KenSea

Environmental Sensitivity Atlas for Coastal Area of Kenya

UNDP

GEUS

KenSea

Environmental Sensitivity Atlas for Coastal Area of Kenya

March 2006

United Nation Development Program

Kenya Marine and Fisheries Research Institute

Geological Survey of Denmark and Greenland

Kolofon

KenSea – Environmental Sensitivity Atlas for Coastal Area of Kenya has been financed by the Fund for Danish Consultancy Services and has been implemented by United Nations Development Programme (UNDP) in Kenya. The editor is responsible for all results and conclusions presented in the report, which do not necessarily reflect the position of the Fund for Danish Consultancy Services and United Nations Development Programme.

Tychsen, J. 2006 (ed.): KenSea. Environmental Sensitivity Atlas for Coastal Area of Kenya, 76 pp. Copenhagen; Geological Survey of Denmark and Greenland (GEUS); ISBN 87-7871-191-6

Editor: Mr. John Tychsen, GEUS
Technical editor: Mr. Henrik Klinge Pedersen, GEUS
Cover and lay-out: Mr. Henrik Klinge Pedersen, GEUS
Photographs: Mr. Ole Geertz-Hansen, AquaSim
Maps: Sources given at each map.
Print: Mr. Afet Neimi, GEUS

ISBN 87-7871-191-6

Ministry of the Environment
10 Oester Voldgade
DK-1350 Copenhagen
Denmark

Table of Contents

List of Abbreviations

CDA	: Coast Development Authority
DEPHA	: Data Exchange Platform for the Horn of Africa
EAF-14	: Eastern Africa Atlas for Coastal Resources. Kenya
EEZ	: Exclusive Economic Zone
ESI	: Environmental Sensitivity Index
FGDC	: Federal Geographic Data Committee
NGDC	: National Geospatial Data Clearinghouse
GEUS	: The Geological Survey of Denmark and Greenland
GIS	: Geographical Information System
GoK	: Government of Kenya
ICS	: Incident Command System
IMO	: International Maritime Office
KenSea	: Kenya Environmental Sensitivity Atlas
KMFRI	: Kenya Marine Fisheries Research Institute
KPA	: Kenya Ports Authority
KWS	: Kenya Wildlife Service
NEMA	: National Environmental Management Authority
NMOSCP	: National Marine Oil Spill Contingency Plan
OSMAG	: Oil Spill Mutual Aid Group
SoK	: Survey of Kenya
ToR	: Terms of Reference
UNEP	: United Nations Environmental Programme
UNDP	: United Nations Development Programme
UNOPS	: United Nations Office for Project Services

Acknowledgement

This report was produced by the Geological Survey of Denmark and Greenland (GEUS).

Overall responsible for the KenSea project and the development of this report was Project Manager Mr. John Tychsen (GEUS) who was assisted by Mr. Ole Geertz-Hansen (AquaSim), Mr. Jesper Kofoed, (GeoQuest), Mr. Anders Mosbech (NERI) and Mr. Harrison Ong'anda (KMFRI) – **The KenSea Team.**

The development of the KenSea coastal resources database (KenseaBase) and the Geographic Information System (GIS) framework, were undertaken by Mr. Jesper Kofoed with assistance from Mr. Johannes Akiwumi (DEPHA) and Mr. Mwangi Theuri (DEPHA). Data entry and map digitizing were done by Mr. Alex Lugadiru (DEPHA) and Ms Jane Wanjiku Wanyiri (DEPHA).

The text was compiled from contributions by members of the KenSea Team. The editor and the members of the KenSea Team benefited greatly from discussions, advice and assistance received from the following:

Kenya Marine and Fisheries Research Institute (KMFRI)
Mr. Johnson Kazungu, Director
Mr. Steve Mwangi, Assistant Director
Dr. James. G. Kairo, Research Officer
Mr. Jared Bosire, Research Officer
Capt. Joseph Mwanthi, Master Fisherman
Miss. Gladys Okemwa. Deputy Vice-Chair Kescom/ Research Officer, KMFRI
Mrs. Pamella Abuodha, Research Officer
Mrs. Pamela Ochieng', GIS Technician
Miss. Irene Githaiga, Administrative assistant/Director's office

Kenya Wildlife Service
Mr. Benjamin Kavu, Assistant Director
Mr. Mohamed Omar, Research Officer
Mrs. Teresa Muthui, GIS Officer.

Coast Development Authority
Dr. Boniface M.J. Mwandotto, Deputy Managing Director
Mr. Zachary Peter Odhiambo, Principal Research Officer

National Museums of Kenya
Dr. Helida A. Oyieke, Director of Research & Scientific Affairs
Mr. Oliver Nasirwa, Head of Secretariat, Wetland Biodiversity Monitoring Scheme

Kenya Ports Authority
Mr. Peter W.K. Mbiriri, Incident Commander Team

Fishery Department
Mr. Leonard N. Thaibo, Assistant Fishery Officer
Mr. Ndegwa Stephen, Principal Research Officer

CORDIO East Africa
Dr. David Obura, Manager Cordio East Africa

The Wildlife Conservation Society. Kenya
Dr. Tim McClanahan, Manager WCSK

IUCN-Kenya
Mrs. Melita Samoilys, Regional Co-ordinator
Prof. Laurent Ntahugo, Regional Technical Co-ordinator

WWF-Kiunga/Lamu
Mr. Sam Weru, Project Coordinator WWF Eastern Africa Regional Programme

Survey of Kenya
Mr. Martin Obuyu, Principal Surveyer

Geological Survey of Denmark and Greenland (GEUS)
Mr. Frantz Von Platen-Hallermund, Senior GIS-officer
Mrs. Birgit Jørgensen, Administrative Assistant
Mr. Henrik Klinge Pedersen, Leader of Graphic Section
Mr. Afet Niemi, Technician
Mr. Anthony Higgings, Research Scientist

Foreword

The problem of oil spill response can be complex if a decision has to be made in short timelines of less than one day as is often the case. The knowledge of the spread and distribution of natural resources along the Kenyan coast would be quite challenging to a command center grappling with operational and political pressure from various sectarian interests all seeking satisfactory response during a spill incidence. In order to arrive at objective compromise decision, information must be available in a speedy manner.

The new product, Kenya Sensitivity Atlas and its GIS database is taking advantage of technology advancement to provide the much needed support in effective decision process for management of the Marine and Coastal Area of Kenya. The principal approach here is the move from static atlas to a GIS electronic atlas.

The development of the atlas by Kenya Marine and Fisheries Research Institute (KMFRI) is an integral part of the National Marine Oil Spill Contingency Plan (NMOSCP). It provides an environmental data dictionary to be utilized as a tool in risk assessment, clean up prioritization as well as in selection of appropriate methods and tools of response.

The GIS datasets include information on environmental parameters and socio-economics data along the coast of Kenya thereby providing vast opportunities for secondary use. Information has been used to generate hard copy and electronic maps showing the degree of sensitivity to oil spill.

This product is part of the Kenya Government's policy on poverty alleviation whereby the Government ensures it has contingency plans and resources in place to combat disasters such as forest fires, floods, drought and oil spills threatening to ruin the natural resource base which provides income to its citizenry.

In addition the atlas represents the Government of Kenya's efforts in fulfilling its obligations with respect to various conventions on prevention of pollution including the International Convention on the Prevention of Pollution by Ships (MARPOL 73/78), the Safety of Life at Seas (SOLAS), the International Convention on Oil Pollution Preparedness and Response Cooperation (OPRC90), the Civil Liability Convention (CLC92) and the International Oil Pollution Compensation Fund (IOPC92).

This product therefore represents a significant step towards support for conservation of our vital marine resources.

DR. KAZUNGU, Johnson M.
DIRECTOR/KMFRI

1 Introduction

1.1 National Oil Spill Response Contingency Plan (NOSRCP)

The Kenya coastline extends some 600 kilometres from the border of Tanzania in the south to the border of Somalia in the north. Among its distinctive features are the nearly continuous coast parallel fringing coral reef, the Lamu archipelago, Marine National Parks and Reserves, sandy beaches, Mombasa Creek as well as Wasini and other coral islands.

Coastal ecosystems

The Kenyan coast features a diverse marine environment including estuaries, mangroves, seagrass beds and intertidal reef platforms and coral reefs, which are vital for the diversity and reproduction of marine organisms. These coastal ecosystems systems are regarded as some of Kenya's most valuable ecosystems; and some are protected by the six marine national parks and reserves. These coastal ecosystems make up the basis for the livelihood of the large coastel population, but do on the other hand face serious threats from the ever increasing human pressure through tourism, industrial pollution, overfishing, destructive fishing, mangrove logging and other unsustainable use of marine resources.

Tanker traffic

These highly productive ecosystems in the coastal area play a crucial role in the socio-economic development of the country. The coastal economy depends heavily on tourism and the tourism sector is dependent on Kenya's coastal and marine resources, but the inhabitants and the visitors to the coast are not the only pressure on the coastal environment. The coastal environment is also at risk from maritime transportation activities at the port and shipping along the coastline. It is estimated that at any given time there are 50 ships in the major shipping lanes off the Kenya coast, approximately 9 are oil tankers with capacities ranging from 50000-250000 tons. Most of this coastal tanker traffic passes 250 nautical miles offshore, however with Mombassa harbour serving as the major port for Kenya as well as the hinterland countries of Uganda, Rwanda, Burundi, Ethiopia, Southern Sudan, North Eastern Tanzania and Somalia the threat for an oil spill is obvious. Further oil pollution may result from normal oil transportation activities such as ship to shore transfers and upland tank storage at the port.

Spill response

In recognition of risks posed by oil pollution the Government of Kenya and the private oil industry have decided to develop a National Oil Spill Response Contingency Plan (NOSRCP) with the purpose of enabling a speedy and effective response by the Response Team at Kenya Port Authority (KPA) within the territorial waters of Kenya. An important element of this plan is the mapping of the coastal resources and the development of an Environmental Sensitivity Atlas showing the sensitivity of the coast to marine oil spill. This atlas should be utilized as a tool in vulnerability assessments and provide oil spill responders with sufficient information allowing them to prioritize the immediate response and the subsequent clean-up effort.

1.1.1 NMOSCP structure

The NMOSCP organization structure is based on the internationally recognized Incident Command System (ICS). The Incident Commander in Kenya includes an environment and wildlife adviser responsible for guiding the Incident Commander on the priorities and method of response in each habitat. This role has been assigned to scientists from institutions such as Kenya Marine Fisheries Research Institute (KMFRI).

Efforts are being made towards legalizing the draft NMOSCP by the government and the stakeholders. United Nations Development Program (UNDP) in Kenya has recognized the tremendous efforts that have been made in the preparation of the development of the engineering/operational phase of an oil spill response. Based on the work progress already made, UNDP decided to provide - through the Danish Trust Fund at UNDP - financial support to the development of phase II of the ongoing national oil spill contingency planning process by facilitating the creation of the Environmental Sensitivity Atlas for Coastal Area of Kenya.

1.1.2 Project Implementation

The project was approved for funding by UNOPS in Copenhagen administrating the Danish Trust Funds at UNDP in 2004 and after an open bidding process the contract was awarded to a Danish consortium with the Geological Survey of Denmark and Greenland (GEUS) as leading company.

The integrated database and GIS system to be developed during the project was agreed to be installed at Kenya Marine and Fisheries Research Institute (KMFRI), having the responsibility for the shoreline classification in the NMOSCP.

KenSea

The Danish/Kenyan consortium and KMFRI agreed at an early stage in the project implementation to use the KenSea (Kenya Environmental Sensitivity Atlas) as an abbreviation for the project.

The project implementation was initiated in January 2005 with a workshop for all stakeholders involved in the NMOSCP process and a number of NGOs operating in the coastal zone of Kenya. The Workshop had the aim of discussing the concept for the development of the environmental sensitivity atlas presented by the KenSea Group. The workshop provided a very good discussion of the preliminary priorities of features to be included in the Atlas an a formula for the ranking of the environmental sensitivity of the coastal area of Kenya. Further the workshop served as a forum to establish the formal contact to the data holding agencies, government institutions, NGOs and the private sector.

Previous work

In the 1990s the Eastern Africa Coastal and Marine Resources Database and Atlas (UNEP 1998) was developed by the United Nations Environmental Programme (UNEP) within the framework of the 1985 Eastern

Africa Action Plan for the Protection, Management and Development of the Marine and Coastal Environment.

The EAF-14 datasets included a variety of information within bio-science, geo-science and human-use with relevance to the present project, wherefore some of the datasets from the EAF-14 have been incorporated either directly or as guideline for further investigations. The main challenge of the EAF-14 in this context is the fact that it has been produced in scale 1:250,000 implying that it has a lower degree of spatial precision than data created in 1:50,000 requested for the KenSea project.

The EAF-14 database was transferred into the KenSea database (KenSea-Base) and the 1: 250,000 maps were the basis for meetings with a large number of data holders. All collected data was digitised and included in the KenSeaBase and preliminary maps were printed. Based on these preliminary maps a field program for data verification and data collection was developed. The results of the field work were integrated in the KenSeaBase and final maps were produced.

Figure 1-1 By removing the door of the plane it was possible to achieve clear and oblique photos of the coastline. All photos were positioned by GPS and labelled by longitude and latitude as well as the altitude of the plane.

Aerial photo missions

It was decided during the planning of the project that a traditional full scale field survey with a team offshore in a boat supported by a team on land was outside the financial framework of the project. Therefore a full coverage of the coast line was achieved by a photo mission along the entire coastline by plane. This dataset provided the KenSea project with an excellent tool for documenting near coast features such as coastal morphologies, extent of corals, mangroves and fishing sites.

Apart from creating the above mentioned new layers and re-using modified versions of data from the EAF-14 database a very large effort was put into harvesting all existing GIS layers with relevance to the project from other data holding institutions or organizations

1.1.3 The Environmental Sensitivity Atlas

The Environmental Sensitivity Atlas for the Coastal Area of Kenya developed through the KenSea project contains three types of maps which have been reproduced in 16 map sheets in scale 1: 50.000 to cover the whole cost line. In addition, 4 map sheets in 1: 25.000 have been produced for the Mombasa Creek Area.

The KenSea project contains the following three thematic maps:

Logistics and Topographic Maps

An important tool in the response strategy is map sheets with reliable near shore information as towns, major constructions and especially access roads to the beach providing the possibility of bringing heavy equipment and man power to the beach for clean-up operations, see details in chapter 5.1.

Coastal Resource Maps

The Coastal Resource Maps represent all available data and are the basis for the calculation of the environmental sensitivity index. The features are grouped according to Coastal types, Biological resources and Human use, see details in chapter 5.2.

Environmental Sensitivity Maps

In addition to their inherent value, and biological value based on biodiversity or production, some coast types are more important for human interests, e.g. local small scale fishery, tourism, protection against coastal erosion, than others. Prioritising is therefore of vital importance for a successful response strategy. But, to be of any use to the oil spill responders, such information has to be compiled, analyzed and published in a comprehensive atlas before the spill happens.

After the development of the Coastal Resource Maps the data layers containing geographic information about these resources were used as the foundation for the calculation of the environmental sensitivity index and the rendering of the index values in a separate set of maps, see details in chapter 5.3.

2 The Coastal Environment

2.1 CLIMATE

The Kenyan coast runs in a south-westerly direction from the Somalian border in the north, at 1° 41'S to 4° 40'S at the border with Tanzania. It lies in the hot tropical region where the weather is influenced by the great monsoon winds of the Indian Ocean. Climate and weather systems on the Kenyan coast are domi-nated by the large scale pressure systems of the western Indian Ocean and the two distinct monsoon periods.

The monsoons

From November/December to early March, the Kenyan weather, particularly at the Coast, is dominated by the Northeast Monsoon (Kazkazi) which is comparatively dry. During March and April the monsoon winds blows in an east to south-easterly direction (Kuzi) with strong incursions of maritime air from the Indian Ocean bringing heavy rains. During the months of May, June, July and August, the South-easterly Monsoon influence gradually sets in and the weather becomes more stable with dull and comparatively cooler temperatures. Between September and November, the Northeast Monsoon gradually re-establishes itself and by December the northern influence is dominant once again.

2.1.1 Rainfall

A relatively wet belt extends along the entire Indian Ocean coast of Africa and annual rainfall on the Kenyan coast follows the strong seasonal pattern outlined above. The main rains come between late March and early June with the rain-fall decreasing from August. Some rain occurs between October and November but from December, rainfall decreases rapidly once again to a minimum during January and February. Mean annual total rainfall ranges from 508 mm in the drier, northern hinterland to over 1,016 mm in the wetter areas south of Malindi. Relative humidity is comparatively high all the year round, reaching its peak during the wet months of April to July.

2.1.2 Wind

The windiest time of the year at the Kenya Coast is during the Southeast Mon-soon from May to September, while the calmest months are March and No-vember when the winds are also more variable in direction. Wind records from Lamu, Malindi and Mombasa show a consistent daily pattern whereby wind strength (in knots) drops during the night and is always less at 0600 hrs than at 1200 hrs. This pattern is less pronounced in Lamu which also tends to be the windiest place on the Coast at 0600 hrs. Overall, it would seem that Mombasa is the windiest, but the strongest winds are likely to be experienced in August in Malindi.

2.2 HYDROLOGY

2.2.1 Rivers and Catchments

The hydrology of the coastal region of Kenya can best be viewed by examining the drainage patterns of both perennial and seasonal rivers draining into the western Indian Ocean basin. There are two main perennial rivers namely the Tana River and the Sabaki River which originates from the Highlands around Mt. Kenya and Nairobi. Discharge from both rivers is highly seasonal, characteristic of dry land rivers, which can deliver over 80 % of their annual sediment loads within a period of a few days at the onset of heavy rains (Dunne, 1979; Obura, 2001)

Tana River

The Tana River is the longest in Kenya being approximately 850 km in length and it has a catchment area of 95,000 km^2. An average of 4,000 million m^3 of freshwater and some 3 million tonnes of sediment are discharged annually. It enters the ocean about halfway between Malindi and Lamu, near Kipini, into Ungwana Bay. However, before it does, and about 30 km upstream, it gives off a branch which leads to the complex of tidal creeks, flood plains, coastal lakes and mangrove swamps known as the Tana Delta. The Delta covers some 1,300 km^2 behind a 50 m high sand dune system which protects it from the open ocean in Ungwana Bay. *(Figure 2-5)*

Sabaki River

The Sabaki River is the second longest with a length of 650 km and a catchment area of 70,000 km^2 extending into the south-eastern slopes of the Nyandarua Range in central Kenya. The Sabaki River discharges 2,000 million m^3 of freshwater and 2 million tonnes of sediment annually into the sea through the Sabaki estuary north of Malindi.*(Figure 2-9)*

Other rivers

There is also a number of semi-perennial and seasonal rivers such as the Mwache, Kombeni, Tsalu, Nzovuni, Umba, Ramisi, Mwachema and Voi, all of which drain into the coastal region from arid and semi-arid catchments. The Ramisi River, which arises in the Shimba Hills forested area, discharges 6.3 million m^3 of freshwater and 1,500 tonnes of sediments annually into Funzi -Shirazi Bay in the southern part of the Kenya coast. The Umba discharges 16 million m^3 of freshwater into Funzi - Shirazi Bay while the Mwachema and Mwache rivers discharge 9.6 million m^3 and 215 million m^3 of freshwater annually, respectively.

2.2.2 Coastal lakes

There is a number of lakes in the Kenya coastal region with the majority found in the Tana Delta. Most of these lakes are quite small and shallow and are typical oxbow lakes, remnants of the various meanders of the Tana River. Some of the lakes, especially the smaller ones, show swamp characteristics. These lakes are either recharged through ground water seepage or by the periodic flooding of the Tana River.

2.3 GEOLOGY AND GEOMORPHOLOGY

The Kenyan coastal environments are set in a passive continental margin, the evolution of which was initiated by the break-up of the mega continent Gondwanaland in the Lower Mesozoic. The initial opening of the Indian Ocean was preceded by doming, extensive faulting and down warping similar to that observed in the modern Great Rift Valley of East Africa. These tectonic movements formed a North-South trending depositional basin. During the Mesozoic, this basin was exposed to numerous marine incursions and by the Jurassic, purely marine conditions are thought to have existed. The coastal range running parallel to the coastal zone appears to have been uplifted through faulting during this time.

Throughout the Tertiary, the coastal areas experienced further faulting and extensive continental erosion. The older Cretaceous deposits were totally removed in many areas. The present coastal configuration, however, evolved during the Pleistocene to Recent times, a period marked by numerous fluctuations in sea level.

Three physiographic zones are observed on the Kenya coastal zone. The Nyika lies at 600 m above the present sea level and represents the higher ground covered by the Duruma sandstone series and older rocks to the west. The Foot Plateau occurs at an elevation between 140 m and 600 m above the present sea level. This coincides well with the relatively younger Jurassic rocks. The Coastal Plain, the lowest step, rises from sea level to 140 m. On average, this belt increases from a few kilometres wide in the southern sector, to over 40 km in the north. The geomorphology of the Coastal Plain is dominated by a series of raised old sea level terraces. Most of the coastal environment and the modern shore configuration follow the 0-5 m and the 5-15 m sea level terrace complexes.

Sedimentary rocks

Due to its evolutionary history, the principal rocks observed along the Kenyan coastal margin, are of sedimentary origin and range in age from Triassic to Recent. The Duruma Sandstone series, the oldest formation, is represented by the Mariakani and the Mazeras sandstones which were deposited under subaqueous, deltaic, lacustrine or possibly neritic conditions that prevailed before the opening of the Indian Ocean. The Upper Mesozoic is represented by marine limestones and shales with occasional horizons of sandstones and early limestones. Cenozoic to Recent rocks comprises mostly of marls and limestone's, and is represented by the sandstones, clays, conglomerates and gravels such as the Marafa beds. Quaternary representatives include windblown Magarini Sands, limestones, cemented sands and coral sands. Recent unconsolidated windblown sands, beach sands and clays overlie the older units.

Kenya has a coastline of over 600 km, but the exact figure depends on the extent to which small islands are included in the measurements. The Kenyan coastal region is generally lowlying and characterised by the extensive fossil reef which lies a few metres above present sea level. The coastal plain is backed in the interior by a line of hills that rarely exceed 300 m except in southern parts where the Shimba Hills reach an altitude of around 1,000 m above sea level. Further inland the Taita Hills rise to an elevation of 1,500 m above sea level.

Soils of the coastal region show considerable variety. The porous parent rocks of sedimentary origin, generally give rise to soils of low fertility. However, patches of highly productive soils have been observed in areas of alluvial deposits. The principal soil types in the region include a narrow strip of coastal sands towards the north where it is permeated by narrow-

Figure 2-1 Photo taken south of Chale island at Funzi looking north against Diana and Mombasa. Typical coastline showing the fringing reefs typical for the southern part of the coastline. The small white beach and the northern part of Chale island is a famous tourist resort.

bands of grumosolis brown clay soils. The soil south of Lamu is composed of bialternate bands of loams beyond which the grumosolis are permeated by thick bands of ash and pumice soils.

Erosion

The shoreline in most of the region apart from the Malindi area is receding as a result of coastal erosion.

Living coral reefs occur along most of the Kenyan coast. A fringing reef colonizes the shallow parts of the continental shelf along most of the Kenyan coastline to a depth of around 45 m and at a distance of between 500 m and 2.0 km offshore, except where river systems create conditions of low salinity and high turbidity which limit coral growth. Estuaries and deltas are instead characterized by extensive mangrove forests.

The shelf

The width of the continental shelf off the Eastern African coast varies markedly throughout the region, but it is generally quite narrow. Kenya, with a coastline of about 600 km, has an estimated continental shelf area of about 19,120km^2. Of this, some 10,994 km^2 is considered trawlable. South of Malindi the continental shelf extends only 5 km offshore, whereas north of Malindi, in the North Kenya Banks, the edge of the shelf is about 60 km offshore (UNEP 1998).

2.3.1 Classification of the Kenya Coastline

Many attempts have been made worldwide to classify coastlines regarding their vulnerability to oil pollution damage. They are usually based on the geomorphology, the degree of exposure to wind and waves, and may also take other conditions into account. Most of these systems are inspired by Gundlach and Hayes (1978) and the IMO publication on "Sensitivity Mapping for Oil Spill Resonse" (IMO/IPIECA 1994)

The classification adopted for this Atlas also builds on these systems. In addition to the coastal geomorphology and degree of exposure the ecological value and biodiversity of the particular stretch of coastline is taken into account. This classification comprises seven categories or types, each of which is described below in terms of its geomorphology, ecological value and vulnerability.

1. **Mangrove swamps**
   Moderate to fully sheltered from wind and wave action and mainly intertidal; a productive environment very sensitive to oil pollution.
2. **Sheltered rias**
   Steep to moderate sloping sedimentary structure inside the creeks; reduced wind and wave actions; a basis of fossil reefs often observed. Moderate biological productivity
3. **Tidal flats**
   Mainly mud flats exposed during low tide; subject to reduced wave energy due to protection from a reef or inside creeks; high biological productivity
4. **Sheltered sand beach**
   Mainly beaches of coral sand sheltered behind a reef; subject more to wind than wave actions; low biological productivity.
5. **Exposed sand beach**
   Long stretches of beach often with windblown dunes; the beach is not protected by a reef and open for wind and wave actions; low biological productivity.
6. **Steep cliff**
   Usually steep dipping to near vertical walls of fossil reef; exposed to wind and wave actions and sometimes protected by a shallow reef; low to medium biological productivity
7. **Coral reefs and reef flats**
   Intertidal to sub tidal and subject to significant wave action; highly productive and very susceptible to oil pollution

The classification of the respective stretches of the coastline may include two or three of the types above. However, in determining the classification of a particular stretch of coast, it must be remembered that there is no definitive and precise measure of qualities such as value and importance. Neither is there an accurate measure of vulnerability. The classification is therefore a comparative one and one which is derived from the collective opinion, experience and technical judgement of experts from the region.

2.4 OCEANOGRAPHY

2.4.1 Coastal currents

There are four oceanic currents affecting the Kenyan coast. These are the South Equatorial Current, the East African Coastal Current, the Equatorial Counter Current and the Somali Current. The westward moving South Equatorial Current divides into two branches once it reaches the African coast at Cape Delgado. It gives off the Mozambique Current which flows southwards, and the East African Coastal Current which flows north-eastwards, parallel to the coast. The East African Coastal Current flows northwards all the year round at least as far as Malindi. During the Southeast Monsoon it continues beyond Malindi northwards, joins with the Somali Current and continues right to the Horn of Africa (*Figure 2-3*). During the Northeast Monsoon (November to March), however, the northward extent of the East African Coastal Current is more restricted. At this time it meets and joins the southward flowing Somali Current (which changes direction under the influence of the monsoon) with this convergence taking place anywhere between Malindi and north of Lamu, depending on the strength of the monsoon in any particular year. The two streams then turn eastward and flow offshore as the Equatorial Counter Current. (*Figure 2-2)*

Figure 2-2 Currents in January during the Northeast Monsoon.

The Somali Current is the only one that reverses its direction of flow under the influence of the monsoon. It flows in a south-westerly direction at about 1.5-2.0 knots with the Northeast Monsoon (November to March). While during the Southeast Monsoon (April to October), the Somali Current reverses its flow and increases its velocity to around 2.0-2.5 knots. It now appears as the north-wards extension of the East African Coastal Current which still arises from the onshore South Equatorial Current. At this time of the year, the Equatorial Counter Current is not so distinctive from the general Southwest Monsoon Drift at the lower northern latitudes of the Indian Ocean. The net onshore currents result in the sinking of surface waters along most of the Kenyan coast. The exception is near Kiunga where some mild upwelling is thought to occur during the Northeast Monsoon (UNEP, 1998).

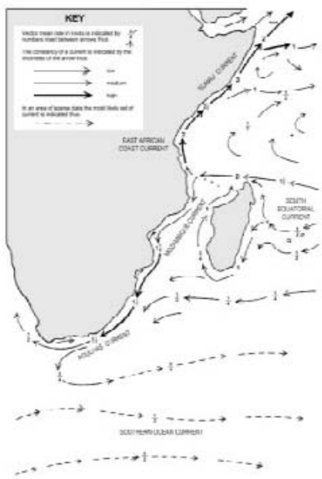


Figure 2-3 Currents in July during the Southeast Monsoon.

2.4.2 Tides

Kenyan coastal waters are characterized by semi-diurnal tides - approximately two tidal cycles for every 24 hour period. Except for limited periods in the year, however, the levels of high and low water of each successive tide differ appreciably from the corresponding tide before and the tide following. The tides can therefore be designated as mixed semi-diurnal tides. Spring tidal variations (Brakel, 1982) in Eastern Africa can be up to 4.0 m, with average variations within the 2.5-3 m interval.

The reference port for tidal observations in Kenya is Kilindini (Port of Mombasa) where the maximum tidal range does not usually exceed 3.8 m. Tidal range for Malindi is 2.0 m for neap tide and 2.9 m for spring tide. There is a lag in the tidal state which increases with distance north along the Kenyan coast. Malindi is normally 5 minutes after Kilindini while Lamu is about 40 minutes behind.

Deviations from the predictions in tide tables are influenced by barometric pressure, onshore winds and oceanic swell. However, the lowest tides occur persistently during the Northeast Monsoon since they combine with the prevailing winds to drive water offshore.

2.4.3 Sea temperature and salinity

Sea surface temperature and salinity also vary with the monsoon season. The highest temperatures of 28-29°C occur following the Northeast Monsoon in the months of March and April. The lowest sea surface temperature occurs in August and September with a minimum of 24°C.

During the Southeast Monsoon the shifting of ocean currents brings Pacific Ocean water of high salinity into the South Equatorial Current while during the Northeast Monsoon the South Equatorial Current draws water of low salinity from the Malay Archipelago. These changes in turn result in changing salinities of the East African Coastal Current waters. A further influence on salinity is the incidence of rainfall, especially the heavy rains of March to May when the discharges from all major river systems as well as all the more minor seasonal ones are at the maximum. As can be expected, offshore waters are influenced mainly by the oceanic currents and surface water salinities in Kenyan coastal waters vary from a minimum of 34.5 ‰ to a maximum of 35.4 ‰. The influence of the river outflow is contained mostly in inshore areas by the prevailing wind conditions and much wider variations in salinity do occur at the local level.

2.5 COASTAL ECOSYSTEMS

2.5.1 Introduction

Terrestrial, inter-tidal and sub-tidal ecosystems usually forms an interdependent continuum, but can often be divided into easy recognizable zones or habitats dominated and even physically structured by a few keystone species (mangrove forests, seagrass beds) or classes (corals).

2.5.2 Rocky coast & man made structures

Geomorphology

Much of the Kenyan cost is formed by low, about 4 - 6 m high limestone coral cliffs. These are fossilized coral reefs build during Pleistocene more than 100,000 years ago. They are exposed by the current sea level and are now eroded by the force of the waves resulting in an irregular and rugged appearance. The wide reef flats usually found in front of the cliffs can be regarded as these fossil reefs "levelled off" by the wave actions in combination with the current reef building activity *(Figure 2-4)*. Usually the cliffs make up the middle and upper part of the intertidal zone, and with a reef flat or sandy beach below.

Biology

Rocks in the upper part of intertidal zone have a sparse biological activity with mostly unicellular algae and a fauna of chitons and limpets and some amphibian crustaceans. Sub tidal rocks and manmade hardsurface structures as piers and wharfs may develop a richer flora and fauna resembling the conditions found on reefs.

Figure 2-4 The ancient reefs are soft and undercut by wave actions.

Sensitivity to oil spill

Exposed cliffs are regarded as less sensitive to oil pollution than most other habitats because of the sparse biological activity and because the wave exposure make the surface self cleaning to some extent. The rugged surface of the eroded ancient reef may reduce the self cleaning ability and leaves oil in cracks and cavities, but manual clean up with low or high pressure flushing are possible on these surfaces.

Figure 2-5 Ungwana Bay. A wind blown sand dune separates the short steep beach from the huge Tana River delta. The beach is exposed to the sea without the protection from a reef.

2.5.3 Sandy Beaches and Dunes

Geomorphology

Two types of sandy shores are present along the Kenyan coast.

Gentle to steep sandy beaches without protection from a reef. The beach is often backed by one or a series of wind-blown sand dunes. The sand may be of terrestrial origin and supplied by the larger rivers (Tana, Sabaki). This type of beach is found around Sabaki River mouth, and from Ngomeni through Ungwana Bay to Lamu Island.

Gently sloping beaches sheltered behind a fringing reef are common along the coast south of Ungwana Bay. The sand is often white calcareous sand of marine origin (coral sand). Diani Beach and Watamu Beach are typical examples.

Biology

Species diversity on sandy beaches is usually low. On the higher parts of the beach, above the high water line, only a few burrowing crabs and amphipods are usually found. The density and diversity of crabs, bivalves, polychaetes and other marine invertebrates increases in the intertidal, but

Figure 2-6 Sheltered sandy beach behind a protective reef. The sand is white coral sand, and intertidal seagrass beds are seen in front of the beach and on the reef flat.

remain low compared to most other habitats. Stranded debris in this zone may attract a variety of foraging waders and other birds.

In protected beaches the lower intertidal zone will usually be covered with seagrass which also covers most back reef lagoons.

In exposed beaches the waves prevent seagrass growth in the upper subtidal zone and the sand remains low in biological value.

Sandy beaches may serve as nesting sites for marine turtles. Green turtles, hawksbill and the rare olive ridley all nests on Kenyan beaches. While green turtles are found nesting on suitable beaches all along the coast, hawksbill is found in Kiunga, Malindi, Watamu, and Funzi, and olive ridley only along beaches near Malindi, Watamu and Mombasa.

Sensitivity to oil spill

Fine grained sandy beaches are less sensitive to oil pollution because of the relative sparse biological activity, and because they are relatively easy to clean. This holds especially for exposed hardpacked sand beaches, *(Figure 2-5)*, but also in more delicate surrounding *(Figure 2-6)* is the beach the least sensitive habitat. Oil does not penetrate deep into fine sand and can be removed either manually or by use of front loaders or other heavy machinery. If the oil is not removed it may form a dense pavement on the beach.

Coarse sand or gravel makes a difference. The oil can sink deep into the sand and can be impossible to remove or clean. The oil weathers slowly deep in the sand and the beach will be seeping oil for an extended period. Coarse sand or gravel not common along the coast of Kenya.

Turtles

Turtles nests high on the beach, usually out of reach of high water and the stranded oil, but the cleanup operation and use of heavy machinery may ruin the nests. And turtles on their way to the nest and broods on their way to the sea may be caught in the oil. Turtles nest during a period of several months, so only a smaller part of a population may be at risk at any given time.

2.5.4 Corals reefs and reef flats

Geomorphology

The wide reef flats seen in front of the cliffs can be regarded as the fossil reefs "levelled off" by the wave actions in combination with the current active reef growth at the reef crest and at the outer slope facing the ocean. This structure is found more or less continuously from Malindi southwards to Chale island. Sometimes the cliff is replaced by sandy beaches, and some-

Figure 2-7 Part of the reef flat north of Mombasa. The waves are breaking at the reef crest and along the coast are seen contrasting sandy beaches and rocky cliffs.

times the continuity is interrupted and the reef flat is degraded - usually at the outlet from creeks or small rivers. The width of the reef flat can be more than 2 km. South of Chale and to the Tanzanian border, the coastline is more degraded and the reef is discontinuous and broken into islands and patch reefs. The distance to the coast (and hence to terrestrial sources of silt and pollution) makes some of these reef - Kisite Island and others - the best and most diverse in Kenya.

On the other hand, the Sabaki and especially the Tana River plume reduce or prevent coral growth within a greater area.

Biology

Coral reef communities in Kenya are found from about mean sea level to a depth of 20-25 m. Coral reefs are among the most diverse ecosystems in the sea. With corals as the keystone species, the rich diversity includes almost all other groups of marine flora and fauna as macroalgae, fish, molluscs, crustaceans etc. The extent, size, and diversity of the coral reef communities decrease northwards along the Kenyan coast due to discharge of sediments from the large rivers and to influence from the Somali current. Corals are slow growing organisms and very slow colonizers. The Kenyan reefs have not yet recovered from the damage they suffered from the increased temperature during the El Niño event in 1998.

The reef flats are usually a mixture of hard and soft substrate and typically with a distinct back reef lagoon close to shore. Most of the reef flat is intertidal and with only few corals. Instead, there is a dense mixed vegetation of seagrass on the soft sediment and seaweed on the hard substrate. The high abundance of fish and invertebrates is an important source of food and income for the local communities.

Sensitivity to oil spill

Most of the reefs are subtidal and therefore sheltered from direct contact with the oil slick. But the reef crest is usually exposed at low tide, and (the few) intertidal corals are killed immediately by contact with oil. But the deeper parts of the reef may be endangered as the waves break on the crest and fine oil droplets are dispersed in the water column. Corals are filtering organisms and the oil droplets are toxic. Recovery of a damaged reef may be a matter of decades, and restoration techniques are usually not very successful.

The reef flat and its organism is vulnerable and sensitive to oil pollution, and is difficult to clean. Waves and tides helps cleaning but not without great damages because the exposed area can be very large.

2.5.5 Rias

Rias are drowned river valleys. They are usually estuaries cut by the river in sedimentary materials and filled during sea level rise. They are characterised by rather steep slopes of sedimentary material along part of the coastline. They includes the well known habitats of sand, mudflats and mangroves, but are usually found as narrow bands along the coast and sheltered from wave. Kilifi Creek is the most typical ria along the Kenyan Coast.*(Figure 2-8)*

Figure 2-8 Rias are creeks or estuaries developed from drowned river vallies. They are sheltered from waves and wind, and include often narrow bands of mangrove, sand and mudflat and sheltered rocky coasts.

Sensitivity to oil spill

The typical ria has a steep slope or a sheltered cliff often with a narrow sub tidal muddy beach with a few mangrove trees. The sheltered environment has only little self cleaning capacity, but it is possible to clean from the sea side because of the narrow extent.

2.5.6 River mouths and estuaries

Geomorphology

Rivers transport sediment from inland and have formed large gentle sloping floodplains as seen around Sabaki River, in the Tana River delta and in the creeks of the Lamu archipelago. Because of the gentle slope, the marine tidal impact and hence the zone with fluctuating salinity can reach far upstream from the river mouth. This is the estuarine zone. The mouths of the smaller rivers are often hidden behind mangrove creeks whereas Sabaki and Tana rivers have pronounced mouths and a clear estuarine zone.

Biology

Few species except for the mangroves are adapted to low or fluctuating salinities. The biodiversity is therefore low within the estuary. The density, on the other hand, is usually very high because of the continuous supply of food and nutrient from the river. The high density of bivalves, snails and other benthic invertebrates usually attracts a wealth of birds.

Figure 2-9 Sabaki River Estuary at high tide. The estuary is a bird area of international importance.

Sensitivity to oil spill

The tide can bring an oil pollution far into an estuary and up the river and in combination with a high density of food items, the sensitivity "per metre coastline" is very high. Only in the seasonal high flow situations are there a fair flushing and selfcleaning capacity.

2.5.7 Mangroves

General

Kenya has about 500 km^2 of mangrove forest. The largest areas are in Lamu district where protective islands, a gentle relief, and slightly estuarine conditions have favoured a lush forest cover of more than 300 km^2. Other important areas are in the Tana River delta and the area north of Ngomeni. The oceanic coast between Ungwana Bay and Gazi is too steep and too exposed, and only the creeks of Mida, Kilifi and Mombasa holds significant mangrove stands. In the south, the bays of Gazi, Shimoni and Vanga also holds large and important mangrove areas.

Geomorphology

Mangroves have a high productivity as they profit from nutrients from both land and sea, and mangrove detritus are often the main source of energy fuelling the estuarine food webs. Mangroves are favoured by fine grained nutrient rich sediment, and are therefore often associated with estuaries and other freshwater outlets where fine grained organic materials settles along

Figure 2-10 Dense mangrove forest north of Lamu.

with mineral particles. Mangroves are not only favoured by the existing geomorphological conditions - they enhance sediment accretion by trapping sediment among their aerial roots. The intricate networks of knee-, stilt-, or prop roots reduce current speed and enhance sedimentation of mineral and organic particles.

Accordingly, clear cutting or otherwise killing of mangrove may cause coastal erosion and sediment transport, with possible adverse effects on neighbouring sensitive habitats as seagrass beds and coral reefs.

Biology

Kenya has 8 species of mangrove trees, or 9 if the *Xylocarpus mollucensis* is included. *Rhizophora mucronata* is the most common and prominent species along the Kenyan coast, easily recognisable from the arching stilt roots supporting the trunk. *Sonneratia alba* and *Avicennia marina* are common species and among the first colonizers of new areas. Especially *Avicennia* is a robust species found as a primary colonizer in the front row along the seaward site and often also on the high shore on the landward side of the mangrove where the soil salinity is too high for most other species except maybe for *Lumnitzera racemosa*. *Heritiera littoralis* is very rare in Kenya and is only found sporadically in the Tana River Estuary and near Gazi.

While the diversity of species of mangrove trees is limited, the physical three dimensional complexities of the mangroves above and below the water surfac creates a multitude of niches suitable for a vast diversity of other organisms. In particular the aquatic communities are diverse, and include a multitude of algae, seagrass, crabs, shrimps, bivalves, fish, etc.

Figure 2-11 Rhizophora mucronata *is the most common and prominent species along the Kenyan cost, easy recognisable from the arching stilt roots. The black band high on the stem and branches marks a recent oil spill.*

Adaption

Mangroves are adapted to growth in salt water by several important features. In the present context, the adaptation to growth in anoxic and acidic sediment in the presence of sulphide is important. Aerial roots are prominent features of mangroves. Stilt-, prop-, and knee roots as well as pneumatophores, does not only to support the tree. The sediment under a mangrove stand is usually strict anoxic and exhibits toxic concentrations of hydrogen sulphide and other reduced components. The root itself needs oxygen for its metabolism. The aerial roots which are exposed once in every tidal cycle, take up oxygen from the atmosphere, and ventilate the subsurface part of the root. If the oxygen uptake by the roots is blocked by e.g. prolonged inundation or by a smear of oil, the roots and subsequently the tree may die.

Mangroves are of vital economic importance throughout the tropics, since they provide spawning and nursery grounds for the fish and shrimps, they protect the shores against erosion, and they provides firewood and building material as well as a long list of other natural products.

Threats

Unsustainable forestry, i.e. logging without replanting is the major threat, but also conversion to salt work evaporation dams and seepage from the dams to the surrounding mangrove have caused loss of mangrove forest. Shrimp farms are a future but realistic threat.

Sensitivity to oil spill

Oil can be acute toxic to mangrove. Especially refined products with high concentrations of water soluble aromatic hydrocarbons are highly toxic. Smothering of the aerial roots by oil by heavier oil types may hinder proper ventilation of subsurface parts and lead to suffocation and stress end eventually death.

Hydrocarbons in the sediment may stay toxic to trees and propagules for years. Oiled debris and sediments may leach oil for months.

Clean up

Clean up operations may prove to be extremely difficult due to the low energy environment of mangrove forests. Manual cleaning is hampered by the depth and impenetrable nature of the mangrove forest. Flushing and absorbing booms may be the only means.

Figure 2-12 Seven years after a spill of 5.000 tonnes of oil, the mangrove in Makupa creek has only started to recover.

Regeneration

Natural regeneration can be a long process, and depends on a proper supply of propagules. Replanting is a relatively simple and usually successful technique.

2.5.8 Intertidal mud flats

Geomorphology

Sheltered mangroves in creeks or bays are often fringed by a broad intertidal mudflat. The open mudflat can either be in balance or the result of mangrove logging or it can be an accreting mudflat where the mangrove forest progression is lagging behind.

Figure 2-13 Mudflats are sheltered accreting areas, often in front of mangrove forests. Mida Creek.

Biology

Intertidal mudflats are accreting areas with high productivity and a high density of marine invertebrates as mussels, snails and crustaceans. The diversity is usually low, but they are very important feeding grounds for aquatic birds.

Sensitivity to oil spill

The mudflats are sensitive to oil spill themselves They are difficult to clean mechanically without downmixing the oil into the sediment. The often close connection with mangrove forest makes the clean up even more difficult - for both habitats. The invertebrates have a high regeneration rate, but the sediment may be unsuitable due to oil remains.

2.5.9 Seagrass beds and Seaweeds

Geomorphology

Seagrass grows mostly on sandy to sandy-muddy sediments from the intertidal zone down to a depth of 20 m or more. In the oil spill context the seagrass beds on the reef flats, in the back reef lagoons, and in shallow mangrove creeks are the most interesting, but seagrass on the outer slope of the reefs and most probably also in suitable areas in Ungwana Bay are important too. Suitable areas mean a proper substrate and enough light. Enough light means approximately down to the depth of visibility (Secchidepth), i.e. from more than 20 m on the reefs far from the coast to a few metres close to the mouth of the large rivers.

Seagrasses have an important function as stabilizers of soft substrates. The network of rhizomes and shelter from the leaves protect the sediment surface from erosion

Biology

At least 12 species of seagrass are found along the coast of Kenya, but with the *Thallasodendron ciliatum* as the dominant species on the reef flats. This species grows even on coral rubbles. The fauna associated with seagrass is very rich, mostly because of the complex physical structure of the seagrass bed creates. It has an important role as spawning and nursery grounds for many fish species. Few species feed directly on seagrass, but may utilize debris of degrading leaves and waders forage in the beach cast of dead sea grass leaves

Figure 2-14 Sea grass may grow from the intertidal zone to more than 20 meters depth.

Two endangered species feed on seagrass, the green turtle and the dugong.

Sensitivity to oil spill

Seagrass in the intertidal zone especially on reef flats are at risk in case of oil spill. Seagrasses are killed by the smothering of oil but may also be uprooted during cleanup actions. Removal of seagrass beds may start coastal erosion. Seagrasses are surprisingly slow colonizers, and restoration of destroyed beds may take from years to decades.

Seagrass distribution along the Kenyan coast has not been mapped, and is therefore not included in the sensitivity index, except as a part of the reef flats.

2.5.10 Endangered species

Marine Turtles

All of the five species of marine turtles found along the East African Coast are also found in Kenya. Three of them nest on Kenyan beaches: Green turtles, hawksbill and more rarely the olive ridley

Hunting of turtles is illegal in Kenya, and the biggest threat is poaching and unintended bycatch by trawlers. Oil spill will not pose a serious threat to marine turtles in Kenya. They are sensitive if smothered, but will usually have the ability to escape. Stranded oil and the cleanup activities may locally threat turtle nests. Most turtle nests are known by position by local NGO's and can in most cases be relocated in case of an oil spill.

Dugongs

The dugong is one of the most endangered species along the African coast and is almost extinct in Kenya. It is on the IUCN Red List of Vulnerable species. It is occasionally sighted or caught in fishing net. Most observations are from the southern coast close to the Tanzanian border and from the Lamu district, but there is no pattern in the observation indicating a stable and viable population.

Dugongs feeds solely on some of the smaller seagrass species which are usually found close to the mangrove forest or on the outer reef slope. The dugongs are not limited by available food but by hunting and unintended bycatch. Dugongs are to scarce to be taken into account in oil spill contingency planning, and although they can be harmed by the oil, they will normally be able to escape.

2.5.11 Migratory and Other Coastal Birds

Coastal birds concentrate usually on intertidal areas. Especially mudflats, but also estuaries, reef flats, and beach cast of seagrass debris may attract waders and gulls. Terns are often attracted to shallow or turbulent waters. The Kenyan coast does not host any globallythreatened species but e.g. the Mida Creek area, and the Kiunga reserve hosts important numbers of crab-plovers, and roseate tern nests on several of the smaller islands. The coast host a number of Palearctic immigrant waders during the Palearctic winter between September and March.

Although waders and terns are less sensitive to oil pollution than swimming sea birds as e.g. auks and ducks, an oil spill near important bird areas, may affect the birds directly (Oil contact) and indirectly by disturbing the feeding ground.

Figure 2-15 Gazi fish landing site.

3 Coastal Resources and Their Use

3.1 HISTORICAL AND CULTURAL RESOURCES

The Kenya coast is rich in historical and archaeological sites, a testament to its long and full history depicting centuries of Swahili culture. Various remnants of mosques and other buildings reflect different ensembles of Islamic architecture using lime, coral stone and timber.

In general the historical and cultural sites are placed in some distance from the coastline and would not be affected by an oil spill. The Atlas includes some of the most important historical and cultural sites located close to the coastline.

3.2 FISHERIES

The fishery sector contributes about 4.7 % of the national Gross Domestic Demand (GDP) and it is an important foreign exchange earner. In the Government's Policy Document on “Economic Recovery Strategy for Wealth and Employment Creation (2003 - 2007)”, fishing is recognised as one of the productive sectors and the need to promote capture fisheries and aquaculture in order to improve food security, nutritional status and incomes is emphasised.

The marine fisheries sector in Kenya land about 10,000 tonnes of fish which accounts for about 10 % of the total fish landed in Kenya. Marine fisheries in Kenya are based on a small number of species, the most important of which are demersal and caught by artesian fishermen operating between the shoreline and the reef. Freshwater fish landings in Kenya have always been higher than those from coastal waters.

At the coast, ecological studies undertaken by KMFRI have documented and highlighted the important and crucial roles played by some critical and sensitive habitats e.g. mangrove forests, seagrass beds and coral reefs in sustaining the coastal fishery. These habitats serve as important nursery and breeding sites for an array of fish species of economic importance. From such findings, measures have been put in place to conserve and rehabilitate the critical habitats.

Along the Kenya coast, rich inshore marine fishing grounds are found in and around Lamu Archipelago, Ungwana Bay, North Kenya Bank, and Malindi Bank. The areas where the two major Kenyan rivers (river Tana and Sabaki) empty into the sea are also very productive. In these rich inshore fishing grounds within the Malindi-Ungwana Bay area prawn trawling has been carried out since the 1970’s. A comprehensive scientific research undertaken by KMFRI on the Malindi- Ungwana Bay prawn fishery revealed that the prawn fishery is not properly regulated and managed. The fishery is also associated with very high conflicts due to the destruction of traditional fishermen fishing nets; competition for common resources; distrust between the semi industrial prawn industry and the local fishermen, and the rampant resources wastage because of the high amount of fish by-catch associated with prawn trawling.

According to fish landing records, Mombasa District accounted for 46.6 % of the mean fish catch between 1988 and 1992, followed by Tana River, Lamu, Kwale and Kilifi in that order. However, fishermen can land their catch anywhere, regardless of where the fish are caught, and they are probably attracted by the bigger market and more affluent potential buyers of Mombasa and Malindi.

There are only about 5,000 coastal fishermen compared to well over 27,000 fishermen engaged in inland fisheries. Of the 5,000 fishermen, around 4,000 are considered artesian fishermen and the rest are classified as marine industrial fishermen.

3.2.1 Small Scale and Subsistence Fishing

Marine fisheries in Kenya are mainly, artisanal and undertaken mostly from small, nonmotorized boats such as outriggers, dhows, cataracts and planked pirogues. Only about 10% of fishing craft are motorized. This constraint limits most of the fishing effort to inside the reef and rarely is fishing undertaken beyond territorial waters (20 km). The exceptions are the

Figure 3-1 Mangrove creeks are highly productive areas providing fish and other produts for subsistence and for the local market.

mediumsized trawlers which fish for prawns mainly in the Ungwana Bay area.

The most commonly used fishing gear is the artesian gill net and the seine, particularly in the Lamu archipelago and around Malindi. Other gear includes traps and handlines in Ungwana Bay and the Malindi/Mambrui area, bottom lines and traps from Mombasa south to the Tanzanian border, and lobster pots in Lamu, Malindi and Kwale districts.

3.2.2 Marine Farming

Marine farming activity in Kenya is in its infancy. Besides some traditional brackishwater ponds and artesian shrimp and oyster cultivation, coastal aquaculture has been restricted to capital intensive shrimp culture on an experimental scale. Unfortunately, this development at Ngomeni has been undertaken at the expense of mangrove productivity, with 60ha of mangrove forest being cleared. However, in spite of this inauspicious beginning, coastal aquaculture in Kenya has considerable potential as a source of economic return and, if properly planned and managed, it need not have an impact on the productive and valuable mangrove ecosystems. There are three types of marine farming activity which could be utilized on the Kenyan coastal environment pond culture in cleared mangroves or on land behind the mangroves, suspension culture (cage and raft) in sheltered waterways that are of sufficient depth, and rack culture in the shallow intertidal areas.

Figur 3-2 Fishtraps is often build along the edge of the mangroves.

3.3 MINERALS AND ENERGY RESOURCES

Coastal geological formations are predominantly sedimentary in origin, with marine, shallow water and lacustrine to fluviodeltaic characteristics. They form a strip of 50 km wide along the Southern part of Kenya coast. Mineral deposits that occur in economically meaningful quantities in the Kenyan coast include salt, coral rocks, limestone, rutile, ilmenite, building sand, pyrochlore, gypsum, barites, gypsum, silica sands, iron ore and clay. Other lesser minerals are apatite, galena, and manganese oxide.

Recent discovery of titanium ores (rutile and ilmenite) in the sedimentary deposits along almost the entire length of the Kenya coast has initiated national debate on environmental impacts of mining, particularly since the recent enactment of the Environmental Act. Tiomin Mining Company has already entered into agreement with the Kenyan Government to undertake mining at Kwale near Diani beach, which is expected to start in early 2006 and is estimated to continue for 11 years. This and other mining activities will result in an increasing amount of sea traffic particularly in Mombasa harbour from where ore will be shipped and mining supplies will arrive.

3.3.1 Salt Works

Salt can be considered as the most widespread mineral in Eastern Africa and its recovery from the sea is a comparatively simple process given certain environmental conditions. The location of solar salt works is controlled by the rainfall regime and the occurrence of suitable impermeable soils. These conditions occur from Ngomeni northwards to the Lamu area. Extensive salt works have been established at the Gongoni-Karawa. The total area dedicated to salt production is over 5,000 hectares that yield an average of over 170,000 tonnes of salt annually (UNEP 1998).

The method of salt production utilised by the five established companies is very much the same throughout the area. Seawater is filled into the ponds which are run in series. Slight variations may occur in the method of filling the ponds which utilize tidal energy or pumps. In the first pond, undesirable salts of low solubility are precipitated and the water then flow into a series of ponds where the brine is further concentrated and crystallizes. Crystallized salt is gathered from the ponds, washed and taken to market.

In addition, in Lamu District, the Mkunumbi area of Mpeketoni Division has salt deposits which have so far not been exploited. It has been observed that the salt deposits exist in economically viable quantities and therefore a salt manufacturing industry could potentially be developed in the area (Republic of Kenya 1997).

3.3.2 Limestone and cement

Limestone deposits are extensive along the coastal zone from the Tanzania border to the Malindi area. The resource is very abundant, forming a 4-8 km wide band, some 70m thick, running parallel to the coast. North of Malindi, older limestone units occur further inland but only a few exposures of isolated limestone occur on the coast between Malindi and the Lamu

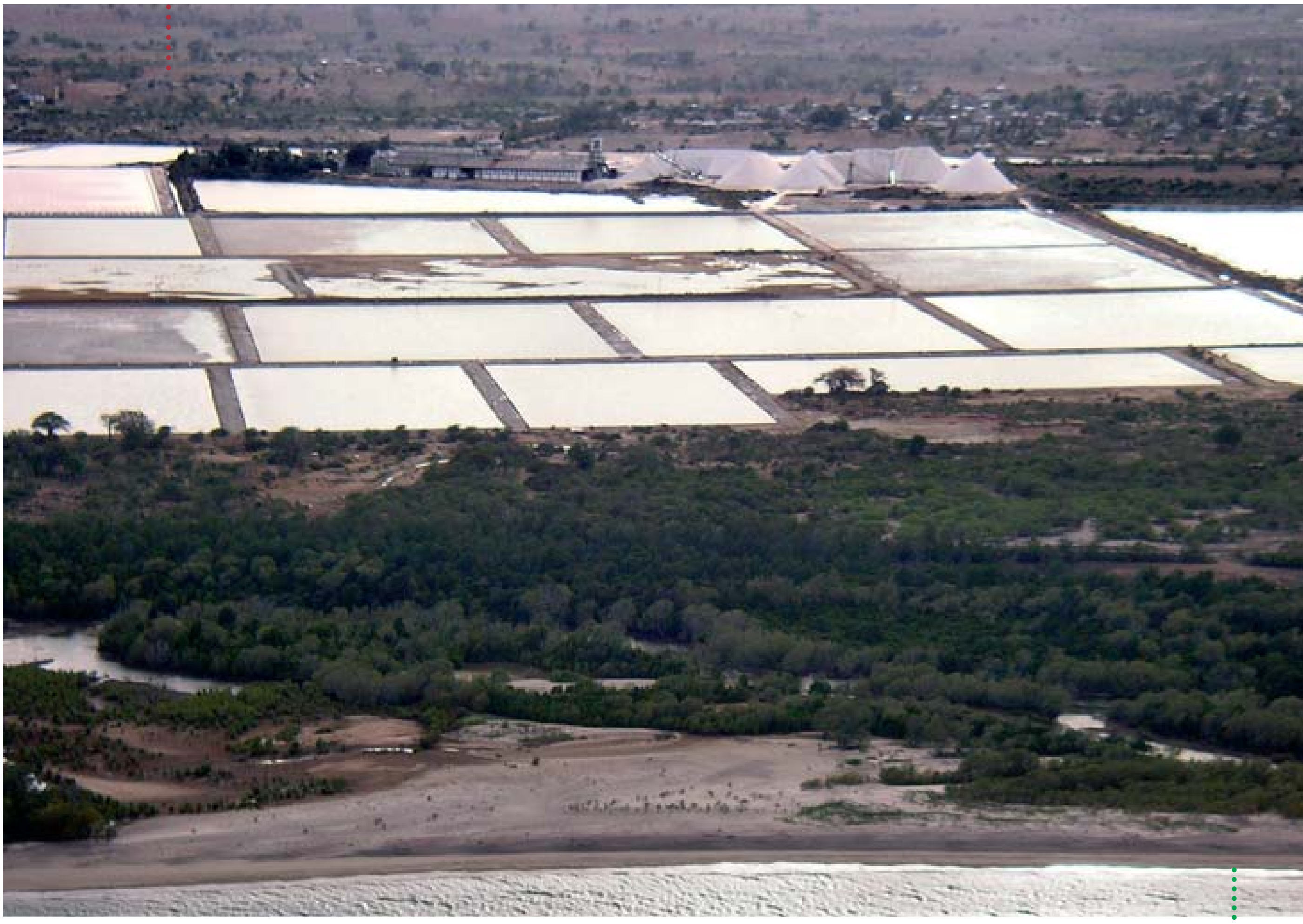


Figure 3-3 Solar salt works are sustainable industries regarding power consumption but do often displace large mangrove areas.

area. North of Lamu and the islands, limestone units occur once more parallel to the coastal zone, however, these are not well mapped. Exploitation of the limestone is widespread and is governed by local variation in the limestone texture, composition and demand for the material. In the Bamburi area north of Mombasa, limestone is used for cement manufacturing and in Tiwi for lime manufacturing. However, all along the coast limestone is being exploited for building stone.

3.3.3 Oil and Gas Exploration

A thick sequence of sedimentary rocks, estimated to reach a maximum of 15,000m in some areas, accumulated along the continental margin in a geosynclinal setting that preceded the opening of the Indian Ocean. The opening of the Indian Ocean was associated with the development of a major north-south basin, probably with several comparatively smaller basins. These smaller depositional areas include the Mombasa, Malindi, Lamu and Anza basins. There is a close relationship between hydrocarbon potential and the occurrence of such ancient sedimentary basins which have the potential for good source rocks. In addition to the presence of good mature

Figure 3-4 Limestone is usually quarried far from the coast, but here it is mined only few meters from the shoreline.

source rocks, the occurrence of hydrocarbon reserves depends also on the timely evolution of good reservoir rocks, and traps. Sandstones and carbonates are good reservoir rocks while shale horizons generate good traps (UNEP 1998).

The potential

From the limited data available in Kenya, analysis of hydrocarbon potential is difficult. However, if there was to be any potential, the most promising areas along the Kenya coast would be the Lamu Basin, the Malindi High and the South Anza Graben. The sediment sequences in these areas vary from Recent to Triassic. However, good source rocks are anticipated at a depth of 3,000 m to 4,000 m in the Tertiary and Cretaceous sequences. The Tertiary deposits have been penetrated by many wells, but the Cretaceous has only been penetrated in a few places. The Cretaceous occurs at a depth of 3,450 m in Lamu and therefore good mature source rocks are anticipated (UNEP 1998)

Off-shore reservoir

Good source rocks and reservoir rocks for hydrocarbon deposits have been observed along the Kenyan coast, with conditions becoming more favourable offshore. Promotion efforts generated new interests in the offshore Lamu Basin and an Australian firm is at an advanced stage with efforts to sink initial exploratory wells about 70km off the Lamu coast (NOCK 2005).

figure 3-5 The beach attracts all kinds of activities.. This photo is taken during low tide and the waves braking at the outer edge of the reef is seen at the upper right. All kind of boats used to bring tourists for diving and snorkelling is seen at the beach.

3.4 TOURISM

The first hotels directed at tourism were built in Malindi during the early part of the 20th century. In the last thirty years, rapid expansion in the recreation and tourism industry has occurred. The main attractions for this new industry include the warm coastal climate slightly mellowed by a cool sea breeze, the beautiful coastal scenery and foremost, the beautiful and clean sandy beaches. All the facilities that support the new expansion in the tourism industry are therefore located next or adjacent to beach environments.

Between 1998 and 2004, the share contribution of coastal tourism has been ranging between 52 % and 68 % and mainly depending on Marine and Coastal resources, and Game Parks and Reserves. At the macro level, the sector generates an average of 18 % of the foreign exchange earning to the economy and contribute 9.2% to the Gross Domestic Product (GDP). The sector also provides 270,000 jobs both directly and indirectly.

In some areas, such as the coastal strip around Mombasa, the rapid development of tourism has put pressure on the sustainable use of coastal resources such as the coral reef. Demand for seafood, shells and coral souvenirs has risen sharply as local supplies have become depleted. The pressure on the coastal ecosystem extends further and further from the resorts, spreading the impact.

3.5 CONSERVATION

3.5.1 Marine Protected Areas (MPAs)

Parks and Reserves

In order keep up with the increasing pressure on the marine resources, and to conserve and manage the most important ecosystems along the cost, the government of Kenya has established a system of protected areas managed by the Kenya Wildlife Service (KWS). There are two level of protection with the strictly protected marine parks as the highest level where no extraction of resources are allowed, and marine reserves where limited exploitation like traditional fishing is allowed but closely managed.

Kenya has five MPA's, each comprising one or more marine park(s) or reserve(s):

- Kisite Marine Parks and Mpunguti Marine Reserve are located on the south coast off Shimoni and south of Wasini Island in Kwale District. The complex covers a marine area with four small islands surrounded by coral-reef and is not connected to the mainland.
- Kiunga Marine Reserve incorporates about 60 km of the northern most coast of Kenya south of the Somalian border. The coast consists of parallel lines of old and living reefs forming a chain of about 50 calcareous islands. Inbetween the islands and the coast, there are sheltered and calm water habitats with mangroves, mudflats, and sandy beaches and dunes. The reserve is also designated as a UNESCO Biosphere Reserve.
- Malindi and Watamu Marine National Reserves which encloses Malindi and Watamu Marine National Parks and includes Mida Creek. Habitats comprise intertidal cliffs, sand-, and mudflats, seagrass beds, coral reefs, reef flats and islets; sandy beaches, and the Mida Creek comprises tidal mud flats with fringing mangrove swamps. The protected areas are also designated as a UNESCO Biosphere Reserve.
- Mombasa Marine Park and Reserve including reefs and reef flats north of Mombasa are the most highly utilised among the Kenyan MPAs, because of the proximity to the city centre. The coastline is heavily developed with tourist facilities and also heavily fished.
- Diani and Chale Marine National Park and Reserve are the most recent established MPA's. They include reefs, fishing grounds, and mangrove forest, and are heavily used by tourists.

Other
Another marine reserve, Ras Tenewi, north of Ungwana Bay is planned but not yet gazetted.

None of Kenya's five designated Ramsar areas (wetlands of international importance) are coastal wetlands.

Important Bird Areas, IBA's, are bird areas which qualify as Ramsar sites. Kenya has 5 coastal IBA's including the MPA's of Kisite, Malindi/Watamu/Mida, and Kiunga and with the addition of the deltas of Sabaki and Tana rivers.

4 The Oil-spill Sensitivity Ranking System

4.1 THE RATIONALE OF RANKING

An Oil spill sensitivity ranking of potentially threaten resources is usually an integrated part of a national oil spill contingency planning. It helps decisionmakers to prioritize the available resources and to focus the emergency response on the most valuable areas.

The sensitivity ranking system provides oil spill responders with a useful tool during several steps in the contingency process:

- during the prespill planning, in order to prepare appropriate response strategies for e.g. particularly threatened or vulnerable areas or other areas that deserve special attention.
- during an oil spill combat in order to plan and continuously optimize the response strategy under the given conditions and limitations (oil type, weather, equipment, crew).
- during the cleanup operation to avoid postspill damages, minimize cost etc.

Sensitivity ranking is one of several considerations during oil spill contingency. Oil type and behaviour, weathering of the oil, meteorology, hydrography, safety of crew and equipment are other topics to consider.

The goal of oil spill response is to minimize the overall impacts on natural and economic resources as well as cultural assets, but some features will be of greater concern than others. The sensitivity ranking includes therefore the actual sensitivity of the features and a more subtle valuation of importance or value.

4.2 THE CONCEPT OF RANKING SENSITIVITY

The concept of mapping coastal environments and ranking them on a scale of relative sensitivity is more than thirty years old. Since then, different ranking system have been developed, refined and expanded to cover all types of shorelines.

The ranking should integrate a multitude of information on geological properties, wave exposure, biological diversity and productivity, oil behaviour, ease of cleanup, human use and cultural assets - properties that are not directly comparable or quantifiable within the same scale of values. The outcome should ideally be a simple statement, a numerical index value, or a colour code.

Incomparable features

Comparing and valuation of incomparable features is a matter of interest and negotiation, and no true or perfect system can be established. A complicated systems is not necessarily better and more accurate than a simple system or qualified judgements. But it is a requirement that the level of details matches the purpose and leaves the decisionmakers with some alternatives. e.g. 20 km coastline with exactly the same sensitivity index value is not of much help. Another requirement is that the system is transparent and generally accepted by the stakeholders.

Three types of features

We have applied a relatively simple system including three types of features: Coastal type, Biological resource, and Human use. The coastal type feature is derived from the well known ESI-index. The sensitivity index is calculated from the indices for each of the features.

4.3 SENSITIVITY RANKING USED IN THE ATLAS - RANKING OF COASTAL FEATURES

The sensitivity index is assigned to an index line running parallel to the shoreline at a distance of 500 m offshore.

The three different groups of coastal features are projected onto the index line:

A - Coastal type
B - Biological resource
C - Human use

The Oil Sensitivity Index (SI) for each point or segment of the coast is calculated simply as the sum of index values from the three groups:

$$SI = A + B + C$$

The coast type index value forms the basics of the index line; there is always a coast type assigned to the coastline. If there is more than one coastal type present, only the type with the highest index value is considered.

The index value assigned to each type of feature is based on the description in Chpt. 2 and 3, but finally calibrated and balanced during a stakeholder seminar where al major stakeholders were invited *(Table 4-1)*.

The final Oil Sensitivity Index shows values from 2 to more than 20. These values are then represented along the index line by a colour code of 5 colours.

It is important to note that the index value does not represent a sort of absolute value at any scale. It is mostly a matter of making changes of sensitivity visible along the index line. An important use of the index will be to select which areas to protect and where to let the oil strand within a coastal strip of few kilometres, and not to compare the sensitivity of e.g. northern and southern Kenya.

Type	Feature	Index Values	Moderator	Horizontal "impact" of point features
A	Rocky coast	1		
A	Sheltered sand beach	2		
A	Exposed sand beach	2		
A	Tidal mud flat	3		
A	Sheltered rias	2		
A	Coral reef and reef flats	3 - 5	Width: <200m/ 200-1000m/>1000m	
A	Mangrove	3/5/7/10	Width: <50m/ 50-200m/ >200m/ inlet	
A	River mouth or creek	8/10/12	Small/large/creek	
B	Important bird area, IBA	1		
B	Waders	0.2/0.6/1	Low/medium/high importance	2000 m
B	Turtle breeding site	0.5/1	Low/high density of nests	1000 m
B	Coral reef, priority	1		
C	Hotel	1		500 m
C	Small scale fishery	0.2/0.6/1	Low/medium/high importance	
C	Fish trap	0.5		500 m
C	Fish landing site	1		500 m
C	Harbour	1		500 m
C	Cooling water intake	2		200 m
C	National park	1		
C	Natural reserve	0.5		
C	Proposed natural reserve	0.5		

Table 4-1 Sensitivity Index Values of features considered in the Coastal Resource Maps. The index values were fixed and agreed among all major stakeholders during a stakeholder workshop.

5 Description of Maps Produced

The Environmental Sensitivity Atlas for the Coastal Area of Kenya developed through the KenSea project contains three types of maps:

- Logistic and Topographic Maps
- Coastal Resource Maps
- Environmental Sensitivity Atlas

which has been reproduced in 16 map sheets in scale 1: 50,000 to cover the whole coastline. In addition, 4 map sheets in 1: 25,000 have been produced for the Mombasa Creek Area.

5.1 LOGISTIC AND TOPOGRAPHIC MAPS

5.1.1 Description of the production of the maps

These raster maps are based on the scanning, cropping (cutting off everything but the actual map) and georeferencing of a total of 34 topographical paper maps from the Survey of Kenya at a scale of 1:50,000 and three maps in scale 1:100,000. The latter covering the very north of the country where no 1:50,000 maps could be obtained from the Survey of Kenya. Due to this, areas between Kiunga and the Somali border contains a slightly lower degree of detail on the logistical maps.

Map frame construction

Upon being scanned and georeferenced, all of these 37 maps where then put together as a single seamless raster layer in the GIS. Consequently a system of 16 map frames was constructed with the objective to render the entire coastline in scale 1:50,000 on a minimum of map sheets in size A1 including sufficient parts of the inland areas.

5.1.2 Description of features on the maps

The natural resources and coastline features on the topographical maps have formed the basis for the Coastal Resource Maps. These features should now be read from these maps, as they represent the most upto-date dataset. The topographic maps are used for terrestrial features which are not all transferred to the resource maps, as contour lines, tracks and buildings. The topographic maps are the maps to use for planning oil combat and cleanup actions from land

5.2 Coastal Resource Maps

5.2.1 Description of the production of the maps

Following the production of the Topographical and logistical maps, all the analoug topographical maps were put into digital format and the raster layer containing all the topographical information was used as the very foundation for the process of creating Coastal Resource Maps. Through the digitization of a number of features from the topographical maps, as series of new vector layers were created. These include:

- Administrative Boundaries (District Admin Level 3 and coast line)
- Contour lines
- Hydrology (rivers and inland water bodies)
- Utilities (health clinics, schools, hotels and ports)
- Railways (lines and stations)
- Airfields (airports and landing strips)
- Towns (major, minor and settlements)
- Pipelines
- Roads (3 classes)
- Mangroves
- Mudflats
- Plantations
- Forests
- Corals

Quality Assurance

The 1:50,000 topographical maps from Survey of Kenya were lacking for the area north of Pate Island. Therefore, features were digitized from the 1:100,000 maps covering the same area. The digitized features now occurring as point, line, and polygon layers have undergone an intensive quality assurance (QA) with respect to their topology and attributes. Further, each vector file is associated with a metadata file created in ArcCatalog to ensure that it is compatible with the Contents standards of the Federal Geographic Data Committee (FGDC) allowing the data to be located via the National Geospatial Data Clearinghouse (NGDC) mechanism. All of this work were accomplished at DEPHA in Nairobi supervised by the KenSea Team and in a dialogue with staff of the UNEP GRID-Nairobi facility.

EAF-14

Another substantial source of data for the Coastal Resource Maps was the project database containing the data behind the Eastern Africa Atlas of Coastal Resources (EAF-14).

The EAF-14 datasets includes a variety of information with high relevance to the KenSea context, wherefore some of the datasets from the EAF-14 have been incorporated in the KenSea either directly or as guideline for further investigations. The main challenge of the EAF-14 in this context is the fact that it has been produced in scale 1:250,000 implying that it has a lower degree of spatial precision than data created in 1:50,000. Especially features digitized from the 1:250,000 topographical maps under EAF-14 do not show compliance with the level of detail necessary for reproduction in scale 1:50,000. This inherited lack of precision is particularly pronounced for polygon and line features. Point features that indicate a certain feature or activity with finite spatial extent such as for instance hotels have been included without any manipulation because of their indicative nature. All features occurring in the EAF-14 that have not been supported by our own information sources have been completely omitted from the KenSea database like for instance the occurrence of Dugongs.

Aerial photo missions

A significant amount of new data was also created during the three aerial photo missions. This dataset provided the KENSEA project with an excellent tool for documenting near coast features such as coastal morphologies, extent of corals, mangroves and fishing sites. A point layer containing an exact GPS position of each photo acquisition locality was also created enabling the use of a hyperlink function embedded within the ArcGIS software allowing an effortless look up of pictures from a certain area of interest. In addition to this all pictures were tagged with coordinates of were they were taken and the KenSea name.

Apart from creating the above mentioned new layers and reusing modified versions of data from the EAF-14 database a very large effort was put into harvesting all existing GIS layers with relevance to the project from other data holding institutions or organizations.

Other data holders

Much information was acquired through consultations with the NMOSCP partners and other stakeholders during the Inception Phase. This was an ongoing process that continued to add information to the KenSea database throughout the entire project. Much information was acquired through the consultative dialogue between the KenSea team and the various partners, since much of which can be considered to be geographic information in that it has a spatial character, wherefore it was distilled into new spatial datasets and included in the database. Good examples of this is information on the importance of the coastal shallows for small scale fishing, areas with high priority corals, turtle breeding sites and fish landing sites.

The following layers were included in the Coastal Resource Maps

Feature Name	Type	Source
Waders	point	KenSea
Turtle breeding area	point	KenSea
Fish landing site	point	KENSEA
Historical site	point	EAF-14 (modified)
Hotels	point	EAF-14
Air strip	point	KENSEA/SoK
Water intake	point	KENSEA
Towns	point	KENSEA
Coastal Morphology	line	KENSEA/SoK
Coral reefs	line	KENSEA
Rivers	line	KENSEA
Roads	line	KENSEA
Importance of small scale fishing	line	KENSEA
Protected areas (parks and reserves)	Polygon	EAF-14 (modified)
Priority corals	Polygon	KENSEA
Mangroves point	Polygon	KENSEA/SoK

5.2.2 Description of features on the maps

The Resource Maps represent all available data and are the basis for the calculation of the environmental sensitivity index. The features are grouped according to Human Use, Coastal Types and Biological resources.

Table 5-1 Human use features on the Coastal Resource Map.

Feature	comment	Oil sensitivity
Town and settlements	From topographic maps	Not considered
Roads, tracks, air-strips and ferries	From topographic maps	Not considered
Historical sites	Virtually none of the sites are in contact with the inte rtidal zone. Data from EAF-14	None are found to be sensitive to oil, but deserve attention during a clean-up operation
Hotels	Data fro EAF-14,	Very sensitive. Most hotels in the coastal zone are tourist hotels with clean beaches and marine activities as major assets
Fish landing sites	Usually small landing sites, without a pier or other facilities in the water dept of fishery. Data from Dept. of Fishery	Sensitive, mostly due to lost fishing opportunities during the spill, and reduced catch during recovery of the fishing grounds
Fish traps	Constructed by mangrove poles and nets. Data from air photos, May 2005.	Sensitive to smothering by oil and to reduced catch if the mangrove is destroyed. Tainting of fish
Small scale fishing	Local fishermen depend on subsistence fishery all along the cost. The three levels of importance reflects the density of fishermen, but also some seasonal fishing grounds in Lamu District. Data from Dept. of Fishery and Sam Weru, WWF	Moderate sensitive due to possible destruction of local fishing grounds and of breeding and nursery areas.
Salt works	Only the evaporation ponds are marked on the maps. There are no indications of the water intakes. Data from satellite and aerial photos	The evaporation ponds are not sen sitive, but the industry depends heavily on clean and untainted water as the sole resource. Water intake may be via the mangrove, and not from open water - which enhance the sensitivity
Water intake	Industrial use of seawater for cooling purposes only known from Mombasa. Data from the port authorities	Highly sensitive, is but small in time and space

Table 5-2 Biological resources on the Coastal Resource Map.

Feature	comment	Oil sensitivity
Mangrove	Data from topographic maps and field observations	Very sensitive due to the sensitivity of the trees, the difficult clean-up, and the slow recovery
Sheltered rias	Data from topographic maps and field observations	Medium sensitive
Tidal mud flats	Data from topographic maps and field observations	Very sensitive and difficult to clean-up. Good capacity for recovery
Sheltered sand	Data from topographic maps and field observations	Sensitive if untreated, but fairly easy to clean
Exposed sand	Data from topographic maps and field observations	Sensitive if untreated, but fairly easy to clean
Rock	Data from topographic maps and field observations	Less sensitive, and good self-cleaning ability of exposed cliffs
Coral	Data from topographic maps and satellite photos	Highly sensitive and slow recovery. Only intertidal part directly exposed

Table 5-3 Coastal types on the Coastal Resource Map.

Feature	comment	Oil sensitivity
Turtle	Data from KESCOM. Positions are not very precise. Each point represent 1000 m coastline. Importance/relative density of nests by expert assessment by KESCOM	Very sensitive, but the turtles only stay in the risk zone in a very short period. The nests may be at risk during clean-up, and should be moved
Waders	Data from EAF-14 and the National Museum of Kenya. Importance/relative density of nests by expert assessment	Sensitive but ephemeral. Can avoid the oil to a certain degree
Mangrove	Data from topographic maps and field observations	Very sensitive due to the sensitiv-ity of the trees, the difficult clean-up, and the slow recovery
Priority coral	Coral reefs of particular importance. Expert assessments by David Obura and Tim McClanahan	Highly sensitive and slow recov-ery, but the most important reefs are sub tidal end therefore less exposed
Forest or thicket	From topographic maps. Not in contact with the coastline	Not considered
Plantation	From topographic maps. Not in contact with the coastline	Not considered
Papyrus swamp	From topographic maps. Freshwater swamps, Not in contact with the coastline	Not considered
Sand or mud	Data from topographic maps and field observations	Mudflats are sensitive and difficult to clean-up. Good capacity for recovery

Table 5-3 (Cont.)

Feature	comment	Oil sensitivity
Seasonal swamp	Data from topographic maps	Not considered
Marine national park	Data from KWS	Fishery and other resource extraction are prohibited and therefore in a better state and more valuable than the reserves.
Marine national reserve	Data from KWS	Only traditional fishery allowed therefore regarded as more valuable than surrounding areas
Proposed marine national reserve	Data from KWS	Regarded as more valuable than surrounding areas

5.3 Environmental Sensitivity Maps

5.3.1 Description of the production of the maps

After the development of the Coastal Resource Maps the data layers containing geographic information about these resources were used as the foundation for the calculation of the environmental sensitivity index and the rendering of the index values in a separate set of maps: The Environmental Sensitivity Maps, with the sum of all index values illustrated by a colour coded line along the coast containing five classes or index levels ranking the coastal sensitivity to oil spills from a low sensitivity to a high sensitivity.

The notion of having three different groups of features A- Coastal type; B- Biological resource; C- human use was all carried on from the Coastal resource maps. The individual index values for each feature are illustrated in table 5-4.

Table 5-4 Agreed Index values and properties for coast types and other features.

	Feature	Index	Length/width	Shape
A	Rocky Coast	1		Line
A	Sheltered sand beach	2		Line
A	Exposed sand beach	2		Line
A	Tidal mud flat	3		Line
A	Sheltered rias	2		Line
A	Coral reef and reef flat	3/4/5	Width: <200 m/ 200-1000 m/>1000 m	Line
A	Mangrove	3/5/7/10	Width: <50 m, 50-200 m, >200 m, inlet	Line
A	River mouth or Creek	8/10/12	Small-large-creek	Line
B	Important BIRD Area	1		Polygon
B	Waders	0.2/0.6/1	2000 m	Point
B	Turtle breeding site	0.5/1	1000 m	Point
B	Coral reef	1		Line

Table 5-4 cont.

C	Hotel	1	500 m	Point
C	Small scale fishery	0.2/0.6/1	Low-medium-high importance	Line
C	Fish trap	0.5	500 m	Point
C	Fish landing site	1	500 m	Point
C	Harbour	1	500 m	Point
C	Cooling water intake	2	200 m	Point
C	National park	1		Polygon
C	Natural reserve	0.5		Polygon
C	Proposed natural reserve	0.5		Polygon

Values for each feature representing the same geographic locality were added up into the final index value for that locality. Since the features are all either point, line or polygon features a method for bringing all these features onto the line had to be developed. Therefore all points were buffered to a certain distance, so that they no longer only represented a point in space but an interval along the coast. Then all line intervals, lines and polygons were projected onto an individual index sub-line for each feature containing index values for that feature. Finally, all of the individual index values along these identical sublines were added into a single line running 500 m off-shore representing the sum of all index values.

Semi automatic

Since the outline of certain areas of the coast is very complex in having numerous estuaries, inlets, archipelagos and individual islands, the projection of features onto a separate index sub-line was done partially manually and partially in an automated manner. It was often necessary to manually project features from its actual location onto the index sub-line. In areas where the coast line had a more unanimous pattern the projection of features onto the sub-lines was done using a search based on the proximity of the features to the line.

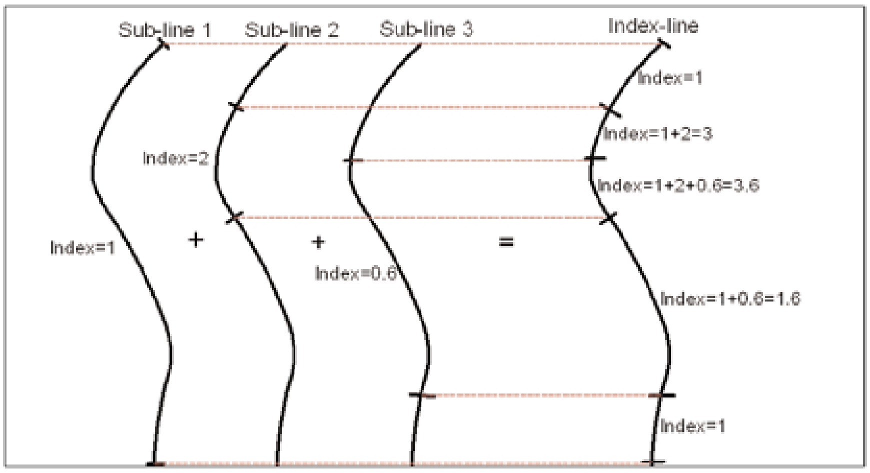


Figure 5-1 Figure Illustrating how segments from the index sub-lines are added up on the final Index Line.

Linear referencing

The process of adding up segmented values along identical lines largely depends on the capacity of ArcGIS to work with so called linear referencing where lines have a measure attribute or address that describe locations along the line. This feature of ArcGIS was used to appoint a system of compatible line addresses to each index segment of each of the identical index sub-lines and then add up all these segments into resulting segments on the final index line Each segment then have an index attribute attached to it containing the sum of indexes from the index attribute of each sub-line.

In order not to distort the comprehensiveness of the Index Line, the linear features illustrating the coast types were omitted from the Environmental Sensitivity Maps. Also the line representing the importance of small scale fishing was left out. Other than that, environmental sensitivity maps contain the same layers and symbols as the Coastal Resource Maps.

5.3.2 Description of the representation of the sensitivity

The Sensitivity Index is calculated as described in chapter 5.3, by use of the agreed index values listed in *Table 5-4*. The Sensitivity Index values range from 1 to 20.6 and the colour code cut-off values are chosen to give as many details along the index as possible. The values do not represent any absolute value, and is best used when comparing parts of the coastline close to each other e.g. while selecting which areas to protect by booms and where to let the oil strand, when a large spill is approaching.

The final products of the project are the 56 map sheet. In the Annex has some of these map sheets been presented in an A4 format to provide the reader with an impression of the final product. The map sheets presented are:

Map sheet 1 (1:50,000) of the Logistic and Topographic Maps
Map sheet 1 (1:50,000) of the Coastal Resource Maps
Map sheet 1 – 16 (1:50,000) of the Environmental Sensitivity Maps covering the coastal are of Kenya
Map sheet 17 -20 (1:25,000) of the Environmental Sensitivity Maps covering the Mombasa Creek Area

All map sheets in full scale as A1 maps can be ordered from Kenya Marine and Fisheries Research Institute (KMFRI), P O Box 81651, Mombasa, Kenya, Tel/Fax: + 254 41475157, http://www.kmfri.co.ke.

6 Selected References

Abuodha, J.O.Z. 2003. Grain size distribution and composition of modern dune and beach sediments, Malindi Bay coast Kenya. Journal of African Earth Sciences 36: 41-54

Abuodha, J.O.Z. 2004. Geomorphological evolution of the southern coastal zone of Kenya. Journal of African Earth Sciences 39: 517-525

Abuodha, P.A.W., Kairo, J.G. 2001. Human-induced stresses on mangrove swamps along the Kenyan coast. Hydrobiologia, 458: 255-265.

Bennun, L., Njoroge, P. 1999. Important Bird Areas in Kenya. RSPB. 389 pp.

Duarte, C.M., Hemminga, M.A., Marbà, N. 1996. Growth and population dynamics of Thalassodendron ciliatum in a Kenyan back-reef lagoon. Aquatic Botany. 55: 1-11

Gundlach, ER; Hayes, MO. 1978 Vulnerability of Coastal Environments to Oil Spill Impacts. Marine Technology Society Journal Vol. 12, No. 4, p 18-27,

Hoff, R. 2002. Oil Spills in Mangroves. NOAA publication, 70pp.

IMO, IPIECA. 1994 Sensitivity mapping for oil spill response. 24 pp.

Kairo, J.G. Dahdouh-Guebas, Bosir, J., Koedam, N. 2001 Restoration and management of mangrove systems - a lesson for and from the East African region. South African Journal of Botany. 67: 383-389

Kaunda-Arara, B., Rose, G.A. 2004. Effects of marine reef National Parks on fishery CPUE in coastal Kenya. Biological Conservation 118: 1-13

NOAA. 2001. Oil Spills in Coral Reefs. NOAA publication, 78 pp.

McClanahan, T.R., Mwaguni, S., Muthiga, N.A. 2006. Management of the Kenyan coast. Ocean & Coastal Management. In Press

McClanahan, T.R., Obura, D. 1997. Sedimentation effects on shallow coral communities in Kenya. Journal of Experimental Marine Biology and Ecology. 209: 103-122.

Mosbech et al. 2000. Environmental Oil Spill Sensitivity Atlas for the West Greenland Coastal Zone. The Danish Energy Agency & Bureau of Minerals and Petroleum, Government of Greenland.

Muthiga, N., Bigot, L., Nielson, A. 1998. EAST AFRICA: Coral reef programs of eastern Africa. ITMEMS 1998 Proceedings. 30 pp.

Obura, D. 2001. Kenya. Marine Pollution Bulletin. 42: 1264-1278

Ochieng, C.A., Erftemeijer, P.L.A. 2003. Seagrasses of Kenya and Tanzania. In: Green, E.P., Short, F.T. (eds.) World Atlas of Seagrasses pp. 82-92

Ochieng, C.A., Erftemeijer, P.L.A 1999. Accumulation of seagrass beach cast along the Kenyan coast: a quantitative assessment. Aquatic Botany 65: 221-238

Ochiewo, J. 2004. Changing fisheries practices and their socioeconomic implications in the South Coast of Kenya. Ocean & Coastal Management 47: 389-408

Okemva, G., Ndirangu, S., Muthama, C., Ong'anda, H., Muen, E. 2005. A Preliminary inventory and characterization of selected sea turtle nesting beaches at the Kenyan Coast UNDP/GEF/KESCOM

Shigenaka, G. 2003. Oil and Sea Turtles, biology, planning and response. NOAA publication, pp. 111

Taylor, M., Ravilious, C., Green, E.P. 2003. Mangroves of East Africa. UNEP-WCMC. 24 pp.

Uku, J., Björk, M. 2005. Productivity aspects of three tropical seagrass species in areas of different nutrient levels in Kenya. Estuarine, Coastal and Shelf Science, 63: 407 - 420

UNEP 1998. Eastern Africa Atlas of Coastal Resources. 1: Kenya. (EAF-14) UNEP, 119 pp.

Zharikov, Y., Skilleter, G.A., Loneragan, .R., Taranto, T., Cameron, B.E. 2005. Mapping and characterising subtropical estuarine landscapes using aerial photography and GIS for potential application in wildlife conservation and management. Biological Conservation 125 (2005) 87-100

Appendixes

Logistic and Topographic Map - Map Sheet 1

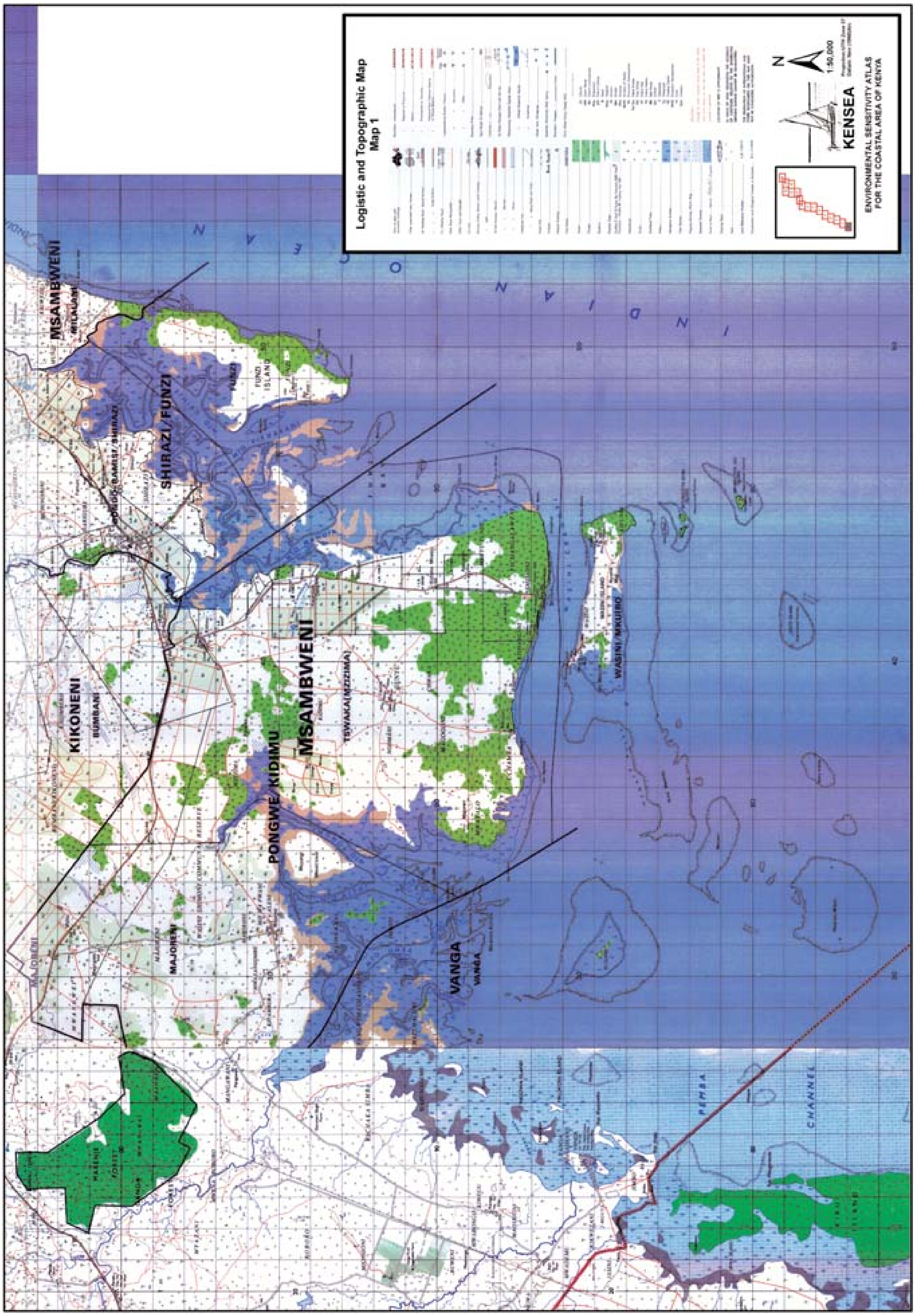
Coastal Resource Map - Map Sheet 1

Environmental Sensitivity Map - Map Sheet 1- 16

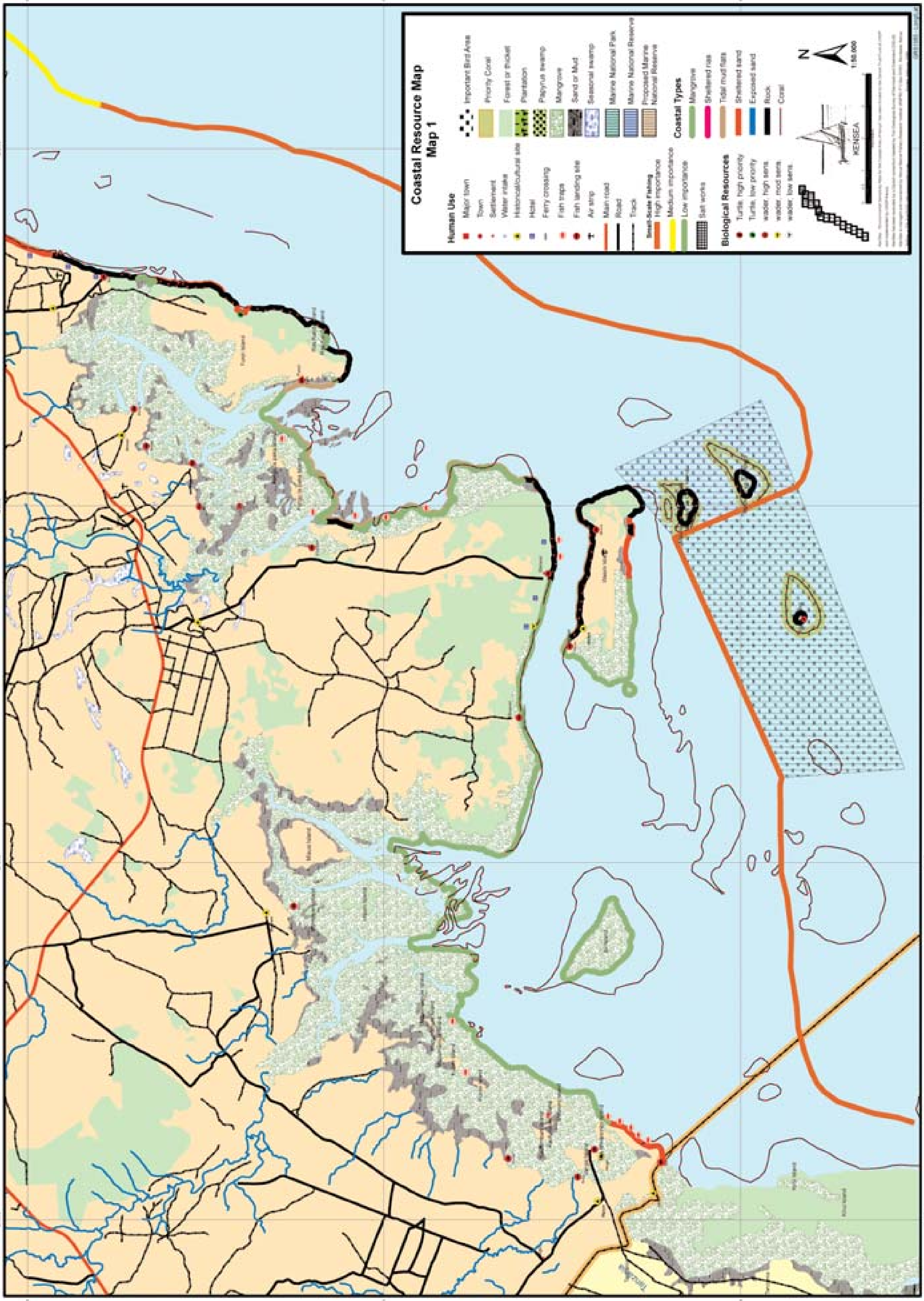
Environmental Sensitivity Map - Map Sheet A,B,C and D

The original maps in 1.50,000 and 1:25,000 are in the following pages presented in A4 format approximately in scale 160,000 and 80,000.

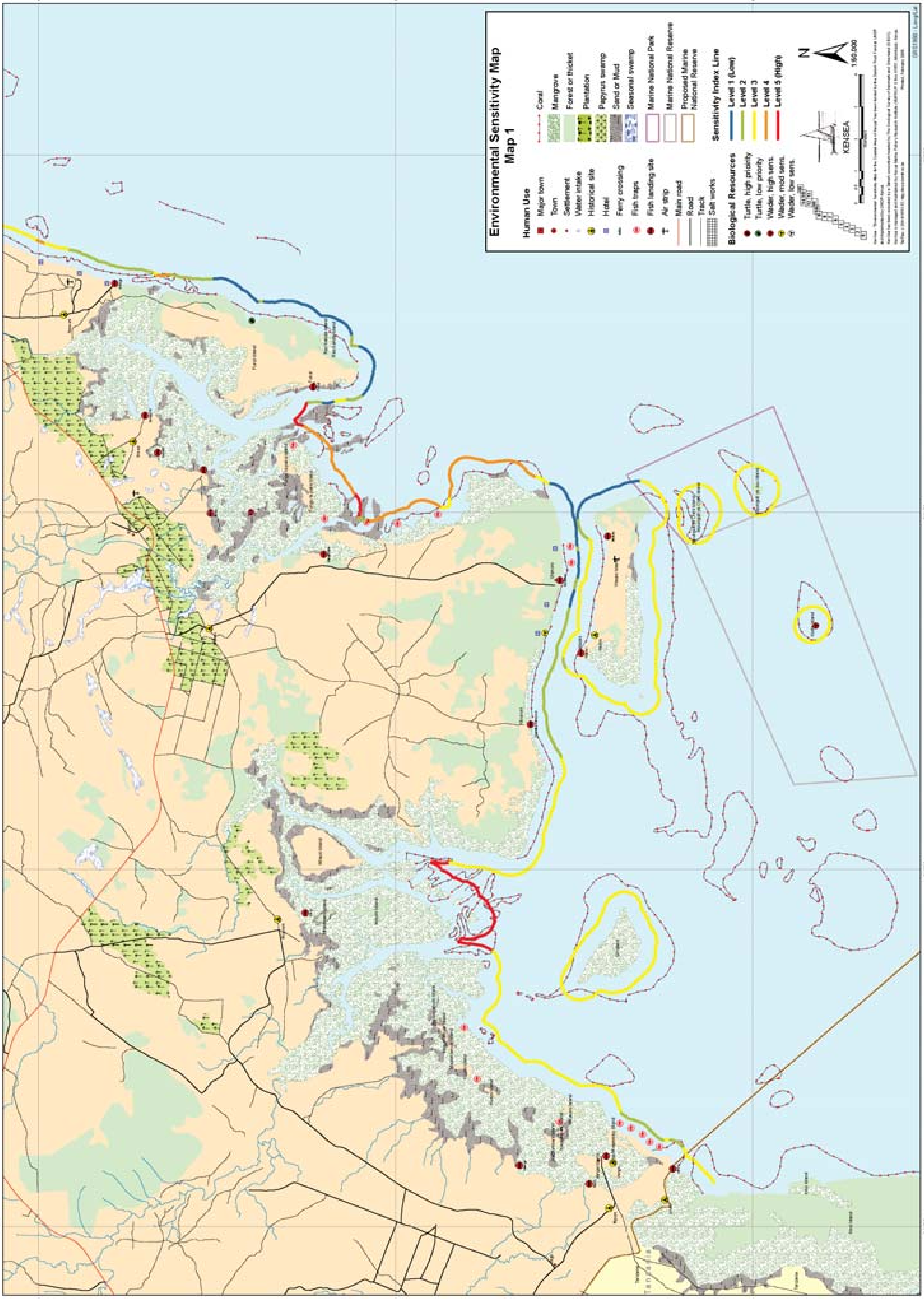
Logistic and Topographic Map - Map Sheet 1

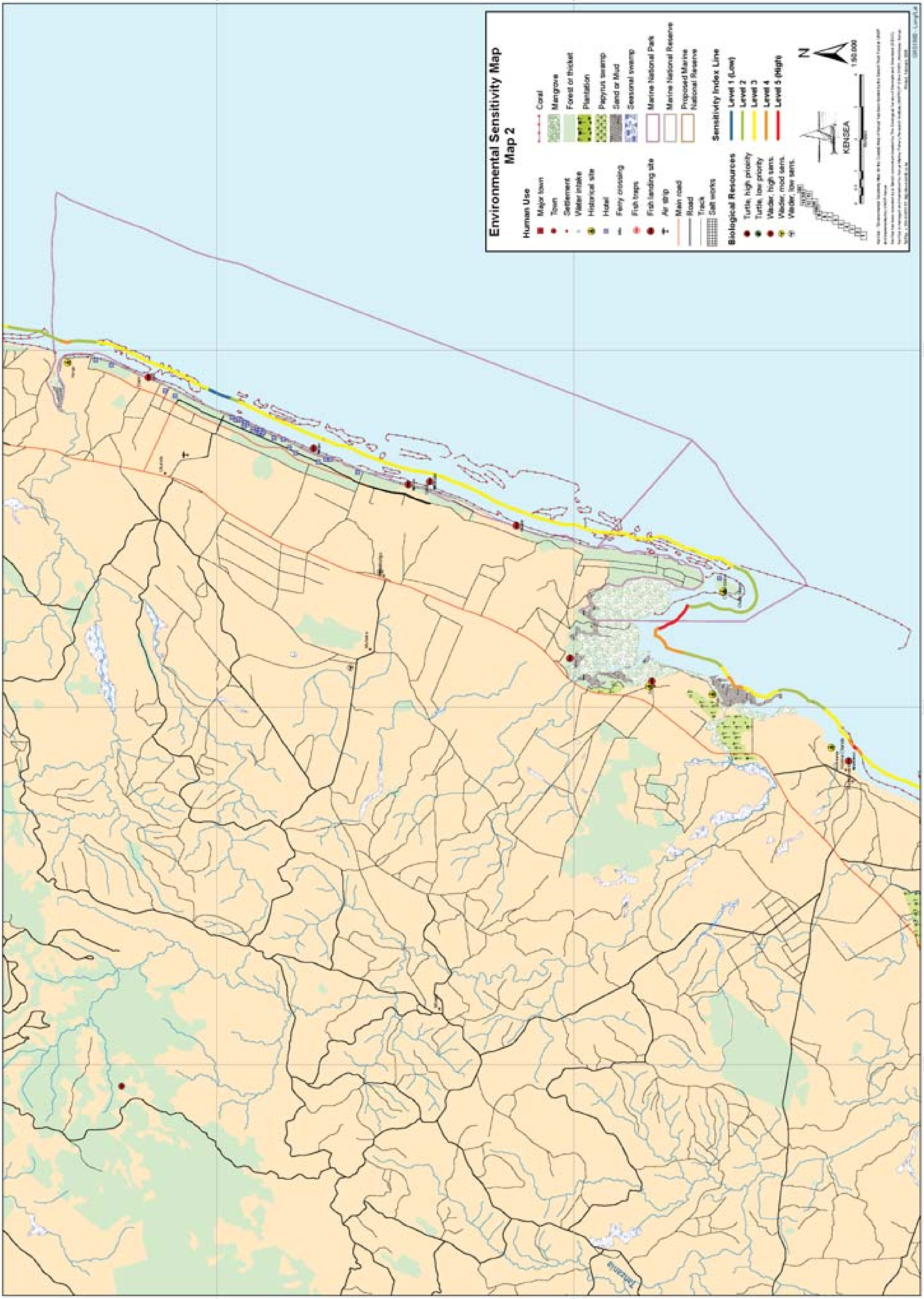


Coastal Resource Map - Map Sheet 1



Environmental Sensitivity Map - Map Sheet 1- 16





Environmental Sensitivity Map
Map 2
Human Use
Major town
Town
Settlement
Water intake
Historical site
Hotel
Ferry crossing
Fish traps
Fish landing site
Air strip
Main road
Road
Track
Salt works
Coral
Mangrove
Forest or thicket
Plantation
Papyrus swamp
Sand or Mud
Seasonal swamp
Marine National Park
Marine National Reserve
Proposed Marine National Reserve
Sensitivity Index Line
Level 1 (Low)
Level 2
Level 3
Level 4
Level 5 (High)
Biological Resources
Turtle, high priority
Turtle, low priority
Wader, high sens.
Wader, mod sens.
Wader, low sens.
N
KENSEA
1:50,000
Tanzania

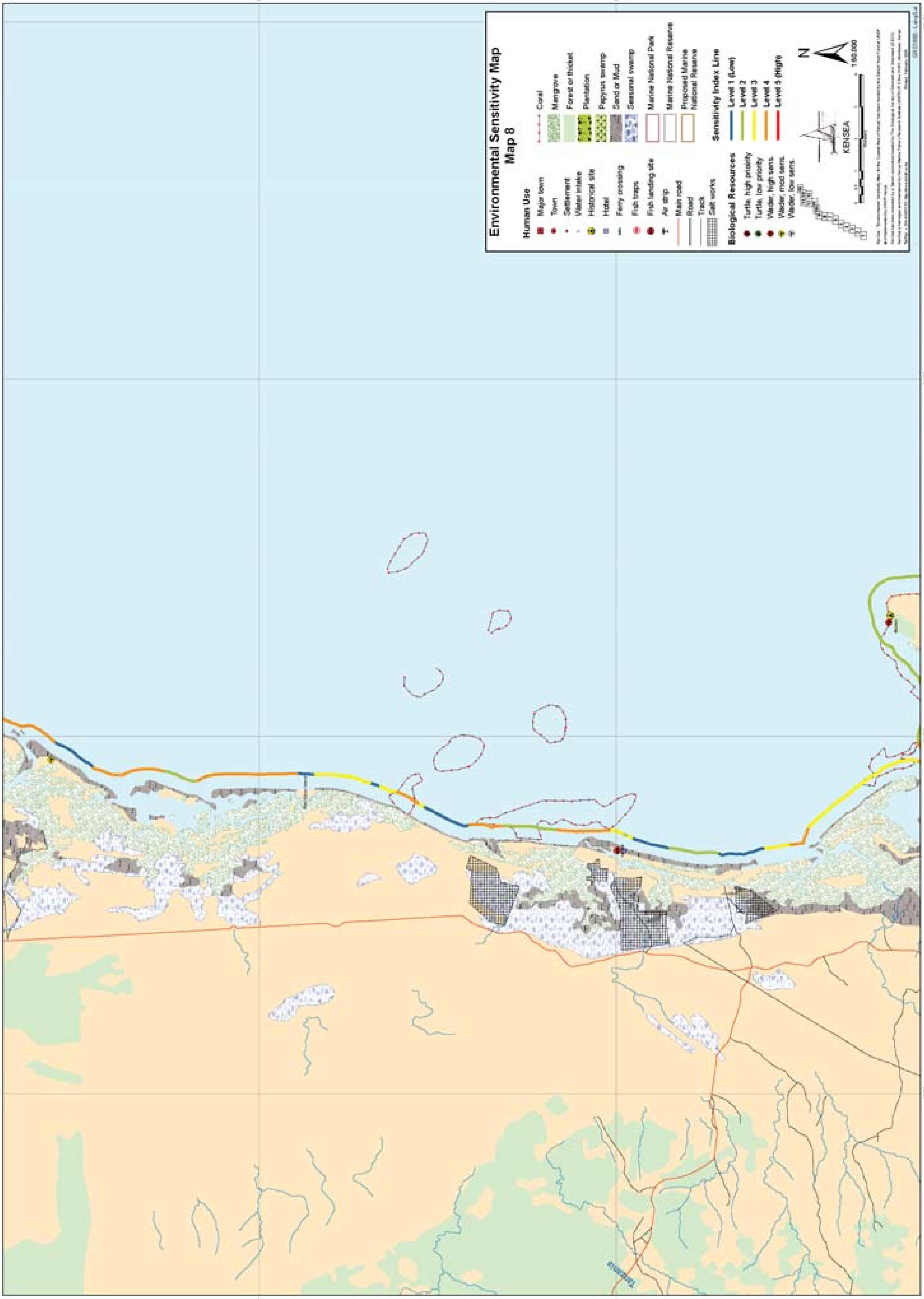

Environmental Sensitivity Map
Map 3
Human Use
Major town
Town
Settlement
Water intake
Historical site
Hotel
Ferry crossing
Fish traps
Fish landing site
Air strip
Main road
Road
Track
Salt works
Biological Resources
Turtle, high priority
Turtle, low priority
Wader, high sens.
Wader, mod sens.
Wader, low sens.
Coral
Mangrove
Forest or thicket
Plantation
Papyrus swamp
Sand or Mud
Seasonal swamp
Marine National Park
Marine National Reserve
Proposed Marine National Reserve
Sensitivity Index Line
Level 1 (Low)
Level 2
Level 3
Level 4
Level 5 (High)
N
KENSEA
Tanzania

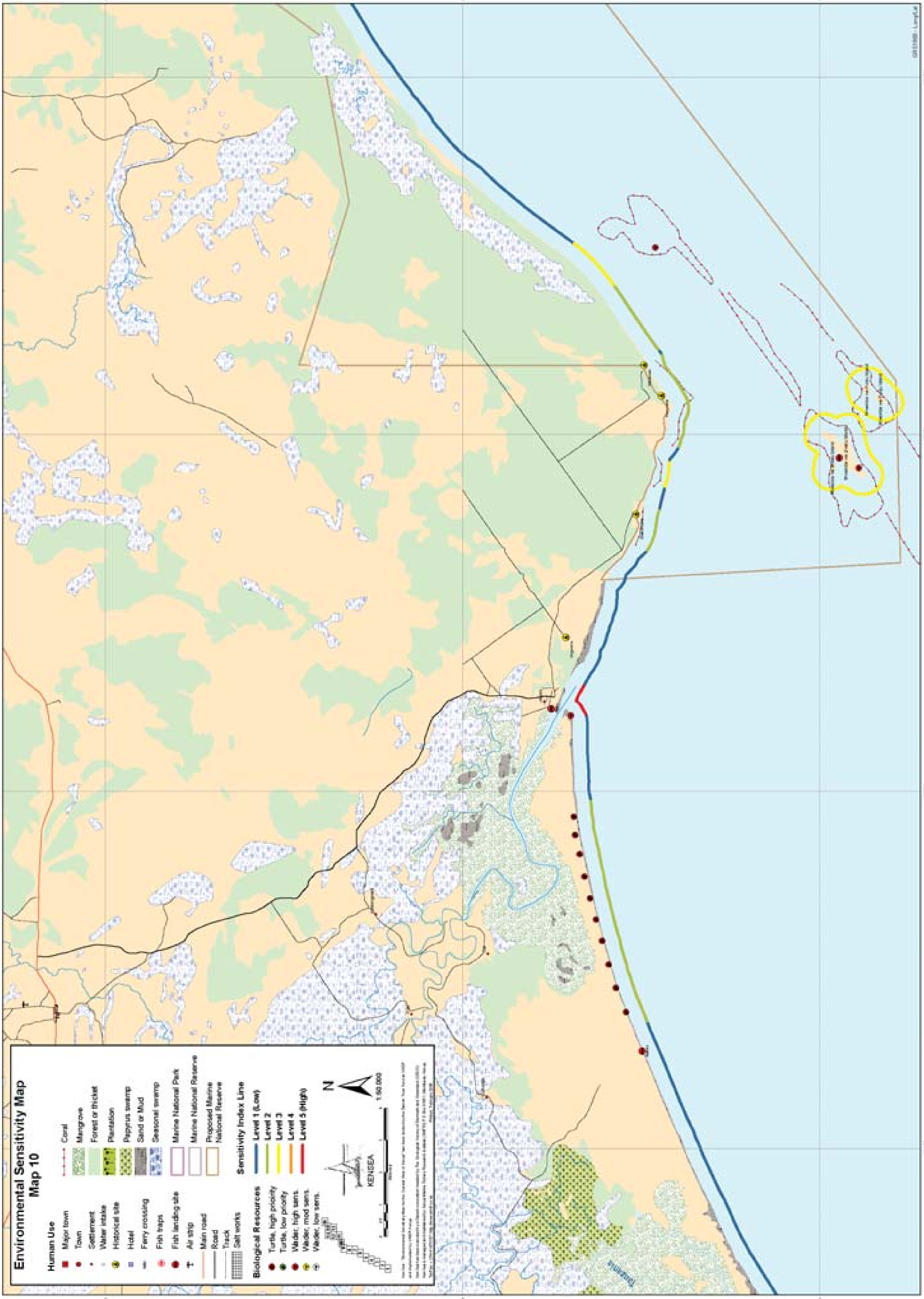

Environmental Sensitivity Map
Map 4
Human Use
Major town
Town
Settlement
Water intake
Historical site
Hotel
Ferry crossing
Fish traps
Fish landing site
Air strip
Main road
Road
Track
Salt works
Coral
Mangrove
Forest or thicket
Plantation
Papyrus swamp
Sand or Mud
Seasonal swamp
Marine National Park
Marine National Reserve
Proposed Marine National Reserve
Sensitivity Index Line
Level 1 (Low)
Level 2
Level 3
Level 4
Level 5 (High)
Biological Resources
Turtle, high priority
Turtle, low priority
Wader, high sens.
Wader, mod sens.
Wader, low sens.
N
KENSEA
1:50,000

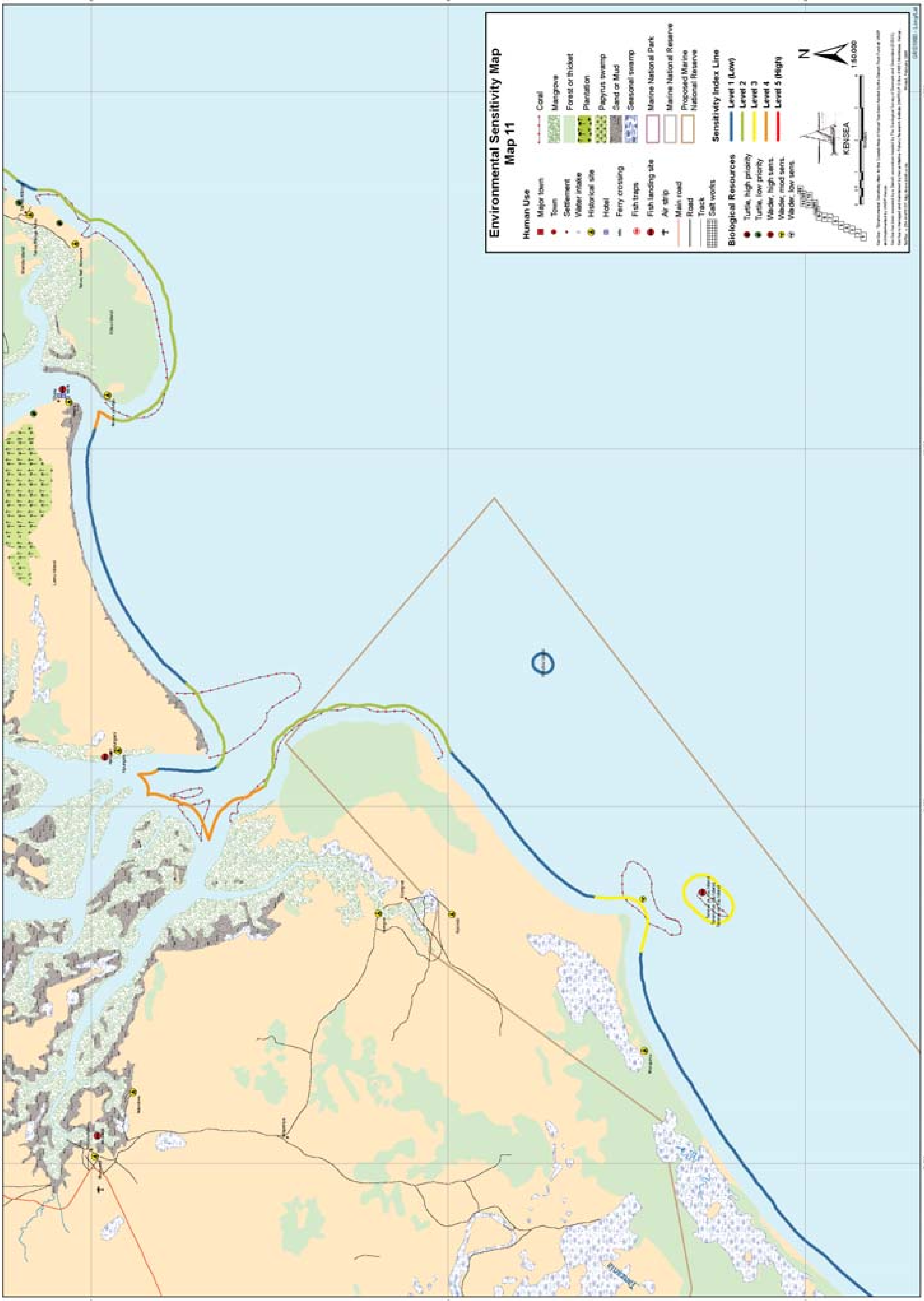

Environmental Sensitivity Map
Map 5
Human Use
Major town
Town
Settlement
Water intake
Historical site
Hotel
Ferry crossing
Fish traps
Fish landing site
Air strip
Main road
Road
Track
Salt works
Coral
Mangrove
Forest or thicket
Plantation
Papyrus swamp
Sand or Mud
Seasonal swamp
Marine National Park
Marine National Reserve
Proposed Marine National Reserve
Sensitivity Index Line
Level 1 (Low)
Level 2
Level 3
Level 4
Level 5 (High)
Biological Resources
Turtle, high priority
Turtle, low priority
Wader, high sens.
Wader, mod sens.
Wader, low sens.
N
1:50,000
KENSEA
Tanzania


Environmental Sensitivity Map
Map 6
Human Use
Major town
Town
Settlement
Water intake
Historical site
Hotel
Ferry crossing
Fish traps
Fish landing site
Air strip
Main road
Road
Track
Salt works
Coral
Mangrove
Forest or thicket
Plantation
Papyrus swamp
Sand or Mud
Seasonal swamp
Marine National Park
Marine National Reserve
Proposed Marine National Reserve
Biological Resources
Turtle, high priority
Turtle, low priority
Wader, high sens.
Wader, mod sens.
Wader, low sens.
Sensitivity Index Line
Level 1 (Low)
Level 2
Level 3
Level 4
Level 5 (High)
KENSEA
N
1:50 000
Tanzania

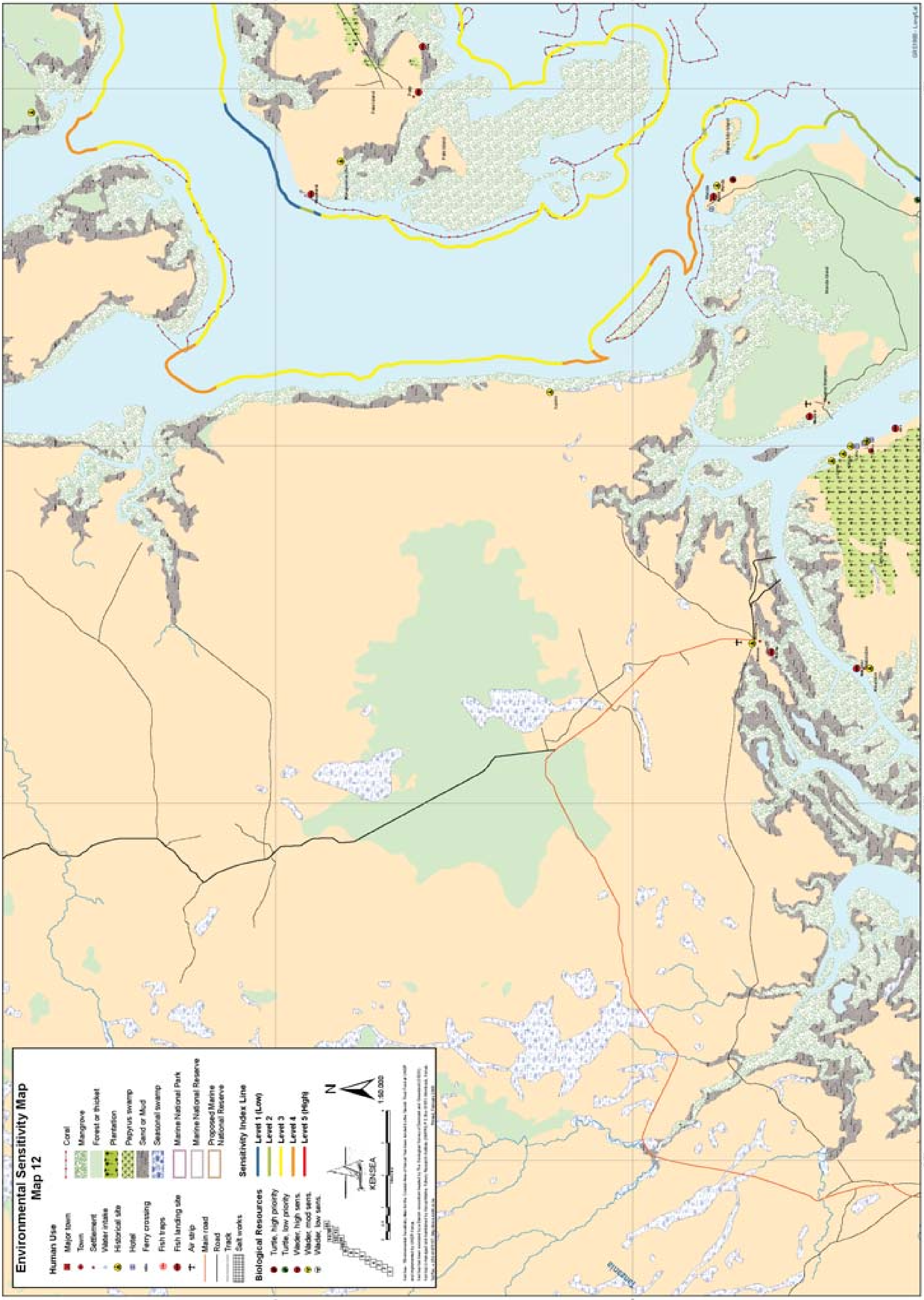

Environmental Sensitivity Map
Map 7
Human Use
Major town
Town
Settlement
Water intake
Historical site
Hotel
Ferry crossing
Fish traps
Fish landing site
Air strip
Main road
Road
Track
Salt works
Coral
Mangrove
Forest or thicket
Plantation
Papyrus swamp
Sand or Mud
Seasonal swamp
Marine National Park
Marine National Reserve
Proposed Marine National Reserve
Biological Resources
Turtle, high priority
Turtle, low priority
Wader, high sens.
Wader, mod sens.
Wader, low sens.
Sensitivity Index Line
Level 1 (Low)
Level 2
Level 3
Level 4
Level 5 (High)
N
KENSEA
1:50,000

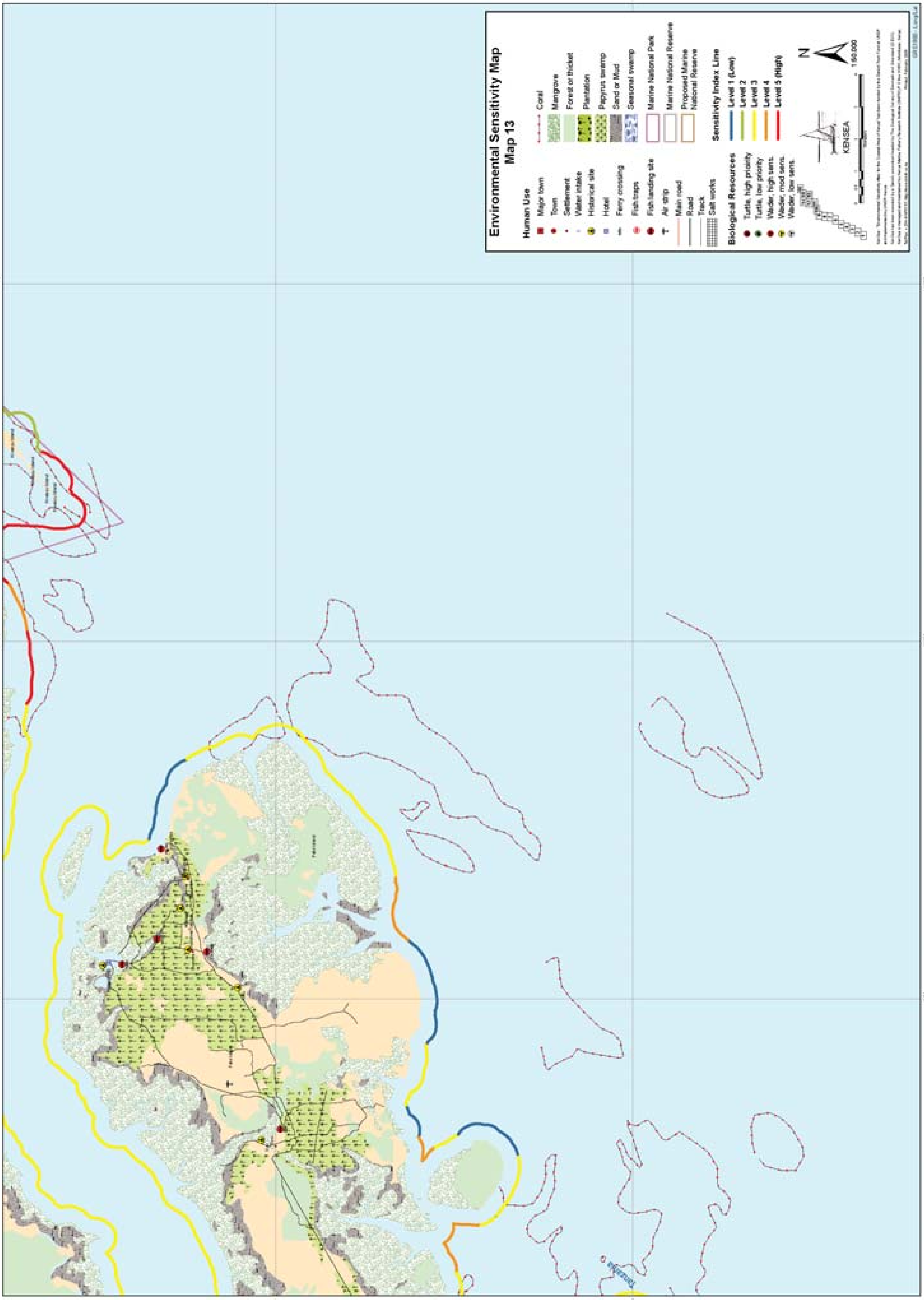

Environmental Sensitivity Map
Map 8
Human Use
Major town
Town
Settlement
Water intake
Historical site
Hotel
Ferry crossing
Fish traps
Fish landing site
Air strip
Main road
Road
Track
Salt works
Coral
Mangrove
Forest or thicket
Plantation
Papyrus swamp
Sand or Mud
Seasonal swamp
Marine National Park
Marine National Reserve
Proposed Marine National Reserve
Biological Resources
Turtle, high priority
Turtle, low priority
Wader, high sens.
Wader, mod sens.
Wader, low sens.
Sensitivity Index Line
Level 1 (Low)
Level 2
Level 3
Level 4
Level 5 (High)
N
KENSEA
1:50,000
Tanzania

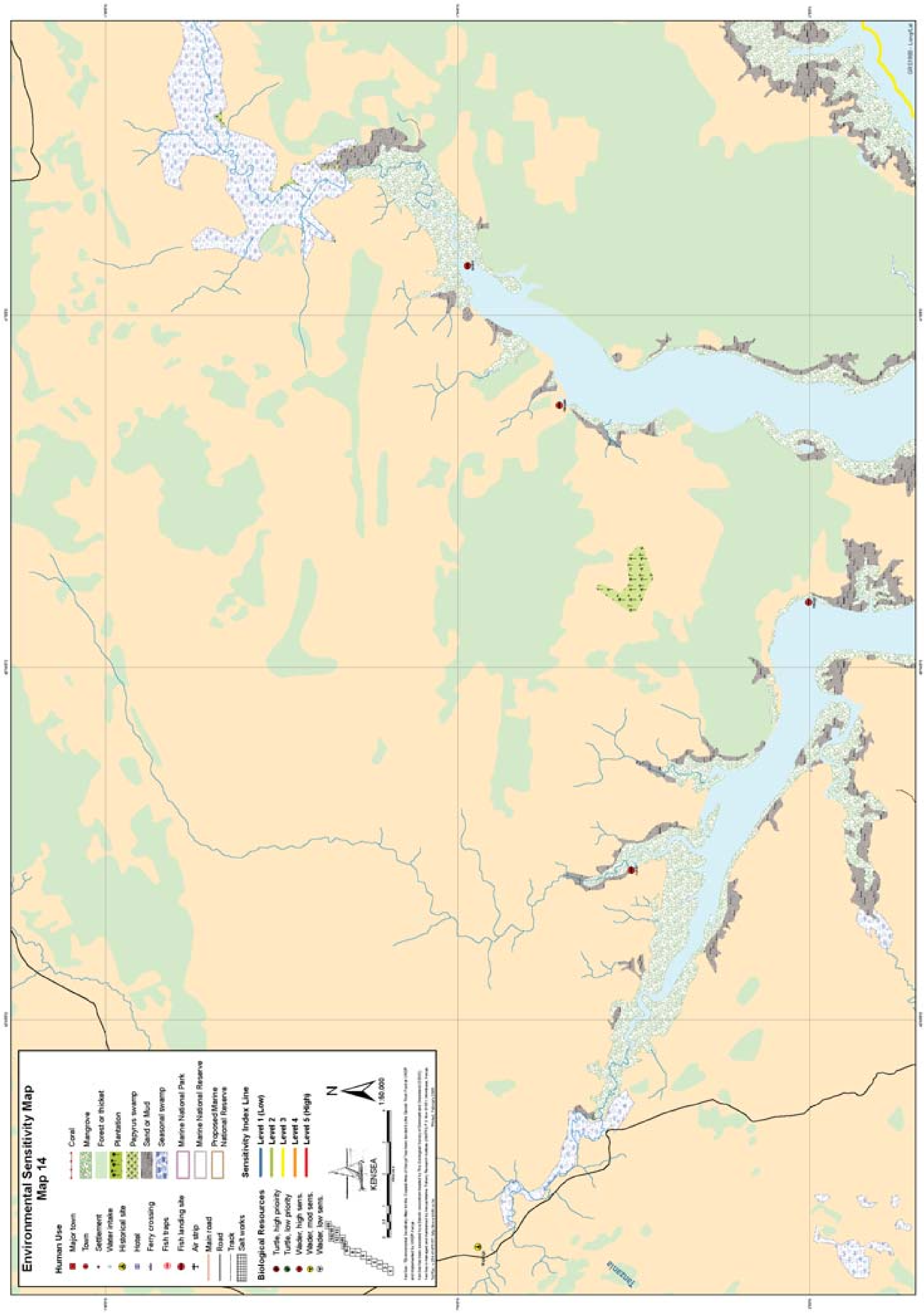

Environmental Sensitivity Map
Map 10
Human Use
Major town
Town
Settlement
Water intake
Historical site
Hotel
Ferry crossing
Fish traps
Fish landing site
Air strip
Main road
Road
Track
Salt works
Coral
Mangrove
Forest or thicket
Plantation
Papyrus swamp
Sand or Mud
Seasonal swamp
Marine National Park
Marine National Reserve
Proposed Marine National Reserve
Biological Resources
Turtle, high priority
Turtle, low priority
Wader, high sens.
Wader, mod sens.
Wader, low sens.
Sensitivity Index Line
Level 1 (Low)
Level 2
Level 3
Level 4
Level 5 (High)
KENSEA
N
Tanzania



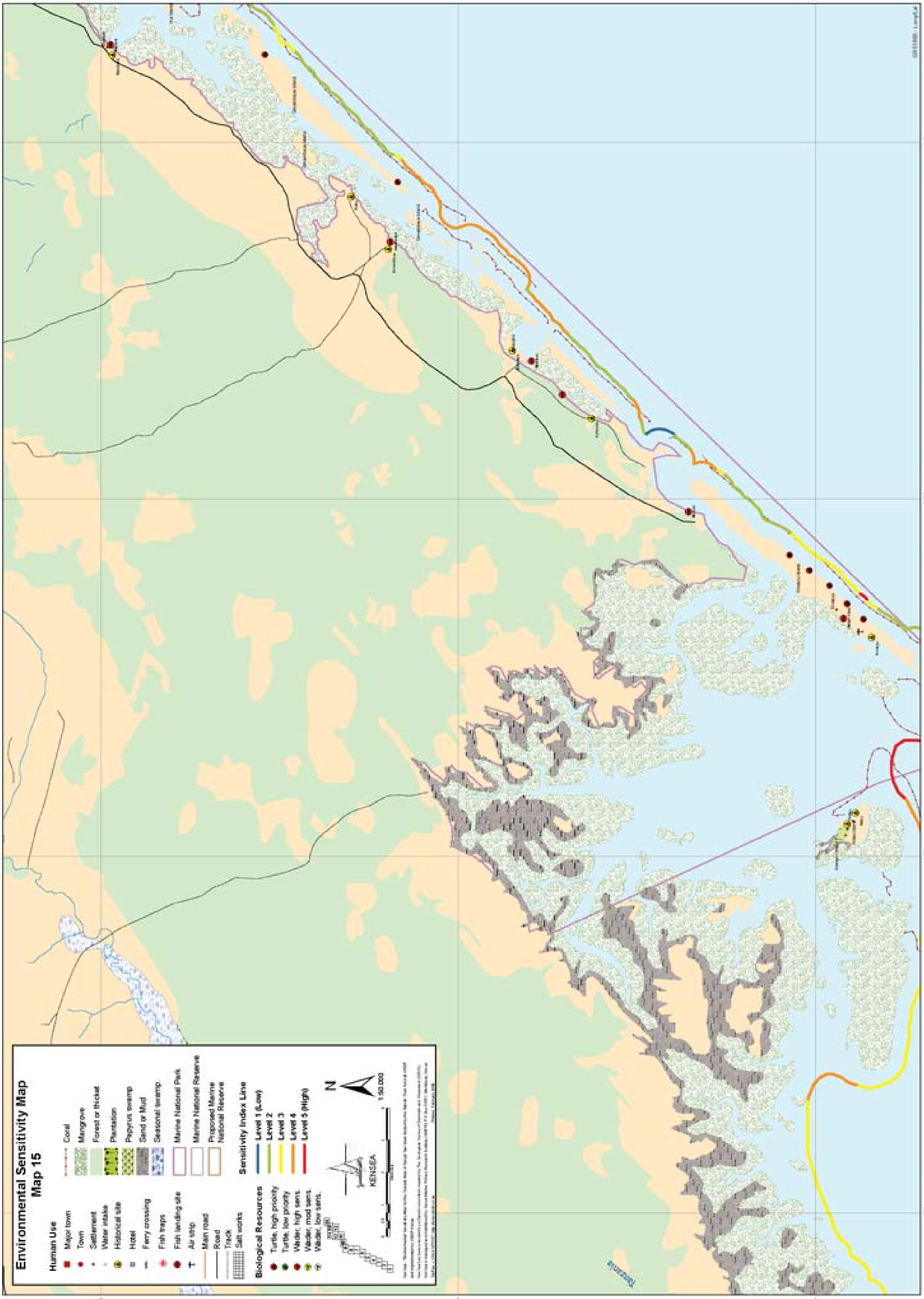
Environmental Sensitivity Map
Map 11
Human Use
Major town
Town
Settlement
Water intake
Historical site
Hotel
Ferry crossing
Fish traps
Fish landing site
Air strip
Main road
Road
Track
Salt works
Coral
Mangrove
Forest or thicket
Plantation
Papyrus swamp
Sand or Mud
Seasonal swamp
Marine National Park
Marine National Reserve
Proposed Marine National Reserve
Sensitivity Index Line
Level 1 (Low)
Level 2
Level 3
Level 4
Level 5 (High)
Biological Resources
Turtle, high priority
Turtle, low priority
Wader, high sens.
Wader, mod sens.
Wader, low sens.
N
KENSEA
1:50,000


Environmental Sensitivity Map
Map 12
Human Use
Major town
Town
Settlement
Water intake
Historical site
Hotel
Ferry crossing
Fish traps
Fish landing site
Air strip
Main road
Road
Track
Salt works
Coral
Mangrove
Forest or thicket
Plantation
Papyrus swamp
Sand or Mud
Seasonal swamp
Marine National Park
Marine National Reserve
Proposed Marine National Reserve
Sensitivity Index Line
Level 1 (Low)
Level 2
Level 3
Level 4
Level 5 (High)
Biological Resources
Turtle, high priority
Turtle, low priority
Wader, high sens.
Wader, mod sens.
Wader, low sens.
KENSEA
N
1:50,000


Environmental Sensitivity Map
Map 13
Human Use
Major town
Town
Settlement
Water intake
Historical site
Hotel
Ferry crossing
Fish traps
Fish landing site
Air strip
Main road
Road
Track
Salt works
Coral
Mangrove
Forest or thicket
Plantation
Papyrus swamp
Sand or Mud
Seasonal swamp
Marine National Park
Marine National Reserve
Proposed Marine National Reserve
Sensitivity Index Line
Level 1 (Low)
Level 2
Level 3
Level 4
Level 5 (High)
Biological Resources
Turtle, high priority
Turtle, low priority
Wader, high sens.
Wader, mod sens.
Wader, low sens.
N
KENSEA
1:50,000



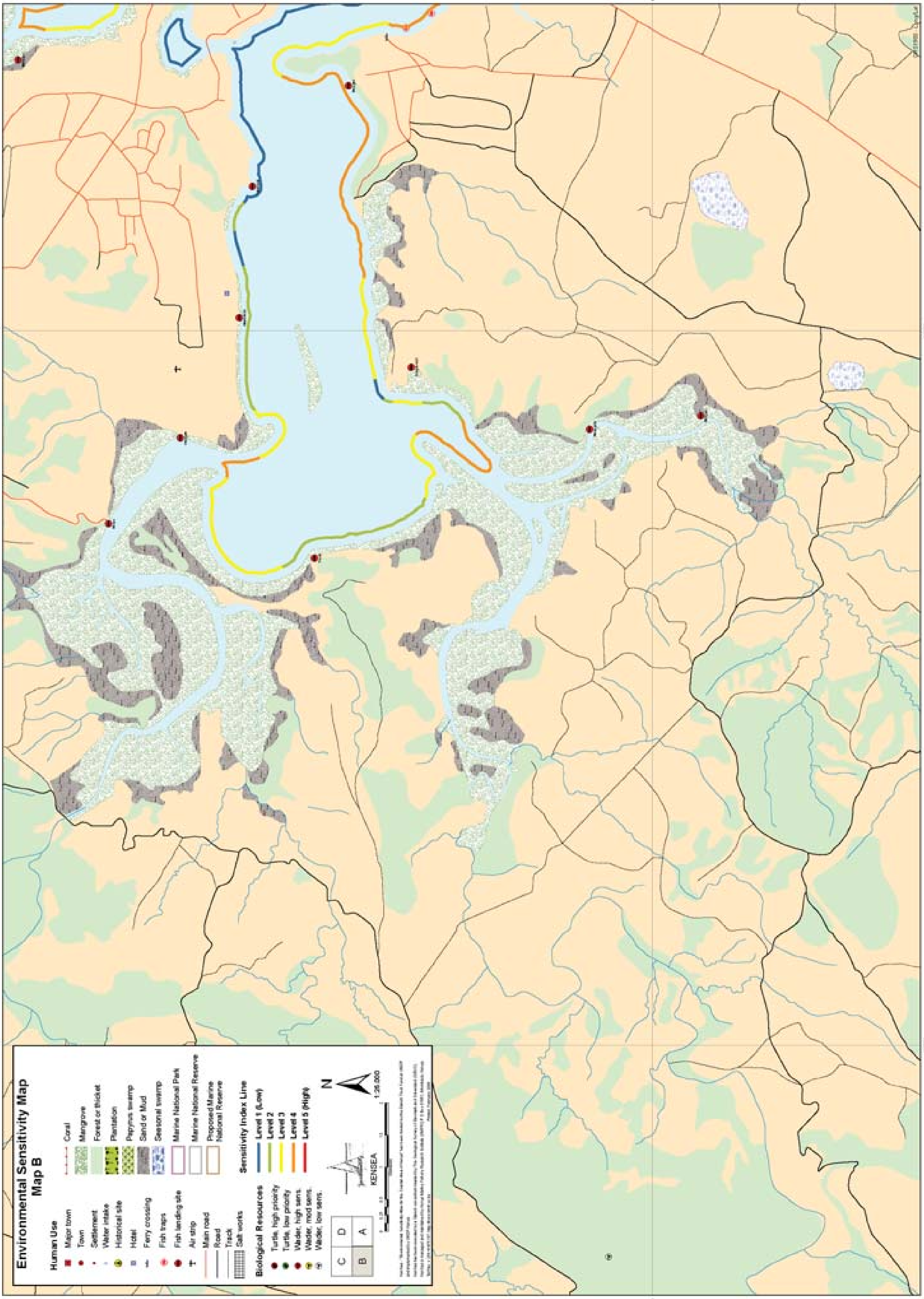
Environmental Sensitivity Map
Map 14
Human Use
Major town
Town
Settlement
Water intake
Historical site
Hotel
Ferry crossing
Fish traps
Fish landing site
Air strip
Main road
Road
Track
Salt works
Coral
Mangrove
Forest or thicket
Plantation
Papyrus swamp
Sand or Mud
Seasonal swamp
Marine National Park
Marine National Reserve
Proposed Marine National Reserve
Biological Resources
Turtle, high priority
Turtle, low priority
Wader, high sens.
Wader, mod sens.
Wader, low sens.
Sensitivity Index Line
Level 1 (Low)
Level 2
Level 3
Level 4
Level 5 (High)
KENSEA
N
1:50,000
Tanzania

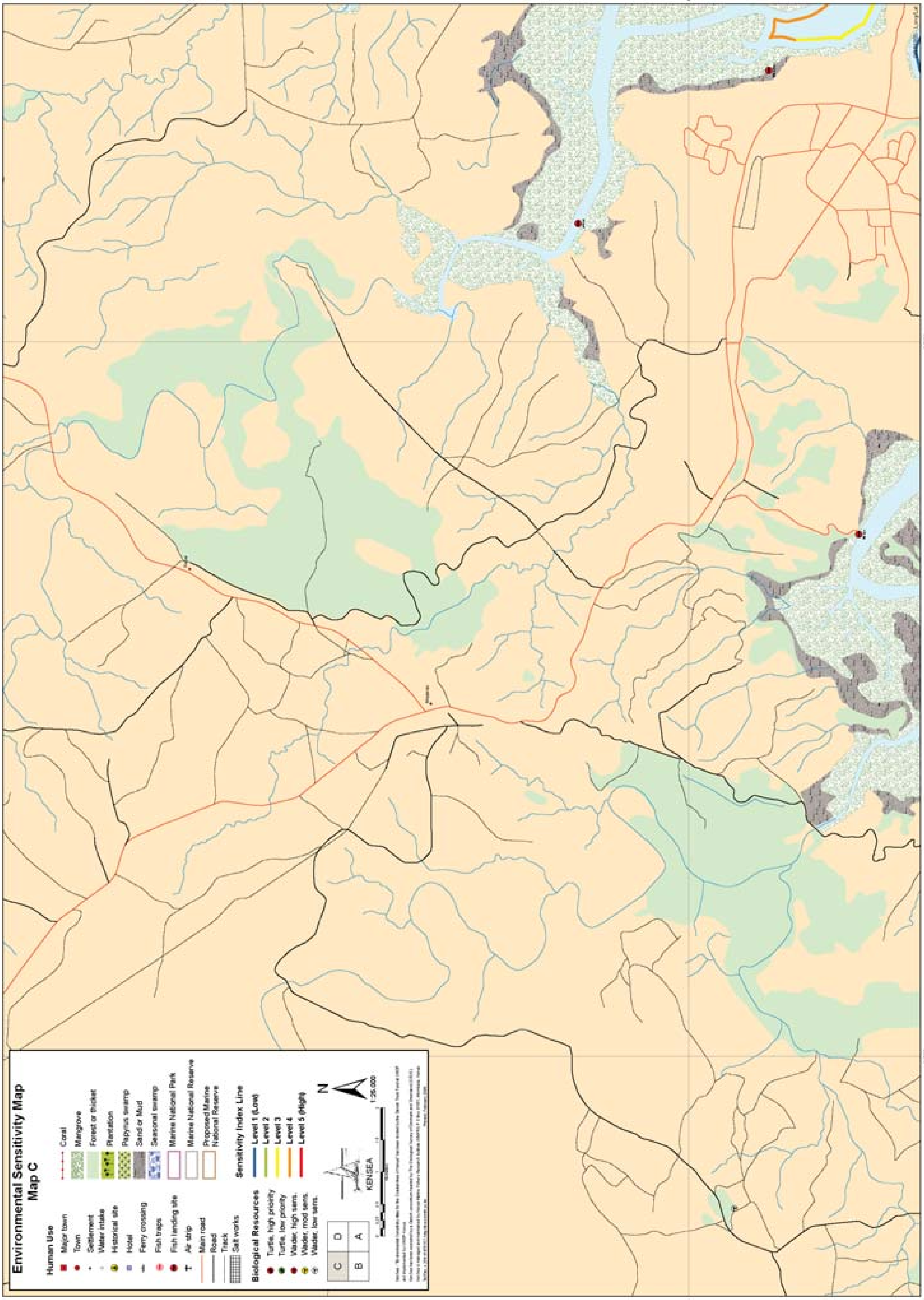


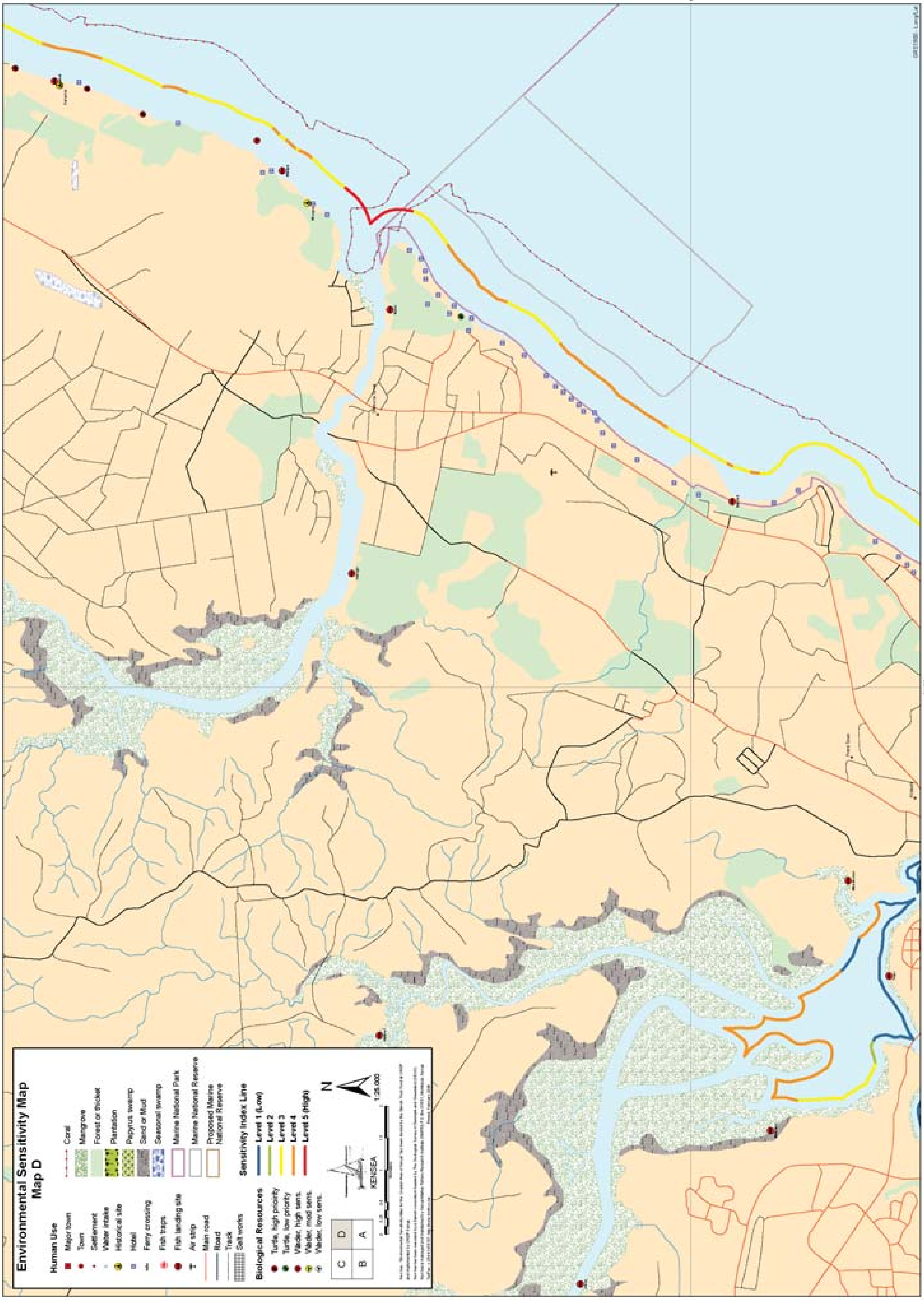
Environmental Sensitivity Map
Map 15
Human Use
Major town
Town
Settlement
Water intake
Historical site
Hotel
Ferry crossing
Fish traps
Fish landing site
Air strip
Main road
Road
Track
Salt works
Coral
Mangrove
Forest or thicket
Plantation
Papyrus swamp
Sand or Mud
Seasonal swamp
Marine National Park
Marine National Reserve
Proposed Marine National Reserve
Biological Resources
Turtle, high priority
Turtle, low priority
Wader, high sens.
Wader, mod sens.
Wader, low sens.
Sensitivity Index Line
Level 1 (Low)
Level 2
Level 3
Level 4
Level 5 (High)
KENSEA
N
Tanzania

Environmental Sensitivity Map
Map 16
Human Use
Major town
Town
Settlement
Water intake
Historical site
Hotel
Ferry crossing
Fish traps
Fish landing site
Air strip
Main road
Road
Track
Salt works
Coral
Mangrove
Forest or thicket
Plantation
Papyrus swamp
Sand or Mud
Seasonal swamp
Marine National Park
Marine National Reserve
Proposed Marine National Reserve
Sensitivity Index Line
Level 1 (Low)
Level 2
Level 3
Level 4
Level 5 (High)
Biological Resources
Turtle, high priority
Turtle, low priority
Wader, high sens.
Wader, mod sens.
Wader, low sens.
N
KENSEA
Somalia

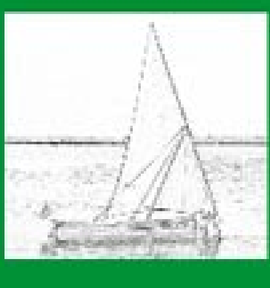
Environmental Sensitivity Map - Map Sheet A,B,C and D


Environmental Sensitivity Map
Map B
Human Use
Major town
Town
Settlement
Water intake
Historical site
Hotel
Ferry crossing
Fish traps
Fish landing site
Air strip
Main road
Road
Track
Salt works
Coral
Mangrove
Forest or thicket
Plantation
Papyrus swamp
Sand or Mud
Seasonal swamp
Marine National Park
Marine National Reserve
Proposed Marine National Reserve
Sensitivity Index Line
Level 1 (Low)
Level 2
Level 3
Level 4
Level 5 (High)
Biological Resources
Turtle, high priority
Turtle, low priority
Wader, high sens.
Wader, mod sens.
Wader, low sens.
C
D
B
A
KENSEA
N
1:35,000


Environmental Sensitivity Map
Map C
Human Use
Major town
Town
Settlement
Water intake
Historical site
Hotel
Ferry crossing
Fish traps
Fish landing site
Air strip
Main road
Road
Track
Salt works
Coral
Mangrove
Forest or thicket
Plantation
Papyrus swamp
Sand or Mud
Seasonal swamp
Marine National Park
Marine National Reserve
Proposed Marine National Reserve
Sensitivity Index Line
Level 1 (Low)
Level 2
Level 3
Level 4
Level 5 (High)
Biological Resources
Turtle, high priority
Turtle, low priority
Wader, high sens.
Wader, mod sens.
Wader, low sens.
C
D
B
A
KENSEA
N
1:25,000


Environmental Sensitivity Map
Map D
Human Use
Major town
Town
Settlement
Water intake
Historical site
Hotel
Ferry crossing
Fish traps
Fish landing site
Air strip
Main road
Road
Track
Salt works
Biological Resources
Turtle, high priority
Turtle, low priority
Wader, high sens.
Wader, mod sens.
Wader, low sens.
Coral
Mangrove
Forest or thicket
Plantation
Papyrus swamp
Sand or Mud
Seasonal swamp
Marine National Park
Marine National Reserve
Proposed Marine National Reserve
Sensitivity Index Line
Level 1 (Low)
Level 2
Level 3
Level 4
Level 5 (High)
N
1:25,000
KENSEA
C
D
B
A

KenSea - Environmental Sensitivity Atlas is an integral part of the National Marine Oil Spill Contingency Plan (NMOSCP) for Kenya and is a key component of the data directory within it. The Atlas will provide an environmental data dictionary and will be utilized as a tool in risk assessment, clean up prioritization as well as in selection of appropriate methods and tools of response.



KenSea – Environmental Sensitivity Atlas for Coastal Area of Kenya has been financed by The Fund for Danish Consultancy Services and has been implemented by United Nations Development Programme (UNDP) in Kenya.

KenSea has been executed by a Danish/Kenyan consortium headed by The Geological Survey of Denmark and Greenland (GEUS).

KenSea is managed and maintained by Kenya Marine and Fisheries Research Institute (KMFRI). P.O. Box 81651, Mombasa, Kenya; Tel/Fax: + 254 41475157; http://www.kmfri.co.ke