A STUDY OF THE PHYSICAL ENVIRONMENT AND WATER CIRCULATION IN FARWA LAGOON, LIBYA

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ABSTRACT

The seasonal distribution of the physical parameters monitored over a period of one year in this shallow lagoon showed that hydrographically, the lagoon could be divided into two parts: the inner which is less saline (38.5 to 41 ‰) due to the open-sea effect, and the inner-hypersaline ($S > 41$ ‰) due to evaporation processes assisted by small-scale gyratory motions. The water temperature ranges between 11°C in winter and 29°C in summer. The dissolved oxygen content is of about 5 ml/L or higher everywhere in the lagoon. The water exchange with the sea is dominated by current's inflow through the southern half of the lagoon's entrance, and an outflow through the northern half with velocities of the order of 25 cm/sec.

INTRODUCTION

According to the general features of coastal lagoons described by Phleger (1981),the Farwa Lagoon situated on the Libyan coast is a typical coastal shallow lagoon. The first comprehensive study of the lagoon's environmental and ecological conditions was carried out by the Marine Research Centre of Tripoli in 1981 (MRC, 1982). To further investigate the physical properties of the lagoon waters and their seasonal variabilities, and to study the current system in the lagoon, an extensive physical survey was conducted in 1981-82. The present paper summarizes the main results of this survey, the detailed description of which is given elsewhere (Gerges and Durgham, 1983).

AREA OF INVESTIGATION

The Lagoon is located on the Mediterranean coast, about 150 km west of Tripoli,Libya (Fig. 1). It has an elongated basin extending from west to east with an axial length of about 12 km and maximal width of about 3 km. Its surface area is approximately 31 sq.km. The lagoon's basin is separated from the sea by a narrow sand bar of about 11 km length, forming what is known as Farwa Island. It has a relatively wide opening to the sea of about 3.5 km width at high tide. This permits free connection, and establishes permanent water exchange with the open sea.

DATA COLLECTION AND ANALYSIS

The hydrographic data were collected at 10 fixed stations, the positions of which are indicated in Fig.(1), at approximately bimonthly intervals from June 1981 to May 1982. At each station, the surface water temperature was measured and water samples were taken for the salinity and dissolved oxygen determinations in the laboratory. The salinity values were determined by the Mohr-Knudsen titration method and Knudsen tables. The dissolved oxygen content (DOC) was determined using the Winkler method.

Surface current measurements were made at all stations using an NBA-direct reading current meter (Model DNC-3). In the mean time, the air temperature and surface wind observations were collected.

RESULTS AND DISCUSSION

The seasonal hydrographic features, as revealed from the horizontal distributions of the physical parameters monitored in the lagoon, are described as follows:

In the summer season: The surface water temperature ranges between about 25^{o} and 29.5^{o}C. It increases from the entrance of the lagoon toward its inner tip, i.e. from west to east. The effect of the inflow of the open sea water into the lagoon is quite obvious. Also, the water salinity,as one would expect, is found to be much higher in the inner part of the lagoon (44.50 ‰) than at its entrance (38.50 ‰) (Fig.2). This is apparently related to the turbulent mixing process, occuring between the lagoon's hypersaline water and the typical Mediterranean water of lower salinity, entering the lagoon under the action of the NW winds prevailing in this season. The degree of mixing, the spreading of the mixed water and hence the salinity distribution are largely dependent on the blowing wind speed, direction and duration. On the other hand, the evaporation plays an important role in defining the water salinity in the inner part of the lagoon. The dissolved oxygen content (DOC) varies between 5 and 7 ml/L, with the higher values being observed in the southern half of the lagoon, particularly near the inlet. The lagoon's water is generally supersaturated in summer, with a maximum of about 125 % in June (MRC,1982).

In the autumn season: Unlike the previous season, the water temperature in the lagoon does not show a marked spatial variability. It varies only between about 24.2^{o} and 25.1^{o}C over the whole area of the lagoon. However, it is noticeable that the temperature in the most inner tip of the lagoon is lower than that at the entrance, apparently due to the greater cooling effect of the surrounding landmass. Meanwhile, the water salinity exhibits a pattern of distribution which resembles that of late summer, with lower values (38.50 ‰) at the entrance, increasing gradually to reach a maximum of 43.57 ‰ in the inner part. The intrusion of sea water into the lagoon was rather limited, and so was the mixing between the Mediterranean water and the lagoon's hypersaline water (Fig.3). The DOC shows a general saturation, with values ranging between 4.75 and 6.58 ml/L. The higher values were still observed in the southern parts of the lagoon, but the region of the highest oxygen saturation was found shifted toward its center.

In the winter season: The water temperature continues to be lower in the inner part of the lagoon(about 10.5^{o}C) and higher in the outer part, where a maximum of 13.0^{o} C was observed. This, as was in the autumn season, is due to the continental cooling effect. The salinity at the entrance was as high as 39.50 ‰. Due to apparent winter instability in climatic and sea conditions, the mixing between the Mediterranean and lagoon waters takes place right at the entrance. Then, under the action of strong winds the mixed water with 41.50 ‰ salinity spreads eastwards, all the way to the innermost part of the lagoon. In general, the salinity in the lagoon is relatively lower than in other seasons, apparently due to winter precipitation and greater intrusion of seawater.

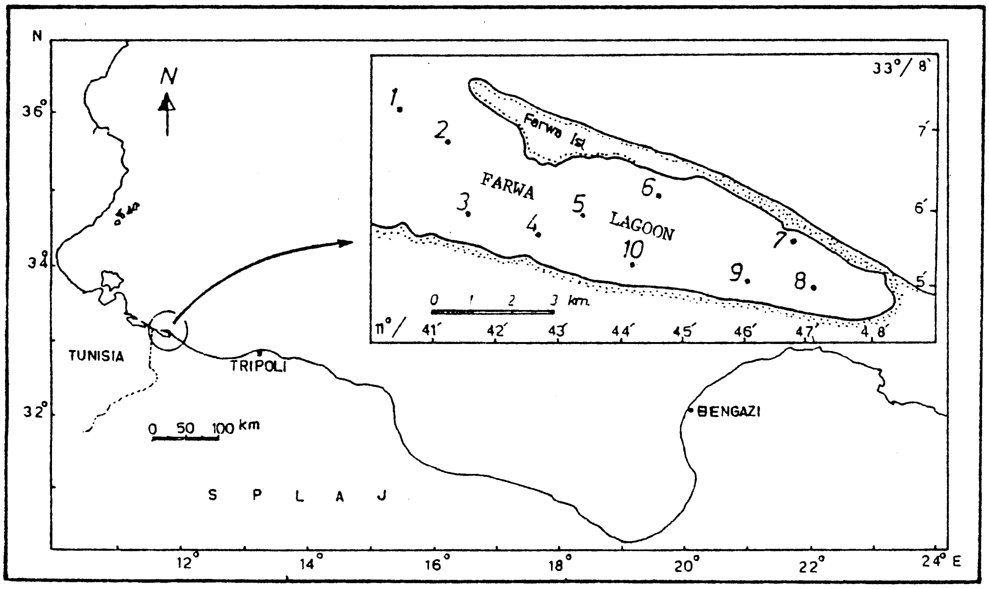

Fig.(1) - Area of investigation and its location relative to the Libyan coast

The DOC is greater than 6.0 ml/L in the middle part of the lagoon, while its value in both the outer and inner parts were always less than 6.0 ml/L (Fig. 4).

In the spring season: The warming up of the air obviously increases the surface water temperature, relative to the previous season, by at least 10°C everywhere in the lagoon. In the mean time, the water in the inner part of the lagoon starts to be warmer than in the outer part, similar to the summer situation. The water salinity shows a distinct distribution pattern. The Mediterranean water of 39.40 ‰ salinity mixes with the lagoon water, but the mixed water does not penetrate further into the inner part of the lagoon as experienced in winter. In general, there is a tendency of salinity increase everywhere in the lagoon, apparently due to a corresponding increase in the rate of evaporation, and a maximum value of 43.20 ‰ is observed in the inner part of the lagoon. The DOC distribution shows also a general increase of the values relative to all previous seasons. The central part of the lagoon, in particular, is indicated to be richer in oxygen than the other parts. Since this seems to be dominant in all seasons, it is thought that the distribution of the Posidonia,covering the greater part of the lagoon's bottom, plays a role in this regard.(Fig. 5).

Water Circulation

The data obtained from the direct measurements of surface currents, when incorporated with corresponding hydrographic and meteorological information, collected simultaneously, reveal the following principal features of circulation:

1. The only water input to the lagoon is the inflow of sea water which consists of typical Mediterranean water driven toward the coast by the prevailing NW and NNW wind. Then, flowing eastwards along the coast, it enters the lagoon over the southern half of its opening with moderate speed of the order of 10 to 20 cm/sec. The intrusion of

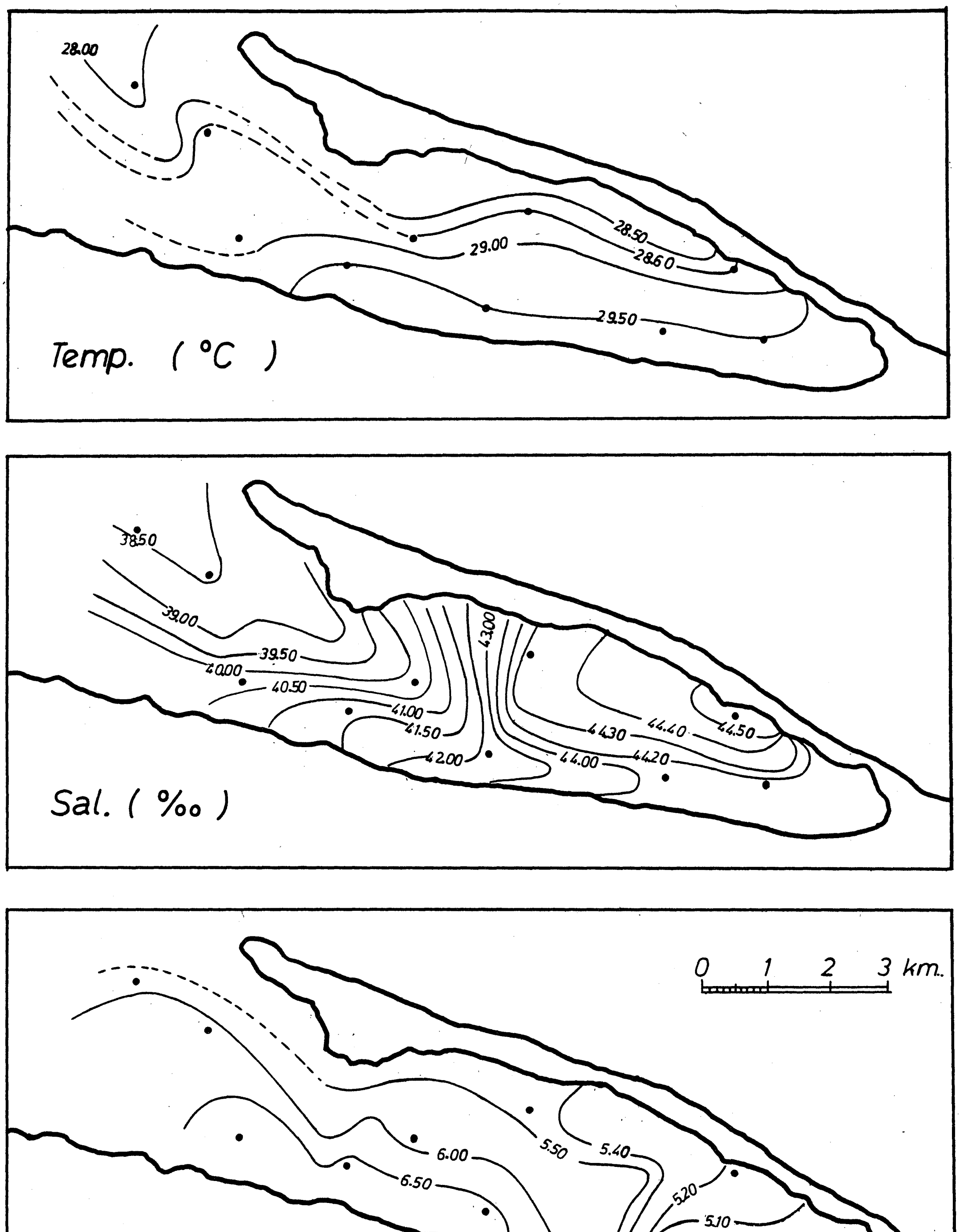

Fig. (2) - Horizontal distribution of physical parameters in SUMMER

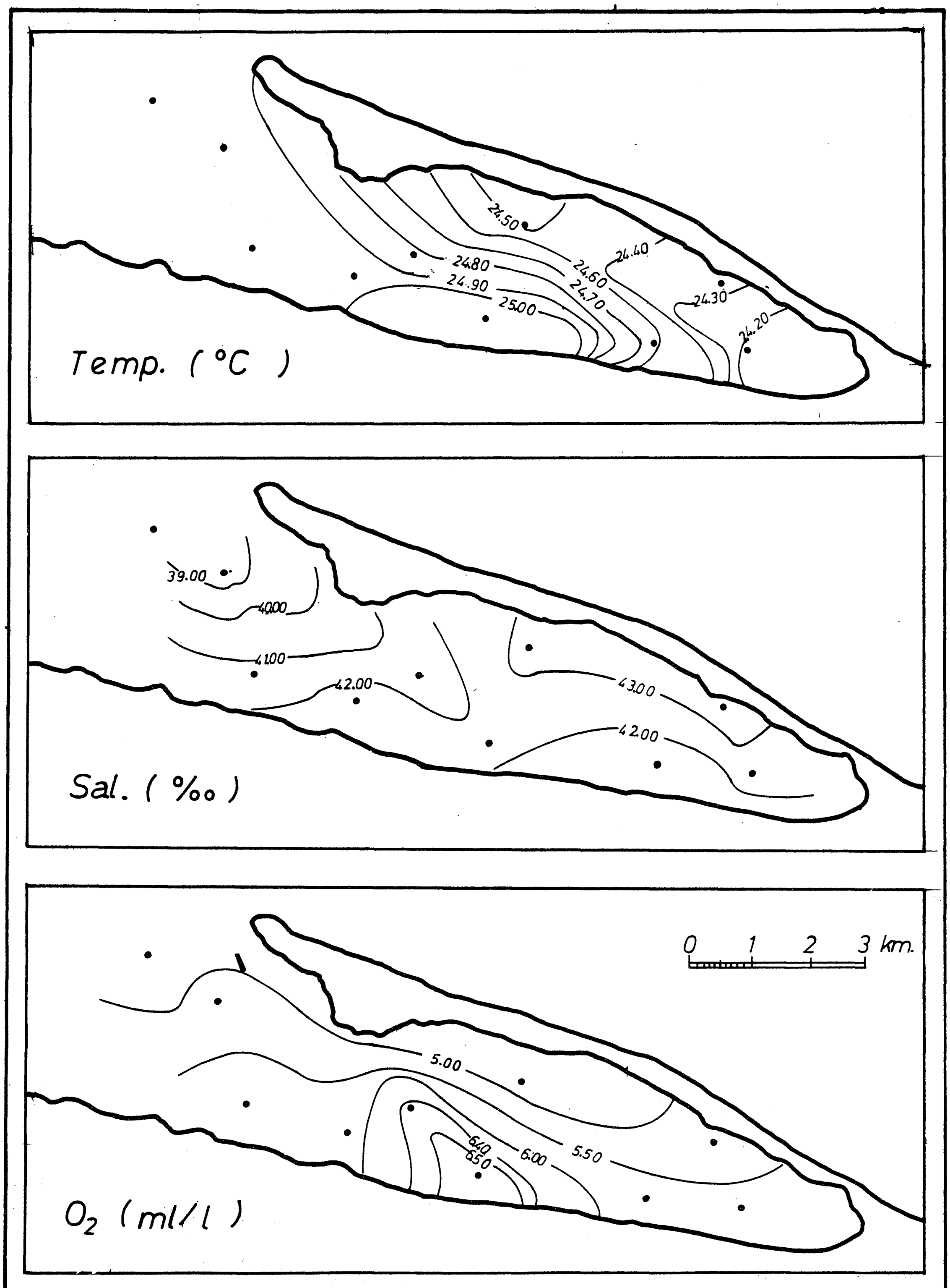

Fig. (3) - Horizontal distribution of physical parameters in AUTUMN

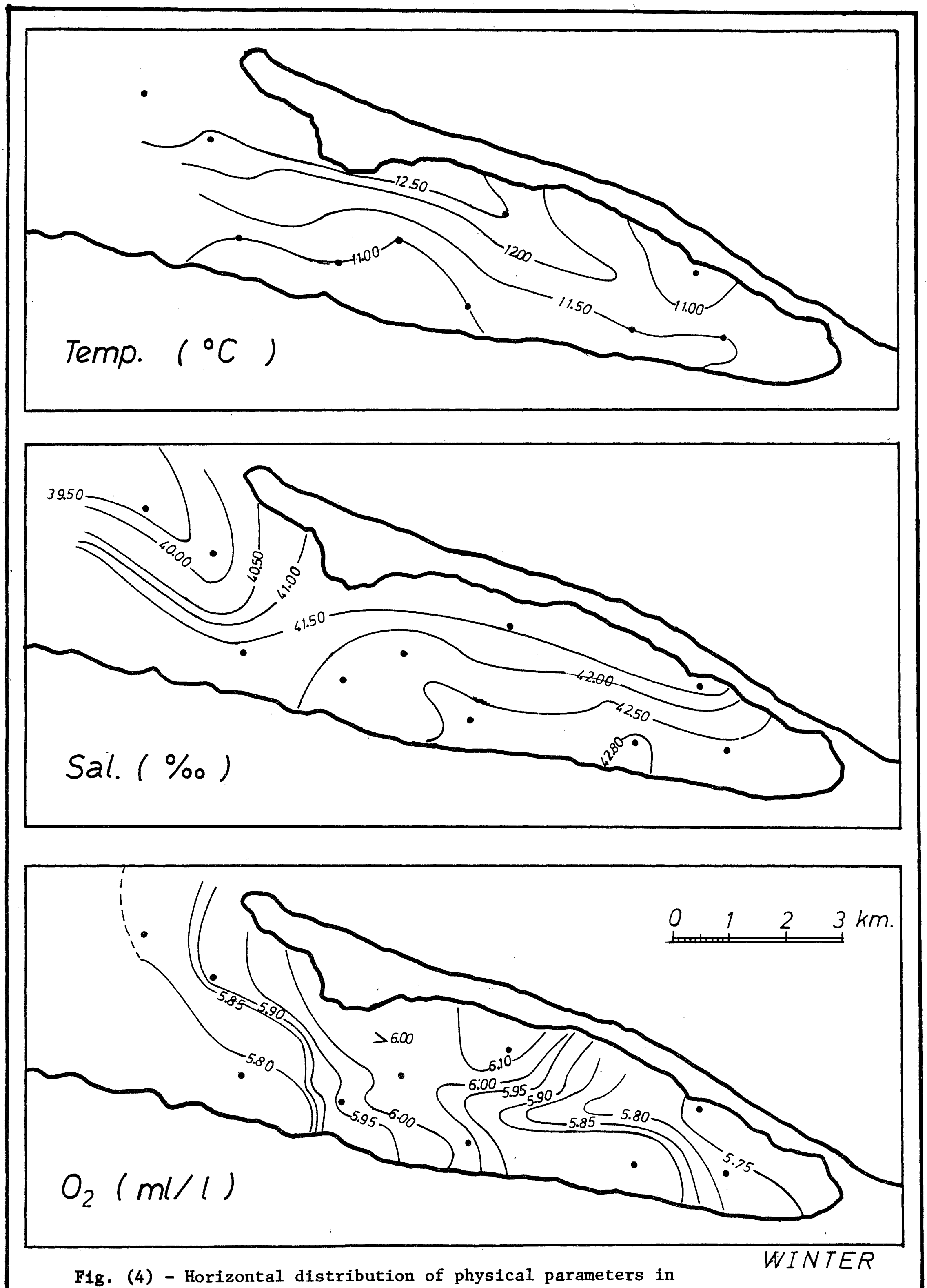

Fig. (4) - Horizontal distribution of physical parameters in

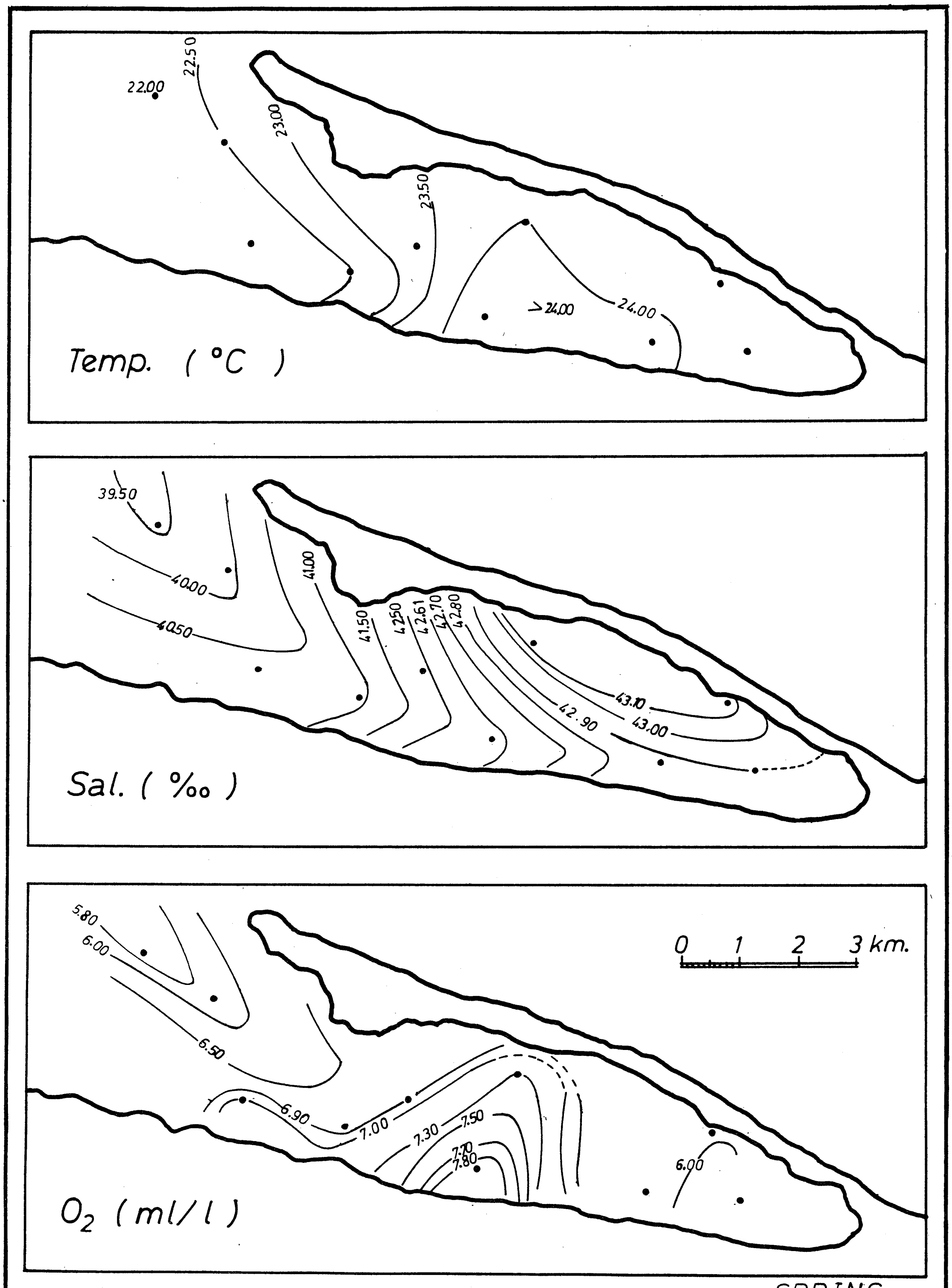

Fig. (5) - Horizontal distribution of physical parameters in SPRING

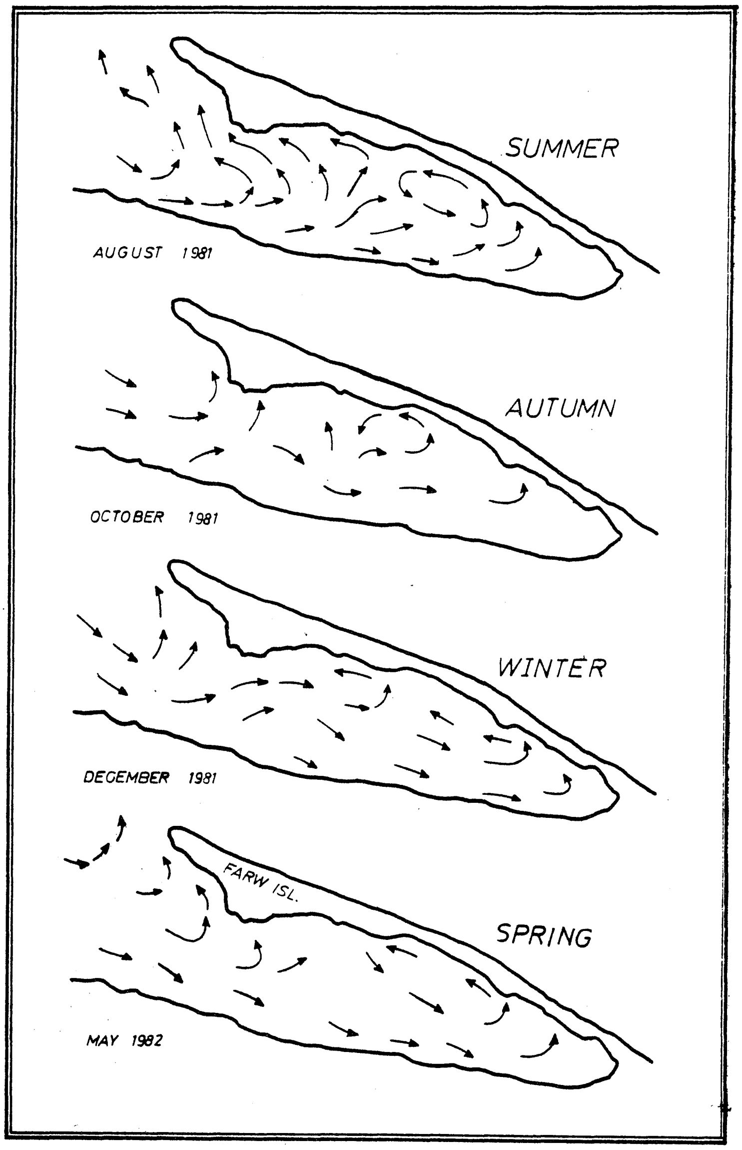

Fig.(6) - Seasonal patterns of water circulation in the lagoon

this Mediterranean water and its extent inside the lagoon vary from season to season, depending upon the prevailing wind direction and speed, and on the associated mixing processes.

2. As the Mediterranean water, which always has a salinity value less than 39.50 ‰, moves eastwards inside the lagoon, the intensity of the flow increases considerably. Upon mixing with the lagoon water, its salinity increases gradually to reach values up to 41 ‰ around the middle of the lagoon. There, the flow splits and the water seems to flow along two directions. One flow deviates to the north and eventually returns to the sea. The other one continues to the east to circulate the inner part of the lagoon counterclockwise,with velocities of the order of 40 cm/sec, before to turn eastwards. The part of the flow returning toward the opening joins the water flowing out of the lagoon. Thus reinforcing its velocity to reach about 25 cm/sec.

3. Inside the lagoon itself, the flow circulating the inner part may form some small-scale cyclonic gyre. This gyre, which is usually located over the deepest spot in the northern part of the inner lagoon, forms a rotating body of water surrounding some areas of relatively higher salinities. These high salinities, approaching 42 ‰ in winter, 43 ‰ in spring, 44.5 ‰ in summer, and 43 ‰ in autumn, are most probably obtained through the evaporation process, particularly in the summer season, with the assistance of the above gyratory motion. However, the location, extent and strength of this gyre may vary from one season to another, or may even disappear sometimes. It appears to be most extensive and pronounced in spring and summer seasons, weaker in the autumn, and much less pronounced in winter (Fig. 6).

In conclusion, it should be emphasized that further physical studies to investigate the water and salt balances of the lagoon, and to estimate the flushing intensity and time scale are necessary and should therefore be carried out in the future.

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