Marine Geology 406 (2018) 1–11

Contents lists available at ScienceDirect

Marine Geology

journal homepage: www.elsevier.com/locate/margo

Sediment flux dynamics over the shallow (25 m depth) shelf of the Mediterranean Sea along the Israeli coast

Timor Katz[a,*], Onn Crouvi[b]

[a] Israel Oceanographic & Limnological Research, P.O.B. 8030, Haifa 31080, Israel
[b] Geological Survey of Israel, 30 Malkhei Israel St., Jerusalem 95501, Israel

ARTICLE INFO

Keywords:
Sediment transport
Sediment traps
Fluxes
Nile
Sand
Littoral cell
Mediterranean Sea
Shelf
Waves
Currents

ABSTRACT

In order to study the dynamics of sediment fluxes at the northern end of the Nile littoral cell, sediment traps were deployed for one year over the shallow shelf of the Mediterranean Sea offshore Israel. The sediment traps (replaced monthly) were suspended on a mooring line two kilometers offshore of the Hadera power station, 10 m above a 25 m deep seafloor. Sea-state conditions near the traps were measured by an acoustic Doppler profiler that provided the bottom water temperature, wave heights and current's velocities and direction. The measured sediment fluxes greatly varied between sampling periods, with a minimum value of 1.8 $g\,m^{-2}\,d^{-1}$ in autumn and a maximum value of 83 $g\,m^{-2}\,d^{-1}$ in winter. This variation was mostly effected by wave-induced re-suspension of sediment. A strong correlation ($R^2 = 0.97$) was found between integrated wave heights that exceeded 1.5 m and the measured sediment fluxes. Based on the sea state conditions and sediment trap data we conclude that the direction of sand transport at the study area was strictly northwards and that almost all of the annual sand transport occurred during several high-energy events in the winter. Fine particles that consisted the majority of the mass flux were absent in the underlying, 25 m deep, seafloor suggesting that they are very effectively winnowed off beyond the sand strip.

1. Introduction

Annual dynamics of particle fluxes over continental shelves their dependence on sea-state and other environmental conditions and relation to lateral transport and accumulation are of much interest to oceanographers, geologists and engineers and were therefore explored in many coastal regions in the world e.g. Ferre et al. (2005); O'Brien et al. (2006); Puig et al. (2003); Wolanski et al. (2008). Such studies provided valuable knowledge that improved our understanding on processes that control the dynamics of suspended sediment fluxes and their relation to mass transport across and along the continental margins (e.g. the formation of gravity flows on the slope; Wright and Friedrichs, 2006). These previous studies also displayed great variability in bathymetry, coastlines, sediment sources, river's discharge, sea-state conditions and measuring setup that limit our ability to generalize or make projections between locations. Thus, there is a need to conduct direct investigations in areas of interest, both for elucidating local conditions and for adding to our general understanding of suspended particles dynamics over continental shelfs.

The shallow Israeli shelf of the Mediterranean Sea serves as a route for longshore (northwards) transport of Nile sands. Approximately 860,000 m^3 of sand are transported east from the Nile-delta and then northwards along the shores of the Sinai peninsula and Israel in what is termed as the Nile littoral cell (NLC) (Inman and Jenkins, 1984). Most of these sands are deposited along the shallow shelf of Israel (some of it behind manmade structures such as port wave breakers; Golik et al., 1997), windblown onshore (Tsoar, 2000) or transported offshore (Nir, 1984). Ultimately, circa 80,000 m^3 of sand reach the end basin of the littoral cell at Haifa-Bay and are deposited there (Zviely et al., 2007). Additional sediments that reach the shallow shelf of Israel arrive from inland rivers (ephemeral or with minute water discharge), during winter floods (Sandler and Herut, 2000), aeolian dust (Ganor and Mamane, 1982), biological production of organic matter and carbonates by marine organisms (Avnaim-Katav et al., 2015) and erosion of the coastal cliff (Katz and Mushkin, 2013). The latter is composed of late Pleistocene – Holocene quartz rich (sand size), carbonate cemented eolianites, and buried soils (Perath and Almagor, 2000; Yaalon, 1967). It was recently suggested, that 64,000 m^3 of the coastal cliff annually erodes into the sea (Mushkin et al., 2016). Existing estimates on sand transport along the Israeli shelf were mostly calculated from longshore transport models based on waves height and direction (Carmel et al., 1984; Goldsmith and Golik, 1980; Perlin and Kit, 1999) and from

* Corresponding author.
E-mail address: timor.katz@mail.huji.ac.il (T. Katz).

https://doi.org/10.1016/j.margeo.2018.09.004
Received 23 April 2018; Received in revised form 12 August 2018; Accepted 5 September 2018
Available online 06 September 2018
0025-3227/

interpretation of sediment cores extracted from Haifa Bay (Zviely et al., 2007). At water depths of 0–35 m, the seafloor is characterized by alternating well sorted fine sands and sunken eolinite ridges (Golik, 2002; Hyams-Kaphzan et al., 2008) positioned sub parallel to the shoreline (Schattner et al., 2010). Beyond this sandy belt and towards the shelf break region at 100–120 m water depth, the shelf sediments become mostly silty, with occasional, submerged eolianite ridges (Almagor et al., 2000; Almogi-Labin et al., 2012).

Despite these recent advancements in our understanding of processes along the shallow shelf of Israel in the Mediterranean Sea, we still lack a quantitative portrayal of sediment fluxes, their annual dynamics, composition, relation to lateral transport and accumulation, and dependence on sea-state and other environmental conditions.

The aims of this study are to 1) record the annual dynamics of sediment fluxes and their composition in the water overlying the shallow shelf of Israel in the Mediterranean Sea, and 2) define the environmental variables that control the mass flux and relate these findings to local, sediment transport processes.

2. Materials and methods

2.1. Study site

The study site is located over the shallow shelf of the eastern Mediterranean Sea, approximately 2 km off the Israeli coast, in front of the Hadera power station ("Orot Rabin") and about 4.5 km southwest of Caesaria's ancient harbor (described by Reinhardt et al., 2006 and Goodman-Tchernov et al., 2009). The area is exposed to winter storms that may exceed 10 m wave heights in return time of 10–20 years (Katz and Mushkin, 2013). Water temperatures ranges between 17 °C in winter and 31 °C in summer with corresponding salinities that generally range between 38.9‰ and 39.8‰ (CTD data between Feb 2014 and Oct 2017). The nearshore water is oligotrophic with very low chlorophyll concentrations (0.13–0.94 $\mu g\, L^{-1}$) throughout the year (Azov, 1986). Precipitation (annual mean ± SD = 497 ± 124 mm; https://ims.data.gov.il) is mostly between October and April. During this period, sporadic flooding events may occur in the nearby Hadera River (Fig. 1) and Alexander River (8.2 km to the south, not shown in Fig. 1). The seafloor at the study site consists mostly of well-sorted, fine sand and to lesser extent of mollusk (mostly bivalve) shells.

2.2. Study setup

2.2.1. Overview

In this study, we measured mass fluxes, particle size distribution, and organic carbon and nitrogen concentrations in sediments that were collected by cylindrical traps between September 2015 and September 2016 (Fig. 1). We compared suspended sediment fluxes and their composition between sampling periods, and studied temporal changes in these fluxes with respect to potential environmental controls e.g. currents, waves, temperature, floods in nearby rivers and chlorophyll concentrations.

2.2.2. Setup

Two "Hydro-Bios", cylindrical sediment traps with an opening section area of 0.015 m^2 and aspect ratio of 4, were suspended on a mooring line, 10 m above the 25 m deep seafloor to collect sediment in duplicate samples (Fig. 2). This vertical placement aimed to minimize the effects of sediment resuspending organisms (Yahel et al., 2002, 2008) and near bottom turbid layers to enable a better representation of particle fluxes in the overlying water column. The traps were located at 32°28.185' N; 34°51.812' E, approximately 50 m to the south of the coal pier, ~2.1 km (109°) westwards from the outlet of the Hadera river mouth (Fig. 1) and 3 km NNW from the nearest coastal ridge.

A 600 kHz acoustic Doppler current profiler (ADCP; Workhorse model by Teledyne) was placed on the seafloor (~25 m water depth) about 100 m west to the moored sediment traps looking up. The ADCP measured water temperature, surface wave height and current speed and direction at 0.5 m intervals (between 4 and 23.5 m water depth). Wave heights were measured at 1 Hz; water temperatures and currents were measured at ten-minute intervals that were averaged to hourly intervals. These measurements were carried out during the deployment period of the sediment traps, with the exception of intermittent malfunctions between November 2015 and March 2016 that amounted to 19 days of missing data.

2.3. Auxiliary environmental data

Monthly chlorophyll concentrations that were measured near the shore of Habonim (17 km north of the study site; a measurement from January 2016 is missing) were obtained courtesy of G. Rilov from Israel Oceanographic and Limnological Research (IOLR). Tides and hydrograph data for the Hadera River (at the Gan Shmuel measuring station) for the time-period of September 2015 to April 2016 were obtained courtesy of Israel Hydrological Services, the Water Authority. Rainfall data for Hadera were obtained from the Israeli Meteorological Service's website (https://ims.data.gov.il).

2.4. Fieldwork

On late August 2015, a 300 kg steel anchor with folded stainless steel cable, trap-rack and three floats with 70 kg lift, was lowered to the seafloor by the RV Shikmona. Two weeks later, on September 12, divers released the cable from the anchor, allowing the floats to rise and pull the cable to 10 m below sea surface to keep the cable tight and upright while minimizing wave effects and risk of damage from passing vessels. An optic backscatter (OBS) sensor was mounted 1 m above the bottom (mab) and the trap's rack was shifted set on the cable, 10 mab. The sediment traps were then mounted onto the rack (Fig. 2). Collection bottles were attached to the bottom funnels of the two traps. The bottles were filled with saturated brine to reduce decay of organic matter, diffusive efflux and grazing by swimmers (mobile organisms that actively entered the traps). The traps' collection bottles and the OBS sensor were replaced monthly by divers starting October 2015 for a 1-year period, summing to a total of twelve deployment periods (Table 1). Replacement of the traps was also required in order to prevent clogging by fouling (sessile organisms) of the mesh baffler at the opening of the trap. The bottles with the collected sediments were taken to the boat and then to a fridge (4 °C) in the laboratory, where they remained until treated within few days. One of the two traps was lost during a winter storm that occurred between 11/1/2016 and 10/2/2016. Thus, there was no duplicate sampling for this (5th) deployment period. The missing trap was replaced thereafter and duplicate sampling continued. On two occasions (May 2016 and September 2016), sediment cores from under the sediment traps were collected by divers using 30 cm long push corers (4.5 cm inner diameter). Additional dives were conducted for maintenance and cleanup of the traps and the monitoring station. A mud sample was scraped from under the water line at the bank of the Hadera River (July 2016; 32°27.933′ N, 34°53.799′ E) for analysis of particle size distribution (PSD) and of carbon and nitrogen concentrations

2.5. Laboratory work

2.5.1. Pretreatment of trap material

Sediment samples from the traps with the brine from the collection bottles were placed in Petri dishes under a stereo microscope where swimmers (mobile organisms that intentionally entered the traps) and fouling debris were removed with fine tweezers. After cleaning, the samples were placed in pre-weighed, 50 ml falcon test tubes and centrifuged at 4000 rpm for 5 min. The brine was decanted, and distilled water was added to the tubes at a water to sediment ratio of about 10.