BENEFIT

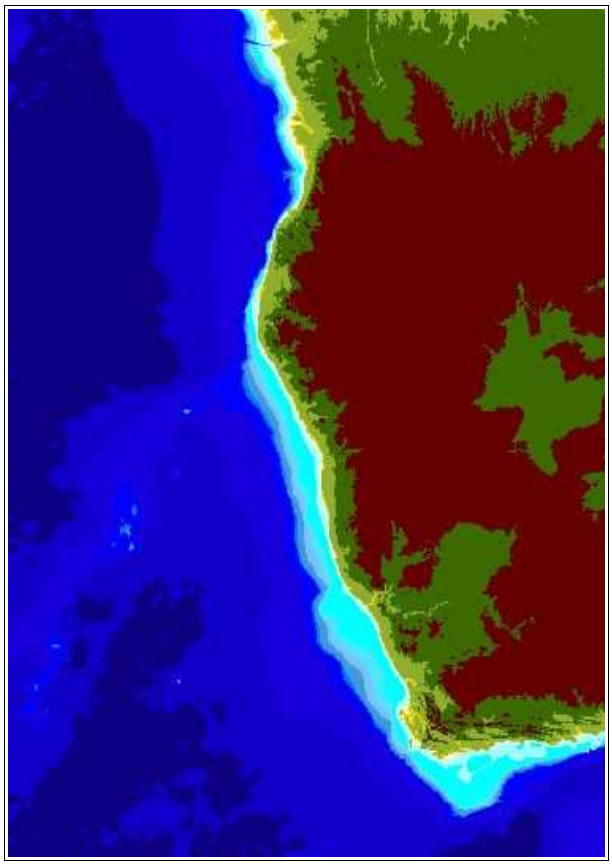
BCLME
Benguela Current Large Marine Ecosystem Programme

FINAL REPORT

BEP/BAC/03/02

MAPPING OF THE BCLME SHORELINE, SHALLOW WATER & MARINE HABITATS

Physical mapping project



Vera De Cauwer

September 2007

Project in collaboration with the Benguela Environment Fisheries Interaction & Training Programme (BENEFIT) for the Benguela Current Large Marine Ecosystem (BCLME) Programme

Abbreviations

BCLME	Benguela Current Large Marine Ecosystem
BENEFIT	Benguela Environment Fisheries Interaction & Training Programme
CSIR	Council for Scientific and Industrial Research (South Africa)
DCW	Digital Chart of the World
EEZ	Exclusive Economic Zone
GEBCO	General Bathymetric Chart of the Oceans
GIS	Geographic Information System
IH	Instituto Hidrográfico (Hydrographic Institute of Portugal)
MET	Ministry of Environment and Tourism (Namibia)
MFMR	Ministry of Fisheries and Marine Resources (Namibia)
MLR	Ministry of Lands & Resettlement (Namibia)
MPA	Marine protected area
NACOMA	Namibian Coast Conservation and Management (Namibia)
NatMIRC	National Marine Information and Research Centre, MFMR (Namibia)
NGDC	National Geophysical Data Center (USA)
NSBA	National Spatial Biodiversity Assessment (South Africa)
SADC	Southern African Development Community
SAN	South African Navy
SANBI	South African National Botanical Institute
SG	Surveyor General (Directorate of Survey & Mapping, Ministry of Lands & Resettlement, Namibia)
SONANGOL	Sociedade Nacional de Combustíveis de Angola
SRTM	Shuttle Radar Topography Mission
WDPA	World Database on Protected Areas

Table of Contents

List of Figures

List of Tables

Summary

The Benguela Current Large Marine Ecosystem (BCLME) programme started in 2002 and is funded by the Global Environmental Facility (GEF). One of its main aims is to address marine and coastal conservation planning in the Benguela region. The region considered under the programme covers Angola, Namibia and South Africa up till Cape Point.

Fundamental to conservation planning is a full assessment of the status and threats of biodiversity within the BCLME domain. To this end the BCLME has commissioned the Benguela Environment Fisheries Interaction & Training Programme (BENEFIT) to undertake a biodiversity assessment and mapping research programme. It consists of an overarching "MOM" project and four component projects who interact with and feed into the MOM project. MOM will utilise the information and data collected by the component projects to bring conservation planning to an operational level in each of the three countries.

One of the component projects is the Physical Mapping project of which the final results are described in this report. The project is officially entitled "Mapping of the BCLME shoreline, shallow water and estuarine habitats", although the scope of this project has been revised in the course of BENEFIT consultations and now includes the shoreline, shallow water and offshore marine areas. The aim of the physical mapping project is to map the distribution of shoreline, shallow water and marine habitats in the BCLME region through the identification and collection of existing physical data related to shoreline, shallow water and marine habitat distribution, synthesis of the collected physical data in GIS format and compilation of habitat maps based on the collected physical data.

Existing physical datasets related to shoreline, shallow water and marine habitat distribution in the BCLME region were identified, as well as physical datasets (with a geospatial component) that contributes to marine and coastal biodiversity conservation planning. The accuracy, resolution, completeness and coverage of the identified data was analysed and the most appropriate datasets for use at regional level or most appropriate sources for the creation of these datasets, were selected and collected. The analysis included a comparison of the GEBCO and ETOPO global elevation datasets with hydro acoustic measurements for the marine areas of the BCLME region.

The geospatial data collected was converted to GIS format and the same coordinate system. This involved a a substantial amount of digitising and conversion of coordinates to point files. The creation of the GIS layer on intertidal coast types required the development of a method to estimate the wave exposure along the coast (adapted from Howes, Harper & Owens, 1994) .

During the project, 2 students of Namibia and 2 students of Angola were trained on-the-job in marine GIS mapping.

A total number of 122 GIS physical data layers were compiled during this project. Most datasets are collected at national level - Namibia, Angola, South Africa - although certain datasets are covering the BCLME region. The datasets follow a standard naming convention and are organised in a systematic folder structure. A meta data file was established per data layer. All meta data was organised in one file per country following a template established by this project. About half of the compiled datasets concern completely new data layers created by the project – i.e. data layers that are not a combination or edition of existing GIS data.

Most effort went into the compilation of datasets considered essential to biodiversity conservation planning (in consulatation with the MOM team). These include the coastline, islands, bathymetry, marine sediments, intertidal coast types, harbours, protected zones, mining areas, human transformation of the coastline, EEZ, roads, untrawable grounds, seamounts, marine canyons, continental shelf and others. Most of these first and second priority data layers could be established for each country with exception of the classification of marine sediments for Angola, untrawable grounds for South Africa and fog data for Angola.

The majority of the established datasets will fit the requirements for use at regional level. There are however a few datasets with weaknesses of which the most important are :

- Angolan bathymetry close to coast : different sources were used of which the accuracy is unknown. It is advised to groundtruth and compare the data with depth measurements (soundings) and possibly correct and complement it.
- Texture of marine sediments : these are based on samples with unknown or low sample density. An upgrade with recently collected samples and acoustic survey data is advised.
- Seamounts and marine canyons : these underwater features were digitised based on the GEBCO information for Namibia and Angola. The resolution of the GEBCO data is however 1' or 1.7 km and seamounts and canyons smaller than approximately 10 km x 10 km can easily have been missed.

One of the most important outputs of this project is the establishment of the biozones dataset, a major input into the MOM biodiversity conservation planning exercise. The biozones dataset could be established based on expert input, the bathymetry, EEZ, country, continental shelf, settlement and places datasets.

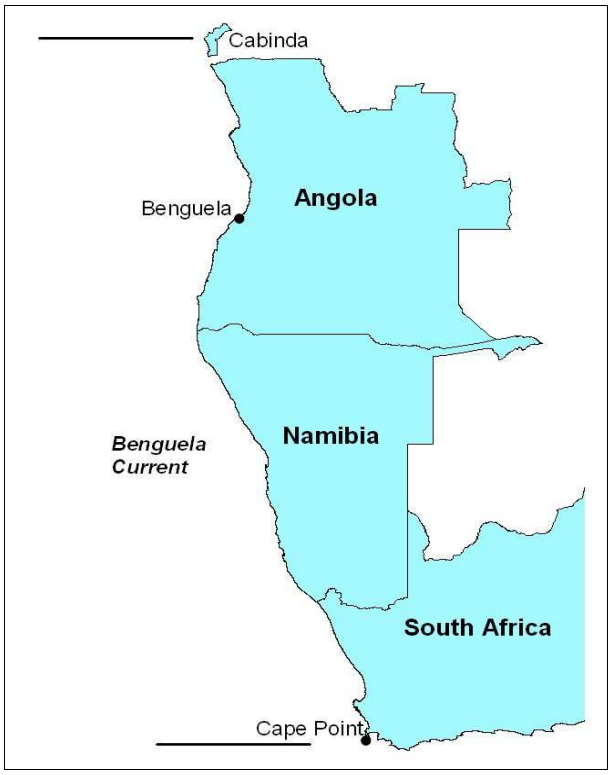
It should be stressed that the datasets established for this project are not all owned by the BCLME/BENEFIT project and that their main purpose is to serve as an input into the MOM project. Certain datasets have copyrights, can not distributed to third parties and/or need acknowledgement or referencing. **It is therefore not permissible to freely distribute the physical mapping dataset as is. The BCLME must take cognisance of this fact as there are legal implications associated with this. Accompanying letter of agreement with data sources are referred.**

This project could not have be realised without the assistance and cooperation of many organisations and persons. All these persons and organisations are mentioned in the report (mainly in unit 2 – project team) or in the meta data. It is recommended to invite all these persons and representatives of the organisations to a final workshop at which the BCLME/BENEFIT biodiversity project results are presented. Several of the persons that contributed data will be interested in the final results, may even want to use them and could be interested in any assessments of their data sets in terms of the accuracy and completeness of the data they provided.

1. Introduction

The Benguela Current Large Marine Ecosystem (BCLME) programme, which is funded by the Global Environmental Facility (GEF), commenced activities in 2002 . One of its main aims is to address marine and coastal conservation planning in the Benguela region. The region considered under the programme covers the area between Cape Point and Cabinda - the northern enclave of Angola - although the Benguela Current formally extends its influence only as far north as the city of Benguela in Angola (figure 1). The southern and eastern coastline of South Africa are part of the Agulhas Large Marine Ecosystem.

Figure 1 – The region covered by the BCLME programme covers Angola, Namibia and western South Africa as indicated by the two vertical lines (own compilation)



Fundamental to conservation planning is a full assessment of the status and threats of biodiversity within the BCLME domain. To this end the BCLME has commissioned the Benguela Environment Fisheries Interaction & Training Programme (BENEFIT) to undertake a biodiversity assessment and mapping programme under auspices of the Biodiversity, Ecosystem Health and Pollution Activity Centre based in Luanda. This programme of activities encompasses several components all interacting and all feeding into the overarching "MOM" project which will utilise the information and data collected to bring conservation planning to an

operational level in each of the three countries. The approach followed for the conservation planning is same as the one used for the marine component of the South African National Biodiversity Assessment (Lombard *et al*., 2004).

The different components of the Biodiversity, Mapping & Conservation Programme are as follows :

- MOM project (BEP/BAC/03/02) ;
- **Physical mapping project (BEP/BAC/03/02)** : Mapping of the BCLME shoreline, shallow water and estuarine habitats : addressed in this report. It must be mentioned that the scope of this project has been revised in the course of BENEFIT consultations and includes the shoreline, shallow water and offshore marine areas. The Estuary project addresses estuary habitats ;
- Biological mapping project (BEP/BAC/03/03) ;
- Estuary project (BEP/BAC/03/04) ;
- Threats project ((BEP/BAC/03/05).

Activities of the Physical mapping project started in October 2005. The aim of the project is to map the distribution of shoreline, shallow water and estuarine habitats in the BCLME region. Following objectives were addressed :

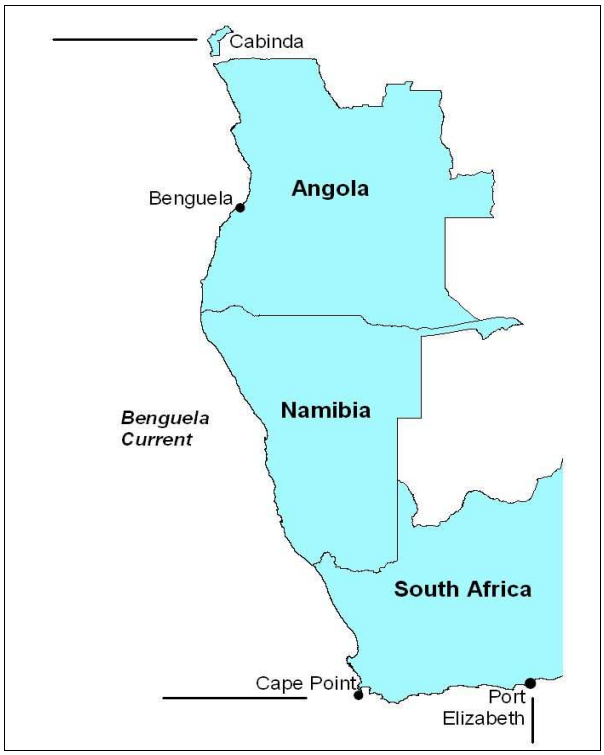
- Identification and collection of existing physical data related to shoreline, shallow water and marine habitat distribution ;
- Identification of data gaps required for mapping habitat coverage and proposal of methods to fill these data gaps ;
- Synthesis of the collected physical data in GIS format based on format specified by the MOM project (BEP/BAC/03/01) ;
- Compilation of habitat maps based on the collected physical data.

Additionally, the project aimed to build capacity in the region by training 4 students of Namibia and Angola in marine GIS mapping.

The objectives were originally designed to address the BCLME region as indicated in figure 1. However during the course of the Physical Mapping project, the MOM team indicated that the study area had to be extended to the Port Elizabeth in South Africa (figure 2), which about doubled the area covered in South Africa and had direct implications on the project time.

This report describes the team who contributed to the project, the methods used and the final results obtained. The results are analysed and discussed, especially with regard to the identification of data gaps.

Figure 2 – The study area was extended to Port Elizabeth in southern Africa (own compilation)



2. Project team

A co-operative approach between three country representatives was originally proposed, whereby the country representative of Namibia functioned as the project leader of the "Physical Mapping Team". This team consisted of Dr. Heitor Timoteo, Dr. Amanda Rau and Vera De Cauwer for respectively Angola, South Africa and Namibia. Each team member was responsible for compiling an inventory and collection of physical marine data in their respective countries.

The project experienced some moderate delays for a variety of reasons, some of these administrative and some related to data access limitations (described in the text). The circumstances required that some of the work had to be reapportioned among the team with the bulk of inventory and collection of geospatial data as well as the creation of GIS data ultimately residing with the project leader and her students.

The final team who contributed to the data collection and compilation was as follows :

- Data collection :
  - Angola : Dr Heitor Timoteo, Sergio Freire, Dr Neville Sweijd, Ben De Cauwer, Emma Gomez, Vera De Cauwer ;
  - Namibia : Hugo Demuinda, Neville Ngahahe-Hangero, Dr Amanda Rau, Trevor Wolf, Heidi Currie, Vera De Cauwer ;
  - South Africa : Taniia Strauss, Trevor Wolf, Dr Amanda Rau, Dr Mandy Lombard, James Wiltshire**,** Vera De Cauwer.
- GIS data compilation :
  - Angola : Neville Ngahahe-Hangero, Vera De Cauwer ;
  - Namibia : Hugo Demuinda, Neville Ngahahe-Hangero, Trevor Wolf, Celeste Espach, Damien Morel, Dr Amanda Rau, Vera De Cauwer ;
  - South Africa : Taniia Strauss, Trevor Wolf, Amanda Rau, Neville Ngahahe-Hangero, Vera De Cauwer.

Neville Ngahahe-Hangero and Hugo DeMuinda (figure 3) are National Diploma Land Use Planning students of the Polytechnic who followed an on-the-job training during the project supervised by the project leader. The students worked about 9 respectively 5 months on the project as part of in-service training and diploma work, which forms part of the third and last year of their curriculum.

In Angola, two students from the Course of Geographical Engineering at the Faculty of Sciences of the Agostinho Neto University in Luanda were selected by Dr Heitor Timoteo : Celina Anabela Chaluca and Sónia Marisa Fernandes Anastácio. They were trained to use the GIS software packages MapInfo 6.5, ArcView 3.1, ArcView 9.1 and ArcGIS for georeferencing and data creation. The students already had a degree in GIS. The training was part of their last year thesis work. It was orginally planned that these students would assist in the digitising of the topographic maps at scale 1:100,000 of Angola, however no digitising work was received from Angola with exception of the coastline. This dataset did not conform the data quality requirements of the project.

Figure 3 - Neville Ngahahe-Hangero and Hugo DeMuinda, in-service training students of the Polytechnic of Namibia working on the project

All data collected in the field was centralised and archived in Namibia, at the Polytechnic of Namibia in Windhoek and incorporated into a marine GIS. A Memorandum of Understanding was made between the Land Management Department of the Polytechnic and the project. It was agreed that the project could use the necessary computer hardware and GIS software of the Land Management Department for a fee.

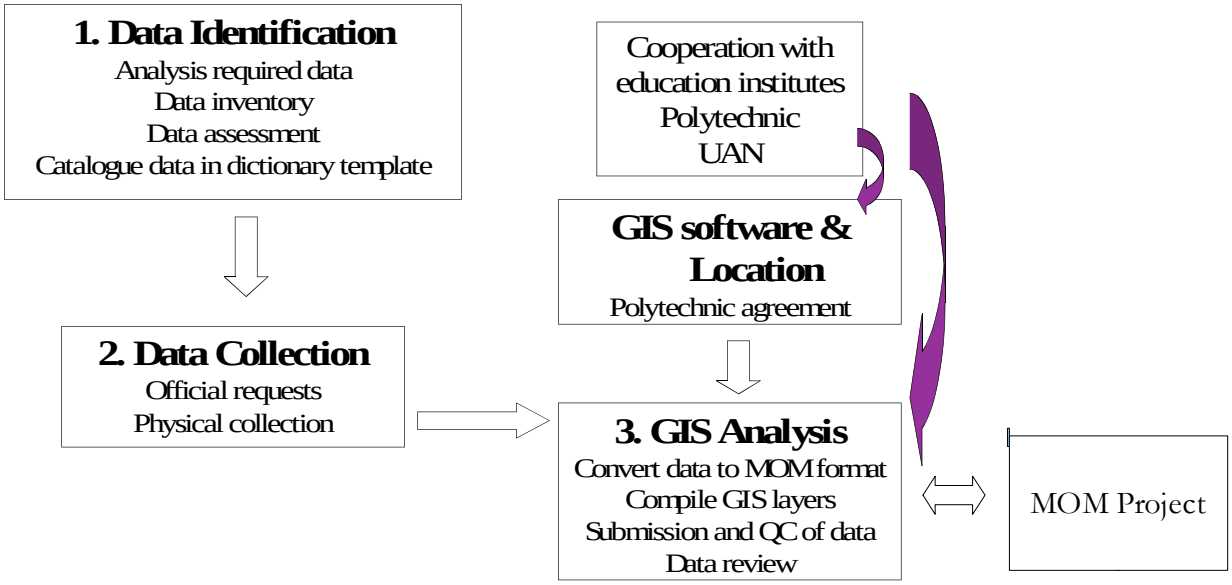
3. Methods

The MOM project will use the information collected by this and other three component projects of the BCLME biodiversity assessment and mapping programme to deveop a coastal and marine conservation plan for the region. The method used for the conservation planning is in broad lines the same as that used for the marine component of the South African National Biodiversity Assessment (Lombard *et al*., 2004) :

- identification of marine and coastal bioregions and -zones within the Exclusive Economic Zone (EEZ) of each country based on input from experts and bathymetric data
- assessment of biodiversity for each biozone based on biological and physical data ; the physical data includes information on marine sediments, coastal habitat types, transformation of the coastline and the location of amongst others reefs, marine canyons, sea mounts and river mouths ;
- assessment of protection status for each biozone ;
- assessment of threats level for each biozone ;
- proposal for conservation planning at biozone level based on the biodiversity, protection status and threats level assessments.

The physical mapping project collected and compiled geospatial physical data that was relevant as input for the zoning exercise. An overview of the work flow is given in figure 4. More details are given in this section.

Figure 4 – Work flow of the physical mapping project



3.1 Data identification

3.1.1 Analysis of required data

The report "National Spatial Biodiversity Assessment – Marine Component" (Lombard *et al*., 2004) made for the National Botanical Institute of South Africa was analysed to determine the physical datasets needed for the BCLME Systematic Conservation Planning process. This analysis, together with additional information provided by Dr Lombard, lead to the establishment of a list with required or useful physical geospatial datasets as illustrated in table 1. It concerns datasets considered as most optimal for input into the final GIS, a 'wish list'. The data assessment compiled at a later stage defined the data to collect for the project.

All data for Namibia and Angola was novel (in terms of the collation and transformation) while several of the datasets for South Africa were already available through the marine component of the National Spatial Biodiversity Assessment (NSBA) project or needed only relatively small changes or refinements (as indicated in table 1). Ultimately, the data requirement for South Africa ermerged as far greater than orginially expected when establishing the original workplan for this project.

3.1.2 Data inventory

A data search was initiated for all geospatial data listed in table 1. All formats available, including hardcopy or softcopy, lists of coordinates or maps, and other were sought and assembled. Preference was given to data with national or regional coverage. For Namibia, the report 'Assessment of marine data in Namibia with respect to GIS' (De Cauwer, 2004) was used as a starting point to locate relevant datasets, while Dr Lombard assisted with the South African data inventory. Establishing the data inventory was time intensive as many different institutions and individuals – mainly within Namibia, South Africa and Angola - needed to be contacted through personal visits, phone or e-mail. A list of the contacted stakeholders is shown in Annex 1. Additionally, literature and information with public access and/or global data sets on the Internet was searched.

The original work plan proposed a workshop in Luanda to assist in the data inventory, however the Angolan representatives for BCLME present at the 'MOM team and project leaders meeting' organised by BENEFIT in Windhoek on the 26th of September 2005 advised that it would be better to replace this by personal visits to stakeholders in Luanda.

The consultation process lead to the establishment of a primary data inventory : an inventory of marine and coastal data that is already existing for the region and that would contribute to the establishment of the final physical data layers in GIS format. The primary data included both hardcopy data such as maps or tables with coordinates, as digital data such as scanned maps, files with coordinates or GIS files. The availability and/or accessibility of the primary data listed in the inventory was assessed where possible.

The data inventory was stored in a inventory template developed by the Vera De Cauwer with input from Dr Mandy Lombard. The data inventory includes traditional metadata (source, accuracy, copyright, format, etc.) but also estimations of processing time and cost required to convert the dataset to a digital format that can be easily imported into a GIS. The data inventory

template was based on the data dictionary version 1 of the MOM project BCLME “BEHP MOM Project Data Dictionary Template Version_1.xls”.

Table 1 – Required data : geospatial data to collect for Namibia and Angola with indication of required accuracy and outstanding data to collect for South Africa

	Data required for Namibia and Angola ('wish-list')	**Accuracy/Scale**	**SA : outstanding data to collect**
1	Coastline, including islands and major estuaries	1:50,000 - 1:100,000	names islands, outcrops + check estuaries
2	Exclusive Economical Zone (EEZ)	1:50,000 - 1:100,000	TO REFINE
3	Coastal topography (on land)	1:50,000 - 1:100,000	**ALL**
4	bathymetry close to coast (i.e. depths of 10 and 30 m)	1:300,000 or best data available	OK
5	bathymetry offshore (i.e. shelf break, 1800 m, 3500 m)	1:1,000,000	**ALL**
6	texture of marine sediments	best data available	obtain permission to use maps of Council for Geoscience
7	coastal types - geomorphology (including salt pans) : rocky, sandy, mixed beach, ...	best data available	editing of dunes and coastal sensitivity
8	Wave exposure coastline	expert knowledge	editing
	main coastal cities, settlements, harbours & place names (+ population where available)	1:50,000 - 1:100,000 or best data available	**ALL**
10	roads/railways along coastline	1:50,000 - 1:100,000 or best data available	**ALL**
11	position of mines, oil and gas extraction	best data available	**ALL**
12	concession areas for mines, oil companies	best data available	**ALL**
13	sewerage/waste/storm water outlet points	expert knowledge	**ALL**
14	reefs	based on bathymetry data	Only deep photic complexity analysis done
15	sea temperature (satellite maps)	based on available satellite data	**ALL**
16	untrawable grounds	best data available	**ALL**
17	natural resources production : guano, aquaculture, algae	expert knowledge	**ALL**
18	marine protected zones	best data available	editing
19	coastal protected zones	best data available	**ALL**
20	submarine canyons	based on bathymetry data	may need refinement
21	sea mounts and banks	based on bathymetry data	OK
22	turbidity (suspended matter)	based on available satellite data	**ALL**
23	rivers	1:50,000 - 1:100,000	**ALL**
24	Relevant oceanographic data and meteorological data samples	available data ministries + oil companies	**ALL**

Following changes were made to the data dictionary version 1 to compile a data inventory template that would also allow to store metadata at a later stage :

- Layout :
  - a worksheet is created for each data layer, this worksheet can later be used as the metadata file accompanying each GIS data layer,
  - an overview worksheet is created that gives an overview of the key information of all data layers,
  - a Macro was programmed that allows automatic creation of the template for each new layer with copying of the key information to the overview worksheet.
- Contents :
  - The column 'Spheroid' was replaced by 'Spheroid/Geodetic Datum' as both need to be indicated for appropriate use in different GIS software packages. For example, for Namibia the standard spheroid is Bessel with geodetic datum Schwarzeck.
  - The column 'GIS data structure' was replaced by 'Data structure' and 'Digital format' with the last referring to the digital file format.
  - The column 'Scale/resolution' were separated into two columns 'Accuracy' and 'Precision' as it concerns two different concepts. Accuracy refers to the positional accuracy of the data and is preferably given in m, alternatively as a scale. Resolution refers to the precision of the data and can include for example the ground size of the pixels in an image or the depth intervals of a bathymetry file.
  - Additional columns were added that are necessary for the data assessments, for example 'Processing steps' and 'Processing time'.

The most important information that had to be completed during the data inventory was information related to the data assessment, such as data source, data structure and steps to obtain data. The final data inventory was submitted as three Excel files to the MOM project, one file for each country. It indicates all potentially useful data that has been identified in one of the three countries. The data dictionary does not only list acquired and digitised data by the project, but also other available geospatial marine data in the region. Not all data of the data inventory was acquired, only the data most useful (e.g. most accurate or most precise) for the project and data that is feasible to collect within the timeline and budget.

The overview work sheet of the data inventories are given in Annex 2, while table 2 gives an example of a worksheet created for one dataset.

Table 2 – Example of a dictionary page for one data layer of Namibia : low water line

Type of metadata	Metadata	Description
Number	3	
Data layer	low_water_line	
Description	Surveyed low water line for Survey General (for extension EEZ) : 407 points	*short description layer*
Source	Ministry of Lands & Resettlement (MLR)	*name of Institution or Project + Location*
Contact details of source person	Dr Owolabi, Surveyor General, +264 61 245056	*Name, institution, telephone number or e-mail*
Data structure	Digital - text	*Hardcopy, Digital - Raster or Digital - Vector (indicate if points, lines or polygons)*
Digital format	*.txt	*shp, mdb, dxf, … (if hardcopy, indicate N/A for not applicable)*
Method of data acquisition	Airborne Laser Solutions 2001 - 2002 : geodetic control points + airborne survey with lidar, GPS, digital camera + hourly tide tables	*indicate how and when data was acquired, edited or updated*
Projection	DD	*dd (for decimal degrees) or name projection / spheroid (e.g. WGS84, Bessel, …)*
Spheroid/Geodetic datum	WGS84/WGS84	*indicate for dd and projected data !*
Accuracy	20 m RMS	*positional accuracy in **metres** (or scale if not known)*
Precision	every 1 to 3 minutes	*detail or precision of data (e.g. for raster : pixel size, for bathymetry : depth interval, …)*
Data coverage	Namibia	*indicate if data covers whole EEZ and or coast or just a part of it (indicate which part)*
Quality assessment	very good, best available	*indicate quality, if best dataset available or if another dataset has a better quality*
Steps to obtain data	Already obtained with official request	*Buy data, Official request, Already obtained, Download from Internet, …*
Cost (SAR)	N/A	*only if data needs to be bought, otherwise N/A - indicate price in **ZAR** (South African Rand)*
Copyright	no distribution before approval Surveyor General	*indicate if project can publish data on maps or if it can redistribute it on final GIS CDROMs*
Processing steps	convert to dbf, import points in GIS, overlay on orthophotos (after projection)	*steps required to convert to final GIS format*
Processing time (h)	2	*estimate time in **hours** required to convert to final GIS format*
Other related files	colour_orthophotos and laser_points	*names of any other files related or complementary to this dataset*

During the compilation of the data inventory, it was considered to purchase high-resolution satellite images for the study area to derive some of the final datasets. High resolution satellite images can be obtained from the Eros, SPOT, Ikonos or Quickbird sensors. However, the budget did not allow it to purchase high resolution images for such a large area as is illustrated by table 3.

Table 3 – Comparison of the prices of satellite images (based on information obtained in 2005 – 2006)

Satellite		**Resolution (m)**	**Estimated price (ZAR/N$) for 700 km coastline**	Estimated width image in km
LANDSAT	colour	15	1,301	95
Aster	colour	15	12,300	60
Eros	b/w	1.8	37,500	14
SPOT	b/w - colour	2.5 - 5	164,947	3
Ikonos	colour (pan-sharpened)	1	297,500	5
Quickbird	colour (pan-sharpened)	0.6	622,860	5

Instead, images in Google Earth were used to derive information on the intertidal coastal types and human transformation of the coastlines of South Africa and Angola. Namibia's coastline is covered by aerial photos (orthophotos) that where obtained from the Surveyor General. Google Earth contains high resolution satellite images for certain parts of the South African and Angolan coast, the other areas are covered by medium resolution satellite images. Orthorectified LANDSAT images were also downloaded from the Internet for Angola and part of Namibia.

3.1.3 Data assessment

The data inventory compiled allowed for 1) prediction of which final data layers could be established, 2) indication of which primary datasets would be used to establish these final data layers, 3) identification of data gaps at a fairly early stage, and 4) identification of potential problems with accuracy. This information was included in the data assessment, as well as a comparison between different bathymetric datasets and hydro acoustic data.

The data assessment was submitted as a report to the MOM project in June 2006 and was later updated with amongst others an indication of priorities for the different datasets. It was advised that the MOM team revised the proposed priorities (progress report 4, September 2006).

An overview of the data assessment for the final data layers with priority 1 is shown in table 4, the complete data assessment overview is added in Annex 3. The table explicitely indicates which data still had to be collected for South Africa after obtaining the GIS data from the National Biodiversity Strategic Action Plan (NSBA) study.

Table 4 – Overview of physical data assessment for data layers with priority 1

	Physical data	**South Africa**	**Namibia**	**Angola**
1	Coastline (with islands) ph_coast_li_*	NSBA (1:50,000 topographic maps) + SAN (Taniia)	Digitised from orthophotos SG + islands of 1:50,000 topomaps	Orthorectified LANDSAT images 2000
2	Country (with islands) ph_country_pol_*	Coastline from previous dataset, rest from Geological Survey of Namibia data	Coastline from previous dataset, rest from Geological Survey of Namibia data	Coastline from previous dataset, rest from Geological Survey of Namibia data
3	Islands ph_islands_pol_*	1:50,000 topographic maps + SAN charts (refinement of NSBA data)	Digitised from orthophotos + name of islands of 1:50,000 topomaps or SAN charts	Orthorectified LANDSAT images 2000 + topomaps
4	Bathymetry close to coast ph_bathy_coast_li_*	1:150,000 maps SA Navy (version CSIR)	1:300,000 maps SAN + 0 depth from ph_coast_li_na	Portuguese IH maps + topomaps 1:100,000 & 1:25,000
5	Bathymetry offshore ph_bathy_off_li_* ph_bathy_off (grid)	GEBCO	GEBCO	GEBCO
6	Classification of marine sediments ph_mar_sedim_pol_*, ...	Dingle (NSBA)	a) for south : Dingle b) Geological Survey of Namibia	/
7	Texture of marine sediments ph_mar_texture_pol_*, ...	a) Council of GeoScience (NSBA) b) Geological Survey of SW Africa (du Plessis & Scoon , 1988)	Geological Survey of SW Africa (du Plessis & Scoon , 1988)	Figures from Bianchi, G. (1992) - redrawn from Stromme & Saetersdal (1991)
8	Intertidal coastal types (with wave exposure) ph_coast_types_li_*	coastal sensitivity atlas + wave exposure (NSBA updated)	colour orthophotos Survey General + Rod Braby	Orthorectified Landsat + 1:100,000 topographic maps + Google + Pat Morant
9	coastal cities, settlements ph_settl_pt_*	1:50,000 topographic maps	Atlas of Namibia + colour orthophotos	1:100,000 + 1:25,000 topomaps
10	places, lighthouses, landmarks, ... ph_places_pt_*	1:50,000 topographic maps	1:50,000 topomaps + fishing map	1:100,000 topomaps
11	harbours ph_harbour_pt_*	ph_settl_pt_sa + ph_coast_types_li_sa + ph_transf_li_sa + info Port authorities	ph_settl_pt_na + Namport info	ph_settl_pt_na + info 1:100,000 topo maps
12	position of coastal mines (up to 80 km inland) ph_mines_pt_*	1:50,000 topomaps	Atlas of Namibia + colour orthophotos	Wells Sonangol
13	Marine and coastal mining areas ph_mar_mining_pol_*	Council for GeoScience : concessions areas	Geological Survey of Namibia	SONANGOL concessions
14	marine protected zones ph_mpa_pol_* ph_prop_mpa_pol_na	NSBA	Laws extracted by Heidi Currie, as well as MPA proposal of WWF	N/A
15	coastal protected zones ph_cpa_pol_* ph_cpa_pt_*	NSBA (terrestrial)	Atlas of Namibia + Survey General	WDPA database

	Physical data	South Africa	Namibia	Angola
16	Rivers (3 km inland) ph_river_li_*	1:50,000 topographic maps	Atlas of Namibia + orthophotos SG	Orthorectified LANDSAT images 2000 + 1:100,000 topomaps
17	Saltpans ph_saltp_pt_*	Input experts and others	Colour orthophotos SG + topographic maps	1:100,000 topomaps
18	Transformation ph_transf_li_*	Google	Colour orthophotos SG	Google + topographic maps + Landsat

3.1.3.1 Comparison of ETOPO versus GEBCO

Part of the data assessment was a comparison between two global elevation datasets : GEBCO (General Bathymetric Chart of the Oceans) and ETOPO for Namibia and South Africa. Although it is indicated that GEBCO has an accuracy of 1 minute and ETOPO2 2 minutes, Belinda Reyers (CSIR) indicated that the CSIR had compared the dataset for a study in South Africa and decided to adopt ETOPO2. This indicated tht a comparison of the datasets for the BCLME region would be required.

The comparison was performed by Trevor Wolf for South Africa and Vera De Cauwer for Namibia. Hydro acoustic measurements were used as reference :

- 152,159 hydro acoustic points obtained from SAN for South Africa ;
- millions of points collected by Gardner (U.K.) for the Surveyor General for Namibia as part of a study to apply for an extension of the Namibian EEZ (approximately 670 MB of data). The points were obtained as text files and imported in MS Access in order to export them to *.dbf format (the files were too large to open in MS Excel). They were imported in ArcView, converted to *.shp files and projected to decimal degrees. The location of the points is illustrated in figure 5. The Walvis ridge is clearly visible.

The method used to compare the ETOPO and GEBCO datasets with the hydro acoustic measurements consisted of following steps :

1. Creation of a grid of the hydro accoustic data points to match the ETOPO2 dataset,
2. Creation of a grid of the hydro accoustic data points to match the GEBCO dataset,
3. Use of ArcView Map Calculator to calculate the absolute value of the difference between two grids : the GEBCO and the hydro accoustic data values,
4. Use of ArcView Map Calculator to calculate the absolute value of the difference between the two grids : the ETOPO and the hydro accoustic data values.

The results of the comparison are shown in table 5. It indicates a slightly better accuracy for the GEBCO data within the Namibian and South African EEZ.

Figure 5 – Position of the hydro acoustic points obtained from the Surveyor General of Namibia (own compilation)

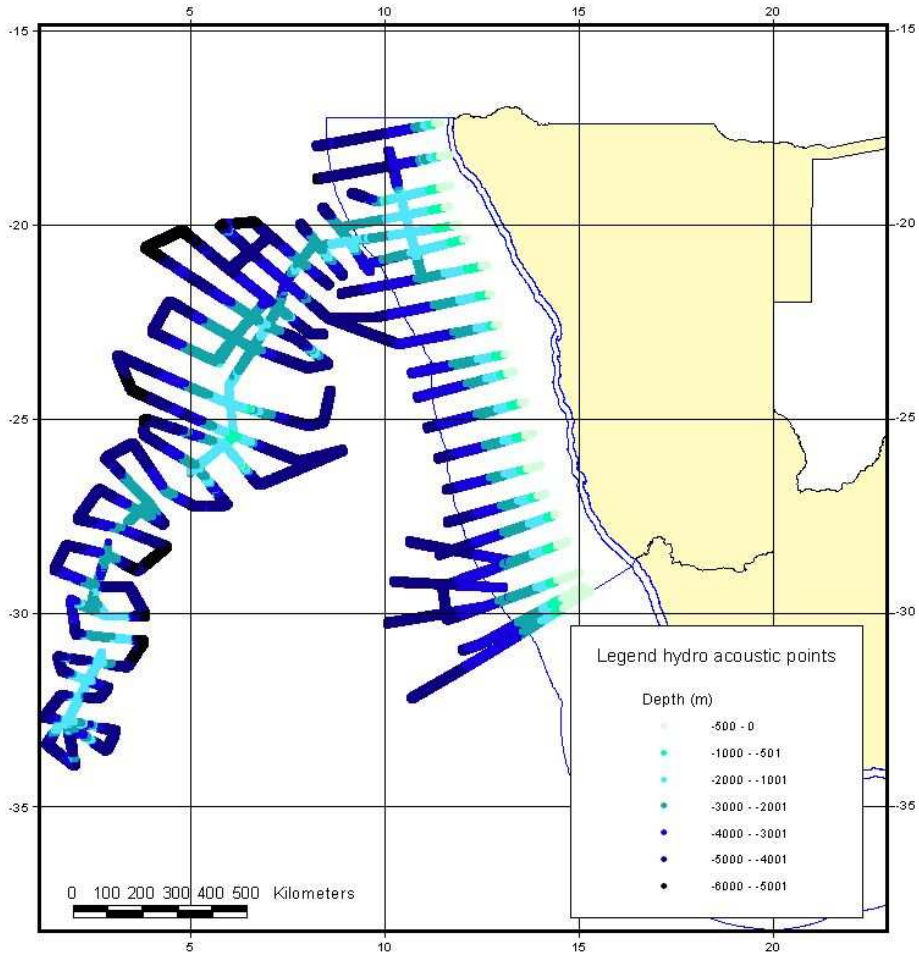


Table 5 – Comparison of ETOPO and GEBCO with hydro acoustic data

ETOPO versus hydro acoustic data			
Area	**Count grid cells**	**Mean Difference**	**Standard Deviation**
South African EEZ	Unknown	135.78	420.21
Namibian EEZ	2,277	86.88	122.31
Outside EEZ[1]	7,635	126.52	188.70
GEBCO versus hydro acoustic data			
Area	**Count grid cells**	**Mean Difference**	**Standard Deviation**
South African EEZ	Unknown	112.62	422.56
Namibian EEZ	9,098	74.93	117.29
Outside EEZ[1]	30,563	131.66	186.28

1 The hydro acoustic points situated outside the EEZ of Namibia or South Africa were supplied by the Survey General of Namibia and can be seen in figure 5.

3.1.3.2 Comparison of Namibian bathymetry data with hydro acoustic data

Several bathymetric datasets were collected for Namibia :

- SAN : isobaths and depth points. According to Captain Kampfer (SAN), data of southern Namibia (Walvis Bay - Orange river) is based on old German measurements/charts (approximately 1911), while the data north of Walvis Bay are based on SAN measurements ;
- Geological Survey : isobaths, origin of data unknown ;
- National Marine Information and Research Centre (NatMIRC) : isobath of 50 m and depth points for isobath of 1000 m, origin of data unknown.

Since the data were either old or their origin unknown, it was not clear which is the most accurate and therefore best to use. A comparison was therefore made with acoustic measurements received from the Survey General of Namibia (see 3.1.3.1) and mining companies to check their accuracy. The data of the mining companies was situated close to shore (mainly in territorial waters), while the Survey General's data were situated far offshore and mainly near the Walvis ridge (figure 5).

Only the values on the isobaths were compared with the measurements. The depth contours were converted to a grid, while the rest of the comparison was similar as for the GEBCO and ETOPO comparison (3.1.3.1). The results are displayed in tables 6 and 7. From the tables it is clear that the SAN dataset appears to be the most accurate. This dataset was used as the Namibian bathymetry dataset close to the coastline (ph_bathy_coast_li_na).

Table 6 - Comparison of Namibian bathymetric datasets for the EEZ with hydro acoustic data Survey General

Dataset : isobaths only	Count grid cells	Mean	Standard Deviation
SAN	484	60.26	66.20
Geological Survey	24171	255.22	396.61
NatMIRC	377	83.62	60.40

Table 7 - Comparison of Namibian bathymetric datasets for the EEZ with hydro acoustic data mining companies

Dataset : isobaths only	Count grid cells	Mean	Standard Deviation
SAN	3244[2]	5.28	5.47
NatMIRC	1716[3]	7.19	5.63

2 99 % of these points were situated in territorial waters
3 All these points were situated outside territorial waters

3.2 Data collection

Data collection of all data identified in the data assessment started as early as possible. Some of the data was already collected before compilation of the data assessment. Other data had to be obtained through an official request of BENEFIT to a Ministry or other institution because they are not officially published. It concerns mainly data in digital format.

Official requests were submitted to :

1. The Permanent Secretary of the Ministry of Lands and Resettlement in Namibia,
2. The South African Navy: Captain Kampfer of the South African Navy (for South African and Namibian data of navigation charts),
3. The Permanent Secretary of the Ministry of Fisheries and Marine Resources (MFMR) in Namibia,
4. Sociedade Nacional de Combustíveis de Angola (Sonangol), Luanda, Angola,
5. Geographical and Cadastral Institute of Angola (IGCA),
6. Direction of Hydro-ports, Angola,
7. Ministry of Geology and Mines, Angola : to obtain marine sediment data,
8. Merchant Navy, Angola,
9. Mohammad Qasim, Commissio Nacional Intersectoral de Desminagem e Assistancia de Humanitaria (CNIDAH), Angola.

Positive feedback was received for the first four requests with Sonangol providing part of the data requested. CNIDAH was also willing to share their GIS data however Dr Timoteo advised us not to use this data because the quality standards used were not sufficient. The Merchant Navy did not have relevant data. In addition, petroleum companies based in Angola were approached but were unable to provide their datasets without express approval of Sonangol (Maria Martins, BP Angola, pers. comm.). Other petrol companies required fees that were beyond the scope of this project (Dr Neville Sweijd, pers. comm.). This implies that datasets do still exist that the project was unable to source and this remains an issue for the BCLME or Benguela Current Commission to resolve.

Data agreements were signed with :

- the South African Navy for the bathymetry data of South Africa,
- the Geological Survey of Namibia for all data they provided.

Certain datasets were paid for (all of them are officially published except the data of the Geological Survey of Namibia) :

- GEBCO CD ROM,
- data of the Geological Survey of Namibia,
- 1:25,000 (Luanda only) and 1:100,000 topographic maps of Angola (IGCA, Luanda),
- 1:250,000 and 1:500,000 topographic maps of Angola (IGCA, Luanda),
- 1:1,000,000 geological maps of Angola : terrestrial geology (Ministry of Geology and Mines, Angola),
- navigation charts of Angola (obtained in Portugal).

The Roads Authority of Namibia indicated that they expected data in return for the data CD-ROM they gave to the project.

The follow-up on data requests and the actual collection of the physical data and centralisation of this data in Namibia took a substantial amount of time. At a certain point, it was necessary to finalise this project phase in order to start converting all data to GIS layers conforming with MOM requirements. After September 2006, data collection efforts were only be made for datasets that have been given priority 1 in table 4. All collected data was centralised in Windhoek.

3.3 GIS Analysis

3.3.1 Conversion to GIS – MOM format

Most datasets collected consisted of data that could not be imported directly into GIS : primary data such as scanned topographic maps, orthophotos, files with geographic coordinates or vague descriptions of locations. The primary data were converted to secondary datasets compatible with GIS software through GIS operations such as :

- photo-interpretation and digitising,
- import of text or database files with coordinates,
- georeferencing of image files,
- conversion of Cape (South Africa), Schwarzeck (Namibia) or Camacupa (Angola) datum to WGS84,
- conversion of projected data (mainly Albers or Gauss conformal) to decimal degrees, ...

The most accurately data available were selected to compile the secondary datasets. Some secondary GIS datasets were obtained directly through the NBSAP project, South African consultants, the Roads Authority of Namibia, the Geological Survey of Namibia or the Atlas of Namibia.

The Atlas of Namibia project aimed to compile and publish an atlas covering all aspects of Namibia's geography. All data of the atlas – which was published in 2002 by the Ministry of Environment and Tourism (MET) and written by Mendelsohn *et al*. - were also posted on the Internet in shape format : http://209.88.21.36/Atlas/Atlas_web.htm.

Establishing wave exposure

Wave exposure was established for South Africa during the NSBA project through input of experts. No primary data could be collected on wave exposure for Namibia and Angola. Rod Braby of the Namibian Coast Conservation and Management (NACOMA) project advised on how the **wave exposure** data could be established. Wave exposure can be derived by the parameters that influence it : wind direction, wave period and wind strength.

A study of Howes, Harper & Owens (1994) uses wave exposure for a physical shore-zone mapping system in British Columbia. They established a wave exposure matrix based on effective fetch and maximum fetch window. Wave period increases with the fetch window, the distance offshore from the shore unit over which the wind can generate waves. The larger the fetch window, the greater wave exposure.

The effective fetch distance is a standard engineering measurement for shore protection studies and involves the measurement of the fetch distance along several directions from a given point from the shore. It is calculated as (Coastal Engineering Research Center, 1977) :

Effective Fetch :

$$Fe = \frac{\sum (\cos a_i) . F_i}{\sum (\cos a_i)}$$

- a : angle between shore normal and direction i ;
- Fi : fetch distance in kilometres along direction i.

Howes, Harper & Owens (1994) introduced the concept "modified effective fetch" to simplify the large number of measurements required for a mapping area. The modified effective fetch technique involves the measurement of three fetch distances: the shore-normal or perpendicular to the general trend of the shore unit, 45^o to the left of the shore-normal and 45^o to the right of the shore normal.

Since the Howes, Harper & Owens method does not take into account the main wind directions, (which seems inappropriate for the BCLME region) a method was developed which builds further on their approach for wave exposure estimation. Instead of measuring along the shore-normal, 45^o to the left and 45^o to the right of the shore-normal, measurements were made along the 4 major swell and wind directions. This results in an estimate of the **average annual wave exposure at different points x along the Namibian and Angolan coastlines** based on the calculations of modified effective and maximum fetch at point x under prevailing wind conditions. The average annual wave exposure is estimated according to the matrix displayed in table 8.

Modified Effective Fetch (x) =

$$F(x) = \frac{[\cos(n - w_1) \cdot f_1 + \cos(n - w_2) \cdot f_2 + \cos(n - w_3) \cdot f_3 + \cos(n - w_4) \cdot f_4]}{[\cos(w_1) + \cos(w_2) + \cos(w_3) + \cos(w_4)]}$$

- n : direction of the shore normal, the normal to the general orientation of the shore line at point x (azimuth in degrees from true north) ;
- w_1, w_2, w_3, w_4 : major swell and wind directions (azimuth in degrees from true north) ;
- f_1, f_2, f_3, f_4 : fetch distances in kilometres along the major swell and wind directions. Most swell in the BCLME region is generated by a high pressure area which on average is centred at about 28°S, 8°E : the South Atlantic High (Anticyclone). North of about 15°S, the latitude of Namibe in southern Angola, the winds are much weaker than off Namibia and South Africa (Shannon & O'Toole, 1999).

Maximum Fetch (x) refers to swell, waves generated in an area remote from the shore unit and is measured as the maximum fetch distance (km) that can be measured from point x (Howes, Harper & Owens,1994).

Table 8 – Wave exposure matrix based on modified and maximum fetch (adapted from *Howes, Harper & Owens)*

Modified Fetch (km)	**Maximum Fetch (km)**					
	< 1	**1 - 10**	**10 - 50**	**50 - 500**	**500 - 1000**	**≥ 1000**
< 1	Very protected	Protected	NA	NA	NA	NA
1 - 10	NA	Protected	Semi-protected	Semi-exposed	NA	NA
10 - 50	NA	NA	Semi-protected	Semi-exposed	Semi-exposed	NA
50 - 500	NA	NA	NA	Semi-exposed	Exposed	Very exposed
> 500	NA	NA	NA	NA	Exposed	Very exposed

Although the prevailing wind direction at the Namibian coast is south-southwest (Rod Braby, pers.comm. ; Molloy, 2003), this is not everywhere and not always the case. Weather information was analysed from following sources to determine the major wind and swell directions along the Namibian coast :

- a report compiled by Lesley Shackleton (1993) «Environmental data workshop for oil spill contingency planning» ;
- publications of the South African weather service, especially « Surface winds » (Kruger, 2002).

Wind and swell information for Angola was obtained from :

- www.wannasurf.com, which contains a document on surfing conditions in Angola (Wannasurf.com, 2003) ;
- Pat Morant, CSIR : provided Voluntary Observing Ship (VOS) measurements from the South African Data Centre for Oceanography on wind and swell ;
- BCLME Thematic report No 5. Integrated overview of the coastal environment between the Congo river mouth and Cape Agulahas (Morant, 1999) : contained climate data from Africa Pilot (1977).

Rod Braby (NACOMA) checked the final wave exposure product for Namibia, while Pat Morant performed a quick control of the wave exposure data for Angola.

3.3.2 Compilation of final GIS layers

All secondary datasets and their metadata were scrutinised and checked for consistency with the MOM format to establish the final datasets. The MOM format refers to following characteristics :

- geographic coordinates (decimal degrees) are used with the World Geodetic System 1984 (WGS84) datum ;
- ESRI shape file, coverage or grid format,
- comprehensive and detailed metadata which includes the accuracy of data captured, source, copyright, explanation of attribute column names, etc.
- clear naming of datasets with unambiguous titles, without cryptic codes or acronyms. Datasets had to be named without spaces in the titles or in 'Camel text', e.g. this_is_no_spaces.shp or ThisIsCamelText.shp. The physical mapping project used following naming convention : ph_name_typ_*, with 'ph' for physical mapping project, 'name' a short name for the dataset, 'typ' indication if it concerns a line (li), polygon (pol) or point (pt) and * the first two letters for the country, for example 'ph_coastl_li_na'. All datasets of the project were delivered per country, except for a few datasets available at regional level (BCLME). The naming convention was always followed with exception of a few grid file names that have a limited number of letters.
- All polygon vector data must have built topology, with no dangling nodes. The fuzzy tolerance must be kept to a minimum, and each polygon must have a label. All spikes must be deleted and smoothed.
- All attribute data must be checked for spelling and consistency (this includes upper/lower case consistency).

A few final datasets were derived from other secondary data through amongst others following operations :

- extraction of data : for example the harbours were extracted from the settlement points after consulting the transformation datasets,
- creation of buffer zones : for example the Exclusive Economical Zones (EEZ) were generated by a 200 nm buffer from the baseline points,
- conversion of polygon to line files or vice versa : for example the country polygons were established from the coastline and the inland boundaries of country polygons provided by the Geological Survey of Namibia (after conversion to line format), after which the line was converted to polygon.

Finally, it was necessary to make sure that the data of the 3 countries coincide at the borders for datasets where this was possible, for example for the rivers. It appeared to be impossible to do this for certain datasets because of the big discrepancies, for example the coastal bathymetry datasets.

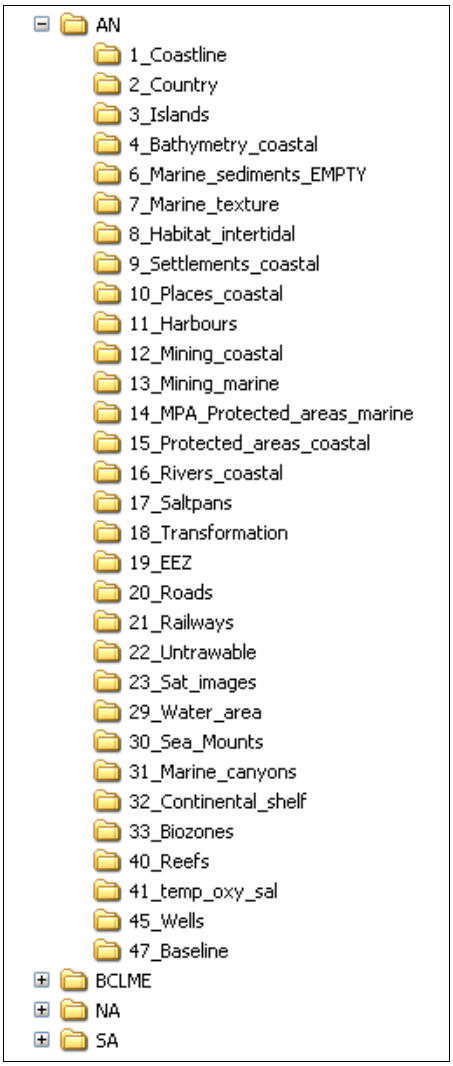
3.3.3 Submission and quality control of data

All end products – data and metadata - were be submitted to the MOM team on DVD early March 2007. A logical data structure was used, grouping similar or like datasets in folders with clear, unambiguous names. Figure 6 illustrates the folder structure. The metadata is stored as four different Excel files : one for each BCLME country and a file for data covering the complete BCLME. A file summarising all GIS layers accompanied the data.

The MOM team performed a quality control and send a document with remarks on certain data layers or indicating which datalayers still needed to be created. The data was adapted and corrected according the remarks. Additionally, some refinement and correction of certain layers was performed and a few other data layers created. The final dataset was submitted to MOM on DVD end of August 2007.

This report was sent after the submission of the final data.

Figure 6 – Illustration of folder structure final dataset



4. Results

A total number of 122 GIS datasets were submitted to MOM with a metadata file per dataset. Most datasets only contain one GIS data layer, although there are some exceptions such as for example :

- the offshore bathymetry dataset contains 3 GIS layers : a grid, a line file and a polygon file,
- the Namibian marine protected area (MPA) dataset contains 2 GIS data layers : the proposed and the existing MPA's.

More detail of the number of GIS data layers according to country and priority is given in table 9. Most datasets were delivered on country basis, with exception of 8 datasets submitted on regional level (BCLME region). The table indicates also the complete new GIS datasets created by this project : it concerns 64 new data layers that are not a combination or edition of existing GIS data. There are less new datasets for South Africa as a lot of layers created by the NSBA project were used and edited.

Table 9 – Number of final data layers submitted

	Number of GIS datasets			**TOTAL**
	South Africa	**Namibia**	**Angola**	
Priority 1 data	18	18	16	**52**
Priority 2 data	10	15	13	**38**
Priority 3 data	11	13	8	**32**
TOTAL	**39**	**46**	**37**	**122**
Compilation of completely new GIS datasets	16	23	25	**64**

The different datasets will be discussed in the next sections in decreasing order of priority. Datasets indicated in blue font are completely new GIS datasets. More information on the GIS datasets can be found in the meta data.

4.1 Coastline including islands (ph_coast_li_*)

South Africa	**Namibia**	**Angola**
NSBA (1:50,000 topographic maps) + SAN (Taniia) **Accuracy 100 m**	Digitised from orthophotos SG **Accuracy 20 m**	Orthorectified LANDSAT images 2000 **Accuracy 75 m**

The coastline and island data is considered to be one of the most important datasets collected by this project as it is a reference for biological survey data and for the conservation mapping. It is also the source data for other datasets such as the mapping of the intertidal coastline types. Therefore a lot of time was spent to obtain datasets that were as accurate and updated as possible at regional level.

4.1.1 South African coastline

The coastline with islands of South Africa was digitised from the 1:50,000 topographic maps for the South African National Botanical Institute (SANBI) and the Surveyor General by several digitising operators. Some digitisers followed the zigzag lines (/\/\/\) representing the rocky outcrops, part of the symbology of the topographic maps, while other digitisers drew a more generalised line through these rocky areas. The coastline was used in this way by the NSBA project as they had no time or budget to fix it, nor did they require a more accurate coastline. The same file was delivered to this project with some small changes and updates performed by Taniia Strauss. The main difficulty with this file is that the zig zag line makes the file very large and difficult to work with. However this difficulty does not compensate the amount of time needed to fix it so it was decided to keep the coastline – and all other datasets derived from it – as it was.

4.1.2 Namibian coastline

The coastline and islands of Namibia is a completely new datalayer digitised from colour orthophotos taken of the Namibian coastline for the Survey General of Namibia between February 2001 and March 2002 (figure 5). The accuracy of the colour orthophotos is less than 1 m, but the position of the low water line has an error of about 20 m. This is mainly due to the position of the waves related to the shore in the photos and to a smaller extent because of the small deviation from the actual low water tide. The survey flight was timed to occur each day from before low tide to after low tide. The start and end times were selected so that the difference in water level was less than 0.5 m off Lowest Astronomical Tide (Banks, 2002).

It is for this reason that the digitised coastline was matched to the 407 baseline points of Namibia : the points indicate the 'official' low water line (figure 7). The baseline points were also obtained from the Survey General. They were originally derived from the same orthophotos by Mr. Ian du Toit, Professional Land Surveyor in Namibia. Their position was corrected by using the hourly tide tables and the slope of the beach based on the laser points (Banks, 2002).

The 1:50,000 topographic maps were used to check if all islands were digitised for Namibia.

4.1.3 Angolan coastline

At the start of the project, the 1:100,000 topographic maps were used to digitise the coastline of Angola. The topographic maps were compiled by the Angolan Instituto de Geodesia e Cartografia based on photogrammetric surveys performed in 1968 – 1968 and aerial photos of mainly the period 1979 – 1980 and for some maps aerial photos of 1963 – 1964, 1984 – 1985 and 1987. All updates were performed in the eighties.

Figure 7 – One of the colour orthophotos obtained from the Surveyor General for the coastline of Namibia - a baseline point is indicated in the middle (own compilation)

The topographic maps were scanned, clipped and georeferenced to WGS84 by the company GISCOE, however it appeared afterwards that the georeferencing error was very large (varying between 100 and 300 m) while edge matching of the maps was of poor quality. The maps were therefore referenced again in GeoMedia Professional with an error of about 20 m. The maps are in the Camacupa datum and had to be transferred to a WGS84 datum. GIS software such as ArcView and GeoMedia can not perform this transformation : ArcView does not include the Camacupa datum while the conversion in GeoMedia appeared to be a conversion from the Cape datum to WGS84 instead of Camacupa to WGS84. GeoMedia Professional however does allow to add own transformation parameters in the ini file. The line "csgdCamacupa,csgdWGS84, csdtStandardMolodensky,-50.9,-347.6,-231" was added based on an article of Clifford & Mugnier (2001) listing several transformations. This transformation of Camapuca 1948 to WGS84 is used by Topnav, Elf and Total in their concession blocks. The conversion parameters from Cape to WGS84 that are used in ArcView and GeoMedia are "csgdCapeNIMA, csgdWGS84,csdtStandardMolodensky,-136,-108,-292". The difference between this and the newly added conversion was about 270 m, which causes a significant error.

While digitising the coastline on the georeferenced topographic maps it appeared that the differences with GeoCover orthorectified Landsat ETM mosaics of 2000 – that have an accuracy of 75 m - were too large to be attributed to datum transformation or georeferencing errors. This was motivated by following facts :

- the differences between the two datasets were inconsistent and varied between 0 m and 500 m,

- the digitised coastline of Angola does not overlap exactly with the colour orthophotos of Namibia (which have an accuracy of about 1 m) in the extreme south : the differences were about 500 m,
- the orthorectified Landsat mosaics of 2000 showed a fairly good overlap with the colour orthophotos of Namibia : differences were in the order of 80 – 140 m,
- the 1:25,000 topographic maps of the Luanda area which were based on a new photogrammetric survey (1998) showed a good overlap with the Landsat images : about 5 to 35 m differences.

The conclusion was that the coastline had changed significantly since that aerial photos were taken in the eighties. This theory was confirmed by the fact that the differences of rivers and roads inland on topographic maps compared to the Landsat images were not so big as the differences in coastline.

4.2 Country polygon without islands (ph_country_pol_*)

South Africa	Namibia	Angola
Coastline from previous dataset, rest from Geological Survey of Namibia data		

The Geological Survey of Namibia provided the project with a polygon file with the SADC countries (more information : see ph_sadc_pol) from which the inland boundaries were extracted. The final country polygons were made of the coastline and those inland boundaries. The first kilometres inland at the country boundaries were refined with the 1:50,000 topographic maps of South Africa, the colour orthophotos of the Survey General of Namibia (see 4.1.2) and the 1:100,000 topographic maps of Angola.

4.3 Islands (ph_islands_pol_*)

South Africa	Namibia	Angola
1:50,000 topographic maps + SAN charts (refinement of NSBA data)	Digitised from orthophotos + name of islands of 1:50,000 topomaps or SAN charts	Orthorectified LANDSAT images 2000 + topomaps

The islands were extracted from the line file ph_coast_li_* and polygons were created. The names of the islands were added in the attribute table. Topographic maps provided island names for all three countries, while additional information could be obtained from the South African navy charts for South Africa and Namibia and from Molloy & Reinikainen (2003) for Namibia.

4.4 Coastal bathymetry (ph_bathy_coast_li_*)

South Africa	Namibia	Angola
1:150,000 maps SA Navy (version CSIR)	1:300,000 maps SAN + 0 depth from ph_coast_li_na	Portuguese IH maps + topomaps 1:100,000 & 1:25,000

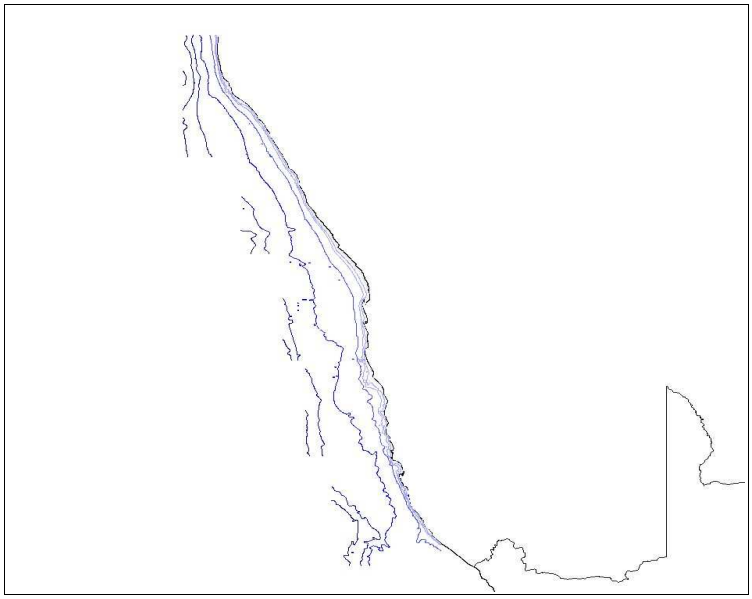
The bathymetry close to the coast is important to determine the different biozones, for example the isobaths of 10 m and 30 m were used during the South African biodiversity assessment (Lombard *et al.*, 2004).

4.4.1 Coastal bathymetry of Namibia

Three bathymetry datasets cover the Namibian waters : the SAN data, a file used by the Geological Survey and one used by MFMR. The origins of the last two datasets are not known. None of the three datasets coincide and therefore a data assessment was made by comparing the each dataset with hydro acoustic measurements (see 3.1.3.2). The SAN data compared best to the depth measurements and was therefore chosen as the basis for the coastal bathymetry set of Namibia.

The SAN data was obtained in S57 format from SAN. Trevor Wolf converted it to ArcInfo format and merged the data of different nautical charts into one ArcView file. Undershoots and a double line in the 200 m isobath were cleaned by Vera De Cauwer. Additionally, the 0 depth line was replaced with the more accurate coastline ph_coast_li_na (4.1). The final result is presented in figure 8.

Figure 8 – Coastal bathymetry dataset (ph_coast_li_na) for Namibia



Additionally, a file ph_200m_pt_na.shp was created. This point file represents a few points on the southern part of the 200 m isobath, according to coordinates given in the Marine Resources Act 27 of 2000 (for more information : see 4.14). The points do however not overlap with the SAN contour.

4.4.2 Coastal bathymetry of Angola

The bathymetry lines on the 1:100,000, 1:250,000 and 1:1,000,000 topographic maps of Angola are not covering the complete EEZ or are missing on certain maps. For example, no bathymetry information is indicated on the maps of the Lobito area and further south. As no bathymetry data could be obtained in Angola, navigation charts of the Hydrographical Institute (IH) in Portugal were collected and scanned. The Hydrographical Institute (IH) of Portugal is the sole official producer of nautical charts for all Portuguese former colonies in Africa, including Angola (Freire, 2006). A few IH maps were missing or not covering the EEZ of Angola. Therefore the final file was a compilation of the topographic and navigation chart data. Large errors in the overlaps indicate however a low accuracy which is estimated to be 700 m.

4.5 Offshore bathymetry (ph_bathy_off_li_*)

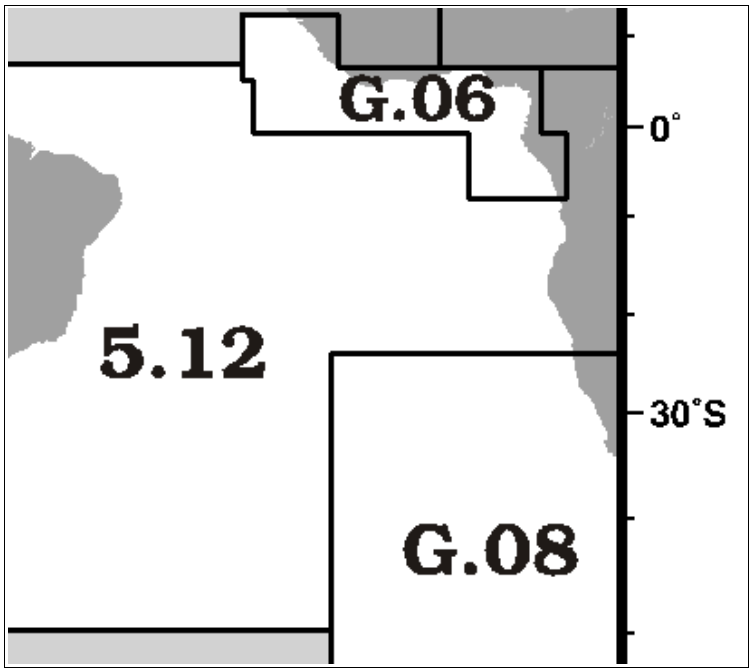
South Africa	Namibia	Angola
extraction from GEBCO		

The Centenary Edition of the General Bathymetric Chart of the Oceans (GEBCO) Digital Atlas was ordered and obtained from the Natural Environment Research Council in the United Kingdom. The resolution is 1' compared to the ETOPO data which has a resolution of 2'. A comparison between GEBCO and ETOPO (see data assessment 3.1.3.1) indicated that GEBCO is the most accurate bathymetry dataset for the South African and Namibian EEZ.

The offshore bathymetry data for the BCLME region was therefore extracted from the GEBCO data. It covers the offshore areas from the -200 m isobath onwards. The data was stored as a depth contour file (ph_bathy_off_li) and as an ASCII file. The ASCII file was converted to grid format (bathy_off, as a grid file name can only contain a minimal number of letters). The line file was also converted to polygon format (ph_bathy_off_li) ; during the process the line file had to be cleaned considerably.

The advantage of using a global dataset is that the acquisition methodology is quite well known and that data is available in the same format for the whole BCLME region. Disadvantage is that the data used for compilation of the GEBCO Atlas in the BCLME region originates from three different sources with different accuracies, as illustrated in figure 9.

Figure 9 - Geographic coverage of sheet areas digitised to form the GEBCO Digital Atlas : extract for BCLME region - the south and east of the South African waters are covered by G.08



The GEBCO One Minute Grid was generated largely using bathymetric contour data from the GEBCO digital atlas. For the South Atlantic area, the data is taken mainly from sheet 5.12. The bathymetric contours were digitised from charts at a scale of **1:5,737,447**. This data set consists largely of contours at a depth of 200 m, 500 m and then 500 m intervals thereafter with additional contours added to help constrain the grid interpolation. In the shallower water areas additional contours were added from NIMA (National Imagery and Mapping Agency) charts at depths of 20 m, 50 m and 100 m. (Pauline Weatherall, British Oceanographic Data Centre, pers. comm., 2004)

For the area covered by GEBCO data set G.06, the data were taken from sheets from IBCEA (International Bathymetric Chart of the Central Eastern Atlantic). This consists of contours at a depth 200 m and then at 200 m intervals thereafter and also includes contours at a depth of 500 m and 1000 m intervals thereafter. In the shallower water areas contours at a depth of 50 m and 100 m are also present. The bathymetric contour data were digitised from charts at a scale of **1: 250,000**. (Pauline Weatherall, British Oceanographic Data Centre, pers. Comm., 2004)

For the area covered by GEBCO data set G.08, the bathymetric contour data were digitised from sheets at a scale of approx. **1:1,000,000**. The bathymetric contours were at a depth of 200 m, 500 m and then 500 m intervals thereafter. (Pauline Weatherall, British Oceanographic Data Centre, pers. Comm., 2004)

The small scale of the charts used to compile sheet 5.12 might explain the lower accuracy of the GEBCO compared to the ETOPO data for the area just outside the EEZ of a BCLME country, as illustrated in table 5. The hydro acoustic data used to make this comparison was mainly located on the 5.12 sheet (see figure 5).

4.6 Classification of marine sediments (ph_mar_sedim_pol_*)

South Africa	Namibia	Angola
Dingle (NSBA)	a) for south : Dingle b) Geological Survey of SW Africa (du Plessis & Scoon , 1988)	/

The Dingle map of the Council of Geoscience was collected during the NSBA project in South Africa and also covers the south of Namibia.

The Geological Survey of Namibia provided information on the sediment composition with regard to faecal pellets, organic matter, glauconite, detritus, phosphorite and calcium carbonate. The data covers both Namibia and South Africa for a major part of the EEZ (about 100 to 200 km offshore) and was already in GIS format. It concerned digitised data of the scanned and georeferenced maps of the Geological Survey of SW Africa edited by du Plessis & Scoon in1988. These maps are not very accurate as they are based on samples collected with an average density of 257 km^2/sample.

No data was obtained for Angola. At the start of the project, an official request was submitted to Sonangol to request amongst other sediment data. However M'vezi Maziano, Head of the Interpretation Section of the Geology Department, informed Heitor Timoteo that the data is private and can not be given to this project. A geology map was seen by Dr Neville Sweijd in the office of Emma Gommez, also of the Geology Department of Sonangol. After several requests spread over the time period of a year, she sent some information. However, this did not include the scanned map of her office but rather some extracts from Environmental Impact Assessments of petrol companies. This information was not at a national level.

4.7 Texture of marine sediments (ph_mar_texture_pol_*)

South Africa	Namibia	Angola
a) Council of GeoScience (NSBA) b) Geological Survey of SW Africa (du Plessis & Scoon , 1988)	Geological Survey of SW Africa (du Plessis & Scoon , 1988)	Figures from Bianchi, G. (1992) - redrawn from Stromme & Saetersdal (1991)

The Geological Survey of Namibia provided data layers on the texture of marine sediments in ESRI shape format. They were digitised from the same maps as described in 4.6 and cover both Namibia and South Africa. It is for this reason that it may be better to use this dataset for South Africa than the dataset provided by the Council of GeoScience to the NSBA project.

The data of the original maps and also the digitised GIS files are organised per texture class : sand, clay, mud, silt and gravel. As the MOM project requested a combined file, a spatial overlay was made of the different layers in GIS. This spatial overlay indicated the low accuracy of the data because 1) the sum of the silt and clay fractions rarely equalled the mud fraction, and

2) the sum of the gravel, sand and mud fractions – estimated as a percentage class - did not always seem to equal 100 %, the estimated sum of the different fractions could be much lower or higher than 100 %.

The attributes of the file obtained by overlaying the five different GIS files were given similar names as the South African texture file. Because the meta data of the South African file did not indicate how those texture classes where named, following rules were followed :

- If one of the fractions was much larger than the others, that fraction would give the name to the final texture class. For example, > 75 % mud would be mud ; 25 – 50 % mud with all other classes less than 25 % would be named mud.
- If fractions were equal, they would both contribute to the name of the final texture class. For example, 25 – 50 % sand and 25 – 50 % mud would be sandy Mud.

For Angola, three figures redrawn from Stromme & Saetersdal (1991) and published in an article of Bianchi (1992) were scanned, georeferenced and digitised to obtain a GIS file indicating the roughness of the Angolan shelf bottom.

4.8 Intertidal coastal types (ph_coast_types_li_*)

South Africa	Namibia	Angola
coastal sensitivity atlas + wave exposure (NSBA updated)	colour orthophotos Survey General + Rod Braby	Orthorectified Landsat + 1:100,000 topographic maps + Google + Pat Morant

4.8.1 Intertidal bottom type

The bottom type of the intertidal coastline is described as belonging to one of following classes : sandy, rocky, mixed, pebbles and boulder. An indication is given of major human transformations of the coastline such as piers, harbours and breakwaters. The texture of the South African coastline was determined by using expert input of Prof. George Branch & Dr. Jean Harris.

The most accurate dataset is available for Namibia as colour orthophotos of the coastline with accuracy and resolution of 1 m (more info in 4.1.2) could be used to identify the different coastal types. However, the difference between pebble, boulder and mixed beaches was difficult to see. The coastal sensitivity file compiled by the Geological Survey of Namibia was used to identify certain pebble beaches. This dataset was not used as the major source of information because it has a very low resolution. It concerns a shape file compiled by Dr Ute Schreiber based on expert input of Dr O'Toole and Bronwyn Currie.

The topographic maps of 1:100,000 gave an indication of sandy beaches in Angola. This information was updated with sandy beaches identified on the GeoCover orthorectified Landsat ETM mosaics of 2000. However, the resolution of those images was not good enough to identify rocky, mixed, pebble or boulder beaches. Therefore, Google Earth was consulted and it appeared that about 49 % of the coastline is covered by high resolution images which allowed a

fairly good identification of bottom type. About 320 Google images were saved for areas along the Angolan coastline. Of these, 168 were high resolution images and were saved with a geographic grid indicating longitude and latitude.

4.8.2 Wave exposure

Information on wave exposure for South Africa was based on expert inputs during the NSBA project. Wave exposure for Namibia and Angola was obtained through an adapted version of the Howes, Harper & Owen method with major swell and wind directions and coastline direction as input (more info in 3.3.1). The final wave exposure product underwent a quick check by experts.

4.9 Coastal cities and settlements (ph_settl_pt_*)

South Africa	Namibia	Angola
1:50,000 topographic maps	Atlas of Namibia + colour orthophotos	1:100,000 and 1:25,000 topographic maps

The position and names of cities, towns and settlements were collected and an indication of size was given. For Namibia, the size of a settlement was based on the estimated population : small > 25,00 - 3,000 habitants and medium circa 10,000 – 50,000 habitants. The last population census in Namibia was in 2001.

For South Africa, data of the file ph_popul_pol_sa (see 4.43) was used to estimate the size of the settlement : very small < 2,500 habitants, small > 2,500 – 3,000 habitants , medium circa 10,000 – 50,000 persons, large > 50,000 habitants.

For Angola, size was based on information of the topographic maps : large (> 50,000 habitants or a provincial capital), medium (10,000 - 50,000 habitants), small (2500 - 10,000 habitants or "vilas"), very small (less than 500 houses/huts). It is assumed that the indication of sizes of settlements in Angola are outdated as they were based on the 1:100,000 topographic maps of the early eighties.

4.10 Coastal places (ph_places_pt_*)

South Africa	Namibia	Angola
1:50,000 topographic maps	1:50,000 topomaps + fishing map	1:100,000 topomaps

These GIS layers contain the locations and names of coastal places such as lighthouses, bays, landmarks, shipwrecks, beaches, etc. They do not contain names of cities or settlements as those are included in ph_settl_pt_* (see 4.9).

4.11 Harbours (ph_harbour_pt_*)

South Africa	Namibia	Angola
ph_settl_pt_sa + ph_coast_types_li_sa + ph_transf_li_sa + info Port authorities	ph_settl_pt_na + Namport info	ph_settl_pt_na + info 1:100,000 topo maps

The harbour points were extracted from the ph_settl_pt_* layers. Harbour characteristics, such as depth, number of vesels per year, amount of cargo per year, were added for South Africa and Namibia based on information of the websites of port authorities. This information was not found for Angola.

4.12 Coastal mines (ph_mines_pt_*)

South Africa	Namibia	Angola
1:50,000 topomaps	Atlas of Namibia + colour orthophotos	Wells Sonangol

This file contains the positions of mines in the coastal zone of the BCLME region and is considered to be most complete for Namibia. Data collected for South Africa were limited to some mines visible on the topographic maps along the west coast, while the data for Angola only include onshore oil wells and no other mines. No other mine related geospatial data for South Africa and Angola could be collected during this project.

4.13 Marine and coastal mining areas (ph_mar_mining_pol_*)

South Africa	Namibia	Angola
Council for GeoScience : concessions areas	Geological Survey of Namibia	SONANGOL concessions

Marine mining concessions in South Africa and Namibia refer mainly to diamond concessions. The South African data was obtained as a hard copy map with indication of coordinates of marine mining concessions. The Namibian data was obtained in GIS format from the Geological Survey. The final dataset contains both marine and coastal mining concessions. The

concession areas in Angola refer to marine oil concessions. Data was obtained from Sonangol as an Excel file with coordinates in decimal degrees (geodetic datum WGS84).

4.14 Marine protected zones (ph_mpa_pol_*)

South Africa	Namibia	Angola
NSBA	Laws extracted by Heidi Currie and MPA proposal of WWF	N/A

The marine protected zones of South Africa were collected during the NSBA project.

Namibia's marine projected marine areas were extracted from the regulation of closed areas as summarised by Heidi Currie for this project :

Regulation of Closed Areas: Legislative Aspects

The Minister's mandate to make regulations regarding closed areas and exclusion zones stems from the provision indicated below.

Part 10 of Namibia's Marine Resources Act (MRA) No. 27 of 2000 empowers the Minister to enact regulations, that are not inconsistent with the above Act, in regard to *inter alia* the following:

- Any license or authorization required, issued or given in terms of the MRA;
- Prescribe conditions and restrictions applicable to fishing rights, exploratory rights, quotas, licenses or other authorizations granted under the MRA;
- Regulate and prohibit the sale or disposal of marine resources, as well as the transportation, importation or exportation thereof ;
- Prescribe rules to be observed during operations for the harvesting of marine resources and measures aimed at preventing interference with or conflict between such operations;
- Regulating or prohibiting the discharge in the sea or discarding on the sea-shore and land of specified substances or materials, or substances or materials not complying with specified requirements or having specified properties;
- The erection, maintenance, use and protection of and control over boundary beacons, buoys, notices, notice-boards or other marks used in connection with the harvesting or protection of marine resources;
- The regulation and control of research and development activities in connection with the harvesting and protection of marine resources;

Regulations pertaining to the above-mentioned provisions can be made applicable to marine resources in a general manner, or apply to a specified marine resource or may differentiate between different marine resources, different fishing vessels, or any other matter the Minister considers necessary.

Closed and Prohibited Areas have been promulgated in Government notice no. 153: *Regulations Relating to the Exploitation of Marine Resources*.

In terms of section 65 of the Marine Resources Act 27 of 2000, the Minister promulgated the following regulations pertaining to closed areas:

Regulation 10: *Prohibited Areas in respect of Fishing for Recreational Purposes*

10. *(1) A person may not harvest marine resources for recreational purposes within a distance of two nautical miles seaward from the high-water line in any of the following areas :*

(a) from the middle of the mouth of the Kunene River to the concrete beacon marked TB 1 situated approximately 5 km north of Terrace Bay;

(b) from the concrete beacon marked TB 2 situated approximately 25 km south of Terrace Bay to the concrete beacon marked TB 3 situated approximately 10 km north of Torra Bay;

(c) from the concrete beacon marked TB 4 situated approximately 10 km south of Torra Bay to the southern bank of the mouth of the Ugab River;

(d) from the concrete beacon marked CC1 situated at latitude 21degrees 45.249' south to the concrete beacon marked CC2 situated at latitude 21 degrees 51.380' south;

(e) from the southern limits of the quay in the harbour of Walvis Bay, along the coastline to Pelican Point;

(f) from the concrete beacon marked SV2 situated at the northern limits of Sandwich Harbour to a concrete beacon marked RL 3 situated approximately at latitude 26 degrees 34' south;

(g) from a concrete beacon marked P 1 situated approximately at latitude 26 degrees 44' south to a concrete beacon marked P 2 situated approximately at latitude 27 degrees 12' south;

(h) the sea shore of any of the islands along the Namibian coast.

Regulation 19: *Rock Lobster*

19. *(1) A person may not, in any manner or for any purpose, harvest rock lobster within any of the following areas :*

(a) the area within 15 nautical miles from the high water-line, bounded in the north by a line drawn due west from a concrete beacon marked RL 1 situated at Danger Point and in the south by a line drawn due west from a concrete beacon marked RL 2 situated at Douglas Point;

(b) *the area bounded by a line drawn from Diaz Point to a point north of Luderitz Bay, where the 26 degrees 34' south latitude intersects the high water-line and which is marked with a concrete beacon marked RL 3.*

Rock Lobster is defined in Part I of these regulations as '*…any individual of the species Jasus lalandii*'.

Trawling and longlining is prohibited in waters shallower than 200 metres, and enforced by means of attaching this prohibition as a condition, in the form of annexure 'C' to the fishing licenses granted to the commercial sector. The co-ordinates for the 200 metre bathometric line, running along the Namibian coastline, creating the Eastern boundary of the area in which trawling and longlining are prohibited, are provided below:

A: 17 degrees, 14'S x 11 degrees, 24'E

B: 18 degrees, 45'S x 11degrees, 39'E

C: 22 degrees, 03'S x 13 degrees, 19'S

D: 26 degrees, 11'S x 14 degrees, 27'S

E: 27 degrees, 46'S x 14 degrees, 45'E

F: 29 degrees, 00'S x 14 degrees, 47'S

Section 40 (3) of the Marine Resources Act empowers the Minister to subject fishing vessel licenses to conditions that he may determine in this regard.

Presently there are discussions under way to refine the above-mentioned 200 metre depth contour, in order to provide for more accuracy for the purposes of installing and regulating Vessel Monitoring Systems (VMS). A meeting has been arranged with the Minister, to propose new and more frequent co-ordinates, consisting of 40 points as opposed to the present above 6 points. Depending on the outcome of this meeting on Tuesday, 21 May, the above-mentioned license conditions may soon be amended. A significant advantage of implementing, regulating and enforcing closed areas through the use of license conditions, as opposed to gazetting regulations, is that the former displays much more flexibility and can be altered in a faster manner with less cumbersome procedures and / or bureaucracy.

There are further conditions applicable to those hake trawling vessels fishing in the area South of 25 degrees latitude, where the fishing exclusion has been extended to a depth of 300 metres.

In addition, the freezer trawlers fishing in this area, are confined to fishing in depths of 350 metres or more. As the 350 metre and 300 metre depth contour line are very close to one another, discussions are also underway to scrap this additional condition presently applicable to freezer trawlers. Depending on the outcome of the Ministerial meeting referred to above, the slightly deeper exclusion presently applicable to freezer trawlers may be amended, and then all trawlers (whether freezer vessels or not) will be confined to fishing in waters deeper than 300 metres.

Apart from the above exclusion zones and single-species sanctuary areas, there are currently no formally declared Marine Protected Areas (MPAs) in Namibian waters. The Minister of Fisheries is however empowered to declare MPAs, in terms of section 51 of the Marine Resources Act no. 27 of 2000 (Currie, 2005).

The proposals made by Currie (2005) for the establishment of MPA's in Namibian waters were also added as a second GIS file : ph_prop_mpa_pol_na. The final MPA files for Namibia are illustrated in figure 10.

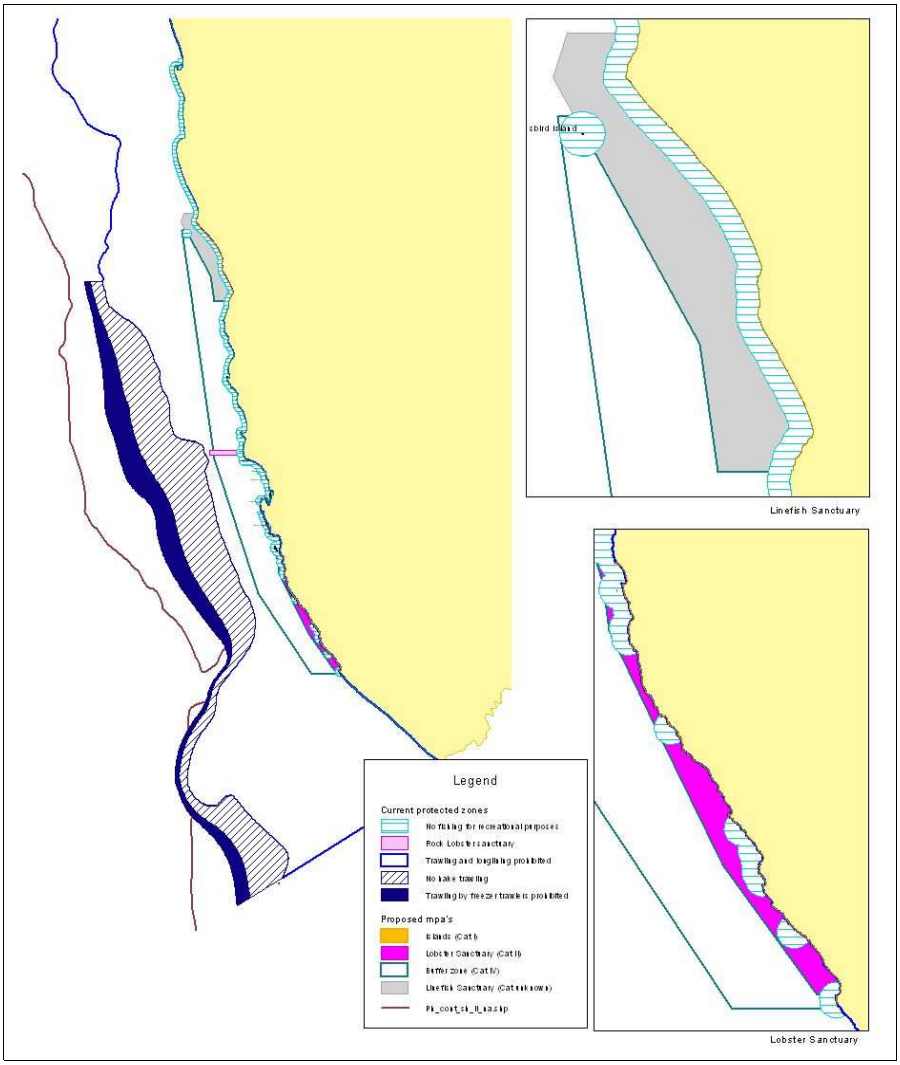
Different experts in and outside Angola contacted during the project informed that they were not aware of the existence of MPA's in Angola.

4.15 Coastal protected zones (ph_cpa_pol_*)

South Africa	Namibia	Angola
NSBA (terrestrial)	Atlas of Namibia + Survey General	WDPA database

The World Database on Protected Areas (WDPA) contains most protected terrestrial and marine protected areas of the world. This database was used for Angola and for checking and editing the available data of South Africa and Namibia. The protected areas of South Africa was obtained from Belinda Reyers who worked on the terrestrial component of the NSBA project "South Africa National Spatial Biodiversity Assessment 2004. Technical Report Volume 1 : Terrestrial component." (Rouget *et al.*, 2004). The data for Namibia was a combination of the proposed and existing protected area datasets from the Atlas of Namibia. The shape files of parks bordering the coast in Namibia and Angola were adapted such that the coastline matched the file ph_coast_li_*.

Figure 10 – Protected zones and proposed MPA's for Namibia (own compilation)



4.16 Rivers along coast (ph_river_li_*)

South Africa	Namibia	Angola
1:50,000 topographic maps	Atlas of Namibia + orthophotos SG + Landsat ETM 1999 - 2002	Orthorectified LANDSAT images 2000 + 1:100,000 topomaps

The river data for South Africa could be obtained from the Directorate of Surveys and Land information, South Africa. The data of the 1:50,000 map sheets along the coast was purchased in vector format and edge matched.

The major rivers along the Namibian coast were digitised on Landsat ETM images up to about 50 km inland. The minor rivers were extracted from the Atlas of Namibia dataset which has a very low accuracy (digitised from map with scale 1:1,000,000). The rivers were adapted to the 1 m accurate colour orthophotos of the Survey General for the last 300 to 500 m before they reach the sea (the area covered by the photos is illustrated in figure 7).

The rivers in Angola were digitised based on the orthorectified Landsat images were possible and otherwise on the 1:100,000 topographic maps.

4.17 Saltpans (ph_saltp_pt_*)

South Africa	Namibia	Angola
Input experts and others	Colour orthophotos SG + topographic maps	1:100,000 topomaps

Pans along the coastline with permanent or ephemeral salty deposits were digitised as a point file. Some of the pans contain water, especially in salt extraction areas in Namibia and Angola. These salt extraction pans are also indicated in the file ph_nat_res_pt_* (4.42).

4.18 Transformation (ph_transf_li_*)

South Africa	Namibia	Angola
Google	Colour orthophotos SG	Google + topographic maps + Landsat

The transformation layer gives an indication of any human transformation in the coastal area, such as a road, a mine or a settlement. A coastal strip of about 300 to 500 m was considered, which is the area covered by the colour orthophotos of the Surveyor General in Namibia.

Transformation information will be outdated for about 50 % of the coastline of Angola for which no high resolution Google Earth images where available (see 4.8.1). Old topographic maps (1980'ies) were used instead.

In Namibia, the information was based on orthophotos of 2001-2001, which means that the new developments between Langstrand and Walvis Bay, as well as the new developments between Swakopmund and Mile 4 are not included. These developments were not on the high resolution images in Google Earth either.

4.19 Exclusive Economical Zone (ph_eez_pol_*)

South Africa	Namibia	Angola
200 nm of baseline points + NSBA and diamond concession map	200 nm of baseline points + Treaty 2005	200 nm of baseline points + map C&C technologies + concession areas Sonangol

The United Nations Convention on Law of the Sea (UNCLOS) indicates that the exclusive economic zone (EEZ) of a coastal state extends 200 nm from the baseline. Within this area, the coastal nation has sole exploitation rights over all natural resources. All three BCLME countries have ratified this convention. (Wikipedia, 2007b)

Normally, a sea baseline follows the low-water line, but when the coastline is deeply indented, has fringing islands or is highly unstable, straight baselines may be used (Wikipedia, 2007b). In that case, the baseline – or part of it - is defined by a set of points : the baseline points (see 4.47 ph_baseline_pt_*).

A buffer of 200 nm was established in GIS based on the line connecting the baseline points and/or low-water line for each country. Additionally, the territorial waters were defined in the same GIS file as the area that extends up to twelve nautical miles from the low-water line or the straight baselines. Within the territorial waters, the coastal state is free to set laws, regulate any use, and use any resource (Wikipedia, 2007b).

The northern and southern boundaries of the EEZ of each BCLME country was established by using other information, such as the recent established Treaty (2005) between Namibia and Angola stating the marine boundary as the latitude line of 17° 15' S starting at its intersection joint with the low water line median of the Kunene River mouth.

The marine boundary between Namibia and South Africa joins the land border that currently is situated on the northern high-water mark of the Orange river, however an agreement signed by the two Surveyors General to place the border in the middle of the river is submitted to the two governments. The marine boundaries of South Africa were based on the EEZ file created during the NSBA project, with as additional information a map of the Council of Geoscience on the diamond concessions of South Africa.

The northern boundary of Angola's EEZ could be derived from the map compiled by C&C technologies, although with rather low accuracy. The map of C&C Technologies, a company in the USA, indicates that Angola intends to apply for an extension of the EEZ of Angola, as is the case for Namibia.

4.20 Roads along the coast (ph_roads_li_*_)

South Africa	Namibia	Angola
1:50,000 topographic maps **Accuracy 50 m**	Roads Authority + Colour orthophotos SG + topographic maps **Accuracy 1 m (– 300 m)**	Orthorectified LANDSAT images 2000 + 1:100,000 & 1:25,000 topomaps **Accuracy 75 m - 150 m**

The roads data for South Africa was obtained in vector format from the Directorate of Surveys and Land information, South Africa. The data of the 1:50,000 mapsheets along the coast was purchased and edge matched.

The Roads Authority provided us with very good quality data for Namibia : the majority of the roads have an accuracy of 1 m. Some smaller roads and tracks were added based on the colour orthophotos of the Surveyor General and on the 1:50,000 and 1:250,000 topographic maps. **The Roads Authority of Namibia expects GIS data of this project in return.**

The roads in Angola were digitised based on the orthorectified Landsat images and the 1:100,000 topographic maps.

4.21 Railways along the coast (ph_rail_li_*_)

South Africa	Namibia	Angola
1:50,000 topographic maps	Atlas of Namibia + topographic maps	Digital Chart of the World (DCW)

The railway data for South Africa was obtained in vector format from the Directorate of Surveys and Land information, South Africa. The data of the 1:50,000 mapsheets along the coast was purchased and edge matched.

The accuracy of the railway data in the Atlas of Namibia is unknown (the metadata indicates they have been digitised from a variety of maps with different scales) but seems very low and outdated The data was adapted for railways within approximately 50 km of the coastline based on the 1:50,000 and 1:250,000 topographic maps, as well as orthophotos of the Ministry of Lands & Resettlement (MLR).

The accuracy of the railway data for Angola is low : the DCW data has a scale of 1:1,000,000 and is created from the Operation Navigational Charts and Jet Navigational Charts. No attempt was made to upgrade the accuracy as this would be a rather large job for the Angolan railway network and the efforts would outweigh the benefits for this project. Most important is to have an overview of the major railway connections to the coast.

4.22 Untrawable grounds (ph_untrawable_pt/pol_*)

South Africa	Namibia	Angola
/ (Not available)	Trawling data MFMR 2000 - 2003	Old Portuguese maps

Untrawable grounds give an indication of the roughness of the seabottom. No trawling data was found for South Africa.

For Namibia, Mr Kainge of the Ministry of Fisheries and Marine Resources (MFMR) provided trawling data for the period 2000 – 2003 after an official approval was given by the Permanent Secretary. The data was obtained in Excel format for freezer and wet trawlers and with minute accuracy. **It is not known if commercial fishing companies provide their GPS data up to a second, but if not, this should urgently be requested by MFMR as the current accuracy is only 1' which equals about 1.7 km.**

The Excel data was converted to *.dbf format and imported in ArcView. A shape file was created for the start and end tow points of freezer trawlers, respectively wet trawlers, in the period 2000 – 2003. The tow points were attributed to a 5' grid. The results are illustrated in the figures 11 and 12. Finally, the tow points per 5' grid square for wet and freezer trawlers were added and a new attribute 'Trawling' was created. This attribute indicates if there is no trawling (Tot_trawls =< 2) "No", partially trawling (Tot_trawls >2 and <7) "Partially" or trawling.

For Angola, untrawable grounds were digitised as points (obstacles) and areas based on old Portugues maps found in a publication of Da Franca, Correia da Costa & Serpa de Vasconcelos (1964).

Figure 11 – Distribution of wet trawling areas in the period 2000 – 20003 : indication of start and end points of tow (own compilation)

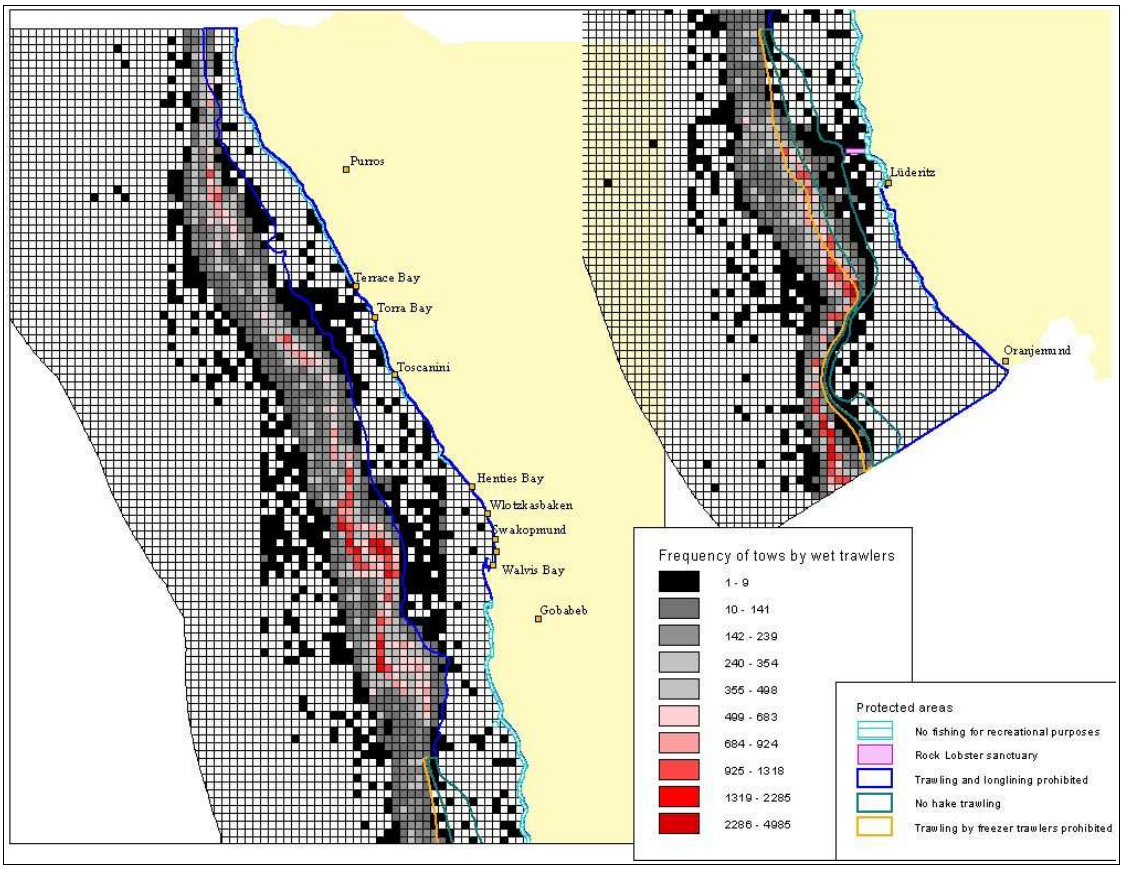
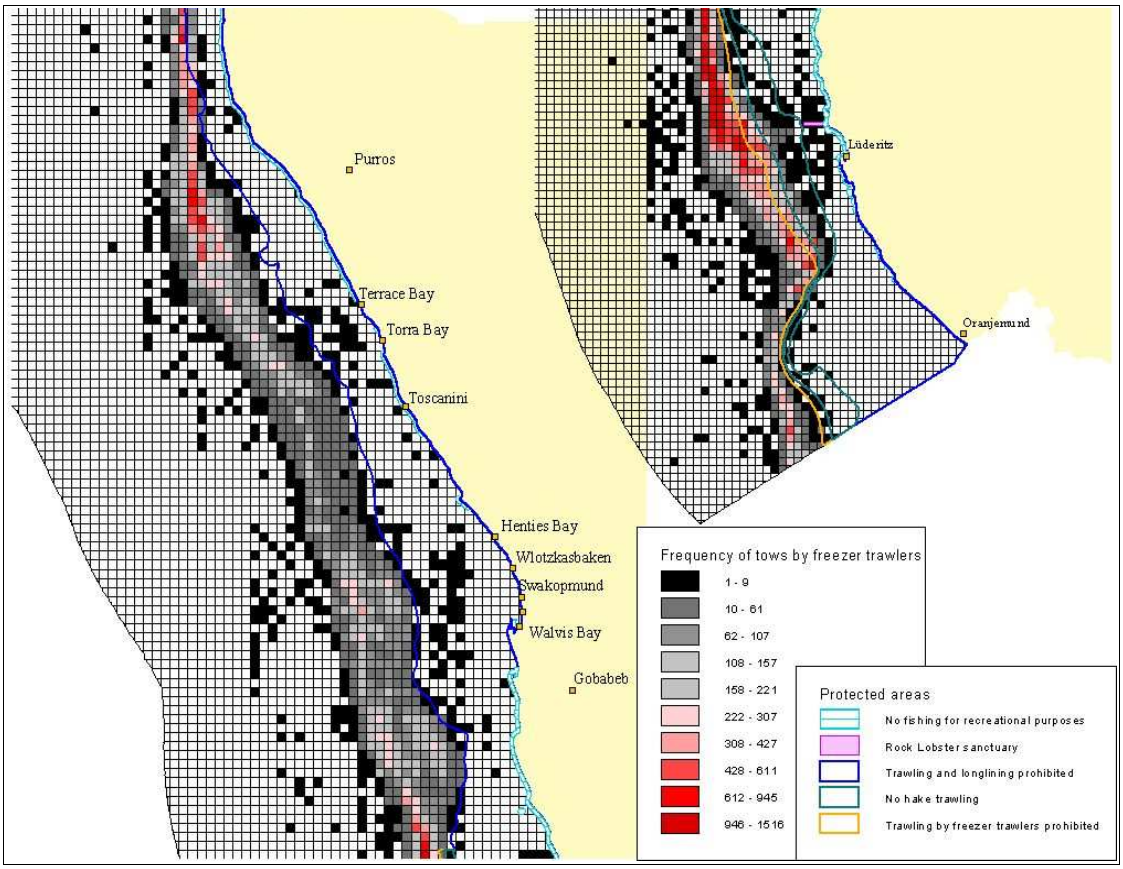


Figure 12 – Distribution of freezer trawling areas in the period 2000 – 20003 : indication of start and end points of tow (own compilation)



4.23 Satellite images coast

South Africa	Namibia	Angola
Google Earth images	Landsat mosaic	Geocover Orthorectified Landsat

Medium to low resolution satellite images were used to establish a lot of the vector GIS data layers. This 'layer' or rather dataset contains downloaded images from the Internet for South Africa and Angola. The Google Earth images of South Africa were georeferenced during the project (up to Cape Point, the remaining part was funded by Mandy Lombard and one of her projects). The georeferenced Landsat 7 ETM mosaic (1999 - 2002) for Namibia's coastal region was created by Celeste Espach in ERDAS software.

4.24 Russian maps

South Africa	Namibia	Angola
downloaded		

Topographic maps at a scale of 1:500,000 were downloaded from www.madmappers.com for the BCLME region. A lot of toponyms on the maps are however in Russian.

4.25 Coastal types as polygon (ph_coast_types_pol_na)

South Africa	Namibia	Angola
/	Colour orthophotos SG	/

The bottom types of Namibia were first digitised as polygons before the file ph_coast_types_li_na (4.8.1) was created. The polygon file stretches about 300 – 500 m inland, the area covered by the orthophotos (see figure 7).

4.26 Population density

South Africa	Namibia	Angola
Landscan data		

This ESRI grid file represents the population density in Africa in 2004. It was created by the Oak Ridge National Laboratory (ORNL) Global Population Project and has a resolution of 30" by 30". **The copyrights and usage restrictions of this file are very strict and should never by used outside the BCLME project without consulting Vera De Cauwer first.**

4.27 Fog (ph_fog_pol_*)

South Africa	Namibia	Angola
/	Atlas of Namibia	Olivier (2002)

Fog is an important factor in the distribution of plant life in the Namib desert. This layer represents the days of fog in Namibia, respectively Angola. The Namibian data was downloaded from the Atlas of Namibia site. It is based on one year of observations in 1984

using satellite imagery[4]. Fog is recorded when visibility on the ground is reduced to 1,000 m or less. The polygons making up the shape file were created from hand drawn contours on a hard copy map. This manual interpolation approach was done by Peter Hutchinson using the point data from all available stations. Because the number of stations was small an automatic interpolation produced nonsense results.

The South African data was digitised from a map obtained in an article of Olivier (2002). This data seems to have a higher level of detail than the Namibian data. He based his interpolation on the measurements of 11 weather stations and personal observations of "fog-watchers". The accuracy is however very low and the data does not match with the Namibian data at the border.

4.28 Sediment thickness (sed_thick_wrld)

South Africa	Namibia	Angola
NGDC - NOAA		

The sediment thickness is measured as the depth to the acoustic basement. This ESRI grid file was created by the National Geophysical Data Center (NGDC) of the USA and provided by Belinda Reyers of CSIR. It can be downloaded from http://www.ngdc.noaa.gov/mgg/sedthick/data/arcgis/.

4.29 Water area (ph_water_pol_*)

South Africa	Namibia	Angola
1:50,000 topographic maps	Landsat	Orthorectified Landsat 2000 + 1:100,000 topomaps

This layer represents any water area situated onshore and close to the coastline. The water areas can be marshes, lakes, dams, large river mouths, salt pans with water, ... The water areas for South Africa were obtained in vector format from the Directorate of Surveys and Land information, South Africa. The data of the 1:50,000 mapsheets along the coast was purchased and edge matched. The water areas for Namibia and Angola were digitised for this project.

4 Data source : Olivier, J. 1995. Spatial distribution of fog in the Namib. Journal of arid environments, 29:129-138

4.30 Seamounts (ph_seamount_pol_*)

South Africa	Namibia	Angola
NSBA	Digitised on slope map derived from GEBCO grid	Digitised on slope map derived from GEBCO grid

A seamount is a submerged submarine mountain rising at least 1000 m above sea floor, characteristically of conical form (The Readers's Digest Association, 1984 ; South African Navy, 2000).

There were no seamounts indicated in the SAN dataset for Namibia nor in the IH data for Angola. Seamounts in Namibian and Angolan waters were therefore identified with a slope map derived from the GEBCO dataset (bathy_off). This slope map is stored as a separate layer (see 4.48). The difference of the seamount summit was checked with the surrounding seafloor and if the difference was 1000 m or more, it was digitised as a sea mount on the slope map. For Namibia, the hydro acoustic data received from the Surveyor General was used as well (see figure 5).

The Kudu gas field Environmental Impact Assessment report (Morant, 2004) mentions the Tripp sea mount WSW of the Orange river mouth, however no submarine mountain rising at least 1000 m above the sea floor was found with the available bathymetry data. The resolution of the GEBCO data is however 1' or 1.7 km and seamounts and canyons smaller than approximately 10 km x 10 km can easily have been missed because of the average depth value per pixel of 1.7 km x 1.7 km.

4.31 Marine canyons (ph_mar_canyon_pol_*)

South Africa	Namibia	Angola
NSBA	Digitised on slope map derived from GEBCO grid	Digitised on slope map derived from GEBCO grid

A marine canyon is a relatively narrow, deep depression with steep sides, the bottom of which generally has a continuous slope, developed characteristically on some continental slopes (South African Navy, 2000). Marine canyons were identified and digitised for Namibian and Angolan waters in the same way as the seamounts (4.30).

4.32 Continental shelf (ph_cont_sh_li_*)

South Africa	Namibia	Angola
Digitised on slope map derived from GEBCO grid	Digitised on slope map derived from GEBCO grid	Digitised on slope map derived from GEBCO grid

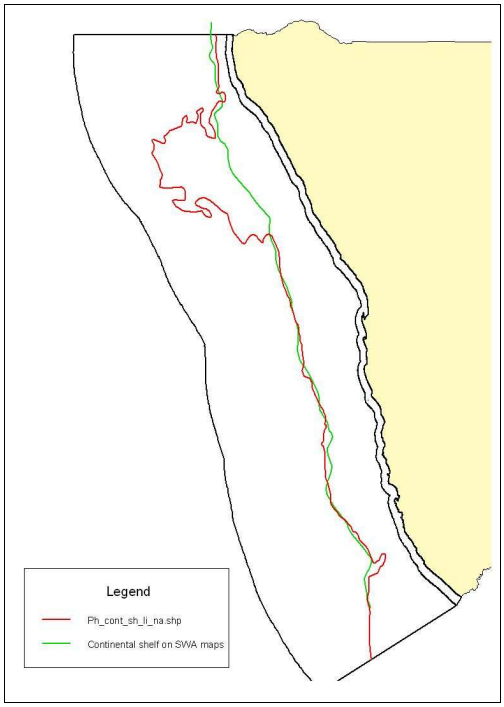
The continental shelf is defined as natural prolongation of the land territory to the continental margin's outer edge, or 200 nautical miles from the coastal state's baseline, whichever is greater. A state's continental shelf may exceed 200 nautical miles until the natural prolongation ends, but it may never exceed 350 nautical miles, or 100 nautical miles beyond the 2,500 meter isobath. States have the right to harvest mineral and non-living material in the subsoil of its continental shelf, to the exclusion of others. (Wikipedia, 2007a)

The shelf break was digitised on the slope map derived from the GEBCO dataset (see 4.48) for all three countries based on following information :

- the slope of the shelf is usually quite low, on the order of 0.5° (Pinet, 1996),
- the continental slope is much steeper than the shelf; the average angle is 3°, but it can be as low as 1° or as high as 10° (Wikipedia, 2007a).

For Namibia, the resulting shelf break was compared with those on the maps of the Geological Survey of SW Africa (1988), as illustrated in figure 13. Although there was a fairly good overlap, there is a major difference at the start of the Walvis ridge. Dr Amanda Rau is in the opinion that the newly corrected shelf break is more correct.

Figure 13 – Shelf break of Namibia : comparison of digitised line with line on old maps



4.33 Biozones (ph_biozones_pol_*, ph_biozo_sym_pol_*)

South Africa	Namibia	Angola
NSBA	Workshop Swakopmund 7 June 2005	Workshop Luanda 30 June 2005 + Pat Morant + Marek Ostrowski + Neville Sweijd

Biozones are depth zones (moving from the coast to the abyss) subdivided by inshore and offshore bioregions (moving from west to east) (Lombard *et al*., 2004). Bioregions are areas for which the biological and geographical conditions are similar.The inshore and offshore bioregions for Namibia, as well as the extension of the offshore bioregions were determined at a workshop held in Swakopmund based on input from experts. The depth strata used were the same as for the NSBA. Some of the isobaths had to be generated from a grid as they were not present in the collected bathymetry datasets. The proposed biozones are shown in figure 14.

The offshore bioregions for Angola were determined at a workshop in Luanda, although there remained some discussion points. The inshore bioregions were not discussed and a proposal of Pat Morant was followed. The extension of the offshore bioregions were not discussed in depth during the workshop and therefore the work of Bianchi (1992) on the distribution of fish groups in Angolan waters was studied. The work focuses on trawling data extending offshore till about the mid continental slope. An attempt was made to attribute the fish groups distinguished by Bianchi - based on species composition - to the offshore bioregions distinguished during the Luanda workshop (see table 7). The fish groups are described in annex 4.

The resulting biozones for Angola where discussed during a short telephonic conference with Marek Ostrowski, Neville Sweijd and Pat Morant. Some minor adjustments were still made. The depth strata used were the same as for the NSBA, with exception of the offshore boundary of the deep photic. Pat Morant indicated that the deep photic went much deeper in northern Angola : up to about 70 m rather than 30 m. The area of Ambriz was selected as were light started to penetrate deeper into the seawater.

Two files were created per country : the file ph_biozones_pol_* represents the actual widths of the biozones, while the files ph_biozo_sym_pol_* represent a symbolic width for the smaller biozones so they would be more visible.

4.34 Coastline with indication of estuaries (ph_estuary_li_*)

South Africa	Namibia	Angola
Expert input	/ (can be found in 8)	/ (can be found in 8)

The location of the estuaries can be found in the transformation file (see 4.8), although a separate estuary file was created for South Africa. This file contains also more information on the estuaries, which is actually part of the work of the Estuary project.

Figure 14 – Biozones proposed at workshop in Swakopmund (from Lombard, 2005)

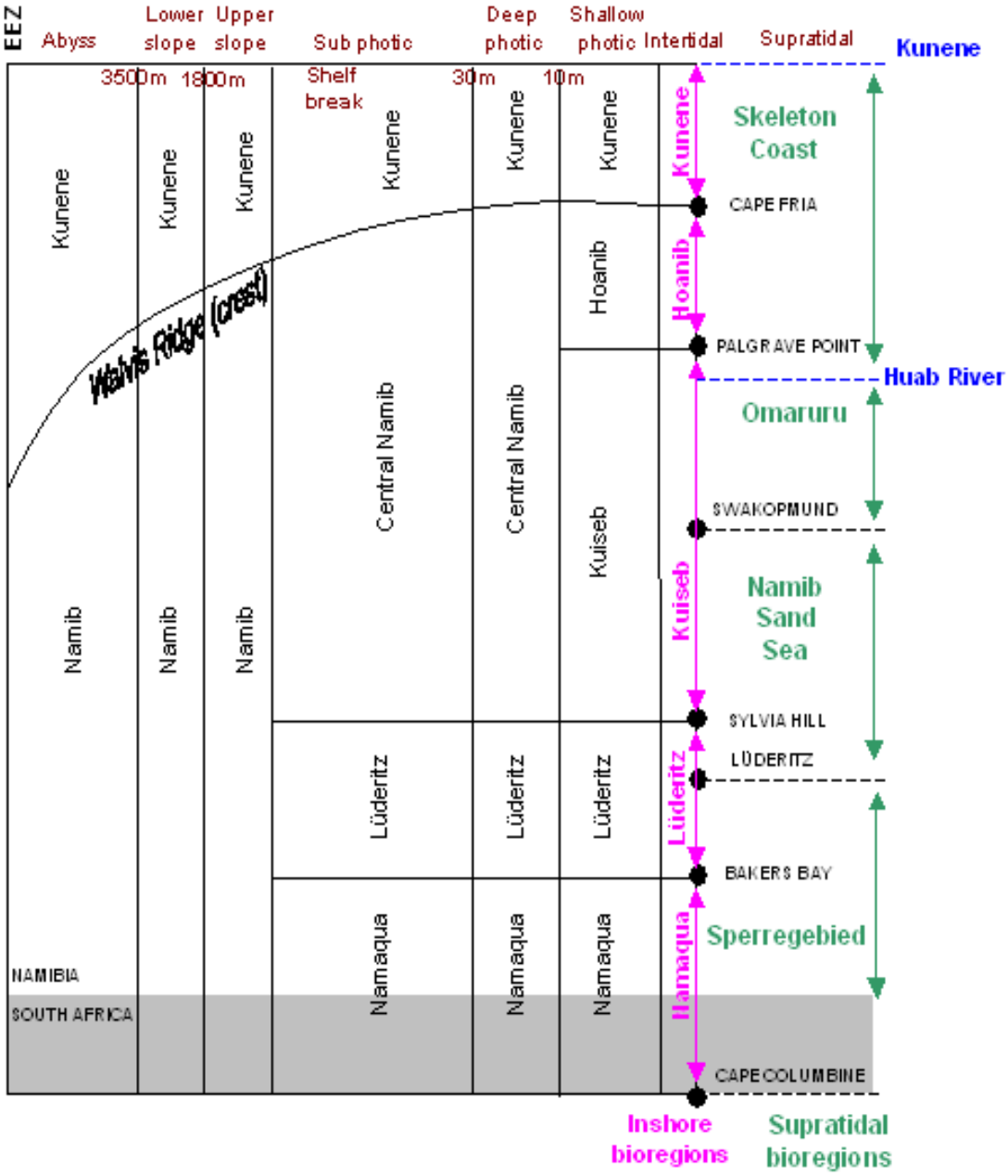


Table 10 – Distribution of fish groups of Bianchi (1992) over proposed offshore bioregions (own compilation)

Abyss	Lower Slope	Upper Slope	Sub photic	Deep photic	Shallow photic	Inter-tidal	OFFSHORE BIOREGIONS
		Group 8	Group 3; Group 4; Group 5	Group 1			**CABINDA**
		Group 8	Group 3; Group 4; Group 5	Group 1			**CONGO** Congo mouth - Nzeto
		Group 7; Group 8	Group 4; Group 5	Group 1			**BENGO** Ambriz – Barra do Dande
		Group 7; Group 8	Group 2; Group 4; Group 5	Group 1			**LUANDA** Barra do Dande – Pta das Palmareinhas
		Group 7; Group 8	Group 2; Group 4; Group 5	Group 1			**KWANZA** Pta das Palmareinhas – Ponto do Morro
		Group 7; Group 8	Group 2; Group 4; Group 5	Group 1			**SUMBE (NGUNZA)** Ponto do Morro – Cabeça de Baleia
		Group 7; Group 8	Group 2; Group 4				**LOBITO** Cabeça de Baleia – Baia Farta
		Group 7	*Group 2; Group 4*				**BENGUELA** Baia Farta - Lucira
		Group 7	*Group 2; Group 4*				**NAMIBE** Lucira – Magellan Rocks
		Group 7	*Group 4*				**TOMBUA** Magellan Rocks – Ponta Albina
		Group 7	Group 6				**KUNENE** Ponta Albina - Cunene

4.35 SADC countries (ph_sadc_pol)

South Africa	Namibia	Angola
Geological survey of Namibia		

A GIS polygon file of the Southern African Development Community (SADC) countries was provided by the Geological Survey of Namibia. Note that all data obtained from the Geological Survey can not be distributed to third parties without their approval.

4.36 SRTM elevation (ph_dem_im_*)

South Africa	Namibia	Angola
Compiled by Celeste Espach		

The Shuttle Radar Topography Mission (SRTM) of NASA collected elevation data on a global scale. This data – which is freely available in different formats - was downloaded by Celeste Espach for this project and a subset image with legend was created for the BCLME region.

4.37 Elevation contours on land (ph_relief_li_*)

South Africa	Namibia	Angola
1:50,000 topographic maps	/	/

The elevation contours for South Africa were obtained in GIS vector format from the Directorate of Surveys and Land information, South Africa. The data of the 1:50,000 mapsheets along the coast was purchased and edge matched.

Accurate digital contour data could not be found for Namibia and Angola. The Survey General did however provide laser points from the complete coastline up to about 300 – 500 m inland which reach an elevation of approximately 30 m. This dataset can be converted to very accurate contour lines, however this would be a very time consuming work and it was assumed that the SRTM dataset (4.36) provided enough information on elevation.

Digitising contour lines present on the topographic maps of Angola would have been possible as well, but as for Namibia, the effort outweighed the cost (time).

4.38 Elevation points on land (ph_relief_pt_*)

South Africa	Namibia	Angola
1:50,000 topographic maps	/	/

The elevation points for South Africa were obtained in GIS vector format from the Directorate of Surveys and Land information, South Africa. The data of the 1:50,000 mapsheets along the coast was purchased and edge matched.

Accurate digital elevation point data could not be found for Namibia and Angola. The data could have been generated during the project (in same way as contours, see 4.37), but this would be a very time consuming work compared to the use of this third priority dataset.

4.39 Coastal and marine mine prospection areas (ph_epl_pol_*)

South Africa	Namibia	Angola
/	Geological Survey of Namibia	/

This dataset is only available for Namibia. It was compiled from GIS data obtained from the Geological Survey of Namibia and contains marine and coastal prospection areas for precious stones (mainly diamonds), oil and gas.

4.40 Reefs (ph_reef_pt_*)

South Africa	Namibia	Angola
1:50,000 topographic maps and Google Earth	Colour orthophotos SG	Cuntala artificial reef 6°38'5"S, 12°9'49"E

A reef is a strip or ridge of rocks, sand or soil that rises to or near the surface of a body of water (The Reader's Digest Association, 1984). Reefs along the coastline of South Africa were digitised based on the 1:50,000 topographic maps and Google Earth.

For Namibia, reefs close to the coastline (up to 500 to 700 m offshore) could be identified on the colour orthophotos of the Survey General. Information of the old topographic maps 1:50,000 was used to complement the photos, especially for the names of the reefs or reefs further offshore. A few reefs were identified based on expert knowledge or the website of Diamondfields.

For Angola, only the location of an artificial reef – provided by Pat Morant - is known.

4.41 Temperature (ph_temp_im_na, ph_kwanza_pt_an)

South Africa	Namibia	Angola
/	MFMR	Data of Kwanza measurements

MFMR provided average temperature data for Namibian waters : for the winter and for the summer period. The data is represented as an image and was created in the software Oceanbase through interpolation of data collected at different depths between 1994 and 2005.

The Angolan data contains measurements collected by the Estuary team in and outside the Kwanza river mouth. Next to temperature, there are also measurements of oxygen and salinity.

4.42 Natural resources production (ph_nat_res_pt_*)

South Africa	Namibia	Angola
/	Compilation of different sources	/

The location of points where natural resources are produced or collected (aquaculture, guano, salt, ...) is digitised based on information gathered from stakeholders and literature. No information could be collected for Angola and South Africa.

4.43 Oxygen (ph_oxygen_pt_*)

South Africa	Namibia	Angola
/	MFMR	See Kwanza measurements (4.41 ph_kwanza_pt_an)

Oxygen data was collected in the same way as temperature data.

4.44 Salinity (ph_sal_pt_*)

South Africa	Namibia	Angola
/	MFMR	See Kwanza measurements (4.41 ph_kwanza_pt_an)

Salinity data was collected in the same way as temperature data.

4.45 Wells (ph_wells_pt_*)

South Africa	Namibia	Angola
Internet : abandoned well heads	See SA	Sonangol : offshore wells

The coordinates of abandoned and suspended well heads along the South African coast was found on the Internet in the SANHO Notice to Mariners no 16. The coordinates include four well heads in the Kudu gas field in southern Namibia. The position of offshore oil wells in Angolan waters was obtained from Sonangol.

4.46 Population along coast (ph_popul_pol_sa)

South Africa	Namibia	Angola
Digitsed by Taniia	/	/

Detailed population data at municipality level could be collected for South Africa. Municipal units that are within 1 km of SA coastline were included with exact population figures and population per km².

4.47 Baseline points (ph_baseline_pt_*, ph_baseline_li_*)

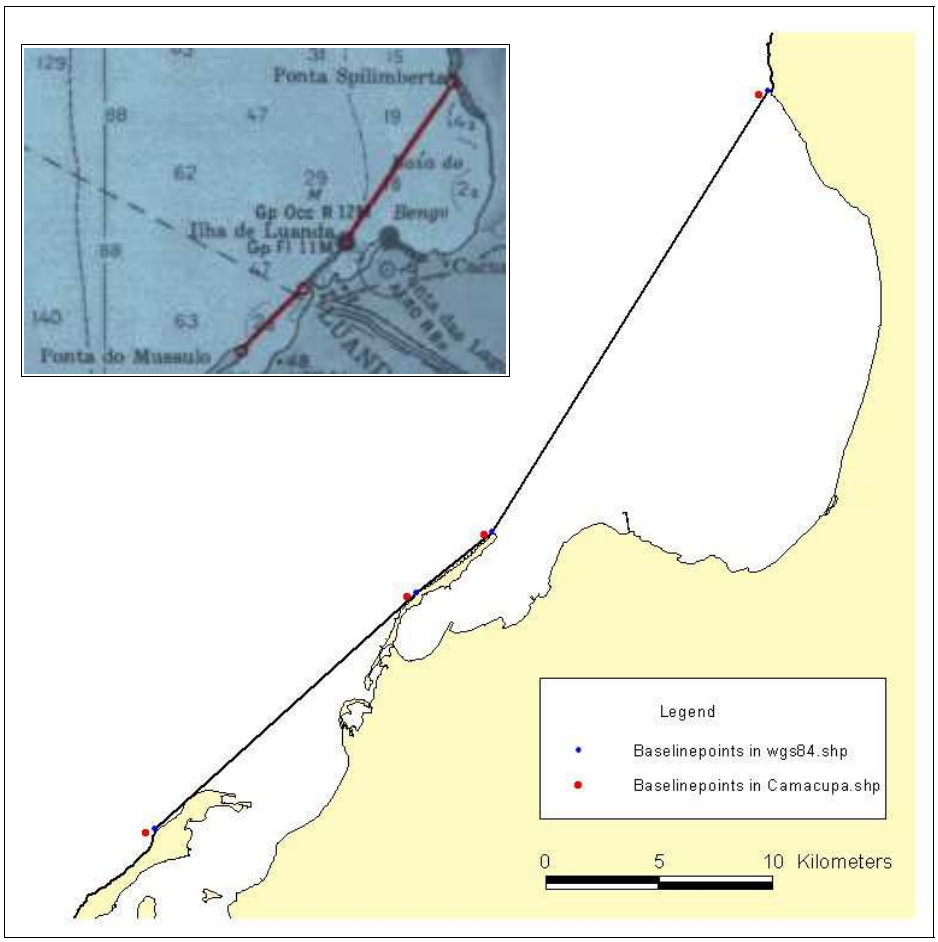
South Africa	Namibia	Angola
Internet	Survey General	Internet

As mentioned earlier, a sea baseline follows the low-water line, but when the coastline is deeply indented, has fringing islands or is highly unstable, straight baselines may be used (Wikipedia, 2007b). The straight baselines join grouped coordinates called the baseline points.

As the EEZ and territorial waters are defined as a distance from the sea baseline, it was necessary to check if any of the BCLME countries has straight baselines and if so, to collect the points defining the baselines. Baseline information for all BCLME countries was found on the website of the United States of America's Department of Defence (http://www.dtic.mil/whs/directives/corres/html/20051m.htm) and for South Africa also in the San notices. For Angola and South Africa, straight baselines supplement the normal baseline and a set of coordinates defined the straight baselines. **The geodetic datum of the baseline point coordinates for Angola was however not indicated.** A comparison was made with the coastline and the baseline points assuming them to be in Camacupa and then in WGS84 (figure 15). The fact that the Camacupa points were situated more offshore than the WGS84 points, lead to the assumption that the points are in WGS84.

For Namibia, baseline points were received from the Surveyor General. These baseline points are situated on the low-water line and do not identify straight baselines. They assisted in digitising the coastline of Namibia (4.1) as they are 'officially' situated on the low-water line.

Figure 15 – Comparison of baseline points with geodetic datum Camacupa and WGS84 : points from Ponta Spilimberta to Ponta do Mossulo. Inset : Old map of straight baselines (Office of the Geographer, 1970)



4.48 GEBCO slope map (ph_slope_off)

South Africa	Namibia	Angola
Calculated from GEBCO grid		

A slope map was derived from the GEBCO grid in GIS. This slope map assisted in digitising the shelf break (continental shelf), seamounts and marine canyons.

4.49 High water mark (ph_hwm_est_li_na, ph_hwm_li_na)

South Africa	Namibia	Angola
/	Colour orthophotos Survey General	/

The high water mark of Namibia was used to create the protected areas and proposed MPA polygons. For parts of the coast (Swakopmund and parts in southern Namibia), the high water mark was digitised on the colour orthophotos of the Surveyor General (ph_hwm_li_na). As this is a very time consuming job with relatively little benefit, it was decided the estimate the remaining part of the high water mark based on the digitised data.

The average distance between the low-water and high-water line was calculated for rocky, mixed and sandy areas by performing about 30 measurements for each intertidal coast type. This resulted in an average intertidal area width of respectively 30 m, 39 m and 55 m. The averages were used to create the file ph_hwm_est_li_na.

4.50 BCLME countries and EEZ (ph_country_pol_bclme, ph_eez_pol_bclme)

South Africa	Namibia	Angola
Compilation of country data		

The BCLME country polygons were merged into one layer ph_country_pol_bclme, and the EEZ polygons into the layer ph_eez_pol_bclme.

4.51 Dunes (ph_dunes_pol_na)

South Africa	Namibia	Angola
/	Landsat + Topographic maps	/

For Namibia, the high sand dune areas in the Namib desert and the Succulent Karoo in the south were digitised up to about 50 km inland. Landsat images of 2000 were the main source, the topographic maps were used in a lesser extent and mainly where in doubt on the Landsat images.

5. Data gaps and flaws

The major goal of this project was to collect existing geospatial physical data and convert it to a format that could be used by the MOM project for biodiversity conservation planning. After more than a year of data collection with the physical mapping team, some datasets could not be obtained, either because the data owners could not provide it to the project (mainly the case for sensitive datasets), because the price of the data was to high or because no existing dataset could be located. Some of the datasets collected or compiled have a very low accuracy and might need further refining and/or updating in the future.

This unit indicates the most important data gaps and flaws of those physical mapping datasets considered to have first and second priority in the data collection and compilation. Important datasets were identified in consultation with the MOM project. The third priority datasets are datasets that are not considered to be really necessary for the biodiversity conservation planning or that are by-products from the generation of the other datasets. Data weaknesses are indicated for use at regional level (BCLME). Some datasets would for example not be accurate enough for studies at national or local level, although a lot are.

5.1 First priority datasets

Most data collection and compilation efforts went into the first priority datasets, datasets that seemed to be essential to perform. The first priority datasets are (see also annex 3) :

- Coastline (includes islands)
- Country (with islands)
- Islands
- Bathymetry close to coast
- Bathymetry offshore
- Classification of marine sediments
- Texture of marine sediments
- Intertidal coastal types (including wave exposure)
- Coastal cities, settlements
- Coastal places (including lighthouses, landmarks, shipwrecks, ...)
- Harbours
- Coastal mines (up to 80 km inland)
- Marine and coastal mining areas (diamonds and oil)
- Marine protected zones
- Coastal protected zones
- Rivers along coastline
- Saltpans
- Transformation.

The only missing dataset is the classification of marine sediments in Angola, all other datasets were compiled or collected.

Following data flaws can be mentioned :

- **South African coastline (ph_coast_li_sa)** : the relatively large size (2.6 MB) makes the file difficult to work with. Reason for the file size is the fact that the coastline is often a zigzag line as digitisers followed the symbology representing the rocky outcrops on the topographic maps (see also 4.1.1). It would take a few days of work to correct this.
- **Angolan bathymetry close to coast (ph_bathy_coast_li_an)** : the sources for this dataset are navigation charts of the Hydrographical Institute (IH) in Portugal and the topographic maps of Angola. The overlap between the datasets was however very poor, but it is not clear which of the two map sets has the poorest accuracy as no depth measurements were available. It would be useful to do an accuracy assessment of this and other bathymetric datsets (such as those of the Real Admiralty of the UK) with depth measurements of the Norwegian research vessel Nansen or of oil companies (who were very reluctant to give data to this project). This exercise would probably take a few weeks as Marek Ostrowski of IMR, Norway, indicated that a lot of the depth measurements need further processing.
- **Texture of marine sediments** : the dataset collected for Namibia (ph_mar_texture_pol_na) is not very accurate as the sample density was very low : an average of 257 km^2/sample. It would however be a very expensive exercise to upgrade this dataset, although relevant mine surveys and acoustic measurements may have already covered a substantial area of the continental shelf. The collection and merging of this data would be a project on its own. No information was obtained on the sample density used to compile the Dingle dataset of South Africa (ph_mar_texture_pol_sa). The Angolan dataset is based on acoustic measurements, however digitised from maps in a scientific article. It would be advisable to collect the original maps or reprocess the acoustic data of the Nansen.
- **Intertidal coastal types** : pebble beaches could not be identified on the colour orthophotos for Namibia and Google Earth and Landsat images for Angola, with exception of a few pebble beaches in Namibia that were indicated on the coastal sensitivity map of Namibia provided by the Geological Survey. Only about 50 % of the coastline of Angola was covered with high resolution images in Google Earth. The Landsat images and topographic maps used for the other 50 % did not always provide enough detail to determine the bottom type. Some parts of the coast were therefore indicates as 'unknown'.
- **Settlements in Angola (ph_settl_pt_an)** : the sizes of the settlements are outdated as they are based on topographic maps for which the last update has been performed in the 1980'ies.
- **Coastal mines** : these datasets are incomplete for South Africa and Angola, with the first only containing a few mines that could be identified on topographic maps of the west coast and the last only including onshore oil wells. Requests were submitted to the relevant authorities but no further data was obtained. The collection of this data is actually a task of the Threats project.
- **Transformation in Angola (ph_transf_li_an)** : Only about 50 % of the coastline of Angola was covered with high resolution images in Google Earth. The topographic

maps used for the other 50 % are outdated (1980'ies) and will not reflect the current situation completely.

5.2 Second priority datasets

The second priority datasets are data that were either compiled from the first priority datasets or datasets considered less essential to the biodiversity conservation planning exercise. The second priority datasets are (see also annex 3) :

- Exclusive Economical Zone and territorial waters
- Roads
- Railways along coastline
- Untrawable grounds
- Satellite images coast
- Russian maps 1:500,000
- Coastal types – geomorphology (polygon)
- Population density
- Fog
- Sediment thickness
- Water area (rivers or other)
- Seamounts
- Marine canyons
- Continental shelf
- Biozones

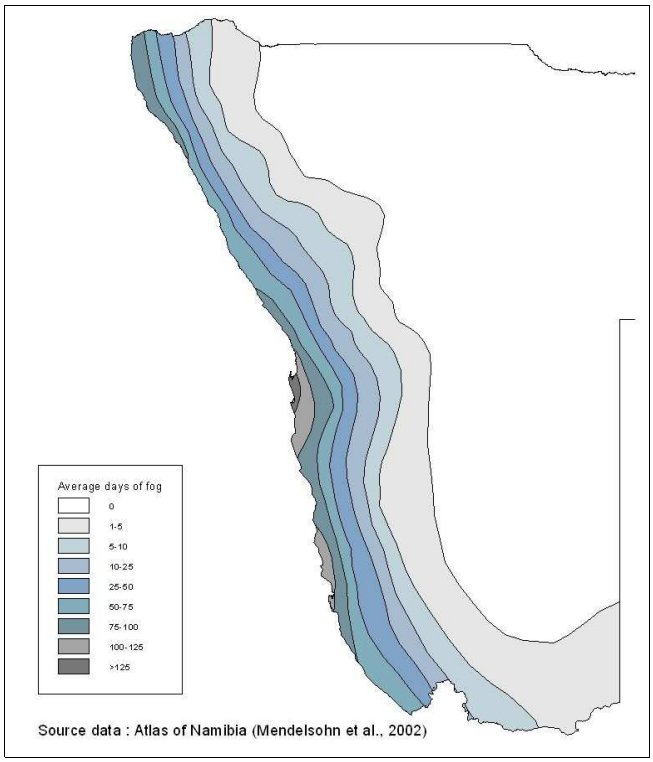
Essential missing datasets are :

- **Untrawable grounds South Africa** : During the course of the project, Dr Amanda Rau and James Wiltshire contacted MCM in South Africa but did not get hold of this dataset. The data is collected in the same way as for Namibia : commercial trawlers submit their GPS data to government. Tebello Mainoane of MCM informed Vera De Cauwer in July 2007 that an official request is required to obtain this sensitive dataset.

- **Fog data for Angola :** the significant number of days with fog in the Namib desert and the Karoo extend into Angola (figure 16). However no fog distribution data was found for that country. Fog influences the distribution of certain plants in the desert, such as lichens and the *Welwitschia mirabilis*, endemic to the Namib desert and also found in southern Angola.

  It would be possible to determine the amount of fog days with the aid of a historical archive of satellite images, but this would be a small project on its own. Such a project could also update the fog data for Namibia as satellite images of only one year were used as input and the data does not match with the South African data at the border. Fog algorithms such as used at the Laboratory of Climatology and Remote Sensing at the University of Marburg, Germany, (http://lcrs.geographie.uni-marburg.de/index.php?id=32) could be very useful. Alternatively, the article "Distribution of *Welwitschia mirabilis*" of Robert J. Rodin in the *American Journal of Botany*, Vol. 40, No. 4 (Apr., 1953), pp. 280-285 could be used.

Figure 16 – Days of fog along the coast of Namibia (own compilation)



Datasets with weaknesses are :

- **Untrawable grounds of Angola (ph_untrawable_pol_an, ph_untrawable_pt_an)** : this dataset was digitised from old Portuguese maps (1964). The positional accuracy of the maps is unknown, but is assumed low dating from a time well before GPS technology. Information of research and fishing vessels, as well as acoustic surveys of oil companies might upgrade this dataset considerably. The collection of this data will however be very difficult and very time consuming in a country such as Angola where only enough money will grant quick access to such datasets.
- **Water areas :** the water areas do not always contain information relevant to biodiversity potential. The polygons for South Africa – obtained from the Department of Land Affairs - contain an attribute feature type (feat_type) indicating if it concerns a sand bank, perennial extent, flood bank, etc. Information on the fact if the area concerns a marsh, salt water, ... is however missing. Some of this information can be found in the estuary or salt pan data. It was attempted to do this for Angola and Namibia but in some cases, information was missing.
- **Seamounts and marine canyons** : for Namibia and Angola, these underwater features were digitised based on the GEBCO information and definitions of the features. The resolution of the GEBCO data is however 1' or 1.7 km and seamounts and canyons smaller than approximately 10 km x 10 km can easily have been missed because of the average value of the depth per pixel of 1.7 km x 1.7 km. It is not known if there are other sources of information to locate seamounts and marine canyons in Namibian and Angolan waters.

6. Conclusions and recommendations

Existing physical datasets related to shoreline, shallow water and marine habitat distribution in the BCLME region were identified, as well as physical datasets with a geospatial component that contributes to marine and coastal biodiversity conservation planning. The accuracy, resolution, completeness and coverage of the identified data was analysed. This included amongst others a price comparison of the data of different satellite sensors.

The most appropriate datasets for use at regional level or most appropriate sources for the creation of these datasets were selected and collected. Certain datasets had to be collected first before a final selection could be made. For example the GEBCO and ETOPO global elevation datasets were compared with hydro acoustic measurements for the marine areas of the BCLME region. Based on this comparison, the GEBCO dataset was selected.

The geospatial data collected was converted to GIS format and the same coordinate system (geographical, WGS84 datum). This involved quite a lot of digitising and conversion of coordinates to point files. The creation of the GIS layer on intertidal coast types required the development of a method (adapted from Howes, Harper & Owens, 1994) to estimate the wave exposure along the coast.

A total number of 122 GIS physical data layers (or rather datasets, as some "layers" contain more than one GIS file) were compiled during this project. Most datasets are collected at national level - Namibia, Angola, South Africa - although certain datasets are covering the BCLME region. The datasets follow a standard naming convention and are organised in a systematic folder structure. A meta data file was established per data layer. All meta data was organised in one Excel file per country following a template established by this project.

About half of the compiled datasets concern completely new data layers created by the project - data layers that are not a combination or edition of existing GIS data. There are less new datasets created for South Africa as a lot of layers created by the NSBA project were used and edited.

Most effort went into the compilation of datasets considered essential to biodiversity conservation planning (in consultation with the MOM project). Following data layers were given first or second priority :

First priority datasets
Coastline (includes islands)
Country (with islands)
Islands
Bathymetry close to coast
Bathymetry offshore
Classification of marine sediments
Texture of marine sediments
Intertidal coastal types (including wave exposure)
Coastal cities, settlements

Second priority datasets
Exclusive Economical Zone and territorial waters
Roads
Railways along coastline
Untrawable grounds
Satellite images coast
Russian maps 1:500,000
Coastal types – geomorphology (polygon)
Population density
Fog

First priority datasets	Second priority datasets
Coastal places	Sediment thickness
Harbours	Water area (rivers or other)
Coastal mines (up to 80 km inland)	Seamounts
Marine and coastal mining areas (diamonds and oil)	Marine canyons
Marine protected zones	Continental shelf
Coastal protected zones	Biozones
Rivers along coastline	
Saltpans	
Transformation	

The first and second priority data layers could be established for each country with exception of the classification of marine sediments for Angola, untrawable grounds for South Africa and fog data for Angola. An official request for the first dataset was made but the data could not be obtained. It is not known if and how this data can be obtained but payment may work. The second missing dataset can be obtained after an official request to MCM but it is expected that such a request will take a long time to process because of the sensitive nature of the data. Fog data for Angola was not found but could be established by doing a study on a historical dataset of satellite images (preferably of a few years).

The majority of the established datasets will fit the requirements for use at regional level. There are however a few datasets with weaknesses of which the most important are :

- **Angolan bathymetry close to coast** : the sources used to establish this dataset are navigation charts of the Hydrographical Institute (IH) in Portugal and the topographic maps of Angola. The overlap between the datasets was very poor and in the order of a few hundred meters up to more than a kilometer. It is not clear which of the two map sets has the poorest accuracy as no depth measurements were available. It would be useful to do an accuracy assessment of this and other bathymetric datsets (such as those of the Real Admiralty of the UK) with depth measurements of the Norwegian research vessel Nansen or of oil companies (who were very reluctant to give data to this project). This exercise would probably take a few weeks as Marek Ostrowski of IMR, Norway, indicated that a lot of the depth measurements need further processing.
- **Texture of marine sediments** : the dataset collected for Namibia is not very accurate as the sample density was very low : an average of 257 km^2/sample. It would be an expensive exercise to upgrade this dataset, although relevant mine surveys and acoustic measurements may have already covered a substantial area of the continental shelf. The collection and merging of this data would be a project on its own. No information was obtained on the sample density used to compile the Dingle dataset of South Africa. The Angolan dataset is based on acoustic measurements, however digitised from maps in a scientific article. It would be advisable to collect the original maps or reprocess the acoustic data of the Nansen.

- **Coastal mines** : these datasets are incomplete for South Africa and Angola. Requests were submitted to the relevant authorities but no further data was obtained. The collection of this data is actually a task of the Threats project.
- **Fog data for South Africa and Namibia** : the data does not match at the border and accuracy of both datasets is low.
- **Transformation in Angola** : The data used to map human transformation along the Angolan coastline is for about 50 % of the coastline outdated (based on topographic maps of the 1980ies). No remote sensing images with high enough resolution and affordable to the project could be obtained for this part of the coast. The information collected by the Threats project should complement this dataset.
- **Seamounts and marine canyons** : for Namibia and Angola, these underwater features were digitised based on the GEBCO information and definitions of the features. The resolution of the GEBCO data is however 1' or 1.7 km and seamounts and canyons smaller than approximately 10 km x 10 km can easily have been missed because of the average value of the depth per pixel of 1.7 km x 1.7 km. It is not known if there are other sources of information to locate seamounts and marine canyons in Namibian and Angolan waters.

One of the most important outputs of this project is the establishment of the biozones dataset, a major input into the MOM biodiversity conservation planning exercise. The biozones dataset could be established based on expert input, the bathymetry, EEZ, country, continental shelf, settlement and places datasets. Most of the last datasets mentioned were also based on a common data source which acted as a reference for this project : the coastline. The establishment of accurate coastline data was considered a priority during this project. This resulted in an accuracy of 100 m or less for each BCLME country.

It should be stressed that the datasets established for this project are not all owned by the BCLME/BENEFIT project and that their main purpose is to serve as an input into the MOM project. Certain datasets have copyrights, can not distributed to third parties and/or need acknowledgement or referencing. It is therefore not permissible to distribute the physical mapping dataset as a complete bundle. A thorough scrutiny of the meta data – indicating copyrights – is first required before distributing, reproducing or publishing any physical mapping dataset.

This project could not have be realised without the assistance and cooperation of many organisations and persons. All these persons and organisations are mentioned in the report (mainly in unit 2 – project team) or in the meta data. It is recommended to invite all these persons and representatives of the organisations to a final symposium on which the BCLME/BENEFIT biodiversity project results are presented. A lot of the persons that gave data will be interested in the final results, may even want to use them and would be interested in any comments on the accuracy and completeness of the data they provided.

References

AFRICA PILOT (1977). *Volume II: Comprising the west coast of Africa from Bakasi Peninsula to Cape Agulhas; islands in the Bight of Biafra; Ascension Island; Saint Helena Island; Tristan da Cunha Group and Gough Island*. Twelfth Edition. Somerset, England. The Hydrographer of the Navy. *In :* MORANT, P. 1999. *BCLME Thematic report No 5. Integrated overview of the coastal environment between the Congo river mouth and Cape Agulahas.* Submitted to UNDP. CSIR REPORT ENV-S-C 98101. ENVIRONMENTEK, CSIR, Stellenbosch, South Africa.

BANKS, N., 2002. *Survey Report Namibian Coastline Survey.* Performed for Survey General of Namibia, Ministry of Lands and Resettlement by Airborne Laser Solutions (Pty.) Ltd. Internal short report.

BIANCHI, G. (1992). *Demersal assemblages of the continental shelf and upper slope of Angola.* Marine Ecology Prog. Ser. Vol. 81: 101 - 120.

CLIFFORD, J. & MUGNIER, C.P., 2001. *Grids and datums. The republic of Angola.* Photogrammetric engineering & Remote Sensing, p. 253 – 257.

COASTAL ENGINEERING RESEARCH CENTER (CERC), 1977. *Shore Protection Manual*. U.S. Army Corps of Engineers, Vicksburg, Mississippi. [Online] *In :* HOWES, D.E., HARPER, J.R. & OWENS, E.H., 1994. Physical shore-zone mapping system for British Columbia. Technical Report. Coastal and Ocean Resources, Inc., Sidney, BC for the Coastal Task Force of the Resource Inventory Committee (RIC), RIC Secretariat. Victoria, BC. URL : ilmbwww.gov.bc.ca/risc/pubs/coastal/pysshore/.

CURRIE, H., 2005. *Proclamation of Namibia's offshore islands and surrounding waters as Marine Protected Areas.* WWF project ZA 1398 . WWF.

DA FRANCA, P., CORREIA DA COSTA, F. & SERPA DE VASCONCELOS, H., 1964. *Notas mimeografadas do centro biologia piscatoria Nos 41 - 46. Contribuicao para o estudo da pesca de arrasto em Angola*. Lisboa.

DE CAUWER, V., 2004. *Assessment of marine data in Namibia with respect to GIS*. Prepared for the **Benguela Current Large Marine Ecosystem (BCLME) programme under** UNOPS SAA – RAF00G32.

FREIRE, S., 2006. *Geospatial data on Angola*. Internal report for Physical Mapping project BENEFIT/BCLME.

HOWES, D.E., HARPER, J.R. & OWENS, E.H., 1994. *Physical shore-zone mapping system for British Columbia. Technical Report*. [Online] Coastal and Ocean Resources, Inc., Sidney, BC for the Coastal Task Force of the Resource Inventory Committee (RIC), RIC Secretariat. Victoria, BC. URL : ilmbwww.gov.bc.ca/risc/pubs/coastal/pysshore/

KRUGER, A.C., 2002. *Climate of South Africa. Surface winds.* South African Weather Service, Pretoria.

LOMBARD, A.T., 2005. *Notes of the Namibia (1st) Stakeholder Workshop. 7 June 2005, Swakopmund, Namibia. BCLME / BENEFIT Marine biodiversity status assessment and*

conservation planning for the Benguela current. Project number: BEP/BAC/03/01. Internal report. BENEFIT, Swakopmund, Namibia.

LOMBARD, A.T., STRAUSS, T., HARRIS, J., SINK, K., ATTWOOD, C. & HUTCHINGS, L., 2004. *National Spatial Biodiversity Assessment – Marine Component.* Prepared for the National Botanical Institute of South Africa.

MENDELSOHN, J., JARVIS, J., ROBERTS, C. & ROBERTSON, T., 2002. *Atlas of Namibia. A portrait of the land and its people.* Ministry of Environment and Tourism, Namibia.

MOLLOY, F., 2003. *Coastal Environment.* p. 26. *In :* MOLLOY, F. & REINIKAINEN, T. (eds.), 2003. *Namibia's Marine Environment.* Directorate of Environmental Affairs of the Ministry of Environment and Tourism, Namibia.

MOLLOY, F. & REINIKAINEN, T. (eds.), 2003. *Namibia's Marine Environment.* Directorate of Environmental Affairs of the Ministry of Environment and Tourism, Namibia.

MORANT, P., 1999. BCLME *Thematic report No 5. Integrated overview of the coastal environment between the Congo river mouth and Cape Agulahas.* Submitted to UNDP. CSIR REPORT ENV-S-C 98101. Environmentek, CSIR, Stellenbosch, South Africa.

MORANT, P., 2004. *Environmental Impact Assessment for the proposed Kudu gas field development project on the continental shelf of Namibia.* Prepared for Energy Africa Kudu Limited. Environmentek, CSIR, Stellenbosch, South Africa.

OFFICE OF THE GEOGRAPHER, 1970. *International Boundary Study. Series A. Limits in the Seas. Straight baselines Angola*. Office of the Geographer, Bureau of Intelligence and Research, Department of State, Washington, USA.

OLIVIER, J., 2002. *Fog-water harvesting along the West Coast of South Africa : a feasibility study.* Water SA, Vol. 28 No. 4. Available at : www.wrc.org.sa.

PINET, P.R., 1996. *Invitation to Oceanography.* 3rd Edition. St. Paul, MN: West Publishing Co. *In :* WIKIPEDIA, 2007a. *Continental Shelf* [Online]. URL : http://en.wikipedia.org/wiki/ (Last accessed on 23 September 2007).

ROUGET, M., REYERS, B., JONAS, Z., DESMET, P., DRIVER, A., MAZE, K., EGOH, B., COWLING, R.M., 2004. *South Africa National Spatial Biodiversity Assessment 2004*. Technical Report Volume 1 : Terrestrial component. SANBI.

SHACKLETON, L., 1993. *Environmental data workshop for oil spill contingency planning*. Windhoek 17 – 18 August 1993.

SHANNON, L.V. & O'TOOLE, M.J., 1999. *Integrated overview of the oceanography and environmental variability of the Benguela Current region. Synthesis and assessment of information on the Benguela Current Large Marine Ecosystem (BCLME).* Thematic report No 2. BCLME, Windhoek, Namibia.

SOUTH AFRICAN NAVY, 2000. S-57 *Appendix A - Chapter 2. SAN attributes.* Edition 3.1. SAN, South Africa.

STROMME, T. & SAETERSDAL, G., 1991. *Surveys of the fish resources of Angola, 1985 – 86 and 1989. Reports on surveys with RV 'Dr. F. Nansen'.* Institute of Marine Research,

Bergen, Norway. *In :* BIANCHI, G. (1992). *Demersal assemblages of the continental shelf and upper slope of Angola.* Marine Ecology Prog. Ser. Vol. 81: 101 - 120.

THE READER'S DIGEST ASSOCIATION, 1984. *Reader's Digest Great illustrated dictionary.* Reader's Digest, New York, USA.

WANNASURF.COM, 2003. *Angola. Africa.* [Online] Wannasurf.com Ltd. URL : www.wannasurf.com (Last accessed on 22 April 2007).

WIKIPEDIA, 2007a. *Continental Shelf* [Online]. URL : http://en.wikipedia.org/wiki/ (Last accessed on 23 September 2007).

WIKIPEDIA, 2007b. *United Nations Convention on the Law of the Sea* [Online]. URL : http://en.wikipedia.org/wiki/UNCLOS (Last accessed on 23 September 2007).

ANNEX 1 – List of contacted persons for the physical data inventory

Persons contacted to obtain data or information on data (AR = Amanda Rau, VDC = Vera De Cauwer, HT = Heitor Timoteo, LM = Livio Mercurio, BC = Barry Clark, SH = Simon Hughes, SF = Sergio Freire)

Country for which data is requested	Contact person	Person/Organisation Contacted, country	Data Requested	Response
SA	AR	Ian McLachlan, SA	Shelf Break, Oil platforms	Ian McLachlan no longer with SA petroleum, has to be requested elsewhere
SA	AR	Belinda Reyers and Lucille Schoenegevel - CSIR, SA	Shelf break, oil platforms, coastal mines, marine mine concessions	Negative for shelf break, oil platforms, mines, concessions
SA	AR	Larry Hutchins, SA	Diamond Concession Areas, natural resource production areas, oil/gas platforms and wells	waiting
SA	AR	Sven Coles, Council for GeoScience, SA	Dingle	received permission to use data
SA	AR, VDC	Trevor Wolf, SA	topo maps	Received (outsourced)
SA	VDC	Mandy Lombard, SA	EEZ, Dingle, texture, submarine canyons, sea mountains and banks, coastal sensitivity atlas, terrestrial parks, sediment texture	All received (submarine canyons included in Dingle)
SA	AR, VDC	Abri Kampfer – SA Navy, SA and Lucille Schoenegevel, CSIR	bathymetry	received through Lucille Schoenegevel, CSIR and official agreement of SAN
SA	VDC	Dave Japp, SA	substrate/trawl assessment	negative, no release data allowed
SA	VDC	Taniia Strauss, SA	refinement certain NBSAP data : terrestrial protected areas, estuary locations and names, coastline, islands, population data, ...	All received
SA	VDC	Taniia Strauss, SA	Downloaded Google images (LANDSAT)	All received
NA	VDC	Abry Kampfer – SA Navy, SA	bathymetry data	received all data in DAF format (Trevor requested in S57 format)
NA	VDC	Karim Owolabi - MLR, NA	Base line points, colour orthophotos coast line, laser points, bathymetry data	All received
NA	VDC	Ute Schreiber, Anna-Karen Nguno and Volker Petzler – Geological Survey, NA	marine sediments, bathymetry, concessions, mines	All received
NA	VDC	Uzo Okafor and Franke - MLR, NA	orthophotos, topographic maps	can be purchased at a certain price (see inventory)
NA	VDC	Roger Swart - NamCor, NA	bathymetry, marine sediments, coastal sensitivity	most detailed data is not at NAMCOR but at other institutes, pointed to useful EIA reports
NA	VDC	Sophia Theki – Roads Authority, NA	roads data	Received (requests to get data of the project in return)

Country for which data is requested	Contact person	Person/Organisation Contacted, country	Data Requested	Response
NA, SA	VDC	Pat Morant and Susan Taljaard - CSIR, SA Roland Roeis - MAWF, NA	water outlet points	Received report for SA but without coordinates
NA	AR	Hans Huckstedt - SAMICOR, NA	bathymetry and sediments	Received data
NA	AR, VDC	Andre Goosen and Lina Maartens – De Beers/NamDeb, NA	bathymetry and sediments	Received data
NA	VDC	Ger Kegge – Energy Africa, NA	Concession area Kudu, EIA Kudu	Received EIA report and a survey report
NA	VDC	Paul Kainge, MFMR	Untrawable areas	Official request approved by PS, data 2000 – 2003 received
NA	VDC	Rod Braby, NACOMA	Wave Exposure	Has given expert input and info on useful websites
NA	VDC	Chris Bartholomae & Anja Van Der Plas MFMR	Oceanographic data	Official request approved by PS, maps obtained
NA	VDC	Celeste Espach, MAFW	Mosaic Landsat images coast	Received (outsourced)
NA	VDC	Heidi Currie and Colette Grobler	Information on existing and proposed MPA's	Received all information
NA/AN	AR	Alex Warne	Obtain transboundary info NA/Angola	waiting
AN	VDC, HT	Maria Martins and Ronnie Gallagher – Department of Environment - BP, AN	bathymetry, sediments, concession areas, habitats	referred to Sonangol as they need to give approval first, received CD-ROM with environmental data
AN	VDC, BC, SH	Cartographic Institute, AN	topographic maps	Bought
AN	VDC, BC, SH	Cartographic Institute, AN	B/w aerial photographs made by Russians in seventies (1:34,600, 1:66,700)	HT to buy photos
AN	HT	Department of Environment - Sonangol, AN	Pollution data	No feedback
AN	HT	Ercílio Almeida, Ângelo Pegado & Victor Manuel Silva – Dep. of Treatment of cartographic data - Sonangol, AN	Coastline, bathymetry, coastal types (geomorphology), mines, rivers	Bathymetry data : not trustworthy, received oil concession areas, negative for other datasets
AN	HT	M'vezi Maziano - Department of Interpretation, Sonangol	Marine sediments	Negative feedback
AN	HT	Geographical and Cadastral Institute of Angola – IGCA, AN	Coastline, EEZ, coastal topography, bathymetry, cities, roads, rivers	Hard copies obtained + scans 1:250K topomaps – no vector data available yet (on-going project)
AN	HT	Ministry of Geology and Mines, NA	Geological maps	Received analogue maps
AN	HT	Ministry of Transport (Direccao de Hidroportos and Marinha Mercante), NA	Bathymetry	No feedback

Country for which data is requested	Contact person	Person/Organisation Contacted, country	Data Requested	Response
AN	HT, VDC	Mohammad Qasim, CNIDAH (Commission Nacional Intersectoral de Desminagem e Assistancia de Humanitaria), NA	All relevant GIS data of their GIS database, Position of land mines	Data quality not good enough (information HT)
AN	HT	Bomba Sangolay – INIP, AN	Oceanographic data, untrawable areas, MPA's	Waiting
AN	HT	Institute of Artisanal Fisheries	Population, ...	No feedback
AN	VDC	B. De Cauwer, Belgium	Download Landsat images Angola	CD-ROM posted to Namibia
AN	SF, VDC	Hydrographic Institute of Portugal (IH)	Nautical Charts	Nautical charts posted to Namibia
AN	SF, VDC	Tropical Research Institute of Portugal (IICT)	Coastal types/geomorphology	No knowledge of such dataset, but a few studies were made on small stretches of coastline (articles sent by SF)
AN	VDC	Gabriella Bianchi, Italy	Data of sediments maps in article 1992	Original data not available, obtained permission to digitise data from article
AN	VDC	Pat Morant	Wind and wave information	Received
NA, SA, AN	VDC	Natural Environment Research Council, UK	GEBCO world bathymetry	CD-ROM arrived
NA, SA, AN	VDC	Dewald Lloyd	satellite images	prices of satellite images
NA, SA, AN	VDC	Celeste Espach, MAFW	SRTM mosaic for BCLME	Received (outsourced)

ANNEX 2 – Physical data inventories for the BCLME countries

Extracted from the overview page of the physical data dictionary.

Namibia

N°	Dataset	Source	Data structure	Digital format	Accuracy	Precision	Data coverage	Quality assessment	Steps to obtain data
1	bw_orthophotos	Ministry of Lands & Resettlement (MLR)	Digital - Raster	tif (+ tfw)	1:80,000	2 m	Namibia, photos 25,8 km width	good quality but colour orthophotos better	buy data
2	topomaps	Ministry of Lands & Resettlement (MLR)	Hardcopy	N/A	1:50,000	height interval ?	original maps not complete for Namibian coastline	not so good, old, bw orthophotos better	buy maps
3	low_water_line	Ministry of Lands & Resettlement (MLR)	Digital - text	*.txt	20 m RMS	every 1 to 3 minutes	Namibia	very good, best available	Already obtained with official request
4	colour_orthophotos	Ministry of Lands & Resettlement (MLR)	Digital - Raster	*.ecw	< 1 m RMS	1 m	Namibian coastline (strip width about 1 km)	very good, best available	Already obtained with official request
5	islands	Namibia's Marine Environment (Molloy & R., 2003), table 4.1	Hardcopy	N/A	not indicated	N/A	not all islands, table 7.3 indicates more	only to be used when islands are not indicated on navy charts	already obtained
6	coastal_bathymetry	SA Navy	Digital - Vector (lines and points ?)	DAF, S57 and maybe dxf or shp	1:300,000	10 m ?	Namibian coastline, see SAN charts	best available for complete coverage	Official request (already submitted)
7	place_names	Atlas of Namibia	Digital - Vector (points)	shp	N/A (see processing steps)	N/A	whole coastline	probably best available, but needs to be checked	Already obtained
8	laser_points	Ministry of Lands & Resettlement (MLR)	Digital - text/dbase	*.xyz (can be imported in Excel)	< 1 m RMS	0,01 m (elevation)	Namibian coastline	very good, best available	Already obtained with official request
9	marine_sediments	Geological Survey	Digital - polygons	ArcInfo coverage and shp	to be determined	to be determined (sample density)	almost whole EEZ	appears to best available with national coverage	request per e-mail pending
10	sea_bottom_texture	Geological Survey	Digital - polygons	ArcInfo coverage and shp	to be determined	to be determined (sample density)	almost whole EEZ	appears to best available with national coverage	request per e-mail pending

N°	Dataset	Source	Data structure	Digital format	Accuracy	Precision	Data coverage	Quality assessment	Steps to obtain data
11	bottom_hardness_roughness	Nansen, IMR, Norway	Digital - Vector (points ?)	ASCII	not known	1 m	ship tracks	better than Geological Survey data, lot of processing work remains	request NatMIRC + quote processing work
12	offshore_bathymetry	Nansen, IMR, Norway	Digital - Vector (points ?)	ASCII	not known	1 m depth, 1 m resolution	ship tracks	more detailed than any other offshore bathymetry dataset	request NatMIRC + Obtain quote interpolation work
13	mineral_deposits	Atlas of Namibia	Digital - Vector (points)	shp	unknown	N/A	whole coastline	best available, but checking necessary	already obtained
14	roads	Roads Authority (RA)	Digital - Vector (lines)	shp	unknown	N/A	Namibia	Roads coastline need checking	request submitted
15	railways	Atlas of Namibia	Digital - Vector (lines)	shp	unknown	N/A	Namibia	best available, but checking necessary	already obtained
16	harbours	Atlas of Namibia	Digital - Vector (points)	shp	unknown	N/A	Namibia	needs updating	already obtained
17	mines	Atlas of Namibia	Digital - Vector (points)	shp	unknown	N/A	Namibia	needs checking and updating	already obtained
18	prospecting_licenses	Geological Survey	Digital - polygons	ArcInfo coverage and shp	Not specified	N/A	EEZ	best available	request per e-mail pending
19	mining_licenses	Geological Survey	Digital - polygons	ArcInfo coverage and shp	Not specified	N/A	EEZ	best available	request per e-mail pending
20	oil_gass_licenses	Atlas of Namibia	Digital - Vector (polygons)	shp	unknown	N/A	Namibia	needs checking and especially updating	already obtained
21	terrestrial_protected_areas	Atlas of Namibia	Digital - Vector (polygons)	shp	variable, see attributes	N/A	Namibia	needs checking and updating	already obtained
22	oceanography	NatMIRC, MFMR	Digital - database	cnv, csv, xls	unknown	depending on data	to be verified	best available	to be verified
23	rivers	Atlas of Namibia	Digital - Vector (lines)	shp	1:1,000,000	N/A	Namibia	good enough for purpose	already obtained
24	catchments	Atlas of Namibia	Digital - Vector (polygons)	shp	1:1,000,000	N/A	Namibia	good enough for purposes	already obtained
25	administrative_boundaries	Atlas of Namibia	Digital - Vector (polygons)	shp	not specified	N/A	Namibia	country boundary needs checking	already obtained

South Africa

N°	Dataset	Source	Data structure	Digital format	Accuracy	Precision	Data coverage	Quality assessment	Steps to obtain data
1	coastline	1:50,000 topomaps, GIMS	Digital - Vector (lines)	AI coverages	1:50,000	0	South Africa	very good, best available	Already obtained (Mandy)
2	coastal_bathymetry	SA Navy	Digital - Vector (polygons)	AI coverages	0	0	SA coast : SAN charts 1:150,000	0	Already obtained (Mandy)
3	coastal_sensitivity	IDYLE project, MCM and Jackson & Lipschitz (1984)	shp	shp	unknown	coastline SA	coastline SA	Already obtained (Mandy)	Already obtained (Mandy)
4	san150000contours	SAN 1: 150 000 charts	Digital lines	shp	1:150,000	to verify	part of SA west coast, no data >1000m north of St Helena	best available, other format than coastal_bathymetry	Official Request SAN
5	san150000coast	SAN 1: 150 000 charts	Digital line	shp	to verify	to verify	full coastline	0	Official Request SAN
6	san150000points	SAN 1: 150 000 charts	Digital points	shp	to verify	to verify	gaps in northern part near Orange River	0	Official Request SAN
7	diamond_conc_SA	Regional Director of Ministry of Minerals and Energy, Cape Town and Kimberly	Hardcopy, can get digital SS/GR	dxf	0	0	Full SA coastline. Bathy contours @ 50m to depth of 3000m; @ 100 m to max depth; Max. depth 4500 m.	Very Good	Request either SS or GR
8	sediments	Dingle et. al., 1987; Council for Geoscience	Digital (Mandy)	0	to verify	to verify	SA coastline to depth ~500m	0	Mandy has Dingle data, Request Sven Coles (scoles@geoscience.org.za) / Rio Leuci (leuci@ukzn.ac.za) as Ramsay now private
9	terrestrial_protected_areas	South African National Spatial Biodiversity Assessment 2004 for SANBI	Digital - Vector (polygons)	shp	to verify	N/A	SA	best available	Already obtained
10	topomaps	0	Hardcopy	N/A	1:50,000	0	SA	best available	buy scans ?

Angola

N°	Data set	Description	Projection	Ref. ellipsoid	Data coverage	Data structure	Digital format	Accuracy / Scale	Resolution	Source
1	ang_bw_aerial_photos_35K	230 black and white aerial photos available for the whole country at scale 1:34,600	N/A	N/A	Angola, photos 10.4 km wide, coastline dataset not complete	Hardcopy	N/A	1:34,600	0	Instituto de Geodesia e Cartografia
2	ang_bw_aerial_photos_67K	260 black and white aerial photos available for the whole country at scale 1:66,700	N/A	N/A	aerial survey Soviets in 1979-1980	Hardcopy	N/A	1:66,700	0	Instituto de Geodesia e Cartografia
3	ang_topomaps_100K	33 scanned and georeferenced topographic maps with scale 1:100,000 covering Angola	DD	WGS84	whole coastline !	Digital - Raster	tiff/tfw	10 m - Scale 1:100,000	10 m	Maps : Instituto de Geodesia e Cartografia, Scanning : GISCOE, SA
4	ang_geol_1000K	Geological map of Angola	0	0	0	0	0	1: 1,000,000	0	Ministry of Geology and Mines
5	ang_concessions	Angolan concession areas for mines, oil companies	0	0	0	0	0	0	0	Sonangol - Department of treatment of cartographic data
6	ang_map_C&Ctechnologies	Preliminary compilation and analysis of the Angolan EEZ, by C&C technologies	Mercator	WGS84	Angolan EEZ	Digital - Raster	jpeg	0	1:2,000,000	Geographical and Cadastral Institute of Angola - I.G.C.A
7	ang_bathymetry	Angolan bathymetry maps	0	0	0	0	0	?	contain 10 m, 30m, 1800m, 3500m contours and shelf break	Geographical and Cadastral Institute of Angola - I.G.C.A, also Sonangol - Department of treatment of cartographic data
8	ang_topomaps_1000K	4 scanned and georeferenced topographic maps with scale 1:1,000,000 covering Angola	DD	WGS84	whole coastline !	Digital - Raster	tiff/tfw	93 m - Scale 1:1,000,000	93 m	Maps : Instituto de Geodesia e Cartografia, Scanning : GISCOE, SA
9	ang_topomaps_250K	scanned topographic maps with scale 1:1,000,000 covering Angola, not georeferenced	UTM	Clarke 1880	0	Digital - Raster	jpeg	1:250,000	to be determined after georeferencing	Geographical and Cadastral Institute of Angola - I.G.C.A
10	ang_mines	position of mines, oil and gas extraction	0	0	0	0	0	0	0	Sonangol - Department of treatment of cartographic data
11	ang_coast_type	coastal types - geomorphology (including salt pans) : rocky, sandy, mixed beach, dunes	0	0	0	0	0	0	0	Sonangol - Department of treatment of cartographic data

BCLME region

N°	Dataset	Source	Data structure	Digital format	Accuracy	Precision	Data coverage	Quality assessment	Steps to obtain data
1	land_topography_SRTM	NASA	Digital - Vector or Raster	various : ArcGrid (USGS), Bil (USGS), GeoTIFF (GLCF), SRTM, …	0	3", about 90 m	global (terrestrial)	not precise enough for supratidal, topographic data will be required	Download from Internet
2	offshore_bathymetry_G	GEBCO	Digital - Raster and Vector (lines)	?, dxf, shp	1' grid or 1:1,000,000	20 to 500 m interval	EEZ	unsure as data originates from 3 different sources	Buy CD-ROM
3	offshore_bathymetry_E	ETOPO2, by Smith & Sandwell, 1997	Digital - Raster and Vector ?	*.dos, …	0	2' (about 3.6 km), vertical 1 m	0	GEBCO has higher resolution (1') but may not necessarily have higher accuracy	Already obtained for SA (Mandy), otherwise from Internet

ANNEX 3 – Final data assessment

This data assessment indicates the final data layers that could be created with indication of the source data. The colours present the priority of the data :

priority 1
priority 2
priority 3

The name of the final datasets are indicated, for example 'ph_coastl_li_*'. The second last part of the name indicates if it concerns a line (li), polygon (pol) or point (pt). The asterix * is representing the abbreviation for the country - an, na or sa – as all datasets will be delivered per country. Note that all final datasets – except for the images and grids - are shape format (*.shp).

The datasets indicated in dark blue font are completely new datasets created by the physical mapping project. The datasets indicated in green are available on regional level : one dataset for the BCLME region.

	Physical data	**South Africa**	**Namibia**	**Angola**
1	Coastline (includes islands) ph_coast_li_*	NSBA (1:50,000 topographic maps) + SAN (Taniia)	Digitised from orthophotos SG	Orthorectified LANDSAT images 2000
2	Country (with islands) ph_country_pol_*	Coastline from previous dataset, rest from Geological Survey of Namibia data	Coastline from previous dataset, rest from Geological Survey of Namibia data	Coastline from previous dataset, rest from Geological Survey of Namibia data
3	Islands ph_islands_pol_*	1:50,000 topographic maps + SAN charts (refinement of NSBA data)	Digitised from orthophotos + name of islands of 1:50,000 topomaps or SAN charts	Orthorectified LANDSAT images 2000 + topomaps
4	Bathymetry close to coast ph_bathy_coast_li_*	1:150,000 maps SA Navy (version CSIR)	1:300,000 maps SAN + 0 depth from ph_coast_li_na	Portuguese IH maps + topomaps 1:100,000 & 1:25,000
5	Bathymetry offshore ph_bathy_off_li_* ph_bathy_off (grid)	Extraction from GEBCO	Extraction from GEBCO	Extraction from GEBCO
6	Classification of marine sediments ph_mar_sedim_pol_*, ...	Dingle (NSBA)	a) for south : Dingle b) Geological Survey of SW Africa (du Plessis & Scoon , 1988)	/
7	Texture of marine sediments ph_mar_texture_pol_*, ...	a) Council of GeoScience (NSBA) b) Geological Survey of SW Africa (du Plessis & Scoon , 1988)	Geological Survey of SW Africa (du Plessis & Scoon , 1988)	Figures from Bianchi, G. (1992) - redrawn from Stromme & Saetersdal (1991)
8	Intertidal coastal types (including wave exposure) ph_coast_types_li_*	coastal sensitivity atlas + wave exposure (NSBA updated)	colour orthophotos Survey General + Rod Braby	Orthorectified Landsat + 1:100,000 topographic maps + Google + Pat Morant
9	coastal cities, settlements ph_settl_pt_*	1:50,000 topographic maps	Atlas of Namibia + colour orthophotos	1:100,000 + 1:25,000 topomaps

	Physical data	South Africa	Namibia	Angola
10	Coastal places (including lighthouses, landmarks, shipwrecks, ...) ph_places_pt_*	1:50,000 topographic maps	1:50,000 topomaps + fishing map	1:100,000 topomaps
11	harbours ph_harbour_pt_*	ph_settl_pt_sa + ph_coast_types_li_sa + ph_transf_li_sa + info Port authorities	ph_settl_pt_na + Namport info	ph_settl_pt_na + info 1:100,000 topo maps
12	Coastal mines (up to 80 km inland) ph_mines_pt_*	1:50,000 topomaps	Atlas of Namibia + colour orthophotos	Wells Sonangol
13	Marine and coastal mining areas (diamonds and oil) ph_mar_mining_pol_*	Council for GeoScience : concessions areas	Geological Survey of Namibia	SONANGOL concessions
14	marine protected zones ph_mpa_pol_* ph_prop_mpa_pol_na	NSBA	Laws extracted by Heidi Currie and MPA proposal of WWF	N/A
15	coastal protected zones ph_cpa_pol_* ph_cpa_pt_*	NSBA (terrestrial)	Atlas of Namibia + Survey General	WDPA database
16	Rivers (coastline) ph_river_li_*	1:50,000 topographic maps	Atlas of Namibia + orthophotos SG + Landsat ETM 1999 - 2002	Orthorectified LANDSAT images 2000 + 1:100,000 topomaps
17	Saltpans ph_saltp_pt_*	Input experts and others	Colour orthophotos SG + topographic maps	1:100,000 topomaps
18	Transformation ph_transf_li_*	Google	Colour orthophotos SG	Google + topographic maps + Landsat
19	Exclusive Economical Zone and territorial waters ph_eez_pol_*	200 nm of baseline points + NSBA and diamond concession map	200 nm of baseline points + Treaty 2005	200 nm of baseline points + map C&C technologies + concession areas Sonangol
20	roads (no tracks needed) ph_road_li_*	1:50,000 topographic maps	Roads Authority + Colour orthophotos SG + topographic maps	Orthorectified LANDSAT images 2000 + 1:100,000 & 1:25,000 topomaps
21	railways along coastline ph_rail_li_*	1:50,000 topographic maps	Atlas of Namibia + topographic maps	Digital Chart of the World (DCW)
22	untrawable grounds ph_untrawable_pt_* ph_untrawable_pol_*	/ (Not available)	Trawling data MFMR 2000 - 2003	Old Portuguese maps
23	Satellite images coast ph_sat_im_*	Google Earth images	Landsat mosaic	Geocover Orthorectified Landsat
24	Russian maps 1:500,000 ph_maps_im	Downloaded Madmappers	Downloaded Madmappers	Downloaded Madmappers
25	coastal types – geomorphology (polygon) ph_coast_types_pol_*	/	Colour orthophotos SG	/

	Physical data	South Africa	Namibia	Angola
26	Population density africa04	Landscan data	Landscan data	Landscan data
27	Fog ph_fog_pol_*	/	Atlas of Namibia	Olivier (2002)
28	Sediment thickness sed_thick_wrld	NGDC - NOAA	NGDC - NOAA	NGDC - NOAA
29	Water area (rivers or other) ph_water_pol_*	1:50,000 topographic maps	Landsat	Orthorectified Landsat 2000 + 1:100,000 topomaps
30	Seamounts ph_seamount_pol_*	NSBA	Digitised on slope map derived from GEBCO grid	Digitised on slope map derived from GEBCO grid
31	Marine canyons ph_mar_canyon_pol_*	NSBA	Digitised on slope map derived from GEBCO grid	Digitised on slope map derived from GEBCO grid
32	Continental shelf ph_cont_sh_li_*	Digitised on slope map derived from GEBCO grid	Digitised on slope map derived from GEBCO grid	Digitised on slope map derived from GEBCO grid
33	Biozones ph_biozones_pol_* ph_biozo_sym_pol_*	NSBA	Workshop Swakopmund 7 June 2005	Workshop Luanda 30 June 2005 + Pat Morant + Marek Ostrowski + Neville Sweijd
34	Coastline with indication of estuaries ph_estuary_li_*	Expert input	/ (can be found in 8)	/ (can be found in 8)
35	Sadc countries ph_sadc_pol	Geological Survey of Namibia	Geological Survey of Namibia	Geological Survey of Namibia
36	SRTM (topography) ph_dem_im_*	compiled by Celeste Espach	compiled by Celeste Espach	compiled by Celeste Espach
37	Elevation contours ph_relief_li_*	1:50,000 topographic maps	/	/
38	Elevation points ph_relief_pt_*	1:50,000 topographic maps	/	/
39	Coastal and marine mine prospection areas (polygons) ph_epl_pol_*	/	Geological Survey of Namibia	/
40	Reefs ph_reef_pt_*	1:50,000 topographic maps and Google Earth	Colour orthophotos SG	Cuntala artificial reef 6°38'5"S, 12°9'49"E
41	Temperature ph_temp_im_na, ph_kwanza_pt_an	/	MFMR	Data of Kwanza measurements
42	natural resources production ph_nat_res_pt_*	/	Compilation of different sources	/
43	oxygen ph_oxygen_pt_*	/	MFMR	See Kwanza measurements (4.41 ph_kwanza_pt_an)
44	Salinity ph_sal_pt_*	/	MFMR	See Kwanza measurements (4.41 ph_kwanza_pt_an)

	Physical data	South Africa	Namibia	Angola
45	Wells ph_wells_pt_*	Internet : abandoned well heads	See SA	Sonangol : offshore wells
46	Population along coast (detail) ph_popul_pol_sa	Digitsed by Taniia	/	/
47	Baseline points ph_baseline_pt_* ph_baseline_li_*	Internet	Survey General	Internet
48	Gebco slope map ph_slope_off (grid)	Calculated from Gebco grid	Calculated from Gebco grid	Calculated from Gebco grid
49	High water mark ph_hwm_est_li_na ph_hwm_li_na	/	Colour orthophotos Survey General	/
50	Bclme countries and EEZ ph_country_pol_bclme ph_eez_pol_bclme	Compilation of country data	Compilation of country data	Compilation of country data
51	Dunes ph_dunes_pol_na	/	Landsat + Topographic maps	/

ANNEX 4 – Description of fish groups Bianchi (1992)

- **group 1 :** shallow water assemblage, average depth 24 m (stand_dev. 14 m), turbid waters ;
- **group 2** : coastal species in thermocline area, average depth 47 m (stand_dev. 16 m), samples of this group go up to Benguela *with one outlier sample at Ponta das Salinas (Group 2 indicated in italic)* ;
- **group 3 :** coastal species in thermocline area**,** only 5 stations, average depth 37 m (stand_dev. 12 m), tropical regime ;
- **group 4 :** subthermocline sparid assemblage, average depth 87 m (stand_dev. 17 m), samples of this group go up to Benguela *with two outlier samples : at Ponta das Salinas and Cabo Negra (Group 4 indicated in italic)* ;
- **group 5** : subthermocline assemblage of soft bottoms, depth 70 - 140 m, , average depth 112 m (stand_dev. 41 m), 52 % of total catch consists of the splitfin which is a species mainly of the upper slope, however the depth range indicates that all trawls were performed on the shelf ;
- **group 6** : subthermocline assemblage in south, no thermocline because of continuous upwelling, average depth 88 m (stand_dev. 36 m), low oxygen levels ;
- **group 7** : upper edge continental slope, average depth 256 m (stand_dev. 56 m), from Ambriz to Lobito with *with one outlier sample at Cunene (Group 7 indicated in italic) – not that no upper slope samples were taken in area between Lobito and Cunene* ;
- **group 8** : average depth 461 m (stand_dev. 91 m), cold water (8 degrees), mainly trawled at night.