An Assessment and Mapping of the Potential Values of Ecosystem Services in the Kingdom of Bahrain

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Government Sector

Bahrain Authority for Culture and Antiquities (BACA)
Central Informatics Organisation (CIO)
Chamber of Commerce and Industry
Economic Development Board
Electricity and Water Authority
National Oil and Gas Authority
Ministry of Education
Ministry of Finance
Ministry of Interior
- Customs
- National Coast Guard

Ministry of Transport
Ministry of Works, Municipality and Urban Planning
- Directorate of Fisheries
- Directorate of Agriculture Affairs

Supreme Council for Environment
Supreme Council for Women
Survey and Land Registration Bureau
- Topographic Survey Directorate
- Hydrographic Survey Directorate

Private Sector

Environment Arabia Consultancy Services
Gulf Petrochemical Industries CO. (GPIC)
Mattar Jewellery
The Bahrain Petroleum Company (Bapco)
The National Initiative for Agricultural Development

Academic Sector
Arabian Gulf University
Bahrain Center for Strategic, International and Energy Studies
University of Bahrain

Civil Society & NGO's
Arab Youth Climate Movement, Bahrain Chapter
Bahrain Environment Society
National Institute for Human Rights
Youth and Environment Association

Intergovernmental
United Nations Development Programme (UNDP)
United Nations Environmental Programme –Regional Office of West Asia (UNEP-ROWA)

EXECUTIVE SUMMARY

This report presents an overview assessment of ecosystem services of the Kingdom of Bahrain, as part of the supporting documentation that together with the Biodiversity Baseline Report, Stakeholder Analysis, and Protected Area Strategy, all comprise foundational elements for the development of an update to the National Biodiversity Strategy and Action Plan (NBSAP) and the revision of the CBD Fifth National Report of the Kingdom of Bahrain.

Several methodologies were used in the Ecosystem Services Assessment, drawing on available data and published studies. The main ecosystem services being provided by the terrestrial and marine natural habitats of the Kingdom of Bahrain are first described, then summarized in terms of classes of ecosystem services being provided. Geographical areas within the Kingdom of Bahrain where there are potentially significant concentrations of ecosystem services are also highlighted.

This qualitative description of ecosystem services being provided by natural habitat in the Kingdom lays the groundwork for a description of the factors affecting ecosystem services delivery – both favourably (in the sense of management to restore or enhance ecosystem services delivery) and negatively (summarizing human pressures and natural factors that contribute to a decline in ecosystem health or a decrease in ecosystem services delivery. Limited information regarding trends in ecosystem services delivery are available, but where present, this information has both been summarized and used to discuss implications for future delivery of ecosystem services in the Kingdom of Bahrain and the wider Gulf region.

Valuation of the ecosystem services of the Kingdom of Bahrain is not possible without economic studies that utilize contingent valuation, travel cost method, and other social surveys. However, ranges of potential values are estimated using available information and benefits transfer, i.e. information derived from studies of that service in other parts of the world. In the absence of contingent valuation surveys of residents, visitors, and businessmen, these estimates of the ranges of values can provide a sense of the potential for investing in natural capital, as well as adequate information for trade-off analyses. The limitations of benefits transfer and the ways in which subsequent research in the Kingdom of Bahrain could fill data gaps and contextualize the ecosystem services valuation are discussed.

The final section of the report presents a short discussion of the implications of the Ecosystem Services Assessment for updating the National Biodiversity Strategy and Action Plan and the Fifth Report to the CBD. More generally, the utility of the ecosystem services approach for marine and terrestrial protected area planning, for ecosystem-based adaptation, for climate change mitigation planning, and for identifying opportunities for private sector investment in natural habitat protection, ecosystem services enhancement, and ecological restoration, is considered.

Five general conclusions can be drawn about ecosystem services, individually and as co-benefits, in the Kingdom of Bahrain:

1) Ecosystem services have both market and non-market values, in the Kingdom of Bahrain and in the wider region;

2) Certain areas that have a mosaic of habitats that generate ecosystem services that are in close proximity, or are particularly extensive and productive, can be flagged as delivering a concentration of ecosystem services; not coincidentally, many of these areas have been flagged in the Protected Areas Strategy (Abdulla 2015);

3) The costs of losing the valuable ecosystem services being generated from both marine and terrestrial ecosystems will be high and felt for many generations to come, and while some restoration may be possible, full ecosystem function is rarely achieved even despite significant investment of time and resources;

4) Island ecosystems (inland and marine habitats) within the Kingdom of Bahrain can be considered to provide risk minimization for existing and prospective investments, as the country continues to grow and as it diversifies its economic base; and

5). Maintaining connections between various valuable natural habitats will allow maximum service delivery, maintenance of values, and maximum resilience in the face of climate change.

The conservation of areas that are providing high levels of ecosystem services cover approximately 12% of the marine territorial water in Bahrain. Thus, if the number of ecosystem services provided is considered, there are four main regions in Bahrain to be highlighted. These are: a) the Northern Hayrat region and specifically Hayr Shtayyah and Hayr and Reef Bulthamah; b) northwest Bahrain including Fasht al Jarim; c) Fasht El Adm; and d) finally northwest of Hawar Islands that all demonstrate a higher number of ecosystem services than other parts of Bahrain and warrant careful management and conservation from the government in order to maintain the provision of these services.

Recommendations related to these conclusions and other implications of the report are offered to serve as supporting information to be presented to the Supreme Council for the Environment, as part of the overall strategy and action plan for the Kingdom of Bahrain.

LIST OF ACRONYMS

AGU: Arabian Gulf University
BD: Bahraini Dinar
BDB: Bahrain Development Bank
CBD: Convention on Biological Diversity
DPSIR: Driving Forces, Pressures, States, Impacts, Responses
EBSA: Ecologically and Biologically Important Areas
ESV: Ecosystem Services Valuation
GDP: Gross Domestic Product
GEMS: Directorate of Precious Metals and Gemstones
IBA: Important Bird Areas
IUCN: International Union for Conservation of Nature
KoB: Kingdom of Bahrain
MEA: Millennium Ecosystem Assessment
MoC: Ministry of Culture
MPA: Marine Protected Area
MRD: Marine Resources Directorate
NAS: National Academies of Science (US)
PMA: Ports and Maritime Affairs
PPA: Proposed Protected Area
PPR: Proposed Protected Regulations
REDD+: UN Program on Reducing Emissions from Deforestation and Forest Degradation
SCE: Supreme Council for the Environment
UNCLOS: United Nations Convention on the Law of the Sea
UNEP: United Nations Environment Programme
UNESCO: United Nations Education, Scientific and Cultural Organisation
UOB: University of Bahrain

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1.0 Background and Purpose of Assessment

The Kingdom of Bahrain is an island archipelago comprising 40 low-lying islands within a marine area of over ten thousand square kilometres (Survey and Land Registration Bureau, Kingdom of Bahrain 2015). Bahrain is very much a marine state; the combined land area of the islands (728 square kilometres) is less than a tenth of the nation's territory. Nonetheless, the terrestrial areas are important to biodiversity and human well-being alike. As is the case in the bulk of the Arabian Peninsula, the soil is predominantly sandy and clay sandy soil in the upper strata, and arable land is confined to the coastal margins (GoB/UNDP 2007). Coastal lands provide areas for development, recreation, and nature conservation, and marine areas offshore support vibrant fisheries, tourism, and a wider array of species, including the world's second largest dugong population.

The Kingdom of Bahrain signed the Convention on Biological Diversity (CBD) on the 6th of September 1992 and formally ratified it on the 8th of August 1996. Under Article 6 of the CBD, Bahrain is required to proceed with updating the National Biodiversity Strategy and Action Plan (NBSAP). In 2007, Bahrain developed the first NBSAP draft in collaboration with the United Nations Development Program (UNDP). The Strategic Plan of Biodiversity 2011-2020 including the Aichi Targets which was adopted at the CBD COP10 held in 2010 in Nagoya- requested that parties update their NBSAPs as per Aichi Target 17 which states: "*By 2015, each Party has developed, adopted as a policy instrument, and has commenced implementing an effective, participatory and updated national biodiversity strategy and action plan*".

A project agreement aimed at updating Bahrain's NBSAP and the development of the Fifth National Report to the CBD was signed in December 2012 between the Supreme Council for Environment (SCE) and the United Nations Environment Program (UNEP), which has catalysed this and other reports. To support the achievement of CBD commitments, this study presents information about the ecosystem services provided by the Kingdom of Bahrain's natural habitats, including what is known about their economic value and factors that affect ecosystem services delivery. Included is a desk-based review of economic valuation literature for biodiversity and ecosystems with particular focus on studies conducted in the Kingdom of Bahrain and the Arabian Gulf. A checklist of environmental, social, economic and cultural services provided by key ecosystems and biodiversity components in the Kingdom of Bahrain is provided, and both qualitative and quantitative assessments of key ecosystems and biodiversity services in the Kingdom of Bahrain were undertaken.

In the Kingdom of Bahrain, strategic approaches include utilizing a DPSIR framework and setting clear targets for conservation and management. Bahrain has the potential to be one of the first nations in the world to incorporate national scale ecosystem services assessment and valuation information within the DPSIR framework to achieve policies that aim to not only conserve ecosystems and biodiversity (and help achieve commitments under the CBD), but also safeguard societal benefits (e.g. Atkins *et al.* 2011 which investigates small scale case study initiatives in the UK).

2.0 Methodology and Information Sources

2.1 Synthesis of literature – published studies

Ecosystem services are the natural by-products of healthy, well-functioning environments. Such services include provisioning for food and water resources, as well as regulating and supporting functions such as flood control, waste management, water balance, climate regulation, and other processes. Human reliance on these ecosystem services is significant, although we rarely recognize the value of ecosystem services until they are lost. The oceans and coasts provide a great many of these critical yet undervalued services, supporting not only coastal inhabitants but all life on the planet.

Human beings derive many benefits from marine ecosystem services. Coastal wetlands maintain hydrological balances, recharge freshwater aquifers, prevent erosion, regulate flooding and buffer land from storms. Marine ecosystems supply us with food, recreational opportunity, pathways for transport, places to do research and learn, and spiritual values. Both coastal and marine ecosystems provide food, shelter, and living space for a broad array of life, in some cases providing essential and unsubstitutable support to wide food webs and biodiversity. Some of these many ecosystem services are illustrated in Figure 1.

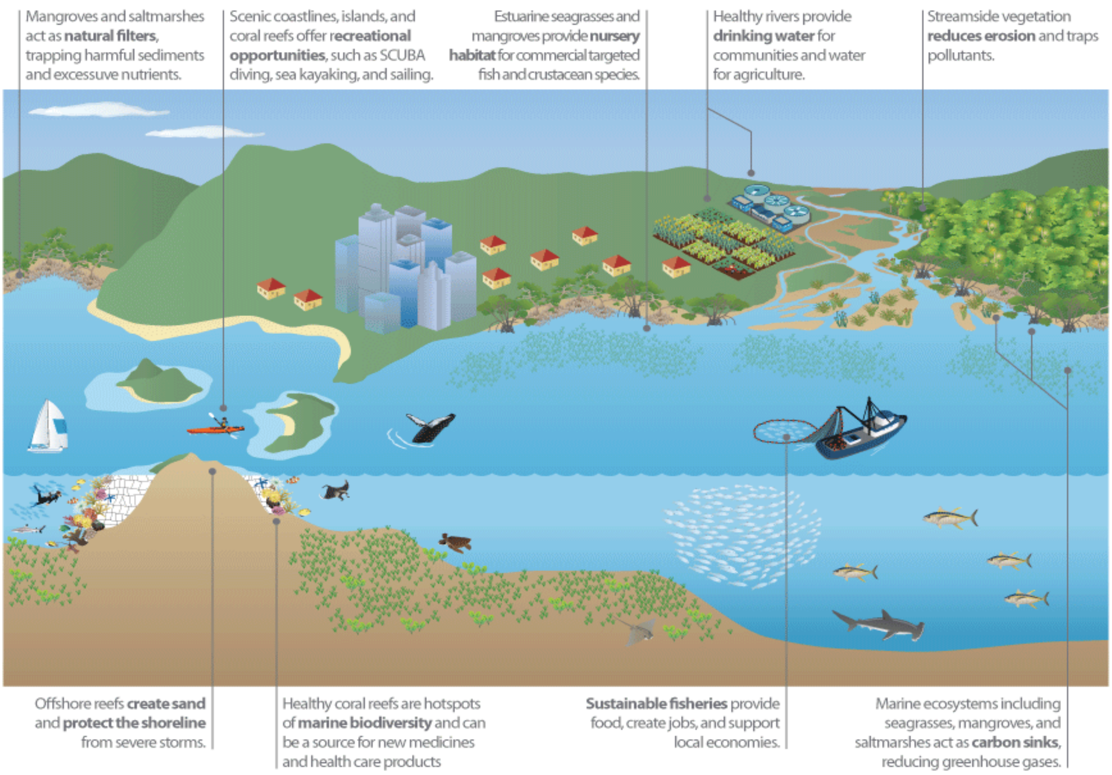


Figure 1. Schematic showing coastal and marine ecosystem services (from Agardy et al. 2011 UNEP EBM Manual)

With the vast majority of the world's coastal population living in close proximity to wetlands, reefs, and other coastal ecosystems, it is apparent that the services they provide present many of the "pull" factors that resulted in initial settlement along coasts as well as subsequent migration to them (Agardy and Alder 2005). Nearly 50% of the global population now lives within the thin band of coastal area that is only 5% of the total land mass, and dependence on these coastal systems is increasing.

Although individual ecosystem services originating from natural habitats on land, along the coast, and in the sea can be identified, assessed, mapped, and analysed for real and potential economic value, it is important to note that no ecosystem service exists in isolation from other ecological processes and delivery of other services. Natural systems are highly interlinked, and human well-being is coupled to the existence of multiple ecosystem services, all being delivered simultaneously. These linkages and feedback loops mean that development decisions or carelessness that cause the loss of habitat or species will affect more than one ecosystem service of value, and a multitude of stakeholder groups (see Figure 2).

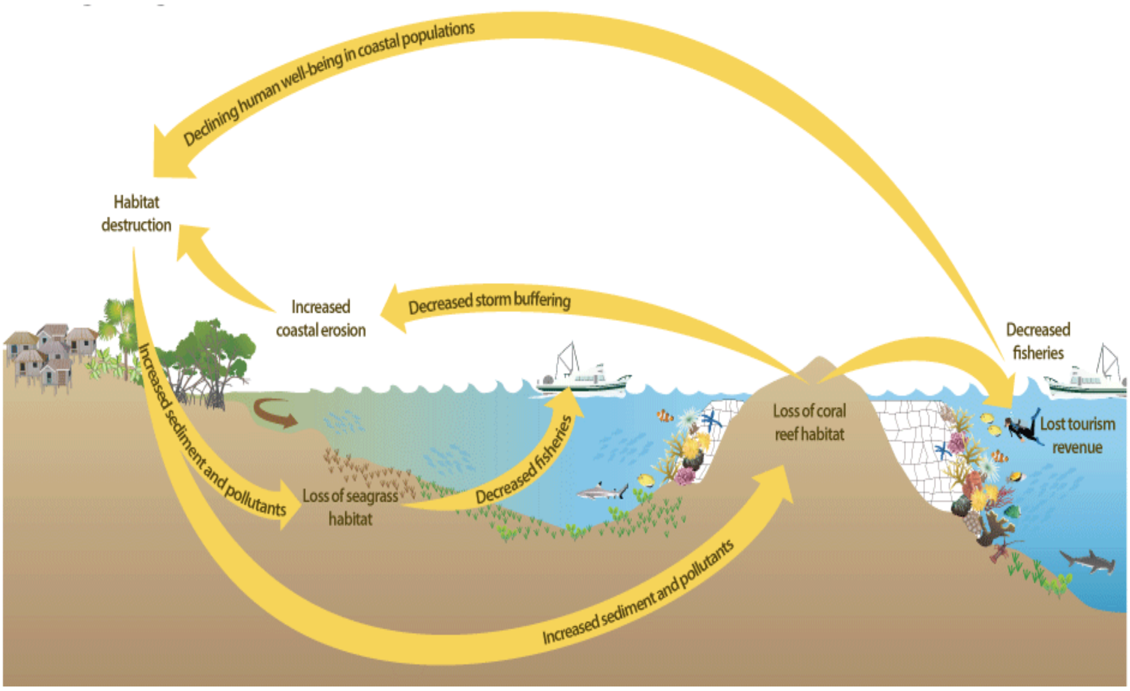


Figure 2. Connectivity between ecosystems, and linkages between ecosystems and human well-being (taken from Agardy et al. 2011 UNEP EBM Manual)

2.2 Habitat Mapping

The Government of the Kingdom of Bahrain has undertaken habitat classification, assessment, and mapping under various initiatives and programs. Given the preponderance of sea area, special attention has been given to determining marine and coastal habitat types and their spatial distribution. Marine habitats in the Kingdom of Bahrain have now been mapped (see Figure 3 below). Synthesis of GIS information shows that Bahrain has a total of

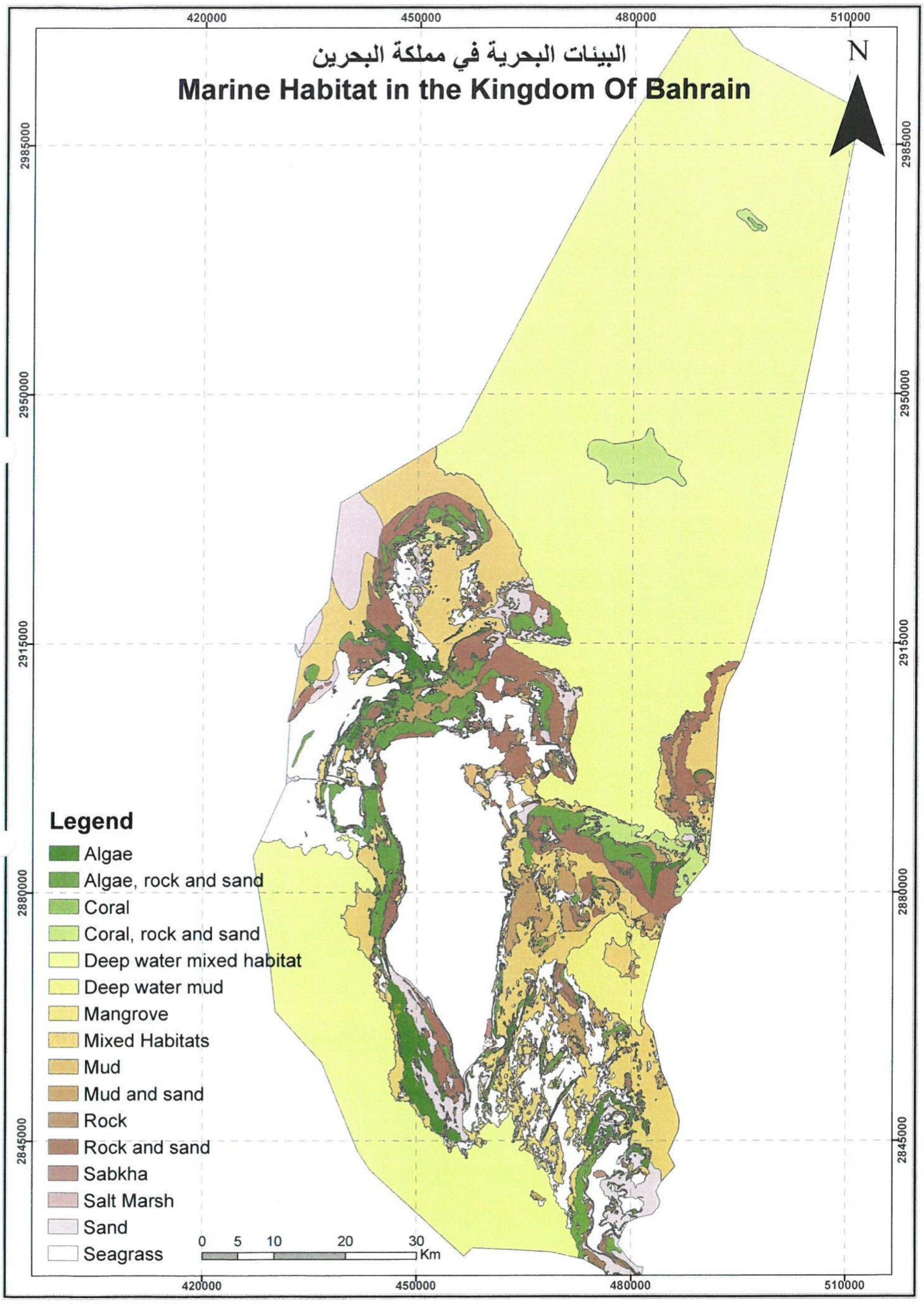


Figure 3. Marine habitats of the Kingdom of Bahrain (Survey and Land Registration Bureau, Kingdom of Bahrain)

2.3 Data on Ecosystem Services Values

Published information on economic values of the full range of ecosystem services being provided by the country's biodiversity and ecosystems is almost non-existent in the Kingdom of Bahrain. Proxy studies done in neighbouring countries within the region can provide an indication of potential economic values, but additional social science will need to be conducted to ascertain true economic values, using the methods described in the next section. Workbook Portfolio 1 that describes the biodiversity of the Kingdom of Bahrain specifies the following ecosystem services of value: provisioning services including fisheries resources, pearls, dates, molasses, natural materials for crafts, date leaves for roofing/ shelter, algal food supplements; regulating services including coastal protection (day-today shoreline stabilization and hazard mitigation), water purification, carbon sequestration; supporting services including nutrient cycling and oxygen production; and cultural services including education, ecotourism, recreation, scientific research, and general aesthetic values (see Figure 4).

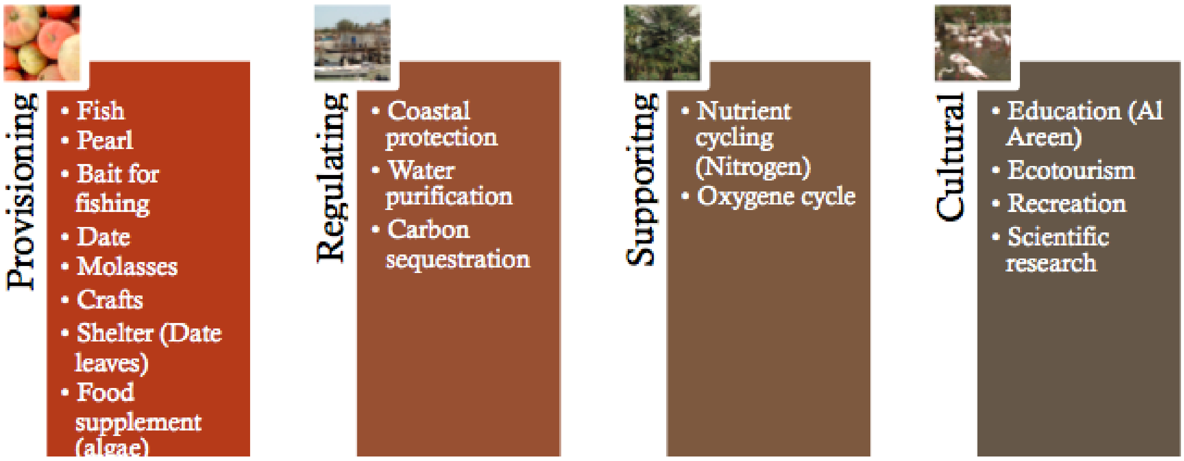


Figure 4. Specific ecosystem services of the Kingdom of Bahrain that have potential economic and social value. (Adapted from Bahrain Biodiversity Workbook Portfolio 1)

2.4 Valuation methods

Although neither a full assessment of all ecosystem services, nor valuation exercises to determine the true economic values of the services identified were within the scope of this study, this assessment highlights ecosystem services provided as co-benefits that have both market and non-market value. As "value" essentially relates to the realization of these benefits, valuation is however somewhat subjective and highly case-specific. As such, important benefits may be being provided by natural habitats in the Kingdom of Bahrain (as elsewhere), which have little apparent value because those benefits are not captured on the market or assessed by non-market valuation. As illustrated in Figure 5, values can be derived that reflect either real or hypothetical value. In the Kingdom of Bahrain, the number of valuation studies undertaken to date is limited, therefore discussion of the value of natural habitats and insular ecosystems is at present hypothetical.

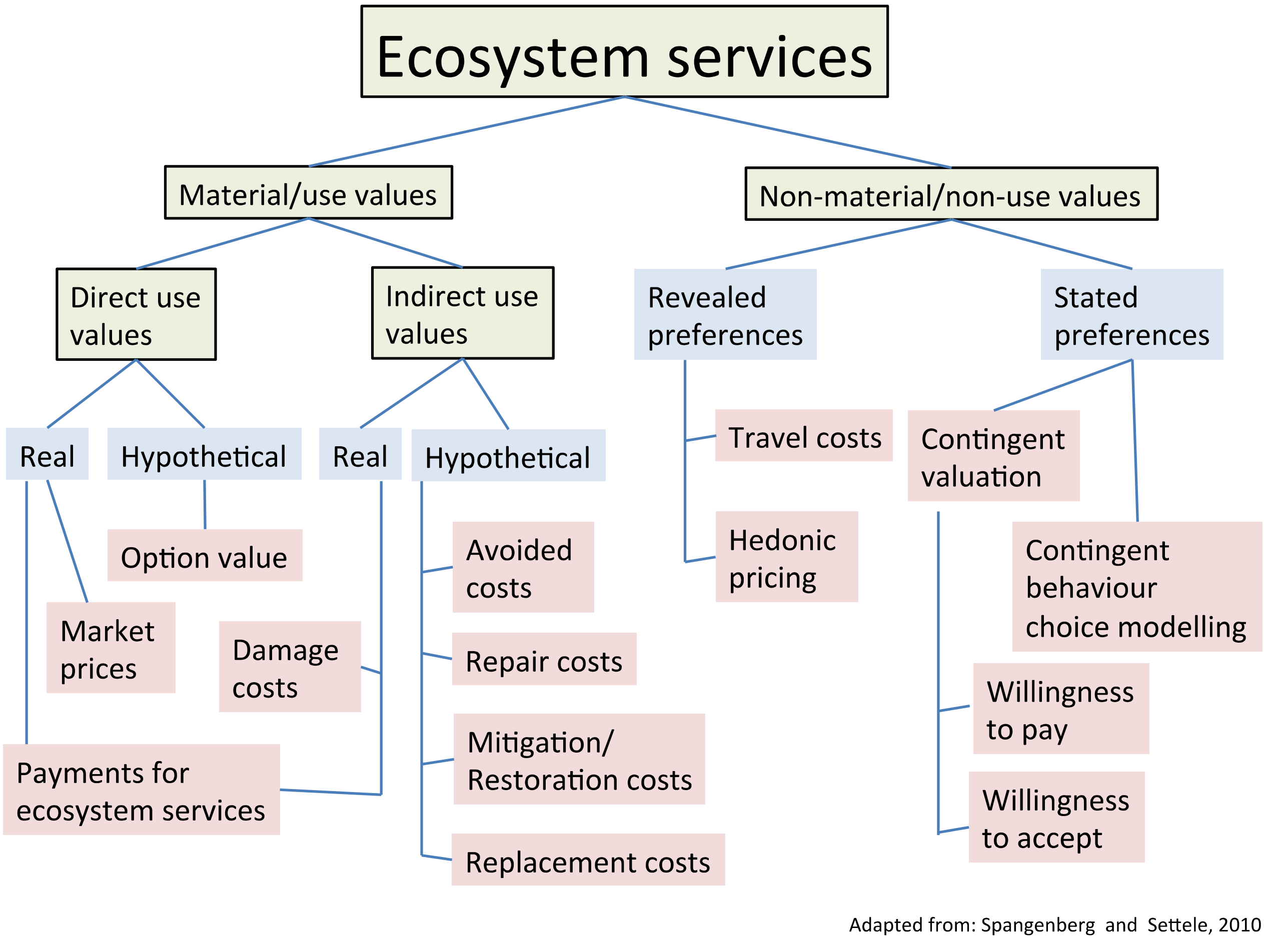


Figure 5. Valuation framework (taken from Spalding 2013)

A robust valuation framework captures all values (market and non-market). The most common, and most appropriate framework for aggregating the value of ecosystem services is Total Economic Value (TEV). According to Philcox (2007), TEV divides the value of ecosystem-based goods and services into two categories:

1) Use values: direct use value (e.g. provisioning services such as food, water); indirect use value (e.g. regulating services such as climate control, waste assimilation, water quality), and; option value (i.e. the value derived from the option to make use of a resource in the future);
2) Non-use values (including existence value, bequest value, and altruism value).

In the case of the Kingdom of Bahrain, some economic values can be attached to certain ecosystem services originating from natural habitats; however a comprehensive assessment has not been done and the exact derivation of known values cannot be ascertained. At the end of this report, recommendations are made for applied research that could help assess the full range of ecosystem services values, and tie these values to specific locations in the Kingdom.
Abdulla 2013 points to localized assessment of some values; for instance it has been estimated that the three northern oyster beds in that region generate US$3.4 to $227 billion

per year. Add to that the fisheries values, estimated at nearly $35 million annually (Directorate of Fisheries, 2013). These values go beyond purely economic market values: fishing contributes to national food security and employment; some 7000 people fished in 2012, for instance (Al-Mealla et al. 2014).

These figures are illustrative, but they do not give the whole picture of ecosystem services values. For the purposes of this report, hypothetical use values based on studies from other regions have also been utilised, and are discussed in relation to the case in the Kingdom of Bahrain from three different perspectives: first, the hypothesized values of coastal ecosystem services to Bahrain itself; second the values from a regional perspective (the Arabian Gulf region), and third, the values of these services on the global stage.

This approach allows a range of values, based on economic analyses undertaken for these ecosystem types elsewhere in the world, to be presented. With this potential range of values, and knowing the areal extent of mangrove, seagrass, salt marsh, sabkha, algal mats, dunes, and plateaus, as well as having some indication of their relative condition around the Kingdom of Bahrain, an estimate of total potential ecosystem services values has been generated by ecosystem type. To ensure robustness it is recommended that additional studies be undertaken to: confirm these values, understand how they are being realized in Bahrain, and use this information to inform investment in ecosystem protection as part of national biodiversity conservation strategies.

3.0 Ecosystem Services Assessment

The ecosystems of the Kingdom of Bahrain have a role in supporting the overall biodiversity, natural productivity, and environmental health of the country, as well as the region. Many coastal and inland habitat types perform pivotal roles, and their loss could create irreversible degradation and lost opportunities to take advantage of natural capital and its benefits. In particular, mangrove, seagrass, nearshore rock or shellfish reefs, macroalgae assemblages, and tidal flats with associated algal mats play a role in maintaining coastal water quality. This in turn allows for recreational and tourism use, reduces costs of desalination, diminishes the chance for public health problems relating to exposure to toxins (via bathing or seafood), and supports profitable and culturally important fisheries. Similarly, mangroves, seagrass, salt marsh, and associated coral reefs offshore maintain shorelines and navigation channels, reduce chronic erosion, and buffer land and property from storm surges. Mangrove and seagrass are particularly critical in supporting fisheries production – valued by commercial, traditional, and recreational fishers alike. Inland arid regions and plateaus support regional biodiversity, and wider ranging migratory birds, and freshwater springs and streams further support biodiversity. Collectively, these natural ecosystems play a key role in contributing to a healthy, aesthetically pleasing, and resilient island environment in the Kingdom of Bahrain.

3.1 Typology of Ecosystems

The Kingdom of Bahrain exhibits a variety of habitats across its inland, coastal, and marine ecosystems. While all these systems are interlinked, it is possible to create a typology of ecosystems that provide ecosystem services of value to humans. This typology is presented in Table 1, below.

Table 1. Typology of habitats found within the Kingdom of Bahrain

Typology of Habitats Within the Ecosystems of Bahrain
a. Marine Ecosystems
i. Coastlines and Beaches
ii. Mangrove
iii. Seagrass
iv. Algal Communities
v. Coral Reefs
vi. Sabkhas
vii. Salt Marsh
viii. Oyster reefs (pearl oyster habitat)
b. Small Islands /Islets
c. Desert Ecosystems
i. Sand Dunes
ii. Jabals / Plateaus
d. Freshwater Springs and Streams

3.2 Assessment of Ecosystem Services from Each Ecosystem Type

3.2.1 Marine Ecosystems

Coastlines and Beaches

The coastline of the Kingdom of Bahrain is 126 kilometres, and includes sandy beaches and rocky/ gravel shores and coastal cliffs. Beaches are sites for recreation, including swimming and picnicking, but also support a diverse fauna that includes shorebirds and seabirds, crustaceans, and meiofauna, *inter alia.* Rocky shorelines are variable in topography, including low elevation cobble and dramatic limestone cliffs, such as occur in the Hawar islands (especially Umm Hazwarah and Al-Wakurs). The distribution of mud flats is usually restricted to low-energy sheltered areas, like Tubli Bay. Mudflats in Bahrain are distinguished by high primary productivity and, thus, provide valuable feeding grounds for a variety of resident and migratory seabirds (KoB 2006).

Mangrove

Mangrove refers to a group salt-adapted trees that form mangrove fringes and forests across the tropical regions of the world, and it occurs as a natural coastal ecosystem in the Kingdom of Bahrain's coastal strip (Naser and Hoad 2011). Mangrove acts to stabilize navigation channels and shorelines, prevent inundation from sea level rise and from shamal-induced flooding of coastal property by the sea (Ellison 2010). Mangrove is also one of the most important buffers against catastrophic flooding brought about by cyclones or tidal waves (Arkema et al. 2013).

Like saltmarsh, mangrove trees can export nutrients to the nearshore environment, and they most certainly trap sediments (in Bahrain entering the sea mainly through atmospheric deposition in natural conditions, and by sediment release during in-filling, dredging, and coastal constructions). They also act to trap heavy metals and other toxins, and to some extent they can maintain salt balances (though this service is likely overcome by the high salinity of Gulf waters, exacerbated by the addition of brines from a multitude of desalination plants across the region). Thus mangrove plays a critical role in maintaining water quality, even as groundwater, freshwater, and seawater become increasingly degraded (UNEP 2014).

Mangrove channels and tide-inundated mangrove support a variety of fisheries species through provision of nursery habitat. These fisheries are of cultural and economic importance to the Kingdom of Bahrain. Recent studies have quantified the contribution of mangrove nursery habitat to fisheries production, by gauging estimated losses in terms of fisheries yield and profitability once mangrove is deforested (Aburto-Oropeza et al. 2008). At the same time, mangrove supports broader avian, fish, crustacean, mollusc, and sponge diversity, and may be one of the most important supporting service-providing ecosystems across the globe as well as at a local level.

Mangroves also fix carbon and sequester it in soils, making this habitat extremely important in climate change mitigation (UNEP 2014). Emissions resulting from mangrove losses make up nearly one-fifth of global emissions from deforestation, resulting in economic damages of some US$6 - 42 billion annually. Mangroves are also threatened by climate change, which could result in the loss of a further 10 - 15 per cent of mangroves by 2100 (UNEP 2014).

Seagrass

Seagrass provides feeding and breeding grounds for most neritic species that live in tropical and subtropical environments. It has been estimated that some 80% of coastal fisheries species rely on seagrass during some part of their life histories. The nitrogen-fixing ability of the seagrass rhizomes allows these aquatic flowering plants to thrive even in the low-nutrient conditions typical of tropical seas. Therefore while the biodiversity of a seagrass meadow at any point in time may be relatively low (especially when compared with coral reefs, or with transitional ecosystems like estuaries and mangroves), the cumulative biodiversity can be high, with support to extensive food chains (van Lavieren et al., 2012). Component species of seagrass meadows, such as tunicates, exert controlling effects on phytoplankton production and thus support wider food webs (Agardy and Alder, 2005).

Eleven species of seagrasses have been recorded from the whole Arabian region; three of these - *Halodule uninervis, Halophila ovalis, Halophila stipulacea* – have been recorded in Bahrain (Sheppard et al., 1992). Seagrass ecosystems occupy approximately 33,700 hectares. The meadows provide habitat for finfish, mollusks, crustaceans, sea turtles, and even marine mammals. The dugong population that Bahraini waters support is thought to be the world's second largest (currently about 3000 individuals), with only Australia's Great Barrier Reef population being larger. Both dugong and sea turtles (green and hawksbill sea turtles) are flagship and umbrella species, indicating ecosystem condition, and both rely on intact and productive seagrass for feeding. Seagrass is especially important for the herbivorous green sea turtle, for which the main source of food in the region appears to be Bahrain's seagrass meadows. Sea turtles are also used traditionally, and although hunting is banned, hawksbill eggs taken from nesting beaches are sometimes eaten. In such cases seagrass has added value of supporting a culturally important traditional use, though whether this is sustainable is open to debate, given the population dynamics of sea turtles in the Gulf region.

Seagrass, like mangrove, acts as a buffer against storm surge, tsunamis, and other catastrophic events, including significant shamals. Plants retain the sediment on the soil, keeping it from being deposited along the shoreline in severe weather events. Similarly, seagrasses stabilize the sea floor, providing a stable environment for infauna (meiofauna and burrowing clams, worms, etc.) as well as demersal marine species. These functions are commonly lost when seagrass is physically damaged. Seagrass meadows can be directly damaged during dredging or infilling, and indirectly affected by pollution (particularly sediments and excessive nutrients), over-fishing, species invasions, and losses of key component species through collection or displacement by invasives. When these factors act in concert, as they do in most stressed coastal and marine ecosystems worldwide, the results can be catastrophic for seagrass. Damaged or degraded seagrass can be restored (Ganassin and Gibbs 2008), but restoration takes time, is highly expensive, and in only successful under optimal conditions.

Seagrass meadows are important for fixing carbon and sequestering it in soils; as such, seagrasses belong to a group of marine habitats known as Blue Carbon ecosystems. While the standing stock of seagrass is relatively low compared to mangrove forests, the ability to store carbon and thus mitigate against climate change is significant, especially in areas like Bahrain where these flowering plants occur in extensive undersea meadows. Recent research indicates protection of seagrasses may be a crucial policy response to climate change (Hejnowicz et al., 2015).

Algal Communities

Macroalgae similarly provide habitat to support a wide array of species (including commercially valuable fishery species), influence water quality, and sequester carbon.
In the Arabian Gulf, and specifically in the waters of Bahrain, macroalgae communities are common on hardbottom substrates (Sheppard and Borowitzka 2011). These algae show seasonality, and many species are annual in terms of frond production. Red, green and small species of brown algae often intermingle in deeper waters, while the larger species of brown algae (especially Sargassum) are generally found in shallower waters (Sheppard and Borowitzka 2011). In Bahrain, extensive concentrations of brown algae and floating algal mats are a focus of conservation interest – these dense areas of plant life may well provide supporting ecosystem services to maintain biodiversity.

Calcareous algae, found in shallow waters and often on reef flats, are another class of algae that provide ecosystem services. The limestone contained in calcareous algae are bioeroded and form the white sand on Bahrain's sandy beaches. Over a hundred algal species have been recorded from the western Arabian Gulf (Sheppard and Borowitzka 2011).

Coral Reefs

The extensive coral reefs that can be found in the waters of the Kingdom of Bahrain provide a wide variety of ecosystem services – of all the natural habitats of the Kingdom, these are the ecosystems that provide the most tangible value to humans. These values include shoreline stabilization and buffering land and lives from cataclysmic storm events, providing areas for diving and other recreation, sequestering carbon, and supporting biodiversity and fisheries or food security (Barbier et al, 2011; Moberg and Folke, 1999; TEEB 2009). Coastal protection, food security and revenue from tourism can be especially important in allowing coastal communities to adapt to climate change threats such as sea-level rise, more extreme weather events and droughts or famine. An additional known value of coral reefs is the value of bioprospected pharmaceutical compounds.

Among the natural habitats present in Bahrain, coral reefs are perhaps the best understood in terms of ecosystem services values, even though the list of species present has not been confirmed and a comprehensive study of Bahrain's coral reefs is needed. Coral reef and reef mosaic habitats account for approximately 500 hectares in the Kingdom, however the values of reefs extend well beyond their geographic footprint. Reefs themselves and organisms associated in some way with reefs, such as manta rays, reef sharks, groupers and wrasses, etc., have been assessed elsewhere for the monetary and non-monetary values they provide. Contingent valuation using the travel cost method and willingness to pay surveys in other countries suggest that both local communities and tourists see value in reefs and reef-associated biodiversity, and that these values can far exceed the extractive values derived from fisheries harvest or use of reef materials for construction (see for example Anderson et al., 2010; Cagua et al., 2014; IUCN 2013).

Physical, biogeochemical, and ecological interactions occur between mangroves, seagrasses, and coral reefs, making these known interconnected systems (Moberg and Ronnback 2003). By dissipating wave and current force, reefs create shallow lagoons and bays that are suitable ecosystem for mangrove and seagrass growth. This is essentially a symbiotic relationship at the beta or habitat level, wherein mangroves and seagrasses then filter pollutants and sediments from the marine waters, allowing further development of the complex reef system. It has been thus hypothesized that the presence of these interlinked ecosystems within a region may considerably enhance the ecosystem services provided by one single ecosystem (Moberg and Ronnback 2003).

Alongi (2008) suggests that the extent to which coral reefs and mangroves offer protection against catastrophic storm events, such as tsunamis, may depend not only on the relevant features and conditions within the mangrove ecosystem, such as width of forest, slope of forest floor, forest density, tree diameter and height, proportion of aboveground biomass in the roots, soil texture, and forest location (open coast vs. lagoon), but also on the presence of healthy foreshore ecosystems, such as coral reefs, seagrass beds, and dunes. Other researchers hypothesize a similar systems interaction for coral reef, seagrass, and salt marsh complexes, as are found in Bahrain (Koch et al. 2009; Mumby 2006). Given the rapid rate of land reclamation and environmental change in Bahrain, the loss of mangrove and other coastal habitats will have concurrent opportunity costs (Nasar 2012 a; Nasar 2012c; Sale et al. 2011). This is reflected in the statement published in the UNU Report (Van Lavieren et al. 2011). "The loss of productive natural coastal ecosystems and associated marine life as a result of development is a major environmental issue facing the Gulf today".

Although not technically coral reefs, oyster reefs occur in a complex mosaic of reef, sand and mud flat, seagrass, and other nearshore habitats within the Kingdom of Bahrain. Oysters are biogenic, in that they create their own reefs and therefore contribute to shoreline stabilization and buffering land from storms and shamal events (Meyer et al. 1997). Oysters also act to purify water and therefore contribute to water quality maintenance. More importantly, in the Kingdom of Bahrain oyster reefs have supported a vibrant and culturally vital pearling trade that dates back centuries, even millennia (Carter 2005).

In June of 2012 the Kingdom of Bahrain was awarded its second UNESCO World Heritage site: the pearling trail known as "Pearling: Testimony of an Island Economy". The site is also said to be the last remaining complete example of cultural tradition and wealth generated by pearling when the trade dominated the Gulf economy (Al-Mealla et al. 2014). Recognizing the value of this cultural and natural resource, parts of World Heritage site are likely to be declared as additional marine protected areas, including three offshore oyster beds namely: *Najwat* and *Hayr Bul Thamah*, *Hayr Shtayyah* and *Hayr Bu Am'amah* (Al-Mealla et al. 2014). According to these authors, based on social science surveys, approximately 500 Bahraini families rely directly on the site and its resources. But perhaps more importantly, the *potential* economic value of this ecosystem service is significant, as it can form the base of high end, profitable, but low impact cultural and eco-tourism. This, together with non-market traditional use values suggest that reef and associated pearl bed ecosystem services have both existing and future economic value. Scientific interest in this area also adds to its ecosystem service value.

Sabkhas

Sabkhas are flat areas that occur between desert and ocean, characterized by efflorescences of salt, gypsum, and calcium carbonate as well as windblown sediments and often tidal deposits. Approximately 700 hectares of sabkha habitat exists in the Kingdom of Bahrain. Of this, a subset is coastal sabkha, which comprises the seaward part of the full sabkha ecosystem. Coastal sabkha is flooded several times a year when exceptionally strong shamal winds drive seawater inland. Coastal sabkha provides an important terrestrial ecosystem unlike any other when found above the high tide mark; below it and in the coastal sabkha provides valuable habitat for migratory, transient, and resident fish species, as well as birds and other taxa. Both forms contribute to Bahrain's unique landscapes, and likely acts to safeguard valuable coastal sites from erosion (Barth and Boer 2002). Sabkhas also cap carbon fixed by other coastal habitats, and thus play a role in climate change mitigation (Agardy et al 2013). Sabkhas comprise approximately 40% of the Kingdom of Bahrain's coastal habitat, and the country supports the predominant representation of this important habitat in the great Arabian Gulf.

Associated with some coastal sabkha are algal mats: communities of cyanobacteria that have their own unique faunal assemblages. Cyanobacteria are critically important in nitrogen fixation, especially in environments where other nitrogen-fixing plants are absent or rare. Cyanobacterial mats are diazotrophic, in that they use atmospheric dinitrogen (N_2) as the source of nitrogen (Stal et al., 2010*)*. These mats sequester large amounts of carbon and likely export that carbon to adjacent ecosystems. But the intrinsic life of the algal mat is also noteworthy: cyanobacteria live in close association with sulphur-fixing and other bacteria, other algae, and even viruses. Paradoxically, these bacteria and viruses may play a role in suppressing the spread of pathogens into other environments, much like the sea surface microlayer achieves this for the open ocean (Colwell, as cited in Agardy and Alder 2005).

Salt Marsh

The salt marshes of the Arabian Gulf region differ from those in temperate environments with major watersheds as they exist in highly saline environments, have sparse vegetation (for the most part) and are typically bordered by xeric vegetation or coastal sabkha. The total saltmarsh area in the Kingdom of Bahrain is approximately 84 hectares. Despite the small area and sparse vegetation, the salt tolerant plants of the salt marshes do provide services such as the filtration of water, and the stabilization of the shoreline. This shoreline stabilization acts by reducing wind erosion and erosion from tidal inundation or storm surges, including shamal events.

3.2.2 Islands

The small islands within this archipelagic nation provide habitat for nesting and wading birds, but also support their own fauna and flora. Extensive mudflats revealed by low tides along the east coast of Al Muhurraq support large numbers of wading birds. The six major islands in the archipelago are Bahrain (the largest); Al Muharraq; Sitrah; Umm an-Na'sān; Nabih Salih; and Jidda. In addition, the Hawār Islands are now a part of the territory of the Kingdom of Bahrain, after being awarded the disputed territory by the International Court of Justice in 2001. Additional small islets of rock are scattered around the Kingdom.

Small islands provide refuge for terrestrial bird and other species, resident and visiting alike. Similarly, the nearshore waters around small islands provide important refuge for marine species, including nursery or other life history stage habitats.

3.2.3 Desert Ecosystems

Sand Dunes

The extreme saline soil conditions of the sand dunes of the Kingdom of Bahrain limit the flora, but the habitats have high biodiversity value nonetheless. These saline habitats are concentrated in the central-southern part of Bahrain, and are dominated by a salt-tolerant flora, including the filamentous fungi *Fusarium* (Mandeel 2006). Such xeric environments are highly sensitive to climate change, as organisms are already living in environmental extremes, and a loss of species richness would be expected (Talhouk and Abboud 2009).

Jabals / Plateaus

Jabals and plateaus are arid landscape features in the Kingdom of Bahrain, found at the highest elevations. Jabals are small hills, reaching elevations of over 130 meters. The most well-known jabal is Jabal ad Dukhan (جبل الدخان) or the Mountain of Smoke (so-named for the haze that envelopes it on most days), at 134 m elevation. Dissolution depressions in the karst at some inland areas of Bahrain can contain both fresh and brackish water (Alsharhan et al. 2001).

Freshwater Springs and Streams

Freshwater springs are important to the biodiversity and ecosystem health of terrestrial habitats in the Kingdom of Bahrain, especially as surface waters are limited. Unfortunately, groundwater is increasingly being depleted across the country (and throughout the region) (KoB 2006). Ephemeral streams create wadis in some areas. In the north, natural springs supply water to lush date palm oases, and artesian wells are used for agriculture. Dates groves also can be found on the island of Nabih Salih, however these and other date palm habitats are increasingly threatened by water over-extraction.

Water in the Kingdom is supplied by several aquifers: the main aquifer, known as the Damaam Aquifer, which is recharged by the Eastern Arabian Aquifer system, and the Rus-Umm Er Radhuma Aquifer, Alat, Khobar, and Aruma subaquifers (Alshabaani 2010) (see Figure 6). These aquifers supply groundwater for human use, and also feed springs that support wider biodiversity. There is indication that salinization is occurring due to aquifer over-extraction, and Alshabaani (2010) cites disappearance of springs around the country.

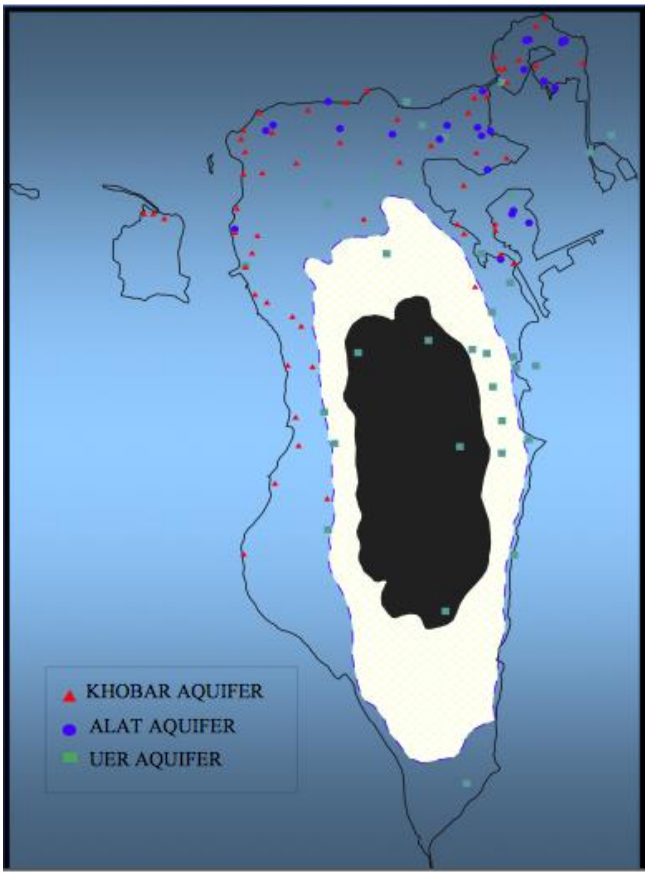


Figure 6. Location of select aquifers in the Kingdom of Bahrain (taken from Alshabaani 2010).

3.3 Matrix of Ecosystems and Services in the Kingdom of Bahrain

	Coral Reefs	Mangroves	Seagrass	Sabkha	Saltmarsh	Oyster Reefs	Beaches /flats	Islets	Algae	Dunes/ Jabals	Streams
Fisheries	X	X	X				X		X		
Pearls						X					
Material - crafts	X	X				X	X				
Dates										X	
Fronds - shelter										X	
Algae			X				X		X		
Coastal defence	X	X	X		X	X					
Water quality		X	X		X	X			X		
Carbon fixing		X	X	X	X						
Disease control	X	X	X	X	X				X		
Nutrient cycling	X	X	X		X	X			X		X
Recreation	X			X		X	X	X		X	X
Ecotourism	X			X	X	X	X	X		X	X
Aesthetic values	X	X		X	X		X	X		X	X
Science	X	X	X	X	X	X	X	X	X	X	X
Education	X	X	X	X	X	X	X	X	X	X	X

4.0 Factors Affecting Ecosystem Services Delivery in the Kingdom of Bahrain

4.1 Ecosystem Services Delivery, Listed by Ecosystem Service Type

The Kingdom of Bahrain, though limited in geographic scope, exhibits unique and globally significant biodiversity *in situ*, while contributing to the support of biodiversity in the wider region. Reports documenting the biodiversity of Bahrain and the Arabian Gulf (e.g. Nasar 2012b; Burt 2014; GoB/ UNDP 2007; Talhuok and Abboud 2009) treat biodiversity as either a characteristic of ecosystems/ habitats, or a metric by which to evaluate ecological functioning. Herein we follow the Millennium Ecosystem Assessment model (MEA 2005) and treat biodiversity as an important, and valuable, ecosystem service.

All natural habitats in Bahrain support floral and faunal species, of course, but certain terrestrial and marine ecosystems harbour more significant biodiversity. Coral reefs are especially biodiverse, and the reefs of Bahrain still exhibit intact coral cover, though coral cover and reef fish density are declining and coral cover averages only 5%. Corals themselves are only represented by a couple of dozen species, but the reef fish and invertebrate diversity associated with coral reefs shows much higher species counts (Wilson et al 2002).

Small islands in the archipelago harbour concentrations of biodiversity, and also provide globally significant critical habitat for key species. For example, Hawar Islands supports the largest breeding colony of the Socotra cormorant (*Phalacrocorax nigrogularis*), and the largest western reef heron (*Egretta gularis*) colony in the Middle East (KoB 2006). Hawar islands, along with Tubli Bay and Maqaba are recognized by Birdlife International as an Important Bird Areas. It is likely that Bahrain's seagrass habitat will also be similarly recognized as an Important Marine Mammal Area (IMMA), once IUCN's Marine Mammal Protected Area Task Force works with local stakeholders in the Middle East to identify priority areas for dugong.

Work to catalogue the Kingdom of Bahrain's biodiversity is ongoing. As of 2005, there were 1361 terrestrial and marine species described (see Table 2 below).

Table 2. Inventoried species in Bahrain by taxonomic group, as of 2005 (Kingdom of Bahrain 2006)

Major Group	Number of Species
Algae	34
Vascular Plants	357
Corals	24
Annelids	27
Sea Shells (Gastropods and Bivalves)	184
Crustaceans	64
Echinoderms	13
Insects	39
Arachnids	6
Fishes	239
Amphibians	1
Reptiles	20
Birds	331
Mammals	22
Total Number of Species	**1361**

The Kingdom of Bahrain has important biodiversity that merits special attention and conservation, and protected areas are both established and planned. Biodiversity at every level: genetic, species, and ecosystem or habitat level, has intrinsic value. In most assessments, the value of biodiversity is measured by how it enhances experiences: recreational use, tourism, cultural values embedded in a species or a suite of species, and maximised resilience of ecosystems in the face of large scale pressures and environmental changes. Most often, biodiversity values are determined by looking at recreational use centred upon it, such as value to bird-watchers, whale watchers, or other eco-tourists (McDonald 2009). Clearly the full suite of values must go beyond this.

Much of Bahrain's biodiversity is noteworthy in terms of regional and even global biodiversity. For instance, seagrasses support the world's second largest population of dugong, a charismatic flagship species that may be considered an indicator or umbrella species as well. Seagrass is also critical ecosystem for sea turtles (both green and hawksbill turtles). Sea turtles can also be considered as both flagship and umbrella species, and indicators of ecosystem condition, and sea turtles hold traditional and cultural values. The Kingdom has an array of habitats important for migratory and resident birds, and some sites are of global significance as Important Bird Areas (IBAs).

4.2 Delivery of Goods/ Productivity

Fisheries are an important sector in the Kingdom of Bahrain, despite the country's small size and geographically constrained fisheries operations. Some 6000 fishers target crustaceans, finfish, elasmobranchs, and other marine species. For some this fishing is a form of livelihood; for others, a culturally important activity. Bahraini fisheries generally employ one of four methods: gills nets, traps (gargoor), longline, and pole and line (Figure 7). Commercial fisheries in the Kingdom of Bahrain netted approximately 13 million BD in 2012 (Directorate of Fisheries, 2013).

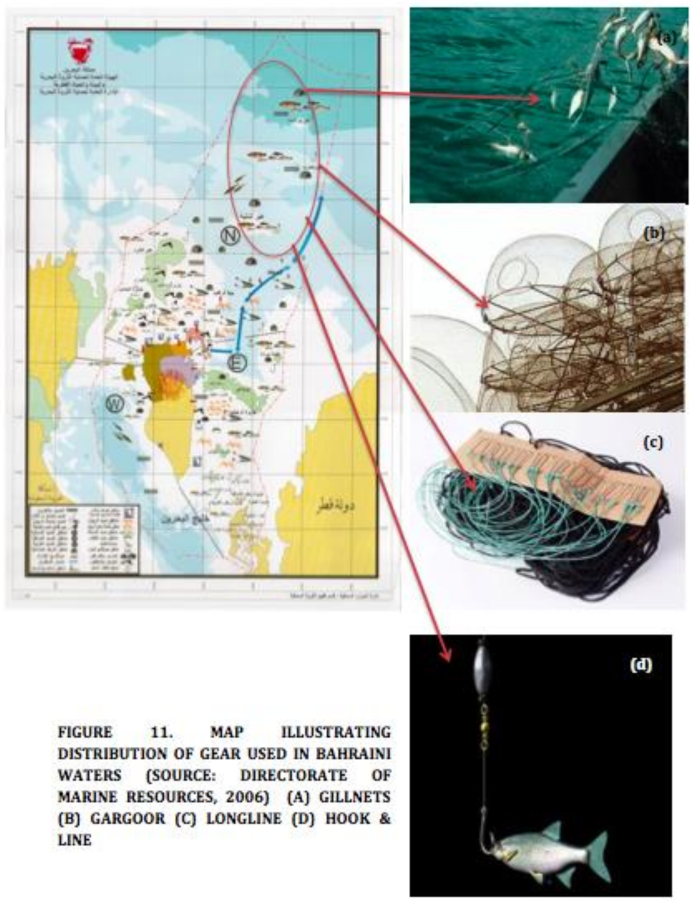


Figure 7. Types of fishing gear typically used in Bahrain.

There is some indication that fisheries populations are declining in Bahrain, as catch per unit effort has decreased, even though absolute catch quantities increased from 2010 to 2012. Table 3 shows changes in fisheries landings, and values, over this time period.

Table 3. Catch and values of main fish groups in 2000 and 2012 (Directorate of Fisheries 2013)

Fisheries	Quantity (mt)		Value (BD)	
	2000	2012	2000	2012
Finned fish	7147	5913	6.217 million	6.991 million
Crustaceans	4486	6809	3.166 million	5.875 million
Molluscs	85	264	0.049 million	0.295 million
Total	**11,718**	**12,986**	**9.432 million**	**13.161 million**

4.3 Provision of Fisheries Nursery Habitat

It is well known that mangrove and other coastal ecosystems provide essential support to fisheries production (fish, shellfish, molluscs, etc.). Organic matter produced by mangroves and associated species can be exported to adjacent ecosystems or consumed in the mangrove ecosystem itself. In Mexico, estimates of the amount of organic matter produced range from 1,100 to 1,417gm per year, providing food for economically important filter-feeding organisms such as clams and oysters. Export of this production also supports zooplankton in the Gulf of California, which in turn support higher trophic levels of organisms including commercially important species (Bouillon *et al.* 2002). Aburto-Oropeza et al. (2008) estimated the value of mangrove fish nursery habitat in the Gulf of California (Mexico): for every kilometre of mangrove forest fringe, an annual value of US$25,149 of services was provided to the coastal fish and crab fisheries. Organic matter exported by mangroves can also support localized agricultural or mariculture production (Hussain and Badola 2008).

Many fisheries species are dependent for some or all of their life histories on mangrove and seagrass. In the Gulf region, shrimp fisheries (approximately 95% of which target *P. semisulcatus*) are highly dependent on Arabian Gulf mangrove ecosystems (Burt, 2014). Falling leaves from mangrove evergreen trees provide energy-rich detritus for marine organisms (Hegazy 1998); it is estimated that mangroves provide over half the nutrients for tissue growth in a particular species of Gulf shrimp species (Al-Maslamani et al. 2013). Bahraini crab fisheries are also dependent on mangrove to some extent, as the juveniles utilize mangroves as nursery areas (Naderloo, Turkay and Sari 2013). Some shark and ray species utilize mangrove or seagrass as nursery habitat, and some finfish species are obligate mangrove utilizers.

4.4 Water Quality Maintenance

Coastal wetlands and marine ecosystems provide the vital ecosystem service of maintaining water quality, even in the face of significant pollution inputs that result from dumping, outfall discharge, riverine inputs, and run-off from land-based sources of pollutants. In the absence of these ecosystem services, threats exist to vulnerable species and humans alike. Human health is impacted by exposure to degraded water during bathing, ingestion of tainted seafood, and indirectly by the cascading effects of poor water quality that often leads to algal blooms and fish kills. There is some evidence that tipping the water quality balance towards degradation can trigger pathogenic activity in marine dinoflagellates and in pathogenic bacteria like *Cholera vibrio* (Anderson 2009). Gilbert et al (2002) makes the link between eutrophication, harmful algal blooms, and bacterial disease, citing research in Kuwait. Degraded water also affects fisheries productivity, mariculture production, and degrades recreational and tourism experiences, including creating the conditions that lead to beach closures (Robertson and Phillips 1995).

The consequence of poor water quality that results from loss or decrease of these ecosystem services is also a feedback loop that causes ecosystem services impairment in associated ecosystems. If, for instance, salt marsh is destroyed to accommodate land reclamation, and if no additional offsetting or mitigation takes place, the impact of the resulting lowered water quality can be to cause degradation of seagrasses and coral reefs, and declines in the delivery of the ecosystem services they provide.

Lowered water quality can occur when coastal ecosystems cannot keep pace with pollution inputs, as sometimes occurs with desalination operations. The drop in water quality then bears costs for desalination, as more energy and effort needs to be put into extracting pollutants from the source water. Apropos, there are indications that the Arabian Gulf as a whole is becoming more saline in response to the massive number of desalination plants operating in the region and releasing their brines into nearshore waters (Bashitialshaaer et al, 2011). The brines contain not only salts and concentrations of the metals found in the source water, but also treatment chemicals that include heavy metals, chlorine, volatile hydrocarbon, anti-foaming, and anti-scaling agents (Abazza, 2012). The environmental impacts of desalination have been well-studied, particularly in the Middle East where desalination will be the major source of freshwater going into the future (Lattemann and Hopner 2008; NAS 2008). However, no published studies to date look at the comprehensive costs in terms of ecosystem services loss or declines in ecosystem services value, though some studies address certain values, such as the impacts on ecotourism (Abazza, 2012). In addition, desalination costs themselves increase as feed water quality diminishes; this is the result not only of brine discharge with its salts, concentrated metals that were already present in seawater, and chemical additives, but also due to the overall degradation of coastal waters from industrial discharge, shipping pollution, sewage effluents, and run-off from land (as well as atmospheric deposition).

4.5 Shoreline Stabilization

Though there is not much longshore drift in Bahrain's nearshore environment, mangroves and other coastal and marine ecosystems may nevertheless be important for shoreline stabilization, as they are in other locations where they occur around the world (McIvor et al., 2012, 2013). Cyclonic events (see next section) are probably more of a threat than chronic erosion or sea level rise, although the preponderance of investment in development is taking place along the shore in the Kingdom of Bahrain, suggests that sea level rise may increasingly be a concern.

4.6 Storm/ Shamal Impact Mitigation

Whilst shoreline stabilization is an issue in all coastal nations around the world, catastrophic events are nonetheless considered a greater risk because they are difficult to anticipate. Shamal events are common in the region; a single shamal event in Dubai caused a 50cm drop in sea level in 5 minutes, then a 1.5m rise in the next five minutes. Intergovernmental Panel on Climate Change (IPCC) forecasting of increased intensity and frequency of storm events in a climate-changed future suggest vulnerabilities can be expected to increase. Earthquake-generated tsunamis and storm surges are also a threat to coastal property that can be mitigated by coastal ecosystems (Alongi 2008).

Published investigations of elevation and modelling at the fine scale to evaluate the contribution of coastal ecosystems to surge buffering and mitigation against storm events have not been undertaken in Bahrain, however existing models can give some indication of risk reduction performed by natural habitats. Figure 8 shows the storm surge build up of water as modelled for a typical intense wind event across the whole of the Arabian Gulf. The presence of mangrove and seagrass, along with coral reefs, can be expected to mitigate such surge activity in the Kingdom of Bahrain.

Many of the studies on ecosystem services derive value from costs accrued after the loss of the service (Agardy and Alder, 2005); existing ecosystem service value is thus thought of as avoided loss. For example, in Cancun (Mexico), the destruction of mangrove and poor building siting that did not obey set-backs has resulted in such severe erosion that the government spent over $70 US million recently to renourish resort beaches, at likely significant but unquantified cost to the source environment and the coral reefs offshore (the north end of the MesoAmerican Reef). Sand is already eroding away, this after the third major renourishment in the last ten years. In recent years sand erosion rates have been so high that hotels have had to close or limit access to grounds mid-season.

In SE Asia, the value of mangroves as a form of coastal protection was estimated at $367,900---$470,000 per square kilometre (McIvor et al 2012). Mangroves have also prevented extensive soil loss and water contamination that result from large storm surges; they have been found to similarly prevent declines in fisheries yields that result from storm-related changes in water chemistry, as well as declines in agricultural yields that occur as soils become salinized (UNEP 2014).

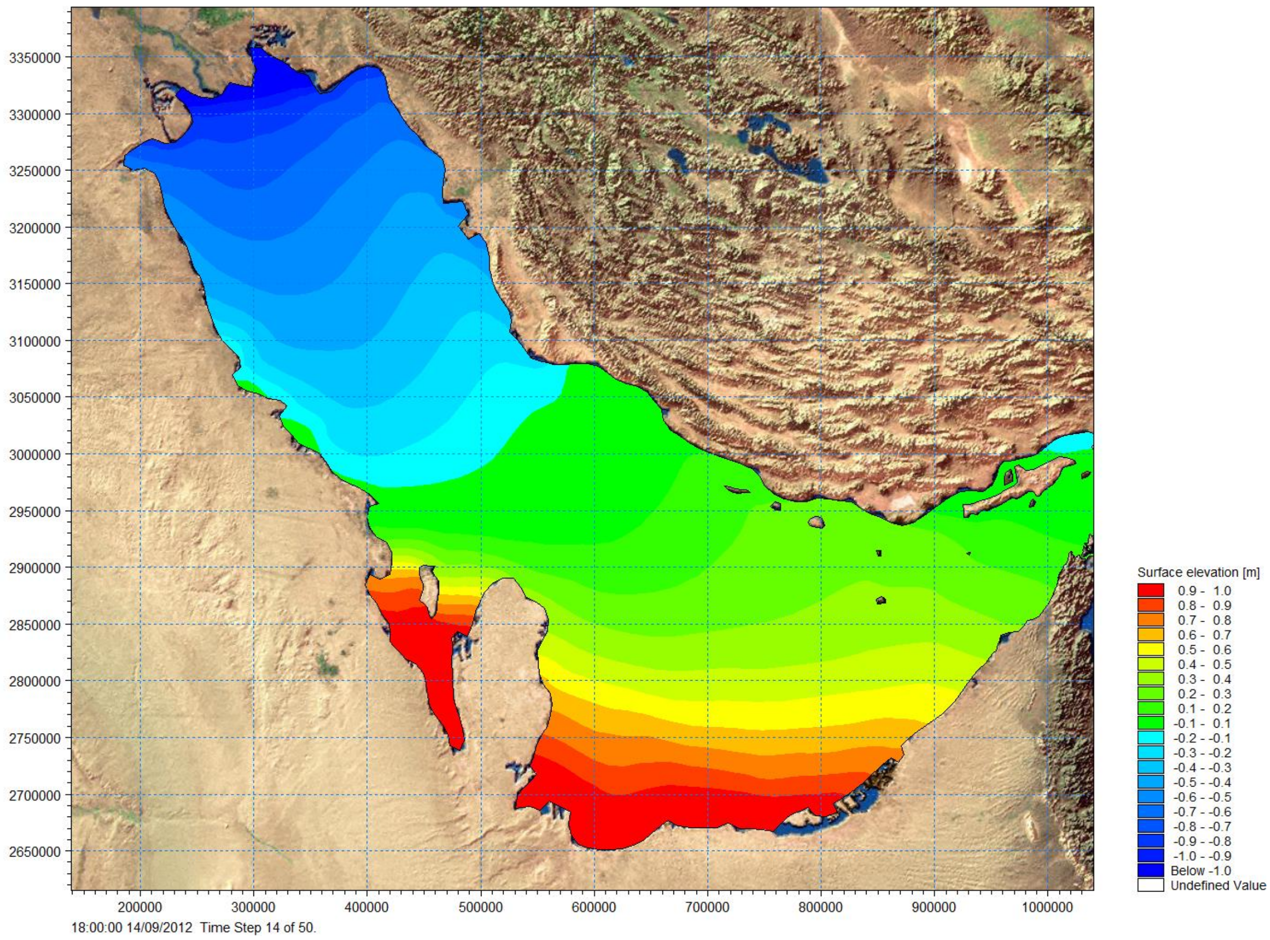


Figure 8. Modelled wind-induced surges across the Arabian Gulf (from Baird & Associates, unpublished database, Ottawa Canada)

4.7 Carbon Sequestration

With the exception of dunes and plateaus with little vegetation, all habitats in the Kingdom of Bahrain fix carbon. In some cases this carbon is sequestered in the soils, potentially mitigating the anthropogenic carbon dioxide release into the atmosphere that drives global climate change. However, no published research has been done on carbon sequestration rates in Bahrain, so the assessment of this ecosystem service has to rely on proxy figures from elsewhere.

One such proxy study was undertaken in nearby UAE. The Abu Dhabi Blue Carbon Demonstration project undertaken in 2012-2013 assessed carbon stocks in mangrove, seagrass, saltmarsh, sabkha, and algal mat habitats in nearby UAE. Although there was some variation in the carbon fixing and carbon stock values from various places in the Emirate, the range of values is considered representative of carbon sequestration rates in Bahrain. The average and standard deviation of these values is given in Table 4 below.

Table 4. Carbon stock measurements from the Abu Dhabi Blue Carbon Demonstration Project (cited in Agardy et al., 2013)

Habitat	Median	Mean	StDev	S.E.	± 95% C.I.	n
Algal flat	133.83	129.07	40.98	11.36	22.27	5
Mangrove	98.29	115.49	64.16	7.04	13.80	15
Sabkha	72.41	75.55	40.61	7.96	15.61	4
Saltmarsh	69.15	81.07	50.12	9.15	17.93	5
Seagrass	51.62	49.56	29.56	6.97	13.66	18

That mangroves sequester carbon at rates comparable to inland tropical forests is no surprise – carbon markets are already gearing for the selling of carbon credits from mangrove, and many countries are incorporating avoided mangrove loss into REDD+ strategies.

4.8 Tourism and Recreation

Tourism is a significant income generator in the Kingdom of Bahrain. According to the Bahrain News Agency (2015), tourism revenues in 2014 topped 228 BH, a 17% increase from 2013, and the number of tourists exceeded 10 million. There are 119 hotels in the Kingdom, 15 of which are 5 star hotels. Cruise tourism is also important: 26 cruise ship visits delivered 41,000 tourists to Bahrain ports. Tourism is thought to directly employ 2100 Bahrainis, and indirectly supports a much vaster number. The extent to which these numbers reflect interest in beaches or other natural habitats is not known, but it is clear that nature-based tourism has significantly growth potential.

Ecotourism is thus not well-developed in spite of the vast potential in the country. Natural habitats combined with culturally important sites could present myriad opportunities for ecotourism in both terrestrial and marine areas, to target coral reefs, sea grass beds, mangrove swamps and the variety of life on and around Hawar Islands (KoB 2006). Infrastructure to accommodate birders could well be developed in Arad Island, as noted in the draft Bahrain National Protected Areas Strategy (see draft report p 13). Cruise tourists could also be directed to natural areas, and boost revenue generation needed for management through the institution of entry fees.

4.9 Culturally Important Areas

The Kingdom of Bahrain has an extraordinarily rich history, and culturally important historical artefacts as well as contemporarily used areas are either provided by natural processes or protected by them (Khalifa and Rice 1986). For instance, the pearl diving traditions for which Bahrain was famous could not have developed without healthy and production marine systems. Archaeological artefacts occur along the coastline and important sites are protected from erosion, sea level rise, and storm impacts by the buffering effect of mangrove and saltmarsh along the coast and/or seagrass beds and coral reefs offshore.

4.10 Opportunities for Research and Education

The arid inland areas, coastal habitats, and marine ecosystems of the Kingdom of Bahrain are a living laboratory. Given the scale of the landscape, and the fact that habitats are in close proximity, studies about the interlinkages of habitats, the factors that affect ecosystem health and service delivery, and the elements of resilience are feasible, and should be encouraged.

4.11 Factors Limiting or Enhancing Ecosystem Services Delivery

The health of ecosystems and the extent to which their functional diversity and general biodiversity is maintained directly affects the degree to which they can provide goods and services of value to human beings. But one critically important consideration is that these ecosystems and the services they generate cannot be viewed in isolation. The delivery of goods and services from natural systems is dependent not only on the condition of the ecosystem but also its functional linkages to associated ecosystems. For mangrove forests to continue to provide nursery grounds for commercially and recreationally important fish populations, the two-way linkages between mangrove and offshore ecosystems such as seagrass beds, coral reefs, and offshore landform features must be maintained. Similarly, offshore systems such as coral reefs create the sheltered conditions necessary for inshore systems such as seagrasses to thrive; while mangroves and saltmarsh act to trap sediments and nutrients that might smother or degrade seagrasses. When the strategies for biodiversity conservation and environmental protection are developed and / or updated in the Kingdom of Bahrain, it will therefore be important to consider the full suite of services, their values, and the impacts that human activities in any sector will have on continued delivery of these services. This is especially true as climate change adds to the spectre of cumulative impacts, and threatens to undermine the resilience of all marine and coastal ecosystems, in Bahrain as well as in the wider Arabian Gulf region.

Five general conclusions can be drawn about ecosystem services, individually and as co-benefits, in the Kingdom of Bahrain:

1) Ecosystem services have both market and non-market values, in the Kingdom of Bahrain and in the wider region;
2) Certain areas that have a mosaic of habitats that generate ecosystem services that are in close proximity, or are particularly extensive and productive, can be flagged as delivering a concentration of ecosystem services; not coincidentally, many of these areas have been flagged in the draft of the protected areas strategy;
3) The costs of losing the valuable ecosystem services being generated from both marine and terrestrial ecosystems will be high and felt for many generations to come, and while some restoration may be possible, full ecosystem function is rarely achieved even despite significant investment of time and resources;
4) Island ecosystems within the Kingdom of Bahrain can be considered to provide risk minimization for existing and prospective investments, as the country continues to grow and as it diversifies its economic base; and
5). Maintaining connections between various valuable natural habitats will allow maximum service delivery, maintenance of values, and maximum resilience in the face of climate change

5.0 Values of Ecosystem Services in the Kingdom of Bahrain

Relative quantity of services being delivered provides an important base for planning. However, knowing the economic values associated with those services can provide decision-makers with even more robust information. Undertaking Ecosystem Service Valuation (ESV) can be a complex and time consuming task as the ecological and social information required to accurately calculate the different facets needed to determine the monetary value of a particular service can be difficult to collect and analyse. Developing direct measures of the value of each service is challenging due to either lack of scientific understanding on ecosystems or lack of available data on the economic conditions associated with the commodities.

ESV has however been shown to be a critical component of decision-making in a variety of situations (from Abdulla 2013):

a) ESV can help prioritize conservation and management efforts in the context of constrained budgets and personnel. Options can be identified to maximize benefits to people by protecting and maintaining specific ecosystem services over others;
b) ESV can also be used as a negotiation tool, a basis for discussion, where stakeholders can participate to discuss the assumptions and parameters of ESV;
c) Monetary values for ecosystem services can be formally included in Cost Benefit Analyses that are the foundation of making decisions on trade-offs (see for instance Costanza et al 2006). In this way, ESV can allow decision-makers to optimize social well-being by making choices that emphasize the benefits over the costs;
d) ESV can be used to set prices and determine the amount payable within the context of a willingness-to-pay or receive approach. Payments for Ecosystem Services (PES) such as entrance fees to MPAs or World Heritage Sites can be built on ESV;
e) In the case of environmental damage such as ship grounding on reefs or oil pollution from a leaking vessel, ecosystem service degradation can be compensated for before (in anticipation) or after (remediating and restoring damage) environmental accidents. Ecosystem service values can also provide guidance in administrative prosecution or court proceedings and rulings;
f) ESV has been used for awareness raising, justification, and persuasion as it provides clear economic arguments by placing monetary values on services that then bolsters environmental arguments in political debates and is more likely to influence choices and decision-making.

A holistic understanding of ecosystems, the services they provide in a concise socio-economic context, and their importance (ecosystem values) is essential for developing an ecosystem-based management approach (McLeod and Leslie 2009). Economists sometimes measure the value of ecosystem services to people by estimating the amount people are willing to pay to preserve or enhance these services. Values are always context specific as they change across space and time.

Such ESV is used in a number of different ways by different actors. The schematic in Figure 9 shows the entry points of information and the potential uptake of it by private individuals, public entities, and commercial actors.

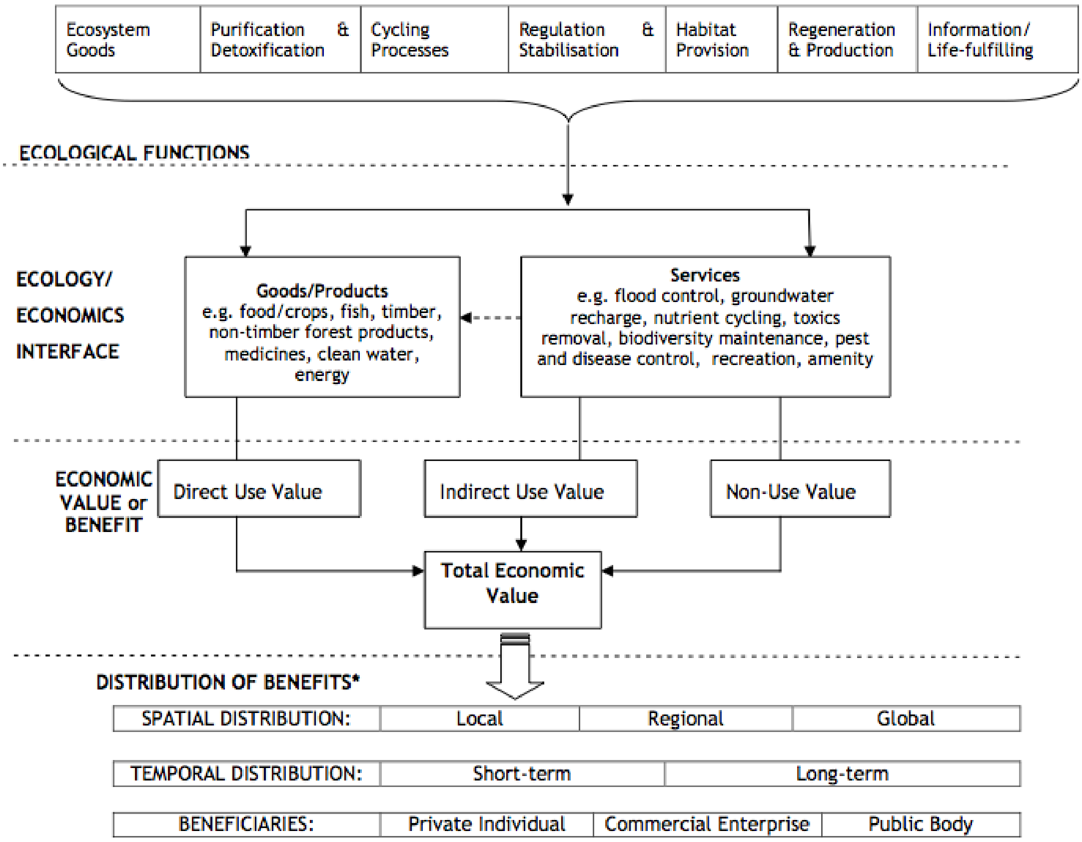


Figure 9. Integrated use of ESV (taken from Eftec 2005).

Regarding marine and insular environments such as Bahrain, it is critical to have the following basic information in order to value services provided by a site or an ecosystem and be able to spatially map them:

a) Fisheries: Landed biomass, net present value of fish and shellfish, and distribution of landings and value to communities;
b) Aquaculture: Harvested biomass and net present value of fish and shellfish, distribution of biomass and value to communities;
c) Coastal protection: Avoided area of land eroded or flooded, avoided beach nourishment and costs, avoided damages to property and infrastructure, number of people affected by erosion or flooding;
d) Wave energy conversion: Captured wave energy, value of captured wave energy, and environmental impact from storms;
e) Recreation: Economic value of recreational activities, visitation rates, and community access to activities;

f) Water purification: Filtration capacity of organisms and costs of human made water processing plants and filter systems.

Both composition and functioning of ecosystems and the resultant flow of ecosystem services will directly affect socio-economic well-being. Economic value of ecosystem services depends on the condition of an ecosystem, as it affects its function and therefore its ability to deliver the services that people rely upon for their lives and livelihoods. The state of the ecosystems (or ecosystem components) that are present needs to be assessed to examine their ecological potential and economic value and capacity to provide specific ecosystem services. An ecological assessment using the appropriate field methodology for each ecosystem is a necessary part of the process, however due to the nature of this study, estimates of mangrove, seagrass, salt marshes, coastal sabkha and algal mats carbon sequestration were based on research undertaken elsewhere (Agardy et al 2013).

5.1 Benefits Transfer and Range of Possible Economic Values of Ecosystem Services

In the absence of economic valuations, including studies that investigate perceptions of value and willingness to pay for services of value, the quantification of ecosystem services in Bahrain must rely on studies from other regions. Included in Table 3 are summarizes of some of the economic assessments of coastal ecosystem services from other areas as presented in the literature review undertaken by Barbier and his colleagues (Barbier et al. 2011). Some of these studies determined net present value for services that support marketable commodities (fisheries nursery habitat, for instance). Other studies model risk to hypothesize on the risk-reduction value provided by ecosystem services (shoreline stabilization and risk reduction in light of sea level rise and storm damage). For instance, Arkema and her colleagues (Arkema et al. 2013) estimated that over the next 90 years, mangroves, coral reefs, and seagrass beds – if left intact -- would protect $4 billion US in properties from sea level rise in Florida alone. A multi-institutional review of ecosystem services values of coral reefs and associated ecosystems (Conservation International 2008) similarly presents very high economic values for a wide range of services, from sites around the world, however these services are not disaggregated and benefits transfer to other areas may be problematic. As Ruffo and Kareiva (2009) point out, ecosystems and habitats must be individually assessed in order to make a case that a particular service is in fact being generated.

Table 5. Examples of ecosystem services and values of coastal habitats (taken from Barbier et al., 2011)

Mangrove

Ecosystem Services	Ecosystem processes and functions	Important controlling components	Ecosystem service value examples
Raw materials and food	Generates biological productivity and diversity	Vegetation type and density, habitat quality	US$484 – 585 $ha^{-1}yr^{-1}$ capitalized value of collected products, Thailand (Barbier, 2007)
Coastal protection	Attenuates and/or dissipates waves and wind energy	Tidal height, wave height and length, wind velocity, beach slope, tide height, vegetation type and density, distance from sea edge.	US$8966 – 10,821/ha capitalized value for storm protection, Thailand (Barbier, 2007)
Erosion control	Provides sediment stabilisation and soil retention in vegetation root structure	Sea level rise, tidal stage, fluvial sediment deposition, subsistence, coastal geomorphology, vegetation type and density, distance from sea edge.	US$3679 $ha^{-1}yr^{-1}$ annualised replacement cost, Thailand (Sathirathai and Barbier, 2001)
Water purification	Provides nutrient and pollution uptake, as well as particle retention and deposition	Mangrove root length and density, mangrove quality and area.	Estimate unavailable.
Maintenance of fisheries	Provides suitable reproductive habitat and nursery grounds, sheltered living space	Mangrove species and density, habitat quality and area, primary productivity.	US$708 - $987/ha capitalized value of increased offshore fishery production, Thailand (Barbier, 2007)

Seagrass

Ecosystem Services	Ecosystem processes and functions	Important controlling components	Ecosystem service value examples
Raw materials and food	Generates biological productivity and diversity	Vegetation type and density, habitat quality	Estimates unavailable
Coastal protection	Attenuates and/or dissipates waves and wind energy	Wave height and length, water depth above canopy, seagrass bed size and distance from shore, wind climate, beach slope, seagrass species and density, reproductive stage	Estimates unavailable
Erosion control	Provides sediment stabilisation and soil retention in vegetation root structure	Sea level rise, subsistence, tidal stage, wave climate, coastal geomorphology, seagras species and density	Estimate unavailable.
Water purification	Provides nutrient and pollution uptake, as well as particle retention and deposition	Seagrass species and density, nutrient load, water residence time, hydrodynamic conditions, light availability	Estimate unavailable.
Maintenance of fisheries	Provides suitable reproductive habitat and nursery grounds, sheltered living space	Seagrass species and density, habitat quality, food sources, hydrodynamic conditions	Loss of 12,700ha of seagrasses in Australia; associated with lost fishery production of AU$235,000 (McArthur and Boland 2006)

Saltmarshes

Ecosystem Services	Ecosystem processes and functions	Important controlling components	Ecosystem service value examples
Raw materials and food	Generates biological productivity and diversity	Vegetation type and density, habitat quality, inundation depth, habitat quality, healthy predator populations	£15.27 $ha^{-1}yr^{-1}$ net income from livestock grazing, UK (King and Lester 1995)
Coastal protection	Attenuates and/or dissipates waves and wind energy	Tidal height, wave height and length, water depth in or above canopy, marsh area and width, wind climate, marsh species and density, local geomorphology	US$*236 $ha^{-1}yr^{-1}$ in reduced hurricane damages, USA (Costanza *et al.* 2008)
Erosion control	Provides sediment stabilisation and soil retention in vegetation root structure	Sea level rise, tidal stage, coastal geomorphology, subsidence, fluvial sediment deposition and load, marsh grass species and density, distance from sea edge.	Estimate unavailable.
Water purification	Provides nutrient and pollution uptake, as well as particle retention and deposition	Marsh grass species and density, marsh quality and area, nutrient and sediment load, water supply and quality, healthy predator populations	US$786 – 15,000/acre capitalised cost savings over traditional waste treatment, USA (Breaux *et. Al.* 1995)
Maintenance of fisheries	Provides suitable reproductive habitat and nursery grounds, sheltered living space	Marsh grass species and density, marsh quality and area, primary productivity, healthy predator populations.	US$6,471/acre and $981/acre capitalized value for recreational fishing (east and west coasts of Florida) (Bell 1997) and $0.19 – 1.89/acre marginal value product in Gulf Coast blue crab fishery, USA (Freeman 1991)

Shoreline habitats (dunes, sabkha, etc.)

Ecosystem Services	Ecosystem processes and functions	Important controlling components	Ecosystem service value examples
Raw materials and food	Provides sand of particular grain size, proportion of minerals	Dune and beach area, sand supply, grain size, proportion of desired minerals (e.g., silica, feldspar)	Estimates unavailable for sustainable extraction
Coastal protection	Attenuates and/or dissipates waves and reduces flooding and spray from sea	Wave height and length, beach slope, tidal height, dune height, vegetation type and density, sand supply	Estimate unavailable.
Erosion control	Provides sediment stabilisation and soil retention in vegetation root structure	Sea level rise, subsistence, tidal stage, wave climate, coastal geomorphology, beach grass species and density	US$4.45/household for an erosion control program to preserve 8km of beach for Maine and New Hampshire beaches, USA (Huang *et al.*, 2007)
Water catchment and purification	Stores and filters water through sand; raises water table	Dune area, dune height, sand and water supply	Estimates unavailable
Maintenance of wildlife	Biological productivity and diversity, habitat for wild and cultivated animal and plant species	Dune and beach area, water and nutrient supply, vegetation and prey biomass and density.	Estimates unavailable

Coral reefs

Ecosystem Services	Ecosystem processes and functions	Important controlling components	Ecosystem service value examples
Raw materials	Generates biological productivity and diversity	Reef size and depth, coral type, habitat quality	Estimates unavailable
Coastal protection	Attenuates and/or dissipates waves, sediment retention	Wave height and length, water depth above reef crest, distance from shore, coral species, wind climate	US \$174 $ha^{-1}yr^{-1}$ for Indian Ocean (Wilkinson et al 1999)
Maintenance of fisheries	Provides suitable reproductive habitat and nursery grounds, sheltered living space	Coral species/ density Habitat quality, food sources, hydrodynamic conditions	US\$15-45,000 $km^{-2}yr^{-1}$ in sustainable fishing for local consumption and \$5-10,000 $km^{-2}yr^{-1}$ for live fish export (White et al 2000)
Nutrient cycling	Provides biogeochemical activity, sedimentation, biological productivity	Coral species/ density Sediment deposition Subsidence, coastal geomorphology	Estimates unavailable
Tourism, recreation, education, and research	Provides unique and aesthetic landscapes, suitable habitat for diverse fauna and flora	Lagoon size, beach area, wave height, habitat quality, coral species and density, diversity	US\$88,000 total consumer surplus for 40,000 tourists to marine parks Seychelles (Mathieu et al 2003) and meta-analysis of recreational values (Brander et al 2007)

The previously listed tables in which Barbier et al (2011) summarized valuations can be used to determine a range of possible ecosystem service values for the Kingdom of Bahrain. This benefits transfer information must be adapted to the particular circumstances of the ecology and environment of Bahrain, and the current and prospective uses of goods and services. For instance, in Bahrain the economic value of sea grass meadows is stemming from their importance as feeding grounds for the commercially important rabbitfish *Siganus canaliculatus*, nursery areas for the commercial prawn *Penaeus semisulcatus*, and a refuge for a high density of the spats of the pearl oyster *Pinctada radiate (KoB 2006)*.

A rigorous look at ecosystem services values must both appraise net present value and perceptions of value; and must also look into the future. The two considerations that must be addressed in this regard are how value changes over the passage of time (including, but not limited to, discounting rates) and the sustainability of stocks (for goods) and services (Bateman et al. 2011). It is thus recommended that future work target the development of predictive models that can better elucidate trade-offs. The result will lead to conserving and enhancing as much as possible of habitats, not just for biodiversity conservation but also to ensure yields of valuable ecosystem services for many years to come.

5.3 Geographic Areas of High Value for Ecosystem Services

The existing protected areas flag concentrations of biodiversity or habitat for special species; as such, these are *de facto* areas of high ecosystem services delivery. These include the Al Areen PA, the Hawar Island MPA, the Mashtan Island Nature Reserve, the Arad Islands, the Tubli Bay Reserve, and – most especially – Hayr Bulthama, with its coral reefs, and pearl oyster beds. Further study is needed to confirm or amend the identification of these particular areas as having the highest relative ecosystem services values.

Seagrass is a habitat with especially high ecosystem service values, including support to biodiversity, water quality maintenance, fish nursery habitat and fisheries productivity, and shoreline stabilization, along with carbon sequestration. The location of major seagrass beds is shown in Figure 10 below:

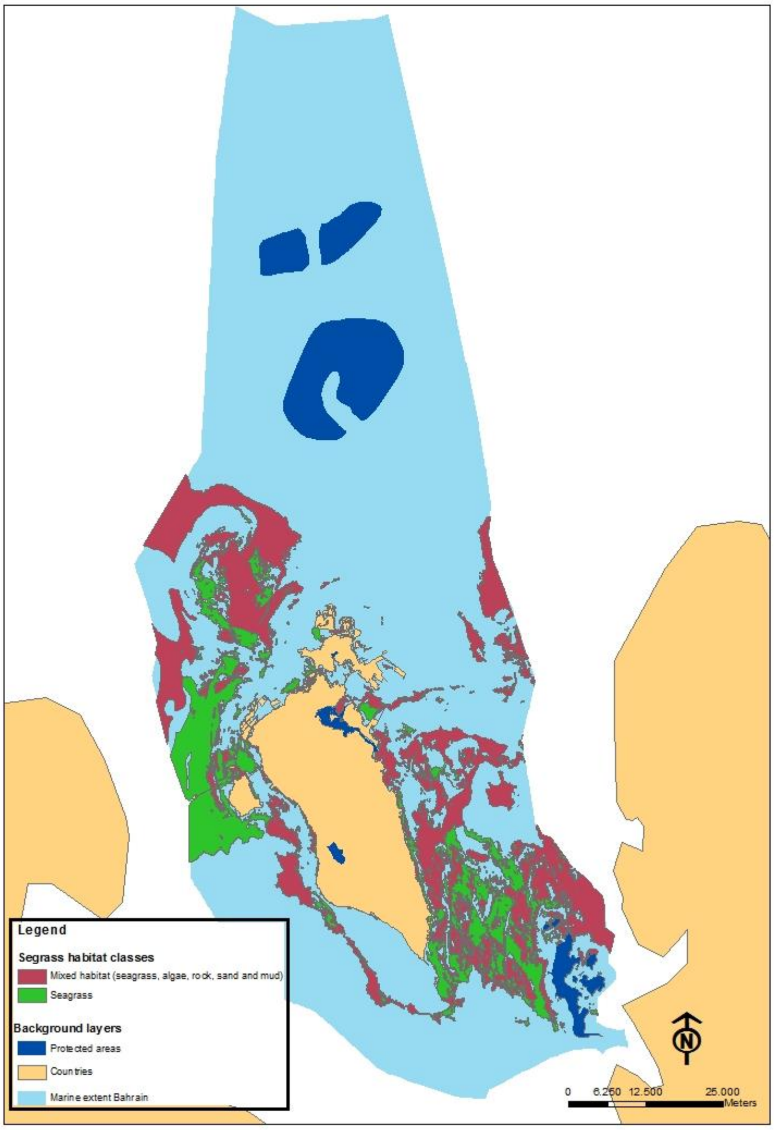


Figure 10. Location of major seagrass beds in the Kingdom of Bahrain (MARGIS). The Northern Hayrat region is a World Heritage Area but only Hayr Bul Thama is formally designated as a Protected Area.

The Bahrain Strategy for Protected Areas (Abdulla 2015) cites a variety of important areas that meet different criteria, all of which bear relation to ecosystem services and potential ecosystem service values. For instance, potential priority areas for biodiversity conservation refer to existing protected areas, as well as three main candidate sites that support threatened emblematic fauna such as marine turtles, dugong, or seabirds (see Figure 11).

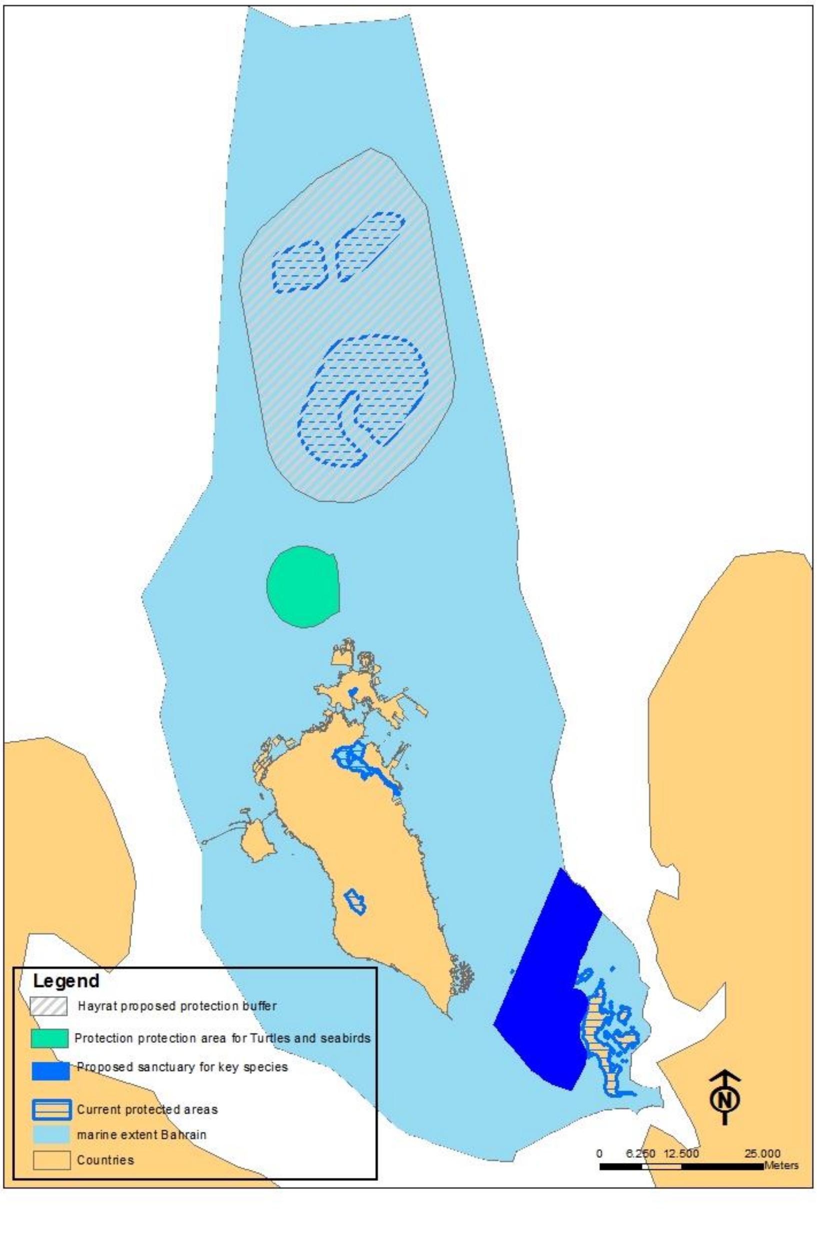


Figure 11. Location of potential priority sites for biodiversity conservation (from Abdulla 2015)

A slightly different picture emerges if one looks at priorities for fisheries. In the Bahrain Protected Areas Strategy (Abdulla 2015), important seagrass meadows (supporting rabbitfish *Siganus canaliculatus*, nursery areas for the commercial prawn *Penaeus semisulcatus*, and a refuge for a high density of the spats of the pearl oyster *Pinctada radiate*); and key areas for landings of shrimp and crab provide a slightly different prioritization (see Figure 12).

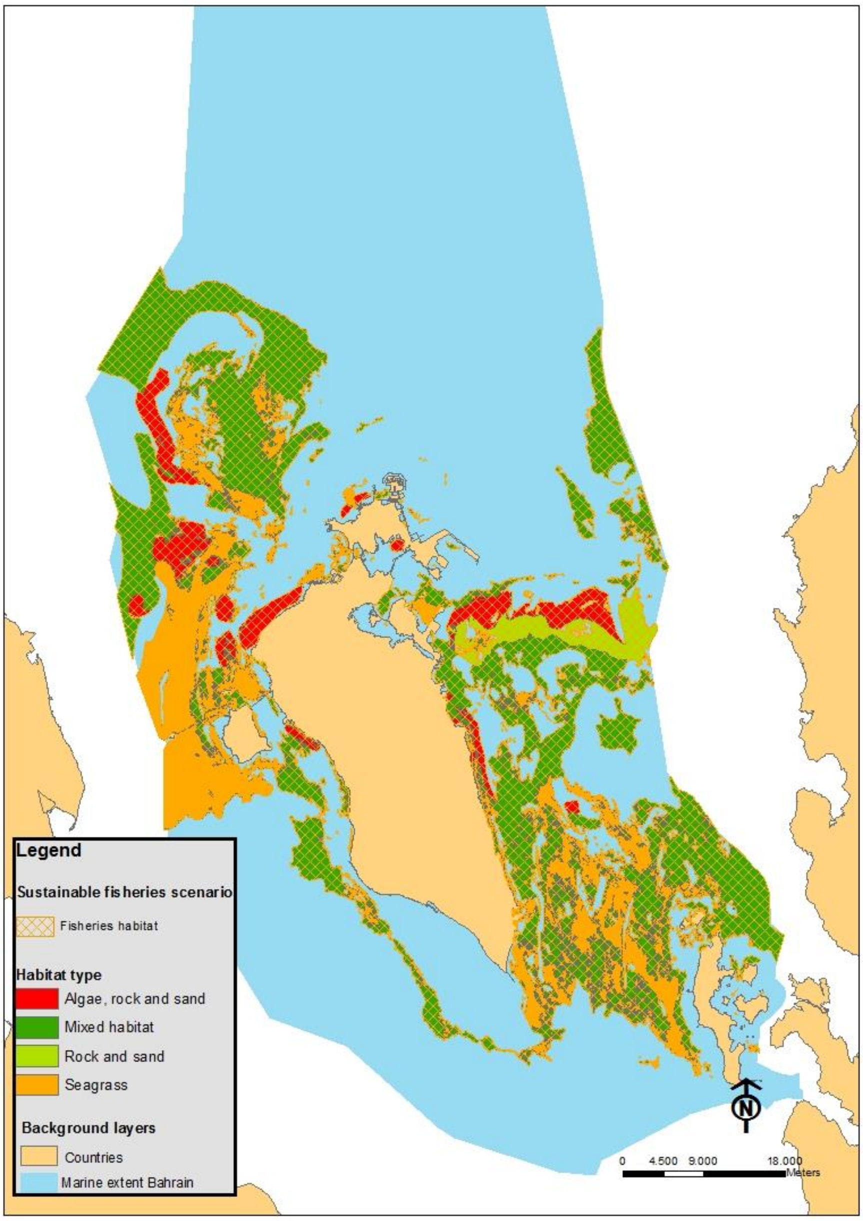


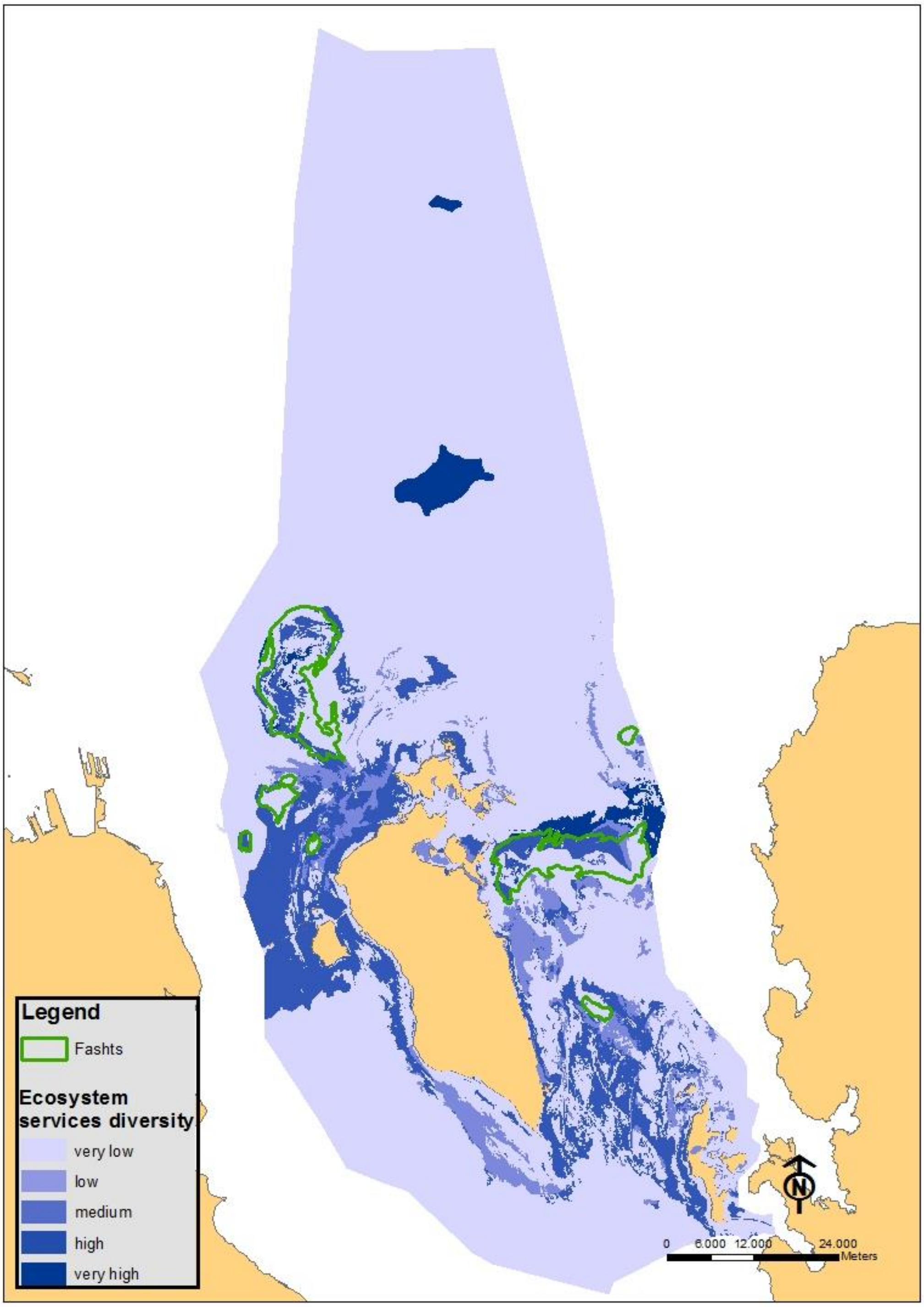
Figure 12. Priority areas for sustainable fisheries

Another scenario presents a case for the conservation and protection of specific areas due to the potential of habitats in these areas to provide a high variety of services. These services are namely provisioning of cultural and recreational services (tourism), regulating services (storm buffers, shoreline stabilization, and carbon sequestration), and genetic diversity (biodiversity), etc. (see Table 6).

Table 6. Categorisation of major marine habitat types in Bahrain by type and number of ecosystem services they provide, and the area (%) covered by each habitat type. * represents habitats / areas that if protected can meet and exceed the Aichi Target of 10%

Marine habitat type	Type/s of ecosystem services	diversity of ecological services	% area
Coral	Biodiversity/ tourism/ shoreline/ fisheries	Very High*	0,06
Coral, rock and sand	Biodiversity/shoreline stabilization/ fisheries/ cultural	Very High*	1,78
Mangrove	Shorelines/ storm buffers/ fisheries	High*	0,01
Salt Marsh	Shorelines/ water quality/carbon	High*	0,01
Algae, rock and sand	Support to biodiversity/ carbon/ fisheries	High*	4,28
Seagrass	Biodiversity/ fisheries/ carbon	High*	6,99
Sabkha	Biodiversity/ cultural	Medium	0,08
Mud	Biodiversity/ shell fisheries	Medium	0,17
Algae	Support to biodiversity/ carbon	Medium	1,77
Mud and sand	Biodiversity/shell fisheries	Medium	2,57
Rock	Fisheries	Low	0,03
Deep water mud	Support to biodiversity	Low	1,46
Sand	Tourism	Low	4,35
Rock and sand	Biodiversity	Low	6,20
Mixed habitat (seagrass, algae, rock, sand and mud)	Fisheries	Low	12,67
Deep water mixed habitat	Fisheries	Low	57,58

The conservation of areas that are providing "high" and "very high" levels of ecosystem services cover approximately 12% of the marine territorial water in Bahrain. The protection of these areas would surpass the Aichi target for 2020 (10%). Thus, if the number ecosystem services is considered, there are four main regions in Bahrain that provide the highest number of services (see Figure 13). These are: a) the Northern Hayrat region and specifically Hayr Shtayyah and Hayr and Reef Bulthamah; b) northwest Bahrain including Fasht al Jarim; c) Fasht El Adm; and d) finally northwest of Hawar Islands all demonstrate a higher number of ecosystem services than other parts of Bahrain and warrant careful



management and conservation from the government in order to maintain the provision of these services.

Figure 13. Areas that demonstrate the highest number of ecosystem services in Bahrain

In the absence of the data that are necessary for a comprehensive valuation of ecosystem services value, benefit transfer methods were used to estimate indicative and potential values of marine ecosystem services in Bahrain (see Table 7). Economic values were derived from meta-data analyses and habitat-specific reviews (Watson et al. 1993; Wilkinson et al 1999; Seenprachawong 2004; White et al 2000; Madani et al 2012; Salem et al. 2012). We also included values from the Bahrain-specific study by the World Bank (2013) in order to present a range of global to local values. However it is important to note that the World Bank study (2013) calculated the Bahraini value by taking the average value from global studies, estimating average GDP from those regions where the studies originated, and then adjusting the average value by increasing it proportionally according to per capita GDP in Bahrain. It did not factor in quality or condition of habitat or how it is valued (in terms of use) by Bahrainis.

Table 7. Potential and indicative values of marine ecosystem services in Bahrain that have been derived from globally and nationally relevant values using benefit transfer methods. Figures for Bahrain have been adopted from *World Bank 2013 and **Abdulla 2013 (value range for the 3 Northern Hayrat $96,911- $6,473,128 /ha/yr)

Marine Habitat	Global Value	Bahrain Value
Seagrass	A) Fisheries: Annual yield and landed value of prawns harvested from seagrass beds was estimated at AUS$ 41,000 per ha /yr (Watson et al 1993).	Mean $32,000 /ha/yr*
Mangrove	a) recreation and tourism: $37,927/ha/yr: mean mangrove valuation for (Salem et al 2012) b) coastal protection: $3,116/ha/yr: mean mangrove valuation for coastal protection/hectare/year (Salem et al 2012) c) Fisheries: $23,613/ha/yr: mean mangrove valuation (Salem et al 2012)	Mean $803/ha/yr*

	D) Water purification: US$ 1385-$6716 ha/ year for nitrogen removal (Grabowski et al 2012).	
Coral + Reef (Fasht)	a) Tourism: US$ 237, 000 / ha in Iran (in 2009) with a total economic value of at least US$ 14.6 mio/ yr (Madani et al 2012) b) Fishing: Local consumption in Philippines valued at US$ 150-450 ha/yr and live- fish export valued at US$ 50 -100 ha/yr for a total of US$200-550 ha /yr and a mean of US$ 375 ha / yr (White et al 2000) C) Coastal protection: US$174 ha/ yr for Indian Ocean based on impacts from 1998 bleaching event on property values (Wilkinson et al 1999) d) Biodiversity: Visitors willingness to pay for coral reef associated biodiversity was valued at US$ 15,118 / ha/ yr (Seenprachawong 2004) E) Water purification: Waste treatment and water purification services of coral reefs were valued at US$ 42/ ha/ yr (TEEB, 2009)	Mean $4422 /ha/yr*
Oyster Reef	a) Fisheries: Commercial fish value of a hectare of oyster reef US$ 4,123 per year (Grabowski et al 2012). b) Coastal protection: (1) Max. US$ 85,998 per hectare per year (Grabowski et al 2012) - (2)	Mean $3,285,020/ha/yr**

	One hectare of oyster reef habitat provides stabilization services valued from US$ 1,074,475 - US$ 1,504,265 as a net present value over the life of a similarly purposed man-made structure (life span of 20 years; Grabowski et al 2012 c) water purification: 1 ha value US$ 1385-US$ 6716 per year for nitrogen removal (Grabowski et al 2012).	

There are some important assumptions that must be stated when using these values, however. First, not all habitats, even when intact and relatively pristine, deliver the same benefits in different regions or contexts. A hectare of coral reef in good condition (with coral cover of greater than 30% coral cover) in Indonesia, for instance, is likely to yield significantly greater values than equivalent reef in the Gulf region. In part this is because high values come from places where benefits are being realized: e.g. where there is a thriving ecotourism (especially dive tourism) industry, where coral-reef fisheries are a critical source of revenue and livelihood, and where perceptions of the value of reefs are widespread and central to government policy and localized decision-making.

In the Kingdom of Bahrain, information on ecosystem services potentially being delivered from reefs (including oyster reefs), seagrasses, mangroves, beaches, and other habitats can be used to identify areas where the likely values, across all benefits, are maximized. Calculating a total value of all marine ecosystem services for Bahrain however would yield a number that is completely theoretical and fraught with compounded error. The values that are presented in the Table 7 and on the map are indicative values that demonstrate the potential economic value of marine habitats. Further targeted economic studies, including user surveys, contingent valuation, etc. will likely yield more robust results on actual values of habitats, which could then be used as a foundation for biodiversity planning and monitoring of management effectiveness.

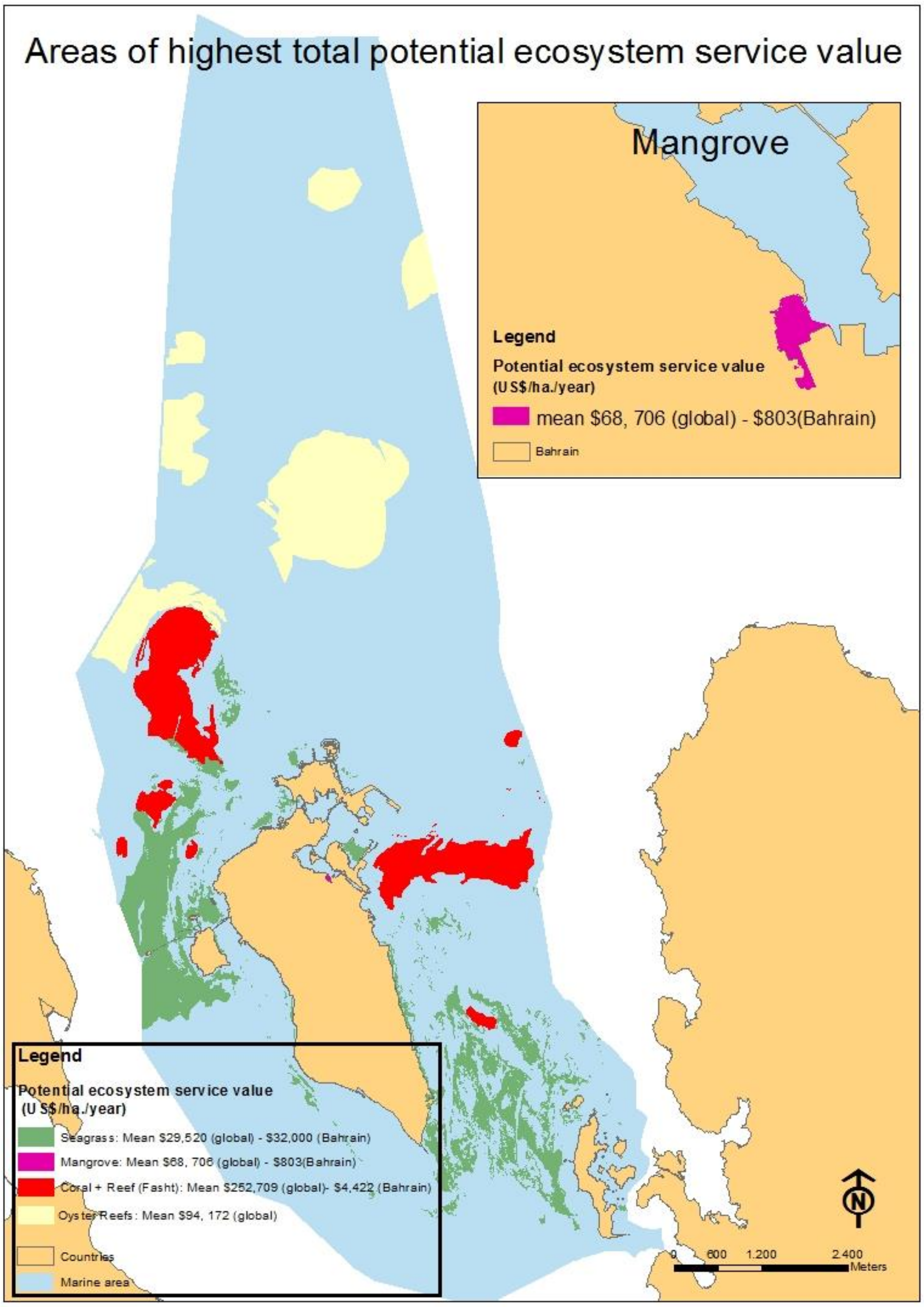


Figure 14. Areas of highest total potential ecosystem service value. The values are obtained using benefits transfer methods and present a range of global to local values.

5.4 Factors Affecting Ecosystem Services Values

Habitat loss appears to be the major driver of ecosystem services decline in Bahrain; many of the services being provided by marine and terrestrial ecosystems are compromised as the collective pressures from development, land reclamation, and pollution exact multiple cumulative impacts on these ecosystems (Figure 15).

The condition of the environment is not purely a function of what happens at sea, along the shore, or inland - these ecosystems are all intricately interlinked, with connections to land use, aquifer condition, and environmental trends happening at the regional and global scales.

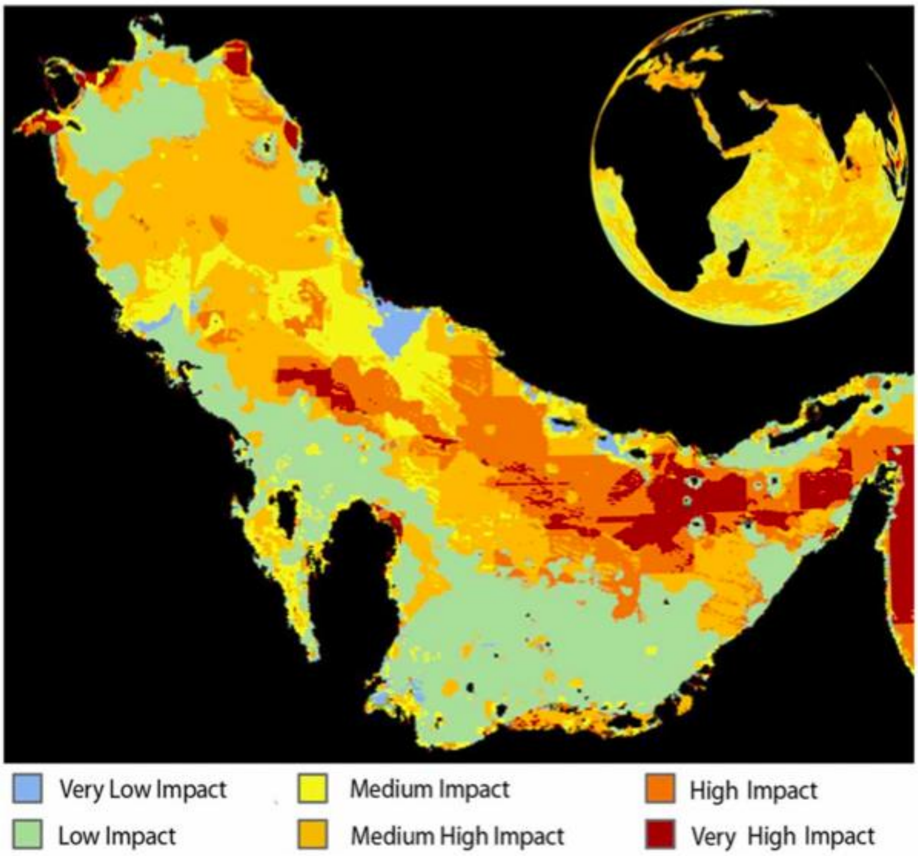


Figure 15. Cumulative impacts in the Arabian Gulf region (from Burt 2014).

At sea, major threats to ecosystems and delivery of their services comes from dredging and infilling, which disrupts the seafloor and also releases sediment into the water column, potentially smothering coral reefs and seagrass beds (Al-Madany et al. 1991; van Lavieren et al. 2011). Infilling and channelization may also be disrupting the coastal oceanography that links marine systems and allows water flushing, nutrient delivery, and movement of organisms from one ecosystem to another. This is turn can affect water quality, fisheries production, and overall environmental (and thus public) health (Kahn 2007; Kahn et al 2002). Researchers cited in van Lavieren et al 2011 indicate that land reclamation and dredging has caused permanent loss of primary nursery grounds for commercial shellfish and fish species in the Gulf (Bishop 2002; Munawar et al. 2002).

Information provided by Hamza of UAE University illustrates the link between terrestrial and marine environments. Hamza and Munawar (2009) discuss nutrient inputs, water quality, the role of atmospheric inputs, cross-subsidies among ecosystems (of nutrients) and general marine conservation in. One important line of inquiry that merits further research is the relationship between water quality and land degradation, especially as climate change and development in the region exacerbate both (Al-Madany et al. 1991, Khan 2007, Hamza and Munawar 2009, UNEP 2010b).

Flagship marine species such as dolphin, dugong and sea turtles continue to be at some risk from illegal fishing activity. It appears that most non-natural mortality of sea turtles and dugong is attributable to drowning in nets (illegal drift nets used at night). Nonetheless, sea turtle populations appear healthy. As in UAE, approximately three quarters of all sightings are green turtles, and this population extends to Pakistan and Oman; there are 6000-7000 adults in total. Hawksbill turtles are residents. There are 150-200 hawksbill turtle nests per year occurring on 17 islands, with another 150-200 occurring in UAE outside of Abu Dhabi. It is not known how many dolphins (IndoPacific humpback dolphin, finless porpoises, bottlenose dolphin, or common dolphin) die or are injured due to fisheries interactions or boat strikes.

Overfishing and illegal fishing may be undermining the Kingdom of Bahrain's marine ecosystems, however this may pale in comparison to the cumulative other pressures that occur locally, regionally and globally, which collectively affect the health of the wider environment. In light of this, it may be that fishing regulations will need to be adjusted in order to accommodate climate change-driven impacts on fish production, as well as related impacts on Blue Carbon ecosystems that support fish production.

As cited in the study undertaken in nearby Abu Dhabi (Agardy et al. 2013) there has been an alarming increase in red tides in the Arabian Gulf, with incidences rising in the last 10-15 years (though baseline was only established in 2002). Alien species are possibly being transported through ballast water, and have a role to play in bloom outbreaks (Anderson, 2009). The duration of some blooms (up to 2 months) suggests that flushing may be compromised in places where infilling has interfered with water circulation in mangroves; this interference with physical oceanography and coastal processes suggests impediment of ecosystem health and a corresponding loss of ecosystem services. Infilling, dredging, land reclamation, and coastal constructions impact not only the natural ecosystems directly in the footprint of development activity, but surrounding and linked areas as well.

All activities that affect the water quality of marine areas have the potential to seriously undermine marine and insular ecosystems and the services they provide; this in turn can feed a positive feedback loop in which water quality accelerates in its decline. Such situations are best avoided by continued careful assessment and thoughtful planning which may be enhanced and informed through additional social and natural scientific research (see recommendations). Being able to identify natural areas of high value, and consideration of the current and future threats that these areas may face, should provide one of the necessary elements for that careful planning.

6.0 Discussion and Recommendations

The values attached to Bahrain's ecosystems for the services delivered can be described in three ways: local value to the Kingdom of Bahrain and its residents; regional values given the trends in ecosystem degradation and loss throughout the Arabian Gulf region, and the value of these ecosystems at the global scale.

Clearly, the marine and terrestrial ecosystems of Bahrain provide valued ecosystem services, some of which are already being realized locally. More precise economic values that these ecosystems generate for the Kingdom and its inhabitants can be determined with future targeted economic studies and surveys, now that the information on ecosystem coverage and potential ecosystem services has been synthesized. Some of these values can be estimated by examining market values; others relate more to perceived value and can only be determined by 'willingness to pay' and other contingent valuation information derived by interviewing users. However, as Wilson and colleagues state (Wilson et al. 2012), no methodology is able to capture the total value of goods and services.

The identification of valuable benefits of nature protection allows a focus on inland, coastal, and marine areas that may need additional protection in the future. Some of the regions of Bahrain generating the most ecosystem services values are already under special spatial management regimes, such as the Al Areen Protected Area, or the Hawar Island, Mashtan Island, and Arad Islands marine protected area. An objective assessment of management effectiveness within existing protected areas is however recommended, especially as it relates to compliance with regulations, and whether the regulations themselves address the highest priority threats to ecosystem function and health. Additionally, there are areas that fall outside protected areas that exhibit high ecosystem services values, in particular those in close proximity to high value assets. Future development in these areas will need careful planning to ensure that ecosystem services are not sacrificed.

It is also important to recognise that the values arising out of these ecosystems are not confined to Bahrain alone. There are numerous ways that these ecosystems provide value outside the Kingdom of Bahrain. For the Gulf region, the value of these coastal and marine ecosystems include support to a wide array of regional (and supra-regional) biodiversity and fisheries, regulation of regional scale fluxes, and mitigation of catastrophic events, the costs of which might otherwise spill over to neighbouring countries in the region. In terms of carbon stock / sequestration and the myriad other services being delivered, the importance of Bahrain's ecosystems is expected to increase over time, as regional coverage and condition of mangroves, seagrass, and salt marsh (as well as coral reefs and shellfish reefs) are expected to decline. Bahrain's natural ecosystems also have value as laboratories for learning, and as such present a hugely valuable resource for the countries of the Gulf region, which share conservation challenges.

At the global level, Bahrain's ecosystems have immense value in allowing us a glimpse into the future, especially as it relates to climate change impacts on ecosystems and ecosystem services. Many of the world's marine regions will face a future which will arrive sooner to the Arabian Gulf than to most other parts of the world: warmer seas; higher salinities in marine and coastal environments alike; increasing acidification, and; potential increase in storm frequency and intensity. The Kingdom of Bahrain can demonstrate how to maximize the resilience of these ecosystems, and can further educate and train others in adopting a holistic approach to ecosystem services.

For the future, it is recommended that targeted research be undertaken in relation to: the economic studies mentioned above; as well as more detailed hydrographic modelling, and; surveys with greater sample sizes, across different seasons, and, if possible, across neighbouring coral reefs and other marine ecosystems not confined to Bahrain's waters alone. As stressed by Daily et al. (2009), production functions in these ecosystems must be fully understood before the continued rates of services delivery can be predicted – in the absence of this, and even if economic values are ascertained, policy decisions rest on uncertainty.

The potential for ecosystem services valuation to influence policy will depend on contextual, procedural, and methodological factors integrated in the process. A clear policy question and objective is necessary to trigger and integrate robust Ecosystem Services Valuation. In addition, it is also recommended that this be based on a local demand for ecosystem services valuation and assessment, including strong local partnerships and stakeholder engagement, that allows discussion of the assumptions behind value calculations and dialogue regarding the perceived values of the services presented.

Effective communication and information flows to decision makers is imperative if the economic argument is to bolster or influence political considerations. Strong governance by an authority institution over the site/ecosystem in discussion will enable implementation of the decisions that are made. Opportunities for raising revenue such as payments for ecosystem services (e.g. park entry or use fees) will facilitate the uptake of the Ecosystem Services Valuation results. Finally, a clear presentation of methods, assumptions, and limitations is critical throughout the process so as to manage expectations and perceptions.

A rigorous look at ecosystem services values must both appraise net present value and perceptions of value; and look into the future. The two considerations that must be addressed in this regard are how value changes over the passage of time (including, but not limited to, discounting rates) and the sustainability of stocks (for goods) and services (Bateman et al, 2011). It is thus recommended that future work in Bahrain target the development of predictive models that can better elucidate trade-offs. The result will lead to conserving and enhancing as much as possible of Bahrain's natural habitats and ecosystems, which will in turn yield valuable ecosystem services for many years to come.

Economic value of ecosystem services thus provides a set of measures that can help inform strategies for biodiversity conservation, and evaluate trade-offs for future development. In this context, ecosystem services assessment and subsequent economic valuation can be used to site and design marine and terrestrial protected areas, integrated protected area networks that span inland, coastal and offshore areas, and land use or marine spatial plans (Agardy et al

2011). Such studies can also be used to develop strategies and regulations that promote ecological resilience (Admiraal et al 2013). Such information is also extremely useful in determining compensation fees for damages to natural habitats, such as is required when ship groundings damage valuable coral reefs or seagrass beds, or when oil spills affect fisheries nursery grounds (Kennedy and Cheong, 2013).

An important point (and one that causes significant misconception among the public and even among some management agencies) is that taking an ecosystem services approach does NOT necessarily require economic valuations of those services to be performed. There is some concern, much of it justified, that placing economic values on ecosystem services trivializes the non-monetary values of habitats, or could lead to a commodification of nature. Certainly economic valuations can be efficiently and effectively used in planning to focus on developing a suite of scenarios for the future, for the decision maker to compare and contrast. But part of such economically-informed scenario development is the acknowledgement that trade-offs might not be wholly monetary. This is especially true in coral reef and other marine systems (pearl oyster beds, for instance) where intrinsic, existence, and cultural values may far exceed monetary values.

Recommended next steps in the Kingdom of Bahrain include: precise quantification of the major types of habitat listed in Table 1; an assessment of the condition of key habitats, including coral reefs and oyster beds, seagrass, and algal communities vis a vis their ability to deliver ecosystem services; a quantification of the economic values and investments made in certain habitats, including nature-based tourism and both recreational and commercial fisheries; and social surveys that elucidate public and decision-maker opinions about the full suite of values of natural habitats in the Kingdom. With such information, a progressive and proactive foundation for the protection of biodiversity can be made, with a full appraisal of values, a better understanding of trends in these values, and a comprehensive consideration of trade-offs inherent in development decisions.

The conservation of areas that are providing high levels of ecosystem services cover approximately 12% of the marine territorial water in Bahrain which would exceed the Aichi Target of 10% marine protection by 2020. Thus, if the number of ecosystem services provided is considered, there are four main regions in Bahrain to be highlighted. These are: a) the Northern Hayrat region and specifically Hayr Shtayyah and Hayr and Reef Bulthamah; b) northwest Bahrain including Fasht al Jarim; c) Fasht El Adm; and d) finally northwest of Hawar Islands that all demonstrate a higher number of ecosystem services than other parts of Bahrain and warrant careful management and conservation from the government in order to maintain the provision of these services.

6.0 Bibliography

Abbaza, H. 2012. Economic considerations for supplying water through desalination in south Mediterranean countries. EU Sustainable Water Integrated Management Support Mechanism Report, Brussels

Aburto-Oropeza, O., E. Ezcurra, G. Danemann, V. Valdez, J. Murray and E. Sala. 2008. Mangroves in the Gulf of California increase fishery yields. *PNAS* 105: 10456--10459.

Admiraal, J.F., A. Wossink, W.T. de Groot, and G.R. de Snoo. 2013. More than total economic value: How to combine economic valuation of biodiversity with ecological resilience. Ecological Economics 89: 115-122.

Agardy, T., A. Abdulla, and R. Irving. 2013. Abu Dhabi Blue Carbon Demonstration Project: Ecosystem Services Assessment. AGEDI, Abu Dhabi UAE

Agardy, T., J. Davis, K. Sherwood, and O. Vestergaard. 2011. Taking Steps Toward Marine and Coastal Ecosystem-Based Management: An Introductory Guide. UNEP Nairobi. 67 pp

Agardy, T. and J. Alder. 2005. Coastal ecosystems and coastal communities. Ch. 21 in the Millennium Ecosystem Assessment. Island Press, Washington DC.

Alongi, D.M. 2008. Mangrove forests: resilience, protection from tsunamis, and responses to global climate change. Estuarine, Coastal, and Shelf Science 76:1-13.

Al-Maslamani, I., M. E. M. Walton, H. A. Kennedy, M. Al-Mohannadi, and L. Le Vay. 2013. Are mangroves in arid environments isolated systems? Life history and evidence of dietary contribution from inwelling in a mangrove-resident shrimp species. *Estuarine, Coastal and Shelf Science* 124 (0): 56– 63.

Al-Maslamani, I., L. Le Vay, H. Kennedy, and D. A. Jones. 2007. Feeding ecology of the Grooved Tiger Shrimp *Penaeus semisulcatus* De Haan (Decapoda: Penaeidae) in inshore waters of Qatar, Arabian Gulf." *Marine Biology* 150 (4): 627–637.

Al-Mealla, R. , E. Husain, and T. Al Olaimy. 2014. The analysis of various socio-economic aspects of the oyster beds. Report to The Supreme Council for the Environment & The Ministry of Culture in the Kingdom of Bahrain.

Al-Sayed, Naser, Al-Wedaei. 2008. Observations on macrobenthic invertebrates and wader bird assemblages in a protected marine mudflat in Bahrain. *Aquatic Ecosystem Health and Management,* 11(4): 450-456

Alshabaani, A.H. 2010. Status of agricultural land, soil, and groundwater in Bahrain. PPT presentation accessed at http://www.fao.org/fileadmin/user_upload/GSP/docs/NENA2014/Bahrein.pdf

Alsharhan, A.S., Z.A. Rizk, A.E.M. Nairn, D.W. Bakhit, S.A. Alhajari.[Eds.] 2001. Hydrogeology of an Arid Region: The Arabian Gulf and Adjoining Areas. Elsevier

Al-Wedaei, K., H. Naser, H. Al-Sayed & A. Khamis. 2011. Assemblages of macro-fauna associated with two seagrass beds in Kingdom of Bahrain: Implications for conservation. *Journal of the Association of Arab Universities for Basic and Applied Sciences,* 10:1-7.

Anderson, D. 2009. Approaches to monitoring, control and management of harmful algal blooms (HABs). Oceans and Coastal Management 52(7):342-347.

Anderson, R.C., M.S. Adam, A. Kitchen-Wheeler and G. Stevens. 2010. Extent and economic value of manta ray watching in Maldives. Tourism in Marine Environments 7(1): 15-27

Arkema, K., G. Guannel, G. Verutes, S. A. Wood, A. Guerry, M. Ruckelshaus, P. Kareiva, M. Lacayo, and J.M. Silver. 2013. Coastal habitats shield people and property from sea-level rise and storms. Nature Climate Change Published online 14 July 2013 DOI:10.1038/NClimate1944.

Atkins, J.P., D. Burdon, M. Elliott, A.J. Gregory. 2011. Management of the marine environment: Integrating ecosystem services and societal benefits with the DPSIR framework in a systems approach. Marine Pollution Bulletin 62 (2011) 215–226

Bahrain News Agency. 2015. Tourism revenues topped BD 228 Million. Accessed at http://www.bna.bh/portal/en/news/654254

Barbier, E.B., S. D. Hacker, C. Kennedy, E. W. Koch, A. C. Stier, and B. R. Silliman 2011. The value of estuarine and coastal ecosystem services. Ecological Monographs 81:169–193

Barth, H.J. and B Boer. 2002. Sabkha Ecosystems: Volume I: The Arabian Peninsula and Adjacent Countries. Tasks for Vegetation Science 36. Kluwer Academic Publishers, Netherlands.

Bashitialshaaer, R.A., k. M. Persson, M. Aljaradin. 2011. Estimated future salinity in the Arabian Gulf, the Mediterranean Sea, and the Red Sea – Consequences of brine discharge from desalination. International Journal of Academic Research 3 (1): Jan 2011 Part 1.

Bateman, I. J. , G.M. Mace, C. Fezzi, G. Atkinson, and K. Turner. 2011. Economic analysis of ecosystem services assessments. Environmental Resource Economics 48:177-218.

Bouillon, S., N. Koedam, A. Raman, and F. Dehairs. 2002. Primary producers sustaining macro invertebrate communities in intertidal mangroves. *Oecologia* 130: 441---448.

Burt, J.A. 2014. The environmental costs of coastal urbanization in the Arabian

Gulf. *City* 18(6): 760-770.

Burt, J. A., K. Al-Khalifa, E. Khalaf, B. AlShuwaik, and A. Abdulwahab. 2013. The continuing decline of coral reefs in Bahrain. *Marine Pollution Bulletin* 72 (2): 357–363.

Cagua, E.F., N. Collins, J. Hancock, and R. Rees. 2014. Whale shark economics: a valuation of wildlife tourism in South Ari Atoll, Maldives. PeerJ 2:e515; DOI 10.7717/peerj.515

Campbell, J. E., E. A. Lacey, R. A. Decker, S. Crooks, and J. W. Fourqurean. 2014. Carbon storage in seagrass beds of Abu Dhabi, United Arab Emirates. *Estuaries and Coasts* 15: 1–10. doi:10.1007/s12237-014- 9802-9

Carter, R. 2005. The history and prehistory of pearling in the Persian Gulf. *Journal of the Economic and Social History of the Orient*, 48 (2): 139-209.

Conservation International. 2008. *Economic Values of Coral Reefs, Mangroves, and Seagrasses: A Global Compilation.* Center for Applied Biodiversity Science, Conservation International, Arlington, VA, USA.

Costanza, R., M. A. Wilson, A Troy, A. Voinov, S. Lui. 2006. The value of New Jersey's ecosystem services and natural capital. Institute for Sustainable Solutions Publication, Portland Oregon.

Daily, G., S. Polansky, J. Goldstein, P. Kareiva, H.A. Mooney, L. Pejchar, T.H. Ricketts, J. Salzman, and R. Shallenberger. 2009. Ecosystem services in decision-making: time to deliver. Frontiers in Ecology 7(1):21-28.

Directorate of Fisheries (Bahrain). 2013. Annual Fishery Statistics Report No. (96). *Fisheries Resources in Kingdom of Bahrain – 2012*.

Fisheries Assessment Section. Ministry of Municipalities Affairs and Agriculture, Agriculture and Marine Resources Affairs.

Eftec. 2005. The Economic, Social and Ecological Value of Ecosystem Services: A Literature Review. Final report for DEFRA, London

Ellison, J. C. 2012. Climate Change Vulnerability Assessment and Adaptation Planning for Mangrove Systems. Washington, DC: World Wildlife Fund (WWF).

Feary, D. A., J. A. Burt, A. G. Bauman, S. Al-Hazeem, M. A. Abdel-Moati, K. A. Al-Khalifa, D. M. Anderson et al. 2013. Future Changes in the Gulf Marine Ecosystem: Identifying Critical Research Needs. *Marine Pollution Bulletin* 72 (2): 406–416

Ganassin, C. and P.J. Gibbs. 2008. A review of seagrass planting as a means of habitat compensation following loss of seagrass meadow. NSW Department of Primary Industries - Fisheries Final Report Series No. 96 ISSN 1449-9967.

Gilbert, P.M., J.H. Landsberg, J.J. Evans, M.A. Al-Sarawi, M. Faraj, A. Al-Jarallah, A.

Haywood, S. Ibrahem, P. Klesius, C. Powell, and C. Shoemaker, 2002. A fish kill of massive proportion in Kuwait Bay, Arabian Gulf, 2001: the roles of bacterial disease, harmful algae, and eutrophication. Harmful Algae 1: 215-231.

GoB / UNDP. 2007. Bahrain National Biodiversity Strategy and Action Plan. V4.0 December. pp. 338. Government of Bahrain/United Nations Development Programme. Woods Hole Group Middle East.

Grabowski, J. H., Brumbaugh, R.D., Conrad, C.R.,, Keeler, A.G., Opaluch, J.J., Peterson, C.H., Piehler, M.F., Powers, S.P. and Smyth, A.R., 2012. Economic Valuation of Ecosystem Services Provided by Oyster Reefs. *BioScience*, 62 (10), pp. 900-909.

Grandcourt, E. 2012. Reef Fish and Fisheries in the Gulf. [In] Coral Reefs of the Gulf: Adaptation to Climatic Extremes, edited by Bernhard M. Riegl and S. Purkis, 127–161. Netherlands: Springer.

Hegazy, Ahmad K. 1998. Perspectives on Survival, Phenology, Litter Fall and Decomposition, and Caloric Content of *Avicennia marina* in the Arabian Gulf Region. *Journal of Arid Environments* 40 (4): 417 – 429.

Hejnowicz, A.P., H Kennedy, M R. Huxham and M A. Rudd. Harnessing the climate mitigation, conservation and poverty alleviation potential of seagrasses: prospects for developing blue carbon initiatives and payment for ecosystem service programmes. *Frontiers in Marine Science*, 2015 DOI: 10.3389/fmars.2015.00032

Hussain, S.A. and R. Badola. 2008. Valuing mangrove ecosystem services: linking nutrient retention function of mangrove forests to enhanced agro-ecosystem production. Wetlands Ecology and l Management. 16: 441---450.

IUCN. 2013. The economic value of biodiversity to the Maldives economy. Atoll Ecosystem Conservation Project Policy Brief. Ministry of Housing, Transport and Environment, Government of Maldives.

Kennedy, C.J. and S. Cheong. 2013. Lost ecosystem services as a measure of oil spill damages: A conceptual analysis of the importance of baselines. J. Envir. Management 128: 43-51

Khalifa, H.A. and Michael Rice. 1986. Bahrain Through the Ages: The Archeology. Routledge (division of Taylor and Francis), London.

Kingdom of Bahrain. 2006. Bahrain First National Report to the Convention on Biological Diversity. Public Commission for the Protection of Marine Resources, Environment, and Environment and General Directorate for Environment and Wildlife Protection. Bahrain

Koch, E. W., et al. 2009. Non-linearity in ecosystem services: temporal and spatial variability in coastal protection. Frontiers in Ecology and the Environment 7:29–37.

Lattemann, S. and T. Hopner. 2008. Environmental impact and impact assessment on seawater desalination. Desalination 220:1-15.

Madani, S., Ahmadian, M., KhaliliAraghi, M., and Rahbar, F., 2012. Estimating Total Economic Value of Coral Reefs of Kish Island (Persian Gulf). *Int. J. Environ. Res.*, 6 (1), pp. 51-60.

Mandeel, Q.A. 2006. Biodiversity of the genus *Fusarium* in saline soil habitats. Jounral of Microbiology 46(6):480-494

McIvor, A.L., Spencer, T., Möller, I. and Spalding. M. (2012) Storm surge reduction by mangroves. Natural Coastal Protection Series: Report 2. Cambridge Coastal Research Unit Working Paper 41. Published by The Nature Conservancy and Wetlands International. 35 pages. ISSN 2050-7941.

McLeod, K and H Leslie. 2009. Ecosystem Based Management for the Ocean. Island Press, Washington DC

Meyer, D.L., Townsend, E.C. and Thayer, G.W. 1997. Stabilization and erosion control value of oyster cultch for intertidal marsh. *Restoration Ecology*, 5:93-99.

Moberg, F., and C. Folke. 1999. Ecological goods and services of coral reef ecosystems. Ecological Economics 29:215–233.

Moberg, F., and P. Ronnback. 2003. Ecosystem services of the tropical seascape: interactions, substitutions and restoration. Ocean and Coastal Management 46:27–46.

Moore, A.B. M. and R. Peirce. 2013. Composition of elasmobranch landings in Bahrain. *African Journal of Marine Science* 35(4): 593-596

Mumby, P.2006. Connectivity of reef fish between mangroves and coral reefs: Algorithms for the design of marine reeserves at seascape scales. Biological Conservation 128:215-222.

Naderloo, R., M. Turkay, and A. Sari. 2013.Intertidal habitats and decapod (Crustacea) diversity of Qeshm Island, A biodiversity hotspot within the Persian Gulf. *Marine Biodiversity* 43 (4): 445–462

Naser, H. 2013. Effects of multi-stage and reverse osmosis desalinations on benthic assemblages in Bahrain, Arabian Gulf. *Journal of Environmental Protection* 2013, 4, 180-187

Naser, H. 2012a. Metal concentrations in marine sediments influenced by anthropogenic activities in Bahrain, Arabian Gulf. In: Metal Contaminations: Sources, Detection and Environmental Impacts, Shao Hong-Bo (Editor), NOVA Science Publishers, Inc. New York, pp. 157-175.

Naser, H. 2012b. Coral reefs in Bahrain: anthropogenic threats and conservation. Coral Reefs of the Gulf Conference. New York University Abu Dhabi Institute

Naser, H. 2012c. Evaluation of the environmental impact assessment system in Bahrain. *Journal of Environmental Protection.*3 (2): 233-239.

Naser, H. 2011a. Human impacts on marine biodiversity: macrobenthos in Bahrain, Arabian Gulf. In: The Importance of Biological Interactions in the Study of Biodiversity, J. Lopez-Pujol (ed.), InTech Publishing. pp. 109-126.

Naser, H. 2011b. Effects of reclamation on macrobenthic assemblages in the coastline of the Arabian Gulf: A microcosm experimental approach. *Marine Pollution Bulletin*, 62: 520-524

Naser, H. 2010. Testing taxonomic resolution levels for detecting environmental impacts using macrobenthic assemblages in tropical waters. *Environmental Monitoring & Assessment* 170: 435-444

Naser, H., Bythell, J., Thomason, J. 2008. Ecological assessment: an initial evaluation of ecological input in environmental impact assessment reports in Bahrain. *Impact Assessment and Project Appraisal*, 26 (3): 201-20

Naser & Hoad 2011. An investigation of salinity tolerance and salt secretion in protected mangroves. Proceedings of Gulf II: The state of the Gulf ecosystem: functioning & services. Kuwait, 7-9 February 2011

NAS (US). 2008. Desalination: A National Perspective. National Academies Press, Wash DC

National Environmental Strategy. 2006, p. 13 (DID0231)

Philcox, N. 2007. Literature review and framework analysis of non-market goods and services provided by British Columbia's ocean and marine coastal resources. Government of British Columbia, Vancouver.

Robertson, A.I. and M.J. Phillips. 1995. Mangroves as filters of shrimp pond effluent: predictions and biochemical research needs. Hydrobiologia 295: 311–321.

Ruffo, S. and P. Kareiva. 2009. Using science to assign value to nature. Frontiers in Ecology 7(1):3

Sale, P. F., D. A. Feary, J. A. Burt, A. G. Bauman, G. H. Cavalcante, K. G. Drouillard, B. Kjerfve et al. 2011. The growing need for sustainable ecological management of marine communities of the Persian Gulf. *Ambio* 40 (1): 4–17

Salem, Marwa E. Mercer, D. Evan "The Economic Value of Mangroves: A Meta-Analysis" Sustainability, 2012

Seenprachwong, U., 2001. An Economic Analysis of Coral Reefs in the Andaman Sea of Thailand. Economy and Environment Program for Southeast Asia, International Development Research Centre.

Sheppard, C., A.R. Price, and C. Roberts. 1992. Marine Ecology in the Arabian Region. Patterns and Processes in Extreme Tropical Environments. Academic Press, London.

Sheppard, C. and M. Borowitzka. 2011. Subitdal habitats. Ch 5 In Marine Atlas of the Western Arabian Gulf. Saudi Aramco.

Sheppard, C., M. Al-Husiani, F. Al-Jamali, F. Al-Yamani, R. Baldwin, J. Bishop, F. Benzoni, et al. 2010. The Gulf: A young sea in decline. *Marine Pollution Bulletin* 60: 3-38

Survey and Land Registration Bureau, KoB. 2015. Kingdom of Bahrain National Report 2015. Available at https://www.iho.int/mtg_docs/rhc/RSAHC/RSAHC6/RSAHC6-7.1-Bahrain%20National%20Report.pdf

Talhouk, S.N. and M. Abboud. 2009. Impact of climate change: Vulnerability and adaptation- Ecosystems and Biodiversity. Ch 8 In AFED.

TEEB 2009*. The Economics of Ecosystem and Biodiversity -TEEB Climate Issues Update,* September 2009.

TEEB. 2010. The Economics of Ecosystems and Biodiversity: Mainstreaming the Economics of Nature: A synthesis of the approach, conclusions and recommendations of TEEB.

UNEP. 2014. *The Importance of Mangroves to People: A Call to Action*. Van Bochove, J., Sullivan, E., Nakamura, T. (Eds). United Nations Environment Programme World Conservation Monitoring Centre, Cambridge. 128 pp.

Van Lavieren, H. ,J. Burt, D. A. Feary, G. Cavalcante, E. Marquis, L. Benedetti, C. Trick, B. Kjerfve, and P. F. Sale. 2011. Managing the growing impacts of development on fragile coastal and marine ecosystems: Lessons from the Gulf. UNU – INWEH, Hamilton Ontario

White, A.T., Vogt, H. P. and Arin, T., 2000. Philippine coral reefs under threat: the economic losses caused by reef destruction. *Marine Pollution Bulletin*, 40, pp. 598–605.

Wilkinson, C., Linden ,O., Cesar ,H., Hodgson, G., Rubens, J., , and Strong, A. E., 1999. Ecological and socioeconomic impacts of 1998 coral mortality in the Indian Ocean: an ENSO impact and a warning of future change? *Ambio*, 28, pp. 188–196.

Wilson, M. A., R. Costanza, R. Boumane, and S. Liu. 2013. Integrated assessment and valuation of ecosystem goods and services provided by coastal systems. [In] J. G. Wilson (Ed.) The Intertidal Ecosystem: The Value of Ireland's Shores: 1-24. Dublin:

Royal Academy

Wilson, S., S.M. R. Fatemi, M.R. Shokri, and M. Claereboudt. 2002. Status of the coral reefs of the Persian/ Arabian Gulf and Arabian Sea region. pp 53-62 In C. Wilkinson [Ed.] Status of Coral Reefs of the World.

World Bank. 2013. The Bahrain Environment Action Plan: Cost of Environmental Degradation. Report prepared by the World Bank for the Kingdom of Bahrain.

Zainal et al. 2012. The cumulative impacts of reclamation and dredging on the marine ecology and land-use in the Kingdom of Bahrain. Marine Pollution Bulletin, 64: 1452-1458.