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Coastal Resources Spatial Planning and Potential Oil Risk Analysis: Case Study of Misratah's Coastal Resources, Libya

Abduladim Maitieg, Kevin Lynch, Mark Johnson

***Abstract*—**The goal of the Libyan Environmental General Authority (EGA) and National Oil Corporation (Department of Health, Safety & Environment) during the last 5 years has been to adopt a common approach to coastal and marine spatial planning. Protection and planning of the coastal zone is a significant for Libya, due to the length of coast and, the high rate of oil export, and spills' potential negative impacts on coastal and marine habitats. Coastal resource scenarios constitute an important tool for exploring the long-term and short-term consequences of oil spill impact and available response options that would provide an integrated perspective on mitigation. To investigate that, this paper reviews the Misratah coastal parameters to present the physical and human controls and attributes of coastal habitats as the first step in understanding how they may be damaged by an oil spill. This paper also investigates costal resources, providing a better understanding of the resources and factors that impact the integrity of the ecosystem. Therefore, the study described the potential spatial distribution of oil spill risk and the coastal resources value, and also created spatial maps of coastal resources and their vulnerability to oil spills along the coast. This study proposes an analysis of coastal resources condition at a local level in the Misratah region of the Mediterranean Sea, considering the implementation of coastal and marine spatial planning over time as an indication of the will to manage urban development. Oil spill contamination analysis and their impact on the coastal resources depend on (1) oil spill sequence, (2) oil spill location, (3) oil spill movement near the coastal area. The resulting maps show natural, socio-economic activity, environmental resources along of the coast, and oil spill location. Moreover, the study provides significant geodatabase information which is required for coastal sensitivity index mapping and coastal management studies. The outcome of study provides the information necessary to set an Environmental Sensitivity Index (ESI) for the Misratah shoreline, which can be used for management of coastal resources and setting boundaries for each coastal sensitivity sectors, as well as to help planners measure the impact of oil spills on coastal resources. Geographic Information System (GIS) tools were used in order to store and illustrate the spatial convergence of existing socio-economic activities such as fishing, tourism, and the salt industry, and ecosystem components such as sea turtle nesting area, Sabkha habitats, and migratory birds feeding sites. These geodatabases help planners investigate the vulnerability of coastal resources to an oil spill.

***Keywords*—**Coastal and marine spatial planning advancement training, GIS mapping, human uses, ecosystem components, Misratah coast, Libyan, oil spill.

Abduladim Maitieg* and Mark Johnson are with the Ryan Institute (Environmental, Marine and Energy Research) and School of Natural Sciences, NUI Galway, Galway, Ireland e-mail: Al_maitig@yahoo.com).

Kevin Lynch is with the School of Geography and Archaeology, National University of Ireland, Galway, University Road, Galway, Ireland.

I. Introduction

MISRATAH is a city in the Misratah district of North-western Libya, situated 200 km to the east of Tripoli on the Mediterranean coast Fig. 1. It includes large ports and a range of wetland habitats including nesting areas for sea turtles [1] and feeding places for migrant birds [2]. The region also supports anthropogenic activities including fishing, tourism, harbor, mineral exploitation, salt industry, cultural uses, and oil and gas industry.

Coastal oil spills, from sources such as oil tanker collisions, oil loading operations, and sewage pipes and fishing activity usually harm coastal habitats and human use activity at two interfaces; foreshore and on backshore [3]. Managing the risk from such spills needs spatially resolved information, appropriate governance and infrastructure. The Misratah district, however, has (1) limited information on oil spill contamination events, oil production and oil tanker transportation, (2) few studies on coastal resources and their existing condition, and (3) a lack of coastal management infrastructure and coastal resource data.

Given the gaps in data for assessing oil spill threats to habitats and human uses, the goal of this study is twofold: Firstly, to collate information on coastal resources, including information from a field survey and secondly to lay the groundwork for the coastal sensitivity index and coastal zone management studies. The study aims to identify and define the potential negative economic and environmental effects of oil spillage. This study will focus on a hierarchy of categories (as shown in Fig. 2) in order to develop a base map for oil spill strategy. The results of this study can help planners to maintain summer resort beaches and to preserve historical and archaeological sites within the coastal area [4]. This introductory information can help to identify vulnerable coastal areas and provide specific details to planners to help them set up protection priorities and clean-up strategies [5], [6].

This paper identifies, and maps information related to the vulnerability of coastal resources with an emphasis on coastal oil spill risk along the shoreline of Misratah. A four-step approach was followed:

1- Definition of coastal resources value.
2- Identifying coastal resources' importance to local communities.
3- Defining existing condition of coastal resources
4- Determining the connection between coastal and marine spatial planning and oil spill risk analysis.

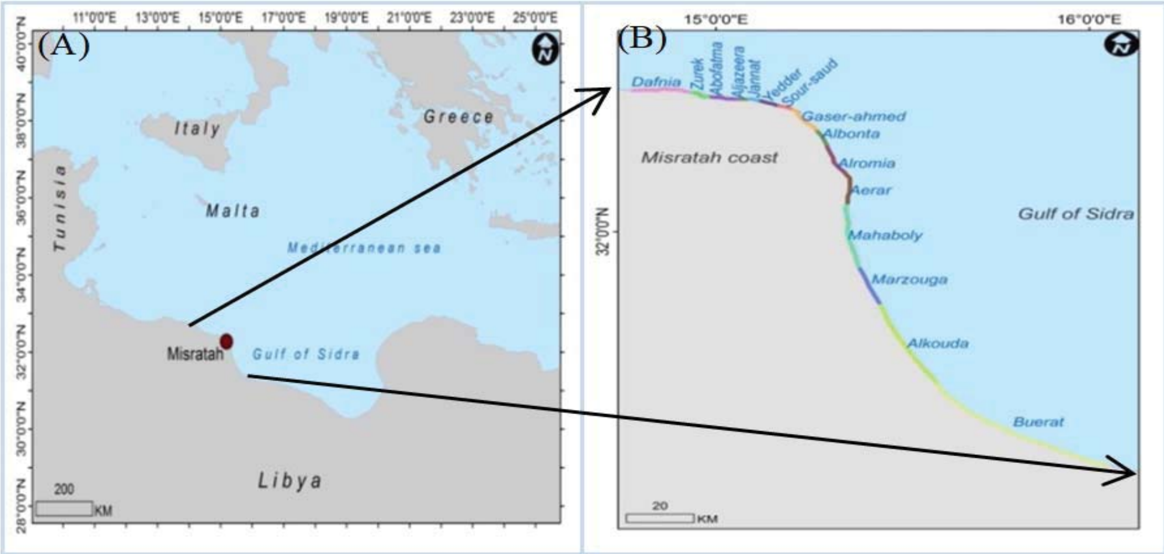


Fig. 1 (a) the study area located within the central Mediterranean Sea, (b) local names of the Misratah coast

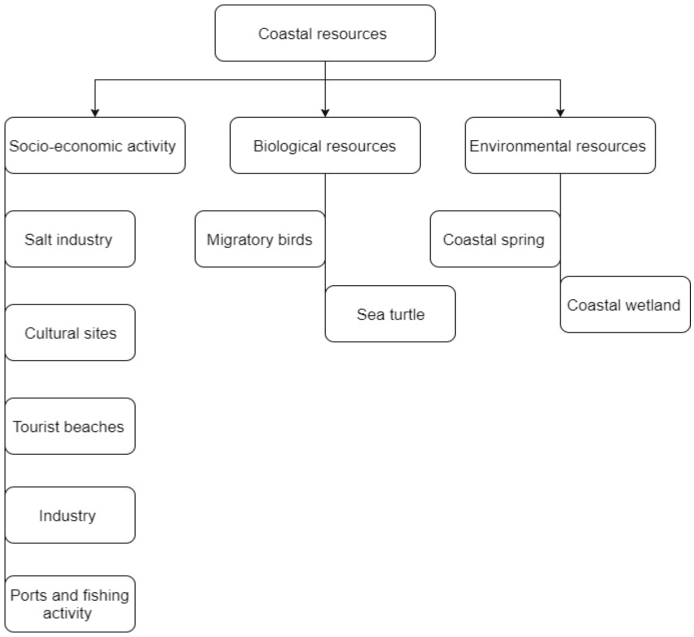


Fig. 2 Classification of coastal resource categories described for the Misratah coast

II. Methodology and Research Process

Coastal and marine spatial planning can provide information about specific issues, resources, or areas needing a quick emergency plan [7]. Well-researched plans can be used to describe future desired conditions and provide information and guidance that supports regional action on coastal resources and provides the flexibility to structure the elements of its plans over time in response to what the coastal region wants to accomplish [8]. In this context, coastal spatial planning and oil spill risk analysis are two distinct processes, needed to achieve effective sustainable management of coastal and marine areas [9]. These processes play an important role in decision-making on coastal oil spill risk events [10]. Moreover, coastal management strategy and conservation of coastal habitats/resources require synthesis of spatial information on the distribution and intensity of socio-economic activities and the overlap of their impacts on the coastal ecosystem [8]

The development of a database can be used to generate ESI maps for the Misratah coast. Coastal resources such as tourism, fisheries, and cultural historical sites, which are often sensitive to oil spills, are represented on the ESI map to help planners address the vulnerability of coastal resources to oil spills with more understanding of coastal processes [11]. Hence, the current study leads to detailed maps of the oil spill risk potential and coastal resources vulnerability that are crucial to support oil spill contingency plans and decision-making [12].

Vulnerable ecosystems and the sustainability of resources for human use are two significant elements for coastal and marine spatial planning. This work considers both ecosystem components and socioeconomic activity in order to identify their spatial pattern along the Misratah coast [11]. In this study, the definition of coastal resource vulnerability depends on the gathering of three kinds of information: abundance and conservation status of the coastal biodiversity, and oil risk possibility according to their proximity to oil spill risk factors.

The most important environmental components within the boundaries of the case study area are the wetlands, the nesting areas for sea turtles and migrant birds feeding sites. The salt industry and coastal tourism are the most important socio-economic activities along the coast. Finally, the selection of ecosystem components presented in this paper is based on their conservation importance as defined by Libyan legislation and international agreements such as The African-Eurasian Migratory Water Bird Agreement (AEWA), Protected Areas and Biological Diversity in the Mediterranean (SPA/BD. Protocol of the Barcelona Convention), and the Ramsar convention on wetlands.

A coastal resources spatial plan is a fundamental tool to help achieve effective coastal zone management [13]. The steps that can be implemented to build capacity to manage oil spills are shown in Fig. 3. To advance a plan, definition of coastal resource value and analysis of oil spill risk from potential oil spill sources along the coast is needed. Prioritization needs definition and analysis of the condition of environmental and socioeconomic resources [9], [14]. Based on the previous information, scenarios are built to define the potential oil risk areas according to the proximity of an oil spill to the resources.

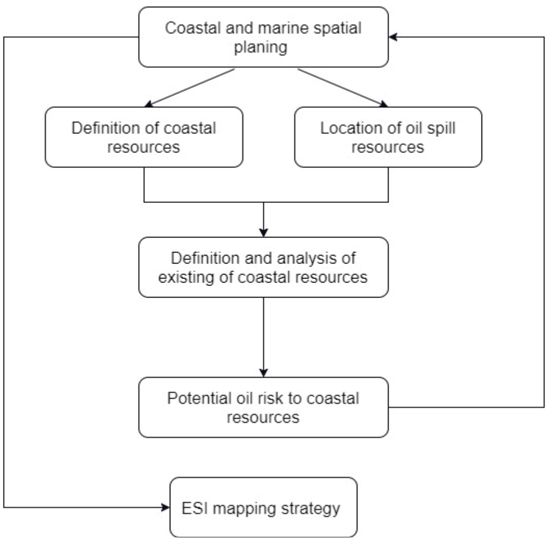


Fig. 3 Schematic chart of the process to use scientific information related to ESI methodology within an MSP framework, to identify the spatial pattern of coastal resources and their existing condition

A. Data Collection

A coastal database was built to initiate the mapping process, data were collected from the available literature and annual scientific reports (Table I) such as the marine turtle nesting area survey and migratory bird sites data from the protection of the marine turtle program and United Nations Environment Programme (UNEP), coastal and marine spatial survey was carried out in 2014. During the fieldwork surveys, observations (notes, photos, measurement) were collected along 248 km of surveyed shoreline. The aims of the fieldwork were to provide a check on literature sourced information, to gain data on the current status of resources and to increase the level of spatial information at scales relevant to the Misratah region. The mapping tools in ArcGIS 10.2 were used to create layers depicting the overlapping uses of the coastal and marine habitats.

TABLE I
GIS DATABASE SOURCES

GIS database	Data type	Recourses
Coast type	Fieldwork, historical maps	National Geophysical Data Centre.
Oil spill resource	Maps, reports	Department of Health, Safety and Environment in National Oil Corporation.
Coastal habitats	Maps	Environmental General Authority. Marine Biology Centre.
Bathymetry	Satellite images	United States Geological Survey (USGU).
Oceanography data	Maps	Libya National Meteorology Centre.
Oil infrastructure	Maps, reports	Environmental General Authority. Department of Health, Safety and Environment in National Oil Corporation.
Product area	Maps	UN for the Environment. Marine Biology Centre.
Environmental coastal issue	Maps, reports	Environmental General Authority. Departments of the Environment Public Authority in municipalities.
Coastal aquifer	Maps, reports	General Authority Water.
Coastal development	satellite images	Biruni Remote Sensing Centre.

III. RESULTS AND DISCUSSION

A. Human-Use Resources and Their Existing Relationships to Oil Spill Contamination

The vulnerability of a coastal resource area can be defined as the capacity of the coastal resources to cope with the impact caused by oil spills [15]. Socio-economic variables are significant factors used to investigate coastal vulnerability to oil spill because socio-economic changes occur more often and more rapidly than physical processes change [16]. Therefore, identifying and analyzing human-use resources and their existing condition can help planners to understand, manage, and reduce the oil spill risk by identifying likely spill scenarios and coastal areas at risk [17]. Moreover, these studies can be used to engage a broad spectrum of stakeholders in raising awareness and increasing resilience.

In mapping socio-economic features, the objective is not to identify all human use activity, but to locate the activities which are most at risk to damage from an oil spill. Fishing, beaches/coastal tourist areas, and the salt industry are under oil spill risk due to their locations near oil spill resources along the shoreline. The socio-economic activity included in recreational sites, e.g. public beaches and summer resort, and cultural resources, e.g. historical sites, which are distributed along the Misratah coast, can be affected economically in the event of an oil spill. Several industries on the Misratah coast are dependent on unpolluted water from the sea (e.g., water is used for cooling purposes in the iron and steel industries and desalination plants). In these cases, the facilities and processes can be negatively affected by oil into their water intakes, possibly leading to pollution of piping systems, which in turn may require that the factory is shut down while cleaning is carried out.

The information generated in this study can help planners to assess the vulnerability of socio-economic activity to oil spills along the coast. GIS and field work data are the principal tools aimed at enhancing basic socio-economic knowledge about the Misratah coast. The basic information is stored in ArcGIS, in layers containing point, polygon and line features. Each feature in the economic activity data layers stores information in an attribute table in the ArcMap software.

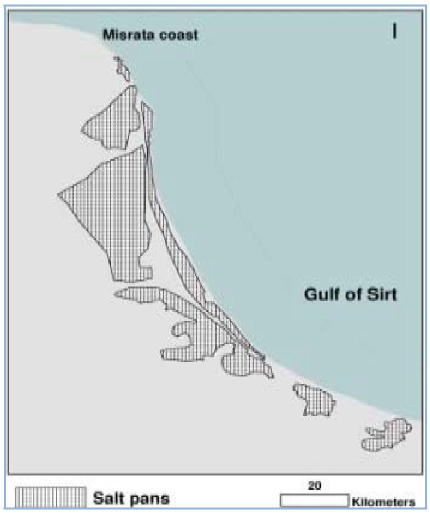
1. Salt Industry

Pans are one of the features of salt marshes [18] which can be classified into two types: Primary pans and channel pans. The former is characterized as a depressed area in the surface of the saltmarsh, while the latter are formed from creek channels [19]. The coastal lagoons are formed and maintained through sediment transport processes, involving sediment carried by rivers, waves, currents, wind, and tides [20]. The salt industry depends on salt flats, which become salt deposits following evaporation of sea water [21]. In Libya, most of the salt industry is spread on Western coast, for instance the cities of Zwara, Azawia, and Misrata, as well as the Sirte coast and Benghazi region. In particular, in 1985, the Gulf of Sidra area from Misrata in the West to Bengasi in the East produced approximately 11,000 tons of salt annually [22] The salt industry is located along the eastern coast of Misratah, from Gaser-ahmed to Buerat, covering 170 km (Fig. 4 (a)). In the Misratah region there are two types of saltpans: man-made salt pans (Fig. 4 (b)) and natural pans (Fig. 4 (c)). Some saltpans are located on the foreshore, with their nearest point located between one and 50 m from the water's edge. The biggest salt industry operation in Libya is located within the study area and covers a total area of approx. 55 km2 [23].

Coastal wetlands (Sabkha) are recorded as a vulnerable to oil spills because the low wave energy of a salt marsh does not physically remove oil effectively [24], [25]. Therefore, accidental spillage of oil into the Gulf of Sidra from oil tankers and drilling rigs could significantly impact the salt industry. The risk of oil spills depends on the proximity of the salt industry to oil spill resources such as oil loading platforms in the Gaser-ahmed area. A previous study, conducted in 2012 on coastal lagoons in the East of Libya, showed that the environment was already polluted by oil [26].

2. Cultural and Historical Sites

The coastal area is of great importance to Libya, containing a number of resources that provide economic, environment and aesthetic benefits. Resource conservation requires long-term planning and management to ensure that value is sustained for the future [27]. Analysis of the condition of cultural and historical sites will allow for comparison of critical oil spills areas with regions of high archaeological and religious value [28].



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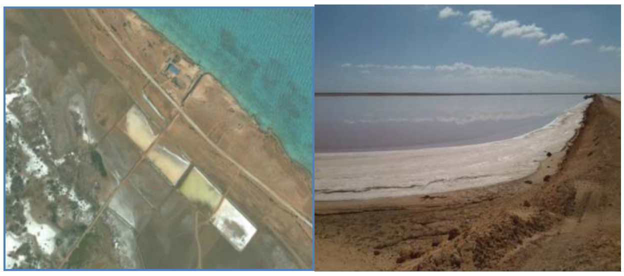


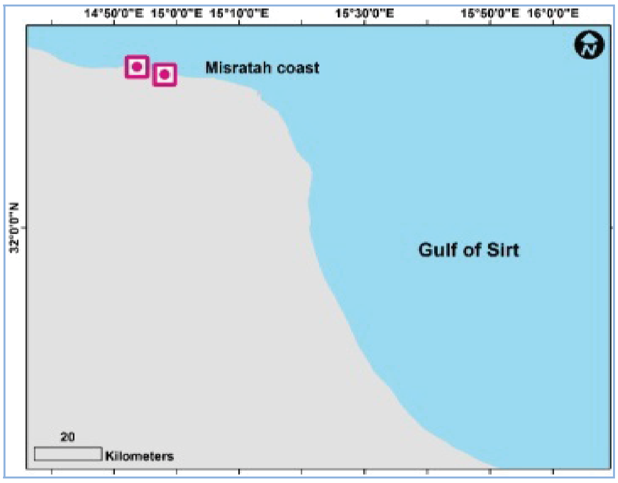
(b) (c)

Fig. 4 (a) The location of salt industry, the map is created in the ArcMap software on the basis of fieldwork data and spot 8 satellite imagery, (b) the view of coastal man-made saltpans, (c) saltpan basin in dry season

No database or cultural heritage list is yet available for all local sites of interest. Relevant data were gathered through a literature review of previous technical reports and from interviews with local people during field work surveys in which resource type and geographic location were recorded.

Libya has a number of heritage sites of socio-economic and religious importance along the Mediterranean coast, such as Cyrenaica, Leptis Magna, and Sabratha. The Leptis Magna complex is one of the largest ancient Roman sites in Africa and is on the World Heritage List, along with the old town of Ghadames and the rock-art sites of Tadart Acacus in the Sahara in the South of Libya [29]. Based on archaeological reports, there are a number of cultural sites along the coast, especially on the North coast, which are located close to the shoreline, such as mosques and shrines (Darih) (Fig. 5 (b)).

The sensitivity of the archaeological and religious sites was discussed with the local people. The most sensitive type of archaeological and religious sites is those that are located in the intertidal zone, which is exposed to coastal environmental stress [30], [31]. In particular, the coastal resource sites (Fig. 5 (a)) along the North coast are at risk, either due to direct or indirect contact with coastal development and oil pollution, because the North coast is also where oil and gas activity takes place. For example, religious sites on the Zurek coast are located close to the Zurek port which is recorded as one of the potential oil spill sources.



(a)

(b)

Fig. 5 (a) cultural and historical sites on the Misratah coast (historical sites location taken by GBS during the coastal survey study, however, historical and archaeological sites are under recorder and have not been mapped yet, (b) a religious site including mosque, cemetery and shrines (Dharih)

3. Tourist Beaches

Summer resorts and open swimming beaches are important places for coastal tourism. Beach tourism is one of the most important economic activities in Misratah and constitutes a part of the Libya gross domestic product [32]. In the event of an oil spill, tourist resorts suffer income losses and property damages, and need time to clean up. In addition, protection strategies for the coast also have a cost [33]. The Misratah coast includes rocky headlands and wide sandy beaches that attract tourists from all over Libya. This region's environmental characteristics support coastal tourist activities; most of the coastal resorts are located on protected sandy beaches along the North coast of Misratah, as well as private and public summer resorts distributed on the North coast (Fig. 6). Some of the most important locations are Zurek beach, Aljazeera resorts, Altoba open beach, and Alhaded resort, as well as the open sandy beach on the eastern coast of Misratah.

In order to have more detailed information about specific coastal resources, examining the value of oil spill damage for each resource is key to coastal resources management [28]. In response to minor and major oil spill resources on the Misratah coast, the tourism industry in is under oil pollution pressure due to their proximity to the spill resources. For example, Alaman resorts, which comprise 206 villas, attract approximately 10.000 tourists in the summer season [34]. The Alaman resort was surveyed during fieldwork in 2014 and tar balls were observed on the sand and rocky shore sections. This may possibly be attributed to the proximity of the resort to Aljazeera port (i.e., within 20 m) and thus, any oil accident that occur in Aljazeera could easily reach the Alaman shore.

The second important coastal place for tourists is Alhaded resort, which is a part of the iron and steel complex located in the Gaser-ahmed area. This area is recognized as highly vulnerable to oil spills due to its location near the iron factory and oil loading platform. Additionally, the resort is situated between the two biggest harbours in Misratah city, which represent one of the oil spill sources in the study area.

The Altoba coastline is an open beach and one of the most common places visited by local people. It might be affected by oil spills due to its location 1 km from sewage pipes. Furthermore, there is fishing activity (anchorage) located within the beaches. Jannat beach has the same situation of Altoba beach, and thus the tourism activity might be harmed by oil spill coming from the Jannat fishing activity and sewage pipes. Therefore, there are oil pollution threats on tourist sites along the Misratah coast due to their co-location with oil spill sources in Gaser-ahmed, Aljazeera, Jannat and Zurek. Some of the summer resorts have been affected by the oil spill and suffered by tar ball pollution, which was observed along all coastal areas, but especially on tourist beaches on the North coast.

4. Misratah iron and steel complex

The iron and steel complex is considered one of the largest industrial sites in Libya, covering a coastal area of 12 square kilometers, spread along 3 km the Misratah Sabkha in Gaser-ahmed on the East side of the Misratah coast. The iron industry, power plants, and desalination plants in the complex are dependent on seawater for cooling purposes and also to produce the steam to run the turbines. The iron factory facilities can be affected oil enters into their water intakes, with consequences for piping systems and production processes.

The complex contains a power plant, a desalination plant, a central water station, an oxygen and compressed air plant, a wastewater treatment plant, and a central electric receiving and distribution station with a total production of steel and iron products of 1,700,000 tonnes/year [35]. The desalination plant was designed to produce 40,000 m^3/day to supply the factories and facilities with industrial and drinking water, as well as to contribute to the supply for Misratah city, which is otherwise dependent on groundwater sources, with 90% coming through an artificial river from the Sahara Desert [36].

The plant site is under oil pollution pressure and oil spills can damage water quality and desalination facilities. During the desalination plant's processing, chlorine is added to the sea water to protect from marine organisms. If the sea water is polluted by oil, chlorine reacts with organic molecules to form Tri-halo-methanes (THM) and adhesion of the oil on the water tanker can damage the plant as well [37]. In addition, not only does the desalination plant use sea water, it is also used for cooling purposes in iron and steel production. Seawater feeds into the station water for industrial plants, then to direct reduction plants, direct cooling water for the rest of the factory's facilities; under the same circumstances, polluted sea water may affect most factory facilities and production processes.

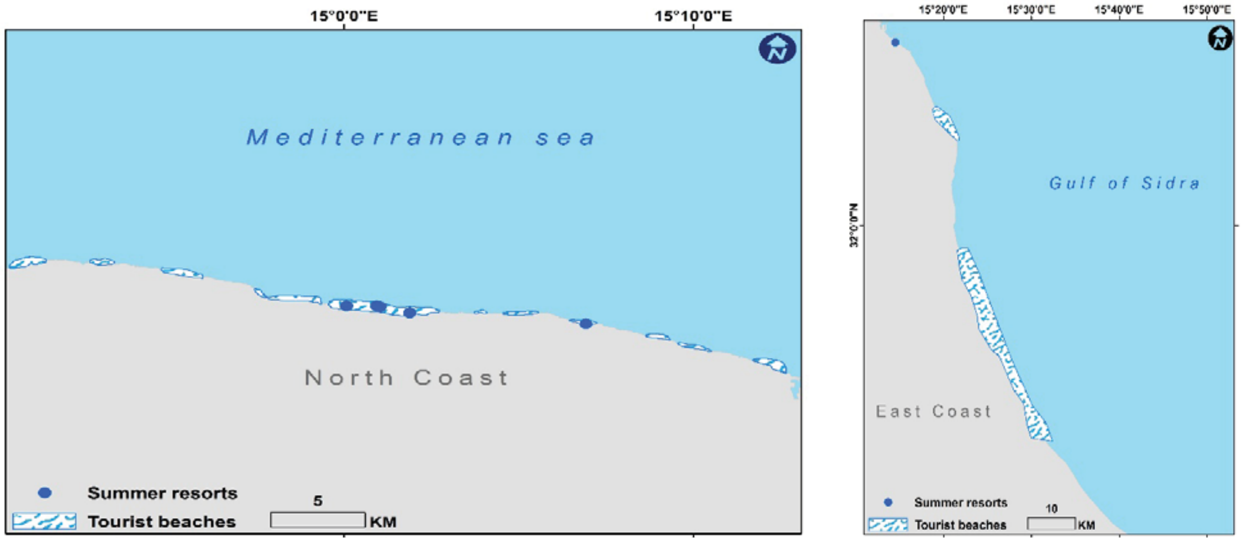


Fig. 6 Distribution of tourist beaches and summer resort along the north coast, (B) tourist beaches and summer resort along the East coast of Misratah (polygon made ArcGIS according to field work study and coastal survey to develop geodatabase for the area).

5. Ports and Fishing Activity

Oil spills can cause serious risk to fishing activity; contamination can impact stocks and damage business activities by fouling gear or impeding access to fishing sites. In spite of available publications from the environmental general authority on the Misratah port situation and fishing activity, fine scale spatial data are limited. The required data was taken during field work in 2013/2015 by communication with fishermen, observations of polluted sites, technical reports, and available online data about the fisheries in the South Mediterranean region.

Libya has the longest coast in the southern Mediterranean, at approximately 1770 km. It has the second largest continental shelf in the Mediterranean, with more than 250 coastal and marine species recorded in shallow and deep-sea habitats [38]. Fishing is one of the main resources for the Libyan economy, after the oil and gas industry [39]. The previous available data shows that fisheries production in Libya in 2004 was 40827 tonnes and Libyan domestic fisheries product in 2006 was approximately 40 827 tonnes, while fish exports in 2006 reached 275 tonnes. In particular, the last annual technical reports [40] on Misratah's production illustrate that fisheries production in 2004 was 343 tonnes. The port at Gaser-ahmed is one of the biggest landing sites in the study area. (Table II) illustrates that there are more than 240 boats landed in the port and fishing production in 2004 was 2680 tonnes. However, the fishing productions of Zurek and Aljazeera harbors in 2004 were 155 and 108 tonnes respectively. Both harbors are located in the protected coastal area from wave energy on the western Misratah coast and contain 34 and 33 fishing boats respectively [41].

Although recent publications on the fishing industry are limited, previous studies and fieldwork observations suggest that the production is decreasing due to stressors such as oil pollution and overfishing [42]. Therefore, this section identifies fishing activity and distribution of this activity along of the coast (Fig .7) to determine how the fishing activity is likely at risk due to its location and oil spill movement on the coastal area. The Misratah ports are now among the most poorly regulated sources of pollution: most Libyan ports are heavy polluters because of weak infrastructure in the marine ports. There is no emergency plan for oil spill accidents, no clean-up equipment, and structures such as used oil storage are absent, leading to fishermen pouring used oil into the sea.

Oil pollution of the Gaser-Ahmed coastal area comes mainly from two sources: oil platforms and shipping (including fishing) activity. The port is the most vulnerable site due to its location beside the industrial coastal area and oil platforms. In the Zurek and Aljazeera harbors, the infrastructure and facilities are poor as well. The remaining fishing activity is characterized as small and seasonal fishing located in small bays or open beaches and representing 44 fishing boats distributed between seven anchorages along the Misratah coast. There are no facilities around these places. By contrast, the Alkouda and Alroumia anchorages are located at the end of the eastern coast (as shown in Fig. 7). Alkouda and Alroumia are the least vulnerable to oil damage due to their location away from oil spill recourses and location on protected coast, sheltered from high wave energy and winds.

TABLE II
DISTRIBUTION OF FISHING CRAFTS OF LANDING SITES IN THE STUDY AREA, [41]

No	Loading sites	Fishing boats
1	Zurek	24
2	Aljazeera	33
3	Altoba	4
4	Jannat	12
5	Gaser-ahmed	247
6	Roumioa	5
7	Mahaboly	10
8	Marzouga	3
9	Alkouda	4
Total		342

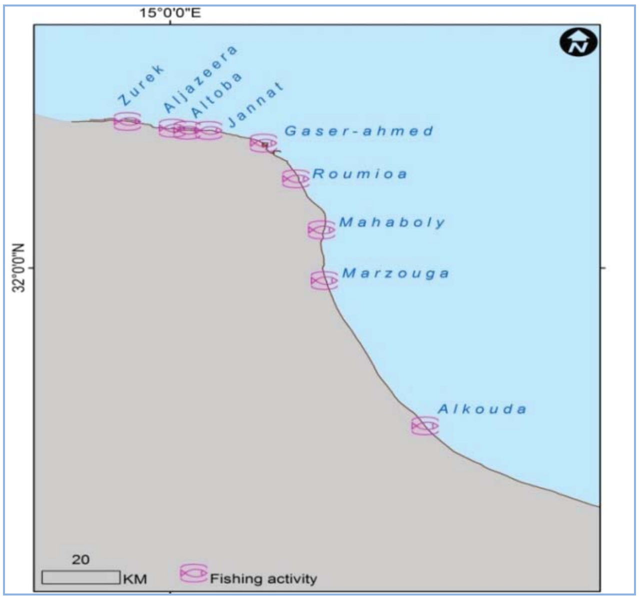


Fig .7 Geographic locations of fishing activity along the Misratah coast as shown in table 2

B. Biological Resources and Their Existing Relationships to Oil Spill Contamination

The coastal and marine habitats in the Mediterranean are highly diverse; the Libyan coastal and marine environment is recognized as one the world's 25 top biodiversity hotspots with a large number of endemic species [43]. In this section, due to unavailability of extensive coastal habitats and species data, two categories of biological resources are presented: migratory birds and sea turtles. Collected data will be used to develop a coastal sensitivity index map to help planners set protection strategies and mitigate coastal damage from oil spills.

1. Sea Turtle Nesting Area

Identifying sea turtle frequented areas is key for conservation and provides information that can be used to define the potential negative environmental effects of spillage on populations, while helping the local responsible authority to set emergency plans in the event of oil spills.

A few studies have focused on the nesting activity of sea turtles on Libyan coast, in addition to annual UNEP reports. The available literature shows (also shown in Fig .8 (a)) some level of nesting activity along the Libyan coast, mainly concentrated in three coastal sub-regions: (1) the sandy beaches of the Gulf of Sidra, (2) sandy beaches located to the South and the North-east of Benghazi, and (3) on the East side of Libyan coast the area of Derna and Tobruk [44], [45]. The west coast of Misratah, characterized by sandy beaches with a wide intertidal zone, was recorded by UNEP as a sea turtle nesting area. In addition, the Misratah saltmarshes are productive biological systems and are major feeding and nesting grounds for sea turtle and migratory birds (as shown in Fig .8 (b)) [45]. Migratory sea turtles come out of the water onto sandy beaches to dig nests and lay eggs within the period from the end of May to beginning of September [45]. Moreover, the eastern Mediterranean basin of Misratah is utilized by turtles as a breeding area for loggerhead turtle nesting [46]. The loggerhead turtle (Caretta caretta) is the most commonly encountered species on the coast [47], [48] However, two other endangered turtles have been recorded in the West Misratah region: the leatherback (Dermochelys coriacea) and the green turtle (Chelonia mydas) [49]. Satellite tracking of sea turtles in the Mediterranean shows the majority of sea turtles recorded on western coast of Misratah using feeding and overwintering grounds around Greece, with some turtles found around Turkey and the eastern Mediterranean (as shown in Figs .8 (c) and (d)) [45].

Although the western Mediterranean Basin is high in biodiversity, many of its species and habitats are threatened by human activities. For example, the loggerhead turtle is listed as an endangered species by the International Union for Conservation of Nature (IUCN) [51]. In addition, the nesting area has suffered from tar balls [46]. In the study area, oil spills will have a different impact on each habitat; for example, sea turtle nesting areas are more exposed to oil, due to their nesting and feeding location within the intertidal zone. Oil pollution risk for turtles and their nesting area might is greatest during nesting season from May to August. The oil industry and national oil tanker routes in the Gulf of Sidra pose an ongoing risk to the survival of the Libyan Sea turtle population and their nesting habitat.

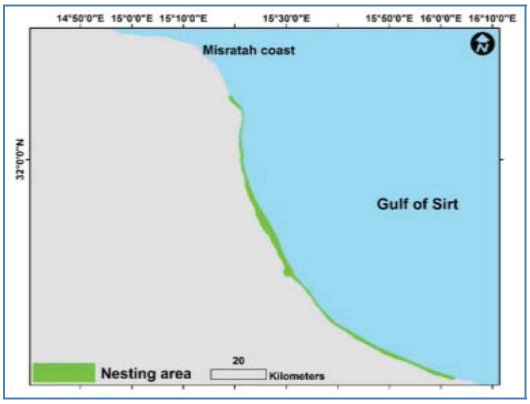
2. Migratory Birds

The wetlands ecosystem in the Mediterranean region is considered an important region for water birds, covering areas of Turkey, Italy, Greece, France, Tunisia, Egypt, and Libya [50]. The Libyan wetlands are important resting areas for the passage of migrant birds. In a study conducted by EGA in

2004, most water birds selected and counted was at 83 sites at Libyan wetlands in winter season (as shown in Fig. 9 (a)). In 2011, the Libyan migratory birds' observation team recorded 35,890 individuals belonging to 88 species [51].

In particular, the coastal area in the East coast of Misratah is dominated by a very wild, sandy coastline with a few rocky shores, bordered by the Misratah saltmarsh (Sabkha) [48]. Several species of birds have been recorded on the western Misratah coast, visiting this area as nesting and feeding sites during spring season [2]. The coast where migratory birds land from September to February stretches from Gaser-ahmed to Buerat, consisting of sand beaches covering approximately 75 km (as shown in Fig. 9 (b)) of the eastern coast of Misratah. The coast has important feeding areas for the birds especially on the wetland bank and in the shallow coastal water [52].

The impact of oil spills on the migrant birds is dependent on the spatial distribution of both the birds and oil resources [54]. Furthermore, identifying potential seabird sites and feeding areas can provide information to planners on how to avoid oil risk to coastal habitats. In addition, analysis of coastal resources value and coastal oil spills can help assess the impact of oil spills on migratory birds. However, it is also important to assess temporal variability due to seasonal migrations of seabirds [55]. For instance, a site may be highly vulnerable for only a limited period each year, i.e. September to February.



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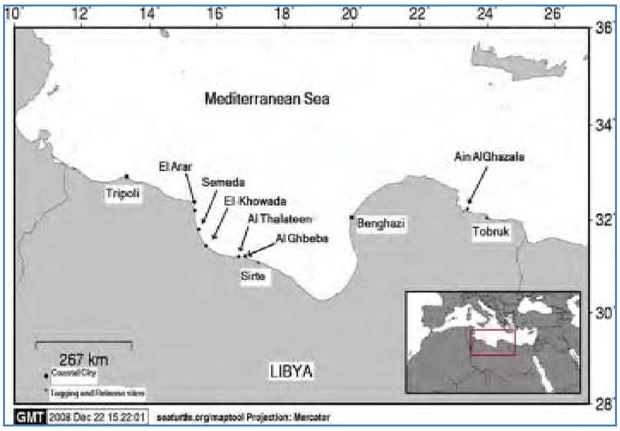

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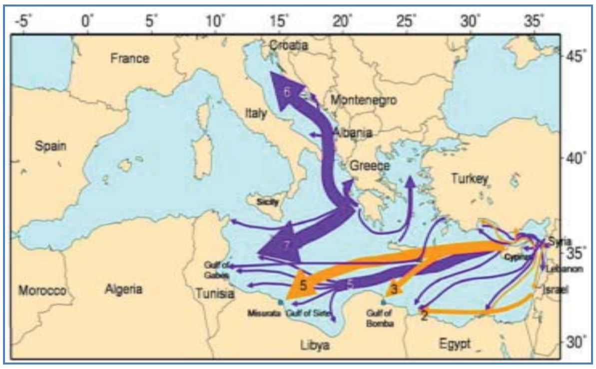
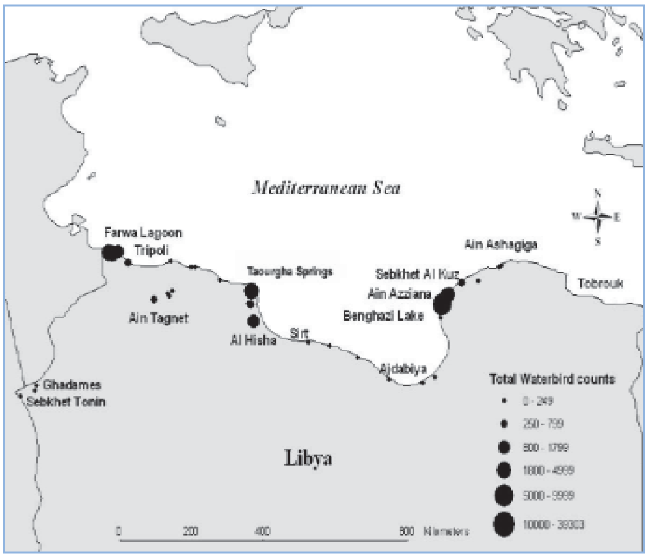


(c)

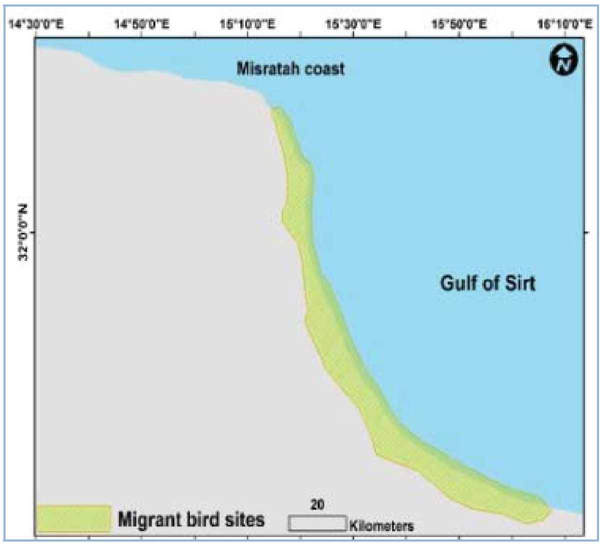
(d)

Fig. 8 (a) Sea turtle nesting area along Sidra Gulf [45], (b) geo-map for nesting area along the sandy beach of eastern coastline of Misratah, data adopted on, (c) nesting area along the Mediterranean coastline post-nesting migrations of sea turtle adult female [46]

Although the migratory birds' sites are not close to oil and gas activity, oil spill simulation map of the eastern coast of Misratah shows that there is a potential for oil slicks on the Misratah sea surface to reach the migratory birds areas, due to winds and currents action.



(a)



(b)

Fig. 9 (a) Distribution of seabird on Libyan coast [53], (b) migrant birds feeding and nesting area at Misratah coast, the shapefile of resting area of the migrant birds was generated in the ArcMap as polygon accruing the survey of migratory birds and field work collected data

Oil spills can create stress on coastal and marine environments where birds nest and roost [56] Oil spill impacts are likely to be on birds when they are present at nesting colonies or feeding in nearshore waters [57] Thus, migratory birds would be affected by oil spill particularly during diving on the sea surface while searching for food [58].

C. Environmental Components and Their Existing Relationships to Oil Spill Contamination

1. Coastal Springs

Misratah city is one of the several areas in Libya that faces severe water shortages [59], [60] the majority of freshwater comes through a number of huge pipes that transfer water across the desert from the South to the North [61]. Therefore, this study also identified coastal water value and examined oil spill likelihood and impact on coastal freshwater to create a practical database for shoreline spring walls for improving the oil spill prevention and management policies of the Libyan government. In general, the groundwater occurs within six main basins in Libya. These basins consist of several groundwater aquifers with different surface water levels (as shown in Table III). The Misratah area is located in the Ghadames basins [62]

As of the current date, there seem to be no available data on the coastal aquifers and springs on the Libyan coast, except a few technical reports on groundwater in the Sahara Desert. The previous studies covering coastal fresh water springs are limited as well, as these sites not well-known yet by the local environmental authority.

To determine the exact location of the coastal springs, interviews were conducted with local people and then the quality of groundwater was assessed by electrical conductivity (EC) meter and PH/ C meter to determine the physicochemical parameters as illustrated in Figs. 10 (c) and (d), electrical conductivity, temperature, and how suitable the water was for human uses. Groundwater springs are most vulnerable to the effects of oil pollution according to their location and they are an important resource for local communities, particularly for communities located near oil spill resources such as in the Zurek and Aljazeera areas.

TABLE III
PHYSICAL FEATURE OF COASTAL SPRING SITES

Wall No	Location	PH	EC MS/cm	°C	Depth	Distance from water edge
1	Gaser-ahmed	8,27	3	21	3 m	10 M/ in intertidal zone
2	Gaser-ahmed	8,27	3,28	21	2 m	20 M in intertidal zone
3	Sour-Saud	8,27	2,80	21	2 m	5 M in intertidal zone
4	Jannat	8,27	2,60	21	2 m	10 M in intertidal zone
5	Marbat	8,27	2,89	21	3 m	5 M in intertidal zone
6	Aljazeera	8,27	2,70	21	50 cm	1m/ in intertidal zone
7	Aboroyeh	8,27	3,28	21	20 cm	1m/ in intertidal zone
8	Zurek	8,27	3,00	21	20 cm	1m/ in intertidal zone
9	Dafnia 1	8,27	2,70	21	30 cm	1m/ in intertidal zone
10	Dafnia 2	8,27	2,70	21	50 cm	1m/ in intertidal zone

2. Saltmarsh (Sabkha)

Sabkha (Subkha), the coastal saltmarsh ecosystem of Libya, are few and limited in overall area (as shown in Fig 11 (a)), but they constitute an important environment, providing coastal habitats for a diverse range of plant and animal species. For example, saltmarshes are a feeding area for seabirds and migrant birds. The Sabkha represents the lowest topographic depression in Misratah region and contains two features, salt flat and vegetation area (as shown in Figs. 11 (b) and (c)) [63]. The Sabkha is flooded in the wet season by seawater seepage or seawater flood [64]. In the Sabkha area there are two different zones; low topography, like a small lake, is generally located near the coastline and is covered by the sea in winter, high elevation of Sabkha is characterized as vegetation area at the border of the Sabkha (as shown in Fig. 11 (d)).

The Eastern Coast of the Misratah region includes broad areas of supratidal salt flats, termed 'dry basins' in the summer and wet with water in the winter [65]. These areas occur behind wide sandy beaches and coastal dunes in relatively low topographic areas [66] The Misratah Sabkha is situated in a coastal Sabkha plain over an approximately 1500 km^2 stretch along the Gulf of Sidra on the western coast of Misratah extending from North to South: 170 km from Gaser-Ahmed to Buerat. This saltmarsh is considered one of the most important coastal resources in the area and is recognized as a protected area in the RAMSAR protocol.

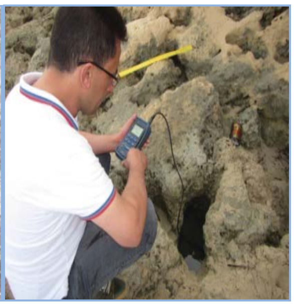
The Sabkha ecosystem has important environmental ecology because it hosts a number of migrant birds and sea turtles during seasonal migrations and nesting and this sensitive area is exposed to coastal disturbances and oil spill pollution due to its location and environmental situation. The Sabkha coast is located in a semi-closed sea and sea energy is low compared to the open sea on the North coast of Misratah in the Mediterranean Sea. Therefore, the Sabkha coast suffers from tar ball pollution.

IV. Conclusions

Coastal and Marine Spatial Planning is considered to be an effective procedure in tackling developmental and management issues related to the coasts and marines, and thus issues related to coastal habitats and resources.

The main purpose of identifying the features of the Misratah coast is for preparing a framework for coastal zone management of areas sensitive to oil spill because coastal parameters analysis plays an important role in decision-making for risk management actions in an oil spill event.

(a)

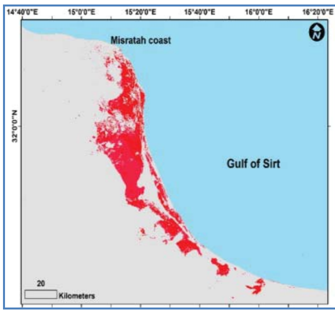


(b) (c)

(d) (e)

(f)

Fig. 10 (a) Coastal freshwater spring distribution at north coast, (b) egress ground water, (c) testing physical and chemical factors of the coastal aquifer sampling took along the Misratah coast in summer season, (d) measuring the dimension,(e) coastal spring located at intertidal area which completely covered by sea water and sand, (f) types of equipment used in the field to determine the physicochemical parameters of the coastal spring water,(1) electrical conductivity (EC), (2) PH/ C meter



(a) (b)

(c) (d)

Fig. 11 (a) Distribution of Misratah wetland, the map adopted on spot 8 imagery, (b) sabkha vegetation, (c) saline pan, (d) sabkha during a flooding phase in winter reason

Because little research has been conducted on coastal habitats mapping and resource values and available related data and publications are limited for the Misratah region, this study uses available coastal and marine information to create a required database for coastal sensitivity index maps along the coast, acting as a reference for how to protect and manage coastal resources in the Misratah coast and the rest of Libya. Moreover, this work describes in detail the value of natural coastal resources such as the salt industry and coastal groundwater quality to the Misratah population and its economy. This study also describes the benefits of coastal resources studies as a tool for protection and management for coastal problems facing coastal resources and local communities in Misratah.

The Misratah coast has multiple uses including fishing, tourism, harbours, mineral exploitation, the salt industry, and cultural uses, each of which has a different economic importance. The coast contains two shores; the North coast is defined by sandy beaches with narrow rocky shores and most human activity takes a place on the North coast, including fishing, coastal tourism, industry, ports, oil platforms, oil storage, and coastal development. However, the eastern coast is exposed shoreline which is mainly composed of wetland coasts.

The coastal parameters were mapped in GIS to generate one map for each variable and features were represented as polygons and points to show the spatial distribution of biological resources, in order to facilitate coastal resources management and classify coastal areas by their sensitivity to oil spills.

Finally, the Misratah coast has suffered from two types of oil spills: onshore oil spills coming from urban areas and flowing to the coast, and oil spills coming from the offshore oil industry and tanker traffic. The Sabkha ecosystems are under pressure due to increasing human activities such as urban development, tourism related activities, and a different pollution type from iron and steel industry located in the Gaser-Ahmed Sabkha, as well as an illegal landfill. This chapter identifies specific economic and ecological resources at risk from oil spills. The potential sources of oil in the marine environment are also shown to be diverse, with major spill risks existing alongside persistent oil pollution from coastal towns and ports.

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