EnviroInfo 2005 (Brno)
Informatics for Environmental Protection - Networking Environmental Information
Copyright © Masaryk University Brno, Brno 2005. ISBN: 80-210-3780-6

MarGIS Marine Geo-Information-System for Visualisation and Typology of Marine Geodata

Kerstin Jerosch[1], Michael Schlüter[1], Roland Pesch[2], Winfried Schröder[2], Andreas Köberle[3], Lutz Vetter[3]

Abstract

MarGIS intends the combination of Geo-Information-Systems (GIS), research data, and multivariate geostatistical techniques for characterization and identification of distinct provinces at the seafloor of the North Sea. Such a typological approach, the analysis of classification based on types, is one prerequisite for management issues related to coastal seafloor. It provides a frame work for improved application of large environmental data sets, allows enhanced visualization of multiple information layers, and supports modeling of temporal and spatial interrelations of coastal and ocean regions. To tackle the problem of presentation of large data sets MarGIS uses a web-based viewer which allows a clear visualisation of the information for the general public. The viewer allows a dynamic actualisation and access of metadata and additional information.

1. Intension

Environmental, economic, and scientific interests in marine coastal environments and ocean margins increased considerably in recent years. Key words are: e.g. benthic habitats, fishery, wind energy or offshore oil and gas. Compared to the increasing amount of data, only few concepts were developed for efficient distribution of data and thematic maps to the research community and general public. MarGIS intends to fulfil these requirements by application of Geo-Information-Systems and geo-statistical techniques to target areas of the North. This allows characterizing distinct provinces of the seafloor by combination of geological, biological and chemical properties. Such a typological approach supports besides scientific needs, management decisions related to upcoming economic use of the seafloor.

Compared to the increasing amount of data and information about marine research, only a few concepts and techniques are applied for efficient visualisation and optimal utilisation of present and upcoming data sets. There is, for example, a considerable need for a generalised analysis and synthesis of seafloor data, clustering the multitude of detail information. This includes spatial budgets of geological and biogeochemical cycles and characterisation of provinces at the seafloor based on the combination of several information layers. Furthermore, a capable distribution of data and thematic maps to the research community and general public should be supported via internet.

Especially the classification (typology) of the seafloor into provinces, an approach well established in terrestrial geosciences and documented in form of geological maps, soil maps, and other thematic maps, is often a prerequisite for management needs and is the main objective of this proposal. The typological approach, combining by multivariate statistics and geostatistical means several information layers for the assignment of areas of the seafloor to types, allows comparisons of geographical different regions. Therefore, this approach is relevant for assessment and modelling of temporal and spatial changes of the marine

[1] Alfred-Wegener-Institute for Polar and Marine Research (AWI), Bremerhaven, Germany
[2] Institute for Environmental Sciences (IUW), Hochschule Vechta, Germany
[3] Department of Geomatics, Fachhochschule Neubrandenburg, Germany

environment. This is one of the key issues of the BMBF research program "Information Systems in Earth Management" which funds MarGIS. Besides scientific needs, the typological approach supports management decisions related to upcoming economic use of the seafloor as offshore wind power plants, offshore platforms and pipelines, seafloor cable deployments, sand and gravel dredging, and declaration of protection zones.

2. Methods and Tools

The MarGIS project has four closely related tasks: 1. field data acquisition and GIS data processing of analogue maps, 2. generation of a Marine Data Model (MDM) in shape of a relational database management system (rDBMS) located on a Microsoft SQL Server, coupling of the MDM to a geodatabase server based on ArcSDE9.0 (ESRI™) and integration of point and polygon information and meta-data about the marine-geodata, marine-biological, and bathymetric data into the GIS supported MDM, 3. spatial subdivision of the seafloor into distinct provinces, based on measured data, GIS technology, multivariate statistics, and geostatistics, and 4. development of a user-friendly Web-GIS application based on ArcIMS9.0 (ESRI™).

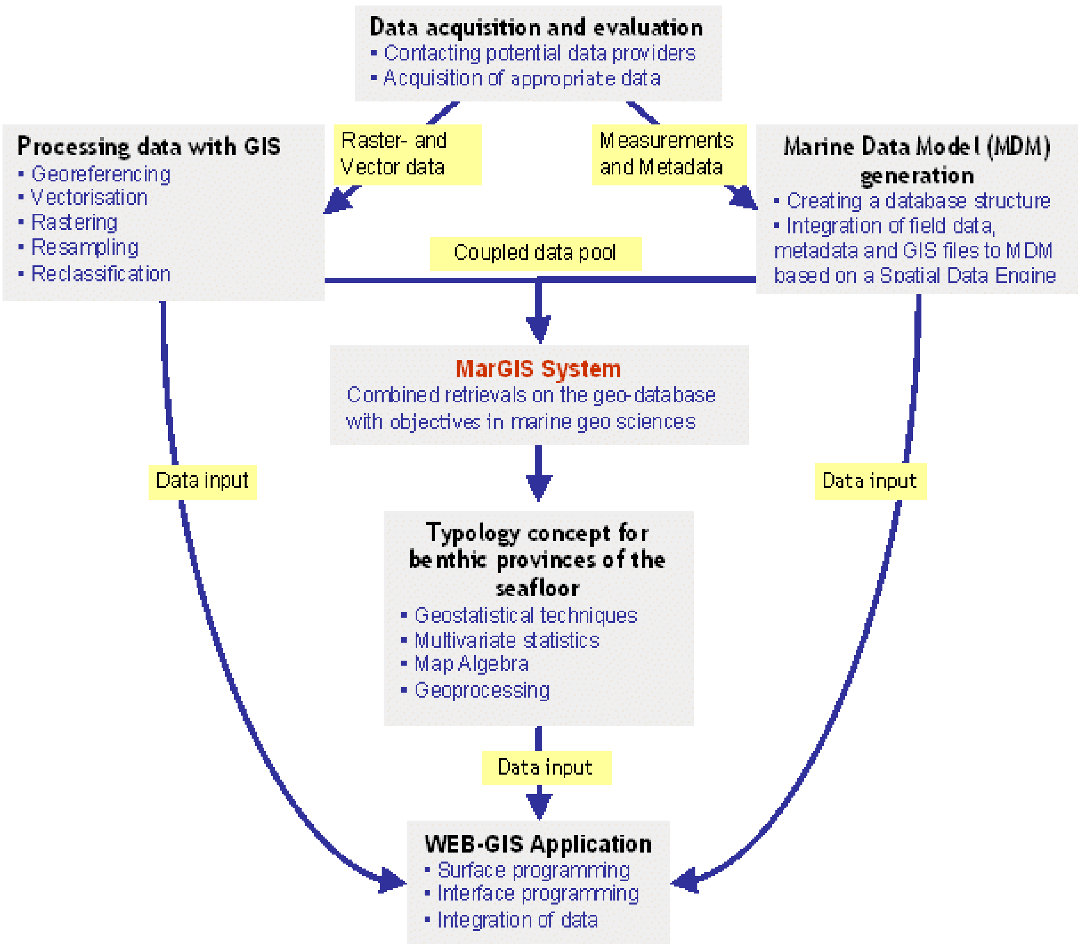

Fig. 1:
Working flow of MarGIS to derive sea floor provinces by means of GIS and statistical methods

3. Results

3.1. Data acquisition: measurements and geodata

The data were derived by an intensive recherché of published literature, reports, and maps, in close co-operation with scientist from various research disciplines and marine data base systems (MDBS). A considerable amount of published data was retrieved from marine data base systems established by international initiatives or by Federal Hydrographic and Oceanographic Agencies. Prominent examples as the data base systems operated by ICES (International Council for the Exploration of the Sea) or the Marine Environmental Database (MUDAB) initiated and operated by the germane Federal Maritime and Hydrographic Office (BSH) and the Federal Environmental Agency (UBA) hosting North Sea data should be mentioned. All the data sources and contributors are referenced in the section Partners and Contributors of our homepage and described on an institutional level in the metadata system of the GIS.

Charge	Period	Region	Object of Study	Description	Data	Sample	Posit.	Station	Exped.
AWI	2000	EEZ	benthos	BT association	184	184	184	184	1
AWI	2000	EEZ	benthos	BT, Van Veen	65341	180	180	180	1
EC	2000	eNS	benthos	BT	7694	270	269	269	5
CEFAS	2000	pNS	abiotics	Sed., WCh	59				
SBS/UWB	2000	eNS	benthos	BT	7653	270	270	270	5
GFS	1999	eNS	benthos	BT	7699	241	241		5
ICES	1976-2002	NS/BS	abiotics	WCh	40820	40820	40764	40764	174
ICES	1999-2002	eNS	fish	GOV, IBTS	57730				
ICES	1985/1986	eNS	fishes	GOV, IBTS	109217	1047	1047	1047	19
ICES	1985/86	eNS	benthos	GOV, NSBS	21386	506	306	235	10
ICES	1999-2002	eNS	fishes	GOV, IBTS	388052	3007	3007	3007	53
IFMHH	1984-2000	eNS	abiotics	WCh	3811	3811	3810	3810	36
BFA/IFOE	1981-1997	eNS	fish diseases	GOV	158855	2175	2175	56	53
BFA/IFOE	1984-2002	sNS	pelag. fishlarva	GOV, dab	1357	1141	1141	514	1
BFA/IFOE	1984-1999	sNS	pelag. fishlarva	species, deformations	5952	1029	1029	595	1
BFA/ISH	2003	GB	fish	pelagic, GOV	4854	47	94	47	1
BFA/ISH	1986	eNS	fish	pelagic, GOV	14097	128	256	128	1
BSH	1982-2000	NS/BS	abiotics	WCh	48691	48477	27884	27884	821
				Σ	943452	103333	82657	78990	1187

BS: Baltic Sea, BT: Beam trawl, EEZ: German Exclusive Economical Zone, eNS: entire North Sea, GB: German Bight, GOV: Grande Ouverture Verticale (Bottom trawl), NSBS: North Sea Benthos Survey, IBTS: International Bottom Trawl Survey, pNS: partial North Sea, WCh: Water Chemistry

Tab. 1:
Heterogeneous data sets (field data) provided by national and international databases and institutes compiled within the Marine Data Model.

In total information, not only field data but also analogue maps. about the following parameters are collected: bathymetry, salinity, temperature, concentrations of oxygen, ammonium, nitrate, nitrite, phosphate, silicate, and suspended matter, data on benthic biology as epibenthic and endobenthic organisms, fish populations, fish ages and length, and on the geology and geochemistry of the sediments. The later includes sediment maps, distribution of gas rich deposits, fault zone, on earth quakes and about distinct features at the seafloor as pockmarks, seeps and reefs. Furthermore, data about the use of the seafloor as pipelines, platform, protected areas, and sand and gravel mining compiled.

Apart from the measurement data further geo-information was gathered if available. The mapping procedure of the sediment map should be mentioned here: the data density of this important parameter was not sufficient for an interpolation. Therefore, several existing maps had to be joined to cover the entire area of the North Sea. Although very detailed and high resolution sedimentological maps were generated and made available by the BSH (Federal Maritime and Hydrographical Office), GEUS (Geological Survey of Denmark and Greenland) and others institutes and authorities, overview maps about the sedimentology of the entire North Sea or beyond the economic zones are still scarce. To derive such an overview, data from maps and raw data on grain size distribution were compiled und converted to the same map projection within the GIS. Varied sediment classification systems and different qualities of raw data (e.g. spatial distribution or counts of sample sites) required a merging of different information levels concerning sediment attribute data. The maps are shown in the lowest common scale, the Folk sediment classification (Folk 1954, 1974), aggregated into one sediment map for the North Sea. Nomenclature describing size distributions is important to geologists because grain size is the most basic attribute of sediments. Traditionally, geologists have divided sediments into four size fractions that include gravel, sand, silt, and clay, and classified these sediments based on ratios of the various proportions of the fractions. Due to joint visualization a reduction of information was necessary. More detailed information is maintained within the geodatabase according to different sediment classification systems.

The aggregation of heterogeneous geodata obtained from very various sources required a rather laborious harmonization procedure and refined data base model. This was one prerequisite for the integration of data and metadata into the geodatabase linked to the Geo-Information-System ArcGIS 9.0 (ESRI™) (see below). Specific emphasize was given to the metadata stored conform to ISO 19115.

3.2. Data management

Marine data storage is organized historically file-based in expeditions. Thus, is not possible to compare easily new raised data with old ones. In addition, the data are kept thematically, i.e. there is a lack of query possibilities of bio tables combined with abiotic parameters - spatially or temporally. The requirement of the MarGIS data model were thus the integration of bio tables and abiotic information l, but also the requirement of marine data in general: Point measurements (at the sea floor and, additionally, in the water column), area measurements (e.g. number of animals per surface), track line measurements by e.g. dragged techniques or time series generated by anchored systems.

Designing such a rDBMS is a fundamental process that requires planning and revision (Böttcher/Teich 2003). The database structure had to be specified to the way of marine data collection and all properties of the heterogeneity of data types. The compilation of marine data is yet made by *expeditions* of research vessels and often organized within international projects. In a research area *stations* are determined according to scientific aspects which are visited by the vessel and its crew. At the stations *samples* are taken and very often the samples, e.g. sediment cores, are subdivided into *series of measurements* analysing divers' *parameters*. For each parameter one *measurement* is required. Each sample is accurately defined by the location (position), the point of time (time and date) and the sampling depth. One of the most important tasks with regard to the use of the spatial database (visualization of queries within the GIS) is the positioning. E.g. the database has to mirror the fact that fishery data often have two pairs of coordinates (heave down and up the gear) belonging to the same sample. In another case only one pair of coordinates is given. Beside this it is nearly impossible to sample the same sample site (position) twice at sea.

The following key words build the columns of the marine database: expedition, station, sample, series of measurements, parameter and measurements. Up to the sample level all data are contiguous, than the data are split thematically. Arriving to the sample level is possible to include biotic as well as abiotic data and bring them back together easily to a certain station (query function). The metadata (persons in charge, literature,...) and the phylogeny establish two further blocks.

The integration of different data sets from several institutes implicates a lot of formatting work and questions of contents, which is underestimated frequently. Attributes had to be converted into the common language of our data management, the tables had to be created and added to the existing tables. Finally, the data must be evaluated and in case of redundancy taken out of the data base. Beside the organization of the large measurement data sets a further goal of MarGIS was their integration into a geodatabase - the platform, which unites measuring data and geo data – the marine data model (MDM).

A geodatabase of ArcGIS 9.0 (ESRI™) (Perencsika 1999) is realized on a spatial data engine (ArcSDE) and supports an object-oriented vector data model. In this model, entities are represented as objects with properties, behaviour, and relationships. Support for a variety of different geographic object types is built into the system. These object types include simple objects, geographic features (objects with location), network features (objects with geometric integration with other features), annotation features, and other more specialized feature types. The model allows defining relationships between objects, together with rules for maintaining the referential integrity between objects comparable to the rDBMS in MS Access. After a good data model design and the database tuning within the ArcGIS the geodatabase is ready to start as a multiuser GIS system. ArcCatalog has various tools for creating and modifying the geodatabase schema, while ArcMap has tools for analyzing and editing the contents of the geodatabase.

This system builds a stable platform also with large datasets and allows a comprehensive analyse altogether digitized maps (sediments, bathymetry, currents, geological processes,...) and field data in one query and to optimize the use of the available data. Furthermore the geodatabase establishes the basis for the implementation of geo-statistical and multivariate statistical applications and finally the definition of distinct provinces at the seafloor. Also the internet map server ArcIMS accesses the geodatabase providing the compiled data, created maps and metadata to the scientific community and to interested public via the internet with interactive online mapping tools.

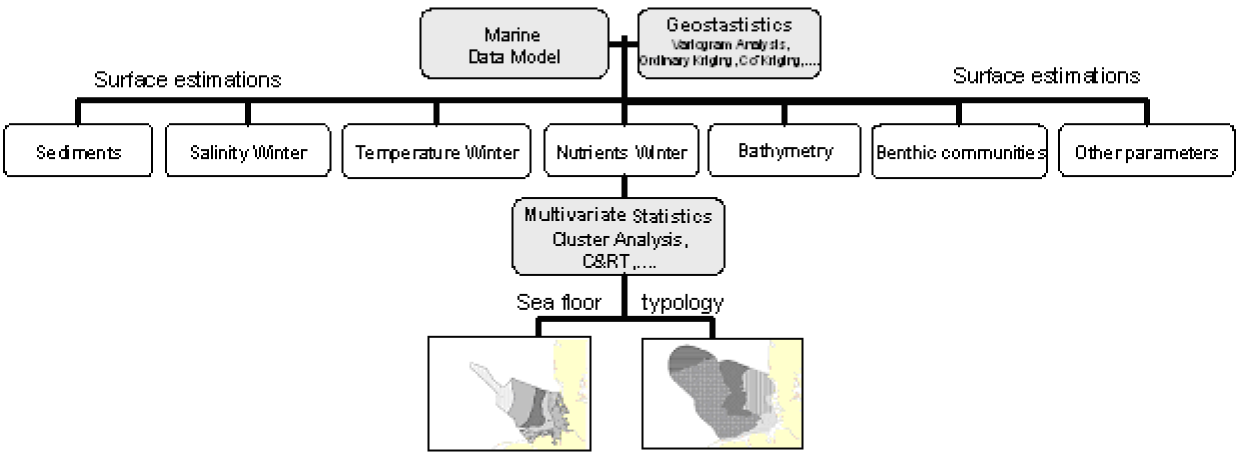

Fig. 2:
Schematic representation of the typology concept: first step is the production of monoparametric surface maps on the basis the measurement data coming from the data model by geoststistical methods, in a second step sea provinces are defined by means of multivariate statistic methods as e.g. the C&RT analysis.

3.3. Typology concept

The ecological regionalisation often is a prerequisite for marine planning and management needs, such as installation of off-shore wind power plants or the declaration of protection zones (Hughes 1997; Moog et al. 2004; Reiniger 1997). The ecoregionalisation approach used in MarGIS consists of two main working steps: (1) By applying geostatistical methods such as variogram analysis and kriging, surface maps are calculated from measurement data (Goovaerts 1997, Krige 1951). (2) Multivariate statistics like Classification and Regression Trees (CART) and GIS-techniques are then used to calculate sea floor provinces from the kriging grid maps. Since the beginning of the project, kriging maps on temperature, salinity and nutrients (phosphate, nitrate, and ammonium) were calculated and used to derive a habitat map for the German Exclusive Economic Zone (EEZ).

A detailierte execution to these geostatistic and multivariate statistic procedures are described by R. Pesch et al. (this issue).

3.4. Web-GIS application

In general the user of MarGIS is not a GIS expert but for instance planner, so he needs a user friendly environment which can easily manage these large amounts of marine geo-information.

To tackle the problem of presentation of large data sets MarGIS uses a web-based viewer which allows a clear presentation of information.This Html-viewer was developed within MarGIS and is based on the mapserver ArcIMS.. The MarGIS viewer enables the user to view the maps interactively in his browser and includes the following functions: pan, zoom, different queries types, measurement, view layers in different categories, download metadata.

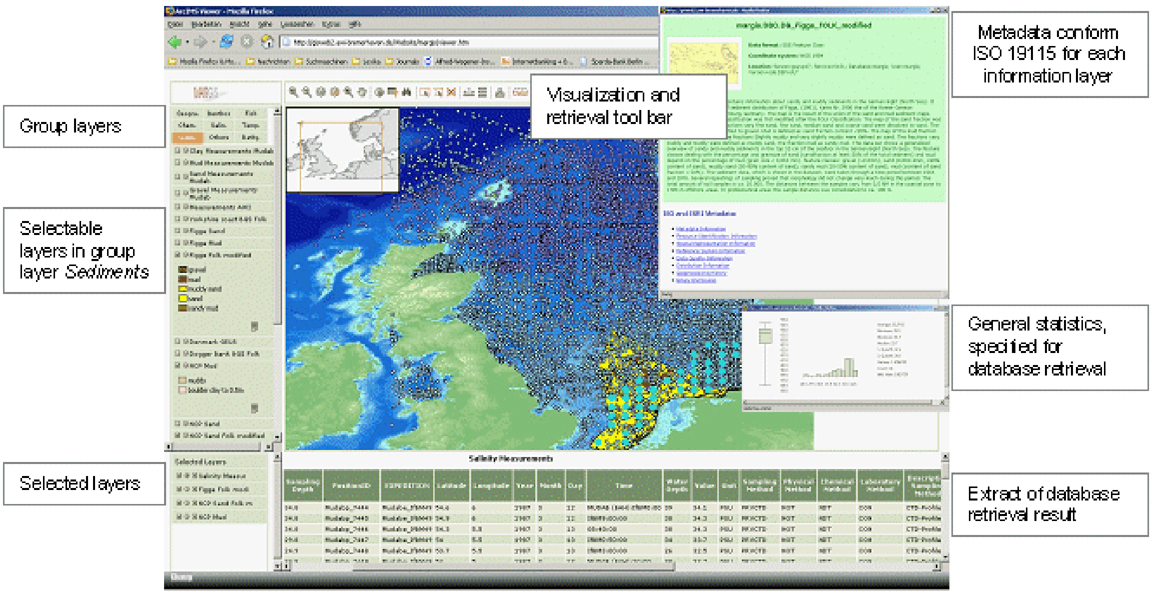

Fig. 3:
Functionality of the MarGIS web viewer based on ArcIMS.

On the basis of cascading the information, the different layers are grouped in thematic blocks as for example geology, temperature, chemistry, fishery data and others. With the help of pull downs the user can select the appropriate layer. To each information layer metadata information (after ISO 19115) are available (cf. Fig. 3). The document of the metadata information is also located on the database server which makes easier the updating process. There are different possibilities of querying the data: as data to a certain object (point, line, polygon, pixel, grid), to a certain region or with the help of SQL commands. A result of such a request (highlighted spots) is presented in figure 3 for the salinity layer. Information layers which include quantitative data for example the concentration of salinity, descriptive statistical parameters as box and whisker plots, average and others can be generated (cf. fig. 3).

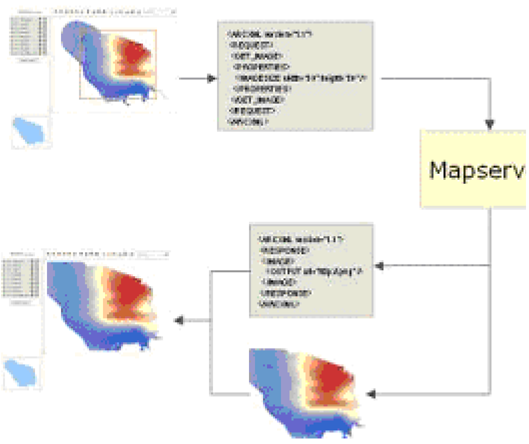

Fig. 4:
Implementation of a Zoom operation

The mapserver: A mapserver is a programme to disseminate maps in the internet. Based on different geodata and inputs of the user, a mapserver creates pixel images or vector data and sends them to the client of the user. Furthermore a mapserver can start different querys on the geodata. The client of the MarGIS project is an HTML-client, who runs in the most modern browsers. The input of the users will be sent to the mapserver by HTML-forms and the response of the mapserver will be analysed and showed by the use of java script. For example, if the user pans the map in the viewer, the coordinates of the new view will be sent to the mapserver. The mapserver creates the image of the new coordinates and saves it on the server. Than a response with a link to these image will be created and sent to the client by the mapserver. The client analyses the response and replaces the old image in the view by the new one. Creating a query is working on the same way. The user creates a SQL-query in a special forms or a spatial query on the map. The query will be sent to mapserver which uses these on the geodata. The response is sending back to the client, where a java script analyses and displays the data. The client and server communicate via a special XML called AXL. The XML has the advantage that it is easily to process by the java script due to standardisation.

4. Summary

With the help of a Geo-Information-System (GIS) it is possible to combine field data and digital maps in one system. The marine spatial data is stored as data sets and as layers in a geodatabase. The marine data model was developed The MDM was build at the same time with the MDM of the ESRI group (D. Wright and OSU Webworks) (Wright/Bartlett 2000), which was still in development. With MarGIS one step is done forward in getting a more precise description of the marine environment of the North Sea. Combining single information layers as contour maps, field data measured at separated sites, or bathymetric charts, with GIS techniques and geo-statistics allows deriving aggregated maps. By these means provinces at the seafloor of coastal areas will be derived. This provides a frame of reference for calculation of spatial budgets, consideration of benthic habitats and for upcoming use of the seafloor (see Bundesamt für Bauwesen und Raumordnung 2004, Jarass 2002). The method was presented in a group of international experts (Working Group of Marine Habitat Mapping of the International Council for the Exploration of the Sea).

MarGIS supplies the need for a generalised analysis and synthesis of seafloor data of marine geodata. Finally the multitude of detailed information was organised within a geographical information system which will be accessed easily by users. The amount of measurement data and meta information about marine research required the generation of a relational database management systems (rDBMS).

The geodatabase provides services for geographic data and supports a model of topologically integrated feature classes and other object-oriented features. Geographic data include all data with coordinates: raster data sets e.g. remote sensing data or geo-referenced images as mosaics as well as field data and planar topologies e.g. digitized maps based on vectors. Within the MarGIS project the ESRI ArcGIS 9.0 applications are used. ArcSDE (Spatial Data Engine) defines an open interface between the database system and the applications of ArcMap, ArcCatalog and ArcIMS. The complete system allows managing geographic information on a variety of different platforms, generating results for research and planning interests and presenting the data via internet in a user-friendly way.

5. Acknowledgement

The authors thank all the data providers listed on the MarGIS homepage (http://www.awi-bremerhaven.de/GEO/Marine_GIS/NorthSea/Data_Sources.htm) especially the ICES (International Council for the Exploration of the Sea) or the Marine Environmental Database (MUDAB) operated by the germane Federal Maritime and Hydrographic Office (BSH) and the Federal Environmental Agency (UBA). Furthermore, we greatly appreciate industrious work during the integration of the data by trainees and colleagues C. Morchner, F. Scharf, and S. Kurtz.

This is publication no. GEOTECH-176 of the programme GEOTECHNOLOGIEN of BMBF and DFG, Grant (03F0370A).

Bibliography

Bundesamt für Bauwesen und Raumordnung (2004): Marine Raumordnung, Heft 7/8, Bonn

Böttcher, U., Teich, P. (2003): SQL: Grundlagen und Datenbankdesign. 1. Auflage. Nackenheim: Herdt-Verlag.

Folk, R.L. (1954): The distinction between grain size and mineral composition in sedimentary rock nomenclature. Journal of Geology 62 (4), 344-359.

Folk, R.L. (1974): The petrology of sedimentary rocks: Austin, Tex., Hemphill Publishing Co., 182 p.

Goovaerts, P. (1997): Geostatistics for Natural Resources Evaluation. Oxford Univ. Press, New York. 512 pp.

Green, D. R., King, S.D. (2003): Coastal and Marine Geo-Information Systems, Kluwer Academics Publishers, Dordrecht

Hughes, R.M. (1997): Use of ecoregions in biological monitoring. In: Loeb, S.L.; Spacie, A. (eds.): Biological monitoring of aquatic systems. - Boca Raton, FL., pp. 125-151

Jarass, H. D. (2002): Naturschutz in der Ausschließlichen Wirtschaftszone, Nomos Verlagsgesellschaft, Baden-Baden

Krige, D.G. (1951): A statistical approach to some basic mine valuation problems on the witwatersrand, J. chem. Metall. Min. soc. S. Africa 52 (6): 119-139.

Moog, O., (et al.) (2004): Does the ecoregion approach support the typological demands of the EU Water Framework Directive? In: Hydrobiologia 516 (1), pp. 21 - 33

Petitgas, P. (1996): Geostatistics and their applications to fisheries survey data. in E. Moksness, editor. Computers in Fisheries Research. Chapman & Hall, London, p. 113-141.

Perencsika, A., (et al.) (1999): Building a Geodatabase. Redlands.

Reiniger, C. (1997): Bioregional planning and ecosystem protection. In: Thompson, G.F.; Steiner, F. (eds.) Ecological design and planning. - New York, pp. 185-200

Wright, D., Bartlett, D. (2000): Marine and Coastal Geographical Information System, Taylor & Francis, London