UNEP

REGIONAL SEAS

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State of the marine environment in the Mediterranean Region

UNEP Regional Seas Reports and Studies No. 132

MAP Technical Reports Series No. 28

Prepared in co-operation with

FAO IOC WHO

UNEP 1990

PREFACE

The better understanding of the changing problems facing the marine environment is a continuing goal of UNEP'S Ocean programme, as it provides the necessary scientific background for shaping UNEP's policy towards the protection of the oceans.

The main sources of factual information used in the assessment of the state of the marine environment are data published in open scientific literature, data available in various reports published as "grey literature" and data generated through numerous research and monitoring programmes sponsored by UNEP and other organizations.

Several procedures are used to evaluate critically the large amount of available data and to prepare consolidated site-specific or contaminant-specific reviews.

GESAMP, the IMO/FAO/Unesco/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on Scientific Aspects of Marine Pollution, is charged by its sponsoring bodies with preparation of global reviews. Reviews dealing with several contaminants have been already published by GESAMP and others are being prepared for publication. The first global review on the state of the marine environment was also published by GESAMP in 1982, and the second global review was published in 1990 [1]

In parallel with the preparation of global assessments, the preparation of a series of regional assessments, following the general format of the second global review of GESAMP, was initiated by UNEP in 1986, with co-operation of the Food and Agriculture Organization of the United Nations (FAO) and the Intergovernmental Oceanographic Commission (IOC). Fifteen task teams of scientists were set up, involving primarily experts from the relevant regions, to prepare the regional reports under the joint overall co-ordination of UNEP, FAO, and IOC, and with the collaboration of a number of other organizations.

The present document is the product of the Task Team for the Mediterranean Region. The final text of the report was prepared by L. Jeftic, as Rapporteur of the Task Team for the Mediterranean Region, with collaboration of M. Bernhard, A. Demetropoulous, F. Fernex, G. P. Gabrielides, F. Gasparovic, Y. Halim, D. Orhon and L. J. Saliba, whose contributions are gratefully acknowledged. A contribution to the report was also received from R. Fukai, Monaco.

This report was edited and prepared for publication by Philip Tortell of Environmental Management Limited, New Zealand.

[1] Publications of GESAMP are available from the organizations sponsoring GESAMP.

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1. CHARACTERISTICS OF THE REGION

1.1. GEOGRAPHIC SETTING

The Mediterranean Sea lies (46°N, 30°N, 6°W and 36°E) between Europe, Asia and Africa and without the Black Sea covers about 2.5 million km^2, with an average depth of about 1.5 km and a volume of 3.7 million km^3.

For the purposes of this report, geographic coverage basically follows the definition from the Convention for the Protection of the Mediterranean Sea against Pollution (Barcelona Convention) which in its article 1 states:

"For the purposes of this Convention, the Mediterranean Sea Area shall mean the maritime waters of the Mediterranean Sea proper, including its gulfs and seas, bounded to the west by the meridian passing through Cape Spatell lighthouse, at the entrance of the Straits of Gibraltar, and to the east by the southern limits of the Straits of the Dardanelles between Mahmetcik and Kumkale lighthouses."

Fig. 1 presents the Mediterranean Sea with its major interactive parts and adjacent areas.

About 30% of the surface area and 50% of the total volume is contained between a 2 and 3 km depth contour. In contrast, the area with a shallower than 200 m contour constitutes more than 20% of the total area of the Mediterranean Sea but contains less than 1.5% of the total volume (Menard & Smith, 1966).

The Mediterranean Sea consists of a series of interacting parts and adjacent seas, with two major basins, Western and Eastern. In the Western Mediterranean (about 0.85 million km^2) such parts are the Alboran Sea, the Algero-Provençal basin, the Ligurian Sea and the Tyrrhenian Sea. In the Eastern Mediterranean (about 1.65 million km^2) such parts are the Adriatic Sea, the Ionian Sea, the Aegean Sea and the Levant (Fig. 1).

The Mediterranean Sea is connected with (and separated from) the Atlantic by the Strait of Gibraltar (15 km wide and 290 m deep), with the Sea of Marmara by the Dardanelles (between 450 m and 7.4 km wide and 55 m deep) and with the Red Sea by the Suez Canal (120 m wide and 12 m deep).

The maximum length of the Mediterranean Sea from Gibraltar to Syria is about 3,800 km and the maximum distance in the north-south direction from France to Algeria about 900 km, yet one is never further than 370 km from the coast, and most often, considerably less, with more than half of the Mediterranean Sea being less than 100 km from the coast.

1.2 GEOLOGICAL AND CLIMATIC CHARACTERISTICS

The Mediterranean basin, situated at the centre of a very complex mosaic formed by the tectonic plates sliding under one another, is subject to heavy seismic and volcanic activity whose consequences for human life and society are a permanent feature of the region. The young relief and the close contact and interpenetration of the sea and the mountains have had significant consequences: few large plains, little good agricultural land, ports and harbours tightly hemmed in between sea and rock, few broad fluvial basins. With the exception of the south-east and some 3,000 km along the Libyan and Egyptian coasts where the Saharian platform directly meets the sea, there are mountains everywhere, sometimes virtually uninterrupted, plunging in numerous places directly into the sea (UNEP, 1987).

In the North, the sea areas are surrounded by mountains from the Sierra Nevada ranges and the Pyrenees in the northwest, the Alps and the Apennines in the north and the Balkan and Anatolian mountains in the northeast. While there are large alluvial plains associated with the Ebro, Rhône and Po rivers, the Mediterranean is essentially bounded by mountainous coasts sloping steeply to the sea. In the southern regions the African Atlas mountains are barriers along the Western Mediterranean, but the remainder of the southern coast is deserts with no high barriers to affect air flow. This imbalance of geomorphology is an external factor affecting the ecology of the Mediterranean (Miller, 1983).

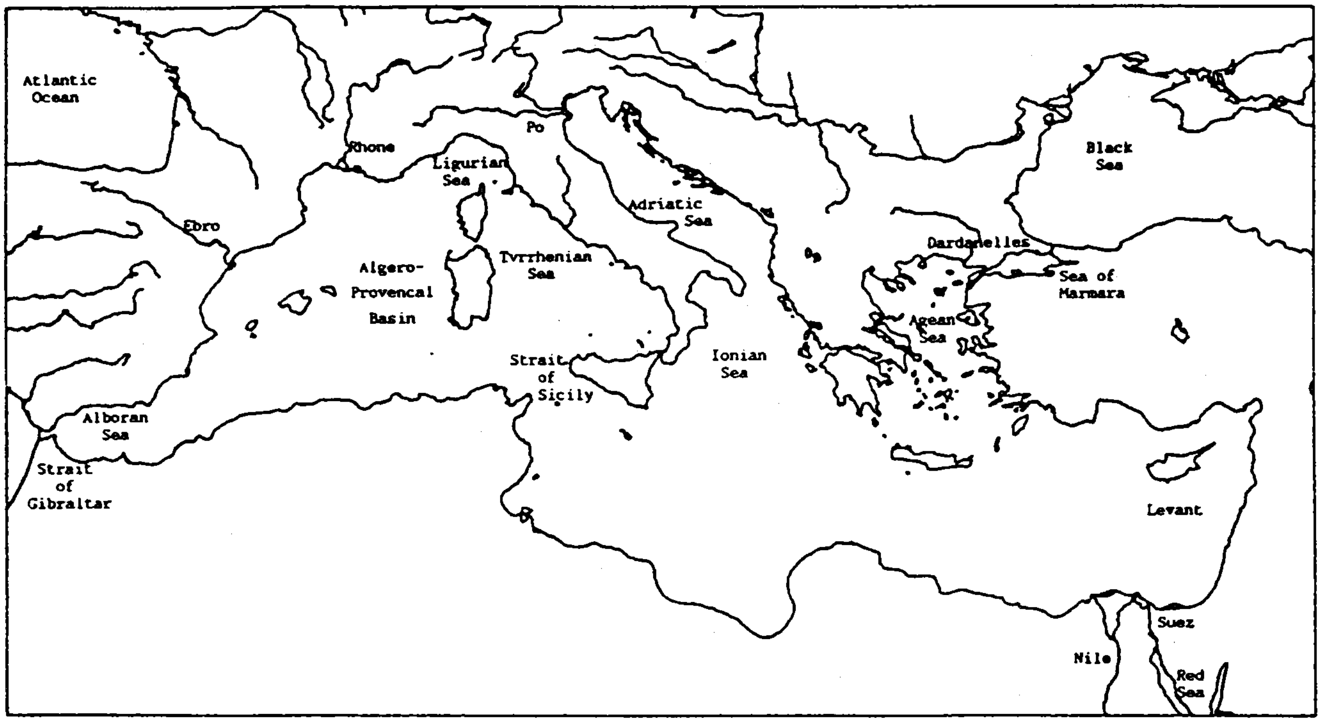

Fig. 1: The Mediterranean Sea

Major Mediterranean rivers (Ebro, Rhône, Po and Nile) drain geological terrains far removed from the present coastline. Although few in number, these major fluvial sources account for very large volume of sediment (over 50 million tons annually) injected into the system. On the other hand, the highly irregular coast, much of which is fronted by high mountain barriers, is distinguished by short, often torrential rivers draining small areas on a highly seasonal basis.

The Mediterranean is a transitional area climatically, with a temperate, damp climate in the north and an extreme arid climate in the south. Orographic rains on the European coasts contrast markedly with minimal annual rainfalls in the southern regions of less than 100 mm. The disparity in the amounts and occurrences of precipitation is influenced by the topography of the land and the climatic conditions of the area (Miller, 1983).

The northern sectors of the basin, lying within the zone of prevailing westerly winds, are characterized by spring and autumn showers that curtail the summer drought, and have a moderate climate. Rainfall intensity and duration decrease both from west to east and from north to south. Temperature, on the other hand, increases from north to south and from west to east. Rainfall throughout the region is seasonal, with a marked minimum in summer.

Surface winds in the Mediterranean are generally from the north and west. The combination of dry winds and sunny days, which occurs as often as 250 times a year, produces a strong evaporating influence over the entire surface of the Mediterranean that counteracts the effects of precipitation and runoff (Miller, 1983).

1.3 CIRCULATION

The surface current system of the Mediterranean shows a migration of Atlantic water, with salinity slightly above 36, towards the east with numerous spin-off eddies along the way (Miller, 1983). The annual thermal changes of surface waters are very large and control the density of surface waters and the basic characteristics of the annual biocycle. There is no surface return system from the east to the west.

The return of Mediterranean water is by way of Levantine intermediate water and Mediterranean deep water flowing from east to west and spilling over the sill of Gibraltar into the deep Atlantic. Such intermediate and deep water is produced by very pronounced evaporation processes which gradually transform surface water with salinity slightly above 36 into denser water with salinity of 38.4 or more. Deep sea water in the Mediterranean has a temperature between 12.5° and 13.5°C in the west and between 13.5° and 15°C in the east with salinity between 38.4 and 39.

The estimated turnover time for Mediterranean waters is 80 years. The basic nature of the Mediterranean circulation system contains components of strong vertical convections which determine the distribution of salinity and produce vertical recycling of nutrients and other dissolved substances (Miller, 1983). When winter storms lower surface temperature in the western Mediterranean to 12°C, deep convection can take place; in the Algero-Provençal basin it was traced to a depth of 2,000 m.

The Mediterranean is characterized by very weak tides, with tidal amplitudes which are very small by world ocean standards. The Mediterranean is often considered a tideless sea; this however gives the wrong impression since although the tidal elevations are almost insignificant, the energy of the tides is not (Hopkins, 1985).

Sea level in the Mediterranean is lower than in the Atlantic, progressively decreasing from Gibraltar towards the North Aegean, with maximum differences of about 80 cm (Miller, 1983).

1.4 WATER BALANCE OF THE MEDITERRANEAN SEA

The Mediterranean Sea has a deficient hydrological balance, with loss through evaporation exceeding the input of water through run-off and precipitation. This deficiency is mainly compensated by the flow of Atlantic surface waters through the Strait of Gibraltar.

On the input side of the water balance are the net inflow through the Strait of Gibraltar, the net inflow through the Dardanelles, river run-off and precipitation. On the negative side of the balance there is evaporation.

The actual flow through the Strait of Gibraltar is about 1.5 million m^3s^{-1} in each direction with net inflow representing only about 3% of the figure (41,000 m^3s^{-1}), (Table 1). The net inflow through the Dardanelles is about 6,000 m^3s^{-1} (Table 1).

The river run-off in the Mediterranean is estimated at about 15,000 m^3s^{-1} of which 92% flows from the northern shore and the rest from the southern shore. The Northwest Mediterranean and the Adriatic Sea receive about 70% of the total Mediterranean river water input (Table 1).

The input of freshwater into the Mediterranean is estimated at about 31,000 m^3s^{-1} (Table 1). Yearly rainfall decreases from west to east and from north to south, varying between more than 1500 mm yr^{-1} (Alps, Pyrenees and western part of Yugoslavia) to less than 100 mm yr^{-1}.

The above figures bring the total input of water into the Mediterranean to approximately 93,000 m^3s^{-1}.

Evaporation, which is the main factor of the negative balance is estimated at about 93,000 m^3s^{-1} for the Mediterranean (Table 1). Most of the evaporation occurs during winter and spring, due to the prevailing strong and dry continental winds and is closely associated with the process of deep water formation.

The precipitation and run-off contribution to the water balance is exceeded by evaporation by about 1 m yr^{-1}. Since Gibraltar constitutes the only access for the renewal of sea water lost through evaporation, the increasing salinity of the Mediterranean water is due to the evaporation of the lower salinity water introduced from the Atlantic (Miller, 1983).

Within the Mediterranean Sea the Strait of Sicily (150 km wide and about 400 m deep) connects the Western with the Eastern Mediterranean. It is estimated that the actual flow through the Strait of Sicily is about 1 million m^3s^{-1} in each direction, with net inflow representing only about 4% of this figure (42,000 m^3s^{-1}) (Table 1).

1.5 CHEMICAL CHARACTERISTICS

Although the Mediterranean Sea is of a semi-enclosed nature, it does not have a chemistry of its own. Since residence time of the Mediterranean waters is about 80 years, most of the elements have plenty of time to tour the Mediterranean Sea. The most outstanding differential characteristic of the Mediterranean when compared to the Atlantic is its high salinity, as a result of evaporation, which is only surpassed in the Red Sea and Dead Sea (Cruzado, 1985).

Another well-known characteristic of the Mediterranean Sea is the relatively low concentrations, even in the deeper waters, of some biologically important chemical constituents. This is caused by the continuous wash-out through the Strait of Gibraltar which receives poor surface Atlantic water and exports relatively rich deep Mediterranean water. After approximately 80 years, almost all the substances dissolved in this surface water have undergone an increase in concentration of about 4.7% and then they flow back into the Atlantic at depth.

A fundamental characteristic of Mediterranean water is its impoverished nutrient concentration. No deep nutrient-rich Atlantic waters take part in the Mediterranean circulation. Since it is only the upper 150 m or so of Atlantic water which provide replenishment for the Mediterranean Sea, the only increase in the concentration of nutrients is due to river input and agricultural run-off or pollution (Miller, 1983).

Phosphate values in the Mediterranean vary from 0.1 to 0.5 µg at l^{-1} with very few definitive patterns other than the occurrence of higher values in deep water. The eastern Mediterranean has a smaller range of phosphate content than the western (Miller, 1983).

1.6 BIOLOGICAL CHARACTERISTICS

The Mediterranean is relatively poor, not in variety, but in the quantity of organisms produced. In a surface layer of water of about 100 m in depth phytoplankton change inorganic ions of nutrients into organic matter. Phytoplankton react rapidly to any increase in available nutrients and growth is limited by the concentration of nutrients. The principal nutrients, such as nitrogen and phosphorus, are often limiting and, together with inorganic carbon, are the basic elements from which the synthesis of organic matter in the natural environment takes place. It is commonly accepted that photosynthesis is slowed by the scarcity of a specific nutrient and that there may be a surplus of others. One of the main causes for the low nutrient content of the Mediterranean as compared with major oceans is that surface Atlantic waters, which are low in nutrients enter through the Strait of Gibraltar to compensate for evaporative losses. At the same time the Mediterranean loses deep water, which is rich in nutrients, to the Atlantic. Colder years tend to be more productive, partly because mixing may reach a greater depth and incorporate more nutrients, and partly because the formation of deep water may occur over a larger area.

Characteristically maximum bioproduction is at about 100 m depth in summer, just at the limit where