ENVIRONMENTAL CHARACTERISTICS AND FUTURE CHALLENGES OF THE EGYPTIAN CHALLENGES OF THE EGYPTIAN_SIDE OF RED SEA: STATE OF THE ART REVIEW

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ABSTRACT

This paper presents an evaluation of published information regarding five hot themes of research, namely, characteristics of both whole Red Sea characteristics, Egyptian-side of Red Sea as well as their environmental challenges of the Egyptian. The coral reefs status and future challenges facing the Egyptian side of the Red Sea. Although, the published engineering studies are very limited, they helped us to find the gaps and the opportunities for future studies.

The paper concluded that further integrated research based on solid reliable field databases is urgently needed. More integration with remote sensing techniques to extract data about Sea Surface Temperature (SST), ocean color, altimetry, and surface winds might help to overcome the data shortage and insufficient field data. Developing more reliable models to study the environmental impacts of various developments especially tourism-related activities on the ecosystems of the Red Sea has a high priority to act as a decision support tools for planning authorities. Moreover, local bleaching monitoring/prediction programs should be established. These programs should be mainly based on the analysis SST which can be obtained remotely by satellite and in-situ data-loggers without neglecting other impacts such as water speeds.

Keywords: Red Sea, Models, Environmental Challenges, Coral Reefs, Bleaching.

1 INTRODUCTION

Figure 1 shows the location of the Red Sea and the Egyptian –Side of the Red Sea. The Red Sea has recently attracted attention from the geophysical and the engineering communities, for its potential exploration of petroleum resources and its unique structures in the ocean hydrology and circulation system (Zhan, 2013). The Red Sea forms a semi-closed and very uneven basin connected with the Indian Ocean and the Gulf of Aden by the narrow Strait of Bab al Mandab. The surrounding lands are mountainous deserts and the climate depends on the monsoon regime. Geomorphologically, the shoreline of the Red Sea varies in both shape and composition from rocky to sandy, with low or high relief topography. This shoreline is backed by a wide coastal plain followed by Rocky Mountains belonging to the Eastern Desert or to Sinai Peninsula (Frihy, et al., 2006). Upon those peculiar conditions, the Red Sea appears as a concentration basin with a deep salty water mass formation and with large seasonal variations in the upper layers (Maillard & Soliman, 1986). The Red Sea is a major international shipping lane linking eastern and southern Asia with the Middle East and Europe. It is also seeing increasing direct and indirect exposure to the aquaculture industry, to which the Sea's relatively warm and clear coastal waters are well suited (Barry & Houdré, 2009).

This nature of the Red Sea attracts many human activities which in turn impacts its environment. The following are the major threats to the marine environment of the Red Sea as related to land-based activities (Agwa, et al., 2013), (Bayoumi & El-Nagar, 2009).

1- Urbanization and coastal development (for example, dredge and fill operations).

2- Industries including power and desalination plants and refineries.

3- Recreation and tourism, waste water treatment facilities and power plants.

4- Coastal mining, quarrying activities and oil bunkering.

5- The offshore drilling process

The Red Sea coasts of Egypt have been the site of intensive tourism developments over the last 20 years (Frihy et al., 2006). The coastline of Hurghada –located on the western coast of the Red Sea- has experienced considerable environmental stress from tourist and residential recreational activities. Uncontrolled tourist development has already caused substantial damage to inshore reefs and imbalance in the hydrodynamic pattern of the coastal sediments (K. M. Dewidar, 2002). Based on remote sensing analysis between 1984 and 2000 images a proportion of 6.55/km^2 of the fringing reef between Hurghada and Safaga has been dumped on or in filled for constructing tourist facilities (Moufaddal, 2005). Most of the Egyptian Red Sea coastal towns have their own desalination plants. These government-owned desalination plants discharge their brine effluent into the sea, which most likely has resulted in considerable local damage to marine life (Frihy et al., 2006). Previous studies on the Egyptian Red Sea have largely concentrated on geology, geochemistry, mineralogical and biological attributes with relatively little emphasis on engineering works related to tourism facilities (Höpner & Windelberg, 1997), (Abul-Azm & Rakha, 2000).

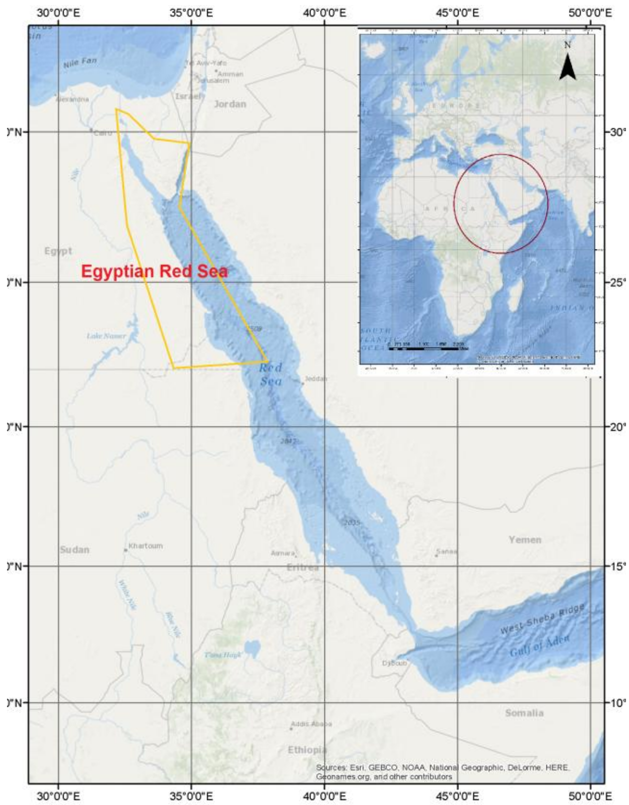

Figure 1. Location of the Red Sea and its Egyptian Site

2 GENERAL RED SEA CHARACTERISTICS

Due to the excess evaporation, the Red Sea is a typical concentration basin and an inverse estuarine circulation is expected at the strait of Bab el Mandeb, with a relatively fresh surface inflow on the top of a deep outflow of higher salinity water. For more than a century the general idea among the scientists investigating the region was that a two layer exchange must persist throughout the year, like in the case of the Mediterranean Sea and the Gibraltar strait (Sofianos, 2003). During the first sixty years after the construction of the Suez Canal, a rapid decrease in the salinity and increase in the depth of Great Bitter Lake were observed. The decrease in salinity has become less noticeable in the last few decades (Marcos, 1990).

The Red Sea is bordered by high mountain ranges that constrain the winds to be closely aligned along the axis of the basin except at few locations where gaps in the mountains exist. The wind field over the Red Sea exhibits considerable seasonality. The climatological wind over the northern Red Sea is northwestern all around the year, in contrast with the southern Red Sea, where winds are southeasterly during winter and northwesterly during summer. Thus, strong wind convergence zone exists at about 19°N in the winter, south of which is monsoon-dominated atmosphere, and north of which is the continental-dominated atmosphere. Near the mountain gaps, the winter wind jets blowing from the Saudi land can cause huge evaporation and ocean heat lost, which would densify the seawater and potentially drive deep convection along the northeastern Red Sea coast (Jiang, et al., 2009), (Zhan, 2013).

The horizontal circulation in the Red Sea consists of multiple eddies, some of which some are semi-permanent. In the northern Red Sea, a cyclonic eddy (CE) exists at least in winter. In the central Red Sea, the circulation is dominated by both CEs and anti-cyclonic eddies (AEs) that occur most around 23-24^{0}N and 18-20^{0}N, which are tied to coastline and topography variations. The process of upwelling and the role of wind on the process have been considered before (Klinker et al., 1976; Morcos, 1970; Schuhmacher, 1974). These authors reported various areas of upwelling as well as conditions under which it occurs. Another study (Morcos, 1970) considered upwelling to occur during summer in the northern part of the gulf as a result of the prevailing north winds.

3 EGYPTIAN RED SEA CHARACTERISTICS

The Egyptian Red Sea extends from 22º N near the Egyptian borders and continues northward till it is divided in the North to form the Gulfs of Suez and Aqaba. The Gulf of Suez is a large semi enclosed shallow area (about 10,000km^2) bounded by Sinai Peninsula on the east and the eastern desert of Egypt on the west. It extends about 250km southeast from Port Suez in the north (29°56`N) to Shadwn Island in the south (27°36`N).

The current in the Suez Canal since its opening in 1869 indicates that undergoes a remarkable seasonal change both in direction and magnitude (El-Wakeel, 2008). It flows towards the Gulf of Suez from July to October, with a peak in August-September. During this season the mean sea level is higher at Port Said than at Suez. During the rest of the year the flow is reversed being predominately northward.

The Gulf of Aqaba is unique for its great depth in proportion to width, being the only ocean basin where such a relationship exists (Por & Lerner-Seggev, 1966), (Morcos, 1970). In addition, the average depth of the Gulf 650 m is nearly equal to the greatest depth of the Red Sea.

In a study (Schuhmacher, 1974) about circulation within the Jordan Gulf of Aqaba, it was reported that a counterclockwise pattern based on very limited observations. Based on repeated measurements with current meters at eight localities to a depth of 50 m and two coastal stations (0.5 to 1.5 m), they found a clockwise circulation along the north and south coasts of Jordan. The velocity of the current at the 50 m stations averaged 10.1 cm/sec at the surface to 7 cm/sec at 50 m while that of the coastal stations averaged 2.8 cm/sec. Reversals in direction occurred with changes in wind direction, especially with prolonged southerly winds.

The Sinai Peninsula divides the northernmost Red Sea into shallow Gulf of Suez and deep Gulf of Aqaba. The Gulf of Suez is 250 km long and 32 km wide, with a flat bottom 55 to 73 m deep. The Gulf of Aqaba is shorter, narrower and much deeper; it extends 150 km and averages only 16 km in width (El-Wakeel, 2008). In the Gulfs of Suez and Aqaba, almost the only part of the Red Sea in which tidal phenomena are well developed, a sharply defined tidal circulation is found. Elsewhere, the surface movements at least are controlled by the prevailing winds, which give rise in places to complex transverse currents, and near the coast are modified by the channels enclosed by the coral reefs.

4 ENVIRONMENTAL CHALLENGES OF EGYPTIAN RED SEA

The Gulf and Red Sea possess diverse coastal and marine environments that support rapidly expanding mass tourism. Despite the associated environmental risks, a study (Gladstone, Curley, & Shokri, 2013) stated that there is no analysis of the tourism-related literature or recent analysis of impacts. Environmental issues reported in 101 publications (25 from the Gulf, 76 from the Red Sea) include 61 purported impacts (27 from the Gulf, 45 from the Red Sea). The reasons for such situation is due to limited tourism data, confounding of impacts with other coastal developments, lack of baseline information, shifting baselines, and fragmentation of research across disciplines.

A research (H. I. El-Gamily, Nasr, & El-Raey, 2001) followed a methodology for separating natural and man-made changes via using satellite images. It was based on the following assumptions: (1) slow changes, which occur within the range of the class reflectance, represent a natural change rather than an anthropogenic one; (2) natural changes tend to be in the same land-use/land-cover class in each date, i.e. slow changes in the reflectance, not leading to changes in the type of land-use land-cover class from the master image to the destination one; and (3) rapid changes in the reflectance of the Earth's objects are usually related to anthropogenic activities. The study detected serious damage occurred to the healthy living corals at the north barrier reef of Giftun El-Saghir island, as well as to the north-east of Giftun El-Kebir island, due to physical damage from extensive diving, in addition to anchoring of diving boats on the living coral reefs. Regarding natural changes, they were predominant in the upland sector as well as in the water sector. In the upland sector, the natural changes were concentrated in the mountainous basement land to the west. Some natural changes can be seen in the Ras Abu Soma peninsula, in the form of coastal dunes. In the water sector, the size of natural changes was larger than that of human-induced ones.

According to a study (Attia, et al., 2010) about impacts of human activities on the sedimentological and geochemical characteristics of Mabahiss Bay located north Hurghada on the Egyptian Red Sea, there are some spots found near the coast where the percent of both silt and clay increases. The study related this change in the nature of sedimentary environment (i.e., pollution) to be caused by land filling accompanied with urbanization and building of touristic resorts and centers. Figure 2 shows the extensive shore line utilization in two cities in the Egyptian Red sea namely El-Gouna and Hurghda.

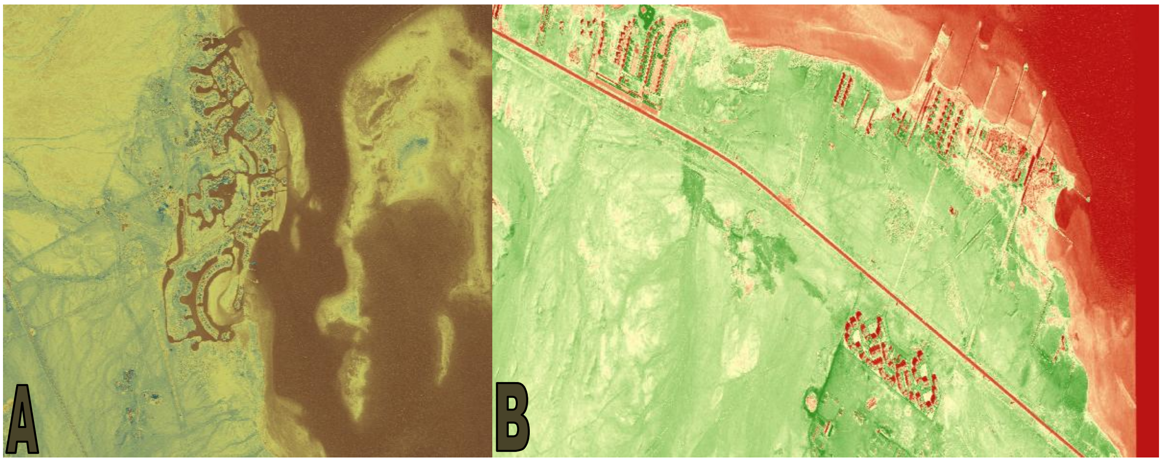

Figure 2. Tourism based development impact on the shoreline in (A) ElGouna and (B) Hurghada

Another paper (K. Dewidar, 2011) utilized different sources of remote sensing data to create shoreline maps illustrating the shoreline erosion accretion pattern in the coastal area between Marsa Alam and Hamata of Red Sea coastline during the period from 1972 to 2007. The study found alongshore pattern along the first stretch from Abu Datab changing from accretion to erosion pattern with rate ranged from 5.5 m to –2.5 m/yr. At Marsa Um Tondoba the along- shore pattern was completely changes to erosion with rates range from –3.7 m/yr. to –1.2 m/yr. during the period of 1990-2007. An explanation for such change by a book (Bird & Bird, 2000) which explained that the changes in coastal wind regimes may increase sand blown from hinterland dunes to beaches, or modify incident wave regimes to increase. It added that beaches erode and accrete naturally over seasonal cycles, driven by fluctuations of wave energy.

As the principal oil productive area of the world is the Middle East, the Red Sea has almost the highest density of oil tanker traffic than any of the regional seas. As the Red Sea is considered, still and will be for long-time, the main transportation route for crude oil, because of this fact and of the actual intensive offshore exploration efforts the risk and potential of oil pollution are augmented in the Red Sea environment (WRI, 1994). A study (Abdel-Maksoud, 1997) reviewed the accidental oil spills from tankers and other causes in the marine environment of the northern Red Sea, Suez and Aqaba Gulfs. The number of accidents attained 18 accidents from 1989 to 1994. The main causes of these accidents are:

1- The equipment failures followed by human errors in addition to the insufficient facilities or oil combating centers belonging to the oil companies and the Suez Canal Authority; and
2- Absence of regular surveillance systems for following up the tankers during shipping.

5 CORAL REEFS STATUS

Coral reefs are vital ecosystems, providing a source of income, food and coastal protection for millions of people; and recent studies have shown that coral reef goods and services provide an annual net benefit of US$30 billion to economies worldwide (Ahmed & Chong, 2004).

Egypt coastline possesses a significant proportion and considerable range of the coral reefs found in the Red Sea with about 3800 Km^2 of reef area (Spalding, Ravilious, & Green, 2001). Among the about 300 hard coral species found in the Red Sea, 2/3 are found in the Egyptian reefs, including some endemic species (Kotb et al., 2004). These numbers are higher than those recorded for the Caribbean and equal to Indian Ocean. Egyptian reefs are fringing reefs alongside the coastline. The reefs extent is in the North to the Gulfs of Suez and Aqaba to Ras Hedarba in the South at the border of Sudan. They are however not continuous because of periodic flooding from wadies created gaps within reef system. The northern part of the Red Sea has the highest coral diversity and number of islands while the south has the highest terrestrial biodiversity for the whole country (Shaalan, 2005a).

According to an economic study (Hilmi, et al., 2012), the cost of coral reefs and fisheries degradation in the Egyptian Red Sea area caused by unregulated tourism activities was estimated between US$ 2626 to 2673 million per year. These include the loss of natural capital, the loss of income from marine recreational activities, the cost of shoreline protection, and the cost of loss of fisheries resources. Uncontrolled tourism constitutes a major threat for coral reefs in two ways: directly, damage caused by tourist use of the reefs and indirectly, by anthropogenic impacts. If some reefs are highly impacted, some remain relatively remote and inaccessible and therefore unimpacted by human activities, but the demand of “virgin” spots for tourism accelerates the urban and coastal development. According to studies (Burke, et al., 2011; El-Gamily et al., 2001; Kotb et al., 2004; Moustafa, et al., 2008), the damage was basically due to the substantial increase of the number of hotels and divining boats, sedimentation and increasing water turbidity due to artificial beaches on rocky shores, and indirect impact there are sewage run-off, sedimentation following urban construction, dredging, coastal alteration and over-fishing.

Regarding natural and global impacts on coral reefs, there had been little evidence of climate change impacts on Egyptian coral reefs except two bleaching events which occurred in 2007. However, thermal stress and ocean acidification are projected to increase threat levels in the Middle East to nearly 90% of the reefs by 2030 while by 2050, these climate change impacts combined with current local impacts will push all Egyptian reefs to threatened status (Burke et al., 2011). A recent trial (Hanafy & Ismail, 2014) to investigate bleaching events in the Egyptian coral reefs, a survey entitled "the first recorded coral mass bleaching event" studied the coverage of bleaching event in 2012 and 2011. The main findings of the survey include the following:

i. The geographical range of the coral bleaching occurrence started from south of Qusier to far south. In comparison, there was no record for bleaching on the coral reefs of the Gulfs of Aqaba and Suez and the area between Hurghada and Safaga. This is found to be in conformity with the water circulation pattern on the Egyptian coasts of the Red sea.
ii. The increase of water temperature affected certain reef building coral genera including; Montipora, Porites, Acropora, Stylophora and Pocilliopora and some non-reef building corals including, Millipora and some of the soft corals and sea anemone.

The coral-reef system fronting most of the coastline of the Red Sea provides natural protection to the aquatic system. A simulation work utilizing two-dimensional (2D) numerical model “SIMulating COastal PROcess” (SIMCOPRO) (Frihy, et al.,2004) examining the role of fringing coral reef in beach protection of Hurghada, Gulf of Suez, Red Sea of Egypt proved that the submerged/emerged geometric nature of the reefal system, both reef flat and reef crest, allow wave dissipation and thus behaves as a submerged breakwater to protect marinas or artificial beaches in the shelter zone of this reef.

6 FUTURE CHALLENGES

The future challenges will be based on two categories; firstly challenges due to global changes and secondly challenges due to development. There is agreement that Earth’s surface temperature has increased over the last 100 years by between ;0.3° and 0.6°C (Houghton, 1996) . A parallel increase in the frequency and extent of coral bleaching and mortality has fueled concern that climate change poses a major threat to the survival of coral reef ecosystems worldwide (Cantin, Cohen, Karnauskas, Tarrant, & McCorkle, 2010). A study predicted that if the global warming trend continues, the coral of the Red Sea could cease growing by 2070 (Cantin et al., 2010). However, previous tourism development in Egypt has resulted in a series of negative environmental impacts. The ambitious development plans to receive 16 million tourists by 2017 should take into consideration sustainability concepts (Shaalan, 2005b).

7 CONCLUSION

Based on the review presented, some additional efforts should be dedicated to developing more accurate models simulating the circulation patterns, patterns of sedimentation, and heat budget analysis of the Red Sea. The modeling work will need improved climatological surface fluxes and wind forcing fields. In addition, data bases of hydrological data for model development and validation. Remote sensing data can be utilized to get Sea Surface Temperature SST, ocean color, altimetry, and surface winds. Utilizing recent development in simulation techniques and computational capacities, dealing with such large size of data will be easier than before. Developing such models will act as an efficient tool and can be utilized by decision makers regarding the management of the sea. Simulating oil spill is one example of the useful applications of this expected developed model.

Local coral bleaching monitoring/prediction programs should be established especially in the Egyptian Red Sea. The programs should have continuous work locating potential stressors, such as warm water as well as approximating the coral's reaction to that stressor. Future studies should come up with the most risky areas and mapping best areas for regeneration of coral reefs in terms of physical conditions.

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