Changes and Stress Signs in Plankton Communities as a Result of Man-Induced Perturbations in Enclosed Coastal Seas (Mediterranean, Baltic)

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Eutrophication induced by nutrient enrichment in coastal waters stimulates development of phytoplankton blooms with frequent deleterious effects to marine life. A number of case histories are described from the land-locked Mediterranean and Baltic Seas. Among them is the recent occurrence of the potentially toxic dinoflagellate *Prorocentrum minimum* in the Adriatic and Kiel Fjord and of the prymnesiomonad *Chrysochromulina polylepis* associated with fish kills in the Baltic.

Other changes affecting the periodicity of the algal blooms with drastic effects on coastal fisheries have been reported from the Levant basin following the activation of the Aswan High Dam on the Nile.

An extensive "before and after" monitoring program is proposed in particularly vulnerable areas aimed primarily towards the detection of stress signs manifested by subtle or abrupt changes in species composition and a size downshift of the phytoplankton components.

The algal blooms induced by cultural eutrophication are generally monospecific although at times, several species may become simultaneously dominant in the plankton at the expense of other components of the pelagic ecosystem. In this way, the phytoplankton, among the marine biota, is the first to react to such man-induced perturbations by changes in its species composition which vary from subtle to abrupt in accordance with the intensity of the causative factors and local conditions. These pollution-induced changes in the phytoplankton species assemblages may take, according to Eppley & Weiler (1979), one of the three pathways: (1) competitive exclusion in the competition for resources; (2) selective kill of sensitive species and the passive survival of resistant ones; and (3) outright stimulation of certain species. Although there are common features in the general pattern of response of enclosed coastal environments to such anthropogenic perturbations throughout the world, it is necessary to relate to specific case histories in given geographical areas for a better understanding of the processes involved.

Examples from Selected Areas in the Mediterranean and the Baltic Seas

The eastern Mediterranean in general, and its Levantine basin in particular, are a classical example of dynamic biogeography due to the impact of two man-made engineering interventions of far-reaching consequences: (a) the opening of the Suez Canal in 1869 providing a pathway for a two-way migration of species between two widely different biotic provinces; and (b) the activation of the Aswan High Dam on the Nile almost one century later. Each of these engineering projects (Fig. 1) affected the biological oceanography of the Levantine basin in its own way, the former by a predominantly northbound migration and establishment of stable populations of species from the Red Sea into the eastern Mediterranean due to the prevailing current regime in the Canal, the latter by the prevention of the nutrient-rich and sediment-carrying waters of the Nile River from reaching the Mediterranean, followed by a noticeable drop in the biological productivity of the coastal waters, primarily in the Nile Delta. This may be considered as a process of eutrophication in reverse, as pointed out by Aleem (1969) in regard to the collapse of the sardine fishery in the Nile Delta very soon after the completion and the activation of the High Dam at Aswan in 1965.

Any changes in the marine biota in general, and in the phytoplankton communities in particular, as a result of cultural eutrophication, should therefore be evaluated within the general context of the different types of anthropogenic perturbations referred to above. Thus, Halim et al. (1980a,b) and Kelley and Naguib (1984) described a severe case of eutrophication caused by municipal outfalls and ship and dock wastes which was recorded in the eastern harbour of Alexandria, a

Marine Pollution Bulletin, Vol. 23, pp. 171–174, 1991.
Printed in Great Britain
0025-326X/91 $3.00+0.00

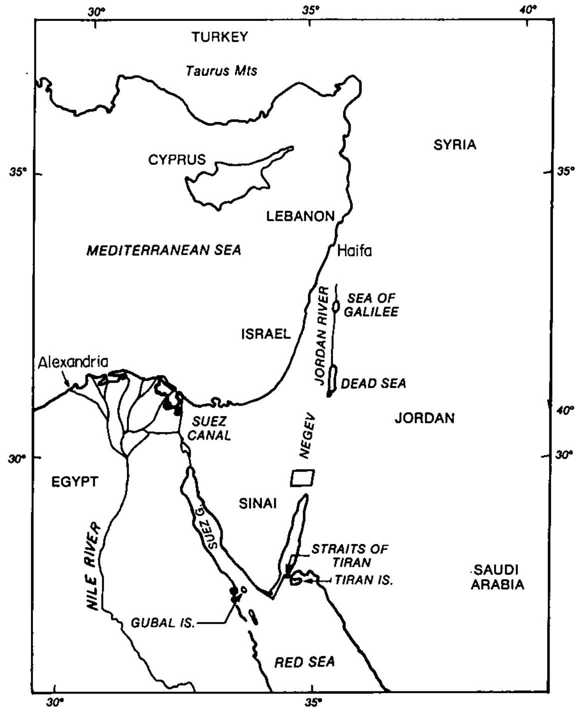

Fig. 1. The general study area of the Levant Basin of the eastern Mediterranean.

semicircular area with only limited connection to the open sea, which resulted in the massive proliferation of the dinoflagellate *Alexandrium minutum*. Moreover, the authors noted that the bloom of *A. minutum* coincided with a parallel decline in the presence of other members of the phytoplankton which, in their view, might be due to an inhibitory effect induced by this dinoflagellate.

Off the coast of Israel, the stoppage of the periodic Nile floods and their fertilizing effect caused a partial obliteration of the plankton blooms during the late summer and autumn (Kimor, 1972, 1983). During the pre-Aswan years, the periodic arrival of the flood waters used to cause a proliferation of the cladoceran *Pleopis (Podon) polyphemoides*, a neritic euryhaline species tolerant of stressed conditions, and as such considered to be a biological indicator jointly with some centric diatoms, particularly *Hemiaulus sinensis*.

In the Bay of Haifa, extreme eutrophication conditions are brought about by the small Kishon river which cuts through the industrial zone of northern Israel on its way to the sea and receives the effluents of a large number of industrial plants, including the oil refineries. Both the commercial harbour and the fishery anchorage are located close to the river estuary, and thus are exposed to the impact of massive quantities of industrial and organic wastes carried by the river. A hydrological survey carried out in the early seventies by the staff of the former Sea Fisheries Research Station showed a progressive decline in the number of algal species towards the downstream stations coupled with a state of seasonal oxygen depletion and an increase in the concentration of sulphate-reducing bacteria (Kimor et al., unpublished reports).

Changes in the phytoplankton composition due to the occurrence and progressive proliferation of species previously rare or unknown have been reported from the Adriatic during recent years by Marasovic (1986) and Pucher-Petkovic & Marasovic (1988). In their view, these changes, often accompanied by a substantial increase in primary productivity, both in inshore and offshore waters of the central Adriatic, were due primarily to increased eutrophication resulting from urban development and riverborne wastes. A case in point noted by Marasovic (1986) is the increasing occurrence in recent years of the potentially toxic dinoflagellate *Prorocentrum minimum*. Further changes associated with eutrophication indicating a downshift in the size class of the plankton community smaller than 20 µm in the Northern Adriatic Sea were noted by Revelante and Gilmartin (1988). The possible relationship between small-celled flagellated and coccoid phytoplankton and pollution was also reviewed by Eppley and Weiler (1979) who stressed, however, the need of supporting evidence from the natural environment.

The sudden occurrence and massive blooming of *Prorocentrum minimum* also in Kiel Fjord on the Baltic Sea in 1983 can serve as a case study of typical coastal eutrophication (Kimor et al., 1985) (Fig. 2). This species was previously recorded in Oslo Fjord in 1979 (Tangen, 1980), and in subsequent years it expanded its area of distribution throughout the Skagerrak and Kattegat into Danish and Swedish coastal waters under conditions of intense eutrophication (Granelli et al., 1983). This was the first record of *P. minimum* in Kiel Fjord, and it fits well with the progressively eastward expansion of this euryhaline and eurythermal species into the Baltic Sea. The development of the bloom was enhanced by favourable weather conditions, unusually high temperatures of the water (>20°C) and prevailing winds as well as by high levels of phosphate-P and nitrate-N compounds. While the phosphate was derived mainly from anoxic sediments, the nitrate was delivered from river runoff and originated from agricultural fertilizers.

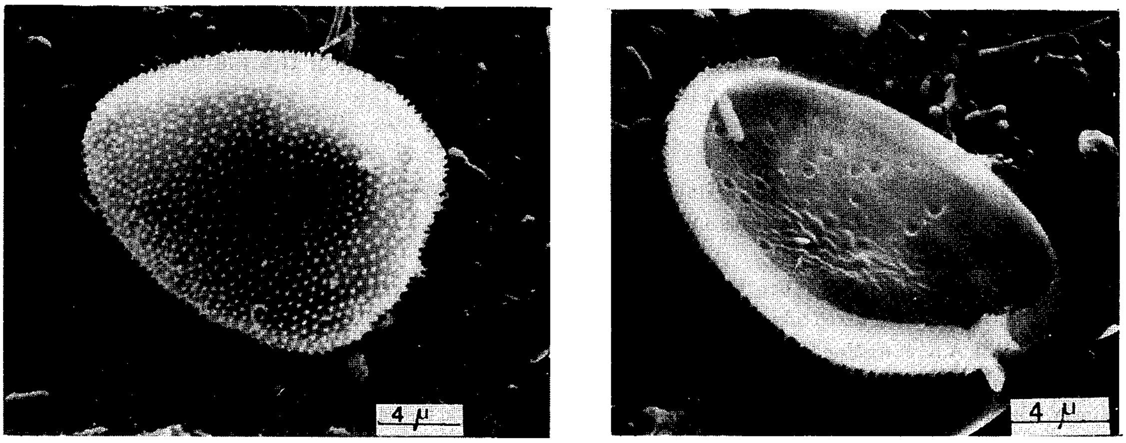

Fig. 2. *Prorocentrum minimum* from the Kiel Fjord, July 1983. Different SEM views. Photograph by v. Brevern, IMK, Kiel.

An even more recent episode of a sudden outburst of a toxic alga as a result of coastal eutrophication in the same general area of the Scandinavian coastline is that of the prymnesiomonad *Chrysochromulina polylepis*. This microflagellate formed a massive bloom during May 1988 with disastrous effects to marine life (Walentinus, personal communication). This species is closely related to the toxic microflagellate *Prymnesium parvum*, a haptophyte responsible for large-scale fish kills during the late forties in inland brackish water fish ponds in Israel and in several European countries (Sarig, 1971). The latter is a case of adaptation and proliferation of a basically marine organism to an artificially created inland water environment where conditions of extreme eutrophication associated with intensive fish culture prevail.

A Monitoring Program for Algal Blooms

Instances of bloom-producing organisms in coastal waters may vary from one location to another both within and beyond specific marine environments. Although the sequence of events involving initiation, support and maintenance of such blooms is common to all or most of the species (Steidinger & Haddad, 1981), the timing, duration and intensity of each phase is typical of the specific coastal environment and its geomorphological characteristics. It is therefore necessary that the monitoring program should establish normal ranges of variation in species assemblages as a baseline for the assessment of sudden or gradual changes that may occur as a result of anthropogenic perturbations. The nature of such perturbations, whether cultural or due to large-scale physical changes in the natural environment, should be closely assessed for the purpose of a meaningful analysis of possible changes in the ecosystem in general and in the phytoplankton communities in particular.

Taxonomy should play a key role in such monitoring programs as only by very accurate determinations of the species involved can a monitoring program on a "before and after" basis be effective in cases of noticeable changes in the species composition at any given time.

In spite of technological advances such as remote sensing as tools in assessing coastal variability on the basis of pigment concentrations, organisms constitute in some cases the only effective method of making ecological and toxicological evaluations (Soule, 1988). This is due to the fact that, at times, even closely related and morphologically similar algal species such as the microflagellate *Prymnesium parvum* and *Wissotzskia* sp. may differ from one another in their respective toxicity to aquatic organisms and physiological responses to various chemicals if used as control measures in confined environments.

An implementation of modern field and laboratory technologies along with better understanding of organismic biology should therefore be used to complement one another for an effective monitoring program in the coastal waters of enclosed seas. Neither of the two lines of approach can provide, by itself, a full answer to the problems affecting this particular type of marine environment.

The author wishes to thank John R. Beers for the critical reading of the manuscript and Keren Diskin for its typing and preparation for publication.

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