Report on the IMAP common indicator 15 "Location and extent of the habitats potentially impacted by hydrographic alterations" for Israel

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List of acronyms

Abrasion Platforms (AP)

Environmental Strategic Survey (Israel Ministry of Energy) (ESS)

Exclusive Economic Zone (EEZ)

International Union for Conservation of Nature (IUCN)

Israel Oceanographic and Limnological Research (IOLR)

Israel Marine Data Center (ISRAMAR)

Israel Ministry of Environmental Protection (IMEP)

Israel National Marine Monitoring Plan (INMMP)

Israel Nature and Parks Authority (INPA)

Israeli Government Central Bureau of Statistics (ICBS)

Israeli Marine Mammal Research & Assistance Center (IMMRAC)

Marine Spatial Planning of Israel (Technion, Israel Institute of Technology) (MSPI)

Maritime Policy for Israel's Mediterranean Waters (Israeli Government Planning Administration) (MPIMW)

Non-indigenous species (NIS)

Sea level rise (SLR)

Submerged kurkar ridges (SKR)

Survey of Israel (SOI)

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1. Introduction

The State of Israel is situated on the southeastern coast of the Mediterranean Sea. Its population, as for November 2021, is 9,347.000 people (ICBS - Israel central bureau of statistics, 2022).
This population has almost doubled over the last 30 years due to waves of immigration, natural growth [Annual population growth rate 1.6% for 2021 (ICBS, 2022)] and improvement in life expectancy. According to a forecast that assumes a moderate level of natural increase and immigration balance, at the end of 2045 the population of the State of Israel will reach more than 15 million people and around 20 million by 2065 (ICBS).
Israel is considered a highly urbanized nation state. According to the ICBS (2021) report (Israel in Figures - Selected Data from The Statistical Abstract of Israel 2021), in 2018 a total of 88.9% of the Israel population, consisting of 8,967,600 inhabitants than, lived either in cities (74.2%) or in local authorities (14.7%). The highest population density is in the central coastal plain which is also the economic center of Israel. In the central district, the population density per km^2 of land has increased since the establishment of the State of Israel in 1948 from 122.3 to 2268.2 at the end of 2020.
More than five million people (about 60% of the Israeli population) and much of the country's marine economic and commercial activity (e.g. ports, harbors, power plants, desalination plants, coal jetties and offshore oil terminals) as well as related industries (e.g., refineries, warehouses) are concentrated in the coastal zone. In addition, some areas are military zones closed for public access, leaving only approximately 130 km (out of 195 km) of coastline open to the public for recreational activities (e.g. marinas, authorized bathing beaches, nature reserves) and very few beaches are left in their natural state with no development.
As a warm country with almost 8 months of summer (average temperatures of 25.3 °C in the north of Israel and 28.4 °C in the south), bathing beaches have become a crucial factor in the leisure and recreational culture of considerable part of the Israeli population. The official swimming season is determined by the Israeli Ministry of Interior, and it lasts 170 days from May 1st until October 31st each year. A typical Israeli beachgoer (i.e. a person who goes to the beach frequently) spends at least 1 day a week on the beach, especially at the weekend. That means about 20 visits during the swimming season (Bitan and Zviely, 2019).

2. General characterization of the coastal area and marine environment

2.1. Types and proportion of the different types of the coast

The Mediterranean coastline of Israel runs about 195 km from Zikim near the border with Gaza Strip in the south, to Rosh HaNikra near the Lebanese border in the north (Figure 1).

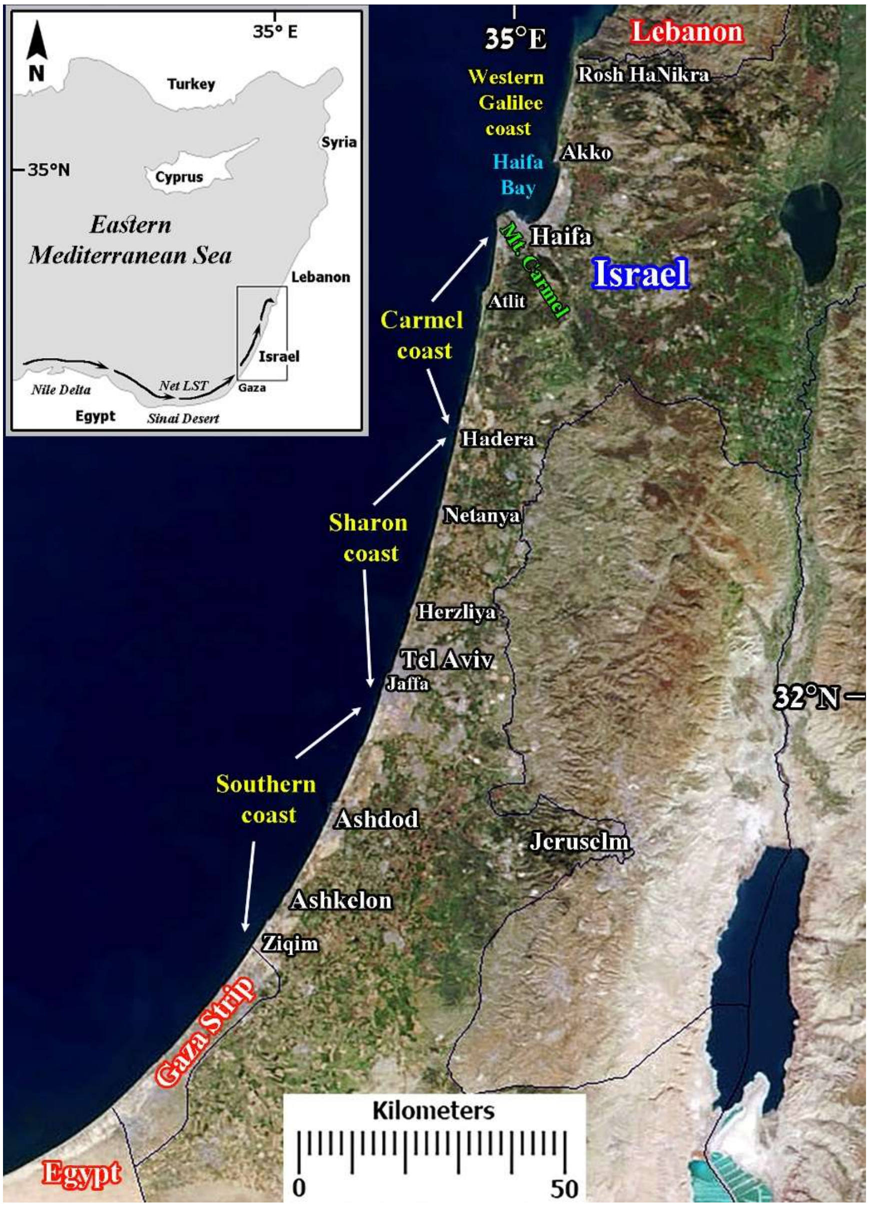

Figure 1. The Mediterranean coast of Israel (Background: Part of "Middle East" space image, Jacques Descloitres, MODIS Rapid Response Team, NASA/GSFC, 31 January 2013).
Top left inset: The Nile littoral cell net LST direction.

With the exception of Haifa Bay, the Carmel headland and few small rocky promontories (e.g. Tel Yavne-Yam, Jaffa, Apollonia, Tel Michmoret, Tel Gador, Tel Taninim, Tel Dor, Atlit and Akko promontory), the coastline is a straight in general, open to the west and gradually changes its orientation from northeast (azimuth 32º) to approximately north (Bitan and Zviely, 2019).

The coast of Israel and its adjacent inner shelf, from the shore to maximum 30 m water depth, can be divided into two main sedimentological provinces. The Southern Province stretches 175 km from Ziqim to Akko promontory (northern Haifa Bay) (Figure 1) and is mainly composed of Nile-derived fine quartz sand (Bitan and Zviely, 2019). This region is considered the northern flank of the Nile littoral cell (Inman and Jenkins, 1984), one of the world’s longest. This huge coastal compartment runs 650 km along the southeastern Mediterranean, from Abu Quir Bay near Alexandria, Egypt, to Haifa Bay (Goldsmith and Golik, 1980; Nir, 1982) (Figure 1: Top left inset). The Northern Province (i.e. the Western Galilee coast), however, is a small (20 km long) isolated and rocky littoral cell, that partly covered with local coarse carbonate sand (Emery and Neev, 1960; Pomerancblum, 1966; Almagor et al., 2000).

Analysis of distribution of sand grain size on the beach and inner continental shelf shows that the sand may be divided into two populations groups according to water depth:

1) Between the backshore and 5 m water depth, has a mean grain size range of 132-335 µm.
2) Between 5 and 30 m water depth, has a mean grain size range of 117-161 µm.

It was found that the mean sand grain size of the deeper water population did not show any dependence on the geographical location along the coast, whereas the shallow water sand showed a decrease in size from the south to Herzliya whereas, on the beaches north of Herzliya, it was similar in size to that of the deeper water (Golik, 2002).

Most beaches in Israel are sandy and have a moderate slope (~ 1:30), and their width ranges from 10 to 50 meters (Figure 2). The beaches consist mainly of fine quartz sand (125-250 µm) (Emery and Neev, 1960; Golik, 2002). Relatively wide sandy beaches (50-100 m) are found mainly in south Israel (for example see figure 3) and around the coastal rivers outlets (100-200 m) (Lichter et al., 2010), while beaches less than 30 m wide and sometimes only a few meters, are mainly located in the center of the country, along the coastal cliff (for example see figure 4).

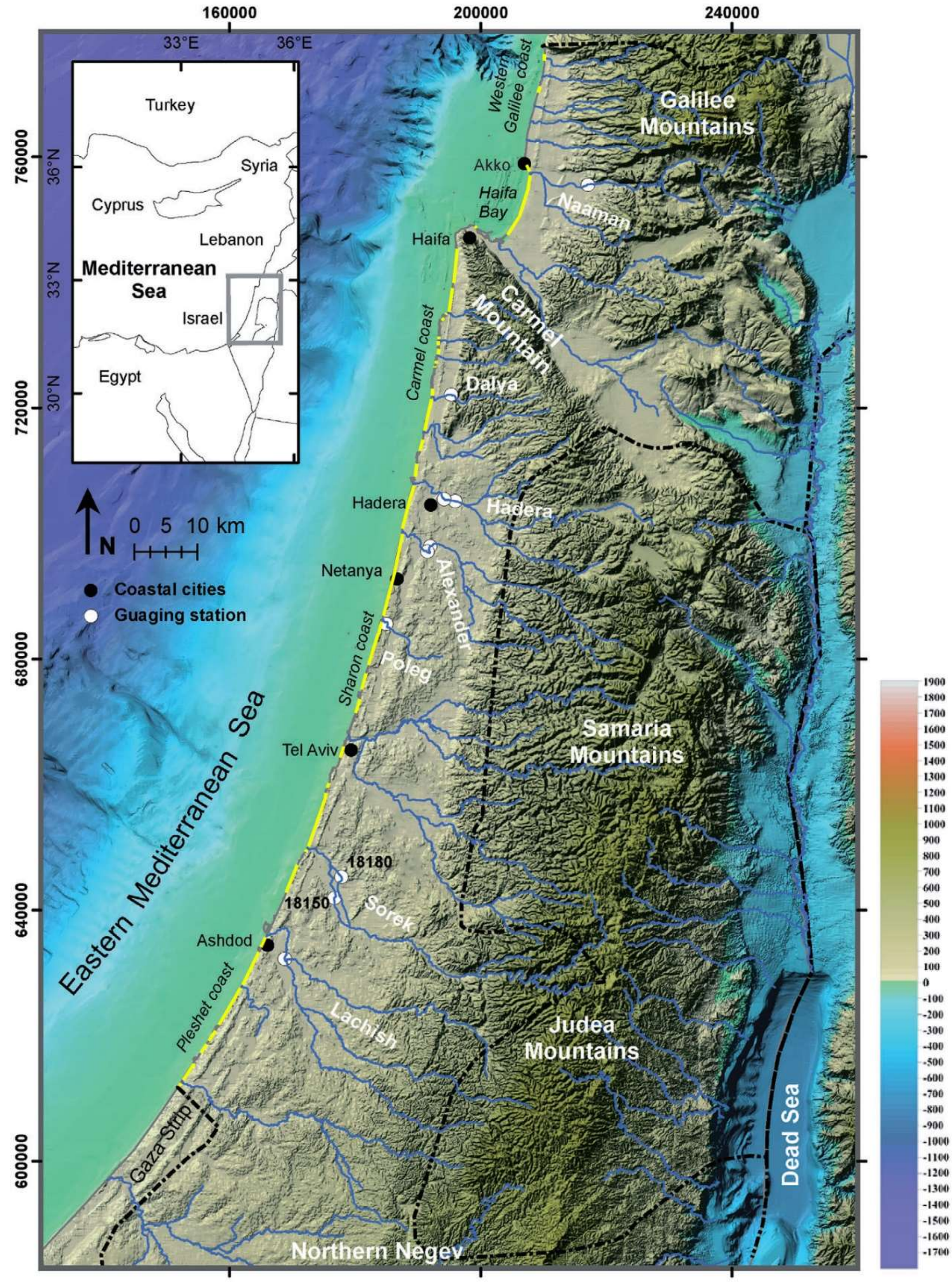

Figure 2. Locations of Israel’s main coastal cities, sandy beaches (sections in yellow), main rivers and ephemeral streams (modified after Lichter et al. 2011).
Background: Shaded relief modified after Hall and Calvo (2005).

Figure 3. Wide fine quartz sandy beach in Zikim (16.11.2017)

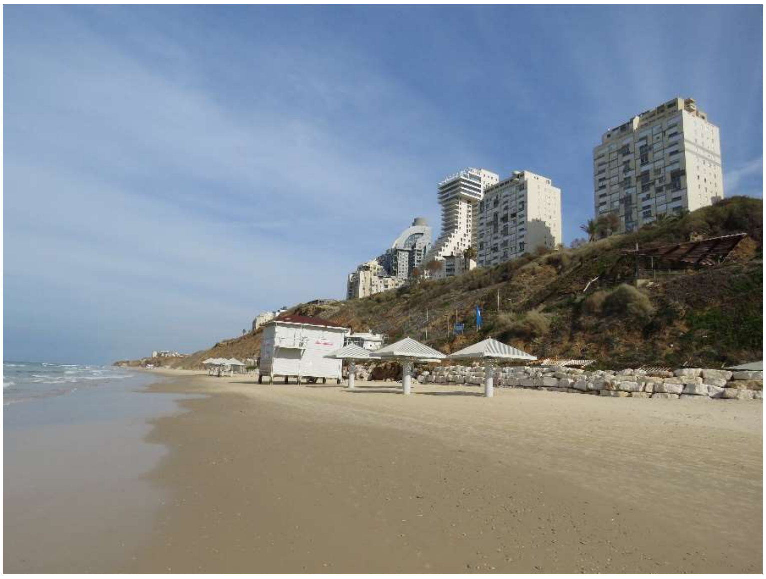

Figure 4. Narrow beach along the coastal cliff in Netanya (the Sharon coast) (5.1.2017)

Compared to the large number of sandy beaches in Israel, the rocky coasts are limited and they are located mostly north of Ashdod Port (~ 6 km long beachrock), around small rocky (i.e. kurkar) promontories, between Tel Dor coast (Figure 5) and Habonim Beach (~ 3.5 km long rocky coast with small pocket beaches), between Neve-Yam and Atilt Bay (~ 2.5 km long rocky coast), around the Carmel headland (~ 5.5 km long rocky coast with small pocket beaches) and along the Western Galilee coast (~ 20 km long rocky coast with few pocket beaches) (Figure 6).

Figure 5. Rocky kurkar coast at Tel Dor (the Carmel coast) (13.2.2008)

Figure 6. Rocky kurkar coast north of Akko (the Western Galilee coast) (10.3.2003)

Israel's coastal cliff extends between Ashkelon and Hadera (Figure 1) to a total length of about 45 km and rises up to 50 m above the beach. Its slope usually about 75°-90° and is consists of alternating layers of kurkar (local term for aeolian carbonate-cemented quartz sandstone) and palaeosols (Gvirtzman et al., 1984; Arkin and Michaeli, 1985; Porat et al., 2004). The cliff is poorly consolidated constantly collapsing and retreating eastwards (Perath and Almagor, 2000; Gil and Almagor, 2002; Zviely and Klein, 2004; Katz and Mushkin, 2013, and references therein).

There are several type of hard substrates along the Israel's coast. These include several kurkar ridges parallel to the coastline that locally forms a rocky substrate rich with crevices and caves (for example see figures 5, 6) and occurs underwater between the shoreline and ~20 m water depth.
Some of the kurkar substrates appear, in the intertidal zone, as abrasion platforms, which are more common in the northern Israel.
Another common rocky formation is beachrock, characterized by the significant presence of marine-associated particles such as shells and coarse sediment, rapidly cemented by calcium carbonate within the intertidal zone. The appearance of beachrock can be describe as tilted stair or tile-like laminated blocks, slightly inclined westward, and known to have the same lamination and a similar declination towards the sea as the hosting beach (for example see figure 7).

Figure 7. Beachrock outcrop at Shavei Tzion (the Western Galilee coast) (18.3.2008)

The beachrock outcrops can reach hundreds of meters in length, more than 40 m in width and up to about 1 m in thickness. Its composition is in many cases identical to the detrital components composing the non-consolidated coastal sediment in its close vicinity (waterline).
There are also conglomerate rocks as well as rare lime rocks along the Carmel Headland and Rosh HaNikra coasts.

Finally, thirty-two small rivers and ephemeral streams cut the Israeli coastal zone and flow westward to the Mediterranean Sea (Figure 2). Some of these streams have small drainage basins of only a few square kilometers, while others have drainage basins exceeding 1,000 km^2 (Lichter et al., 2010; 2011).

2.2. Coastal erosion and accretion, including data and studies on the sandy beaches, their length, spatial positions, and their shoreline evolution/change

Several dozen marine structures are located along the Mediterranean coast of Israel. These structures can be classified into four groups according their projecting into the littoral zone:

1) Groins and beach-parallel detached breakwaters, projected 100 to 200 m offshore, at water depth of 3 to 5 m.
2) Marinas, harbors and power plants cooling basins, projected 400 to 600 m offshore, at water depth of 5 to 9 m.
3) Haifa and Ashdod ports, projected about 2 km offshore from the natural coastline, at water depth of 21 m and 24 m respectively.
4) Offshore coal pillars Jetties at Hadera and Ashkelon, projected 2 km offshore, at water depth of 28 m.

The morphological impact of the marine structures on their adjacent beaches and seabed were studied in detailed by using aerial photographs, coastal geodetic measurements, hydrographic surveys, bathymetric charts and some ecological surveys.

The studies show that sand accretion has developed at the southern side (up-stream), while the northern side (down-stream) of marine structures along Israel’s southern coast has eroded.

Along Israel’s central and northern coasts, however, this morphological phenomenon is less dominant - even inverted around some small coastal structures (Emery and Neev, 1960; Goldsmith and Golik, 1980; Rohrlich and Goldsmith, 1984; Carmel et al., 1985; Golik, 1993; 1997; 2002; Shoshany et al., 1996; Perlin and Kit, 1999; Zviely et al., 2000; 2007; Klein and Zviely, 2001; Klein and Lichter, 2006; Klein et al., 2007; Zviely and Kit, 2012; 2019; Dror, 2017) (Table 1).

Marine structure	Length of built-up coastal section	Maximum seawards projection	Maximum distance of the morphological impact to the south	Maximum distance of the morphological impact to the north	Remarks
Ashkelon Port	700 m	~ 500 m	~ 1,200 m accretion	~ 3,500 m erosion	
Ashkelon Marina	500 m	~ 315 m	~ 1,200 m accretion	~ 3,500 m erosion	South and north of the marina, two series of three detached breckwaters are located
Ashdod Marina	500 m	~ 400 m	~ 800 m accretion	Ashdod Port morphological impact's area)	The marina is located ~2,550 m south of Ashdod Port
Ashdod Port	3,800 m	1,800 m	~ 2,250 m accretion	~ 6,000 m erosion	Refers to the South Port
The Rock Beach in Bat Yam	420 m	200 m	~ 600 m erosion	~ 300 m accretion	A coastal pool protected by low rocks
Herzliya Marina	800 m	500 m	~ 1,500 m erosion, except for a 200 m long section adjacent to the marina main breckwater	~ 3,000 m erosion, except for a 1,100 m long section in the vicinity of the detached breakwaters	South of the marina a series of three detached breckwaters is located
Pair of detached breckwaters in Central Netnaya coast		~ 200 m	More than 1,000 m erosion	More than 1,500 m accretion	The southern and northen detached breckewaters are 250 m and 210 m long repectivily
Hadera Port	750 m	~ 600 m	~ 700 m erosion	~ 1,000 m accretion	
Dado grion in Haifa	20 m	~ 100 m	~ 1,000 m erosion	~ 150 m accretion	
Carmel Coast detached breckwater in Haifa		~ 150 m	~ 700 m erosion	~ 150 m accretion	The detached breckewater is 275 m long

Table 1. Examples of morphological impacts of marine structures located on the Israeli coast

2.3. The main physical characteristics of the marine environment

2.3.1. Climate regime

The eastern Mediterranean Sea (east of Italy) can be divided into four sub-seas or basins (from west to east): The Adriatic, the Ionian, the Aegean and the Levantine seas (El-Geziry and Bryden, 2010). The Levantine Sea is characterized by hot, dry summers with stable atmospheric conditions, cold, wet winters and relatively short transitional seasons in spring and autumn (Kit and Kroszynski, 2014).

The seasonal mean winds are mainly westerly, although migratory low-pressure systems moving eastward across the Mediterranean Sea (Alpert et al., 1990) force downwelling-favorable, strong southerly to southwesterly winds along the Israeli coast (Rosentraub and Brenner, 2007).

During transition seasons, the Red Sea Trough, a tongue of low pressure originates in the Sudanese-Ethiopian "low", extends northward from the southern Red Sea towards the Eastern Mediterranean and the Levant, at lower atmospheric levels (Krichak et al., 1997).

2.3.2. Wind regime

The Israeli climate is characterized by hot and dry summers with stable atmospheric conditions, cold and wet winters, and transitional seasons in spring and autumn (Reiter, 1975). During the summer, steady westerly and northwesterly winds dominate over the Levantine Basin, strengthened by the Aegean Etesian regime and superimposed by a well-developed coastal sea breeze. The winter winds are predominant westerlies. In contrast to summer, the winter atmospheric conditions are unstable and variable, with occasional cold and dry air outbreaks from the north local cyclogenesis such as the Cyprus low (Özsoy, 1981; Alpert and Reisin, 1986). Also important are the depressions moving eastward across the Mediterranean Sea (Alpert et al., 1990), which force strong southerly to south-westerly winds along the Israeli coast (Rosen, 2006).

In Israel, the source of long term wind measurements is the Israel Meteorological Service (IMS). In the IMS website (www.ims.gov.il/IMSEng/Tazpiot), last-day hourly wind speed (and direction) is available online at the coastal stations (Hadera, Tel Aviv west, Ashkelon). The winds at Hadera harbor, Tel Aviv west and Ashkelon harbor are measured at 5, 10 and 4 m above sea level, respectively. However, it is customary to convert raw data in order to specify wind at standard height of 10 m above sea level for communication and use in applications

Based on wind data recorded in Ashdod Port area, between April 1st 1993 and March 31, 2011, the Israeli Coastal and Marine Engineering Research Institute (CAMERI) found that approximately 90% of annual winds, 86% of winter winds and 83% of summer winds were light (wind speed below 6 m/s) (Figure 8). In addition, about 9% of annual winds, 16% of winter winds and 7% of summer winds, were fresh (wind speed between 6 and 10 m/s). In general, only 1.2% of annual winds, 2.7% of winter winds and 0.34% of summer winds, were strong and exceeded 10 m/s (Levin et al., 2012a).

The wind direction with speed above 6 m/s was northwest (1.64% occurrence), while the dominant wind direction, in general, was south-southeast (Figure 8). Strong winds (above 10 m/s), that able to generate wave storms and strong currents, was southwest (0.30% occurrence).

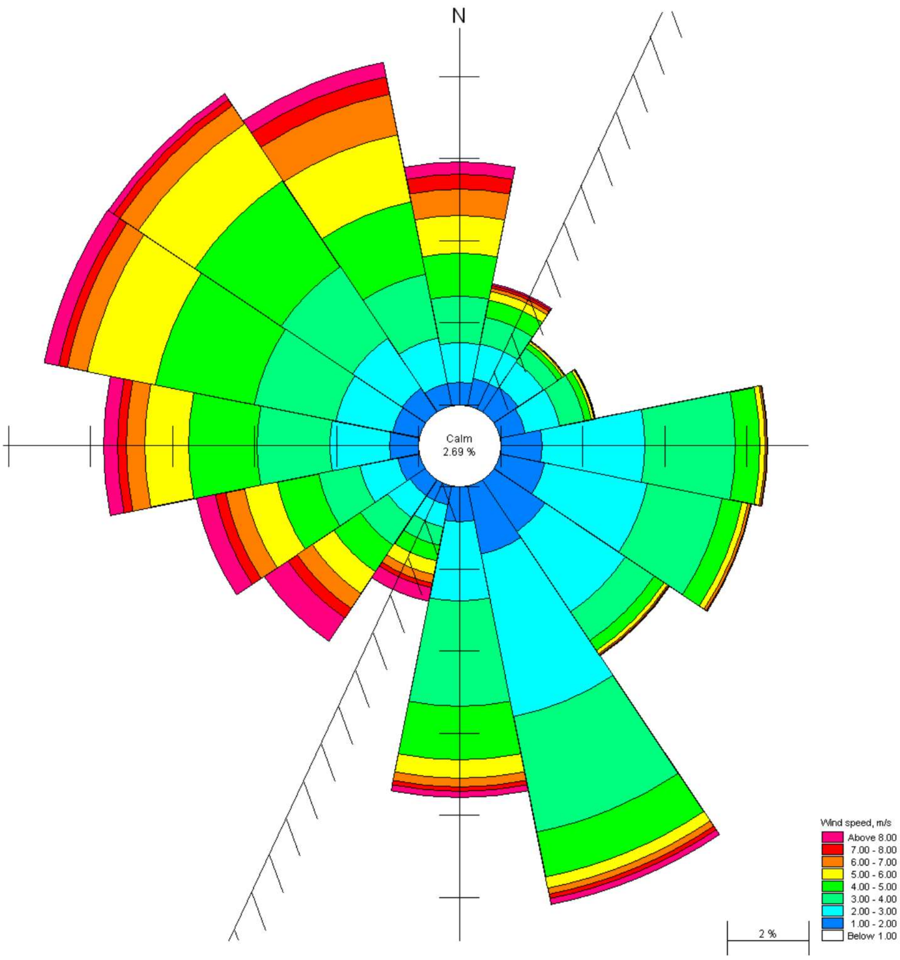

Figure 8. Wind rose diagram for 18 years (1.4.1993-31.3.2011) of 10 min averaged wind records at Ashdod (Levin et al., 2012a)

The maximum wind speed (21.8 m/s) was recorded on December 12, 2010, during a winter storm event. According to Levin et al. (2012a), the strongest winds were in reasonable agreement with wave storm events in deep water. An analysis of extreme events indicates wind speed of 22.7 m/s with return period of 10 years, 24 m/s for 20 years, 25.5 m/s for 50 years and 27 m/s with return period of 100 years.

Similar wind regime was found by CAMERI in south Haifa Bay. Based on wind data recorded at the former Haifa Port main breakwater tip, between April 1st, 1995, and March 31, 2011, it was found that approximately 88% of annual winds, 83% of winter winds and 90% of summer winds were below 6 m/s (Figure 9). In addition, ~12% of annual winds, 16% of winter winds and 9.4% of summer winds were between 6 and 10 m/s. In general, only 0.67% of annual winds, 1.2% of winter winds and 0.34% of summer winds were strong and exceeded 10 m/s (Levin et al., 2012b). The wind direction with speed above 6 m/s was north (2.03% occurrence), while the dominant direction in general was southeast. Strong winds (above 10 m/s) was west (0.15% occurrence).

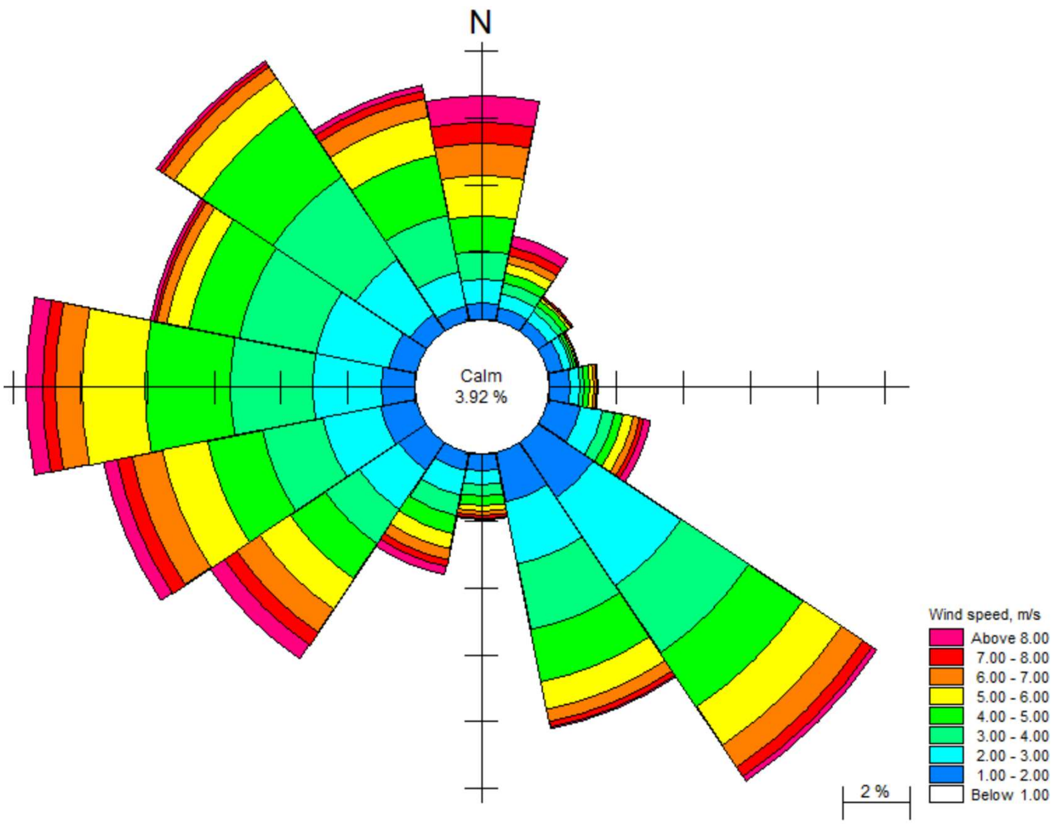

Figure 9. Wind rose diagram for 9 years (1.4.1995-31.3.2011) of 10 min averaged wind records at Haifa (Levin et al., 2012b)

The maximum wind speed (19.1 m/s) was recorded on January 21, 2007, during a winter storm event. An analysis of extreme events indicates wind speed of 18 m/s with return period of 10 years, 18.5 m/s for 20 years, 19.5 m/s for 50 years and 20.3 m/s with return period of 100 years (Levin et al., 2012b).

2.3.3. Wave regime

The Mediterranean wave climate of Israel can be divided into two seasons: summer (April to October) and winter (November to March). During the summer season, the wave climate is characterized by relatively calm sea with a wave height rarely exceeding 2 m (Hs < 2 m). In the winter season, however, the wave climate is characterized by alternating periods of calm seas and storm events of up to 5 m significant wave height (Hs) (Rosen and Kaplan, 2006; Kit and Kroszynski, 2014).

Since April 1st, 1992, north of Ashdod Port, and November 1st, 1993, off the Carmel headland (Haifa), quality wave data have been measured by the Coastal and Marine Engineering Research Institute (CAMERI) (www.cameri-eng.com), on behalf of the Israel Ports Company (IPC). At these sites (110 km apart), where water depth is about 24 m, a Datawell Waverider directional buoy is deployed to acquire 30-min records of surface elevation and directional spectral information (Perlin and Kit, 1999).

Other wave measurements are continuously conducted at Hadera and Ashkelon ports by the Israel Oceanographic and Limnological Research (IOLR) (https://isramar.ocean.org.il/isramar2009/).

A study based on long-term wave measurements recorded in Ashdod between 1992 and 2015 (Figure 10) and in Haifa between 1993 and 2015 (Figure 11) shows that 86.8% of annual waves in Ashdod and 82% of annual waves in Haifa, were small waves up to 1.5 m (Hs ≤ 1.5 m) (Tal, 2020). The most common significant wave height (Hs) in Ashdod and Haifa, was measured in the range of 0.5 m ≤ Hs ≤ 1.0 m (Ashdod 46.5% and Haifa 47.1%). This prevalence is double the wave height range of 0.0 m ≤ Hs ≤ 0.5 m (Ashdod 26.2% and Haifa 20.8%) and three times the range of 1.0 m ≤ Hs ≤ 1.5 m (Ashdod 14.2% and Haifa 14.0%). The rest of the time in an average year, 7.7% of the waves measured in Ashdod and 8.1% of the waves in Haifa were at medium height, in the range of 1.5 m ≤ Hs ≤ 3.0 m, and only 1.0% in Ashdod and 1.2% in Haifa were high waves in the range of 3.0 m ≤ Hs ≤ 5.0 (Tal, 2020). Extremely high waves (i.e. extreme events) (Hs > 5.0 m) were rare and measured in Ashdod and Haifa less than 0.1% of the time (3 hours in Ashdod and

7 hours in Haifa). During the last 28 years (1993-2021), four extreme storms with Hs > 7 m (in February 2001, December 2002, December 2010, and February 2015) occurred in Haifa (Bitan and Zviely, 2020). These events show that the Israeli coast is affected by relatively very high waves.

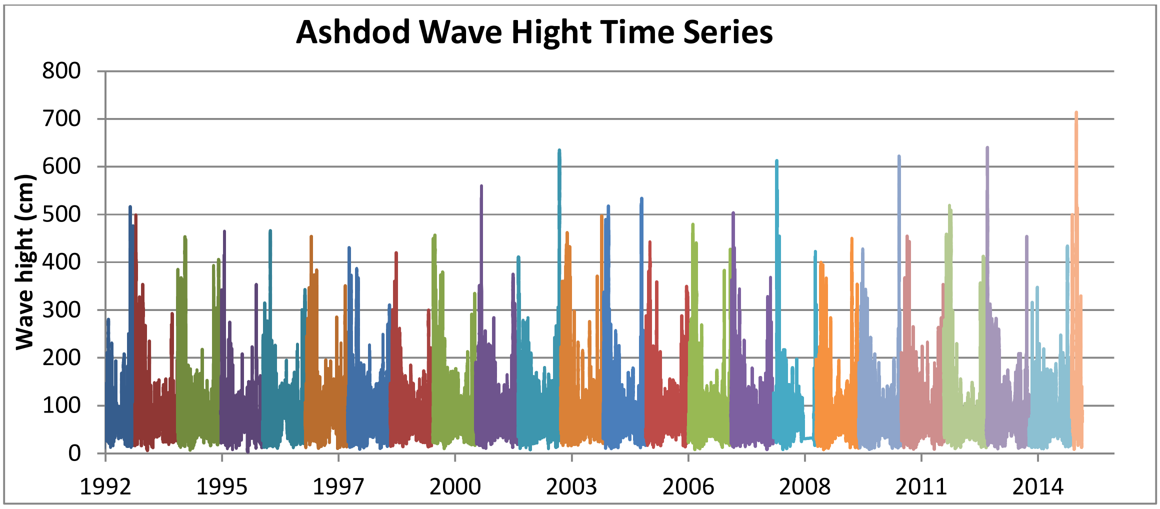

Figure 10. A significant wave height (Hs) time series for Ashdod (24 m water depth) Recorded by CAMERI in the period of 1.4.1992 - 31.3.2015 (Tal, 2020)

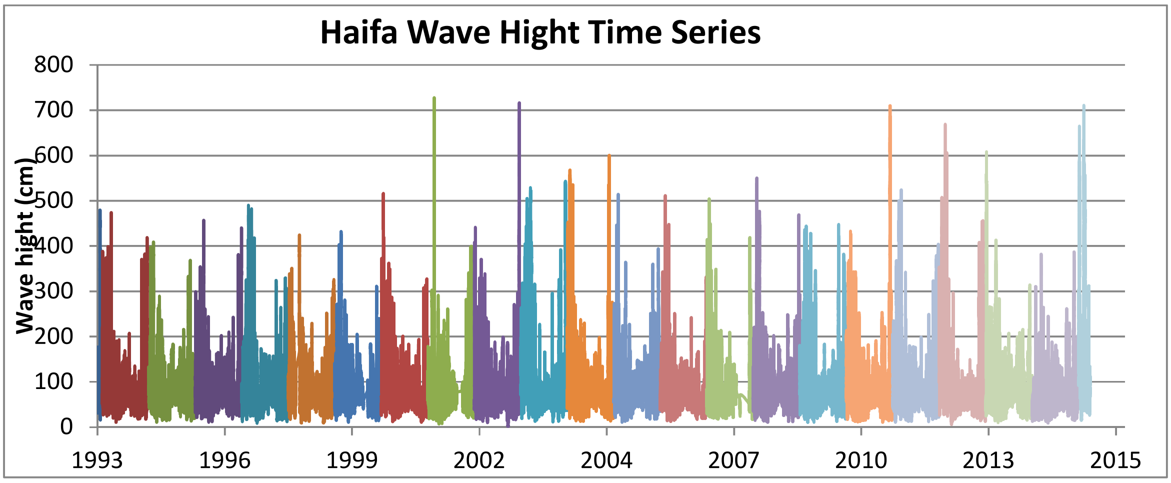

Figure 11. A significant wave height (Hs) time series for Haifa (24 m water depth) Recorded by CAMERI in the period of 1.11.1993 - 31.3.2015 (Tal, 2020)

By using the Weibull distribution with a 3.5 m Hs threshold, an analysis of extreme wave events recorded in the buoy location at Ashdod (1992-2015) and Haifa (1993-2015) shows that the return period of extreme storms with Hs > 7 m, is more than 1:20 year in Ashdod and at least 1:10 year in Haifa (Tal, 2020) (Table 2).

Parameters	Weibull	
	Ashdod	Haifa
Number of years, Y	23	21
Number of observations, N	111	116
Av. number of observations per year $\lambda = N/Y$	4.82	5.43
Scale parameter α	74.584	89.485
Location parameter β	347.457131	348.6227
Correlation coefficient	0.9231	0.9920
Hs for return period 5 years, cm	585	644
Hs for return period 10 years, cm	637	706
Hs for return period 20 years, cm	688	768
Hs for return period 30 years, cm	719	804
Hs for return period 40 years, cm	740	830
Hs for return period 50 years, cm	757	850
Hs for return period 100 years, cm	808	912
Hs for return period 200 years, cm	860	974

Table 2. Parameters of extreme Weibull distribution and maximal waves with different return periods at the buoy location (24 m water depth) at Ashdod (1.4.1992-31.3.2015) and Haifa (1.11.1993-31.3.2015) (Tal, 2020).

A long-term analysis of wave measurements recorded in Ashdod between 1992-2011 and in Haifa between 1993-2011 shows that about 51% of the annual waves in Ashdod came from west-northwest (Levin et al., 2012a) (Figure 12), while about 70% of the annual waves in Haifa came from west to west-northwest (Figure 13) (Levin et al., 2012b).

The most common direction sector for all waves measured in Ashdod between 1.11.1993 and 31.3.2015 and in Haifa between 1.11.1993 and 31.3.2015, was 295º-290º and 285º-290º respectively. Extreme waves (Hs > 5m) however, came from a wider direction sector of 255º-315º in Ashdod and a 275º-310º in Haifa (Tal, 2020).

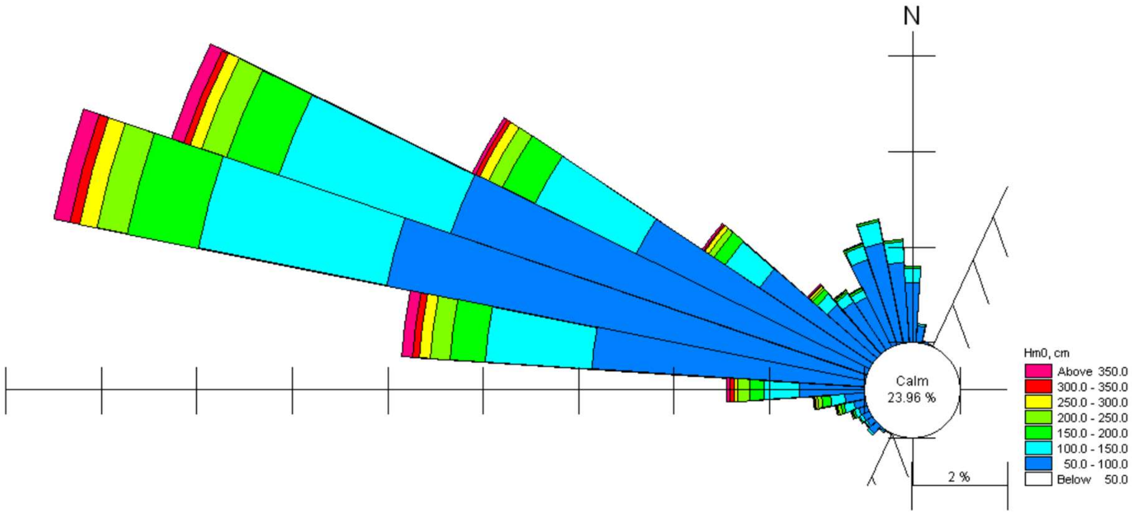

Figure 12. Annual rose diagram of significant wave height (cm) in deep water offshore Ashdod, recorded by CAMERI in the period of 1.4.1992 - 31.3.2015 (Levin et al., 2012a)

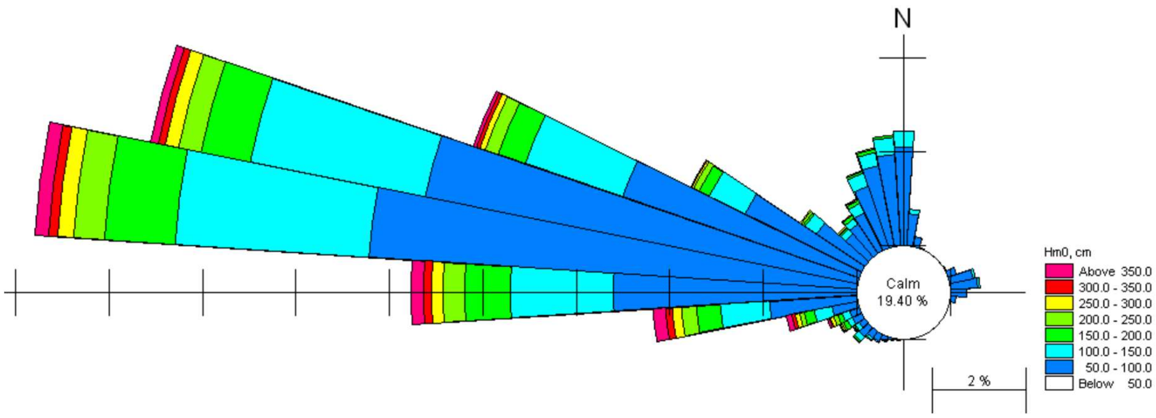

Figure 13. Annual rose diagram of significant wave height (cm) in deep water offshore Haifa, recorded by CAMERI in the period of 1.11.1993 - 31.3.2015

2.3.4. Longshore currents

Longshore currents are generated along the Israeli coast by radiation stresses of breaking waves in the littoral zone and shearing stresses of local winds acting across the shelf (Kit and Sladkevich, 2001; Kunitsa et al., 2005; Kit and Kroszynski, 2014). Wave-induced currents are generated in the surf zone, generally limited to about 5 m water depth, and during extreme events may extending to about 10 m water depth. Since radiation stresses are generally at least an order of magnitude greater than shear stresses, the former predominate in the surf zone during storms. Beyond this region, however, to about 30 m water depth, shelf currents are generated by local winds).

2.3.5. Longshore sand transport

Until the construction of the Low Dam at Aswan (1902) and especially after the construction of High Dam at Aswan (1964) the primary source of sand for the Nile littoral cell was the Nile River. The dam's construction, however, effectively blocked this flow, and forced the longshore currents to take sand from the Nile Delta coasts and its seabed, that eroding consecutively (Zviely et al., 2007, and references therein).

The sand from the Nile Delta is transported by longshore currents eastward to northern Sinai coast (Manohar, 1981; Zaghloul et al., 1982; Stanley, 1989; Sharaf El Din and Mahar, 1997) and continues northeastward along the Gaza Strip and Israel's coasts, up to Haifa Bay which constitutes the northernmost final depositional sink of the Nile littoral cell (Emery and Neev, 1960; Goldsmith and Golik, 1980; Nir, 1982; Rohrlich and Goldsmith, 1984; Carmel et al., 1985; Perlin and Kit, 1999; Zviely et al., 2007) (Figure 1: Top left inset).

LST estimates along the Nile Delta and northern Sinai coasts, indicate a continuing decrease of sand transport rate, as the longshore currents move eastwards and then north-eastwards, up to the Gaza Strip and southern Israeli coasts.

Khalifa et al. (2009) estimated the net annual LST rate in Port Said (i.e. the eastern Nile Delta coast) at ~ 1,000,000 m^3 eastbound. This rate decreases at El-Arish (northern Sinai coast) to about 700,000 m^3 toward east-northeast (Frihy et al., 2002) and continues decreases to about 350,000 m^3 net LST to the northeast, along central Gaza Strip coast (Delft Hydraulics, 1994; Bosboom, 1996). Further northeast, along the Israeli coast, the net annual LST rate decreases from 400,000 m^3 at Zikim (Zviely, 2019), to about 200,000 m^3 at Ashdod. This rate decreases at Tel Aviv to ~ 100,000 m^3 toward north-northeast, and diminishes to about 80,000 m^3 (± 20,000 m^3) toward east, at the entrance to Haifa Bay, the northern end of the Nile littoral cell.

The wave-induced and wind-induced longshore currents, occur in both directions along the Israeli coast. However, the pattern of net longshore sand transport (LST) is complicated (Zviely and Kit, 2012; 2019). This important topic was widely studied in the last 60 years, due to its impact on coastal morphology and its practical engineering importance.

2.3.6. Tides and sea level changes

The tidal regime along the Israeli coast exhibits a semi-diurnal and fortnight periodicity and ranges from 15 to 40 cm, which is not sufficient to create sediment transporting or beach eroding currents (Golik and Rosen, 1999). The Survey of Israel (SOI), which is the national body authorized for geodesic measurements, has been measuring sea level since 1958. An analysis of the data obtained by SOI indicates that since 1958 there has been an increase in sea level. During these past 63 years, the sea level has risen by an average increase of about 0.8 mm per year. The rate of sea level rise has increased through the years (Fig. 14).

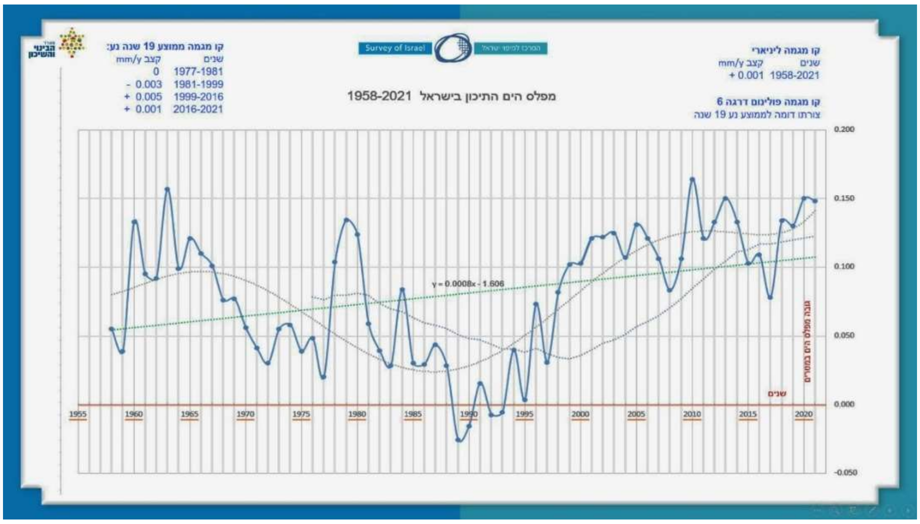

Figure 14. Sea level changes along the Mediterranean coast of Israel during the years 1958-2021 (Survey of Israel)

2.3.7 Cartographic data on bathymetry

The Survey of Israel is responsible for basic mapping products in the country. It is also responsible for the national geographic information system (GIS), which includes a topographic layer, a cadastral layer, and so on (www.gov.il/en/departments/survey_of_israel/govil-landing-page).

In the past the mapping information was based on printed maps originating in the period of the British mandate in Palestine (Survey of Palestine) and on the Israeli mapping authority (Survey of Israel). Starting in early nineties and up to the present, the SOI was charged by the government to establish a National GIS. The source for the GIS has been a news and detailed mapping from aerial photography and land surveying as well as bathymetric and marine mapping.

2.4. The main ecological characteristics of the marine environment

2.4.1. Environmental characteristics

The Mediterranean waters of Israel are part of the Levant Basin. As such, they are far from the connection of the Mediterranean to the Atlantic Ocean at the Gibraltar Straits. Thus, they have unique physical, chemical and geological, and therefore ecological characteristics that are different and more extreme than the rest of the Mediterranean. The Mediterranean Sea is characterized by a gradient of environmental conditions from West to East: evaporation increases and precipitation decreases, salinity increases, water temperatures increase, nutrients content in the photic zone decreases and primary production decreases – reflected in the rest of the food web (including fisheries) – an ultra-oligotrophic Levant basin (Ozer et al., 2017) (e.g., Figure 15). Hence, the Mediterranean water of Israel are characterized by: i). Poverty of the biological production ii). Dynamics – continuous a-biotic changes (e.g., increasing water temperature) and biotic alternations (e.g., alien species). iii). Uniqueness- of habitats and ecological processes. iv). Intense manmade effects with threats to the marine and coastal ecosystems – multiple stakeholders with conflicts of interest between them as well as with the marine ecosystems (Spanier et al. 2015a, 2015b, 2016).

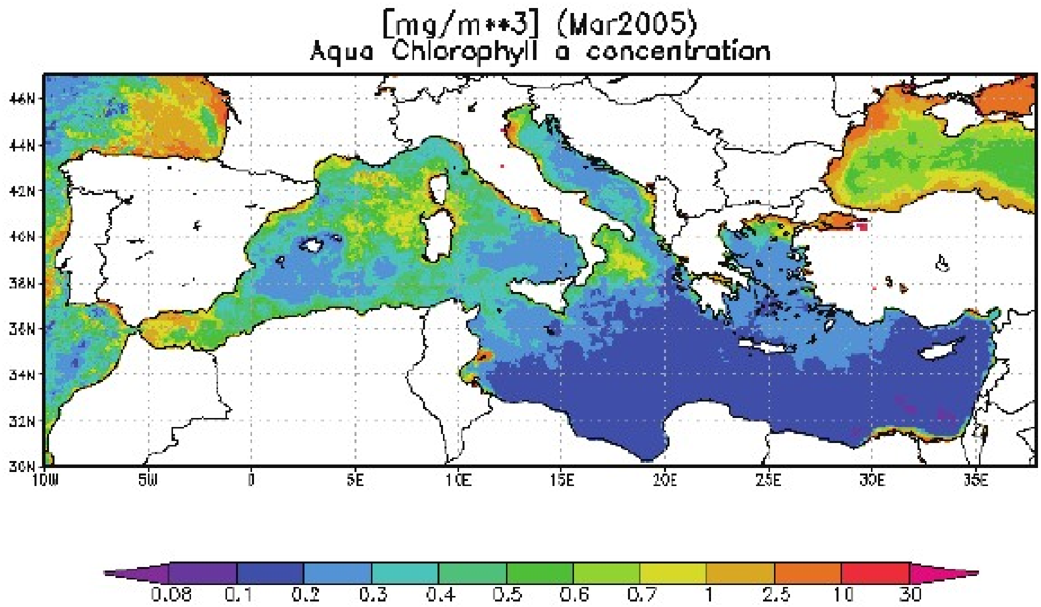

Figure 15. MODIS-Aqua chlorophyll a concentration area plot of the Mediterranean Sea for March 2005

Before the completion of the Aswan High Dam in 1964, the Nile discharged into the southern Levant Sea annually (between August and November) 60-180 million tons of sediments and 18 × 109 to 55 × 109 m^3 of freshwater (Sharaf El Din, 1977). Hydrographic measurements of shelf waters revealed abrupt decline of salinity of surface water in the late summer months off the southern Israeli coast (Oren and Komarovsky, 1961). Since the ending of the Nile flood in 1965, salinity has increased, reaching 39.3 ‰ in the fall (Oren and Hornung, 1972). Average salinity in the upper mixed layer (0–10 m depth) in the open sea was 39.75 ‰ (Kress et al., 2014).

The southeastern Mediterranean Sea is characterized by the highest surficial water temperature in the Mediterranean Sea. Measurements over 40 years revealed a warming trend (0.13˚C/y) far higher than those projected by the Intergovernmental Panel on Climate Change (IPCC) (0.035˚C/y, 2016–2035), possibly due to the waters’ longer residence time in the Levant (Herut and Rahav, 2017a). Temperature in the shallow waters of the Eastern Mediterranean has risen during the summer by over three degrees, from a maximum of 28.4°C in the 1960s to 31.5°C in present times (e.g., Ozer et al., 2017).

2.4.2 Marine habitats

The marine habitats in Israel Mediterranean territorial water and EEZ are described in details following an Environmental Strategic Survey (ESS) accomplished by Israel Ministry of Energy and ILOR:

www.gov.il/BlobFolder/guide/enviromental_info/he/SEA_G_%20After_Public_comments_102016.pdf

and in Spanier et al. (2015a).

The coastal habitats include soft and hard habitats and open coastal water.

2.4.2.1 Hard substrates

In the above-mentioned survey, the hard substrates received a high vulnerability index. This survey indicated that almost all the hard substrata is located on the continental shelf of Israeli Mediterranean coast up to 100 m depth and most of it is concentrated in the northern part of Israel. The hard substrata include abrasion platforms [also called "vermetid reefs" (Rilov et al., 2020)], submerged kurkar ridges, coastal rocks and artificial hard substrates.

2.4.2.1.1. Abrasion platforms

The abrasion platforms (AP) (e.g., Figure 16.) found in the inter-tidal zone, are considered internationally a unique habitat. They are inhabited by a characteristic biota and are relatively rare especially in the southern coast of Israel. The natural rocky substrates are ecologically imported as well as are highly threatened habitats. They are horizontal rocky (kurkar) platforms covered by a biogenic crust. The surface of the platforms is exposed to the air in low tide and are covered with water during high tide. The organisms that live on the platforms are adapted to survival in environmental conditions (of temperature, humidity, salinity and oxygen saturation) that change drastically during 24 hours. The zonation phenomena, associated with the tidal conditions, is typical to all coastal marine natural and artificial habitats east to the water line, including AP. Each zone is different in the living conditions between areas constantly covered by water, those flooded only part of the time and those which are dry most of the time. The living organisms are distributed in various zones according to their ability to withstand desiccation and other environmental stressors (such as extreme values of salinity and temperature, strong currents) as well as their need for water cover for feeding and reproduction. The different adaptations of diverse organisms frequently create clear boarder lines between the distribution areas of each species that is manifested as separated zones. On the surface of the platforms dissolved craters are created, shallow ponds and tidal pools (that retain water during low tide). These give rise to various sub-habitats different in their conditions and are populated with a high diversity of macro algae and animals. The erosion of the platforms has been prevented by a biological building of sessile gastropod vermetid worm, *Dendropoma anguliferum* (Figure 17), which, together with calcareous algae, used to be the main ecosystem engineer of the AP. A process that enabled the platforms to keep a steady state until the waterline and thus functioned as a natural "breakwater" that helped to protect the coastline and the kurkar cliffs. However, in recent years it has been reported that the vermetid population is nearly extinct in the southeast Levant (Rilov et al., 2021) presumably resulting in extensive coastal ecological shifts. Additionally, sea level rise (SLR) is a major threat to coastal ecological communities, including the AP that will permanently drown under even modest SLR scenarios. Anthropogenic activities such as coastal development, building and silting also endanger the AP. There is a need for more accurate mapping of this habitat.

Figure 16. Abrasion platforms in the Mediterranean coast of Israel with green macro-algae

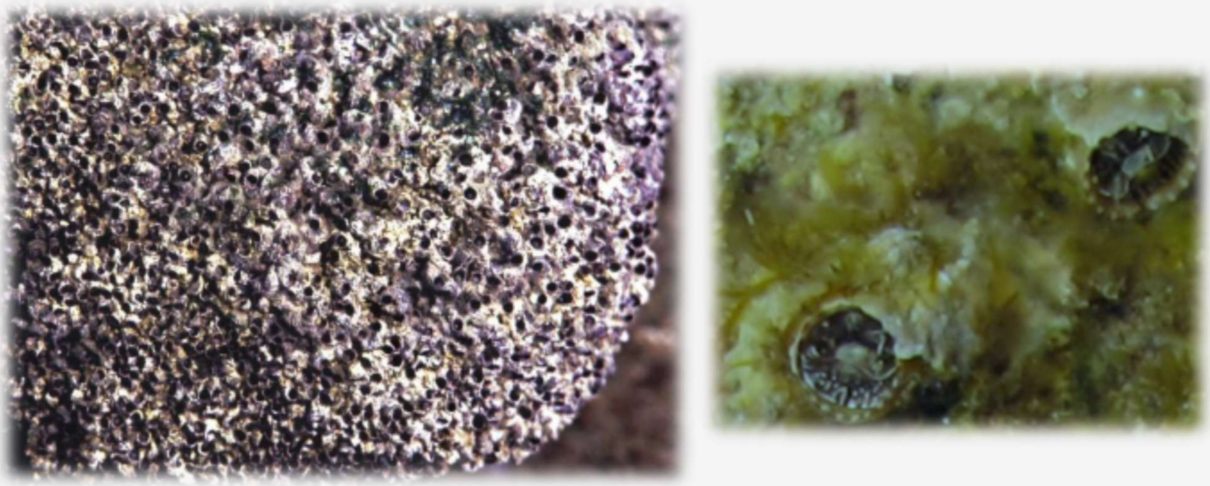

Figure 17. A sessile gastropod vermetid worm,

Dendropoma anguliferum on the abrasion platform (left) and a single individual (right)

2.4.2.1.2. Submerged kurkar ridges

Along the Israeli Mediterranean coast, mainly in the north, there are several parallel Submerged kurkar ridges (SKR) between 10 and 130 m water depth (e.g., Figure 18). They cover about 25% of the area up to 30 m depth but the coverage decrease in deeper depths. In the southern coast there are a few SKR that are not continuous. In the northern coast and up to a depth of, at least, 20-30 m this is the dominant habitat. It is ecologically important because of the high species richness and diversity. Most ridges are submerged but in certain locations they protrude above the water surface, creating tiny coastal islets, especially around Akhziv - Rosh HaNikra, that serve as nesting sites for water fowls. The rocky reef of this habitat supports a very high biological diversity of organisms inhabiting the rocky substrate and around it as well as those dwelling inside the substrate. This diverse biota includes algae, invertebrates and fish with rare and threatened species such as sea urchins, dusky groupers and Mediterranean slipper lobsters (Figure 19). One of the surprising and disturbing findings of surveys conducted in the recent years in this habitat is the almost complete dominance of invaded species in several main taxa and the complete absence of local species that were very common in the past. There is a need for more research to determine the effects of various anthropogenic activities such as fisheries, sedimentation from underwater dredging, deposition of pipes and cables, pollution from various sources, etc. This knowledge is necessary to estimate the level of conservations needed for different components of the rocky substrates.

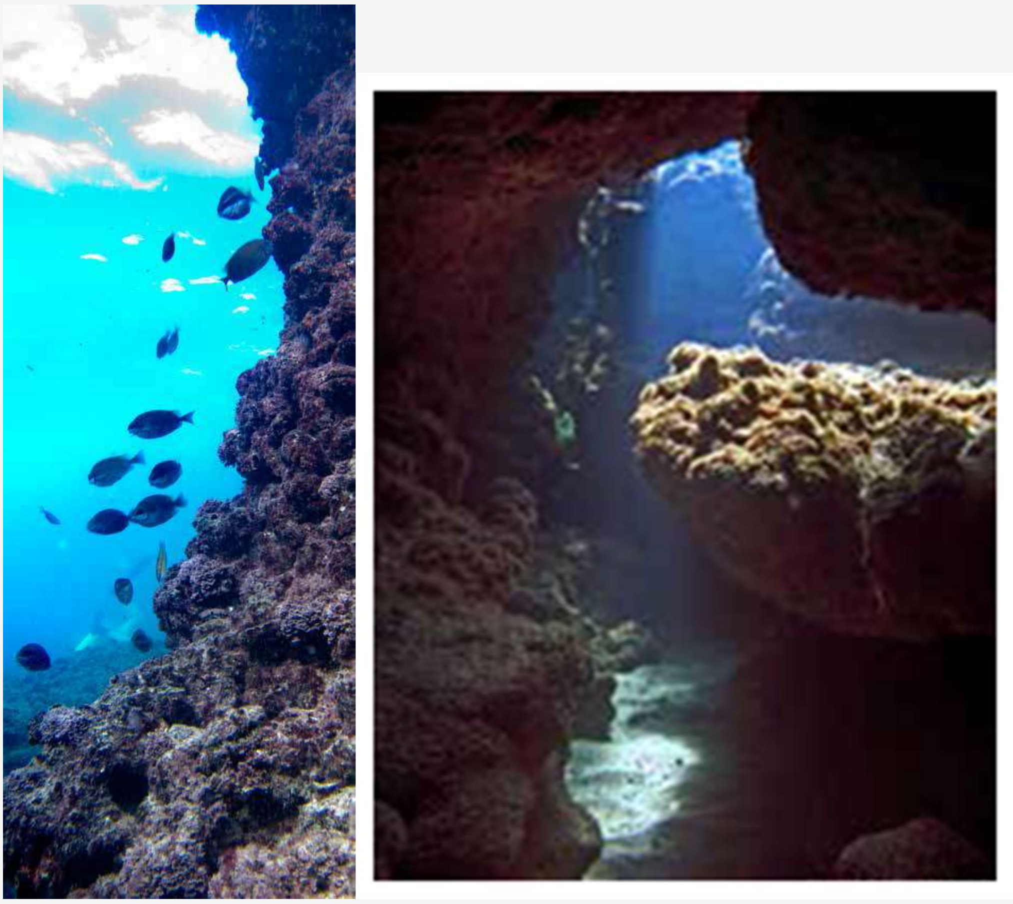

Figure 18. A submerged kurkar ridges in the Mediterranean coast of Israel

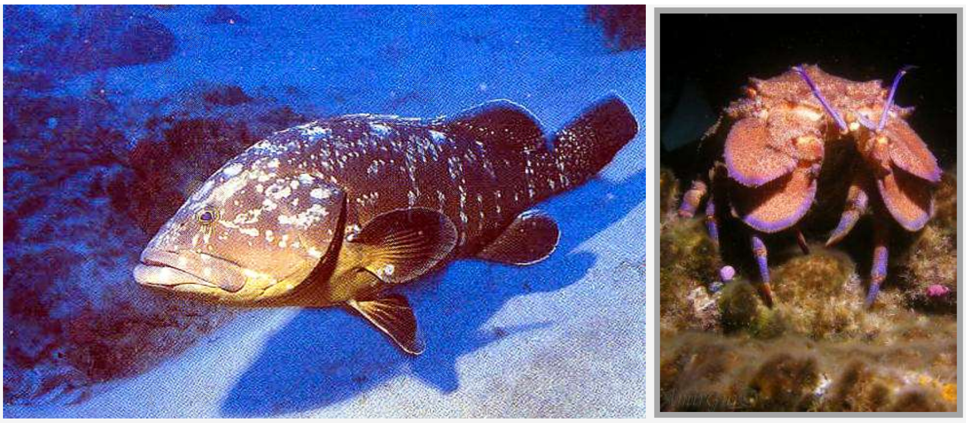

Figure 19. A dusky groupers (left) and a Mediterranean slipper lobster in a submerged kurkar ridge

2.4.2.1.3. Beachrocks

The beachrocks (e.g., Figure 7) are found in the shallowest part of the shore and are considered common and accessible in Israel, yet this habitat has been studied less compared to other coastal marine formations. Zonation is typical also to beachrocks (e.g., Figures 7 and 20). In the driest conditions of the supra-littoral microorganisms such as Cyanobacteria (“blue-green algae”) live on and inside the hard substrate as well as gastropods of the Littorinidae family, and isopods crustaceans of the genus *Ligia.* Other biotic components of the beachrocks are barnacles, crabs, bivalves and mobile gastropods. Limited studied have been done on a few species, such as bivalves, but a study examining the species richness and diversity and the structure of the ecosystem in this habitat in view of invasion of alien species, climate change and human activities, is needed.

Figure 20. Beachrock in the northern Mediterranean coast of Israel with a clear zonation of algae, barnacles and other organisms

2.4.2.1.4. Artificial hard substrates

The Mediterranean coast of Israel is rich with artificial infrastructures such as ports, marinas, breakwaters, power and desalination plants. They serve as artificial hard substrates that actually function as additional, man-made, habitat for marine biota since they supply accessible substrate for settlement of organisms. When constructed in areas where the previous bottom was soft (sand) they change the nature of the marine environment. Therefore, the coastal infrastructures enable the settlement of organisms typical to hard substrates such as sessile and mobile invertebrates (sponges, bryozoans, bivalves, barnacles, sea anemones, crabs, etc.), are grasping surface for algae and concentrate fish. Most of the coastal infrastructures are made from material that are strange to the marine environment, including natural terrestrial material such as wood and quarry rocks and man-made material like concrete and steel. Frequently, these materials do not constitute appropriate surfaces for the settlement of typical marine biotic community (e.g., Figure 21) and thus are populated by invaded and pest species.

Figure 21. Artificial habitats (element of port breakwater) in the Mediterranean coast of Israel

Also the structure of coastal and marine infrastructures may be problematic since they are often made of repetitive elements with smooth surfaces and low complexity. This bring about the development of biotic communities with low species diversity and productivity. Today there is no regulations in Israel that require biological monitoring of artificial substrates. There is a need for more research to understand the marine industrial ecosystems and the development of methods to reduce the ecological footprints of marine infrastructures. Artificial reefs are man-made structures, including old vessels, sunk/built to imitate natural reefs as diving attractions or for fisheries purposes. The biota developed on and attracted to these structures (e.g., Figure 21) attract SCUBA divers and thus may reduce the pressure of divers on natural habitats such as the SKR.

Inter-ministerial committee has developed regulations for proper preparations and establishment of artificial reefs in order to prevent disintegration of the structures, damage to the environment, and risk to divers or fishing gear and/or obstacle to navigation. Five locations in the coastal waters were allocated as potential sites for artificial reefs.

2.4.2.2. Soft substrates

These habitats are characterized by unstable and often mobile substrate that is influenced by currents, waves and mechanical disturbances preventing settlement of many organisms. There is a lack of complex niches which limits the settlement of sessile species and thus the species diversity is relatively low, especially in shallow areas (although biomass may be high). As we move off shore to deeper water, the effect of the waves on the bottom decreases and the conditions stabilize, enabling a gradual increase in the diversity of invertebrates and fish, including commercial species such as shrimps (e.g., Figure 22) and soft bottom fish that are the targets of the trawl fisheries. Despite the fact that the biological diversities of soft bottom habitats is lower than those of hard bottoms, one should not minimize the importance of the soft habitat because of deficiency in the knowledge of its species diversity and richness. Alternation, fragmentation and destruction of this habitat are caused by construction of hard substrates, trawl fisheries, etc. Without sufficient background knowledge and research, it is difficult to determine the order of magnitude of the damage inflicted and the recovery time of the soft habitat from these disturbances.

Figure 22. Commercial shrimps from the fisheries in the soft bottoms of the Mediterranean coast of Israel

2.4.2.3. The water column

The water column (pelagial) contains most of the marine biomass. It has a huge ecological importance to the energy balance as well as the biodiversity of the coast and the bottom since water carry with them food particles and propagules also of bottom organisms and distribute them. The biological diversity of the water column includes hundreds of species of plants, invertebrates and fish. Primary producers such as photosynthetic bacteria and microalgae are the basis of the food web in this habitat. Primary consumers that feed on these primary producers include species of zooplankton – unicellular animals, copepod crustaceans, shrimps, worms, jellyfish (e.g., Figure 23) as well as larvae of higher bottom and pelagic taxa. There is a partial reasonable knowledge on the planktonic ecosystem in shallow water up to 10 m water depth but not in deeper offshore water. There is no sufficient information, even less than for the deep benthic biota, especially spatial one, on any pelagic taxa including large organisms such as marine mammals, turtles, sharks and birds. Lack of knowledge exists also for taxa that have considerable effect on the marine ecosystem and human activities such as jellyfish and comb jelly.

Figure 23. Swarm of nomadic jellyfish in the open water of the Bay of Haifa

2.4.2.4. Rare habitats

There are also rare habitats such as Achziv submarine canyon near Rosh Hanikra (Elasar et al., 2013), meadows of the Slender Seagrass *Cymodocea nodosa,* and maërl habitats - coralligenous assemblages of calcareous rhodophytes (e.g., Martin et al. 2014) (Figure 24). The ecological, spatial and temporal knowledge of these habitats is minimal or does not exist at all.

Figure 24. Slender Seagrass *Cymodocea nodosa* (left),
and maërl habitats - coralligenous assemblages of calcareous rhodophytes (right)

2.4.3. Biota

Despite the oligotrophic nature of the Levant and the relatively low biomass, the biodiversity may be locally high due to the presence and prevalence of many species and some unique habitats such as the abrasion platforms (Spanier et al. 2015a). Most indigenous marine biota are from Atlantic origin but since the opening of the Suez Canal in 1869, there is considerable influx of alien marine species, mainly from the Red Sea and the Indian Ocean in a processed called Lessepsian migration (e.g., Spanier and Galil, 1991; Galil, 2008; Galil et al., 2021). Many of these migrants’ species have established viable reproductive populations in the Mediterranean coast of Israel. Some of the invaded species are dangerous to humans by being venomous [e.g., stinging jellyfish (Figure 25), venomous striped eel catfish (Figure 26)] or poisonous [e.g., pufferfish (Figure 26) other are threat also to the ecosystem [e.g., rabbit-fish (Figure 26), lionfish]. Four hundred and 52 multicellular non-indigenous species (NIS), in 245 families, were recorded so far from the Mediterranean coast of Israel. Most of Israeli NIS (87.4%) are considered to have been introduced through the Suez

Canal. The most speciose NIS are mollusks, fish, crustaceans and macro algae, comprising 33%, 21%, 14%, 12% respectively of the total number of recorded NIS.
Some additional biological data can be obtaining in The Israel Marine Data Center (ISRAMAR) of the ILOR https://isramar.ocean.org.il/isramarbio/default.aspx

Figure 25. The invasive Lessepsian jellyfish, *Rhopilema nomadica*

Figure 26. Lessepsian non-indigenous marine fish in the Mediterranean coast of Israel: venomous striped eel catfish (left), the herbivore rabbitfish (center) and poisonous pufferfish (right)

Plankton: In the oligotrophic environment of the Levant, the coastal phytoplankton depends on nutrient supply; some of it originates from land runoff. This dependence on nutrients affects also the coastal zooplankton community. In a recent study in the southeastern Mediterranean (Belkin et

al., 2022**)** it was shown that in a mesoscale cyclonic (upwelling, ~13 months old) integrated nutrients concentrations were higher at the cyclone compared to the anti-cyclonic (down-welling, ~2 months old) eddies or the background stations by 2–13 fold. In the cyclone, pico- and nano-eukaryotes such as dinoflagellates, Prymnesiophyceae and Ochrophyta contributed substantially to the total phytoplankton abundance. Primary production was highest in the cyclonic eddy. Total zooplankton biomass in the upper 300 m was tenfold higher in the cyclone compared with the anti-cyclone or background stations. Copepod diversity was much higher in the cyclone (44 species),
Representatives of many classes of marine animals can be found in the zooplankton of the Mediterranean coast of Israel. Some are hollo planktonic (spend all their life as pelagic plankton) while other spend only part of their life cycle as plankton. Several benthic taxa have planktonic propagules (eggs, larvae, juvenile stages). Swarms of the Lessepsian jelly *Rhopilema nomadica* (Figures. 23 and 25) was found to feed mainly on micro-zooplankton (Kuplik and Angel 2020).
In the recent years, repetitive appearance of swarms of ctenophores and siphonophores were also reported from the Mediterranean coast of Israel (e.g., Gokoglu and Galil, 2020).
Macro-algae: Israel and Einav (2017) report on 307 species of macroalgae in the Israeli Mediterranean shore (e.g., Figure 27), 86 species regarded as exotic. Of which 68% are Lessepsian species and 20% are of Atlantic origin. The benthic macroalgae are important component in the community of primary producers. In addition to their contribution to the food web, they add to the hard substrate of their habitats by trapping and depositing grains of sand. They add to the complexity of the habitats and enable settlement of other marine biota. There is a deficiency of knowledge re macroalgae in depth of 10-30 m, the distribution of the primary productivity in the marine space, the rates of CO_2 fixation (for climate regulation) and the species that have the largest contribution to productivity.
Benthic Invertebrates: Among the sessile benthic invertebrates there are representatives of diverse phyla, including sponges, coelenterates [early life stages of jellyfish, adult's corals (~ 10 species in the shallow coast) and sea anemones], Polychaeta (500-800 species) Decapod crustacean (at least 170 species), barnacles (~ 10 species) echinoderms and Bryozoa (~ 50 species), (Scheinin, 2013; Stambler, 2013; Spanier et al., 2015a). Although mollusks' species used to be the most numerus along the Israeli Mediterranean coast [with 948 species including 636 gastropods, 257 bivalves, 34 cephalopods, 10 Scaphopoda, nine Polyplacophora (chitons) and two Aplacophora

(Scheinin, 2013)] a recent study by Albano et al. (2021) indicates that populations of marine mollusks have collapsed in recent decades in parts of the eastern Mediterranean. This collapse is due to warming of the sea waters that has made conditions unsuitable for local populations of marine mollusks, as well as the arrival of invasive Indo-Pacific species via the Suez Canal (e.g., Figure 28).

Figure 27. Brown macro-algae of the genus *Sargassum* and green macro-algae of the genus *Ulva.*

Figure 28. The invasive Lessepsian gastropod *Conomurex persicus*

Pelagic Invertebrates: Also pelagic invertebrates are divided to those which spend all their life in the open water and those who have only certain life stages in the pelagial. Among the known pelagic invertebrates in the coastal water of Israel are mollusks such as octopuses, squid, and nudibranchs, swimming marine worms, jelly fish and comb jelly (Ctenophora).

Cartilaginous fish: There are 58 species of Cartilaginous fish (Condrichthys) listed in the Mediterranean water of Israel (Golani, 2021). The main taxa are rays **(**Batoidea) (stingrays, guitarfish, skates and other) and sharks. Most species are predators or scavengers.

The population in the whole Mediterranean includes at least 81 species including 49 sharks, 34 rays and one chimera. Most of the species (35 sharks, 30 rays and the chimera) were recorded also in the eastern Mediterranean. Despite some advance in research in recent years the scientific knowledge of cartilageous fish in the coasts of the Levant is limited. Only recently it was found that the sharks’ population includes also Lessepsian species. Similar research is needed also for guitarfish and other taxa. For example, in 2013 around 500 giant devil rays, *Mobula mobular,* were caught by fishermen in southern Gaza Strip. These large creatures can reach ~ 5 m in their disk width, are famous in their impressive leaps above water surface and are listed as “endangered species “in the IUCN list. The fact that they were never recorded in the close-by Israeli coast indicate the poorness of our knowledge on this important group of marine organisms (Spanier et al., 2015a). Shark aggregation near the output of the warm cooling water of large electric plants (e.g., Figure 29) has recently created a new type of eco-tourism with opportunities and challenges of this emerging phenomenon (e.g., Zemah Shamir et al., 2019).

Figure 29. Shark aggregation near the output of the warm cooling water of Orot Rabin Power Plant (i.e. Hadera Power Station)

Bony fish: Golani (2021) lists 411 species of bony fish in the Mediterranean water of Israel. Most newly-recorded species, at least 38, are of Red Sea origin. The majority of fish species are found only on the shelf (e.g., Figure 30) while their richness and prevalence drop sharply in deeper water. The most common species with considerable biomass are small pelagic planktivorous fish, mainly sardines, true and jack mackerels. On the substrate of the shelf they are joined by small fish species that feed mainly on benthic invertebrates. The prominent species concerning biomass are Atlanto-Mediterranean goatfish, bogues, Indo-Pacific goatfish, bream and lizardfish. The last 3 taxa are Lessepsian migrants (Spanier et al., 2015a). The Levant, and especially the Israeli Mediterranean shelf, is the most invaded marine ecosystem in the world, at lease regarding bony fish. A staggering 55 Indo-Pacific fish species have established permanent populations in the Mediterranean until 2013, more than any other marine ecosystem (Edelist et al., 2013, Figure 31). This process is accelerating with, at least, 13 of 27 new arrivals having established in the 21st century alone. Golani (2021) suggests that the recent dramatic increase in the number of Lessepsian migrants (an average of 2.5 species per year) is most likely due to the increased water influx between the Red Sea and the Mediterranean, following the recent opening of the new parallel, 72 km, “new canal” and the enlargement of other parts of the Suez Canal.

Figure 30. Red squirrelfish - a Lessepsian migrant in an artificial reef off the coast of Haifa

On the rocky substrate shallower than 30 m the dominants activity is of fishes from the family Sparidae (sea breams and porgies), mullets and Lessepsian rabbit fish. The overgrazing activity of the herbivorous invasive alien rabbitfish is responsible for the elimination of vast areas of benthic macro-algae on the shallow shelf (e.g., Rilov et al., 2020). The rocky habitat is also the home of the groupers, the most valued fish in the Israeli market, including the dusky grouper, *Epinephelus marginatus*, which is on the IUCN list of endangered species (Figure 19).

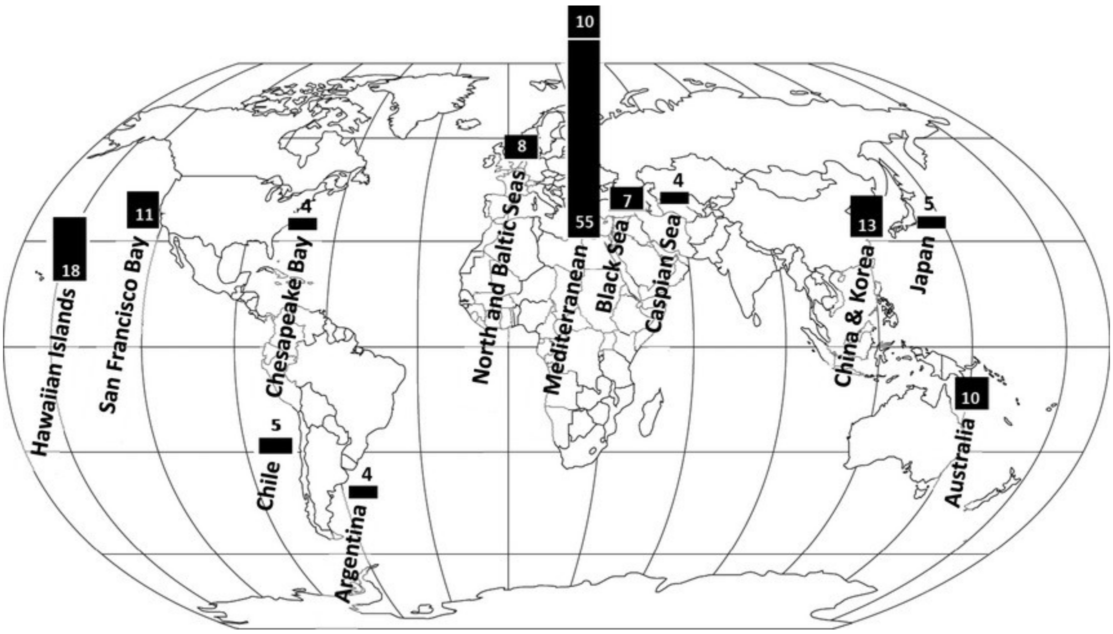

Figure 31. Number of established invasive marine and brackish fish species reported from invasion hotspots (more than four invasive established species).

Marine birds: There are 34 species of marine birds known from the Mediterranean coast of Israel (e.g., Figure 32). Only 10 species can be considered true marine birds (those arriving to shore only for nesting) but there is no quantitative information on their numbers or the number of nesting pairs. Among those are the rare Mediterranean shearwater, *Puffinus yelkouan,* and other species of shearwater, 3 species of boobies, several dozens of species of seagull, terns, storm petrels and skuas. This is a species richness considered relatively high for the Mediterranean (Spanier et al., 2015a).

Figure 32. Marine birds above a Mediterranean rocky coast of Israel

Marine Turtles: The two species of marine turtles that are relatively common, reproduce and nest on the Mediterranean coast of Israel are the loggerhead (*Caretta caretta*) and green (*Chelonia mydas*) sea turtles (Levy et al., 2017) (Figure 33) with estimated 100 spawning females for the first species and not more than 10 spawning females for the second one. The leatherback sea turtle, *Dermochelys coriacea*, is a rare visitor to our coasts. Since the majority of the Israeli coasts are not suitable for nesting due to human activities, the Israel Nature and Parks Authority (INPA) transfers more than 80% of the spawning to six nesting farms in wide sandy beaches. Since the establishment of the National Sea Turtle Rescue Center by the INPA in 1999 it has cared for more than 700 individuals. Recently 10 loggerheads and 5 green turtles were tracked via satellite telemetry tags (Levy et al., 2017). Tracked sea turtles spent their time foraging in a median of 137 km^2 core home. Home range size increased to a median of 464 km^2 during the inter-nesting season. Migration varied widely, ranging from 87 km from the tagging site in to >3000 km. Most turtles migrated short distances within the south-eastern Levant Sea, which seems to be a multifunctional habitat for reproduction, migration and foraging. A large proportion of the migrations (72%) occurred along the coastline and the rest were in open waters.

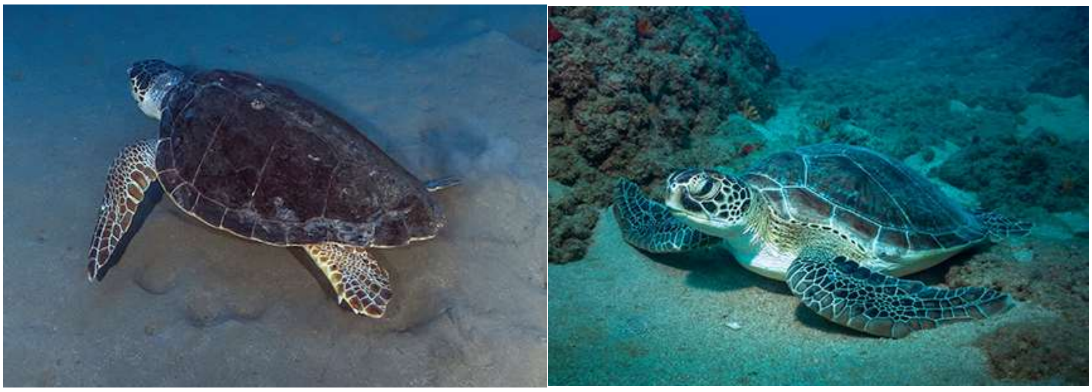

Figure 33. The loggerhead (*Caretta caretta*) (left) and green (*Chelonia mydas*) (right) sea turtles

Marine Mammals: Most of the cetacean species known to be present in the Mediterranean Sea also occur in the oligotrophic waters of Israel. Overall, the cetacean fauna of Israel includes 12 species that are either regular or vagrant (for details see Bearzi 2020). Only one species -- the long-finned pilot whale -- has no records in Israel and in the whole Levantine Basin. The knowledge on marine mammals in the Mediterranean coast of Israel, especially quantitative information, is partial and limited in time and space to a narrow strip along the shore and is based on limited observations and stranding records of the investigators and volunteers of IMMRAC (Israeli Marine Mammal Research and Assistance Center). Only one species, the common bottlenose dolphin, *Tursiops truncatus* (Figure 34), is relatively prevalent, predictable and accessible to enable a comprehensive study of its coastal population (e.g., Scheinin et al., 2014). Despite multiple anthropogenic threats such as habitat destruction, overfishing, unintended catch in fishing equipment and chemical and acoustic pollution, this species is successful in maintaining, so far, a permanent reproductive population of a stable size estimated as 300-400 individuals.

Figure 34. Common bottlenose dolphin, *Tursiops truncatus,* in the Mediterranean coast of Israel.

There are rare reports on sighting of the Mediterranean monk seal on the coast of Israel (Roditi-Elasar et al., 2021) (Figure 35).

Figure 35. Mediterranean monk seals recorded in the coast of Israel – Herzelia marina (left) and Rosh HaNikra (right)

3. Anthropogenic activities present in marine environment

3.1. Main human activities present in coastal and marine environment

Regional hydrological changes (such as the construction of the Aswan High Dam, diversion of many of the coastal streams, enlargement of the Suez Canal) and climate change have affected the Israeli Mediterranean coastal and marine environments. The continued role of the enlarged Suez Canal as corridor for invasion, and the increasing temperature of Mediterranean seawater, portend unceasing propagule pressure and likely rising establishment success of NIS not yet introduced (Galil et al., 2021).

Additionally, the Israeli Mediterranean coastal environment has been exposed to multiple pressures due to rapid population growth and urbanization, coastal development and intensive agriculture and industrial activities. The discharges of these manmade activities released nutrients, heavy metals and toxic organic compounds to the costal water. Haifa Bay, in particular, suffered the highest pollution load along the Israeli coast. Since the 1970s and 1980s high levels of trace metal accumulation originating in effluents of chemical and petrochemical industries in the Haifa Bay area were found in the bay’s fish and benthic invertebrates (e.g., Shefer et al., 2015). Despite efforts to reduce this pollution, the bay’s sediments are still polluted with metals (including Hg), as well as concentrations of metals and nutrients in the vicinity of rivers, streams and outfalls (Herut and Rahav, 2017b; Shoham-Frider et al., 2020). Physical disturbances due to maritime construction (port enlargements, erosion protection, desalination plants, exploration and production of offshore energy resources, recurrent maintenance dredging and beach nourishment), and shipping are abundant and often result in disturbances, damage and destruction of natural habitats, sedimentation, chemical, acoustic and light pollution (Maritime Policy for Israel's Mediterranean Waters (www.gov.il/BlobFolder/guide/current_situation_policy/he/Report_1.pdf in Hebrew). Intensive, and sometime, uncontrolled fishing activities, threaten the sensitive coastal and marine ecosystems. Marine debris, especially plastic, mainly from onshore sources, endanger the coastal and marine organisms and inflict negative effects on coastal tourism (Pasternak et al., 2017).

In the years 1930-1964, the coastal sand was the main source of sand for construction. The sand dredging caused a disturbance in the natural sand balance and therefore there was an increase in the rate of retreat of the coastal cliff. Since 1964, sand mining from the beach has been banned.

3.2. New coastal installations in the last 5 to 10 years

3.2.1 The Southport Terminal in Ashdod Port

Ashdod Port is situated on the southern coast of Israel about 30 km south of Tel Aviv (Figure 1). It handles the largest cargo volume, and is the major gateway for cargo to and from the State of Israel. The port was built on a straight sandy beach backed by sand dunes between 1961 and 1964, and started operations in 1965. When the port was completed its main breakwater length was 2,200 m, and that of the lee breakwater was 900 m. At that time, the head of the main breakwater was located at a water depth of 15 m, projecting about 1,100 m from the shore (Bitan and Zviely, 2020). Between 2001 and 2005, the main breakwater was extended by 1,150 m to protect a new large container terminal (Hayovel Port). The main breakwater head was located at a water depth of 21 m, some 1,600 m from the shoreline. Between 2015 and 2020, another huge container terminal (Southport Terminal) to handle the largest container vessels (Class EEE) has been constructed, and the terminal and the additional main breakwater extension became operation recently.

3.2.2. The Bayport Terminal in Haifa Port

Haifa Bay, in northern Israel, is the most significant morphological feature on the southeastern Mediterranean coast. It is open to the west, bordered by the Carmel headland to the south and Akko promontory to the north (Zviely, 2006) (Figure 1). The bay's 18 km-long coastline is crescent-shaped, with about 6 km of continuous marine structures (including Haifa Port, Kishon Harbor, Haifa power plant cooling basin and seawalls) in the southern part, and about 12 km of sandy beaches in the eastern part. Haifa Port is situated about 110 km north of Ashdod Port, and about 30 km south of the Lebanese border. It is Israel's largest and leading container port, and includes facilities allowing for shipping and transportation of all types of cargo, as well as docking facilities for large passenger liners. The port was built between 1929 and 1933 on the seafront of the city of Haifa, and on completion the length of its main breakwater was 2,210 m, and that of the lee breakwater was 765 m (Zviely, 2006). At that time, the head of the main breakwater was located at a water depth of 11.5 m, projecting about 1,150 m from the shore. Between 1978 and 1980 a container terminal (the Eastern Quay) was built in the eastern part of the port. To protect this terminal from waves from the northwest the port's main breakwater was extended by 600 m to a water depth of 13.5 m. During 2005 and 2008 another container terminal (the Carmel Terminal) was built in the eastern part of the port, between the Eastern Quay and the power plant cooling basin. The construction of the latest container terminal (Bayport Terminal) has been ongoing since 2015, and it is due to become operational during 2021. This huge terminal, designed to handle Class EEE container vessels, is located relatively close to the Kiryat Haim beaches. To protect the Bayport Terminal, the main breakwater was extended by 882 m to a total length of 3,682 m, and its head located at a water depth of about 20 m.

3.3. Dredging and dumping activities

The Mediterranean coastal zone of Israel and the inner shelf, as mention above, is mainly composed of fine quartz sand. This non-renewable resource, which has been used for various purposes in the 20th century, has a high environmental value and is essential for the Israeli economy and its development.

Over the past 20 years, there has been a dramatic increase in the use of marine sand that dredged along the Israeli coast. During this period, the seaports in Ashdod and Haifa (Figure 1) were significantly expanded to include large container terminals that could serve large container ships (e.g. the new Panamax E class and Maersk Triple). For the construction, a huge amount of sand of about 25 million m^3 dredged from the ports vicinity, was used to fill the new terminals. Simultaneously with the ports expansion, various projects that required several millions of cubic meters of marine sand, were carried out along the Israeli coast, for example: covering pipelines embedded in the seabed, sand bypass operations around the port of Ashdod, and sand beach nourishment activities that carried out on several eroded coasts.

The significant increase in demand for marine sand since the beginning of the 21st century and current development plans on the continental shelf and many beaches, raises questions about the Israel's future ability to supply marine sand for various uses and raises serious concerns to the marine environment and to the fate of the sandy beaches.

Beach nourishment may affect natural ecosystems in the imported site (i.e., borrow area) as well as on the nourished beach. The ecological consequences of the nourishment on coastal biota may be short- or long-term. The environmental impacts may lead to sedimentation and turbidity that affect light penetration and filtering organisms. It may cause burial of organisms that reside in the nourished area, and the effects of heavy equipment used in the nourishment operation may injure, kill or affect the behavior and physiology of the native biota. It can change the nature of the local habitat (e.g., altering the grain size and type, or change hard substrate to a soft one). Changing the sediment composition may alter the types of organisms that inhabit the nourished beach. Beach nourishment may also displace native biota. Innocenti et al. (2017) claimed that beach nourishment in the Bay of Haifa, enhanced the introduction and dispersal of the non-indigenous, aggressive, omnivorous, invasive Lessepsian moon crab *Matuta victor.* Yet, the study of Zviely et al. (2021) proved that the spread and establishment of this invasive species in the Eastern Mediterranean is not associated with beach nourishment.

3.3.1. Sand filling of marine structures

During the 20th century, two main ports and several marinas were built along the Israeli coast. In order to build these structures, large amounts of sand were dredged from the seabed surrounding these structures. According to estimates, the total amount of sand used to fill the piers and reclaim land for the ports and marinas was ~ 10 million m^3, of which about 4.3 million was for the building of the port of Haifa and its expansion over the years.

Starting from the beginning of the 21st century, there has been a dramatic rise in the amount of dredging in the vicinities of the Haifa and Ashdod ports in order to build new container terminals. Most of the sand was used for the filling of the Carmel Terminal (2.3 million m^3), the Eitan Terminal (Hayovel Port) (1.5 million m^3), the Bay Port Terminal (~ 10.2 million m^3) and the South Port Terminal (~ 9 million m^3).

3.3.2. Maintaining operational depth in the port and marinas

Dredging of sand and other sediment from the seabed in the vicinity of ports and marinas located along the Mediterranean coast of Israel, is also carried out in order to maintain the operational depths of these marine structures. These routine activities involve the dredging of large volumes of sand in order to maintain sailing channels, harbor entrances, maneuvering areas and the area of the terminals in the Ashdod and Haifa ports, and to a lesser extent the entrances and other areas of the Trans-Israel Pipeline port (Ashkelon) and the Hadera Port, the main marinas (Ashkelon, Ashdod, Tel Aviv and Herzliya) and other smaller anchorages.

Most of the sand dredged in the ports' channels and anchorage areas was used to build new container terminals. The rest of the sand was dumped in deep water or near the beaches, according to the grain size and the polluting material it contained. It is worth mentioning that polluted sediment (including sand, silt, clay and sediment from the ports) was removed to maritime waste sites (i.e., Epsilon and Alpha) which are in deep water, far beyond Israel’s continental shelf.

In contrast to the dumping of sand that has been dredged in the ports, the sand dredged near the marinas was largely dumped in shallow water (5-10 m water depth) north of the dredging area. It can be estimated from the existing data that the amount of sand dredged in a normal year in all of the marinas in Israel is ~ 100,000 to 150,000 m^3. Although this is a large-scale activity, there is no data on the total amount of sand dredged so far around the marinas. Moreover, not all of the quantity of sand approved for dredging by the authorities is actually dredged.

3.3.3. Sand bypass and beach nourishment activities

From the 1960s until Late 1990s, ports, marinas, detached breakwaters and other small coastal structures were built along the Mediterranean coast of Israel. These marine structures interfere the LST drift at their vicinity and as a result local morphological changes had developed at the vicinity seabed and the neighboring sandy beaches (Nir, 1976; Golik and Rosen, 1999; Zviely, 2000, 2006; Dror, 2017; Almagor and Perath, 2020).

During the 1990s, the planning and environmental authorities in Israel had change their approach to the measures to be adopted in order to reduce the negative impact of marine structures on the natural LST drift. As a result, and according to National Master Plan 13/B/2 (the "Yovel Port"), the Port and Railways Authority (today IPC - The Israel Ports Development & Assets Company Ltd.) was required to bypass sand accumulated south of Ashdod Port, to areas north of Eshkol During the period 2000-2004, large amounts of sand were dredged from the seabed (at water depth of 6-10 m) between the Ashdod Marina and the port of Ashdod and dumped north of the Eshkol Power Station, at a water depth of 6-10 m. The sand bypass was carried out four times, where each time a sand volume of ~ 180,000 m^3 was transferred (a total volume of about 720,000 m^3).

Between May and August 2011, IPC renewed the sand bypass in Ashdod Port area. During this activity, sand beach nourishment was implemented for the first time on the Mediterranean coast of Israel. The aims of this activity were: (1) to bypass sand from the huge sandbar stretching south of Ashdod Port main breakwater and (2) to nourish the eroded coast north of the port. For the nourishment, a total volume of sand of about 315,000 m^3 was dredged from two sites: between the Ashdod Marina and Ashdod Port at a water depth of 5-8 m (~ 100,000 m^3), and in Ashdod Port area (~ 215,000 m^3). The sand was deposited between the coastline and water depth of 3 m by rainbowing via a discharge pipe at the bow of the dredging vessel anchored at a water depth of 6 m (Figure 36).

Figure 36. Nourishment rainbowing operation via discharge pipe.

North of Ashdod Port, May-August 2011 (Photographed by EDT Marine Construction)

At the end of the operation, a 1 km-long coastal section had received nourishment, starting about 2.8 km north of the Ashdod port’s lee breakwater in an area of 30 by 80 m (Figure 37a). In spring 2012, a few months after the nourishment was completed, a site visit found no evidence of the massive sand nourishment, while the beach had reverted to its previous rocky state (Figure 37b). A comparative analysis of bathymetric maps showed that in July 2012 half of the nourished sand volume had left the nourished site, and the rest had migrated to deeper water.

Figure 37. The beachrock coast north of Ashdod Port
(a) during nourishment operation (May–August 2011) and (b) about a year later (May 2012)

Since 2011, beach nourishment has been a preferred method of the Israeli authorities for preserving and expanding eroded beaches and is was carried out north of Ashkelon Marina (2015-2019), Bat-Yam beach (2020) and in Kiryat Haim beaches (Haifa Bay) (2016 - 2022).
For detailed information on sand nourishment projects carried out in North Ashkelon, Ashdod Port area and Haifa Bay, between 2011 and 2017, please see Bitan and Zviely (2020) (Figure 38).

The sand bypass in Ashdod Port area, continued in 2013 (103,000 m^3), 2016 (~ 100 m^3) and 2019 (203,000 m^3). These activities had been carried out as part of the Coastal Sand Resource Management Mechanism (the "Manganon"), whose activity and responsibility are specified in the appendix to National Master Plan 13/B/2/1/A (i.e., the South Port project) (Zviely, 2017).

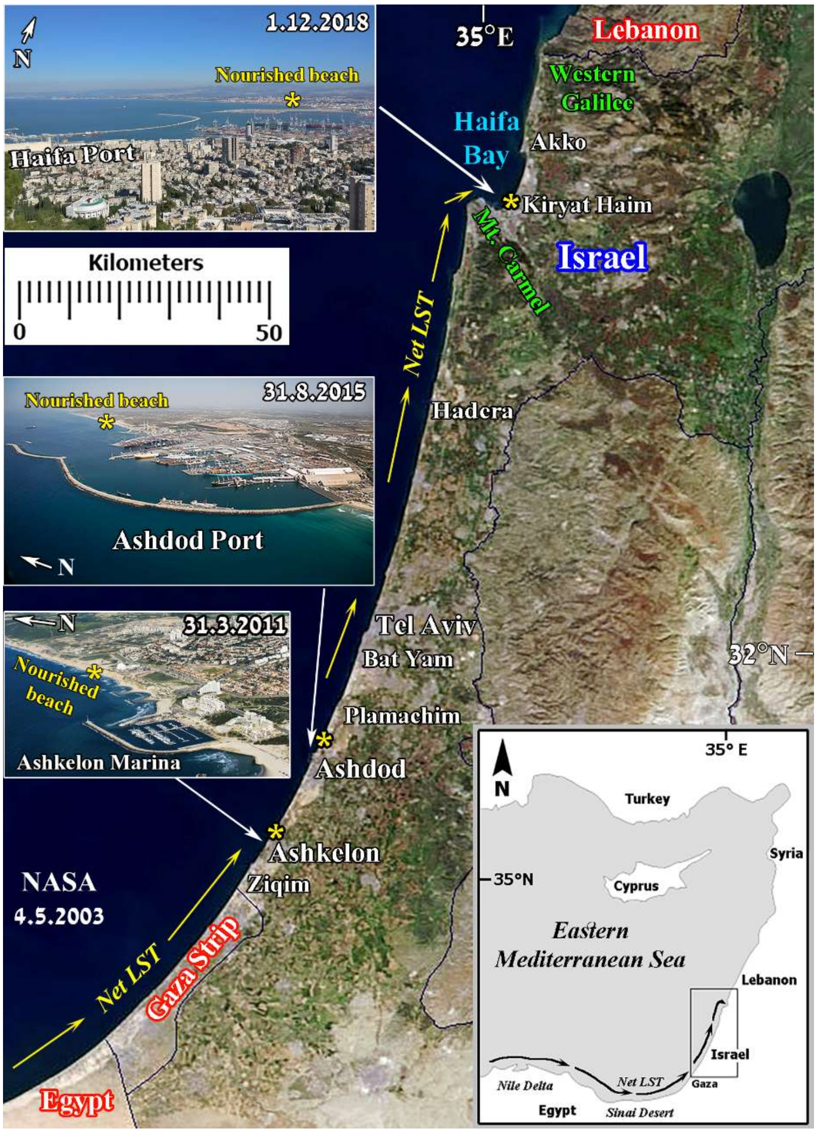

Figure 38. The Mediterranean coast of Israel and the three sites where beach sand nourishment was carried out between 2011 and 2017: south of Haifa Bay (top inset); north of Ashdod Port (central inset); north Ashkelon (bottom inset). Net longshore sand transport direction (yellow arrows). Background: part of “Middle East” space image, Jacques Descloitres, MODIS Rapid Response Team, NASA/GSFC, 31 January 2013.

3.4. Authorization requests, impact studies and monitoring

Following the enactment of the State of Israel Coastal Law in 2004, it was determined that in order to implement the law, the Coastal Environment Conservation Committee (under the Israel Planning Administration, Ministry of Interior, with members from other Israeli ministries such the Ministry for Environmental Protection, Ministry of Transportation, etc.) will be established to approve or reject any activity in the coastal environment, defined for the coastal hinterland up to 300 meters from the shoreline. This determination required a definite "shoreline" definition.

The legislature took into account the possibility that the sea level will rise and therefore the law stipulates that the shoreline for the purposes of the law is a + 0.75 m (above geodetic zero) line. The committee members are appointed by the government ministries represented on the committee, as well as by representatives of the green bodies who also have representation on the committee. In addition, three representatives have been appointed as experts on the coastal environment.

When a plan is submitted for discussion to the committee, among the various requirements there is a requirement for a survey of the environmental impact of the requested structure.

4. Planned new installations in coastal environment

4.1. Ministries responsible for authorizing construction

The responsibility in State of Israel for any man-made construction in the coastal environment requires the approval of both the Ministry of the Interior and the Ministry of Environmental Protection. For specific issues, additional offices such as the Ministry of Transport for ports and marinas issues should also be involved.

The military (IDF – Israel Defense Forces) is sovereign to carry out activities in the coastal area according to military requirements. For example, the construction of the groin on the border with Gaza Strip was not approved by a government ministry.

4.2. New/expected structures

1) In April 2021, the Mediterranean Coastal Cliffs Preservation Government company LTD (MCCP) has started to construct six detached breakwaters, south of the existed detached breakwater in Central Netanya coast, in order to provide a significant protection for the coastal

cliff collapse. As a second phase of this plan, six additional detached breakwaters will be erected to protect the cliff in Netanya South (Levin et al., 2011).

2) The total mooring places in marinas in Israel is about 2,800 places. There is a great demand for additional moorings. The Israel Administration of Shipping and Ports, in the Ministry of Transport, has initiated a plan to expand the number of marinas in Israel. The issue was brought up for discussion in the Coastal Environment Conservation Committee and at this point the green bodies prevented the construction of about five new marinas. Permission is granted for further planning for only one marina in northern Israel in Nahariya.

5. Conclusion

1) The current report presents basic information on the habitat potentially impacted by hydrographic alternations in the coastal waters of the State of Israel in accordance with to the guidance of IMAP common indicator 15. It incorporates the recent data and research results available.
2) Additional detailed material can be obtained from the official sources mentioned in this document as well as the references cited in the present report. However, high resolution hydrographic and ecological data may be lacking, partial or incomplete in certain aspects and need further exploration, research and analysis.
3) Certain ecological processes [e.g., "Levantine nanism" - smaller body size of specimens in the Levantine basin compared with conspecifics in the western Mediterranean (e.g., Sonin et al., 2007; Sharir et al., 2011)], environmental developments [e.g., microplastic (Van der Hal et al., 2017)] and effect of modern marine devices [such as electromagnetic fields (EMF) created by communication and electric underwater cables (e.g., Hutchison et al., 2020) that may influence marine species], have not been mentioned or elaborate. Hopefully newly installed measuring devices and innovative research and survey projects will diminish these knowledge’s gaps.
4) The first steps of Israel towards a soft solution for coastal erosion were the unsuccessful beach sand nourishment projects carried out in north Ashkelon, north of Ashdod Port and in south Haifa Bay between 2011 and 2017. Regarding the short-term durability of the nourished sand in all projects, the unique physical characteristics of the Israeli coast and

sand should have been taken into consideration. However, these projects provide accumulated experience for future projects.

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