



# SIERRA LEONE

## STATE OF THE MARINE ENVIRONMENT REPORT 2015



ABIDJAN CONVENTION  
CONVENTION D'ABIDJAN



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# Foreword

The Government of Sierra Leone recognizes the threats to the coastal and marine environment from anthropogenic sources as well as from global climate change which is one of the biggest challenges of our generation that threatens the natural resource base of the country. The State of the Marine Environment (SOME) report highlights the threats to our marine environment and underscores resources exploitation as one of the primary causes leading to the degradation of our marine and coastal environment. Without immediate and concerted efforts, it will be impossible for the present and succeeding generations to achieve sustainable development. Overexploitation of natural resources from the coastal and marine areas is one of the greatest threat to the marine environment. This is predicated on overwhelming dependence by rural and coastal communities on such resources in the face of limited alternative livelihoods. The Government has noted such issues that require priority attention such as potential threats of invasive species, coastal erosion, pollution control, increasing uncontrolled coastal development leading to habitat degradation and changing land-use patterns, and climate change.

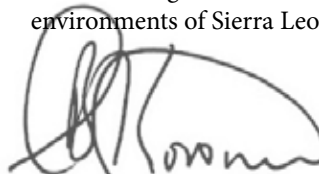
However we remain committed to reverse the resultant environmental degradation and to address the identified trans-boundary issues as demonstrated by the participation of Sierra Leone in the Guinea Current Large Marine Ecosystem (GCLME) projects and the ratification of the Abidjan Convention.

The Government of Sierra Leone is already developing and implementing improved management strategies in order to mainstream environmental concerns into national policies, programmes and projects, regulatory, and institutional mechanisms that are critical to achieving environmental sustainability. These include improvements in many of the regulations governing the marine environment and designation of Marine Protected Areas. Government also recognizes that improved regulations also require focused enforcement efforts to assist in sustaining gains in environmental protection, rebuilding fish stocks, conserving biodiversity and maximizing the long-term benefits of the goods and services provided by the ecosystem.

The current SoME report is part of the regular process in assessing the state of the global marine environment. This assessment is also in response to the identified threats facing the country's coastal and marine environment and attempts to address the causes and effects of such threats and other emerging issues.

It is important to note that the vulnerability of the coastal and marine areas and associated risks from unsustainable resources exploitation need adequate and robust strategies that will effectively address the current trend in coastal and marine degradation in making blue growth a reality.

My government remains committed to providing the political leadership towards addressing the issues and challenges confronting the marine and coastal environments of Sierra Leone.



**Dr. Ernest Bai Koroma**  
**The President of Sierra Leone**

# Executive summary

The coastal zone and “Exclusive Economic Zone” of Sierra Leone covers an area of about 160,000 km<sup>2</sup> from Kiragba in the north to Mano in the south. Sierra Leone’s coastline measures 560 km, much of which is sheltered. The sheltered coast is dominated by extensive mangrove systems (230 km) and mudflats. Only 150 km of the coastline is significantly developed or urbanized and this includes Freetown (the capital).

Currently about 70 hotels and tourist resorts are found along the western Area Peninsula coastline. Elsewhere

the coastline is largely undeveloped except for some fish landing sites and cold storage infrastructure used to process and store fish and shrimps. The contribution of the coastal zone to the national economy is significant.

The coastal zone of Sierra Leone is one of the most densely populated areas of the country and is already vulnerable to a number of natural and man-made hazards including inundations from the major rivers flowing through Sierra Leone to the coast, flash floods which come down from a number of rivers during the monsoon period and also saline



intrusions due to decreased low water flows in the dry season. Because of all these characteristics the coastal zone of the country is particularly vulnerable to climate change impact.

This report provides a description of the coastal and marine environment of Sierra Leone as well as the oceanography of its coastal waters. The report further deals with the pressures and impacts of anthropogenic activities that directly affect the quality of the coastal and marine environment, such as fishing, shipping, ports and harbour development, submarine cable and pipelines, off shore



hydrocarbon exploration and exploitation, other marine based energy industries and offshore mining industries. It looks at other uses of ocean space such as waste disposal/ discharge, marine debris, tourism and recreation, and the potential impacts of climate change and sea level rise.

The report also provides a qualitative assessment of the state of the coastal and marine habitats as well as the current and future risks to the marine environment. The assessment is the result of the national workshop for production of the National State of the Coast Report, which was organized in Freetown, Sierra Leone from 4–7 February 2014. The methodology used at the workshop was based upon expert elicitation<sup>1</sup> (annex 1) to assess the state of the marine environment in Sierra Leone. A total of 50 scientists and experts from Sierra Leone attended the workshop. The workshop was organized by the Environment Protection Agency of Sierra Leone, in cooperation with the Abidjan Convention and under the guidance of experts from GRID-Arendal.

The qualitative assessment of marine and coastal habitats showed that most habitats are still in good and very good condition, and the trend during the last 5 years has been stable. A total of 13 habitat types were assessed. Condition of the seabed habitat of the inner shelf zones are believed to be improving. This is related to restrictions on bottom trawling which were implemented in recent years.

A total of 29 biodiversity parameters (species and species groups) were assessed. On average, biodiversity is assessed to be still in good condition for most places. Some species and species groups have strongly declined during the past 5 years, and are in poor condition: shark and rays, some bird species such as terns, demersal fish assemblages, small pelagic fish species and crustaceans. Declines in fish stocks can be attributed to overfishing.

It can be assumed that the ecological functioning of the marine ecosystem along the coast of Sierra Leone is still largely intact, as large stretches of the coast and marine zone are unexploited and undeveloped with limited pressures on the marine ecosystem. Two ecological processes have been assessed: spatial and physical disjunctions and biological migration processes. Spatial/ physical disjunctions are still in good condition as infrastructures (ports etc.) which impact the coastal and marine environment are still limited.

The condition of 16 physical and chemical processes has been assessed. On average, condition of physical and chemical processes, which are important to support marine

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1. A methodology paper is available on <http://some.grida.no>

habitats and species, are in a good to very good condition. An increased sedimentation is observed in several estuaries and bays along the coast and is problematic for these habitats (siltation). This phenomenon is related to intensification of agriculture and mining in inland areas. An increased turbidity is observed in the vicinity of Freetown. This is related to pollution, eutrophication and increased sediment and nutrient loads.

A number of pressures have been analysed for their impact on the environment and socio-economy. Artisanal fisheries exert little pressure on the marine environment, while it contributes significantly to the local economy and local communities. Industrial fisheries exerts a more profound impact on the environment, but it is assessed that the impact so far is still limited. Industrial fisheries scores high in terms of costs and benefits for the local economy and society.

The environmental impact of shipping is currently limited. The contribution of shipping to the local economy is rising, as shipping is increasing and brings economical developments. In general, considering the limited port infrastructure, the impact of ports in Sierra Leone on the overall marine environment is limited. Socio-economic benefits are rising as new port developments are underway. Submarine cables and pipelines presently exert almost no pressure on the coastal and marine environment of the country, as there are very few. Benefits of submarine cables and pipelines are high considering the value for communication and transport. Exploration and prospecting for oil and gas is in progress. Oil pollution of the beaches from sources external to Sierra Leone is a common characteristic. Oil pollution is usually limited, but medium to large pollution events have been recorded with a temporary serious nuisance. At this stage no visible effect on the coastal and marine environment has emerged yet. Marine pollution can be serious in some spots but, most of the time it is almost insignificant in most places. Pollution due to untreated industrial wastewater is currently limited as the few industries in Sierra Leone are mainly of a non-

polluting type. The Freetown sewage waters get directly into the sea but they were formerly not considered as a serious pollution problem due to their limited volume. However, various reports and studies conducted in relation to coastal and marine pollution in Sierra Leone have revealed that the management domestic waste including sewage is a serious problem. The intense rate of urbanization is prominent along the Freetown Peninsula or Western Area, much of which is poorly planned or unplanned. Marine litter pollution hot spots are associated with this area. Marine litter also originates from shipping.

Tourism infrastructure along the coast of Sierra Leone is currently limited and little pressure exists from this sector on the marine environment.

A total of 12 potential risks for the marine environment in Sierra Leone have been assessed at the workshop. The assessment examined whether the risk is likely to exert a significant effect in a 5 or 50 years timeframe. The assessment is based on likelihood of occurrence and consequence for the environment.

Shipping, coastal erosion, climate change and mining are identified as high risk factors that could have a high impact on the marine environment within 5 years. Fishing, oil and gas exploitation, pollution, tourism, port facilities and overfishing were identified as significant risks to the marine environment within 5 years. Harmful algal blooms and eutrophication were identified as moderate to low risk within the 5 year timeframe. Considering a 50 year timeframe, the risks of all these factors will increase with several of the factors moving from the 'significant' to 'high' risk category. Eutrophication is considered as a moderate risk.

The general outlook for the coastal and marine environment of Sierra Leone could be said to have improved over the last five years. This is due to considerable awareness and positive national and regional actions which have resulted in conscientious environmental stewardship and its sustainability nationally and within the region.



# 1. Introduction

## 1.1. Location, climate and relief of Sierra Leone

Sierra Leone is situated along the Atlantic west coast of Africa, between latitudes 6°55' and 10°00' north, and longitudes 10°14' and 13°18'. It has a coastline of about 560 km stretching from 6°55' north to 9° north. The coastal zone covers an area of about 71,740 km<sup>2</sup> (Fig. 1.1).

The climate is tropical with two well-defined seasons of wet and dry weather. The wet season generally lasts from May to November with two periods of squally weather, in March-April and May, and again in September to October. The highest observed cloudiness from the area is 6–7 oktas and is closely related to the influence of the equatorial monsoons blowing from June to November. The cloud amount decreases to 3–5 oktas during the months of December to April.

The highest amount of rainfall occurs during the rainy season. The heaviest rains occur in July and August. The

mean monthly amount of rainfall reaches its maximum in July and August, when the average number of rainy days is 27 out of 60 days in July and August.

The country is divided into the following main relief regions: the coastline interior lowland plains, the interior plateau and mountains. The shelf covers an area (to 200 meter depth) of 30,000 km<sup>2</sup>.

## 1.2. Demography

Sierra Leone's population doubled from around 2.5 million in 1970 to 5 million in 2004. It is estimated to have reached 6.4 million by 2012, and projected to grow moderately to 6.5 million by 2018. The growth rate peaked at 2.3% per year in 1985, but had declined to 1.8% in 2004.

Up to 55% of Sierra Leone's population inhabits the coastal zone and makes substantial use of the coastal resources. As the coastal population continues to grow, these resources

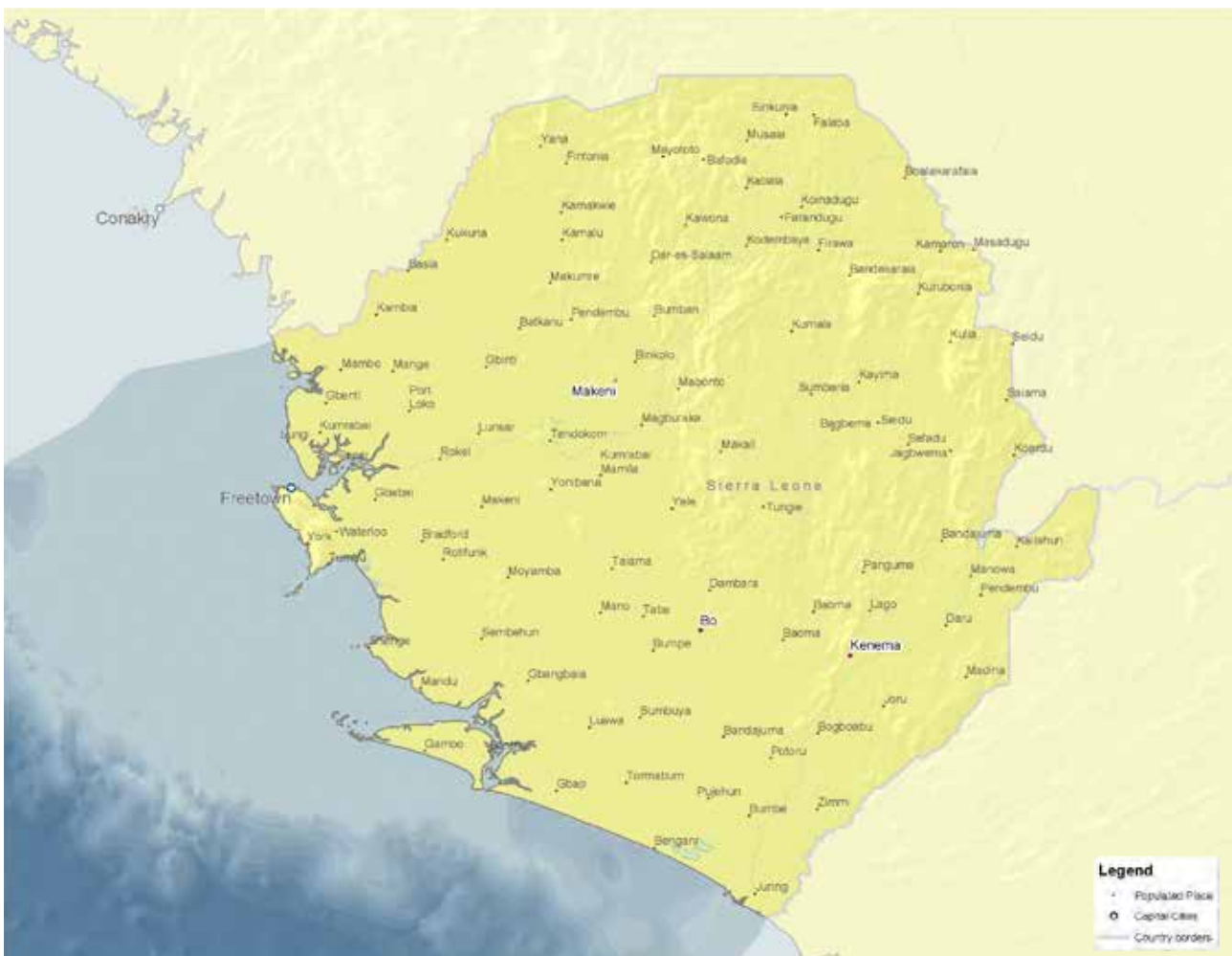


Figure 1.1: Map of Sierra Leone (GRID-Arendal)

correspondingly experience an increasing stress. However, the degree of coastal resources exploitation is to a large extent influenced by the population of the entire country in general and by the coastal population in particular.

The coastal population is not uniformly distributed. In the north, around the Scarcies River and Lungi areas, the population is around 80,000 whilst in the Freetown Peninsula areas it is about 1,250,000. In the south around Shenge, the population is close to 9,000 inhabitants and is around 8,000 in the Bonthe Sherbro area. The population of the coastal area is therefore approximately 1,347,000 persons. With an annual growth rate of about 2.5% it is important that a sound policy for the national exploitation of the coastal resources be pursued with the parallel development of appropriate institutional framework.

### 1.3. Socio-cultural and political structure

As indicated earlier, the social structures of the districts where the coastal resources are located are similar except for the Western Area. In the districts, there are chiefdoms each of which is ruled locally by paramount chiefs representing the various tribes in the chiefdom. Chiefdom councils made up of tribal authorities (chiefdom councilors) are set up to administer the chiefdoms and to advise the paramount chiefs who in turn coordinate with district councils etc. The villages are headed by headmen and village area committees administer the villages. The lowest level is the household level. These socio-cultural and political structures have a significant role in the development of effective management strategies for the coastal resources. In the Western Area, the administration is under the supervision of the Freetown City Council, which in turn coordinates with the various village area committees, tribal headmen and district councils.

Sierra Leone is a country where religious (as well as non-religious and within the context of tribal based traditional societies) traditions and customs are widely observed. The socio-economic activities of coastal communities include boat building, handicrafts, fishing, farming, animal husbandry (livestock rearing), petty trading and coastal marine transport.

### 1.4. Economy

#### Marine aggregates, minerals, oil and gas

There is a limited variety of natural resources found and extracted from the coastal area of Sierra Leone (Tab. 1.1). Diamond, gold, iron, ore, platinum, copper, cobalt, zircon and manganese nodules are reported to be present offshore. It is however worth noting that exploitation of natural resources is entirely in the hands of foreign companies and the national programs for development and use of these marine resources are not advanced. These quantities of natural resources are likely to be conservative estimates as exact data are not always available. Exploration and prospecting for oil and gas is currently in progress.

#### Coarse Aggregates

Alluvial gravel deposits in the coastal zone of Sierra Leone have not been assessed and no data are available regarding its exploitation in areas within and outside the zone.

#### Fine Aggregates

Beach sand is being extracted from beaches along the entire Sierra Leone Coast as construction material. However, data on the quantity extracted is anecdotal.

#### Clay

Clay soil is being extracted near beach areas and rivers. Traditionally, the clay soil is used for brick and ceramic making. The clay factory in Freetown used to produce about 130,000 bricks annually for both local consumption and export. If clay extraction is not controlled, the result will be a change in land-use to a non-vegetable open area vulnerable to erosion and a reduction in nearby water quality due to runoff.

#### Hard Rock

Hard rock has been mined along the banks of coastal streams as a source of construction material for the development of road networks and for export by foreign companies.

#### Salt

Salt production is gradually developing with a few ponds but is still at a rudimentary stage. However, there is a need to improve the national capacity to produce more and better quality salt with well-developed national programs for development and use of the resource.

The extraction of a limited variety of minerals from the coastal area of Sierra Leone particularly ilmenite and zircon, but also the extraction of coltan, hard rock and sand aggregates have led to an increase in the sediment load of the shoreline water column. Worst areas include the northern and southern coastal districts.

#### Port infrastructure, transportation, trade

Harbor infrastructure has been recognized as a possible threat to coastal and marine ecosystems through the modification of the coastal water dynamics, sediment dynamics and disruption of benthic habitats, flyways

**Table 1.1:** Annual estimate of mineral resources exploited from the coastal zones of Sierra Leone (Chaytor 1985)

Natural resource	Quantity (Metric tons)
Sand and gravel	80,000
Rutile	2,300,000
Ilmenite	1,800,000
Zircon	230,000
Monazite	2,500



and coastal vegetation. The Freetown harbor is the best natural harbor along the West African coast. International commercial vessel traffic to and from Sierra Leone has however been low over the past years since the rebel war started in 1991.

Traders and other business class people travel by sea to neighbouring countries (Guinea and Liberia) mainly by medium size boats, ferries and catamarans. This limits the amount of goods they transport. It is also an important means of transporting goods to and from Freetown to landing sites in the north and south of the country. Two other ports, point Sam and Nitty mainly serve the mining industry.

### **Urban Expansion**

One of the consequences of urban expansion is the increase in sand extraction and the risk of accelerated coastal erosion. Urbanization is also associated with a population increase and the attendant problems of waste generation and disposal as well as putting pressure on the use of other coastal resources e.g. mangroves.

### **Tourism, Recreation and Seaside Residences**

Tourism, recreation and seaside residences also contribute to the degradation of coastal ecosystems through increased effluent discharge into coastal waters and beach litter as well as to coastal population increase. These development activities may interfere with biological migration flyways and flyway stop over sites. Worst areas include the Freetown peninsula tourist area.

### **Fishing**

The most common methods of fishing involve the use of cast and ring nets, and hook and line, trawling, longlining and purse seining. Since the common method of catch preservation is drying, fuel wood is widely used, the main source of which are the mangroves. Different kinds of fish drying kilns are used but the traditional 'bandas' are the most popular. Fish landing sites are often polluted with huge piles of rubbish as inhabitants of the fishing communities often try to reclaim land from the sea. Worst areas include all fishing villages along the coast.

## **1.5. Methodology**

This report is the product of a desktop compilation of reports and studies, conference and seminar papers as well as personal communications, in combination with the outcomes of an assessment of the state of the marine environment using the expert elicitation (EE) methodology.

The expert elicitation methodology is essentially a scientific consensus methodology, aimed at generating an assessment of any chosen parameters by synthesising information available in existing assessments, scientific publications and data in conjunction with the subjective judgment of experts across a broad base of evidence related to those parameters. In the assessment workshop, grading scores are given for three aspects of each condition parameter: 1) the condition in the worst-impacted 10% of the region under consideration; 2) the condition in the least-impacted 10% of

the region under consideration; and 3) the condition in most (the remaining 80%) of the region under consideration.

The method has been applied successfully in a range of situations, including the 2011 Australian State of Marine Environment (SOME) Report (Australia State of the Environment 2011), and has the advantages that it is cost- and time-effective. It utilizes the existing knowledge of marine experts from the target region and it can incorporate non-conventional knowledge and information. A full overview of the methodology is available on the SOME website (<http://some.grida.no>) and as Annex 1.

In the absence of comprehensive regional or national indicator datasets, the SOME-EE process uses consultation with national and regional experts to gauge expert opinion about the condition of the marine and coastal ecosystems and dependent socio-economic sectors. There are commonly datasets from local areas, and there are many sub-regional scale studies and short-term datasets about various aspects of marine ecosystems, but these have often a too coarse resolution and are not part of a systematic collection of data and knowledge routinely synthesised for reporting purposes. The SOME-EE process draws upon these disparate datasets and the knowledge-base dispersed across a broad range of sources and institutions to capture a representative sample of existing expert knowledge about the condition of the national or regional marine and coastal environment in a manner that can be used for reporting purposes.

The outcome of the process include:

- Assessment of the condition of marine and coastal ecosystems: habitats, species and ecological/physical-chemical processes
- Assessment of pests, introduced species, diseases and algal blooms
- Assessment of environmental pressures and socio-economic benefits
- Risk assessment: consequence/impact and likelihood (5 and 50 year timeframes)

The ultimate success in the production and the legitimacy of a report ensuing from an expert elicitation process depends on the thoroughness of the steps leading to and after the elicitation has been carried out. The procedure included the following steps:

1. Identification of National Experts and Stakeholders: This step begins with the identification of the national and/or regional public and private bodies, agencies and organizations that, in addition to the one with the mandate of producing the report (in this case

the Environment Protection Agency of Sierra Leone (EPA)), deal with the major aspects of marine and coastal environment research, monitoring, management and regulation (“the stakeholders”). Experts from relevant agencies, ministries and universities were identified by EPA for participation in the workshop.

2. Relevant information identification and compilation: The EPA, with the support of the experts nominated, should initiate the identification and collation of relevant information (publications, scientific papers, databases and data sets) and make it electronically available to all experts involved.
3. Expert review of the assessment themes and parameters: GRID-Arendal and EPA identified a structure for the assessment built around a set of relevant themes and parameters. Of course not all may apply directly to a particular region, but they provide a guide for the design of the assessment to be carried out. Experts from EPA were requested to review and make suggestions on the parameters for condition, threats and risk, and the elicitation procedures. They will also review the collated relevant information and suggest additions.
4. Expert Elicitation assessment workshop: The EE assessment is carried out during a workshop or series of workshops, attended by the appointed experts. The scores assigned to the parameters are recorded during the workshop. Notes are taken by a rapporteur on the discussion and the details of relevant reports, papers or other documents are recorded. The interaction and discussions during the workshop/s should allow the editorial board to identify potential authors to participate in the subsequent report-writing phase of the process.
5. Report drafting: The scores of the assessment parameters and any details were compiled and analysed by GRID-Arendal and provided in a concise and organized way for inclusion in the report. The actual report was developed by Dr. Raymond G. Johnson.
6. Report reviewed, revised and published: The first draft was reviewed by GRID-Arendal and by the EPA editorial committee. The report was reviewed and endorsed at the validation workshop, which was attended by EPA, stakeholders and experts involved in the EE assessment. GRID-Arendal technically edited the peer-reviewed, final version of the report with graphic design and layouting prior to publication.

# 2. Major marine ecosystems

## 2.1. Oceanic Habitat in the Territorial Water

The Exclusive Economic Zone (EEZ) of Sierra Leone covers about 160,000 km<sup>2</sup> (Fig. 2.1, Tab. 2.1). The continental shelf of the coast of Sierra Leone is about 100 km wide in the north and tapers to about 13 km in the south towards Liberia. The total continental shelf area covers about 30,000 km<sup>2</sup> and it is perennially enriched by nutrients from the river networks, rendering the coastal environment a unique ecosystem, which serves not only as an important habitat for assemblages of marine organisms but also as a feeding and breeding ground for most economically targeted species.

The Sierra Leone continental shelf can be divided into four zones: the inner shelf, the middle shelf, the outer shelf and the shelf edge. The shelf is characterized by relatively plain surfaces inclined at angles of a few minutes and with an average width of about 62 km. The outer shelf limit lies at an average depth of 160 m. Each shelf zone is characterized by different angles of inclination of the bottom and they lie parallel to the coast in extensive strips. The inner shelf zone could be traced up to depths of about 20–30 meter, and is the zone of active wave activity. The geomorphology of this zone is closely related to that of the adjacent coast.

Major relief features include the coastal valleys of the Futa-Jallon highlands composed mainly of Paleozoic sands. The coastal valleys are covered with weathered and erosion products of the Futa-Jallon highlands. High temperature and moisture enhance intensive chemical weathering. The weathered material finds its way into rivers and is carried to the coast, where it is transported alongshore. The relief of the rivers catchments enables the movement of large quantities of terrigenous material (mainly quartz) into the ocean with waters of the surface flow. Other sediment sources including biogenic sediment sources are of secondary importance to the region. The chemical composition of the sedimentary material has a wide range and various types can be identified.

The middle shelf zone lies at depths between 20–30 meter and 60–70 meter and is usually the widest part of the shelf with a comparatively smooth surface. The bottom slopes at an angle of some few minutes and at some locations it is less than a minute. The outer shelf lies below 60–70 meter depth and is smaller in width with greater angles of inclination of the bottom. In some parts bed rock is common. This part of the shelf is commonly incised by the heads of canyons.

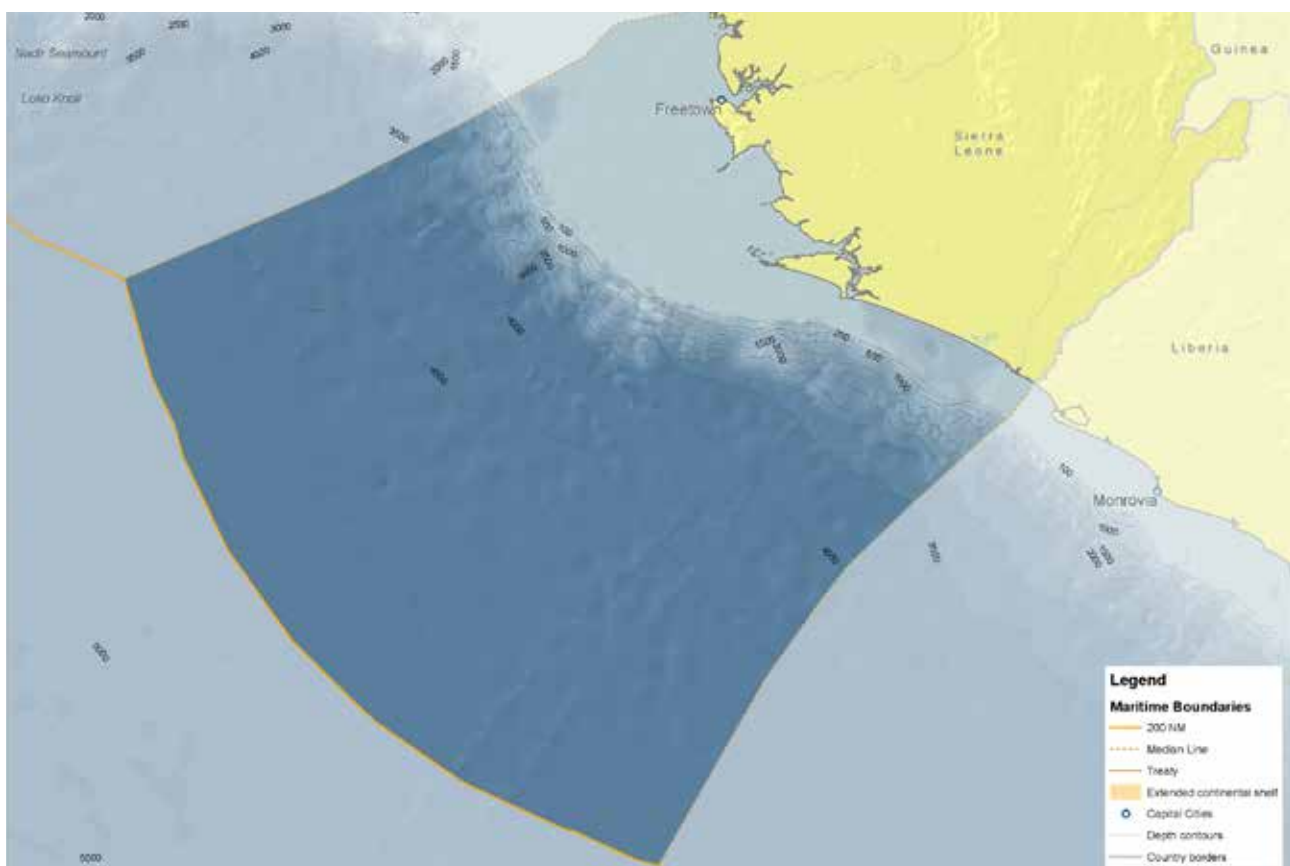


Figure 2.1: Maritime boundaries of Sierra Leone (GRID-Arendal)

**Table 2.1:** Basic statistics of Sierra Leone's EEZ (www.searoundus.org)

EEZ area	159,300 km <sup>2</sup>
Shelf area	26,611 km <sup>2</sup>
Inshore Fishing Area	18,301 km <sup>2</sup>
Tropical Coral Reefs	0.032 % of world
Seamounts	0 % of world
Primary production	651.22 mgC/m <sup>2</sup> /day
EEZ declaration year	1971

The northern portion of the Sierra Leone continental shelf is fairly wide about 50–100 km on average. Its central part is incised by laterally sloping valleys which have connections with present day river valleys and may well be their submarine continuation. Prominent features on that part of the shelf include the submarine deeps of Konakrdee and Yelliboya. The southern portion of the shelf is narrow being part of the Liberian shield and is about 45 km wide. The bottom slope is steeper than in other parts of the shelf, probably due to its narrowness. Amongst the prominent geomorphic features in that part of the shelf are the St. Ann shoals and Galinas delta. The St. Ann shoals trend northwest from Sherbro Island, reaching the outer shelf at the southern edge of the area and is roughly 30 km wide. It rises to depths of 5-14 meter and the surface is marked by several linear sand ridges oriented northeast southwest which are 3-5 meter wide and up to 7 meter high.

## 2.2. Water column systems

The water column systems comprise of the internal and continental shelf waters. The hydrological structure of the waters of the Sierra Leone Exclusive Economic Zone appears to be made up of an above thermocline upper mixed quasi-homogeneous layer, the vertical extent of which varies over the entire shelf. On average it occupies a layer from the surface to a depth of 20 to 25 meter, depending on location and season. It is otherwise called the shoreline water column.

Below this mixed layer is the thermocline, which is a layer with a sharp temperature gradient. The roof of the thermocline coincides with the base of the upper isothermal mixed layer and lies at some 20 to 25 meter also varying with location and season. The upper boundary of the thermocline is sharp with a gradient of more than 3° C per 10 meter but gradually decreases towards the floor to less than 0.4 ° C per 10 meter.

Below the thermocline are subsurface layers of the tropical Atlantic and the central waters of the North and South Atlantic. It was observed that during the rainy season, the quasi-homothermal waters are found in the quasi-homothermal layer as a result of mixing between the oceanic tropical water masses and the inshore waters from river discharge. Surface waters are characterized by horizontal inhomogeneity resulting perhaps from the diluting effect

of river discharge and increased precipitation. The possible diluting effect of river discharge is revealed to the West and South of Sherbro Island where zones separating dilute shallow water from seawater of high salinity can be clearly distinguished. A sub-surface salinity maximum is a prominent feature possibly resulting from horizontal advection from the sub-tropical and equatorial zones of high salinity waters and the fresh water diluting effect. During the dry season the main features described above are characteristic of the study area but with less prominence as the effects of high atmospheric precipitation, river discharge and solar radiation are diminished.

The possible diluting effect of river discharge is revealed to the west and south west of Sherbro.

## 2.3. Biological systems

One of the most important coastal biological systems are the mangrove forests. The mangrove forest is a salt water wetland dominated by mangroves which are halophytic, evergreen woody plants, tall and shrubby, belonging to several related families that share common habitat preferences, physiognomy, functional and structural adaptation. They are found along the shores of estuaries, sheltered creeks, lagoons, deltas and the brackish water zones. The mangrove ecosystem is a complex comprising of biota similar to that found on muddy intertidal flats and include invertebrate and vertebrate fauna, micro-organisms and the interacting biotic factors such as temperature, salinity and chemical constituents of the muddy deposits. Mangroves are noted for their high productivity.

Mangroves in Sierra Leone occupy 47% of the Sierra Leone coastline, covering a total area of 183,789 hectares (Chong 1979). In Sierra Leone the mangroves occur along the Scarcies River, Sierra Leone River, along creeks and bays in the Western area, the Yawri Bay and along the Sherbro River. The extent of the mangroves in these locations is summarized in Table 2.2. The rich mangrove forests of Sierra Leone have for long been exploited by the local population of the coastal areas whose main preoccupation is fishing. The mangroves forest and trees had been used basically for fish smoking which is

**Table 2.2:** Distribution and extent of mangroves in Sierra Leone (Chong 1987)

Location	Area (ha)	Percentage (%)
Scarcies River	13,007	7.1
Sierra Leone River	34,234	18.6
Western Area	7,189	3.9
Yawri Bay	29,505	16.1
Sherbro River	99,854	54.3
Total	183,789	100

an indigenous traditional way of preserving fish caught for sale, and also as an important source of fuel wood (Chong, 1987). The environmental role of this natural resource includes, coastal barriers in storm protection, flood and erosion control, and as habitat nursery ground for fish, shrimps and other marine fauna.

## 2.4. Structural systems

### 2.4.1. Canyons and Shelf break

According to surveys conducted by a number of international institutions, the Sierra Leone continental margin is incised with a number of canyons which serve as sediment traps (Fig. 2.2). The outer shelf lies below 60–70 meter depth and is smaller in width with greater angles of inclination of the bottom. In some parts bedrock is common. This part of the shelf is commonly incised by the heads of canyons. The state of these canyons is stable.

### 2.4.2. Seamounts

Seamounts are not characteristic of Sierra Leonean waters.

### 2.4.3. Large gulfs

Large gulfs are also not characteristic of Sierra Leonean coastal and marine areas.

### 2.4.4. Offshore banks, shoals, islands

Amongst the prominent geomorphic features in the southern part of the shelf are the St. Ann shoals and

the Galinas delta. The St. Ann shoals trends northwest from Sherbro Island, reaching the outer shelf at the southern edge of the areas. This shoal is roughly 30 kilometre wide and rises to depths of 5–14 meter and the surface is marked by several linear sand ridges oriented northeast southwest which are 3–5 meter wide and up to 7 meter high.

## 2.5. Major river deltas/wetlands

The Sierra Leone coastal area can be divided into four main hydrological areas. These are the Scarcies River, Sierra Leone River, Sherbro River and the Gallinas and Mano Rivers basins (Fig. 2.3).

### 2.5.1. Scarcies River basin

The river is tidal and during the rainy season rises about 2.7m. The wide estuary mouth has mud banks and sand bars forming Yelibuya and Kortimaw islands. Further inland, it splits into the Great and Little Scarcies Rivers which are relatively narrow and lined with mangroves.

### 2.5.2. Sierra Leone River basin

The main rivers entering this hydrological area are the Rokel, Port Loko creek and Kumrabai Creek.

### 2.5.3. Sherbro River basin

Three major river systems, the Taia, Sewa and Wange rivers enter the Sherbro River Estuary through a complex system of brackish water channels draining an extensive area

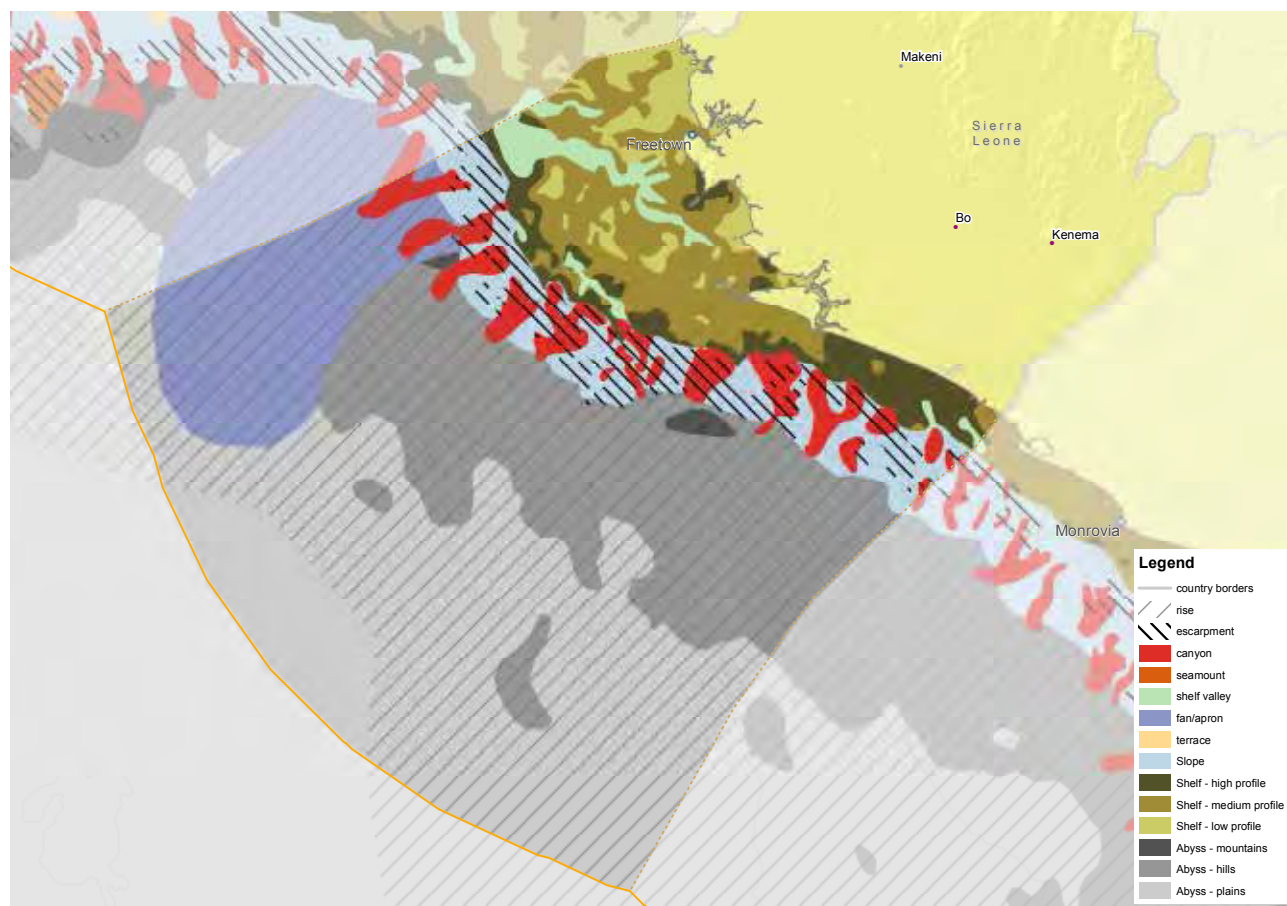


Figure 2.2: Geomorphology of the Sierra Leone maritime zone (GRID-Arendal, Harris et al. 2014)



**Figure 2.3:** Sierra Leone’s major river deltas/wetlands (GRID-Arendal)

behind the ancient beach ridges in the south east region. The water divides around Sherbro Island and flows west into Yawri Bay and south along Turner’s Peninsula.

**2.5.4. Gallinas and Mano rivers basin**

The Mano River divides Sierra Leone from Liberia and drains a large catchment area in the south. The strong surf and currents have formed an 8 km spit between the open sea and the narrow lagoon fed by the rivers.

**2.6. Coastal landforms**

The coastline of Sierra Leone can be divided into two sections:

- North of Bonthe characterized by a series of indentations representing estuaries, bays and creeks
- South of Bonthe Island which has about 200 kilometre of nearly unbroken steep sandy coast, and beach ridges backed with coastal swamps.

The coastal environment also consists of low cliffs (5–20 meter high) of poorly consolidated clay, silt, sand and gravel of Eocene to upper Pleistocene age, some of which have been subjected to intense erosion e.g. at Konakridi, Tisana, Shenge and Sulima point.

**2.6.1. Beaches**

Sierra Leone is endowed with beautiful expanses of yellow sandy beaches. They occur all along the Freetown Peninsula interrupted only by a few rocky headlands and bays. Some areas of the Sierra Leone coastline are dominated by mangroves and are devoid of beaches, or if present they are generally narrow and composed of fine-grained sand. The total length of the beaches is approximately 350 kilometer. Beaches along the Freetown peninsula are all-natural and are mainly sandy facing the eastern Atlantic. The beaches comprise mainly of fine-grained sand which offers a suitable habitat for a variety of invertebrate fauna. They also serve as nesting grounds for turtles and birds including gulls, sandpipers, terns and pelicans.







# 3. Marine Biodiversity

## 3.1. Plankton

Several studies confirm the close correlation between the seasonal oscillations of hydrological conditions of the habitat, abundance variability of planktons, and fish abundance on the Sierra Leone shelf and the West African waters.

The most recent study on plankton on the Sierra Leone shelf is found in Lamin (2011) and much emphasis is placed on the taxonomic diversity in relation to physico-chemical processes prevalent in 2008–10. The study recorded a taxonomic diversity of 49–61 zooplankton species from 20–24 genera/families, Calanoid copepods (30%) predominated throughout, followed by decapods.

For over a period of about 50 years now the mean depth of the thermocline has not changed, and accordingly the bathymetric distribution of the major species assemblages has not changed either. Lamin (2011) further noted that surface temperature increased from 28.43 °C in May 2008 to 30.20 °C in May 2010, but this should be viewed as synoptic and inconclusive to be attributable to climate change.

It could therefore be concluded that the plankton biodiversity has not shown any significant change over the past 2–3 decades, spatial distribution has remained fairly unchanged and oscillating with the seasons, whilst the relative predominance among plankton species in terms of biomass has changed with time as ecosystem trophic indices change.

## 3.2. Macro algae

There are three major categories of algae with about thirty species in Sierra Leonean waters belonging to the following groups: *Chlorophyta*, *Phaeophyta* and *Rhodophyta*. In 2011, the seaweed *Sargassum vulgare* and recently (2014), *Sargassum natans* and *Sargassum fluitans* invaded the country's coastal waters in unusually large amounts for the first time littering the entire coastline beaches. Since then this phenomenon seems to be a usual occurrence appearing around June and disappearing around October. During this period, activities such as fishing, navigation and tourism are being affected. The decaying plants produce an offensive odor on the beaches. This occurrence is now a national concern triggering studies initiated by the Environment Protection Agency Sierra Leone.

## 3.3. Coastal fisheries

### 3.3.1. Fish species of the Sierra Leone coastal estuarine environment

The Sierra Leone River Estuary has been studied in Sierra Leone with respect to fisheries resources (Watts 1957, Longhurst 1965, Sentengo and Ansa-Emmin 1986), individual studies on single species or assemblages have also been undertaken by various workers including *Pseudotolithus senegalensis* and *P. typus*, *Drepane africana* (Beresford-Cole 1982), *Pseudotolithus elongalensis*, *P. brachygnathus*, *P. typus*, *Pterocion peli*, *Pomadasy jubelini*, *Drepane africana*, *Chaetolipterus gorensis*, *Psettodes selchen*, *Galeoides decadatylus* and *Pentanemus quinquarus* (Fofana 2000).

As a matter of convention shrimps and crabs of estuaries and deltas are also included here. Only 3 (*Penaeus notialis*, *P. atlantica* and *P. kerathurus*) out of 6 species of shrimps are found in the coastal waters of Sierra Leone. There may be post larval stages and juveniles found in plankton. The species of crabs of commercial importance found in the Sierra Leone River estuary are the entire genus *Callinectes* and are *Callinectes pallidus*, *C. amnicola* and *C. marginatus*.

### 3.3.2. Ichthyofauna

A large number of species of fish have been recorded for the Sierra Leone River estuary (as high as 80 species). The fishes of Sierra Leone estuary belong to two categories (Longhurst 1969, Fager and Longhurst 1968, Longhurst and Pauly 1987): Pelagic fish species and estuarine and creek species.

### 3.3.3. Pelagic fish community

This is a rather diverse group and has been the subject of investigations for several years (Longhurst 1963, Williams 1968, Williams 1969, Villegas and Garcia 1983, Nieland 1980, Nieland 1982, Sentengo and Ansa-Emmin 1986, Anyangwa 1988, Coutin 1989). The dominant members of this group are the Clupeidae (*Ethmalosa fimbriata*, *Sardinella maderensis*, *Ilisha africana*). Others include: Carangidae (*Caranx*) and *Chloroscombrus chrysurus*. Some members of the Carangidae may make periodic incursions into the estuary at high tide: *Deceperus rhonchus* and *Trachurus tracea*. Tetraodontidae (*Lagocephalus cephalus*, *Liza falcipinis*), Sphyrnaenidae (*Sphyrna barracuda*), *Pristis pristis*, Dasyatidae (*Dasyatis margarita*).

The inshore demersal stocks include mainly the Sciaenid fauna. Members of the Sciaenid assemblage live above the thermocline on shallow muddy bottoms. Although some

60-80 species have been identified as belonging to this community, only some species are dominant. These include *Pseudotolithus elongatus*, *Drepane africana*, *Cynoglossus goreensis*, *Arius lasticutus* and *Dasyatis maragaritu*.

Stocks are under pressure from artisanal fishermen and from commercial trawlers. They are in poor condition and in a state of decline according to results of stock assessments and the present assessment.

### 3.3.4. Estuarine and Creek Community

The fish production in estuaries in Sierra Leone is not known. However, Blaber (1997) and Baran (2000) have calculated that West African estuarine fish production ranges around 15-16 tonnes/km<sup>2</sup>/year. Based on available information, fish production in the estuaries is between 3,855 and 4,144 million tonnes per year.

## 3.4. Marine fisheries

### 3.4.1. Inshore Pelagics

Among the inshore pelagic species, the most important species are the clupeids (*Ilisha africana*, *Ethmalosa fimbriata*, *Sardinella maderensis* and *Sardinella aurita*), the carangids and the scombrids. These fish categories are mainly migratory and closely related to the fluctuations of the environmental conditions within the estuaries and near-shore.

### 3.4.2. Offshore Pelagic Fisheries

The offshore pelagic fisheries consist mostly of species associated with three types of hydrographic regimes. *Engraulis encrasicolus*, *Sardinella aurita* and Decapterus species are found associated with the thermocline. *Scomber japonicus* and Trachurus species are found in the upwelling zones. Tuna species are also found in this zone, which include: Yellowfin tuna (*Thunnus albacares*), Skipjack tuna (*Katsuwonus pelamis*) and Little tuna (*Euthynnus alletterates*).

### 3.4.3. Inshore Demersal Fisheries

This community consists mostly of demersal fish species. It is diverse but in terms of abundance it is dominated by Sciaenidae. The prominent members of the Scianidae are *Pseudotolithus elongatus*, *P. senegalensis*, *P. brachygnatus*, *P. typhus*, Plynemidae (*Galeiodes decadactylus*, *Pentanemus quinquarius*, *Polydactylus qadrifilis*), Drepanidae (*Drepane africana*), Monodactylidae (*Monodactylus sebae*), Pomadasysidae (*Pomadasys jubelini*, *P. peroteti*), Lutjanidae (*Lutjanus goreensis*).

### 3.4.4. Offshore Demersal Fishery

The offshore demersal fishers include the spared fauna of the continental slope community and shellfish. The spared



fauna normally inhabits the regions below the thermocline on sandy and rocky bottoms. The shallow shelf lutjanidae sub-community is dominated by species, which include *Balistis capriscus*, *Pagellus bellotti* and *Dentex canariensis*. The deep shelf sparid community includes the *Dentex sp.* and the *Pendtheroscusion sp.*

The continental shelf edge community inhabits depths between 200–300m and is dominated by the genera, which includes Bembrops and Antigonina. The continental slope community, which includes genera such as Gleus and Citta, are found below 400m depth.

### 3.4.5. Shell Fish (Invertebrates, Squid, crustaceans etc.)

The crustacea and molluscs consist of the shrimps, cuttlefish and squid. Of the shrimp species of commercial importance *Penaeus notialis* accounts for about 96% of the landings and occurs of the Freetown peninsula especially around Banana Island. *Penaeus kerathurtus* occurs in the southern part of the coast. Both species inhabit the mangrove swamps, estuaries and inner continental shelf to a depth of 55m. Other species occur in deeper waters of 40–70m and above the continental slope. The inner shelf shell fish populations are assessed to be in good but declining condition.

## 3.5. Birds

There are 23 species of seabirds of globally important conservation status which frequent Sierra Leone's coastal waters, including Lesser Flamingo, Damara Tern, Avocet to name a few in addition to the list (Tab. 3.1). These birds

**Table 3.1:** List of sea- and waterbird species groups in the world and Sierra Leone

Common name	Family/Order	Number of species	
		World	Sierra Leone
Ducks, geese and swans	<i>Anatidae/Anseriformes</i>	14	
Storks	<i>Ciconidae</i>	19	7
Cormorants	<i>Phalacrocoracidae</i>	38	1
Boobies and gannets	<i>Sulidae</i>	9	2
Darters	<i>Anhingidae</i>	4	1
Bitterns, herons and egrets	<i>Ardeidae</i>	61	16
Storm petrels	<i>Hydrobatidae</i>	21	5
Shearwaters and petrels	<i>Procellariidae</i>	75	4

congregate around the mouths of rivers and estuaries on mud and sand foreshores which provide good feeding and nesting areas.

According to WIWO there are 89 species of marine and coastal birds. Also Sierra Leone lies on the Eastern Atlantic Flyway making it very important internationally.<sup>2</sup>

### 3.6. Turtles and Reptiles

Sierra Leone's coast is home to five species of marine turtles: the Green Olive Ridley (*Lepidochelys olivecea*),

Loggerhead (*Caretta caretta*), Leatherback (*Dermochelys coriacea*) and Hawksbill (*Eretmochelys imbricate*). These species nest directly on the beaches mainly in the south, around Turtle and Sherbro islands (Fretey 2001). Turtles in Sierra Leone are reported to be endangered. Nesting sites have been reported along the Peninsula but the expanding tourism industry have driven away much of these species from the beaches.

There are three species of Crocodiles: the Nile crocodile (*Crocodylus niloticus*), the Slender-snouted Crocodile (*Mecistops cataphractus*) which lives in streams found in the coastal areas for example No II River and the Dwarf crocodile (*Osteolaemus tetraspis*) found in mangrove swamps.

2. <http://www.imf.org/external/pubs/ft/scr/2011/cr111195.pdf>

# 4. Habitat

Oceanic habitats reach from the shoreline to the deep sea. Surface marine waters in the tropics are generally depleted in nutrients but in certain coastal regions, the nutrients are locally enhanced as a result of upwelling. The Sierra Leone coast as part of the Guinea Current coast is characterized by such an upwelling which is seasonal and occurs from Cape Palmas to Benin Republic.

The shallow coastal waters of the Sierra Leone have a highly diverse fish and invertebrate fauna, many of which are important in commercial fishing. Fish diversity in the coastal waters is reasonably well documented (FAO 1990). What is poorly known is the diversity of the benthic macro-fauna i.e. animals that live on the bottom or within the bottom sediment and can be retained on a 0.5 mm

sieve. The situation is much worse for the meiofauna i.e. organisms smaller than 0.5 mm. Sub-tidal benthic habitats are among the least studied in the waters of the Sierra Leone Continental shelf.

According to the assessment resulting from the workshop held in Freetown in February 2014, thirteen (13) habitats were assessed (Fig. 4.1).

## 4.1. Estuaries and deltas

While Sierra Leone is developing its fishing, mining and tourism industries, it is faced at the same time with intense rate of urbanization of the coastal areas. Owing to the increase in coastal population, coupled with

### Habitat quality assessment

Component	Summary	Assessment grade				Confidence	
		Very poor	Poor	Good	Very good	In grade	In trend
estuaries and deltas		Very poor	Poor	Good (Stable)	Very good	In grade (Adequate)	In trend (Limited)
small bays		Very poor	Poor	Good (Stable)	Very good	In grade (Adequate)	In trend (Adequate)
beaches (sandy beaches)		Very poor	Poor	Good (Stable)	Very good	In grade (Adequate)	In trend (Adequate)
rocky coasts, including non-coral reefs fringing coasts (intertidal and subtidal)		Very poor	Poor	Good (Stable)	Very good	In grade (Adequate)	In trend (Adequate)
seabed inner shelf (0-50m)		Very poor	Poor	Good (Improving)	Very good	In grade (Adequate)	In trend (Adequate)
water column shoreline (0-20m)		Very poor	Poor	Good (Stable)	Very good	In grade (Adequate)	In trend (Adequate)
water column inner shelf (20-50m)		Very poor	Poor	Good (Stable)	Very good	In grade (Adequate)	In trend (Adequate)
water column outer shelf (50-200m)		Very poor	Poor	Good (Stable)	Very good	In grade (Limited)	In trend (Adequate)
mangroves		Very poor	Poor	Good (Stable)	Very good	In grade (Adequate)	In trend (Adequate)
mudflats		Very poor	Poor	Good (Stable)	Very good	In grade (Adequate)	In trend (Adequate)
offshore banks, shoals, islands		Very poor	Poor	Good (Stable)	Very good	In grade (Adequate)	In trend (Adequate)
seabed outer shelf (50-200 m)		Very poor	Poor	Good (Stable)	Very good	In grade (Limited)	In trend (Limited)
coastal lagoons		Very poor	Poor	Good (Stable)	Very good	In grade (Evidence too low)	In trend (Evidence too low)

<b>Grades</b>	Very poor	Poor	Good	Very good
<b>Recent trends</b>	Declining	Improving	Stable	Unclear
<b>Confidence</b>	Adequate high-quality evidence and high level of consensus			
	Limited evidence or limited consensus			
	Evidence and consensus too low to make an assessment			

Figure 4.1: Summary of the habitat assessment for “most” places

unplanned settlements and poor waste management, the coastal area has become pollution hotspot which has contributed to the deterioration in surface and ground water quality.

In general the estuaries and deltas of Sierra Leone are found to be in good condition and stable. Estuaries and bays around Freetown receive most of the effluents from the industries. Pesticides from agricultural run-offs may also enter the estuaries as well as sediments from river mining activities and the indiscriminate clearing of the mangroves and forests. The most affected (worst) places are along the Freetown coastline and the best places are found along the Freetown peninsula coastline and in the north and south of the country.

#### **4.2. Small bays**

The bays and estuaries support diverse ecosystems for which inhabitants of the coastal areas and beyond derive their livelihood. Around these coastal water bodies occur extensive fringes of mangroves, tidal swamps and intertidal mud flats. Because of their location near terrestrial sediment sources, the estuaries and bays contain large amounts of nutrients. The combination of this nutrient supply with generally shallow water gives rise to a diverse and large flora and fauna. These areas are important as a source of recreation, transportation and food and also they serve as a receptacle for waste disposal.

According to the assessment, small bays are in fairly good condition in Sierra Leone.

#### **4.3. Beaches (sandy beaches)**

In general, beaches are found to be in good condition. Ten percent of the best beaches along the Sierra Leone's coastline are all-natural without major human influences and are mainly sandy facing the eastern Atlantic (e.g. Kent beach). The worst ten percent include the Goderich, Lakka and Hamilton beaches, all of which show signs of erosion. This is mainly due to sand extraction activities taking place at those sites. The Lumley beach is probably undergoing erosion due to the changing regime of the sea (accelerated sea level rise). Most of the beaches outside the western area do not have tourist recreational facilities and are used mainly as fish landing sites: e.g. Tombo, Shenge, Konakridi, Kambia, Pujehun, Port Loko, Moyamba and Bonthe. The best places are along the Turner's peninsular.

The sandy beaches are in generally good condition.

#### **4.4. Rocky coasts and islands**

The biodiversity of the rocky shores include mollusks, barnacles, oysters, mussels, periwinkles, limpets, gastropods, algae and coralline sponges. The loss of biodiversity and integrity of rocky coasts is mainly due to human activities, e.g. infrastructure development and resource exploitation such as sand and stone excavation, but also sea level rise. The wildlife observed include birds, lizards, crabs and mollusks.

In most places, the rocky coasts are in very good condition. However most of the islands are being eroded namely, Plantain, Yeliboya and Bunce Islands.



#### 4.5. Seabed inner shelf (0–50m)

The seabed inner shelf is mainly under threat from trawling activities. However, this habitat is in good condition and is improving.

#### 4.6. Seabed outer shelf (50–200m)

The seabed outer shelf will possibly be affected in the future from offshore oil extraction activities. However, this habitat is assessed to be currently in very good condition and stable in the past 5 years.

#### 4.7. Water column shoreline (0–20m)

Possible threats for the water column in the shallow areas near the shoreline include fishing, waste disposal and habitat degradation due to pollution. However, this habitat is in good condition and is in stable condition the past 5 years.

#### 4.8. Water column inner shelf (20–50m)

Possible threats for the water column in the inner shelf areas include fishing activities, waste disposal and habitat degradation due to pollution. This habitat is assessed to be in good condition and stable the past 5 years.

#### 4.9. Water column outer shelf (50–200m)

Possible threats for the water column in the outer shelf areas include fishing activities, waste disposal and habitat degradation due to pollution. This habitat is assessed to be in good condition.

#### 4.10. Mangroves

Forest resources in the coastal zone are exploited for a variety of uses. Prominent amongst these is the fuel wood trade in mangrove forest wood as well as poles for building and other purposes. Coastal forests are exploited for boat building and handicraft. Oyster farming from mangroves and other hard sub-strata is another activity of coastal dwellers. Oysters are harvested for both commercial and subsistence purposes.

Peri-urban agricultural practices are common in Sierra Leone and are a usual feature of the coastal area. Swamp rice is one of the main crops cultivated in the coastal area. In some areas notably in the Kambia district, rice has been cultivated in areas previously occupied by mangroves. Mangrove areas have also been cleared for salt extraction. The mangroves are generally in a good condition along most parts of the coastline. In other parts, mangroves have been decimated due to conversion to other uses. The best places are found along parts of the Sierra Leone River Estuary, the Jong and Moa rivers. The worst places include the Scarcies river estuary, Ribbi and Kargboro creeks.

#### 4.11. Mudflats

Mudflats in general are in good condition in areas along the Freetown peninsula and parts of the northern and southern sectors of the coastline. However, shelter construction is threatening the stability of mudflats near Freetown. Garbage and debris also contribute to the degradation of mudflats.

#### 4.12. Offshore banks, Shoals and Islands

These structural habitat systems currently face little or no pressure and are therefore assessed to be in in very good condition and stable. The confidence in grade is high and for the above submission is derived mainly from project reports and studies as well as from Environmental Impact Assessment studies.

#### 4.13. Coastal lagoons

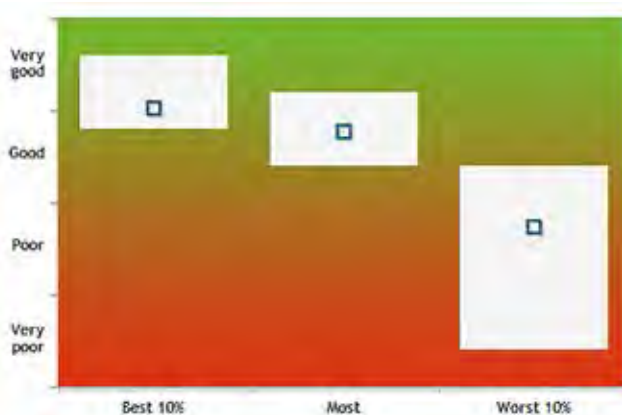
The drainage system consists of a series of rivers from north to south including Great Scarcies, Little Scarcies, Rokel, Jong, Sewa, Moa and Mano and their associated estuaries.

The coastal water resources include the bays and estuaries of the rivers of the Rokel (Sierra Leone River), Great and Little Scarcies, Sherbro, Jong, Sewa, Moa and Mano. Nearly all these rivers flow parallel to one another right across the country from the high interior plateau in the east towards the lowland coastal areas before debauching into the Atlantic Ocean.

In general, coastal lagoons are in very good condition. In some areas, incidents of pollution have been reported although not serious. These areas are found mainly downstream of mining areas.

#### 4.14. Summary (habitat assessment)

Thirteen habitat types were assessed at the workshop. The average score for the habitats indicates a good condition for most places (Fig. 4.2). The condition of the habitats is assessed to be stable in the last 5 years.



**Figure 4.2:** Summary table of the habitat assessment. Average, high and low scores for the condition assessment in the Best 10 %, Most (80 %) and Worst 10 % of places

# 5. Species

A total of 29 species or species groups have been assessed (Fig. 5.1). On average biodiversity seems to be in good condition. Several groups show a declining trend over the past 5 years (e.g. inner shelf demersal and pelagic fish species, terns). Condition of other species or species groups seems to be stable. A discussion on the results is provided below.

## 5.1. Dolphins

Little is known about the status of populations in Sierra Leone with the exception of sporadic sightings. The Atlantic Humpback dolphins (*Sousa teuszii*) frequently occur in the artisanal bycatch. Other cetaceans include the Clymene and common dolphins which are often sighted in deep waters beyond the 50 m isobar.

According to results of the assessment, dolphin populations are in a very good condition. This is because they are not harvested.

## 5.2. West African Manatee (*Trichechus senegalensis*)

A single representative of the Sirenean, the African manatee (*Trichechus senegalensis*) occurs in river estuaries of Sierra

Leone. They frequently occur in the vicinity of the Ribbi River, Bonthe, Gbondapi etc. The assessment revealed that manatees are still in good condition.

## 5.3. Sharks and rays

Sharks and rays are exploited using bottom set nets respectively and their fishing efficiencies are subject to environmental variability. The artisanal fish landings for sharks appear to be at a peak in the dry season (March–April) and generally lower in rainy season (June–August). The reason for the apparent differences in seasonal shark landings has been attributed to the turbulence in the water column as a result of the ensuing tidal current caused by the rains. The situation would normally create difficulty in setting the net and hence undermine catchability and landings of shark species.

The dominant ray species in shrimp trawl fisheries are *Dasyatis pastinaca* (44%) and *D. margarita* (23%). The shark species are dominated by *Sphyrna lewini* (72%) and *Carcharhinus obscurus* (15%). In the case of finfish demersal trawl fisheries, the dominant shark species are *Carcharodon carcharias* (44%), *Carcharhinus brevipinna* (15%) and *Sphyrna lewini* (15%).

These stocks are under pressure from commercial trawlers.





# Species Assessment

Component	Summary	Assessment grade				Confidence	
		Very poor	Poor	Good	Very good	In grade	In trend
Dolphins					☐	■	■
West-african manatee ( <i>Trichechus senegalensis</i> )				☐		■	■
Sharks and rays - targeted and bycatch			☐			■	■
Sharks and rays - non exploited				☐		■	
Blue shark ( <i>Prionace glauca</i> )			↗			■	■
Scalloped hammerhead ( <i>Sphyrna lewini</i> )				☐		■	■
Common tern ( <i>Sterna hirundo</i> )			☑			■	■
Sandwich tern ( <i>Sterna sandvicensis</i> )			☑			■	■
Tuna and billfish				↗		■	■
Inner shelf (0-50m) demersal fish assemblages			☑			■	■
Outer shelf (50-200m) demersal & benthopelagic fish assemblages				☐		■	■
Slope - demersal fish assemblages (>200m)				☐		■	■
Meso-pelagic fish assemblages				☐		■	■
Small pelagics - inner shelf (0-50m)			☑			■	■
Small pelagics - outer shelf (50-200m)				☐			
Inner-shelf reef fish assemblages (0-50m)				☐		■	■
Inner shelf – squid etc				☐		■	■
Inner shelf - crustaceans			☐			■	■
Inner shelf – other invertebrate spp.				☐		■	■
Shoreline and intertidal soft sediment invertebrate spp.				☐		■	■
Shoreline and intertidal rocky shore invertebrate spp.				☐		■	■
Benthic filter feeders of soft and hard substrata				☐		■	■
Seabirds (resident)				☐		■	
Seabirds (migratory)				☐		■	■
Turtles				☐		■	■
Mangrove species				☐		■	■
Seagrass species				☐		■	■
Algae species	Some data			☐		■	■
Dune, saltmarsh, foreshore, wetland species				☐		■	■

<b>Grades</b>	<span style="display:inline-block; width:15px; height:15px; background-color:red; border:1px solid black;"></span> Very poor	<span style="display:inline-block; width:15px; height:15px; background-color:orange; border:1px solid black;"></span> Poor	<span style="display:inline-block; width:15px; height:15px; background-color:yellow; border:1px solid black;"></span> Good	<span style="display:inline-block; width:15px; height:15px; background-color:lightgreen; border:1px solid black;"></span> Very good
<b>Recent trends</b>	<span style="display:inline-block; width:15px; height:15px; border:1px solid black; text-align:center; vertical-align:middle;">↗</span> Improving	<span style="display:inline-block; width:15px; height:15px; border:1px solid black; text-align:center; vertical-align:middle;">☐</span> Stable	<span style="display:inline-block; width:15px; height:15px; border:1px solid black; text-align:center; vertical-align:middle;">☑</span> Declining	<span style="display:inline-block; width:15px; height:15px; border:1px solid black; text-align:center; vertical-align:middle;">?</span> Unclear
<b>Confidence</b>	<span style="display:inline-block; width:15px; height:15px; background-color:green; border:1px solid black;"></span> Adequate high-quality evidence and high level of consensus		<span style="display:inline-block; width:15px; height:15px; background-color:yellow; border:1px solid black;"></span> Limited evidence or limited consensus	
	<span style="display:inline-block; width:15px; height:15px; background-color:red; border:1px solid black;"></span> Evidence and consensus too low to make an assessment			

Figure 5.1: Summary of the species (and species groups) assessment for 'most' places

## 5.4. Tuna and Billfish

The tuna species, which include *Thunnus albacares* (yellowfin tuna), *Katsuwonus pelamis* (skipjack) and *Euthynnus alletterates* (little tuna) are associated with upwelling zones. Tuna stocks are in good condition and improving according to results of the present assessment.

## 5.5. Inner shelf (0–50m) demersal fish assemblages

The shelf demersal stocks include mainly the sciaenial fauna. Members of the sciaenial assemblage live above the thermocline on shallow muddy bottoms. Some 60–80 species have been identified with the dominant ones being *Pseudolithus elongatus*, *Drepane africana*, *Cynoglossus goreensis*, *Arius laticutis* and *Dasyatis margarita*.

These stocks are under pressure from artisanal fishermen and from commercial trawlers (Fig. 5.2). They are in poor condition and in a state of decline according to results of stock assessments and the present assessment.

## 5.6. Outer shelf (50–200) demersal and benthopelagic fish assemblages

According to the assessment and results of stock assessment surveys (2005, 2010) these assemblages are in good condition and stable.

## 5.7. Slope-demersal fish assemblages (>200m)

According to the results of stock assessment surveys; (2005, 2010) these assemblages are in good condition.

## 5.8. Meso-pelagic fish assemblages

These assemblages are in good and stable condition.

## 5.9. Small pelagics – inner shelf (0–50)

These fisheries are in a poor and declining condition.

## 5.10. Small pelagics – outer shelf (50–200)

Stocks of small pelagics are in good but declining condition.

## 5.11. Inner shelf Shell Fish (Invertebrates, Squid, Crustaceans etc.)

The two species of Cuttle fish, *Sepia officinalis* and *Sepia berthelotii* are found in the north and south of the EEZ on coarse ground at depths of 17–18m. There are four squid species; *Thysanoteuthis rhombus* and *Toderopsis eblanae* are demersal below 1000 meter depth.

Molluscs such as bivalves are commercially important shell fish resources for the coastal communities. Mangrove oyster (*Crassostrea tulipa*) can be found on the roots of mangrove trees in coastal swamps and estuaries where they are harvested for subsistence as well as for commercial purposes. Other bivalves exploited include clams such as *Senilia senilis*, *Anadara senegalensis*, cockles and periwinkles (*Tympanotonus* spp.).

The Inner shelf shell fish populations are assessed to be in good condition.

## 5.12. Outer shelf and inner slope invertebrate species

The invertebrate species of the outer shelf and inner slope also consist of the shrimps, cuttlefish and squid. These stocks are being exploited by commercial trawlers. They are in good condition according to results of the present assessment.

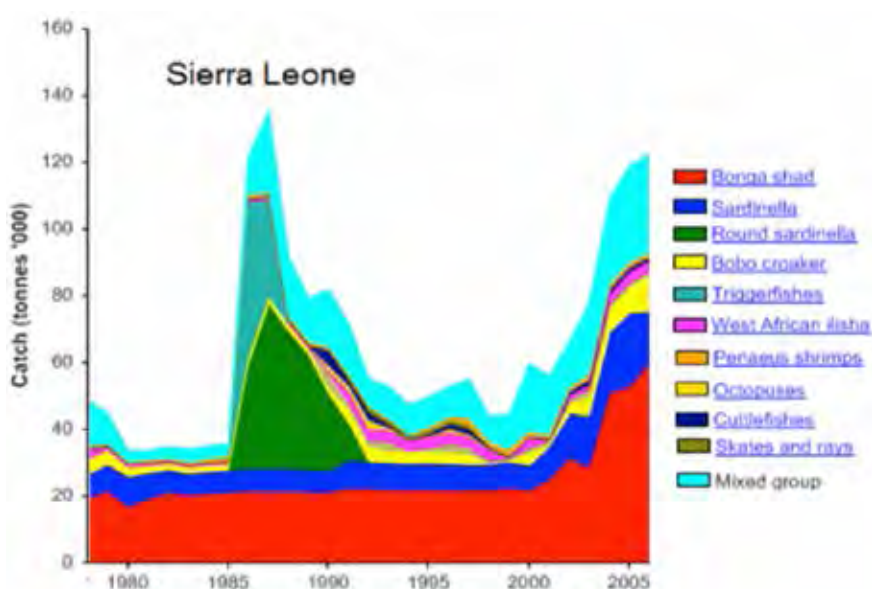


Figure 5.2: Fish landings Sierra Leone (Sea Around Us project 2011)



### 5.13. Shoreline and intertidal rocky shore invertebrate species

Shrimps and crabs of estuaries and deltas are also included here. Only 3 (*Penaeus notialis*, *Penaeus atlantica* and *Penaeus kerathurus*) out of 6 species of shrimps are found in the coastal waters of Sierra Leone. There may be post larval stages and juveniles found in plankton. The species of crabs of commercial importance found in the Sierra Leone River estuary are the entire genus *Callinectes* and are *Callinectes pallidus*, *C. amnicola* and *C. maginatus*.

Two of the six shrimp species of commercial importance *Penaeus notialis* and *Penaeus kerathurtus* inhabit the mangrove swamps, estuaries and inner continental shelf to a depth of 55m.

As in the case above, these fisheries are in good condition.

### 5.14. Benthic filter feeders of soft and hard substrata

Several benthic fauna species occur in the estuaries of Sierra Leone (Tab. 5.1). Longhurst (1958) has identified the following assemblages of benthic organisms in the Sierra Leone River Estuary:

Venus community, *Amphioplus* sub-community, *Venus/Amphioplus* transition, *Pachymelania* sub-community and Estuarine gravel community.

The Venus community is found near the mouth of the estuary and in the deep channel on shelly-sand and fine lateritic gravel. It is dominated by poriferans, nemerteans, small crustaceans, brachyuran, pagurids, procellanids, lamellibranches, asteroids, echinoderms and ascidians. The most important members include: *Brachiosstoma leonense*, *Aloidis sulcate*, *Astroecten michaelsoni*, *Tris carbonorea*,

*Modiolus stutorum*, *Astrangia* sp., *Oliva accuminata* and *Rotula orbiculus*.

The *Amphioplus* sub-community occurs on mud, shelly-mud and sandy mud in the lower reaches. It is a much more diverse group and may consist of poriferans, brachyurans, crustaceans, gastropods, bivalves, polychaetes and ophiuroids. The representative members may include: *Upogebia furcata*, *Callianassa balssi*, *Clymene monilis*, *Pectinoria sourei*, *Goniada multidentata*, *Glycera convolute*, *Deopatia neapolitanea*, *Nereis senegalensis*, *Notomastus*

**Table 5.1:** Dominant benthic fauna of Sierra Leone's estuaries

<b>Polychaeta</b>	
<i>Clymene monilis</i>	<i>Lumbrineris impatiens</i>
<i>Glycera convoluta</i>	<i>Goniada multidentata</i>
<i>Diopatra neapolitana</i>	<i>Terebellida</i>
<i>Pectinaria sourei</i>	
<b>Gephyrea (Sipunculidae)</b>	
<i>Ochetostoma Mercator</i>	<i>Sipunculus titubens</i>
<b>Branchiopoda</b>	
<i>Lingula parva</i>	
<b>Echinodermata</b>	
<i>Rotula orbiculus</i>	<i>Acrocnida semisquamata</i>
<i>Holothuroidea</i>	<i>Ophiuroidea</i>
<i>Amphioplus congensis</i>	<i>Astropecten michaelsoni</i>
<b>Mollusca</b>	
<i>Iphigenia truncata</i>	<i>Surcula coerulea</i>
<i>Tellina nymphalis</i>	<i>Pachymelania aurita</i>
<i>Donax owenii</i>	<i>Neritina oweniana</i>
<i>Mactra</i> sp.	<i>Neritina rubricata</i>
<i>Glycimeris</i> sp.	<i>Neeritina glabrata</i>
<i>Aloidis dauzenbergi</i>	<i>Aloidis trigona</i>
<b>Cephalochordata</b>	
<i>Branchiostoma leonense</i>	
<b>Crustacea</b>	
<i>Squilla africana</i>	<i>Polyonyx</i> sp.
<i>Callianassa balssi</i>	<i>Diogenes pugilator</i>
<i>Alpheus pontederiae</i>	<i>Paguristes</i> sp.
<i>Penaeus notialis</i>	<i>Uca tangeri</i>
<i>Parapenaeus atlantica</i>	<i>Heteropanope caparti</i>
<i>Bigelowina septemspinosa</i>	<i>Menippe nodifrons</i>
<i>Upogebia furcata</i>	<i>Porcellana longicornis</i>
<i>Latreutes parvulus</i>	<i>Clibanarius cooki</i>





*latericeus*, *Nephtys polybranchia*, *Marginella amygdale*, *Natica mapochiensis*, *Cerebratulus sp.*, *Iphigenia laevigata*, *Cutellus tenuis*, *Clibenarius cooki*, *Tellina angulayus*, *Talona explanata* and *Tellina nymphalis*.

The *Venus/Amphioplus* transition is a mixture around the lower and middle reaches in the sand-mud regions. It consists mainly of an *Amphioplus* sub-community with the addition of isolated individuals from the *Venus* community. Dominant members of this community are *Nassa tritoniformis*, *Olivia sp.*, *Pusionella rifat*, *Luidia alternate*, *Astropecten michaelsoni*, *Rotula orbiculus*, *Branchiostoma leonese* and *Upogebia furcata*.

The *Pachymelina* sub-community occurs on deposits of coarse sand in the upper reaches of the estuary. It contains the bulk of the truly estuarine communities. The members are found on sand and muddy sand with the filter feeding gastropod; *Pachymelina aurita* being the most dominant. Other gastropods may include *Aloidis trigona*, *Neritina glabrata*, *N. owenians*, *N. rubricata* and the bivalve *Iphigenia truncate*.

The Estuarine gravel community is a specialized community consisting mostly of sedentary, epifaunal organisms found on patches of lateritic gravel. The characteristic species found on estuarine gravel community are *Astrangia sp.*, *Actinian sp.*, *Thelepus sp.*, *Balanus amphirite*, *Aspidosipton venatum* and *Arca imbricate*.

At the Bunce River the benthic fauna recorded consisted of the following: *Pectinaria sourel*, *Uca tangeria*, *Tympanotonus fuscatus* and *Metagrapsus curvitus*.

The assemblages of benthic organisms in the Sierra Leone River Estuary are not known to be exploited. They are therefore in good condition.

### 5.15. Turtles

The population is assessed to be in good condition.

### 5.16. Mangrove species

Mangrove species in the coastal zone are exploited for a variety of uses. Prominent amongst these is the fuel wood trade in mangrove forest wood as well as poles for building and other purposes. They are also exploited for oyster production. These species are in a good condition. Recent monitoring of mangroves of Sierra Leone suggests they will decline unless actions are implemented and enforced.

### 5.17. Macro-algae

Macro-algae species are not known to be exploited and are therefore in good condition.

## 5.18. Plankton

The plankton of the Sierra Leone River estuary and parts of its creeks and bays have been studied by many researchers (Watts 1958, Aleem 1979, Leigh 1973, Findlay 1978, Conteh 2001).

Horizontal distribution and seasonal fluctuations in plankton production are intricately linked with the changes in climate during the rainy and dry season. During the rainy season (May–September), there is a reduction in solar insolation, increased discharge of freshwater, increase in sediment input on the shelf and the lowering of the temperature. During this period there is instability. Stability returns in November after a complete mixing of the estuarine water in October by strong winds. In the dry season (November–April) there is a reduction in river discharges, reduction in stream velocity, increase in wave and tidal effects, and increase in solar radiation and temperature leading to stratification.

Phytoplankton production increases in December followed by an increase in zooplankton density in January and February. There is rapid reduction in nutrients due to corresponding uptake by phytoplankton and loss from surface waters due to dying plankton sinking to the bottom. There is a gradual increase in salinity due to intrusion of oceanic waters and a high evaporation rate reaching a maximum in May or June. Cold oceanic water intrusion during the prevailing Harmattan depresses temperature at optimum salinities, thus favouring high standing stocks of plankton during the middle of the dry season at the middle

reaches (Leigh 1973). Seawater temperature reaches a second peak in April and May during which period plankton production decreases.

In general high plankton production is between the end of the rainy season to the middle of the dry season (October–February). There is a decline from March to June, which extends into the rainy season.

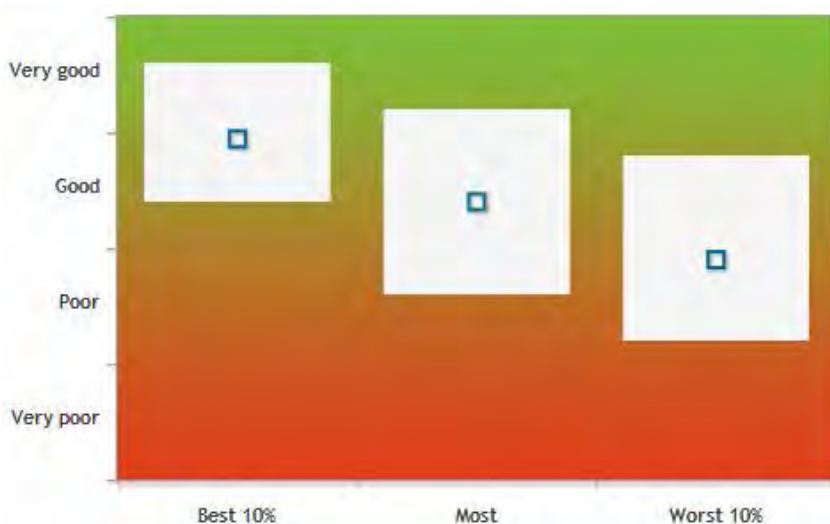
The major phytoplankton species are: *Thalassiosira*, *Nitzschia*, *Pleurosigma*, *Coscinodiscus*, *Thalassonema*, *Skeletonema*, *Amphora*, *Ceratium*, *Peridinium*, and *Oscillatoria*. Some blue green algae may occur in the rainy season.

Dominant phytoplankton species in the dry season appears to be *Coscinodiscus* and *Thalassiothrix*. In the rainy season the dominant species are *Thalassiothrix*, *Coscinodiscus* and *Thalassiosira*.

Algae species are not known to be exploited, no major changes in composition have been observed and are therefore in good condition.

## 5.19. Summary (species assessment)

A total of 29 parameters (species and species groups) were assessed at the workshop. The average score for species indicates a good condition for most places (Fig. 5.3). The condition of species in the best 10% places is assessed as being good, ranging from good to very good. The condition of species in the worst 10% places is assessed as being poor, ranging from poor to good.



**Figure 5.3:** Summary of the species assessment. Average, high and low for the condition of species in the best 10%, most and worst 10% of places

# 6. Physical, chemical and ecological processes

The Sierra Leone continental shelf is located in a unique position on the West African coast where it comes under the influence of the Guinea Current, southern off-spins of the Canary Current, the Equatorial Counter Current and the coastal drift occurring in the shallower waters. The resultant effect of these forces is crucial to the ecology of the shelf by creating a vacuum in the northern parts of the shelf and generating some amount of upwelling so necessary for primary production.

The physical and chemical processes of a marine environment determine the quality of its biodiversity and habitats. The overall health of marine ecosystems can therefore be assessed by examining the status and trends of the major physical and chemical processes taking place in it. Such processes as erosion of rock and sediments, volcanic activity, gas exchange with the atmosphere, the metabolic and breakdown products of organisms and precipitation, affecting the coastal morphology, marine biota, biological productivity and the structure of marine assemblages.

The continental shelf of Sierra Leone is very broad in the north and tapers towards the south. Wave action and tidal activity play a significant role in the shallow areas. Besides regulating the diurnal life of aquatic organisms they are involved in the transport of pollutants and the disposal of waste especially along the beaches.

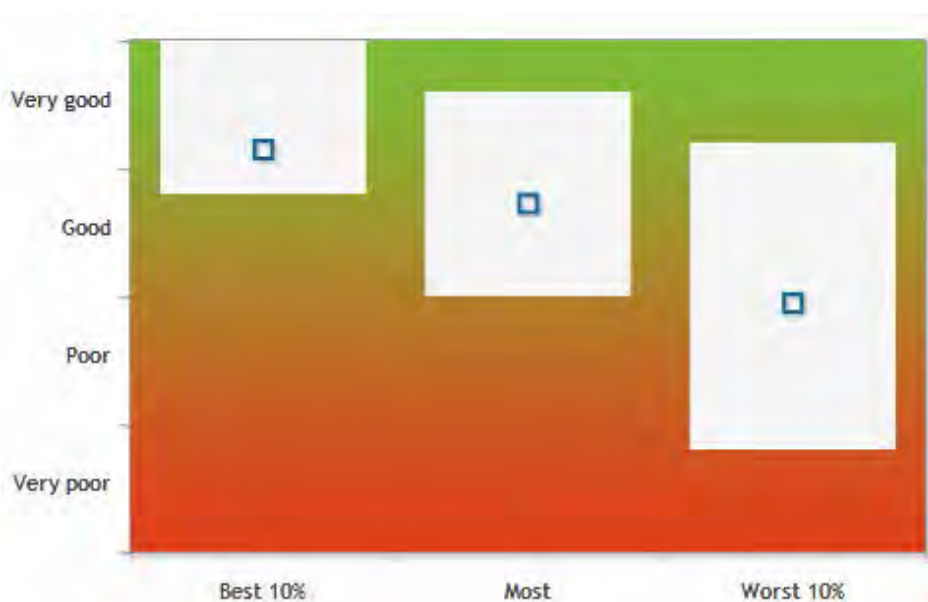
Sixteen physical and chemical processes have been assessed. Most of them were found to be in good condition (Fig. 6.1), according to the assessment at the workshop (Fig. 6.2). Sediment transportation is a problem (assessed to be in poor condition) due to large amounts of sediments of agricultural and mining activities entering some of the rivers, estuaries and lagoons.

In addition to the physical and chemical processes that have been assessed, two ecological processes have been assessed as well (Fig. 6.3). These are related to disturbances in the physical environment. In general the processes are still in good condition and functioning due to the fact that the coasts of Sierra Leone remain largely undeveloped.

The impacts of spatial or physical disjunctions are high around harbours and seem to have increased over the past 5 years. Some wetlands have been affected by dredging and development, with an impact on their function as stop-over site for migrating birds.

## 6.1. Sea water Temperature

Sea surface temperatures, derived from COADS 1950-1990, show a temperature range from 27 to 28.5°C between February and May, a temperature drop to 26.8°C between May and August and again a rise to 27°C from August and November. The average temperature in December is 28.5°C and 27.8°C in January.



**Figure 6.1:** Summary of the physical and chemical processes. Average, high and low for the condition of the physical and chemical processes in the best 10%, most and worst 10% of places

## Physical and chemical processes assessment

Component	Summary	Assessment grade				Confidence	
		Very poor	Poor	Good	Very good	In grade	In trend
Guinea Current structure and dynamics	Some changes (worst places) due to climate change and Guinea Current North Atlantic 'El Niño'.				[-]	■	■
Severe storms, wind patterns	Increase in severe storms and wind patterns is climate change related. Areas in the north and south of Sierra Leone are more affected.			✓		■	■
Sediment inputs	Examples of least impacted coastal areas are found in the Scarries river region. The worst places are influenced by agriculture, damming of rivers, deforestation, diamond mining, coastal development (most extreme around Freetown).			✓		■	■
Inshore water turbidity, transparency and colour	The best locations are found near the Scarries river region. Examples of the worst impacted areas are around mining areas north and south, the Freetown coastal development in bays and estuaries.		✓			■	■
Sea surface temperature	The global rise in SST has not caused any significant local impacts, no ENSO effects are being recorded.				[-]	■	■
Sea level	Places in Sierra Leone where there is no significant impact include rocky coasts and natural mangrove coasts. This phenomenon is associated with global sea level rise, coastal erosion and local subsidence (eg, at Bonthe Island)				[-]	■	■
Land-sourced nutrient supply and cycling	This includes river and ground-water input plus surface runoff. The best examples are found around the Scarries river. The worst places are associated with fertilizers, sewage etc. Examples include the Adjar area (Rokel River, Malien River) with sugarcane and palm oil plantations for biofuel, pineapple plantations.			✓		■	■
Ocean-sourced nutrient supply and cycling	Includes upwellings, mangroves and anthropogenic inputs (eg. fish farms)			■		■	■
toxins, pesticides, herbicides	The best places include the Scarries river region.			[-]		■	■
Dumped waste	Domestic waste and trash are widely dumped into the sea. Worst examples include the Freetown bays, Kingtom Granville dump site. Fish kills reported in the 1980's were caused by suspected dumping, dredge spoil dumped in Freetown estuary and sewage discharge from Freetown.			✓		■	■
Marine debris, wracks	Worst places include the Freetown beaches, Mahers Beach in Lungi			[-]		■	■
Sediment transportation	Examples of least impacted coastal areas are found around the Scarries river. Examples of places most disturbed by humans causing sediment mobilisation (mining, coastal development, sand mining, deforestation, etc). Examples of these areas are found around Freetown and mining areas in the north and south.		✓			■	■
Coastal/shoreline erosion	Examples of locations where erosion is not an issue include the southern region around Sulima and Bonthe island. Examples of areas severely affected by erosion include the area around Freetown, the Freetown peninsula and islands.			✓		■	■
Freshwater inflow, surface and groundwater runoff	Best examples: many rivers in Sierra Leone which are free flowing into the sea: Scarries river region. Worst example: Rokel river and Moa river which have been dammed but freshwater still reaches the coast.			[-]		■	■
Ocean land salinity/acidity	Worst places are found in zones affected by the acid sulphate soils disturbed in rice farming - Kambia region.			[-]		■	■
Nutrient supply and cycling: ocean based	Best places: open coasts and well mixed and flushed by the ocean: Southern coast, Turners peninsula. Worst places: bays where ocean sourced nutrients supplies and cycling have been disturbed by human impacts: Kroo Bay, Susana Bay, Man-of-War Bay, Jul Port (Bunce River).			?		■	■

<b>Grades</b>	Very poor	Poor	Good	Very good
<b>Recent trends</b>	Improving	Stable	Declining	Unclear
<b>Confidence</b>	Adequate high-quality evidence and high level of consensus			
	Limited evidence or limited consensus			
	Evidence and consensus too low to make an assessment			

Figure 6.2: Summary of the physical and chemical processes assessment for 'most' places

## Ecological process assessment

Component	Summary	Assessment grade				Confidence	
		Very poor	Poor	Good	Very good	In grade	In trend
Spatial/physical disjunctions	Harbour authorities are reporting impacts around harbours due to dredging (Sierra Leone River estuary). Other caused: aggregate mining, removal of mangroves, beach mining, coastal development over habitats (Aberdeen marine creek)			↗		■	■
Biological, migration, flyways	The Aberdeen creek flyway stop-over site is threatened. The Sierra Leone River estuary is affected by dredging and development.			—		■	■

<b>Grades</b>	<span style="color: red;">■</span> Very poor	<span style="color: orange;">■</span> Poor	<span style="color: gold;">■</span> Good	<span style="color: green;">■</span> Very good
<b>Recent trends</b>	<span style="border: 1px solid black; padding: 2px;">↗</span> Improving	<span style="border: 1px solid black; padding: 2px;">—</span> Stable	<span style="border: 1px solid black; padding: 2px;">↘</span> Declining	<span style="border: 1px solid black; padding: 2px;">?</span> Unclear
<b>Confidence</b>	<span style="color: green;">■</span> Adequate high-quality evidence and high level of consensus			
	<span style="color: yellow;">■</span> Limited evidence or limited consensus			
	<span style="color: red;">■</span> Evidence and consensus too low to make an assessment			

Figure 6.3: Ecological process assessment for “most” places

Mean temperature profiles up to 500m depth in the area of the continental shelf show the development of a sharp thermocline below the warm surface waters. The gradient of temperature here sometimes exceeds 3°C per 10m. Below the thermocline temperatures continue to fall gradually with depth.

It is worth noting that the global rise in SST has not caused any significant local impacts in Sierra Leone.

### 6.2. Salinity

The average salinity of the sea surface waters off the Sierra Leonean coast is generally less than 35.5 psu (Fig. 6.4). The salinity is influenced by fresh water run-off from land and rainfall especially during the rainy season. Mean

salinity profiles in the shallow areas close to the coast are characterized by low salinities at the surface, which result from the inflow of fresh water. The limits of the salinity homogeneous layer correspond to the upper limits of the thermocline showing that the salinity and thermal structures are similar in the surface layer. Below the surface a sub-surface salinity maximum (S=35.7°) exists between 60–70m depth. Below the maximum, salinity gradually decreases to a minimum around 500m depth.

### 6.3. Ocean Currents

Currents are dynamic features of coastal waters of Sierra Leone and affect the coastal zone in a number of ways. The surface currents are significantly influenced by the Southeast and Northeast trade winds. During the spring in the Northern

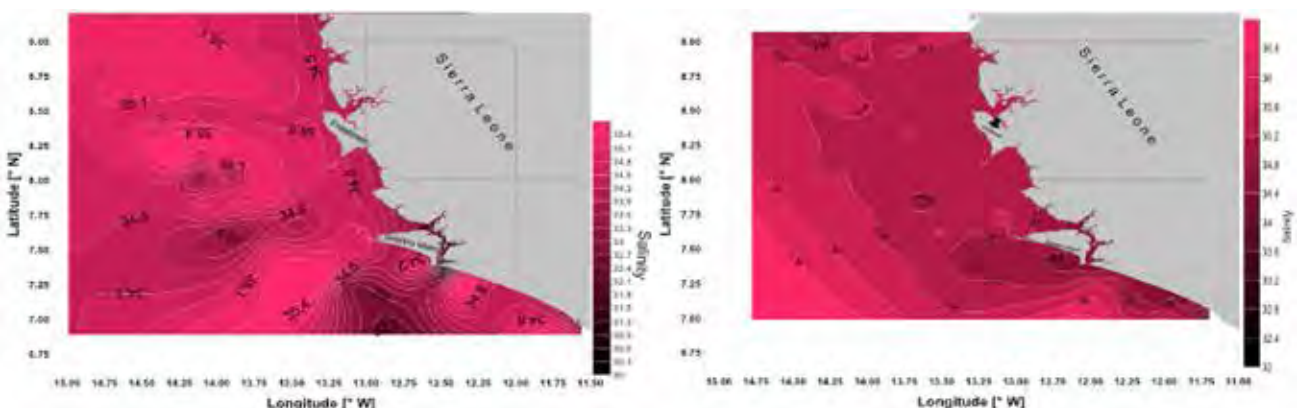


Figure 6.4: Surface salinity (Lamin 2011)



Hemisphere when the Southeast Trades noticeably weaken, the Northeast trades are full developed. During this period the Canary current intensifies bringing cool water to the coast of Sierra Leone. This current generally flows in a southeasterly direction at the surface in the near-shelf regions.

The Canary current is mainly southward from August to April. When this current approaches the equator, it turns westward as the North equatorial current. The monsoon period generally lasts from July to August; during the Northern Hemisphere summer. During this period, the equatorial counter current is strongly developed and is the source of much water joining the Guinea current. In the winter months (December to February) however, the equatorial counter current ceases to be of importance and the canary current is the main source of water joining the Guinea current. In the autumn the southeast trades strengthen reaching maximum strength in August. During the May – July period, the canary current moves northward carrying low salinity Liberian surface waters to the north as far as Senegal (Berrit, 1969).

#### **6.4. Seasonal Upwelling and Productivity**

The Sierra Leone coastal zone lies at the southernmost extension of the upwelling system which occurs along the entire northwest African coast Dakar – Freetown region. In Sierra Leone, the continental shelf is isolated from the seasonal coastal upwelling areas of North-West Africa and central Gulf of Guinea by a complex of shoals (submerged sand banks) that comprises the Bissagos Archipelago, off Guinea-Bissau in the North and the shoals of Saint Ann to the South. The area of the continental shelf up to a depth of 200 m is about 30,000 km<sup>2</sup>.

The western tip of Sherbro Island delimits two contrasting coastal waters. The narrow southern shelf has limited fish resources and is influenced by the eastward flowing Guinea current. The northern Sierra Leonean coast on the other hand constitutes the productive shelf of Sierra Leone. Therefore, most of the artisanal fishing activities in Sierra Leone occur in the North. Here, there are three major estuaries: the Scarcies River, the Sierra Leone River and the Sherbro River, as well as the Yawri Bay. The continental shelf has good yield potential for demersal and pelagic fish as well as shrimps.

According to Coutin (1989), a strong upwelling occurs each year along the coast of North-West Africa between December and April and especially between October and February for the Dakar – Freetown region during the Harmattan. These Harmattan winds cause aerobic upwelling along the entire northwest African coast.

Longhurst (1983) indicated that the continental shelf waters of Sierra Leone are influenced by the Cape Verde divergence to the north and the convergence at the northern margin of the Equatorial Counter Current (ECC) further south of the equator. Upwelling is characteristic of the former whilst down welling is a feature of the latter.

Analysis of limited hydrographic data suggests that upwelling off the Sierra Leone coast is characterised by a shallower thermocline and nutrient enrichment below the surface at 20m depth (Johnson & Johnson 1996).

The upwelling phenomenon has not been studied in detail with regards to causes, timing, persistence and impacts climate and productivity of the Sierra Leonean coastal zone. Productivity and upwelling are inextricably interwoven.

#### **6.5. Tides**

At the northern mouth of the Sierra Leone River estuary, a sand bar of considerable magnitude obstructs the flow of water from and into the estuary and consequently the velocity of the tidal stream is very great. In the dry season, during spring tides, the flood stream runs from 1 to 1,5 knots lasting for about 5 hours, and the stream on the ebb tide varies from 2 to 2,5 knots for about 7 hours. In the wet season, however, when the tidal prism is augmented by the flood discharge from the river, the ebb stream attains velocities in the region of 5 knots. The tide brings in fair quantities of sediments from the upper reaches of the estuary.

The highest astronomical tide of maximum tidal range goes up to 3.38 metres above the lowest astronomical tide or the admiralty chart datum. Mean high water neaps are 3.0 meter above Chart Datum whereas mean low water neaps are 1.0 meter above Chart Datum.

#### **6.6. Waves and Swells**

Almost a perennial swell of moderate height, coming in from the Atlantic disturb ships at their moorings within the estuary. This phenomenon is particularly evident during the wet season when both frequency and amplitude are greatest. The maximum amplitude is in the region of 1.0 meter. Winds waves, usually not higher than 1.0 meter, only occur for brief spells usually just before the change of seasons about May and October.

#### **6.7. Sediment Transport Processes**

Longshore drift current is the main mechanism by which sediments are transported along the Sierra Leone coast. The sediment transport takes place mainly within 1–10m water depth. Three main longshore drift current directions can be recognized along the Sierra Leone coastline. These currents flow in a north eastern direction causing erosion of the northern coastline around Yeliboya Island and Konakrdee. Similar south easterly flowing currents in the south carry sediments from the Freetown Peninsula beaches and along the entire southern coastline of Sierra Leone.

Tidal currents also influence the sediment transport dynamics particularly those of very fine sand and mud mainly at the entrances of bays and estuaries.

Examples of least impacted coastal areas are found around the Scarcies River. Examples of places most disturbed by humans causing sediment mobilization (mining, coastal development, sand mining, deforestation, etc.) are found mainly in the north and south of the country.

## **6.8. Longshore Currents**

Along the Sierra Leone coast, longshore currents accompany large swell waves breaking obliquely to the coastline. These currents flow in a northeast direction along the northern shores causing a fairly serious erosion of the northern parts of the coastline around Yelibuya Island and Konakridee.

In the south, similar south-easterly flowing currents carry sediments from the coastal beaches of the Freetown Peninsula and all along the southern part of the Sierra Leone coastline to the Liberian border enhancing beach erosion.

The waves, which generate these currents, are themselves generated by wind force of 3-4 beaufort, which are strongest during the Harmattan (northeast trade winds) months of December and February and August to October during the monsoon winds from mainly the Southwest. Longshore current velocities along the Freetown Peninsula can range from 0.20m/sec to 1.5m/sec.

## **6.9. Tides and Tidal Currents**

The astronomical tide manifest itself as a periodical rising and falling of the sea level which results from the attracting forces of the celestial bodies, mainly those exercised by the sun and moon on the adjacent water masses.

Off the Sierra Leone coast, the tide is mainly semi-diurnal, with two daily maximums and minimums, the mean height of the tide or mean tidal range is between 1.8m to 2.6m. The tidal currents are generally of moderate velocities of between 0.1–0.2 meters per second.

## **6.10. Rip Currents**

These are localized out flowing currents through occasional depressions or 'lows' in offshore bars resulting from the outflow of water that would otherwise accumulate inside the zone of breakers after wave breaking.

Rip currents may sometimes appear as long lanes of foamy or turbid water stretching out to sea. They weaken and gradually die out further out to sea. These currents have not been reported along the coast of Sierra Leone.

## **6.11. Storm Surges**

Storm surges manifest themselves in periodic often seasonal flooding events of low lying coastal areas along the Sierra Leonean coastline. However, reports of such events are lacking. These flooding events occur mostly during the months of June to September and are usually

associated with the development of low pressure systems far out in the south Atlantic which result in high winds and the generation of large swells at sea.

The northern areas of Sierra Leone along parts of the Kambia district as well as close to the southern border with Liberia are frequently affected. The Freetown peninsula coastline has also suffered from these storms although to a lesser extent. These events are particularly severe when reinforced by high and spring tides.

## **6.12. Spatial/physical disjunctions, harbour infrastructure**

Harbour infrastructure can interfere with community structure of benthic communities. Worst areas include the Sierra Leone harbour at the mouth of the estuary, Nitti port in the Sherbro estuary and around Pepel in the upper reaches of the Sierra Leone River (Rokel).

The marine and coastal space is utilized for transportation, fishing, trade, mining, tourism and recreation, communication, ports and harbours etc. Both marine and river transportation facilities have to be improved with regards to port facilities safety standards and quality of service mainly for local coastal transport. All of these processes cause special and physical disjunctions to various ecological systems and biological migration flyways.

## **6.13. Sea Level**

Places in Sierra Leone where there is no significant impact include rocky coasts and natural mangrove coasts. This phenomenon is associated with global sea level rise, coastal erosion and local subsidence (e.g. Bonthe Island).

## **6.14. Land-sourced nutrients supply and cycling**

This includes river and ground water input plus surface runoff. The best examples are found around the Scarcies River. The worst places are associated with fertilizers, sewage etc. Examples include the Addax area (Rokel River, Malen River) with sugar cane and oil palm plantations for biofuel and pineapple plantations.

## **6.15. Ocean-sourced nutrient supply and cycling**

This includes upwelling, mangroves and anthropogenic inputs e.g. fish farms.

## **6.16. Toxins, pesticides, herbicides**

The present level of agricultural wastes, herbicides, pesticides and fertilizers discharged may not yet constitute a major concern but the rate at which mangrove vegetation is being lost to rice-planting is worrisome. The best places include the Scarcies river region.



### **6.17. Dumped waste**

Domestic waste and trash are widely dumped into the sea. Worse examples include the Freetown bays, KingTom, and Granville dumpsites. Fish kills reported in the 1980s were caused by suspected dumping, dredge spoil dumped into the Freetown estuary and sewage discharge from Freetown. Ndomahina (1994) reported the mass mortality of catfishes (*Arius spp.*) along the entire coastline.

### **6.18. Marine Debris Wracks**

The condition is assessed to be good, but the worst places include the Freetown beaches and the Mahera beach in Lungi.

### **6.19. Sediment Transportation**

The condition is assessed to be poor and declining. Examples of least impacted coastal areas are found around the Scarcies River. Examples of places most disturbed by humans causing sediment mobilization (mining, coastal development, sand mining, deforestation, etc.) are found mainly in the north and south of the country.

### **6.20. Coastal Shoreline Erosion**

The condition is assessed to be good, but declining. Examples of areas where erosion is not an issue include the southern region around Sulima and Bonthe-Sherbro Island. Examples of worst areas affected by erosion include the area around Freetown, the Freetown peninsula and islands.

### **6.21. Freshwater inflow, Surface and Groundwater runoff**

Many rivers in Sierra Leone are free-flowing into the sea. However, worse conditions occur in the Scarcies River region. The Rokel River and the Moa River have been damned, but fresh water is still flowing.

# 7. Pests, introduced species, diseases and algal blooms

Outbreaks of diseases, non-natural algal blooms and infestations by pests have been assessed as symptoms of an unhealthy marine ecosystem.

The results of research estimates indicate that a very high percentage of the pollution currently discharged into the coastal area is done by the local inhabitants. Untreated waste on beaches and in the nearshore zone is directly related to the health status of the local population. Epidemics such as typhoid fever, cholera and similar outbreaks are the results of poor sanitation or the symptoms of consuming raw or partially cooked oysters, clams and mussels harvested from coastal waters into which raw or inadequately treated sewage had been discharged (Meith-Avcin and Helmer, 1978).

High concentrations of harmful nutrients and micro-organisms are usually contained in untreated and inadequately treated waste. Aquatic 'over nourishment' from nutrients may lead to eutrophication of coastal receiving water bodies like estuaries and bays bringing various negative consequences such as plankton blooms, oxygen depletion and fish kills. Such adverse circumstances are sometimes observed in the streams, rivers, and estuaries but they go unrecorded.

The Sierra Leone marine environment is overall in good condition with regards to pests, introduced species, algal blooms and outbreaks of diseases that can disturb the ecological balance of the aquatic realm.

However, the problem of coastal and marine invasive species is likely to worsen over the coming decade due to increases in shipping activities throughout the region. Ship traffic is projected to continue growing into the coming decade with economic growth and therefore the outlook for transfer of alien organisms through ship's ballast water could be expected to grow.

The Queen Elizabeth II quay is the primary international gateway for all foreign vessels entering into the country. There have not been documented any pest species from this quay or any of the wharfs to have caused any significant ecological impact in the local areas. There have been reports of malaria and such outbreaks, especially in coastal areas of high urbanisation and population densities, and these have been attributable to poor sanitation where mosquitoes have been able to proliferate in stagnant water settlements. The high risk areas for such incidents to happen are in



Sector II (Sierra Leone River estuary) and Sector IV (Yawri Bay) in and around the port and other smaller shallow bays and estuaries.

There is limited knowledge on adverse marine impact or outbreaks affecting populations of birds and marine mammals. Incidents of poisoning of marine species affecting the trophic hierarchy of the marine food chain have also not been reported recently.

There are visible evidences of fouling organisms such as barnacles on ships' hulls but these are local mollusc species which are not known to be harmful to man or other marine species. In fact they are edible for local residents!

The intense level of shipping activity that is associated with the increasing traffic at the main port in Sector III has probably made a big contribution to this minor problem. However, no data are available on the ecological impacts of such fouling and, for now, these effects are assumed to be neutral in terms of ecological function.

There are occasional incidents of natural algal blooms and the proliferation of jelly fishes (*Physalia sp.*) occurring in some coastal areas directly connected to the ocean, like the Peninsula, but only low levels. Blooms of *Sargassum spp.* have been occurring in coastal waters since 2011. Worst areas affected include the coastal water column and beaches along the entire coastline.

In other bay areas of coastal and related development occurred outbreaks of cholera due to poor catchment management in these areas because of sediment and nutrient input (such as in floods), local groundwater contamination, urban run-off and sewage management. No data exists on the relationship between these causes and effects.

In the 1980s there had been reports of one pest species, the grey triggerfish from the family Balistidae (*Balistes spp.*) Its proliferation on the Sierra Leone shelf had been a source of great worry because its presence was associated with the decline in the population of some other more highly valued species. Its occurrence however had been attributable to hydrographic cycles when colder waters from the northern Canary currents affected distribution patterns in the lower latitudes until the Gulf of Guinea.

The Queen Elizabeth II Quay is an international port and therefore exposed to many hazards including the introduction of invasive species from ships' ballast waters.



These questions have not been scientifically investigated and as such no comparison or conclusion can be drawn about such issues.

There were evidences of the proliferation of the crown-of-thorns starfish at No. 2 River estuary acting as a 'fouling' organism on cultured oysters. That observation was only in the 1980s and such population increases have not been observed during the past two decades.

The proliferation of populations of the sea urchin is sometimes still reported by local fishermen at fishing grounds especially in the southern parts below the Freetown peninsula, but these occurrences are sporadic and do not cause alarm. There have been no reports of fish kills over the past 5-10 years.

Little information is available on this subject and no assessment was produced.

# 8. Pressures – Environmental and socioeconomic impacts

There are several factors that affect the coastal environment of Sierra Leone (Tab. 8.1). Seven different pressures were assessed during the workshop. How they impact the condition of the marine environment, and their socio-environmental impacts (Fig. 8.1).

## 8.1. Fisheries

Artisanal fisheries exert little pressure on the marine environment, while it contributes significantly to the local economy and local communities. Industrial fisheries exerts a more profound impact on the environment, but the pressure is still assessed as moderate. Industrial fisheries contribute some socio-economic benefits for the local economy and society.

The industrial fisheries is made up of local trawlers or shrimpers owned by Sierra Leoneans or chartered through agreements, and produces fish for the local market; they also produce high-priced products like shrimps, cuttlefish, tuna, spiny lobster and some finfish. There is also a foreign fleet set up under various joint-venture agreements exploiting pelagic as well as demersal stocks. These foreign vessels comprise trawlers, shrimpers, longliners and carrier vessels.

The living marine resources of Sierra Leone are utilized by commercial and artisanal fisheries for providing livelihood and employment for thousands of fishermen and foreign exchange for the participating countries. The resources are both locally important resident stocks supporting artisanal fisheries and transboundary migratory stocks that have attracted large commercial offshore foreign fishing fleets that create additional stress on the fishery resources. A number of countries also have fishing rights agreements with coastal countries.

There is little capacity in Sierra Leone as well as in the nations of the region to effectively monitor and enforce those agreements. It is believed that some of the fish caught in the region by the distant water fleets are imported to the region.

The countries are also net importers of fish and fish products. Some reports seem to suggest that some fish stocks are depleted.

## 8.2. Shipping

Presently there is moderate pressure on the coastal and marine environment of the country emanating from the development of shipping activities. As the country is aspiring to become a middle income country by 2025, foreign investment in the mining sector in particular is definitely going to increase.

The socio-economic benefits of shipping is significant. The contribution of shipping to the local economy is also rising, as shipping is increasing and brings economic developments.

## 8.3. Ports and harbour infrastructure

The Queen Elizabeth II Quay is the country's only port that could accommodate ocean-going vessels. It was completed and commissioned in 1954. It is located at the mouth of the Sierra Leone River Estuary. After rehabilitation in 1986, it was extended to accommodate up to 6–8 normal cargo vessels as opposed to 3–4 in 1954. Some of the areas which were natural and under-developed are now undergoing transformation as a result of large scale development of ports and harbours and ancillary facilities linked to the

**Table 8.1:** Significance of factors affecting the coastal environment of Sierra Leone

Issue	Significance	Remarks
Manufacturing Industries	Moderately high	< WHO standards GCLME reports & studies NBSAP reports & studies Fisheries reports & studies
Recreation and Tourism	High	
Fishing Industry	High	
Development of Urban settlements	Moderately high	
Harbour infrastructure	High	
Transport		
Road infrastructure		
Climate change vulnerability	High	IPCC 5th Assessment report.
Agriculture		
Oil and gas exploration		

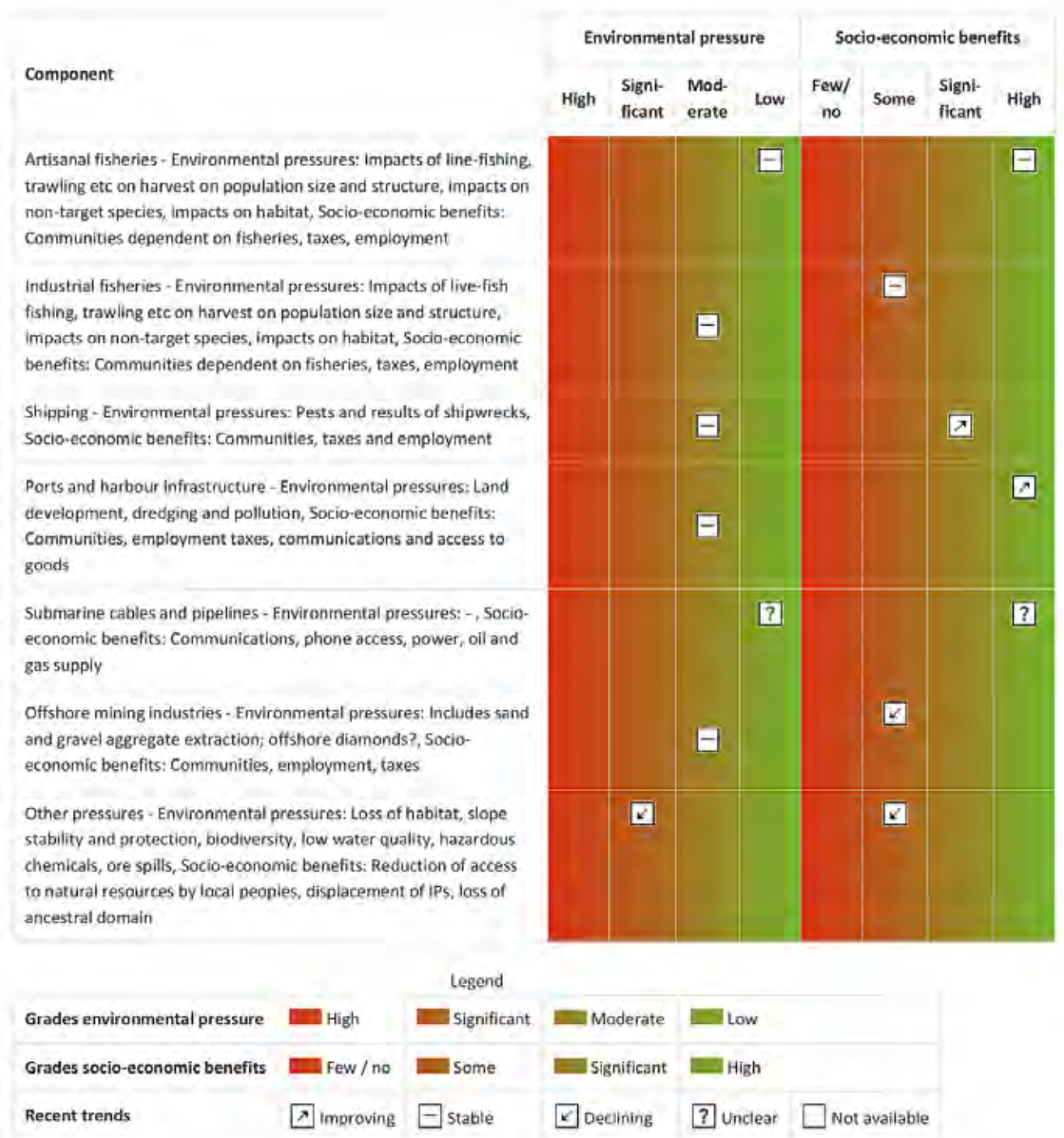


Figure 8.1: Assessment of environmental pressures and socio-economic benefits

export of iron ore and other minerals. The areas affected include Port-Loko district in the north of the country and the upper reaches of the Sierra Leone River in particular.

Presently there is moderate pressure on the coastal and marine environment of the country emanating from the development of ports and harbours. Socio-economic benefits are high and rising as new port developments are underway. In Sierra Leone the transportation systems of land, air and sea are somewhat heavily linked with the coastal areas. Freetown for instance has the main seaport, while the international airport is located on the Lungi landmass, which is a coastal landmass.

#### 8.4. Submarine cables and pipelines

The environmental pressures caused by submarine cables and pipelines are low. Socio-economic benefits are high considering the value for communication and transport.

#### 8.5. Offshore hydrocarbon industries

Exploration and prospecting for oil and gas is in progress. Oil pollution of the beaches from sources external to Sierra Leone is a common characteristic, being normally very weak but sometimes quite heavy thus creating a temporary serious nuisance. At this stage no visible effect on the coastal

and marine environment has emerged. Presently there is not yet a developed hydrocarbon industry along the coast. As a result there is currently little or no pressure on the coastal and marine environment of the country emanating from the development of offshore hydrocarbon industries.

## 8.6. Offshore mining industries

The environmental pressures arising from the offshore mining industry are moderate with some socio-economic benefits showing a decreasing trend.

There is a limited variety of natural resources found and extracted from the coastal area of Sierra Leone, such as diamond, gold, iron, ore, platinum, copper, cobalt and manganese nodules. Apart from alluvial diamond, which is currently being explored, the deposits of other resources exploited from the coastal zone of Sierra Leone are shown in Table 1.1. It is however worth noting that exploitation of natural resources is entirely in the hands of foreign companies and the national programs for development and use of these are not advanced. The quantities are likely to be conservative estimates as exact data are not always available. Exploration and prospecting for oil and gas are in progress. Along the Sierra Leone Coast, the major extractive activities are based on deposits of sand, clay and hard rock.

## 8.7. Solid waste disposal

Marine pollution in Sierra Leone can be temporarily serious but, most of the time is almost insignificant. All categories of waste are dumped without sorting at the three major dumpsites that exist in Freetown. These include heavy toxic metals such as lead, mercury and asbestos as well as plastics, bottles and cans. Industrial wastes are not treated and although they all reach the sea, they do not for now constitute a real nuisance due to the limited outfall originating from the few industries mainly of a non-polluting type. The Freetown sewage waters get directly into the sea but they were formally not considered as a serious pollution problem due to their limited volume. However, various reports and studies conducted in relation to coastal and marine pollution in Sierra Leone have revealed that the management of domestic waste including sewage is a serious problem. In Freetown, sewage from pit latrines and cesspits are only partially treated and discharged into the sea.

Siltation in the rivers along the diamond mines area is very heavy and, although this area is located quite inland, the Sherbro estuary which is widely opened to sea is partially polluted; siltation problem is also present in the Rokel estuary at Freetown.

## 8.8. Marine debris

Sierra Leone's developing industry (fishing, mining, agriculture, tourists, manufacturing) and the intense rate of partly unplanned urbanization in the coastal districts, especially on the Freetown Peninsula and in the Western

Area, has created pollution hot spots with deterioration in surface and ground water quality. The problem is aggravated by an increase in marine debris from other areas and shipping activities.

## 8.9. Tourism and recreation

Tourism activity in Sierra Leone is fairly low despite the fact that the country is endowed with sandy beaches and other coastal and marine ecosystems of value to tourism and recreation. There is limited hotel accommodation in Freetown for overseas tourists and beachfront development although gradually increasing in density is still appreciably low.

## 8.10. Desalinisation

Presently there is little or no pressure on the coastal and marine environment of the country emanating from the development of desalination facilities.

## 8.11. Other pressures

Other pressures on the country's coastal and marine environment have been assessed. Generally, they were found to cause significant environmental pressure on the marine and coastal environment with only some socio-economic benefits. Trends for both parameters show a decline. The pressures also result from the following socio-economic activities:

- Developmental activities: construction, uncontrolled tourism
- Population, deforestation and agriculture
- Creation of dams for hydro-electric power generation

### Developmental activities

Construction of housing units, industry, roads, health centers, security posts, schools etc. is on the increase in the coastal area of Sierra Leone particularly in the Freetown area due to government's attempt to implement the Freetown Structure Plan. As a result a number of quarrying industries located close to the coast have emerged as well as settlements.

The character of the coastlands (fairly high population and recent economic growth) has encouraged road development along the coast, and at the same time permitting considerable transportation by coastal and inland waterways.

The manufacturing sector in Sierra Leone is small and accounts for about 6–7% of the Gross Domestic Product (GDP) in the country. These industries of mainly small-scale import substitution manufacturing are located on or near the coast. They include food, cement, paint, nails, detergents, pulp, mineral water, beer, matches etc. Solid and liquid wastes derived from production activities are usually disposed close to source.

### Population Pressure

The poor in urban areas tend to be concentrated in congested areas or marginal landscapes such as steep



hill slopes or depressed river valleys. They lack access to vital services such as water and sanitation, road network, electricity, educational and health facilities as well as municipal waste collection services. These communities have to literally coexist with their own excrement. The urban poor often have to use local streams for the multiple purposes of washing, bathing, and faecal waste disposal.

The water quality is important at the national level in sustaining the marine living resources. The quality of the continental shelf waters of Sierra Leone is satisfactory. The adjacent coastal water bodies receive most of the effluents from the nearby settlements located in Freetown. Pesticides from agricultural run-offs may also enter the estuary as well as sediments from river mining activities and the indiscriminate clearing of the mangroves.

Forest resources in the coastal zone are exploited for a variety of uses. Prominent amongst these is the fuel wood trade in mangrove forest wood as well as poles for building and other purposes. Coastal forests are exploited for boat building and handicraft. Oyster farming from mangroves and other hard sub-strata is another activity of coastal dwellers: Oysters are harvested for both commercial and subsistence purposes.

The coastal swamps where the mangroves are found, consist of alternating banks of gravel, sand, silt and clay. Silt is predominant in the northwest. In the south, large areas of coarse sand are alternately waterlogged or very dry. The soils in the Scarcies estuary area are characterized by partly compacted, cohesive silts and clays.

The clays have a good salt-fixing capacity and therefore provide an ideal base for the development of potentially acid sulphate soils (sulfaquents) and also because of the marine influence. Generally acid sulphate palaeosols tend to occur in the contact zone between the tidal flats and pre-holocene non-estuarine deposits usually colonised by fresh water grasses and herbs.

Peri-urban agricultural practices are common in Sierra Leone and are a usual feature of the coastal area. Swamp rice is one of the main crops cultivated in the coastal area. In some areas notably in the Kambia district, rice has been cultivated in areas previously occupied by mangroves.

Other resources exploited from the coastal area include coarse aggregates, fine aggregates, clay, hard rock and salt.

Alluvial gravel deposits in the coastal zone of Sierra Leone have not been assessed and no data are available regarding its exploitation in areas within and outside the zone.

Beach sand is being extracted from beaches along the entire Sierra Leone Coast as construction material. However, data on the quantity extracted is anecdotal.

Clay soil is being extracted near beach areas and rivers. Traditionally, the clay soil is used for brick and ceramic



making. The clay factory in Freetown used to produce about 130,000 bricks annually for both local consumption and export. If clay extraction is not controlled, the result will be a change in land-use to a non-vegetable open area vulnerable to erosion and a reduction in nearby water quality due to runoff.

Hard rock has been mined along the banks of coastal streams as a source of construction material for the development of road networks and for export by foreign companies.

Salt production is gradually developing with a few ponds but is still at a rudimentary stage. However, there is a need to improve the national capacity to produce more and better quality salt with well-developed national programs for development and use of the resource.

Marine and coastal space is utilized for transportation, fishing, trade, mining, recreation etc. Both marine and river transportation facilities have to be improved with regards to port facilities safety standards and quality of service mainly for local coastal transport. Proper pollution control measures should also be put in place.

### **Climate change**

The IPCC in their Fourth Assessment Report, Working Group 1 (IPCC 2007), tells us that climate is often defined as 'average weather'. Climate is usually described in terms of the mean and variability of temperature, precipitation and wind over a period of time, ranging from months to millions of years. The unimpeded growth of greenhouse gas emissions is raising average temperatures. The consequences include changes in precipitation patterns, more and more extreme weather events, and shifting seasons. The accelerating rate of sea level rise as a result of climate change, combined with global population and income growth, threatens coastal area integrity everywhere in Sierra Leone.

# 9. Risks to the marine environment – Coastal and marine ecosystem conservation and management strategies

The general outlook for the coastal and marine environment of Sierra Leone could be said to have improved over the last six years. This is due to considerable awareness and positive national and regional actions which have resulted in conscientious environmental stewardship and its sustainability nationally and within the region. This has been borne out of increased political will and commitment by successive governments to mainstream environmental considerations into every aspect of governance at the local/provincial, national and regional levels.

Common environmental issues, such as declining fish stocks, land-based and sea-borne pollution, coastal erosion, physical alteration and destruction of habitats, etc. pose critical challenges both nationally and regionally. Efforts need to be made to address specific transboundary issues through regional and international agreements and conventions developed and facilitated through bilateral and multi-lateral International and intergovernmental institutions. The United Nations agencies (FAO, UNEP, UNDP, UNIDO, UNESCO/IOC etc.) have been particularly active in facilitating and supporting such initiatives within the region.

Some projections regarding the outlook/risks for the Sierra Leone's coastal and marine environment based on observed trends are important as they may serve to further enhance general awareness and understanding of current and emerging issues, and perhaps act as wake-up call for appropriate governance, or enable adequate planning and strategy.

The specific outlook/risk issues considered here relate to coastal and marine ecosystem conservation strategies, water quality, natural resources (especially fisheries and mangroves), coastal development, coastal erosion, marine litter, invasive alien species, petroleum and mineral resources, natural hazards, climate change, environment-related conventions and protocols including those of the Abidjan Convention.

## 9.1. Risk assessment

A total of 12 potential risks have been assessed at the workshop (Fig. 9.1). The assessment examined whether the risk is likely to exert a significant effect in a 5 or 50

years timeframe. The assessment is based on likelihood of occurrence and consequence for the environment.

Shipping, coastal erosion, climate change and mining are identified as high risk factors that could impact the marine environment within 5 years.

Fishing, oil and gas exploitation, pollution, tourism, port facilities and overfishing were identified as significant risks to the marine environment within 5 years. Harmful algal blooms and eutrophication were identified as moderate to low risk within the 5 year timeframe.

Considering a 50 year timeframe, the risks of most factors such as oil and gas exploitation, pollution, port facilities and overfishing will increase from the 'significant' to 'high' risk category. Harmful algae bloom is even going to increase from moderate to high risk. Eutrophication is considered as a moderate risk.

## 9.2. Water quality

Recent monitoring of coastal waters of Sierra Leone suggests that coastal water quality will continue to deteriorate unless actions to reverse the degradation are implemented and enforced. Land-based sources and activities are on the increase affecting near shore waters, estuaries, lagoons, creeks, etc. and inevitably the adjacent seas. With increasing population and drift to coastal areas, coastal water degradation will persist for the foreseeable future.

## 9.3. Fisheries

The major fish resources in the area are Round sardinella, Skipjack tuna, Bigeye grunt and Bonga shad. The neighbour countries and Sierra Leone have several shared fish stocks and identified a need for cooperation and shared management of these resources.

In general, capture production decreased by more than 10 percent after 2000 in both the Western and Eastern Central areas of the Atlantic Ocean. The preliminary results of the assessments of the FAO CECAF Working Group on the Assessment of Small Pelagic Fish (WGASPS) Sub-Group South indicate the overexploitation of *Sardinella aurita*

**Short and long term risks to the marine environment if current policies are not changed. Based on likelihood of occurrence and consequence for the environment.**

Group	Risk factor	Risk in 5 years				Risk in 50 years			
		High	Significant	Moderate	Low	High	Significant	Moderate	Low
Fishing	Illegal fishing continues unchecked	High	Significant	Moderate	Low	High	Significant	Moderate	Low
Oil and Gas	Oil exploration will result in blowout or major oil spill	High	Significant	Moderate	Low	High	Significant	Moderate	Low
Shipping	Shipwrecks will cause a major oil spill	High	Significant	Moderate	Low	High	Significant	Moderate	Low
Coastal erosion	Coastal erosion will continue	High	Significant	Moderate	Low	High	Significant	Moderate	Low
Climate change	Global sea level will raise and cause inundation	High	Significant	Moderate	Low	High	Significant	Moderate	Low
Pollution	Pollution will cause contamination of seafood	High	Significant	Moderate	Low	High	Significant	Moderate	Low
Tourism	Tourism causes environmental damage	High	Significant	Moderate	Low	High	Significant	Moderate	Low
Mining	Catchment disturbance will cause siltation of estuaries	High	Significant	Moderate	Low	High	Significant	Moderate	Low
Harmful algae bloom	Harmful algae blooms will occur	High	Significant	Moderate	Low	High	Significant	Moderate	Low
Eutrophication from coastal non-point sources	Pollution affects the marine environment	High	Significant	Moderate	Low	High	Significant	Moderate	Low
Port facilities	Port activities will cause environmental damage	High	Significant	Moderate	Low	High	Significant	Moderate	Low
Overfishing	Collaps of fish stock from overfishing	High	Significant	Moderate	Low	High	Significant	Moderate	Low

**Risk value**

**Risk grades**

- High
- Significant
- Moderate
- Low

**Figure 9.1:** Risk assessment results (5 and 50 year timeframe)

(northern and western stocks) and *S. maderensis* (northern and western stocks). The *Ethmalosa fimbriata* (southern stock) is underexploited while *Trachurus trecae* (southern stock) is fully exploited.

The expert workshop regarded the risk to be significant in a 5 and 50 years perspective both because of illegal fishing and overfishing. The risk of a collapse of the fish stock in the next 50 years was even regarded as high if overfishing continues.

**9.4. Mangroves**

A wide range of commercial and non-commercial fish and shellfish also depends on these coastal mangrove forests. The role of mangroves in the marine food chain is crucial. The average yield of fish and shellfish in mangrove areas is about 90 kg per hectare, with maximum yield of up to 225 kg per hectare (FAO 1994).

Recent monitoring of mangroves of Sierra Leone suggests they will continue to decline unless actions to reverse the degradation are implemented and enforced. Deforestation activities are on the increase due to urban expansion, coastal agriculture (mainly rice production), poles for construction, salt production and fish drying. With increasing population and drift to coastal areas, mangrove degradation is likely to persist for the foreseeable future. However, a regional mangrove charter has been adopted by Sierra Leone which if implemented together with other conservation measures, will significantly reverse the trend.

**9.5. Coastal development**

The pace of coastal development is dictated by economic growth in the country. Of importance is recent development of export processing zones and ancillary



handling facilities such as ports and harbors, jetties, oil terminals, ship repair yards etc. for industrial parks within the zone. There is concern for deforestation of mangroves, dredging for approach/access channels and for coastal sand for reclamation of sometimes vast areas.

The main coastal degradation problems arising from uncontrolled coastal development are coastal erosion, flooding, storm surges and in a few cases landslides in the region. These issues are likely to be of greater importance with rapid development in the coastal areas.

### **9.6. Coastal erosion**

Coastal erosion is the most prevalent coastal hazard in the GCLME. It has received some attention through research and engineering options in the last three decades. Natural coastal dynamics such as currents, waves and tides, but also the nature of sediments and coastal topography play a role concerning coastal erosion. Anthropogenic activities such as construction of harbour protecting structures (e.g. moles), jetties, beach sand mining, construction of dams upstream depriving the beach of sediment nourishment, and deforestation are causes of high rates of erosion. Human activities aggravate the erosion problem on most coastlines when coastal development is undertaken without cognizing near shore ocean dynamics and shoreline evolution.

Periodic monitoring of the coastline of Sierra Leone suggests that it has been subjected to periodic erosion which is severe at some locations due to both natural and man-made causes. Coastal erosion will continue to be aggravated unless actions to reverse the trend are implemented and enforced. Sand extractions from

beaches are on the increase due to urban expansion. With increasing population and drift to coastal areas coastline erosion is likely to persist in the foreseeable future.

The risk for coastal erosion was regarded as high by the workshop.

### **9.7. Marine debris**

The results of field observations and qualitative assessments have so far clearly indicated that the Sierra Leonean beaches will be constantly polluted by debris items, as long as coastal population increases daily, and fishing, tourism, leisure and vessel transit activities continue.

The outlook for the country's marine litter issue over the coming decade is an increase as a result of ongoing urban and coastal industrial development, gradual increases in shipping activity and exponential growth in oil prospecting and production nationally as well as within the region. This prediction is based entirely on examination of related trends and relationships regarding the sources, causes, quantities and distribution of marine litter at the national and regional levels.

The implementation of MARPOL 73/78 is ongoing in some of the countries in the region with regard to the provision of adequate waste processing for ship garbage and port waste reception facilities in major ports. When fully implemented this would contribute to reducing the threat of marine debris at local, national and global levels.

The risk that pollution will cause contamination of seafood was regarded as significant in a 5 years perspective and high in a 50 years perspective.



## 9.8. Invasive species

Fortunately, the number of species documented to date are few, about 4-5 in the region. However, the problem of coastal and marine invasive species is likely to worsen over the coming decade due to increases in shipping activities throughout the region. Ship traffic is projected to continue growing into the coming decade parallel to economic growth and therefore the transfer of alien organisms through ship's ballast water is expected to grow.

Active participation by Sierra Leone in programs such as the Globallast Programme through the GCLME Project and the implementation of the newly adopted IMO Ballast Water Convention, including the involvement of the private sector with partners from major maritime companies, should reduce the regional exposure to the global threat of invasive species.

## 9.9. Petroleum and other resources

The outlook for the oil and gas sector over the coming decade is very likely to involve significant increases in exploration and exploitation of proven reserves by current producers. Sierra Leone could become a major oil producer in the future. It is evident that a wide variety of policy tools and strategies will be needed in order to protect the marine environment from unacceptable pollution derived from oil and gas activities.

The risk that oil exploration will result in a blowout or a major oil spill was regarded as significant in a 5 years perspective and high in a 50 years perspective. The risk that catchment disturbance due to mining activities causes

siltation of the estuaries was also regarded as high in a 5 years period and significant in a 50 years perspective.

## 9.10. Climate change

Climate change is widely accepted as a real threat and developing countries are already being affected. For the region, climate change is a development issue. Climate risks are highest in poor countries and the poorest countries and communities stand to suffer the earliest and the most. Climate change threatens the development gains and achievement of the Millennium Development Goals (MDGs). African countries are highly vulnerable to climate change which is expected to affect all key sectors such as agriculture, water, health, disaster risk reduction, coastal zones, and ecosystem management.

Key impacts would include drought, dust and sand storms, water resources (water stress), agriculture/food security (reduction in soil fertility, livestock productivity and increased incidence of pest attacks), and coastal zone (flooding and extreme weather events). UNDP reported that the African continent is vulnerable to climate change because of its large population living along the coast, 25 per cent within 100 km of the coast and in low lying areas. With a heavy reliance on rain-fed agriculture, and high dependence on natural resources and poor access to modern and sustainable energy services, the continent is particularly vulnerable.

The risks of catastrophic events will increase with temperature, and the workshop regarded the risk as high. Perhaps, these are sufficient assessments of projected environmental impacts for formulating actions for mitigation and adaptation.



# 10. Conclusions

It seems clear that the problems of the nearshore and coastal zones pose the most pressing threats to the marine environment. These threats are primarily terrigenous in origin and are related to sewage disposal and pollutant run-offs. The assessment also reveals that the trend of increasing pressure on the environment will certainly continue for as long as urban migration remains high. Such issues requiring priority attention include the potential threats of invasive species, marine litter, increasing uncontrolled coastal development leading to habitat degradation and changing land-use patterns, and climate change.

Moreover, overexploitation of natural resources from the coastal and marine areas also contribute to the threat to the marine environment. This is predicated on overwhelming dependence by rural and coastal communities on such resources in the face of widespread poverty and limited opportunities for alternative livelihoods.

The present level of agricultural wastes, herbicides, pesticides and fertilizers discharged may not yet constitute a major concern but the rate at which mangrove vegetation is being lost to rice-planting is worrisome.

A challenge is the lack of a proper data base. Lack of data has made it very difficult to compare time scales and rate of changes over time. However, it is clear that the national awareness already exists and remedial mechanisms are being implemented without waiting for scientific tools to be developed. A total of 60 parameters were assessed during the expert elicitation workshop, 8 were assessed as very good and 43 as good so the present situation is not critical. But 12 of the parameters were assessed as declining during the last 5 years so there is reason to take action. To repeat the assessment in regular intervals will be a cost efficient way to monitor the trend.

Other pressures including mining and associated infrastructure is assessed as the biggest pressure with loss of habitat, slope stability and protection, biodiversity and low water quality.

Four out of the twelve potential risks were considered high in a 5 years perspective, and 8 in a 50 years perspective.

In the last decade a great number of actions and important management measures have been taken to improve the state and outlook of Sierra Leone's coastal and marine environment. Several other initiatives within the country, by partners and collaborators, have augmented and assisted in the realization of a healthier environment for

sustainable economic and social development. The actions advocated are both in response to the identified threats facing the country and attempts to address climate change and other emerging issues.

Sierra Leone is already developing and implementing improved management strategies in order to mainstream environmental concerns into national policy, regulatory, and institutional mechanisms that are critical to achieving sustainable results. These include improvements in many of the regulations governing the marine environment, designation of new Marine Protected Areas and proposals for additional coastal protected areas. Improved regulations also require focused enforcement efforts to assist in sustaining gains in environmental protection, rebuilding stocks, and maximizing the long-term benefits of the goods and services provided by the ecosystem.

Also, there is an increased awareness of environmental problems by both the government and the population and a growing commitment to allocate the necessary resources to resolving current problems and tackling proactively other emerging issues.

Finally, it could be concluded that the Sierra Leone marine environment is in a stable and fairly good condition. Environmental management has improved over the last 5–10 years, the national awareness is there, and the country currently has the will and potential to make more improvements.

# 11. Recommendations

The following recommendations have been formulated<sup>3</sup>

## 11.1. Measures to address physical loss of seabed/coastal habitats in the marine/coastal environment

- With technical support from IMO and the Abidjan Convention the government should develop robust environmental standards for the oil and gas sector, with the aim to minimize disturbance of the seabed.
- Coastal Beach Sand mining especially at sensitive coastal areas must be regulated and controlled by all relevant institutions.
- EPA-SL and other institutions must take commitment to strengthen the enforcement of the existing regulations and adoption of workable strategies for addressing coastal erosion and pollution issues.

## 11.2. Measures to address marine litter

- EPA-SL and other institutions must take commitment to strengthen the enforcement of the existing regulations and adoption of workable strategies for addressing pollution issues (avoidance of marine litter).

## 11.3. Measures to address contamination by hazardous substances (synthetic substances, non-synthetic substances, radio-nuclides) and the systematic and/or intentional release of substances in the marine environment from sea-based or air-based sources.

- EPA-SL and other institutions must take commitment to address land based sources of pollution through robust law enforcement and monitoring.
- Sierra Leone Maritime Administration and the Office of National Security should develop workable contingency plans for natural disasters and oil spills incidences in the marine environment.
- With technical support from IMO and the Abidjan Convention the government should develop robust environmental standards for the oil and gas sector (use of hazardous substances, treated water).

## 11.4 Measures concerning nutrient and organic matter inputs to the marine environment from sea-based or air-based sources

- EPA-SL and other institutions must take commitment to strengthen the enforcement of the existing regulations and adoption of workable strategies for addressing pollution issues (avoidance of excessive nutrients).

## 11.5. Measures to address biological disturbances in the marine environment from the selective extraction of species including incidental non-target catches.

- Promote sustainable use and conservation of marine living resources by combating IUU fishing and enforcement of existing fisheries regulation (relevant national laws and international treaties).

## 11.6. Measures to address other types of biological disturbance, including death, injury, disturbance and translocation of marine species, introduction of genetically-modified individuals and introduction of microbial pathogens

- EPA-SL in collaboration with line Ministries and Departments and the civil society organizations must embark on conservation and restoration of degraded critical habitats such as wetlands.

## 11.7. Measures related to Spatial Protection Measures for the marine and coastal environment

- EPA-SL together with the University should conduct regular monitoring of ecological sensitive coastal and marine environments and identify and designate ecologically or biologically significant marine areas.
- Facilitate coastal zoning and marine spatial planning.
- Efforts should be made by the Government and all concerned stakeholders to prohibit uncontrolled and unplanned settlements in the coastal areas.

<sup>3</sup>. The structure of the recommendations is based upon the EU MSFD 'Key Type of Measures'





### **11.8. Research, improvement of knowledge base reducing uncertainty in the marine and coastal environment**

- EPA-SL should in collaboration with its partners conduct regular assessment of the state of the environment of coastal and marine areas every 3–4 years.
- EPA-SL should in collaboration with partners conduct regular monitoring of ecologically sensitive coastal areas and the marine environment.
- EPA-SL and where possible other institutions with the availability of resources should prepare and maintain profiles of coastal area resources, activities, uses, habitats and protected areas.
- In order to establish a basis for proper management and control on coastal environmental activities and issues, the existing data base must be improved both with regards to information on environmental characteristics and information on contaminant levels in the biota, sediments and possibly water.

### **11.9. Other measures**

- Strengthening institutional cooperation and coordination for the management of the coastal and marine environment.
- Implementation of integrated coastal and marine management and sustainable development plans and programmes at national level.
- EPA-SL, Ministry of Fisheries and Marine Resources and the Ministry of Forestry should develop a comprehensive management plans for the designated protected areas along the coastline.
- Through the Ministry of Lands Country Planning and the Environment marine research in the country needs to be strengthened and intensified and participation in the regional programs including those initiatives of UNEP and WACOM are commendable and should continue.

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# 14. Acronyms

CECAF	Fishery Committee for the Eastern Central Atlantic
COADS	Comprehensive Ocean-Atmosphere Data Set
ECC	Equatorial Counter Current
EE	Expert Elicitation
EPA-SL	Environment Protection Agency – Sierra Leone
FAO	Food and Agricultural Organization
GCLME	Guinea Current Large Marine Ecosystem
GDP	Gross Domestic Product
IMBO	Institute of Marine Biology and Oceanography
IMO	International Maritime Organization
IOC	Intergovernmental Oceanographic Commission
IPCC	International Panel on Climate Change
ISFM	Institutional Support for Fisheries Management
MARPOL	International Convention for the Prevention of Pollution from Ships
MDGs	Millennium Development Goals
NBSAP	National Biodiversity Strategy and Action Plans
SOME	State of the Marine Environment
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNIDO	United Industrial Development Organization
USL	University of Sierra Leone
WACOM	West African Coast Observation Mission
WGASPS	FAO/CECAF Working Group on the Assessment of Small Pelagic Fish Sub-Group South
WHO	World Health Organization
WIWO	Working Group International Waterbirds and Wetland Research

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# Appendix

## Methodology Paper: Measuring the State of the Oceans and Coasts



# Measuring the State of the Oceans and Coasts:

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*Guidelines for the Production of  
State of Marine Environment Assessments and Reports  
Based on Expert Elicitation*

*A background paper by GRID-Arendal  
January 2015*

## 1. Background

It is fundamental to marine environmental management that states have the capacity to assess and monitor the condition and trend of coastal and marine ecosystems within their jurisdiction. Undertaking integrated assessments can be expensive and time consuming, but sound information is critical to understand the State Of the Marine Environment (SOME) to underpin decision-making and achieve or maintain ocean health. Most importantly, large-scale integrated assessments must not be overly biased by information that is limited only to places or issues that are well studied, since this might result in outcomes that are not balanced or properly represent conditions across the whole of the area assessed.

Further, SOME assessments are a critical data source used by global assessments like the UN World Ocean Assessment ([www.worldoceanassessment.org](http://www.worldoceanassessment.org)), or large regional assessments like the ones produced under the umbrella of UNEP's Regional Seas Programme.

In order to support the production of the first global ocean assessment a series of regional workshops have been conducted over the last 2 years to identify relevant assessments, regional experts and capacity gaps. At the workshops for the SE Asian Seas (Sanya City, China), the Caribbean (Miami, USA), Western Indian Ocean (Maputo, Mozambique), the South Atlantic (Abidjan, Côte d'Ivoire) and recently the Eastern Indian Ocean (Chennai, India), experts from developing states have articulated that, while there is no scarcity of marine environmental experts, the capability to undertake SOME assessments and reports is a major gap due to both the lack of systematic monitoring data and proficiency in environmental reporting.

With the intention of exploring options to bridge this gap, regional and national pilot capacity-building workshops have been held in Bangkok, Thailand, Sept. 2012 (Ward, 2012; Feary et al., 2014); Abidjan, Côte d'Ivoire, Oct. 2013; and in Freetown, Sierra Leone, Feb. 2014. The purpose of the workshops was threefold: i) to expose national or

regional experts to the *expert elicitation*<sup>1</sup> methodology; ii) to produce an initial expert elicitation assessment of the national or regional target areas; and iii) test the potential of the EE methodology and process for the production of SOME reports.

The process and methodology described in this paper is largely based upon the Australian SOME process and report developed in 2011 (State of the Environment 2011 Committee, 2011; Ward et al., 2014) and we acknowledge the authors of that report for a significant portion of the content presented below. The experience and lessons learnt from the pilot workshops have been used to optimize the process and the methodology to better match the needs and challenges raised by the experts from developing states participating in the World Ocean Assessment process and encountered during and after the workshops and the production of the actual reports. This paper is intended to provide background information for individuals or agencies interested in learning more about the Marine Environment Expert Elicitation (SOME-EE) process, its advantages and disadvantages and the steps necessary in order to complete a SOME report. It also provides background and guidelines for experts who are intending to participate in a SOME-EE workshop; it explains the underlying concepts and the approach followed during the workshop so that experts can be prepared to fully participate at an optimum level of engagement.

## 2. The SOME Report Production Process

The expert elicitation methodology is essentially a scientific consensus methodology, aimed at generating an assessment of any chosen parameters by synthesising information available in existing assessments, scientific publications and data in conjunction with the subjective judgment of experts across a broad base of evidence related to those parameters. The method has been applied successfully in a range of situations, including the 2011 Australian SOME Report (State of the Environment 2011 Committee, 2011), and has the advantages that it is cost- and time-effective, it utilizes the existing knowledge of marine experts from the target region and it can incorporate non-conventional knowledge and information.

In the absence of comprehensive regional or national indicator datasets, the SOME-EE process uses consultation with national and regional experts to gauge expert opinion about the condition of the marine and coastal ecosystems and dependent socio-economic sectors. There are commonly datasets from local areas, and there are many sub-regional scale studies and short-term datasets about various aspects of marine ecosystems, but these have often a too coarse resolution and are not part of a systematic collection of data and knowledge routinely synthesised for reporting purposes. The SOME-EE process draws upon these disparate datasets and the knowledge-base dispersed across a broad range of sources and institutions to capture a representative sample of existing expert knowledge about the condition of the national or regional marine and coastal environment in a manner that can be used for reporting purposes.

The ultimate success in the production and the legitimacy of a report ensuing from an expert elicitation process depends on the thoroughness of the steps leading to and after the elicitation has been carried out. An ideal procedure should include the following steps but of course this should be revised to ensure it matches the needs and constraints of the state or region for which the report is being produced (Fig. 1):

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<sup>1</sup> Expert elicitation is the synthesis of opinions of experts on a subject where there is uncertainty due to insufficient data.



- 1. Identification of National Experts and Stakeholders:** This step begins with the identification and charting of the national and/or regional public and private bodies, agencies and organizations that, in addition to the one with the mandate of producing the report (“the reporting agency”), deal with the major aspects of marine and coastal environment research, monitoring, management and regulation (“the stakeholders”). In principle the steps following the stakeholder mapping should try to involve a representative fraction of the experts engaged by those bodies, agencies and organizations as this will improve the quality of the assessment and ensure the report holds a legitimate basis for decision-making. The reporting agency should announce the initiation of the report production process and invite the relevant stakeholders to participate in the process through the nomination of experts. The expert nomination should be confirmed by the reporting agency together with clarification on the mode and roles of involvement of the experts having due regard to time and budgetary constraints. An editorial board/committee for the report should be appointed by the reporting agency at this stage. This step is critical because if the experts invited are not representative of all aspects of the marine environment, or if they are skewed in number towards one particular discipline (eg. biology), then the assessment will be biased. In most cases a minimum representation of each of the key discipline areas (eg. ecology, biology, fisheries, physical sciences and socioeconomics) will be needed. Experts representing the full range of marine sectors are needed to produce a rigorous assessment. Upon acceptance, each participant should be provided with detailed background information on the assessment process.
- 2. Relevant information identification and compilation:** The reporting agency, with the support of the experts nominated, should initiate the identification and collation of relevant information (publications, scientific papers, databases and data sets) and make it electronically available to all experts involved.
- 3. Expert review of the assessment themes and parameters:** A suggested structure for the assessment built around a set of themes and parameters is included below. Of course not all may apply directly to a particular region, but they provide a guide for the design of the assessment to be carried out. Experts will be requested to review and make suggestions on the parameters for condition, threats and risk, and the elicitation procedures. They will also review the collated relevant information and suggest additions.
- 4. Expert Elicitation assessment:** The EE assessment is carried out during a workshop or series of workshops, attended by the appointed experts. The scores assigned to the parameters (as described below) are recorded during the workshop. Notes are taken by a rapporteur on the discussion and the details of relevant reports, papers or other documents are recorded. The interaction and discussions during the workshop/s should allow the editorial board to identify potential authors to participate in the subsequent report-writing phase of the process.
- 5. Report drafting:** The scores of the assessment parameters and any details are compiled, analyzed by the reporting agency and provided in a concise and organized way to the editorial committee. These are distributed to the different author/s appointed for the different themes/chapters who are tasked with producing draft chapters based on the outcomes of the EE assessment and any generic introductory insight they may want to bring in. The editorial committee should also produce text for any introductory chapters describing the scope, approach, process and methodology used to produce the report. The editorial committee should then compile and edit a first draft with focus on completeness and evenness of the different sections of the report.

**6. Report reviewed, revised and published:** Once the first draft is compiled by the Editorial Committee it should be circulated to all the experts involved in the EE assessment and writing of the report in order to be thoroughly reviewed. This review exercise could be done remotely but the organization of a validation workshop could bring added value as it would provide the editorial committee a good sense of the overall endorsement of the whole of the report by the experts that have contributed to its production. Next, peer reviewed by an independent, geographically diverse, group of experts that have not been involved in its production is carried out and the report is revised by the authors taking into account the reviewers comments. The peer-reviewed, final version of the report may go through technical edition, graphic design and layout processes prior to publication.

This whole process may differ in duration depending on the natural and political heterogeneity of the assessment area, the amount of experts to be used for the assessment and the specific steps chosen from the ones suggested above. A reasonable duration would normally be between 6 and 18 months.

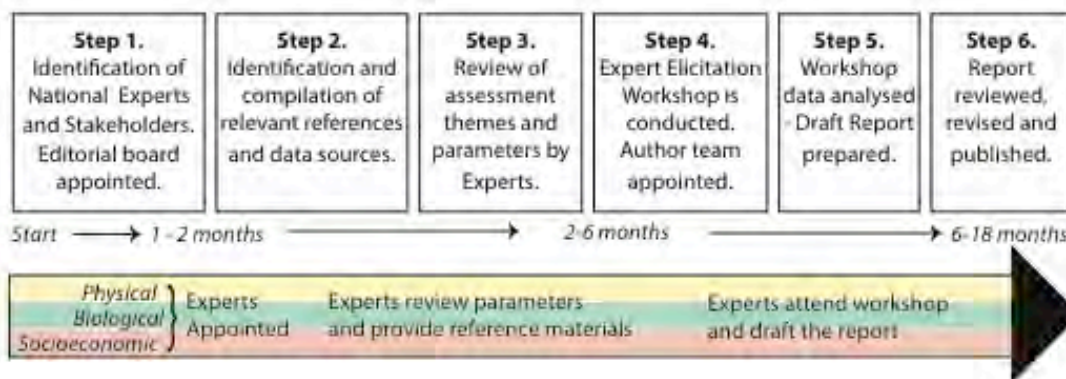


Figure 1. Diagram illustrating the time-line for one complete cycle of the SOME-EE process. Between 6 and 18 months are needed to plan and execute the process.

### 3. The SOME Assessment Expert Elicitation Method

#### 3.1. Assessment Framework

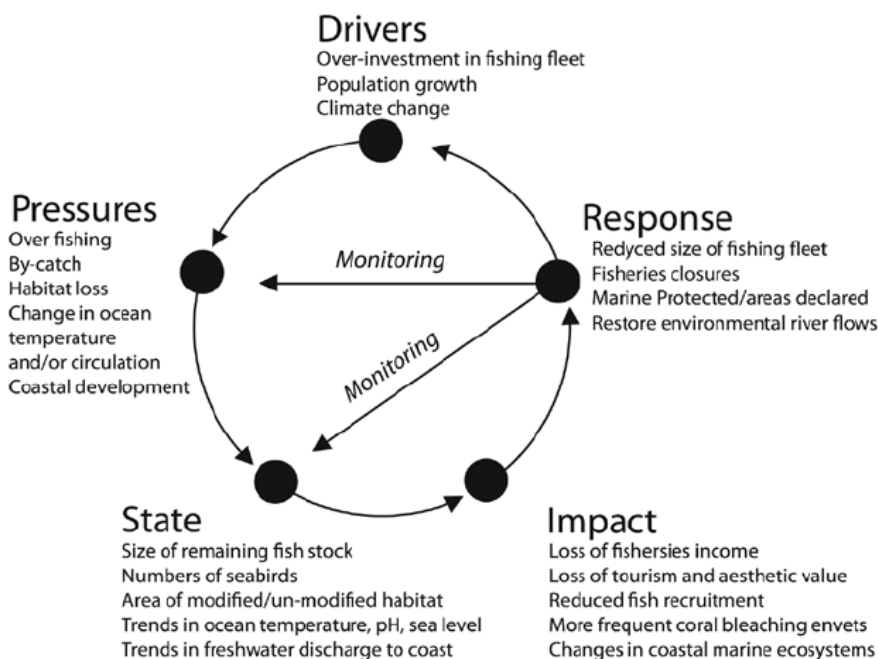
The United Nations World Ocean Assessment ([www.worldoceanassessment.org](http://www.worldoceanassessment.org)) uses the Drivers-Pressures-State-Impacts-Response (DPSIR) framework (Fig. 2) as a basis on which to build its structure and organize its content. The DPSIR, in turn, clearly identifies the place of assessment of environmental condition (the State) within a broad management framework. The purpose of SOME assessments is to fulfill the need of measuring the “State” and the “Impacts” in order to design new government policy “Responses” as well as to gauge the effectiveness of those already implemented.

The DPSIR framework suggests at least three possible approaches for structuring any SOME assessment: i) Pressures; ii) Habitats; and iii) Ecosystem Services.

Using pressures to structure an assessment has the advantages that the associated human activities are commonly linked with data collection and reporting structures for regulatory compliance purposes. For instance, permits that are issued for offshore oil and

gas development require specific monitoring and reporting obligations be met by operators. Pressures are linked to socioeconomic benefits that states derive from marine based industries and the inclusion of socioeconomic aspects is a key component of the World Ocean Assessment.

Using marine habitats to structure an assessment has the advantage that habitat is the property that inherently integrates many ecosystem features, including higher and lower trophic level species, water quality, oceanographic conditions and many types of anthropogenic pressures. The cumulative aspect of multiple pressures affecting the same habitat, that is often lost in sector-based environmental reporting, is captured by using habitats as reporting and assessment units.



**Figure 2. Drivers-Pressures-State-Impact-Response (DPSIR) Framework as used by the UN World Ocean Assessment in relation to the ocean environment. Drivers result in Pressures that have an effect on the State of the environment (the assessment of which is the purpose of SOME reporting). The implementation of monitoring is required to gauge the effectiveness of policy Responses.**

Using ecosystem services to structure an assessment follows the approach of the Millennium Ecosystem Assessment. This has the key advantage of broad acceptance in environmental reporting. It includes provisioning services (food, construction materials, renewable energy, coastal protection) while highlighting regulating services and quality-of-life services that are not captured using a pressures or habitats approach to structure the assessment.

Given that all three approaches have their own particular advantages, all three approaches should be included in the structure of SOME Assessments as far as possible.

### 3.2. Assessment Parameters

Based on the approach adopted by the UN World Ocean Assessment, the present SOME-EE process will use the following condition parameters for the **condition assessment**: habitats and the species they support, ecosystem processes (and services) including physical and chemical processes, pressures and socioeconomic benefits.

Most condition parameters used in the SOME-EE process are the same between all assessments, regardless of country or region, because they are common to all marine environments. For example, the habitats that most assessments will need to consider include estuaries, bays, beaches, intertidal flats, etc. Many regions already have programs in place to monitor specific environmental indicators (see review by Johnson et al., 2013) that can provide input to the assessment and identify parameters for scoring. Other parameters can be added if they are viewed as being of particular importance to a given region. Using a standard set of parameters that have been widely considered in other regions enables direct comparisons to be made and eliminates any bias (or the appearance of bias) in the choice of parameters; for example, where a list of parameters might appear heavily slanted towards those that are at risk in a particular region from a particular pressure.

Parameters may be chosen from any level of the natural biophysical and taxonomic hierarchy of ecosystems and biodiversity of the region under consideration. However, participants should recognise that SOME reporting is of necessity a broad overview process. Each parameter will be the focus of an assessment, and so each parameter should be relevant to (or an important part of) the region as a whole.

In addition to the condition assessment, the SOME assessment also includes an the assessment of the risks (**risks assessment**) faced by the components/parameters assessed. Risks are identified impending threats to the condition of the components/parameters assessed here. The risks are assessed over both short (5 year) and long (50 year) timescales.

### **3.3. Grading System**

#### **Grading scores for condition assessment**

During the assessment workshop, scores will be assigned by the expert participants to each condition parameter on a scale from 1 to 8, where 1 is consistent with the poorest state of condition of the grading criterion, and 8 is the highest level. Scores are assigned on the basis of group consensus. Based on the scores agreed by the experts, four grades are derived as follows: 1 to 2 = Very Poor, 3 to 4 = Poor, 5 to 6 = Good and 7 to 8 = Very Good.

GRID-Arendal has created a web-based system to facilitate the capture and display of scores for the different parameters discussed here (see Appendix 1). The web site allows for the real-time capture and display of data (scores for parameters, confidence, risks) during the workshop and provides a template for the production of a State of Marine Environment Report.

#### **Grading statements**

A key part of the process is developing and applying a set of grading statements that have been uniquely derived for each major aspect of the assessment to represent the four grades of condition (Very Poor, Poor, Good, Very Good). Grading statements provide guidance to inform the experts about the thresholds they should use in determining a score. They are general, descriptive terms of the spatial extent, temporal extent, and magnitude of improvement or decline in condition of the parameters in relation to the selected benchmark (i.e. how to assess pressures, socioeconomic benefits, habitats, species, ecosystem processes, physical and chemical processes both in terms of condition and spatially). Each statement is associated with a range of numeric scores to guide the experts in reaching an agreed score for the parameter in question.

#### **Confidence estimates**

Each score is also assigned a confidence estimate (High, Medium or Low) based on the expert's current state of knowledge and judgement. In general terms, a high level of confidence implies that there are published peer-reviewed papers or refereed reports that support the scores attributed to the parameter in question. A medium level of confidence may be based on one or more expert's knowledge of unpublished data, un-refereed reports or other information. A low confidence score is given where the experts agree to assign a score based mainly on expert opinion and inference.

### **3.4. Benchmarks**

In forming judgements about the condition of any parameter, a "benchmark" (a point of reference for the condition) is needed. Ideally, the benchmark is the condition of the parameter prior to the time when human impacts started to occur. In practice, benchmarks are mainly chosen for convenience and to represent times when data are available.

"Ideal" benchmarks will vary greatly from one part of the world to another; it may be the time of European settlement in one place, or before the Roman Empire in another. Humans may have had significant impacts on some ecosystems prior to the "benchmark" time and impacts may have accumulated gradually over a long time period afterwards. Where it is difficult to identify an appropriate benchmark we recommend that the year 1900 be used. This date (1900) has the advantage that most scientific observations of the marine environment are subsequent to it.

The use of a benchmark should not be confused with an objective for management; it is not the purpose of the SOME-EE process to make recommendations on national marine environmental goals or policies. The establishment of a benchmark is only for the purpose of quantifying environmental change relative to the present time.

## **4. Condition assessment**

In the assessment workshop, grading scores are given for three aspects of each condition parameter: 1) the condition in the worst-impacted 10% of the region under consideration; 2) the condition in the least-impacted 10% of the region under consideration; and 3) the condition in most (the remaining 80%) of the region under consideration. The scores are given based on pre-agreed condition-specific grading statements. Each score is also assigned a confidence estimate (High, Medium or Low) as defined above.

The logic of selecting "10%" of an area for best and worst scores is justified for several reasons. Firstly, an area of 10% of the region under consideration has a higher predictive power than extreme examples of small spatial extent for detecting and/or resolving significant changes created by human activities. By looking at the worst and the best 10% of the region, both ends of the gradient are assessed, providing two independent measures and thereby constraining the "most" (80%) to a score within the identified range.

In addition to giving scores and confidence estimates, the experts will next judge the recent trend in each parameter as declining, stable or improving. The trends are assessed only for the last 5 years (and not in relation to the benchmark). The reason for this is to provide policy- and decision-makers with feedback on how policy responses have or have not had the desired effect. The choice of 5 years is based on the typical recurrence interval of SOME reporting in many states and also because it is unlikely that

measurable differences in condition could be detected in less than 5 years following policy changes implemented by government. A confidence estimate is also assigned to trends agreed by the experts (High, Medium, Low).

## 4.1 Habitats

To score habitats, experts will follow these steps:

1. Estimate a consensus score for the condition of habitats in the Best 10% and Worst 10% of the habitat (eg. relative to 1900). Score both the area and condition of habitat; for example if it is estimated that 10% of the area of habitat has been destroyed since the benchmark date then the Worst 10% of that habitat will have a score of 1. Conversely, if 100% of the habitat area is in the same (pristine) condition that prevailed in relation to the benchmark, then the Worst 10% of that habitat will have a score of 8.
2. Estimate a consensus score for the condition of the habitats in Most areas of the habitat (eg. relative to 1900).
3. Assign a confidence grade for the each of the condition estimates (High, Medium, Low).
4. Estimate the trends for each of Best 10%, Worst 10%, Most (Improving, Declining, Stable) over the last 5 years.
5. Assign a confidence grade for the each of the trend estimates (High, Medium, Low).
6. Record the main anchor references, and any commentary/notes relevant for the assessment of the condition and trends of each habitat.

Habitats	Grading statements for habitats that occur in the state and/or region under consideration.
Very Good (7-8)	The habitat type is essentially structurally and functionally intact and able to support all dependent species
Good (5-6)	There is some habitat loss or alteration in some small areas, leading to minimal degradation but no persistent substantial effects on populations of dependent species
Poor (3-4)	Habitat loss or alteration has occurred in a number of areas, leading to persistent substantial effects on populations of some dependent species
Very Poor (1-2)	There is widespread habitat loss or alteration, leading to persistent substantial effects on many populations of dependent species

## 4.2 Species

To score species, experts will follow these steps:

1. Estimate a consensus score for the condition of populations of the species in the Best 10% and Worst 10% of places where they occur (eg. relative to 1900). Score both the area and condition of species; for example if it is estimated that the species is no longer found in 10% or more of its range relative to the benchmark date, then the Worst 10% of that species will have a score of 1.
2. Estimate a consensus score for the condition of the species in Most areas of the habitat (eg. relative to 1900).
3. Assign a confidence grade for each of the condition estimates (High, Medium, Low).
4. Estimate the trends for each of Best 10%, Worst 10%, Most (Improving, Declining, Stable) over the last 5 years.
5. Assign a confidence grade for each of the trend estimates (High, Medium, Low).

- Record the main anchor references, and any commentary/notes relevant for the assessment of the condition and trends of each the species.

Species	Grading statements for different species assessed, given what is best understood about their status and trends expressed in terms of populations and groups of species including threatened, endangered or protected species.
Very Good (7-8)	Only a few, if any, species populations have declined as a result of human activities or declining environmental conditions
Good (5-6)	Populations of a number of significant species but no species groups have declined significantly as a result of human activities or declining environmental conditions
Poor (3-4)	Populations of many species or some species groups have declined significantly as a result of human activities or declining environmental conditions
Very Poor (1-2)	Populations of a large number of species or species groups have declined significantly as a result of human activities or declining environmental conditions

### 4.3 Ecological processes

To score ecological processes, experts will follow these steps:

- Estimate a consensus score for the condition of ecological processes in the Best 10% and Worst 10% of the habitat (eg. relative to 1900). Score both the area and condition of ecological processes; for example if it is estimated that human activities have caused the ecological processes to no longer occur in 10% or more of the places where it did occur relative to the benchmark date, then the Worst 10% of that ecological process will have a score of 1.
- Estimate a consensus score for the condition of the ecological process in Most areas (eg. relative to 1900).
- Assign a confidence grade for each of the condition estimates (High, Medium, Low).
- Estimate the trends for each of Best 10%, Worst 10%, Most (Improving, Declining, Stable) over the last 5 years.
- Assign a Confidence grade for each of the trend estimates (High, Medium, Low).
- Record the main anchor references, and any commentary/notes relevant for the assessment of the condition and trends of each the ecological processes.

Ecological Processes	Grading statements for the main ecological processes, and affects from human activities
Very Good (7-8)	There are no significant changes in ecological processes or ecosystem services as a result of human activities
Good (5-6)	There are some significant changes in ecological processes as a result of human activities in some areas, but these are not to the extent that they are significantly affecting ecosystem functions
Poor (3-4)	There are substantial changes in ecological processes as a result of human activities, and these are significantly affecting ecosystem functions in some areas
Very Poor (1-2)	There are substantial changes in ecological processes

	across a wide area of the region as a result of human activities, and ecosystem function is seriously affected in much of the region
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#### 4.4 Physical and chemical processes

To score physical and chemical processes, experts will follow these steps:

1. Estimate a consensus score for the condition of physical and chemical processes in the Best 10% and Worst 10% of the habitat (eg. relative to 1900). Score both the area and condition of physical and chemical processes; for example if it is estimated that human activities have caused the physical and chemical process to no longer occur in 10% of the places where it did occur relative to the benchmark date, then the Worst 10% of that physical and chemical process will have a score of 1.
2. Estimate a consensus score for the condition of the physical and chemical process in Most areas (eg. relative to 1900).
3. Assign a confidence grade for the each of the condition estimates (High, Medium, Low).
4. Estimate the trends for each of Best 10%, Worst 10%, Most (Improving, Declining, Stable) over the last 5 years.
5. Assign a confidence grade for the each of the trend estimates (High, Medium, Low).
6. Record the main anchor references, and any commentary/notes relevant for the assessment of the condition and trends of each the physical and chemical processes.

Physical and Chemical Processes	Grading statements for the main physical processes as modified by human activities
Very Good (7-8)	There are no significant changes in physical or chemical processes or ecosystem services as a result of human activities
Good (5-6)	There are some significant changes in physical or chemical processes as a result of human activities in some areas, but these are not to the extent that they are significantly affecting ecosystem functions
Poor (3-4)	There are substantial changes in physical or chemical processes as a result of human activities, and these are significantly affecting ecosystem functions in some areas
Very Poor (1-2)	There are substantial changes in physical or chemical processes across a wide area of the region as a result of human activities, and ecosystem function is seriously affected in much of the region

#### 4.5 Pests, Introduced Species, Diseases and Algal Blooms

Definitions of what constitutes Pests, Introduced Species, Diseases and Algal Blooms may need to be first agreed based on a review of regional and national studies. The term 'pest' generally refers to marine plants or animals that are not native to the region but have been introduced by human activities such as shipping; they have the potential to significantly impact marine industries and the environment. Any other non-indigenous species introduced to the marine environment by humans is considered to be an 'introduced species'. When considering the spatial frame of reference, it should be viewed from the perspective of the habitats affected. So if the pests, introduced species, diseases and algal blooms are confined to coastal and estuarine habitats, for example,



then the best 10% would refer to coastal and estuarine habitats affected least and the worst 10% would refer to coastal and estuarine habitats affected most. To score the pests, introduced species, diseases and algal blooms experts will follow these steps:

1. Estimate a consensus score for the impact of pests, introduced species, diseases and algal blooms in the Best 10% and Worst 10% of the relevant habitats (eg. relative to 1900). Score both the area and degree of impact caused by pests, introduced species, diseases and algal blooms; for example if it is estimated that pests, introduced species, diseases and algal blooms are not found in 10% of the habitats where they do occur elsewhere in the region, then the Best 10% will have a score of 8. Conversely, if it is estimated that an introduced species has completely displaced an indigenous species in 10% of the area of habitats where they previously occurred, then the Worst 10% will have a score of 1.
2. Estimate a consensus score for the impact of pests, introduced species, diseases and algal blooms in Most areas (eg. relative to 1900).
3. Assign a confidence grade for the each of the condition estimates (High, Medium, Low).
4. Estimate the trends for each of Best 10%, Worst 10%, Most (Improving, Declining, Stable) over the last 5 years.
5. Assign a confidence grade for the each of the trend estimates (High, Medium, Low).
6. Record the main anchor references, and any commentary/notes relevant for the assessment of the impact of Pests, Introduced Species, Diseases and Algal Blooms.

Pests, Introduced Species, Diseases and Algal Blooms	Grading statements for Pests, Introduced Species, Diseases and Algal Blooms
Very Good (7-8)	The incidence and extent of diseases and algal blooms are at expected natural levels, there are insignificant occurrences or numbers of pests, and the numbers and abundance of introduced species is minimal.
Good (5-6)	Incidences of diseases or algal blooms occur occasionally above expected occurrences or extent, and recovery is prompt with minimal affect on ecosystem function. Pests have been found, but there have been limited ecosystem impacts. The occurrence, distribution and abundance of introduced species are limited and have minimal impact on ecosystem function.
Poor (3-4)	Incidences of disease or algal blooms occur regularly in some areas. Occurrences of pests require significant intervention or have significant effects on ecosystem function. The occurrence, distribution and abundance of introduced species triggers management responses, or have resulted in significant impacts on ecosystem functions.
Very Poor (1-2)	Disease or algal blooms occur regularly across the region. Occurrences of pests or introduced species are uncontrolled in some areas, have displaced indigenous species and are seriously affecting ecosystem function.

## 4.6 Pressures and socioeconomic benefits

This part of the assessment is carried out in three steps. First, the pressures associated with separate industries that impact the condition of the marine environment are assessed. The total environmental footprint of the industry is examined and given a score based on the expert's judgement of the industries' impact on all aspects of the

marine environment, including condition of habitat, species, ecosystem processes and physical-chemical processes.

To score environmental impact of marine-based industries (pressure), experts will follow these steps:

1. Estimate a consensus score for the condition of the environment that coincides with the spatial footprint (i.e. the space where the industry operates) of the industry (eg. relative to 1900). For Best 10% and Worst 10% areas, we focus on the spatial footprint of where the industry operates. For example if it is estimated that the condition of the environment has not changed within an area of 10% of the industry footprint (with reference to the benchmark), then the Best 10% of places will have a score of 8. Changes in condition of the environment should be attributable only to the industry under assessment. For example, if two or more industries are impacting on the same habitat we try to score only the impact of the one industry we are assessing.
2. Assign a confidence grade for the each of the condition estimates (High, Medium, Low). The confidence score may be influenced by uncertainty in attribution of impact where two or more industries are impacting on the same area.
3. Estimate the trend for the condition of the environment within the footprint of the industry (Improving, Declining, Stable) over the last 5 years that is attributable only to the industry under assessment (i.e. not including changes related to other, additional pressures, etc.).
4. Assign a confidence grade for the each of the trend estimates (High, Medium, Low).
5. Record the main anchor references, and any commentary/notes relevant for the assessment of pressures.

Pressures	Grading statements for pressures - the environmental impact of marine-based industries.
Very Good (7-8) Low Pressure	This industry has caused no significant changes in the overall environment (condition of habitat, species, ecosystem processes or physical and chemical processes) within its footprint.
Good (5-6) Moderate Pressure	This industry has caused some significant changes in some components of the overall environment, but these are not to the extent that they are significantly affecting ecosystem functions.
Poor (3-4) Significant Pressure	This industry has caused substantial changes in many components of the overall environment, and these are significantly affecting ecosystem functions in some areas of its spatial footprint.
Very Poor (1-2) High Pressure	This industry has caused substantial changes in many components of the overall environment across its spatial footprint and ecosystem function is seriously affected.

The second step is to assess the totality of all socioeconomic benefits that society receives from the industry. There are several aspects that must be evaluated, including:

- 1) whether it is a major national employer, paying fair wages, either through direct employment or supporting industries;
- 2) whether or not the state receives significant taxes, royalties and/or license fees and if a significant portion of profits remain in the country;
- 3) whether the industry exploits a sustainably managed renewable resource;
- 4) whether the industry contributes to education and training programs, human health or medical benefits for its employees;
- 5) whether the industry creates national infrastructure such as roads, communication systems or other facilities;

6) whether the industry is mainly or wholly owned by national interests (i.e. the profits from the industry remain in the country).

The industry is given a score from 1 to 8 based on the expert's judgement.

To score socioeconomic benefits of marine-based industries, experts will follow these steps:

1. Estimate a consensus score for the socioeconomic benefits derived from the industry. Consider the spatial footprint of the industry and score the best and worst 10% of areas in terms of socioeconomic benefits received.
2. Assign a confidence grade for each the benefits estimate (High, Medium, Low).
3. Estimate the trends for the socioeconomic benefits (Improving, Declining, Stable) over the last 5 years.
4. Assign a confidence grade for the each of the trend estimates (High, Medium, Low).
5. Record the main anchor references, and any commentary/notes relevant for the assessment of socioeconomic benefits.

Socioeconomic benefits	Grading statements for the benefits society receives from marine industries – this is the total benefit including employment, taxes, royalties and license fees paid to the state, education and training, human health benefits and infrastructure (buildings, roads, etc.). It includes both the direct employment benefits as well as dependent and supporting industries.
Very Good (7-8) High benefits	The industry is mainly or wholly owned by national interests and is a major national employer both through direct employment as well as through supporting industries. The state receives significant taxes, royalties and/or license fees and a significant portion of profits remain in the country. The industry exploits a sustainably managed renewable resource and contributes to one or more of: education and training programs, human health and medical benefits and national infrastructure.
Good (5-6) Significant benefits	The industry is an important national employer both through direct and indirect employment and the state receives taxes, royalties and/or license fees. The industry may contribute to education and training programs, human health or medical benefits.
Poor (3-4) Some benefits	The industry is a minor employer both through direct and indirect employment and the state receives some taxes, royalties and/or license fees. The industry is partly or mainly foreign-owned.
Very Poor (1-2) Few or no benefits	The industry is mainly or wholly foreign-owned and is not a nationally important employer, with most/all employment based overseas. The industry exploits a non-renewable resource (or an unsustainably managed renewable resource) and the state receives very little from taxes royalties or license fees from this industry.

The third step is to plot the environmental and socioeconomic scores for the industry on a graph to classify its overall rating (Fig. 3). Thus each industry will be rated as having either: 1) low environmental pressure and high socioeconomic benefit; 2) low environmental pressure and low socioeconomic benefit; 3) high environmental pressure and high socioeconomic benefit; or 4) high environmental pressure and low socioeconomic benefit.

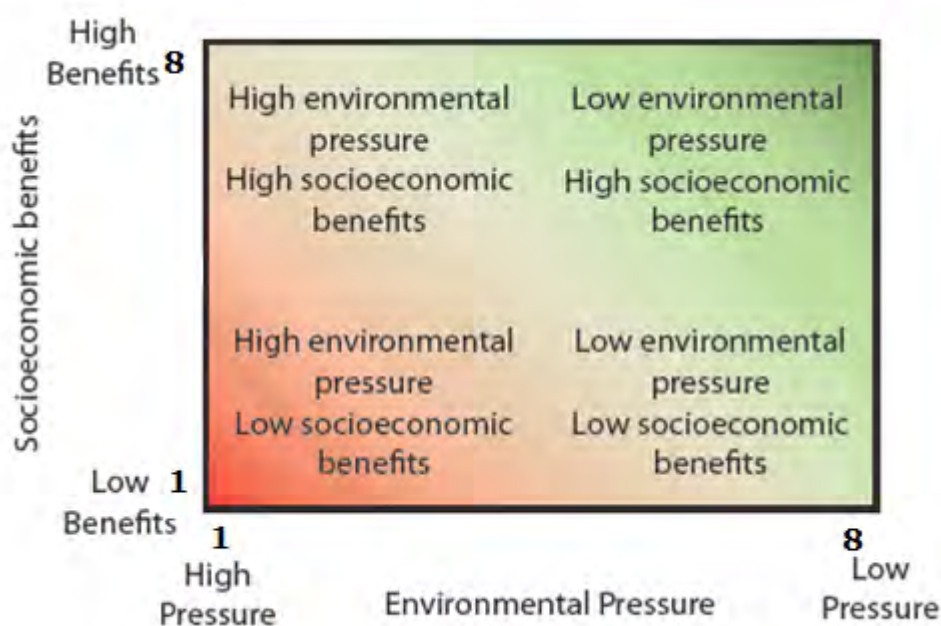


Figure 3. Matrix for assessment of environmental pressures and economic benefits for marine-based industries. The optimum situation is for the combination of low environmental pressure (shown in green) to coincide with high socioeconomic benefits. The worst situation is for the combination of high environmental pressure (shown in red) to coincide with low socioeconomic benefits.

## 5. Risk assessment

The condition, pressure and socioeconomic assessment part of the assessment methodology is backward-looking in time; it is essentially attempting to describe the state of the marine environment relative to a benchmark and recent trends in environmental condition manifested by changes in condition over the past 5 years. It is a statement of the current situation of the marine environment.

In contrast, the risk assessment part of the assessment methodology is forward-looking. Its purpose is to provide statements of the situation that the marine environment is likely to be in if current management of human activities is not changed. It is designed to provide policy- and decision-makers with feedback on the short-term (5 year) and long-term (50 year) consequences of current management and to highlight specific risks that are deemed by the workshop experts to warrant the greatest attention. It is emphasised that the experts are instructed to only consider what is likely to occur if there are no changes to current policies; experts are not allowed to second-guess what decisions governments may or may not take in the future.

The risk of any event is the sum of the likelihood of the event occurring and the consequences of the event should it occur. The likelihood and consequences associated with a given risk will be scored on a scale from 0 to 5. The correspondence between scores and likelihood and consequences is given in the Risks assessment section below.

As in the case of parameters selected for condition assessment, the risks assessed in the workshop will be a combination of those which are nearly universal to all maritime nations and others which are of particular significance to the nation or region considered in the workshop. An example list of standard risk scenarios is as follows:

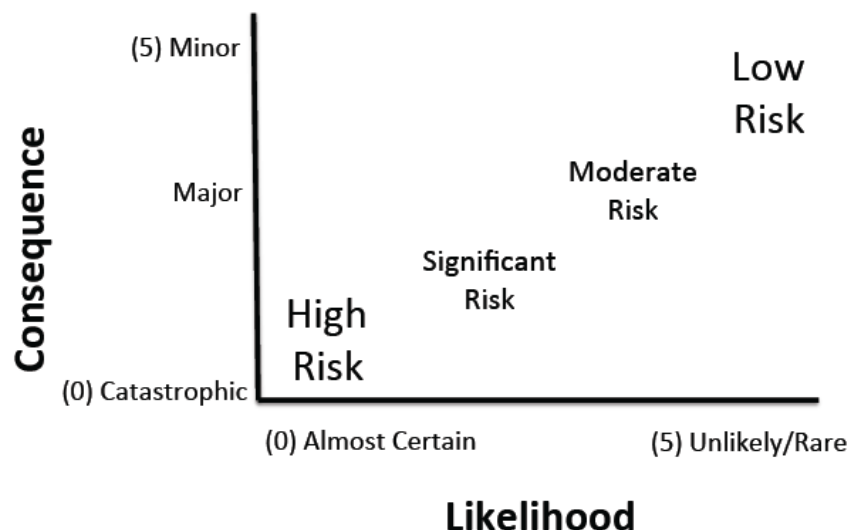
- The risk that illegal and unreported fishing will increase

- The risk that overfishing will cause fish stocks to collapse
- The risk that oil exploration will result in a blowout or major spill
- The risk that shipwrecks will cause a major oil spill
- The risk that global sea level rise will cause coastal inundation
- The risk that pollution will cause seafood poisoning
- The risk that tourism will cause environmental damage
- The risk that catchment disturbance will cause siltation of estuaries
- The risk that use of fertilizers will cause widespread eutrophication
- The risk that harmful algal blooms will occur

The risk assessment is a two-step process. Experts first assess the likelihood that an event will occur: a) in the next 5 years; and b) in the next 50 years. The experts are then asked to judge the consequences of an event occurring in terms of its overall impact on the marine environment. The addition of scores gives the risk as per Figure 4.

Likelihood	
This is the probability of the impact occurring over a 5-year or 50-year timescale, taking into account the effectiveness of present and recently implemented (not planned) management arrangements and activities.	
Almost certain (score = 0)	Expected to occur often within 5 (50) years
Likely (score = 1-2)	Expected to occur at least once within 5 (50) years
Possible (score = 3-4)	Occurrence is not certain within 5 (50) years
Unlikely/Rare (score = 5)	Not expected to occur within a 5 (50) year period

Consequence/Impact	
This is the extent and severity of the expected impact taking into account the effectiveness of present and recently implemented (not planned) management arrangements and activities.	
Catastrophic (Score = 0)	Impact will seriously affect the ecosystem in the region, disrupting major ecosystem structure or function, and have recovery periods of more than 20 years (potentially irreversible)
Major (Score = 1-2)	Impact will seriously affect the ecosystem in the region, disrupting major ecosystem structure or function, and have recovery periods of less than 20 years
Moderate (Score = 3-4)	Impact will affect the ecosystem in the region, disrupting some aspects of ecosystem structure or function, and have recovery periods of less than 5 years
Minor (Score = 5)	Impact will be very limited and affect only minor components the ecosystem in the region



**Figure 4.** The Inherent Risk Rating score for each risk is calculated by adding the Likelihood and Consequence ratings. This provides a risk score of between 0 and 10 that gives a risk rating of High (0-3), Significant (4-5), Moderate (6-7) or Low (8-10).

## 6. Conclusions

The Production of State of Marine Environment Assessments and Reports based on Expert Elicitation provides an alternative to the classical data intensive environment reporting methods which may prove very useful to allow make most use of existing expert knowledge in regions where environmental data has not been recorded and reported in a systematic way. The existing expert knowledge may be enough and the only available means to draw an assessment that allows stakeholders taking decisions to initiate or improve environmental management without further delay in hope that enough systematic data is recorded. The Expert Elicitation Approach if used to the full extent of its capacity may deliver a high quality report within a limited budget.

The pilot workshops conducted so far have proven to be very useful means of gathering available knowledge in the pilot regions and have received very good feedback for the experts participating in it as they allowed a quick and meaningful integration of the knowledge existing in a certain region. Ongoing efforts should lead to the finalization of the Reports emanating from these workshops in the near future.

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# Appendix 1. Web-based system for State of the Marine Environment reporting

GRID-Arendal has created a pilot, web-based system to capture and analyse workshop scores: <http://some.grida.no>, with the following main features:

- A core set of marine environmental and socio-economic parameters is included in the system. This set is based upon the WOA chapters. The set of parameters can easily be adapted with relevant parameters for a country or region identified by experts.
  - Relevant data and information identification and compilation: the system allows the capture of relevant information sets. Important reference datasets and publications that are identified by the experts during the development process of the SOME reports can be added to the website, either as external links or uploaded to the web site in pdf, word or other formats.
  - The website allows for the real-time capture and display of data and statistics (scores for parameters, confidence, risks) during the workshop.
  - The website provides a template for the production of a State of Marine Environment Report. This outline is based upon the DPSIR system, the WOA outline and other relevant report templates (e.g. SOE report of Australia). The content and graphics can be exported and used as the basis for a national or regional SOME report or the contents can be adapted for use within other formats as required.
  - The database allows direct correlation to the outline of the World Ocean Assessment, thereby permitting cross-referencing and combining outcomes of the assessment to optimize it as a contribution to the international effort.
  - Another key aspect is that the diagrams and outputs that are produced by the web site are designed for easy communication of the workshop results to policy- and decision-makers. The diagrams are simple, jargon-free and clearly communicate the main findings of the judgments made by the experts.
- The system allows the assignment of different roles to contributing experts during the development process of the SOME reports: main editors, contributors, reviewers, etc. Contributors can be made responsible for one or more chapters in the SOME outline. Draft versions of the report can be circulated to all participants for updating and review of the report and workshop outcomes, including recording of key references and anchors that may have been overlooked.





