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Morphodynamic changes as an impact of human intervention at the Ras El-Bar-Damietta Harbor coast, NW Damietta Promontory, Nile Delta, Egypt

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A B S T R A C T

Due to the absence of a national strategic plan for coastal management, the Nile Delta coast is no longer described as a fully dissipative, divergent, low-gradient beach face composed of fine to very fine sand. Instead, new patterns have emerged depending on rock type, geomorphology of the coast, direction of the shoreline in relation to waves and current, and the implemented defense measures. This study attempts to record the morphodynamic changes which occurred due to human intervention. Landsat satellite images acquired for the periods of time of 1973, 1984, 1989, 2003, and 2015 are used together with geomorphologic observations in order to monitor the changes along the coastal strip between Ras El-Bar and Damietta Harbor. This study reveals two beach segments; one of which lies to the east, it is protected with detached breakwater system, and shows average shoreline accretions of +4.73 myr^{-1}, +5.0 myr^{-1}, and +0.89myr^{-1} during the periods of 1984–1998, 1998–2003, and 2003–2015 respectively. This segment still has the geomorphologic imprints of the dissipative beach, wave divergence, low-gradient beach face, fine grained sand and spilling breakers. The second is to the west, between the detached breakwaters and the eastern jetty of the Damietta Harbor. It is an erosional segment with shoreline retreat of −7.43 myr^{-1}, −10.90 myr^{-1}, and −3.11myr^{-1} for the same periods. This segment shows intermediate "d" beach or intermediate-reflective, wave convergence, rip currents, with the characteristic steep sloped and cuspate beach face, cliffy, reworked sediments of coarse grained sands, mud clasts, discoidal gravels, shelly beach, and plunging breakings. The presence of convergent waves along this segment confirms the concept of an emergence of a new wave pattern of reversed eddy which enhances the steepness of the beach face, accelerates erosion, and increases the possibility of drowning of swimmers at Ras El-Bar resort. Under such circumstances the plunge step approaches the shore and its shell content forced by wave to accumulate forming the shelly beach. To secure the coastal strip against erosion and sea level changes the detached breakwaters should be extended to reach the eastern jetty of the Damietta Harbor. The protection of this segment is a matter of interest for investment projects related to industries and trading along the Damietta Harbor as well as the touristic investments at Ras El-Bar, as one of the important tourist destinations in Egypt. Millions of pounds spent by beach visitors and investment annually provide significant input to local and regional economy. Hazards associated with the morphodynamic effects on recreational beaches can influence the suitably of any given stretch of coast as a recreational resource, and thus impact tourist money spent in addition to the safety and well-being of beach visitors.

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1. Introduction

The annual amount of sediment discharged by the Nile River at Aswan was calculated in the range of 160 × 10^{12} m^3 yr^{-1} (Sestini,

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1989). Aswan High Dam, completed in 1964, was built to control the flow of the Nile, to generate electricity and to provide water for irrigation. However, the dam has also impacted the sediment flux; amounts of sediment delivered at the river mouths of Rosetta and Damietta range between 100–115 $\times$ 10^6 m^3yr^{-1} (El-Dardir, 1994; Frihy and Lawrence, 2004) are no longer sufficient to nourish the Nile Delta coastline and prevent coastal erosion (Orlova and Zenkovich, 1974; Smith and Abdel Kader, 1988; Lotfy and Frihy, 1993; Stanley, 1996). As a result, a great deal of effort has been expended on construction of coastal defense structures to protect sections of the coast of particular socioeconomic importance, such as recreational beaches (El-Asmar, 2002), and new communities and harbors (White and El-Asmar, 1999; El-Asmar and White, 2002). Due in part to the absence of a unified strategy for protecting the whole Nile Delta coast, contemporary erosion of the coastline threatens to become a major environmental hazard (White and El-Asmar, 1999).

In Egypt, several studies discussed the issue of coastal erosion along the Nile Delta coast based on beach and nearshore profiles semi-annually collected by stations belong to Coastal Research Institute (CORI) since the Eighties of the last century. Contemporary to that time the coastal research along the Nile Delta using remote sensing technology had been used (Klemas, and Abdel-Kader, 1982) and focused on mapping the shoreline and offers the potential updating maps in order to distinguish sites of erosion and accretion (Smith and Abdel-Kader, 1988) and led to subdivision of the coast into subcells of convergence and others of divergence waves (Frihy et al., 1991). In attempts to save beaches, such inadequate human intervention, led to an emergence of unsuccessful project enhanced the changes in morphodynamic. Consequently a new approach of thematic mapper imagery (El-Asmar and White, 1997) was used for the purpose of integrated coastal zone management along the Nile Delta using segmentation process, based on the orientation, the nature of shoreline sediments and the implemented defense measures. Later, Dewidar and Frihy (2010) estimated rates of shoreline changes from three statistical approaches of Digital Shoreline Analysis System (DSAS) (the end point rate, the Jackknife and a weighted linear regression) are validated with ground observations of beach profile survey data at the same positions. El-Asmar and Hereher (2011), Dewidar (2011) used two techniques to estimate rate of shoreline retreat. The first technique corresponds to the formation of automated shoreline positions by digitizing for mapping erosion/accretion pattern and the second one is for estimating rate of shoreline change based on data of remote sensing applying Digital Shoreline Analysis System (DSAS) software. The End Point Rate (EPR) was calculated by dividing the distance of shoreline movement by the time elapsed between the earliest and latest measurements at each transect. El-Asmar and Hereher (2011); El-Asmar et al. (2012, 2013), Hereher (2014) identified changes in lagoons surface area using water index algorithms.

The Damietta promontory as one of the two promontories of Nile river mouths at Damietta and Rosetta is a fragile costal area subjected to severe erosion, we emphasize on monitoring this coastal strip due to its economic and touristic value. This coast includes the elite, historical and favorable resort beach at Ras El-Bar. At present and due to population expansion, Ras El-Bar has become a new permanent community for about a quarter of million. Together, Ras El-Bar, the historical Damietta City with the Damietta Harbor and City represent the Damietta governorate of about 2 million of Egyptian populations, with tens of billions of EL investments in activities of real-estate, accommodations, hotels, and entertainments and the consequent taxes collected by the government related to such activities. In addition to shipping, logistics and free industrial zone at the Damietta Harbor and the traditional furniture industry at the Historical Damietta City, all these spots may be threatened by sinking hazards and complete disappearance of such activities.

1.1. The study area

The study coastal area at Ras El-Bar is part of this fragile Damietta promontory (Fig. 1A), which was described as wave convergent subcell (Frihy et al., 1991, 2003). At Ras El-Bar coast; several defense measures were implemented including two jetties lining the Damietta branch of the Nile River, seawall, revetment, three jetties and 8 detached breakers parallel to shoreline. Together these defense measures and the Damietta Harbor constructions led to the emergence of a new pattern of wave reflection with consequent erosion and accretion along the coast.

In the early 1980s, a decision was made to construct a new harbor and city to the northwest of Damietta (Fig. 1B) in order to increase the trade potential along the Mediterranean coast. It was also decided to construct the harbor some distance inland to be protected from winter storms so that it could be used year-round and avoid shipping delays. A site location (Fig. 1A) was selected in a coastal embayment with minimal effects from waves and currents (Sogreah, 1982). The selection of the harbor site is characterized by a wave divergent and a sediment convergent (sink area) (Abo Zed, 2007). Before the construction of the harbor (1978–1982), the coastal stretch extends from the Gamasa drain to the Damietta mouth (Damietta Harbor lies in the middle), it was marked by accretion (Abo Zed, 2007). The location was described by UNESCO/UNDP (1978) as one of long-term coastal accretion. It is supported by significant fields of active dunes fed by beach sands (Frihy et al., 1991; Fanos et al., 1995). The harbor (Fig. 1B) is composed of two parts: the shipping area, which is an inland basin containing 12 platforms, and an access channel connecting the shipping area with the Mediterranean Sea. In 1982, the entrance to the access channel was protected against littoral drift by two jetties, which were extended in 1985. The western jetty is 1300 m long and the eastern jetty is 600 m long (El-Asmar, 1995, Frihy et al., 2002). After the construction of Damietta Harbor (1988–1997), the western area of the harbor (2 km west) was marked by accretion, whereas the eastern area (5 km east) was marked by erosion (Fig. 4). This could be attributed to the fact that the western jetty (1.5 km long) interrupts the eastward sediment transport along the coast and blocks the eastern sediment transport. The annual net rate of littoral drift on the western side of the harbor is about 1.43 $\times$ 105 m^3 (accretion), while the annual net rate of littoral drift on the eastern side is about 2.54 $\times$ 105 m^3 (erosion) (Abo Zed, 2007). Presently, the Damietta Harbor is one of the Egyptian harbors expected to receive new investment projects such as the global logistics center for storage and handling of grain and cereals. The sustainable development of the harbor is a public request, and the most important hazards threatening the harbor are the erosion issue and siltation of the navigation channel. The latter was discussed in El-Asmar and White (2002); Frihy et al. (2002); Abo Zed (2007); and in Gad et al. (2013).

1.2. Wave climate

Wave action along the Nile Delta coast is seasonal with high storm waves approaching from the NW– NNW during the winter (October to March). These generate eastward longshore currents with velocities of up to 0.9 m s^{-1} (Tetra Tech, 1984), driving a sediment flux. Swells during the spring and summer are predominantly from NNW–WNW, with a small component from NNE (Fig. 2). These can cause either easterly or westerly sediment transport depending on local shoreline orientation (Fanos et al.,

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