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ZOOPLANKTON BIOMASS IN THE SARONIKOS GULF, WINTER 1972—1973.

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INTRODUCTION

During the Saronikos Systems Project, initiated in December 1972, sampling of zooplankton for biomass estimations was conducted. The results of the three first cruises are given in this paper. Previous data have been given from observations published by Yannopoulos and Yannopoulos (1973)which provided approximate information on the biomass values in the Saronikos Gulf.

The present study has provided more detailed information on the distribution and the standing stock of zooplankton in the Saronikos Gulf proper.

METHODS AND MATERIALS

Zooplankton samples were collected by the first author at 25 stations from a station grid. The collections were made during December 1972, January and March 1973. Figure 1 shows location of the major areas sampled.

A WP-2 nylon net, recommended by the Working Party No. 2 (UNESCO, 1968), with a mesh size of 0.24 mm, was used for vertical collections of zooplankton from the bottom to the surface. Collections were usually made during the day between 1000 and 1700 h. At stations with depths over 100 m, occasional vertical hauls from a depth of 50 m to the surface and oblique hauls from 20 m to the surface were made with the WP-2 or with the WP-3 net (UNESCO, 1968).

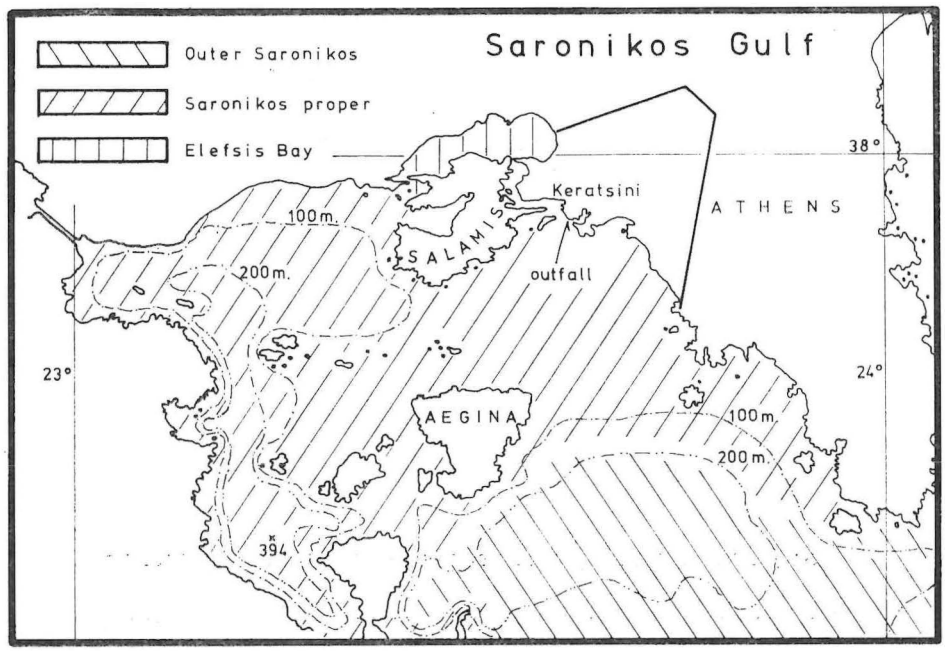

Fig. 1 — Map of Saronikos Gulf and subdivisions.

A Tsurumi-Seiki depth recorder, with a range of 0 to 500 m and a flowmeter with two stoppers were attached to the net to obtain the maximum depth and the total water volume passing through the net. The length of the wire and the angle were also measured.

The zooplankton samples were preserved in CaCO3 buffered 4 percent formalin. After a few days, the samples were filtered through plastic tubes, one opening of which was closed with netting and then dried in an aerated oven at 50 to 60°C long enough to obtain a double-checked standard weight. The samples were predried for 5 hours until the weights checked. A Mettler balance (with an accuracy of $\pm$ 0.0005 g) was used. The samples were then placed in a dessicator for 24 hours and the final weight obtained (Lovergrove, 1966). Before the drying process, all individuals bigger than 3 cm, including all large salps, siphonophores and medusae, were separated under the microscope. Zooplankton dry weights are expressed in relation to the filtered water volume in mg/m^3.

RESULTS

Dry Weight

A total of 17 samples were collected during the December 1972 cruise (Figure 2) and subsequently analyzed. The maximum dry weight values obtain

ed for samples from stations K4 and O6 were 16.3 and 16.6 mg/m^3 respectively. High values were also found in Keratsini Bay, the water body between the mainland and the northeast coast of Salamis Island, and also in the area extending a short distance below Salamis to the west. The outfall station, at the east end of Keratsini, showed no unusual values. The minimum value of 2.6 mg/m^3 was obtained at station P4 (Figure 2).

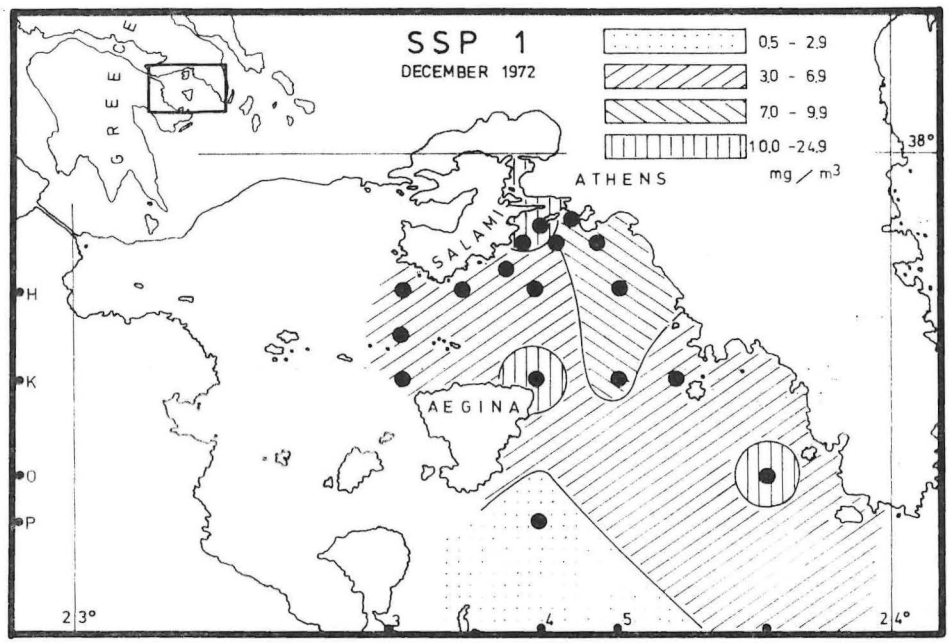

Fig. 2 — Distribution of zooplankton biomass (mg/m^3) in the Saronikos Gulf in December 1972.

In January 1973, a series of 29 samples were analyzed and dried (Figure 3). From these data, three major areas of zooplankton biomass can be distinguished; the outer Saronikos Gulf, the Saronikos proper and the Elefsis Bay. Dry weights from the Elefsis Bay had a maximum value of 78.9 mg/m^3 and a minimum of 44.8 mg/m^3. From the Saronikos proper, maximum values were 17.2 mg/m^3 near Keratsini outfall and 13.8 mg/m^3 at station H3. The minimum value from the outer Saronikos was 2.0 mg/m^3 observed at station O6.

During March 1973, a series of 37 samples were obtained and the dry weights determined (Figure 4). The maximum and minimum values for Elefsis Bay were 98.1 mg/m^3 and 22.7 mg/m^3 respectively. In the Saronikos proper the maximum value was 11.3 mg/m^3, east of Salamis Island. The minimum value from the outer Saronikos was 0.5 mg/m^3 obtained at station P5.

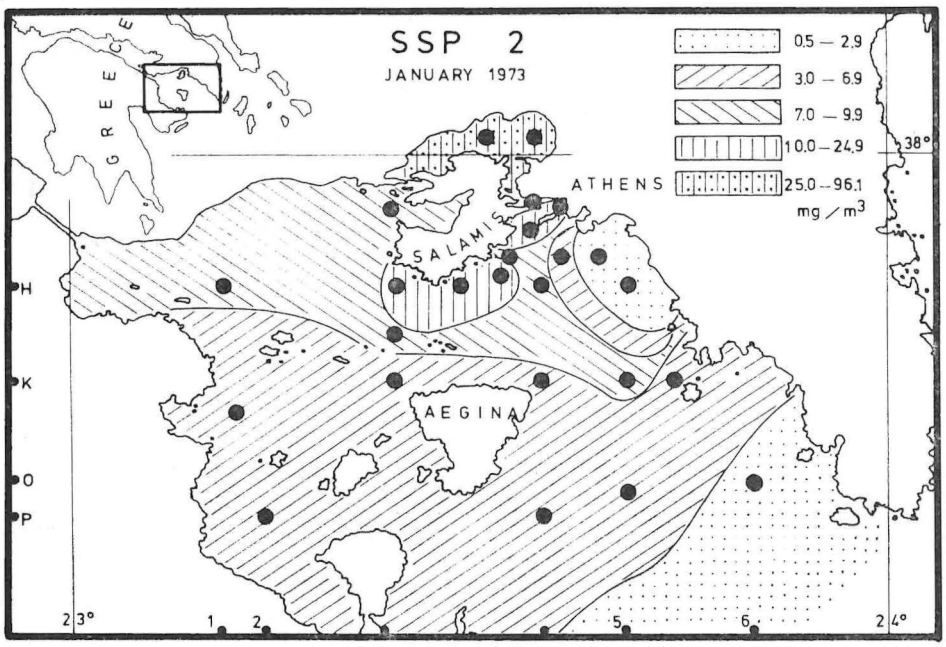

Fig. 3 — Distribution of zooplankton biomass (mg/m³) in the Saronikos Gulf in January 1973.

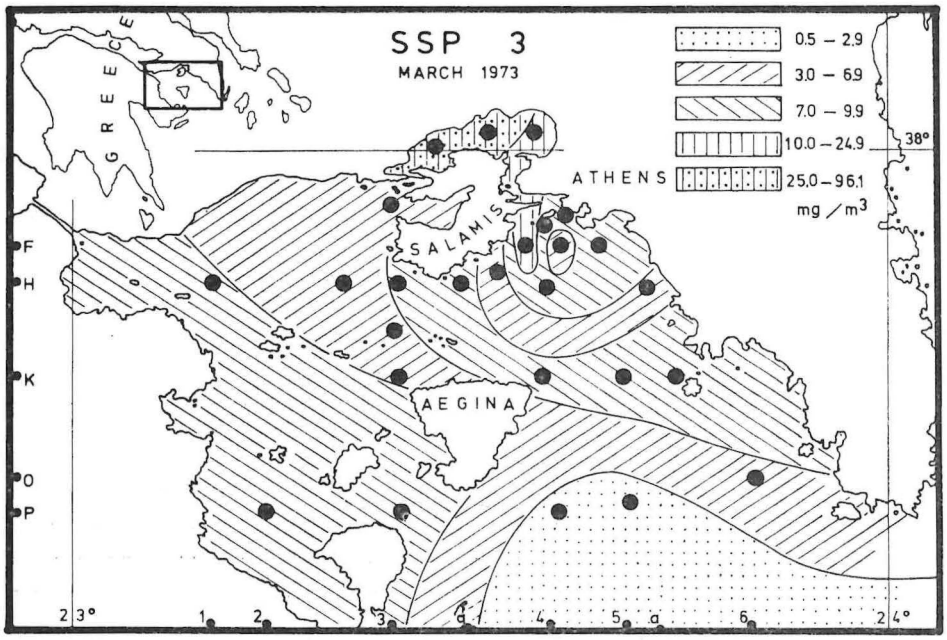

Fig. 4 — Distribution of zooplankton biomass (mg/m³) in the Saronikos Gulf in March 1973.

Zooplankton Composition

Based on zooplankton species composition, three major areas including the outer Saronikos Gulf, the Saronikos proper (Yannopoulos and Yannopoulos, 1973) and the Elefsis Bay can be recognized.

The zooplankton collected from Elefsis Bay in January and March 1973 was extremely monospecific. At least 99 percent of the individuals were *Acartia clausi*. The remaining one percent was represented by *Centropages, Oithona* and *Podon* spp. together with decapods and polychaetes larvae and chaetognaths. In the east channel, between Salamis Island and the mainland, the species composition was the same as in Elefsis Bay with the addition of *Corycaeus* sp. and Appendicularia.

The species composition in the Saronikos proper and the outer Saronikos was quite different from that of the Elefsis Bay. All Aegean species reported Kiortsis et. al. (1970) were found in significant quantities. For example, the predominate copepods were species of *Acartia, Temora, Calanus, Eucalanus, Clausocalanus, Centropages, Candacia, Ooithona,* and *Corycaeus. Acartia clausi* was the most abundant species making up approximately 30 percent of the individuals. Other groups such as Appendicularia, siphonophores, chaetognaths, salps, decapods and polychaetes larvae were well distributed throughout the Saronikos Gulf.

DISCUSSION

Based on zooplankton dry weights obtained from oblique hauls (from 20 or 25 m to the surface) it is possible to draw conclusions about the vertical distribution of zooplankton. In general, the zooplankton concentration was almost homogenous at all depths at stations H1, K3, K5, O5 in January 1973. At the same period, the maximum zooplankton biomass was concentrated in the deeper layers at stations P2 and H3, and at the surface at station O6. In March the zooplankton biomass seemed to be homogenous in the water column at station H1. Concentrations at surface layers occurred at stations H4 and P2 and in deeper layers at K5 and P3.

Some of the vertical zooplankton distribution might be explained as a result of the water circulation in the Gulf. The occurrence of homogenous concentrations suggest that the water masses are well mixed. The existence of higher zooplankton concentrations at surface or at deeper layers suggest that enriched water has drifted into the surface or into the deeper layers.

On the basis of dry weight values, it is possible to recognize various masses of seawater. The open Aegean Sea water mass has biomass values from 0.5 to 2.9 mg/m^3 during winter (Yannopoulos and Yannopoulos, 1973). A second is characterized by considerably higher concentrations which are probably associated with previously enriched water but at the same time disconnected from the nutrient source (see station P6, Figure 1). Biomass values for this water mass vary between 7.0 and 9.9 mg/m^3. The larger part of the Saronikos Gulf presents intermediate biomass values. This signifies extensive proportional mixing of the two aforementioned masses of water.

Much higher concentrations appear in waters directly in contact with the nutrient source. In this case, dry weights are between 10.0 and 24.9 mg/m^3. Apparently, extreme physical and biological conditions not yet clarified existed in Elefsis Bay thereby permitting very high biomass concentrations of between 25.0 and 96.1 mg/m^3.

Acartia clausi was more abundant in areas near Keratsini (at the east channel of Salamis where the outfall is located) and less abundant further from this point. The H4 sample of the March cruise had almost the same appearance as those obtained from Elefsis Bay with a species composition of 90 percent *A. clausi*, 5 percent of *Centropages* and 5 percent of the remaining groups. This suggested that the water at station H4 originated in the Elefsis Bay. It should be mentioned that samples from the surrounding stations were similar to the ones described for the Saronikos proper, implying that Elefsis Bay water either existed sporadically in time or that the spatial grid was not close enough to detect the pathway of this water. Recent observations by C i t a r e l l a (1973) on zooplankton of the Gulf of Lion, indicated that *A. clausi* and *Calanus minor* were very abundant in polluted waters. As stated above, *A. clausi* was more abundant near the outfall, becoming less abundant away from Keratsini into the Saronikos Gulf. This observation coincided with that of C i t a r e l l a (1973). In Elefsis Bay, the situation was quite the opposite; the biomass of A. *clausi* increased further away from the nutrient source. For the March cruise, calculations for 3 stations in Elefsis Bay, from the west to the east, were 96.1 mg/m^3, 59.2 mg/m^3 and 22.7 mg/m^3, respectively. The same occurred in January, that is, *A. clausi* biomass increased from the east to the west while nutrient values decreased in the same direction (C o a c h m a n, H o p k i n s and D u g d a l e, 1976). Nutrient values were very high throughout Elefsis Bay and the distribution may have been dictated by other chemoenvironmental effects. In the Saronikos proper, high concentrations of *A. clausi* occurred at station H4 (March) indicating a recent exit of some water from Elefsis Bay. It is assumed that the presence of *A. clausi* at that station is the result of a drift out through the east channel and a dispersion into Saronikos proper. In such a case, the observations of C i t a r e l l a (1973) do not apply to the Saronikos. Apparently, there were other environmental factors that effected the concentrations of *A. clausi* in heavily polluted areas such as the eastern part of the Elefsis Bay and the Saronikos proper near the outfall. In Elefsis Bay 80 percent of the total phytoplankton in January consisted of dinoflagellates (G u d e n b e r g, 1976), while the main group for the Saronikos proper were diatoms. This probably favored *A. clausi* to flourish significantly.

During the March cruise, a bloom of *Noctiluca miliaris* was observed and the number per m^3 was calculated. From the oblique hauls, it was noted that concentrations of *N. miliaris* were in the deeper and not in the surface layers. At stations K5 and H4, there were no *N. miliaris* in the samples obtained between 20 or 25 m and the surface. In contrast, there were significant amounts in vertical hauls at the same stations, at K5, 1272 and at H4, 1695 individuals per m^3 respectively. The main concertration of *N. miliaris* was obtained from vertical hauls along line H on 8 March, with maximum numbers of 4562 and 4200 individuals per m^3 from stations H3a and H5a respectively. Stations along the F line, were relatively poor in *N. miliaris* during the first

sampling of 9 March, on repeated sampling of these stations on 13 March, the biomass was quite different and also great numbers of *N. miliaris* were found, 6533 at station F 4, 4973 individuals at station 5 and 6343 at the station which is near the outfall. This very important result suggests the need for further investigations which would combine data on water movements, nutrient concentrations and phytoplankton.

Comparing previous data on zooplankton, it is assumed that the standing stock of the Saronikos Gulf was of the same abundance as that in the Gulf of Lion reported by Arellano-Lennox (1970) and the middle Adriatic Sea reported by Vučetić (1961) and as shown in Table 1.

Table 1. A comparison of the zooplankton biomass obtained from several areas in the Mediterranean Sea.

Author	Location	Dry weight (mg/m^3)	
ARELLANO-LENNOX (1970)	Marseille and Lion Gulfs	max 7.39	March-May
		min 7.04	
VIVES (1968)	Catalan Plateau	max 21	March-July
		min 7	
VUČETIĆ (1961)	Adriatic Sea	max 26.0	June-July
		min 4.7	
YANNOPOULOS and YANNOPOULOS (1973)	Saronikos and South Evoikos Gulfs	max 5.5	August 1969
		min 2.3	
		max 11.5	March 1970
		min 2.3	
YANNOPOULOS and YANNOPOULOS (present paper)	Saronikos Gulf	max 16.6	December 1972
		min 2.6	
		max 17.2	January 1973
		min 2.0	
		max 11.3	March 1973
		min 0.5	
YANNOPOULOS and YANNOPOULOS (present paper)	Elefsis Bay	max 78.4	January 1973
		min 44.8	
		max 96.1	March 1973
		min 22.7	

CONCLUSIONS

The zooplankton biomass in the Saronikos proper is 5 to 10 times higher than that of the outer Saronikos Gulf and the open Aegean Sea.

The proportions between the various species are about the same in the Saronikos Gulf and in the Aegean Sea with the exception of the species which are favored in eutrophic waters such as *Acartia clausi* and *Noctiluca miliaris*.

The zooplankton biomass in Elefsis Bay is extremely high, 20 to 50 times that of the open Aegean Sea.

The zooplanktonic community in Elefsis Bay appears extremely monospecific, probably because of yet undetermined factors which in addition inhibit the flourishing of all other species.

SUMMARY

The Saronikos Gulf can be divided into three major areas based on the eutrophication. The areas include the outer Saronikos Gulf with a zooplankton biomass from 0.5 to 2.9 mg/m^3; the Saronikos proper with zoobiomass from 3.0 to 17.2 mg/m^3 and Elefsis bay with zooplankton biomass from 25.0 to 96.1 mg/m^3.

The zooplankton concentrations at the surface or at deeper layers varied from one place to another and depended mainly on the circulation of the water masses.

The zooplanktonic community appeared extremely monospecific in Elefsis. Bay and consisted of *Acartia clausi* only. In the Saronikos proper all the Aegean Sea species were present but *A. clausi* was the most abundant, roughly comprising 30 percent of the total population. *A. clausi* in the Saronikos Gulf may have originated in the Elefsis Bay.

It was apparent that the eutrophic waters had a higher zooplanktonic biomass and altered the species composition. In the extreme case of Elefsis, a mono-specific population of very high biomass was found. In the less eutrophic waters of Saronikos proper a predominance of certain species *(A. clausi* and *N. miliaris)* and intermediate biomass values were found.

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KRATAK SADRŽAJ

Zaljev Saronikos se prema stupnju eutrofikacije može podijeliti u tri osnovne zone: vanjski dio zaljeva ima zooplanktonsku biomasu od 0.5 do 2.9 mg/m^3, zaljev u užem smislu od 3.0 do 17.2 mg/m^3, a zaljev Elefsis od 25.0 do 96.1 mg/m^3.

Koncentracija zooplanktona na površini i u dubljim slojevima ovisi pretežno o cirkulaciji vode.

Zooplanktonska zajednica u zaljevu Elefsis je ekstremno monospecifična i sastoji se samo od kopepoda *A. clausi*. U samom zaljevu Saronikos su prisutne sve vrste Egejskog mora, ali *A. clausi* predstavlja 30% ukupne populacije. Ona moguće potječe iz zaljeva Elefsis.

Jasno je da eutrofne vode imaju višu zooplanktonsku biomasu i izmijenjen sastav. Zaljev Elefsis je ekstreman s vrlo visokom biomasom samo jedne vrste. U manje eutrofiziranom području samog zaljeva Saronikos uz umjerenu biomasu prevladavaju određene vrste.