THE NATIONAL MONITORING PROGRAM OF ISRAEL'S MEDITERRANEAN WATERS – SCIENTIFIC PERSPECTIVES

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Abstract – The Levantine Basin (LB) is considered an impoverished and sensitive ecosystem in the Mediterranean Sea. Since the beginning of the industrial revolution this sea has been influenced by increasing global, regional and local anthropogenic pressures. The LB is at the eastern most terminus of the Mediterranean Sea with relatively long residence time of water subject to warming, salinization and acidification. The opening of the Suez Canal in 1864 linking the Red Sea with the Mediterranean has facilitated the migration and settling of hundreds of Eritrean species along the Levantine coasts at the expense of native species and irreversibly altering the ecosystem. The damming of the Nile at Aswan in the mid 1960's reduced freshwater, nutrients and sediment fluxes into the LB resulting in probably reduced primary productivity, increased salinity and shore erosion along the Mediterranean coast of Israel. Locally, intense human activity including ports expansion, development of desalination plants, gas drilling, power plants, increase in maritime transportation (and more) impose heavy pressure on the coastal and deep-water ecosystems.
The National Monitoring Program of Israel's Mediterranean Waters (NMPIL) show significant signals of changes in the marine ecosystem off the shore of Israel, corresponding to the above pressures. In December 2018, a government decision on expanding the NMPIL was adopted in line with the United Nations Environmental Program's (UNEP) Integrated Monitoring and Assessment Program (IMAP) under the Barcelona Convention, considering also climate change perspectives. This communication shows the NMPIL structure and scientific rationale, and present three representative case studies of the monitoring results.

Introduction

The NMPIL is implemented based on the Ecosystem Approach (EcAp) for Good Environmental Status (GES) of the Mediterranean Sea by Ecological Objectives and indicators (in line with the Marine Strategy Framework Directive, MSFD) and on Climate Change indicators. The program covers large spatial (up to ~24 000 km^2) and temporal scales (several orders of magnitude) (Figure 1) and implement diverse monitoring methodologies and infrastructures (from molecular to ROVs) and complex logistics. These include molecular tools, barcoding and meta-barcoding, imaging using AI, radioisotopes (rates measurements), diverse sampling (rossette/CTD, box and piston corers; nets; diving; etc.), autonomous vehicles/measurements (mooring, gliders), remote sensing, operational/ecological models.

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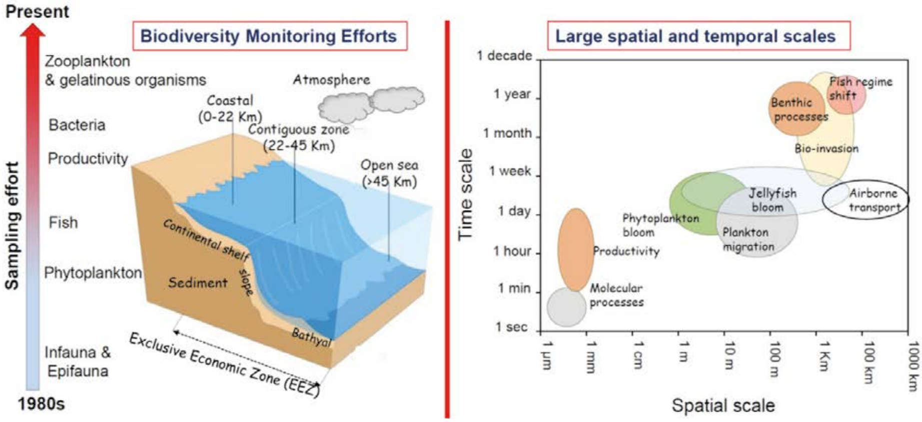

Figure 1 – The scales of spatial and temporal trends and the evolution of biodiversity monitoring efforts in the National Monitoring Program of Israel's Mediterranean Waters.

The annual monitoring and long-term results are reported via 5 main scientific reports:

- **Monitoring Climate Change and Hydrography** [1] (sections: thermohaline changes and continuous measurements; sea-level changes; Acidification and the carbonate system; changes in dissolved nutrients and oxygen in the open sea; Israel Marine Data Centre).
- **Monitoring Marine Pollution** [4] (sections: heavy metal in marine and estuary sediments; heavy metals and organic pollutants in ports and marinas; pollutants in marine biota; heavy metals and nutrients in atmospheric precipitates; nutrients and chlorophyll in estuaries and the continental shelf).
- **Monitoring Marine Litter** (litter and microplastic: beaches; marine sediments; surface seawater).
- **Monitoring Marine Biodiversity** [3] (sections: biology and ecology of phytoplankton in seawater; biology and ecology of bacteria in seawater and sediments; biology and ecology of zooplankton; biology and ecology of infauna; biology and ecology of epifauna; ecology of populations in rocky shores and hard substrates; barcoding and genetic resources).
- **Monitoring Sea-floor integrity and Sedimentology.**

In addition, part of the marine pollution and eutrophication annual results are submitted to the UNEP/MAP Secretariat/MED POL Programme database as agreed upon the Barcelona Convention parties. The implementation of the Integrated Monitoring and Assessment Cluster is still under discussion and probably soon will be adopted in order to contribute to the delivery of the MED QSR (quality status report) 2023.

Materials and Methods

The monitoring sites were designed to cover different bio-types or habitats – littoral, continental shelf, slope, bathyal, atmosphere, rivers and estuaries, benthic and pelagic; and the potential impacts of land base sources or marine infrastructures (Figure 2).

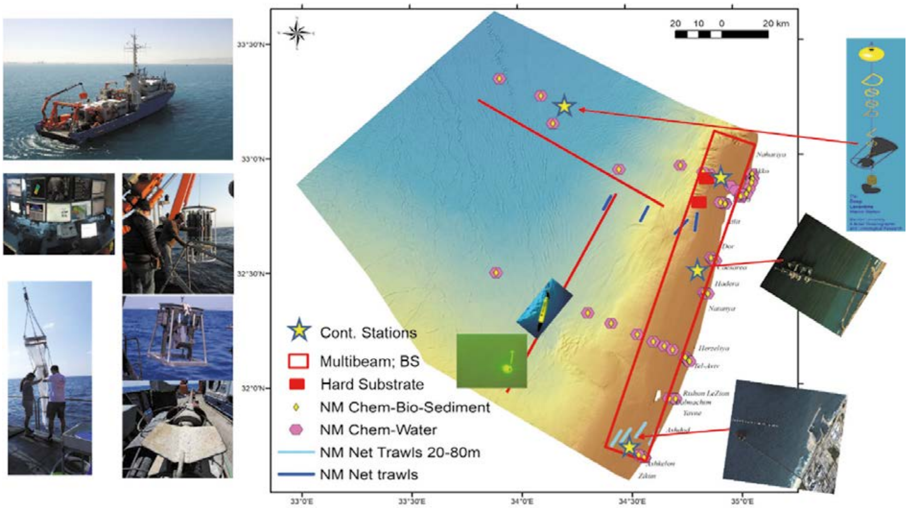

Figure 2 – Location of monitoring stations or transects in frame of the National Monitoring Program of Israel's Mediterranean Waters. Pictures includes the R.V. Bat Galim operated by IOLR and different sampling devices and continous measurement stations.

A summary of the different ecological objectives (EO), as defined by MAP-ECAP, which are implemented within the NMPIL, and monitored matrices, are presented in Table2.

Table 2 – Ecological objectives (EO) and monitored matrices as implemented within the National Monitoring Program of Israel's Mediterranean Waters.

Ecological Objective (EO)	**NMPIL**	**Matrices**
Biodiversity	√	Water, soft and hard sea-floor
Non-indigenous species	√	Water, soft and hard sea-floor
Harvest of commercially exploited fish	√	Benthic/pelagic
Marine food webs	√	Complex/in process
Eutrophication	√	Water
Sea-floor integrity	√	Soft and hard sea-floor
Hydrography	√	Water
Coastal ecosystems	√	complex
Pollution	√	Water, sediment, biota
Marine litter	√	Water, sediment, beach
Energy incl. underwater noise		Not yet
Climate Change	√	Temp, Sal, Acidity, Sea-level, Bio-invasive, hydro-meteorology

Results and Discussion

Here, we present three representative case studies of results from the long-term record of the NMPIL attributed to climate change and to marine pollution.

Climate Change case study 1 - Over the past ~32 years the Levantine Surface Water (LSW) and Levantine Intermediate Water (LIW) masses displayed positive long-term trends in salinity of +0.008±0.006 and +0.005±0.003 year^{-1}, respectively, and temperature of +0.13±0.05°C year^{-1} and +0.03±0.01°C year^{-1}, respectively (Figure 3). Inter-annual variations in salinity, temperature and nutrients were superimposed on all long-term trends [1,5,6]. The thermohaline variability in the LB coastal waters during 2011-2021 showed a statistically significant long-term warming and salinification trends with yearly rates of 0.048°C and 0.006, respectively [6], similar to the LIW rates.

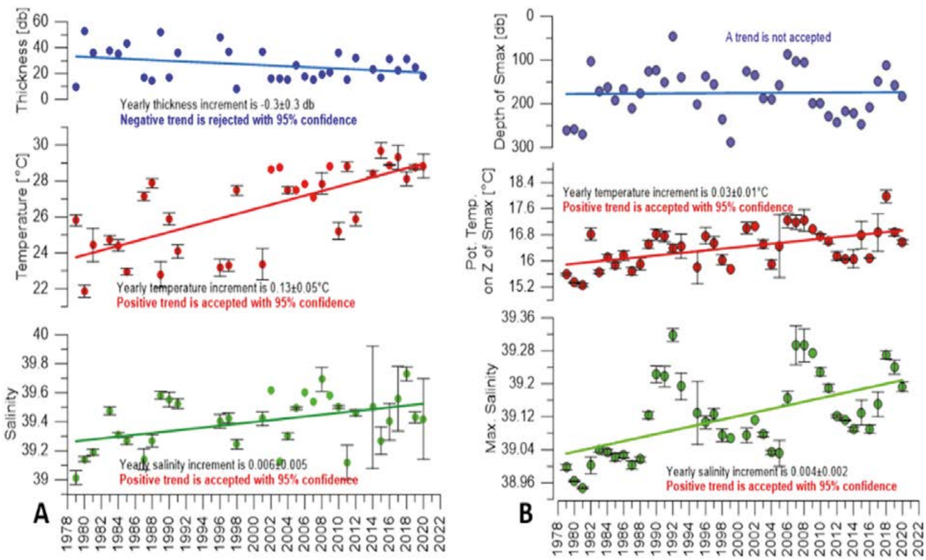

Figure 3 – Inter-annual and long-term changes of temperature and salinity in the Levantine Surface Water (LSW) and Levantine Intermediate Water (LIW), derived from 32 years of CTD profile measurements [5,6]. For the LSW only observations performed during the warm period (July-October) presented.

Climate Change case study 2 - Sea level variations are monitored by the Hadera Gloss #80 station (Figure 1) since 1992, at the LB coastal waters. During 1992 – 2020 an average sea level rise of 4.7 mm per year was observed (Figure 4) [1], higher than the global average of 3.2 mm per year. The sea level annual maximal and minimal levels (Figure 4) represent the seasonal summer and winter temperature variability, respectively.

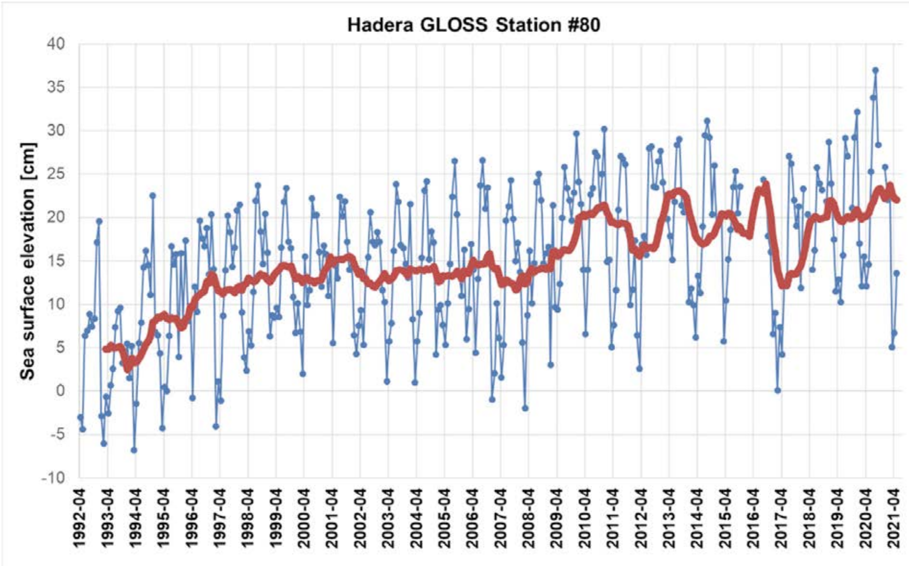

Figure 4 – Long-term changes of sea surface elevation as recorded at Hadera Gloss #80 Station [1; Ayah Lazar].

Marine Pollution case study 3 - Haifa bay (HB), located at the northern Israeli Mediterranean shoreline, was contaminated in the past by mercury through a point source of effluents discharge of a chlor-alkali plant (Electo-Chemical Industries) located at the northern part of the bay, which operated until 2004 [4]. The sediments and biota in HB have been monitored annually since 1978, as part of the NMPIL [3]. The long-term variations of total Hg (THg) concentration in surface sediments is monitored at 2 stations (8 and 9), off the former location of the chloro-alkali plant, and by sediment cores colected at station 9 between 1985 and 2021 [3,4]. The total amount of anthropogenic THg in the top 23 cm of each core is represented by the area integrated under each curve, corrected for the naturally-occurring THg. A general systematic decrease in the mercury surface sediment concentrations and total amounts is evident over the years (Figure 5).

Despite the long-term exponential decrease in the concentrations of THg in sediments and in the marine biota, an unexpected increase in the levels of mercury in coastal fish was observed after the closure of the chloro-alkali plant during 2006-2014 (Figure 6). To determine the cause of this increase, THg and methyl Hg (MeHg) were measured in seawater, coastal groundwater, suspended particulate matter, plankton, macroalgae, benthic fauna, and in marine and beach sediments. Extremely high concentrations were found in groundwater and sediments from the vicinity of chloro-alkali plant. This finding suggested a discharge of polluted groundwater into the northern part of HB after stopping groundwater pumping for internal use of the plant and ceasing the consequent seawater intrusion. Thus, the intrusion of anthropogenic Hg via the groundwater marine discharge enabled the assimilation of Hg by plankton or adsorb onto inorganic particles, which are further ingested by benthic and pelagic consumers [7]. These findings were used by the Ministry of Environmental Protection to instruct for the restoration of the polluted area.

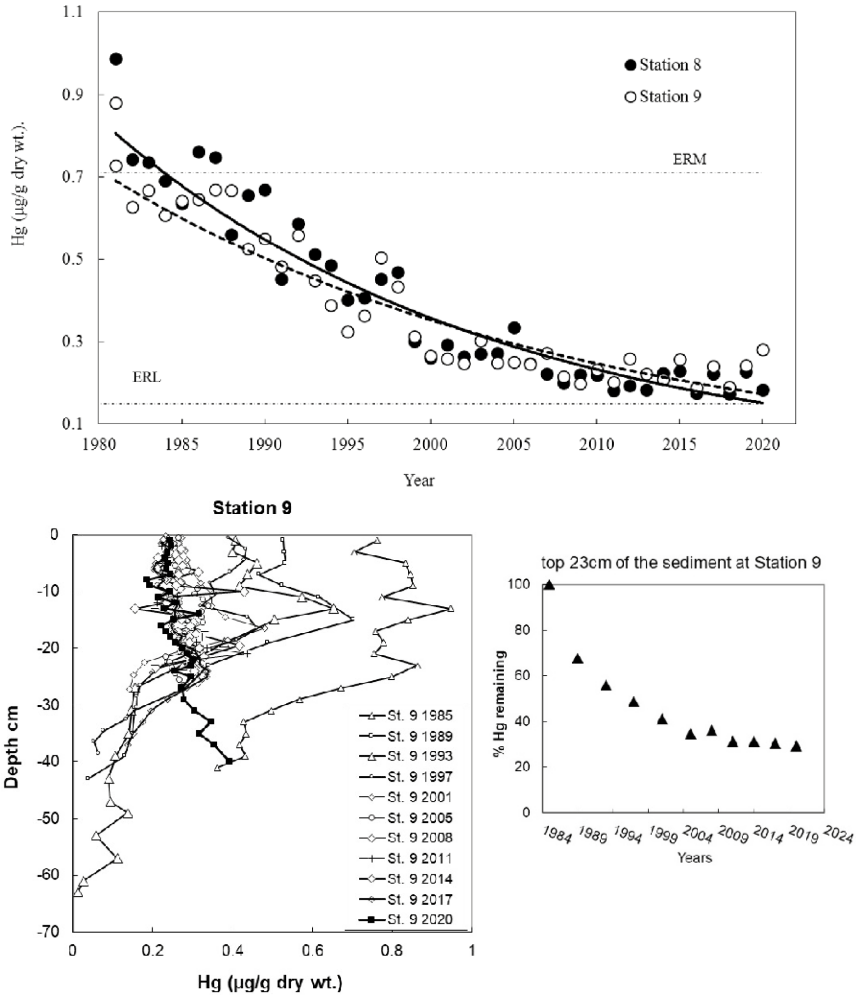

Figure 5 – Total Hg concentrations in surface sediments (top) and in sedimentary depth-profiles (lower left) at station 9 at the northern part of Haifa bay. A decrease of total Hg in the top 23 cm of sediments at station 9 between 1985 till 2020 is presented as percentage of the total Hg content in the 1985 core [3,4].

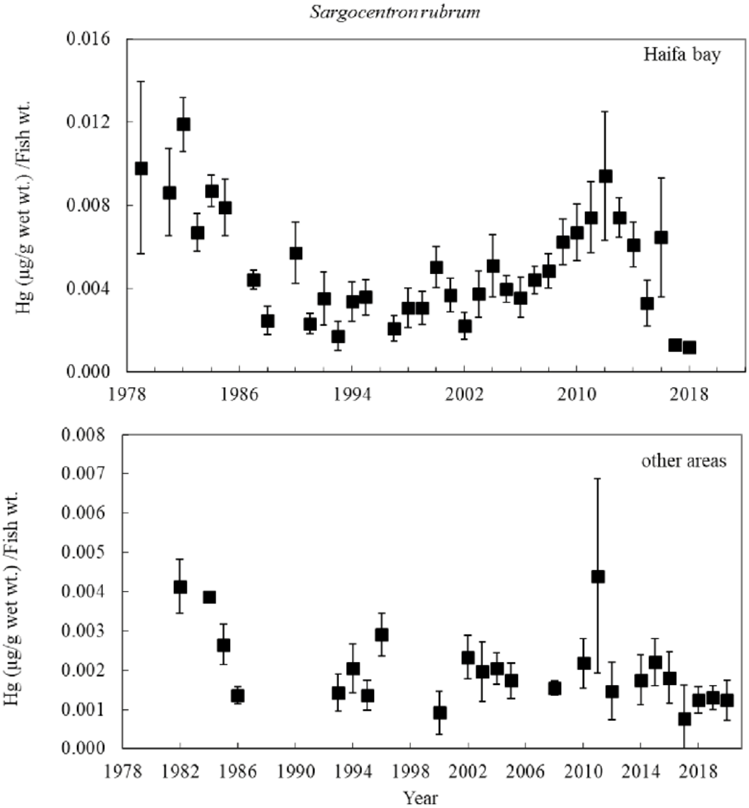

Figure 6 – Levels of Hg in the fish *Sargocentrum rubrum* (concentration normalized to fish weight) at Haifa bay (upper panel) and in other areas along the Mediterranean coast of Israel (lower panel) during 1980 till 2020.

Conclusion

The NMPIL has been developed over time in terms of its monitoring tools, methodologies, sampling efforts, spatial coverage and food web scales. While during the 80s of the former millennium the program was focused solely on marine pollution aspects at the coastal belt it has been expanded to include different habitats entering into the deep sea (littoral, continental shelf, slope, bathyal, atmosphere, rivers and estuaries, benthic and pelagic) and across the food web populations: bacteria, phytoplankton, zooplankton, mollusca, echinodermata, crustacea, polychaeta and fish. While Israel's national practice brings its NMPIL to the forefront of IMAP implementation, more monitoring efforts are needed to better address all the ecological objectives (or descriptors as defined in the MSFD). In addition, more knowledge is needed to better assess IMAP ecological objectives and indicators and the implementation of the Ecosystem Approach (EcAp) for Good Environmental Status (GES) of the Mediterranean Sea.

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