ENCLOSED COASTAL SEAS - A CASE STUDY THE GULF OF AQABA RED SEA

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Nowhere is the delicate balance, between economic development and environmental stability, more important than in the coastal waters of littoral States. This is particularly significant in enclosed, or semi-enclosed, marine environments with limited access to open seas, where the accumulation factor of the effects of prolonged man-induced perturbations, primarily pollutants, tends to pose an ever-increasing danger. This is a result of the physical and ecological degradation of coastal and offshore waters by land-based sources of pollution, as well as actual or potential maritime disasters. The very concept of environmental management in such habitats is, of necessity, regional rather than local or national, and therefore the co-operation and co-ordination of littoral States bordering on the same marine geographical entity is absolutely essential.

Enclosed coastal seas, such as the Mediterranean, the Baltic, Chesapeake Bay, the Seto Inland Sea and many others, have received special attention in recent years and have formed the subject of two international symposia, code-named EMECS '90 and EMECS '93 (Environmental Management of Enclosed Coastal Seas).

The impact of coastal development, in relation to the preservation of living resources in the marine environment, also received special attention during the course of the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro, Brazil, in June 1992. The conference devoted a special chapter, Agenda 21, addressed particularly to the dangers posed by pollution, harmful fishing practices, sedimentation and climatic change. Immediately following the Rio conference and its resolutions relating to the oceans, an International Conference on Ocean Management in Global Change was held in Genoa, Italy, in the context of the celebrations for the Quincentenary of the Discovery of the Americas. An outcome of the latter conference was the establishment of a non-governmental International Centre for Coastal and Ocean Policy Studies (ICCOPS), based in Genoa. The centre is interdisciplinary in character and aims at addressing key issues in coastal and ocean planning and management, including scientific research and technology transfer in coastal and semi-enclosed coastal seas.

Large Scale, Regional, and Local Monitoring of Water Quality in Enclosed Coastal Seas

The conflicting uses of geographically-restricted marine environments, simultaneously involving coastal development, navigation and the safeguarding of their living resources, make continuous monitoring of the physical, chemical and biological parameters of the water masses, a prime necessity and the responsibility of the littoral States. In this major endeavour, the remote sensing of biological (phytoplankton, pigment concentration) and physical (sea surface temperatures) parameters, mainly used for large marine ecosystems, complements the in-situ measurements of such data by the conventional methods of sampling and processing data. The close co-ordination and correct interpretation of the data obtained from the two techniques is a desirable and much needed aim for the bio-assessment of anthropogenic perturbations, and the remedial measures to be enacted by decision makers.

The outline of biological monitoring that follows will focus on the use of planktonic microbiota, including representative species of the lower trophic levels in the marine food chain, the phytoplankton and the microzooplankton, as bio-indicators of pollution and other forms of man-induced perturbations. The Gulf of Aqaba in the Red Sea, will be used as a case study.

Remote Sensing in the Service of Oceanography

The last two decades have witnessed remarkable progress in the use of satellites, to estimate the global distribution of photosynthetic organisms in the world's oceans from space. Colour images have been produced showing concentrations of phytoplankton in both inshore and offshore waters, varying from different shades of green to blue, corresponding to highly eutrophic and oligotrophic waters, respectively. The images have been quantified by correlating them to actual concentrations of chlorophyll a (mg/m3) in accordance with a given conversion code.

The first observations of ocean colour from space were made from the Coastal Zone Colour Scanner (CZCS), which operated on NASA's Nimbus 7 research satellite from 1978 to 1986. Among the images produced by this satellite prepared by the NSF/NASA-sponsored United States Global Ocean Flux Study Office, in Woods Hole, Massachusetts, are those of the Mediterranean Sea showing vast areas of highly

oligotrophic pigment-poor waters, in contrast with the plankton-rich Atlantic waters off Northwest Spain and France. Similarly coloured areas are located off river outflows into the sea, showing high biological productivity as a result of pollution from land-based sources. Another image shows areas of upwelling dynamics off Peru and Northwest Africa, which are among the most productive in the global ocean, as indicated by the high phytoplankton biomass and biological productivity, supporting the world's richest fisheries.

Although satellite imagery is primarily designed for coverage of large stretches of Marine Large Ecosystems (MLE's), the technique is being increasingly used for documenting more restricted areas of coastal waters which are exposed to land-based pollution and other forms of anthropogenic perturbations.

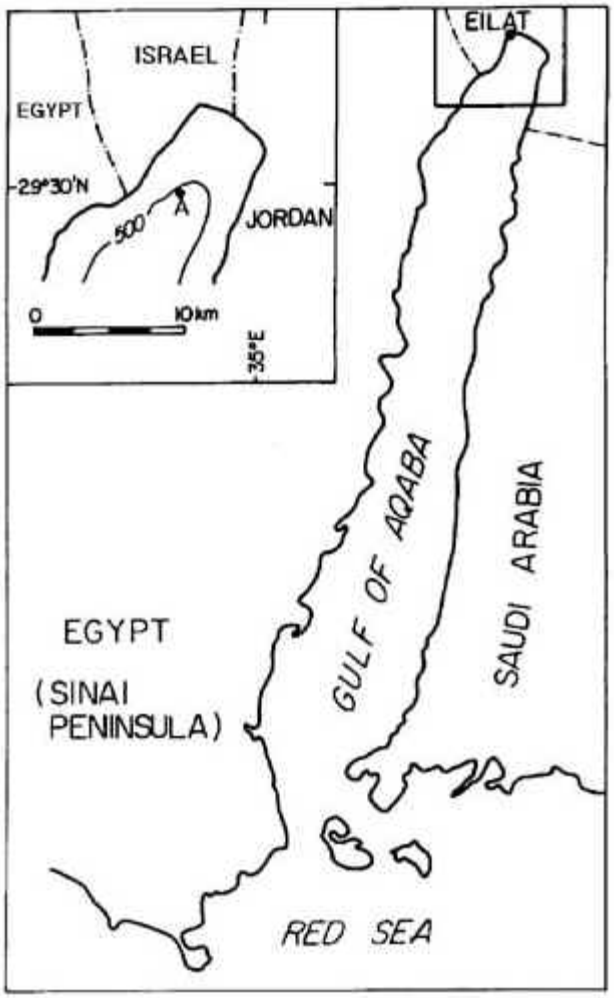

Figure 1. The gulf of Aqaba showing location of reference station A

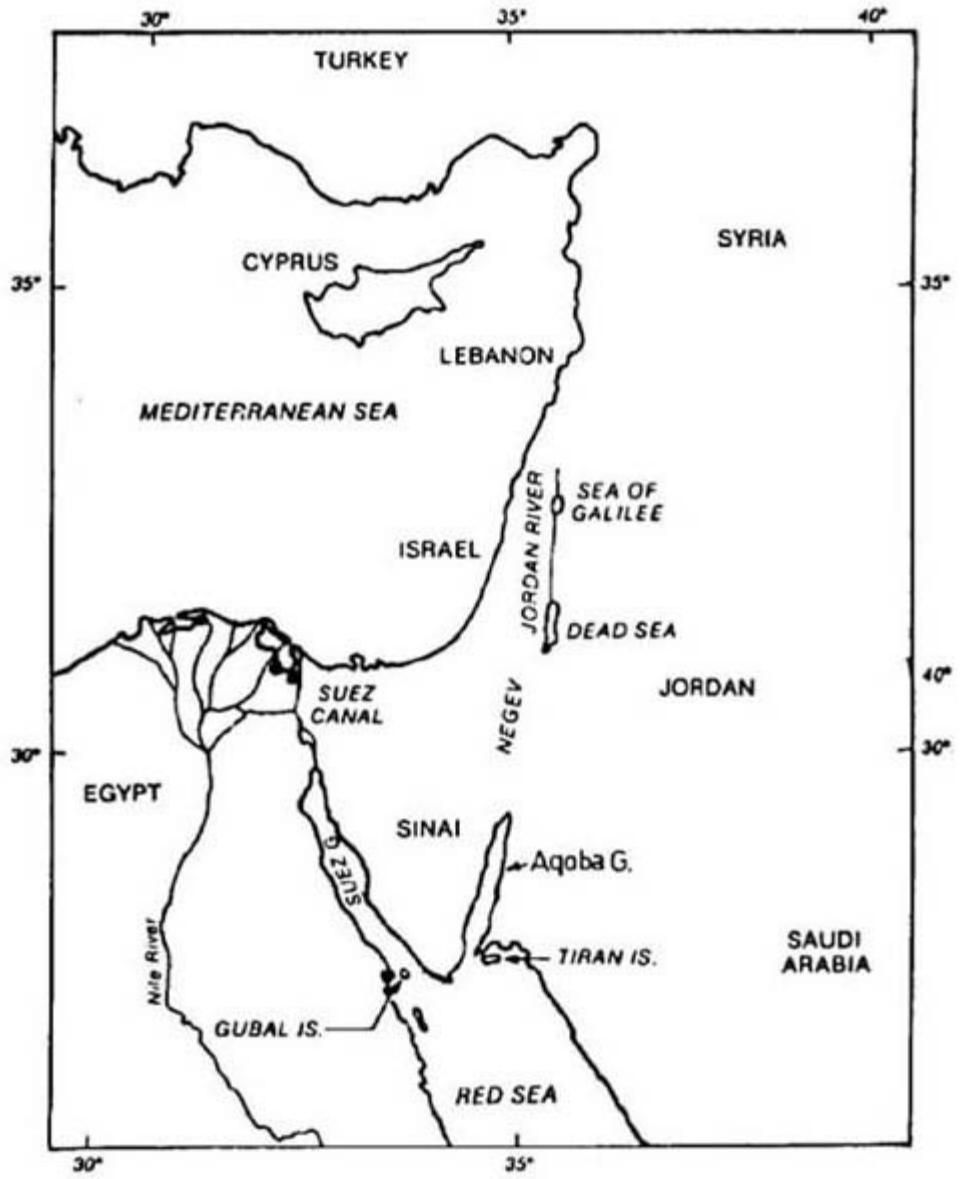

Figure 2. Northern Red Sea and Eastern Mediterranean showing the link between the two environments through the Suez Canal

Monitoring a Typical Enclosed Marine Environment The Gulf of Aqaba, Red Sea

Characteristic Features of the Gulf

The Gulf of Aqaba is the eastern of the two northerly extensions of the Red Sea (Figs. 1 and 2). In contrast to the Gulf of Suez on the west side, it is a deep, narrow trench, 177 km long, 14-25 km wide, and descending to over 1,800 m in its deepest regions, and is part of the Syrian-African Rift System. It is a desert-surrounded marine environment, separated at its southern end from the Red Sea itself by a shallow sill, 250 m deep at Tiran. This is a feature which contributes to the relative isolation of the Gulf waters and affects the circulation pattern over the straits. There is very little precipitation and a high rate of evaporation which is compensated for, by an inflow of less saline water from the main body of the Red Sea, over the sill. The residence time of the surface waters in the Gulf is about one year, while that of the deeper strata is about three years. These features, and the fact that there is no input of fresh water through rivers into the Gulf, make the Gulf of Aqaba particularly vulnerable to the accumulation of pollutants, both organic and chemical waste, from land-based sources. The Gulf is also vulnerable to oil pollution close to the oil terminals in Israel and Jordan, at the port cities of Eilat and Aqaba, as well as beside the navigation lanes along the Gulf.

The Gulf of Aqaba is home to varied tropical fauna and flora including about 1,000 species of fish, 110 species of reef-building coral and 120 species of soft coral (the northernmost in the world) as well as mangrove forests located on the western side of its southern end.

Brief History of Scientific Research in the Gulf of Aqaba

The first co-ordinated multi-disciplinary research programme, following earlier isolated visits and expeditions to the area, was carried out in the mid seventies by scientists belonging to the major Israeli universities and the country's newly-established umbrella organisation for limnological and oceanographic research, the Israel Oceanographic & Limnological Research Ltd. (IOLR). The work undertaken within this programme was largely carried out from the H. Steinitz Marine Biological Laboratory (MBL), currently the Interuniversity Institute, Eilat, established a few years earlier close to the Egyptian border. It provided the first yearly-cycles of nutrients, primary production, plankton cycles and biomass, as well as information on the physical and geological characteristics of the Gulf. This multi-disciplinary study was code-named DCPE (Data Collection Programme Eilat). While the observations covered a line of sampling stations along the Gulf and the Tiran Straits, the main volume of data derived from a reference station code-named "A," at its northern end, 550-600 metres deep. It was visited at regular intervals by all research groups and still serves this purpose today. The ensuing monograph, "The Gulf of Aqaba," by Reiss and Hottinger, 1984, summed up the main results of the individual scientific reports, too numerous to be bibliographically reviewed here.

The establishment of the National Centre for Mariculture (NCM), a branch of the IOLR, recently relocated on a well-developed campus close to the Jordanian border, provided the facilities and scientific and technical manpower for the current monitoring programme.

Monitoring of the Planktonic Microbiota in the Gulf of Aqaba

The current study, carried out under the auspices of the NCM, is aimed at studying the temporal and spatial composition and distribution of the microplankton, including the major groups of phytoplankton (primarily diatoms and dinoflagellates) and microzooplankton (primarily tintinnids) as bio-indicators of pollution and other forms of anthropogenic perturbations. At the same time the scientific team involved in this study is aware of natural phenomena, such as climatic changes, which may affect the biotic environment, gradually or suddenly. This particular study is one of several monitoring programmes carried out by scientists from universities and other research institutes in the country, using the MBL as a base, and most of them use the coral reef system along the coast of Israel for their individual studies.

The study of the microbiota began in 1986 on a more or less regular basis of the collection, preservation and processing of the microplankton samples at Station A, by special methods as described in Kimor et al. (1992) and Gordon et al. (1994). The relevant data concerning microplankton cycles, primary production, nutrients and physical processes, as summarised in Reiss and Hottinger (1984), were used by the author and his associates from the NCM for comparison purposes.

A data-base of fully identified representative species of the taxonomic categories mentioned above is in the process of being established for use as reference material in the event of the sudden or gradual deterioration of water quality in the Gulf.

As Station A is relatively remote from the direct effects of the expanding tourist industry in the northern part of the Gulf, both at Eilat and Aqaba, as well as from the industrial centres and port facilities in both Israel and Jordan, additional sampling stations, closer to the shore, are planned for inclusion in the future monitoring programme.

Special attention was given in the Gulf of Aqaba monitoring programme to symbiotic and commensalic associations among the microplankton components. An example is the consortia of heterotrophic dinoflagellates with symbiotic cyanobacteria capable of molecular nitrogen fixation, of particular importance in oligotrophic marine environments such as the Gulf of Aqaba.

General Considerations

The monitoring programme of the microbiota in the Gulf of Aqaba is one phase in the multi-disciplinary studies being carried out simultaneously by various groups of scientists in Israel and the neighbouring countries. The importance of co-ordinating such research activities among the four States bordering on the Gulf is highly emphasised in a recent publication by the Environmental Law Institute in Washington DC entitled Protecting the Gulf of Aqaba. A Recent Environmental Challenge (1993). It considers the scientific and legal status in the Gulf, based on contributions by experts from Israel, Jordan and Egypt. The general consensus is that a supreme effort should be made to ensure the protection of the natural resources of this unique marine environment, without hindering the continuously expanding development along the coasts, in the areas of urbanisation, tourism, industry and navigation. In this respect, the Gulf of Aqaba could serve as a field laboratory oriented toward reaching the correct balance between protection of the environment and development, through multinational collaboration and co-ordination in research and management.

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Professor Baruch Kimor's life-time work has been dedicated to Mediterranean Planktonology, for which he was awarded the Tregouboff Prize by the French Academy of Sciences, in 1991. Born in Romania but living in Israel, his career has included teaching at the Israel Institute of Technology (where he was one of the founding members of the Lowdermilk Faculty of Agricultural Engineering), the Department of Oceanography at the Hebrew University of Jerusalem, and at the Interuniversity Institute in Eilat, The Red Sea. On an international level, he has frequently worked on behalf of UNESCO and SCOR (Special Committee for Oceanic Research), serving as first chairman for the UNESCO- sponsored Advisory Council for all oceanographic sorting centres in the world. He has also served as a member of the Group of Experts on the Preservation of Materials in the Marine Environment, sponsored by the OECD. He has also undertaken extensive research both in California and Germany. He has published widely and frequently spoken at international conferences, recently on the topic of the Impact of Man-Induced Perturbation on Marine Ecosystems.