The Israel National Monitoring Program in the Northern Gulf of Aqaba

(Funded by the Israel Ministry of the Environment)

Science Report for Year 2004

Submitted to the Steering Committee by:
Prof. Amatzia Genin, Program Manager
Jacob (Jack) Silverman, Team Leader
(March 2005)

Background

This Report describes the results of the monitoring program in 2004. The Report is divided into a several working chapters. Each chapter consists of a short description of the methods followed by a detailed description of the results and discussion. Detailed descriptions of the methods can be found in the program's first Annual Report (2003). The entire report can be found at the web site of the Ministry of the Environment: (www.swiva.gov.il). The raw data are available for viewing and download at the program's web site www.inm-eilat.org.il.

This year the monitoring project was in parallel with the IET Project, the goal of which was to test the effects of the fish cages on the Gulf's open water and coral reef ecosystems. Tight cooperation between the IET Project and the Monitoring Program allowed the construction use of a joint database as well as productive exchange of ideas and opinions. The IET Project used the database of the NMP Program (especially the results of the monthly cruises and the reef metabolism).

The state of the water column

1. The deep mixing of winter 2004 was relatively shallow (350m). Consequently, this year nutrients continued to accumulate in the deep waters and the concentration of oxygen continued to decline. The level of these two parameters reached the most extreme values since their measurements started some three decades ago. (The concentration of nitrite and nitrate reached 7 $\mu mol\text{-}L^{-1}$ while oxygen concentration declined below 150 $\mu mol\text{-}L^{-1}$.) This trend indicates a continuation of the organic enrichment and eutrophication observed in the Gulf's deep waters since 1999.
2. The rate of primary productivity in the open waters declined to half the level of 2003 but is still higher (approx. x1.7) than its average value in the years prior to 2000 and is higher that the values "typical" for oligotrophic seas. The decrease in primary productivity this year was apparently due to the relatively shallow vertical mixing in winter 2004.
3. Ammonium concentrations increased and became a major component of the dissolved inorganic nitrogen pool near the north beach. This process is an indication of local eutrophication.
4. Evidence of substantial denitrification was observed, for the first time, near the bottom. This process is the reduction of nitrate through bacterial respiration of organic matter in oxygen-poor waters. It indicates the occurrence of organic enrichment in the sediment.

5. Substantial amounts of nitrogen from allochtonous (outside) sources are delivered to the northern region of the Gulf. The main source, amounting to ~280 tons N /year (IET report), is the fish cages. Our measurements in the Arava stream (the "Kinet Canal") indicate a transport of ~10 tons N / year. Measurements made by the Israel Geological Survey as part of the IET Project indicate a sub-terrain transport of ~30 tons N / year in the entire northern Gulf region (including Aqaba).
6. The Meridian Hotel uses N-rich, sub-terrain water for its cooling system. Under permit this hotel is allowed to pump 300m m^3/hr, thereby delivering ~12 tons N / year to the sea. Our measurements in the water column off Meridian Hotel indicate a significant increase in the concentration of dissolved inorganic nitrogen and significantly elevated rates of primary production in surface water. This observation indicates a local effect of the Hotel on the water quality in its proximity (probably because of slow exchange of water in this part of the Gulf).
7. The shallow mixing in the past few years and the high primary production have caused a small increase in pH (decrease in acidity) in the surface water in the northern Gulf. This situation shows an improvement in the conditions needed for the formation of a biological carbonate skeleton by the corals, carbonate alga and other invertebrates in the reef.
8. Despite the above, the chemical monitoring of seawater overlying the reef (at the reef lagoon in the Nature Reserve) showed a decrease of 20% in the annual rate of biological production of carbonate skeletons (compared to years 2001-2003).
9. Our long (17 years) time series of chlorophyll *a* in the surface water above the coral reef at the Nature Reserve indicates a lack of long-term increase, which had been expected due to the aforementioned increase in primary productivity and elevated nutrients in the deep waters. That chlorophyll *a* (a proxy for phytoplankton biomass) had not increased was probably due to the efficient functional (and probably numerical) responses by herbivorous zooplankton.
10. Our 17 year-long time series of sea-surface temperature indicates a lack of warming trend. This differentiates the northern Gulf of Eilat from many other places in the world where a warming trend was found. This is important for the "well-being" of the reef, since coral bleaching is frequently associated with sea warming.

Coral Reefs

11. The percentage of stony coral cover at the reef of Eilat is very low compared with many other sites in the world. A survey of the reef, in comparison to previous reef surveys, indicates a decrease in percentage cover especially at the shallow part (5m) of the Nature Reserve, and a very noticeable decrease in the abundance of sea urchins (their function as algal grazers is very important for coral settlement in the reef). A change in the species composition of stony corals in comparison with a few decades ago was also documented. However, compared to previous surveys there were no dramatic changes in the diversity of coral families. The density of *Stylophora* in the area of the lagoon in the Nature Reserve (situated between the beach and the reef table) has stabilized over the past 3 years after an increasing period which started following the

closure of the area to visitors in 1996. This species dominated that lagoon zone in the past (Loya, 1971).

12. A continuous increase in the potential growth rate of macro algae has been observed in the coral reef in the past 7 years. However, no such trend has been observed in the realized growth (on plates open to herbivores). This observation indicates that the herbivores (especially fish, as sea urchins have declined) are important in keeping macro algae at low abundance. At several coral reefs in the world (e.g. Jamaica) the reef severely deteriorated because of algal growth following the disappearance of fish (over-fished) and sea urchins (due to disease).
13. The biogenic formation of $CaCO_3$ skeleton in the shallow waters of the reef, in respect of aragonite saturation in the water, decreased. This trend could be due to a reduction of live cover of calcifying organisms (especially corals), a decrease in the rate of dissolved $CaCO_3$, or both.
14. This year, for the first time, the Report includes "ad hoc" work that compared the rates of coral growth and respiration between different sites in the northern section of the Gulf (from the IUI reef in the south up to the fish cages in the north). The results indicate no significant inter-site difference.

Discussion: the major ecological problems

1. Coral-reef deterioration

The decline in the cover of live corals at the shallow zone of the reef at the Nature Reserve, as well as the low cover found elsewhere (relative to many other reefs in the world), are very worrisome. Several hypotheses relating the poor state of the reef to recent anthropogenic activities have been suggested, however, so far, there is no strong evidence corroborating any of the proposed mechanisms. Therefore, we strongly recommend a "sweeping response" through which a substantial reduction will be enforced on all potential sources of deterioration known to date.

2. Eutrophication

A significant trend was observed in four different parameters the measurements of which are analytically independent: (i) increase in the deep pool of dissolved inorganic nitrogen [DIN]; (ii) decline in oxygen in the deep water; (iii) increase in the potential growth of macro algae in the reef; (iv) and increase in the organic content of the sediment. In addition, the water column primary productivity was high and new evidence for denitrification over the deep bottom were found. All these observations strongly support the conclusion that the northern section of the Gulf is exposed to an on-going eutrophication. Eutrophication is a substantial disturbance and a major change in water quality.

The central question at stake is whether the observed eutrophication is part of a natural cycle or an outcome of both anthropogenic and natural processes. If the latter is the case, a key objective is to resolve the relative contributions of the anthropogenic and natural sources. It is possible that the increase in the nitrogen pool and the decrease in oxygen in the deep waters are part of a natural, quasi-decadal cycle, as follows. The deep vertical mixing in anomalously cold year, and the ensuing strong

spring bloom after such mixing, "reset" the system by delivering substantial amounts of dissolved nitrogen to particulate form (in the bodies of phytoplankton). Consequently, the DIN concentration in the deep waters decreases to a low level (about 2 μmol/L). Then, in the following years, as long as no anomalously cold winter occurs, the nitrogen pool in the deep water gradually increases due to the sinking of particulate matter from the photic layer and its re-mineralization at depth. This cycle has been observed in the past and was well documented in two such cycles: one after the deep mixing of winter 1993 until late 1999 and the other after the mixing of winter 2000 until now. It is possible that the substantial flux of nitrogen from anthropogenic sources, especially from the fish cages (~280 ton N / yr), strongly augments the cycle. In order to assess the anthropogenic contribution to the above cycle, the following research projects will be necessary: (i) Characterizing the current regime in the region; (ii) modeling the nutrient dynamics, including physical advection, uptake and recycling in the water column food web, sinking, decomposition and re-mineralization in deep water and on the bottom, and upward entrainment via re-suspension and mixing; (iii) monitoring the bio-geo-chemical and physical parameters hoping for a cold winter to occur soon, which will allow a comparison between the DIN values after deep mixing in the future and those in the previous cycles. If anthropogenic sources of DIN contribute substantially to the above cycle, we should expect the new "post-reset" values to remain at significantly higher levels than in the past.

Although, as mentioned above, more research is needed to evaluate the anthropogenic contribution to the aforementioned DIN cycle, some indirect evidence suggests that this contribution may be substantial. A comparison between the rate of increase of DIN pool in the deep waters between the previous cycle (1993-2000) to the current one (2000-present) indicates that the rate of DIN accumulation was faster in the latter. This accelerated accumulation corresponds to the concurrent increase in the aquaculture fish production. This tentative suggestion will be tested following the next "reset" in a cold winter, when it occurs.