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Water quality monitoring in Strymonikos Gulf and Gulf of Ierissos, Northern Greece

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Abstract
Strymonikos Gulf is located at the north-eastern part of Halkidiki Peninsula, being affected by the fresh water outflow of Rivers Strymon and Richios. The distribution of nutrients shows in general low concentrations, with higher values being observed at the coastal areas, where human activities take place (tourism, agriculture, industry). Rivers Strymon and Richios outflow at its north and west part, respectively, constituting the main sources of fresh water, nutrients and pollution (domestic and agricultural pollutants) in the area. Salinity varied seasonally at Strymonikos Gulf due to the trapping of the surface Black Sea water masses at Halkidiki Peninsula.

1 Introduction

Strymonikos Gulf is located at the north-eastern part of Halkidiki Peninsula, occupying an area of 540 km^2 (Figure 1). Its coasts have a total length of 70 km and it is connected to the open north Aegean Sea through an open boundary at its eastern side (Koukouras, Voultsiadou-Koukouras & Kattoulas, [1]). Rivers Strymon at the north and River Richios at the west (near Stavros) consist the main sources of fresh water, nutrients and pollution (domestic and agricultural pollutants) in the area (Dounas and Koukouras, [2]).

The reduced mean annual discharge (59,8 m^3/sec) of Strimon River (Figure 2) during the last decade (Mertzianis, [3]), in connection to the deflection of the discharged freshwater rightwards due to the occurrence of a strong geostrophic current, results in the development of a weak Region of Fresh Water Influence (ROFI). There are no permanent rivers flowing into Gulf of Ierissos, but only local streams, discharging fresh water in seasonal response to rainfall. Strymonikos Gulf and the Gulf of Ierissos, at its southern part, consist two of the most important

nursery and fishing grounds for pelagic species of north Aegean Sea, whose environmental conditions have not been studied sufficiently.

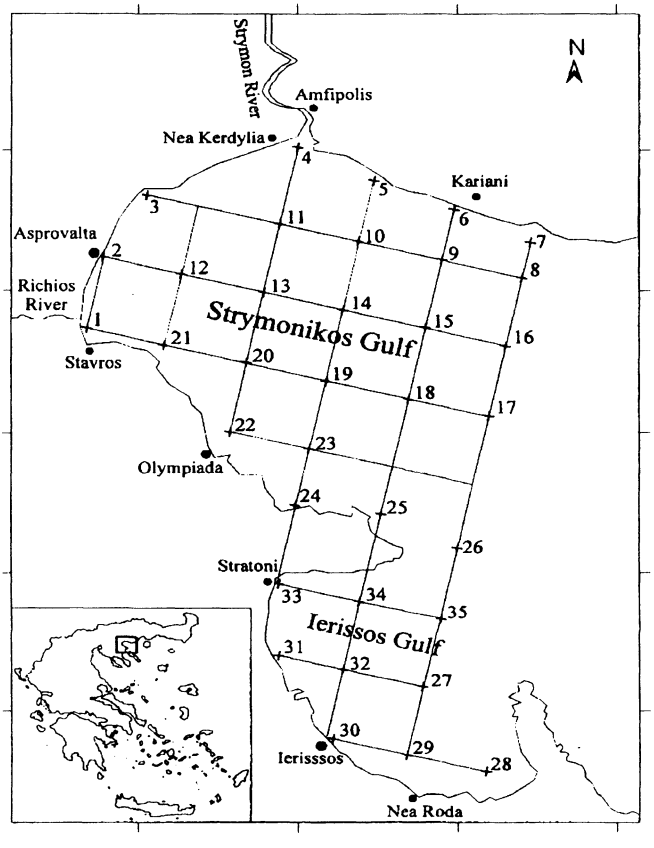

Figure 1. Sampling positions at Strymonikos Gulf and Gulf of Ierissos.

2 Materials and Methods

Hydrographic field data in 35 stations (26 at Strymonikos and 9 at Ierissos Gulf) took place during four seasonal monitoring periods (June, September, November 1997 and February 1998), within the framework of EU Demonstration Program LIFE on "Concerted Actions for Management of the Coastal Zone of Strymonikos Gulf". Profiles of physical and chemical parameters (temperature, salinity and dissolved oxygen) were obtained using an IDRONAUT 301 CTD probe. The collection and preservation of water samples for nutrients determination followed the Standard Methods for the Examination of Water and Wastewater [4]. Nutrients samples were frozen in polyethylene bottles for analysis on land, following for

nitrates, nitrites, phosphates and silicates the techniques described by Parsons et al. [5]. Ammonium was measured by the methods of Liddicoat et al. [6]. All samples were analyzed at the biochemistry laboratories of Fisheries Research Institute.

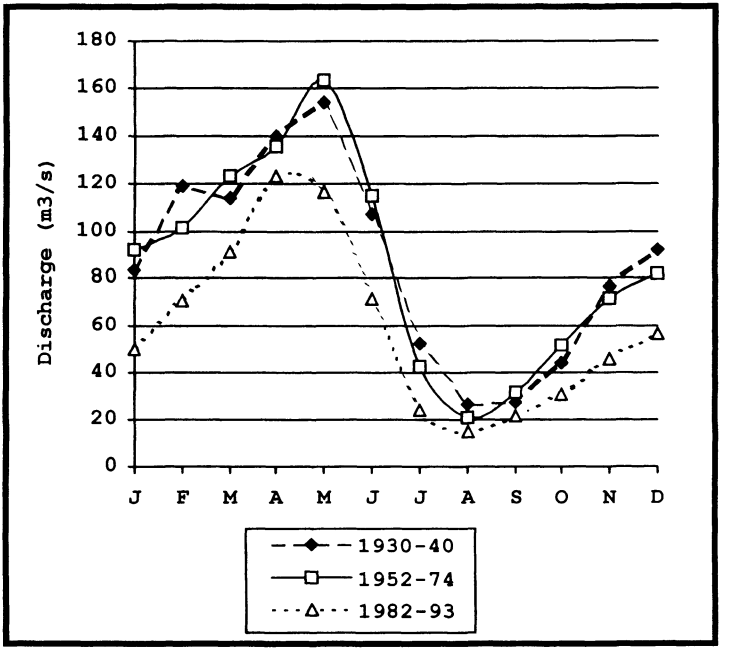

Figure 2. Mean monthly water discharge of River Strymon.

3. Results and Discussion

3.1 Water Mass Identification

Summer T-S-DO diagrams (Figure 3) show the presence of three water masses in Strymonikos Gulf and Gulf of Ierissos, a surface layer (0-4 m) of fresh warm water (T=20°C; S=15-20 psu; DO= 8.0-8.5 mg/l), an intermediate water mass (4-30 m) with high salinity and lower temperature (T=13°C; S=37.0 psu; DO= 7.0-7.5 mg/l) and a bottom water mass occupying depths over 30 m. with increased temperature and salinity (T=14°C; S=37.9 psu; DO= 7.0 mg/l). Well mixed conditions exist during winter at the surface of the water column (0-20 m), with the rest two layers being suppressed at the bottom of the gulf. Dissolved oxygen remains at low levels (6.5-7.5 mg/l) at the first 20 m. and increases its values (8.0-9.5 mg/l) at the bottom layer due to the trapping of phytoplankton biomass from the thermocline.

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3.2 Surface Variability

3.2.1 Temperature

The summer surface temperature distribution reveals the more important influence of River Richios discharging warmer water (22-23°C) than Strymon River (19-20°C) at Strymonikos Gulf. Similar warm water outflow appears at the Gulf of Ierissos near Stratoni, due the effect of local streams. The rest of the area has lower temperature of 19.0°C (Figure 4). Winter distribution shows low temperature values (T~14.0-14.8°C), especially at the coastal zone of Stavros, Asprovalta and the mouth of Strymon River, due to the supply of cold water masses from Rivers Strymon and Richios. Warmer homogeneous conditions appear at the rest of the gulf (T~16°C).

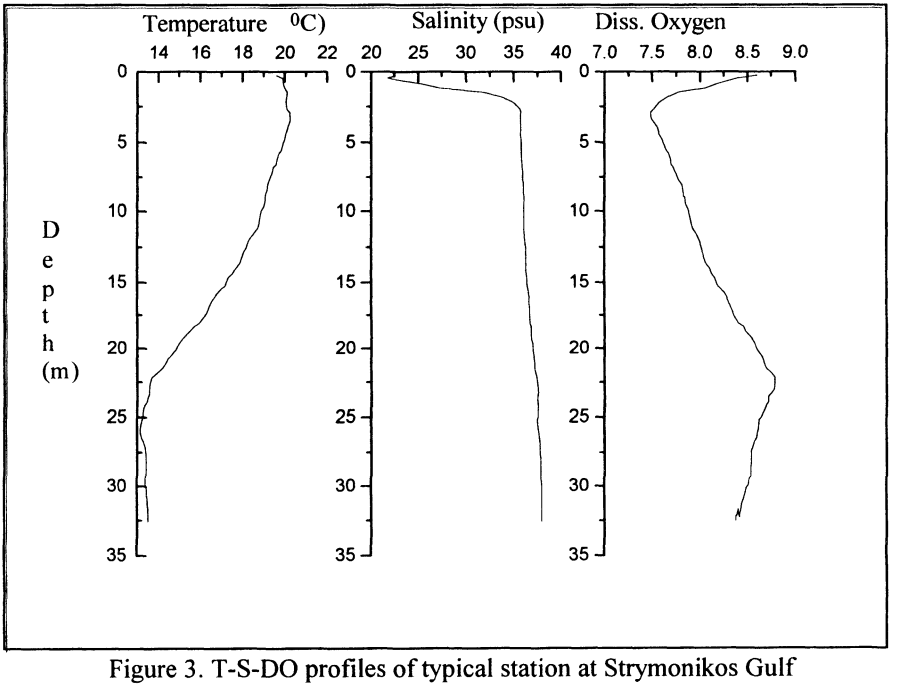

Figure 3. T-S-DO profiles of typical station at Strymonikos Gulf (June 1997).

3.2.2 Salinity

The influence of Rivers Strymon and Richios becomes obvious at the surface salinity field during summer by the intense gradients developed at their mouths (Figure 5). The rest of the gulf is characterized by high salinity water (S~35.0-35.5 psu) that follows the general geostrophic circulation of North Aegean Sea and is being trapped in a great extent at Strymonikos Gulf (Kaloumenos, [7]). This

behavior becomes more obvious during September by the important decrease of surface salinity at the gulf (S~33.0 psu).This occurs due to the trapping of Black Sea Water that inflows at North Aegean through Dardanellia Straits, with characteristic high salinity during winter and reduced in the summer (Yuce, [8]).

3.2.3 Dissolved Oxygen

The surface distribution of dissolved oxygen and nutrients is highly related to hydrodynamic conditions and human and biological activity in the area. Hence, the cold and less saline water of River Richios shows during summer lower dissolved oxygen concentration (6.8-7.0 mg/l) compared to Strymon River (7.8-8.2 mg/l). During winter, strong oxygen gradients occur, with low values near the coastal zone of Stavros to Kargiani (6.0-6.5 mg/l) and higher (7.5-7.8 mg/l) at the rest Strymonikos Gulf.

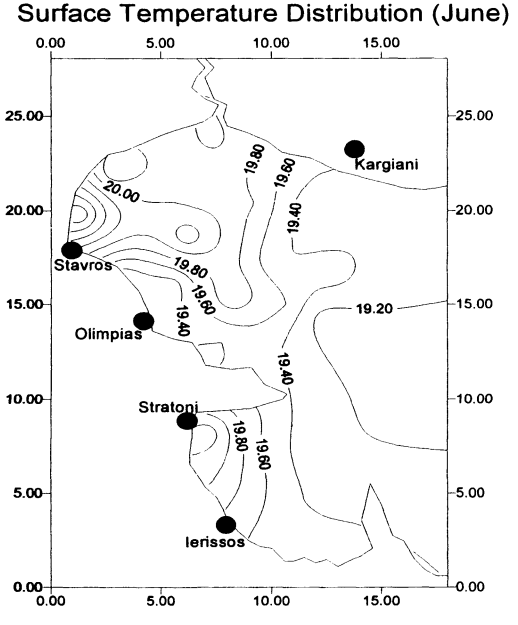

Figure 4. Surface temperature distribution (June 1997).

3.3 Nutrients

In general, low values of nutrients were found in Strymonikos Gulf, with the exception of the area affected by River Strymon, which is the main source of nutrients in the gulf. Increased surface nitrate concentrations appear at the Gulf of Ierissos near Stratoni (5.2 μg-at/l) and Olympias (2.2 μg-at/l). Nitrites ranged at the surface between 0.05 and 0.23 μg-at/l, with higher concentrations observed at the mouth of River Strymon and at the open boundary of Ierissos Gulf (Figure 6).

Phosphates showed increased concentrations at the coastal zone of Olympias and Ierissos and the mouth of Strymon River, while silicates at the area of Stratoni (10.65 μg-at/l). At deeper water layers, the reduction of nutrients concentration is observed, showing that local eutrophic conditions are mostly associated with the fresh water discharge from Rivers Strymon, Richios and local streams.

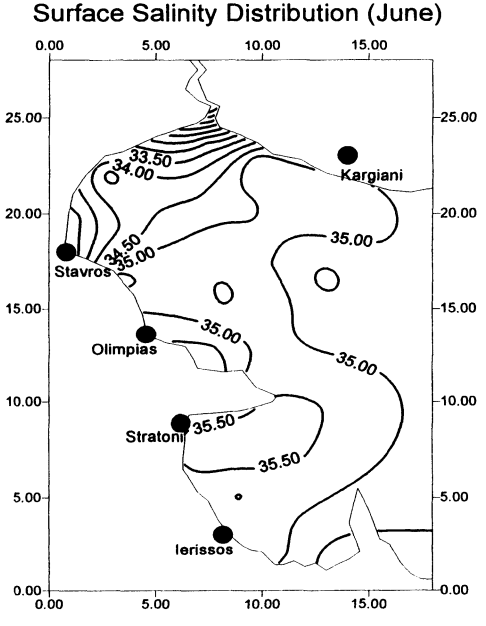

Figure 5. Surface salinity distribution (June 1997).

Relationships between salinity and nutrients have been used to identify water masses in several areas [e.g., Stefansson and Atkinson, [9]; Kamykowski and Zentara, [10]]. In Strymonikos Gulf and Gulf of Ierissos salinity exhibits sufficient variability over space for salinity-nutrients relationships to serve as indicators of water masses. The salinity-nutrients diagrams (Figure 7) clearly differentiate the characteristics of water masses in Strymonikos Gulf. The low salinity extreme ($S<34.0$ psu) of the diagrams have high nutrient concentration and come from stations affected by the river plume of Strymon and Richios. The high salinity extremes ($S>35.0$ psu) have low nutrients and are representative of water masses of Levantine origin mixed with water moving westwards in North Aegean through Dardanellia Straits.

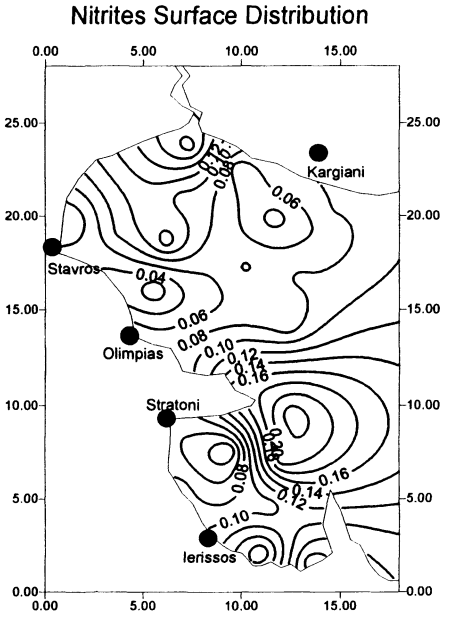

Figure 6. Surface nitrite distribution (June 1997).

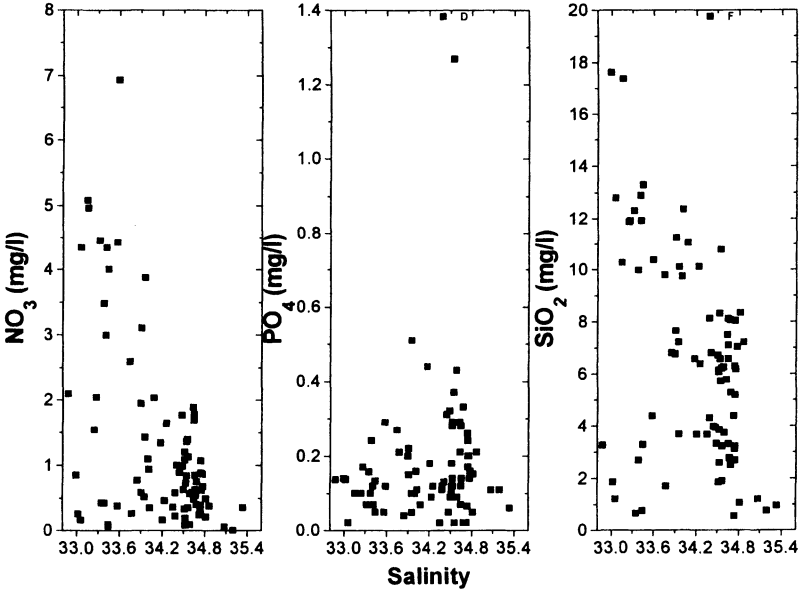

Figure 7. Variability of nutrients with salinity at Strymonikos Gulf and Gulf of Ierissos.

4. Conclusions

The results described in this paper suggest the division of the water column into a surface layer, an intermediate layer and bottom water. The influence of Rivers Strymon and Richios becomes obvious by the intense gradients of surface salinity developed at their mouths. Low oxygen content values observed in the area occur as a result of continuous consumption by bacteria, which decompose and mineralize particulate and dissolved organic material supplied from river outflows. The distribution of nutrients in Strymonikos Gulf and Gulf of Ierissos shows in general low concentrations, with higher values being observed at the coastal areas where human activities take place (tourism, agriculture, industry).

References

1. Koukouras, A., Voultsiadou-Koukouras, E. & Kattoulas, M., Benthic bionomy of the North Aegean Sea. I. Physico-chemical characteristics of the Strymonikos Gulf, *Thalassia Jucoslavica,* **20**, pp. 53-72, 1984.
2. Dounas, K., & Koukouras, A., Circalittoral macrobenthic assemblages of Strymonikos Gulf (North Aegean Sea), *Marine Ecology*, **13**, pp. 85-99, 1992.
3. Mertzianis, C., *Study of tidal waves along River Strymon*, M.Sc. Thesis, Univ. of Thessaloniki, 1994.
4. American Public Health Association, *Standard Methods for the Examination of Water and Wastewater*, Eigenverlag APHA, Washington D.C., 134 p., 1982.
5. Parsons, T.R., Maita Y., & Lalli, C.M., *A manual of chemical and biological methods for sea water analysis*, Pergamon Press, New York, 357 p., 1984.
6. Liddicoat, M.T., Tibbits, S., & Butler, E.T., The determination of ammonia in sea water, *Limnology Oceanography*, **20**, 1974.
7. Kaloumenos, L., Hydrological characteristics of the Strymonic and Kavala gulfs, *1st Greek Symposium on Oceanography and Fishing*, edited by National Centre for Marine Research, **1**, pp. 56-65, 1984.
8. Yuce, H., Northern Aegean water masses, *Estuarine, Coastal & Shelf Science*, **41**, pp. 352-343, 1995.
9. Stefansson, V., & Atkinson, L.P., Relationship of potential temperature and silicate in the deep waters between Cape Look out, North Carolina and Bermuda, *Journal of Marine Research*, **29**, pp. 306-318, 1971.
10. Kamykowski, D., & Zentara, S.J., Predicting plant nutrient concentrations from temperature and sigma-t in the upper kilometer of the world ocean, *Deep Sea Research*, **33**, pp. 89-105, 1986.