



The cumulative impacts of reclamation and dredging on the marine ecology and land-use in the Kingdom of Bahrain

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ABSTRACT

This article assesses the ecological and economic impacts of land reclamation and dredging through consulting recent environmental impact assessment reports. Geographic features of Bahrain during 1963–2008 are produced using Geographical Information System. Extensive but inexpensive shallow coastal areas and tidal flats have been reclaimed particularly from 1997 to 2007 at a high rate of 21 km²/year. Formal records show the increase in the original land mass by the year 2008 to be 91 km². An estimated total cumulative loss of major habitats resulting from 10 reclamation projects was around 153.58 km². Also much larger scale impacts should be considered resulting from the borrow areas used for the extraction of sand or infill materials. A number of key habitats and species are affected in the vicinity of these projects. The study attempts to assign a monetary value to the marine ecosystem functions. There is a need for efficient coastal zone management to regulate a sustainable use of the marine resources.

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1. Introduction

The Kingdom of Bahrain is an archipelago of around 40 islands, the largest is the main island of Bahrain, all of which are low-lying islands between latitudes 27°10' and 25°22' North and longitudes 51°07' and 50°16' East. The water around Bahrain is shallow ranging between <0.5 and 30 m. The islands are located in the subtropical region east of Saudi Arabia and Qatar. The salinity is high reaching up to 50‰. The total area of Bahrain islands is currently 755.8 km² and the territorial waters area is about 7151 km² according to the Geographical Information System (GIS) information (GEOMATEC, Bahrain, 2009). Another smaller archipelago, Hawar is about 20 km off the south east of Bahrain. It consists of six main islands and more than 30 smaller ones, all together cover around 51.5 km². The total population of Bahrain according to statistics of 2008 is around 1,400,000. Relative to the size of the land, the country's population density is considered very high.

Bahrain is located in the Arabian Gulf which is a semi-enclosed sea with a limited exchange of water through the open Indian Ocean. The Gulf is situated in a semi-arid area within the Middle East bordering eight countries forming the GCC (Gulf Cooperation Council). The Arabian Gulf has a number of unique natural productive coastal ecosystems. However, discovery of oil and the subsequent socio-economic developments have subjected these ecosystems to various types of stressors (Ahmed et al., 1998; Linden et al., 1990;

Madany et al., 1987; Zainal et al., 2008). The coastal environment has been subjected to a variety of factors that resulted in a sharp decline of the mangrove and coral ecosystems, as well as seagrass habitats which accommodate a wide variety of marine biota (Linden et al., 1990; Sheppard et al., 1992).

During the last two decades, the coastal and marine areas in most of the GCC countries has also witnessed massive dredging and land reclamation activities (Sheppard and Price, 1991; IUCN, 1987), particularly, along the northern and eastern coastal areas of Bahrain. Due to the shallowness of the sea large areas of the intertidal zone is exposed to the sun during low tide forming tidal flats. Such topographical feature is prevalent in northern and eastern parts of Bahrain, especially in Muharraq and Sitra. Flat and shallow features of some shoreline therefore, make infilling relatively easy and inexpensive (Al-Madany and Al-Sayed, 2001). In recent years, many issues have emerged creating conflicts and clashes between different interests and a need of an appropriate policy for a sustainable and integrated coastal zone management has been recognised. Although fragmented, there are some environmental policies and legislations to avoid damaging sensitive coastal areas during developmental projects (Ministry of works, Bahrain, web page).

Geographically, Bahrain suffers from land limitation relative to the increasing population density and economic development. In order to accommodate the vast and diverse developmental programmes, unplanned land reclamation through dredging the seabed has been one of the 'problem solving' processes. Few quantitative studies on the effect of dredging and coastal infilling

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have been undertaken in Bahrain, although, qualitatively, a number of environmental issues have been investigated. For example Madany et al. (1987), Al-Madany et al. (1991), Al-Madany and Al-Sayed (2001), IUCN (1987), IUCN/UNEP (1985), Sheppard and Price (1991) and Vousden and Price (1985) predict loss of habitats and smothering of communities and species due to land reclamation. Zainal (1993) uses remote sensing to assess changes in the size and nature of the habitats over time and attributes such changes to the sedimentation associated with dredging activity. Al-Ghadban and Price (2002) give a comprehensive review on environmental problems associated with land reclamation and dredging in the Arabian Gulf. In some Gulf States, as much as 40% of the coastline has been developed eliminating critical habitats for wildlife and biodiversity (Ahmed et al., 1998; Al-Duaij and Mabey, 2008; Linden et al., 1990).

Limited amount of information is available on the impact of reclamation and dredging on the Gulf marine ecosystem for example, in Saudi Arabia, 46.5 km² of coastal habitats have been dredged during the land-filling operation for the Jubail city and more than 200 Mm³ of sediment was removed (IUCN, 1987). The present investigation assesses environmental, economic, land-use issues relating to the cumulative impacts on the marine environment with reference to the geo-morphological feature of the islands.

2. Materials and methods

Environmental impact assessment (EIA) reports conducted during 2002–2008 have been studied and their reported total reclaimed areas used to estimate a cumulative size of the reclamation around the coastal areas of Bahrain. Data was also obtained through creating Geographic Information System (GIS) maps and from the literature. Ecologically important areas were further depicted from the literature.

The geographic features of Bahrain during 1963, 1977, 1982, 1989, 1997 and 2004 were produced using all purposes topographic maps with a scale of 1:50,000. The maps of 1963 and 1977 were historically produced by the British Military Surveying Department. Additional maps were produced and printed by the National Surveying Authority in the Kingdom of Bahrain. Thematic map for marine habitats developed by the Environmental Protection Committee in 1986 as a part of Bahrain Marine Habitat Survey developed using field surveys. Another thematic map developed by the Ministry of Housing describing the land-use in Bahrain was adopted. This land-use map illustrates the locations (coordinates) of borrow areas using Global Positioning System (GPS). The GIS data on the shore line for Bahrain during the years 2006 and 2007 provided by Geographical Information System for Marine Technology (GEOMATEC). Digital data were produced by scanning processes. The digital copy of the maps was then geo-referenced to a standard projection and datum to produce a rectified digital copy maps. These were further digitized to convert them to vector forms and were stored in a geo-database. GPS data of the borrow areas were re-projected and converted into GIS data format. MARGIS data (Sims and Zainal, 2000) was re-calibrated prior to storing into the geo-database.

Geo-referencing is a process of resetting the pixel coordinates to meet the real coordinates on the earth scale. This process includes scaling, rotating, translating and skewing the image to match a particular size and position using sophisticated calculations based on ground control points. The shoreline of 2006 and 2007 were also imported from MARGIS dataset. MARGIS dataset however, uses different projections. These data were re-projected to the standard projection defined by the Universal Transverse Mercator, UTM Zone 39 North Hemisphere – World Geodetic System WGS 1984 projected coordinate system. A set of six points were extracted from the

modified MARGIS dataset and compared to the dataset developed by the present study. The location error was found to be 0.45 m. GPS data describing the borrow areas were presented in the form of tables attached to routine reporting system developed by the General Directorate for Protection of the Marine Resources. These data were not projected to the same datum/projection system. In addition, some data were described geographically (using longitude and latitude) and some others were described using the UTM/WGS. All GPS data were re-projected to the standard projection. Finally, data was converted to ESRI shape-file GIS format. Coastal changes were identified using 'Union Overlay' which calculates the geometric intersection of any number of feature classes and feature layers within the system. Using this system of intersections, lost marine habitats and current land use on the reclaimed areas were defined. The present study focuses on three case studied locations namely, Tubli bay, Muharraq and the Northern coast of Bahrain. A number of species including keystone species were identified.

The average global annual ecosystem services based on Costanza et al. (1989, 1997) has been utilized in the estimation for the opportunity cost associated with the damage to the marine and coastal resources. The estimated figures were adjusted to Purchasing Power Parity (PPP), and other factors such as time value of money and inflation. Some assumptions and adjustments had to be made prior to the estimation of the value of the lost habitats.

The calculation was based on the requirement of the adjusted benefit value approach which has been selected to estimate the resource damage associated with land reclamation in Bahrain. The figures given in Costanza et al. (1997) were for the year 1994 prices. To extract the present value for the dollar today, the time value and the inflation over the past 14 years were accounted for. This value should be added to the Purchasing Power Parity (PPP) between Bahrain and the US.

It has been assumed that the commodities and services index rise annually by average of 3% and the inflation rate by 2%. Therefore, a 5% adjustment rate could be applied in order to obtain the present value for one dollar of 1994:

$$\$ = 1(1 + 0.05)^{14} = 1.98$$

Therefore, the ecosystem service value was multiplied by 1.98 to obtain today's values as per market price in the US. The theory of (PPP) and an equilibrium equation between the exchange rate for the US \$ and Bahrain Dinnars (B.D) were applied. The basis of PPP is the "law of one price" in the absence of transportation and other transaction costs, competitive markets will equalize the price of an identical good in two countries when the prices are expressed in the same currency hence:

$$PPP = (PPP_{GNP_y} / PPP_x)^E$$

where PPP GNP is the Purchasing Power Parity to Gross National Product for country y, and y in this case is Bahrain and x is the US; E denotes to the elasticity factor. According to World Bank statistics in 2004, the PPP GNP for Bahrain was about \$ 19,670 and for US was 29,240. Therefore, by applying elasticity factor equal to 1, we can obtain the PPP for Bahrain which was used in the calculation.

3. Results

The original land mass of the Kingdom of Bahrain was increased from 667.88 km² in 1963 to 759 km² in 2007/08. The land mass was 711 km² in 1998 which was a 7% increase but it increased by 13.6% in the year 2009, to around 759 km². The calculated reclaimed coastal areas during the last few decades reached up to 91 km² (Table 1). The period from 1997 to 2007 has particularly,

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