

Marine ecological baselines and environmental impact assessment studies in the Sudanese coastal zone: A review



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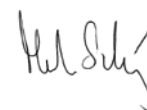
Abstract

The unique coastal and marine ecosystems of Sudan need protection against anthropogenic influences. This report provides a review of the key Valued Ecosystem Components (VECs) which occur in Sudanese coastal and offshore areas, with emphasis on their localisation, importance and state of condition. The report also highlights some of the major threats to the stability of these VECs and includes information which may be important in connection with industrial environmental impact assessment (EIA) studies and monitoring activities in Sudanese coastal and marine waters. Environmental legislation and governing systems of Sudan with special relevance to marine ecosystem resources are described in addition to industrial and societal developments and the most important Sudanese research and educational institutions and programmes that are relevant for the issues addressed. Finally, a list of key gaps of knowledge and recommendations of future actions which may serve to improve the environmental management and protection of VECs in Sudanese coastal and marine waters is presented in the last section of the report.

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Preface

This report is made as part of a bilateral collaboration programme between Sudan and Norway and the work has been funded by the Norwegian Oil for Development (OFD) programme. In the collaboration, the Norwegian Environment Agency (NEA) assists the Sudanese Ministry of Petroleum, General Directorate for Environment and Safety (MoP-GDES), in the development of a good environmental management regime for the Sudanese coastal area. In this connection, NIVA was commissioned to compile a summary report of the status of the marine and coastal ecological resources in Sudan. The involved personnel at NIVA have been Jonny Beyer (PL), André Staalstrøm and Bente M. Wathne. Focal persons and main contributors from MoP-GDES have been Ms. Rihab Kamal Omer and Dr. Siddig Eissa Ahmed. Contact person for this project at NEA has been Frank Eklo.

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Oslo, 17.11.2015

Jonny Beyer

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Summary

As part of a bilateral collaboration programme funded by the Norwegian Oil for Development (OFD) programme, the Norwegian Environment Agency (NEA) assists the Sudanese Ministry of Petroleum, General Directorate for Environment and Safety (MoP-GDES), in the development of a good environmental management regime for the Sudanese coastal area. Included in these efforts is the development of two reports, covering (1) an overall baseline summary report (this document) for marine ecosystems and ecosystem components in the coastal zone of Sudan made from an open source literature survey and (2) a marine environmental monitoring plan for Sudanese marine waters made with initial structure from the environmental monitoring guidelines that are used in the offshore petroleum sector in Norway supplemented with locally adapted monitoring methods. The key aims of this collaboration are: (a) to make a comprehensive and popular overview of present knowledge and management systems relating to marine ecosystem resources in Sudan; (b) to identify institutions in Sudan that are most essential in this connection (on governmental, academic, societal and industrial levels); (c) to contribute to the continued collaboration of Sudan and Norway on matters of sustainable management and efficient conservation of valuable marine ecosystem resources.

In this review process, data and information have been collected from open literature sources, at project meetings and workshops and by direct communication with relevant contacts and experts in Sudan and Norway. The present report is meant to provide a status overview of the ecological resources in the Sudanese coastal zone with special emphasis on high priority Valued Ecosystem Components (VECs) such as coral reefs, pristine coastal and island habitats, seagrass and seaweed areas, mangroves, fisheries, coastal birds, sea turtles and dugongs and other sea mammals. The present report highlights relevant competence institutions in Sudan and also knowledge gaps and recommendations for actions related to the protection of the VECs of concern in the Sudanese coastal zone.

The key findings of this study are as follows:

- Literature surveys show that a substantial amount of information is available regarding a range of VECs in Sudanese marine waters. Much is available through open sources, but many literature sources are old and the information/data is therefore to some degree outdated.
- The collected information indicate that the marine ecosystems within the Red Sea State of Sudan are (overall) in a good state, but certain VECs, e.g. mangroves, are in a severe condition that calls for immediate protection measures.
- Given the rich ecological resources, there is much to lose if the developments within the coastal zone result in a deterioration of VECs.
- Coral reefs are common all along the Sudanese coast and these areas are the key VECs in the Sudanese marine waters.
- Industrial and societal developments have led to significant damage locally to marine habitats and also to coral reefs. Systems for EIA have been formally and legally implemented, but on site implementation appears not to have been adequate.
- Petroleum industrial activity in nearshore and other shallow regions of the Sudanese Red Sea represents particularly large threats to sustainable management of coral reef and other VECs, since it is very likely that there are coral reefs present where these operations are conducted or planned.
- With increased petroleum industrial activity, the risk of marine oil spills may increase. This is considered to be a serious threat to VECs and ecosystems along the Sudanese coast.
- Mangrove and areas that contain seagrass and seaweed beds represent important nursery habitats for fish and other marine species, and these areas also require urgent protection. Currently mangrove marshes are probably the most threatened habitats, but not necessarily only from petroleum activity.
- There is too little information available on the population status and trends of the endangered dugongs in Sudanese waters, but reports from fishing communities suggest a rapidly declining trend. Immediate action is required to improve the knowledge and to implement efficient protection measures for this species.

Definitions and abbreviations

Baseline survey: A survey that is conducted in a geographical area to characterise its ecological and environmental condition status, normally performed before the start of a new industrial/societal development/activity in the area.

Biological impact: This is indicated in an area if the fauna in a sample is significantly different from that at comparable regional stations. Calculations of biological impact are based on an overall evaluation of all the statistical analyses carried out on the biological material.

Chemical contamination: Present in areas where the levels of the selected metals, radioactive substances and/or hydrocarbons are significantly higher than the expected background level.

ECA: The Economic Commission for Africa.

Ecologically sensitive area: A geographically delimited area containing one or more natural resources (species and habitats) or Valued Ecosystem Components (VECs) that are sensitive to a particular pressure and that at best will need a long recovery period to return to a normal state after significant damage.

Environmental Impact Assessment (EIA): A public process by which the likely effects of a project on the environment are identified, assessed and then taken into account by the consenting authority in the decision making process.

Environmental monitoring activities: Routinely measurements of specified assessment endpoints for a specified VEC over a specified period of time. Hence, environmental monitoring will over a time-period provide empirical documentation on whether the status of the ecosystem component is in a stable, improving or worsening condition.

EPSA: Exploration and Production Sharing Agreements.

HCENR: The Sudanese Higher Council for Environment and Natural Resources.

ICUN: International Union for Conservation of Nature. ICUN is an international organization located in Switzerland and working in the field of nature conservation and sustainable use of natural resources.

ICZM: Integrated coastal zone management, a dynamic, multidisciplinary and repetitious process to promote sustainable management of coastal zones.

ISO 14000: A family of standards that provides practical tools for companies and organizations of all kinds looking to manage their environmental responsibilities.

JAMP: Joint Assessment and Monitoring Programme: An international monitoring programme organised by OSPAR, with joint guidelines for planning, implementation, analysis and reporting.

Monitoring: Repeated assessment of conditions in a specified environmental location, most often relating to a specific action.

Monitoring of benthic habitats: Physical, chemical and biological monitoring investigations of the seabed.

Monitoring survey: A routine investigation of environmental conditions in a field or region (conducted after a specified activity has started).

MoP-GDES: Sudanese Ministry of Petroleum, General Directorate for Environment and Safety.

MPA: Marine Protected Area.

NCEA: The Netherlands Commission for Environmental Assessment.

NEA: The Norwegian Environment Agency.

OFD: The Norwegian Oil for Development programme

PAHs: Polycyclic aromatic hydrocarbons: all hydrocarbons in which the molecule contains three or more aromatic rings. Hydrocarbons with only two aromatic rings (naphthalenes) are often included as well.

PERSGA: The Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden.

Plankton: Organisms that spend all or part of their life cycle floating or drifting in the water and that have little or no independent mobility.

PSU: Practical salinity unit. Unit used when measuring content of salt in the ocean by measuring conductivity. 1 psu is approximately but not exactly equal to the older unit ‰ (or g/kg) that is from 2010 reserved for the newly defined parameter Absolute Salinity.

Radioactive substance: A substance that emits alpha, beta or gamma radiation.

Region: A delimited area of the continental shelf defined by geographical coordinates. The boundary towards the shore follows the coastal baseline.

RESPOC: The Red Sea Petroleum Operating Company, a consortium of five companies led by China National Petroleum Corporation (CNPC) and Malaysia's state oil firm Petronas, along with the Sudan National Petroleum Corporation (Sudapet), Nigeria's Express Petroleum and the Sudanese private company High Tech Group.

RSGA: Red Sea and Gulf of Aden.

Strategic Environmental Assessment (SEA): A form of environmental assessment intended to identify and assess the likely significant effects of a plan or programme on the environment, the result of which are then taken into account in the decision-making process.

UNEP: United Nations Environment Programme.

UNIDO: United Nations Industrial Development Organization.

VEC: Valued Ecosystem Component.

Scope of study

Through the Norwegian Oil for Development programme, the Norwegian Environment Agency (NEA) assists its Sudanese partner, the Sudanese Ministry of Petroleum, General Directorate for Environment and Safety (MoP-GDES), with capacity development on pollution prevention, environmental conservation and environmental monitoring in Sudanese marine waters.

The key aims of the collaboration are to (A) develop an environmental overview baseline based on existing literature for the Sudanese coastal zone with special attention to vulnerable marinebiological resources and regions that may be affected by oil & gas developments (this document), (B) to develop an environmental monitoring plan that is specially adapted to the Sudanese Red Sea and the environmental risks which typically are connected to oil & gas industrial operations in coastal and offshore regions (Beyer et al., 2015), and (C) in the possible continuation of the work, to develop a specially designed capacity development course targeted to training of Sudanese personnel in environmental monitoring activities.

NIVA - the Norwegian Institute for Water Research (Oslo, Norway) was commissioned to this programme and has carried out the work in cooperation with NEA and MoP-GDES. The present report represents the deliverable related to aim A – the ecological baseline study and the main scopes of this study are:

1. To develop a structure for collecting, systemizing and examining literature data required for completing the marine ecological baseline report and the marine environmental monitoring plan.
2. To collect and collate relevant data/information from existing literature and other sources and assess the sufficiency and quality of the collected information and data. Identify significant knowledge gaps and specify recommended actions to fill these gaps.
3. To identify major types of Valued Ecosystem Components (VECs) in Sudanese marine waters with a special emphasis on VECs for which site-specific baseline conditions, EIA studies and environmental monitoring activities should be established in cases of offshore oil & gas developments in Sudanese marine waters.
4. Identify the types of environmental and ecological data which are important for each of the prioritised VECs, and suggest a structure for environmental monitoring activities that aim to establish a study resolution in space and time for VECs that should be protected in connection with offshore oil & gas developments in Sudanese marine waters.

Since this baseline report in practice concerns the whole range of VECs that exist in the coastal waters of Sudan, the study will necessarily be addressing the large picture and to a lesser degree all the details that are important and relevant at each location. We have within the very restricted time frame of the present programme aimed to find a level of details that both is practically achievable but also content-wise meaningful for the users of this report.

1 Introduction

1.1 Background

The Sudanese part of the Red Sea (Figure 1) is world famous for harbouring extraordinary rich and beautiful natural habitats with many endemic marine species, pristine coastline locations and large areas with undisturbed coral reefs. If managed in an ecologically sustainable manner these natural ecosystems represent key resources for future wealth for the Sudanese population. It is a concern that multiple concurrent processes of change within the Sudanese society presently produce a mounting challenge to the condition of the unique coastal zone ecosystems. Central pressures include rapid coastal population growth, increased urbanisation and industrial developments at the coastline and regional climate change. Serious and worrying symptoms are clear signs of overexploitation of marine fish and invertebrate populations, degradation of coral reefs, overgrazing of mangrove stands, declining populations of particularly vulnerable species and increasing coastal pollution originating from land-based sources and maritime transport. The combined effect of these stressors poses a complex challenge to the coastal environment of Sudan and marine biodiversity in the area (Nasr et al., 2012). Fortunately, an increasing awareness is emerging in Sudan with relation to the value of coastal zone ecosystems and the need for establishing efficient systems for maintaining the condition of these ecosystem resources for the future. In particular, possible oil and gas resources in the area and plans of increased oil and gas industrial activities both at the coast and at the narrow Sudanese shelf accentuate the urgent need for action to establish regulatory and technical measures which are able to protect the fragile and valuable ecosystems within the Sudanese coastal zone.



Figure 1: The Red Sea coast of Sudan, its Exclusive Economic Zone (EEZ) and shelf waters to 200 m depth. Map source: Tesfamichael and Ekawad (2012).

For environmental regulation to be effective, it is crucial that there is a proper level knowledge about the ecological resources which the regulation is meant to protect. In the Red Sea area there has recently been substantial progress on issues related to knowledge, management and ecosystem

conservation. Much of the progress is resulting from the important work of the intergovernmental organisation PERSGA¹. PERSGA is dedicated to the protection of the unique marine waters of the Red Sea and the Gulf of Aden (the so-called RSGA area). The Marine Environment Protection Administration (MEPA), which is part of the federal Ministry of Environment, Natural Resources and Physical Development, is the Focal Point of PERSGA in Sudan. Among the important achievements of the PERSGA organisation is the development of the PERSGA Technical Series reports, which is a broad collection of studies concerning the environment of the Red Sea and the Gulf of Aden, including also several reports and report-sections specifically addressing the Sudanese marine waters. One of key TS reports (TS 10) is a manual of standard survey methods for key habitats and key species in the RSGA area. That manual describes how to collect baseline data and conduct condition surveys on coral reefs, mangroves, and other key habitats and species. Within PERSGA, regional action plans (following regional surveys) have been developed for corals, mangroves, turtles and breeding seabirds and these plans are currently being implemented nationally via national action plans in the PERSGA participating countries (PERSGA, 2010). The importance of the PERSGA organisation in connection with environmental knowledge development in the whole RSGA area and the relevance of the PERSGA reports as information sources for the present study are further discussed in section 3.1.

1.2 Environmental regulation of oil industry operations in the coastal zone

When oil & gas reserves and other significant natural resources are discovered in environmentally sensitive regions (Figure 2), it is important that national environmental legislation and regulation is constructed and enforced in such a manner that it gives sufficient protection to the ecological resources.

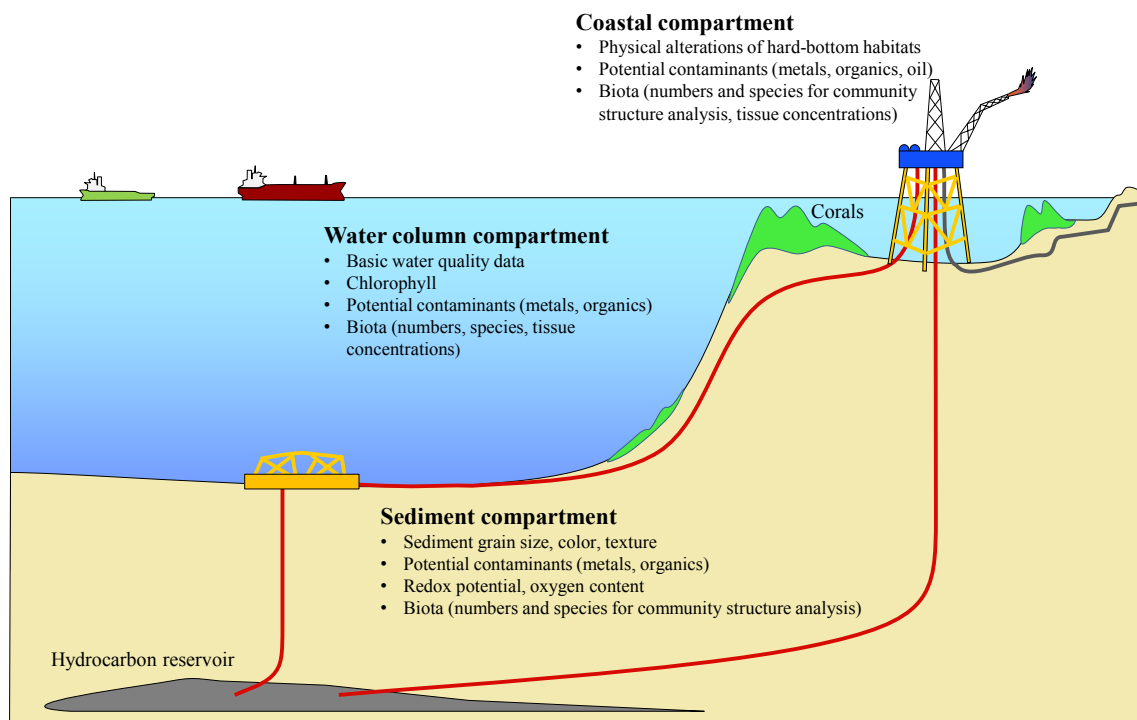


Figure 2: The water column and soft-bottom sediments are the main ecosystem compartments that most commonly are addressed in offshore oil & gas industry environmental monitoring studies. But the common presence of valuable coral reefs along the Sudanese coastline highlights the importance of including these ecosystem components in EIAs and monitoring activities in connection with oil & gas industrial developments in the Sudanese coastal waters.

¹ The Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden. The URL to the PERSGA organisation website is: <http://www.persga.org>

Environmental Governance and Rule of Law covers the areas of policy development, planning and legislation that are needed in connection with protection of ecosystem resources. In some case, this entails the reform of existing structures, policies, plans and laws. The earliest national law and regulation process which were relating to Sudan's coastal and marine environment and resources was initiated with the marine fisheries ordinance of 1937, which later was amended in 1975 and 1978 (Table 1). The regulation prohibits over-fishing, dumping refuse including oil into the sea, and the collection of corals, shells, aquarium fish and seabird eggs. In addition, the Environmental Health Act, established in 1975, prohibits the dumping into the sea of any item that is harmful to humans or other animals. The central environmental law document in Sudan is the Environmental Conservation Act of 2001 (ECA 2001). The ECA 2001 law document formalised Environmental Impact Assessment (EIA) as a key decision making instrument to be used in assessing whether proposed or performed activities are likely to have significant adverse impact on the environment. Briefly described, an EIA study is a public process by which the likely effects of a project on the environment are identified, assessed and then taken into account by the consenting authority in a decision making process. A broader description of EIA studies and the regulatory use of EIAs in the Sudanese context are provided in section 1.4. The Sudanese Higher Council for Environment and Natural Resources (HCENR) was formally responsible for enforcing the ECA 2001 regulation.

Table 1: Main national laws and regulations related to coastal and marine environments and resources in Sudan.

Law Ordinance, Regulation	Year (in force)	Government Agency Concerned
Marine Fisheries Ordinance	1937	Marine Fisheries Administration
Amendments to marine fisheries regulation	1975, 1978	Marine Fisheries Administration
Sudan Marine Conservation Committee Regulations	1975, 1995	Ministry of Environment and Tourism
Environment Health Act	1975	Ministry of Health and Local Councils
Sudan Maritime Law	Draft proposal 1996	Maritime Administration
Environmental Policy Act	Draft proposal 1996	HCENR and Attorney General
Environmental Conservation Act	2001	HCENR and Attorney General

The Netherlands Commission for Environmental Assessment (NCEA), an independent expert body that provides advisory services and capacity development on environmental assessment, has made a country profile for Sudan (<http://www.eia.nl/en/countries/af/sudan/>) to provide a historical, dynamic and updated summary (and also a quality assessment) of the process of developing environmental regulation and legislation systems for oil and gas industrial activities in Sudan. According to the information provided, the ECA 2001 sets a legislative framework with use of EIA as a key approach for policy, plans and programmes developments

The environmental regulations that petroleum industry companies and other industrial stakeholders must comply with are described in greater details in sector specific regulation documents. The Petroleum Resources Act 1998 and the Petroleum Regulations of 1973 regulate exploration and production of oil and gas resources in Sudan both onshore and offshore. Major amendments have been introduced in the Petroleum Resource Act which gives the Minister of Energy and Mining, with the approval of the Board of Petroleum Affairs, the right to conclude agreements for the exploration and production of oil and gas in Sudan. All the Agreements signed by the Sudan Government with the international oil companies are Exploration and Production Sharing Agreements (EPSA). The EPSA embodies the entire rights and obligations of the Government and the Oil Company. The Oil Company, under the EPSA, recovers its operations cost from an agreed and negotiable percentage of

the total production. The profit of oil production activities is divided between the Government and the Oil Company according to certain percentage to be agreed upon by both parties.

In exercising its powers under Article 35 of the Sudanese Petroleum Resources Act of 1998, the Sudanese Petroleum Affairs Council (2005) approved the Regulations for Protection of the Environment in the Sudanese Petroleum Industry. That document specifies in an overview manner what issues that must be addressed by the industry and also the possible legal responses that will be effectuated in cases of misconduct of the operations. For example, it demands that any agreement concluded in relation to petroleum operations at Sudanese territories shall include:

- Taking of measures and procedures necessary for the protection and cause no destruction or mischief of the land layers which contain the petroleum, metals and water during the exercise of the petroleum operations or abandonment of the wells; together with determining and conservation of the resources of the discovered fresh water, during the practice of any petroleum operations.
- The need to take the precautions and the required procedure against fire or unjustifiable loss of petroleum metals, water or vegetation cover.
- The need to take preliminary precautionary measures required to avoid causing environmental pollution during loading and unloading or transportation of petroleum by road, sea, river or air.
- The need to adopt contingency plan to overcome and control any environmental pollution or, damage.
- The need to follow the process of care and attention as well as the good measures during the exercise of the petroleum operations, to avoid the occurrence of environmental pollution.
- Submission of an insurance certificate or financial guarantee to cover, restore and compensate the damage in the occurrence of environmental damage.
- To avoid unjustifiable repetition and severalty in the establishments, equipment and tools concerning the petroleum operations in the same area.
- To submit a study containing overall evaluation of the environmental impacts likely or definitely may result on exercise of the petroleum operations, the same shall be submitted before the actual commencement of the activity for approval by the competent bodies in accordance with Regulations.
- To obligate to any international environmental agreements to which the Republic of Sudan is a party.
- To adhere to any law or custom enforce recognized by the Republic of Sudan or the state where the petroleum operations or industry is exercised.

1.3 Ecological baseline studies of Valued Ecosystem Components (VEC)

An ecological baseline study can be defined as the collection, systematisation and analysis of environmental and ecological data from a specified area (site, location or region) to characterise its condition status, often also including societal data. A baseline study is typically performed at a specific location before a planned industrial development activity is started; such as before the construction of a new industrial facility or before the expansion of an existing industrial facility. A recent and relevant example of a baseline study in Sudan is the study performed by the Institute Of Marine Research (Red Sea University) in connection with the proposed Phase II construction of the Elkhair Oil Terminal (IMR, 2014), a site which is located at the south side of the new container terminal in Port Sudan. Another relevant recent example of a medium-size marine baseline study is the ecological characterisation and condition assessment work that was conducted in connection with the development of the Dungenab Bay and Mukawwar Island National Park, which was declared by the Government of Sudan in Oct. 2004 following several years of preparatory work by the Sudan Wildlife Conservation General Administration and PERSGA (Nasr, 2015b; PERSGA/GEF, 2003a, 2004a).

The collection of data for a baseline study can be based on existing ecological information/data, or it can be based on new information which is obtained in new field surveys in the area of concern; or a combination of these two options. The spatial expansion of the area covered by the baseline may vary considerably, from large regions in the case of regional baselines to relatively small areas in the case of site-specific baselines. When a baseline is developed in connection with ecosystem protection measures, such as a special protected area, the baseline study will often be included as an integrated part of a Master Plan developed for the protection area.

Most baseline studies are site-specific studies that are limited to a relatively small area or location which is often in a relatively natural and undisturbed condition, e.g. prior to any significant alterations caused by human actions. Site specific baseline studies can be very narrowly defined, for example limited to one single ecological quality characteristic (study parameter) at the location of study, for example the size of a local population of a certain species. Alternatively, in the case of a very biodiverse location such as a coral reef, the site-specific baseline may be widely defined, including a broad set of parameters and assessments of the ecological status at the site as well as data and parameters related to the societal use of the ecological resources at the site. A baseline study is typically communicated by means of a report (baseline report) which sometimes is communicated as an integrated part of an EIA study (Sadler and McCabe, 2002).

The present ecological baseline study is based solely on existing information/data and addresses in practice all different kinds of Valued Ecosystem Components (VECs) that are found in the coastal zone in the Sudanese Red Sea State. In this connection, the term “VEC” may refer to any kind of environmental feature (habitat, fauna component, etc.) that is important to a local human population, or that has a particularly high value nationally or internationally. If altered from its existing status, the quality status of a VEC is important for the evaluation of environmental impacts of urban or industrial developments, and for the focusing of management efforts. The cluster of VECs that is addressed in the present overview baseline study includes:

- Pristine coastal habitats
- Coral reefs
- Mangroves
- Areas with seagrass and seaweeds
- Fish populations and fisheries
- Sea turtles
- Sea birds
- Sea mammals

Given a primary emphasis on ecological matters, this present baseline study is not addressing societal data in any great details. If possible, a baseline should include a description of VECs and an assessment of their quality or condition status. In addition, the study will normally include assisting information as well, such as information about climatic and meteorological conditions or specifications of different ecosystem stresses that are relevant for the region in question. Optimally, the data which are collected within a baseline study should allow for an analysis of the situation on the ground and serve to highlight issues of special concern. As a part of the baseline study, significant knowledge gaps related to the study area and to the specific VECs in question, should also be identified. When an ecological baseline is established, it forms a knowledge basis to which later environmental assessments and monitoring data can be compared. This is the case both for site-specific and regional baselines.

A good indication of the current state of the art for marine baseline investigations in Sudan is provided by the recent environmental baseline study that was conducted by the Institute of Marine Research (Red Sea University) at the Al khair (Alkhair, El Khair, Elkhair) marine oil export terminal (IMR, 2014). In the study, the selection of baseline components and parameters was addressed in the selected set of biotopes and diving transects (Figure 3), the addressed compartments and issues included:

LITTORAL ZONE

Physical and chemical characteristics of seawater
Phytoplankton community
Zooplankton communities
Sediments characteristics

MACRO-FLORA ANALYSIS

Seaweeds (diversity, zonation, % cover)
Seagrass (Species composition, distribution, % cover, shoot density)

MACRO-FAUNA ANALYSIS

Epifauna and infauna

FISH POPULATION OCCURRENCE

Fish larvae

SUBLITTORAL ZONE

Reef slope coral survey (density, diversity & distribution)

Reef slope fishes (density, diversity & distribution)

Reef slope Macro-invertebrates (density, diversity & distribution)

REEF CREST SURVEY

BACK REEF SURVEY

Back reef fishes (as above)

Back reef invertebrates (as above)

SOCIOECONOMIC SURVEY

EOT workers questionnaire analysis

Fishermen questionnaire analysis

In addition to the above components, the baseline report also included an overview of the laws, regulations, regional conventions and protocols that are of relevance to the issues addressed. The collection of baseline data that are provided set the basis for the subsequent EIA and monitoring follow-ups which are to be conducted at the location.



Figure 3: Study locations and sampling stations used in the recent environmental baseline study at the Al khair marine oil export terminal (IMR, 2014).

1.4 EIA/SEA and environmental monitoring studies

As noted in section 1.2, the regulatory practice of using EIA studies in connection with industrial developments was legalized by the Sudanese National assembly with the passing of the Environmental Conservation Act of 2001 (ECA 2001). Before that EIAs were done on a voluntary basis (see the list

of EIAs in Ali (2002)). The ECA 2001 provided the legal basis for EIAs in the Sudanese regulation system, and also listed specific EIA requirements for projects that were likely to have a negative effect on the environment.

An EIA study can be defined as the formal process used to predict the environmental consequences (positive or negative) of a plan, policy, program, or project prior to the decision to move forward with the proposed action (Figure 4). The use of EIAs is an important tool in assuring that industrial and societal projects will not give an adverse impact on the environment beyond what can be considered as acceptable.

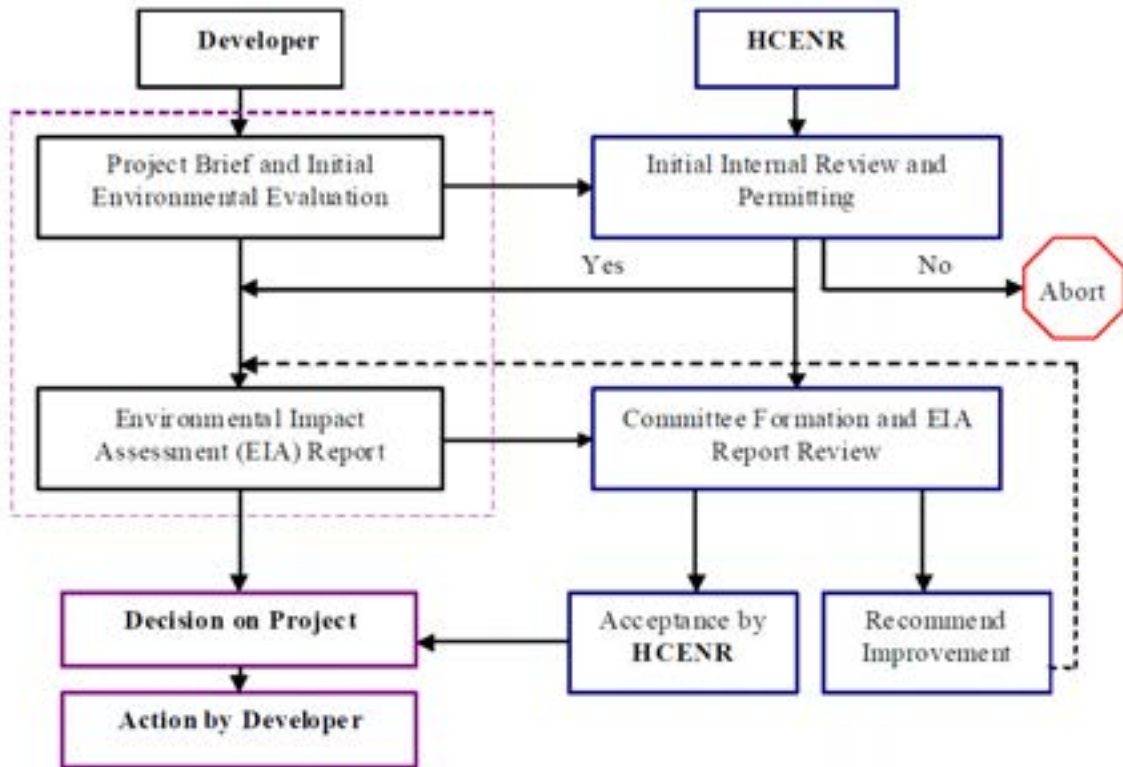


Figure 4: The typical structure and work-flow of an EIA oriented process as it is practiced in Sudan. Source: Ahmed and Abdella Elturabi (2011).

Typically, an EIA study is done in connection with site-specific investigations, but more seldom in connection with regional studies. However, site specific EIAs may often make use of baseline information/data collected in regional baseline studies. In an EIA study, the environmental condition of a defined study site is assessed before and after a certain human activity has been undertaken, often using a predictive approach (e.g. by using theoretical analyses, scenario predictions and modelling data) or a descriptive approach (e.g. by using empirical measurements and data collected in the field). The use of EIA studies has developed throughout the world and many different applications exist. There is therefore no such thing as a global standard procedure for how to conduct an EIA study. However, there is a broad literature base describing alternative procedures targeted for specific ecosystems and more or less specified situations of environmental stressors. As a general perspective, the performance of ecological baseline studies and EIA studies are steps within a more superior environmental management process that is aimed to protect the quality of specified ecosystem or ecosystem components (i.e. VECs). Based on information and conclusions from baseline studies and EIA studies, decision makers can implement appropriate measures in order to avoid unnecessary degradation of specified VECs in specified environments.

In a report prepared to a HCENR / UNEP workshop, Badawi (2006) examined the status on environmental management procedures in Sudan’s oil industry and provided a summary of the industries environmental challenges and an evaluation of different methods to regulate environmental performance of operating companies. He recommended implementing an environmental management

system based on a combination of ISO 14000 and a Market Based Initiative (MBI), the latter which harnesses public praise or vilification towards the operating companies, as that probably would be the best way of developing a proper culture of meeting or exceeding environmental regulatory standards in connection with oil industry activities. He also suggested that environmental impact control in the oil industry should be managed by the Sudanese Ministry of Energy (MoE), perhaps under the auspices of the Ministry of Environment, and that the MoE should consider sharing the risk that the operators face when making decisions centred on environmental issues, e.g. by using the risk sharing model which is implemented in the Norwegian oil industry.

Based on the ECA 2001 law, the use of EIAs became the key approach used by Sudanese Authorities to define, communicate and enforce the environmental regulation demands in conjugation with industrial activities. How good this EIA oriented regulatory framework actually works in a Sudanese context was critically discussed by Ali (2007) who identified several weaknesses and flaws in the legislative, administrative, institutional and procedural frameworks. An effective implementation of the EIA process, he argued, requires proper institutionalization of the process within the legislative, administrative, political, and education system in the country, with a special emphasis for the federal system of governance. Other key issues include accreditation, sectoral regulations, establishing of a National Centre of EIA for advising the government and for training of human capacities. The experience of EIA use in conjugation with sector specific environmental regulations in Sudan has recently been further examined by Ahmed and Abdella Elturabi (2011), who assessed EIAs conducted in the oil industrial sector and several other sectors (agriculture, power, roads and highways, river engineering). Although identifying several problems, they found that the performance of EIAs was in general relatively good, taking in mind the limited availability of appropriate guidelines.

There is a growing contention worldwide that the classical EIA approach falls short of addressing the complex underling issues of policy-development and planning (ECA, 2005; Sadler and McCabe, 2002). To meet this shortfall of EIAs a new decision-making philosophy known as Strategic Environmental Assessment (SEA) has therefore emerged. The Economic Commission for Africa (ECA) has published a thorough description of EIA and SEA processes and why it is important to involve both EIA and SEA principles in connection with the development of environmental regulations systems (ECA, 2005). The key differences between EIA and SEA oriented studies are shown in Table 2 below. The use of SEA is yet not practiced in Sudan, but Ali (2012) recently suggested to start involving SEA in the environmental regulation systems of Sudan, as a necessary supplement to the EIA oriented principles. In contrast to EIA, the SEA process typically concerns the superior policy development process, i.e. by addressing the questions, issues and alternatives that need to be considered in connection with the policy, plan and programme (PPP) making process (Figure 5).



Figure 5: The principle relationship of SEA and EIA studies.

Table 2: Comparison of key features of EIA and SEA (Sadler and McCabe, 2002), adapted from Ali (2012).

EIA of projects	SEA of policy, plans and programmes
Takes place at the end of the decision-making cycle	Takes place at earlier stages of the decision making cycle
Reactive approach to development proposal	Pro-active approach to development proposals
Identifies specific impacts on the environment	Also identifies environmental implications and issues of sustainable development
Considers limited number of feasible alternatives	Considers broad range of potential alternatives
Limited review of cumulative effects	Early warning of cumulative effects
Emphasis on mitigating and minimizing impacts	Emphasis on meeting environmental impacts objectives, maintaining natural systems
Narrow perspective, high level of detail	Broad perspective, lower level of detail to provide a vision and overall framework
Well-defined process; clear beginning and end	Multi-stage process; overlapping components, policy level is continuing, iterative
Focuses on standard agenda; treats symptoms of environmental deterioration	Focuses on sustainability agenda; gets at sources of environmental deterioration

1.5 Integrated coastal zone management

As described in the project implementation plan in the PERSGA Strategic Action Programme for the RSGA area PERSGA (1998) integrated coastal zone management in most countries in the RSGA region is adversely affected by weak co-ordination between ministries, overlapping jurisdictions, conflicting objectives, and weak implementation of area planning. UNEP has in previous environmental status assessments in Sudan acknowledged the importance of this issue and has strongly recommended two key themes which Sudanese authorities should address in order to achieve sustainable management of the marine and coastal ecosystem riches found in the Red Sea state, namely the establishment of an integrated governing and management system based on the concept of Integrated Coastal Zone Management (ICZM), and devolution of more responsibility to the Red Sea state level (UNEP, 2007).

According to the definition by the European Commission, ICZM represents a dynamic, multidisciplinary and repetitious process to promote sustainable management of coastal zones and including the full cycle of information collection, planning, decision making, management and monitoring of implementation. An ICZM process will typically aim to use the informed participation and cooperation of all stakeholders to assess the societal goals in a given coastal area, and to take the proper actions towards meeting these objectives. ICZM seeks, over the long-term, to balance the long-term objectives of environmental, economic, social and cultural issues that are relevant in connection with a set of ecosystem resources in a given target area; all within the limits set by natural dynamics. The integration also concerns the many political and administrative instruments needed to meet the defined objectives. A successful implementation of ICZM plans will reduce the incidence of inappropriate development decisions and provide an effective mechanism for sustainable long-term use of the coastal zone. Both in Sudan as well as throughout in the RSGA region the adoption of an ICZM oriented planning and management process to support development decisions could significantly decrease unnecessary degradation of the coastal and marine environments. The effective use of ICZM is especially important in supporting the co-operating countries to meet challenges related to long-term development of coastal settlements and development zones, further expansion of

international and domestic tourism, and maintenance of the rich biodiversity and cultural heritage of the coastal zone (PERSGA, 1998).

A process for implementing ICZM within the Sudanese Red Sea State Governing system has previously been initiated with support from the PERSGA organisation but the status and progress of this process is unclear at the present moment (Prof. M.E.Hamza, pers. comm.).

1.6 Map overviews of the Sudanese coastline

The Sudanese coastline which stretches from Egypt in north to Eritrea in south borders the Red Sea and is characterized by a relatively narrow reef studded shelf of about 4,000 km² (Figure 1, Figure 14). Small embayments or inlets (Arabic “marsa”) that cut into the coastal plain are found many places along the coast, in particular in the northern part. These inlets are used as shelters by the artisanal fishermen. Fringing reefs are found virtually all along the Sudanese coastline and around the multiple sandy islands, which occur in particular great numbers off the southern part of the coast.

The whole coastline of Sudan lies within the Red Sea State, which is one of the states (or wilayats) that currently are included in the Sudanese nation. The total number of Sudanese states was larger previously but was reduced to 19 states following the secession of South Sudan in July 2011. The Red Sea State is divided into the eight administrative areas known as Localities: Bur Sudan (Port Sudan), Gebiet Elma'din, Hala'ib, Haya, Sawakin, Sinkat, Gunob Awlieb, Derodieb, Tokar and Ageeg. Port Sudan is the capital of the Red Sea State. According to official figures, the total area of the Red Sea State is 218,887 km² and its population was in 2010 estimated to just below 1.4 million, whereas the current population of Sudan is a little over 30 million.

The Sudanese jurisdiction on the Red Sea is limited to a coastline of some 750 km and an Exclusive Economic Zone of 91 600 km². Variable information in different literature sources is found with regard to the size of the Sudanese shelf area. The shelf area data ranges from 22,300 km² (Saeed, 2004), 9,800 km² (Sanders and Morgan, 1989), to 4,000 km² (Tesfamichael and Ekawad, 2012). The discrepancy is possibly due to a variable use of shelf depth criteria in the different literature sources. The shallow part of the shelf area in Sudan is generally narrow, especially in the central part of the coast, in the area off Port Sudan (Figure 1 and Figure 14).

The estimated total length of the Sudanese coastline varies considerably among different literature sources (i.e. 720 – 875 km), and this variability is apparently depending on whether or not all embayments and inlets are included and whether or not the Hala'ib area (Figure 6) is included as a part of the Sudanese territory. The issue with Hala'ib triangle area is an ongoing territorial dispute between Sudan and Egypt. The dispute originates back to the difference in the Egypt–Sudan border between the "political boundary" set in 1899 by the Anglo-Egyptian Condominium, which runs along the 22nd parallel north, and the "administrative boundary" set by the British in 1902, which gave administrative responsibility for an area of land north of the line to Sudan, which was an Anglo-Egyptian client at the time. With the independence of Sudan in 1956, both Egypt and Sudan claimed sovereignty over the Hala'ib area. Egypt forcibly annexed the area in 1992, but Sudan has each year since the early 90's filed a complaint with the UN against Egypt because of this unresolved issue. The Hala'ib case is a political issue which falls outside the scope of the present report. However, the Hala'ib case is relevant to mention herein as the area obviously includes a range of coastal and marine habitats of great ecological value, and there are also most likely significant natural resources on land.



Figure 6: The coastline of Sudan runs from the border to Eritrea in the south to the border to Egypt in the north, but the length varies quite considerably among literature sources (720 – 875 km) depending on whether all embayments and inlets are included and depending on whether the disputed Hala'ib area is included as Sudanese territory.

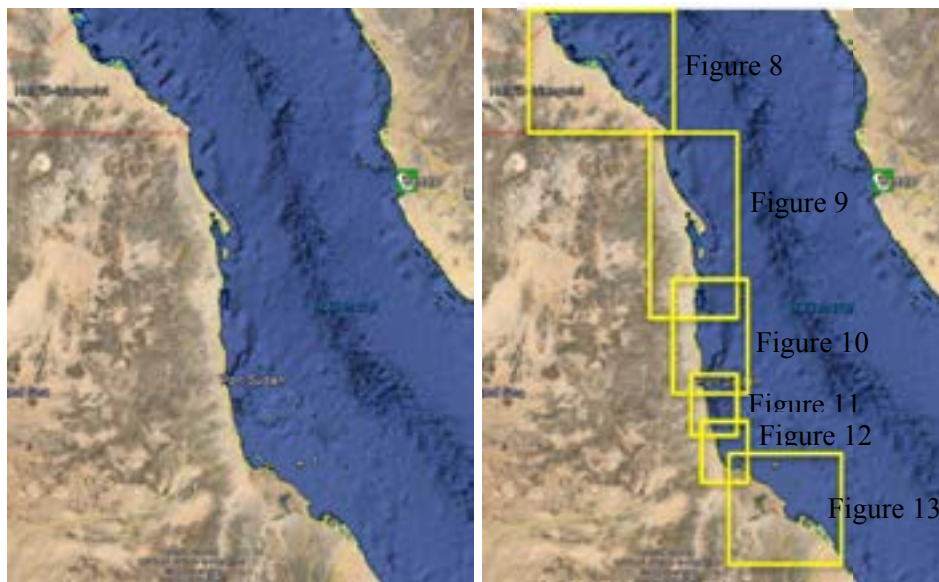


Figure 7: Overview map of Sudan's 875 km long coastline to the Red Sea with further map details shown in the subsequent figures (Source of maps in Figs 7 – Fig. 13: Google maps).

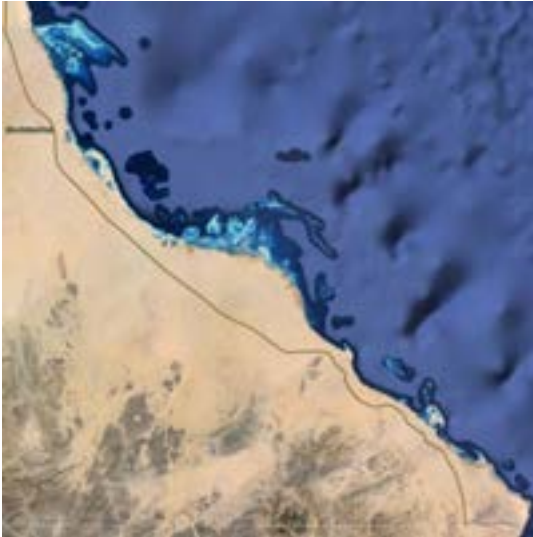


Figure 8: The northernmost area known as the Hala'ib Triangle, is a source of ongoing border dispute between Sudan and Egypt.



Figure 10: Sudanese coast north of Port Sudan. The Sanganeb marine protection area is located 35 km 35 km northeast of Port Sudan



Figure 9: North part of Sudanese coast, including the marine protection area of Dunganab Bay and the Mukawwar Island. Mukawwar Island is also called Jazirat Magarsam.



Figure 11: Central part of Sudanese coast south of Port Sudan, between Port Sudan and Suakin



Figure 12: Southern part of coast, south of Suakin. The southern part of the area includes the Saqir Island which is an area with numerous small islands.

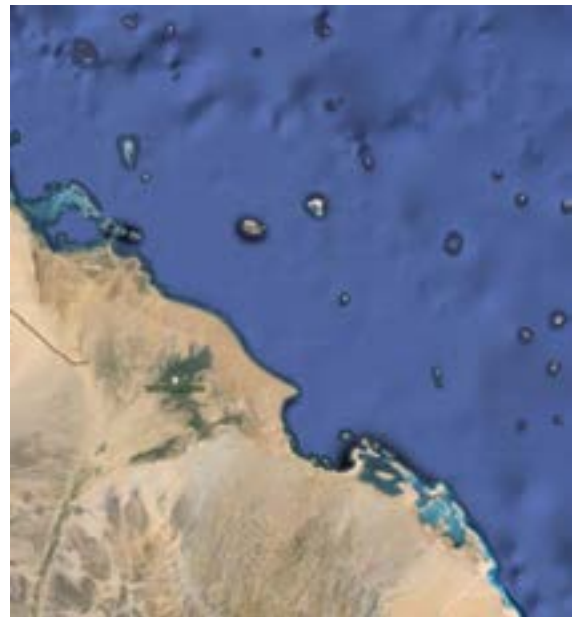


Figure 13: Southernmost part of Sudanese coast towards the border to Eritrea. The area includes the Saqir Island, the Tokar game reserve, the Talla Talla and Kebir Islands and the Er Rih Island.

2 Ecological baselines of Sudanese coastal waters

2.1 Physical and chemical characteristics of Sudanese Red Sea

The Sudanese marine waters are part of the Red Sea, which is a long (2,250 km) and narrow (355 km) oceanic basin located between Asia and Africa, quite isolated from world oceans and surrounded by hot deserts (Tesfamichael and Pauly, 2012) (Figure 14). The Sudanese coastline stretches from Egypt in north to Eritrea in south and is characterized by a narrow continental shelf area. As discussed in section 1.6, the estimated total length of the Sudanese coastline varies considerably among different literature sources (i.e. 720 – 875 km), and this variability is apparently depending on whether or not all embayments and the Hala'ib area in the north is included. Three distinct depth zones are recognized in the Sudanese part of the Red Sea: shallow coastal shelves less than 50 m deep, the steep drop zone to the deep shelves at 500 to 1,000 m depth, and the central trench which is more than 2,000 m deep at the deepest (Figure 14).

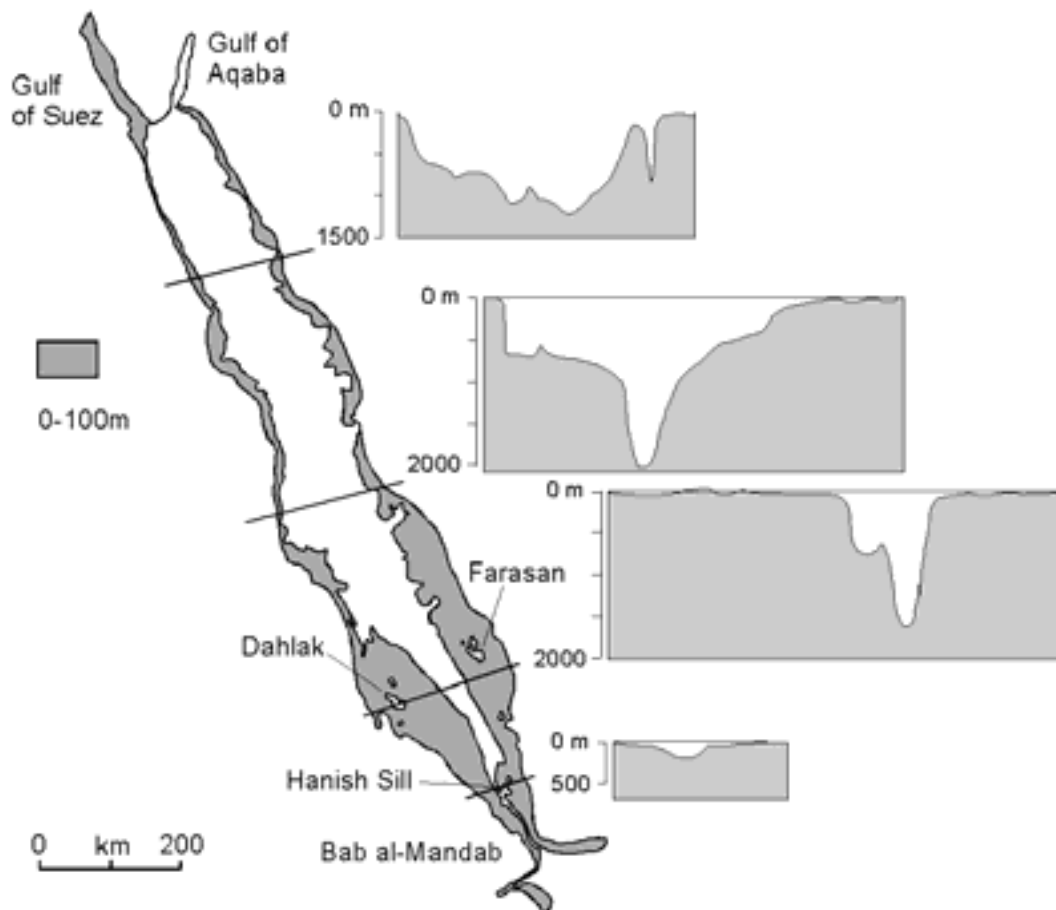


Figure 14: The Red Sea shelf areas. This illustration shows the variable amount of land exposed at the –100 m bathymetric contour in different regions. Illustration source: Bailey (2009).

In the south, the Red Sea is connected to the Indian Ocean through the narrow strait of Bab al Mandab, the door of fortune. From its geographical characteristic, the Red Sea is considered as a tropical water course with a prevailing desert and semi-desert climate. The seawater in the Red Sea is generally

characterized by high temperature and high salinity due to high evaporation, negligible precipitation and a general lack of runoff water. The Red Sea is one of the saltiest bodies of water in the world, owing to the high evaporation. Salinity in the surface water ranges from between ~36 PSU in the southern part water and 41 PSU in the northern part. The high evaporation result in formation of dense water that sinks down bringing with it a large amount of heat. As a result of this, the deep water in the Red Sea is extremely warm, normally more than 21 °C at 1500 m depth Klevjer et al. (2012).

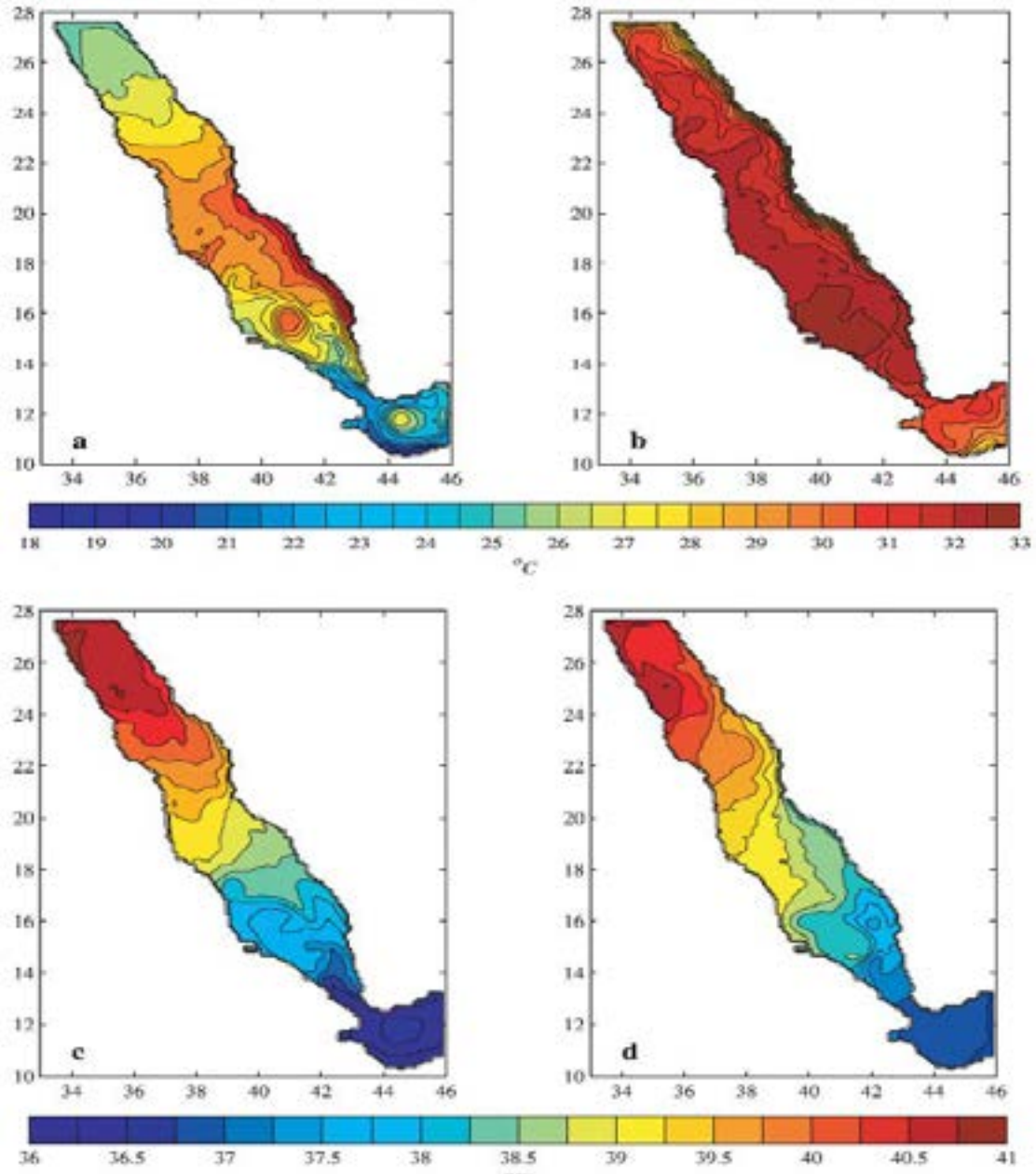


Figure 15: Seasonal variability in temperature distribution (a &b) and salinity distribution (c &d) in sea surface waters of the Red Sea. The figures to the left show the situation during winter season and the figures to the right show the situation in the summer season. Source: Sofianos and Johns (2002).

The seawater of the whole Red Sea is very clear due to the low rate of precipitation and surface runoff. As the water exchange via the Suez Canal in the north is negligible, the only significant seawater exchange goes through the Bab el Mandeb strait in the south which connects the Red Sea with the Gulf of Aden. The strait is rather narrow and shallow with a sill depth of 160 m and a minimum width of about 25 km. The average depth in the Red Sea is about 490 m and the depth in the central trench is

more than 2000 m, however. The maximum depth of the Red Sea is found in Sudanese waters off the coast of Port Sudan and reported to be more than 3000 m (Tesfamichael and Ekawad, 2012).

The Red Sea oceanic basin is surrounded by high mountain ranges that constrain the prevailing winds to be closely aligned along the axis of the basin. The prevailing winds over northern Red Sea have north-western direction all year around, whereas in the southern Red Sea the prevailing winds have a north-western direction during summer and a south-eastern direction during winter (November-May). During the winter season, the water exchange between the Red Sea and the Gulf of Aden has a two-layer structure with a relatively fresh surface inflow on the top of the Red Sea outflow. During the summer season (June-October), a three-layer exchange occurs consisting of a shallow layer of outflow water in the surface, an intermediate intrusion layer with water from Gulf of Aden having relatively low salinity and low temperature, and a weaker deep hypersaline outflow. The seasonal winds are most likely the drivers of this seasonal water exchange pattern.

The waters of Red Sea have generally low productivity, mainly due to lack of nutrient-rich terrestrial run off and lack of upwelling to lift nutrient-rich deep water to the surface where photosynthesis can occur (Tesfamichael and Pauly, 2012). Moreover, the vertical mixing of water is prevented by a permanent thermocline, as the temperature of the sub-surface water is always lower than the warm surface temperature. The depth of the thermocline is deeper in winter than summer (Edwards, 1987). Generally, the southern part of the Red Sea is more productive than the northern part due to the flow of nutrient rich water from the Indian Ocean, the main nutrient input, and the re-suspension of nutrients from the bottom sediments by turbulent mixing over shelf areas (Sheppard et al., 1992).

The surface seawaters in Sudan's part of the Red Sea are characterized by weak currents, lack of upwelling, small tidal differences (1-2 feet), high water temperature (typically 20 degrees in February and 33 degrees in August), high salinity (39-45 ‰), limited freshwater input due to little precipitation and surface runoff and a lack of permanent rivers.

Many places along the Sudanese coast seasonal rainfall have formed short-lived streams (so-called khors) and these seasonal streams have formed the characteristics inlets (marsas) which many places cut through the coastal plain. In the south, the seasonal Baraka (or Barka) stream has formed the Tokar (or Towker) delta.

The Sudanese shelf area is characterized by a large number of nearshore and offshore coral reefs in the inner and outer continental shelf area (see section 2.3).

Marine sediments in the Red Sea have been investigated and characterised in a large number of studies, and only a brief review of a few studies with emphasis to Sudanese waters will be provided in this report. Relevant sedimentary parameters to characterise include particle size distribution and other texture parameters, organic carbon content, calcium carbonate (CaCO₃, calcite) content, organic nitrogen and total phosphorus content, mineralogy, geochemistry, sedimentation rate and concentration of anthropogenic pollutant chemicals (oil hydrocarbons, heavy metals, pesticides, radionuclides, etc.). The sediment studies show in general that most parameters vary greatly depending on the area, water depth and habitats studied. The Red Sea coral reefs are, together with climatic conditions and the large scale geology of the Red Sea area (Figure 16), key controlling factors for the regional sedimentary processes as well as for the development of the recent strata of sediments found at the sea floor close to the coast. The sediments in shallow areas of the Sudanese shelf are mostly coral reef sediments with high content of calcium carbonate. Coral reef sediments are generally loose and unconsolidated in nature. They generate mainly from reef rock, calcareous algae, fragmented solid biogenic material, calcium carbonate skeletal remains such as foraminifera and mollusc shells, beach rock fragments, faecal material produced by organisms which ingest sediments and terrigenous material driven from the surrounding land by winds or seasonal runoff. Studies from elsewhere in the Red Sea have shown that coral fragments typically make up 15-40 % of the coral reef sediments while mollusc fragments make up 4-22 %. Chemical composition studies of reef sediments need to be considered with caution as analytical problems can result in strongly significant systematic errors and render comparison between different studies meaningless.

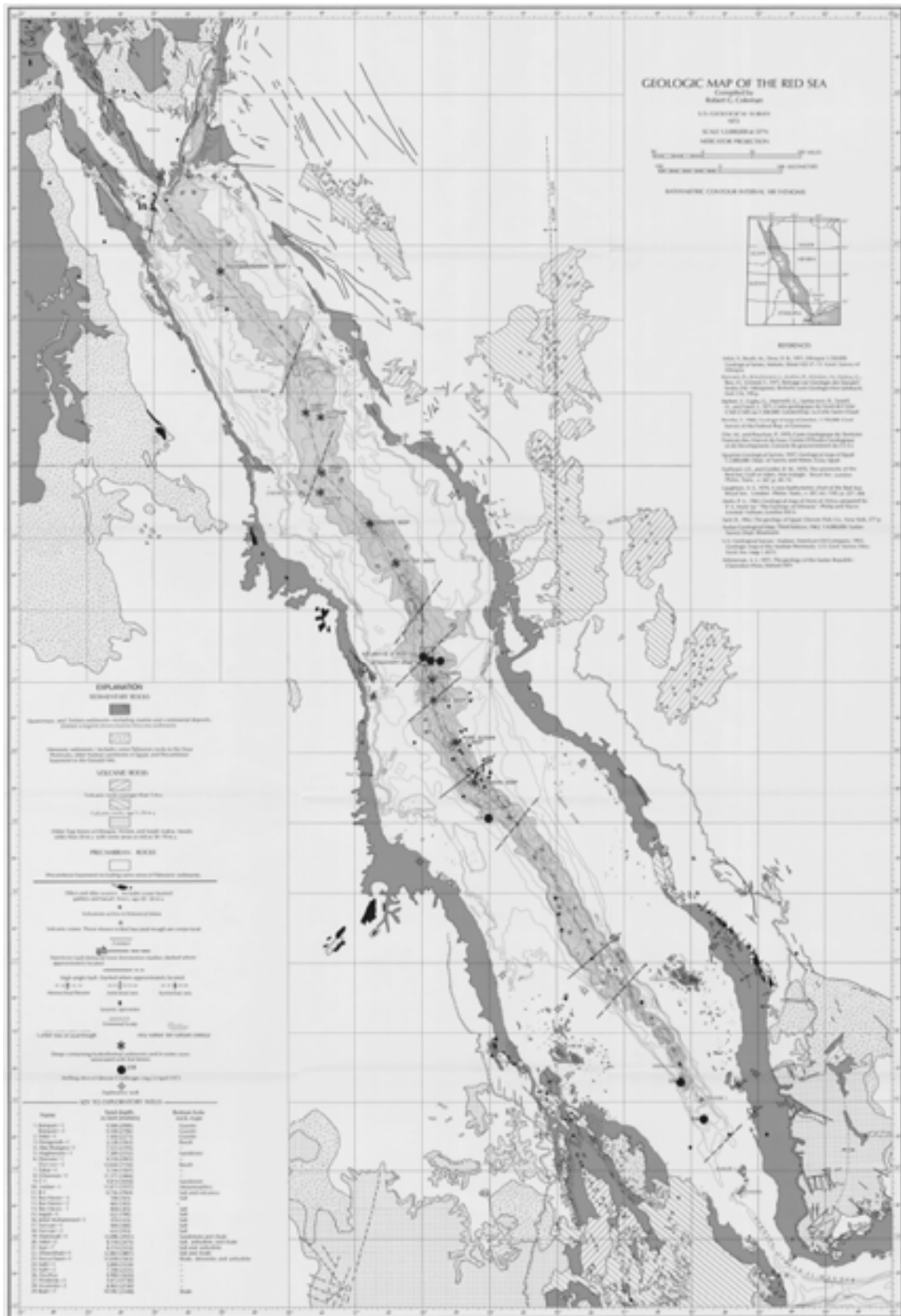


Figure 16: Geologic map of the Red Sea. Map Source: http://www.deepseadrilling.org/23/volume/dsdp23_fgeologicmap.pdf

In two articles Branford (1981a, b) analysed particle size distributions, organic carbon content, CaCO₃ content and visual estimates of composition of sediments in different parts of the Sudanese coast and

correlated these data to the abundance of five different species of penaeid shrimps. He found that the fineness of the sediment was the most important factor controlling which shrimp species that was the dominant. Farah et al (1990) studied sediment particle distribution, total carbonate and organic carbon content in the Shanaab Bay (Khor Shin'ab), a large and pristine marsa embayment located north of Dungenab Bay area. They found that the total carbonate content within this inlet ranged between 2% and 98% with an average of 62%. The carbonate was found to be mainly biogenic although some physicochemical precipitation of calcium carbonate also might have contributed to the levels observed. The organic matter contents varied between 1.18% and 5.88%, with an average of 2.76%. The organic matter derived largely from in-bay sources.

In a recent PhD study Hamed (2015) studied fossil coral reefs, diagenetic sedimentary rock formation and coastal sediment development processes in the central part of the Sudanese coastline with the objectives of identifying the coral composition of Pleistocene fossil reefs, to recognize different reef zones and their microfacies composition as well as depositional environments, to reveal absolute and relative ages of the emergent reefs and to acquire the palaeoclimatic information represented by them and to outline the diagenetic setting of the reefs. He found that Pleistocene coral reefs are well exposed over a width of about 3 km parallel to the Red Sea coast in Sudan and used the recorded patterns of fossil corals, sedimentary facies, diagenetic features and age of the reefs to construct a sedimentation model for the whole area. The study included identification of a total of 29 scleractinian coral species that belong to 8 families and 16 genera. Three coral communities were distinguished: distal communities predominated by pipe-like packed *Galaxea facicularis*, middle communities predominated by branched *Porites sp.* and proximal communities predominated by massive and columnar *Porites columnaris*. Four major reef zones and ten sub-facies were recognized. The major reef zones recognized were (1) rock-reef rim, (2) reef-front zone, (3) reef-flat zone, and (4) back-reef zone. Age estimations of fossil reefs were mainly based on $\delta^{18}\text{O}$ values of the reef-front zone and the observed sedimentary succession of the reefs. The results suggest equivalent ages of 120,000 years and 122,000 years that correspond to the marine isotope stage (MIS) 5.5 age, whereas $\delta^{18}\text{O}$ values and field relationship to the reef-front zone suggested that the ages of the reef-flat and back-reef zones could be assigned to the MIS 9 and MIS 7 periods, whereas MIS 5.1 was suggested for the reef-rock rim, respectively. The sedimentation model proposed by Hamed (2015) differs, when compared to previous models for the Red Sea region, in the formation of the back-reef zone during the MIS 7 period, while previous studies assigned it to MIS 9. High diversity and excellent preservation of corals in MIS 7 reefs reflect their growth in protected structural troughs landward of the reef-flat. The study describes the complex story of how palaeoclimatic conditions with periods of increased rainfall and stream flooding and different sea-level have influenced the present characteristics of the coastal sediments found in the Sudanese marine waters.

Other useful information sources:

(Al-Aidaros and Satheesh, 2014; Anschutz et al., 1999; Arz et al., 2003; Bower et al., 2000; Bower et al., 2005; Chang et al., 2008; Clifford et al., 1997; Ganssen and Kroon, 1991; Hartmann et al., 1998; Ionita et al., 2014; Manasrah et al., 2004; Ozgokmen et al., 2003; Peters et al., 2005; Qurban et al., 2014; Shpaykhe, 1968; Sofianos and Johns, 2007; Sofianos et al., 2002; Souvermezoglou et al., 1989; Wahr et al., 2014; Zhan et al., 2014).

2.2 Pristine shoreline and subtidal habitats

The coastline of Sudan on the Red Sea is some 750 km long, not including all the embayments and inlets. Numerous islands are scattered along the coast, the majority of which have no water or vegetation. The dominant coastal forms are silty beaches, rocky headlands and salt marshes, commonly bordered with mangroves. Fringing coral reefs are very common all along the Sudanese coast and water clarity is generally high due to the lack of sedimentation. Average precipitation in the coastal areas is extremely low, ranging from 36 mm per year at Hala'ib in the north to 164 mm per year at Suakin, so that the desert extends right to the tide mark. The only exception is the Tokar delta, which receives substantial run-off from seasonal streams originating in the Ethiopian and Eritrean highlands. The islands and most of the coastline are relatively undisturbed and host important feeding and nesting sites for a variety of seabirds.

Assessment of condition: Far most of the Sudanese coastline is very sparsely populated and characterised by a pristine beach landscape, ecologically diverse subtidal habitats and fringing coral reefs located close to shore. According to most reports, the general ecological condition of the coastline and the nearshore and offshore waters in Sudan is overall good (UNEP, 2007). The overall good condition of the Sudanese shoreline is largely a direct consequence of the small human population present and the limited amount of infrastructure developments.

Potential stresses and risks: Rapid population growth combined with economical and industrial developments which now are ongoing within the coastal zone, especially between the cities of Port Sudan and Suakin, represent a serious threat to the ecological quality of this coastline.



Figure 17: Overview map of the coastline of Sudan showing locations of the marine nature reserve and national parks along the coast.



Figure 18: (A): A typical pristine shoreline location north of Port Sudan, with sparse vegetation on a sandy-silty beach, with a sheltered zone and the fringing reef indicated by the breaking waves in the distance. Photo courtesy of UNEP. (B): Shoreline vegetation at the Sudanese coast by the Taila Island south of the Mukawwar Island, a bird of prey is seen central in the photo.



Figure 19: The Taila Island, just south of the Mukawwar Island (Photo: Google Earth).



Figure 20. Close-up picture of a giant sea clam *Tridacna* sp. taken at a location south of Port Sudan. (Photo courtesy of Arpad Dudas).

Anthropogenic sources of coastal pollution

UNEP has previously provided overview information about the status and trends on different categories of environmental pollution in Sudan, suggesting that the development of better measures for waste management is urgently needed both generally in the society as well as in different industrial sectors (UNEP, 2007, 2012). The studies by UNEP suggest that the less populated area of the Sudanese coast is relatively pristine and little contaminated, whereas the population centres (Port Sudan and Suakin) are general hotspots for anthropogenic impact as a consequence of the rapid population growth and the poorly developed infrastructure for sewage treatment and waste/litter management. Environmental governance of the Sudanese industry was virtually non-existent until 2000, and the negative effects of this are clearly visible at some of the industrialised sites today, although some facilities more recently have implemented significantly improved routines to minimise environmental pollution problems. According to the UNEP reports, major challenges remain in the areas of project development and impact assessment, improving the operation of older and government-managed facilities, and influencing the policies and management approach at the higher levels of government.



Figure 21: The Port Sudan landfill is located at the head of a seasonal watercourse. Every wet season, the run-off draws pollution from the site to the coastal lagoons. Picture courtesy of UNEP, source: http://postconflict.unep.ch/sudanreport/sudan_website/index_photos_2.php?key=Coastline



Figure 22: Lagoon in the centre of Port Sudan burdened with urban litter pollution and shoreline development. Picture courtesy of UNEP, source: http://postconflict.unep.ch/sudanreport/sudan_website/index_photos_2.php?key=Coastline

Measurements of concentrations of anthropogenic chemical pollutants in different ecosystem compartments (e.g. beaches, seawater, sediments, seafood) represent powerful markers for assessing the degrees of negative human impact in the area. In this connection, certain pollution situations are clearly more visible than others, e.g. the presence of plastic litter (e.g. Figure 21 & Figure 22), and major oil spill, whereas most chemical contaminations situations are practically invisible without advanced chemical analyses. A summary is previously provided by PERSGA of the many human threats to coastal and marine environments and resources in Sudan and the priority actions taken for managing these threats (PERSGA/GEF, 2001). Some of these threats are directly related to the discharges or improper management of pollution from land-based sources (Table 3). The Public openness and transparency about the investigations concerning environmental threats and pollution levels is important. There are positive signs currently that public dissemination of performed field studies in Sudan is about to improve significantly. For example, the digital repositories at the Khartoum University and the Red Sea University have very recently provided access to a range of both new and older studies that contain pollution level data from the coastal zone (see an overview in Table 15). It is a well implemented principle in many countries that pollution characterisation studies should be funded by the polluter with the requirements to the study based on demands embedded within established environmental laws and regulation documents; and the practical performance of the studies should normally be conducted by an independent second party group (a consultant or research institute); and the final results and conclusions of the study should be made available for all third party users (the society).

Table 3: Overview of land-based pollution in Sudan, summarised from (PERSGA/GEF, 2001)

Issue	Symptoms/ Impacts	Immediate Causes	Root Causes	Extent	Severity
Industrial pollution	Decline in water quality	Chronic release of pollutants	Lack of enforcement, inadequate technology	Localised, emerging issue in Free Zone	Currently moderate
Discharge of untreated or insufficiently treated sewage	Groundwater impacts, eutrophication and alteration of marine environment, threats to public health	Lack of sewage treatment plants, lack of maintenance of existing plants	Inadequate pollution control regulations, monitoring and enforcement	Localised, urban areas	Moderate to severe
Disposal of solid waste	Damage to coastal and marine life, deterioration of aesthetics	Improper garbage disposal	Lack of adequate waste disposal regulations and enforcement, lack of a waste management system, inadequate public awareness	Localised	Low to moderate
Use of pesticides in the coastal zone	Contamination of soils and water	Large-scale use of pesticides for locust control	Inadequate planning and surveillance, lack of awareness	Throughout much of the area	Moderate to severe

In Sudan, the environmental consultant groups that have performed the pollution characterisation studies for industrial companies at coastal locations have most often had a close connection to the universities (e.g. Khartoum and Red Sea Universities); see section 3.1 for more details. The involvement of university associated groups in such studies is obviously a good thing; as such studies always demand a certain level of scientific expertise and often also laboratory infrastructure. The required content of the studies will normally be described by the environmental regulation documents issued by the appropriate Authorities, e.g. as regulation demanded baseline work, environmental impact studies, monitoring or other environmental investigations. In some cases these pollution characterisation studies have been performed as a thesis work at different levels, e.g. (Alrahman, 2004; Elfahal, 2011; Gaiballa, 2005; Hamed, 2015; Suga, 1998).

An issue of key importance when conducting chemical pollution characterisation studies is the actual quality of the different parts of the investigation; including the study approach, the samples used, the analytical work and the statistically and scientifically examination of the obtained analytical results. It is a clear positive experience from other parts of the world that involvement of researchers and research groups at high academic levels, who have experience in publishing their data under a peer review scrutiny, is an efficient measure to safeguard the technical quality of the studies and data produced. The amount of ecotoxicological data published in international peer reviewed journals are yet very limited from Sudanese research institutions, but it can be expected that the broad and ongoing collaboration between the Sudanese and many foreign Universities will enhance this knowledge production process significantly in the next period. The quality issue is further discussed in section 3.7.

2.3 Coral reefs

The Red Sea coral reefs are the northernmost coral reefs in the Indian Ocean. Most of the Red Sea coast is rimmed by shallow submarine shelves and extensive fringing reef systems. The Red Sea also contains numerous offshore reefs that defy classic reef type categorization. Included in this catch-all category are atoll-like rings of coral, elongated coral ridges that rise abruptly from considerable depths on both sides, and peculiar complex reef patterns of odd shapes. Fringing reefs (Figure 24) are by far the dominant reef type found within the whole Red Sea area, and also in the Sudanese waters. Red Sea fringing reef platforms are over 5000 years old, and the entire coastal reef complex extends along some 2,000 km (1,240 miles) of shoreline. Most such reefs grow directly from the shoreline. The dominant and most actively growing corals include most notably highly branched species of the genera *Acropora* and *Porites*. Red Sea coral reef formations are almost certainly the result of the active and unusual tectonic forces that have been at work here for millennia and continue today. The geological history of the Red Sea area is distinctive, and there is only slow and restricted water (and larval) exchange between this sea and the adjacent Indo-Pacific waters. Thus, Red Sea coral reefs have developed a number of features that distinguish them from reefs found elsewhere. Particularly important in the light of global warming predictions is the fact that Red Sea corals have developed an unusually high tolerance to the extreme temperatures, salinity, and occasional turbidity (caused by huge seasonal dust storms) that occur in this area. Such conditions that would be lethal or highly damaging to most hard corals found elsewhere. Also, water clarity is exceptional in the Red Sea because of the lack of river discharge and low rainfall. Thus, Red Sea reefs are not heavily impacted by the suspension and dissipation of fine sediments that plague reefs in tropical oceans near large land masses. In the south part of the Red Sea, coral growth is somewhat inhibited by the influx of nutrient laden water where the Indian Ocean enters the Red Sea. The surface waters of the more southerly areas are also subject to far greater mixing with deeper water caused by strong winds coming off a high mountainous coast. The marine biota that is associated with Red Sea coral reefs is characterized by high degree of endemism (species found nowhere else). For example, of the 1200 or so coral reef fish species recorded, more than 10%, and possibly as much as 20%, are endemic. About 300 hard coral species have been recorded from the Red Sea as a whole, belonging to approximately 50 different genera. This represents about four times the hard coral biodiversity found on Caribbean reefs, and is comparable to the coral biodiversity found in the Maldives and Seychelles in the Indian Ocean.



Figure 23. Red Sea coral reefs are particularly well developed in the north and central parts of the Red Sea (off the coasts of Sudan, Egypt and Saudi Arabia), with large sizable offshore reef complexes containing small islands, fringing reefs, and a variety of reef-associated habitats (see photo, above).

The many coral reefs in Sudan represent a unique and highly regarded national heritage that deserves utmost attention and protection. The pristine and coral rich areas constitute a huge potential asset for a future tourism industry in Sudan, a tourist industry which can have its key orientation to ecologically sustainable diving activities at coral reef sites. Furthermore, coral rich areas include a multitude of

other values, for example the fish resources which are associated with the coral reefs can contribute, apart from food security, in supporting a vigorous ornamental fish industry. Descriptions of the coral reefs found within the Sudanese waters and assessments of their current status were recently provided by Rebecca Klaus (2015) and by Dirar Nasr (2015a). According to Klaus et al. (2008) the coral reefs that are found in Sudanese waters can be grouped into five broad types:

- i. Mainland fringing reefs
- ii. Island fringing reefs
- iii. Offshore “barrier-type” reef complexes
- iv. Nearshore “barrier-type” reef complexes
- v. Other isolated offshore reefs structures (platform, tower, pillar or atoll reefs)

In addition, other types or categories of coral reefs, e.g. patch reef, are described in the literature. A short description of the different types with special reference to Sudanese waters is included below.

Fringing reefs: This is the most common type of coral reef both in the Red Sea, the Sudanese waters and elsewhere in the world. This type of reef grows seaward directly from the shore (Figure 24). They form borders along the shoreline and surrounding islands. Fringing reefs are present along the entire Sudanese coast, expanding typically 0.1-3 km from the shoreline. Fringing reefs are characterised by having a reef crest towards the ocean outside, a reef flat of variable breadth (typically 50 to >1000 m) and then a shallow zone between the reef flat and the shoreline. At the Sudanese coast the size of the shallow zone varies a lot and may extend up to several km off the shoreline. Fringing reefs in Sudan are found also close up to the country’s largest ports (Figure 25, Figure 26, Figure 30). At urban and industrial locations the fringing reefs are often physically damaged in connection with the development of harbours and other infrastructures.

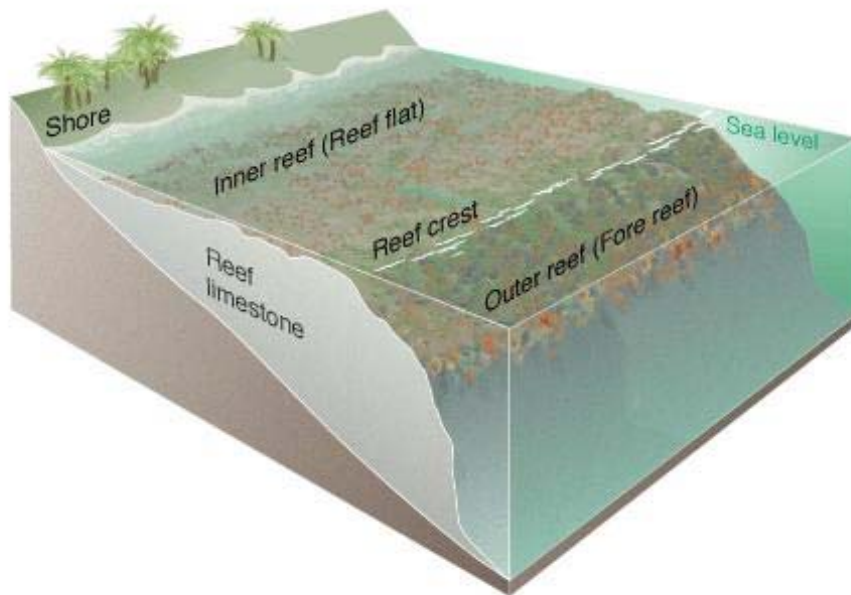


Figure 24: In the Red Sea, the most common type of coral reef is the fringing reef (Source of illustration Wikipedia).

Barrier reef: Barrier reefs are similar to fringing reefs in that they run parallel to and border a shoreline; however, instead of growing directly out from the shore, they are separated from land by an expanse of deep channels (100-400 m deep). At their shallowest point barrier reefs can reach the water’s surface forming a dangerous barrier to maritime navigation. Barrier reefs are about 1-14 km in width such as the Wingate reef (north-east to Port Sudan harbour) and the Towartit reef (south part of coast). Both these reefs have been proposed as Marine Protected Areas (MPA'S).

Patch reefs: Small, isolated reefs that grow up from the open bottom of the island platform or continental shelf. They usually occur between fringing reefs and barrier reefs. They vary greatly in

size, and they rarely reach the surface of the water. In Sudan they lie up to 15 km offshore, separated from the fringing reef by deep and wide channels.

Pillar or atoll reefs: Atoll reefs are rings of coral that create protected lagoons and are usually located far out in the middle of the sea. Atolls usually form when islands surrounded by fringing reefs sink into the sea or the sea level rises around them. The fringing reefs continue to grow and eventually form circles with lagoons inside. The coral reef in the Sanganeb Marine National Park is by several literature sources referred to as the only atoll reef structure within the whole Red Sea, but according to other sources several atoll reefs are found 20 km or more off the coast of Sudan, although the Sanganeb atoll is by far the best known. Due to its unique structure and coral diversity the Sanganeb reef has been declared as MPA since 1990.



Figure 25: The fringing reefs are common also just outside the port in Port Sudan. This picture also clearly visualises the physical destructions to the reef that was done in connection with new harbour developments.



Figure 26: The reef crest of the fringing reef is from a few hundred meters to up to several km off the shoreline, as in this location just south of Suakin (the yellow line represents a distance of 2,9 km).

National Park protection of coral reef areas:

The Sanganeb atoll reef, located 35 km northeast of Port Sudan, was in 1990 declared as an internationally recognized Marine National Park managed by the Environmental and Wildlife Protection Force of the Sudanese Ministry of Interior. Also several other areas and locations along the Sudanese coast are identified as have high value for their coral reefs, and have either been suggested for or have already entered into a process of developing national park protection status.



Figure 27: Picture taken from the Sanganeb lighthouse showing a part of the Sanganeb National Park which in 1990 became the first marine national park gazetted in Sudan. The Sanganeb sanctuary covers an area of length 6 km and width 2 km and lies about 30 km north-east of Port Sudan city and is famous for its corals and richness of marine life forms including sharks, dolphins, turtles, fishes, molluscs and urchins. (Pic courtesy Google Earth).

The large area of Dugonab Bay and Mukawwar island (Figure 28) was in 2004 proposed as a Marine Protection Area by the Sudan Wildlife Conservation General Administration (WCGA) and the PERSGA organisation (PERSGA/GEF, 2004a) and later the same year the Dugonab Bay and Mukawwar Island National Park was declared by the Government of Sudan (UNEP, 2007). The southern border of the Park is located about 115 km (by distance in air) north from the city of Port Sudan. The Park contains extensive and diverse coral and reef fish communities (Figure 31), overlying fossil reefs, very extensive and diverse seagrass beds, and spectacular and unspoiled coastal landscapes, a regionally important population of dugong, regionally or globally important nesting areas for marine turtles and seabirds, and seasonal aggregations of whale sharks and manta rays that are unique in the entire western Indian Ocean region (Nasr, 2015b).

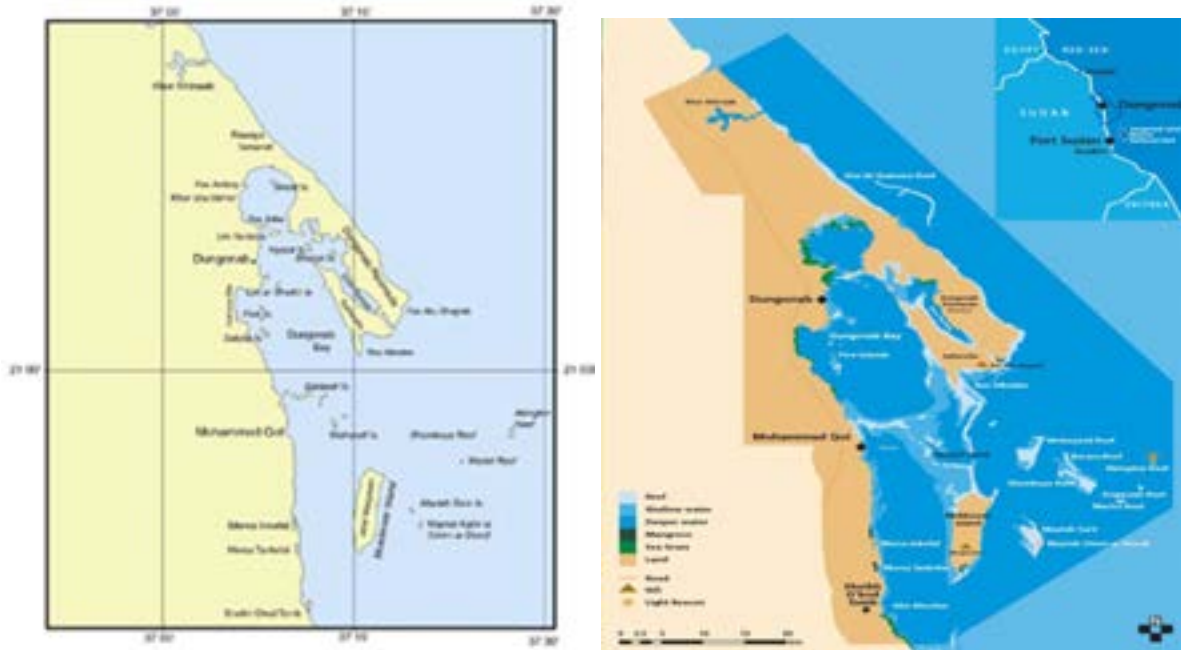


Figure 28: Maps of the Dugonab Bay and Mukawwar Island area which contains an array of unique Valued Ecosystem Components, and which has been declared as a National Park Marine Protection Area.



Figure 29. (A): Green Eyed Cup Coral *Mycedium umbra* in Red Sea. The individual coral animal is called the polyp. This simple sac-like animal sits in a skeleton cup made of calcium carbonate, called a corallite. The picture shows corallite details with costal ridges can be seen extending from the edges of the corallites to the colony margin. Photograph courtesy: Charlie Veron. (B): This coral picture was taken just south of the Mukawwar Island: 20° 44' 37.46" N 37° 15' 3.02" E



Figure 30: Fringing reefs and other reef systems at the central part of the Sudanese coast. Map source: (IMR, 2008a).

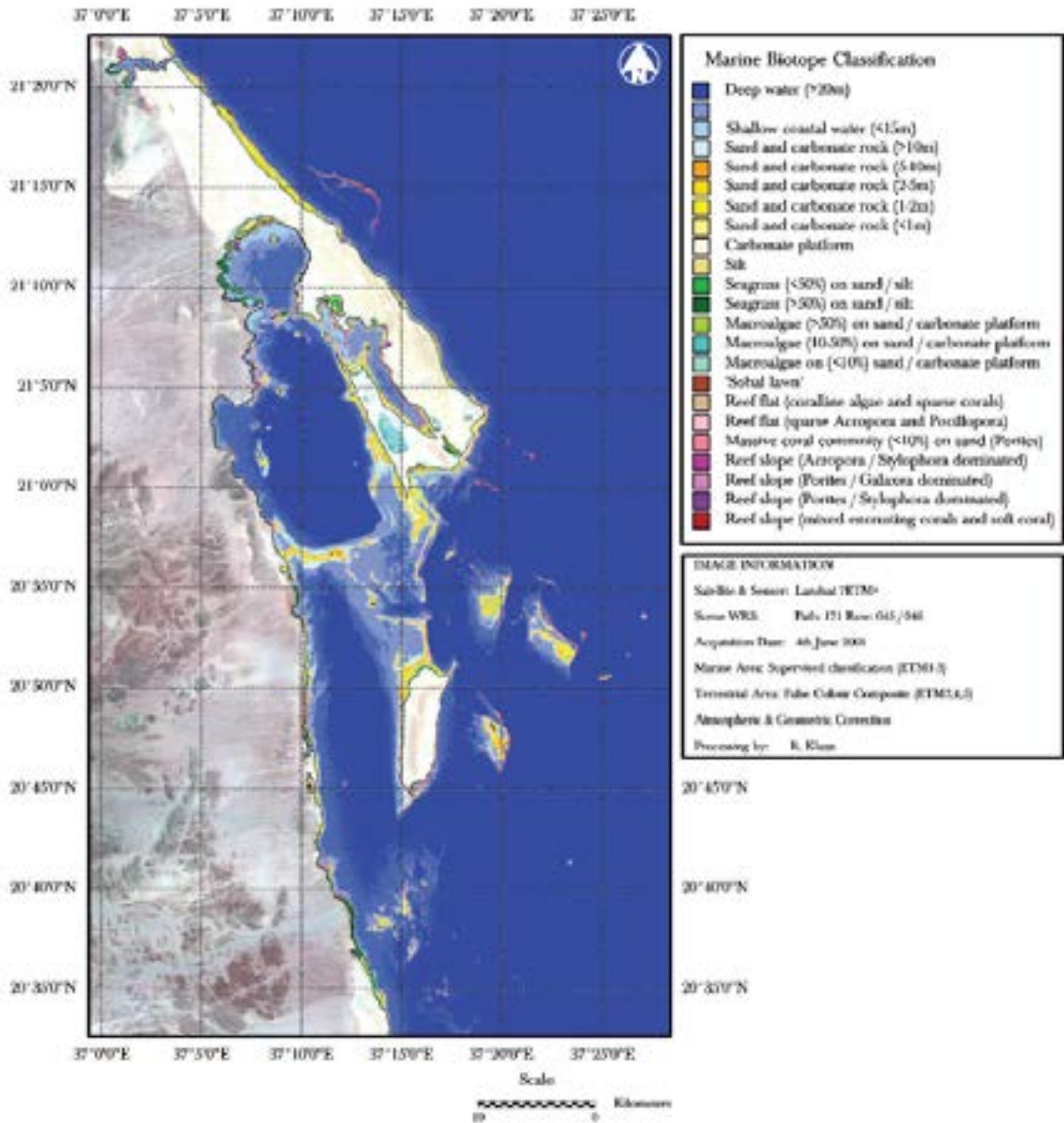


Figure 31: The marine habitats and biotopes of Dungenab Bay and Mukawwar Island, (source: (PERSGA/GEF, 2003a)

Condition status of the Sudanese coral reefs:

The most recent summaries of the condition status of the coral reefs within the Sudanese waters are provided by Rebecca Klaus (2015) and by Dirar Nasr (2015a).

There are three major types of reefs in the Sudanese waters the fringing reef, barrier reefs and atoll reefs. Several regional surveys have previously been conducted under PERSGA organisation to assess the condition of coral reefs in the whole RSGA area, including the Sudanese reefs. The assessment of a coral reef’s condition and monitoring of the condition trend over time require diving inspections and repeated transect inspections over time. A survey of reef conditions along the Sudanese coast was conducted by PERSGA in 2009 (PERSGA, 2010). Despite the extreme environmental conditions which are characteristic of the Red Sea area, the coral reefs in the region are generally healthy. Coral reefs range widely in condition and cover, with up to 85% living coral cover at the best sites and over 50% live coral cover at many other locations. There is usually minimal coral bleaching evident, although some localized outbreaks are reported from time to time. The coral reefs of Sudan are in

general considered to be in moderate to good health, although extensive algae cover problems occur over some fringing reefs and some dieback/coral bleaching has been observed in some shallow coral beds (PERSGA/GEF, 2003e; UNEP, 2007).

Surveys conducted in 1997 and 1999 indicated that the coral reefs were in moderate to good health, despite reports of an extensive coverage of algae over a high proportion of the fringing reefs (PERSGA/GEF, 2003e; Pilcher and Nasr, 2000). The surveys found that the Sudanese reefs were patchy at depths down to 10 m, with average live coral cover typically ranging from 5 to 75 %. Below 10 m, the reefs contain healthy colonies of framework corals. The health condition of the fish fauna associated with the reefs was considered good and over-fishing was not a severe problem on the coral reefs. Key indicator species were abundant and biodiversity appeared high relative to other Red Sea sites. The crown-of-thorns starfish was not recorded in plague numbers at any of the Sudanese reefs. In 1999, bleached corals were estimated to cover 14 % of the substrate (Pilcher and Nasr, 2000).

In order to assess the present condition status of coral fields in Sudanese waters and to predict the future development it is relevant to consider remote/pristine reef sites with no anthropogenic impact as well as reef sites close to sources of anthropogenic stress where adverse impacts are likely. For example, status assessments of corals and other VECs have recently been done at sites in and close to the Port Sudan harbour (IMR, 2008a). Port Sudan represents the main maritime port of Sudan and the port area has been in a continued process of expansion both north and south of the current port. The study showed that fringing reef sites that were located very close up to the main port still included apparently healthy corals with a % cover of the reef locations ranging between 50-60% (Figure 32), and with a diversity of reef associated fish species Figure 33.

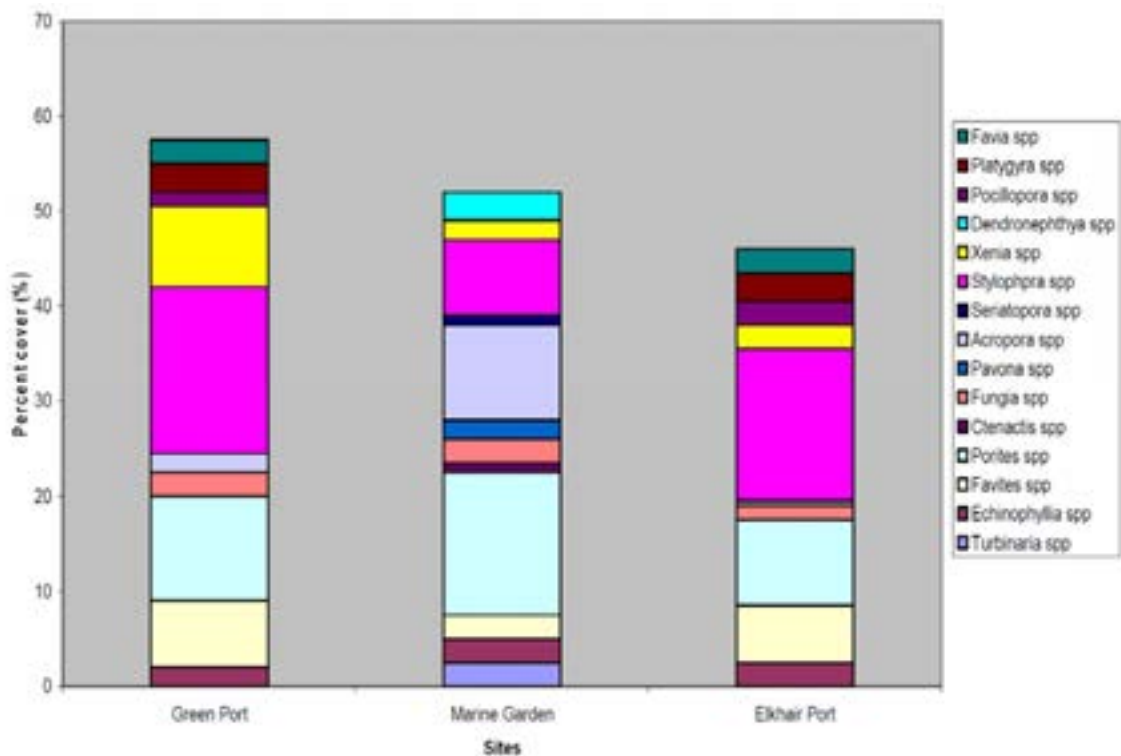


Figure 32: Average density cover of dominant corals recorded at reef sites within or close to the Port Sudan harbour. Source: (IMR, 2008a).

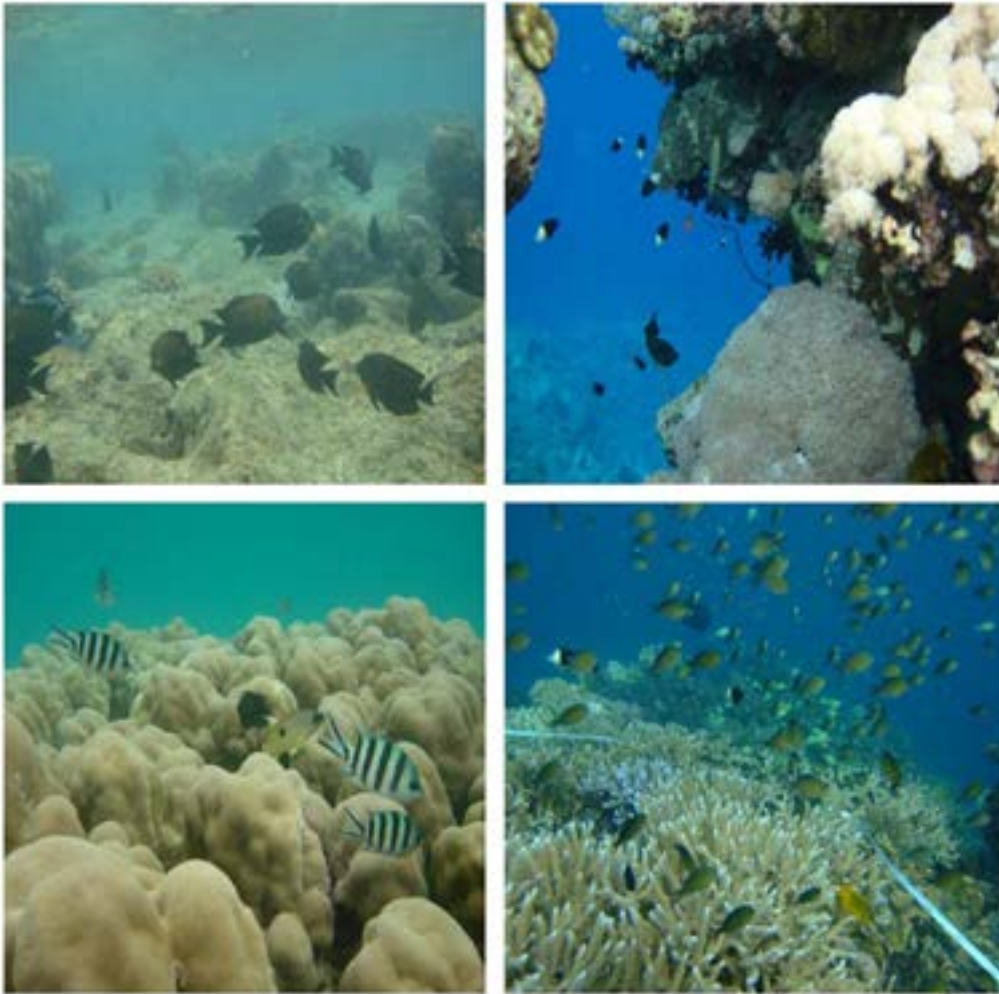


Figure 33: Examples of reef associated fish communities close to Port Sudan harbour. Source: (IMR, 2008a).

In a collaboration study of Equipe Cousteau organisation (Paris, France), CORDIO East Africa (Nairobi, Kenya) and the Red Sea University (Port Sudan), Klaus et al. in 2007 assessed the condition status of many coral reefs along a 195 km long part of the Sudanese coast (Klaus et al., 2008). The survey included a total of 40 detailed transect sites and many reef sites which never previously had been surveyed. The study included also some reef sites within the 70 km long strip between Port Sudan and Suakin, where most of the ongoing coastal developmental activities take place. The key findings of the survey are shown in Figure 34. Klaus et al. found that both the condition status of reefs and the abundance of reef associated fish and invertebrates, was highly variable at different reef sites. The survey found significant signs of coral bleaching and coral mortality at some of the reef sites, although these effect tendencies were clearly influenced by variability in coral reef community composition as well as by variability in local environmental conditions. At many of the sites, they recorded a low abundance of several key families of commercial fin fish (particularly groupers and larger snappers) and also important invertebrate groups (particularly sea cucumbers and larger gastropod molluscs); signs that indicate that severe overfishing is a chronic problem in these locations. There was also a conspicuous absence of sea urchins (*Diadema* spp. and *Echinometra* spp.) from many sites. The study concluded that significant anthropogenic influences of the reefs are still mainly limited to the strip extending from Port Sudan to Suakin, where there are two major ports, oil refineries, a desalination plant, saltworks, power station, a shrimp farm and the new Red Sea Economy Free Trade Zone. Major industrial facilities have been constructed with little or no regard to their potential negative environmental impact leading to extensive damage to coastal habitats several places. Klaus et al. concludes that the recent discovery of oil and gas reserves in the region is likely to lead to

a further economic transformation and increased coastal developments which can result in a surge of development associated risks for these vulnerable coastal habitats. The need for effective planning, and a strategic approach which incorporates considerations of environmental sustainability, is therefore urgent.

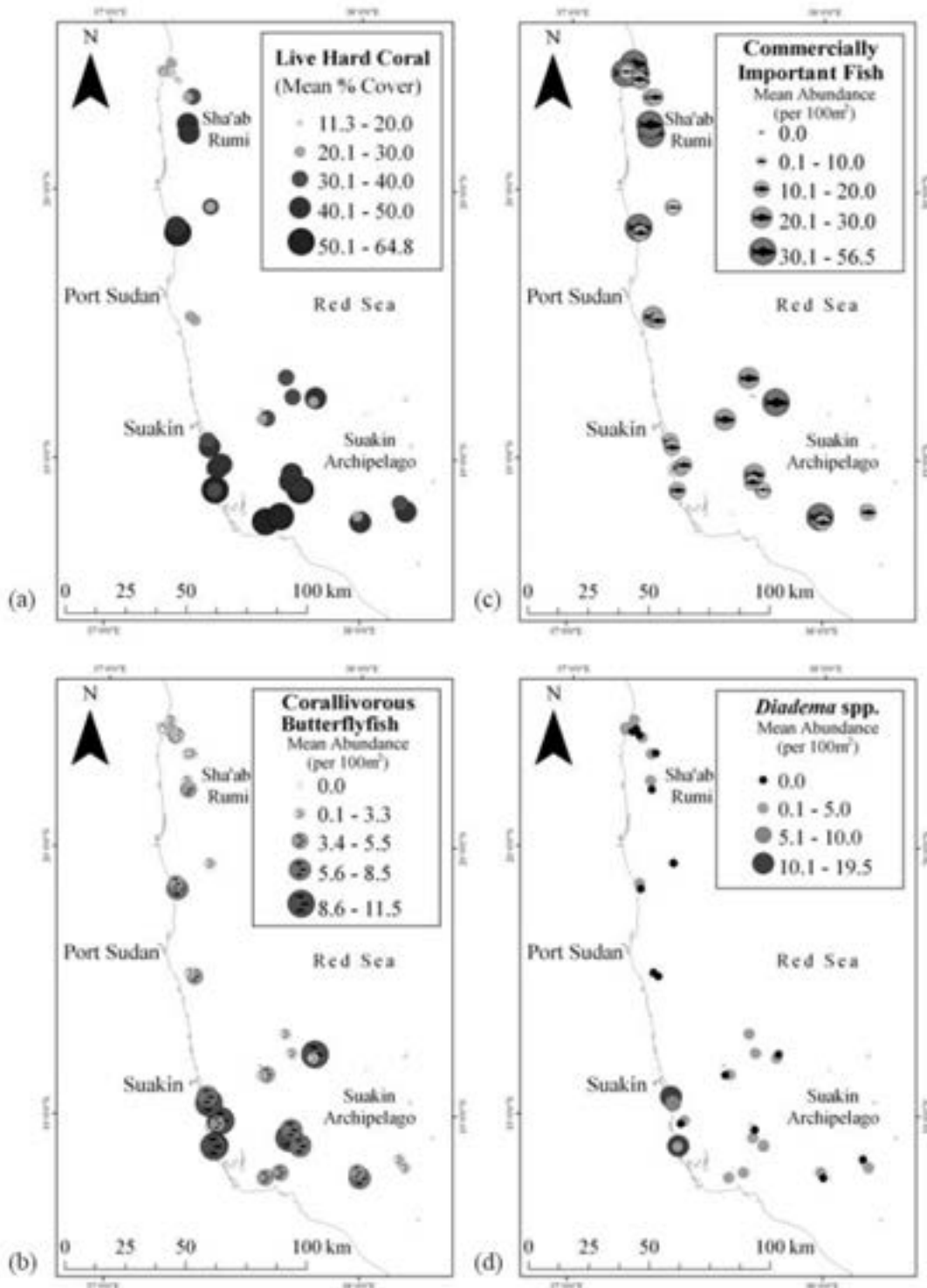


Figure 34: The key findings of the comprehensive reef condition status survey performed along the Sudanese coast in 2007 by Klaus et al. (2008). The maps show (a) mean percent live hard coral cover, (b) mean abundance of corallivorous butterfly fishes (per 100m²), (c) mean abundance of commercially important fishes (per 100m²) and (d) mean density of *Diadema* spp. (per 100m²).

Natural and anthropogenic sources of coral damage:

In complex marine ecosystems there are many natural factors that may contribute to conditions of stress and mortality and to decimation of populations and communities. As stony corals are key organisms in the Sudanese marine ecosystems and natural factors that may cause significant damaging influence to individuals and populations of corals may cause negative knock-on effects on many other marine species in the area. The issue of natural stress factors that influence coral reefs are therefore discussed briefly with some relevant examples below.

Bleaching of stony corals is a well-known stress phenomenon in shallow-water coral fields all over the world (Turak and Brodie, 1999) (Figure 35). Stony corals live as large and long-lived colonies that consist of many identical individuals of coral polyps. Each coral colony gets their colour from microscopic algae that live within the cells of the individual coral polyp tissue; the polyps own tissue is actually transparent. Bleaching of parts or the whole colony occurs when the conditions necessary to sustain the algae within the coral tissue cannot be maintained, resulting in expulsion of the algae or loss of the algal pigmentation. A bleached coral colony turns totally white because of coral's calcium carbonate (CaCO_3) skeleton, and this colour change is easy to observe. The symbiotic collaboration with algae is essential for the health and survival of the coral as the algae provides the coral polyp with essential supplement food in exchange for protection. The bleached condition is therefore stressful for the coral and if the condition persists the affected polyps will eventually die from the stress. The link between bleaching and increased risk for coral mortality has led bleaching to become an important parameter for assessing the health condition of coral reefs.



Figure 35. Bleaching of stony corals can be observed as a dramatic whitening of the affected coral colony which is caused by the loss of symbiotic algae revealing the corals white calcium carbonate skeleton. In this picture from Keppel Islands (Great Barrier Reef), a bleached colony (foreground) and normal colony (background) of *Acropora* coral is seen. Picture courtesy: "Keppelbleaching". Licensed under CC BY 3.0 via Wikipedia - <https://en.wikipedia.org/wiki/File:Keppelbleaching.jpg#/media/File:Keppelbleaching.jpg> Wikipedia.

Coral bleaching can be triggered by environmental factors; such as increased sea temperature, increased solar irradiance, pH drop, increased sedimentations, bacterial infections, and others. An increasing trend of mass bleaching events has been reported in different parts of the world, and this is a source of widespread concern. In particular, a severe mass bleaching event devastated coral reefs in large parts of the wider Indian Ocean in 1997-1998, coinciding with an extreme large El Niño event. Patchy coral bleaching occurred in the Red Sea and also in Sudanese waters, e.g. on reefs south of Port Sudan (Pilcher, 2000) in the Dungonab area (Kemp et al., 2002), but surveys tend to conclude that the coral fields in the Red Sea were considerably less impacted by the 1997-98 mass bleaching event in comparison to coral fields in other parts of the world. This could indicate that the Red Sea corals are

more adapted to high seawater temperature, high salinity conditions and other environmental extremes, making them more resistant to bleaching caused by physicochemical environmental factors (Merwe et al., 2014).

Outbreaks of the large and coral-killing Crown-of-Thorns sea star (*Acanthaster planci*) (Figure 36) are known to cause mass mortality in local populations of corals, and with cascading effects on reef fish and benthic communities (Birkeland and Lucas, 1990; Ormond et al., 1973). Normally, the density of the *A. planci* predator is low (5 to 20 per km of reef face), but in connection with an outbreak significant increased densities of it can cause a devastating impact to a coral reef. Cyclic occurrences of such outbreaks are reported from many tropical reefs throughout the Indo-Pacific, including in the RSGA, and Sudanese waters suffered a large outbreak in the late 1960's. The causes of these outbreaks are much debated among scientists, and their spatio-temporal dynamics and impacts to reef communities remain unclear. Earlier studies in Sudanese waters have demonstrated *A. planci* densities of, but during outbreaks several hundred individuals within a few hundred metres reef face can be found (Ormond et al., 1973).



Figure 36: The crown-of-thorns sea star is a large, multiple-armed species of starfish that preys upon hard, or stony, coral polyps. It receives its name from venomous thorn-like spines that cover its upper surface.

Another biological factor that may cause significant mortality in stony coral colonies is the presence of high densities of coral eating snails; such as *Drupella* spp., a muricid gastropod (Turak and Brodie, 1999). Severe *Drupella* outbreaks have been reported to cause mass mortality of corals comparable to those caused by *A. planci*. Snail induced mortality of corals has previously been observed in both Sudan and Bay of Aqaba (Antonius and Riegl, 1997; Schuhmacher, 1992), although the impact did not appear to be extensive (<1% cover) (Turak and Brodie, 1999).

According to Nasr (2015a) the most pronounced human sources of stress to coral reefs and coral communities in Sudan and the Red Sea include land-filling and dredging activities in connection with coastal expansion, destructive fishing methods, shipping and maritime activities, sewage and other pollution discharges, damage from the recreational scuba diving tourists, global climate change, and insufficient implementation of legal instruments that affect reef conservation such as Marine Protected Areas (MPAs). Also Pilcher (2000) summarised significant sources of human impact to corals and emphasising on: the collection of corals for production of cement and lime; collection for curios, souvenirs and jewellery; reef destructive fishing methods (by using explosives, cyanide poison, trawl or purse fishing); discharges (sewage, oil containing effluents, heavy metals in industrial effluents, hot outflow from desalination plants, airborne dust); dumping of non-degradable solid waste; construction activities (port development, dredging, urban and industrial developments); spills from port activities; recreational diving activities; runoff from farming activities (containing fertilisers and pesticides) as well as indirect effects from human induced climate change. Sudan has much of the infrastructure needed for performing regular monitoring activities to provide a basis for an effective management of

coral reef resources, but many of the present problems with coral reef conservation are attributed to a lack of law enforcement, a lack of awareness, a weak legal framework, and the general absence of surveillance activities (Pilcher and Nasr, 2000).

Coral reef communities are vulnerable both to declines in seawater quality and to variability of the physical conditions in the seawater (Figure 37). Reduced seawater quality can be caused by a number of factors. Oil spills and other contamination events may originate from tanker traffic and other maritime activities. Physical reef destruction and increased sedimentation may be caused by dredging activity in connection with the construction and maintenance of seas ports and other coastal infrastructure developments. Already, several coral reefs which are situated near urban centres on the Sudanese coast have been significantly damaged due to coastal urban/industrial developments (see example in Figure 25). In the most pristine and undisturbed coral reef locations, the potential for increased development of an insufficiently managed diving tourism may represent a significant risk factor for reef degradation, as have been observed in several of the most active tourist diving areas of the Red Sea, e.g. Hawkins and Roberts (1994). Tourist boats dropping their anchors or discharging litter at the reef and recreational scuba divers and snorkelers swimming too close to the corals may cause a damaging impact to the reef.

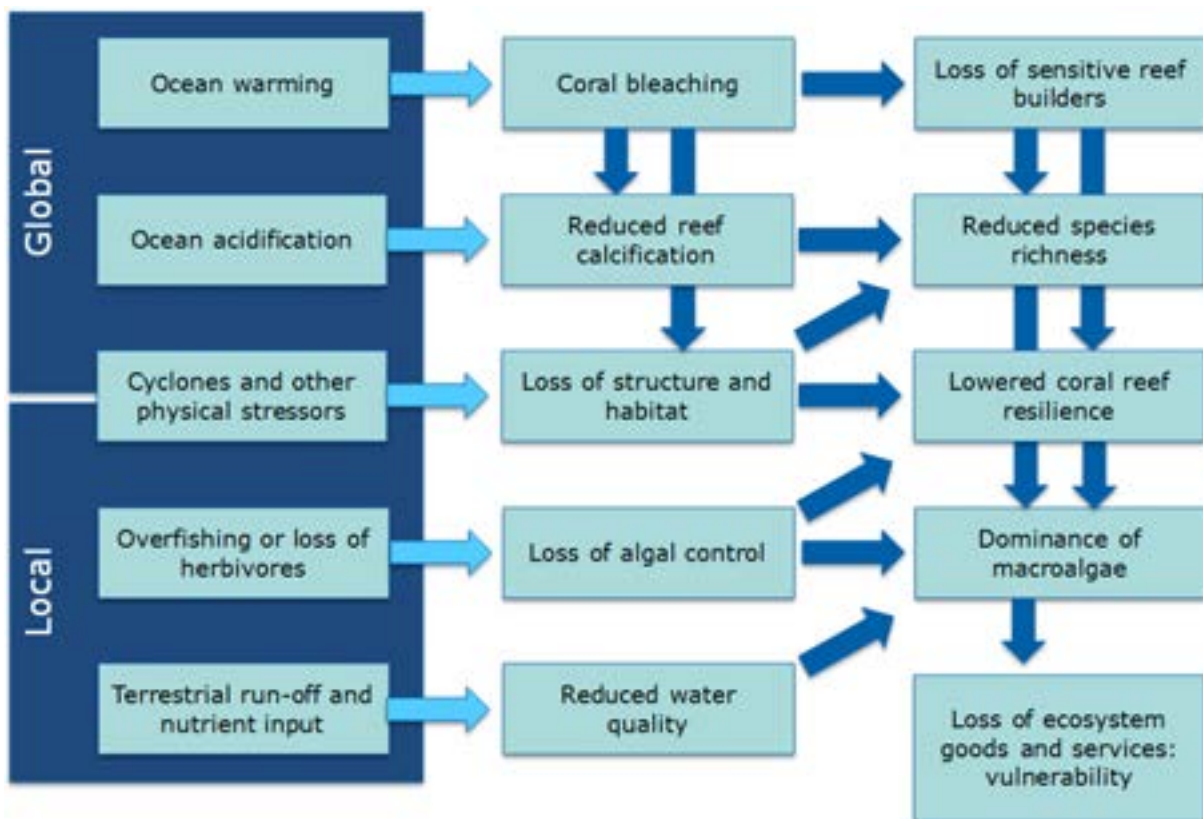


Figure 37: Links between global threats of carbon emission (here mainly climate change, ocean acidification and tropical storms) and local or regional disturbances from overfishing and declining water quality and their combined flow-on effects on reef resilience and ecosystem goods and services. Illustration source: Anthony and Marshall (2009).

As coral reefs develop very slowly over hundreds and even thousands of years these kinds of incidences will with time accumulate and lead eventually to a significant degradation of reef quality. In the Red Sea, a growing number of marine protected areas (MPAs) have been established to help alleviate some of these problems. The Sanganeb National Park (Figure 27) was declared as early 1990, as the first Sudanese MPA, to preserve and protect the atoll's uniquely biodiverse coral reefs. PERSGA has published a site-specific master plan with management guidelines for the Sanganeb Marine National Park (PERSGA/GEF, 2004b). And in 2004, the large Dungonab National Park, which includes large coral reef resources, was declared.

However, also several natural factors represent a risk to the wellbeing of coral reefs, including for example the previously described outbreaks of the large and coral-killing Crown-of-Thorns sea star (Figure 10). Such outbreaks may cause mass mortality of corals in a local reef and this mortality will indirectly lead severe effects to multiple species of reef fish and other reef associated organisms. Another significant risk factor is warmer sea surface temperature coming as a result of global climate change. This increase of surface temperatures is considered a major threat to coral reefs worldwide. Several episodes of widespread mass-bleaching of coral fields have been observed in periods of un-normal warm sea-surface temperatures, such as during the 1997-98 El Nino event; an El Nino event which is the strongest on record to date. According to Wilkinson et al. (1999), the event resulted in an unprecedented coral bleaching and coral mortality across the globe (see example at Figure 38). Fortunately, although some coral bleaching also took place in the Red Sea as well as in Sudanese waters during that event, e.g. on reefs in the Dugonab area (Kemp et al., 2002), the Red Sea reefs were considerably less impacted than coral fields in most other parts of the world. This could indicate that the Red Sea corals are already adapted to high seawater temperature and other environmental extremes, possibly making them more resistant to bleaching events caused by increased temperature and other physicochemical environmental factors (Merwe et al., 2014).

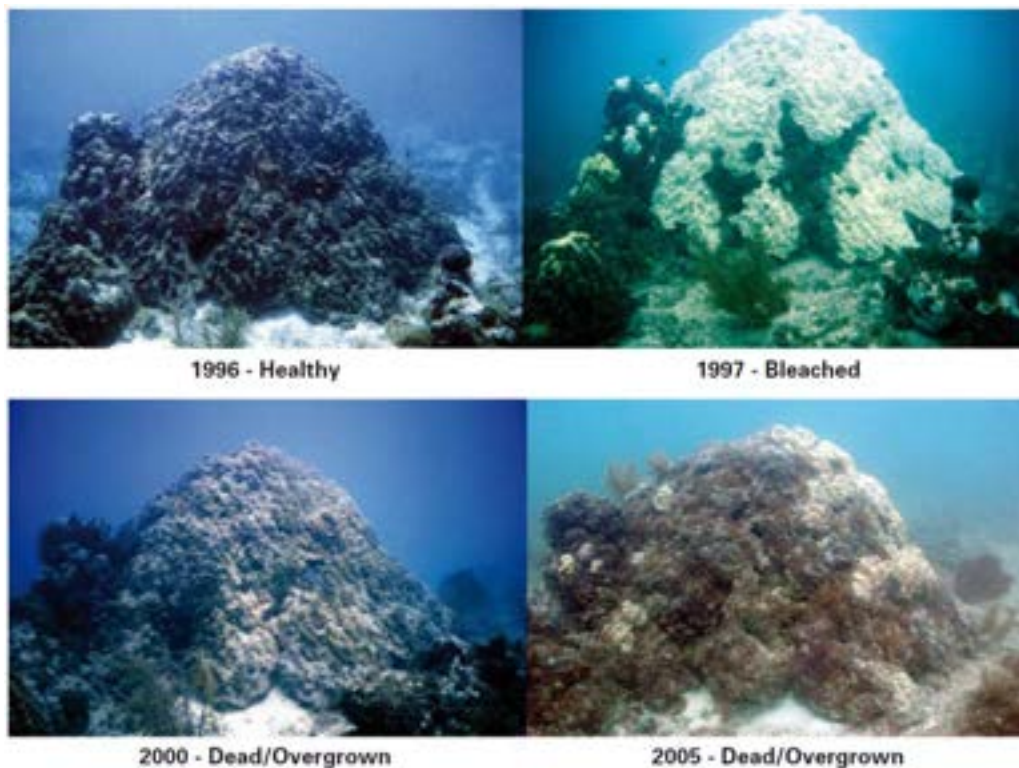


Figure 38: An illustrative case of bleaching and subsequent mortality of a coral colony which most likely was caused by the un-normal high surface temperature during the record-strong El Nino event in 1997-1998. Image courtesy: Craig Quirolo, Reef Relief/Marine Photobank, in: "Climate, Carbon and Coral Reefs".

Other useful information sources:

(Barker and Roberts, 2004; Brokovich et al., 2006; Edwards and Emberton, 1980; Edwards and Rosewell, 1981; Genin et al., 1995; Hassona et al., 2008; Hawkins and Roberts, 1993; Hawkins et al., 2000; Hussey et al., 2013; Mazeroll and Montgomery, 1998; Mergner and Schuhmacher, 1985; Moore and Huxley, 1976; PERSGA, 2009; PERSGA/GEF, 2003b; Reinicke et al., 2003; Roberts and Ormond, 1987; Roberts et al., 1992; Schuhmacher et al., 1995; Schuhmacher and Mergner, 1985; Sirelkhatim et al., 2008a; Spiridonov and Neumann, 2008; Taylor and Reid, 1984; Temraz and Abou Zaid, 2005; Vine, 1974; Vine and Baileybrock, 1984; Vine and Vine, 1980), <http://www.coral-reef-info.com/red-sea-coral-reefs.html>.

2.4 Coastal mangrove areas

Mangrove stands represent a key intertidal biotope along the Sudanese coastline (PERSGA/GEF, 2004e; UNEP, 2007) (Figure 39, Figure 41, Figure 42). *Avicennia marina* is the sole mangrove species in Sudan (Suga, 1998). Its wood-like landscape supports an all ecologically tuned assemblage of fauna and flora. Mangroves are the main conspicuous coastal vegetation (macrohalophytes) that constitute a characteristic feature of the Sudanese Red Sea coast. They are highly productive habitats (500 – 4000 mg C / m² / day) (IMR, 2008a) and are favourable for fishery activities as they are nurseries for many commercially important fishes (molluscs, crustaceans & finfishes), and also breeding sites for various seabirds. The mangrove trees are generally found (as stands or patches), at the coastline, at edges or around bays (Mersas) and some offshore islands. Mangroves in Sudan occupy protected shallow muddy habitats and lagoons which receive considerable amount of fresh water and sediments carried to the Red Sea via a network of seasonal khors, where muddy cracking sediments is deposited. In a PhD study submitted in 1998, Suga examined a total of 19 identified and sizeable mangroves stands and assessed how the local topography at each site affected the forest structure and productivity (Suga, 1998).

In the Dugonab area, three or four mangrove sites are particularly important (southern Mukawwar; southern Dugonab peninsula and Mersa Inkefal). A significant mangrove stand is also reported inside Dugonab Bay, at the north-western part of the peninsula (Abdel Salam, 2006). The mangroves provide forage, wood products and breeding grounds for fish. Extensive mangrove stands were originally found in areas where the seasonal streams (khors) reach the coast, as these produce the brackish and sediment-rich conditions necessary for mangroves to thrive. The species found include mainly *Avicennia marina* and *Rhizophora mucronata* (PERSGA/GEF, 2004e).



Figure 39. A coastal mangrove stand of *Rhizophora* sp. found in the Hala'ib Triangle area. Photo courtesy: DR. M. Abdel Razik.



Figure 40: Mangrove stand at Mersa Sheikh Ibrahim. Photo source: IMR (2012).

The *Avicennia marina* stands are typically thin, mostly ranging between 15 to 300 m in width. They grow along the shore-line (Figure 41), on near-shore islets and fringing tidal inlets or creeks (Figure 42), which extend landwards along depressed areas of various sizes, locally known as Mersas. The majority of the stands are typically small, rarely exceeding 1-2 km in length. The density and size of the stands increases towards the southern coast, which supports muddier substrates and receives more freshwater influx from surface run-off. However, at some localities in the northern parts, the better oxygenated, sandier substrate and considerable underground freshwater seepage may favour growth of *Avicennia* trees to a greater height and Girth at Breast Height (GBH) (e.g. Arakiyai). Based on ecological features and the extent and distribution of mangrove stands, the Sudanese coastal area may be divided into three stretches:

1. The coastal area from the Egyptian border in the north to Port Sudan in the south. This area represents a long coastal stretch comprising about two-thirds of the Sudanese Red Sea coast. It is characterized by extensive sandy beaches e.g. Arus, protected bays e.g. Dungonab Bay and Mukkawar Island National Park, tidal inlets, saltmarshes, rocky shores, and rich coral reef growth fringing most of the coastline and islands. The southern half of this coastal stretch, between Port Sudan and Dungonab, supports sparsely distributed *Avicennia* stands growing at some localities. The northern half extending north of Dungonab to Hala'ib is relatively rich in tidal inlets and has more dense mangroves.
2. The coastal area from Port Sudan in the north to Suakin town in the south. The shoreline of this 60km stretch of coast is rich in tidal inlets, mud and sand flats and has extensive saltmarshes in the lower reaches of valleys. Mangroves grow in relatively dense stands, in which the trees are close to each other.
3. The coastal area between Suakin to the Eritrean borders in the South. This area is characterized by relatively wide coastal plains intersected by massive valleys. The shoreline is rather undulating with numerous tidal inlets that support dense mangroves. The stands are adjacent to each other on most of the shoreline forming a thin, semi-continuous belt of *Avicennia marina* interrupted only by a few gaps of bare shore areas.



Figure 41. Satellite picture of small patches of mangroves at a beach location south of Port Sudan.



Figure 42. Satellite picture of a mangrove stand at a location just south of Port Sudan. The yellow line represents 100 m.

Condition status of mangroves:

The mangroves stands in Sudan are in general considered to be under severe pressure along the entire coastline due to a combination of overgrazing and over-cutting, and in some areas, destruction caused by industrial and infrastructure development. In the PERSGA report (PERSGA/GEF, 2004e) mangrove stands were surveyed in 2002 at 14 localities along the Sudanese Red Sea coast (Table 4), several mangrove stands are located in the Egyptian-Sudanese border area (Hala'ib Triangle area) (Table 5). According to the (PERSGA/GEF, 2004e) report, these are the vast majority of the mangrove areas in the country. Several other localities were reported to have mangrove vegetation but were not visited during that PERSGA survey, these include three areas: Hala'ib, Mukawwar Island (Magarsam) and Agig. In the PERSGA report (PERSGA/GEF, 2004f) a regional action plan for the conservation of mangroves in the whole RSGA area is presented.

In the Dunganab area, the mangroves found inside the Protection Park are generally in good condition, with little human impact, although camel grazing is a factor at all the mainland mangrove sites, and may be limiting the further expansion of many of these mangrove areas. The mangroves stands near Mersa Inkefal to the south of Mohammed Goal appear to have suffered very heavy cutting in the past, but may now be regenerating. The mangrove at the southern end of the Dunganab peninsula is subject to cutting, probably for animal fodder and / or firewood for the salt works on the peninsula. This activity is moderately severe in some parts of the mangrove and should be addressed by improved management.



Figure 43. Coastal area north of Port Sudan with sparse coastal mangrove vegetation.

Table 4: Location and extent of mangrove stands surveyed, Red Sea coast of Sudan, July 2002. Information source: PERSGA/GEF (2004e).

Stand Code	Stand site	Position	Approximate Length (km)
RSS1	Mohammed Qol	20° 47'N, 37° 10'E	1.3
RSS2	Arakiyai	20° 18'N, 37° 11'E	0.9
RSS3	Hahut	19° 48'N, 37° 15'E	1.1
RSS4	Kilo Tammania	19° 35'N, 37° 15'E	0.8
RSS5	Klanieb	19° 30'N, 37° 16'E	2.0
RSS6	Mersa Atta	19° 18'N, 37° 18'E	3.5
RSS7	Fagum-Lagagengeeb	19° 01'N, 37° 23'E	3.9
RSS8	Haydob	18° 57'N, 37° 23'E	1.6
RSS9	Sheikh Ibrahim	18° 56'N, 37° 24'E	0.4
RSS9	Sheikh Saad	18° 50'N, 37° 26'E	1.4
RSS10	Shabarango-Gofud	18° 46'N, 37° 29'E	3.5
RSS11	Ashat	18° 45'N, 37° 30'E	7.0
Total length			27.5

Table 5. Mangrove stands located in the Egyptian-Sudanese border area (Hala'ib Triangle area). Information source: PERSGA/GEF (2004e).

Location	Condition
Sharm- El-Madfaa (22° 57'N, 35° 40'E)	The shoreline at this locality comprises sabkha flats that are periodically flooded by tides through a shallow inlet. Dense growth of <i>Avicennia marina</i> fringes the shoreline around the inlet. Mean tree height was 2m, while some trees with larger crowns reach up to 6m in height.
Mersa Shaab (22° 50'N, 35° 45'E)	This large stand grows for 6km along mouth of the alluvial fans of Wadi Shaab and Wadi Abib. The northern parts are dominated by <i>Avicennia marina</i> . Seaward, a mixed zone of <i>Avicennia marina</i> and <i>Rhizophora mucronata</i> occurs. The former reaches up to 4.8m and the latter up to around 6m in height. Several turtle nests were reported in the area, while pollution by domestic solid waste was minimal.
Mersa Abu Fassi (22° 41'N, 36° 00'E)	The mangrove stand at this site extends 2.5km along the shoreline. Minimal impacts of grazing were reported due to the remoteness of the stand.
Wadi Al-Hoor (22° 38'N, 36° 13'E)	Both <i>Avicennia marina</i> and <i>Rhizophora mucronata</i> occur in this area. The northern and southern sectors of the stand are dominated by <i>Avicennia marina</i> , while <i>Rhizophora mucronata</i> forms dense thickets at the seaward margin of the central sector of the stand. The <i>Avicennia marina</i> reaches up to 5.8m in height, while <i>Rhizophora mucronata</i> attains higher crowns reaching 7m at some localities. The landward fringes of the stand are affected by grazing.
Adaldeep (22° 33'N, 36° 17'E)	The mangrove stand at this locality extends for 2000m along the shoreline. Mean tree height was 4.5m, maximum height was 7m. The landward parts of the stand are impacted by wood cutting and grazing.

Table 6. Characteristics and condition of mangrove stands north of Port Sudan. Information source: PERSGA/GEF (2004e).

Variables and characteristics	Site					
	Moh. Qol (outer zone)	Moh. Qol (inner zone)	Arakiyai (outer zone)	Arakiyai (inner zone)	Halut (outer zone)	Halut (inner zone)
<i>Mangrove trees (quadrat size 10 x 10m):</i>						
Density of trees	15	20	13	17	99	13
Height range (m)	0.75-1.95	0.6-4.1	6-9	7-10	40-85	6-9
GBH range (cm)	--	15-35	95-185	100-195	--	5-80
Dead standing trees	0	1	1	0	21	4
Dead felled trees	0	0	1	2	4	1
Grazed trees and shrubs	10	7	11	13	74	8
Mature trees with dropped limbs	0	1	11	9	9	6
Trees with top dying uppermost and outermost branches	5	1	7	9	74	6
Multi-stemmed trees	14	20	13	15	60	5
Number of seedlings	6	7	3	10	5	56
Dead seedlings	0	1	0	0	1	4
Deformed propagules and seeds	NR	NR	NR	NR	NR	F
Leaves with spotty chlorosis and necrosis	NR	NR	NR	NR	NR	NR
Twisting and curling leaves	NR	NR	NR	NR	NR	NR
<i>Pneumatophores (quadrat size 0.5 x 0.5m):</i>						
Density of pneumatophores	26	46	43	37	16	61
Branched pneumatophores	5	4	8	10	1	4
Twisting and curling pneumatophores	1	6	3	0	1	0
Pneumatophores with dead tips	12	11	16	9	13	46

NR: not recorded, F: few, M: many

Table 7. Characteristics and condition of mangrove stands between Port Sudan and Suakin. Information source: PERSGA/GEF (2004e).

Variables and characteristics	Site					
	Kilo Tannania (outer zone)	Kilo Tannania (inner zone)	Klamieb (outer zone)	Klamieb (inner zone)	Mersa Atta (outer zone)	Mersa Atta (inner zone)
<i>Mangrove trees</i> (quadrat size 10 x 10m):						
Density of trees (/10m ²)	12	21	39	18	27	32
Height range (m)	0.35-1.0	1.0-4.5	0.5-1.2	3.0-5.0	0.5-1.5	0.5-7.0
GBH range (cm)	--	5-20	--	--	15-30*	45-80*
Dead standing trees	2	0	24	2	6	7
Dead felled trees	1	0	0	0	2	6
Grazed trees and shrubs	8	3	15	12	13	4
Mature trees with dropped limbs	1	3	0	1	2	4
Trees with top dying uppermost and outermost branches	6	0	15	4	5	3
Multi-stemmed trees	11	18	39	18	24	23
Number of seedlings	1	8	0	23	2	5
Dead seedlings	0	0	0	4	0	0
Deformed propagules and seeds	NR	NR	NR	NR	NR	NR
Leaves with spotty chlorosis and necrosis	NR	NR	NR	NR	NR	NR
Twisting and curling leaves	M	F	NR	NR	NR	NR
<i>Pneumatophores</i> (quadrat size 0.5 x 0.5m):						
Density of pneumatophores	25	24	35	41	51	53
Branched pneumatophores	13	6	7	1	14	21
Twisting and curling pneumatophores	1	0	0	0	2	2
Pneumatophores with dead tips	8	1	33	8	18	10

NR: not recorded, F: few, M: many. (*): For mature trees only

Table 8. Characteristics and condition of mangrove stands south of Suakin to the Eritrean border. Information source: PERSGA/GEF (2004e).

Variables and characteristics	Site									
	Lagengeeb-Fagum		Haydob		Sheikh Saad		Shabarango-Gafad		Ashat	
	Outer zone	Inner zone	Outer zone	Inner zone	Outer zone	Inner zone	Outer zone	Inner zone	Outer zone	Inner zone
<i>Mangrove trees (quadrat size 10x10m):</i>										
Density of trees (/10m ²)	21	26	35	26	19	22	14	7	22	17
Height range (m)	3.0-5.0	3.0-8.0	4.0-5.0	5.0-7.0	4.0-5.5	5.5-8.0	2.0-4.0	4.8-5.0	3.0-5.0	3.0-5.5
GBH range (cm)	15-70	20-120	30-50	35-70	37-85	65-125	10-55	50-65	15-60	30-75
Dead standing trees	1	3	0	5	0	0	1	0	3	2
Dead felled trees	8	11	28	14	15	13	5	3	4	11
Grazed trees and shrubs	9	7	6	7	4	7	8	7	15	4
Mature trees with dropped limbs	5	6	5	6	4	5	4	4	7	4
Trees with top dying uppermost and outermost branches	4	4	2	4	2	5	5	4	15	4
Multi-stemmed trees	5	5	4	5	0	3	8	0	8	6
Number of seedlings	11	5	14	16	0	2	29	0	6	2
Dead seedlings	2	0	0	0	0	1	2	0	2	0
Deformed propagules and seeds	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Leaves with spotty chlorosis and necrosis	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Twisting and curling leaves	NR	NR	NR	NR	NR	NR	NR	NR	M	F
<i>Pneumatophores (quadrats 0.5 x 0.5m):</i>										
Density of pneumatophores	27	20	37	27	35	47	37	16	41	36
Branched pneumatophores	7	6	13	9	12	15	20	6	9	6
Twisting and curling pneumatophores	0	3	2	2	2	1	0	0	2	1
Pneumatophores with dead tips	16	1	23	16	29	33	19	12	16	10

NR: not recorded, F: few, M: many. (*): For mature trees only

Threats to mangroves:

According to PERSGA/GEF (2004f), the mangroves within the whole RSGA region face increasing levels of threats at national, regional and global scales. Because the coastal mangroves in Sudan are growing in environments near the extremes of mangrove development, they are particularly threatened by future increases in disturbance.

Major threats to mangrove stands include camel grazing and cutting and various forms of pollution from shipping, urban, industrial and tourism developments, raw sewage, dredging and land-filling and other coastal construction and changes in land use. Uncontrolled coastal developments adjacent to, or in the mangroves, have already damaged or destroyed these habitats in many parts of the region. Threats to mangroves also include major pollution events, such as those associated with large oil spills, which also have serious trans-boundary implications, intensive camel grazing and firewood extraction (Figure 44), diversion of freshwater input and other hydrological modifications, and the

developing aquaculture industry in the coastal zone. Predicted climatic changes over the next several decades are expected to cause major changes in mangrove distribution and productivity, and lower the capacity of mangroves to recover from stress or disturbance. This loss of resilience is linked to projected increases in sea level, and in combination with impacting activities, threatens the continued existence of mangrove ecosystems in the RSGA region.

The PERSGA/GEF (2004f) report include a set of recommendations and guidelines for mangrove rehabilitation and management in the RSGA region and also a regional action plan for the conservation of mangroves in the region.



Figure 44: Camels grazing in a mangrove stand 20 km south of Suakin. The negative impact of the grazing can be seen in the absence of foliage below three metres. This mangrove stand also shows signs of extensive timber-cutting. Picture courtesy of UNEP. Source: http://postconflict.unep.ch/sudanreport/sudan_website/index_photos_2.php?key=Coastline

Other useful information sources:

(Eriksson and Wiktelius, 2011; Mohamed, 1984; Price et al., 1998).

2.5 Seagrass and seaweed beds

Seagrass can easily be confused with seaweeds (marine macroalgae), but there are many important differences between the two. While the seagrasses have evolved from terrestrial plants in the lily family, the seaweeds are not plants but rather plant-like macroalgae which belong to the large taxonomic group of protists (together with protozoans, prokaryotes, fungi, sponges, and other algae species). While the seagrasses consist of a relatively small number of species (55 characterised species worldwide) the seaweeds/macroalgae is a much larger group (5-6000 species worldwide). With regard to marine ecological protection issues the emphasis tend to be on seagrass beds and less on seaweed beds, although both serve partly the same ecosystem function by providing shelter for many fish and invertebrate species. Seagrass are in particular important as food for dugongs and the green sea turtles, although the green sea turtle also eats seaweeds.

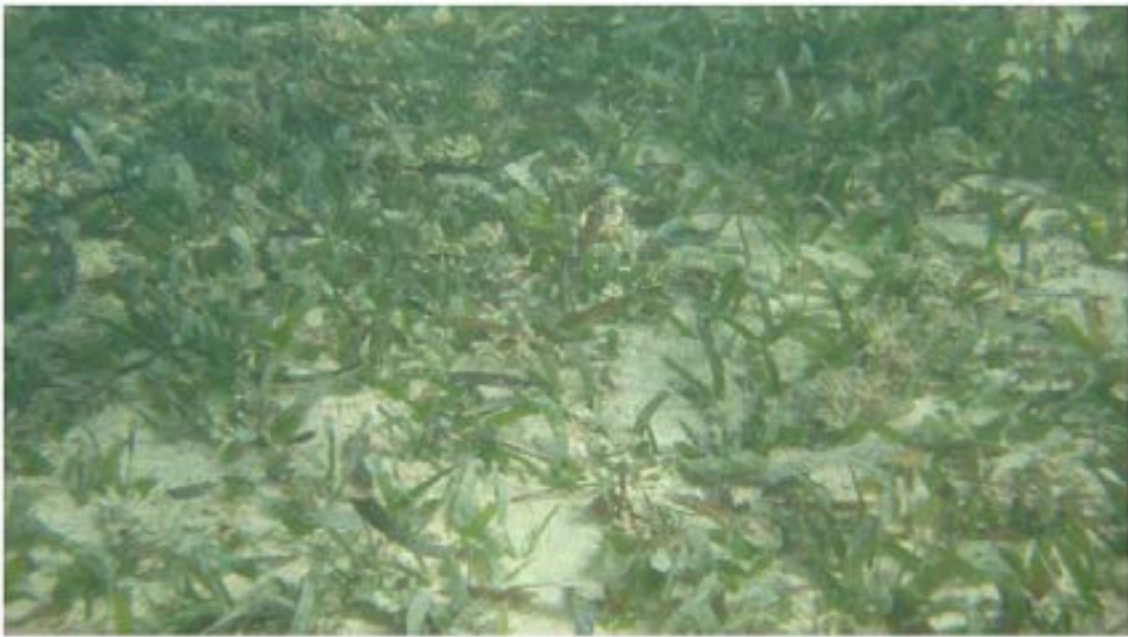


Figure 45: Seagrass bed in the Mersa El- Sheikh Ibrahim location. Photo source: (IMR, 2012).

Seagrass beds are known to be widespread in the Red Sea and are commonly found in Sudanese shallow water areas with soft-bottom sediment from mid-tidal levels and down to a depth of about 70 m depth (Figure 46). The seagrass beds are common in shallow coastal waters, around mangroves and between the low tide line and fringing reefs. Seagrass beds represent VECs of high ecological relevance as they are highly productive habitats that provide grazing for endangered populations of marine grazers such as dugongs and turtles, and the presence of seagrass habitats is essential to support local populations of many species of fish species, sea birds and marine invertebrates. Eleven seagrass species have previously been recorded within the RSGA area (Price et al., 1988; Sheppard et al., 1992).

In the master study of Gaiballa (2005), a total of ten seagrass species under two families (Hydrocharitaceae and Cymodoceaceae) were encountered within totally six field locations studied; i.e. Marsa Bashayer, Marsa Dama Dama, Eastern part of Port Sudan Harbour (Green Area), Northern part of Port Sudan Harbour, (Shipyard), Marsa Halout and Dongonab Bay (Figure 48). The six study locations varied greatly in industrial activity that affected the water quality, and significant degradation of seagrass was evident at the most industrialised locations, in particular in Northern Part of Port Sudan Harbour (Shipyard). However, the overall evaluation was that the impact was not severe (Gaiballa, 2005).

In the area of the Dugonab Park, there are particularly large areas of seagrass beds. The total area of sea grass in the park is estimated from Land Sat images to cover almost 12 km²; which is a very substantial area. These extensive sea grass beds are a nationally and regionally important feature of the Dugonab Park. This is especially true given the population of globally endangered dugong that is found inside the park. Most of the sea grass areas inside the park are known to be important feeding areas for the dugong population.

In connection with EIA investigations at the site of the Bashayer marine oil terminal in 2004, four species of seagrass were registered, including *Halodule uninervis*, which had the highest relative abundance, followed by *Cymodocea rotundata*, *Halophila stipulacea*, and *Halophila ovalis* (IES, 2005). In the same study, a total of 34 seaweed species (Figure 47) belonging to three classes (Chlorophyta, Phaeophyta and Rhodophyta) were recorded in the Bashayer study area, with *Enteromorpha compressa* (Chlorophyta) and *Jania sp.* (Rhodophyta) have the highest relative abundance, and *Gelidium sp.* (Rhodophyta) lowest relative abundance (ibid.).



Figure 46: Seagrass beds are commonly found along the Sudanese coast. A: *Thalassia hemprichii* (Ehrenberg) Scherson at Eastern part of Port Sudan Harbour (Green Area); B: *Thalassia hemprichii* (Ehrenberg) Scherson at Dama Dama area; C: *Syringodium isoetifolium* (Ascherson) Dandy at Dugonab Bay. Pictures courtesy: (Gaiballa, 2005).

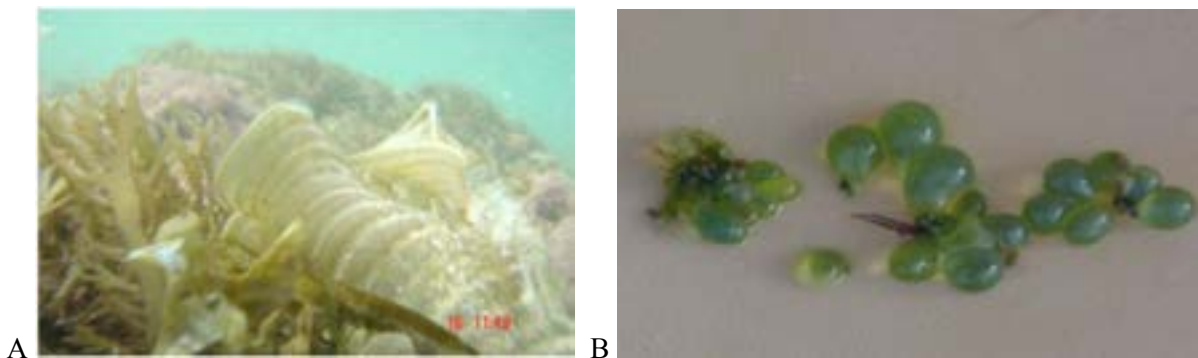


Figure 47: Examples of seaweed species recorded at the site of the Bashayer marine oil terminal in 2004. A: The brown seaweed *Padina sp.* and the red seaweed *Gracilaria sp.* and B: The green seaweed *Valonia sp.* (IES, 2005).

Potential stresses:

Human activities that represent stress factors for seagrass beds include fishing activity (trawling), boats propelling, dredging, construction work in connection with developments of harbours and jetties, dumping of particulate materials at sea, discharging of sewage and industrial waste materials, release of cooling water from desalination plants and marine oil spills. A brief review of previous studies which have investigated different stressor situations for seagrass beds in the RSGA area is provided in Gaiballa (2005), addressing problems associated with oil pollution, heavy metals (e.g. discharge of wastes from tanning factories), physical alteration and destruction of habitats, discharge of sewage and treatment plants effluents, uncontrolled use of insecticides and pesticides); heavy metals (discharge of

wastes from tanning factories), and leakage from landfills. Generally, very limited documentation of possible impact on Sudanese seagrass beds was provided prior to the study of Gaiballa (2005).

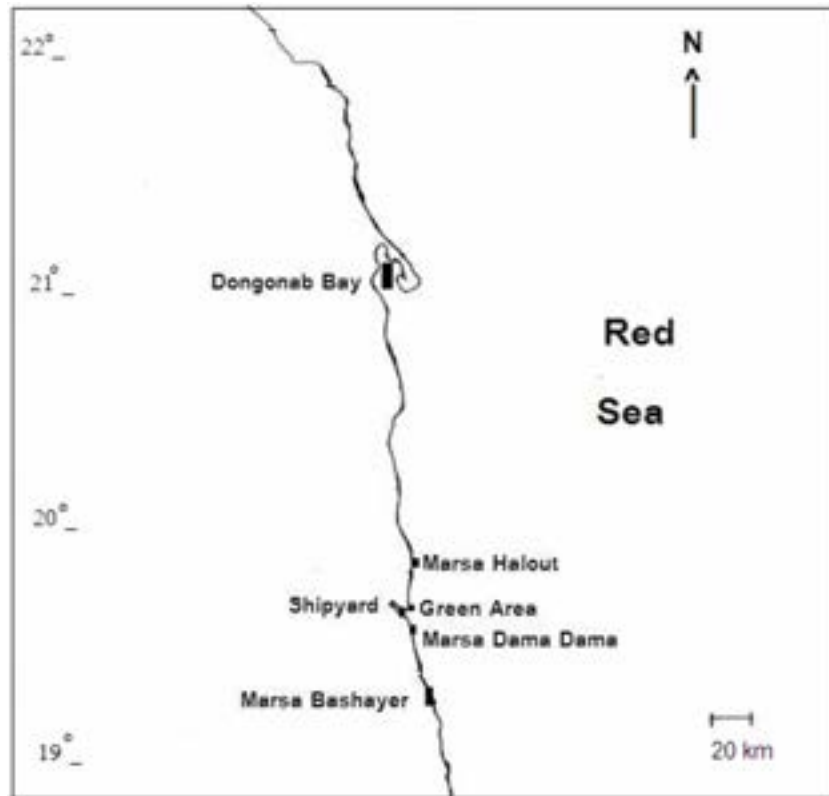


Figure 48: The geographical location of the six study sites in the seagrass study of Gaiballa (2005).

Assessments of condition:

The possible negative influence of coastal development activities and other human activities on the condition of seagrasses beds along the Sudanese Red Sea coast were investigated by Gaiballa (2005). The study included qualitative and quantitative assessments of seagrasses at six coastal sites with variable degrees of development activities (Figure 48). : Marsa Bashayer, Marsa Dama Dama, Eastern part of Port Sudan Harbour (Green Area), Northern part of Port Sudan Harbour (Shipyard), Marsa Halout and Dungonab Bay, and covered both summer and winter seasons. The human activities which were assessed included trawling, harbours and jetties construction, boats propelling, anchoring, dredging and drilling, dumping of material, metal contaminants, discharging of sewage, cooling water and industrial waste and oil spill. The magnitude of impacts ranged between very low at Dungonab Bay and high at the Northern Part of Port Sudan Harbour (Shipyard). The study concluded that the observed impacts were not severe and recommended that future conservation and management of seagrass beds should be one of the key priorities in the Integrated Coastal Zone Management of Sudan. It also suggested that further studies should be conducted in the fields of taxonomy, ecology, dynamic and utilization.

Other useful information sources:

(Price et al., 1998; Sam et al., 1998a).

2.6 Marine fish and seafood resources

The dominating activity in the marine fisheries sector in Sudan is artisanal fishing activities using traditional methods with small vessels and low level of mechanisation, although some semi-industrial and industrial activities occur or have occurred previously (PERSGA/GEF, 2003c). The relative size of the marine fisheries is small, only about 5 % in comparison to the freshwater fisheries (in landing value). The relative contribution to Sudan's GNP from marine fisheries is presently considered to be negligible. Nevertheless, the marine fisheries are very important for local coastal communities in the Red Sea State, both as a source of food and income.



Figure 49. A typical Sudanese fishing vessels by a coral reef. Photo: Erik Olsen, IMR, Bergen, Norway

Historically, there are two major sectors of marine fisheries in Sudan: the shellfish collection industry, which was very important previously; and the artisanal finfish fishery. In the Sudanese waters there is a rich biodiversity of reef associated fish species of which many are endemic to the Red Sea (species found nowhere else). It has been estimated that of the 1200 or so coral reef fish species recorded within the Red Sea, more than 10% and possibly as much as 20% are endemic. The Red Sea is also home to a variety of pelagic fish including tuna, although the overall density of pelagic fish in the Red Sea area, and in the Sudanese sector in particular, is relatively low due to the low levels of nutrients in the sea. The high degree of endemism of fish and other marine species in the Red Sea highlights the importance of establishing a high quality biodiversity database for this area, as a basis for environmental conservation measures.

There is little systematic information available about the ecological status of sea life resources within the Sudanese Exclusive Economic Zone (EEZ) (Figure 1). Resource estimates have mostly been based on fish landing data obtained at fish markets, e.g. Abdalla (2013). These data are hampered with much uncertainty. An important paper was recently reported by Tesfamichael and Ekawad (2012) addressing a reconstruction of the marine fisheries in Sudan during the period 1950-2010. The key results show that the Sudanese fisheries went through a major shift during that six-decade period, from being dominated by shellfish fishery up until the collapse of the shellfish resources in the late 1960 and 70s, and then from the late 1970s being dominated by the artisanal finfish fishery sector. The total marine catch was about 2,000 tons per year during the 1950s, and remained at this low level until the end of 1970s when developmental projects aided by foreign organizations led to an increase of the total catches reaching more than 5,000 tons per in the 2000s (Tefamichael and Ekawad, 2012).

A significant shortcoming has been the lack of reliable catch survey programmes and data recording systems which can provide reliable estimates of the Sudanese seafood resources. Some early studies were done within the FAO system in the 1950 (Kristjonnsson, 1956; Oswald, 1958), and the earliest

known test fishing survey in Sudan was documented by Reed (1962) on exploratory trawling for shrimp. The next test fishing was a trawling study conducted by the UK Overseas Development Agency with catch surveys conducted in 1976 and 1981 (ODA, 1983). Later FAO has organised several studies in the RSGA seas to assess marine fish stocks and the potentials for development of fisheries (FAO, 2008; Sanders and Kedidi, 1981; Sanders and Morgan, 1989). In 2012, Sudan and Norway started collaboration on the issue, first with the UNIDO project “*Surveys of renewable marine resources in the Red Sea State, Republic of Sudan*” (TE/SUD/12/004) which was financed by the Norwegian Embassy in Khartoum. The project activity includes a practical collaboration of the Norwegian Institute for Marine Research (Bergen, Norway) and the Marine Fisheries Administration in the Ministry of Agriculture, Animal Resources and Fisheries of Red Sea State. The project aims to collect and analyse information, implement monitoring surveys of the coastal fish stocks, and develop a state of the art database on fish landings. The collaboration programme has during 2012-2014 performed three comprehensive surveys of the renewable marine resources along the Red Sea coast of Sudan (Olsen et al., 2013a; Olsen et al., 2013b; Palm et al., 2014) (further details from these surveys are included below), and further collaboration activities and follow-up surveys are scheduled from the fall of 2015 as a part of the three-year project “*Building institutional capacities for the sustainable management of the marine fishery in the Red Sea State*”. Preliminary estimates from this programme indicate that the ecological sustainable use of the marine fisheries resources in Sudan represents an economic potential of 13-25 million EUR per year. In order to realize the potential in a sustainable way, the institutional resource governance capacity must be strengthened and more reliable information on the status of the fish resources as well as the actual fish landings is required.

According to (Eldardiry and Farah, 1999) the most important marine products in Sudan are: (i) Finfish, (ii) Shrimp, lobster and crab, (iii) Bêche-de-mer (Sea Cucumber), (iv) Aquarium fish, (v) Oyster and trochus, (vi) Shark fin, (vii) Corals. The reported bony fishes amount to 280 species whereas cartilaginous fishes include 30 species of sharks and 21 species of skates and rays. The principal finfish species caught as seafood in Sudanese waters are the groupers (*Variola louti*, *Epinephelus aereolatus*, *E. tauvina*, *Cephalopis sp.*), Emperor fish (*Lethrinus mahsena*, *L. miniata*, *L. harak*, *L. ientjan*), the blue-spotted seabass (*Plectropomus leopardus*) and the two spot red snapper (*Lutjanus bohar*). Spanish mackerel (*Scomberomorus commerson*) barracuda (*Sphyraena sp.*), trevallies and jacks (*Caranx sp.*) are also caught by trolling when traveling to and from the fishing grounds (Kedidi, 1984). Of these species in particular the *Lethrinus lentjan* which is a species of Emperor fish (Figure 50) is considered as particular important for fishing. This fish species can reach a size of more than 50 cm; is found in lagoons, coral reefs and seagrass beds; juveniles enter estuaries and mangrove swamps. It is carnivorous, feeds on crustaceans, molluscs, polychaetes and fishes, and is esteemed as food fish. It was earlier the only species in Sudanese marine waters subjected to detailed resource assessment studies (Kedidi, 1984).



Figure 50: Pink ear emperor fish, *Lethrinus lentjan* (Lacepède, 1802) is one of the principal finfish species caught as seafood in Sudanese waters.

Status of marine fisheries in Sudan:

The artisanal Sudanese fisheries are generally small-scale, labour intensive and mostly carried out by small vessels (<10 m) using traditional methods in nearshore areas (Khalid et al., 2008). Fishermen usually collect the fish in limiting areas near their small fishing villages, which are found many places along the coast. Fish landed close to Port Sudan are marketed fresh on ice to the local market. The typical fishing methods used include baited handline, hook and line for the coral reefs fishes and gillnet and purse seiner nets for bottom fishes (Mishrigi et al., 1993). It has earlier been estimated that approximately 1800 local fishermen are registered and they operate approximately 410 fishing boats; including mostly small boats less than 10 meters long. It is estimated that the hand lining and gillnetting for reef-associated species accounts for about 80% of the annual catch (Eldardiry and Farah, 1999; Sanders and Morgan, 1989). Some pelagic purse-seiners and shrimp trawlers are reported to take part in Sudanese fisheries but their catches are considered as limited due to poor fleet management and restricted trawling grounds.

The total economic contribution of marine finfish fisheries to the Sudanese GNP is small. The inland fisheries in the Nile River are significantly, at least one order of magnitude, larger (Eldardiry and Farah, 1999; Saeed, 2004). The marine fisheries occur preferably in connection to the many coral reefs in the continental shelf zone (Figure 1). The offshore reefs are separated from the mainland by channels of some 50 to 150 m in depth and 5 to 10 km in width. The most productive grounds for the Sudanese fishermen are the inner edges of the offshore reefs (Sanders and Morgan, 1989). As of yet, any significant industrial and or recreational fisheries have not emerged in Sudanese marine waters. However, a limited number of foreign trawlers operate on seasonal basis mainly targeting shrimps and discharge the by-catch (Saeed, 2004). Also a limited number of small size trawlers are used in the coastal and offshore fisheries, but the irregular sea bed conditions confine trawling operations to a limited number of small trawling areas.

Regionally important populations of sharks are known to occupy the waters off the coast of Sudan, and these species are a very important attraction for the marine tourism trade. Seasonal aggregation of hammerhead sharks (*Sphyrna* sp.) are known to occur around the Sanganeb Atoll, at Shaab Rumi, and around many of the reefs in Dungenab Bay area in winter, although only very few were observed in surveys (PERSGA/GEF, 2003a). In the Dungenab area, small reef sharks (blacktip reef, *Carcharhinus melanopterus*) occur at several sites, most notably on the western side of Mukawwar Island and inside Dungenab Bay (Nasr, 2015b), whereas the hammerhead sharks have been reported to occur preferably at the offshore reefs (PERSGA/GEF, 2003a). Shark fishing has apparently been common in the Dungenab area, usually carried out by fishers from Port Sudan or elsewhere (Nasr, 2015b). Evidence of shark fishing is observed in a number of other locations and this is a concern as shark fishing can severely deplete local shark populations very rapidly (PERSGA/GEF, 2003a). The Dungenab Bay area is also well known for seasonal aggregations of whale sharks (*Rhyncodon typus*) over the summer period, and also for aggregations of manta rays (*Manta birostris*) which are considered to show a more stable presence throughout the year.

In Sudan, the artisanal fishery for marine invertebrates includes collection of different species of shellfish, shrimp and sea cucumber. Diving in search of wild molluscs is an old dating occupation for the coastal population along the Sudanese coastline and there are signs of large scale collection activity dating back more than 1500 years (MEPI, 1993). Molluscs of highest commercial importance include *Pinctada margaritifera*, *Trochus dentatus*, *Strombus*, *Lambia*, *Chicorus*, *Fasciolaria* and *Sypraya* spp. The first two species contribute to over 90 percent of the wild mollusc collection which is exported to Europe as raw material for button manufacturing, cosmetics and inlay works. Species such as *Strombus Lambia* and *Tridachnia* are fished for local market as souvenirs or use of the shell and meat as ingredients in poultry feed and local perfume production. The available production statistics, which are said to need updating (Saeed, 2004), suggest a total annual landing of 500 tonnes of *Trochus* spp., and 30 tonnes of *Pinctada* spp., 600 pieces of *Strombus* and 500 kg of *Lambia* spp. In the contemporary history of Sudanese artisanal fishery, shell collection was dominant and the tradition continued until the end of the 1960s when a mass mortality event of local shellfish resources forced the local fisheries to switch to finfish fishing or other activities. The major shellfish species collected in Sudan are the mother-of-pearl oyster (*Pinctada* spp.) and trochus (*Trochus* spp.). In particular, the

Dungonab Bay area is famous for its natural populations of mother-of-pearl oysters. In this area, a marine cultivation industry was established based on the natural population of the black lipped mother-of-pearl oyster *Pinctada margaritifera* (L.) (Figure 51). Dungonab Bay is considered to be an ideal location for the collection and rearing of *Pinctada margaritifera* spats for production of cultivated pearls. The earlier shell cultivation activities were geared towards production of oyster shells for export as raw material for button manufacturing, cosmetics and inlay works, but in particular the cultivated pearl production has in periods attracted considerable commercial interest (Elamin and Elamin, 2014; Elamin et al., 2014a), and was also financial supported from the Ministry of Agriculture, Animal Resources and Irrigation of the Red Sea State, OXFAM and ACCORD (Saeed, 2004). In recent years, the shell cultivation activity in Dungonab Bay has apparently faced significant problems and the current activity is thought to be low, although the information about its current status is unclear.

For crustaceans, eight shrimp species are fished by local inhabitants along the coast or by bottom trawling by local and foreign vessels. Of these, *Penaeus semisulcatus*, *Penaeus latisulcatus* and *Metapenaeus monocerus* contribute the highest population density (Saeed, 2004). Discordant statistics suggest that shrimp catches do not exceed 20 tonnes/year but proper stock assessment studies have been carried out to quantify the local shrimp populations.

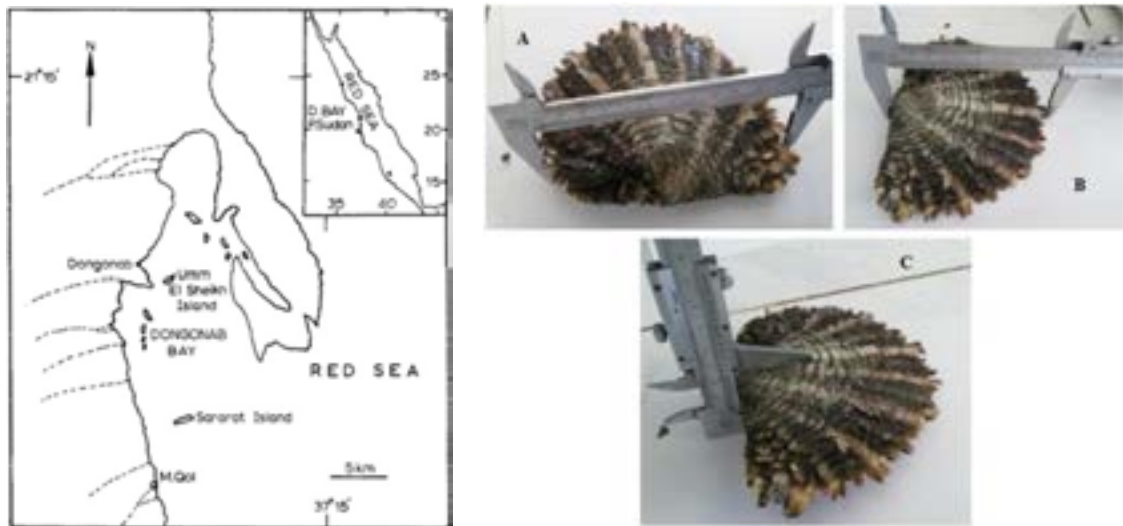


Figure 51: In the area of Dungonab Bay cultivation of pearl oysters *Pinctada margaritifera* has a long history. Photos A-C are obtained from Elamin and Elamin (2014) and show morphometric measurements of black-lip mother-of-pearl shells, *Pinctada margaritifera* var *erythraensis*, (A=Shell length, B= Shell height and C= Shell thickness).

Previous marine seafood resource estimates

The present status of the marine finfish resources in Sudan is generally uncertain due to the general paucity of trustworthy resource monitoring data on different key marine species. There is no reliable catch survey and data recording system in place to provide reliable estimations of the condition status of the different natural resources and because of this lack of good resource data the fisheries legislation in Sudanese marine waters cannot be effectively enforced (PERSGA/GEF, 2003c). No proper stock assessments were conducted prior to 1998, but, according to previous British estimates, the maximum sustainable yield was at that time approximately 35,000 tons (Eldardiry and Farah, 1999). However, despite considerable efforts by the Sudanese Government through development projects, the marine fish catches have most years not exceeded 2,000 tons per year. The estimated potential for fisheries in Sudanese marine waters are rather discordant with figures e.g. for finfish species ranging between 6,000 and 35,000 tons/year. For precautionary approach measures, a fisheries resource potential of 10,000 tons/year has been suggested, and of this total the current annual finfish

landing should not to exceed 5,000 tonnes (Saeed, 2004). Resource assessing studies have typically used fish landing data obtained from the fish markets in Port Sudan or elsewhere as a tool for assessing the trends in the resource base from the Sudanese marine waters. Possibly the most thorough report of this kind was published recently by Tesfamichael and Ekawad (2012). They addressed a long-term reconstruction of the Sudanese fisheries during the period 1950-2010. In addition to providing a long term summary of the major landing trends both of key marine finfish species (Figure 52) and key marine invertebrate species (Figure 53) they also show that the resource estimation data which is extracted from commercial landings are hampered with much uncertainty due to irregularities in the reporting regime, leading potentially to significant over-reporting as well as under-reporting of the actual catches (Tesfamichael and Ekawad, 2012).

A significant problem by basing resource estimates on commercial landing is the fact that the data represent only a (small) fraction of the amount of fish that actually is killed by the fishing activity (Figure 54). For some Red Sea countries, it has been estimated that more than half of the fish catch does not go through the fish market, where the official recording occurs (Chakraborty, 1983), and, as illustrated by Figure 54, this is just one of the factors that lead to severe underestimation of the actual exploitation pressure of the different marine population resources. Optimally, the actual effect of fishery should thus be measured by the amount of fish killed rather than fish landed.

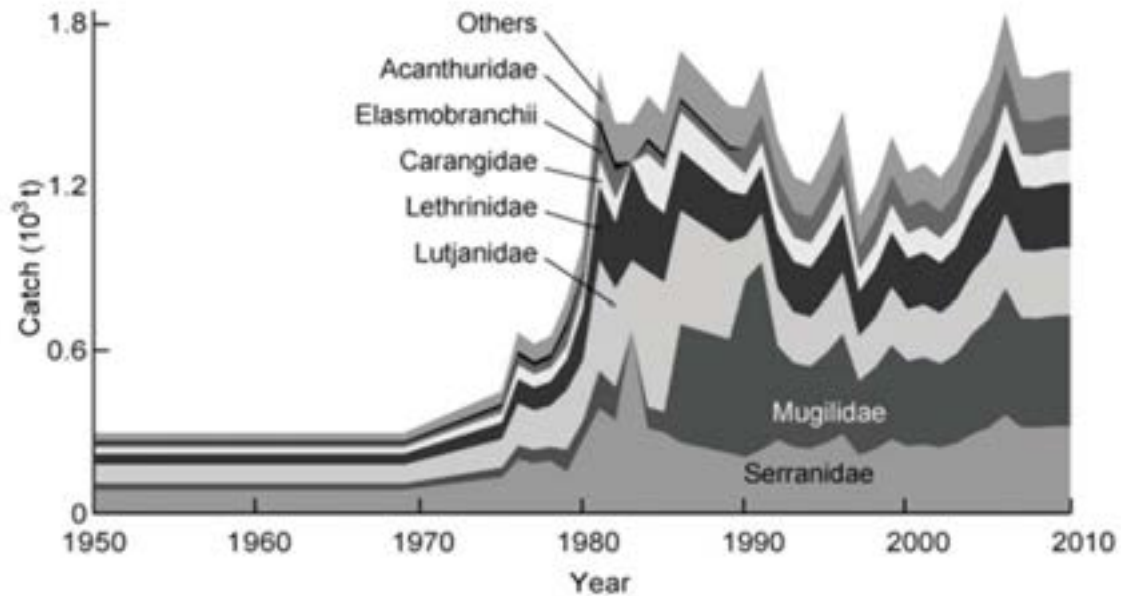


Figure 52: Estimated catch composition of the artisanal finfish fishery of Sudan during the period 1950 – 2010, source: Tesfamichael and Ekawad (2012).

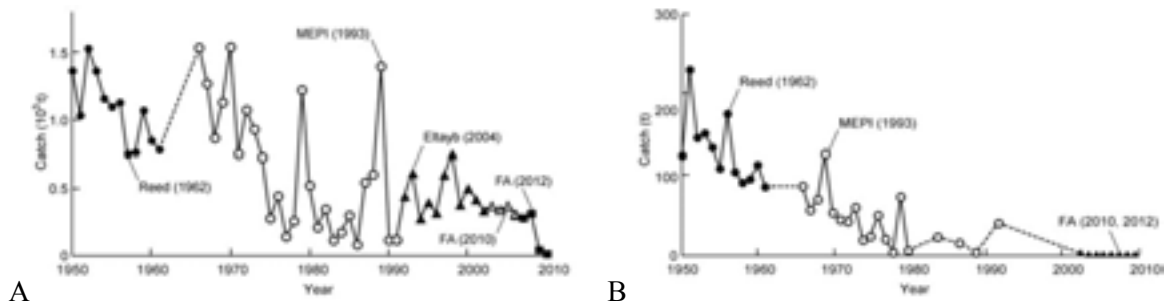


Figure 53: Estimated catch composition of (A) trochus shell fishery and (B) the oyster shell fishery of Sudan during the period 1950 – 2010, source: Tesfamichael and Ekawad (2012).

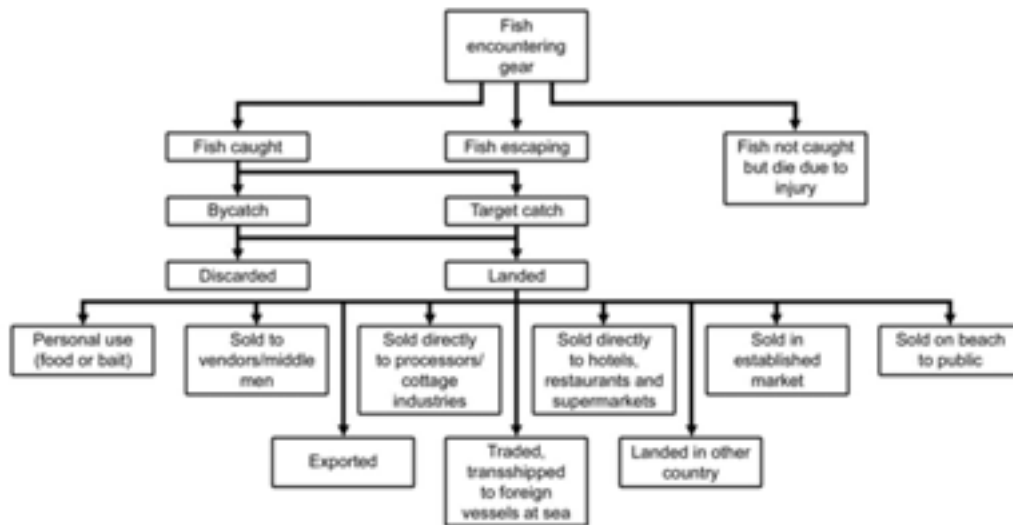


Figure 54: Possible fates of fish following an encounter with a fishing gear, based on Mohammed (2003).

Sudanese-Norwegian collaboration on marine fisheries resource mapping

As part of an ongoing Sudanese-Norwegian collaboration project “Surveys of renewable marine resources in the Red Sea, Republic of Sudan” several fisheries resource mapping surveys have recently been conducted along the entire Red Sea coast of Sudan (Olsen et al., 2013a; Olsen et al., 2013b; Palm et al., 2014). The key aims of the collaboration were to increase the knowledge regarding the marine finfish resources of Sudan and to train local scientists and technicians in fish and data sampling methods.

The pilot resource mapping survey within the programme was conducted in November 2012 along the whole Sudanese coast (Olsen et al., 2013a) and was carried out by The Marine Fisheries Administration (Red Sea State) and Sudanese scientists under guidance by IMR experts using two survey vessels, including the diving ship M/S «Don Questo» (Figure 55, Figure 56). The second and third surveys were conducted in May-June and Nov-December 2013, respectively (Olsen et al., 2013b; Palm et al., 2014). A collection of fish catching methods was used during the cruises, including baited traps (large and small), hand line, gill-nets, long-line and beach-seines. The data-set of collected fish is currently being analysed and more surveys are being scheduled for the coming period.

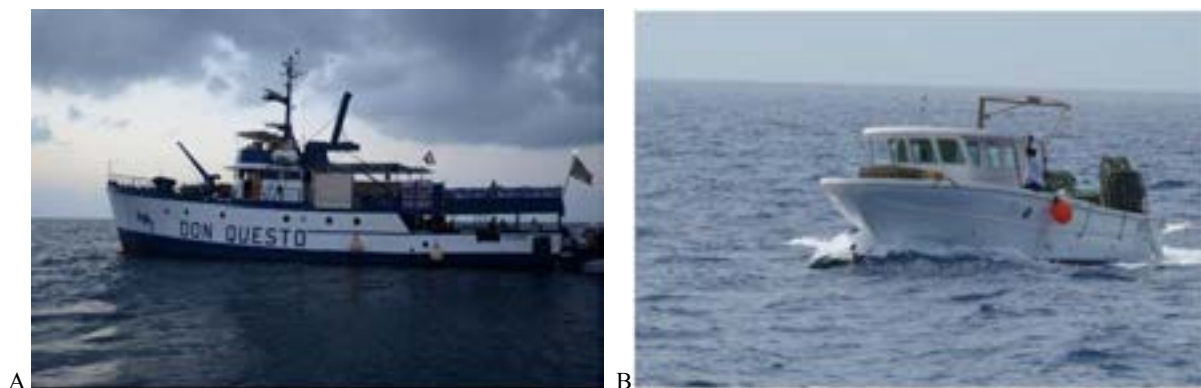


Figure 55. The two vessels used for fishing operations during the fisheries resource surveys in the Sudan-Norway collaboration programme. The commercial diving vessel M/S Don Questo (A) and the 34' inboard-engine glass fibre vessel which currently is operated by the Marine Fisheries Administration in Port Sudan. Photos: Erik Olsen, Institute of Marine Research, Bergen, Norway.



Figure 56: Baited fish traps (150 x 180 cm in area, 80 cm in height) were among the fishing methods used during the fisheries resource mapping surveys. Photo source: Palm et al. (2014).

Some key preliminary results from the fish resources survey reports of the ongoing Sudan-Norway collaboration programme are shown below (Figure 57, Figure 58, Figure 59). The preliminary catch data which are available from the cruise reports are highly interesting sources of information for the present report as well as for the environmental monitoring guideline for offshore oil industrial activities, e.g. in conjunction with the choice of catch methods and target species for collection of fish samples in connection with environmental monitoring work. During the second survey that was conducted in May-June 2013 (Olsen et al., 2013b), a total of 99 different species of fish were caught during the whole survey, and of these the snappers, *Lutjanus bohar* and *Lutjanus gibbus* were the most common species, occurring in 91 and 56 catches respectively followed by the emperor *Lethrinus lentjan* with 47 occurrences (Figure 59). Of the 99 species, only 17 occurred in 10 or more stations – indicating large spatial variability in the species structure along the Sudanese coast.

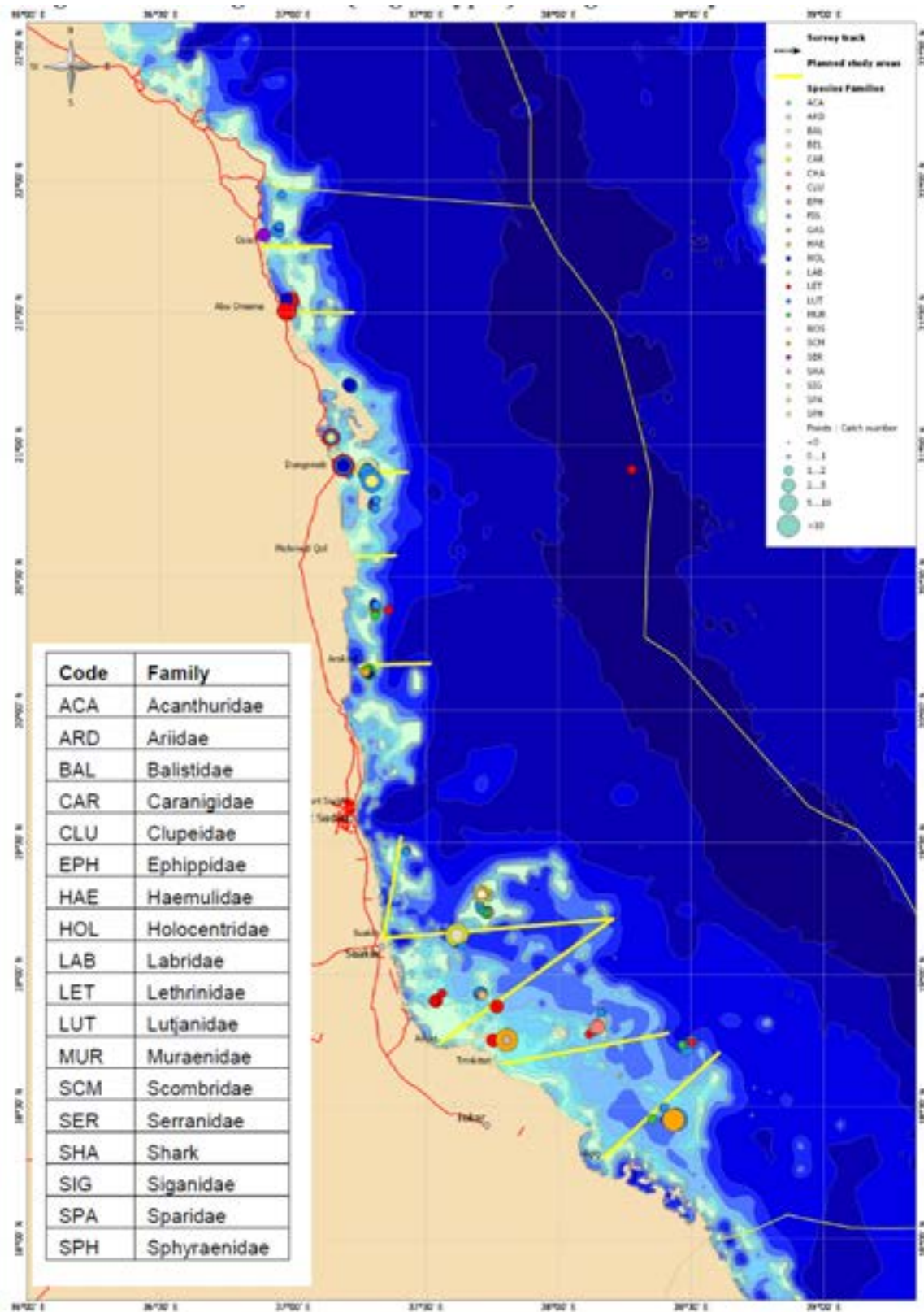


Figure 57: Example of data from the first fisheries resource cruise (Olsen et al., 2013a) showing the realized survey track, the proposed study areas and the catches at the different stations (single traps) split according to fish families.

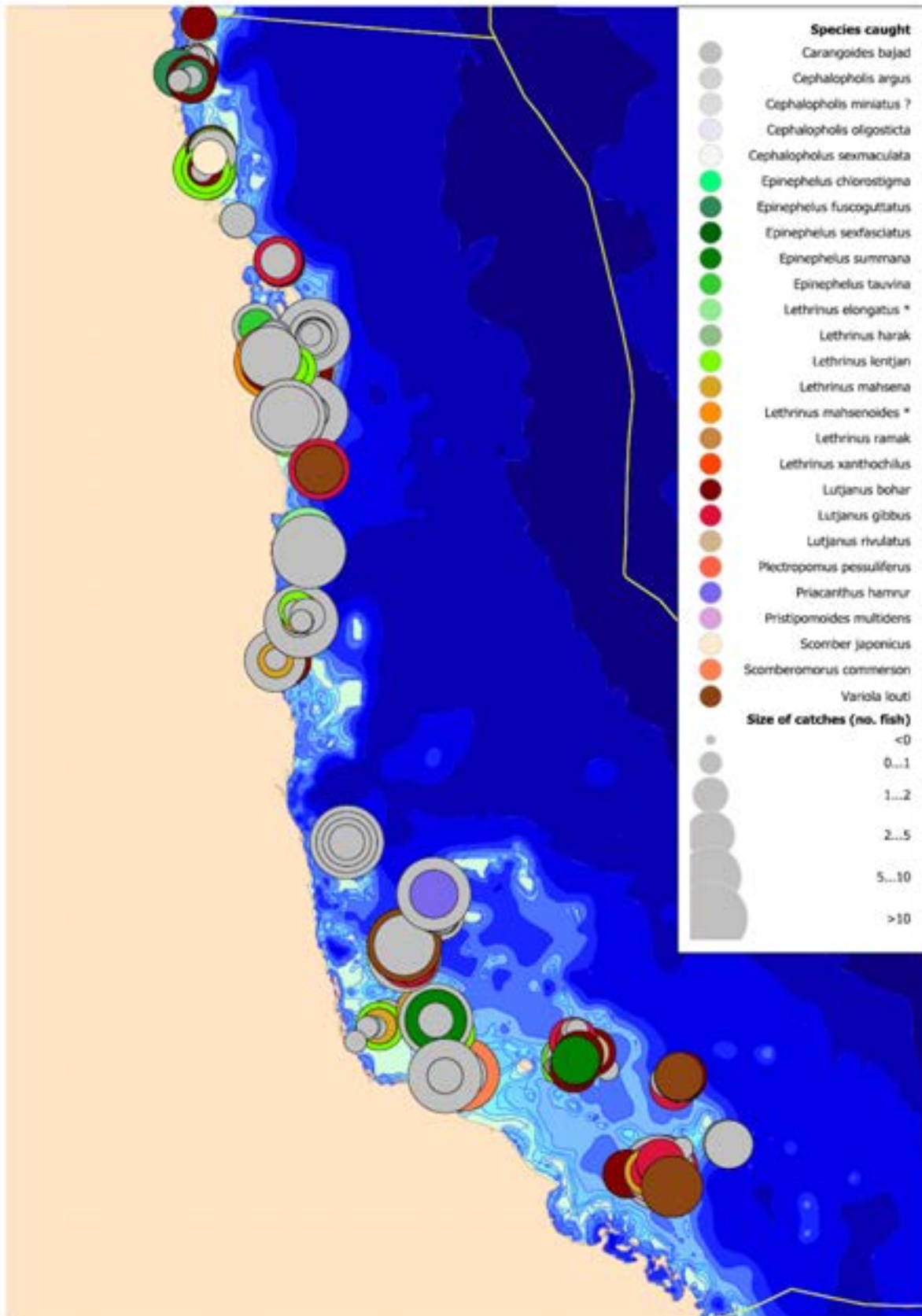


Figure 58: Example of catch data from the second fisheries resource cruise report (Olsen et al., 2013b) showing the numbers of fish (aggregated to families) that were caught at each sampling station, i.e. showing the catches at the different stations (single traps) split according to the 26 most common fish species.

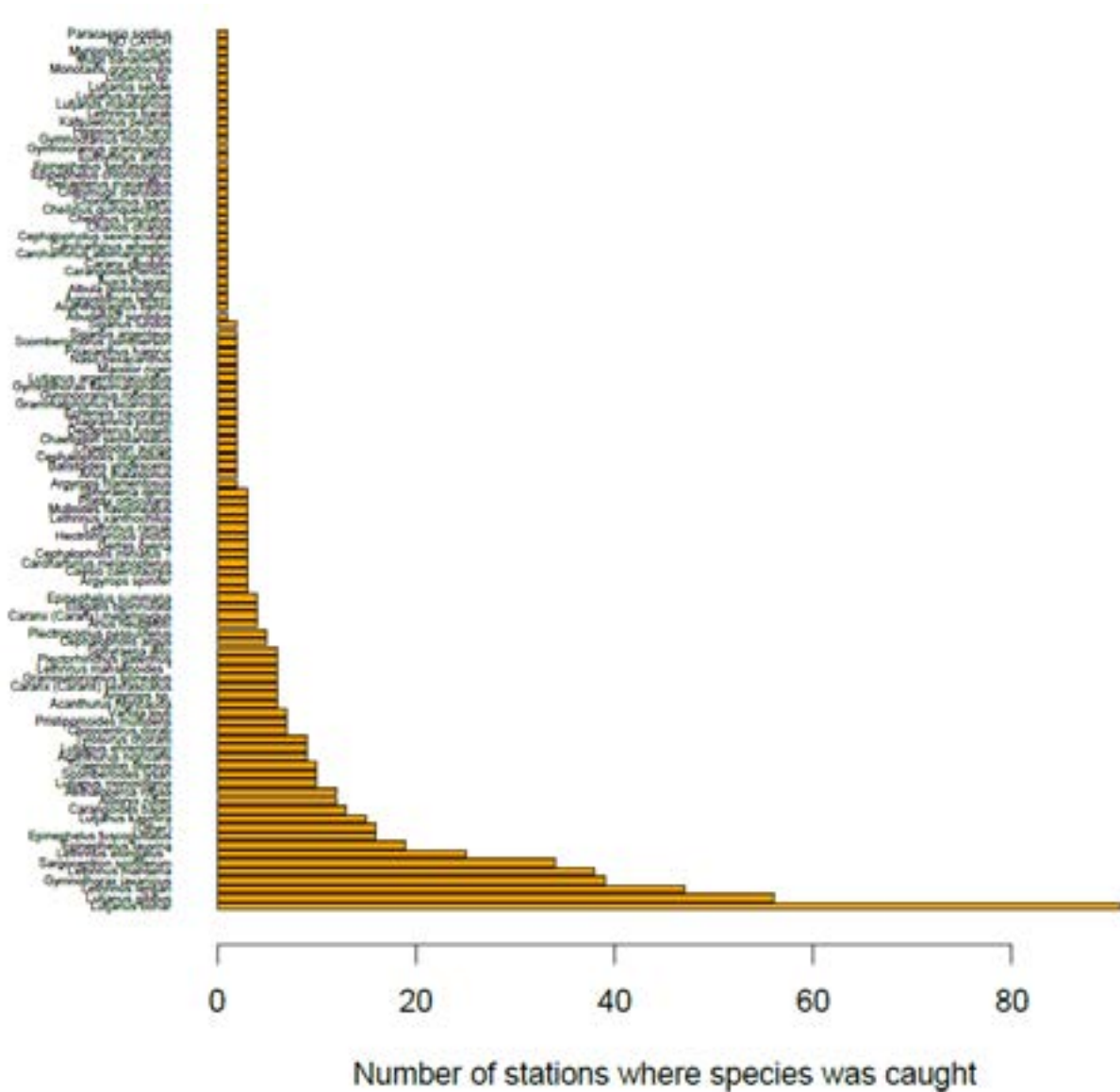


Figure 59: Example of catch data from the second fisheries resource cruise report (Olsen et al., 2013b) showing the occurrence of different fish species (number of stations where the species was caught) for all gear types and both seasons (years).

Potential anthropogenic stresses with relevance to marine fisheries:

The marine environment and fisheries have been observed to be apparently subject to various hazards and risks that demand high priority attention. Some of these negative impacts are cited below (source: (Saeed, 2004)):

- There is a pronounced lack of effective fisheries management in the area at present, and this has resulted in overexploitation, especially of certain high value species, such as the groupers (*Plectropomus* spp.) including nagil (*Plectropomus areolatus*) (Figure 60).
- Overfishing of some fisheries resources has happened as a consequence of improvement of fishing gears and techniques (e.g. overexploitation of historical locations for wild oyster collection in Dungonab Bay and Mohamed Goal area in the north coast and Suakin Archipelago in the south).
- There are also signs of overexploitation in a number of invertebrate species, particularly for trochus sea snails (kokian) and for edible sea cucumber (Holothuroidea).

- Illegal fishing performed by unlicensed foreign vessel and smuggling of catch.
- By-catch and discards of untargeted fish which is thrown back to the water particularly by shrimp trawlers and its negative economic and environmental impacts.
- Use of illegal fishing methods (e.g. dynamite) by foreign fishermen or fishing during the breeding season.
- Destruction of coral community stands and dredging of fishing grounds in the process of construction of new ports (e.g. Bashayr Petroleum Port, rehabilitation of Suakin Port and Ooseif Port).
- Deterioration of coastal environment through cutting of mangroves and blocking of natural water courses from reaching the sea by the fast pace of industrial and economic development.
- Oil pollution



Figure 60: Nagil, the squaretailed leopard grouper (*Plectropomus areolatus*), is one of the high value fish species that suffer from overexploitation in the Sudanese marine waters.

Other useful information sources:

(Brokovich et al., 2006; Edwards and Rosewell, 1981; Eldardiry and Farah, 1999; Golani, 1993; Hassona et al., 2008; Hawkins et al., 2000; Hussey et al., 2013; Mazeroll and Montgomery, 1998; Nowlis and Roberts, 1999; PERSGA/GEF, 2004c; Roberts and Ormond, 1987; Roberts et al., 1992; Said et al., 2014; Suzuki et al., 2012; Temraz and Abou Zaid, 2005; UNEP, 2007; Vine, 1974).

2.7 Sea turtles, seabirds and sea mammals

The Sudan Red Sea hosts important populations of sea turtles and seabirds, as well as sea mammals such as dugong, dolphins and whales.

Sea turtles:

There are in total only seven species of sea turtles existing in the world, these include:

- | | |
|------------------|-------------------------------|
| 1. green turtle | <i>Chelonia mydas</i> |
| 2. hawksbill | <i>Eretmochelys imbricata</i> |
| 3. loggerhead | <i>Caretta caretta</i> |
| 4. Kemp's ridley | <i>Lepidochelys kempii</i> |
| 5. olive ridley | <i>Lepidochelys olivacea</i> |
| 6. flatback | <i>Natator depressus</i> |
| 7. leatherback | <i>Dermochelys coriacea</i> |

According to Gasparetti et al. (1993), the waters of the Red Sea and Gulf of Aden waters may support as many as five of these marine turtle species: the green, hawksbill, loggerhead, olive ridley and leatherback. However, only the first three are considered to nest within the RSGA region (Table 9). The status of marine turtle populations in the Red Sea was summarised by Ross and Barwani (1982), and that study is still considered one of the most accurate regional reports available. Egyptian HEPCA is among the non-profit organisations targeting the status of marine turtles of the Red Sea.

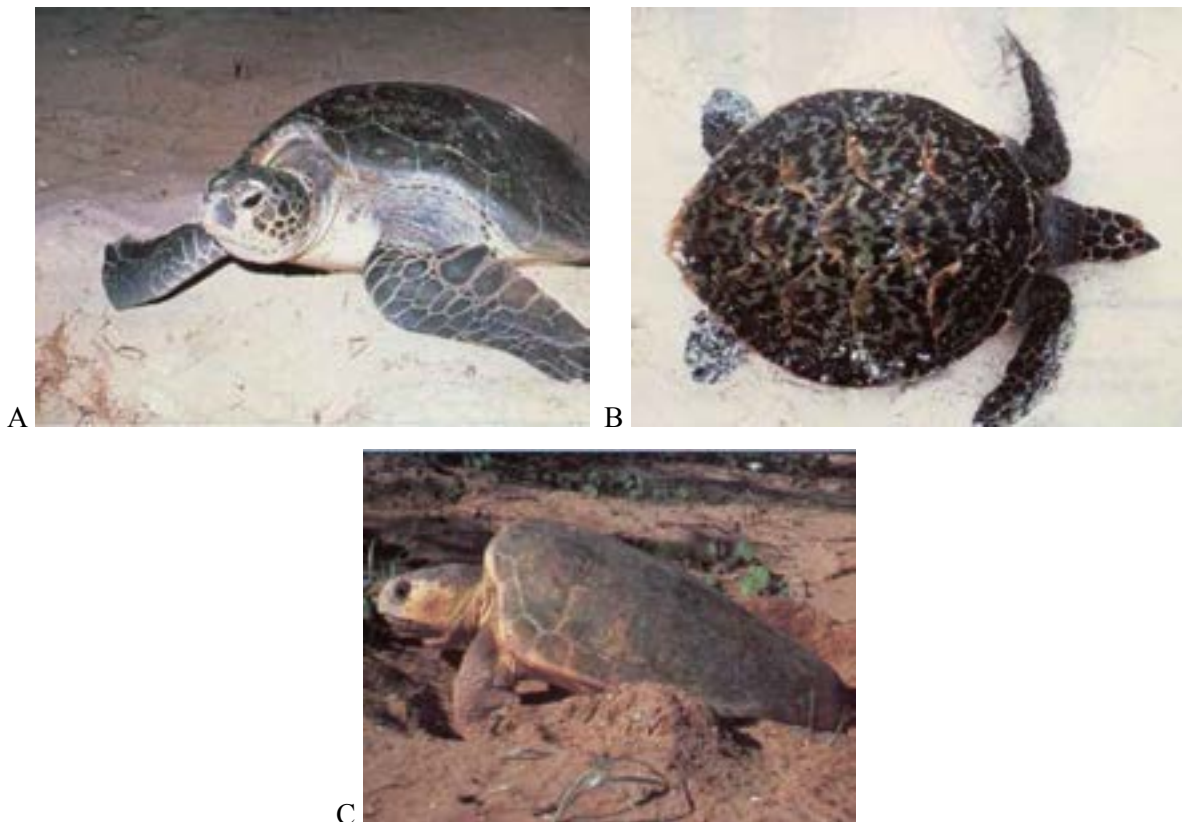


Figure 61. Two species of sea turtles occur in Sudanese waters A) Green turtle (*Chelonia mydas*) and B) Hawksbill turtle (*Eretmochelys imbricata*), whereas C) Loggerhead turtles (*Caretta caretta*) are present in Gulf of Aden. Pictures courtesy of: Queensland Department of Environment and Heritage.

The Red Sea marine turtles are subjected to multiple threats including human activities that destroy nesting beaches and feeding grounds; artificial lighting on nesting beaches that disorients nesting turtles and hatchlings; plastic bags and other litter items which is mistaken as food and ingested by the turtles; water pollution which possibly is associated with diseases like the fibropapilloma tumor

disease; high speed boats and jet-skis that can seriously wound or kill sea turtles; incidental fishing in particular in industrial trawlers and purse seines.

Table 9. Sea turtles populations in the Red Sea and Gulf of Aden. Key nesting and foraging sites and population statistics for the RSGA region (source: PERSGA/GEF (2004g)).

	Species	Key Nesting Sites	Nesting Season	Size of Nesting Population	CCL (cm)	CCW (cm)	Key Foraging Sites
Djibouti	Green	Iles Moucha & Maskali, Ras Siyyan, Iles des Sept Frères	Jan.-Apr.	~100	66.67	63.3	Gabel
	Hawksbill	Ras Siyyan, Sept Frères	Mar.-Jun.	ND	59.5	65.5	All fringing reefs
	Loggerhead	ND	ND	ND	ND	ND	Haramous Loyada
Egypt	Green	Wadi Al-Gimal, Ras Banas, Sarenka, Siyal, Zabargad & Rowabil Islands	Jun.-Aug.	~200	--	--	ND
	Hawksbill	Shedwan, Gifrun Kabir & Gifrun Sagheir Islds.	May-Jul.	~200	--	--	All fringing reefs
Jordan	Green	None	n/a	n/a	--	--	All fringing reefs
	Hawksbill	None	n/a	n/a	--	--	All fringing reefs
Saudi Arabia	Green	Ras Baridi	Aug.-Nov.	~100	105.60	96.5	Al Wash Bank, Farasan Islands
	Hawksbill	Farasan Islands	Feb.-May	~50	ND	ND	All fringing reefs
Somalia	Green	Raas Xaaf to Raas Cuda, Berbera	Jan.-Apr.	<50	ND	ND	ND
	Hawksbill	Sa'adadin, Aibat Islands, Raas Xaaf to Raas Cuda	Mar.-Jun.	<50	ND	ND	All fringing reefs
Sudan	Green	Seil Ada Kebir Island, Sudan Mukawwar Is.	All year	<50	ND	ND	Unknown
	Hawksbill	Mukawwar Is. Seil Ada Kebir Sudan	Mar.-Jul. ND	ND ND	71.93 66.0	64.63 ND	All fringing and barrier reefs
Yemen	Green	Ras Sharma	July	~6000	106.0	96.0	Khor Umeira
	Hawksbill	Jabal Anz	ND	~500	ND	ND	All fringing reefs
	Loggerhead	Socotra	Jul.-Aug.	~50-100	94.3	85.8	Unknown

Sources: Djibouti: PERSGA 2003b; Egypt: FRAZIER & SALAS 1984, PERSGA 2003a; Saudi Arabia: PERSGA 2003c, MILLER 1989, PILCHER & AL-MERGHANI 2000; Somalia: SCHLEYER & BALDWIN 1999, IUCN 1997; Sudan: DIAMOND 1976; PERSGA 2003e; Yemen: PERSGA 2003d, PILCHER & SAAD 2000, NEP/IUCN 1996. ND = No Data.

In 2004 PERSGA published a "Regional Action Plan for the Conservation of Marine Turtles and their Habitats in the Red Sea and Gulf of Aden" (PERSGA/GEF, 2004g), whereas a comprehensive set of technical tools for assessing the condition of marine turtle populations within the RSGA area was provided in PERSGA/GEF (2004d). The procedure suggestions also include a set of central questions to address related to population condition status assessment and suggestions of survey methods to fill gaps in knowledge (Table 10).

Table 10: Questions related to marine turtle populations in the RSGA region and suggested survey methods to fill gaps in knowledge. Those marked with a * require significant training and should only be conducted with the assistance of experienced professionals.

Problem	Survey Method	Notes
Need to record and map all areas of concern to turtle populations	Desktop and literature surveys	Provide information on previous studies in the area on which to base further studies
	Preliminary presence-absence surveys	Identify where turtles are found
	Rapid coastal surveys	Identify potential and actual nesting habitats and their characteristics
	Interviews	Provide subjective data on turtle distribution, threats, species presence, etc.
Need to quantify nesting on beaches	Aerial surveys	Provide (limited) but high coverage information on nesting numbers and success
	Detailed nesting beach surveys	Provide accurate nesting volume and success assessments, and options for reproductive biology studies
	Short term nesting beach inspections	Provide rough nesting assessments
	Track counts (short- or long-term)	Provide relatively accurate nesting volume and success assessments and can be rapid
Need to quantify turtle abundance at foraging grounds	Aerial surveys	Provide counts of turtles at the surface for sampled areas, which may be extrapolated to an estimate of total abundance
	Mark and recapture studies	Provide estimates of foraging population size through recaptures of marked individuals. Can be resource and time consuming.
Need to identify individual turtles	Tagging studies	Provide an option for recapture of individuals over time
Need to discover migration destinations	Tagging studies	Based only on recaptures and public participation for tag returns (low cost)
	Satellite tracking	Provide extremely accurate migration path trajectories and destinations (expensive)
Need to determine short-distance movements	Radio or sonic tracking	Provides data on short distance movements of turtles, requires training and experience, can be demanding on financial resources and time
Need to determine reproductive success	Nesting beach surveys	Can evaluate nesting success, egg deposition, incubation period and success, etc.
Need to identify diet of turtles*	Stomach content analysis	Identification of stomach contents requires experience; must be performed by trained personnel
Need to identify reproductive state of turtles*	Laparoscopy	Surgical procedure, requires trained expert and laparoscope
Need to identify impact of fisheries	Observer programmes	Provide data on mortality and accidental captures; can provide additional useful data
Need to determine genetic affiliation of turtles	mtDNA and nDNA analysis	Requires small samples, which can be collected by field researchers; analysis requires laboratory with trained technicians
Need to identify sex ratios of hatchlings*	Histology studies	Requires sacrificing hatchlings for gonad inspection; requires training and experience

The Dungonab National Park is considered to be a particularly important area for marine turtles, with both green turtles (*Chelonia mydas*) and hawksbill turtles (*Eretmochelys imbricata*) being common

throughout the area. The range of different egg sizes (assessed on the basis of old, empty, shells) indicates that at least three species of turtles nest within the park. The green turtles are particularly widespread in Dungonab. In the large shallow areas of reef flat and sand at the northern end of the Mukawwar Island many green turtles gather during the day, waiting for nightfall when nesting takes place on the nesting beaches of the island immediately to the south. Also at the beaches on the eastern side of Mukawwar Island high levels of nesting activity has been reported. The hawksbill turtles are more common in the northern end of Dungonab Bay where they are reported to feed on shallow Stylophora corals. The beaches throughout the entire Dungonab Park, but particularly the beaches on the islands and the Dungonab Peninsula, constitute a nationally and regionally significant turtle nesting area (Table 11).

Table 11. Sea turtles populations in the Red Sea and Gulf of Aden. Overlap (shaded regions) between regional network of marine protection areas and key marine turtle habitats (source: PERSGA/GEF (2004g).

Country	Key Marine Turtle Habitats	PERSGA Network of Established and Proposed MPAs
Djibouti	Iles des Sept Frères / Ras Siyyan Moucha & Maskali Islands	Iles des Sept Frères / Ras Siyyan Moucha & Maskali Islands
Egypt	Giftun Islands	Giftun Islands and Straits of Gubal
	Shedwan Wadi Al-Gimal	Straits of Tiran Ras Mohammed National Park
	Ras Banas Sarenka Siyal Islands Zabargad Rowabil Islands	
Jordan		Aqaba Marine Park
Saudi Arabia	Farasan Islands	Farasan Islands Protected Area
	Wajh Bank Ras Baridi	Wajh Bank Straits of Tiran
Somalia	Aibat and Sa'adadin Islands	Aibat and Sa'adadin Islands
	Raas Xatiib to Raas Cuuda	
Sudan	Mukawwar Island and Dungonab Bay	Mukawwar Island and Dungonab Bay Sanganeb Marine National Park
Yemen	Jabal Aziz	Belhaf Bir Ali Area
	Socotra	Socotra Islands Group

Seabirds:

A comprehensive list of all the bird species that have been recorded in Sudan can be found at Wikipedia (https://en.wikipedia.org/wiki/List_of_birds_of_Sudan#Bitterns,2C_herons_and_egrets), including a total of 653 bird species. According to the TS8 report from PERSGA/GEF (2003f), the information on seabirds breeding in Sudan is generally sparse, anecdotal and outdated, with most seabird assessment reports dating back to the 1980s, e.g. (Moore and Balzarotti, 1983; Nikolaus, 1987). In the same report, certain areas where local seabird populations need protection was indicated (Figure 63).

In surveys in the Sanganeb and Dungonab National Parks in 2002 and 2006 a total of 20 different bird species were recorded. In Dungonab, the bridled tern and the crab plover were nesting in significant numbers whereas also goliath heron, spoonbills, flamingos and a number of sooty falcons were observed. In 2002, also vultures, pelicans, and abundant osprey were observed.

In connection with environmental investigations at the site of the Bashayer marine oil terminal, 11 species of birds were encountered in the baseline study in 1999 (UKCC, 1999), and in follow-up EIA studies 18 and 17 species were encountered in 2001 and 2004, respectively (IES, 2005) (Table 12). The discrepancy in the bird observations between the 1999 baseline and the follow-up EIAs was explained by the fact that the studies were performed in different seasons, i.e. in August 1999, October 2001 and December 2004.



Figure 62. Flamingos and other coastal birds south of Port Sudan. (Photo courtesy of Arpad Dudas).



Figure 63: Sudanese Red Sea coast showing the most important bird sites needing protection. Source: (PERSGA/GEF, 2003f).

Table 12: Birds species sighted at the Bashayer oil terminal site in 1999, 2001 and 2004 (IES, 2005)

Common name	Scientific name	Status	1999	2001	2004
Ardeidae					
White Little Egret	<i>Egretta alba</i>	R	-	15	7
Reef Heron	<i>Egretta garzanti</i>	R	-	4	4
Gray Heron	<i>Ardea cinerea</i>	WV	2	24	2
Goliath Heron	<i>Ardea goliath</i>	WV	-	-	2
Black-headed Heron	<i>Ardea melanocorypha</i>	WV	-	-	4
Legadidae					
European Spoonbill	<i>Platalea leucoroda</i>	M	4	5	3
Dromedidae					
Crap Plover	<i>Dromas ardeus</i>	R	-	20	5
Scelopacidae					
Sandering Little Stilt	<i>Calidris alba</i>	WV	-	70	4
	<i>Calidris minuta</i>	R	6	28	-
Burhinidae					
Curtlew	<i>Numenius squatarola</i>	WV	-	5	3
Recurvirostridae					
Black Winged Stilt	<i>Himantopus himantopus</i>	WV	6	15	-
Phoenicopteridae					
Greater Flamingo	<i>Phoenicopterus ruber</i>	WV	12	64	2
Pelecanidae					
Pelican	<i>Pelicanus ruficomis</i>	R	-	4	1
Pandionidae					
Osprey	<i>Pandion haliaetus</i>	R	1	3	2
Laridae					
Little crested Tern	<i>Sterna bergiiensis</i>	R	12	40	24
Little Tern	<i>Sterna albifrons</i>	R	10	8	8
Masked Tern	<i>Sterna anaethetus</i>	R	3	-	-
Whiskered Tern	<i>Chalidonias hybridus</i>	R	1	16	-
Sooty Gull	<i>Larus hemipterus</i>	R	-	-	12
White-Eyed Gull	<i>Larus leucophthalmus</i>	R	10	65	25
Sulidae					
Brown Booby	<i>Sula leucogaster</i>	R	10	19	9
Alcedinidae					
Kingfisher	<i>Alcedo atthis</i>	M	-	5	-

R= resident, WV= winter visitor, M= migratory.

Marine mammals:

According to an overview assessment provided in PERSGA/GEF (2004d), there is generally little information about the marine mammal fauna of the whole RSGA region, and the lack of good data is also the case for the Sudanese waters (Abdel Salam, 2006). PERSGA emphasises the need for more information on the marine mammals of the whole RSGA region. Only with data on distribution, abundance and threats can effective management be implemented for the conservation of this important and vulnerable group of animals.

44 species of cetacean (dolphins, porpoises and whales) and one species of sea cow (the dugong) (Figure 64) are known to occur in the Indian Ocean, and of these only 15 species have been reported from the Gulf of Aden and 11 species are recorded from the Red Sea (Table 13). The marine mammals species list for the Red Sea is most certainly incomplete, e.g. the fact that baleen whales appear to be common in the southern part of the Red Sea, but have not been reported, demonstrates the need for more survey work. Of totally 16 species of marine mammal confirmed within the whole RSGA region, three are listed as threatened species (endangered or vulnerable), five are considered dependent upon specific conservation efforts to prevent threatened listing, five are insufficiently known to ascribe any status and three are considered secure (Table 13). Marine mammals are in general highly mobile and may move and migrate over vast distances. Even species thought to be relatively sedentary, such as dugongs, are indeed mobile. Furthermore, sea mammals are generally rare compared with most marine life. Consequently, a population survey must necessarily cover a large area (e.g. by airborne sightings) and must often expect only a low rate of encounters. Suggestions for standard survey methods for assessment of distribution and abundance of marine mammals are provided in PERSGA/GEF (2004d). The need to cover large areas typically means that sea mammal surveys are expensive to conduct. The

low sighting rate also has implications for the accuracy and precision of the population estimates and considerable uncertainty of the result can be expected.



Figure 64: A dugong (*Dugong dugon*) feeds in a seagrass bed in Marsa Alam (Egypt). Photo: Wikimedia Commons.

The dugong (*Dugong dugon*) (Figure 64) is a globally threatened species of sea-cow (order Sirenia). They are peaceful and tranquil animals, they appear fat, but are fusiform, hydrodynamic, and highly muscular, reaching up to 3 metres in length and weighing up to 500 kg. The Red Sea is home to one of the last remaining populations of dugongs in the western Indian Ocean region. In the Al Sanbouk newsletter no. 10 (1999) Dirar Nasr provides a short summary of the biology and current status of dugongs in the RSGA area. The species is found in sheltered and shallow bays and lagoons where it feed on seagrass for subsistence. The optimal dugong habitat is shallow sea water of 3 - 15 m depth; sheltered from rough winds and heavy waves; with an abundant food supply (seagrass), and a water temperature between 21° and 38°C. The reproductive cycle of dugongs is characterised by a long gestation period (13 months), after which the female will give birth to a single calf that will receive considerable parental care until it reaches sexual maturity (between age 8 and 18 years old). Dugongs are long living animals (50 years or more), but because of the long effort invested in their young, females give birth only a few times during their life span. The distribution of dugongs in the Red Sea is often very patchy with local populations typically found in isolated channels and bays. Dugongs are reported regularly in the Sudanese waters but are not considered as common. There are no recent estimates available of the total number of dugongs in Sudanese waters. The Dugong National Park is considered to be a key area for dugongs in Sudan, although the animals are only rarely observed here. In a recent field survey conducted in the Dugong National Park, three dugong sightings were made during the whole survey, one in northern Dugong Bay, one on the mainland coast to the north of Sheikh Okod, and one in the lagoons of southern Mukawwar Island (Abdel Salam, 2006). Given the shy nature of the species these three dugong sightings obtained during one survey mission is actually considered a very large number of observations. Local fishermen have confirmed sightings of dugong also outside the Dugong National Park, both to the north and south, indicating that the Dugong region is

home to a significant dugong population. The distribution of dugongs matches the availability of seagrass beds. The large areas of seagrass beds present inside the Dungonab Park is believed to be a key factor for the survival of the local dugong population. Dugongs prefer undisturbed, isolated areas with abundant seagrass beds. Local fishermen suggest that dugongs move from one place to another according to food availability, in the same way as camels. Aerial surveys indicate that dugongs indeed migrate though conclusive evidence of extensive or regular migrations is not available. In 2006, PERSGA suggested that the dugong population in Dungonab Bay/Mukawwar Island could possibly be the most important remaining dugong population on the coast of Africa (PERSGA, 2006). But according to the local fishing communities in the Dungonab area the dugong population in this area has declined significantly and rapidly. A major reason for dugong killings is accidental capture and consequent drowning of the animal in fishing nets (Abdel Salam, 2006). The most likely declining trend of the Sudanese dugong population must be considered a great concern and the situation clearly emphasises the urgent need of better protection measures for this sea mammal species in Sudanese waters as well as in the RSGA area in general.

Table 13. Species of marine mammal reported from the Red Sea (RS) and Gulf of Aden (GA), and their conservation status. IUCN (1996) categories: EN: endangered; VU: vulnerable; CD: conservation dependent; DD: data deficient. Detailed information of cited references is found in PERSGA/GEF (2004d).

Species	IUCN status	Distribution & Reference		Rarity	
		GA	RS	1=more common 2=less common	
Dugong	<i>Dugong dugon</i>	VU	1	5	1
Blue whale	<i>Balaenoptera musculus</i>	EN	2,4		2
Bryde's whale	<i>Balaenoptera edeni</i>	DD	2		1
Sperm whale	<i>Physeter macrocephalus</i>	VU	2,4		1
Melon-headed whale	<i>Peponocephala electra</i>		2		2
False killer whale	<i>Pseudorca crassidens</i>		2	3,4	2
Killer whale	<i>Orcinus orca</i>	CD	2	4	2
Short-finned pilot whale	<i>Globicephala macrorhynchus</i>	CD	2,4		1
Indo-Pacific humpbacked dolphin	<i>Sousa chinensis</i>	DD	2	3,4	1
Common dolphin	<i>Delphinus delphis</i>		2	4	1
Bottlenose dolphin	<i>Tursiops truncatus</i>	DD	2	3,4	1
Risso's dolphin	<i>Grampus griseus</i>	DD	2	3,4	1
Pantropical spotted dolphin	<i>Stenella attenuata</i>	CD	2	3,4	1
Striped dolphin	<i>Stenella coeruleoalba</i>	CD	2	4	2
Spinner dolphin	<i>Stenella longirostris</i>	CD	2	4	1
Rough-toothed dolphin	<i>Steno bredanensis</i>	DD		4	2

1. ROBINEAU & ROSE 1982. 2. SMALL & SMALL 1991. 3. BEARDON 1991. 4. FRAZIER et al. 1987. 5. PREEN 1989.

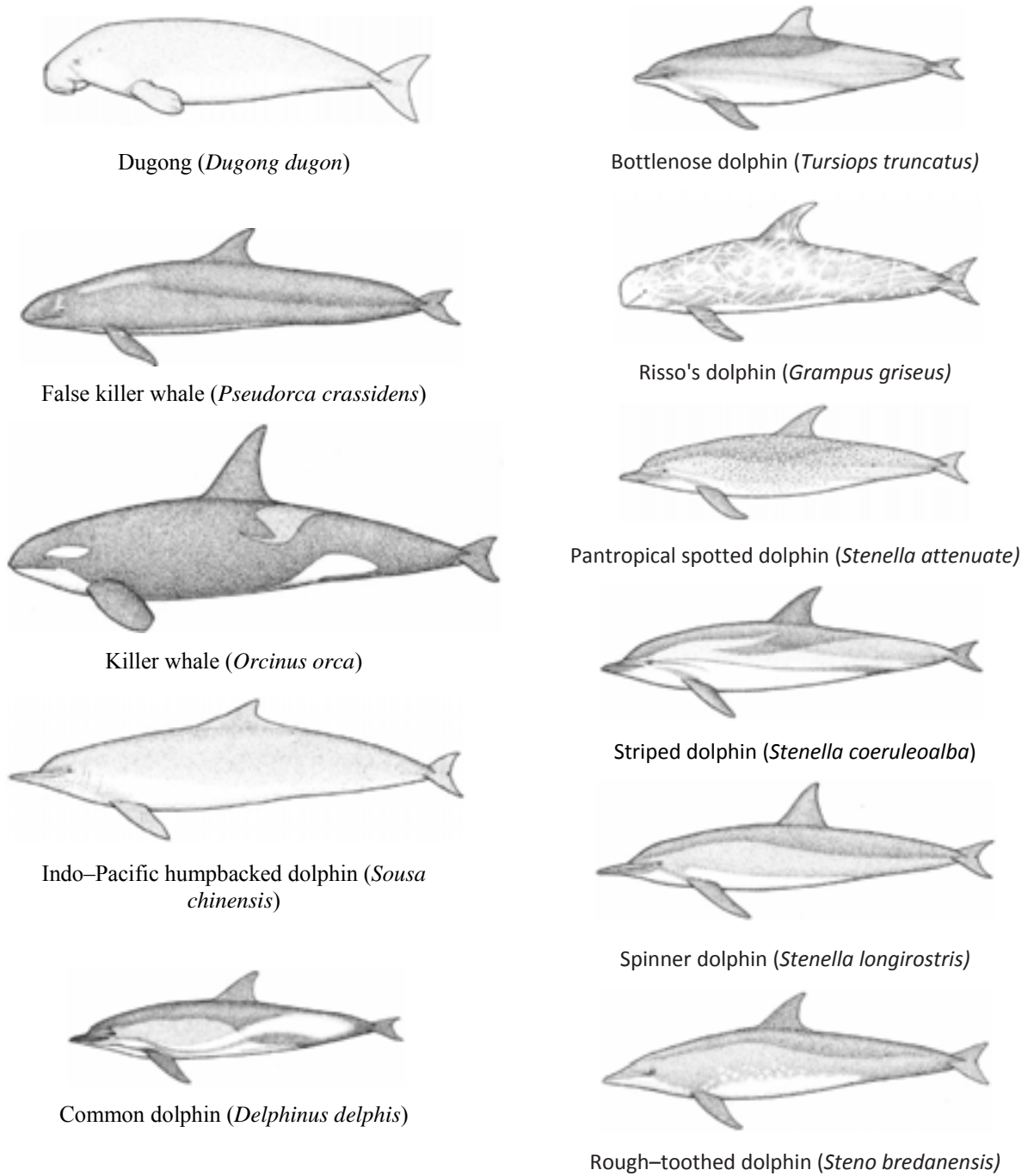


Figure 65. Marine mammal species that recently have been observed in the Red Sea. Source of illustrations: PERSGA/GEF (2004d).

Other useful information sources:

(Attum et al., 2014; Frazier and Salas, 1984; Hirth and Latif, 1980; PERSGA/GEF, 2004h; Price et al., 1998; UNEP, 2007).

2.8 Marine Protection Areas for conservation of key habitats

According to UNEP (2007) the three most ecologically important habitats in the Sudanese coastal zone are:

- the coral reefs
- the mangroves
- the seagrass beds

The development of Marine Protection Areas (MPA) in regions where these high value habitats are particularly rich is a key strategy for the ecological conservation efforts in Sudan as well as in the whole Red Sea and Gulf of Aden Region (Abdel Salam, 2006). In Sudan, there are currently two declared Marine Protected Areas: The Sanganeb National Park (SNP) (Figure 66) and the Dugonab Bay and Mukawwar Island National Park (DMNP) (Figure 67). A detailed description of these two MPAs is provided in Abdel Salam (2006).

The Sanganeb National Park was declared in 1990. According to PERSGA, the Sanganeb atoll reef includes a highly biodiverse and complex coral reef community that also include sharks and marine mammals and biodiversity surveys in the whole Red Sea region indicate that the Sanganeb atoll lies at or close to the very centre of marine biodiversity in the Red Sea.

The Dugonab National Park was declared in Oct. 2004 and is located 125 km north of Port Sudan and covers 60 km of coastline and a shallow bay with a wide diversity of marine habitats, including coral reefs and seagrass beds that support a large population of endangered dugong. The park also has a significant resident human population in a number of small fishing villages, and hosts a salt plant.

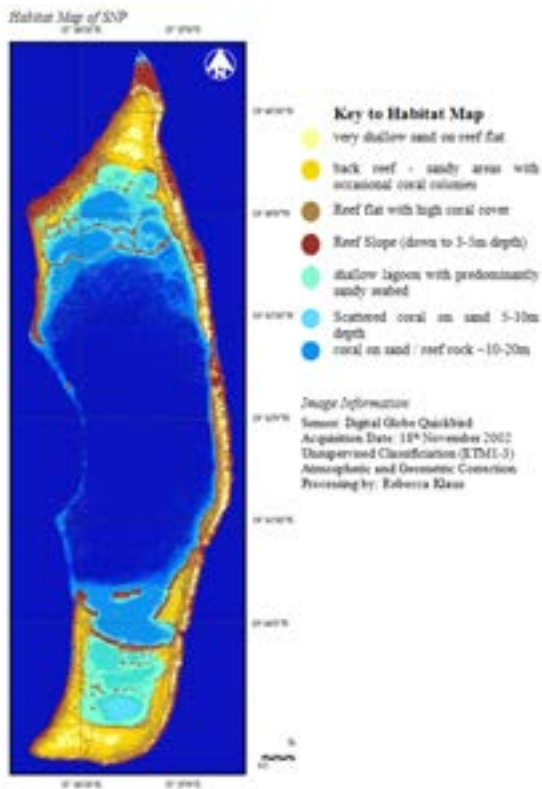


Figure 66. The Sanganeb National Park

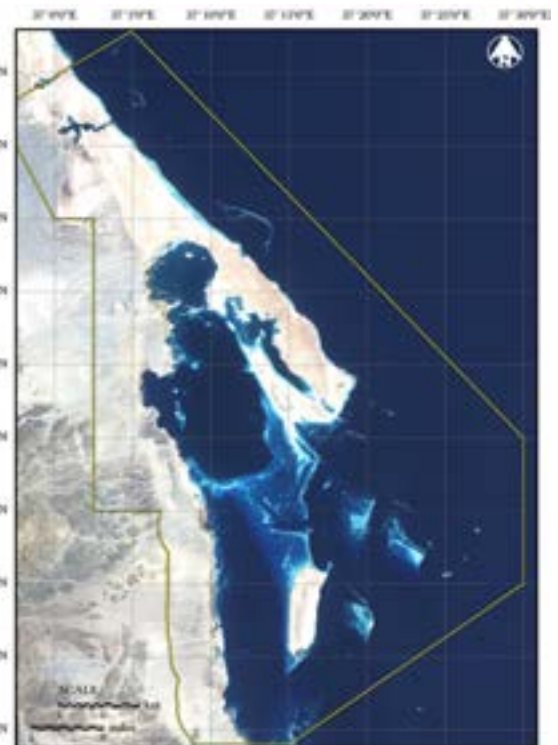


Figure 67. The Dugonab Bay and Mukawwar Island National Park

Field surveys of the fish resources present inside the two main marine protection areas Sanganeb and Dungonab National Parks have revealed biologically very diverse fish communities. Both parks are regarded as excellent examples of the globally unique coral reef fish assemblages of the central and northern Red Sea. In particular the Dungonab Bay is known from its unique fish biodiversity. However, in both parks fish resource surveys conducted in 2002 and 2006 have indicated that several important species of reef associated fish species are suffering from chronic overexploitation, this include groupers, emperors, snappers and sweetlips as well as species in the genera *Epinephelus* and *Plectropomus* (Nagil). This indicates the importance of introducing a sustainable ecosystem-based fisheries management to both these National Parks.

Several other areas of special high value have been proposed as new MPAs, including:

- **The Suakin Archipelago:** A large area (about 1,500 square kilometres) located approximately 20 km south-east of Suakin city. It includes many sandy islands surrounded by coral reefs. The sandy islands are important nesting sites for marine turtles and sea birds. The Suakin Archipelago area has been proposed for IUCN category II protection (national park).
- **Shuab Rumi** (Shi'b Rūmī or Shaab Rumi): This site is a 4 km² coral rich area located 50 km north of Port Sudan and about 20 km off the coast at the Khawr Agwetit wadi between Ashrāf and Jabal Darhīb. The location was made famous from the pioneering Conshelf II research project conceived by the legendary Jacques Cousteau in 1963, in which divers lived underwater for one month.

Other locations that are included on the candidate list for protection areas may represent VECs that are under particular strong pressure or they are located so close to urban centres that they have a special value for public knowledge and awareness development purposes; examples of this category of locations are:

- Khor Kilab (or Kelab) Bird Sanctuary: A relatively small (about 2 km²) estuarine and seasonal river area located on the south side of Port Sudan harbour.
- The Abu Hashish (Abū Hashīsh) area: This is a 5 km² area on the north side of the new Green port in Port Sudan. The site contains numerous coral reefs.

In addition to the specified areas and locations on the candidate list of new protection areas, UNEP has proposed to add a more general protection system that covers all of the remaining mangrove stands along the Sudanese Red Sea coastline, as this habitat is presently under severe pressure and is disappearing rapidly in some areas (UNEP, 2007).

According to UNEP (2007), the principal threats to the stability of the VECs within the Sudanese coastal zone stem from:

- Coastal habitat destruction caused by urban or industrial development
- Major accidental oil spills
- Deliberate pollution from passing ships
- Pollution from land-based sources
- Invasive species imported in ballast water on ships
- Poor management of fisheries
- Mangrove destruction caused by wood-cutting and overgrazing
- Uncontrolled tourism activities

3 Discussion

3.1 Key sources of information for the present study

The present baseline review report is the result of a desktop study in which most parts of the collected information items that have been found by the use of generic search engines (such as Google) or academic search engines such as ISI Web of Knowledge (Thompson Reuters) and ScienceDirect. Some parts of the information have been made accessible for the project by MoP-GDES during project meetings in Sudan or Norway. The project meetings in Sudan have included visits in Khartoum and Port Sudan enabling the direct contact and discussion with the core executives of the collaboration partners, the MoP-GDES, as well as local academic institutions, industrial facilities and NGOs in Port Sudan have been visited for developing a network of local contacts. Some of the key information sources are further described below:

International databases for research literature: An important source of information to this baseline has been peer reviewed scientific articles that are available from international databases for research literature, in particular Thomson's Web of Knowledge (ISI database) and ScienceDirect. As the Red Sea is very unique in many aspects, this marine region has since long attracted the interest from researchers in many sectors of science, including geophysicists, oceanographers as well as marine biologists. Some of the information that was found concerned ecosystems in Sudan in particular but much of it concerned the Red Sea ecosystems more generally and with data from Sudanese waters being part of a broader context. Several hundred scientific articles include data from Sudanese marine waters and these are in general quite dominated by geophysical/oceanographical and zoological/marinebiological studies.

PERSGA, the Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden, is an organisation of profound importance for the long-term process of protecting marine environments in the Sudanese waters and elsewhere in the RSGA area. PERSGA represents a regional locomotive on knowledge and relevant processes regarding marine environmental issues and has been the single most important source of information to the present study. PERSGA is a regional intergovernmental organisation which was established in Cairo in 1995 on the basis of an agreement to the Jeddah Convention of 1982 and with its secretariat based in Jeddah (Saudi Arabia). The member states are Djibouti, Egypt, Jordan, Saudi Arabia, Somalia, Sudan, and Yemen. PERSGA is responsible for development and implementation of regional programmes targeted for the protection and conservation of the marine environment in the RSGA area. The organisation has over a long period been able to provide a well-structured and comprehensive set of studies that describe the presence and conditions of a range of marine habitats within the RSGA. The organisation has played an active role in promoting regional cooperation and has organised regional workshops and training programmes concerning a broad range of high-priority environmental issues in the RSGA area. It is essential that PERSGA is centrally involved in connection with continued efforts for ecological conservation and monitoring in the Sudanese marine waters. For example, PERSGA have developed systems for environmental data collection based on standard survey methods and by which environmental monitoring data can be fully geo-referenced, collated by trained personnel and stored in a geographical information system (GIS) database that is run by the PERSGA organisation. The GIS storage of environmental data allows temporal and spatial changes to be displayed graphically and in a form suitable for a wide range of data users. In addition, national workshops in the member states have been sponsored by PERSGA to facilitate the development and review of country reports prepared as part of PERSGAs Strategic Action Plan (SAP) process. A broad set of reports from studies organised, performed or by PERSGA are available at the organisations website and PERSGA has also a well-functioning outreach activity to strengthen public awareness, and since 1996, PERSGA has published the newsletter, Al-Sambouk to disseminate information about its activities. As Sudan is a member of

PERSGA, all the organisations methods and infrastructure are available for Sudanese institutions. This is essential in connection with planning, training and performance the activities that are required in connection with the environmental assessments and monitoring programmes for Sudanese waters. Of particular importance, the PERSGA Technical Series reports comprise a broad collection of relevant research studies concerning an array of essential issues related to the environment of the RSGA area, including also several reports and report-sections specifically addressing the Sudanese marine waters. The titles and refs of the PERSGA Technical Series reports are shown in Table 14.

Table 14: An overview of relevant reports in the PERSGA technical series (<http://www.persga.org/inner.php?id=145>). This report collection represented a valuable source of information for the present baseline study.

Title	Ref:
TS1 - The Red Sea and Gulf of Aden Regional Network of Marine Protected Areas. Regional Master Plan.	(PERSGA/GEF, 2002a)
TS2 - A Bibliography of Oceanographic and Marine Environmental Research 1985-1998. Red Sea and Gulf of Aden Region	(PERSGA/GEF, 2002b)
TS3 - Regional Action Plan for the Conservation of Coral Reefs in the Red Sea and Gulf of Aden	(PERSGA/GEF, 2003b)
TS4 - Status of the Living Marine Resources in the Red Sea and Gulf of Aden and Their Management	(PERSGA/GEF, 2003c)
TS5 - Survey of Habitats in Djibouti and Plans for their Protection	(PERSGA/ALECSO, 2003)
TS6 - National Oil Spill Contingency Plan for Sudan	(PERSGA/GEF, 2003d)
TS7 - Coral Reefs in the Red Sea and Gulf of Aden. Surveys 1990 to 2000 Summary and Recommendations	(PERSGA/GEF, 2003e)
TS8 - Status of Breeding Seabirds in the Red Sea and Gulf of Aden	(PERSGA/GEF, 2003f)
TS9 - EIA and EMS Guidelines for Fishery/Aquaculture Projects in the Red Sea and Gulf of Aden	(PERSGA/GEF, 2004c)
TS10 - Standard Survey Methods for Key Habitats and Key Species in the Red Sea and Gulf of Aden	(PERSGA/GEF, 2004d)
TS11 - Status of Mangroves in the Red Sea and Gulf of Aden	(PERSGA/GEF, 2004e)
TS12 - Regional Action Plan for the Conservation of Mangroves in the Red Sea and Gulf of Aden	(PERSGA/GEF, 2004f)
TS13 - Regional Action Plan for the Conservation of Marine Turtles and their Habitats in the Red Sea and Gulf of Aden	(PERSGA/GEF, 2004g)
TS14 - Regional Action Plan for the Conservation of Breeding Seabirds and their Habitats in the Red Sea and Gulf of Aden	(PERSGA/GEF, 2004h)
TS15 - Guidelines for Compensation Following Damage to Coral Reefs by Ship or Boat Grounding. Part 1	(PERSGA, 2009)
TS16 - The Status of Coral Reefs in the Red Sea and Gulf of Aden: 2009	(PERSGA, 2010)

Khartoum University: Researchers and environmental consultancy groups affiliated to the Institute of Environmental Studies (IES), Khartoum University (KU), including the University of Khartoum Consultancy Corporation (UKCC), have conducted a number of relevant investigations on environmental issues along the Sudanese coastline, such as (UKCC, 1999) (Ali, 2012; Gaiballa, 2005; IES, 2005). Some of the investigations have been done in connection with industrial developments at the coastline and in close collaboration with the Red Sea University in Port Sudan. Access to relevant theses, baseline and EIA reports prepared by KU, IES and UKCC is possible through the University of

Khartoum Digital Repository (<http://dspace.uofk.edu:8080/>), although the option of downloading may often be restricted.

Red Sea University: Researchers and consultancy groups at the Institute of Marine Research (IMR), Red Sea University (RSU) have conducted a number of relevant studies including baseline studies, EIA studies and monitoring surveys at different coastal and offshore locations along the Sudanese coastline and often in connection with various kinds of industrial developments. Access to relevant reports and papers is possible in the Red Sea University Digital Repository: <http://repository.rsu.edu.sd:8080/jspui/>. A chronologic collection of relevant reports/papers/theses which have been found and downloaded from the digital repositories at KU and RSU and used as sources of information for the present study is shown in Table 15.

Table 15: Overview of relevant baseline studies, EIA studies and monitoring work at Sudanese coastal and offshore locations conducted by researchers from Red Sea University and Khartoum University.

Title:	Ref:
Dungonab Bay/Mukawar Island Area (SUDAN) - An Ecologically Significant Marine Area.	(Nasr, 2015b)
Pleistocene Reefs of the Red Sea Coast, Sudan: Depositional Environments, Fossil Coral, Age Dating and Diagenesis.	(Hamed, 2015)
Elkhair Oil Terminal (Phase II) Environmental Baseline Study.	(IMR, 2014)
Survey Report - Survey on Renewable Marine Resources in the Red Sea State, Republic of Sudan 5th November - 4th December 2013.	(Palm et al., 2014)
DRAFT SURVEY REPORT - Survey of renewable marine resources in the Red Sea State, Republic of Sudan 27th May – 26th June 2013.	(Olsen et al., 2013b)
Marine Algae as Biomonitors for Heavy Metals Pollution at the Red Sea Coast: A review.	(Ahmed, 2013)
First survey of renewable marine resources in the Red Sea State, Republic of Sudan 1 – 30 Nov 2012.	(Olsen et al., 2013a)
Seasonality of Surface Chlorophyll in the Red Sea	(Ahmed, 2012)
Seasonal and Interannual Variations of Surface Nutrients and Hydrography in the Norwegian Sea.	(Ibrahim, 2012)
Environmental Baseline Study For Mersa El- Sheikh Ibrahim (A New Port Planned For Livestock & Fishes Export).	(IMR, 2012)
Management and Conservation of Marine Biodiversity in Sudan.	(Nasr et al., 2012)
Physiological response of the intertidal copepod <i>Tigriopus japonicus</i> experimentally exposed to cadmium.	(Mohammed et al., 2011)
Physiological and biochemical responses of marine copepods in different ecological habitats to nickel and cadmium exposure.	(Elfahal, 2011)
Level of Pesticide Contaminants in the Dangerous Area of Port Sudan Harbour	(Abu baker and Abdelbagi, 2008)
Environmental Baseline Study Final Report: Contract No. Cpoc/2008/Hse – 001 For Provision Of Baseline Study & Environmental Impact Assessment For Seismic Operations Offshore Block 13 – Sudan.	(IMR, 2008b)
Assessment of the present state of the environment in Port Sudan harbour area.	(IMR, 2008a)

Environmental impact assessment & baseline study for Block 15 (onshore and offshore), Red Sea State, Sudan: Environmental Impact Assessment Final Report.	(IMR, 2007b)
Environmental impact assessment (EIA) in Osman Digna (Suakin) harbour.	(IMR, 2007a)
Prevalence of Marine Zooplankton around Port Sudan.	(Ginawi, 2005)
Impacts of coastal development activities on seagrasses along the Sudanese Red Sea coast	(Gaiballa, 2005)
Environmental and monitoring study for Bashayer marine terminal (GNPOC).	(IES, 2005)
Environmental impact of industrial wastes on marine area, case study: Port Sudan coastal area.	(Alrahman, 2004)

UNEP (the United Nations Environment Programme) is another source of relevant information for the present study. UNEP is especially important in connection with identifying challenges and possible solutions for the development and strengthening of environmental governance systems that necessarily must underlie any efficient environmental management plans and activities. UNEP has been represented with its activities in Sudan for a number of years and several reports commissioned by UNEP describe the process of building the legislative and institutional framework in Sudan that also the environmental management efforts in Sudanese marine waters will rely on. The United Nations Environment Programme completed in 2007 a comprehensive environmental assessment report of whole Sudan (UNEP, 2007). The study addressed environmental issues related to water, agriculture, forests, desertification, wildlife, marine areas, industrial pollution, the urban environment, environmental governance and the role of environmental pressures in previous conflicts in Sudan. The report and its recommendations formed the basis of UNEP's continued engagement in Sudan which in the period 2007-2012 resulted in the development of the [Sudan Integrated Environment Programme](#). In section 12 in the UNEP 2007 report, issues relating specifically to marine and coastal environments and resources of Sudan were addresses. According to that assessment, the marine and coastal environments of Sudan were found to be in relatively good condition, although some isolated areas being badly degraded and although the environmental pressures in general were increasing mainly because of urban and industrial development and due to overgrazing in mangrove areas. UNEP has in several ways followed up the effort to strengthen the focus on the environmental issues in Sudan by conceiving an analysis of the environmental governance in Sudan (UNEP, 2012). UNEP also has made available a large collection of photos that are addressing different kinds of issues related to environmental resources and problems in Sudan. Many high-quality pictures that are relevant to marine issues are found at this website: http://postconflict.unep.ch/sudanreport/sudan_website/index_photos.php.

Cousteau Society and Equipe Cousteau organisation: The two non-profit marine conservation organisations the Cousteau Society and the sister organisation Equipe Cousteau, which both were founded by the French marine explorer Jacques-Yves Cousteau, have organised several comprehensive research programmes and field studies in the Sudanese marine areas together with Sudanese partners. For example, Equipe Cousteau have been working since 2007 on a Scalloped hammerhead shark and manta ray monitoring programme and the organisation was awarded a grant by the UK's Darwin Initiative to support vital marine conservation research and poverty alleviation work in Sudan's Red Sea. An important study was conducted by Klaus et al. in Oct-Nov 2007 addressing a comprehensive field survey of the ecological patterns and condition status of the Sudanese coral reefs. Klaus et al. reported their study to the 11th International Coral Reef Symposium (Ft. Lauderdale, Florida, 7-11 July 2008) presenting there a conference paper (Klaus et al., 2008) which is an excellent source of relevant information for the present report. In 1963, Cousteau and a team of six divers spent 30 days inside a pioneering undersea lab structure called "Continental Shelf Station II" (Conshelf II) at 10 metres depth at the Shuab Rumi coral reef location north of Port Sudan. Today, the site which still includes the remains of the Conshelf II structure is among Sudan's most popular diving destinations. Weblink to the Cousteau society: <http://www.cousteau.org/>

3.2 Anthropogenic sources of environmental stress in the coastal zone

Population centres and industrial facilities are often hotspots for the deliberate or accidental release of anthropogenic contaminants to the environment. Some contaminants are nondegradable, i.e. they are not broken down by natural processes, and may accumulate in specific ecosystem compartments in the adjacent environments (such as in soil, groundwater, marine sediments and also in living organisms). Data on the concentrations of specific environmental contaminants in specific environmental matrices are therefore useful and relevant information in connection with assessments of human impact in an area. Baseline and EIA studies that are conducted on specific locations of industrial developments should normally include the measurements of chemical contaminants that are characteristic for the type of industrial process/facility that is developed on the site and type of effluents/contaminants that are released. A discharge permit issued by the regulatory authorities is normally included in the licence for operation. The discharge permit will typically include information about the type of contaminants and matrices that must be monitored at a regular frequency in order to demonstrate compliance of the facility with the demands set by the regulation. Repeated monitoring conducted in the adjacent environment will also demonstrate whether the pollution level increases as a result of the industrial activities at the site.

Some environmental contaminants (e.g. chlorinated pesticides, flame retardants, plastic particles and larger litter items) have solely an anthropogenic origin whereas others (e.g. heavy metals, inorganic nutrients, some radioisotopes, excess organics, hydrocarbons) may also have natural sources in addition to the human sources. The relative input that originates from the natural sources will depend on several factors, such as the chemical/mineral composition of the bedrock in the area. For the naturally occurring contaminants, the term anthropogenic pollution is normally understood as a situation of increase significantly beyond the natural levels. Baseline studies are therefore necessary in order to define what the natural condition is at the location in concern.

In an early study George (1976) discussed coastal water pollution issues, in particular in relation to possible marine aquaculture in Sudan. He states that the problem of pollution in marine and inland water resources existed to some degree also in Sudan at that time, but the problem was small in comparison to in industrial countries. He considered the main source of marine pollution to be oil and chemicals discharged from ships at the main harbours. Although the problem was not yet severe, he advocated formulating pollution control laws focussed in particular to cease the marine pollution of oil and chemicals which were pumped into the harbour area by ships cleaning tanks or leaked from pipes or spilt accidentally. He also pointed at the potentials for aquaculture developments along the Sudanese coastline, especially regarding the cultivation of indigenous fish and shellfish species such as *Chanos chanos*, *Mugil cephalus* and *Penaeus monodon* as well as exotic species and also to safeguard the culture industry of *Pinctada margaritifera* in Dongonab Bay.

Several scientific papers have addressed the concentration levels of radioactive isotopes in different types of environmental matrices from the Sudanese coastal zone (Sam et al., 2000a; Sam et al., 2000b; Sam et al., 1998a; Sam et al., 1998b; Sirelkhatim et al., 2008a, b). However, beside these studies on radioactive contaminants there is very little high-quality information available from international peer-reviewed journals regarding the concentrations of different classes of anthropogenic contaminants occurring in different habitats and ecosystem compartments in the Sudanese coastal zone. In the most remote, non-developed and very sparsely populated coastal areas there are good reasons to believe that the local sources of pollution are negligible. However, also at these remote sites anthropogenic contamination may possibly be transported into the coastal zone area from far away sources, e.g. in connection with the shoring of marine oil spills or the transport of pesticides in runoff water from agriculture areas in connection with seasonal rainfall. Furthermore, physical litter objects such as discharged plastic bags, fishing nets and other synthetic items that degrade very slowly can be transported far with the Red Sea currents and cause impact in individuals and populations of vulnerable species such as sea mammals, seabirds and turtles living at otherwise clean and pristine locations. More knowledge and high-quality data is needed about the current pollution situation in different ecological compartments along the Sudanese coastline, both with regard to undeveloped areas and urban/developed areas. This information should be shared with all stakeholders to provide them with useful baseline information as well as useful information to assess the relative severity of

human impact, e.g. at locations where EIA are conducted in connection with industrial and societal developments.

3.3 Societal implications

The UNEP (2007) report also discusses the issues of marine protected areas and tourism. There are two declared marine protected areas in Sudan: Sanganeb Marine National Park and Dugonab Bay (with Mukawwar Island). The Sanganeb Park is the best known as it lies close to Port Sudan. The Dugonab Bay National Park lies 125 km north of Port Sudan and covers 60 km of coastline and a shallow bay with a wide diversity of marine habitats, including coral reefs and seagrass beds that support a large population of endangered dugong. Dugonab also has a significant resident human population in several small fishing villages, and hosts a salt plant. In addition to the Sanganeb and Dugonab parks, several coral sites have been proposed as new protected areas (Suakin Archipelago, Abu Hashish, Shuab Rumi). International diving associations advertise diving holidays to Sudan with visits to a range of diving locations all along the coast, see for example: <http://www.diving-world.com/redsea-sudan.html>. At present, the diving tourism activity is centred mainly on Sanganeb and to some lesser extent on Shuab Rumi, Dugonab bay and Suakin Archipelago. The tourists who take part at international diving cruises fly to Port Sudan and reside then most of the time on the diving vessels which travel to anchor at the various diving sites. There is also some limited local recreation along the coastline. A major environmental issue related to the marine diving tourism in Sudan is the lack of mooring buoys at the popular dive sites. Diving vessels are forced to anchor on the reefs, causing damage to the reef. Tourism operators are highly aware of the problem, but they do not have the legal mandate to install and maintain the necessary mooring equipment, as that responsibility rests with the Sea Ports Corporation. In the light of the possible significant expansion of the diving activities in the Sudanese marine waters the issue of establishing mooring buoys and other practical measures to minimise reef damage is a significant and urgent problem that hopefully will find its solution with an update of the Sudanese governance system for the marine parks and protection areas.

An expansion of the tourist industry within the coastal zone of the Red Sea State must be built on ecological sustainability criteria. Along the Sudanese coast, the market for small local companies and service providers may increase significantly with an increased tourism activity in the years ahead. It is essential that these small-scale commercial players operate in an environmentally responsible and sustainable manner. In Port Sudan, several local seafood restaurants have been established within the Abū Hashīsh area (Figure 68), which is one of the coastal sites that currently is on the candidate list for protection. Such local seafood restaurants may often want to utilise the seafood which can be caught locally. They represent small-scale commercial activities which provide jobs and income-possibilities for the local population. At the same time as they are directly depending on the long-term health and integrity of the ecosystem surroundings from where they get their seafood resources. For a local seafood restaurant to operate in an ecologically sustainable manner means its activity must not compromise local seafood population neither must it cause any significant stress (e.g. through waste discharges or litter disposal) to its natural surroundings. These goals are achievable, but it requires commitments from the local enterprises themselves as well as the Sudanese governing system which must develop and provide required societal services such as waste management systems, etc. In the case of the Abū Hashīsh area, there are recent studies indicating that this coral reef ecosystem is significantly stressed. For example, the recent study by Elamin et al. (2014b) found that the number of butterflyfish species living within Abū Hashīsh has declined from nine to seven species during the 10 years period 2003-2013. They suggest that this apparent reduction could be due to increased pollution, dredging work and/or collection of members this family for trade in ornamental fish. Currently, the coastal areas, in particular between Port Sudan and Suakin, experience significant population growth and increased industrial developments. Without the development of efficient measures to avoid or minimize negative ecological impacts, these ecological assets can be significantly reduced, and this also reduces to possibilities for the local population to draw long term benefit from these currently unique ecosystem resources.



Figure 68: (A) Map of Port Sudan with the Abū Hashīsh area located north of the Green harbour. This area is on the list of suggested marine protection sites. (B) The entrance of the local fish restaurant situated at the beach within the Abū Hashīsh area.

3.4 Method resources for quality assessment and monitoring of VECs

A broad set of the methods, tools and procedures is required for assessing the quality status of different VECs and for the performance of marine environmental monitoring activities in the Sudanese marine waters. As a general rule, the use of nationally and internationally standardised procedures of quality assessment and monitoring will be wanted for ensuring good quality of data. However, the use of best quality procedures can sometimes be too technically demanding or too expensive under Sudanese conditions. In that sense, simplified methods can sometimes be better to use if it means that

important information-collections in the field or required analyses in the laboratory are not stalling because of possible shortage of competence or due to modest analytical budgets. Obviously, there is a balance that must be reached on these matters with regard to what information that is wanted and which activities that are feasible or realistic to do. The environmental regulatory demands set by the Sudanese authorities are essential in this respect. It should also be emphasised that the involvement of regionally harmonised methods for condition assessments and monitoring is important as this will secure a better comparability with VEC condition assessments obtained elsewhere in the RSGA area. For example, in a comprehensive report from PERSGA, Technical Series report no.10 (PERSGA/GEF, 2004d) a broad collection of standard survey methods was presented for key habitats and key species in the Red Sea and Gulf of Aden (i.e. the PERSGA area). That comprehensive guidance document includes a total of 320 pages that include both a comprehensive set of practical procedures and study tools as well as references to literature sources for the different organisms and issues addressed. The document is indeed essential as it describes a set of regionally agreed tools for assessing the conditions of a broad range of marine VECs that also are found in the Sudanese marine waters, including:

- COASTAL ENVIRONMENTAL ASSESSMENT (RAPID ASSESSMENT SYSTEM)
- INTERTIDAL AND MANGROVE
- CORALS AND CORAL COMMUNITIES
- SEAGRASSES AND SEAWEEDS
- SUBTIDAL HABITATS
- REEF FISH
- MARINE TURTLES
- SEABIRDS
- MARINE MAMMALS

Detailed guidelines that describe environmental assessment and monitoring work that are implemented elsewhere in the world can assist the development of similar procedures for the Sudanese conditions. For example, the environmental monitoring procedures which are implemented for the offshore oil & gas operations at the Norwegian shelf are described by Iversen et al. (2011). In Norway, the industry in general, and the oil & gas industry in particular, must adapt their operations to a very strict regulatory regime set by the Norwegian environmental authorities. Another source of good information is the guideline document for offshore environmental monitoring published by the International Association of Oil & Gas Producers (OGP, 2012). Both these guidelines as well as different reports published by PERSGA have in the present programme given input to the development of suggested environmental monitoring guideline for oil & gas industrial activities in Sudanese marine waters (Beyer et al., 2015).

3.5 Map based methods for visualization of VEC information

Organizing geographical data and visualising this information is a powerful tool in an EIA. Many software packages to handle this are available, called GIS (Geographical Information Systems). One example is the free and open source software QGIS (qgis.org). This advanced software however requires some training before it can be used efficiently.

If the amount of information that needs to be visualised in a map is less extensive, the information can be visualised with Google Earth (www.google.com/earth/) in combination with the freeware GEPATH (ge-path.soft32.com/).

The geographical information about the Sudanese Mangrove sites in Table 1 will here be used to demonstrate how this can be done, by following the steps:

1. Edit the geographical information in a spreadsheet like Microsoft Excel (any other spreadsheet software can be used), and mark and copy the information (Figure 69).

2. Open the program GEPATH and paste the information in the clipboard (Figure 70). Click on the “Run” menu and save the information as a KML-file. The KML-file is a text file that can be opened in Google Earth.
3. Open the KML file in Google Earth (Figure 71).

	A	B	C	D	E	F	G
1	Name	Approx. Length (km)	Latitude	Longitude	Alt		
2	Mohammed Qol	1.3	20.78333	37.16667	0		
3	Arakiysi	0.9	20.30000	37.18333	0		
4	Halut	1.1	19.80000	37.25000	0		
5	Kilo Tammania	0.8	19.58333	37.25000	0		
6	Klanieb	2.0	19.50000	37.26667	0		
7	Mersa Atta	3.5	19.30000	37.30000	0		
8	Fagum-Lagangneeb	3.9	19.01667	37.38333	0		
9	Haydob	1.6	18.95000	37.38333	0		
10	Sheikh Ibrahim	0.4	18.93333	37.40000	0		
11	Sheikh Saad	1.4	18.83333	37.43333	0		
12	Shabrango-Gofud	3.5	18.76667	37.48333	0		
13	Ashaf	7.0	18.75000	37.50000	0		

Figure 69: Illustration on how geographic information can be edited in a spreadsheet.

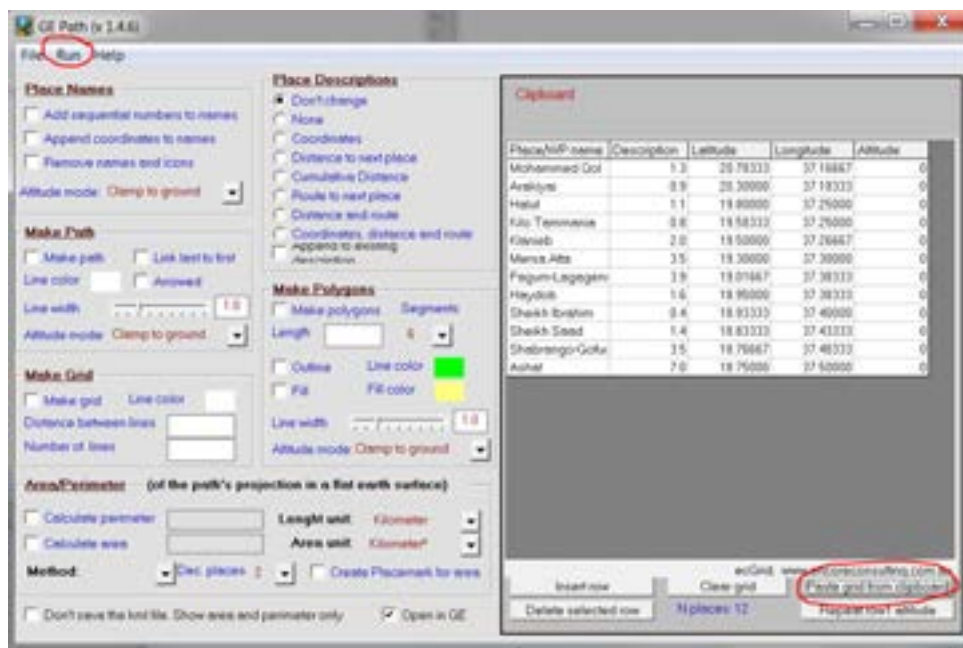


Figure 70: Illustration on how geographic information can be pasted into the program GEPATH.



Figure 71: Illustration on how geographic information can be visualized in Google Earth by saving it as KML file.

An important source for geographical information is the web-site www.bluehabitats.org, a collection of information on seafloor habitats (Figure 72 and Figure 73). The information from this web site can be downloaded as shape-files that can be visualised in a more advanced GIS software like QGIS.

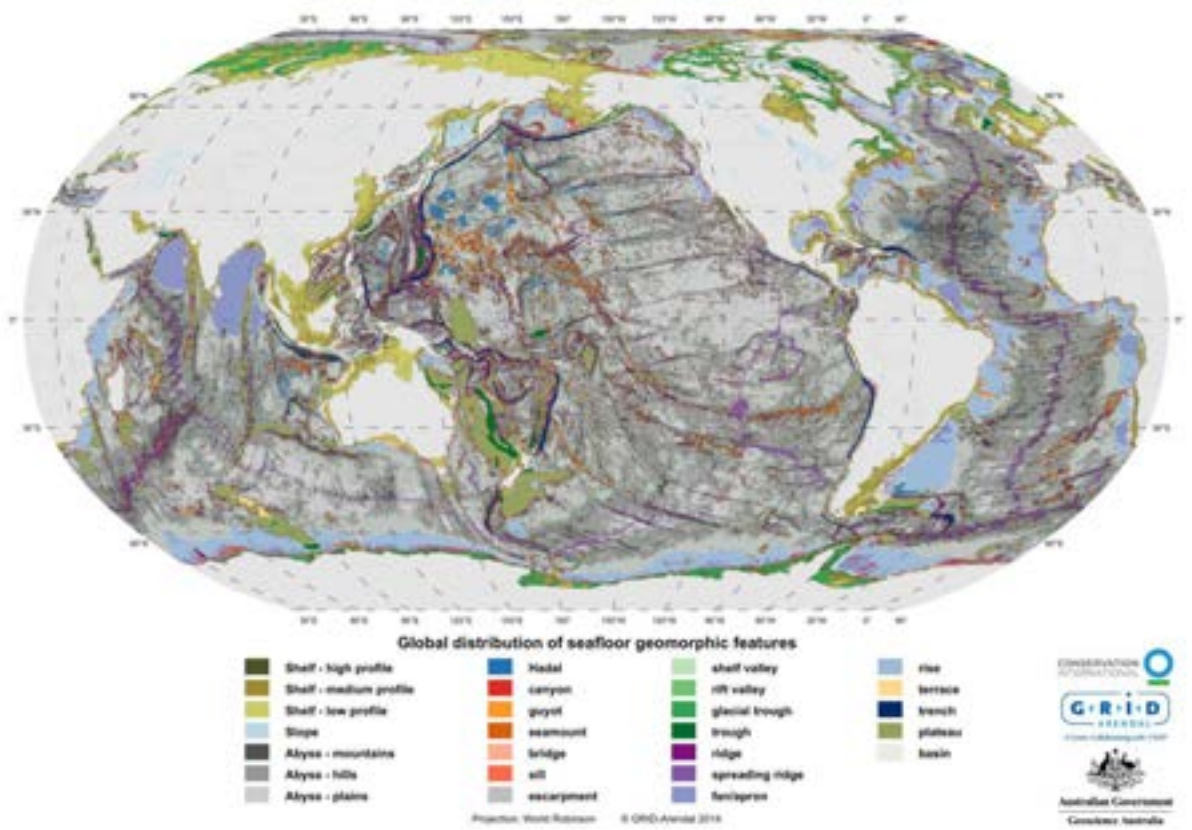


Figure 72: Global map of seafloor geomorphic features from bluehabitates.com.

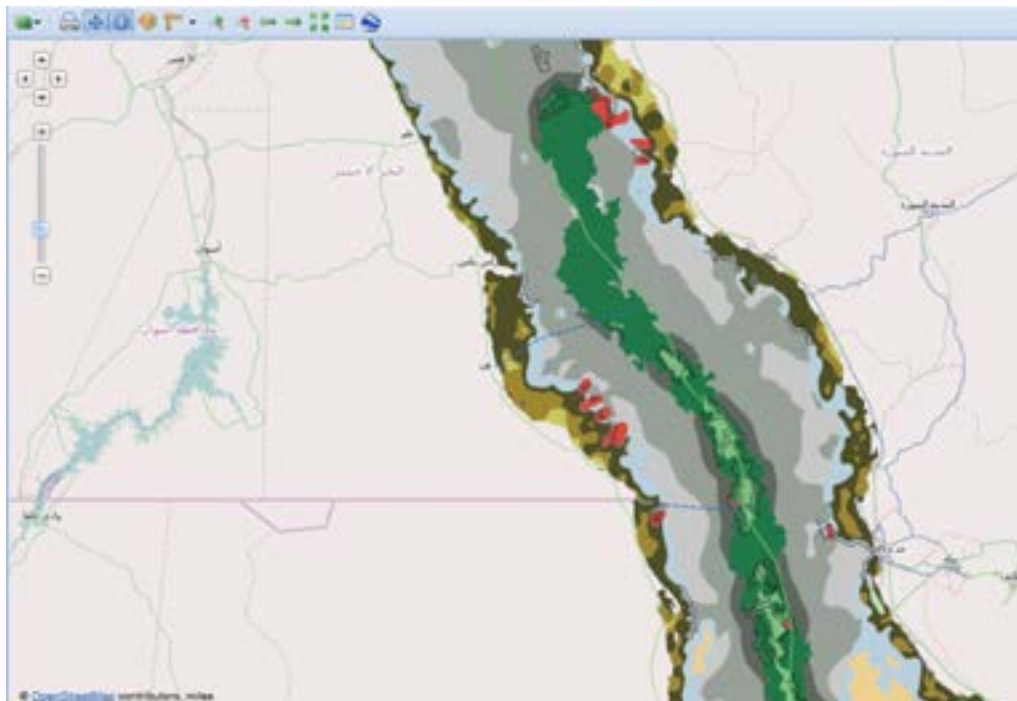


Figure 73: Map of the Red Sea seafloor geomorphic features outside Sudan (bluehabitates.com).

3.6 Petroleum industry activities and environmental issues

3.6.1 Petroleum industry activities in the coastal zone

The petroleum industry represents an important sector of the Sudanese economy. The proper law regulation of the sector is therefore an issue of profound importance to the country (IBUS, 2008). Before the separation of Sudan and South Sudan in July 2011, the Sudanese oil revenues constituted more than half of the country's income value and 90% of its export value. After the separation about 75% of the known Sudanese oil reserves became located in South Sudan. South Sudan is still depending on the transport of its oil through the pipelines that run over Sudan's territory and end in the refineries and oil terminals located in the Port Sudan area (Figure 74), although the possibility of building a new pipeline through Kenya has been evaluated.



Figure 74: Oil fields and pipelines in Sudan and South Sudan.

Many of the activities that normally are carried out in connection with the petroleum industry may represent significant hazards to coastal environments, including:

1. Generation of large volumes of mud and cuttings during the well drilling
2. Generation of large volumes of "produced water" during well production operations
3. Refinery waste streams
4. Crude oil transportation by tankers
5. Bulk glycols
6. Discharge of oily water from tank washing

Physical damage to natural habitats in connection with infrastructure developments, insufficiently managed operational discharges (during drilling and production) and large scale pollution events e.g. in connection with major oil spills are among the most severe environmental hazards. The development of environmental regulation measures that are efficient and locally adapted is of key importance for efforts to avoid, or at least minimise, the ecological damage resulting from oil & gas industrial operations.

Maritime oil transport with large tankers is one of the key environmental hazards in connection with petroleum industry activities. As long as the South Sudanese crude oil is exported via the Sudanese Red Sea coast the volume of oil tanker traffic in this area will be kept high. Crude oil is exported from the Bashayer Oil Terminal (Figure 75) located about 25 km in air-distance south of Port Sudan. The Bashayer Oil Terminal was previously constructed for receiving oil tankers of a max size of 150,000 deadweight tonnes, but recent developments at Bashayer have increased the mooring capacity to 300,000 deadweight tonnes tankers, according to official information from Petrodar Operating Company. The Single Point Mooring (SPM) system is located 2 km off the coastline and consists of a Catenary Anchor Leg Mooring (CALM) Buoy, a Pipeline End Manifold (PLEM), semi-submerged tank and the ship anchoring system (Figure 76). The oil export from Bashayer heads mainly to the Far East.



Figure 75: The Marsa Bashayer marine oil terminal (1 and 2) is located about 25 km south of Port Sudan and the location has been addressed in marine baseline and EIA studies, as described in the text.



Figure 76: The Single Point Mooring (SPM) system used for loading oil tankers at the Bashayer marine oil terminal. The SPM is located approximately 2 km off the coastline.

The Al-Khair Petroleum Terminal in Port Sudan (Figure 77) exports light petroleum products from a refinery in Port Sudan. The terminal is currently able to receive tankers of size up to 50,000 deadweight tonnes and the annual capacity of the terminal is 2.67 million tons according to info from the Seaports Corporation. Export of liquid Petroleum Gas (LPG) is handled from a terminal located at Suakin.



Figure 77: The Al-Khair marine oil terminal with the berth (arrow) is located just south of the Port Sudan harbour and has recently been addressed in a repeated marine baseline study in connection with an ongoing expansion process.

Offshore drilling operations are performed to explore for and subsequently extract oil or gas hydrocarbon resources from rock formations beneath the seabed. It is most typically done in shallow continental shelf areas (< 300 m depth), but as the offshore fields in the shallow regions become depleted the industry has developed technologies that enable them to carry out drilling and production operations in steadily deeper areas. Offshore drilling is always challenging and includes a number of activities that pose significant hazards to the marine environment, both in connection with normal operations and in particular in cases of accidents (e.g. the Deepwater Horizon accident in 2010). After the cessation from South Sudan the Sudanese Government has focussed more of its petroleum search operations to licensing blocks in the Red Sea State (Figure 78). The offshore oil and gas searching

operations in the Sudanese part of the Red Sea has included performance of seismic surveys, e.g. DMNG (2008) (Figure 79), and development of a number of offshore drilling locations and drilling operations within Block 13, Block 15 and Block 16 (Table 16, Figure 80, Figure 81, Figure 82). Although the amount of information about these operations is yet both scarce and unsatisfactory it seems clear that there have been a substantial number of drilling operations taking place in the Sudanese coastal zone and in offshore waters, also in areas of great ecological value. Proper access to correct information and survey reports from all these operations is crucial as this information can provide insight into how environmentally sensitive issues are managed from the side of the Sudanese authorities as well as from the side of the companies that are performing the drilling operations. During the present review study, it has been difficult to get access to systematic and good-quality information on these matters. It is possible that the difficulty on acquiring information is rooted in information-restrictions concerning survey data about searching and drilling operations. If this is the reason, it is strongly recommended that better transparency is established with regard to all data that are related to ecological resources. An alternative (and possibly less likely) explanation could be that a systematic collection and organisation of this type of information is not carried out.

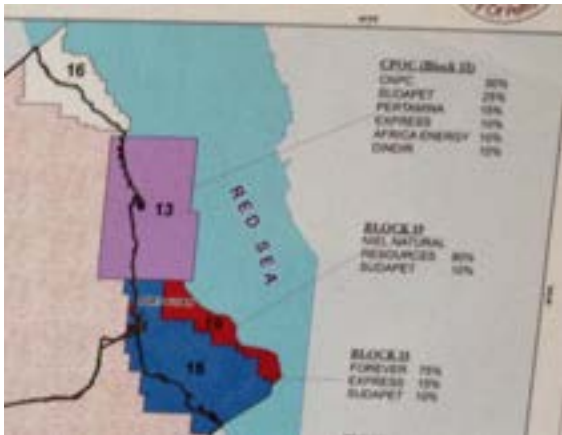


Figure 78: Official map of the hydrocarbon exploration and production license blocks located in the coastal and offshore areas of Sudan. Source: Ministry of petroleum, Sudan.

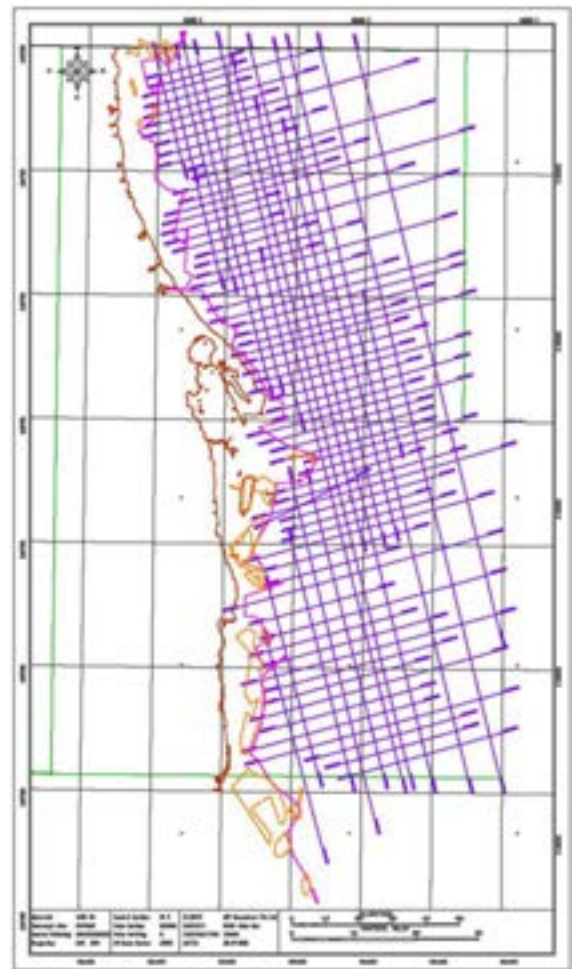


Figure 79: Map of the seismic survey areas in connection with the CPOC08 offshore searching project north of Port Sudan in 2008. Map source: DMNG (2008).

Table 16: Names of drilling wells in the different licencing blocks the Sudanese coastal zone, including indication of main results obtained during the performed drilling operations

Block 13	Block 15	Block 16
Abu Shagara-1 Gas shows with CO2 and Methane Dungunab-1 Dry well Maghersum-1 Gas shows	Bashayer-1a Gas discovery (tested) Bashayer-2 Suakin-1 Gas and condensate discovery (tested) Suakin-2 Hydrocarbon shows Digna-1 Oil shows Durwara-1 Durwara-2 Marafit-1 South Suakin-1 Tokar-1 Hydrocarbon shows Talla-1 Gas shows	Halaib-1 Dry well

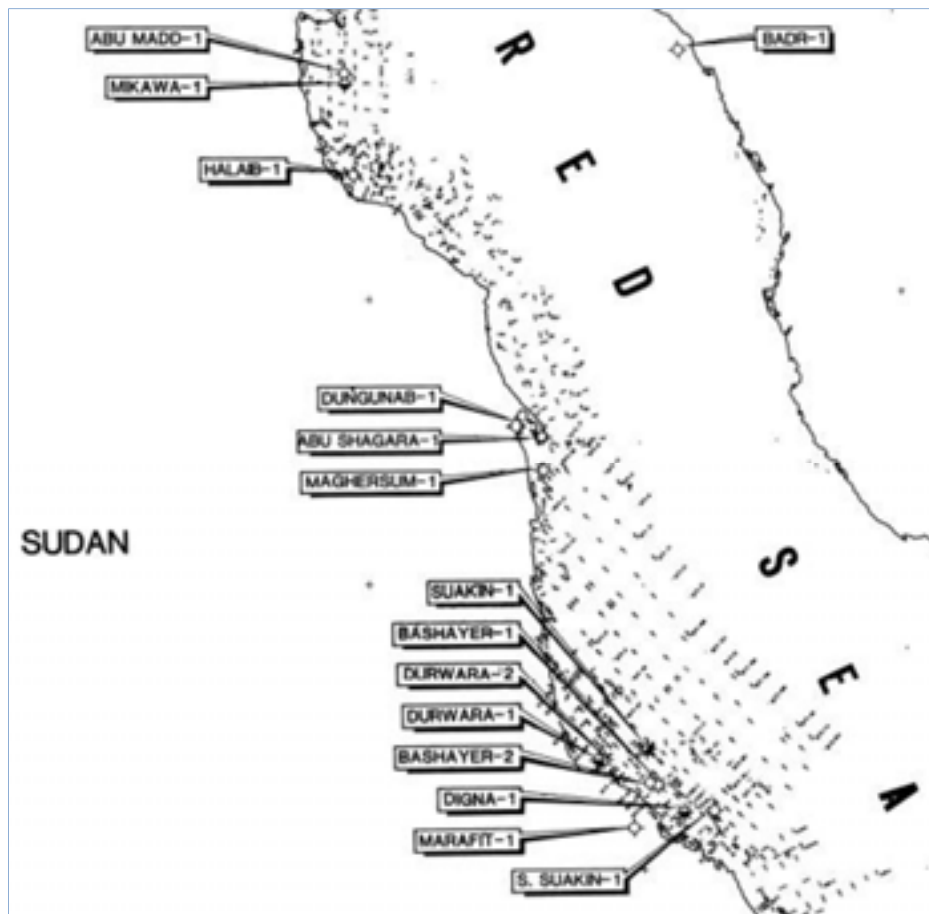


Figure 80: Map of drilling locations in the Sudanese coastal and offshore areas.

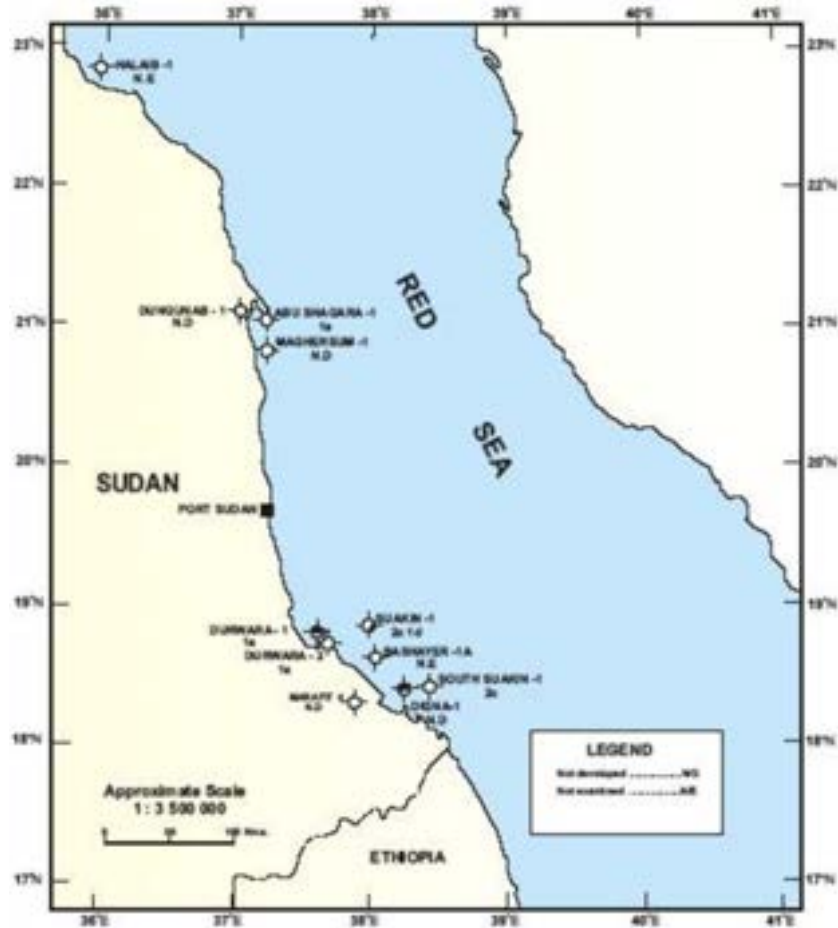


Figure 81: Map of drilling locations in the Sudanese coastal and offshore areas.



Figure 82: Map of offshore drilling locations in the licencing block 15 in the Sudanese coastal areas.

3.6.2 Petroleum industry baseline and EIA studies

Baseline studies and EIA investigations that have been conducted for Petroleum industry companies by Sudanese research institutions are key studies for the present report, both as they show the selection of methods that presently are employed for such studies in Sudan, and since they can be used to assess the current levels of knowledge within key competence institutions in Sudan.

A baseline and EIA study was in 2007 prepared for the Block 15 in the south of the Sudanese coast by the Institute of Marine Research (IMR) of the Red Sea University in collaboration with the Newtech Industrial & Engineering Group Ltd (IMR, 2007b). The study was performed prior to the onshore and offshore exploration activity that was to be conducted within block 15 by the RESPOC consortium. The baseline/EIA report includes information that shows the presence of several high priority VECs in the survey area. However, due to report confidentiality it is unclear to what degree NIVA can disclose this information. Within the surveyed area both seismic surveys as well as offshore exploratory drilling operations were planned for. Within the Tokar field the Tokar 1 offshore well (Figure 82) was drilled in February 2010 by the RESPOC consortium, apparently as the first offshore exploration well drilled in Sudanese waters. The Tokar-1 position was located some 130 kilometres southeast of Port Sudan well and this was one of two exploration wells drilled in Block 15. The Tokar site drilling took place at shallow water depths of 38-50 meters and the planned total drilling depth was 3,700 meters. No information about the environmental impact of the drilling operations at the Tokar field information is made available (yet) to the present study. It is unclear whether and to what degree this kind of site-specific effect information exists. It is important to stress that baseline/EIA studies that are conducted prior to offshore drilling operation such as the Tokar-1 drilling must be followed up with an appropriate impact-assessment / effect monitoring work at the drilling site after the drilling operations has ended. If such aftermath effect-studies indeed have been carried out, then these investigations should be made public without restrictions, regardless of what they show. Secrecy on these matters is not acceptable. However, if adequate effect studies at the Tokar-1 drilling site have *not* been performed, then an effect survey at this site must be performed as soon as possible. The Tokar-1 site represents an important example site for investigating and characterising the possible impact potential of offshore drilling operations in Sudanese marine waters. The same demand is valid for all other locations that have been drilled within Block 15, referring to the overview shown in Table 16.

In 2008, IMR and Newtech conducted an environmental baseline study prior to seismic operations for the offshore block 13, which is located north of Port Sudan and south of Hala'ib area (IMR, 2008b). The key aims of the baseline study were to provide adequate baseline information for the region and to identify and evaluate the current condition status of key habitats and ecosystem components in the study area (Figure 83). Secondly, the study aimed to assess the possible magnitude of impacts on coastal and marine environments which could come as a result of industry activities in the area. Similar as for the baseline/EIA study discussed above, there are no monitoring studies yet available that can indicate whether impacts have occurred as a result of any industrial operations in this region, e.g. as a result of seismic surveys or new drilling operations if such have been performed in the area. As based on the map info shown above (Figure 80, Figure 81), and the wellbore names shown in Table 16, there are several drilling sites (located even within the area which now is the Dungonab bay and Mukawwar Island marine protected area, but apparently these drilling locations (Dungonab-1, Abu Shagara-1, Maghersum-1) are old and onshore drilling sites which have been drilled several decades ago.

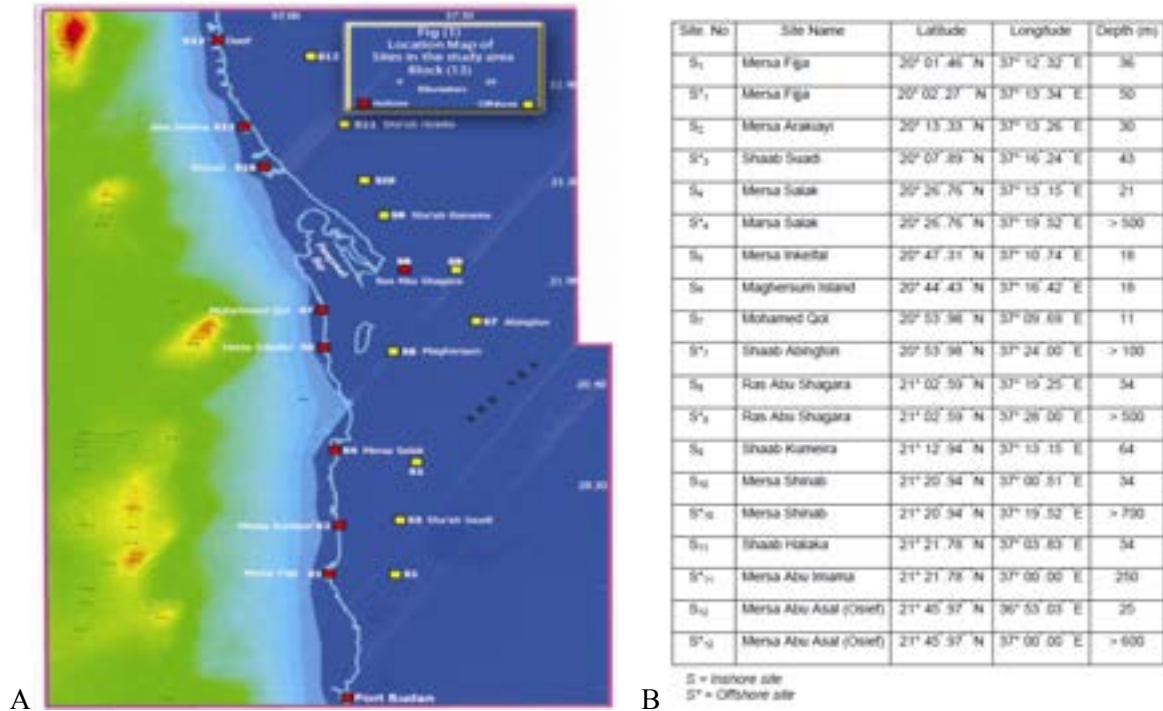


Figure 83: Location map (A) and station names (B) of the study stations used during the IMR organised environmental baseline survey for the offshore block 13. Source: (IMR, 2008b).

Marine oil export terminals are potential hotspots for environmental impacts to coastal habitats. Two major marine oil export terminals are currently in operation in the Port Sudan area, i.e. the Al khair (Alkhair, El Khair, Elkhair) marine oil terminal (Figure 77) and the Marsa Bashayer (1 and 2) marine oil terminal (Figure 75). Several of the activities that are associated with these marine oil terminals (major construction activities, operational effluents and discharges, waste production, tanker transport, etc.) may represent significant environmental impact risk factors unless proper mitigation & precautions measures are implemented. As shown previously (Table 15), several environmental baseline studies, EIAs and monitoring work have been conducted for these oil terminals by researchers from the Institute of Marine Research & The Faculty of Marine Sciences & Fisheries – Red Sea University or from the Institute of Environmental Studies (IES), the University of Khartoum in collaboration with consultancy companies (e.g. New Tech). The Al khair terminal is presently in a process of significant expansion (phase II) and a recent baseline study was in this connection prepared by IMR (IMR, 2014).

By comparing the content of different baseline and EIA studies that have been prepared by Sudanese institutions, a clear indication can be obtained about the knowledge development process on issues related to environmental management and monitoring. At the Bashayer Marine Terminal, which is operated by the Greater Nile Operation Petroleum Company, the baseline study was reported in 1999 (UKCC, 1999), although this report have yet not been found in open sources. Follow-up environmental impact assessments and monitoring studies At the Bashayer Marine Terminal were performed in 2001 and in 2005 (IES, 2005). All these studies were performed by teams led by Dr. Osman Mirghani Mohamed Ali at the Institute of Environmental Studies, Univ. of Khartoum (pers. comm. O.M.M Ali). An overview of the environmental parameters and monitoring data that are provided from the EIA study at Bashayer marine terminal conducted by Ali et al. (IES, 2005) is shown below (Table 17 and Table 18). O.M.M. Ali was also the leader in a team with the Italian consulting company APS engineering in connection with an EIA study for Port Sudan new refinery reported in 2004, although this report have yet not been found in open sources. IMR has also conducted other relevant studies at coastal locations such as the EIA study in Suakin Harbour (IMR, 2007a) and the

baseline study in connection with the new port in the Mersa El- Sheikh Ibrahim bay which is located south of Suakin (IMR, 2012).

Table 17: Environmental parameters, pollution relevant parameters and measurement procedures in air and seawater that are used in connection with environmental monitoring studies reported in EIA reports for the Bashayer marine terminal close to Port Sudan, data source: IES (2005)

Parameter	Method used for measurement
Air temperature	Centigrade thermometer
Seawater temperature	Portable HANNA meter model 8314
Transparency	Vertical and horizontal assessed mid-day by a Secchi disc
Turbidity (within reef)	Hach apparatus providing Formazin Turbidity Units (FTU) measured in water collected from within local reefs
TDS - Total dissolved solids	Not informed
Conductivity	Not informed
pH	Portable HANNA meter model 8314.
Salinity	Refractometer fixed at 20 °C
Dissolved oxygen (DO)	Winkler method as modified by Strickland, J. D. H. and Parsons, J. R. (1965). Manual of Seawater Analysis, UK.
Biochemical Oxygen Demand (BOD)	Determined by subtracting the oxygen in water incubated in the dark for five days at around 22 °C from the initial DO value
Inorganic nutrients (nitrates, phosphates and silicates)	Chemico-spectrophotometric methods as described by Strickland and Parsons (1965), Manual of Seawater Analysis, UK
Oil and grease in water	Oil content was determined gravimetrically using petroleum benzene as a solvent for seawater. The solvent was separated from the water in a separator funnel. Using a water bath, the oil and grease was allowed to stay as the solvent evaporated. The residue was weighed and the oil and grease content was calculated as part per million.
Hydrocarbons in sediments	Analysed in accordance to the method described in APHA, AWWA, and WEF (1998). Standard Methods for examination of water and wastewater. Washington: American Public Health Association; http://www.standardmethods.org/

Table 18: Environmental monitoring data in air and seawater that are reported from EIA studies at the Bashayer marine terminal close to Port Sudan, data source: IES (2005)

Parameter	1999	2001	2004	Unit
Air temperature	36	-	26.5	°C
Temperature (surface)	30.5	29.9	27.6	°C
Transparency (Vertical)	4.00	4.25 - 8.25	>1.50	m
Transparency (horizon)	-	-	3.0	m
Turbidity	-	1	4	FTU
TDS	-	37325	38580	ppm
Conductivity	-	56.4	58.04	mS/cm
Salinity	39.0	40.83	40.00	‰
pH	8.21	8.07	8.29	
Dissolved Oxygen	2.52	5.89	4.75	mg/l
BOD5	-	2.09	2.09	mg/l
NO3 –N	4.18	2.65	2.65	mg/l
PO4–P	0.3	0.3	0.3	mg/l
SiO3	4.0	4.25	4.30	mg/l
Fe	-	0.056	0.08	mg/l
Chloride	-	22.6	27.12	g/l
Oil and grease (Water)	-	*	0.1798	%
Oil and grease sediment	-	*	*	%
Hydrocarbons (HC) in sediments	-	*	0.0014	%

- Not measured, * Below detection limit

3.7 Quality aspects of environmental assessment data

Baseline studies, EIA studies and monitoring work that are conducted in Sudanese marine waters should be subjected to suitable Quality Control (QC) and Quality Assurance (QA) measures in order to maximise the quality of the studies and the reported data. Issue of relevance include the study approach, the samples used, the analytical work and the statistically and scientifically examination of the obtained analytical results.

It is essential that analytical data of measured contaminant concentrations can be trusted also that they are put into an interpretation context where the actual severity of the observed contamination level can be clarified. To achieve an adequate level of technical and academic quality the performing institute should establish suitable Quality Standard (QS), Quality Assurance (QA) and Quality Control (QC) systems. In developed countries, the environmental regulation and discharge permits typically require that chemical pollutant analyses are done by accredited laboratories; a demand which normally will safeguard the good quality of studies and data, but also which may involve a considerable increase of the analytical costs. An alternative approach is to establish some form of quality systems based on direct collaboration between laboratories on analytical quality issues and training programs.

Correct and updated information about the ongoing and planned operations, at least to a certain level of details, are necessary in order to identify possible conflicts between the oil & gas industrial

operations and ecological conservation interests as early as possible, and especially before the status of unique VEC resources becomes significantly damaged. However, the information about ongoing, planned and performed activities/developments in the oil & gas industry is normally treated as classified information. Such a lack of information transparency may represent a serious problem in areas like the Sudanese coastal zone, as extremely valuable VEC resources may become significantly damaged if the operations are conducted without the implementation of appropriate precautions measures to avoid ecological impacts.

Researchers and research groups at high academic levels will normally want to publish their data under a peer review scrutiny in good-quality international scientific journals. When a research institute manage withhold a good peer-review dissemination rate over time it will normally be considered as a sign of good academic quality of the institution. The amount of ecotoxicological data published in international peer reviewed journals are yet very limited from Sudanese research institutions, but it can be expected to improve, given the broad collaboration which is ongoing between the Sudanese Universities and foreign Universities.

3.8 Education and training in marine environmental science in Sudan

The development of a sustainable management for Sudan's ecological resources requires involvement and participation from institutions at several levels; including governmental authorities at different levels, universities and research institutes, industrial companies, expert consultants, and non-governmental organisations. In this connection, it is useful to compile an inventory of Sudanese institutions that have various kinds of responsibilities, mandates, competences and practical roles within the total process of coastal zone management and governing.

Many of the tasks which are required in connection with an integrated coastal zone management process are highly knowledge dependent. The Sudanese universities are therefore institutions of key importance in this connection, especially when it comes to education and training of personnel who are going to be involved in the practical performance of competence sensitive activities, such as field studies to monitor of the quality status of different VECs.

There are in total more than 30 public and private universities in Sudan and many of them include research and educational activities that make them relevant as providers of research and knowledge in connection with the presently addressed issues. The University of Khartoum and the Red Sea State University in Port Sudan are possibly the two most relevant university institutions in connection with the present study, and an overview of what they have to offer on relevant education programmes and courses is shown below.

University of Khartoum:

The University of Khartoum is the top-ranked university in Sudan and plays a central role in many fields of science and knowledge development in Sudan. At Univ. of Khartoum, the Institute of Environmental Studies (IES) is particular important as this institute both provides Diploma and MSc education programmes in environmental sciences and have performed EIA studies and environmental research on coastal zone issues.

In the following text an overview is provided about student courses in Environmental Sciences at IES - Univ. Khartoum (source: webpage of IES - Univ. Khartoum):

Web-link to IES: <http://ies.uofk.edu/index.php?lang=en>

1. Fundamentals of Environmental Science

Course Objectives

- To introduce the students to the environment as an integrated components.
- To provide an understanding of the systems analysis and the system approach as applied to the solution of environmental problems.
- To acquire and understanding of the basic physical principles, that control environmental interactions;
- To provide information about the way in which flows of energy and matter, controlled by the basic physical principles, link the biotic and a biotic environment within the human system.
- To study how these flows and interactions operate in the context of the Sudan Environment.
- To study how these flows and interactions operate in the context of the Sudan Environment.

Course Contents: Biophysical aspects of the environment: definitions (ecology, environment, ecosystem, niche, biosphere, etc.) -Basic ecological principles: environmental factors (biotic and abiotic), population, communities: - Ecological energetic: (solar radiation, photosynthetic radiation, energy efficiency of try production, the flow of energy in the biosphere) - The interaction of ecosystem structure and function (Ecosystem homeostasis) - Man-environment interactions: basic approaches-evolution of man-environment interactions-contemporary models-perceptions of the environment and natural resources use.

2. Statistics

Course Objective: To study the basic statistical concepts and procedures for representation and analysis of data.

Course Contents: Introduction -Frequency distribution - Graphical representation -Measures of Central tendency - Measures of dispersion -Probability distributions -Correlation theory - Regression analysis.

3. Rural Development

Course Objectives: Introduction to Sudan rural environment - Traditional cultivation and pastoralism -Cultivation of marginal areas and deforestation - Settlement of nomads and carrying capacity of land -Overgrazing and pastoral tribes attitudes -Pollution of agricultural ecosystems by fertilizers and pesticides -Desertification and the associated decline in crop yield, animal loss, migration to urban centres, wildlife degradation and decrease in the index of biological diversity-Integrated land use and community participation in environment protection and sustainable development.

4. Meteorology and Climatology

Course Objectives:

- To provide the students with adequate knowledge of the physical processes that produce the weather and climate phenomena.
- To emphasize the importance of weather and climate as factors that influence and interact with the environment.
- To enable the students to use weather and climate data and information for understanding, analysing and solving the associated environmental problems with emphasis on Sudan situation

Course Contents: Types and nature of natural resources - Resource management - Environmental conservation - Activities for environmental management - Environment and sustainable development (origin of sustainable development, environment interface, components of sustainable development) - Sustainable development practices.

5. Urban Environment

Course Objectives: To increase the student's awareness and knowledge of the urban centres and the associated environmental problems in the Sudan

Course Contents: Introduction to Sudan urban environment problems - Unplanned urban growth and the associated deterioration of services - Urban slums, squatters and diseases -Lack of urban infrastructure and insufficient services of energy, water and housing -Sewage and garbage disposal Pollution of traffic and industry.

6. Environmental Pollution

Course Objectives:

- To acquaint the students with the intricate link between science, technology, population and pollution.
- To present and overview of the different sources, types and impacts of environmental pollution.
- To elucidate the different measures of pollution control and to enable the students to review and appraise current national pollution control methods and to encourage their thinking towards anticipating appropriate strategies for tackling the problem of environmental pollution in the Sudan.

Course Contents: Introduction: Science, technology and population as sources of environmental pollution - Definition of pollution - Sources of pollution (natural-anthropogenic) Media of pollution - Types of pollution - Different aspects of atmospheric, hydrospheric, lithospheric and biospheric pollution - Pollution control (Fundamental concepts, different methods-technological , legislative, cultural-educational).

7. Environmental and Natural Resources Laws

Course Objectives:

- To provide the students with solid understanding of the current state of Sudan environmental and natural resources laws.
- To raise the students awareness regarding the importance of the law in the conservation of the environment and natural resources.
- To give the students reasonable knowledge of the problems that may be encountered when enforcing environmental and natural resources laws.

Course Contents: Sources of international and Sudanese law -Basis of civil and criminal liability -Sovereignty over natural resources - Land use and tenure in the Sudan - Impact of legislation on customary and Islamic law - Regulation of use of resources: land, minerals, forests, water and fisheries - Industrial regulation - Pollution - Industrial safety - Promotion of investment laws and impact on the environment - Settlement of international disputes - Human rights and the environment - Transborder environmental pollution - Nile water convention - International water courses - The sea (Red Sea) Maritime Zone - Ozone depletion - Climate change - Conservation of Biodiversity - Problems of enforcement.

8. Environment and Technology

Course Objectives: To introduce the students to the effects of engineering on the biosphere and the methods used to combat the negative impacts of such technologies.

Course Contents: Power generation and the environment (coal, petroleum, hydrogenation, nuclear generation) - Industrial production and the environment (air, water and soil pollution, gaseous, liquid and solid pollution, noise, radiation and heat) - Agricultural production and the environment (Pesticides, fertilizers, irrigation, etc.) - Urban environment (water supply, liquid and solid wastes, waste management) - Transport and the environment (vehicles, planes, ships, pollution, noise, etc.) - Cleaner technologies.

9. Environmental Economics

Course Objectives:

- To qualify the students to deal with various environmental aspects particularly those link the environment with the economic activity.
- To gain the necessary skills to conduct environmentally oriented economic analysis.
- To qualify planners and policy makers to account for environmental elements in their development plans and policies and the national and sub-national levels.

Course Contents: Microeconomics: nature and elements of the economic problem -market mechanism-consumer's efficiency - Firm efficiency. Environmental economics: relationships between economic activity and environment-renewable and non-renewable resources - extensities - public good- market failure and public good- environmental quality as a public good-economic aspects of environmental pollution as an externality - income distribution aspects of environmental policy - the role of economics in valuation of environmental effects of development projects aspects of environmentally oriented economic analysis - the context for economic analysis of projects -some examples of valuation of environmental effects of development projects -economics and biodiversity strategies.

10. Statistical Inference

Course Objectives: To use the statistical methods to assess and predict environmental variables.

Course Contents: Sampling distribution - Sampling theory - Estimation and test of hypothesis - Small sampling theory - Analysis of variance and regression - Experimental design and data analysis - Fundamentals of research methods.

11. Environmental Impact Assessment

Course Objectives:

- To provide the students with knowledge of the procedures and methods for assessing the environmental impacts of development policies, programmes and projects, within a sustainable developmental framework.
- To enable the students to take part confidently in the preparation or review of an EIA.

Course Contents: History and evolution of EIA-Advantages and benefits of EIA-legal requirements for EIA - EIA core elements and guiding principle -Public involvement in EIA - Stage of EIA process: screening, scoping, assessing impact (Natural, social, economic) - mitigation of Impact -Reporting - Reviewing -Monitoring programmes and post-auditing - Moving towards sustainability - Sudan experience of EIA.

12. Remote Sensing and GIS

Course Objectives:

- To provide the students with a sound knowledge of RS and GIS principles.
- To train the students in the techniques and practices of geographic data handling and analysis via RS and GIS.

Course Contents: Introduction to resource assessment -History and principles of RS and GIS - The electromagnetic spectrum - Platform and sensors - Radar - Infrared photography (analysis, treatment, interpretation) - Satellite and airborne remote sensing - Visual image interpretation -Computer based image analysis (ILWIS 2.2. programme) - Principles of Vector and Raster GIS -Overlay analysis and special modelling.

13. Community Health

Course Objectives:

- To appreciate the role of health on socio-economic development.
- To understand biomedical, ecological and psychosocial concepts of health.
- To recognize, assess and control environmental and occupational health factors of the individual and the community.

Course Contents: Introduction to community health - Principles of epidemiology - Primary health care - Environmental health - Occupational health - Some tropical diseases - Common diseases between humans and animals.

14. Ecology and Management of Aquatic Resources:

Course Objectives:

- To present water as a unique environmental source.
- To provide up-to-date information about the types, volumes and uses of aquatic resources in the Sudan.
- To emphasize the very special aquatic situation in the Sudan and the resultant national, regional and global implications.

Course Contents: Water as a unique environmental element: Characteristics, global distribution, stocks and flows - Types of aquatic systems: lotic, lentic, Aquatic systems in the Sudan: surface, ground, marine - The Nile system in the Sudan: characteristics, ecology - Utilization of aquatic systems: domestic, industrial, irrigation, power generation, transport, fisheries, tourism- Management of aquatic systems in the Sudan: institutional, legislative - Environmental appraisal: Natural-anthropogenic constraints - Aquatic resources: Regional-global perspective -Special issues.

15. Arid Land Environment

Course Objectives: To emphasize arid land as complex large ecological zones that has variation in diversity, productivity and uses.

Course Contents:

The concept of aridity - Ecological Arid Zones and their variation - Biodiversity - Productivity and dynamics of Arid Zones: (carbon sequestering and its budgets) Soil and water conservation - Desertification - Arid land uses in the Sudan - International conventions.

16. Environmental Microbiology

Course Objectives: To highlight the microorganisms diversity and importance and their dynamics and interaction with the environment.

Course Contents: Microbial biodiversity - Commensals, symbionts and parasites - Cellulose digestion - Industrial fermentation - microbial energy conversion - Bioremediation of polluted environments (petroleum and sewage treatment) -Microbial indicators of pollution - Microbial water pollution - Environmental impact of transgenic microbes and the advent of genetic engineering - The Conventions of Biological Diversity and the Biosafety Protocol.

17. Environmental Sociology:

Course Objectives:

- To introduce the students to the socio-cultural context in which development takes place.
- To emphasize the need to integrate this social dimension with the development process.
- To direct the student's perception towards the importance of indigenous knowledge and the role it can play in achieving an economical visual and socially accepted sustainable development

Course Contents: Definition of concepts - Forms and appropriate use of technology (traditional, intermediate - advanced) - Socio-cultural systems in Sudan in relation to: means of livelihood and economic activities - Ecological and adaptations - Political organizations - Environmental resource planning - Community participation (Stakeholders - environmental awareness) - Indigenous knowledge (Importance, role in sustainable development) - Environmental movement and globalization.

18. Archaeology and the Environment

Course Objectives:

- To enable the students to synthesize the components of the environment in the past based on the remains.
- To enable the students to identify and analyse the role of the environment in the human cultural and civilization development process.
- To enable the students to identify the negative and positive factors that lead to temporal land spatial environmental changes and civilization.

Course Contents: Introduction explaining the rule of the environment on the early man's life - The inter action between man and the surrounding environmental elements - The three Stone Ages: a) Paleolithic (Khour Abu Anga - Jebel El Sahaba) b) Mesolithic Age (Early Khartoum) c) Neolithic Age (Esh-Shaheinab) - The Early Nubian Cultures, their social and economic life - Kerma Culture, its cultural components and foreign relations - The Kingdom of Napta and Meroe, its social , cultural aspects and relations with the external world. The role of the environment in shaping the economic and social life in each - The Post - Meroitic Culture (The X-Group).

19. Environmental Education

Course Objectives:

- Providing the student's with knowledge in the field of environmental studies that enables them to analyse the environmental problems and to participate in increasing the environmental awareness in their communities
- Dissemination of knowledge, values and behavioural attitudes that help in maintaining our natural resources sustainability and accelerate the rate of development without negative drawbacks on the environment.

Course Contents: The philosophy of Environmental Education - History and development of Environmental Education - Environmental concepts (conjunctions, relational, theoretical, deduction and induction concepts). -

Environmental Education Curriculum planning - Planning at the National, State and Local Levels - Strategy for curriculum planning - Planning at the National, State and Local levels - Strategy for curriculum development, implementation and evaluation in environmental education - Skill developing activities - Values clarification activities - Environmental Education resource materials, (sources of prepared environmental education curriculum materials for teachers, non-governmental organizations active in environmental education) - Environmental Education monitoring kits.

The Red Sea University, Port Sudan

(Website address: <http://www.rsu.edu.sd/en>)

With around 340 academic staff, 7800 undergraduates, 4300 diploma and 1060 postgraduate students, The Red Sea University (RSU) in Port Sudan is classified as one of the largest Sudanese university institutions. RSU is not among the highest ranked universities in Sudan, but it must still be considered as particularly important in the present connection because of its central localisation in the coastal zone of the Red Sea State and also because its orientation towards the marine environment as one of its key fields of education and research. The Marine Research Institute (IMR) is a key institute at RSU and is also one of the established Excellence Centres at RSU. In 2014, the present project made a visit to IMR (Figure 84) for examining the facilities and discussing the educational activities of the institution.



Figure 84: In 2014, the present project made a visit to The Marine Research Institute at the Red Sea University in Port Sudan for examining the research facilities of the institution and discussing the status of the educational activities of the institution.

The Marine Research Institute has established relevant collaboration partnerships with a number of related research and competence institutions at the national, regional, and international levels; including:

- Faculty of Marine Science and Fishery - Red Sea University (RSU) - Port Sudan
- Institute of Environmental Studies (University of Khartoum, UoK)
- Marine Biological Station at Suakin / Faculty of science (UoK).
- Marine Fishers Research Station (Port Sudan) / the Federal Ministry of Animal Wealth.

- Fishery administration / Ministry of Agricultural and Animal & Fishery Wealth (Red Sea State).
- Ministry of Environment and Tourism and wildlife (Red Sea State)
- Sea Ports Corporation (Port Sudan)
- Marine Security and Sudan Navy (Port Sudan)/Ministry of Defence.

The RSU Marine Research Institute has also a number of important regional and international collaboration partnerships established; some of the most important ones are:

- PERSGA (with headquarters in Jeddah, Saudi Arabia)
- Geophysical Institute, University of Bergen (Norway)
- Research Institute for Humanity and Nature (RIHN) – Japan
- Coastal Marine Resource lab - King Abdullah Univ. of Sci and Technol. (KAUST) – Saudi Arabia
- Senckenberg Museums of Natural History (Germany)
- Institute of Hydrobiology and Fisheries, Hamburg University (Germany)
- University of Berlin (Germany)
- ODINAFRICA (Oceanographic Data Information and Network in Africa) www.odinafrica.org
- International Organizations (IUCN, WWF, UNEP, UNISCO, FAO, UNIDO)

The localisation of RSU Institute of Marine Research within the Port Sudan Harbour area is very close to the marine habitats off the coast of Port Sudan. This makes it the optimal place for organising and performing educational and research based activities in coastal zone ecotoxicology and practical training on issues and methods relevant to marine environmental monitoring.

RSU IMR also participates in the implementation of a national environmental monitoring programme in the Sudanese Red Sea which is an integrated part of the regional environmental monitoring programme (REMP) that has been developed by PERSGA and which has been conducted regularly since 2006 with the aims to provide reliable & comparable oceanographic baseline data for the region employing common standard methodology & techniques.

Information of relevant education programmes and course activities at RSU IMR is less available at RSU webpages as compared to the webpages of IES (Univ. of Khartoum).

Other institutions of high relevance

In addition to the two university institutions that are described above, a range of other institutions and stakeholders in Sudan (some of them being present locally in the Red Sea State) can be classified as competence and/or capacity institutions with relevance for the issues addressed in this baseline study; including:

- The Marine Fisheries Administration (Port Sudan)
- Sudan Higher Council for Environment and Natural Resources (HCENR), Khartoum
- Sea Ports Corporation (Port Sudan)
- PDOC (PetroDar Operating Company Ltd)
- GNPOC (Greater Nile Petroleum Operating Company Ltd)
- Sudanese Environment Conservation Society (SECS) (Port Sudan and Suakin)
- Sea Friends Association (Port Sudan)
- OXFAM (Port Sudan and Tokar)
- The Sudan Marine Conservation Committee (semi-NGO)
- MEPSS - marine environment protection society – Sudan (Port Sudan)
- The Wildlife Research Center (Khartoum)
- Animal Health Research Laboratory

3.9 Regional and international expert institutions

The list of relevant contacts may be extended to also include international institutions and experts who have knowledge, experience and roles which make them relevant for activities in connection with ecosystem characterisations, protection efforts and status monitoring activities in the coastal zone of Sudan.

The regional intergovernmental collaboration organisation PERSGA is essential in this connection. PERSGA's legal basis stems from the so-called Jeddah Convention, signed in 1982. The operational mandates governing PERSGA's conservation activities and programmes are described in PERSGA's Strategic Action Plan developed in 1997. The first phase of the SAP was implemented during 1999-2005, with the support of GEF (the Global Environmental Facility). As of 2006, PERSGA has been conducting its work under SAP Phase 2, which concentrates primarily on sustainable development and institutional strengthening.

Several global organisations have established partnership with Sudanese and regional organisations on issues related to marine ecosystem protection within the RSGA region. An efficient way of identifying these organisations is to explore the international supportive partners of PERSGA, which include: the Global Environmental Facility (GEF); the World Bank; the Food and Agricultural Organization (FAO); United Nations Environmental Programme UNEP; UNEP Regional Seas Program; the International Coral Reef Action Network (ICRAN); the Arab League; the Center for Environment and Development for the Arab Region and Europe (CEDARE); The Islamic Education Scientific and Cultural Organization (ISESCO); UNEP- Regional Office for West Asia- UNEP-ROWA; International Maritime Organization (IMO); KAUST - King Abdullah University of Science and Technology in Jeddah, Kingdom of Saudi Arabia; the intergovernmental Oceanographic Commission (IOC); the World Health organization (WHO); UNIDO - the United Nations Industrial Development organization. A number of technical studies, field studies and training programmes have been conducted under the PERSGA umbrella and the institutions and scientists that have taken part in these efforts are parts of the long-term competence and institution strengthening process that currently is ongoing in Sudan and the PERSGA region as a whole.

A range of other institutions and stakeholders at the international levels are relevant with regard to the issues addressed in this report. Some of the most important include:

- IMR - Institute of Marine Research (Bergen, Norway)
- The Geophysical Institute, University of Bergen (Bergen, Norway)
- Univ. of Berlin, Germany.
- Japan Natural Research Institute (Kyoto)

3.10 International key scientific experts

Environmental scientists who previously have carried out high quality marine ecological research studies on VEC resources within the RSGA area have most probably gained valuable knowledge about Sudanese marine waters. To make use of this existing scientific expertise can be of key importance for ensuring best possible quality of novel studies in this area. Depending on the issue addressed, different scientists can be commissioned as consultants or advisors, most preferably in close collaboration with Sudanese institutions. However, the active involvement of Sudanese institutions and scientists in any new research endeavours in Sudanese marine waters should be considered as mandatory as this will ensure an important competence training effect of the studies that are performed. A contact list of the key scientists who have been in charge of developing the survey manuals on the different VEC assessment and monitoring issues in the RSGA area was included in the PERSGA Standard Survey Methods manual (PERSGA/GEF, 2004d).

4 Knowledge gaps and recommendations for practical actions

Background: Knowledge is a key in order to find the best solutions for the many environmental issues in the Sudanese Red Sea State. This study has aimed to provide an ecological baseline of coastal zone ecosystems in Sudan based on data that are available from open sources and the scientific literature. To identify knowledge gaps and suggestions for further research, development activities and practical actions of relevance was also an objective of the present work. “Gaps of knowledge” may in this connection relate both to information concerning the ecosystems and specific ecosystem components and also the governance systems that are required at national, province and local levels for obtaining an ecologically sustainable management of the ecological resources in the Sudanese coastal zone and offshore areas. A set of relevant recommendations with special focus on marine ecosystem protection/management in Sudan was earlier developed by UNEP (2007) and these recommendations are also in large parts repeated within the list of recommended actions in this report.

Systematisation of existing ecosystem data: As the great ecological value of the Sudanese coastal zone has been recognised by biologists for more than 100 years, e.g. Crossland (1907), the total set of scientific literature originating from this area is huge and includes an array of books, reports and scientific articles addressing a multitude of ecosystems components. Although many of these information items are rather old and partly outdated they have great value for the total information overview. It is recommended that this information is followed up, further systemised and made available. One possible approach is to fund Sudanese and international experts to prepare a set of peer review manuscripts that hold a quality that will merit their publication in peer reviewed international scientific journals.

More systematic collection of new data: The collection and analysis of marine ecological baseline data and environmental monitoring data in Sudan is too poorly organised.

Better knowledge about pollution levels: More knowledge and high-quality data is needed about the current pollution situation in different ecological compartments along the Sudanese coastline, both with regard to undeveloped areas and urban/developed areas. This information should be shared with all stakeholders to provide them with useful baseline information as well as useful information to assess the relative severity of human impact, e.g. at locations where EIA are conducted in connection with industrial and societal developments.

Characterisation of high priority VECs: There is an urgent need for providing better status information of coral reef areas, mangroves and populations of dugongs, sea turtles and large fish species in Sudanese marine waters.

Stop population decline of dugongs: Immediate actions are required for providing better data on population trends of dugongs in Sudanese marine waters, and efficient dugong conservation measures should be implemented in key areas, such as in the Mukawwar Island and Dugonab Bay Marine Protected Area. As a minimum, the conservation measures should include an immediate ban on fixed fishing nets in parts of the Dugonab MPA important for the dugong.

Strengthen the support of the PERSGA organisation: Sudanese research institutions take active part in PERSGA activities. During recent years, this regional collaboration organisation has conducted a number of relevant surveys in the Red Sea and also in the Sudanese coastal zone. The important information and reports coming from these PERSGA studies hold overall an impressively high quality level and this offers a promising outlook for the future characterisation and protection of ecosystems in the Sudanese coastal zone, as well as in the rest of RSGA area. It is strongly recommended that the Sudanese institutions and researchers working with PERSGA cooperation activities are allowed suitable and long term working conditions so they may continue with these important knowledge development activities.

Better information sharing: A practical action that is directly linked to this issue can be to establish a dynamic (and preferably internet based) information sharing system about the status of Valued Ecosystem Components (VECs) in the Sudanese coastal zone. Unless there are good reasons for keeping specific VEC information secret (e.g. protection measures for particularly endangered VECs), marine ecosystem information should be made open and available for the public. Such openness can be a powerful instrument in the effort of raising environmental awareness levels among all Sudanese people. Better information sharing will also facilitate the follow up of EIA studies which industrial enterprises must carry out in cases when activities are in conflict with VECs of particularly high value.

Encouraging openness of information: The information sharing system suggested above can also be seen in a wider context which concerns long-term strengthening of governing systems and competence development institutions in Sudan. It is interesting to note that the concept of sustainable use of Valued Ecosystem Components in the Sudanese coastal zone may represent a long-term goal that easily can be understood and agreed by all parties within the Sudanese society, also by stakeholders who have commercial interests in the area (fishermen, industrial companies, etc.). The goal of avoiding ecosystem degradation is therefore valuable in itself as an issue of mutual interest and cooperation, which when used successfully may strengthen the societal development in Sudan and in the Red Sea state in particular. A key to achieve this will be to stimulate information openness on issues of common ecosystem resources.

Implement Integrated Coastal Zone Management: As earlier recommended by UNEP (2007) the transfer of governance mandates from national levels to Red Sea state levels and implementation of an integrated governing system for management of the environmental resources in the coastal zone is possibly a way forward for converting ambitions into practical actions at the local level. An integrated governing system can be based on the concept of Integrated Coastal Zone Management (ICZM), combined with devolution of formal responsibility to the Red Sea state level. The objective of ICZM is to establish sustainable levels of economic and social activity in the coastal areas (fisheries, coastal development, land-based marine pollution sources and tourism) at the same time as protecting the coastal environment.

Develop, strengthen and enforce required legal instruments: The legal instruments required for ensuring sustainable management of the high-priority VECs in the Sudanese marine environments must be developed, and properly ratified and enforced in cases when they already have been developed. These include the Sudanese Maritime Law, the National Oil Spill Contingency Plan and legislation covering marine fisheries. Each legal instrument must include the definition of standards of parameters that are appropriate for checking the stakeholder's compliance to the specific regulation. Enforcement of each regulation must also include the organisation and adequately funding of authorised inspectors with mandate to carry out both notified and unscheduled inspections and controls. Penalties for infringements are too low to act as an effective deterrent or to encourage compliance by fishers, tourist diving organisers, etc.

EIA legislation: Enforce existing EIA legislation on planned developments on the Sudanese coastline. This will require more direct involvement of the Red Sea State Government in support of the Marine Environment Protection Authority.

Strategic Environmental Assessment (SEA): Start involving Strategic Environmental Assessment (SEA) in connection with environmental regulation, planning and decision making of major societal and industrial developments in Sudan. This to address the limitations of the current EIA oriented regulatory approach.

Strengthen and follow up the marine protected areas (MPA): Follow up and fund existing management plans for established marine protection areas (Sanganeb and Dugonab). Forward the processes for consideration of new areas of particular high value that should be given national protection status. Among the sites/areas previously listed for MPA consideration are the Suakin Archipelago, the Abu Hashish coral reef area, and the Shuab Rumi coral reef area.

Water pollution legislation: Enforce existing water pollution legislation on industrial and utilities plant discharges into the Red Sea. This will require more direct involvement of the Red Sea State Government in support of the Marine Environment Protection Authority.

Environmental regulatory institutions: Advocate and progress federal/state power-sharing on marine environmental issues. Set out and restructure the power-sharing arrangements for coastal and marine natural resources management to allow direct liaison and resolution at the state level.

Integrated Coastal Zone Management: Introduce the concept of Integrated Coastal Zone Management through revised master-planning for the whole Sudanese coast with a focus on the areas of Port Sudan, Suakin and Tokar.

5 Summary and conclusion

The coastal zone in the Sudanese Red Sea State hosts a wide array of unique ecosystems which are world famous for their natural beauty and outstanding biological diversity. A summary of the available information for these Valued Ecosystem Components is provided in the present report. It is a matter of uttermost importance that the ecological treasures in the Sudanese marine waters are protected against the multiple anthropogenic threats that comes with population growth and increased use of the coastal zone for societal and industrial developments.

Areas with undisturbed marine and coastal habitats are the most important foreign tourist attractions of this country and exploitation of fish and other biological resources in these marine and coastal areas is also important for the local population. The management of shared resources such as shipping channels, coral reefs, mangrove stands, estuaries, and pelagic fisheries cannot be addressed in isolation but requires an integrated approach. An increasing level of environmental awareness and interest is currently shown by Sudanese national authorities and Red Sea State stakeholders, and this offers an optimistic promise for the development of a sustainable management of this valuable and vulnerable coastal zone.

The coastal habitats with highest ecological value include the coral reefs, seagrass areas, and mangroves. The seagrass beds provide food for green turtles and dugongs and a variety of invertebrates and fishes, while the mangroves support much marine life and contribute to the significant increase of local fisheries. The coral reefs are important as a shelter, source of food, breeding and nursery areas for diverse communities of marine organisms including fishes. The Sudanese coral reefs are yet little exploited as a tourist attraction and these valuable ecosystems represent a great asset which can bring wealth to the local population if just they are managed with great care and in a sustainable manner.

The most direct and significant threats to the long-term stability of the marine ecosystem in Sudan stem from an increase in human population within the coastal zone in the Red Sea State and a rapid rise in the economic growth, ecological resource exploitations and coastal infrastructure developments. These factors have already brought about coral reef destruction and decline of mangroves and have contributed to increased pressure of and possible declining trends for threatened marine species, such as sea turtles and dugongs. Overexploitation represents a major problem for several fish and invertebrate species. Pollution pressures and physical alteration of the coastline due to dredging and filling operations in connection with urban developments and harbour activities represent significant threats to vulnerable coastal habitats. The Sudanese marine waters represent an important route for maritime transport of oil and other cargo between the Far East and Europe. The transportation represents a matter of environmental concern as ship accidents can contribute to large scale oil spills and long term pollution of pristine coastal habitats. Currently, there is a particular high pressure on coastal habitat along the coastline between the cities of Port Sudan and Suakin. Serious symptoms in this area are overgrazing of mangrove stands, land degradation, and increasing coastal pollution originating from land-based sources and maritime transport. These pressures pose a complex challenge to the unique marine and coastal environments of Sudan and therefore require urgent attention. In this connection it is recommended that the Sudanese authorities establish integrated systems for governing and ecosystem management for example based on the concept of Integrated Coastal Zone Management (ICZM), and also that more formal responsibility is transferred to the Red Sea State level.

Sudan takes part in regional collaboration efforts which aim to address protection of the Red Sea ecosystems. The key organisation in this connection is the Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden (PERSGA). PERSGA is an intergovernmental organization and was established in 1995 following the 1982 signing of the Jeddah Convention by the seven countries surrounding the Red Sea and the Gulf of Aden (Sudan, Djibouti; Egypt; Jordan; the Kingdom of Saudi Arabia; Somalia; and Yemen) and is governed by a council of representatives of the PERSGA member states. PERSGA develop and implement both regional and national programmes for characterisation, protection and conservation of the marine environment in the RSGA region. Institutes at the Universities of Khartoum and in the Red Sea State are active participants in PERSGA organised activities.

This baseline review report is prepared as a part of an ongoing collaboration between Sudan and Norway and represents an attempt to provide a short and popular overview of the unique ecological resources within the Sudanese coastal zone; highlighting their value, their current condition status and the main threats to their long-term stability. As a second part of this collaboration, a marine environmental monitoring plan is prepared with special emphasis to issues relevant for offshore oil and gas industrial activities (Beyer et al., 2015). In addition, follow-up activities that include practical training and capacity development in Sudan on marine monitoring relevant issues are suggested for the continuation of the collaboration programme.

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