	C	+	-	-
- *Tadorna ferruginea*		A?			+	+	-
Anas penelope	Wigeon		D	70.000 (70)	-	-	+
Anas strepera	Gadwall	?		500 (70)	+	-	+
Anas crecca	Teal		C	3.570 (73)	-	-	+
Anas platyrhynchos	Mallard	C	C	8.360 (73)	-	-	+
Anas acuta	Pintail		C	390 (71)	-	-	+
Anas querquedula	Garganey	?	D		+	-	-
Anas clypeata	Shoveler		C-D	270 (71)	+	-	+
Netta rufina	Red-crested pochard			B	+	-	+
Aythya ferina	Pochard		B		-	-	+
Aythya nyroca		A-B?	B		+	-	-
Aythya fuligula	Tufted duck		B		-	-	+
Mergus serrator	Red-breasted merganser				-	-	+
Pernis apivorus	Honey buzzard	A'			+	+	+
Milvus migrans	Black kite	A'			-	+	+
Milvus milvus	Kite		A		-	+	+
Haliaeetus albicilla	White-tailed eagle			A	+	+	+
Neophron percnopterus	Egyptian vulture		B		+	+	+
Circaetus gallicus	Short-toed eagle		B		+	+	+
Circus aeruginosus	Marsh harrier	A			+	+	+
Circus cyaneus	Hen harrier		B		+	+	+
Circus macrourus			B		+	+	+
Circus pugargus	Montagus harrier		B		+	+	+
Accipter bravipes		A?			-	+	+
Accipter gentilis			A		-	+	-
Accipter nisus			B	B	-	+	-
Buteo buteo			B	B	-	+	-
Buteo lagopus				A?	-	+	-
Buteo rufinus			A		-	+	+
Aquila pomarina		A'	B		+	+	+
Gavia stellata				A	-	+	-
Gavia arctica				A	-	+	-
Tachybaptus ruficollis				C	-	+	-
Podiceps cristatus				C	-	-	-
Podiceps grisegena				A	+	+	-
Podiceps nigricollis				C-D	+	+	-
Calonectris diomedea	Cory's shearwater		B		+	+	+
Pufficus puffinus			B		+	+	-
Phalacrocorax carbo sinensis	Cormorant		B	B	-	-	+
Phalacrocorax aristotelis			A?		-	-	+
Phalacrocorax pygmaeus			C	C	+	+	+
Pelecanus onocrotalus			B		+	+	+
Pelecanus crispus			B	B	+	+	+
Botaurus stellaris	Bittern	?		A	+	+	+
Ixobrychus minutus		B-C			-	+	+
Nycticorax nycticorax	Night heron	100+			+	+	+
Ardeola ralloides	Squacco heron	100+			-	+	+
Egretta garzetta	Little egret	200+	C	B	-	+	+
Egretta alba	Great white heron	?	B	B	+	+	+
Ardea cinerea			B	B	-	-	-
Ardea purpurea	Purple heron	20+			-	+	+
Ciconia nigra	Black stork		A		+	+	+
Ciconia ciconia	White stork	B	C		-	+	+
Plegadis falcinellus	Glossy ibis	?	C		+	+	+
Platalea leucorodia	Spoonbill	?			+	+	+
Phoenicopterus ruber	Greater flamingo		A	A	+	-	+
Cygnus olor	Mute swan			A	-	-	+
Aquila clanga				A	+	+	+
Aquila heliaca		A	A		+	+	+
Hieraaetus pennatus	Booted eagle		A		+	+	+
Pandion haliaetus	Osprey		A		+	+	+
Falco naumanni			C		-	+	-
Falco tinnunculus		B	B	B	-	+	-
Falco vespertinus			C		-	+	-
Falco columbarius				A	-	+	-
Flaco subbuteo		A'			-	+	-
Falco eleonorae	Ekeibira's falcon		B		-	+	+

Specie	Common name	Nestling	Passing	Resting	Red list	Protected under rules B.C.	ANNEX I, II,1, II,2
Falco biarmicus	Lanner falcon		A		-	+	+
Falco cherrug		A?			-	+	-
Falco peregrinus	Peregrine		A	A	-	+	+
Perdix perdix	Partridge	B?			+	-	-
Coturnix coturnix	Quail	B			-	-	+
Rallus aquaticus	Water rail	B	B	B	-	-	+
Porzana parva		?			+	+	+
Gallinula chloropus	Moorhen	B	B	B	-	-	+
Fulica atra	Coot	C	D	70,000 70	-	-	+
Grus grus			?		+	+	+
Haematopus ostralegus	Oyster catcher	B	B		-	-	+
Himantopus himantopus	Black-winged Stil	400+	C		+	+	+
Recurvirostra avosetta	Avocet	50+	C	350	+	+	+
Burhinus oedicnemus	Stone Curlew	20			+	+	+
Glareola pratincola	Pratincike	500+	C		-	+	+
Charadrius dubius		B	C		-	+	-
Charadrius hiaticula			C		-	+	-
Charadrius alexandrinus		C	C		-	+	-
Pluvialis apricaria	Golden plover		?		-	-	+
Hoplopterus spinosus		A?			+	+	+
Pluvialis squatarola	Grey plover		700	C	-	-	+
Vanellus vanellus	Lapwing		C-D	C	-	-	+
Calidris alba			?		-	+	-
Calidris minuta			C	C	-	+	-
Calidris temminckii			B		-	+	-
Calidris ferruginea			6000		-	+	-
Calidris maritima			A		-	+	-
Calidris alpina			D	D	-	+	-
Limicola falcinellus			A-B		+	+	-
Philomachus pugnax			3000		-	-	+
Lymnocryptes minimus	Jack snipe		B		+	-	+
Gallinago gallinago	Snipe		C		-	-	+
Gallinago media	Great snipe		B		+	+	+
Scolopax rusticola	Woodcock		B		+	-	+
Limosa limosa	Black-tail godwit		4000		-	-	+
Limosa lapponica	Bar-tailed godwit		B		-	-	-
Numenius phaeopus	Whimbrel				+	+	+
Numenius tenuirostris			C	C	-	-	-
Numenius arquata	Curlew		4000		-	-	+
Tringa erythropus	Spotted redshank	200+	C	C	-	-	+
Tringa totanus	Red shank		C		+	+	+
Tringa stagnatilis			C		-	-	-
Tringa nebularia	Green shank		B		-	+	+
Tringa ochropus			B		+	+	-
Actitis hypoleucos			B		-	+	+
Tringa glareola			B		-	+	-
Arenaria interpres		3000	D	D	+	+	+
Larus melanocephalus			D		-	+	-
Larus minutus			D	D	-	-	-
Larus ridibundus	Black-headed gull	B'	B	B	+	+	+
Larus genei	Slender-Gilled gull				+	+	+
Larus audouinii	Audonin's-gull		A		-	-	+
Larus canus	Common-gull		A		-	-	+
Larus fuscus	Lesser black-backed gull		C		-	-	+
Larus argentatus	Greater black-backed gull	B'			+	+	+
Gelochelidon nilitica	Gull-gilled tern		B		+	+	+
Sterna caspia			C	C	+	+	+
Sterna sandvicensis	Sandwich tern						
Sterna hirundo	Common tern	200+	C		-	+	+
Sterna albifrons	Little tern	300+	C		-	+	+
Chlidonias hybridus			C		+	+	+
Chlidonias niger	Black tern		C		+	+	+
Chlidonias leucopterus			C		-	+	-
Columba palumbus	Wood pigeon		C		-	-	+
Streptopelia decaocto	Collared turtle dove	B'			-	-	+
Streptopelia turtur	Turtle dove	B	C		+	+	+
Clamator glandarius			A		+	+	-
Cuculus canorus		B			-	-	-
Tyto alba		A	B	B	+	-	-
Otus scops		A			-	-	-
Athene noctua		B	B	B	-	+	-

Specie	Common name	Nestling	Passing	Resting	Red list	Protected under rules B.C.	ANNEX I, II,1, II,2
Asio otus			B		-	-	-
Asio flammeus	Short-eared owl			A-B	+	-	+
Captimulgus europaeus		B	B		-	-	-
Apus apus		B´			-	-	-
Apus melba			C		-	+	-
Alcedo atthis	Kingfisher	A	B	B	-	+	+
Merops apiaster		B	C		-	+	-
Coracias garrulus		A	B		-	+	-
Upupa epops		A–B	B		-	+	-
Jynx torquilla			B		+	+	-
Dendrocopus syriacus		A			-	+	-
Dendrocopus minor			A		-	+	-
Melanocorypha calandra		C			-	+	-
Calandrella brachydactyla		C			-	-	-
Galerida cristata		C			-	-	-
Lullula arborea			C		-	-	-
Alauda arvensis	Skylark	C			-	-	+
Riparia riparia		D	D		-	+	-
Ptyonoprogne rupestris			C		-	+	-
Hirundo rustica		C	D		-	+	-
Hirundo daurica		B	C		-	+	-
Delichon urbica		C	D		-	+	-
Anthus camplestris		B	C		-	+	-
Anthus tribialis			C		-	+	-
Anthus pratensis			D		-	+	-
Anthus spinoletta			C		-	+	-
Motacilla flava			D		-	+	-
Motacilla cinerea			C		-	+	-
Motacilla alba		B	C		-	+	-
Cinclus cinclus			A?		-	+	-
Troglodytes troglodytes				C	-	+	-
Prunella modularis				C	-	+	-
Cercotrichas galactotes		B?			-	+	-
Erithacus rubecula				C	-	+	-
Luscinia luscinia			?		-	+	-
Luscinia megarhynchos		C	C		-	+	-
Luscinia svetica	Blue-throat		?		+	+	+
Phoenicurus ochruros		A?	B	A	-	+	-
Phoenicurus phoenicurus			B		-	+	-
Saxicola rubetra			C		-	+	-
Saxicola torquata		B	C		-	+	-
Oenanthe oenanthe		B	C		-	+	-
Oenanthe hispanica		B	C		-	+	-
Turdus torquatus					-	-	-
Turdus merula	Black bird		C	C	-	-	+
Turdus philomelos	Jong-thrush		C	C	-	-	+
Turdus viscivorus	Mistle-thrush		C		-	-	+
Cettia cetti		B–C			-	+	-
Cisticola juncidis		C			+	+	-
Acrocephalus melanopogon		?	B		+	+	-
Acrocephalus schoenobaenus			B		-	+	-
Acrocephalus palustris		B	?		+	+	-
Acrocephalus scirpaceus		?	C		-	+	-
Acrocephalus arundinaceus		C	C		-	+	-
Hippolais icterina			C		-	+	-
Hippolais pallida		C	C		-	+	-
Sylvia cantillans		B?	C		-	+	-
Sylvia melanocephala	Black head warbler		C		-	+	+
Sylvia hortensis			C		-	+	-
Sylvia curruca			C		-	+	-
Sylvia communis		C	C		-	+	-
Sylvia atricapilla			B		-	+	-
Phylloscopus bonelli			C		-	+	-
Phylloscopus sibilatrix			C		-	+	-
Phyloscopus collybita			D	C	-	+	-
Phylloscopus trochilus			C		-	+	-
Mucicapa striata			C		-	+	-
Ficedula parva					-	+	-
Ficedula albicollis			B		-	+	-
Ficedula hypoleuca			B		-	+	-

Specie	Common name	Nestling (in pairs)	Passing	Resting	Red list	Protected under rules B.C. ANNEX I, II,1, II,2	
Panurus biarmicus		C?	C		+	+	-
Aegithalos caudatus			C		-	+	-
Parus caeruleus		?	C		-	+	-
Parus major		B	C		-	+	-
Remiz pendulinus		B	C		-	+	-
Oriolus oriolus		B	C		-	+	-
Lanius collurio		C	C		-	+	-
Lanius minor		B	C		+	+	+
Lanius excubitor				?	-	+	-
Lanius senator		?	B		+	+	-
Garrulus glandarius			C		-	-	-
Pica pica			C		-	-	-
Corvus monedula		B'	D	D	-	-	-
Corvus frugilegus			D-E	D	+	-	-
Corvus corone		C	C	C	+	-	-
Corvus corax			B		-	-	-
Sturnus vulgaris			D-E		-	-	-
Sturnus roseus			C		-	+	-
Passer domesticus		C	D		-	-	-
Passer hispaniolensis		D	D		-	-	-
Passe montanus		?	C		-	-	-
Fringilla coelebs		B	D	D	-	-	-
Serinus serinus			C		-	+	-
Carduelis chloris			C	C	-	+	-
Carduelis carduelis			C		-	+	-
Carduelis spinus			C	C	-	+	-
Carduelis cannabina			C		-	+	-
Emberiza citrinella				C	-	+	-
Emberiza cirlus		B	C		-	+	-
Emberiza cia			B?		-	+	-
Emberiza hortulana			C?		-	-	-
Emberiza schoeniclus		?	C	C	-	+	-
Emberiza melanocephala		C	D		-	+	-
Miluria calandra		C	D	C	-	-	-

Bird population

A 1-10
B 11-100
C 101-1000
D 1001-10000
E over 10000

A' significant host species of the wetlands

() year of observation in brackets

AMPHIBIANS - REPTILES - MAMMALS

Specie		Red list	Protected/rulled under Greek	Protected/rulled under International
Reptiles				
Emys orbicularis	water turtles	**	+	+
Mauremys caspica			+	+
Lacerta viridis	Lizards		+	+
Podarcis erhardii			-	v
Anguis fragilis		+	v	
Testudo hermanni	Turtles	**	+	1
Testudo graeca		*	+	+
Natrix natrix	Water snakes		+	v
Natrix tesselata		*	+	v
Coluber jugularis			+	v
Coluber najadum			+	
Elaphe quatorlineata			+	+
Elaphe longissima			+	+
Malpolon mospessulanus			+	v
Vipera ammodytes				+
Amphibians				
Bombina variegata	Frogs			+
Bufo bufo			+	v
Bufo viridis		*	+	+
Rana dalmatina			+	+
Rana ridibunda				v
Hyla arborea		*	+	+
Triturus vulgaris			+	v
Mammals				
Vulpes vulpes				
Canis aureus				
Spalax sp.		*		
Lepus capensis				
Rattus rattus				
Erinaceus roumanicus			+	v
Microtus arvalis				
Lutra lutra		**	+	+
Talpa romana			+	
Nycteridae sp.			+	+
Mus musculus				
Microtus guentheri				
Clethrionomus				
Spermophilus cittelus			+	+
Mustela nivalis			+	v
Martes foina				v
Meles meles				v

** = threatened by extinction
* = threatened
\+ = high protected
v = protected

ALIAKMON RIVER FISH FAUNA

<u>Salmonidae</u>	
Salmo trutta macrostigma	
Salmo gairdneri	+
<u>Esocidae</u>	
Esox lucius	+
<u>Cyprinidae</u>	
Rutilus rutilus	
Rutilus macedonicus	o
Leuciscus cephalus vardarensis	
Phoxinus phoxinus	
Tinca tinca	
Chondrostoma nasus vardarense	
Gobio gobio bulgaricus	
Gobio uranoscopus elimeius	
Gobio kessleri banarescui	
Barbus barbus macedonicus	
Barbus meridionalis petenyi	
Alburnoides bipunctatus thessalicus	
Alburnus alburnus macedonicus	o
Vimba melanops	
Rhodeus sericeus amarus	o
Carassius auratus gibelio	o
Cyprinus cario	
<u>Cobitidae</u>	
Cobitis taenia	o
Sabanejewia aurata	
<u>Siluridae</u>	
Silurus glanis	
<u>Anguillidae</u>	
Anguilla anguilla	
<u>Casterosteidae</u>	
Casterosteus aculeatus	
<u>Poeciliidae</u>	
Cambusia affinis	
<u>Percidae</u>	
Perca fluviatilis	
<u>Cobiidae</u>	
Knipowitschia causasica	
Cambusia affinis	+

\+ imported species
o only downstream/estuary

FISHES

AXIOS RIVER FISH FAUNA (down stream)

Anguillidae
Anguilla anguilla

Salmonidae
Salmo trutta macedonicus

Cyprinidae
Rutilus rutilus
Rutilus macedonicus
Leuciscus cephalus vardarensis
Scardinius erythrophthalmus
Gobio gobio balcanicus
Gobio hessleri banarescui
Gobio uranoscopis elimeius
Rhodeus sericeus amarus
Vimba melanops
Cyprinus carpio
Alburnus alburnus macedonicus
Alburnoides bipunctutus thessalicus
Barbus barbus macedonicus
Barbus meridionalis petenyi
Barbus cyclolepis
Carassius auratus gibelio
Tinca tinca

Cobitidae
Cobitis taenia
Sabanajewia aurata
Noemacheilus barbatulus vardarensis

Siluridae
Silurus glanis

Percidae
Perca fluviatilis

Gasterosteidae
Pangitius platygaster

Gobiidae
Knipowitschia causasica

Sources: Economidis et al. (1981) after Ministry of Environment (1980)

BIBLIOGRAPHY

Angouridakis V.E. and Machairas P.C. (1973) - Precipitation (I), Sci. Annais, Fac. Phys and Mathem. Univ. Thessaloniki 13:347-380

Bach W., Wigley T.M.C. and Pitovranov S.E. (1987) - Climate scenario, Europ. Worksh. on Inter. Bioclim. and Land Use Chang. Vol A.

Balopoulos Th. E. (1986) - Physical and dynamical processes in a coastal embayment of the northwestern Aegean Sea, Thalassographica 9:59-78

Brambati A. and Stefanini S. (1970) - Sedimentological research of the coastal sediment of the Gulf of Thessaloniki, Boll. Soc. Geol. It. 899:383-400 (in Italian)

Chronis Th. G. (1986) - The modern dynamic and recent Holocene sentimentation at the Inner Thermaikos Plateau, PhD thesis, Dept of Geol., Univ. Athens (in Greek)

Evmorphopoulos L. (1961) - The Changes of Thessaloniki Gulf, Techn. Annal No 205-208:51-76

Friligos N. (1977) - Seasonal Variation of Nutrients Salts (N, P, Si) dissolved oxygen and chlorophyll-a in Thermaikos Gulf (1975-76), Thallasia, Yugoslavia 13 (3/4):327-342

Ganoulis J. (1987) - Oceanographic elements and environmental investigation of the impacts of the draining project of Thessaloniki Gulf, Dept of Hydraulics, Univ. Thessaloniki, Rep. Minist. of Environment (in Greek)

Knithakis E. and Tzimourtas S. (1987) - Chemical study of the underground water of the Axios-Loudias River basin, I.G.M.E., Thessaloniki, Unpubl. (in Greek)

Livadas G.C. and Sahsamanoglou C.S. (1975) - Wind in Thessaloniki, Greece, Sci. Annals. Fac. Phys and Mathem. Univ. Thessaloniki 13, 411-414

Maheras P.C. (1987) - Temporal fluctuations of annual precipitation in Palma and Thessaloniki, Jour. of Meteo. V12, 123:305-308

Mavromatis G. (1980) - The bioclimate of Greece, relations to the natural vegetation and bioclimatic maps, Inst. of Forest. Research, Athens (in Greek)

Min. of Environment (1986) - Boundary determination programme of the Wetlands of Ramsar contract, Deltas of Aliakmon-Loudias-Axios (in Greek)

Nicolaidis C.G. (1985) - Qualitative and Quantitative Study on the benthic macrophycae at the polluted areas of Thessaloniki Gulf, PhD thesis, Univ. Thessaloniki V23, sect. 46

Nedeco and Grontmy (1970) - Regional development project on the Salonica plain, Min. of Agriculture (O.E.C.D.)

Prefecture of Thessaloniki (1986) - Agricultural developing program, year 1986, Direct. of Agriculture, Thessaloniki (in Greek)

Struck (1908) - Mazedonisch Fahrten II, Die Makedonischen Miederlander, Serjevo (in German)

Therianos D.A. (1974) - The geographical distribution of river water supply in Greece, Bull. Geol. Soc. Greece XI:28-58 (in Greek)

Thessaloniki Port Authority (1987) - Statistical data, year 1986

UNEP/GEMS (1987) - The greenhouse gases, Nairobi, Env. Lib. No 1

Wilding A., Collins M. and Ferentinos G. (1980) - Analyses of sea water level fluctuations in Thermaikos Gulf and Salonica Bay NW Aegean Sea, Eustar. Coast. Mar. Sci. 10:325-334

Zimerman J. and Ross V.J. (1976) - Structural evolution of the Vardar root zone northern Greece, Geol. Soc. Amer. Bul., V87:1547-1550