Advances in Bioresearch
Adv. Biores., Vol 7 (6) November 2016: 134-140
©2016 Society of Education, India
Print ISSN 0976-4585; Online ISSN 2277-1573
Journal's URL:http://www.soeagra.com/abr.html
CODEN: ABRDC3
ICV Value 8.21 [2014]

Advances in Bioresearch

ORIGINAL ARTICLE

Impacts and Management of Oil Spill Pollution along the Chabahar Bay by ESI Mapping, Iran

[1]M. Sanjarani, [2]A. Danehkar, [3]A. Mashincheyan, [4]A. H. Javid, [5]S. M. R. Fatemi
[5]Seyed Mohammad Reza Fatemi is with the Department of Marine Biology, Science and Research Branch, Islamic Azad University, Tehran, Iran (corresponding author, e-mail: reza_fatemi@hotmail.com).
[1,3]Department of Marine Biology, Science and Research Branch, Islamic Azad University, Tehran, Iran.
[2]Department of Fisheries and Environmental Sciences, Faculty of Natural Resources, University of Tehran, Karaj, Iran.
[4]Department of Marine Industries, Science and Research Branch, Islamic Azad University, Tehran, Iran

ABSTRACT
The oil spill in marine water has direct impact on coastal resources and community. Environmental Sensitivity Index (ESI) map is the first step to assess the potential impact of an oil spill and minimize the damage of coastal resources. In order to create Environmental Sensitivity Maps for the Chabahar bay (Iran), information has been collected in three different layers (Shoreline Classification, Biological and Human- uses resources) by means of field observations and measurements of beach morphology, personal interviews with professionals of different areas and the collection of bibliographic information. In this paper, an attempt made to prepare an ESI map for sensitivity to oil spills of Chabahar bay coast. The Chabahar bay is subjected to high threaten to oil spill because of port, dense mangrove forest, only coral spot in Oman Sea and many industrial activities. Mapping the coastal resources, shoreline, and coastal structures was carried out using Satellite images and GIS technology. The coastal features classified into three major categories as: Shoreline Classification, Biological and Human uses resources. The important resources classified into mangrove, Exposed tidal flats, sandy beach, etc. The sensitivity of shore was ranked as low to high (1 = low sensitivity, 10 = high sensitivity) based on geomorphology of Chabahar bay coast using NOAA standards (sensitivity to oil, ease of clean up, etc.). Eight ESI types were found in the area namely; ESI 1A, 1C, 3A, 6B, 7, 8B, 9A and 10D. Therefore, in the study area, 50% was defined as High sensitivity, less than 1% as Medium, and 49% as low sensitivity areas. As this study was carried out up to Chabahar Bay, it will be of immense help to initiate the preventive measures at local level decision makers in case of spill approaching the coast. It is necessary to have this kind of maps for all ecosystem sensitive coasts.
Keywords; *ESI, oil spill, GIS, Chabahar Bay, Iran*

Received 28/04/2016 Accepted 18/10/2016

How to cite this article:
M. Sanjarani, A. Danehkar, A. Mashincheyan, A. H. Javid, S. M. R. Fatemi. Impacts and Management of Oil Spill Pollution along the Chabahar Bay by ESI Mapping, Iran. Adv. Biores. Vol 7[6] November 2016. 134-140. DOI: 10.15515/abr.0976-4585.7.6.134140

INTRODUCTION

Coastal environments have a high ecological, socioeconomic and cultural value, while being highly vulnerable to a wide range of impacting agents, whether natural or men induced. Within coastal hazards and pollutants, oil spills are among the most damaging. Their impacts vary according to a range of factors, from spill size and physicochemical characteristics of the oil, to weather conditions, namely winds and currents [12]. Specificities of the impacted areas are also a distinctive factor: in most cases, when the oil reaches the shoreline, impacts are more significant than if the spill is contained at sea; in addition, if sensitive biological or human-use resources are present in the impacted shoreline, the effects will be more damaging. A third aspect relates to the time before response and restoration actions take place, i.e., if they occur almost immediately after the spill, the impacts will not be as negative [2], [3], [6]. In order to define priority protection areas, information on coastal environments must be available, and pre-existing characterization studies on coastal resources and subsequent assessment of the shoreline sensitivity provide the base information needed to develop accurate contingency plans [6]. The assessment of coastal sensitivity in the scope of oil spill events was started in the 1970's in the U.S.A. [5] and has evolved since then, mainly due to technology improvements; namely, Geographic Information Systems (GIS) and Remote Sensing techniques [2], [4], [7], [8]. Worldwide a large number of projects have dealt with this field of research, especially during the last decade [12], showing the increasing importance of coastal sensitivity assessment.

The Bay of Chabahar is located in the south-east of Iran, north-west of the Indian Ocean, and north-east of the Oman Sea at 25°17′28″N 60°38′15″E and this bay is one of the five major ports in Oman Sea and provides an ideal breeding ground for many fish and shell fish [16]. The bay is located between Chabahar and Konarak cities. The Chabahar bay is subjected to high threaten for oil spill because of ports, dense mangrove forest, only coral spot in Oman Sea, many industrial and other human activites . Shahid – Kalantary port is one of two important ports in Chabahar. The executive operation of this port was started in 1981 and it became operational with the completion of four jetties in 1983. During the war between Iran and Iraq, the Iranian government noticed the important role of the port of Chabahar in Iran's imports and exports, because of its unique characteristics such as being out of the Strait of Hormuz and the Persian Gulf. So, Shahid-Beheshti port was built and equipped as the most important port in Chabahar. Whereas, Chabahar has high capacity with plans to expand it from its current capacity of 2.5 million to 12.5 million tons annually. Unlike Bandar Abbas, Chabahar has the ability to handle cargo ships bigger than 100,000 tons. The main objective of the present work is to identify the best coastal sensitivity assessment approach for the Chabahar Bay coast, in the scope of an oil spill event.

MATERIALS AND METHODS

This study was carried out in the Chabahar Bay in the north of Oman Sea (Fig. 1) covering about 55 km coastline. Chabahar Bay with an area near 320 km2 is the largest bay on the northeast of Oman Gulf along the Sistan and Baluchestan province, Iran. The average depth of this bay is 6 m while the deepest part of it, is about 20 m. No major rivers exist in the vicinity of it.

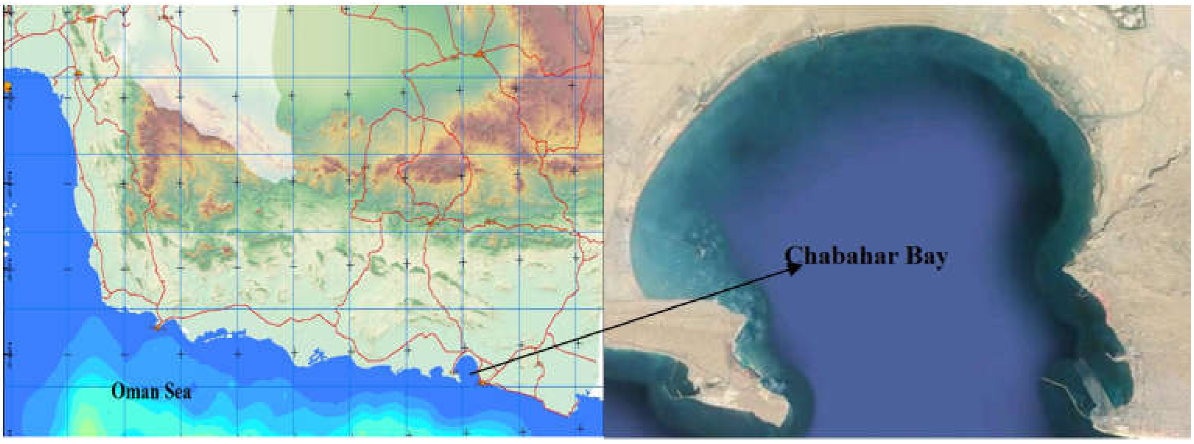

Fig I. Research Area, Chabahar Bay, Iran

This bay has a tropical climate characterized by south-west monsoon (May-September), post monsoon (October-February) and pre monsoon (March-April). Contrary the other places in Indian Ocean, no rainfall occurs during south-west monsoon at this area [14]. The upper boundary of the coastal zone was specified in accordance with the Hazard Line determined by the ICZM [Integrated Coastal Zone Management] National Project in Iran [11]. The procedure for the classification of shoreline sensitivity was prepared based on NOAA's Environmental Sensitivity Index guidelines as described in the diagram of Fig. 2 and sensitivity maps were prepared using Geographic Information System (GIS) with a scale of 1:25,000. ESI maps are drawn by three general types of information: shoreline classification (Table I), biological resources and human-use resources, as provided in Environmental Sensitivity Index Guidelines Version 3 [9]. Google earth maps were used as the base map with 1:25000 scales. For the determination of Shoreline types, basic geological maps made by Geological Survey of Iran with a scale of 1:100,000 were used and then completed and combined with field survey data scaled to 1:25000 maps. Tidal information were collected from Port and Maritime Organization of Iran (PMO) and Topography of shoreline data was extracted from Iranian National Cartographic Center (INCC) maps, while protected areas layer were received from the Department of the Environment. Consequently, by a comprehensive field surveys all data and information regarding type and exposure of shorelines, sediments grain size, vegetation, habitats biological resources and human-use data were collected and recorded with their precise geographical positions and specific descriptions. Documentation was done by taking pictures and other media and all features were then incorporated into the maps. Finally, after preparing the maps for the three main components, all features on these maps were showed on the main map that represents the ESI map of the study area. The final layout was printed on A4 size paper using ArcGIS layout viewer, which enables the production of the same map in a larger size and scale when needed.

RESULTS

Table I presents the observations along the shores of Chabahar Bay. It guides in understanding the potential behaviour of oil slick along shores and the ESI types each shoreline belongs. Shoreline & Coastal structures were mapped using digital images. The Costal structures like rocky shores, Sandy shores, tidal flats and Riprap were identified and shoreline types were identified and shoreline classified in to 8 types (Tables I and II) based on NOAA classification. The sensitivity of shore was ranked as low to high that 1 means low sensitivity and 10 means high sensitivity which based on geomorphology of Chabahar Bay using NOAA standards (sensitivity to oil, ease of clean up, etc.). Information in Table I revealed 8 ESI types in the study area; this is more explicit in Table II. 1A (Exposed rocky shores), 1C (Exposed rocky cliffs with boulder talus base), 3A (Fine sand beaches), 6B (Riprap), 7 (Exposed tidal flats), 8B (Sheltered, solid man-made structures), 9A (Sheltered tidal flats) and 10D (Mangrove). The shoreline is ranked on a scale from 1 to 10 based on sensitivity to oiling determined by:

1. Relative exposure to wave and tidal energy
2. Biological productivity and sensitivity
3. Substrate type (grain size, mobility, penetration and trafficability)
4. Shoreline slope
5. Ease of cleanup

For each shoreline type, these publications include a description of the habitat, predicted oil behavior and response considerations. they also include a matrix that evaluates response options for spills of different types of oil (Fig. 2). Optimally, the priority would be to protect the shorelines ranked with the higher values, as these are the more sensitive areas and the areas where oil would be more appropriate to persist and cleanup, if even possible, would be the most difficult. Mangroves are to be considered as the most important resource in the Chabahar Bay. The groups of protected animals are of equal importance in the evaluation of protected areas of the Chabahar Bay coastal area. Mangrove communities of the Chabahar Bay is comprised of one species, the dominant one is Avicennia marine (called "Harra" in local name). Mangrove coast was ranked as 10D which is considered as high economic importance and need to be protected first at the time of a spill event. The inter-tidal regions which are exposed during low tide and oil may strand on mudflats which is of high biological resource region ranked [12] next to mangroves followed by sheltered structures [8]. The Coastal structures like rocky shores, port area and concrete jetties were ranked as 1 due to low biological resources and also these areas are easy to clean more over oil cannot accumulate on the rocky shores because of wave actions. Coral reefs are the second most productive biome in the world after the tropical forests. In Chabahar Bay, the coral reefs are in danger of destruction due to the development program of Shahid Beheshti Port, therefore appropriate measures should be conducted for conservation and recovery of them.

Finally, Environmental Sensitive Map was generated in the GIS environment. The ESI map prepared with all the information's covering the entire Chabahar Bay coast with 1:100000 scale Fig. 3. This will be more useful for planning purpose at the time of oil spill event and also for environmental planning.

Table I:Physiographic Characteristics of the Shorelines in Chabahar Bay

Ranking No	Category	Physical Factors
1A	Exposed rocky shores	A shoreline that has regular exposure to wave and tidal energy, no potential for subsurface oil penetration, and a slope of 30°or greater is included into this ranking. Because of the impermeable substrate and its exposure to waves, oil remains on the surface, thus allowing natural forces to remove the oil. Little or no cleanup is usually required. This is the least sensitive classification
1C	Exposed rocky cliffs with boulder talus base	
3A	Fine- to medium-grained sand beaches	This shoreline is composed of low-sloping, well-compacted sediment, which limits oil penetration to less than 10 cm. Cleanup is simplified by a hard substrate, permitting both foot and vehicle traffic
6B	Riprap	Because of the large grained sediments, oil can penetrate up to 100 cm below the surface. An intermediate slope, between 10 and 20°, restricts vehicles from assisting in the cleanup effots. Riprap, a man-made break wall to limit wave and tidal energy, has added problems. Riprap usually is constructed at the high-tide line, which is where oil concentrations are strongest. Because of the large size of riprap boulders,

		oil penetrates deeply, and flushing is not always effective. Only by removing and replacing it can one ensure it is completely clean
7	Exposed tidal flats	The sediments on this shoreline are water saturated, which limits the oil from penetrating. Low trafficability, high infaunal densities, and a slope of less than 10°are also characteristics of this rank. Cleanup can be difficult because of a potential to grind the oil deeper into the substrate because of increased foot traffic
8B	Sheltered, solid man-made structures	This shore line is similar to that in Rank 1B except that it is shelterd from the wave and tidal forces. The substrate is compacted and hard, composed of bedrock, man-made materials, or stiff clay, and the slope is greater than 15°.High algae and organism coverage is usually present. Shoreline cleanup can be difficlt and intrusive, usually done for aesthetic reasons
9A	Sheltered tidal flats	Again, this shoreline classification is sheltered from wave and tidal energy, with a slope less than 10°. The sediment is water saturated, limiting oil penetration. Cleanup efforts face the same difficulties as in Rank 7
10D	Mangroves	The substrate is generally flat, with a high concentration of organic, muddy soil. Grassy or woody vegetation frequently covers this classification. Cleanup tends to cause significant damage and long-term impacts to this delicate ecosystem. This is the most sensitive classification

Table II: Shoreline by Categories

ESI	Shore types	Location	Total length (km)	Percentage of entire shoreline
1A	Exposed rocky shores	ship making, South East Chabahar Bay	8.02	14.79
1C	Exposed rocky cliffs with boulder talus base	South west Chabahar Bay, Tis promontory	8.36	15.42
3A	Fine- to medium-grained sand beaches	Tis, Chabahar	10.28	18.96
6B	Riprap	Konarak pier, Tis pier, Konarak Desalination	0.13	0.23
7	Exposed tidal flats	North West Chabahar Bay	21.37	39.42
8B	Sheltered, solid man-made structures	Shahid beheshti and Kalantari Pier	3.7	6.82
9A	Sheltered tidal flats	Namaki estuary, Parak estuary	1.08	1.99
10D	Mangroves	Naser abad estuary, Tis estuary	1.27	2.34

Oil Category Descriptions
I – Gasoline products
II – Diesel-like products and light crudes
III – Medium grade crudes and intermediate products
IV – Heavy crudes and residual products
V – Non-floating oil products

The following categories are used to compare the relative environmental impact of each response method in the specific environment and habitat for each oil type. The codes in each table mean:
A = The least adverse habitat impact.
B = Some adverse habitat impact.
C = Significant adverse habitat impact.
D = The most adverse habitat impact.
I = Insufficient information - impact or effectiveness of the method could not be evaluated.
– = Not applicable.

Response Method	Oil Category I	II	III	IV	V
Natural Recovery	A	B	B	C	C
Booming-Containment	–	A	A	B	–
Booming-Deflection/Exclusion	A	A	A	B	–
Skimming	–	A	A	A	–
Physical Herding	B	B	B	B	–
Manual Oil Removal/Cleaning	–	–	C	B	B
Sorbents	–	B	B	B	–
Debris Removal	–	A	A	A	B
Dispersants	B	B	B	B	–
Emulsion-treating Agents	–	B	B	B	–
Elasticity Modifiers	–	B	B	–	–
Herding Agents	–	B	B	–	–
Solidifiers	–	B	B	–	–
In-situ Burning	–	A	A	B	–

Fig 2 Character and response recommendations of oil spills for bays and estuaries [9]

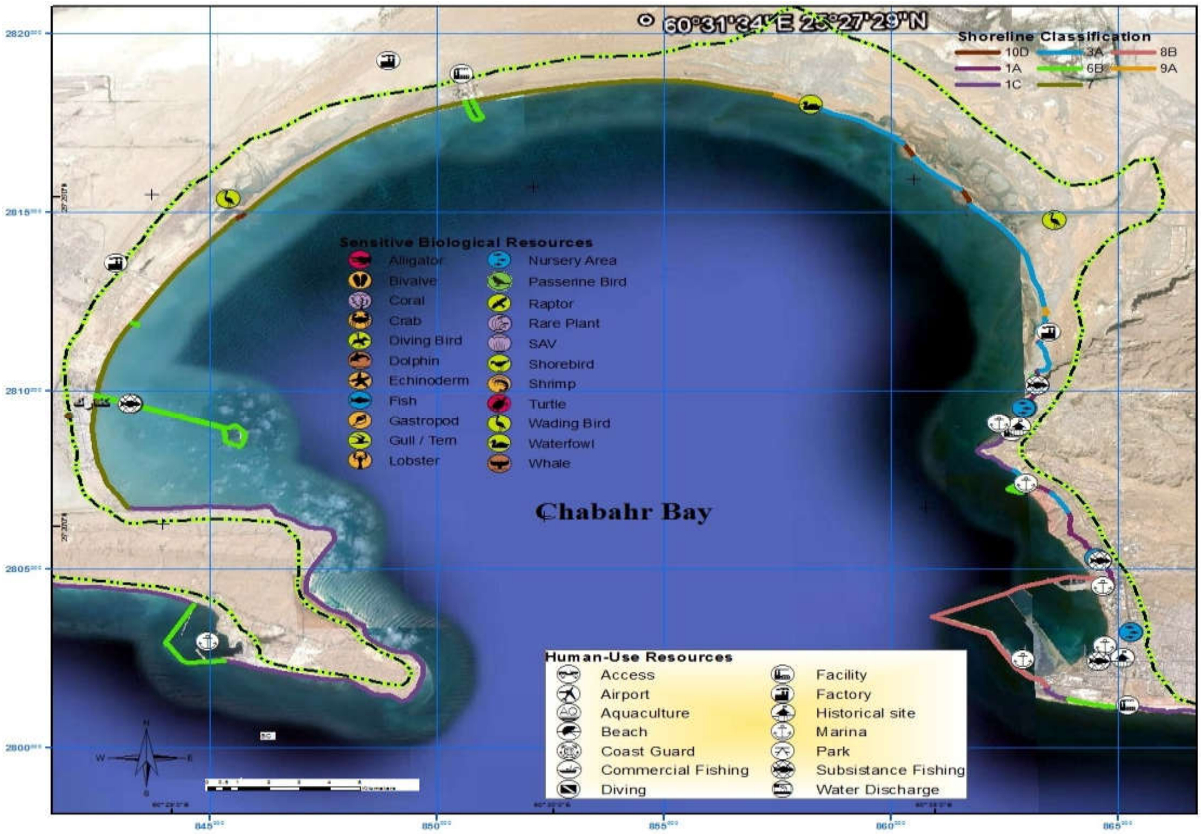

Fig. 3 Environmental sensitivity maps for oil spill hazard for Chabahar Bay coast

DISCUSSION

To distil the complexities of shorelines into biodiversity distribution pattern and proportion of shore types alone will lead to gross simplification and the underlying assessment becomes unavoidably subjective. Looking at the importance attached to individual issues in ESI mapping, it was essential to dwell on the physical attributes of each shorelines [10]. Disasters such as the Deep Water Horizon oil spill and the Exxon Valdez oil spill, provide evidence that coastal oil spills pose danger to the economy and natural resources, and could directly affect the public's health [15]. Sensitivity maps have a long history of effectiveness and success (they were first developed in the 1970's) in a wide and diverse extension of coastal areas, which is clearly an advantage. In addition, they provide an objective and synthetic view of decisive information which is also an advantage, since it facilitates the decision making process . Impacts on coastal environments caused by oil spills are complex and spill response teams must be always prepared to assimilate a great deal of information to achieve an optimal response action. These informations include the type of oil, likely trajectories considering various physical processes, probable resources threatened by oil, presence of sensitive areas, and available protection equipment and the applicable clean up techniques [1]. The consequences of a large oil spill are severe and long term for all coastal. therefore, a great deal of attention has been placed on public outreach and educational material concerning types of oils spills, impacts of oil spills on marine resources, as well as what the oil spill response process involves [13]. Both government and nongovernment groups have an interest in how ESI maps evolve in the Chabahar Bay. One key challenge for starting the discussion of ESI mapping in the Chabahar Bay is the lack of a biogeographic and ecological classification for the area. There are no national standards applied to terminology and classification of natural communities, critical species habitats, or biodiversity inventory. The goal of ESI mapping is to integrate maps of a region with geographically referenced biological resources, human-use resources, and ESI-classified shorelines that are ranked based on their sensitivity to oiling. This can only be accomplished by an interagency team of professionals that not only understand GIS, but also have first-hand knowledge of the biological and human-use resources. Thus, the responsibility for ESI mapping is often multiagency, with one lead person or management committee. The Chabahar bay is subjected to high threaten to oil spill because of port, dense mangrove forest,only coral spot in Oman Sea and many industrial activities. Eight ESI types were identified in the Chabahar Bay namely; 1A, 1C, 3A, 6B, 7, 8B,9A and 10D. Based on sensitivity to oil spill, 50% were defined as High sensitivity, less than 1% as Medium and 49% as low sensitivity areas.

Mangrove forests of Tis, Parak and Naserabad (ESI- 10D) are rich in biodiversity providing a habitat for wide varieties of animal and plant species. They are dynamic areas, rich in food. Many of the fish caught commercially in tropical regions reproduce and spend time in the mangroves as juveniles or adults. Mangroves are also home to many birds. The mangroves ranked highest with scores of 10D respectively support the fact that mangroves are about the most sensitive in terms of impact of oil spill on biodiversity in shore line. Oiling would certainly impact heavily on the area since it would be difficult to cleanse easily and several life forms would be affected. The mangroves have low exposure to wave energy but since the slope is a gentle one, slight tidal increase will get oil on to it. The beaches have High sensitivity. Under light oiling, the best practice is natural recovery. Heavy accumulations of pooled oil can be removed by vacuum, sorbents, or low-pressure flushing. Any cleanup activity must not mix the oil deeper into the sediments. Trampling of the roots must be minimized and Woody vegetation should not be cut.

Coral reefs vary widely in sensitivity to spilled oil, depending on the water depth, oil type, and duration of exposure. Coral reefs of Chabahar Bay, located in the southeastern part of Iran and northern coast of Gulf of Oman, are subjected to many threats including fishing, oil pollution, coastal construction, development of recreational sites, etc. Solid man-made structures in a sheltered area (8B) exist here. The most appropriate response method are Natural Recovery and Sorbents. Boom and skimmer are useful for preventing the spread of oil. Exposed tidal flats (ESI-7) are broad, flat intertidal areas composed primarily of Sand. It is also high vulnerable area for oil spill. North West and West of Chabahar Bay are in this category. These beaches are high ranked in the ESI scale and has the highest sensitivity. Cleanup is very difficult (and possible only during low tides). The use of heavy machinery should be restricted to prevent mixing of oil into the sediments.

The ESI maps can be provided to the National Emergency Management Agency to serve as a quick reference for oil spill responders and coastal zone managers. A single map or an entire atlas of maps may be needed, depending on the size of the oil spill. According to the law in Iran, Port and Maritime Organization of Iran (PMO) is responsible for combating oil pollution in water bodies with the assistance of the Department of the Environment (DOE). They have the defense team for combating the oil spills and they can easily know from the map how their shoreline habitats are ranked in terms of sensitivity and determining their priorities depending upon that. A significant problem with large ESI and coastal assessment datasets is keeping information current. An outdated ESI map poses potential problems because the information on the map can suggest emergency responses that are no longer appropriate. Communities and citizen scientists can contribute timely and critical information on the state of the coast. At a minimum, the digital map should be revisited each year for populated islands because coastal alterations are occurring rapidly. If an ESI mapping team is working continuously, the ESI mapping process can be updated more frequently and can engage local communities to monitor the status of their local coasts.

CONCLUSION

Oil spills can be extremely harmful, both to the environment and to society, especially when the spilled material reaches coastal areas. In order to prevent and minimize their impacts, an effort should be made to improve prevention and intervention tools, and their effectiveness. Pre-existing information on coastal resources, and prioritized protection areas allow for a faster response and a better distribution of the protection and clean-up efforts, thus allowing for a correct coastal management. Chabahar Bay is at high risk of being impacted by an oil spill occurring in or near its coastal areas. For that reason, the existence of a decision support tool for the assessment of coastal sensitivity and subsequent definition of protection priorities is critical. The ESI maps are useful to the oil spill responders, coastal managers and contingency planners. The overall ESI mapping product can provide a valuable management tool not only for oil spill response but for better integrated coastal zone management.

REFERENCES

1. Carmona,L, Gherardi, D. F. M. and Tessler, M. G. (2006). Environment Sensitivity Mapping and Vulnerability Modeling for Oil Spill Response along the São Paulo State Coastline. Journal of Coastal Research :1455 – 1458.
2. Dicks, B. and Wright, R.. (1989). Coastal sensitivity mapping for oil spills. In: Dicks, B. (ed.), Ecological Impacts of the Oil Industry. New York: J. Wiley & Sons Ltd: 235-259.
3. Dicks, B. (1999). The environmental impact of marine oil spills – Effects, recovery and compensation. London, United Kingdom: The International Tanker Owners Pollution Federation Ltd.
4. El-Raey, M.; Abdel-Kader, A. F.; Nasr, S.M., and Gamily, H.I. (1996). Remote sensing and GIS for an oil spill contingency plan, Ras-Mohammed, Egypt. International Journal of Remote Sensing. 17: 2013-2026.
5. Gundlach, E.R. and Hayes, M.O. (1978). Vulnerability of coastal environments to oil spill impacts. Marine Technology Society Journal, 12(4): 18-27.

6. Jensen, J. R.; Halls, J. N., and Michel, J. (1998). A systems approach to environmental sensitivity index (ESI) mapping for oil spill contingency planning and response. Photogrammetric Engineering & Remote Sensing, 64(10): 1003-1014.
7. Jensen, J. R.; Ramsey, E.W.; Holmes, J. M.; Michel, J.; Savitsky, B., and Davis, B. A. (1990). Environmental sensitivity index (ESI) mapping for oil spills using remote sensing and geographic information system technology. International Journal of Geographical Information Systems, 4(2): 181-201.
8. Krishnan, P. (1995). Research report – A geographical information system for oil spills sensitivity mapping in the Shetland Islands (United Kingdom). Ocean & Coastal Management, 26(3): 247-255.
9. NOAA, 2002. Environmental Sensitivity Index Guidelines Version 3.0
10. Oyedepo, J. A and Adeofun, C.O. (2011). Environmental Sensitivity Index Mapping of Lagos Shorelines. Global NEST Journal. 13( )3: 277-287.
11. PMO. (2011). Iranian Seas Wave Modeling (ISWM) program report. Port and Maritime Organization. 10.
12. Santos, C.F. (2008). Development of an Environmental Sensitivity Assessment Model for the Portuguese Coast Concerning Oil Spills. Lisbon, Portugal: Sciences Faculty of Lisbon University, Master's thesis, 77.
13. Sealey K.S and Patus J. (2015). Resources, Methods, and Effort Associated with ESI Mapping of the Bahamian Archipelago for Great Exuma, Bahamas. Journal of Coastal Research, 31(4)
14. Taheri M., Yazdani M and Bagheri H. (2010). Community Structure and Biodiversity of Intertidal, Sandy Beach Macrofauna in Chabahar Bay, Northeast of Oman Gulf, IR Iran. Journal of the Persian Gulf. (Marine Science).191):17-25.
15. Walther III Henry R. (2014). Clean up thechniques used for coastal Oil Spills: an analysis of spills occurring in Santa Barbara, California, Prince William Sound, Alaska, The Sea of Japan and The Gulf Coast. Master's Projects. 104.
16. Wilson S.C. (2000). The Arabian Sea and Gulf of Oman. In: C.R.C. Sheppard. (Ed.), Seas at the Millenium Pergamon Press. Amsterdam : 17-33