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Three decades of remote sensing habitat mapping, along the Egyptian Coast of Aqaba Gulf, Red Sea

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ABSTRACT

Over the last three decades, the Egyptian Red Sea shorelines had seen significant growth. In this short period, the Gulf of Aqaba's coastline has been turned into a lengthy belt of tourism settlements and hotels. Due to scarcity of information about this area, herein, a first-time ultimate remote sensing time-series change detection in the region. Landsat satellite data collected over the Gulf of Aqaba during the period from 1985 to 2020 and analysed to estimate urban expansion and shoreline changes in the study area, in addition, from 1995 to 2020 to monitor changes in the coral reef and benthic habitats coverage over time. Landsat 5-TM, Landsat 7-ETM+, and Landsat 8-OLI imagery were used to create a time series of satellite observations. The results showed that the urban development had a large scale increase in the past three decades by about 4.1 km^2 and 2.8 km^2 at Dahab and Nuweiba'a sectors respectively. While shoreline changed on a smaller scale than the urban development in a regular way without harm to natural resources. Changing – urban and shoreline – came along with tourism intensity. Concerning key environmental factors results of Time Series Analyses showed high variance in time especially during the period from 1993 to 2003, while the sea surface temperature had a stable trend. Benthic habitat mapping at Dahab showed stability of the coverage area of the most benthic habitats except for an increase of both corals and macroalgae between 1995 and 2005, whereas there is a fluctuation in coral coverage at Nuweiba'a area over time.

INTRODUCTION

Sinai Peninsula is in Egypt's northeast, surrounded by the Red Sea, Gulf of Aqaba from the east, Gulf of Suez from the west direction, and by the Mediterranean Sea from the north direction **(Sherif *et al*., 2016).** Sinai is known by its diverse ecosystem, biodiversity, dry climate, and distinctive natural environment **(Baldwin *et al*., 1988).** Abou Gallum, Saint Catherine, Nabq, Taba, and Ras Muhammed are five natural protectorates in south Sinai with many indigenous coral reefs and species, mainly in the Gulf of Aqaba. Furthermore, the Egyptian Environmental Affairs Agency (EEAA) which is linked with the Ministry of Environment protects the whole coast of Aqaba. The gulf is about 300 kilometers long, stretching from the Protectorate of Ras Mohammed in the south to Taba in the north. The tourist economy in south Sinai, received a lot of attention, so, many hotels have been built along the gulf, resulting in Bedouins didn't have an opportunity to fishing in the front of the hotels back then **(Basha, 2017).** In the 1990s and 2000s, the tourism business thrived and the natural resources were over exploited and became endangered **(Ali, 1998).**

On the other hand, Gulf of Aqaba is experiencing an increase in anthropogenic disturbances, mostly due to the increases in the tourism **(Rinkevich, 2005** and **Naumann *et al*., 2015).** Intensive diving and snorkeling, coastal development, and eutrophication have all been reported to have negative effects on the health of northern Red Sea coral reefs in past studies **(Zakai & Chadwick-Furman, 2002;** and **Naumann *et al*., 2015).** Increases in the cover of turf algae and macroalgae have been recorded in short-term studies in the region (1–3 years), which were positively connected with ambient organic manures **(Bahartan *et al.*, 2010** and **Naumann *et al*., 2015).**

Dahab is a city on the South Sinai Peninsula; it is a part of the Nabq Protectorate and was once a Bedouin community whose livelihood was based on fishing and herding. The city of Dahab's urban fabric, development pattern, city planning, and demographical structures have all been changed by a 1997 plan aimed to change the source of revenue to a tourism-oriented place and the principal activities taking place in the city. Dahab's economy has shifted from fishing to relying entirely on the tourism sector **(MOUNCHU, 1993; Ali, 1998** and **Sherif *et al.*, 2016).** On the other hand, Nuweiba'a is one of Egypt's most distant outlying with isolated locations and located on the Gulf of Aqaba. It covers 6,977 square meters, or 22.31 percent of the entire area of south Sinai. Nuweiba'a is a tiny coastal community in south Sinai recognized for its real Bedouin culture and pure scenery. After the liberation of Sinai, plans were made to begin developing the entire peninsula; however Nuweiba'a was not completely planned and did not receive much attention **(Basha, 2017).**

Land cover change has been detected and monitored at various scales using satellite remote-sensing methods by some authors such as **Wilson *et al.* (2003)** and **Hedley *et al.* (2018).** Remote sensing observations throughout time are useful for observing and evaluating changes in urban landscapes and land use as development **(Batty & Howes, 2001; Herold *et al.*, 2003; Alberti *et al*., 2004; Xiao *et al.*, 2006** and **Ampoua *et al.*, 2018).** Remote sensing when paired with GIS and studies involving global positioning systems (GPS), is a strong technique for assessing change in land and coastal substrates **(Muller & Zeller, 2002).**

To identify regions of disturbance and assess the areal extent and spatial pattern of change, change detection algorithms are applied **(Macleod & Congalton, 1998).** To illustrate change, some change detection algorithms adopt simple image overlays, while others use image difference. For measuring change over time, a prominent quantitative technique uses sequences of thematically identified photographs **(Singh, 1989).** To date, nothing is known about the amount of coral cover in the Red Sea. To characterize distribution, previous research had used qualitative density metrics such as 'low, medium, and high' coral density **(Zainal *et al*., 1993** and **Ahmad & Neil, 1994).**

Habitat mapping is a spatial representation of how to describe and identify the various habitat components **(Valentine *et al.*, 2005)**. The features of spatial mapping and the distribution of habitats are essential for the analysis and management of the coastal and marine environment **(Hamel & Andrefouet, 2010** and **Coggan & Diesing, 2011).** Various geospatial technologies might be used to generate maps of benthic habitat **(White & Fitzpatrick, 2007** and **Australia, 2012).** The capability to characterize the seabed and its related ecosystems has improved as GIS and remote sensing tools have improved **(Williams *et al.*, 2010** and **Brown *et al.*, 2011).** Use of remote sensing can help with both appropriate sample site selection and mapping the distribution of benthic life **(Blakey *et al.*, 2015** and **Zakaria *et al.*, 2019).** Previously, satellite imaging had been applied to detect benthic cover in shallow water in the marine environment (**Lucas & Goodman, 2014**). Remote sensing plays an important role in such approaches, hence a thorough understanding of the spectral features of organisms **(Swift & Bower, 2003).**

Key environmental factors include light regime is among the most important environmental aspects, wave activity, long water residence durations in lagoons with restricted tidal exchange, as well as wave and tidal-driven current flows on fore-reefs, can all have a major impact on bleaching occurrence patterns and changes in water turbidity, as well as other environmental variations can affect coral resilience **(Coles & Jokiel, 1978; Nakamura & van Woesik, 2001; Nakamura *et al*., 2003; McClanahan *et al*., 2005** and **Anthony *et al*., 2007)**

In this study, The Egyptian waters of the Gulf of Aqaba have been subjected to quantitative evaluations of coral reef habitat over the past three decades during the period from 1995 to 2020 and change detection in urban development and shoreline takes place from 1985 to 2020.The major purpose of this study is to use remote sensing techniques to (1) analyse anthropogenic effects on shoreline and urban development changes in the study areas and (2) identify benthic habitat changes over the previous decades in conjunction with effective environmental factors.

MATERIALS AND METHODS

1- Study Area

Two sectors were selected along the Egyptian coast of Gulf of Aqaba to express the main human activities (tourism and fishing). The first sector is Dahab area which represents the tourism activity and extended about 43.3 Km, and the second sector is Nuweiba'a area which represents the fishing activity and extended about 48.5 Km **(Fig. 1).**

2- Field survey

Field survey was planned to represent the range of physical environments within the study area. The locations of approximately 90 points (**Fig. 2**) were recorded for all water body habitat types as a guide for multispectral classification. Ground truth points at the study area were conducted over a period of 6 days during August 2020 using handheld Trimble GPS inside waterproof case. At each site the handheld GPS unit to pilot the boat to the pre-programmed waypoint of the site's coordinates was used (**English *et al*., 1997**).

3- Remote Sensing Data

Five satellite images were collected by the Landsat series of sensors (Landsat 5-TM, Landsat 7-ETM, and Landsat 8-OLI) were used to evaluate urban development, shoreline, and marine habitat changes during the years 1985, 1995, 2005, 2015, and 2020. Images were downloaded from the United States Geological Survey (USGS) (http://earthexplorer.usgs.gov/). Each of the Landsat sensors had slightly different spectral band combinations (**Table, 1**). All satellite images were georeferenced and geometrically corrected to match a WGS 84 datum (world geographic system), UTM (Universe Transverse Mercator) Projection with Zone 36 North. Images were radiometrically and atmospherically corrected, and a water-column correction was applied. All images were processed using the ENVI 5.3 software.

Table 1. Landsat sensors and spectral bands.

Band	Name	Landsat 8 OLI_TIRS + µm)	Landsat 5 and 7 TM and ETM + (µm)
1	Ultra blue (coastal band)	0.433–0.453	----------
2	Blue band	0.450–0.515	0.45-0.52
3	Green band	0.525–0.600	0.52-0.60
4	Red band	0.630–0.680	0.63-0.69
5	Near Infrared (NIR)	0.845–0.885	0.76-0.90

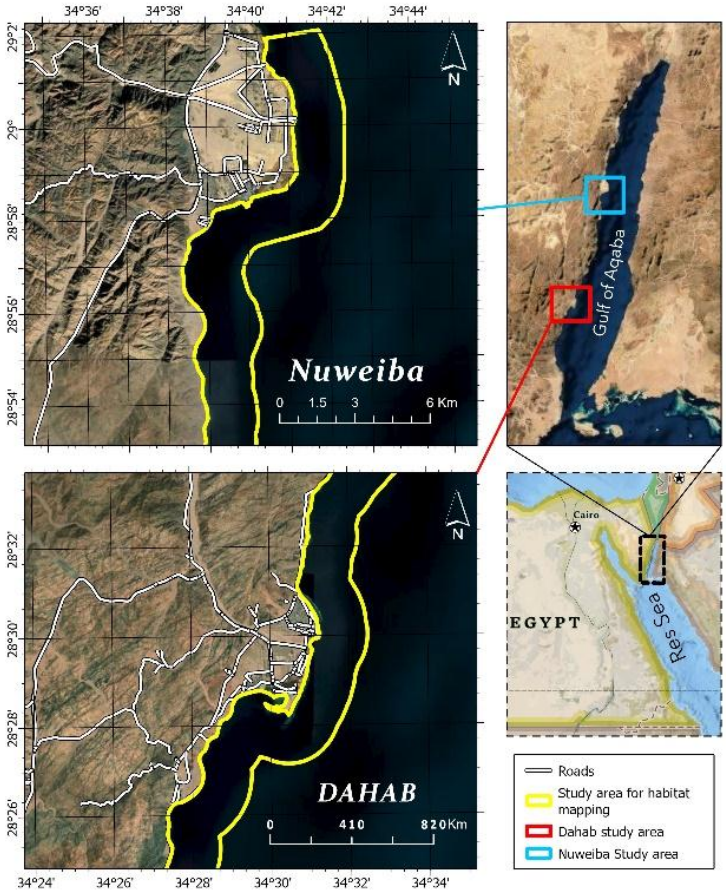

Fig. (1). Landsat satellite image showing the locations of the study sectors.

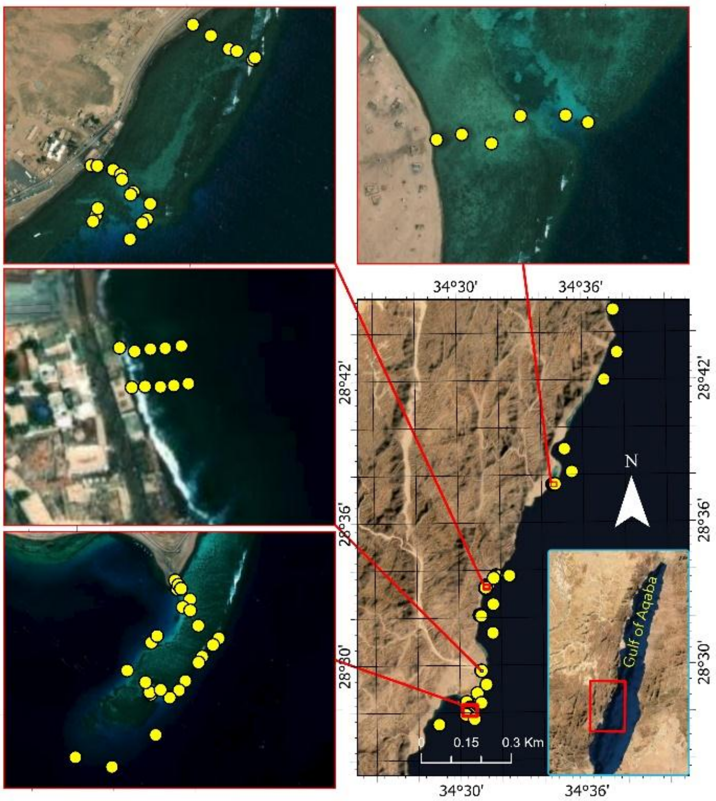

Fig. (2). Landsat satellite image showing locations of ground truth data.

4- Habitat Mapping

Image pre-processing:

The data collected from Landsat satellites sensors included significant amount of information that is not reflectance from the area of interest because of the complex pathways in the atmosphere and water column. Only about 10 % of the data received comes from the ocean bottom (**Mishra *et al*., 2005**). In fact, atmospheric scattering accounts for the majority of the signal received by the sensor (**Robinson, 2004**). After compositing satellites bands, the resolution enhancement took place by pan-sharpening, the purpose of pan-sharpening was to spectrally sharpen low spatial resolution image data with high spatial resolution image data figure. The 5-band multispectral ETM and TM low-resolution (30 m) have been enhanced to (15 m) with ENVI modules. Also resampling achieved for TM sensor to reach the unified resolution.

Atmospheric correction computed for all images using dark object subtraction (DOS). ENVI software was used for performing the DOS correction as it is an automated process which produces a corrected multispectral image. Sun glint removal technique was applied to the atmospherically corrected and masked subset. A sample of image pixels was selected from multiple sites of optically deep water featuring uniform sun glint. This process was performed according to **Hedley *et al*. (2005)**. Water column correction technique was performed on the atmospherically corrected satellite images subset after the sun glint correction, sun glint and water column correction implemented using ENVI 5.3 software.

Image classification:

Satellite Image Supervised classification techniques require the analyst to specify the types of ground cover in a scene through the use of training data **(Lillesand *et al*., 2004)**. The generation of a classification has two distinct steps (training and classification). Training is the process of setting a spectral envelope for a class and, for supervised classification, requires a priori information about the image data and habitats to be mapped (**Green *et al*., 2000).** Maximum Likelihood Classifier is one of the most popular methods of categorization in remote sensing technique, where the pixel with the maximum likelihood is classified into the corresponding class (**Richards and Ervin, 2008).**

In this study, the image classified to 5 classes: (coral, sand, macro algae, seagrass and deep water). Supervised classification done by using 90 field ground truth points representing all these classes. Training points converted to defined region of interest (ROI) on satellite image in the same date of field survey. ROI data converted to spectral library depending on one date validated to be used in other dates and depending on spectral signature to each class. The supervised classification performed by maximum likelihood algorithm sing ENVI 5.3 software.

5- Change detection analysis

The benthic habitat change detection analysis was performed using the results of the supervised classification of four satellite images from (1995-2020). Results of the supervised classification were converted into vector layers. (QGIS) software used to perform a contextual editing for each class to complete the calculation of class's areas. The difference in the area of each class in sequential satellite images was then computed. From 1985 -2020 five satellite images were used for classification are used for urban and shoreline digitizing.

6- Key environmental parameters

The data of key environmental parameters (sea level rise, turbidity and sea surface temperature) were obtained for study area during the period from 1993 to 2020. Diffuse water column attenuation coefficient (KD 490 m^{-1}) was obtained from the Goddard Earth Sciences Data Information Services Centre's (GES DISC). High-resolution blended analysis of daily sea surface temperature (SST) (°C) was downloaded from the NOAA Earth System Research Laboratory Physical Sciences Division (https://www.esril.noaa.gov/psd/). Daily sea level was obtained from the National Aeronautics and Space Administration Jet Propulsion Laboratory NASA JPL (https:// sealevel.nasa.gov/data-analysis-tool/).

RESULTS AND DISCUSSION

1- Urban development and shoreline changes

Results of changes in urban area during the 35 years are presented in **Figures (3-5).** The data clearly showed that the total changes in the urban area reached + 4.1 km^2 and 2.8 km^2 at Dahab and Nuweiba'a sectors respectively. However, the urban area in the year 1985 was about 0.48 km^2 at Dahab sector then it markedly increased during the following successive years reaching to 4.583 km^2 in the year 2020. While at Nuweiba'a sector, the urban area was 0 km^2 in the year 1985 after that it exhibited the same pattern as in Dahab area reaching to 2.818 km^2 in the 2020.

Changes in the shoreline occurred primarily due to man-made development (accretion) or natural causes (erosion). Total changes in land area along the shoreline from 1995 to 2020 at Dahab sector was about 0.36 km^2 by which, the total rate of changes by accretion was 0.19 km^2 and by erosion rate was 0.17 km^2. While at Nuweiba'a sector, the changes in the shoreline were mainly due to the erosion rate (0.45 km^2) if compared with the accretion rate (0.01 km^2) **(Figs. 6 & 7).** The results of the present study reflect the succession of political events and economical phases change, which had a huge impact on the coastal and urban structure development at Dahab and Nuweiba'a areas during the past four decades.

Between 1980 and 1988, Bedouins began to settle in southern Sinai area **(Lavie, 1991**); in the meantime, the Egyptian Government began to play a role in the development of Sinai **(Ali, 1998).** According to Law 3 of 1982, the process of orienting urban growth based on land use, services, infrastructure, and other factors to provide an efficient living environment was described as urban planning **(MOHPUC, 1997).** To nationalize Sinai, the Government encouraged the tourist industry to promote internal migration **(Hemdan, 1980** and **Karkabi, 2013).** The Bedouins benefited financially from tourism, but it also had an impact on their culture, since it led them to settle and leave their nomadic lifestyle. Some Bedouins migrated to coastal tourist towns, South Sinai became a popular tourist destination, and the built environment, including residential units, expanded. Many career possibilities arose as a result of the tourist industry's development. Europeans, also, sought for chances that provided a higher quality of life. "Tourism migration" and "lifestyle migration" are two terms used to describe this type of migration. In 1980s, as a result in the increases interest in marine life and the shortage of local specialists in that sector the Europeans in their twenties and thirties moved to Sinai to pursue careers in such fields **(Karkabi, 2013).** The tourism industry grew dramatically between the year 1988 and 2005 (**Karkabi, 2013).** By the 1990s, the number of foreign migrants had grown to the point that the Government had to adopt residential legislation for them (Law 230 of 1996) **(Ali, 1998).**

After 2011 Egypt's domestic and international political concerns were unsteady, affecting the country's economic status and its significant progress. Political events slowed the growth of Sinai, which was relied on the tourism business **(Sherif *et al*., 2016).** On the other hand, Nuweiba'a city is seeing rapid development, particularly in the construction. The Egyptian Government is willing to provide critical capacity building in the elements of public housing, services, and infrastructure; however, this is no longer the case. The majority of these projects, on the other hand, have been in action since the 1990s in order to attract resources and manpower to the newly built urban area **(Basha, 2017).**

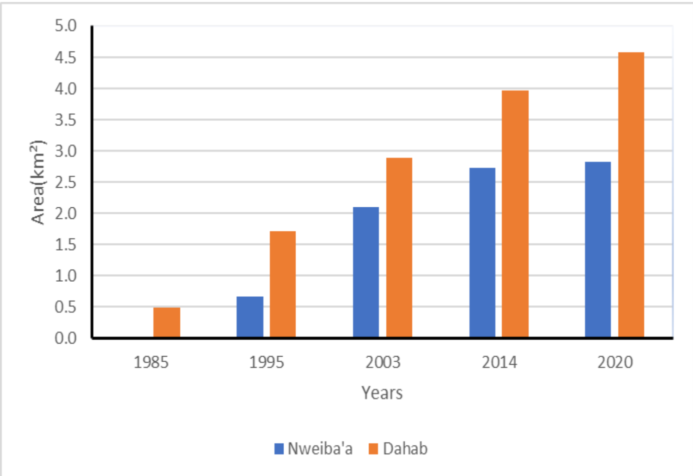

Fig. (3). Changes in urban area (km^2) at Dahab and Nuweiba'a sectors during 1985-2020.

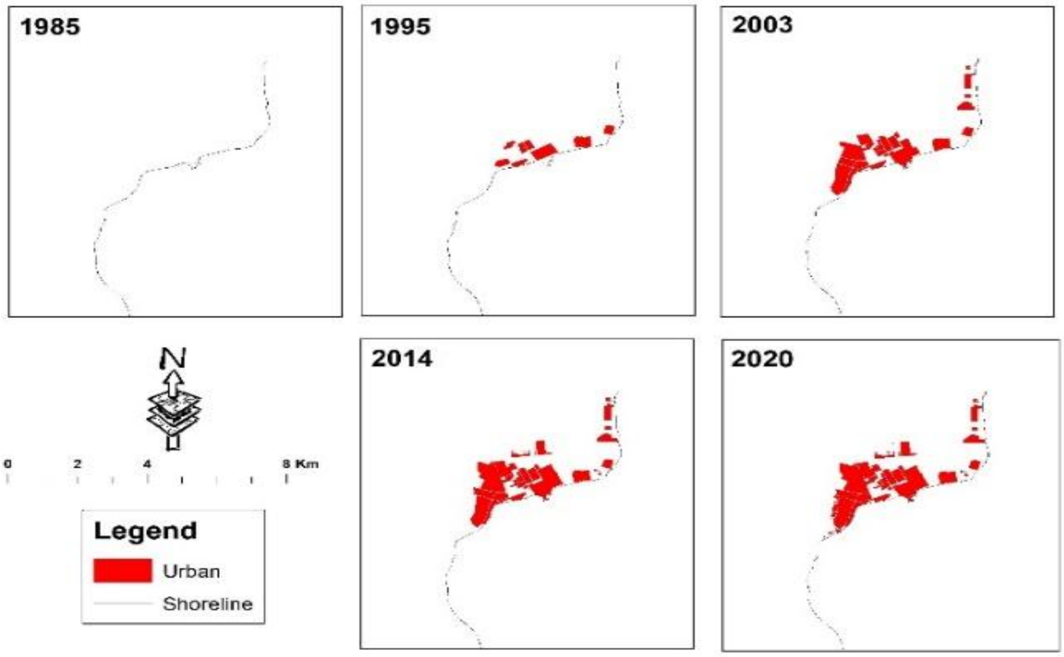

Fig. (4). Changes in urban area at Nuweiba'a area during the period from 1985 to 2020.

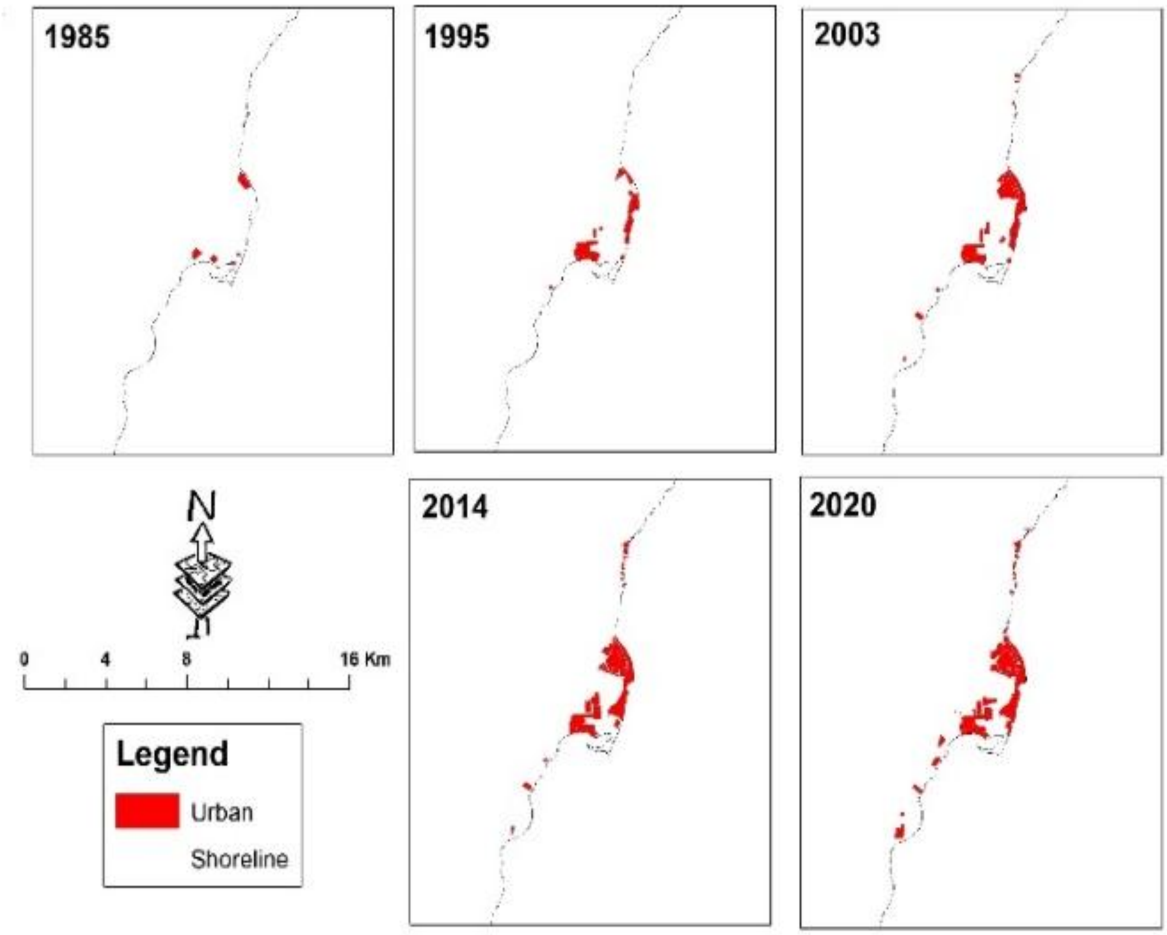

Fig. (5). Changes in urban area at Dahab area during the period from 1985 to 2020.

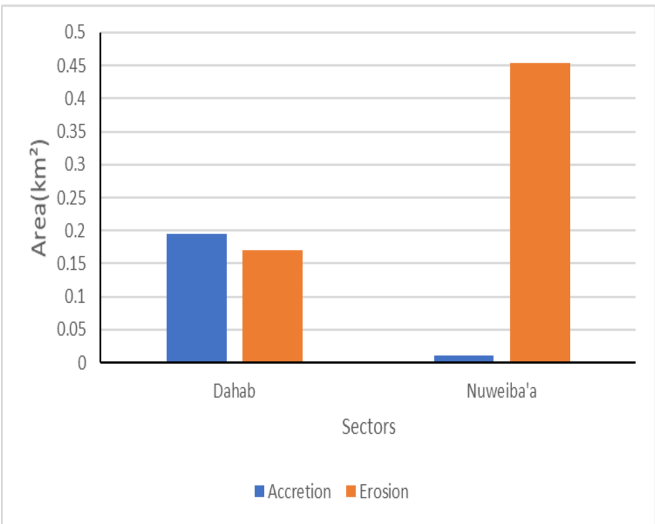

Fig. (6). Changes in shoreline area (km^2) at Dahab and Nuweiba'a sectors during the period from 1985 to 2020.

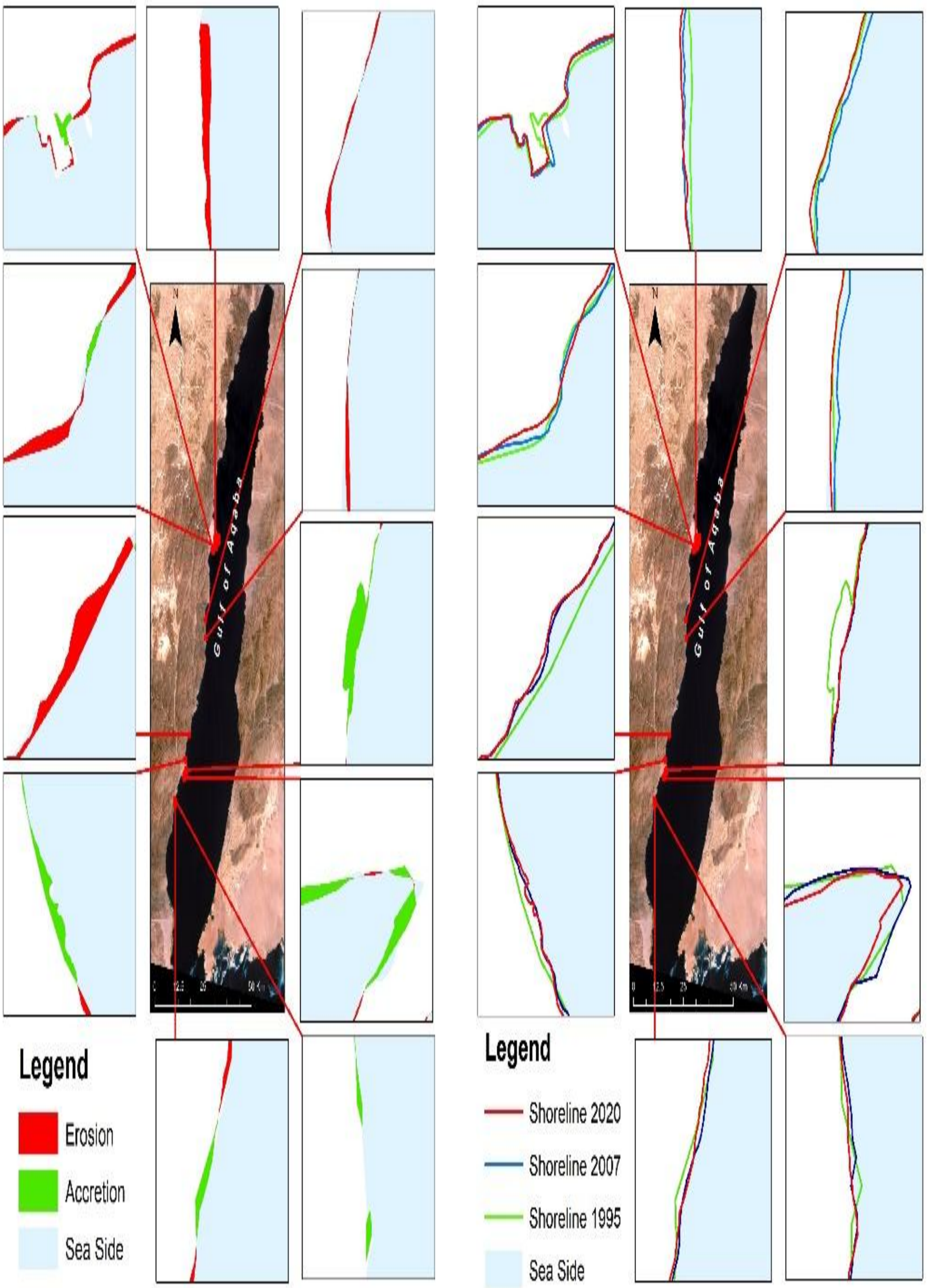

Fig. 7. Changes in the shoreline at Nuweiba'a and Dahab sectors during the period from 1985 to 2020.

2- Time- Series Analysis of key environmental factors changes:

Results of Time Series Analyses of the averages sea surface temperature during 27 years (1993- 2020) showed a stable trend during summer (peak) and winter (bottom) seasons **(Fig. 8).** Sea surface temperature increasing in larger scale such as oceans can be potentially related to bleach events models known as "time to reef extinction had been driven" **(Hoegh-Guldberg, 1999** and **Sheppard, 2003).** Generally, it is well known that coral populations living in warmer seas can tolerate greater temperatures than those living in colder waters of the same species **(Coles *et al.,* 1976).** Moreover, based on **Berkelmans & Willis (1999)** observations **Buddemeier & Fautin (1993)** suggested that corals may be able to acclimate (a physiological response at the individual level) or adapt (a genetic response at the population level) to changing in thermal regimes. According to **Buddemeier & Fautin (1993)** opinion, the shifts in coral host-dinoflagellate relationships, resulting in "different" ecospecies of corals have high tolerances against temperature with tolerant strains of zooxanthellae.

Regarding to the sea level which indirectly refers to the tidal movement, in the present work, the obtained results of the sea level analyses (low tide) showed that there is markedly decline in sea level with long hours exposure during the period from 1993- 2003. After that it took the normal trend of rise and fall curve **(Fig. 9).** The moon and sun's gravitational forces influence not only the astronomical shelf and ocean surface tides, but also the flow and flood tidal currents. When tides interact with the seabed and shelf structures (coral reefs and atolls), friction, vertical fractures, turbulence, eddies, and energy transfer to other processes like internal waves and fronts occur **(Dixon, 2011).** It's difficult to link the highest limit of coral development to a single tide level since so many things influence it. A better description would be a range between mean low water springs and mean low water neap tides **(Scoffin, 1977** and **Hopley, 1986).** In many tropical regions impacted by rainy seasons, mean low water springs vary significantly by season; for example, mean low water springs in the Red Sea and Gulf of Aqaba vary by 0.5 m between winter and summer monsoons **(Dixon, 2011).** The timing of local severe spring low water is crucial for coral reef upper development, i.e., when and how long they are exposed to air and direct UV sunshine, which can lead to coral desiccation. In **1986**, **Hopley** mentioned that corals exposed to air and direct sunlight for more than 3 hours begins to wilt and expel their symbiotic algae zooxanthellae**.** However, in assessing coral development, exposure durations, and desiccation, the contrast between local diurnal and semi diurnal tidal regimes is essential **(Dixon, 2011).**

The obtained data of turbidity (KD490) showed that there is an elevation rate during the period from 1997 to 2002, and then it gradually decreased till 2020 year except during 2012 which was relatively higher **(Fig. 10).** Turbidity is a key water quality parameter that represents the amount of light absorbed or scattered in the water column by suspended particulate matter **(Van Duin *et al*., 2001** and **Flores *et al.*, 2012).** Despite occupying 30 % of reefs in the coral triangle and 12 % of reefs globally, turbid coral reefs are relatively unexplored (**Sully & Van Woesik, 2020)**. The lack of data on turbid reefs is largely due to logistical issues associated with working in low visibility conditions both directly (in situ) and indirectly using remote sensing technologies **(Morgan *et al.,* 2020).** This has resulted in a poor understanding of how these reefs function, from the individual coral to the reef ecosystem **(Zewlifer *et al*., 2021).**

Suspended sediments have traditionally been thought to have a strong influence on coral reef health **(Larcombe *et al*., 2001; Sanders & Baron-Szabo, 2005; Palmer *et al*., 2010** and **Weber *et al*., 2012)** and coral resilience **(Rogers, 1990; Gilmour, 1999** and **Fabricius, 2005).** Over the last 20 years ago, several studies have revealed high coral cover in turbid reefs, implying that turbid coral communities may be able to withstand natural marginal growth conditions, implying that they may be more resilient to both local and global stressors, so that turbid coral reefs as a habitat may became important for coastal conservation **(Anthony & Larcombe, 2000; Palmer *et al*., 2010; Goodkin *et al*., 2011; Wilson *et al*., 2011; Browne *et al*., 2013; Morgan *et al*., 2016; Pizarro *et al*., 2017** and **Browne *et al*., 2019).** The influence of future global and local environmental disturbances on coral reefs and other habitats till now are still unknown and unexpected. Coral reef resilience to global climate impacts (e.g., warming oceans, cyclones, rising sea levels) will be influenced by the coral communities' ability to adapt these threats. Yet, we have a limited understanding of how these multiple stressors interact with water quality to influence reef function (**Zewlifer *et al*., 2021).**

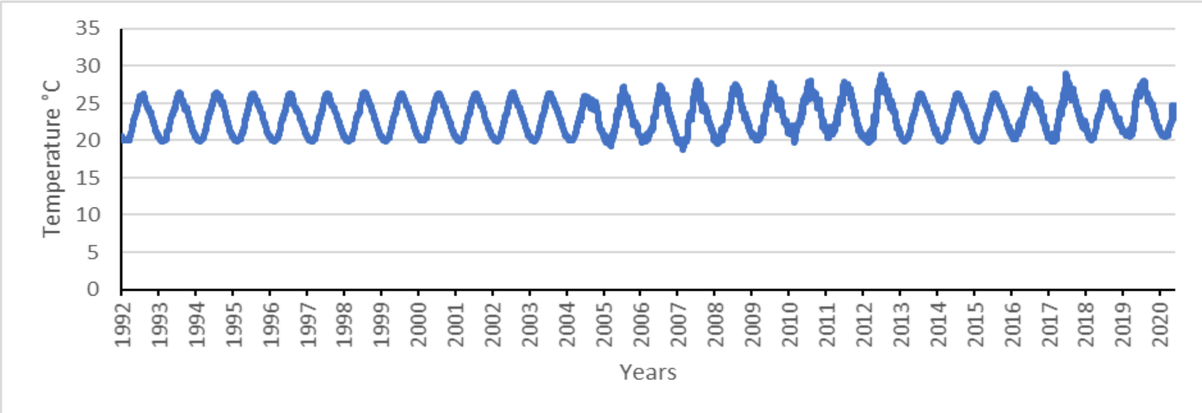

Fig. (8). Time-Series Analysis of changes in the averages of sea surface temperature (°C) in the Gulf of Aqaba during the period from 1993 to 2020.

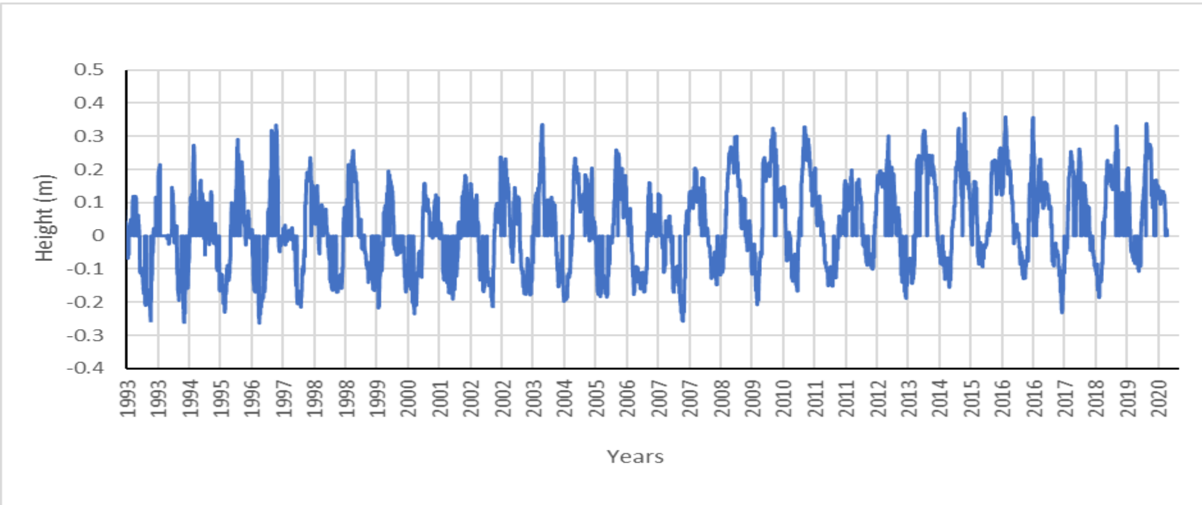

Fig. (9). Time-Series Analysis of changes in sea level (meter) in the Gulf of Aqaba during the period from 1993 to 2020.

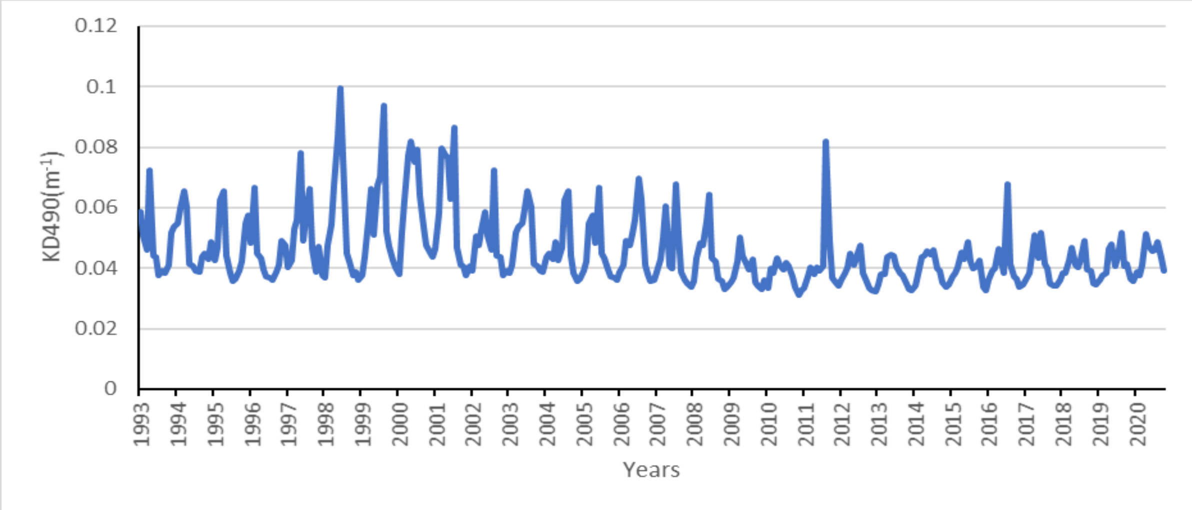

Fig. (10). Time-Series Analysis of changes in turbidity – KD490- ((m – 1) in the Gulf of Aqaba during the period from 1993 to 2020.

3- Benthic habitat changes:

Data obtained from the satellite images at Dahab sector showed that coral reef and seagrass cover in the study area increased by about 0.27 km^2 and 0.35 km^2 respectively during the period from 1995 to 2020. In contrast, macro algae and sand habitat decrease by about 0.23 km^2 and 0.27 km^2 respectively at the same period of study **(Figs. 11a & 12).** While at Nuweiba'a sector, seagrass, macroalgae and sand habitats decreased by about 0.32 km^2, 0.2 km^2 and 0.7 km^2 respectively; on the other hand, coral reef habitat slightly increased by about 0.01 km^2 **(Figs. 11 b** & **13).** In the present study, results showed that there was an increases area of coral reef during the period from 1995 to 2005, unlike the expected of shrinking as a result from the interference of man with intense activities in this region. Due to scarcity of the information about status of benthic habitat during such period, which lead the authors to suggest the first hypothesis for explanation, and linking the key environmental factors with habitat mapping. The long term neap tide which is happening mainly in summer season at Gulf of Aqaba leaving the whole reef flat including corals and macro algae exposed to intensive solar energy and high UV radiance for long hours of photo period. The authors indicated that due to such conditions may be led eventually to desiccate corals and put macro algae beyond its tolerance range. These findings are agreement with that found by **Hopley (1986), Häder *et al.* (2001)** and **Dixon (2011).** Also, **a**fter that, with the end of such conditions and the rises of sea level corals could flourish faster than macro algae and the competition between them on space is naturally.

In the present study at Dahab sector, the results also showed that there was stability in benthic habitats especially in coral reef habitat with tourism development during the period of study. Our results confirmed the findings obtained by **Tilot *et al.* (2008)** and **Darweesh *et al.* (2021)** who concluded that there was no relationship between intensity of tourism and coral cover and unlike with the findings obtained by **Khaled *et al*. 2019** and **Abo El Enin *et al*. (2020)** who indicated that the expansion of the touristic urban along Hurgada area was the main reason for coral coverage area degradation.

In their long-term research, **Reverter *et al*. (2020)** reported that hard coral cover did not affected negatively in any of the site groups, although it did significantly grow. However, in the present study at the Southern part of the Nuweiba'a region, there was a fluctuation in the hard coral cover over the past decades, although there is low intensity of human impact except for the Bedouin traditional fishing activity. These findings are agreed with that reported by **Sarnowski (2010)** and **Darweesh *et al.*(2021)** who mentioned that the Bedouin fishermen used primitive and destructive fishing methods that could have caused severe damage to coral reef habitats at Nuweiba'a area. Also, in their study **Mona *et al*. (2019)** stated that, the illegal and traditional fishing methods of the Bedouin community are of the most reasons for altering ecosystems at Nabq Protectorate, South Sinai. Because algae are natural space competitors with corals and when herbivores capacity is decreased due to overfishing, algae can spread and affect coral reef functioning, resulting in coral reef degradation and a community phase change leading to increased coral mortality. These findings are in full agreed with many investigators such as **Bellwood *et al*. (2004), Rasher & Hay (2010), Hoey & Bellwood (2011), Dixson *et al.* (2014), Haas *et al*. (2016)** and **Zaneveld *et al*. (2016).**

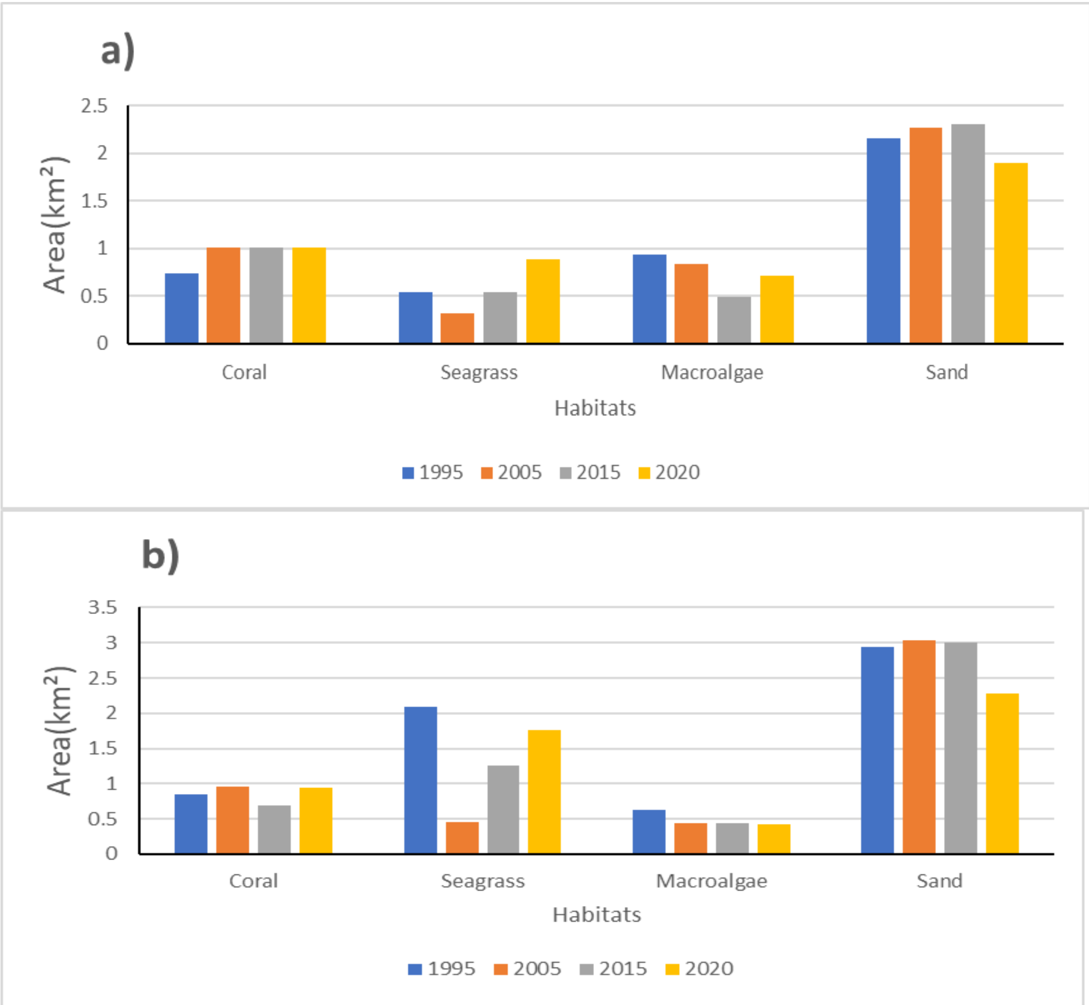

Fig. (11 Changes in benthic habitat areas (km2) at Dahab sector (a) and Nuweiba'a sector (b) during the period from 1995 to 2020.

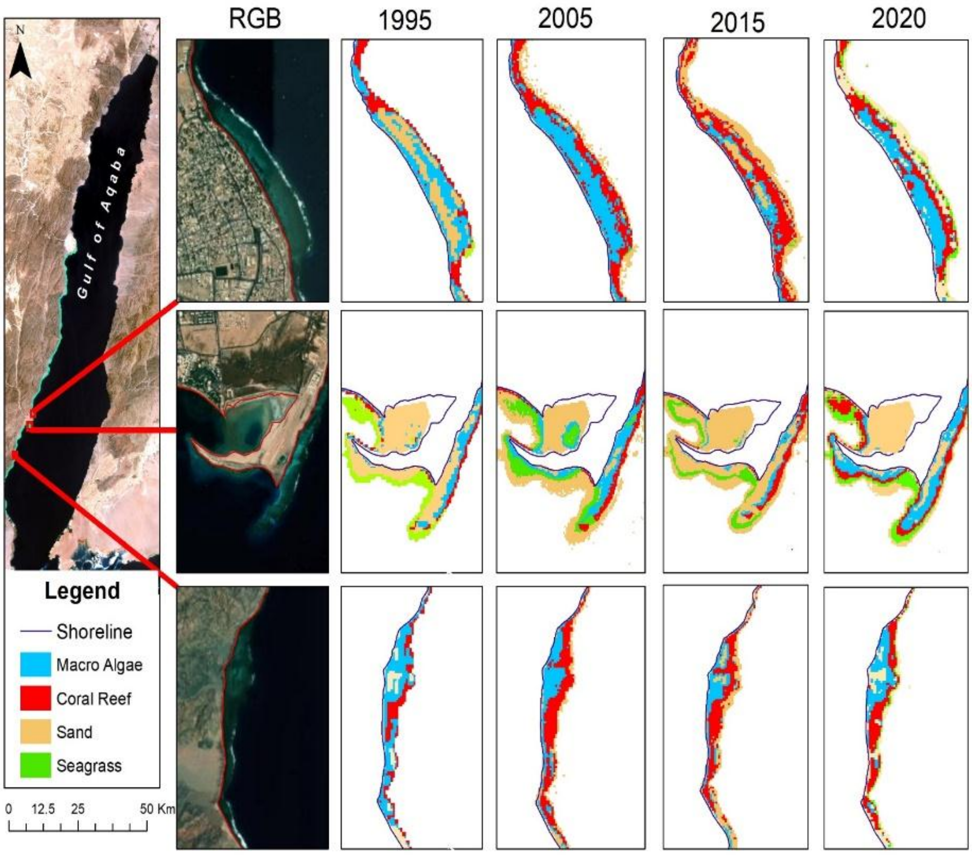

Fig. 12. Supervised classification of benthic habitats (coral, seagrass, macro algae and sand) changes between 1995 and 2020 at Dahab sector.

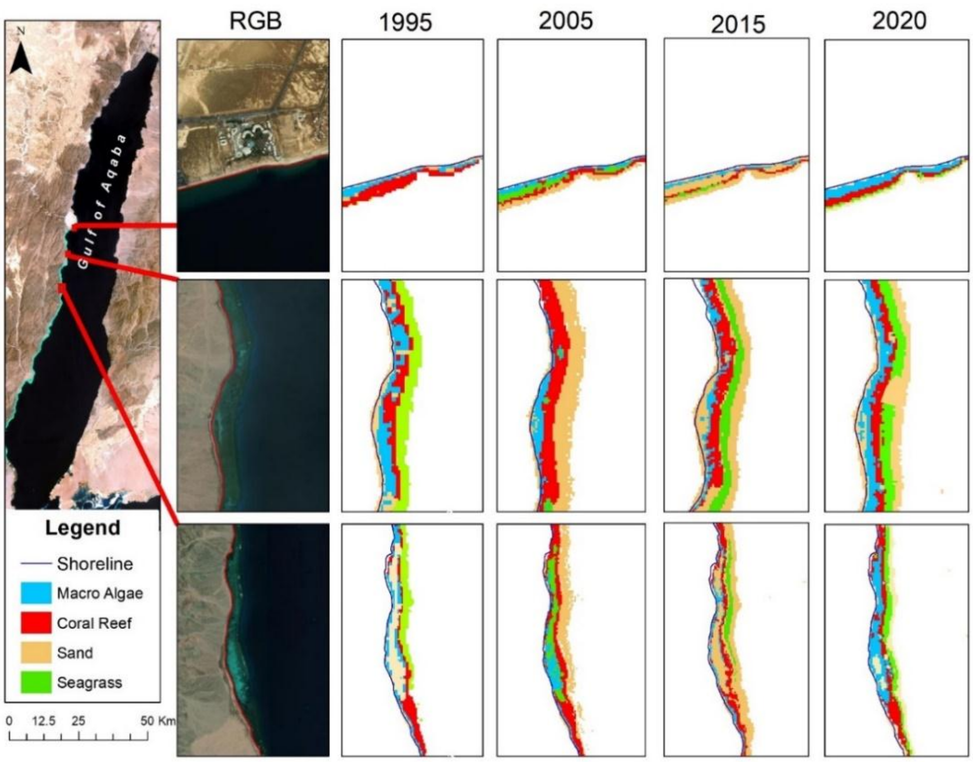

Fig. 13. Supervised classification of benthic habitats (coral, seagrass, macro algae and sand) changes between 1995 and 2020 at Nuweiba'a sector.

CONCLUSION

Pooled data from the deferent remote sensing changes detection, showed that:

1- Urban development had a large scale increasing in the past three decades due to the community change from being dependent on fishing to be a touristic orientation
2- Shoreline change in a smaller scale than the urban development in a regular way without harm to natural resources.
3- Both above mentioned changing – urban and shoreline- came along with tourism intensity didn't relate to hard coral cover or the benthic habitats.
4- A local decreasing in hard coral cover at the hot spots of intensive Bedouin's fishing areas.
5- Sea level and turbidity time series analyses showed a high variance in time especially in a period from 1993 to 2003, while the sea surface temperature had a stable trend.
6- Habitat mapping at Dahab area showed a stability of the coverage area of most of benthic habitats except for an increasing of both corals and macro algae between 1995 and 2005.
7- Nuweiba'a coral reef coverage area revealed a fluctuated coverage may be due to the Bedouin's fishing behaviour.

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الملخص العربي

ثلاثة عقود من مراقبة التغير في البيئات القاعية باستخدام الاستشعار من البعد على الساحل المصري لخليج العقبة، البحر الأحمر

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شهد ساحل البحر الأحمر خلال الأربعة عقود الأخيرة تغيرا ونموا كبيران. في خلال فترة قصيرة من الزمن تحول ساحل خليج العقبة الي سلسلة من المنشآت السياحية. نظرا للندرة الشديدة في المعلومات الخاصة بتلك المنطقة، في هذه الدراسة تم وضع تحليل زمني شامل لتحديد التغيرات باستخدام تقنيات الاستشعار من البعد لهذه المنطقة. تم استخدام البيانات المستخرجة من القمر الصناعي (Landsat) في خلال الفترة من ١٩٨٥ الى ٢٠٢٠ في منطقة خليج العقبة فيما يخص تحديد التغيرات في المنشآت و خط الشاطئ و الفترة من ١٩٩٥ الي ٢٠٢٠ في تحديد التغيرات المتعلقة بتوزيع البيئات القاعية كما تم استخدام الصور من Landsat 5-TM, Landsat 7-ETM+ Landsat 8-OLI, في وضع سلسلة من مشاهدات الأقمار الصناعية. أظهرت النتائج تغيرا ملحوظا في الثلاثة عقود الأخيرة في قطاع دهب و قطاع نويبع بواقع ٤.١ و ٢.٨ كم مربع على الترتيب، بينما كان التغير في خط الشاطئ في نطاق اقل من سابقه بشكل منقي و من دون احداث الضرر للموارد الطبيعية. تبين ان التغيرات في كلا من المنشآت وخط الشاطئ تتناسب طرديا مع الزيادة في النشاط السياحي. فيما يخص التحليل الزمني العامل الفيزيائية البيئية كان هناك اختلافات واضحة خصوصا في الفترة الزمنية من ١٩٩٣ الى ٢٠٠٣ في كلا من ارتفاع سطح الماء والعكارة بينما كانت درجة حرارة سطح ماء البحر اتجاه ثابت مستقر. توزيع البيئات القاعية الزمني اظهر ثبات في معظم البيئات في قطاع دهب ماعدا زيادة ملحوظة في بيئة الشعاب المرجانية في الفترة من ١٩٩٥ الى ٢٠٠٥ ، كما كان هناك تقلب في توزيع الشعاب المرجانية في قطاع نويبع.