Volume 23/1991/EMECS '90

Eastern Mediterranean—a Marine Desert?

Y. AZOV
Environmental and Water Resources Engineering, Technion, Israel Institute of Technology, Haifa 32000, Israel

The Mediterranean Sea is considered by many as one of the less productive seas of the world. Due to geophysical and arid climatic conditions, the Eastern Mediterranean is the most oligotrophic part of that sea. After the operation of the Aswan Dam in 1965, the major nutrient contribution to this area was very considerably diminished. Several cruises and laboratory studies of the pelagic waters off the Israeli shore, indicated that the Eastern Mediterranean is comparable with the most oligotrophic parts of open oceans. The neritic waters, overlying the narrow continental shelf (10-20 km), were relatively much more productive than the pelagic waters, having in average three times the chlorophyll concentration and five times the primary production. However, even the neritic zone is very poor as compared to similar regions in the world. It is not surprising, therefore, that the total catch of marine fishes along the Israeli Coast is only few thousand tons annually.

Mediterranean Productivity

The Mediterranean Sea is an almost closed sea basin, connected to the Atlantic Ocean through the Straits of Gibraltar with an opening of only 50 km (Fig. 1). The sea has maximal length of 4,000 km, maximal width of 800 km, an area of 2.5 million square kilometers, and a mean depth of 1470 m. For many years, the Mediterranean was considered by scientists as "the most impoverished large body of water known" (Ryan, 1966). The reasons for the low productivity of the Mediterranean are the lack of significant upwelling areas, and the relatively small amounts of discharge from land, resulting in low nutrient concentration in the trophogenic layer.

In contrast to most oceans, many scientists consider phosphorus rather than nitrogen, to be the main limiting factor of primary production in the Mediterranean Sea (Berland *et al*, 1980), which has phosphorous concentrations between 0.1-0.5 μg-at l^{-1} (McGill, 1965).

The main river inflows are the Ebro, the Rhone and the Po, all located at the northwestern side of the sea, which discharge to the Mediterranean approx. 10^{11} m^3 water annually. The effect of riverine discharge on the productivity of the Mediterranean is usually only local and seasonal, causing increased productivity at coastal areas during fall and winter.

The arid climatic conditions in the Eastern Mediterranean cause intensive year round evaporation which is not compensated by precipitation or river discharge. Thus, a constant current of water from the Atlantic Ocean, approx. 32,000 km^3 per year, flows eastward through Straits of Gibraltar along the African coast and circulates westward along the southern Europe coast (Hopkins, 1978). However, none of the deep, nutrient rich Atlantic water, takes part in the Mediterranean circulations, as only a 150 m layer flows across the Gibraltar (Miller, 1983).

Marine Pollution Bulletin, Vol. 23, pp. 225-232, 1991.
Printed in Great Britain
0025-326X/91 $3.00+0.00

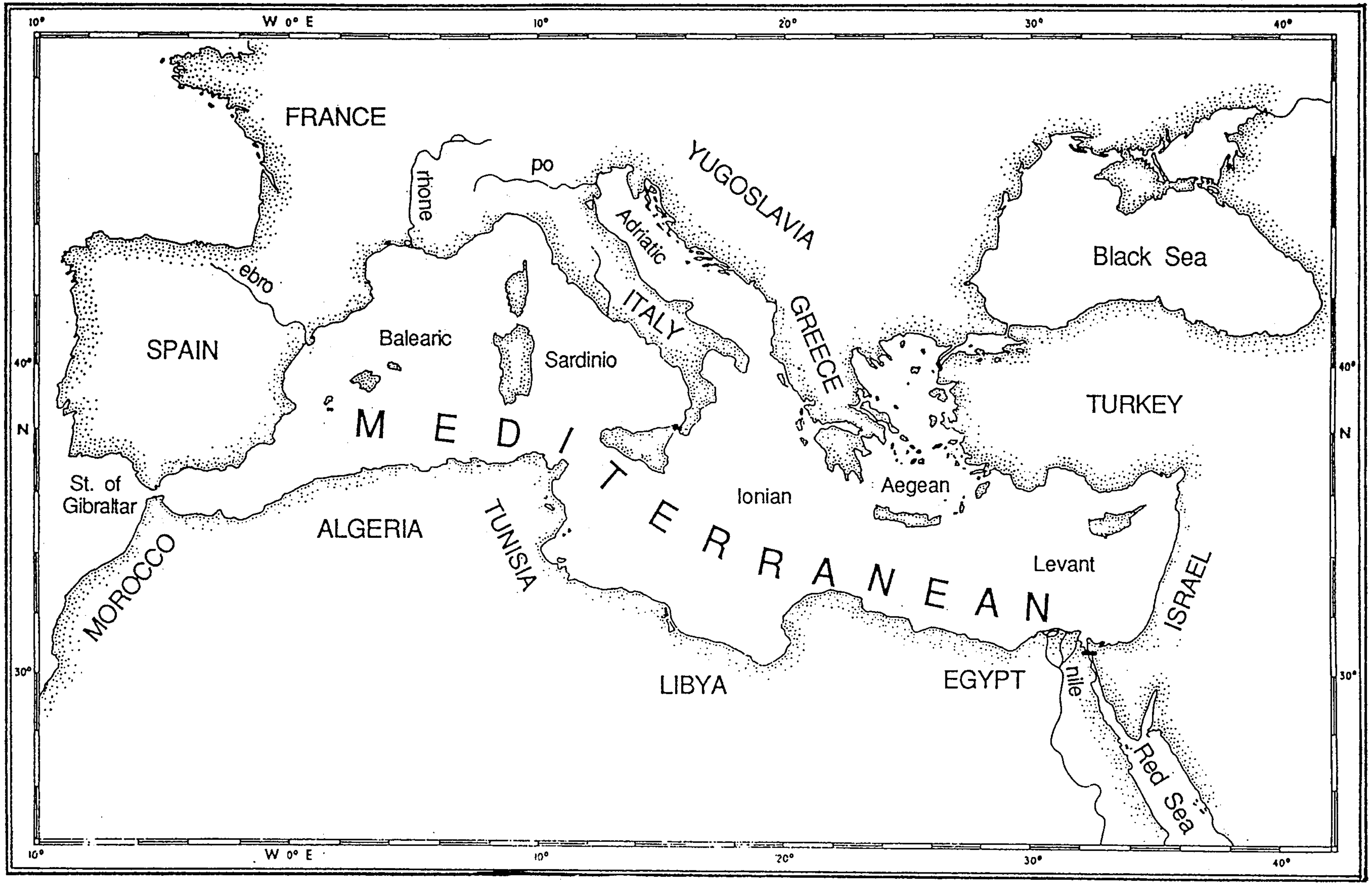

Figure 1: The Mediterranean Sea.

Eastern Mediterranean Productivity

Even before the construction of the Aswan High Dam, the data on productivity of Eastern Mediterranean, although scarce, indicated that this region is the most oligotrophic part of the Mediterranean .Based on intensive research efforts during the years 1962-1966, Oren estimated annual productivity values at this region of 30-60 gC m^{-2} (Sournia, 1973).
The Nile discharge to the Mediterranean was about $43x10^{9}$ m^{3} $year^{-1}$, carrying 140 million tons of mud and silt and supplied most of the nutrients to the Levant Basin (Fig. 1). During the flood season (September-October), phosphorous and silica concentrations increased almost ten fold, causing algal blooms in the Nile delta (Ben Tuvia, 1983). Since the completion of the Aswan High Dam in 1965 the Nile discharge is limited to overflow of the dam and diminished at first years of operation to almost ten times to only $4\text{-}5x10^{9}$ m^{3} $year^{-1}$, mainly during winter (Al-Kholy & El Waleel, 1975). The damming of the Nile has dramatic effects on the Levant Basin in physical, chemical and biological aspects (Gerges, 1976).
During the years 1981-1985, a comprehensive study of the southeastern Mediterranean was conducted as part of joint Israel-Egyptian-U.S. research effort supported by US-AID. Typical parameters characteristic of oligotrophic seas were observed at the study area (Berman *et al*, 1986; Azov, 1986):
1. Surface chlorophyll *a* concentrations averaged 0.07 μg/l.
2. Photosynthetic carbon fixation averaged 45 mgC m^{-2} d^{-1}.
3. Deep chlorophyll maxima were observed at approx. 100 m.
4. Most of the chlorophyll concentrations and primary production were associated with picophytoplankton (<3μ).

The neritic waters overlying the narrow (10-20 km) continental shelf along the coast of Israel, are more productive than the pelagic waters. Azov (1986), found mean annual chlorophyll *a* and primary productivity values of the neritic waters 3 and 5 times higher respectively than in the pelagic waters. Nevertheless, the basic level of primary productivity at the neritic area was low and resembled that of the pelagic waters. However, dramatic changes in both phytoplankton concentrations and activity were observed during relatively short periods of time. These changes were always associated with weather conditions which caused increased turbulence of the water column leading to elevated concentrations of phosphates in the water (Fig. 2). Differences in phytoplankton species composition was also observed between neritic and pelagic waters (Azov, 1986., Schneller *et al*, 1984). At times of high productivity, the phytoplankton population shifted, with a decrease of picoplankton (<3μ), and an increase of nanoplankton (3-20μ).

Fishery at the Levant Basin

The Mediterranean Sea encompasses 0.8% of total marine surface area of the world. As an enclosed large sea basin, surrounded with populated countries, it could be expected to contribute more than its actual 2% of total marine fish catch (Table 1). Calculations indicate that the average catch in Mediterranean is low, being 300 kg km^{-2} for all areas and 1400 kg km^{-2} over the continental shelf (Ben Tuvia, 1983). This may be attributed to the low productivity and the lack of wide continental shelf in most Mediterranean coasts. However, fishery in the Mediterranean is of considerable economical value as the price per weight unit is much higher compared to other fishing areas. Annual value of fisheries in the Mediterranean Sea is estimated at 650 million dollars (Levi & Troadec, 1974).

Table 1: Total annual catch of marine fish (x1000 tons)*.

Year	World	Mediterranean	Levant Basin
1978	70,000	1,300	33
1979	71,000	1,500	36
1980	72,000	1,600	34
1981	75,000	1,800	39
1982	77,000	1,900	31
1983	78,000	2,000	37
1984	84,000	2,000	34
1985	86,000	2,000	38
1986	92,000	2,000	43
1987	93,000	1,900	49

(*) Based on data from FAO (1989): Yearbook of fishery statistics.

The Levant Basin consititutes about 15% of the Mediterranean surface area (Fig. 1), but contributes only 2.5% of the fishery in this sea (Table 1). Fishery in the Levant Basin, near the Egyptian coast, decreased dramatically after the operation of the Aswan Dam in 1965 (Table 2). Before the damming of the Nile river, the main fish species of the Levant Basin catch was *Sardinella aurita* (Clupeidae). The fall off in the Egyptian fishery during the years after 1965 was due to the disappearance of the large shoals of this fish from the area in front of the Nile Delta. However, fishery at the Egyptian coast as well as at the Levant Basin as a whole, has increased in recent years, mainly due to different fish species caught by fishermen in this area (e.g. Seabreams, Mullets etc.), and reappearance of Clupeidae and Sauridae.

Table 2: Annual catch of marine fish in Egypt and Israel (x1000 tons)*.

Year:	1964	1965	1966	1967	1968	1969	1970	1971
Egypt:	26.5	24.5	15.0	12.4	13.6	8.5	7.9	10.7
Israel:	2.7	2.9	2.8	2.6	3.3	2.9	3.1	3.8
Year:	1972	1973	1974	1975	1976	1977	1978	1979
Egypt:	4.0	3.9	3.3	5.4	6.2	6.7	11.8	19.9
Israel:	4.4	4.2	3.8	3.2	3.3	3.6	3.5	3.2
Year:	1980	1981	1982	1983	1984	1985	1986	1987
Egypt:	17.5	17.8	11.2	12.5	11.4	16.6	19.3	25.0
Israel:	3.7	3.6	4.1	4.1	4.6	4.6	5.0	4.8

(*) Based on data from FAO - GFCM (1989): Statistical bulletin No. 7.

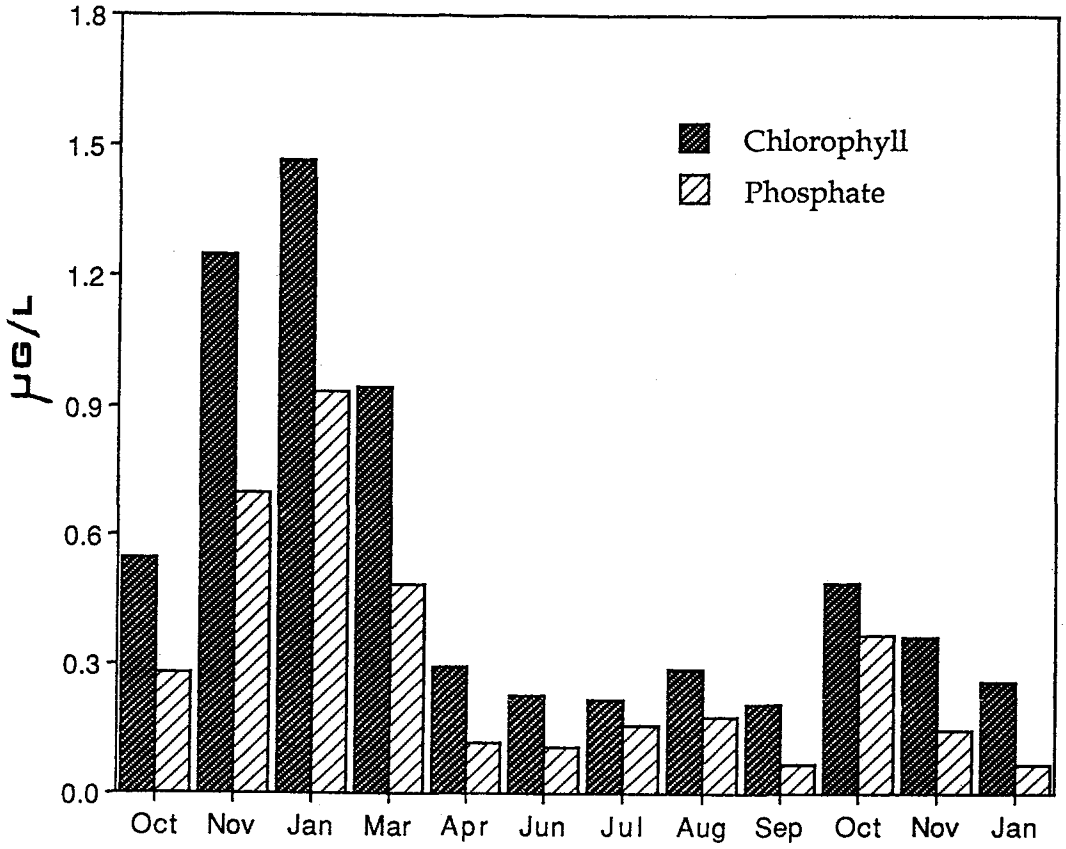

Figure 2: Relations of Chlorophyll *a* and of the phosphate concentrations in neritic waters of Israel (1982-84).

A Marine Desert?

Ryther (1969), defined oligotrophic oceanic areas, coastal rich areas and upwelling areas, as having primary productivity of 50, 100 and 300 gC m^{-2} $year^{-1}$ respectively. Koblentz-Mishke et al., 1970, defined oligotrophic oceans as those having primary productivity of 70 mgC m-2 day-1, with maximal values of 100 mgC m-2 day-1. As indicated by Table 3, most of the Mediterranean may be considered oligotrophic, except for few coastal areas. However, the Levant Basin is the most oligotrophic part of the sea.

The nutrient reservoir of Eastern Mediterranean is also very limited as compared to a rich fishing area like Eastern Atlantic Ocean (Fig. 3). Moreover, the Eastern Mediterranean lacks the upwelling processes which elevate nutrients rich waters to the surface in rich fishing areas. Therefore, layers mixing in Eastern Mediterranean is very slowly and nutrients flux to the trophogenic layer is probably the limiting factor of primary productivity in this region.

All recent research (Berman *et al*, 1984, Azov, 1986), indicates that Eastern Mediterranean area can be compared with the most oligotrophic regions of oceanic waters in the world, both in terms of primary productivity and chlorophyll *a* concentrations (Tables 3,4).

Table 3: Annual values of primary productivity at different locations in the Mediterranean ($gC\ m^{-2}$).*

Algiers Bay	120-200
Barcelona Bay	44-71
Castellone area	17-100
Levant Basin	10-45
Marseille Gulf	60-80
Saronicos Gulf	44-71
Split area	100-235
Venice Lagoon	80-150
Villefranche Bay	65-90

(*) Based on data by Sournia (1973), Berman *et al* (1984).

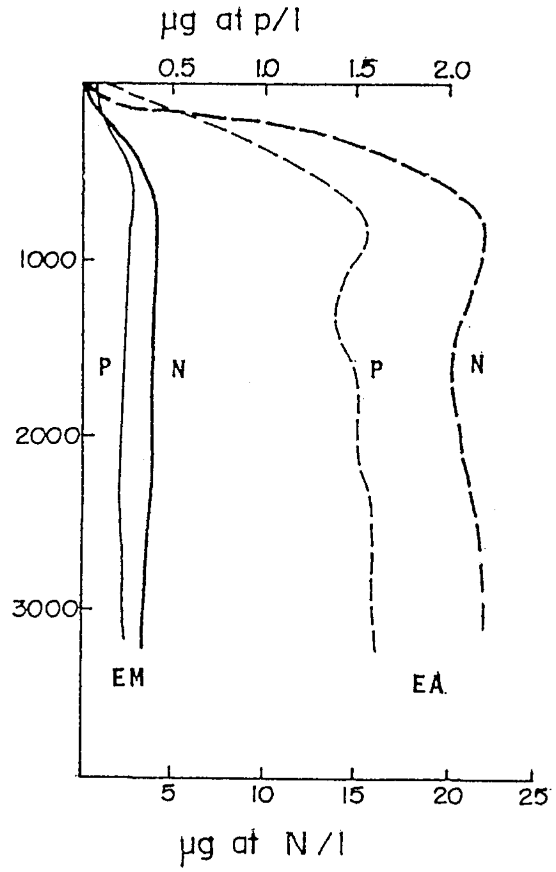

Figure 3: Profiles of nitrogen and phosphorous concentrations in Eastern Mediterranean (EM) and in Eastern Atlantic Ocean (EA). (After Sournia, 1973).

Table 4: Chlorophyll concentrations in Eastern Mediterranean compared to other oligotrophic regions in the world's oceans.

Region	**Chlorophyll *a*** (µg/1)	**Reference**
Sargasso Sea	0.05-1.00	Menzel & Ryther, 1960
North Pacific Central Gyre	0.04-0.14	Beers *et al.*, 1982
North Equatorial Current	0.06-0.15	Gieskes *et al.*, 1979
Central North Pacific Ocean	0.04-0.15	Sharp *et al.*, 1980
Tropical Pacific Ocean	0.05-0.35	Li *et al.*, 1983
Eastern Mediterranean	0.02-0.12	Berman *et al.*, 1984,1986

The extreme transparency of the Levant Basin (Megard & Berman, 1989), is a further indication of the extreme oligotrophy of this region. Indeed, the pelagic waters of Eastern Mediterranean are usually so clear, that they have been claimed for a "world Secchi Disk record" (Berman *et al.*, 1985).

During a cruise on board the Glomar Challenger, K.J. Hsu and his colleagues concluded that between ten to fifteen million years ago the Mediterranean Sea dried up and became a desert which was later refilled by the Atlantic Ocean water (Hsu, 1983). It seems that "desert" or rather "marine desert" is still an apt descriptor for this sea especially its Eastern Basin.

References

Al-Kholy, A.A. & El Waleel, S.K. (1975). Fisheries of the South Eastern Mediterranean Sea along the Egyptian coast. *Bull. Inst. Oceanogr. Fish. A.R.A.*, **5**, 3-280.

Azov, Y. (1986). Seasonal patterns of phytoplankton productivity and abundance in nearshore oligotrophic waters of the Levant Basin (Mediterranean). *J. Plankton. Res.*, **8**, 41-53.

Beers, J.R., Reid, M.H. & Stewart, G.L. (1982). Seasonal abundance of the microplankton population and its major taxonomic groups in the North Pacific Central Gyre. *Deep-Sea Res.*, **29**, 227-245.

Ben Tuvia ,A. (1983). The Mediterranean Sea, Biological Aspects. in: *Ecosystems of the world*, **26**: Estuaries and Enclosed Seas. Elsevier Sci. Publ. pp. 239-251.

Berland, B.R., Bonin, D.J. & Maestrini, S.Y. (1980). Nitrogen or phosphorous? Considerations on the "nutritional paradox" of the Mediterranean Sea. *Oceanol. Acta*, **3**, 135-141.

Berman, T., Townsand, D.W., El-Sayed, S.Z., Trees, C.C. & Azov, Y. (1984). Optical transparency, chlorophyll and primary productivity in the Eastern Mediterranean near the Israeli coast. *Oceanol. Acta*, **7**, 367-372.

Berman, T., Walline, P.W., Schneller, A., Rothenberg, J. & Townsand, D.W. (1985). Secchi disk record: a claim for the Eastern Mediterranean. *Limnol. Oceanog.*, **30**, 449-450.

Berman, T., Azov, Y., Schneller, A., Walline, D.W. & Townsand, D.W. (1986). Extent, transparency and phytoplankton distribution of the neritic waters overlying the Israeli coastal shelf. *Oceanol. Acta*, **9**, 439-447.

Gerges, M.A. (1976). The damming of the Nile River and its effects on the hydrographic conditions and circulation pattern in the Southeastern Mediterranean and the Suez canal. in: *Symposium on the Eastern Mediterranean IBP/PM UNESCO*, pp. 177-191.

Gieskes, W.W.C., Kraay, G.W. & Baars, M.A. (1979). Current ^{14}C methods for measuring primary productivity: gross underestimates in oceanic waters. *Neth. J. Sea Res.* **13**, 58-78.

Hopkins, T.S. (1978). Physical processes in the Mediterranean basins. in: *Estuarine Transport Processes*. B. Kjerfve (ed.), Bell W. Baruch Lib. in Mar. Sci., No. 7.

Hsu, K.J. (1983). The Mediterranean was a desert. Princeton University Press, 179 pp.

Koblentz-Mishke, O.J., Volkovinsky, V.V. & Kabanova, J.G. (1970). Plankton primary production of the world ocean. in: *Scientific Eexploration of the South Pacific*. Standard Book No. 309-01755-6, National Academy of Sciences, 183-192.

Levi, D. & Troadec, J.P. (1974). The fish resources of the Mediterranean and the Black sea. in: *Studies and Reviews, FAO*, 29-52.

Li, W.K.W., Subba Rao, D.V., Harrison, W.G., Smith, J.C., Cullen, J.J., Irwin, B. & Platt, T. (1983). Autotrophic picoplankton in the tropical ocean. *Science*, **219**, 292-295.

McGill, D.A. (1965). The relative supplies of phosphate, nitrate and silicate in the Mediterranean Sea. *Rapp. Proc. Verb. Reun. CIESM*, **18**, 737-744.

Megard, R.O. & Berman, T. (1989). Effects of algae on the Secchi Transparency of the southeastern Mediterranean Sea. *Limnol. Oceanog.* **34**, 1640-1655.

Menzel, D.W. & Ryther, J.H. (1960). The annual cycle of primary production in the Sargasso Sea off Bermuda. *Deep Sea REs.* **6**, 351-367.

Miller, A.R. (1983). The Mediterranean Sea, Physical Aspects. in: *Ecosystems of the world*, **26**: Estuaries and Enclosed Seas. Elsevier Sci. Publ. pp. 219-238.

Ryan, W.B.F. (1960). Mediterranean Sea: physical oceanography. in: *The Encyclopedia of oceanography*. R.W. Fairbridge (ed.), Van Nostrand and Reinhold, pp. 492-495.

Ryther, J. (1969). Photosynthesis and fish production in the sea. *Science*, **166**, 72-76.

Schneller, A., Kimor, B. & Azov, Y. (1984). Seasonal distribution of diatoms and dinoflagellates off the coast of Israel. *XXIX Congress and Plenary Assembly, Lucerne, Rapp. PV Reun. CIESM.*

Sharp, J.H., Perry, M.J., Renger, E.H. & Eppley, R.W. (1980). Phytoplankton rate processes in the oligotrophic waters of the central North Pacific Ocean. *J. Plankton Res.* **2**, 335-353.

Sournia, A. (1973). La production primaire planctonique en Mediterranee, *Newslett. Coop. Invest. Mediter.* Spec. Issue. No. **5**, 128 pp.