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Preparation of a bathymetric map and GIS of the
South Atlantic Ocean and a review of available
biologically relevant South Atlantic Seamount data
for the SEAFO Scientific Committee

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<i>ABSTRACT</i> <p>This report has brought together various data sets from a number of public sources around the world to produce the most up-to-date regional bathymetric map of the South Atlantic in both printed and digital form. The use of a data control layer in the GIS allows users of this report an indication of the data accuracy and quality. Physical and chemical parameters have also been included in the GIS, so that the Temperature, Salinity and Oxygen content of the South Atlantic, all primary agents in the distribution of the various forms of biology can be examined, at different critical depths at the same time. These critical depths were determined to be those that had most effect on the biology, and were the sea surface (0m), the lower limit of the photic zone, which we approximated to 200m, and the lower limit of the likely vertical migration of zooplankton, a major source of food at 1000m depth. Other elements presented include biogeographical provinces defined by Longhurst, a geographic depiction of the formally UN-backed named Seamount gazetteer along with a further seamount-science web-based product sponsored by the National Science Foundation in the USA, and a biological catalogue of data supported by the Census of Marine Life.</p>	
<i>KEYWORDS</i> South Atlantic seamounts bathymetry salinity dissolved oxygen sea temperature	
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Executive Summary

This report discusses the data used in the production of the map and GIS layers, and also briefly outlines and discusses each type of delivered data layer.

It has brought together various data sets from a number of public sources around the world to produce the most up-to-date regional bathymetric map of the South Atlantic in both printed and digital form, along with an interactive 3D view of the same data. This will allow not only an appreciation of the gross bathymetric features of the region, but the use of a data control layer in the GIS will allow users of this data an indication of the data accuracy and quality.

Physical and chemical parameters have also been included in the GIS, so that the Temperature, Salinity and Oxygen content of the South Atlantic, all primary agents in the distribution of the various forms of biology can be examined, at different critical depths at the same time.

These critical depths were determined to be those that had most effect on the biology, and were the sea surface (0m), the lower limit of the photic zone, which we approximated to 200m, and the lower limit of the likely vertical migration of zooplankton, a major source of food at 1000m depth.

Other elements presented include biogeographical provinces defined by Longhurst, a geographic depiction of the formally UN-backed named Seamount gazetteer along with a further seamount-science web-based product sponsored by the National Science Foundation in the USA, and a biological catalogue of data supported by the Census of Marine Life.

These final elements of this report suggest that data on South Atlantic seamounts, especially in terms of biologically-significant data is at best described as very patchy and of variable quality.

Table of Contents

Executive Summary	1
Table of Contents.....	2
Bathymetry Grid	3
Printed Map.....	4
ArcGIS Data	4
3D Data	9
Seamount Biological Data	10
Discussion.....	11
Recommendation	13
Figure List	14
List of Acronyms	15
References	16
Additional Notes (for GIS use)	18

Bathymetry Grid

The bathymetry compilations (map, GIS and 3D view) have used the very latest (February 2010) version of the GEBCO_08 global bathymetric dataset (www.gebco.net). The global bathymetric grid was generated by combining over 290 million quality-controlled ship depth soundings (single and multibeam) with interpolation between sounding points based upon version V16.1 (created in March 2007) of the Sandwell and Smith gravity anomaly from Geosat and ERS1 satellite altimetry (Sandwell and Smith 1997). The grid used here is a sub-set of that global grid.

The GEBCO global bathymetry grid was originally derived from the SRTM30_plus grid released by Becker et al in 2004. Version 5.0 of the Becker et al's SRTM30_plus grid, released in September 2008, forms the basis of the GEBCO_08 grid, which itself was first released in January 2009 and updated in November 2009. The latest version of the GEBCO_08 grid has undergone six iterations of identifying and removing apparent "bad soundings" and construction of updated grids. However the GEBCO_08 grid is a development product and will be periodically updated as more artefacts are identified and new, good-quality data added. It should be noted that there appear to be some "bad" data tracks along the continental margin off South Africa which give rise to a highly convoluted 200 m depth contours. It was beyond the scope of this report to remove and/or edit such data.

The bathymetry grid is essentially a series of "tiles" that contain either a real or predicted depth value. Where real depth values are used, it may be that there is one or more actual sounding within that tile, whereupon the depth value for that tile will be derived from the median value of all the depths contained within that tile. To enable identification of what tiles are controlled and which contain predicted depths, a 'source identifier' grid has also been made available in the GIS, labelled as "Data Control". The GEBCO_08 grid has a spatial resolution of 30 arc-seconds (so each data tile is 30 arc-seconds in length and width, approx 900m), and the datum is nominally mean sea level.

The land elevation data is from the US space shuttle SRTM mission, and as it is not a primary requirement of the report is not discussed further here. Further information if required can be obtained from the references and list if Acronyms.

Printed Map

The printed map (Figure 1) supplied shows the primary interest features, namely the bathymetry, colour coded with depth, with as highlighted contours the approximate lower limit of the photic zone (200 m, contoured in orange) and the likely vertical limit of zooplankton migration (1000 m, contoured in red).

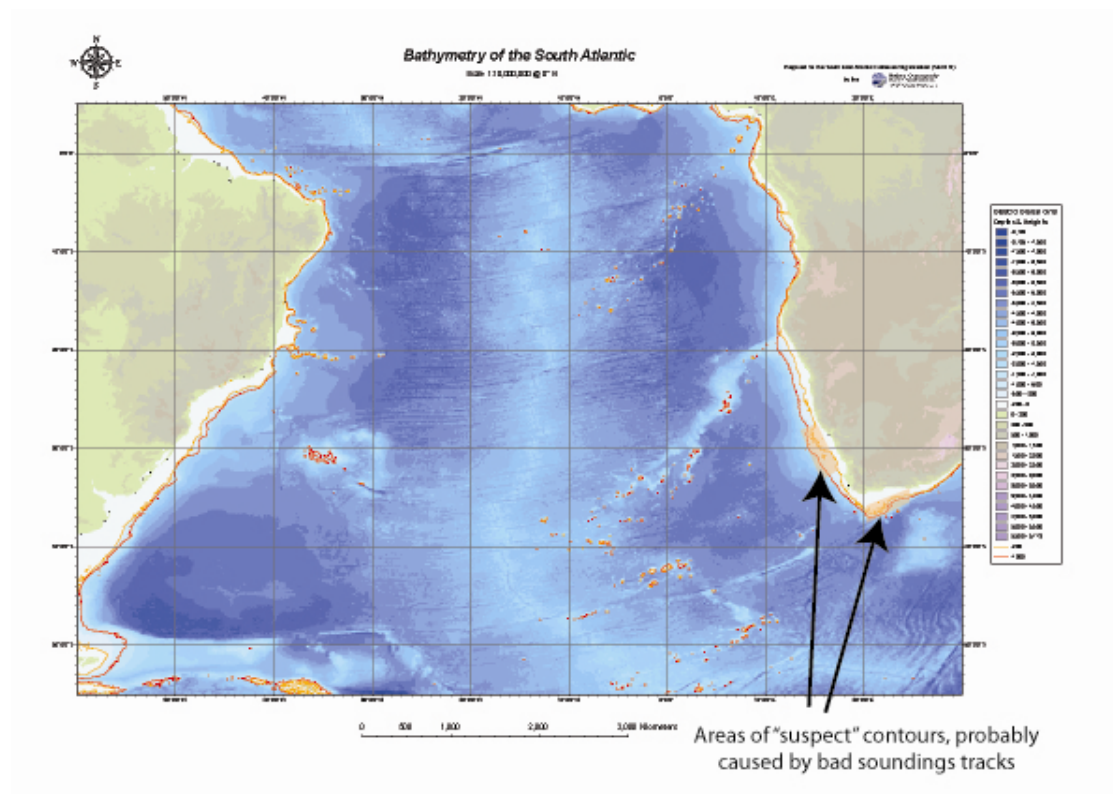


Figure 1. The bathymetry of the South Atlantic Ocean colour-coded by depth. Also highlighted here are areas of probable erroneous depths (contour irregularities).

ArcGIS Data

The ArcGIS data files include the bathymetry (as seen above and in the separate printed plots), along with a number of other parameters that either help understand the underlying bathymetry data, or have a direct relevance to

the biophysical parameters that occur in the South Atlantic Ocean. These are all listed and briefly described below.

The ArcGIS data have been assembled using the latest version of ESRI ArcMap™ and ArcCatalog™ – version 9.3 (build 1770). They can be displayed using either of the ESRI ArcMap Documents SEAFO_Arc93.mxd¹ or SEAFO_Arc92.mxd² dependant upon whether the user is using ArcMap 9.2² or ArcMap 9.3¹.

All data and derivatives have an assigned spatial reference of geographic coordinates reduced to the World Geodetic System 84 datum reference for altitude (or depth) data (WGS84).

Each of the physical and/or chemical parameters (Oxygen, Salinity and Temperature) has been set a “transparency” of 50% so that the raster grids may be overlain on other grids. Further, each of the above parameters have been coordinated in their colour-coding so that for example all Oxygen values within different raster files have the same colour for the same absolute value (e.g. 6-7 mil per Litre of Oxygen is always shown with an RGB value (colour) of 255/110/60 in all of the layers in which that value occurs).

This report assumes a working knowledge of ArcMap and other ArcGIS components and does not include a guide to the use of these systems, although some notes on use and transportation of the files will be given in the Additional Notes section at the end of this report.

GEBCO South Atlantic Grid

This is a raster layer comprising the elevation and bathymetric depths of the study region, cut from the latest version of the GEBCO digital global grid (GEBCO, and see above). The colour codes change every 500m vertically both on land and offshore.

Data Control

This is a layer show where data has been gathered in the form of soundings (Figure 2). Switching this layer “on” on top of the GEBCO global grid shows a series of depth-coded “lines” and “blocks”. These are in fact windows through a blank layer that represents areas of “no data”. Thus the “Data Control” layers colours are in fact the depth colours from the bathymetry. There areas of “Data Control” that appear as blocks, with bathymetric detail showing through are in fact areas of publically available multibeam bathymetry, and are thus of the highest quality and accuracy. The other “lines” are representative of single beam (or point) soundings and could be of significant vintage (i.e. pre-GPS navigation).

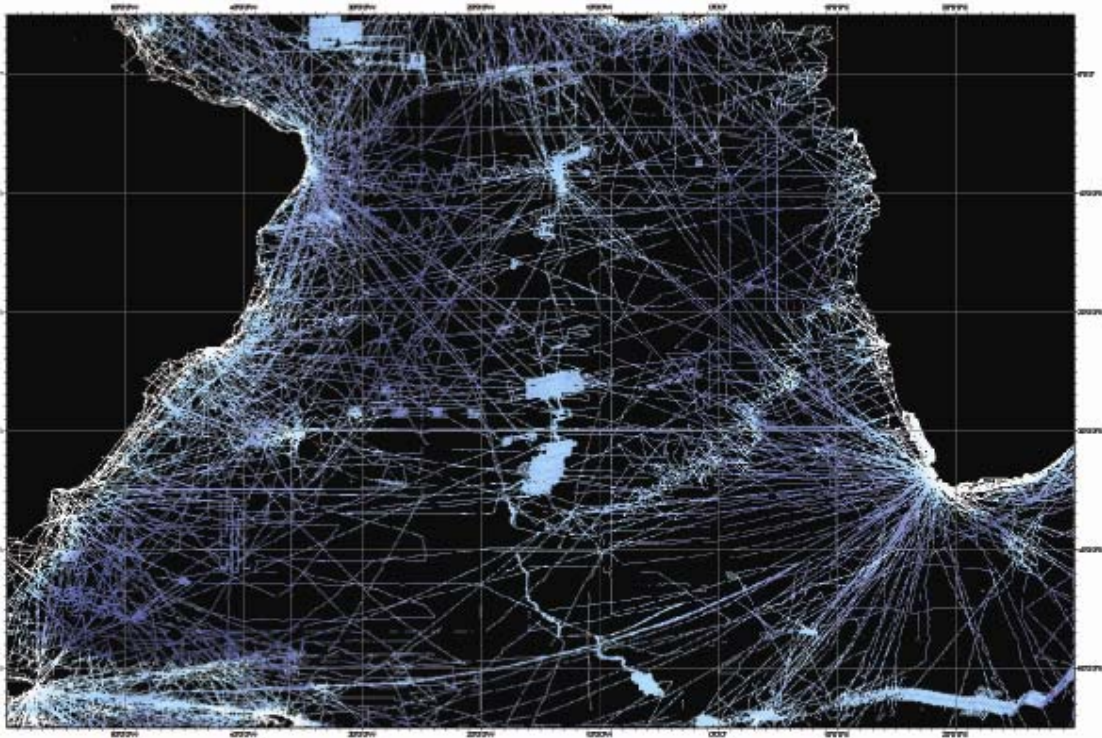


Figure 2. This shows the areas of real soundings data (blue) and areas where predicted bathymetry has been used to compile the bathymetric grid (black).

Oxygen

These layers show the concentrations of dissolved Oxygen at three critical depths, namely 0m (surface), 200m and 1000m. The data were obtained from the World Ocean Atlas (2005) and have been used to construct both raster grids (each labelled Oxygen – ml per L @ “Depth”) and contours (each

labelled Oxygen Contours – ml per L @ “Depth”) so the user can choose how to overlay each of these layers upon other parameters such as the Bathymetry or Temperature to obtain their preferred view.

Temperature

These layers show the water temperature at three critical depths, namely 0m (surface), 200m and 1000m. The data were obtained from the World Ocean Atlas (2005) and have been used to construct both raster grids (each labelled Temperature °C @ “Depth”) and contours (each labelled Temperature Contours °C @ “Depth”) so the user can choose how to overlay each of these layers upon other parameters such as the Bathymetry or Salinity to obtain their preferred view.

Salinity


These layers show the salinity at three critical depths, namely 0m (surface), 200m and 1000m. The data were obtained from the World Ocean Atlas (2005) and have been used to construct both raster grids (each labelled Salinity PSU @ “Depth”) and contours (each labelled Salinity Contours °C @ “Depth”) so the user can choose how to overlay each of these layers upon other parameters such as the Bathymetry or Oxygen to obtain their preferred view.

Longhurst Biogeographical Provinces

This dataset represents a partition of the world oceans into provinces as defined by Longhurst (1995; 1998; 2006), and are based on the prevailing role of physical forcing as a regulator of phytoplankton distribution. The dataset represents the initial static boundaries developed at the Bedford Institute of Oceanography, Canada. Note that the boundaries of these provinces are not fixed in time and space, but are dynamic and move under seasonal and interannual changes in physical forcing. At the first level of reduction, Longhurst recognised four principal biomes (also referred to as domains in earlier publications): the Polar Biome, the Westerlies Biome, the Trade-Winds Biome, and the Coastal Boundary Zone Biome. These four Biomes are recognisable in every major ocean basin. At the next level of reduction, the

ocean basins are partitioned into provinces, roughly ten for each basin. These partitions provide a template for data analysis or for making parameter assignments on a global scale. Please refer to Longhurst's publications when using these shapefiles, and note that as this is published material from a referenced global dataset, the whole of the world is included in the GIS product here rather than a cut-down version.

1000m Contours

This is a layer showing the bathymetric depth contours at an interval of 1000m. The contours are unlabelled though they can be interrogated for which depth they represent by using the  tool. The zero contour is effectively the coastline and is coloured differently to the isobaths which are all black except for the 100m contour which is red as it has a particular meaning for this study – namely the probable lower limit of vertical zooplankton migration

-1000m Contour

This is a layer showing the 1,000m contour only.

-200m Contour

This is a layer showing the 200m contour only, the probable lower limit of the photic zone.

GEBCO Named Seamounts

This layer shows the location of those Seamounts whose names have officially been recognised and endorsed by the GEBCO Sub-Committee on Undersea Feature Names (GEBCO – SCUFN), the UNESCO-backed body responsible for such function, and included in their official Gazetteer (IOC-IHO/GEBCO SCUFN 2010). Seamounts are features defined as “*A discrete (or group of) large isolated elevation(s), greater than 1000m in relief above the sea floor, characteristically of conical form.*” (IHO-IOC 2008). The Attribute Table for this layer records the position (latitude and longitude) and

official feature name, along with the naming history and where they occur, additional notes (usually pertaining to minimum depths or summit descriptors).

“Seamount Catalog” Named Seamounts

This layer shows the location of those Seamounts who have been catalogued and digitally archived by the global Earth Reference and Data Models website (Seamount Biogeosciences Network 2010). Many of the seamounts listed here duplicate those from the GEBCO-SCUFN list, although there are a significant number that are not included on the official UN-backed database. The Attribute Table for this layer simply gives a position and name of the feature, though the name may be liable to change if that particular seamount has not been recognised by the officially recognised international body (GEBCO-SCUFN).

3D Data

Although not specifically a part of the product specification, a 3D rendering of the bathymetry of the South Atlantic has been added as it will likely prove useful to SEAFO. The 3D visualisation was produced using Fledermaus™ V7 software, and can be used using the free to download viewer iView4D™ from Interactive Visualization Systems (IVS 3D). The viewer software for Windows PCs will be included in the download folder containing the GIS data. The referenced website can provide viewing software for alternative platforms. The bathymetry data in the 3D viewer is exactly the same as used in the GEBCO South Atlantic Grid layer of the ArcMap document. However the interactivity of the iView4D™ software means that users can zoom in and out and view the seabed from various angles allowing seafloor features to be seen in ways that may lead to new understandings of processes.

Another advantage of viewing the bathymetry in 3D are that it becomes relatively simple for even inexperienced viewers to get an idea of the underlying data quality (Figure 3).

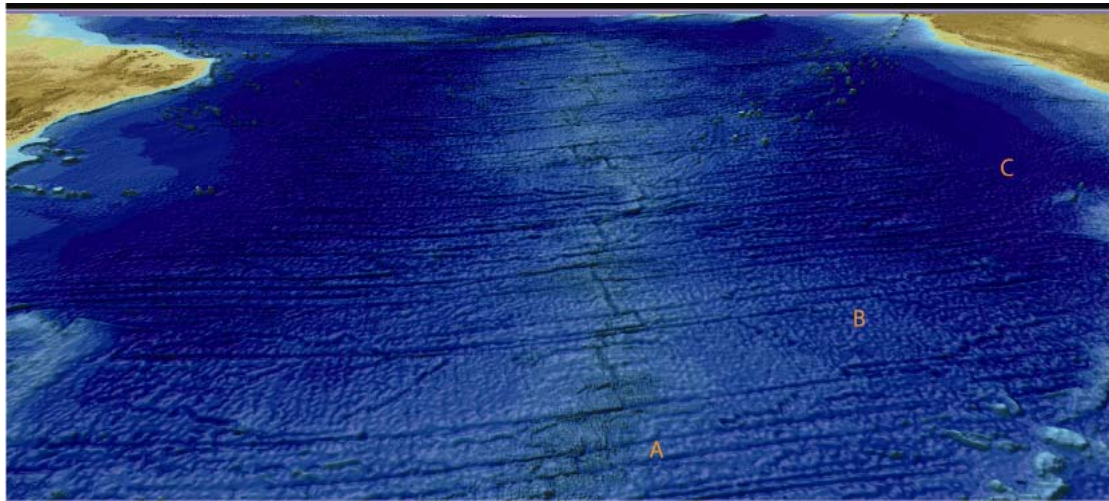


Figure 3. An oblique view of the mid-ocean ridge on the South Atlantic. The detail show in the area immediately to the west of “A” indicates that this area has been mapped with a multibeam bathymetry system, whereas the more generalised topography exhibited around “B” suggest this has mostly been surveyed using single beam echo-sounders. Around area “C” there is what is often described as an “orange-peel” texture (much easier to see on a screen than in print), which indicates (usually over areas of abyssal plain) that here predicted depths from satellite altimetry are used.

Seamount Biological Data

The Census of Marine Life (<http://www.coml.org/>) project CenSeam (a Global Census of Marine Life on Seamounts; <http://censeam.niwa.co.nz/>) represents an international effort to coordinate seamount research. The project includes a digital database element known as “SeamountsOnline” (<http://seamounts.sdsc.edu/>). The database includes biological records from seamount locations and can be searched by world sea regions (e.g. South Atlantic). Note that this is not an exhaustive database and remains a work in progress. The records are highly variable in nature, for example, a record may relate to an extensive biological survey or simply to the occurrence of a single species of fish. As such, these data can not be synthesised in any uniform manner, the database is nevertheless a useful resource for existing information on seamounts in the region. At present (consulted 11 Feb 2010)

the database contains biological records for the following South Atlantic Seamounts:

Table 1. A listing of South Atlantic Seamounts that contain some type of “biological” data.

Seamount name	Latitude (°N)	Longitude (°E)
B. 150	-3.02	0.74
Bank 405	-6.38	0.24
Ydachnaya	-7.92	0.93
Topaz Seamount	-8.20	0.77
B. 245	-9.91	-5.42
Dampier Seamount	-11.15	-0.59
Bank 157	-11.62	-5.25
B. 384	-12.78	-2.63
Davis Bank	-20.64	-34.77
Columbia Seamount	-20.73	-31.96
Zubov Seamount	-20.78	8.68
Ewing	-23.22	8.26
Radoznaya	-24.88	6.43
Schedraya	-25.63	6.20
Walvis Ridge	-25.83	5.83
Smejnyaya	-26.13	5.47
Valdivia Seamount	-26.19	6.29
Tripp Seamount	-29.64	14.30
Sentyabr'skaya	-30.25	3.16
Vema Seamount	-31.63	8.35
Beta	-31.72	2.12
Unnamed Shirshov 1	-32.64	-15.37
Alfa-II Bank	-32.89	2.57
Discovery Seamount 2	-41.94	1.38
Discovery Seamount 1	-42.10	-0.10
Spiess Seamount	-54.73	0.11

Discussion

Any isolated topographic feature that rises to within 1000m of the ocean/sea surface should be regarded as having the potential to host vulnerable marine ecosystems. This conclusion follows from two points:

- (a) Commercial fishing operations are possible at these depths.
- (b) Isolated topographic features at these depths may experience both enhanced primary production and interaction with vertically migrating zooplankton, providing increased food resources to seafloor populations. Combined with likely increased water movements over/across the topography and the possible occurrence of hard substratum (rocky terrain) these factors are likely to produce “biological

hotspots” with increased standing stocks (abundance and biomass of the seabed fauna) and species richness (biodiversity).

Appropriate protective/conservation measures should therefore consider all isolated topographic features that rise above 1000m water depth. It is also important to consider the likely regional variations in the vulnerable marine ecosystems present. For example, the study area encompasses five major oceanic biogeochemical provinces; each of these may be home to significantly different seamount biological communities. The designation of Marine Protected Areas or Fisheries Restriction Areas should, therefore, attempt to provide some protection in each province, rather than for example a large single closed area within a single province.

In addition, seamounts with summits at any depth do have the potential to host biological communities associated with hydrothermal systems. Such communities are generally thought to have high conservation value.

The occurrence of seamount ‘hotspot’ or hydrothermal biological communities can only be definitely established by direct survey. An assessment of bathymetry and oceanographic properties and processes can, however, provide sufficient information for the establishment of protective measures on a precautionary basis.

Recommendation

Above we have indicated that there is some biological data available over a more-or-less random selection of a few of the seamounts within the general South Atlantic region. Thus it may be possible to identify specific seamounts that have particularly vulnerable ecological systems, but it is highly probable that most of the vulnerable seamount communities in the region will go unrecognised unless, considering the paucity of available data, the most generic potential bio-markers as outlined in the discussion (above) are used. SEAFO are urged to review any catch records of both fish and invertebrates that they may have access to for use in vulnerable ecosystem assessments.

Whilst a detailed study could be undertaken to identify exactly what datasets are available for what seamounts, and then identify those whose ecosystems could be considered “at risk”, it would prove very labour-intensive, and we would suggest that SEAFO examine alternatives. As an example we would suggest exploring the possibility of requesting this to be an MSc research topic at a suitable academic institution of one of the SEAFO member nations, and NOC would be happy to explore this possibility further if so requested.

Figure List

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|----------|---|----|
| Figure 1 | The bathymetry of the South Atlantic Ocean colour-coded by depth. Also highlighted here are areas of probable erroneous depths (contour irregularities). | 4 |
| Figure 2 | This shows the areas of real soundings data (blue) and areas where predicted bathymetry has been used to compile the bathymetric grid (black). | 6 |
| Figure 3 | An oblique view of the mid-ocean ridge on the South Atlantic. The detail show in the area immediately to the west of “A” indicates that this area has been mapped with a multibeam bathymetry system, whereas the more generalised topography exhibited around “B” suggest this has mostly been surveyed using single beam echosounders. Around area “C” there is what is often described as an “orange-peel” texture (much easier to see on a screen than in print), which indicates (usually over areas of abyssal plain) that here predicted depths from satellite altimetry are used. | 10 |

List of Acronyms

CenSeam – Census of Marine Life on Seamounts
ERS1 – European Remote Sensing Satellite
GEBCO – General Bathymetric Chart of the Ocean
Geosat – GEOdetic SATellite
GIS – Geographical Information System
GPS – Global Positioning System
IHO – International Hydrographic Organisation
IOC – International Oceanographic Commission
NOCS – National Oceanography Centre, Southampton
PSU – Practical Salinity Units
SCUFN – Sub-Committee on Undersea Feature Names
SEAFO – South East Atlantic Fisheries Organisation
SRTM30 – Shuttle Radar Topography Mission
SRTM30_plus – Shuttle Radar Topography Mission elevation data plus
bathymetry
UN – United Nations
UNESCO – United Nations Educational, Scientific and Cultural Organisation
USA – United States of America
WGS84 - World Geodetic System 84 datum reference
3D – Three Dimensional

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Additional Notes

When transferring the GIS data between users, the best method is to “zip” the folder beforehand. The zipped file should be ~800Mb in size, the un-compressed SEAFO_2010 folder is ~ 1.2Gb.

Once “un-zipped” the folder, named SEAFO_2010 will contain all the relevant data files, including the written report, figures and an A0-size pdf file of the printed chart, and the install software for the windows version of iView4D (win32_iview4d.exe).

Upon loading into ArcMap, the links may appear broken, however all that is required is to click on a broken link, for example the GEBCO South Atlantic Grid, and use the folder windows to navigate to the SEAFO_2010 folder and select the file labelled “bathymetry”, and “GEBCO Named Seamounts link to GEBCO_Smts.shp. Re-linking in this way should automatically restore all the other links – so long as the individual files are not moved or renamed, although the Longhursts’ data is contained in its own separate folder and may also need to be re-connected with ArcMap.

Key File Names -Types

SEAFO_Arc92.mxd	ArcMap Document containing opening and coding instructions for ArcMap 9.2
SEAFO_Arc93.mxd	ArcMap Document containing opening and coding instructions for ArcMap 9.3
win32_iview4d.exe	Windows installer for iView4D 3-dimensional visualisation software
SEAFO.sd	3D bathymetry data for visualising in Fledermaus or iView4D software
SEAFO_Arc93.pdf	PDF document of the printed bathymetric map at A0 size