Estimating the environmental risk of construction activities on the ecological receptors along the Egyptian Red Sea coast

A. H. Sherif[1], A. H. El Sherbiny[2] & A. N. Hassan[3]
[1]Construction Engineering Department, The American University in Cairo, Egypt
[2]Komex "Environment and Water Resources", Cairo, Egypt
[3]Institute of Environmental Studies & Research, Ain Shams University, Cairo, Egypt

Abstract

Tourism is one of the main contributors to the Egyptian economy. The Red Sea coastal area represents one of the major tourist attractions. It has witnessed a large increase in tourism developments. Uncontrolled tourism developments, with their associated construction activities, have led to deterioration in the ecological resource base of the region. The paper investigates the construction activities and associated stressors that could result in deterioration of the valuable ecological components existing along the Egyptian Red Sea coast. Fulfilling that aim required estimating the ecological risks associated with the construction of an already established development, and tracking backward the stressors that were responsible for high-risk levels. An Environmental Risk Assessment (ERA) Model was used. It estimates the risk of causing environmental harm to existing ecological receptors, while considering the cumulative effect of different stressors and impacts resulting from various construction activities. As a result, changes in the master plan, construction methods and/or mitigation measures were suggested to decrease the magnitude of these stressors and minimize the ultimate impacts and final risk over existing significant ecological receptors.
Keywords: tourism coastal development, construction activities, environmental risk assessment, ecological risks, El-Gouna tourism center, Red Sea, Egypt.

1 Introduction

Tourism is one of the main contributors to the economy of Egypt. It is among the three main sources of foreign exchange after oil and Suez Canal [1]. It contributes about 11.2 % of the Gross Domestic Product (GDP) [2]. In 2002, the number of tourist nights they bought was 2.3 million [3]. It is expected that the number of tourists in Egypt would reach 14 Million by year 2017 [3]. The Red Sea is planned to accommodate about 14 % of the tourist nights coming to Egypt in 2017 [4]. Besides its sunny climate, sandy beaches and tranquil sea, the Red Sea area is characterized by unique marine and terrestrial environment. The area contains more than 1,500 km of coral reefs and associated ecosystems such as Mangroves [5]. The marine ecosystem is home to over 300 species of coral, 500 species of aquatic plants and numerous fish and marine animals [6]. In addition, the magnificent valleys of the coastal Wadis support the highest diversity of terrestrial plants in Egypt [5].

The Egyptian Government has been encouraging investment in tourism development in the Red Sea area. Uncontrolled tourism developments have led to deterioration in the resource base of part of the Red Sea. The northern part of the Red Sea, for example, has witnessed a great deal of development that was responsible for the deterioration of some unique natural resources [7–13]. El-Gouna region, located north of Hurghada, has witnessed a great deterioration in the existing Sabkha, Sea grasses and Mangroves due to their direct removal [14]. It became apparent that unless there are management tools to regulate the relationship between development and natural conservation, the natural resources would deteriorate placing economic growth at jeopardy.

Construction along the Egyptian Red Sea coast could be very damaging due to the presence of highly sensitive ecosystems that could be easily affected by direct impacts, such as dredging in the reef flat, as well as indirect impacts, such as sediments transport to nearby corals.

2 Aim and methodology

This paper aims at investigating construction activities and associated stressors that could result in deteriorating the valuable ecological components existing along the Egyptian Red Sea coast.

This entailed: 1) Selecting an already established development; 2) Utilizing an ERA model to estimate the ecological risks associated with its construction; 3) Comparing the model results with previous research work that identified the adverse ecological changes associated with its construction; and, 4) Tracking backward stressors, and thus construction activities that were responsible for high-risk levels.

The ERA model, proposed by El-Sherbiny, Sherif and Hassan [15], was utilized to estimate the risk over each receptor from various impacts. After comparing the model results with previous research that considered adverse impacts associated with the construction of the case study project, a backward tracking analysis was performed for the impacts responsible for high-risk levels.

Thus, different alternatives regarding proposed master plan, mitigation measures and/or construction methods were analyzed and the risk was reevaluated according to the new conditions.

3 Description of the ERA model

An ERA model is utilized to estimate the risk of causing an environmental harm to the ecological receptors existing along the Red Sea coast as a result of proposed developments. It describes the various links between construction activities and the ecological receptors existing along the Red Sea coast (Fig. 1). In addition, it depicts and tracks secondary order impacts, which represent possible deterioration to the ecological receptors, and its relation to lower-order impacts and related stressors.

As presented by El-Sherbiny et al. [15], the ERA model incorporates four parts: area investigation, project analysis, risk characterization and risk evaluation. Area investigation is concerned with identifying the ecological receptors that exist within the study area, as well as evaluating their status significance and sensitivity. Project analysis involves specifying the project components and activities conducted during the construction phase as well as identifying the volume of work of each activity to evaluate the stressors magnitude. As for the risk characterization, it entails identifying the probability of stressors' transport through different pathways, impacts' duration (short term versus long term) and any direct removal that could be encountered during construction for existing ecological receptors. Finally, the risk estimation involves integrating the outputs of the previous three parts.

4 Description of the case study project

A case study was selected for this purpose. El-Gouna tourism center was selected based on its size, and accomplishment level, as well as the availability of data on construction activities and environmental conditions before and after development.

El-Gouna is located in the northern part of the red sea coast, 20 km north of Hurghada. It lies on the northern part of the alluvial fan of Wadi Abou Shaar and Wadi Umm Diheis, and the southern part of the alluvial fan Wadi Bali [14]. It is concentrated along the coastal strip with a length of about 10 km. It is built through in-land dredging to create a number of man-made islands that are separated by a number of artificial lagoons and channels, and connected by a complex system of roads and bridges. It includes 14 hotels, real estate villas and apartments, complete infrastructure and extensive support facilities and services, such as marinas, restaurants and cafes, sports and health clubs, nursery and school, hospital and pharmacy, aquarium, museum, airport, etc. (Fig. 2). Most of El-Gouna tourism center has been developed completely. However, according to El Gamily [14], modifications are continuously in process.

Prior to the area development, the existing location of El-Gouna resort was characterized by the presence of significant natural resources and unique habitat.

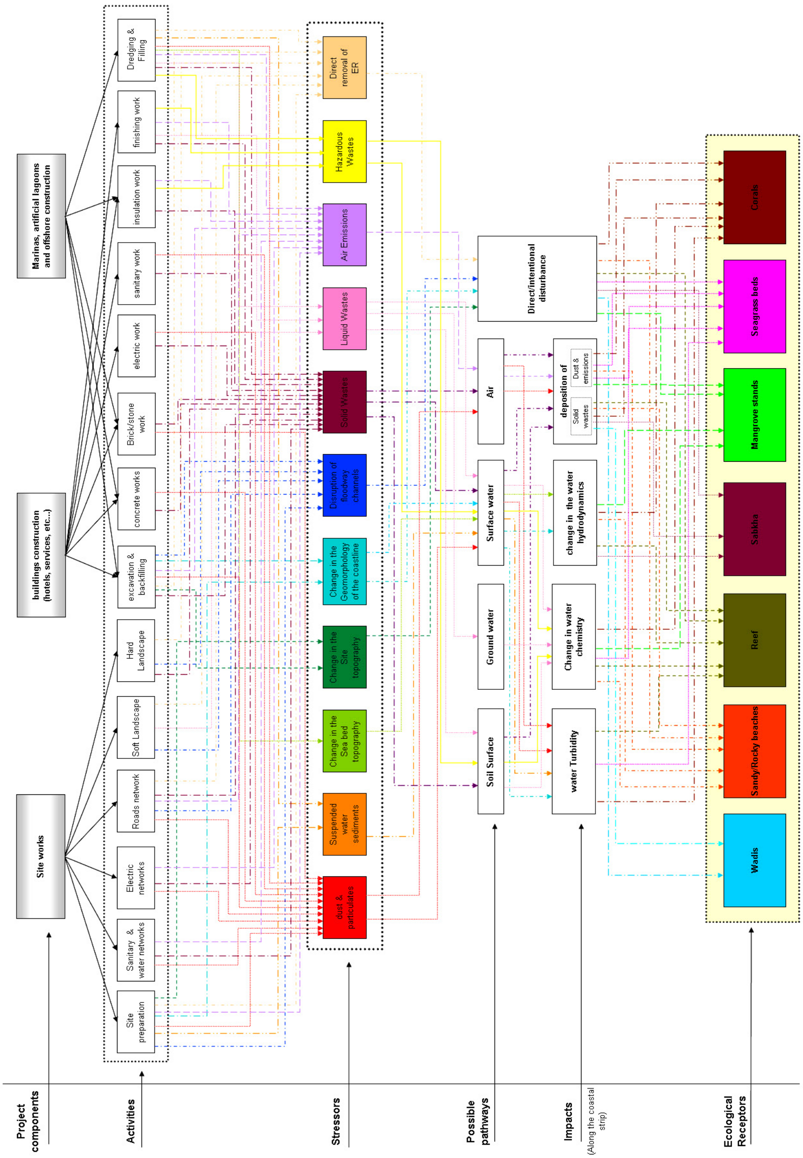

Figure 1: Model network diagram.

The coastal plain of El-Gouna region consisted of Sabkha, Mangrove Stands, Seagrass beds, reef and Corals [14]. The area was dominant with Sabkha deposits that used to cover about 6.3 km2. In addition, there was a Reef flatparallel to the coastline. Sea grass beds were also found along the coastline and next to the offshore reef. Coral communities only existed in the northern and southern part of El Gouna, and along the edge of the offshore reef. Mangrove stands were also scattered along the coastline.

Figure 2: El-Gouna Master plan (Tourism development Authority).

Previous research studies have been performed to assess the adverse impacts of El-Gouna development on existing ecological receptors. El Gamily [14] indicated that Sabkha is the most deteriorated ecological receptor. He estimated that 51% of the existing Sabkha was directly removed and substituted by other soil, 45% changed to man-made canals, 2.03% changed to various anthropogenic activities such as buildings and 1.26% deteriorated from construction related activities. The study also indicated that Mangrove stands followed by Sea grass beds are impacted mostly by the direct disturbance associated with the direct removal and changes in the geomorphology of coastline.

In another research [9], it was clear that the land-cover along the coastline was completely substituted with man-made canals and buildings. He indicated that the deterioration of corals is limited to the southern part of the development where two small marinas are located. He also added that the reef flat was distressed from the excavation and construction of near shore pathways.

5 Risk evaluation

Fig. 3 presents the maximum risk over each receptor. Sabkha is subjected to the highest risk level (1.00). It is then, followed by Mangrove stands (0.70), and sea grass beds (0.50). As for the corals and reef, they are exposed to risk levels below the mean (0.35 and 0.1, respectively). This output is consistent with the results of previous research work [9, 14] through which adverse changes associated with El-Gouna development were identified. Running the ERA model on El Gouna tourism center yielded the expected risks over each ecological receptor from related impacts (table 1).

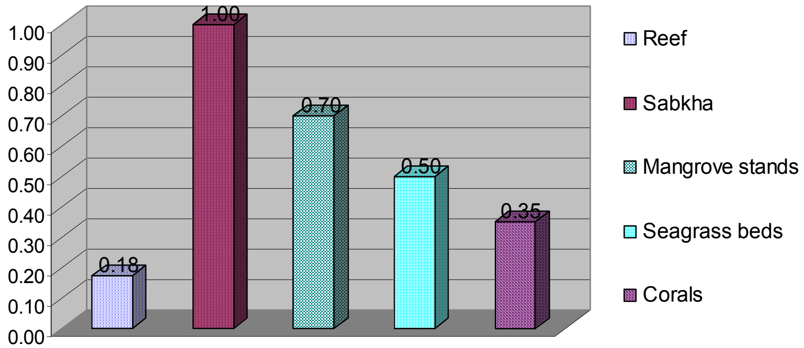

Figure 3: Maximum risk over each receptor.

Table 1: Individual risk, risk from related impacts.

Impacts	**Ecological Receptors**						
	Wadis	Sabkha	Mang. Stands	Seagrass beds	Reef	Corals	Beaches
Water turbidity	x	x	x	0.13	0.12	0.18	x
Change in water chemistry	x	x	0.00	0.00	0.00	0.00	x
Change in water hydrodynamics	x	0.35	0.50	x	0.09	0.35	x
Direct deposition of:							
- *Solid wastes*	x	0.00	0.00	0.06	0.00	0.04	x
- *Dust and particulates*	x	x	x	0.18	x	0.18	x
Direct disturbance by:							
- *Change in the site topography*	x	1.00	x	x	x	x	x
- *Change in coastline Geomorphology*	x	1.00	0.70	x	x	x	x
- *Direct removal of the ecological receptor*	x	1.00	0.50	0.50	0.18	0.00	x

(x) No relation

According to table 1, Sabkha is exposed to three sources of high risk attributed to direct/intentional disturbance: direct removal (1.00), changes in coastline geomorphology (1.00) and changes in site topography (1.00). Mangrove stands are also exposed to a high-risk level from three sources. The first source is the direct/intentional disturbance by changes in the geomorphology of coastline (0.7) and the direct removal (0.5). The other source is the changes in water hydrodynamics (0.5). As for the Sea grass beds, the highest risk emerges from the direct removal (0.50). However, the dust deposition and water turbidity posses risk levels of 0.18 and 0.13 respectively. For the Corals, the highest risk sources include the changes in water hydrodynamics (0.35), dust deposition (0.18) and water turbidity (0.18). As for the reef, it is exposed to a risk level of 0.18 due to its direct removal.

5.1 Backward tracking

According to the presented results, impacts that endanger the existing ecological receptors include:

1. Direct/intentional disturbance through direct removal
2. Changes in the geomorphology of the coastline
3. Changes in the site topography
4. Changes in water hydrodynamics
5. Dust deposition and water turbidity.

Tracking each impact backward through the network diagrams presented in Fig. 1 provided related stressors responsible for the high-risk levels (table 2). There are four stressors, generated from almost all the development related activities, responsible for the identified impacts. These stressors include the direct removal of the specified receptors; changes in the geomorphology of the coastline, dust and particulates generated and air emissions as well as changes in the seabed topography.

Table 2: Receptors at risk and related impacts/stressors.

Ecological Receptors	Impacts	Stressors
Sabkha	- Direct/intentional disturbance	- Direct removal - Changes in coastline geomorphology - Change in the site topography
Sea grass beds	- Direct/intentional disturbance - Dust deposition - Water turbidity	- Direct removal - Dust & particulates - Air emissions - Dust & particulates - Water suspended sediments
Mangrove stands	- Direct/intentional disturbance - Changes in water hydrodynamics	- Changes in coastline geomorphology - Direct removal - Change in the Sea bed topography
Corals	- Changes in water hydrodynamics - Dust deposition - Water turbidity	- Change in the Sea bed topography - Dust & particulates - Air emissions - Dust & particulates - Water suspended sediments
Reef	- Direct/intentional disturbance	- Direct removal

5.2 Alternative construction activities and mitigation measures

After identifying ecological receptors at risk, and tracking backward responsible stressors and activities, required changes in the master plan, construction methods and/or the mitigation measures could be identified. Thus, the input data could be modified, and the risk could be estimated according to the new conditions, if the model was to be applied before the construction phase.

Since Sabkha, Mangrove and Seagrass beds are subjected to the highest risk levels, they were considered the receptors at risk. Some of the mitigation measures that could help in decreasing High-risk levels could include [16]: Avoiding disturbing high quality areas; using siltation control: silt curtains, settling ponds and/or appropriate dredging techniques; productive use of dredge spoils; proper disposal of contaminated spoil; working with natural topography as mush as possible; timing of construction to avoid migratory and spawning seasons; applying grading controls and require rapid re-landscaping of disturbed areas; fencing the construction site to contain litter and secure construction materials; daily pick up and proper disposal of construction wastes; applying emission limits; and control use of dangerous and hazardous material.

Within that respect, the ERA model was employed over four hypothetical consecutive cases to reevaluate the risk associated with each case. Consequently, the most suitable alternatives could be selected as early as possible before commencement of construction activities. Fig. 4 presents the obtained risk levels in each case in comparison to that of the original one.

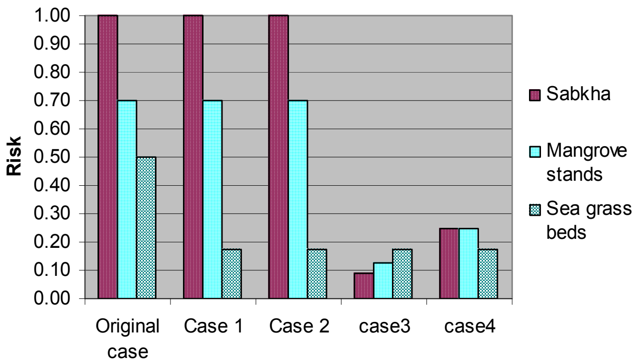

Figure 4: Comparison between the results of the effects of the mitigation measures and that of the original case.

In the first case, it is assumed that there is no direct removal, while keeping the magnitudes of other stressors in their original values. Eliminating the direct removal practices effectively reduced the risk over Sea grass beds. However, other receptors were still under stress. This consequential effect was expected. As mentioned earlier in the results analysis section, the maximum risk over the sea grass is associated mainly with the direct removal. However, other receptors, Sabkha and Mangrove stands, are subjected to other sources that posse high risk levels.

In the second case, it is assumed that the mitigation measures were revised so that the magnitudes of concerned stressors regarding related activities were taken to be either mild or negligible (i.e. stressors having negligible magnitude were kept the same, while others with severe, high or mild were considered to have mild magnitude). Suggested mitigation measures were not enough to decrease the risk levels. Sabkha and Mangrove stands are still under stress mainly from the direct disturbance. Sabkha suffers from the performed changes in coastline geomorphology and site topography. Mangroves are under stress from the changes in the coastline geomorphology and the changes in water hydrodynamics.

In the third case, it is assumed that direct/intentional disturbance due to changes in the coastline geomorphology and the site topography were eliminated, while keeping the status reached from the previous case. As shown in Fig. 4, this action has significantly decreased the risk over Sabkha and Mangroves.

In the fourth case, instead of eliminating the direct disturbance, it is assumed that the mitigation measures were revised so that all concerned stressors, shown in table 4, have negligible magnitudes. Such modifications also effectively decreased the risk levels.

6 Conclusion

As coastal zones are considered distinctive areas with sensitive ecosystems, rapid and unregulated development can lead to a great deterioration in coastal and marine environment. Adverse changes in the land-use/land-cover have been already witnessed along the coastline of developed zones. Investigating the ecological deterioration in El-Gouna region showed that Sabkha is the most deteriorated receptor, followed by Mangrove stands, Sea grass beds and finally the corals and reef flat.

Impacts that endanger existing ecological receptors included direct/intentional disturbance, changes in water hydrodynamics, dust deposition and water turbidity. Four stressors were found to be responsible for the generated impacts; they are direct removal of the specified receptors, changes in the geomorphology of the coastline, dust and particulates generated and air emissions as well as changes in the sea bed topography. Finally, activities generating previously identified stressors and related impacts were specified through backward tracking to include most of the construction related activities. Accordingly, different alternatives regarding the master plan, construction methods and/or the mitigation measures were examined, such that appropriate changes and precautions would be applied to significantly decrease the risk over existing ecological receptors.

References

[1] Euromonitor International. *Travel and Tourism in Egypt,* September 2000. www.euromonitor.com/travel_and_tourism_in_egypt.htm

[2] Egyptian State Information Service. *Tourism industry contributes by 11.2% of GDP,* 24 July 2003, www.sis.gov.eg/online/html9/o240723j.htm
[3] Egyptian State Information Service. *Egypt's tourism reports good harvest in 2002,* 27 Jan. 2003. www.sis.gov.eg/online/html8/o270123q.htm
[4] General Authority for Urban Planning. *Urban development plan for Red Sea governorate: Year 2017*, General Authority for Urban Planning: Cairo, 2000.
[5] Tourism Development Authority *Environmental management guidelines for coastal hotels and resorts: volume I,* Egypt: Tourism Development Authority: Cairo, 2000.
[6] Egyptian Environmental Affairs Agency, Tourism Development Authority and Red Sea Governorate, *Red Sea coastal and marine protected area strategy,* Egypt, 1999.
[7] Fanos, A. M, Khefagy A. A., Abu Aesha K. A. and Frihy O. E., Human impacts on the coastal zone of Hurghada, northern Red Sea, Egypt. *Geo-Marine Letters,* 16, pp. 324-329, 1996.
[8] Hawkins, J. P. and Roberts C. M., The growth of coastal tourism in the Red Sea: present and possible future effects on the coral reefs. *Biological Conservation,* 76 (2), pp. 216-216, 1996.
[9] Moufaddal, W. M. Remote sensing approach for assessment impacts of some human activities on the sensitive habitats of the NW Egyptian Red Sea coast. *Proc. of the International Conference on Tourism Development in Environmentally Sensitive Areas,* Cairo, Egypt, 2003.
[10] El Gamily, H. I., Naser S. and Raey M. E., An assessment of natural and human induced changes along Hurghada and Ras Abu Soma coastal area, Red Sea, Egypt. *Int. J. Remote Sensing,* 22 (15), pp. 2999-3014, 2001.
[11] Abozaid, M., *Impact of various human activities on the natural resources of the Red sea.* Egypt: Report, 2003.
[12] Tourism Development Authority, *Land use management plan, south Marsa Alam, Red Sea coast.* Egypt: report, 2003.
[13] United Nation Environment Program, Assessment of land-based sources and activities affecting the marine environment in the Red Sea and Gulf of Aden. *UNEP Regional Seas Reports and Studies*, No. 166, UNEP: Nairobi, 1997.
[14] El Gamily, H. I. Assessment of environmental deterioration due to the land use/land cover changes using multi-dates LANDSAT, case study: El Gona region, Red Sea, Egypt. *Proceedings of the International Conference on Tourism Development in Environmentally Sensitive Areas.* Cairo, Egypt, 2003.
[15] El Sherbiny, A., Sherif A. and Hassan A., A model for Environmental Risk Assessment of Tourism Projects' Construction on Egypt's Red Sea Coast. *Journal of Environmental Engineering,* under review, 2005.
[16] Tourism Development Authority, *Best practices for tourism center development along the Red Sea Coast,* Tourism Development Authority, Cairo, 1998.