Bull. Inst. Oceanogr. & Fish., ARE, 13 (1), 1987: 219 - 228

SEASONAL VARIATIONS IN THE STANDING STOCK OF PHYTOPLANKTON NEAR JEDDAH, RED SEA.

ABDEL - GHANI N. KHALIL* AND AHMED M. IBRAHIM**

*Department of Oceanography, Faculty of Science, Alexandria University, Egypt.
**Institute of Oceanography and Fisheries, Alexandria, Egypt.

ABSTRACT

Seasonal variations in the standing crops of phytoplankton (measured as cell numbers and as chlorophyll a content) of the coastal waters at three sites near Jeddah, were investigated. Autumn represents the most productive season around the year. One peak of chlorophyll a concentration was observed in November, whereas the lowest value was estimated in May. The seasonal variations in the chlorophyll a concentration follows a similar pattern of the standing crop of the phytoplankton. Lower values of chlorophyll a content were noticed when the number of dinoflagellate species surpassed that of the diatoms.

The coastal waters of Jeddah area are oligotrophic during most of the year and comparable to the central part of Red Sea. However, variations in chlorophyll a content and standing crop of the phytoplankton may be attributed to the prevailing ecological conditions.

INTRODUCTION

Few studies have been done on the marine phytoplankton in the neritic waters off Jeddah area on the eastern coast of Red Sea concerning the species composition and distribution in relation to the environmental factors (Dowidar et al 1978; Khalil et al 1984; Khalil and Ibrahim 1988). Moreover, little is known about the phytoplankton pigments in the coastal waters of Jeddah (Khalil et al.,1984; Dowidar and Sheikh,1984).

The standing crops measured as cell numbers and as chlorophyll (a) content of phytoplankton communities. Despite some drawbacks as contamination of extracts of living cells with inactive chlorophyll degradation products from dead cells, chlorophyll (a) remains the one substance, entirely specific to plant cells, measurable with ease, precision and accuracy (Moss 1967).

The present study deals with the seasonal variations of the phytoplankton standing crops measured as cell numbers and as chlorophyll (a) content of the coastal waters near Jeddah on the eastern coast of Red Sea.

MATERIAL AND METHODS

The study area is located at about 35 Km north of Jeddah at Obhur Creek. The Creek is connected to the Red Sea and extending for about 9 Km eastward, (Fig. 1). Station I is located in the Red Sea proper at 4 Km offshore, station II lies at the entrance of the Creek and station III is situated in the middle of the Creek, (Fig. 1).

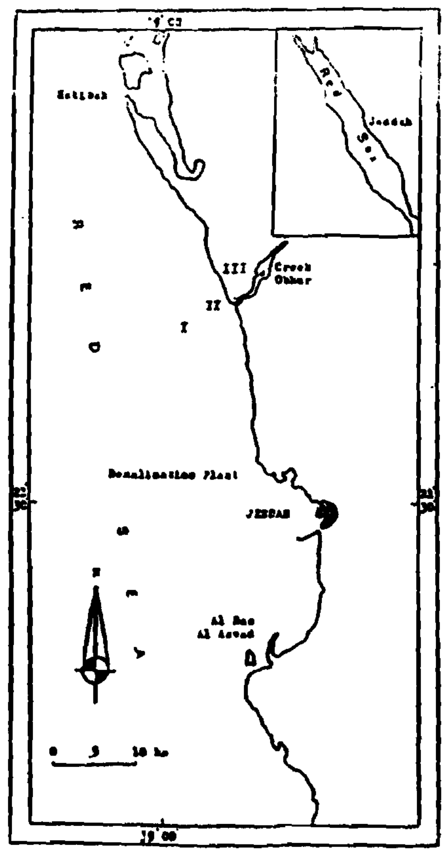


Fig. (1)
Map of the sampling stations.

A total of 96 phytoplankton samples (5 liters of water for each sample) were collected seasonally during February, May, August and November 1982 from the three forementioned stations at a depth of 50 cm below the surface. Chlorophyll (a) concentration was estimated using the method described by Strickland and Parsons (1968). For standing crop assessment (cells/litre), the collected samples were preserved in 4 % neutralized formaline and concentrated to a 100 ml volume by the sedimentation method (Utermohl 1936).

The rate of increment of the standing crop, chlorophyll (a) content, number of diatom species and number of dinoflagellate species was estimated as the difference between two successive values at a definite time to determine the period of high production in the investigated area.

RESULTS AND DISCUSSION

The seasonal values of chlorophyll (a) concentrations in the surface sea water at the three sites north to Jeddah, exhibited a different seasonal pattern of distribution, (Fig. 2). Only one peak of the chlorophyll a content occurred in November, that attained to 0.47, 0.32 and 0.20 mg m^{-3} at the stations I, II and III respectively, (Fig. 2). However, the lowest values were estimated in May.

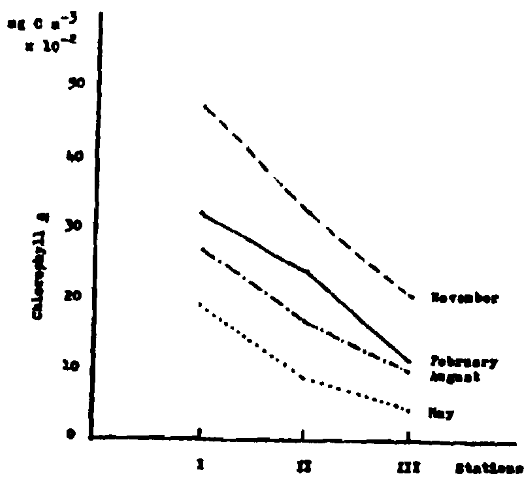


Fig. (2)
Seasonal variation of the chlorophyll a concentrations in the coastal waters, north to Jeddah.

The seasonal variations in the chlorophyll a concentration (Fig. 2), followed a similar pattern of those of the standing crop (cells/litre) of phytoplankton, (Table I). A gradual increase in the number of the phytoplankton species was noticed from May to November (Table II). The higher values of chlorophyll a in autumn were correspond to the accretion of the standing crop of the phytoplankton (4800, 3700 and 2200 cell/litre at the sites I, II and III respectively), (Table I).

Table (1)
Seasonal variations in the standing crop of the phytoplankton (cell/liter) in North Jeddah.

Seasons (1982)	STATIONS I	II	III	Seasonal Average of the whole area
Winter	3500	1750	1100	2110
Spring	2100	900	400	1130
Summer	2000	1550	950	1500
Autumn	4800	3700	2200	3570
Annual Average	3100	1980	1160	2080

The chlorophyll (a) concentrations in August were nearly found to be 1.5, 2 and 2.5 - fold of those estimated in May at the localities I, II and II, respectively, (Fig. 3-b). However, the rate of increment of the standing crop, chlorophyll (a) content and number of the phytoplankton species, was obviously augmented during the periods of May-August, (Fig. 3-b) and August-November, (Fig. 3-c), otherwise, it exceeded that noticed during February-May, (Fig. 3-a). Accordingly, the increment rate of the standing crops and the nimber of phytoplankton species shows that the optimum period of high production was during August-November, (Fig. 3-c).

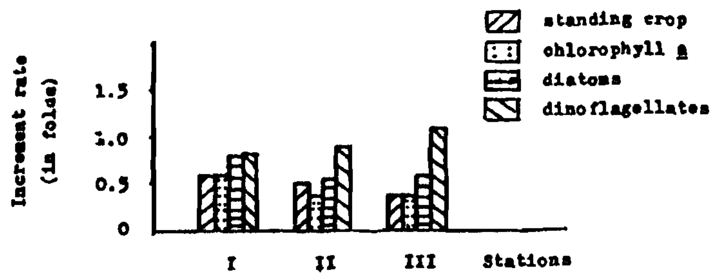
Table (2)
Seasonal variations in the number of phytoplankton species in North Jeddah, during 1982, (Khalil and Ibrahim, 1988). (Ph.: Phytoplankton, DT: Diatoms and FG: Dinoflagellate).

Seasons	STATIONS								
	I			II			III		
	Ph.	DT	FG	Ph	DT	FG	PH	DT	FG
Winter	73	40	33	43	24	19	23	14	9
Spring	59	32	27	30	13	17	18	8	10
Summer	61	28	33	36	16	20	20	12	8
Autumn	88	46	42	56	30	26	36	21	15

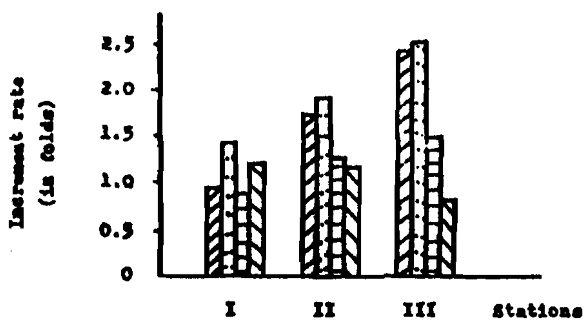
It is worthy of note that the lower value of chlorophyll (a) was observed when the number of dinoflagellate species surpassed that of the diatoms, (Fig. 2 and Table II), which indicated a negative correlation between the number of dinoflagellate species and the chlorophyll (a) content of the phytoplankton. Therefore, the lower the number of the dinoflagellate species, the higher the content of chlorophyll (a) in the coastal waters of Jeddah area. These results agree with that of Holland (1969), who revealed a positive correlation between average values for both chlorophyll (a) and total diatoms. In winter, the standing crop of phytoplankton and chlorophyll (a) content were less than those noted in autumn, (Table II and Fig. 2). The diatoms declined in spring and summer and generally were exceeded by dinoflagellate, (Table II). This phenomenon may be attributed to the increase in both the surface sea water temperature and intense illumination, (Khalil et al, 1984).

Otherwise, Scott (1979) indicated that temperature may be related to primary production indirectly, since the biochemical regeneration of nutrients both in the water column and in the sediments can be dependent upon temperature. He also added that increased temperature may increase the grazing activity of zooplankton on, and thus increase the rate at which nutrients are recycled in the water column.

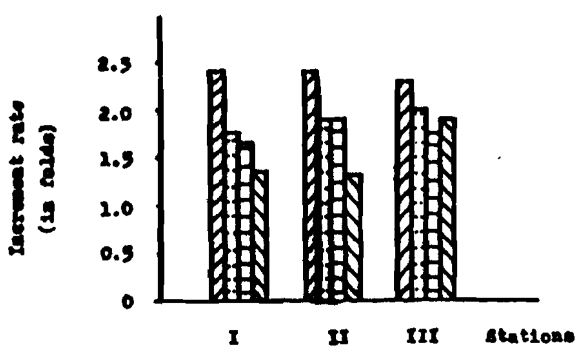
The present results follow also the same trend as those observed by Khalil et al (1984) at South Jeddah, in which the lower values of chlorophyll (a) estimated in May, however, they attributed that to surface



(a) February-May period



(b) May-August period



(c) August-November period

Fig. (3)
Rate of increment in the standing crop, chlorophyll a content, number of diatom species and number of dinoflagellate species, during February - May, May - August and August - November periods.

water temperature and photo-inhibition. Moreover, the low nutrient concentrations during summer period are the important factors responsible for the low standing crop of the phytoplankton, (Dowidar et al, 1978). Under other circumstances, Dowidar and Sheikh (1984) recorded higher values of chlorophyll (a) and primary production near Bangalah (fish market at Jeddah Center), because of the highly enriched seawater with nutrients as a result of waste water discharge near the fish market. However, these values decreased seaward far from the sewage outflow. On the other hand, the phytoplankton production was greatly reduced near the areas of Desalination Plant and Petromeen (Dowidar and Sheikh 1984) due to the thermal pollution effect of the hot brine effluents from the Desalination Plant and to oil dispersion from the oil refinery at Petromeen area on the shoreline.

The population of diatoms and dinoflagellates of North Jeddah area is highly diversified and mainly composed of cosmopolitan, tropical and subtropical, besides Indo-Pacific tropical-equatorial belt forms (Khalil and Ibrahim 1988). The important recorded species of phytoplankton in the area of study belonging to the following genera: **Asterionella, Chaetoceros, Nitzschia, Rhizosolenia,** and **Thalassiothrix** of the diatoms and **Ceratium, Dinophysis, Gonyaulax, Peridinium, Prorocentrum** and **Pyrocystis** of the dinoflagellates. The seasonal variations in occurrence and distribution of the phytoplnakton of Obhur area were discussed by Khalil and Ibrahim (1988).

McGill and Lawson (1966), observed that the productivity in the central part of the Red Sea was in winter (0.12 mg cm^{-3}) at the surface water. Furthermore, the chlorophyll a concentration in the northern part of the Gulf of Aqaba, Red Sea, was found at the highest values (0.25 to 0.40 mg m^{-3}) in autumn and winter and the lowest values (0.05 to 0.20 mg m^{-3}) during summer (LevanonSpanier et al, 1979). Otherwise, Morcos (1970) indicated that, the upward movement of deep water, during summer, in the northern part of the Red Sea on the eastern coast may affect the phytoplankton productivity. However, the high values of chlorophyll (a) and primary production observed in autumn and early winter are due to the mixing process during this period (Levanon-Spanier et al, 1979). Nitrogen is the major limiting nutrient and its supply during mixing to the upper waters enables phytoplankton to bloom. Accordingly, Saad and Fahmy (1984) demonstrated that the nitrate concentration in the surface waters of North Jeddah ranged from 0.07 µg at N l^{-1} in May to 3.46 µg at N l^{-1} in November, that entirely coincided with the lowest and highest values of chlorophyll (a) content and the standing crop of the phytoplankton in the present study. Thus, the increase in nitrate content of the sea water is followed by an increase in both production and chlorophyll (a) levels. Furthermore, Levanon-Spanier et al (1979) revealed that correlation of phosphate values with the biological parameters is much weaker.

In general, the rather low overall chlorophyll (a) concentration and primary production observed in North Jeddah (the present study) are similar to those of South Jeddah (Khalil et al, 1984) which indicate that these waters are oligotrophic during most of the year and comparable in this respect to the central part of the Red Sea (McGill and Lawson 1966), the northern basin of the Aqaba Gulf (Levanon-Spanier et al 1979), the Sargasso Sea (Menzel and Ryther 1961) and the tropical Pacific (Eppleyet al 1973; Gundersen et al 1976), (Table III).

Table (3)
Comparison between chlorophyll (a) contents in the Red Sea and other marine oligotrophic water bodies.

Region	Chlorophyll (a) mg m^{-3}	References
North Jeddah	0.04 - 0.47	The present data
South Jeddah	0.12 - 0.58	Khalil et al, 1984
Central Red Sea off Jeddah	0.04 - 0.68	Dowidar, 1984 - b
Central part of the Red Sea	0.12 - 0.69	McGill and Lawson, 1966
Gulf of Aqaba	0.03 - 0.45	Levanon-Spanier et al, 1979
Sargasso Sea	0.05 - 1.00	Menzel and Ryther, 1961
N. Pacific, central gyre	0.04 - 0.23	Eppley et al, 1973
N. Pacific, off Hawaii	0.03 - 0.40	Gundersen et al, 1976
Sea of Japan	0.14 - 0.34	Ohwada, 1971
Mediterranean:		
Oceanic	0.05 - 0.50	Dowidar and Mostafa, 1983
S. Eastern part (neritic)	4.0 - 7.0	" " " "
Black Sea (Bosphore)	0.30 - 0.55	Bologa et al, 1983
" " , Western Part		
(Caliacra)	0.25 - 0.50	
(New Danub)	3.0 - 35.0	

The relatively high content of chlorophyll (a) and the primary production in some coastal waters (Table III) may reflect the effect of the drainage discharge that enriched with nutrients as in Bangalah (Dowidar and Sheikh 1984), or by the continuous outflow of nutrients discharged from the Danube to the Black Sea, particularly in the superficial layer (Bologa et al 1983) and also may be due to discharge waters off the Nile Delta which is usually rich in nutrient salts, growth promoting substances which lead to high phytoplankton crop (Dowidar and Mostafa 1983).

Around the year, the lowest value of standing crop of the phytoplankton was noticed during autumn in Northern part of the Arbian Gulf (Jamal and Pavlov 1979), Sea of Japan (Ohwada 1971), Saronics Gulf (Karydis et al, 1983) and South-Eastern Mediterranean (Dowidar 1984-a). Contrarily, the Red Sea exhibited a different and unique trend, in which autumn represented the most productive season in the year round (Levanon-Spanier et al 1979; Khalil et al 1984 and Khalil and Ibrahim 1988).

The relatively low standing crop and variations in the distribution of the phytoplankton species in the different regions of the Red Sea may be attributed to the prevailing ecological conditions such as the paucity of nutrients... etc.

REFERENCES

Bologa A.S., Z.P. Burlakova, V.D. Tchmyr and V.I. Holodov, 1983. Donnees sur la distribution de la chlorophyll a et de la production primaire dans la partie outes de la Mer Noire. Rapp. Comm. Int. Mer. Medit., 28 (9): 79-81.

Dowidar N.M., 1984 (a). Phytoplankton biomass and primary productivity of the south-Eastern Mediterranean. Deep-Sea Res.,31 (6-8A): 983-1000.

Dowidar N.M., 1984 (b). Primary production in the central Red Sea off Jeddah. Bull. Inst. Ocean. and Fish., 9:160-170.

Dowidar N.M. and H.M. Mostafa, 1983. Phytoplankton biomass and primary production in the South Eastern Mediterranean off the Egyptian Coast. Rapp. Comm. Int. Mer. Medit., 28 (9): 85-88.

Dowidar, N.M. and E.A. Sheikh, 1984. Primary productivity and standing crop of phytoplankton in the coastal waters of Jeddah (Red Sea). Proc. Symp. Coral Reef Environ. Red Sea, Jeddah, 577-596.

Dowidar, N.M., S.A. Raheem Eldin and A.A. Aleem, 1978. Phytoplankton population in the region of obhur (Jeddah, Saudi Arabia). Bull. Fac. Sci., K.A.U., Jeddah, 2: 271-292.

Eppley, R.W., E.H. Ranger, E.L. Venrick and M.M. Mullin, 1973. A study of plankton dynamics and nutrient cycling in the central gyre of the North Pacific Ocean. Limnol. Oceanog., 18: 534-551.

Gundersen, K.R., J.S. Corbin, C.L. Hanson, R.B. Hanson, D.J. Russel, A. Stollar and O. Yamada, 1976. Structure and biological dynamics of the oligotrophic ocean photic zone off the Hawaiian Islands. Pacific Science, 30: 45-68.

Holand R.E., 1969. Seasonal Fluctuations of Lake Michigan Diatoms. Limnol. Oceanog. 14 (3): 423-436.

Jamal, H.H. and V. Pavlov, 1979. Introduction to the phytoplankton study in the Arbian Gulf. **Minis. Publ. Works. Fish. Res. Adm. Kuwait**, 1-10.

Karydis, M., N. Moschopulou and L. Ignatides, 1983. Carotenoid/ chlorophyll a ratio in relation to nutrient distribution. **Rapp. Comm. int. Mer. Medit.**, 28 (9):69-71.

Khalil, A.N. and A.M. Ibrahim, 1988. A seasonal Study of the Surface Phytoplankton of the Red Sea North of Jeddah. Arab. Gulf **J. Scient. Res.**, 6 (2): 189-204.

Khalil, A.N., A.K. Khafaji and A.M. Ibrahim, 1984. Preliminary survey of micro- and macrophytes South of Jeddah, Red Sea. **Proc. Symp. Coral Reef. Envir. Red Sea, Jeddah**, 555-576.

Levanon-Spanier I., E. Pandan and Z. Reiss, 1979. Primary production of a desert-enclosed sea-the Gulf of Elat (Aqaba), Red Sea. **Deep Sea Res.**, 26 (6): 673-685.

McGill, D.A. and T. J. Lawson, 1966. The distribution of Chlorophyll in the western Indian Ocean durin the Northeast monson period. **Woods Hole Oceanographic Institution, Ref.**, 66-12, 69 p. (unpublished manuscript).

Menzel, D.W. and J.H., Ryther, 1961. Annual variation in primary production of the Sargasso Sea off Bermuda. **Deep Sea Res.**, 7: 282-288.

Morcos, S.A., 1970. Physical and chemical oceanography of the red Sea. **Oceanogr. Mar. Biol. Ann. Rev.**, 8: 73-202.

Moss B., 1967. A note on the estimation of chlorophyll a in freshwater algal communities. **Limnol. Oceanogr.**, 12: 340-342.

Ohwada, M., 1971. Distribution of chlorophyll and phaeophytin in the Sea of Japan. **The Oceanographical Magazine**, 23 (1): 21-32.

Saad, M.A. and M.A. Fahmy, 1984. Chemico-physical characteristics of the coastal Red Sea waters north of Jeddah, Saudia Arabia. **Proc. Symp. Coral Reef Environ. Red Sea, Jeddah**, 109-128.

Scott B.D., 1979. Seasonal variations of phytoplankton production in an estuary in relation to coastal water movements. **Aust. J. Mar. Freshwater Res.**, 30:449-461.

Strickland J.D. and T.R. Parsons, 1968. A practical hand-book of sea water analysis. **Bull. Fish. Res. Bd. Canada.**, 167: 311.

Utermohl H., 1936. Quantitative Methoden Untersuchung des Nannoplankton in Adderheldens, **Handbuch der Biolog. Arb. Methoden. Abt.**, IX (I).