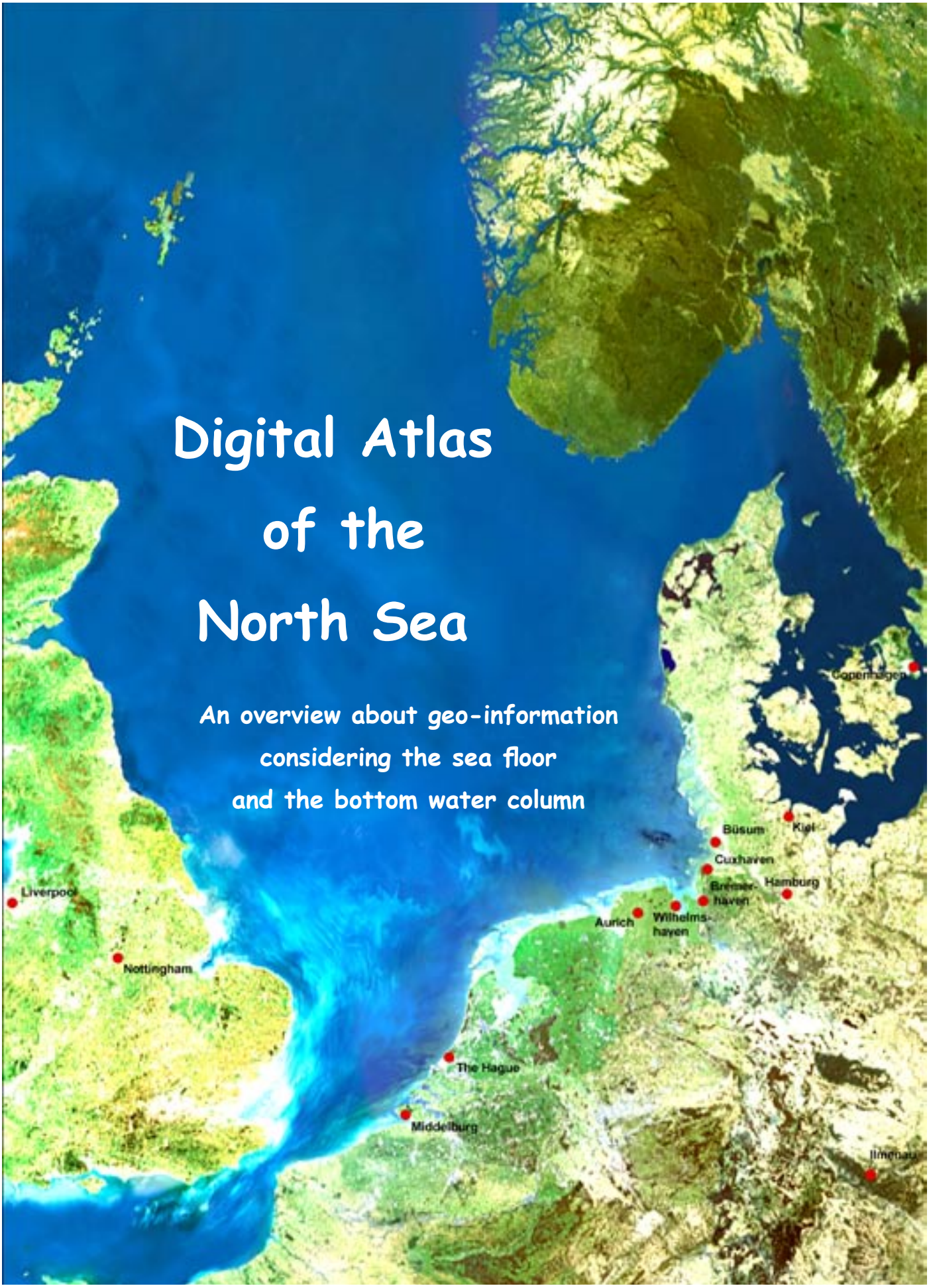

The *Digital Atlas of the North Sea* was supported by several national and international research groups and institutes.

Institutes and partners supporting the *Digital Atlas of the North Sea*

AWI
Alfred Wegener Institute for Polar and Marine Research

BAW
Federal Institute for Waterway Engineering

BGS
British Geological Survey

BODC
British Oceanographic Data Centre

BFN
Federal Nature Conservation Agency (D)

BSH
Federal Maritime and Hydrographic Office (D)

CEFAS
Centre for Environment, Fisheries & Aquaculture Science

GEUS
Geological Survey of Denmark and Greenland

ICES
International Council for the Exploration of the Sea

IfM
Institute of Marine Research, University of Hamburg

IfÖ/BFA-Fi
Institutes for Fishery and Fishery Ecology / Federal Research Centre for Fisheries (D)

ISH/BFA-Fi
Institute for Sea Fisheries / Federal Research Centre for Fisheries (D)

RIKZ
National Institute for Coastal and Marine Management (NL)

SBS/UWB
School of Biological Sciences, University of Wales, Swansea and Bangor

TNO-NITG
Netherlands Institute of Applied Geo-science TNO - National Geological

UBA
Federal Environmental Agency (D)

WSD
North Directorate for Water and Navigation North Region (D)

WSD
Northwest Directorate for Water and Navigation North West Region (D)

Content

Digital Atlas of the North Sea

The marginal seas and coastal regions are important habitats. They are of major significance for the future climate development, the play a central role for global biogeochemical cycles and are vital economic zones. Due to global change as well as increasing economic demands, considerable environmental changes are expected for coastal regions. This includes sea level rise, storm surges altering circulation and stratification, acidification, eutrophication and overfishing as well as the impact of global warming on coastal regions and the permafrost in the arctic.

For scientific objectives as well as coastal management issues, detailed geo-information[1] about offshore coastal environments are required to identify trends, feedback mechanisms and local environmental changes. This implies the availability of geological, geochemical, sediment-related or biological data as well as of thematic maps about distribution patterns of pelagic and benthic organisms or geological structures in the deep bedrock.

The *Digital Atlas of the North Sea* is a result of projects MarGIS (Funded by the BMBF/DFG specific research program Geotechnologies) and METROL (Funded within the 5th framework program of the EU) as well as on AWI additional data acquisition and analysis following these projects. The *Digital Atlas of the North Sea* is considered a step towards an increasing availability and visibility of environmental data about the North Sea.

We focused our data compilation on the sea floor and the bottom water, due to their importance for the bio- and geosciences as well as for economic demands like construction and operation of offshore wind parks, oil- and gas extraction, sand- and gravel mining, or pipeline and cable laying.

The data compilation is a result of an intensive research of publications, available project reports, geo-data archived in Marine Database Systems (MDBS) as well as a strong cooperation with scientists of various expertises. A considerable amount of published data is derived from databases which are operated by national and international organizations and agencies. Prominent examples are the ICES database (International Council for the Exploration of the Sea) or the Marine Environmental database (Marine Umweltdatenbank, MUDAB) which was initiated and is operated by the Bundesanstalt für Seeschifffahrt und Hydrographie (German Federal Maritime and Hydrographical Office (BSH) and the Umweltbundesamt (German Federal Environmental Agency; UBA).

In addition to published and generally accessible data, we were also supplied with unpublished and still protected geo-data. The *Digital Atlas of the North Sea* represents the geo-data not in the form of “raw data” but as distribution maps. These maps show the regional pattern of the measurements as well as the range of values. Furthermore, they provide information about the data provider of the supplied information.

At this point, we would like to express our gratitude for the support and the interest in the project *Digital Atlas of the North Sea*.

Acting on behalf of numerous experts, we would like to thank in particular Dr. E. Rachor (AWI), Prof. Dr. U. Brockmann (Institute for Marine Research), Prof. Dr. B.B. Jørgensen (Max Planck Institute for Microbiology Bremen), Prof. Dr. S. Ehrich (von Thünen Institute Hamburg), F. Nast (German Federal Institute of Hydrography), J. Jensen (Geological Survey of Denmark and Greenland), J.G. Hiddink (University of Wales, Bangor), D .d.Jong (Dutch National Institute for Coastal and Marine Management), M.J. Zarecki (International Council for the Exploration of the Sea), as well as scientists and fellow employees of AWI for their support and advice.

We hope that the *Digital Atlas of the North Sea* will support scientific objectives and will promote academic education in schools and universities.

Michael Schlüter & Kerstin Jerosch
Alfred Wegener Institute, Januar 2009

[1] data sets which are ultimately linked to the geographic coordinates of the observation

MarGIS - Marine Geo-Information System for the visualization and typology of marine geoscientific data

Funded by the BMBF/DFG specific research program Geotechnologies *Information Systems in Earth Management: From geo-data to geoservices*

One of the objectives of MarGIS was the characterization of provinces at the sea floor of the North Sea. The classification is based on the combination of several information layers of geological, biological, and chemical parameters within a Geo-Information System (GIS) and application of geo-statistical techniques.

This typological approach is considered as a step towards a refined analysis of large environmental datasets as allows refined visualization of multiple information layers and supports modelling of temporal and spatial interrelations of coastal and ocean regions. With the application of GIS it is possible to combine field data (point data which were collected at discreet sampling sites as well as measurements obtained along transects and vertical profiles) with theme-related maps into one system. This supports visualization and spatial analysis of heterogeneous geo-data in order to identify regional distribution patterns. For this purpose, a GIS-based database was established combining geo-information about the bottom water and the sediment-water interface (the sea floor) of the North Sea. Besides data measured at sampling points or along transect, georeferenced maps were integrated into the geo-database. This allows spatial analysis of e.g. the distribution of sediment types, benthic biota or oxygen as well as nutrient concentrations in the bottom water. Geo-statistical techniques such as kriging or multivariate analysis allow computation of contour plots and identifying provinces characterized by a specific set of biogenic and abiogenic parameters. This offers the comparison of geo-statistical methods applied for calculation of spatial budgets, of methods applied for identification of benthic or geochemical habitats and of techniques applied for decision support which might be required for the upcoming use of the sea floor, for example.

Partners:

Prof. Dr. Michael Schlüter
(Coordinator)
Dr. Kerstin Jerosch
Alfred Wegener Institut for
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Prof. Dr. Winfried Schröder
Dr. Roland Pesch
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Prof. Dr. Lutz Vetter
Dipl. Ing. Andreas Koeberle
University of Applied Sciences
Neubrandenburg

Internet Map Viewer of MarGIS
Information layer as depths, salinity, temperature, nutrients or benthic biology can be compiled interctively by the user.
http://gisweb2.awi-bremerhaven.de/Website/margis/viewer.htm

Funded by:
Federal Ministry for Education and Reserch (BMBF), special program Geotechnologies and the German Research Foundation (DFG)

METROL - Methane fluxes in ocean margin sediments: microbiological and geochemical control

Funded within the 5th framework program of the EU

Worldwide, several coastal environments are characterized by high methane concentration in surface sediments. This is due to high organic carbon contents and the resulting formation of methane (CH_4), caused by burial and microbial degradation of plankton material and organic matter derived by rivers and surface run-off. Oil and gas reservoirs are observed from deeper strata along coastal margins and in marginal seas like the North Sea as well as the occurence of methane in surface sediments .

The target of METROL was the exploration of the methane production and breakdown in the seabed, and how efficiently the sub-surface methane barrier, the “microbial filter”, controls the emission of this important greenhouse gas. The research objectives and activities include microbiological studies, geophysical mapping of gas occurrences, biogeochemical profiling, process measurements, numerical modelling, and data compilation and spatial analysis by application of a Geo-Information System (GIS).

Within the framework of the *Digital Atlas of the North Sea* geo-data indicative for high gas content and specific sea floor features as pockmarks and fault zones in greater depth were compiled. The data and thematic maps cover sediment depths down to deep tectonic structures and fault zones which might be potential conduits for the transfer of thermogenic gas to the sea floor. It is a superior objective of this research to better understand the processes which lead to the formation and decomposition of methane, and to calculate area-related budgets about the deposits and the release of the climate-related greenhouse gas.

Partners of METROL with respect to the application of GIS

Prof. Dr. Bo Barker Jørgensen
(Coordinator)
Dr. Christian Borowski
Max Planck Institute for Marine Microbiology (MPI)

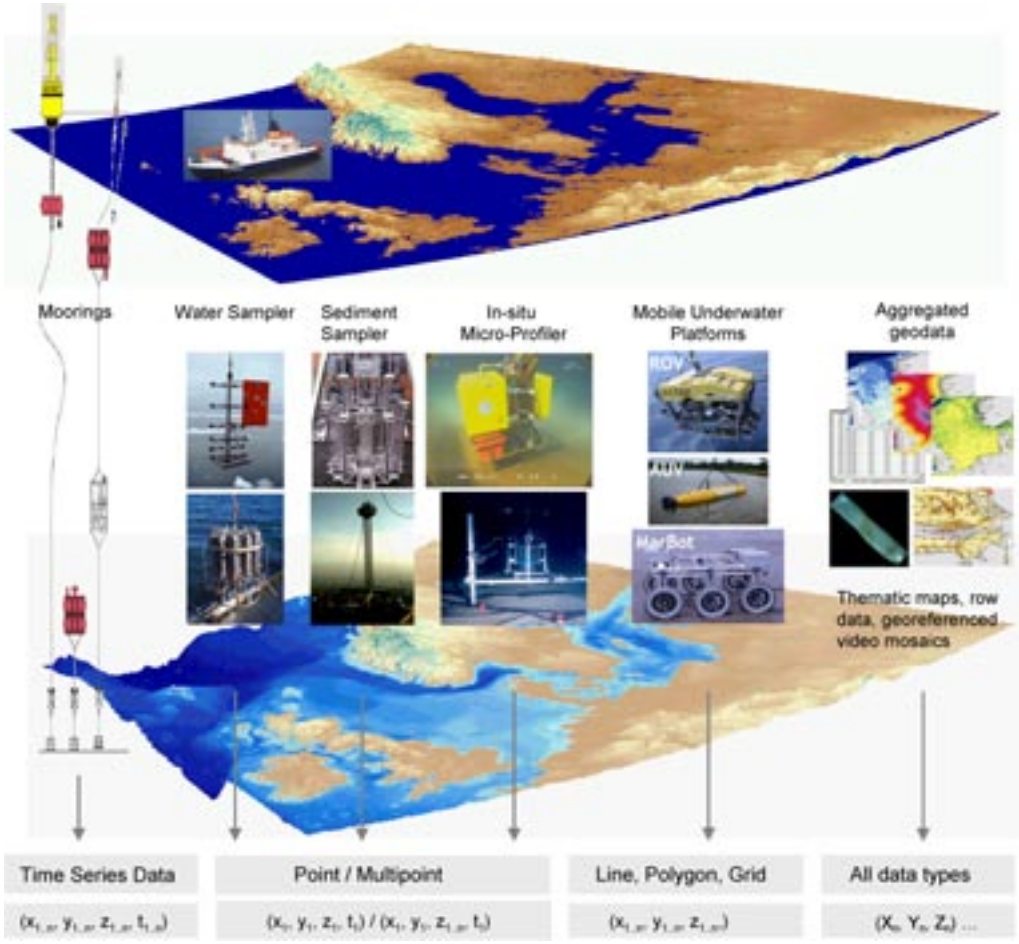
Prof. Dr. Michael Schlüter
Dipl. Geol. Ulrich Fritsche
Alfred Wegener Institut for Polar and Marine Research

Dr. Jørn Bo Jensen
Dr. Troels Laier
Geological Survey of Denmark and Greenland

Internet Map Viewer of METROL
Information layer as geology, free gas in sediments or earthquakes can be compiled interctively by the user.
http://gisweb2.awi-bremerhaven.de/Website/metrol/viewer.htm

Funded by:
Projects of Research and Developement of the EU, 5th framework program

Data acquisition for marine research: “Remote Sensing” of the sea floor



Data collection at the sea floor and within the water column up to several 1000 meters water depth. Nowadays, the fast technological development enables the scientists to apply extensive equipment like water sampler, box corer, sensors and in-situ devices, as well as mobile underwater platforms.

Scientific and commercial investigations of the ocean and sea floor are mostly being carried out by means of research and surveying vessels. During expeditions, multi-beam echo sounders to investigate the bathymetry or the texture of surface sedimentsare applied and sediment samplers (e.g. box corer, multicorer, gravity corer) as well as sensors systems (e.g. a CTD) are deployed through the winch on the research vessel for geological, biological and geochemiacal research.

The sediment and water samples are transferred onboard ship and are often analyzed during the research cruise. Furthermore, systems towed by the research vessel are applied for data acquisition (e.g. temperature, salinity or nutrient concentrations) along transects.

Besides sampling and analysis onboard of the research vessel, sensor systems and specific sampling devices are transferred to the sea floor for in-situ measurements like in-situ micro-profiler and moorong systems at water depths of several hundred to thousand meters. Some of these systems operate unattached to the surface vessel and are deployed by free-fall Lander Systems or moorings. This allows long-term observations not restricted by the permanent availability of a research vessel.

Furthermore, rather new in-situ sensor packages and samplers can be installed on mobile underwater platforms like AUV’s (Autonomous Underwater Vehicles), ROV’s (Remotely Operated Vehicles) or wheel-powered platforms (CRAWLER’s like MarBot).

Consequently, during a cruise a multitude of geo-data - measurements which are ultimately tied to the position (Latitude, Longitude, Sampling Depth) and time of recording or sampling – are compiled. Especially multi-disciplinary studies as well as data compilations benefit from the application of Geo-Information Systems which support an efficient management of heterogeneous geo-data as well as the associated meta data, and which provide specific tools for visualization and spatial analysis.

Geo-Information Systems for marine research

Geo-Information Systems are used for basic and applied research as well as for socio-economic applications or transportation logistics.

One of the starting points for the development of GIS was the work of the American landscape architect Ian McHarg in 1962. He displayed geo-information about the real world by means of multiple information layers joined into one map. Each single aspect, such as topography, geology, vegetation, land use etc. was mapped transparently on, e.g., an "overhead transparency". Areas of specific interest were hatched in darker shade. These single maps were assembled one above the other ("overlaid"), whereas the factors could be weighted seperately. By this mean, McHarg was able to determine very efficiently potential areas for new buildings etc.

Today, a GIS consists of a database management system and a cartographic module integrated within a rather complex and powerful software package. This allows the combination and analysis of different sets and types of geo-data. For example, different thematic maps (e.g. sediment maps, bathymetry maps, maps about offshore pipelines or shipping lanes) can be combined with datasets measurement at distinct sampling sites or along transects. This allows identification of spatial distributions like the occurrence of benthic organisms on sandy sediments in water depths of 20-30m and at a distance of more than 5 km to pipelines, for example.

The high potential of GIS for scientific and technical applications was recognized rapidly and led to the establishment of institutes and companies such as "Canada Geographic Information System" (1963), "Harvard Laboratory for Computer Graphics and Spatial Analysis" (1964), "Environmental Systems Research Institute" (ESRI) and "Intergraph Corporation" (both 1969).Today's GIS technology has been developing since approximately 1982 with integrated programs like Intergraph, ArcGIS, Sicad, GRASS, or Smallworld.

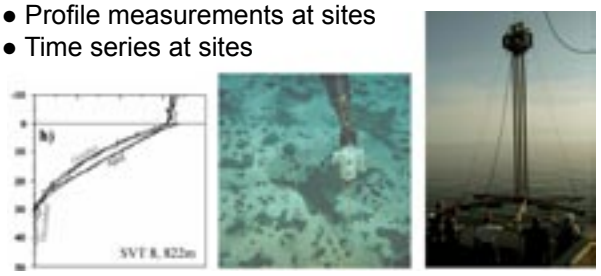
In addition to the overlay procedure, a still increasing number of techniques have been developed to support spatial analysis. This includes multi-variate statistics as well as geo-statistics, or multi criteria decision analysis. Furthermore, a large number of cartographic map projects can be applied.

By these means, GIS allows the combination of thematic maps generated with different map projections with datasets obtained at distinct locations (point data), measurements obtained along transects (line/polyline data) or derived by multi-beam surveys or video-observations of larger areas (area related data).

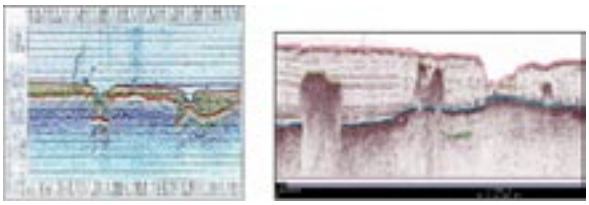
Implemented within several GIS software systems is the important concept of "meta data". The "meta data" document how the "modality" of a map or how an information layer was generated. This includes data about the applied geodetic datum, the type of projection, as well as applied analytical methods, for example. For the *Digital Atlas of the North Sea*, we applied meta data standard ISO 19115. Through this, references about the geo-information contained in the *Digital Atlas of the North Sea* are transparent for users.

Typs of marine data

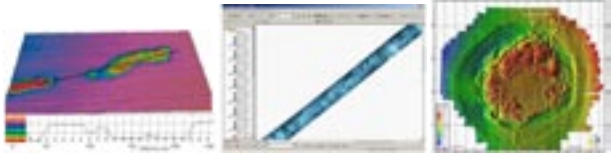
Point data (X, Y, Z) or (X_1, Y_1, Z_1, ... X_1, Y_1, Z_n)
- Point measurements at sites
- Profile measurements at sites
- Time series at sites



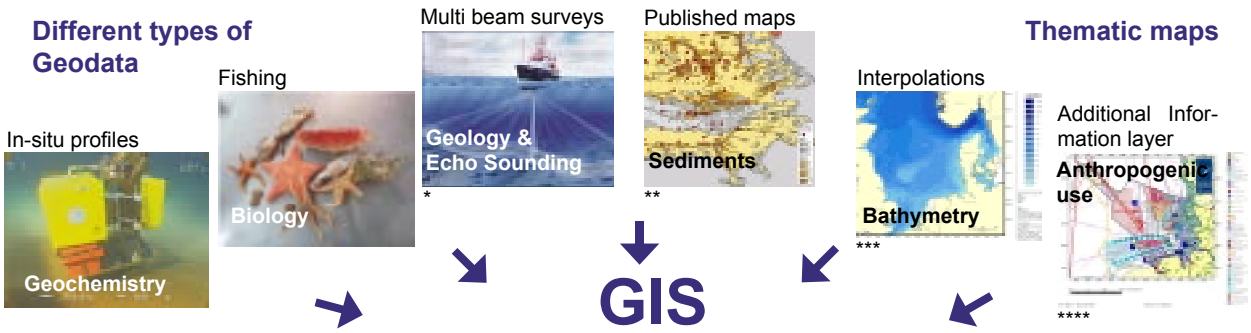
Line/polyline data (X_1, Y_1, Z_1) ... (X_n, Y_n, Z_n)
- Single-beam bathymetry
- Marine geochemical measurements
- Geophysical measurements (seismics, magnetism)



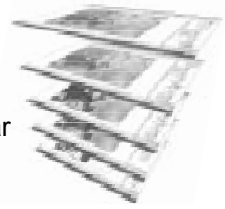
Area related data (X_n, Y_n, Z_n)
- Multi-beam surveys
- Side scan sonar
- Video mosaics



Methodology of GIS based analyzes

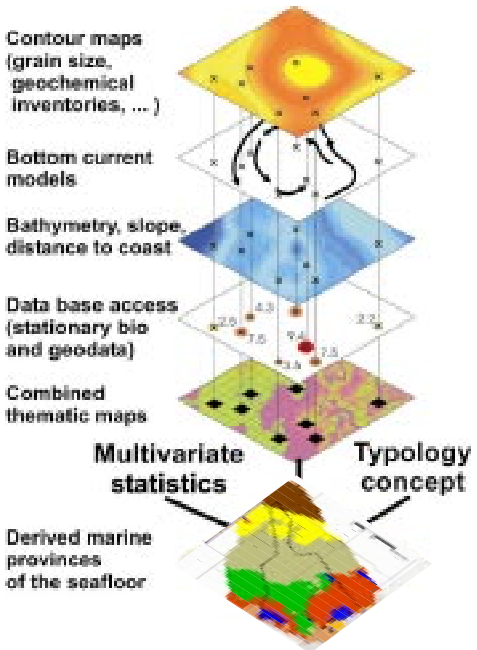


- ► Integration of all formats of spatial-oriented geo-data into a geo-database (e.g. maps, point or profile measurements, etc.)
- ► Analysis of single information layers:
  - ● Display and retrieval of field data referring to geology, geochemistry, biology, etc.
  - ● Creation of bathymetric maps
  - ● Implementation of multi-beam and side scan sonar data, georeferenced images and video mosaics
- ► Application of GIS technology like overlay, buffer, trend surface and geo-statistical analysis

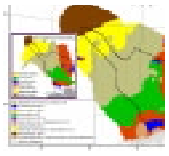


Result: single thematic map layer

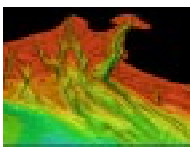
Multi layer analysis



By means of the combination of different information levels (e.g. water temperature, salinity, nutrient range, sedimentology, benthic communities), spatial connections between these parameters can be investigated.
Applying geo-statistics and multivariate statistics, provinces at the bottom of the sea can be identified and surface-related budgets can be computed.



Benthic provinces



3D Bathymetry DEM

3D data (digital terrain model Eckernförde Bay) combinied with 2D data (seismic profiles).

* ATLAS Hydrographics GmbH,1998 ** Figge, 1981 *** MarGIS, 2005 **** BSH, 2007

Data compilation

The *Digital Atlas of the North Sea* visualizes a compilation of marine datasets on the oceanography, geology, geochemistry and biology with specific emphasis on the lower water column and sea floor. The data were derived through an intensive recherché of published literature, reports and maps, in close cooperation with scientists from various research disciplines and marine database systems.

Especially the databases of Mudab (Marine Environmental database, German Federal Maritime and Hydrographical Office), ICES (International Council for the Exploration of the Sea) and BODC (British Oceanographic Data Centre), hosting North Sea data must be mentioned. All data sources and contributors are referenced in the section *Instiutes and Partners supporting the Digital Atlas of the North Sea*, as well as in the meta data system of the GIS. The table below provides an overview about the compiled data. We are grateful to all colleagues for their support!

In total, not only field data but also analog maps (“paper maps”) about the following parameters were collected: bathymetry, salinity, temperature, concentrations of oxygen, ammonium, nitrate, nitrite, phosphate, silicit acid 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 latter includes sediment maps, distribution of gas rich deposits, fault zones and on earth quakes, as well as about distinct features at the sea floor as pockmarks, seeps and reefs. Furthermore, data about the use of the sea floor for pipelines, platforms, protected areas, and sand-gravel mining are compiled.

The aggregation of heterogeneous geo-data obtained from various sources required a rather laborious harmonization procedure and a refined database model. This was one prerequisite for the integration of data and meta data into the geo-database linked to the Geo-Information System ArcGIS 9.3 (ESRI™). Specific emphasis was given to the meta data stored conform to ISO 19115.

In addition to published and generally accessible data we were also supplied with unpublished and still protected geo-data. To honor the intellectual property rights of data contributors, the *Digital Atlas of the North Sea* represents the geo-data not in form of “raw data” but as distribution maps. These maps show the regional pattern of the study sites as well as the range of values. Furthermore, they provide information

Data Source	Period	Region	Object of Study	Data	Position	Expedition
AWI	2000	EEZ	benthos	184	184	1
AWI	2000	EEZ	benthos	65341	180	1
EC	2000	eNS	benthos	7694	269	5
CEFAS	2000	pNS	abiotics	59		
SBS/UWB	2000	eNS	benthos	7653	270	5
GFS	1999	eNS	benthos	7699	241	5
ICES	1976-2002	eNS/BS	abiotics	40820	40764	174
ICES	1999-2002	eNS	fish	57730		
ICES	1985/1986	eNS	fishes	109217	1047	19
ICES	1985/86	eNS	benthos	21386	306	10
ICES	1999-2002	eNS	fishes	388052	3007	53
IFMHH	1984-2000	eNS	abiotics	3811	3810	36
BFA/IFOE	1981-1997	eNS	fish diseases	158855	2175	53
BFA/IFOE	1984-2002	sNS	pelag. fish larva	1357	1141	1
BFA/IFOE	1984-1999	sNS	pelag. fish larva	5952	1029	1
BFA/ISH	2003	GB	fish	4854	94	1
BFA/ISH	1986	eNS	fish	14097	256	1
BSH	1982-2000	eNS/BS	abiotics	48691	27884	821
			∑	943452	82657	1187

* BS: Baltic Sea, BT: Beam trawl, EEZ: German Exclusive Economical Zone, eNS: entire North Sea, GB: German Bight,

Overview about the provided field data compiled in the *Digital Atlas of the North Sea*. Furthermore, analog maps concerning sediment composition, gas rich deposits, fault zones, earth quakes, pockmarks, seeps and reefs, use of the sea floor as pipelines, platforms, protected areas, and sand-gravel mining have been digitized.

Meta data ISO 19115

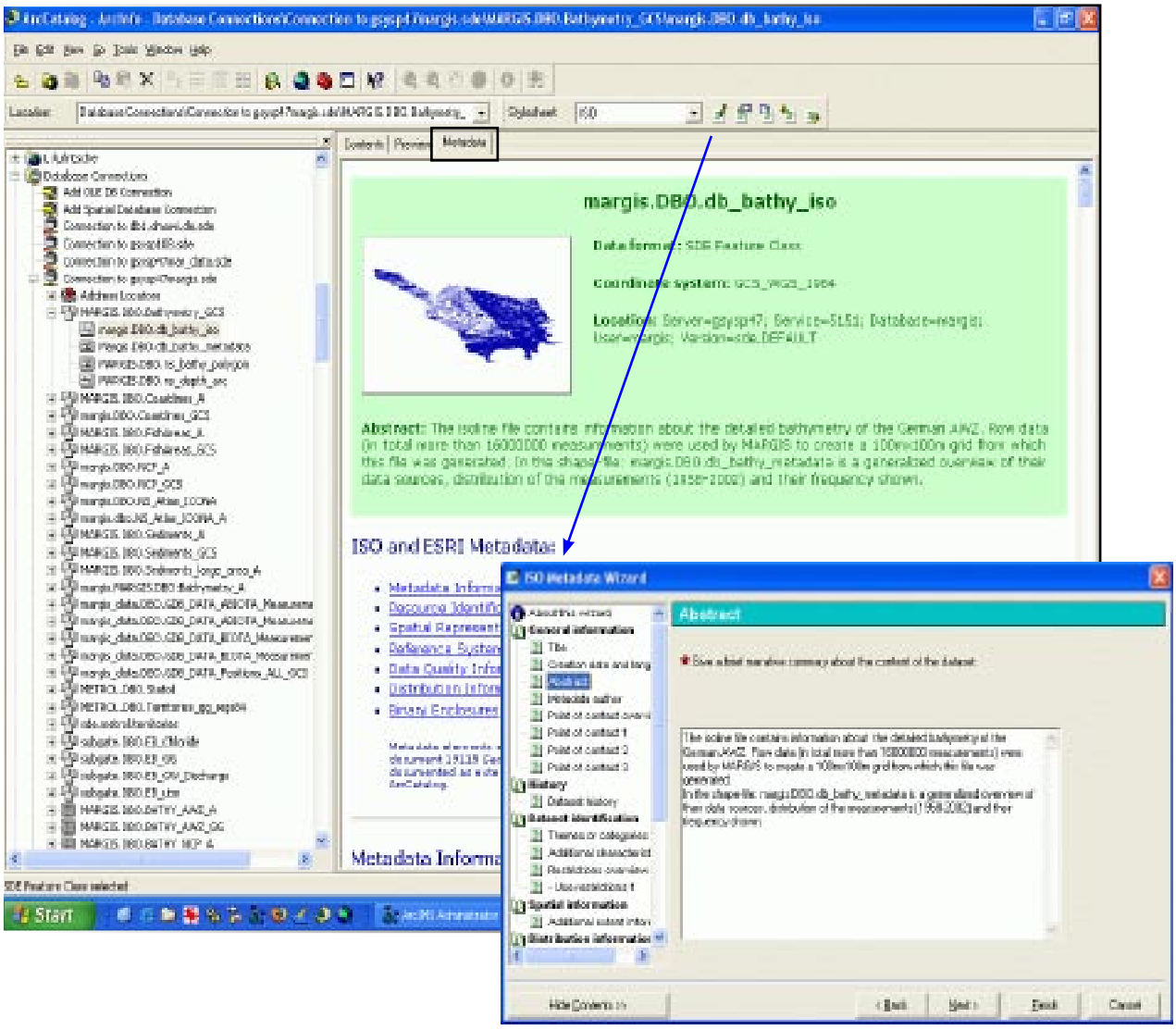
The purpose of meta data is to provide the context of data: meta data is „data about data“.

Meta data is used to facilitate the producing, characteristics, and management usage of data. The meta data required for effective data management varies with the type of data and context of use.

Meta data has many different applications. In a library, e.g., meta data about a book title would typically include a description of the content, the author, the publication date and the physical location. Meta data also is a set of optional descriptions that could be publicly available. Then, it concentrates on the purpose to find objects, entities or resources. Especially on the World Wide Web meta data has become important because of the need to find useful information from the mass of information available.

The meta data concept has been extended to include any information data about data: the names of tables, columns, programs, and the like. Meta data can describe all aspects of systems: data, activities, people and organizations involved, locations of data and processes, access methods, limitations, timing and events, as well as motivation and rules.

Geospatial meta data usually is presented as an XML file and is used to document geographic digital resources such GIS files, geo-databases, and earth imagery. It includes core library catalogue elements such as title, abstract, and publication data as well



Meta data visualization provided by ArcGIS 9.3 (ESRI). Wizards help to fulfil the information following the ISO Standard 19115.

as geographic elements such as geographic extent and projection information of the data set. Geospatial meta data also documents the properties of measurement data and the evaluation of derived results.

Related to marine research, meta data include all information about the sampling location, the devices and gear used for sampling the water column or sediment, the methods applied to split the sample in sub-segments and the analytical techniques to generate the final measurement.

Meta data describing maps includes information about the data provider (e.g. Mudab database), the applied map projections (e.g. Albers Conic Equal Area), cartographic information as computing techniques (e.g. contour plots or slope calculations from bathymetric data, interpolation methods as Indicator Kriging,...).

Finally, the availability of meta data is critical for sharing and evaluating geo-data.

For the *Digital Atlas of the North Sea*, the ISO 19115 Standard for Geographic Information is applied. ISO 19115 attempts to satisfy the requirements of all existing meta data standards. It allows for either general or detailed descriptions of data sources, makes some allowances for describing resources other than data, and has a small number of mandatory elements.

Bathymetry map derived from point measurements suiting several scientific needs

High resolution and accurate bathymetric maps are produced and made available by the Federal Maritime and Hydrographical Office (BSH) and other oceanographic institutions. Nevertheless, there seems to be still a demand on overview maps, detailed maps of subregions as well as on thematic maps derived from bathymetry as slope or 3D maps of the sea floor and distance maps e.g. from shore lines. Such aspects are important for a multitude of scientific questions and support geochemical, geological and biological research.

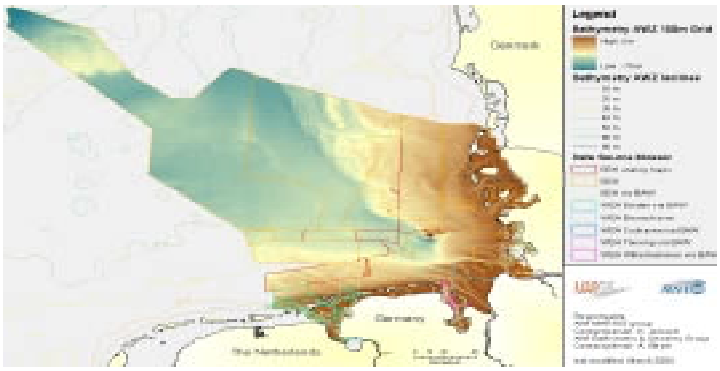
1. Data compilation

The bathymetric map of the North Sea is based on more than 42 500 measurements. For the German Exclusive Economical Zone (EEZ) more than 16 million measurements were compiled.

Distribution of ca. 16 million (EEZ) and ca. 42 500 (North Sea) single beam measurements building the basis for the bathymetry maps of the German EEZ and the North Sea.

2. Evaluating and processing

The data were e.g. converted to the same sea level reference scheme (e.g. from the Amsterdam to the German ‚Normal Null' sea level). Meta data were assigned to each data source and information layer.



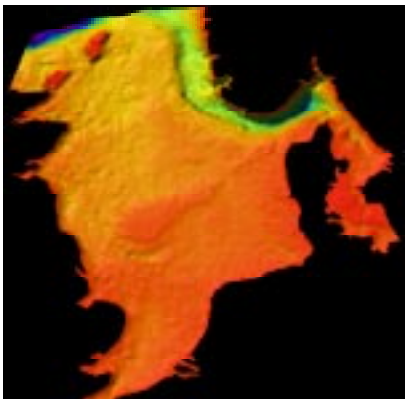
2D view on bathymetry of the German EEZ including marks for the identification of the different datasets and data provider.

3. Interpolation of raster and contour plots

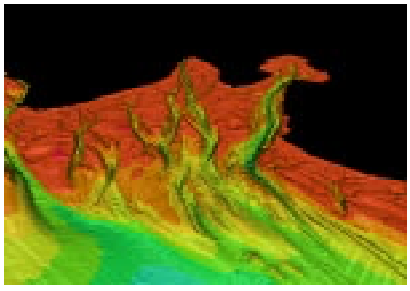
The Triangulated Irregular Network (TIN) technique was applied for calculation of bathymetry maps based on point measurements. TIN bears the advantage to maintain the coast lines during the interpolation process. Subsequently, the TIN was transformed into a regular raster dataset with the 'Topogrid' interpolation method, which is specifically designed for creating digital elevation models (DEMs). To avoid any over-interpretation of this overview map, the detailed raster was re-gridded to a coarser grid, e.g. with a raster cell size of 2.5 km.

4. Visualization

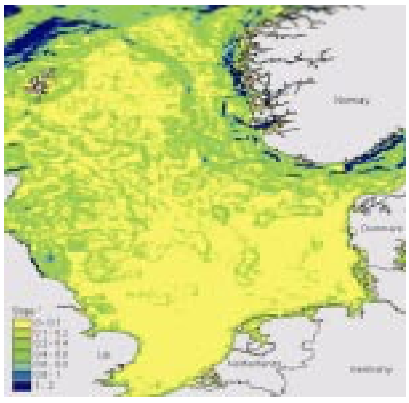
To identify links between sedimentological features or the shape of pockmarks, 2D, 3D and slope maps were derived from the bathimetric grid. This supports spatial analysis. by e.g. overlay techniques.



3D view on bathymetry based on the interpolated data of the North Sea (2500 m grid).



3D view on a detailed section (Jade Busen) of the EEZ bathymetry grid (100 m x 100 m grid cell).



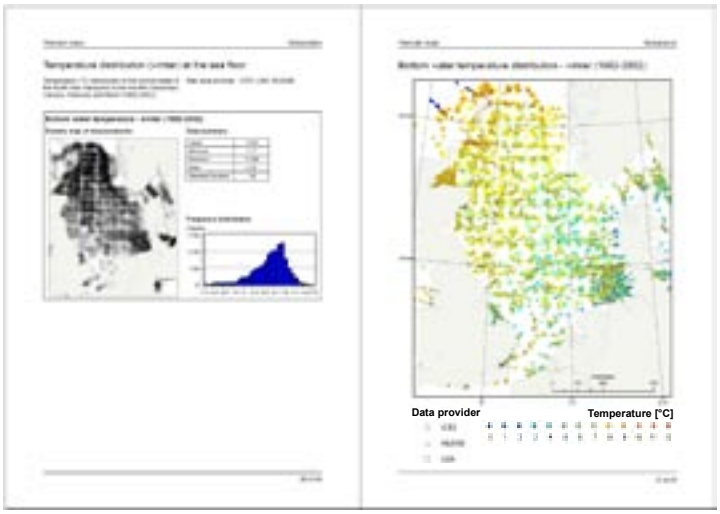
Result of a GIS application: slope map of the North Sea based on the bathymetry map.

General information about the Thematic maps section

The major intentions of the Thematic Maps compiled in the *Digital Atlas of the North Sea* are:

1. to provide information about the spatial distribution of sites, thus, where data as bottom water tempera ture, nutrient concentrations etc. is available
2. to visualize the regional pattern of the measured data (for this purpose the data are divided into several color coded value ranges) in a common map projection (Albers Equal Area Conic)
3. to assign to each data point the data provider, where raw data are stored (this is indicated by the shape of the symbols)
4. to provide an overview about each dataset in terms of statistic values like measurements per km^2, a histogram as well as the number of observations, the mean values etc.

The topics 1 to 3 are displayed on the left hand site and the data summary (topic 4) is shown on the right hand site for each information layer.



On the left page, a short description of the data is given, including a table of statistical data summary, a density map of measurements (measurements per km^2) and a histogram presenting the range of data values.

The maps on the right page show the spatial data distribution in Albers Equal Area Conic projetion, and the data provider presented as different symbols, as well as the range of values expressed in colors.

This system is maintained consistently for all maps (data provider symbols).

Coordinate systems basics

Cartographic coordinate systems provide a common basis for communication about a particular place or area on the earth‘s surface. The most critical issue in dealing with coordinate systems is knowing what the projection is and having the correct coordinate system information associated with a dataset. There are two types of coordinate systems: geographic and projected.

A geographic coordinate system uses a three-dimensional spherical surface to define locations on the earth. It includes an angular unit of measure, a prime meridian, and a datum (based on a spheroid). In a geographic coordinate system, a point is referenced by its longitude and latitude values.

Longitude and latitude are angles measured from the earth‘s center to a point on the earth‘s surface. The angles often are measured in degrees (or in grads).

A projected coordinate system is defined on a flat, two-dimensional surface. Unlike a geographic coordinate system, a projected coordinate system has constant lengths, angles, and areas across the two dimensions. A projected coordinate system is always based on a geographic coordinate system that is based on a sphere or spheroid.

In a projected coordinate system, locations are identified by x,y coordinates on a grid (horizontal and vertical position), with the origin at the center of the grid (Hake and Grünreich, 1994) .

Exclusive Economical Zone

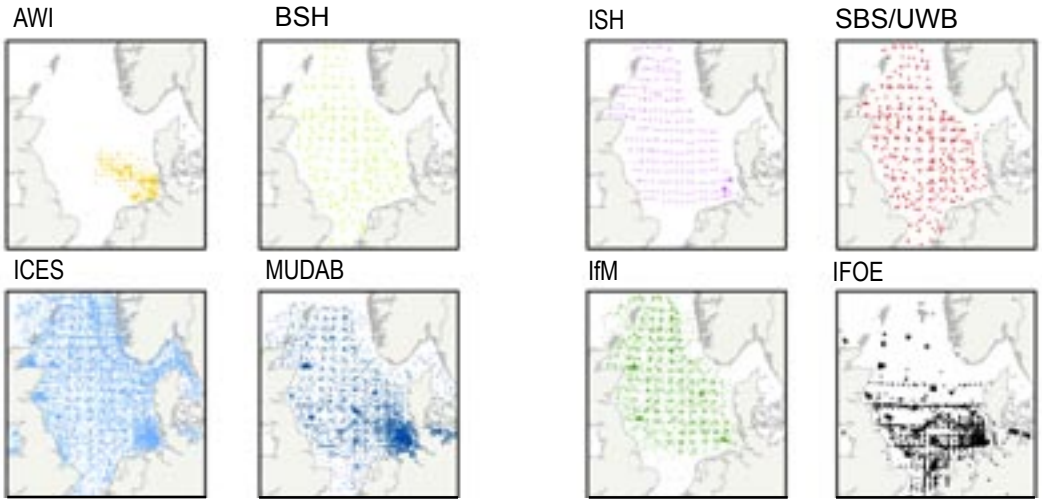
The German waters in the North and Baltic Seas consist of the 12 nautical mile zone (so-called territorial sea) and the Exclusive Economic Zone (EEZ). The German territorial sea is under the jurisdiction of the Federal coastal states. The area seaward of the 12 mile zone, which extends maximally 200 nm from the coastline, is the Exclusive Economic Zone (EEZ) (http://www.bsh.de/en/Marine_uses/Industry/Wind_farms/EEZ.jsp).

Data distribution

The *Digital Atlas of the North Sea* geo-database includes measurements of bathymetry, salinity, temperature, concentrations of oxygen, ammonium, nitrate, nitrite, phosphate, silicide acid, and suspended matter, data on benthic biology such as epibenthic and endobenthic organisms, fish populations, fish ages and lengths, and on the geology and geochemistry of the sediments.

Using existing data from variable data providers requires an aggregated database design, which both maintains the original data information and the demands of a marine geo-database.

The distribution of all measurements (1982-2002) exclusively the bathymetric data, is shown on the map (right hand). The figure below spatializes the sample sites to the data provider respectively.



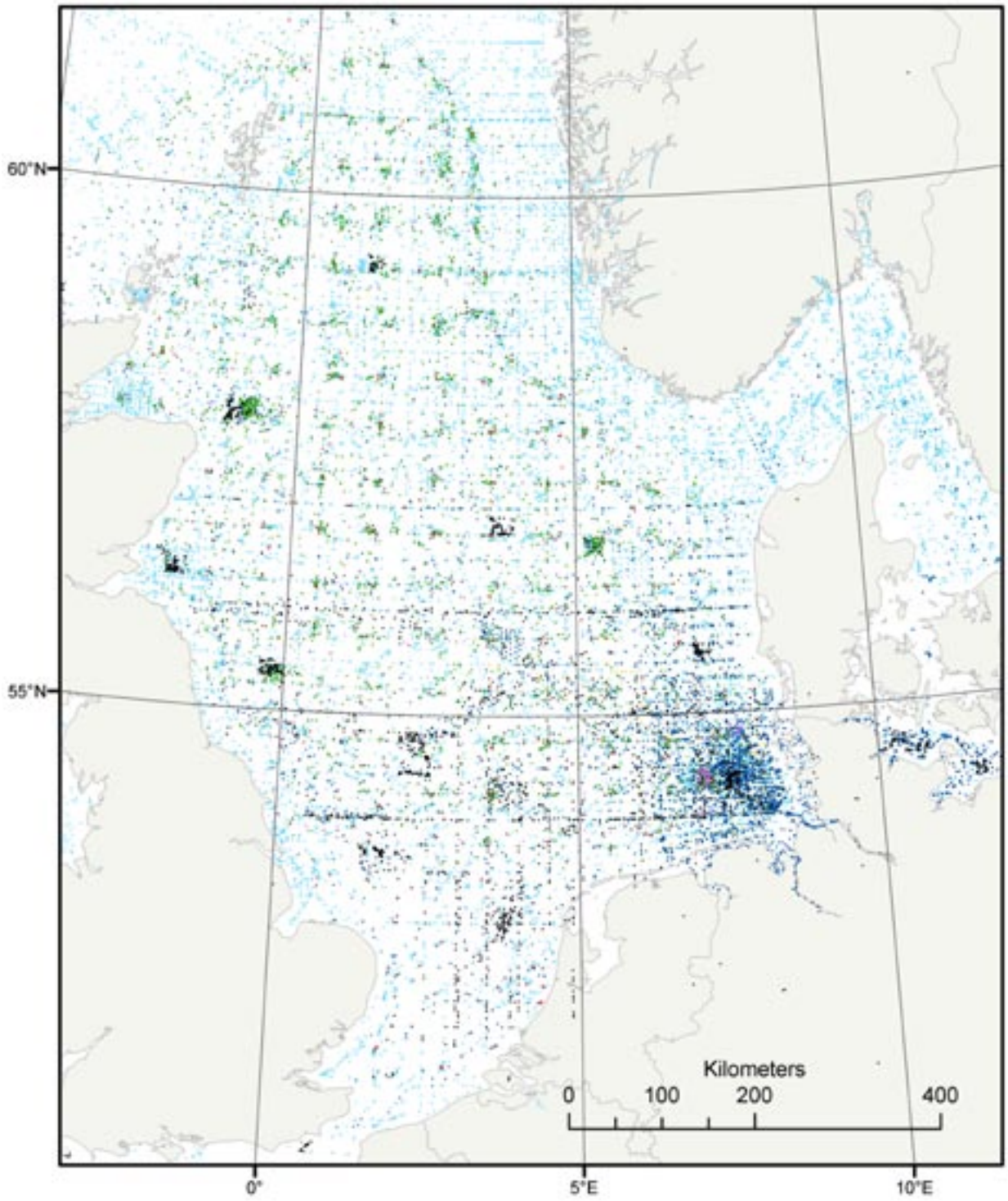
Distribution of the measurement data incorporated in the *Digital Atlas of the North Sea* geo-database exept bathymetry.

Density map of the sampling sites: the quantity of all measurements per unit area (km^2).

Obviously, the data is not evenly distributed for the entire North Sea. An applied neighborhood analysis using ArcGIS reveals that the *Digital Atlas of the North Sea* database contains large datasets for the German Bight and the regions of the central North Sea. A comparable low density of information was compiled for the southern North Sea.

The left hand the density of points and the quantity of all measurements per unit area (km^2) are presented. Conceptually, a neighborhood is defined around each raster cell center, and the number of points that fall within the neighborhood is totalled and divided by the area of the neighborhood.

Data compilation: overview of all data



Heterogeneous datasets (field data on bathymetry, salinity, temperature, concentrations of oxygen, ammonium, nitrate, nitrite, phosphate, silicide acid, and suspended matter, data on benthic biology such as epibenthic and endobenthic organisms, fish populations, fish ages and lengths, and on the geology and geochemistry of the sediments) provided by national and international databases and institutes have been compiled within the *Digital Atlas of the North Sea* data model.

Residual currents, water masses and stratification

The North Sea is situated on the continental shelf of north-west Europe. It opens into the Atlantic Ocean to the north and, via the Channel to the south-west, and into the Baltic Sea to the east, and is divided into a number of loosely defined areas. The open North Sea is often divided into the relatively shallow southern North Sea (including e.g. the Southern Bight and the German Bight), the central North Sea, the northern North Sea, the Norwegian Trench and the Skagerrak. The shallow Kattegat is seen as a transition zone between the Baltic and the North Sea. The North Sea (including its estuaries and fjords) has a surface area of about 750 000 km2 and a volume of about 94 000 km^3 (OSPAR Commission, 2000).

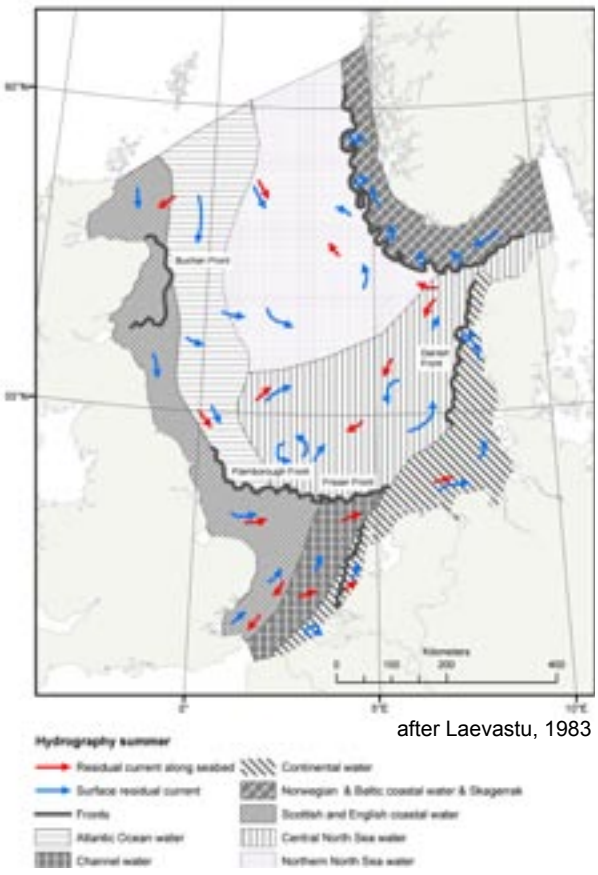
Water masses are often separated from each other by fronts, transitions within a relatively short distance (a few kilometers). These transitions are measurable in salinity, temperature, and nutrients. The fronts are more clearly marked in summer than in winter. This is because the water is less strongly agitated by the wind in summer, so a less vertical mixin occurs. A well known front is the Frissian Front, which forms the boundary between water from the English Channel and water from the Atlantic Ocean.

The water in the North Sea is generelly well mixed, particulary in the relatively shallow areas with strong tides. a stratification occurs in deeper parts in summer. The action of waves and currents is then insufficient to transport the solar heat to greater depths. As soon as a temperature difference exists between different water layers, mixing is made more difficult, because the warmer water continues to float on top of the colder bottom layer (thermocline).

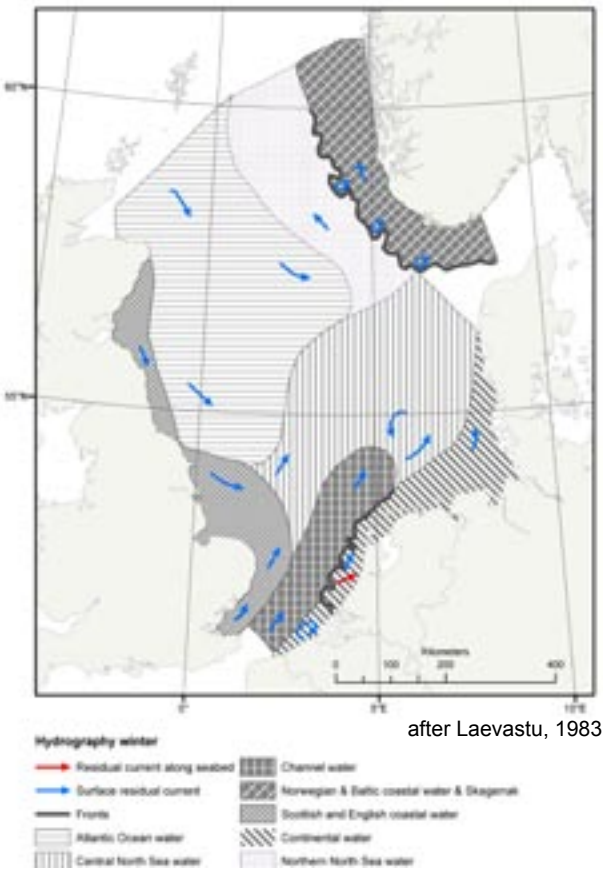
The consequence of the thermocline is that oxygen and nutrients in the lower layer are used up by the organisms and an anaerobic situation may arise by the end of the summer.

In autumn the sea is so churned up by storms that the thermocline is disrupt, and the water mixes again vertically (Saetre and Becker, 1990).

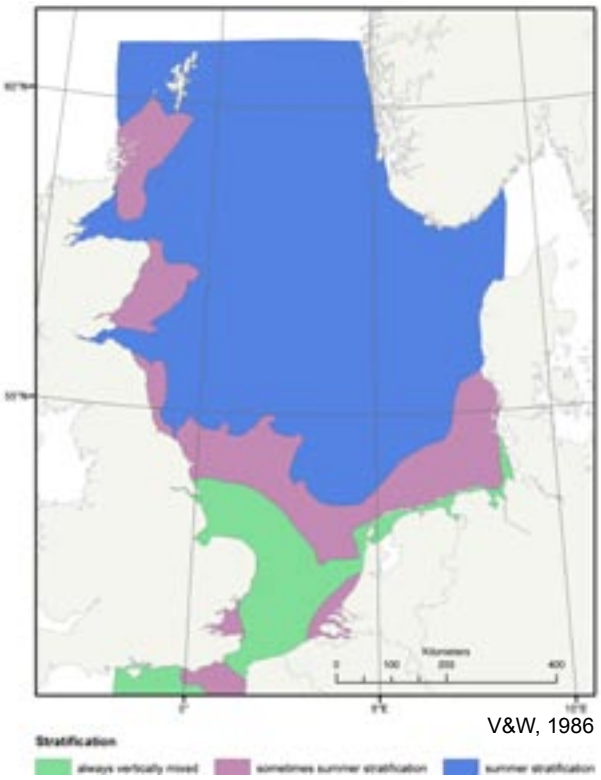
Residual currents, water masses and stratification



after Laevastu, 1983



after Laevastu, 1983



V&W, 1986

Bathymetry map of the North Sea

The bottom topography is important in relation to its effect on water circulation and vertical mixing and shows evidence of river valley systems (German Bight, Strait of Dover) that were carved into the seabed during glacial periods when the sea level was lower. Multiple invasions of Scandinavian and Scottish mountain glaciers spread over the North Sea causing large sea level changes and supplies of additional sediment into the North Sea basin. It also shaped the general style of the present underwater topography, for instance, elevations such as the Dogger Bank and depressions like the Oyster Ground, the submerged part of the Elbe valley, Devil's Hole, Fladen Ground and the Norwegian Trench.

The map shows the bathymetry of the North Sea in a 2712 m x 2712 m raster. Due to higher data density the bathymetry grid for the German EEZ offers an upgraded resolution (141 m x 141 m), whereas the Dutch EEZ grid was provided by the RIKZ in a 1069 m x 1069 m raster. Furthermore, the EEZs of the North Sea are included.

All maps are available in a Geographic coordination system (WGS 84) and concern area calculations in an Conic Equal Area Albers projection (ED 50).

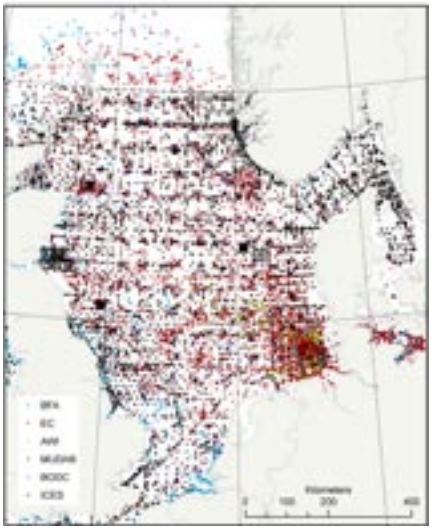
The depth of the North Sea increases towards the Atlantic Ocean to about 200 m at the edge of the continental shelf. The Norwegian Trench, which has a sill depth of 270 m off the west coast of Norway and a maximum depth of 700 m in the Skagerrak, plays a major role in steering large inflows of Atlantic water into the North Sea. On the north-west side of the Dutch part of the continental shelf lies the shallow area of the Dogger Bank where depths can be less than 20 m. This bank has a significant impact on the circulation in the southern North Sea and is an important fishing area (OSPAR Commission 2000).

Density of measurements

The left hand maps and the table below present information about the spatial distribution and the density of used measurements producing the bathymetry grid (right page). One aim of the *Digital Atlas of the North Sea* is to provide a transparent quality of the maps, which is important for further (GIS-based) use of the map. The distribution information refers to the bathymetry map of the entire North Sea. The generation of the bathymetry grid of the German EEZ is described later in this chapter.

Data summary

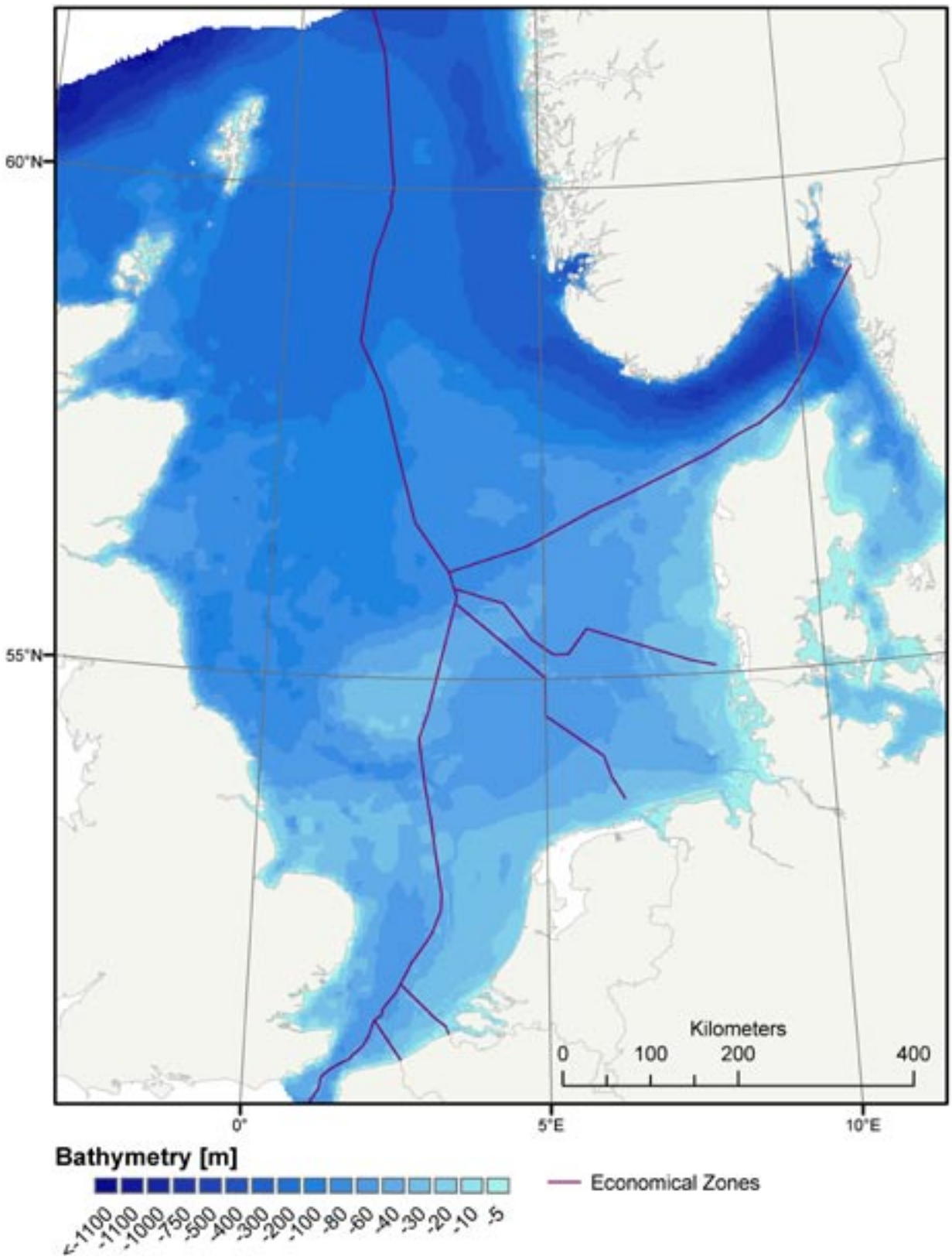
	BODC	ICES	MUDAB	BFA	EC	AWI	Total
Count	3778	11932	18952	4695	269	259	39885
Minimum	0	5	0	0	0	12	2.83
Maximum	1182	961	688	64	275	71	540.2
Mean	92	96	33	21	72	35	58.2
Median	31	64	25	19	61	37	39.5
Stan. Dev.	176	100	36	17	45	11	66



Distribution of approximately 40 000 single beam data.

Density map of of single beam data.

Bathymetry and Exlusive Economical Zones (EEZ) of the North Sea

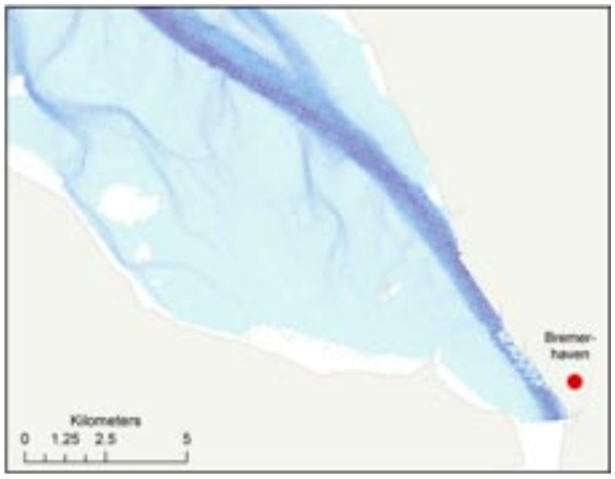


Bathymetric raster dataset of the North Sea. The derived grid has a resolution of 2 712 m x 2 712 m and is the result of the interpolation of approximately 40 000 data points.

Bathymetry map of the German Exlusive Economical Zone

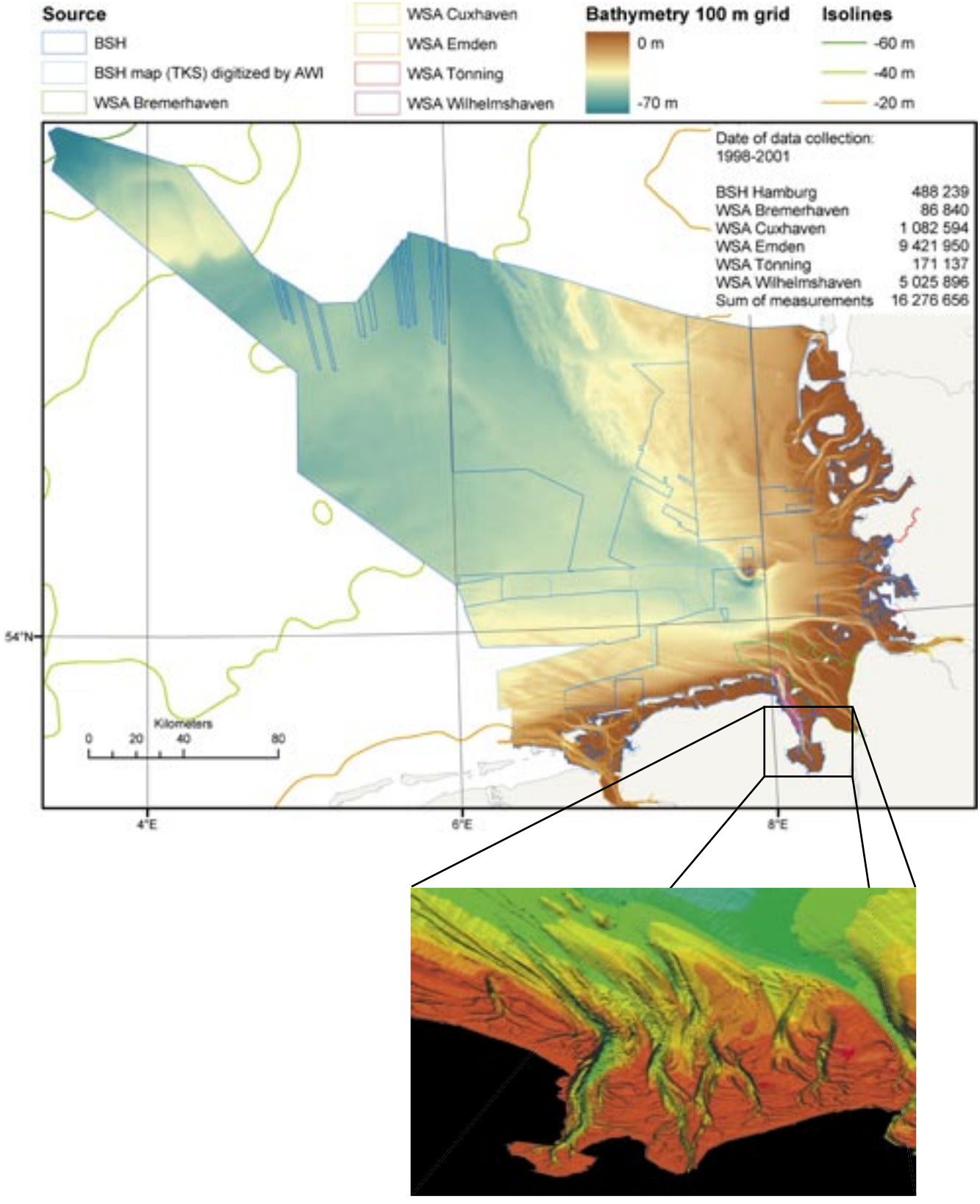
The bathymetric map of the German Exclusive Economical Zone (EEZ) is based on more than 16 million measurements. During the evaluating and processing, the data were calculated into the same data type, sea level and geographic reference scheme. Data provider were assigned to each region and are represented as an single information layer.

The Triangulated Irregular Network (TIN) technique was applied to the values. This bears the advantage to preserve the sustained coast lines during the interpolation process. The TIN was transformed into regular raster datasets with the ‘Topogrid’ interpolation.



Detailed view on the high single beam density within the Weser estuary applied for the interpolation of the German EEZ bathymetry.

Bathymetry map of the German Exlusive Economical Zone



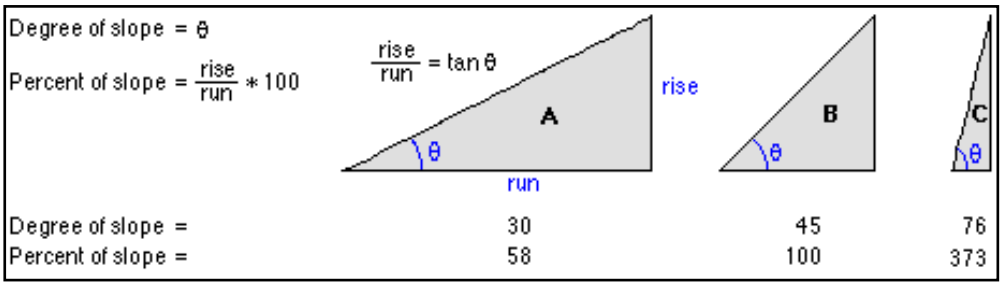
The slope of the sea floor

The North Sea is recognized as a flat marginal sea with nearly no slope values (on the average 0,1 degrees). Slightly increased values (0.2-0.3 degrees) define the Dogger Bank, the Elbe Urstromtal and the northern North Sea. The highest results (1,5-2 degrees) identify the areas around the Shetlands, the Norwegian Trench as well as the continental slope.

The slope map was derived from the bathymetry raster applying the slope algorithm implemented in the GIS.

Method box: Calculation of slope maps

For each cell, slope calculates the maximum rate of change in value from that cell to its neighbors. Basically, the maximum change in elevation over the distance between the cell and its eight neighbors identifies the steepest downhill descent from the cell.
Conceptually, the slope function implemented in GIS fits a plane to the z-values of a 3 x 3 cell neighborhood around the processing or center cell. The slope value of this plane is calculated using the average maximum technique (Burrough, and McDonell1998). The direction the plane faces is the aspect for the processing cell.
The lower the slope value, the flatter the terrain; the higher the slope value, the steeper the terrain.



The percent rise can be better understood as the rise divided by the run, multiplied by 100. Consider triangle B above. When the angle is 45 degrees, the rise is equal to the run, and the percent rise is 100 percent. As the slope angle approaches vertical (90 degrees), as in triangle C, the percent rise begins to approach infinity (Burrough and McDonell,1998).

The slope algorithm

The rate of change of the topographic height in the north-south (dz/dx) and east-west directions (dz/dy) from the center cell determines the slope. The basic algorithm used to calculate the slope is:

slope_radians = ATAN (√ ([dz/dx]2 + [dz/dy]2))

Slope is commonly measured in degrees, which uses the algorithm:

slope_degrees = ATAN (√ ([dz/dx]2 + [dz/dy]2)) * 57.29578

The slope algorithm can also be interpreted as:

slope_degrees = ATAN (rise_run) * 57.29578

where:

rise_run = √ ([dz/dx]2 + [dz/dy]2]

The values of the center cell and its eight neighbors determine the north-south and east-west deltas. The neighbors are identified as letters from ‘a‘ to ‘i‘, with ‘e‘ representing the cell for which the aspect is being calculated.

a	b	c
d	e	f
g	h	i

The rate of change in the x direction for cell ‘e‘ is calculated with the algorithm:

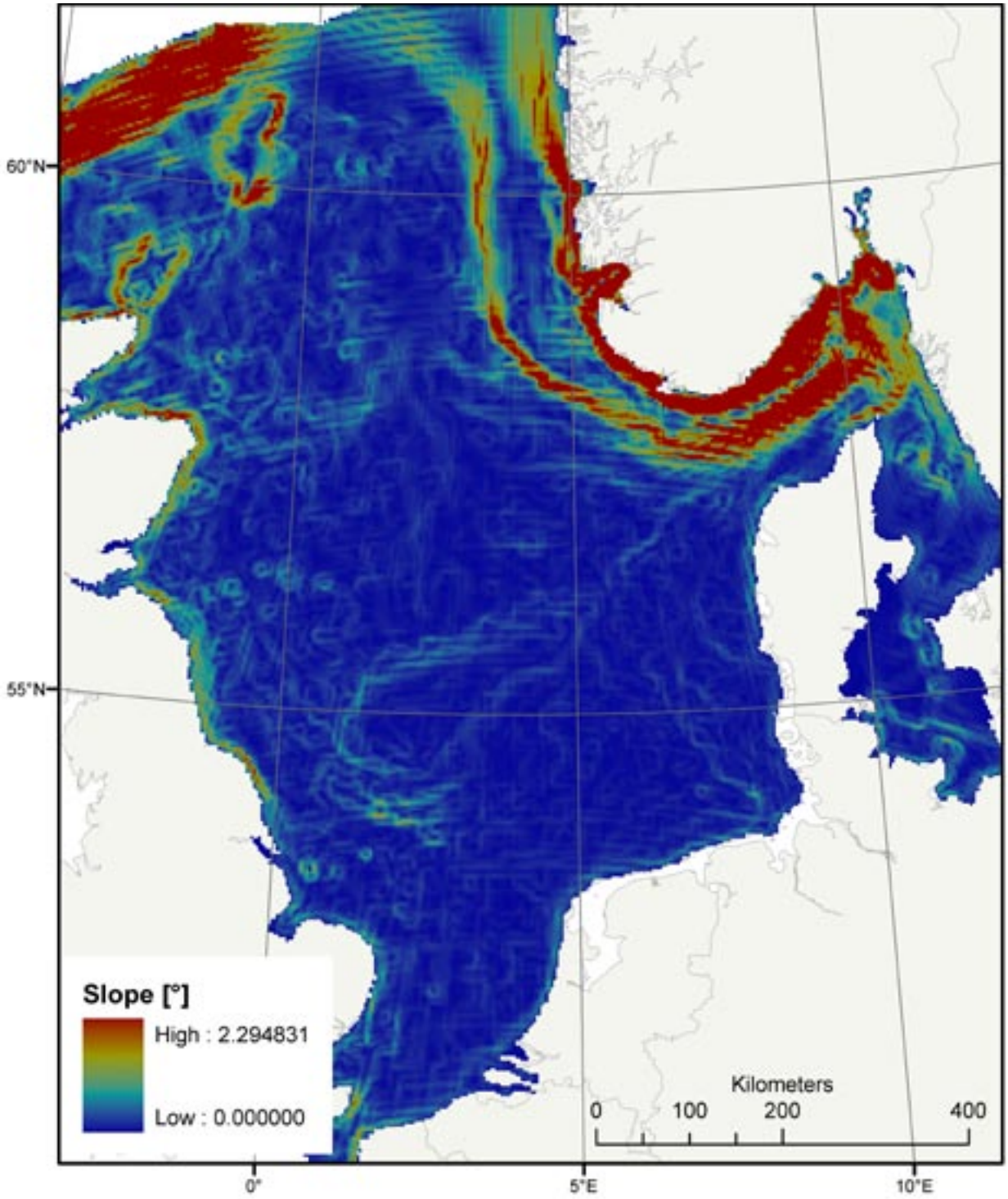
[dz/dx] = ((c + 2f + i) - (a + 2d + g) / (8 * x_cell_size)

The rate of change in the y direction for cell ‘e‘ is calculated with the following algorithm:

[dz/dy] = ((g + 2h + i) - (a + 2b + c)) / (8 * y_cell_size)

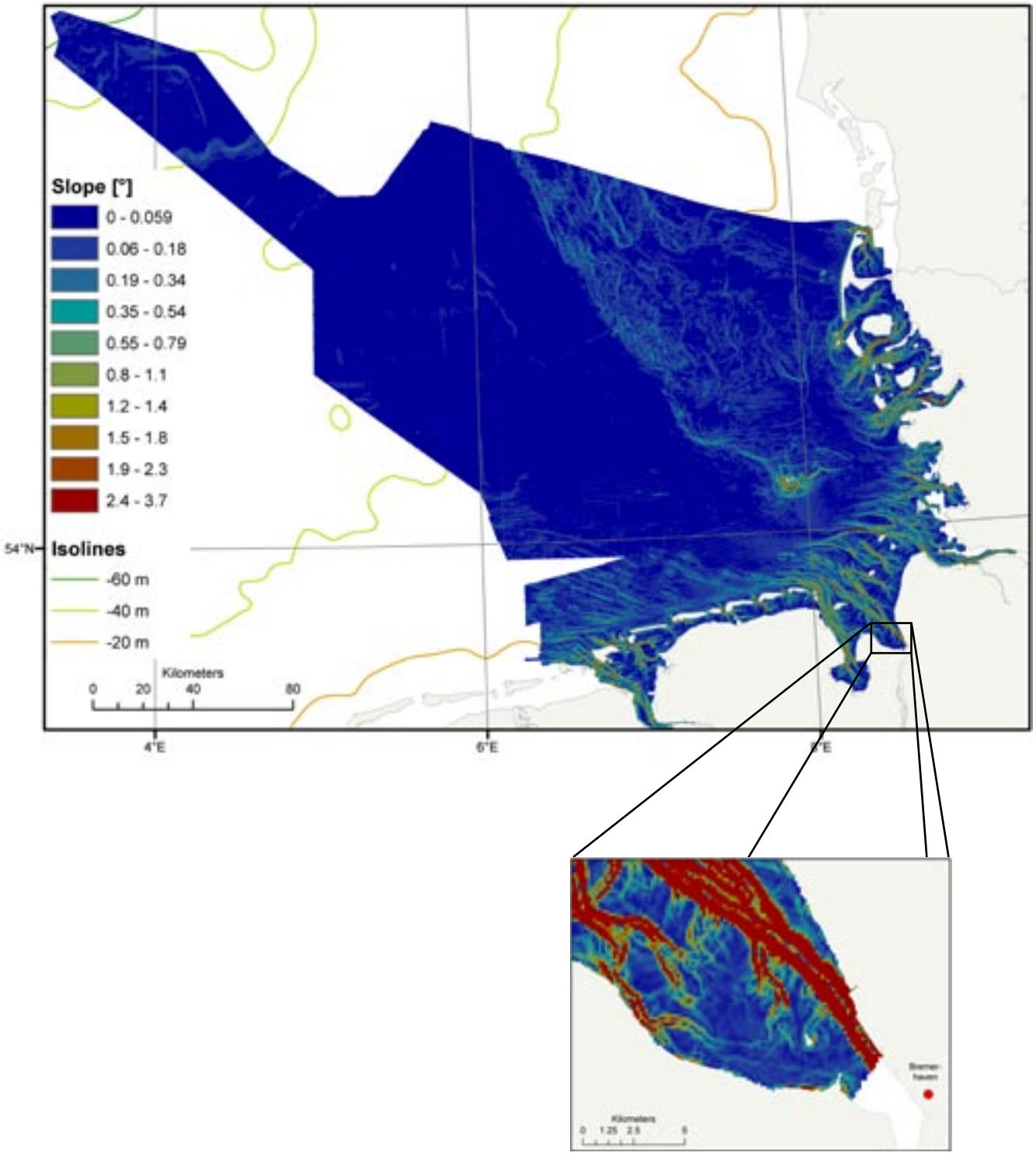
(Burrough and McDonell, 1998)

Slope map of the North Sea



Raster dataset of the slope in degrees. The resolution of the map (2 712 m x 2 712 m) results from the GIS-based application of the slope algorithm on the bathymetry map.The Dogger Bank and the Norwegian Trench can be considerably identified by slightly increased slope values.

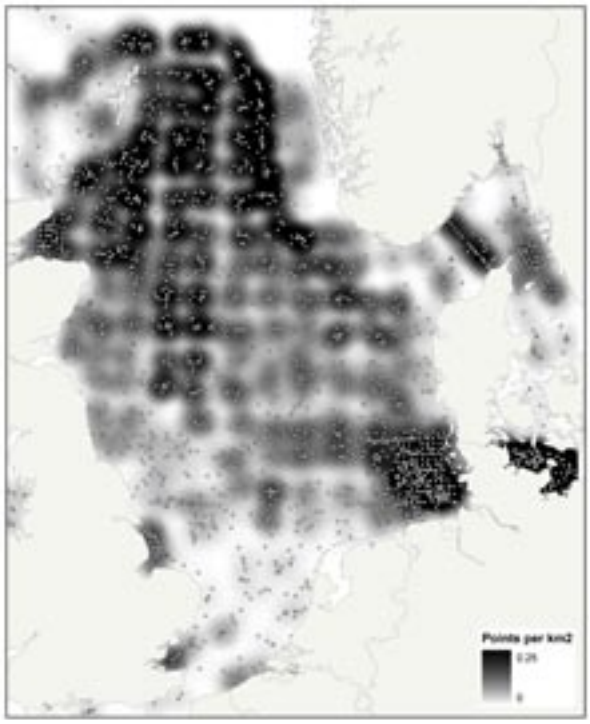
Slope map of the German Exlusive Economical Zone



Temperature distribution (winter) in bottom waters

Temperature (°C) distrubution in the bottom water of the North Sea measured in the months December, January, February and March (1982-2002). Raw data provider: ICES, UBA, MUDAB.

Density map of temperature measurements (1982-2002)

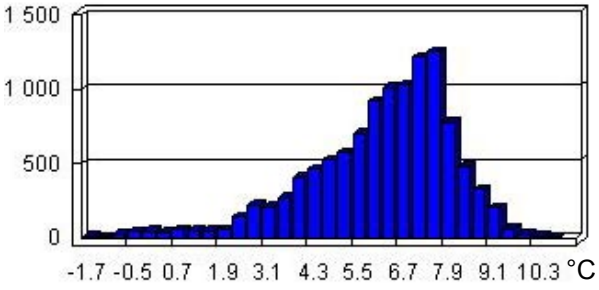


Data summary

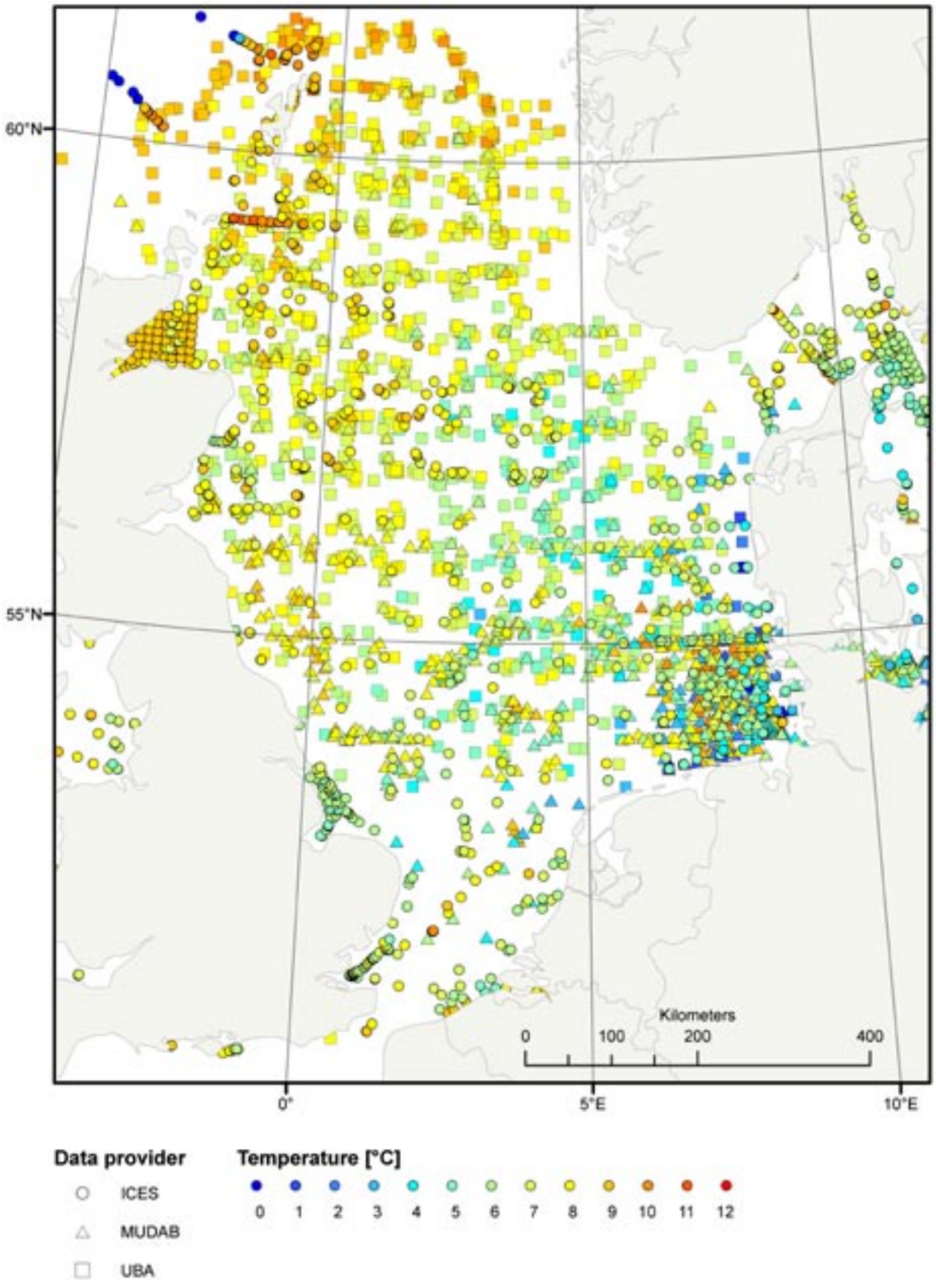
Number of values	11213
Minimum	-0.8
Maximum	11.1
Mean	6.3
Standard Deviation	1.9

Frequency distribution

Counts



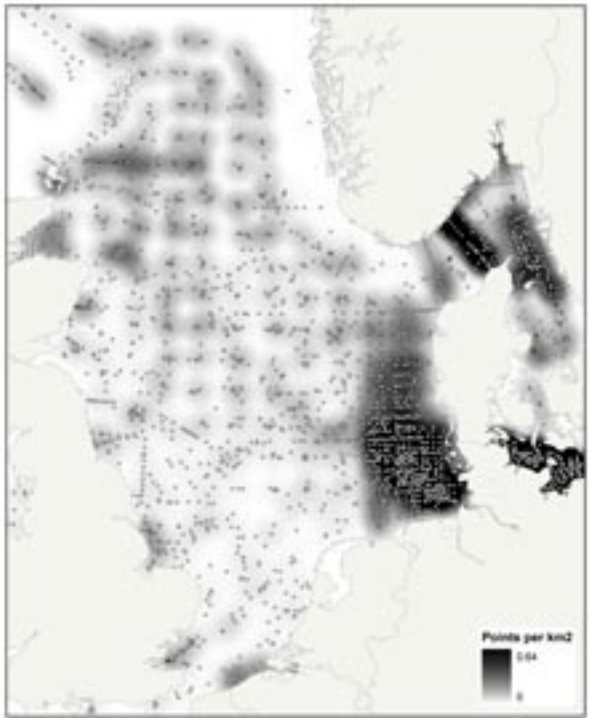
Temperature distribution in bottom waters - winter (1982-2002)



Temperature distribution (summer) in bottom waters

Temperature (°C) distrubution in the bottom water of the North Sea measured in the months June, July, August and September (1982-2002). Raw data provider: ICES, MUDAB.

Density map of temperature measurements (1982-2002)

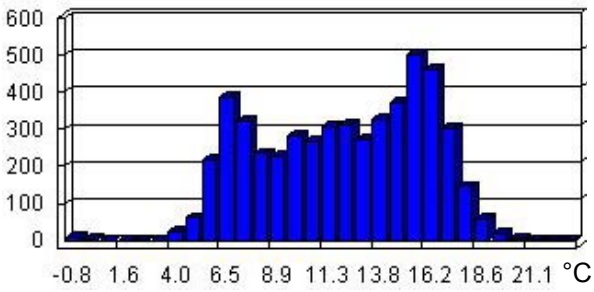


Data summary

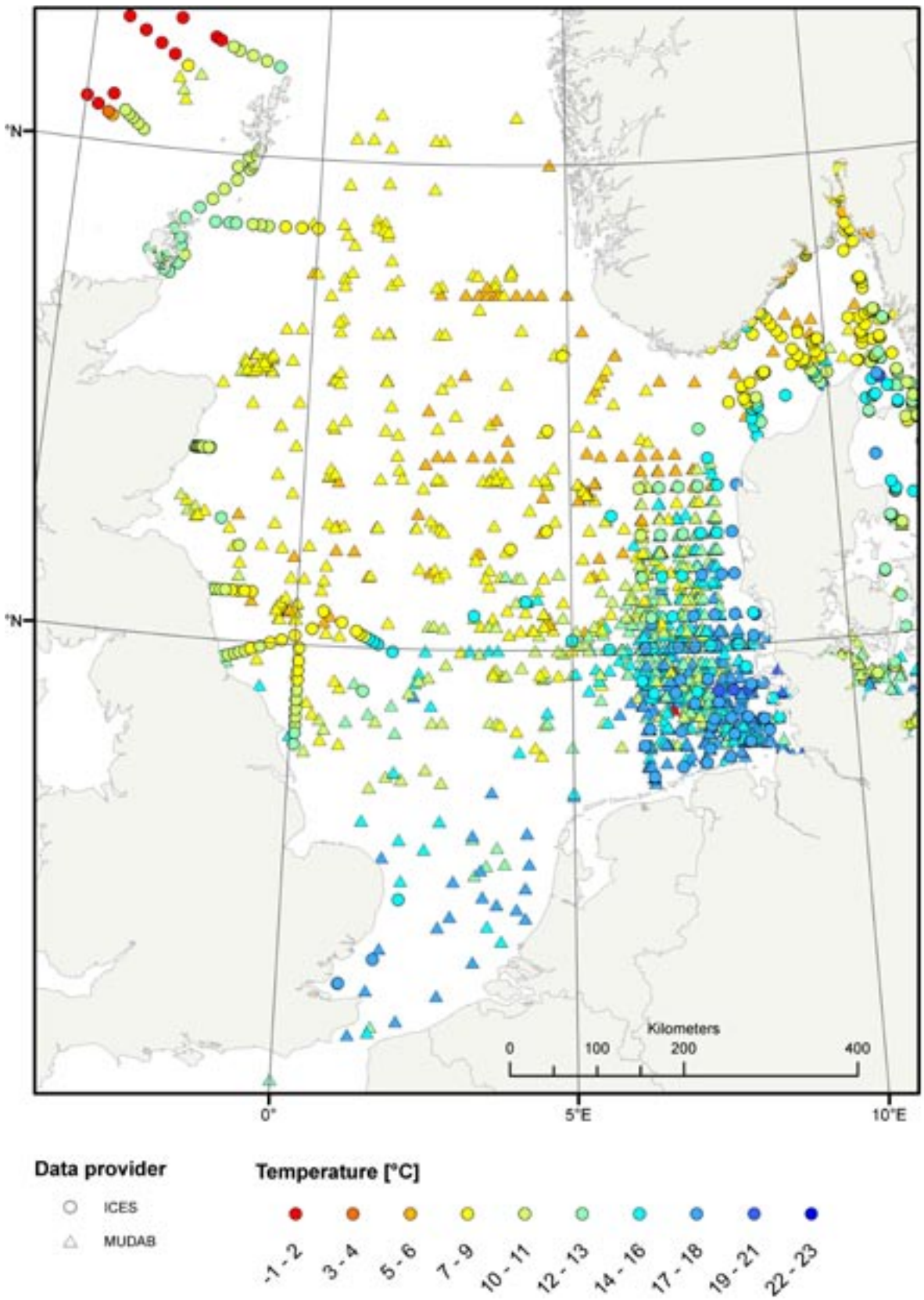
Number of values	5121
Minimum	-0.8
Maximum	23
Mean	12.4
Standard Deviation	3.9

Frequency distribution

Counts



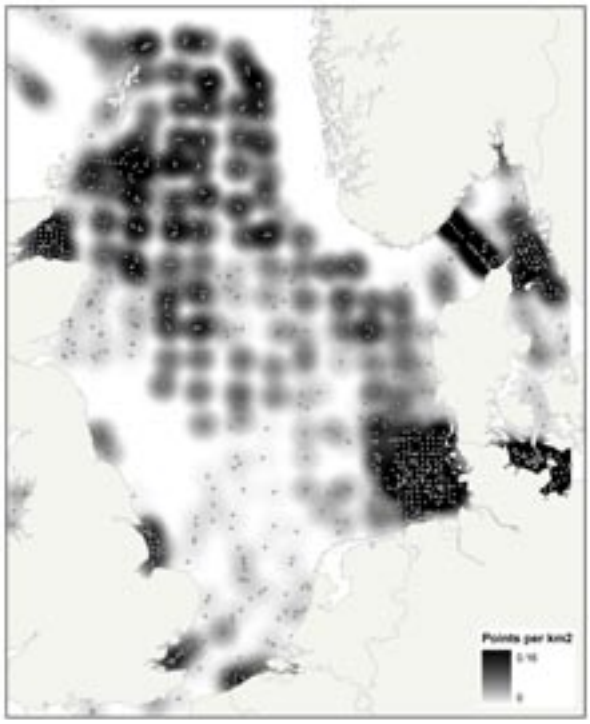
Temperature distribution in bottom waters - summer (1982-2002)



Salinity distribution (winter) in bottom waters

Salinity (°‰) distrubution in the bottom water of the North Sea measured in the months December, January, February and March (1982-2002). Raw data provider: ICES, MUDAB, UBA.

Density map of salinity measurements (1982-2002)

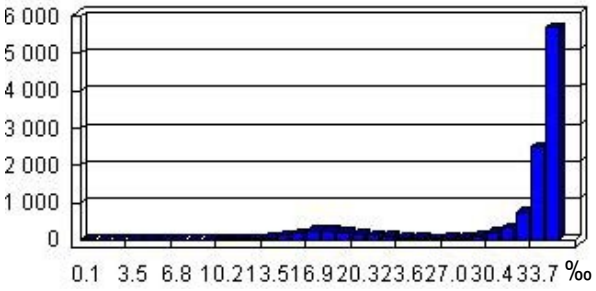


Data summary

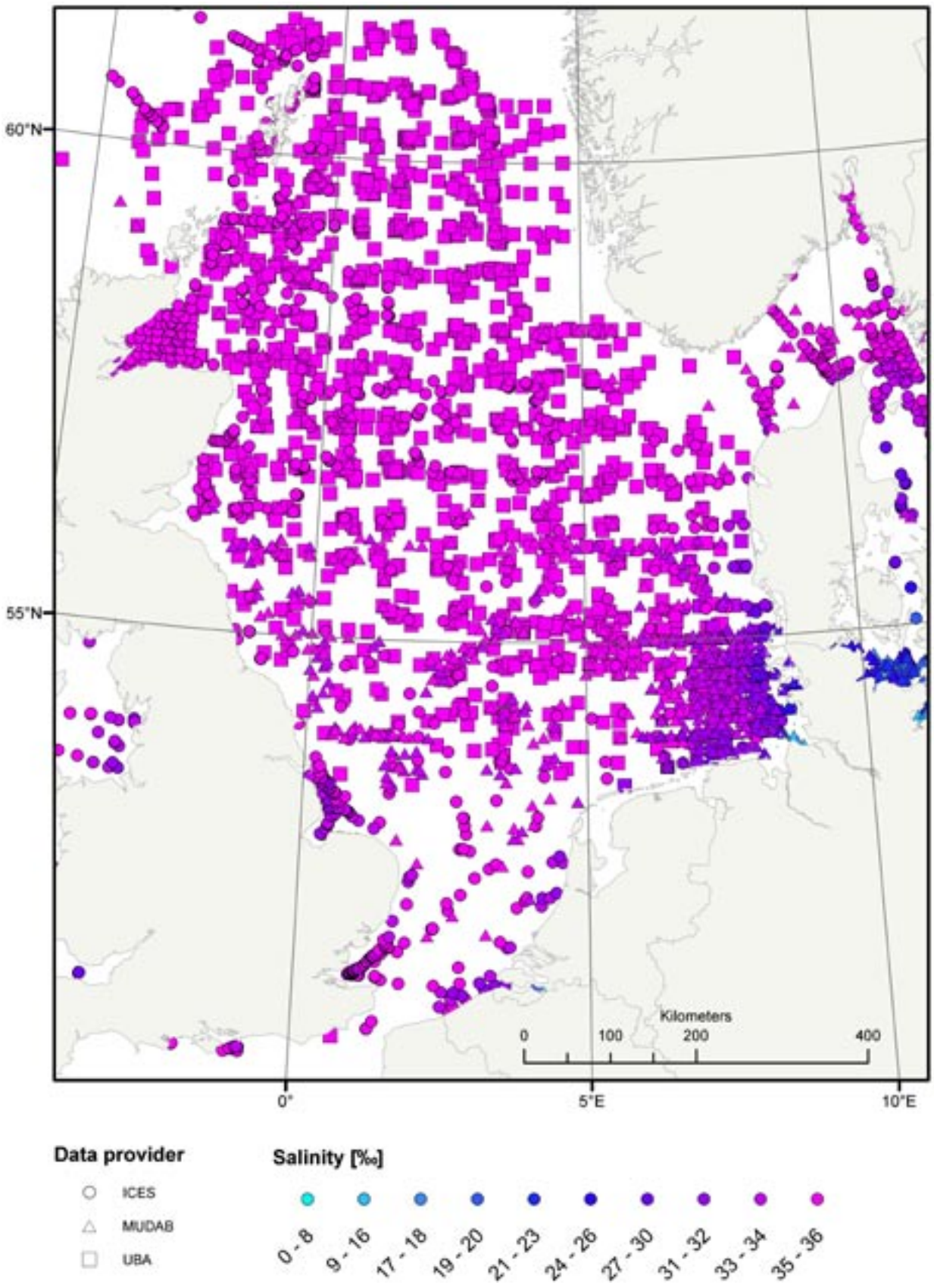
Number of values	11160
Minimum	0.1
Maximum	35.9
Mean	32.4
Standard Deviation	5.7

Frequency distribution

Counts



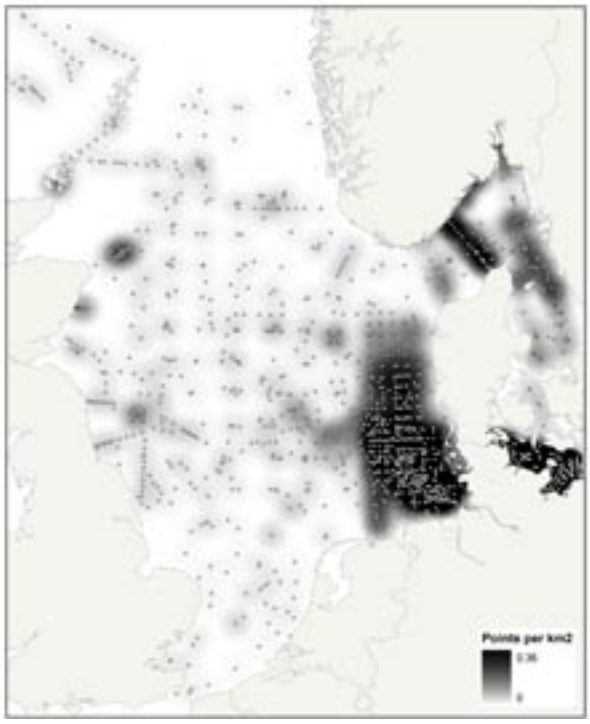
Salinity concentration in bottom waters - winter (1982-2002)



Salinity concentration (summer) in bottom waters

Salinity (°‰) concentration in the bottom water of the North Sea measured in the months June, July, August and September (1982-2002). Raw data provider: ICES, MUDAB.

Density map of salinity measurements (1982-2002)

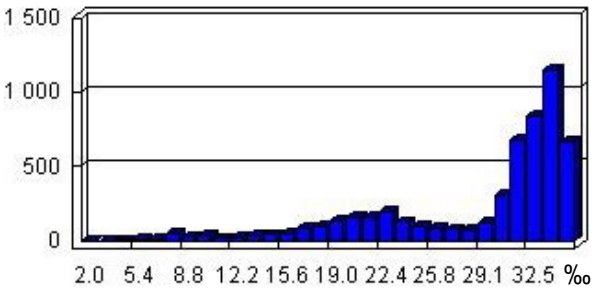


Data summary

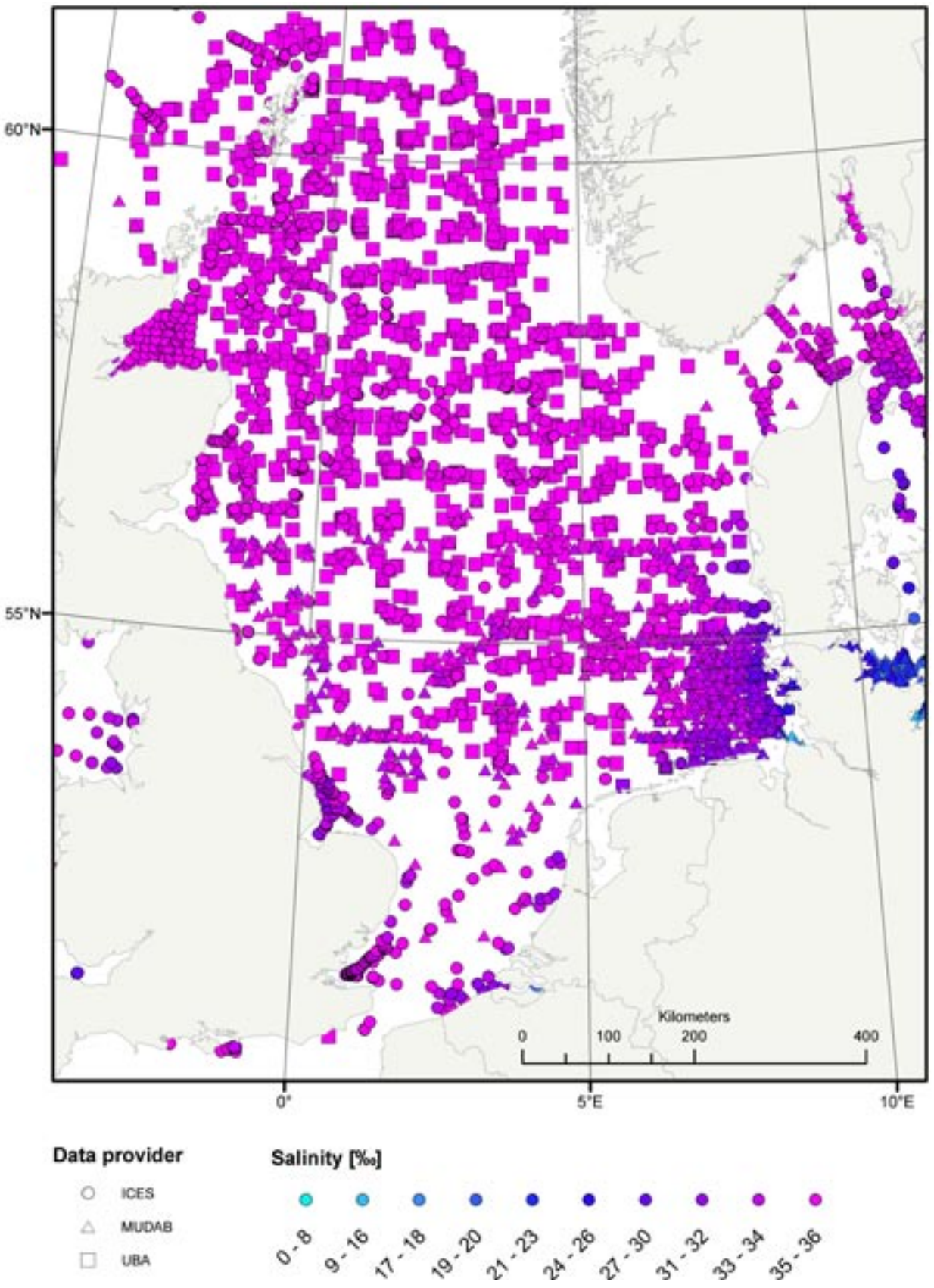
Number of values	5358
Minimum	1.9
Maximum	35.4
Mean	29.6
Standard Deviation	6.5

Frequency distribution

Counts



Salinity concentration in bottom waters - summer (1982-2002)



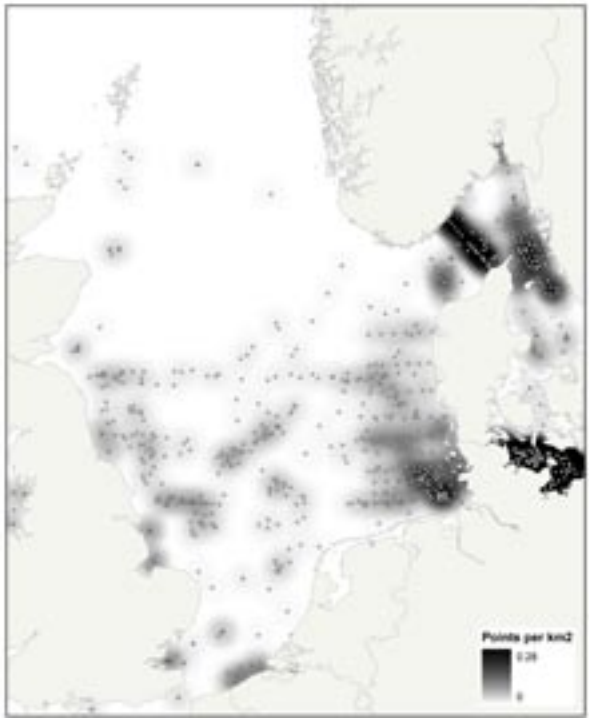
Thematic maps - Oxygen and nutrients

In the North Sea winter, nutrient concentrations determine the starting conditions for the phytoplankton spring bloom and subsequent seasonal cycling. This is coupled with strong shifts of nutrients like nitrogen, phosphate and other dissolved components between inorganic and organic phase. Gradients of nutrients in time or space reflect the current status within the North Sea ecosystem (Radach and Gekeler, 1996). Since nitrogen and phosphorus are among the main limiting elements for phytoplankton development, they determine the maximum annual yield of biomass and affect all processes linked to the turnover of organic matter (Brockmann et al., 1994). This chapter represents data distribution maps about dissolved oxygen and nutrient data.

Dissolved oxygen concentration in bottom waters - winter (1982-2002)

Dissolved oxygen (µmol/l) concentration in the bottom water of the North Sea measured in the months December, January, February and March (1982-2002). Raw data provider: ICES, MUDAB.

Density map of diss. oxygen measurements (1982-2002)

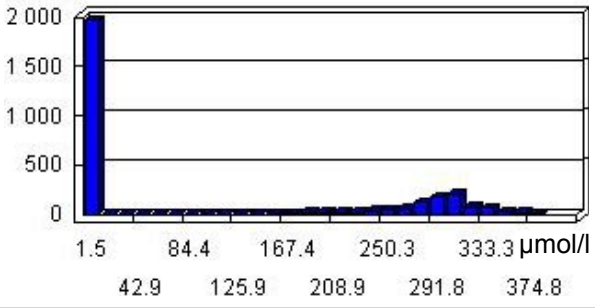


Data summary

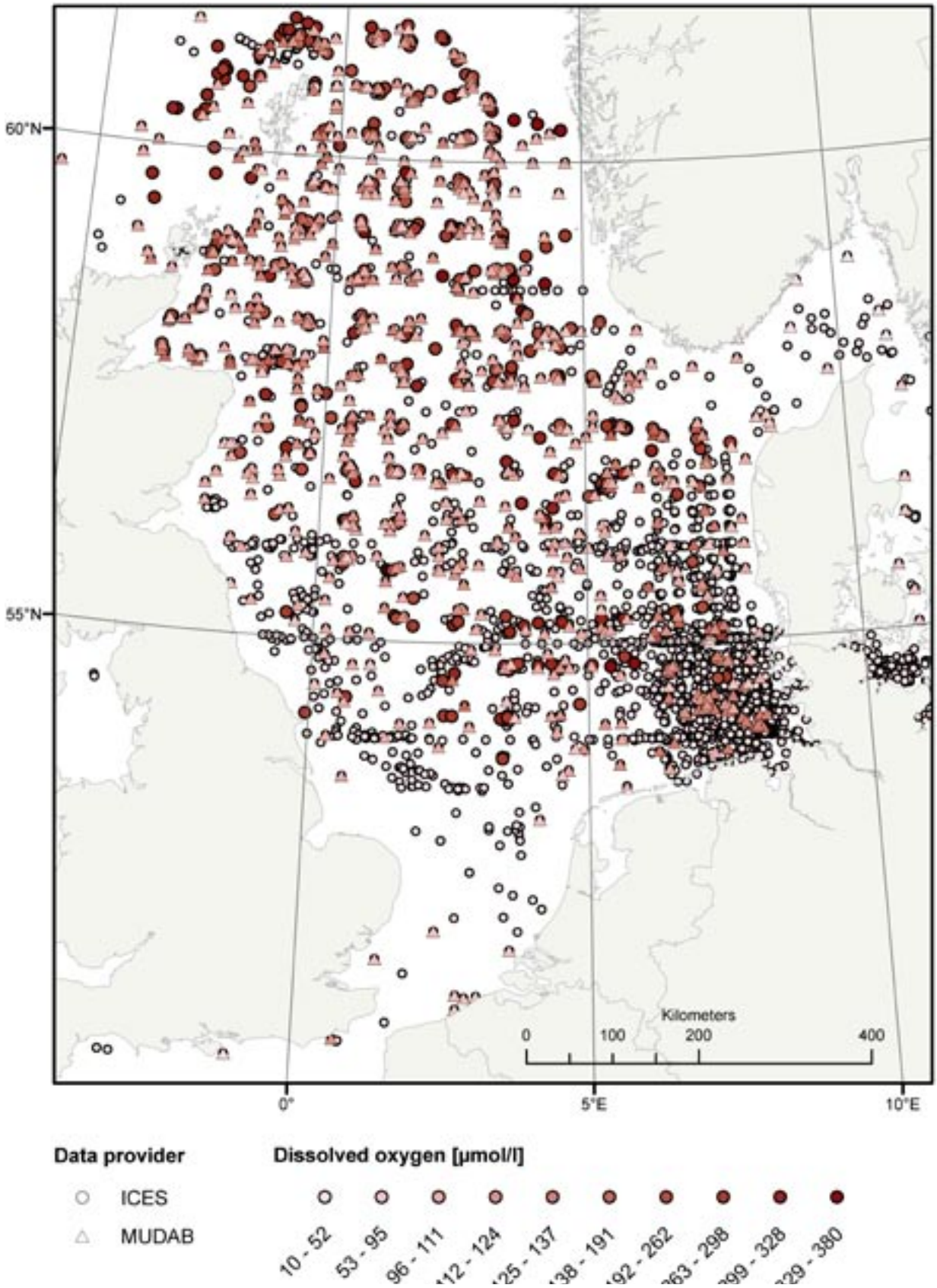
Count	2811
Minimum	1.5
Maximum	380.1
Mean	94.4
Standard Deviation	134.3

Frequency distribution

Counts



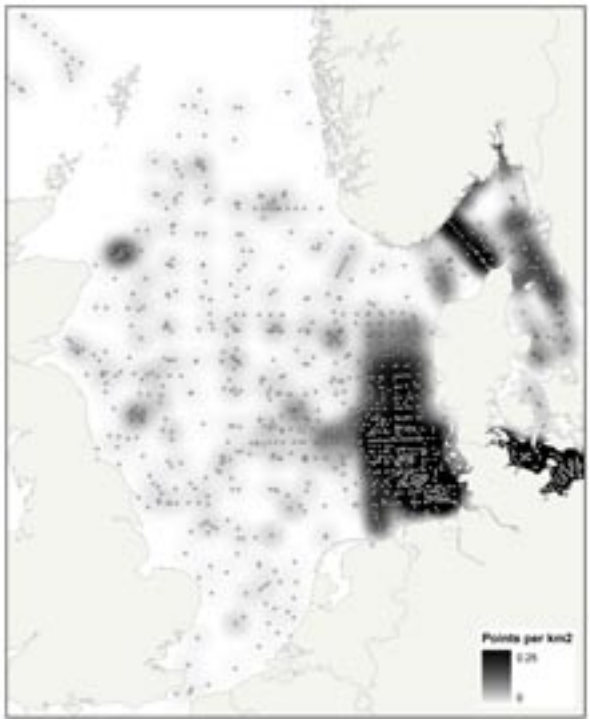
Dissolved oxygen concentration in bottom waters - winter (1982-2002)



Dissolved oxygen concentration in bottom waters - summer (1982-2002)

Dissolved oxygen (µmol/l) concentration in the bottom water of the North Sea measured in the months June, July, August and September (1982-2002). Raw data provider: ICES, MUDAB.

Density map of diss. oxygen measurements (1982-2002)

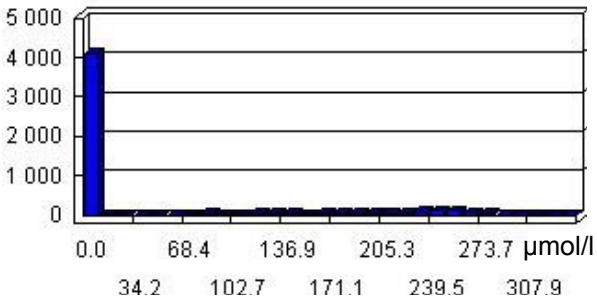


Data summary

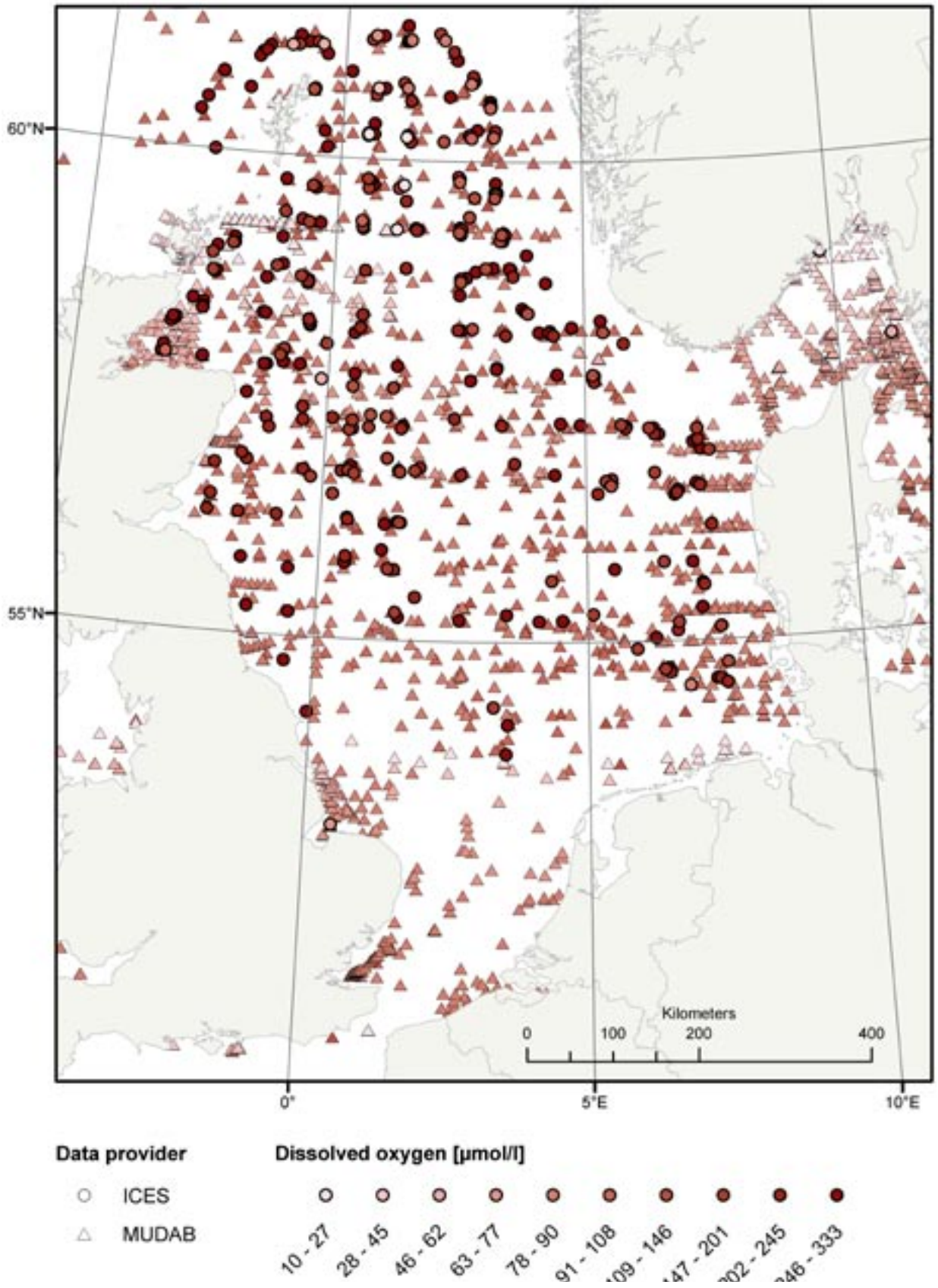
Number of values	4878
Minimum	0.01
Maximum	333.2
Mean	37.9
Standard Deviation	80.3

Frequency distribution

Counts



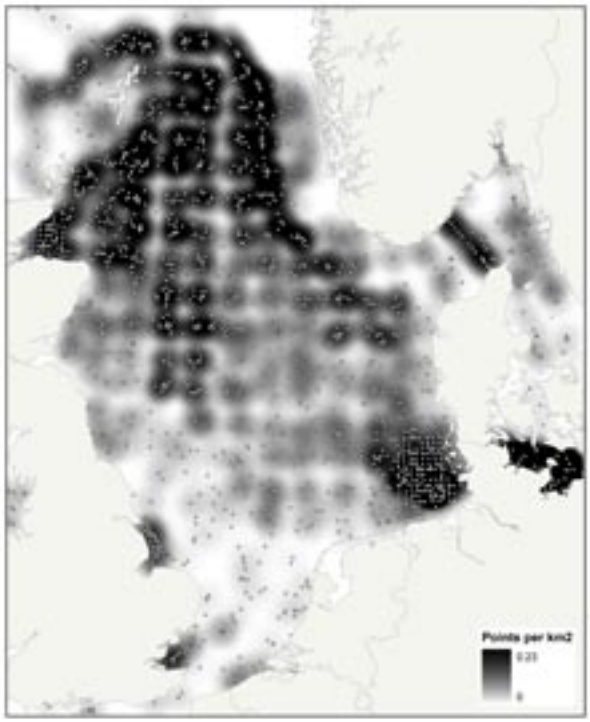
Dissolved oxygen concentration in bottom waters - summer (1982-2002)



Nitrate concentration (winter) in bottom waters

Nitrate (µmol/l) concentration in the bottom water of the North Sea measured in the months December, January, February and March (1982-2002). Raw data provider: ICES, MUDAB, UBA.

Density map of nitrate measurements (1982-2002)

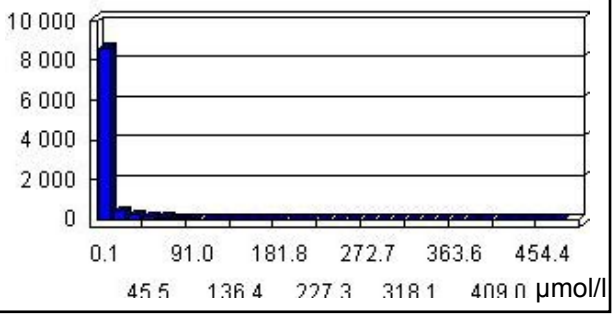


Data summary

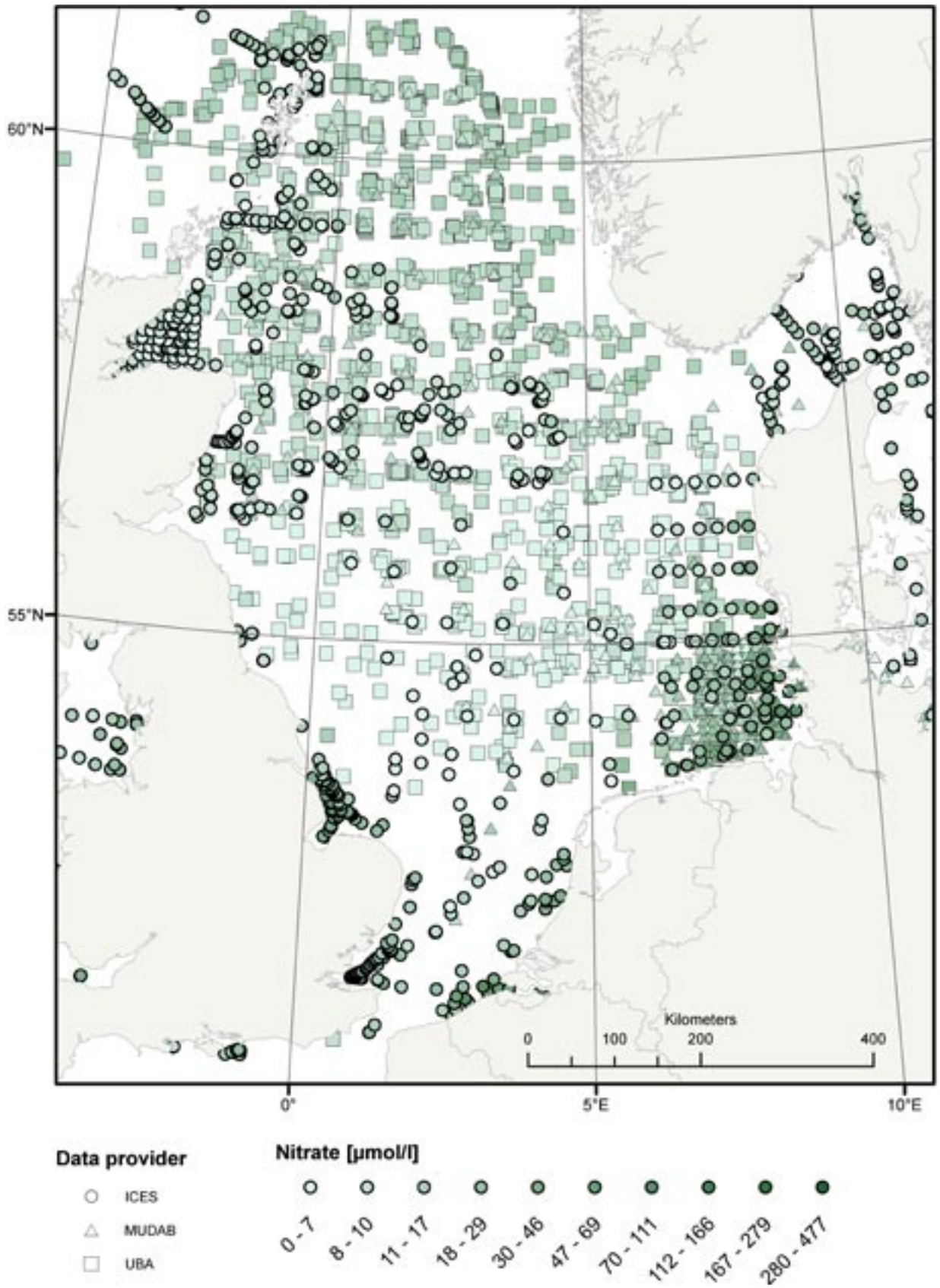
Number of values	9604
Minimum	0.1
Maximum	476.6
Mean	11.9
Standard Deviation	18.5

Frequency distribution

Counts



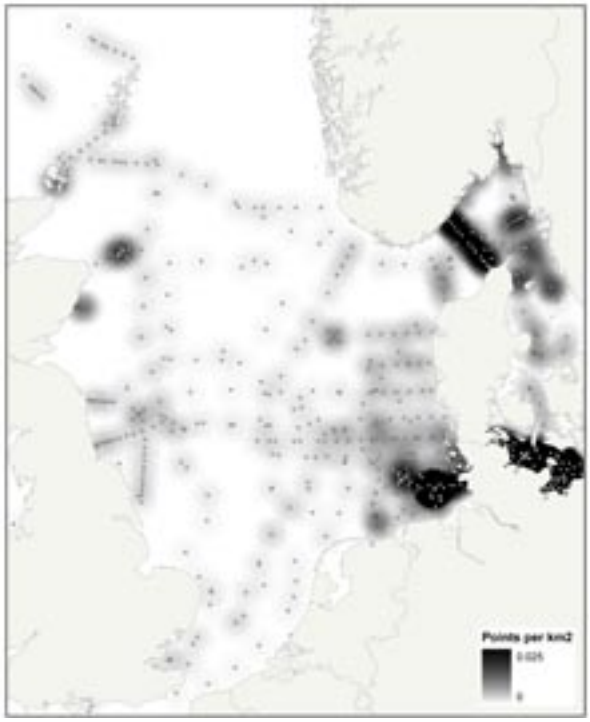
Nitrate concentration in bottom waters - winter (1982-2002)



Nitrate concentration (summer) in bottom waters

Nitrate (µmol/l] concentration in the bottom water of the North Sea measured in the months June, July, August and September (1982-2002). Raw data provider: ICES, MUDAB.

Density map of nitrite measurements (1982-2002)

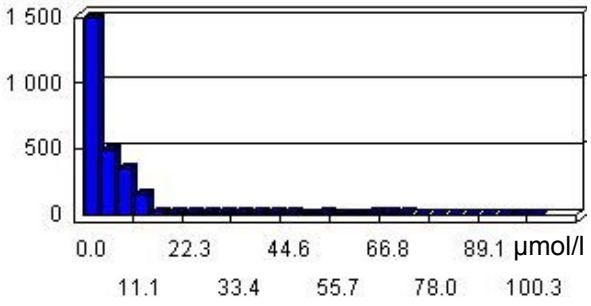


Data summary

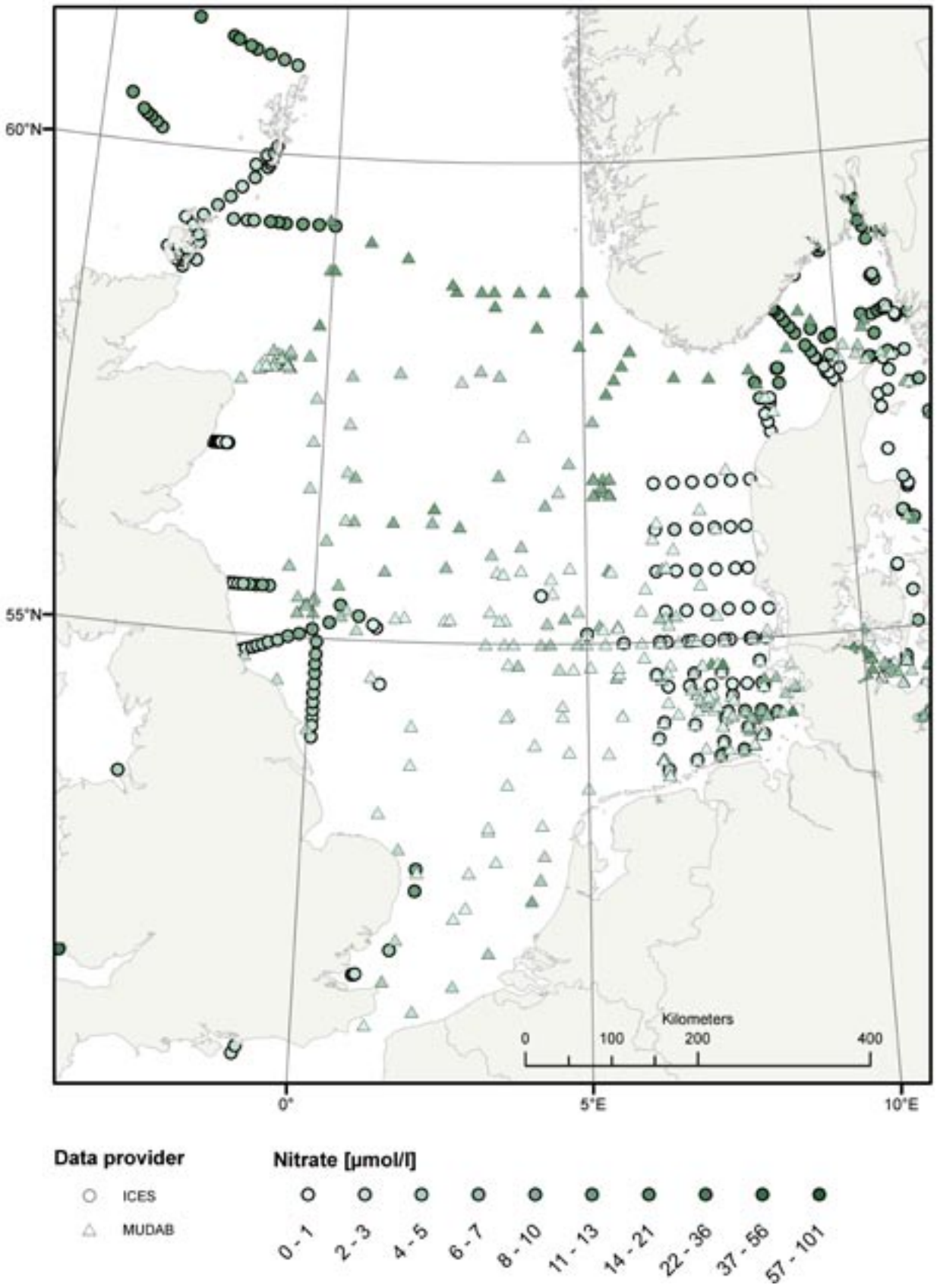
Number of values	2592
Minimum	0.01
Maximum	100.7
Mean	5.4
Standard Deviation	9.5

Frequency distribution

Counts



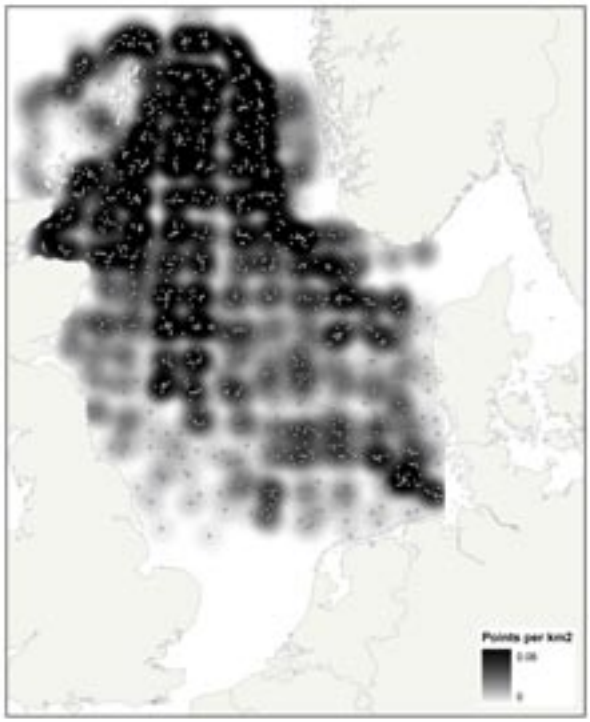
Nitrate concentration in bottom waters - summer (1982-2002)



Silicic acid concentration (winter) in bottom waters

Silicic acid (µmol/l) concentration in the bottom water of the North Sea measured in the months December, January, February and March (1982-2002). Raw data provider: UBA.

Density map of silicic acid measurements (1982-2002)

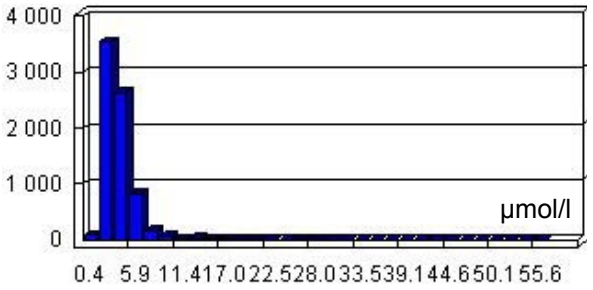


Data summary

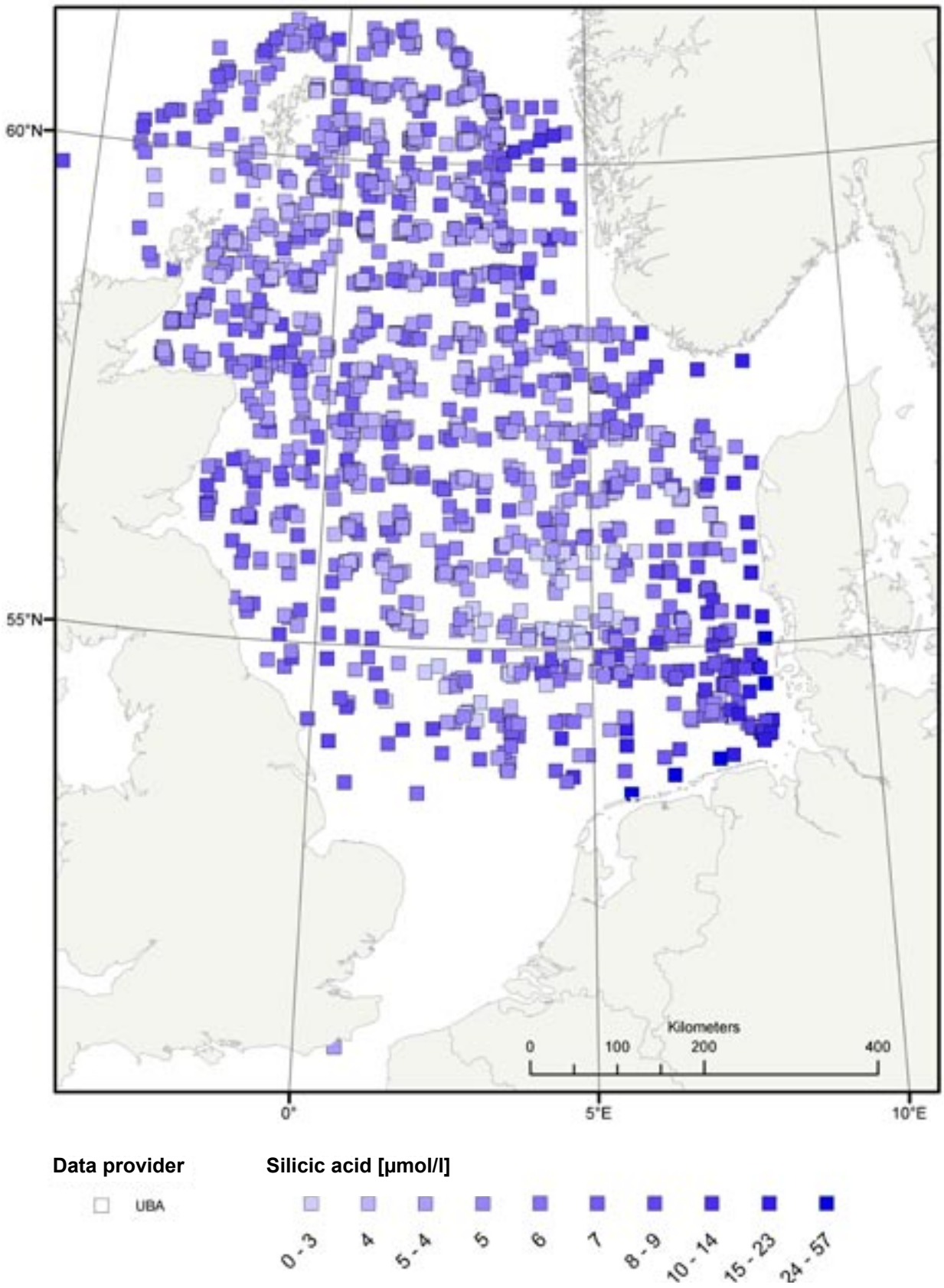
Number of values	7418
Minimum	0.4
Maximum	56.8
Mean	4.7
Standard Deviation	2.7

Frequency distribution

Counts



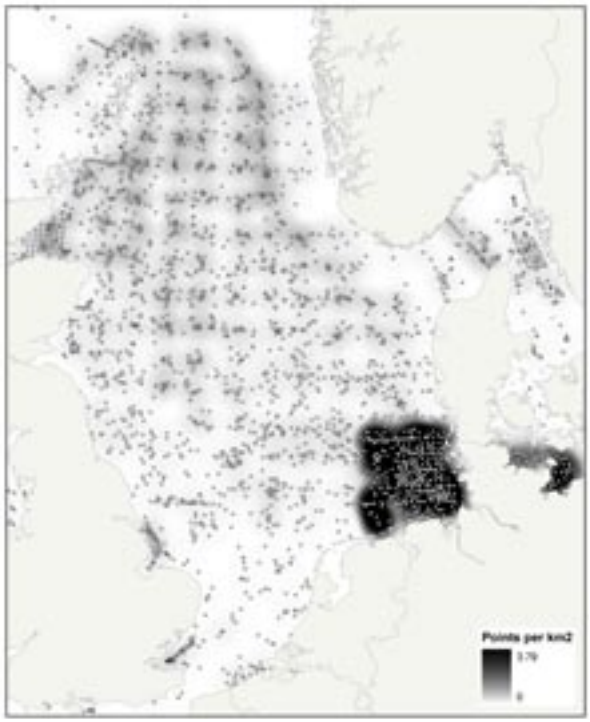
Silicic acid concentration in bottom waters - winter (1982-2002)



Phosphate concentration (winter) in bottom waters

Phosphate (µmol/l) concentration in the bottom water of the North Sea measured in the months December, January, February and March (1982-2002). Raw data provider: ICES, MUDAB, UBA.

Density map of phosphate measurements (1982-2002)

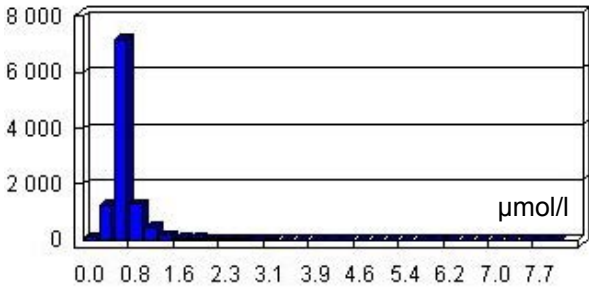


Data summary

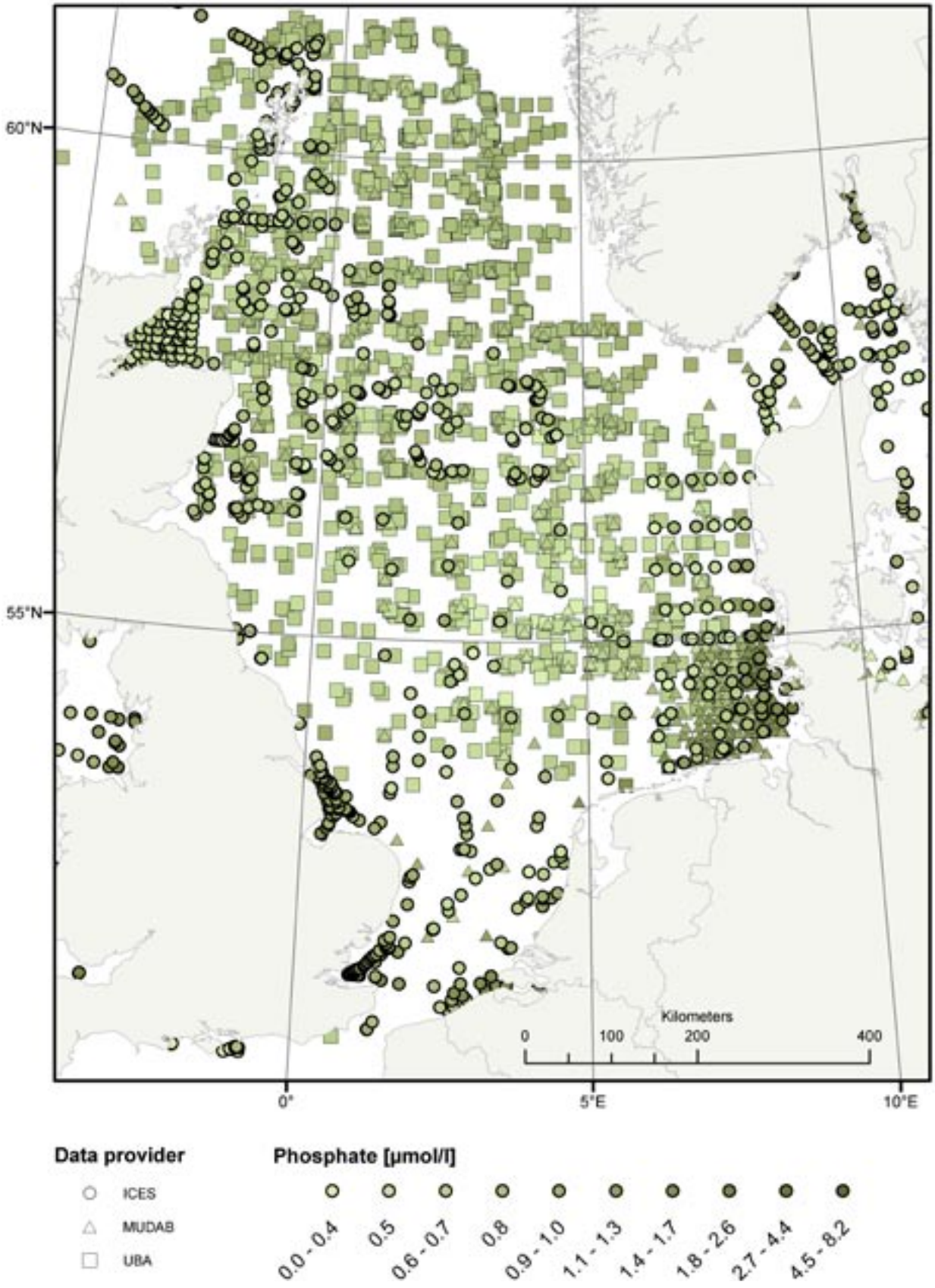
Number of values	10738
Minimum	0.01
Maximum	8.2
Mean	0.7
Standard Deviation	0.4

Frequency distribution

Counts



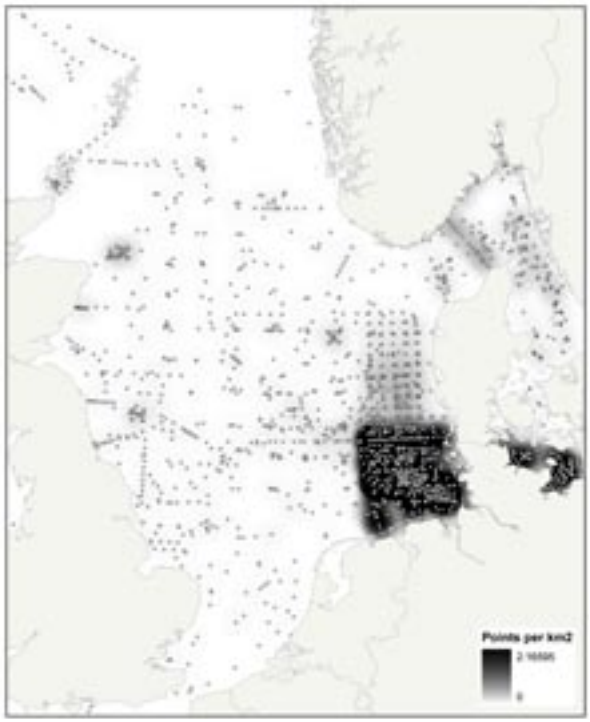
Phosphate concentration in bottom waters - winter (1982-2002)



Phosphate concentration (summer) in bottom waters

Phosphate (µmol/l) concentration in the bottom water of the North Sea measured in the months June, July, August and September (1982-2002). Raw data provider: ICES, MUDAB.

Density map of phosphate measurements (1982-2002)

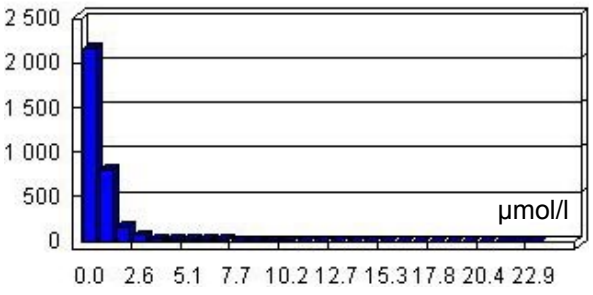


Data summary

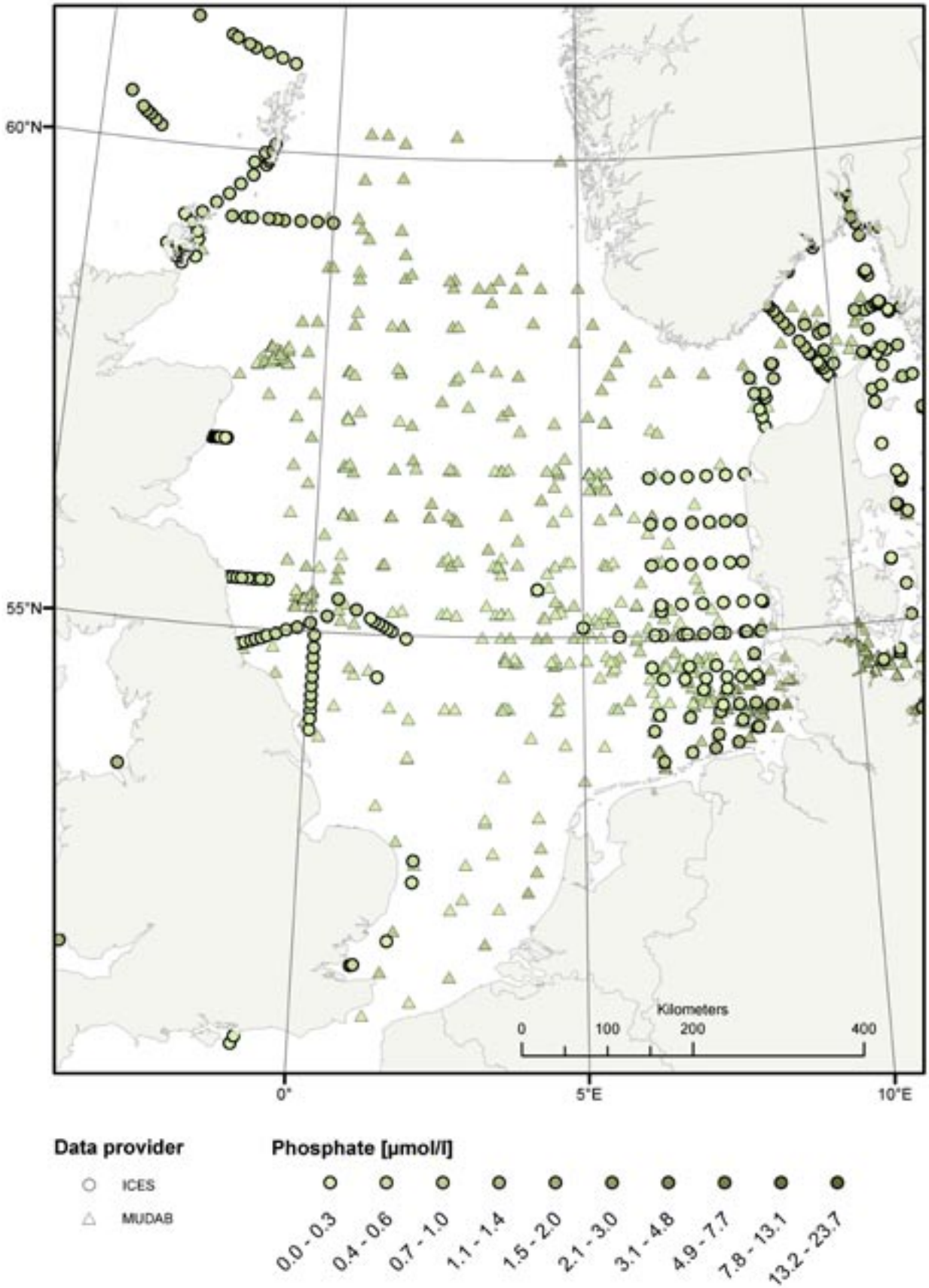
Number of values	3311
Minimum	0.01
Maximum	23.7
Mean	1.0
Standard Deviation	1.4

Frequency distribution

Counts



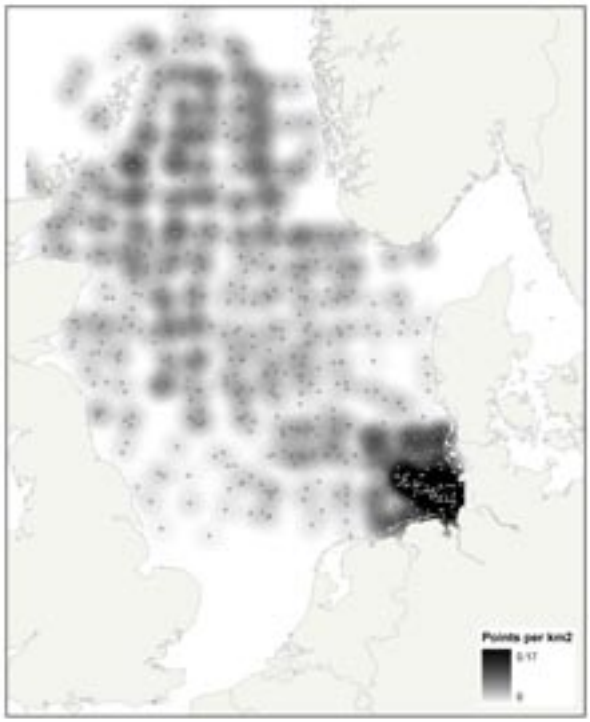
Phosphate concentration in bottom waters - summer (1982-2002)



Ammonium concentration (winter) in bottom waters

Ammonium (µmol/l) concentration in the bottom water of the North Sea measured in the months December, January, February and March (1982-2002). Raw data provider: UBA, MUDAB.

Density map of ammonium measurements (1982-2002)

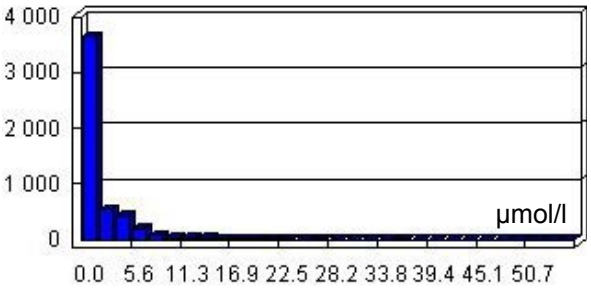


Data summary

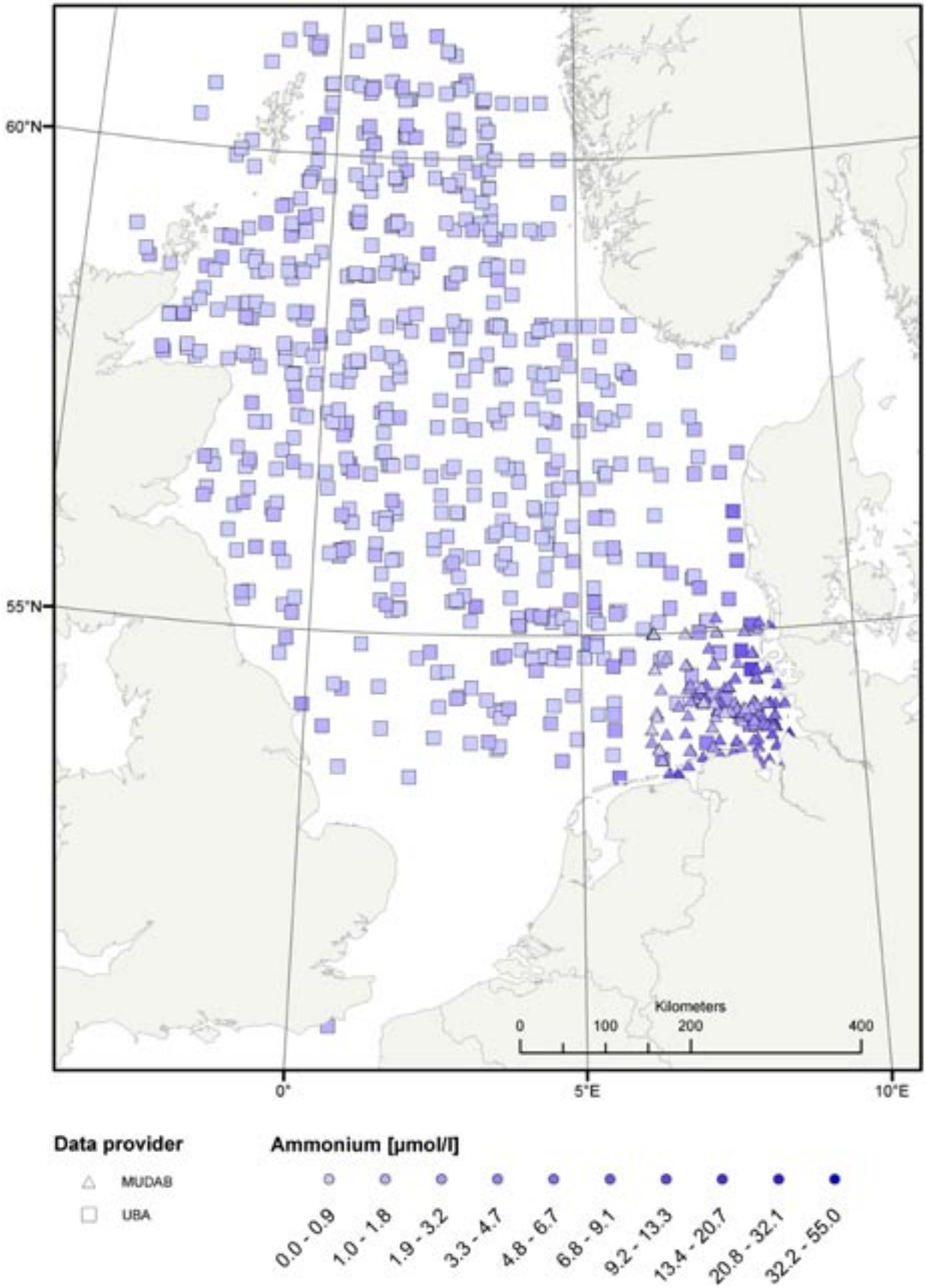
Number of values	4984
Minimum	0.01
Maximum	55.0
Mean	2.1
Standard Deviation	3.5

Frequency distribution

Counts



Ammonium concentration in bottom waters - winter (1982-2002)



Thematic maps - Benthic biology

The distribution of diversity and community structure of benthic communities is an important indicator of impacts of trawling disturbance, climate change, pollution and other natural and anthropogenic factors. This chapter presents the distribution of in the *Digital Atlas of the North Sea* database implemented benthic sample sites and a map of selected endangered benthic species in the North Sea area.


K. Jerosch, AWI


A. Schöder, AWI

Diversity of benthic communites in the North Sea

Epi- and endobenthic invertebrates constitute a major part of the North Sea fauna. Several studies have been carried out on their diversity and community structure during the past century (Jennings et al. 1999, Rogers et al. 1998, Frauenheim et al. 1989, Dyer et al. 1983, Petersen 1914). Rees et al. (1999) studied the English part of the North Sea, Basford et al. (1989) the northern North Sea, Duineveld et al. (1991) the southern North Sea and Kröncke (1990) described the benthos of the Dogger Bank.

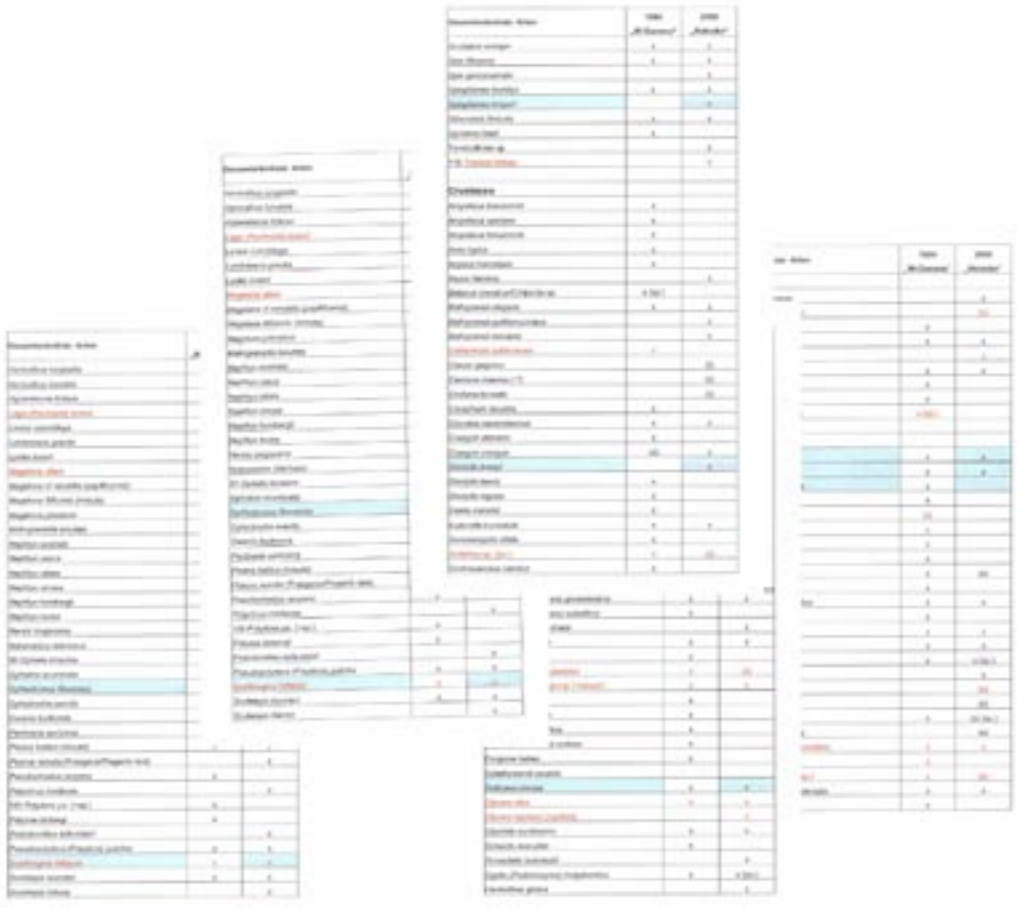
These studies generally support the zonation proposed by Glémarec (1973), showing a division between faunal communities in the southern and northern North Sea. Environmental factors like depths, sediment composition, temperature and currents are regarded as being mostly responsible for distribution pattern of the epibenthic communities (Frauenheim et al. 1989, Basford et al. 1998, Jennings et al.1999).

However, the previous studies of North Sea epibenthos differend in their sampling methods and often based their analysis on a limited number of stations. The first detailed and wide ranging account of the biodiversity in the North Sea using standardized equipments was given by Callaway et al. (2002).

The *Digital Atlas of the North Sea* database includes 605 stations of the ICES North Sea Benthos Survey (NSBS) 1985/86. The species composition and biodiversity patterns were discussed in Heip et al. (1992), Künitzer et al. (1992) and Heip & Craeymeersch (1995).

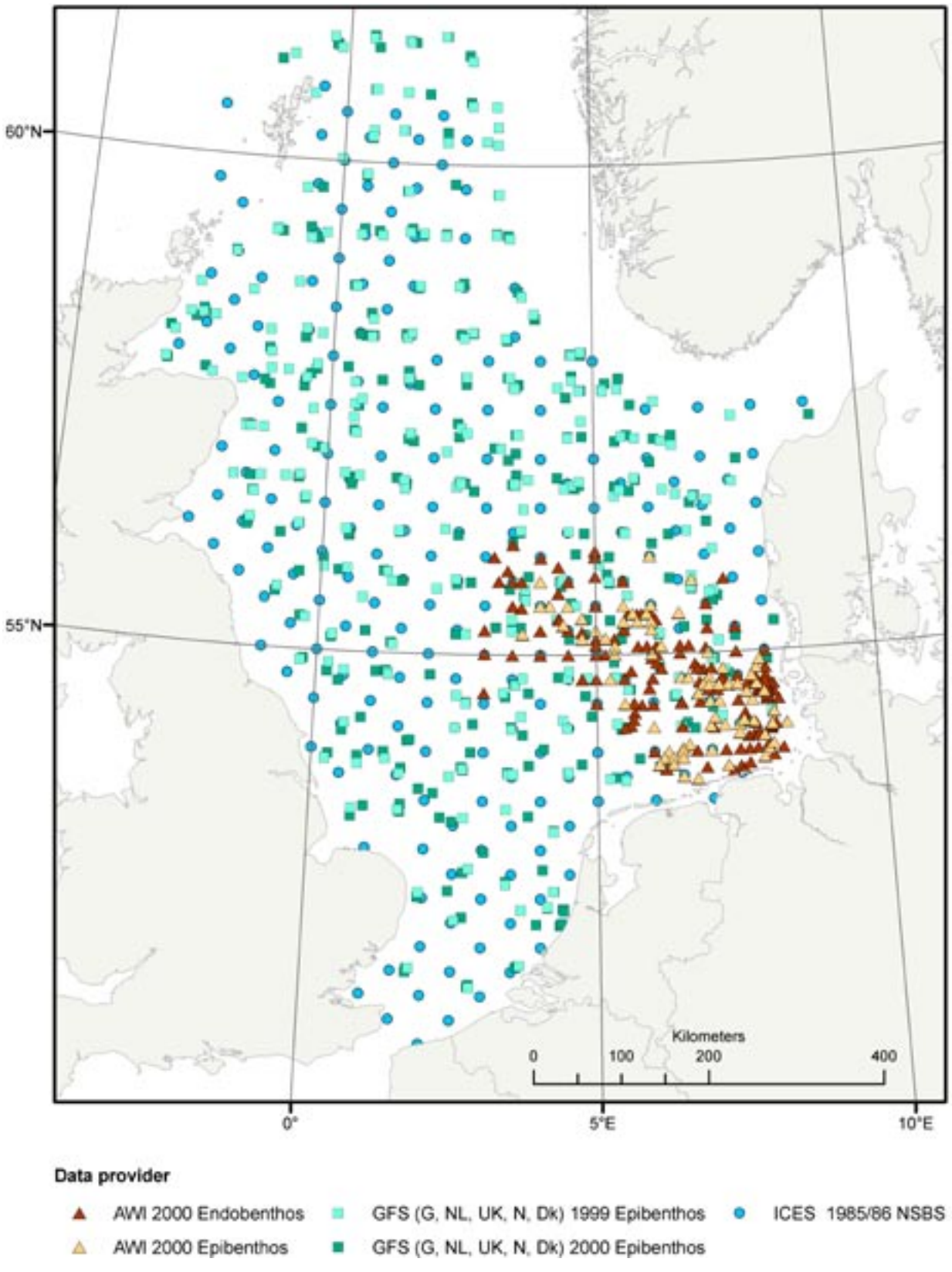
241 and 270 stations of the European groundfish surveys (GFS) 1999 and 2000, respectively (a.o. Callaway et al. 2002) are also taken into account of the *Digital Atlas of the North Sea* database.

Furthermore, 227 endobenthic and 79 epibenthic stations are contained, collected in the frame of *Natura 2000* and located mainly within the German EEZ (Rachor and Nehmer, 2003).



Example of a species index concerning benthic invertebrates and fishes. Species written in red are registered on the Red List of Threatened Species.

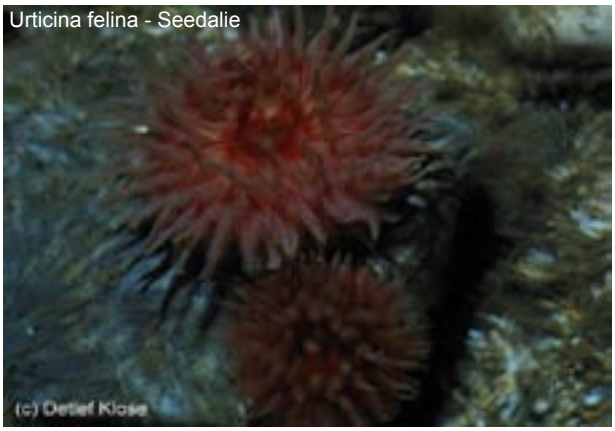
Benthos stations of the North Sea



Examples for macrobenthos populating the North Sea

There is increasing observational evidence that the communities (spectrum and abundances of species) of the North Sea are changing on a long-term temporal scale. The reasons are diverse and mainly anthropogenic. A shift in North Sea climate towards more oceanic conditions may be among the most important factors driving the recent changes in species spectrum. *Arctica islandica* and *Nephrops norwegicus*, for instance, are recorded on the Red List of Threatened Species.
The map was generated within the BMBF/DFG-project MarGIS. Raw data provider: AWI, ICES, SBS/UWB (GFS 2000).


Islandmuschel - *Arctica islandica*
Photo: Jan Johan ter Poorten


Urticina felina - Seedalie
(c) Detlef Klose


Kaisergranat - Nephrops norvegicus
Photo: Hans Hillewaert

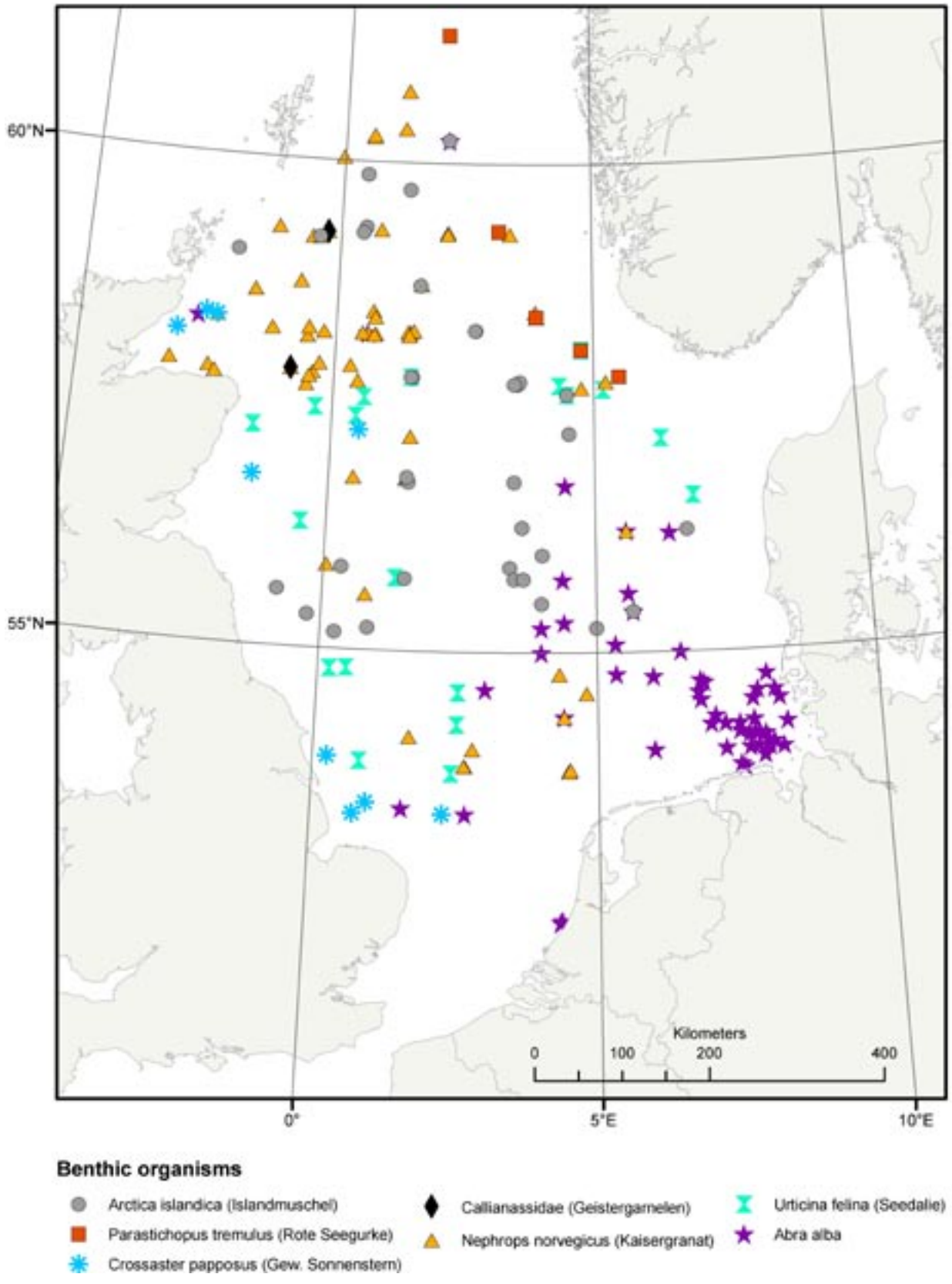

Gewöhnlicher Sonnenstern - Crossaster papposus
Foto: Peter Jonas


Ghost shrimp - Callianassa tyrrhena
Photo: Hans Hillewaert


Kleine Pfeffermuschel - Abra alba
Photo: Jon Davies


Rote Seegurke - Parastichopus tremulus
Photo: Peter Jonas

Distribution of selected benthic species



Data provider: AWI, ICES, SBS/UWB (GFS 2000).

Thematic maps - Surface sediments

The North Sea shelf area is an ancient continental drift depression with a general north-south axis. This depression is overlain by sedimentary deposits several kilometres thick originating from the surrounding land masses, and some of their strata contain large amounts of liquid and gaseous hydrocarbons, which are intensively exploited.

The hydrographic circulation, as well as the wave and tidal regime, created the sediment dynamics and the sediment distribution pattern seen today. Mainly sand and gravel deposits occur in the shallower areas and fine-grained muddy sediments accumulate in many of the depressions.

Tidal flats like the Wadden Sea receive their sediments directly or indirectly from rivers and from adjacent North Sea areas. The suspended particulate matter settles to form either sandy or muddy sediments according to its composition and the predominant local hydrodynamic conditions (OSPAR Commission 2000).

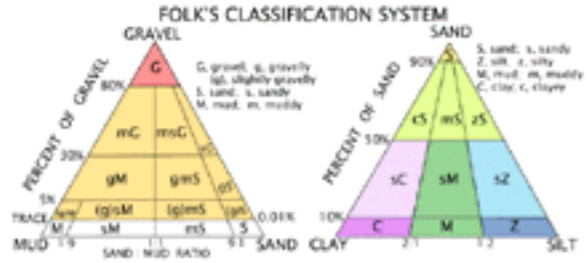
Sedimentological classification systems

Describing sediment texture distributions is important to geologists and sedimentologists 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 the dominant size fractions. Definitions of the fractions have long been standardized to the grade scale described by Wentworth (1922).

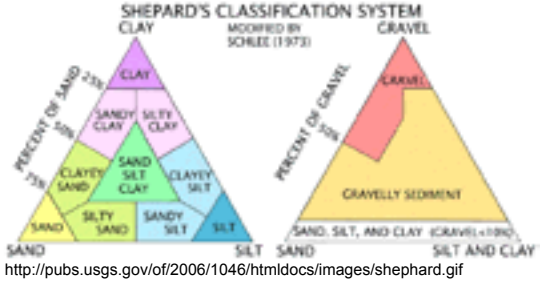
Although several classification schemes have been adopted to describe the approximate relationship between the size fractions, most sedimentologists use one of the systems described either by Shepard (1954) or Folk (1954, 1974), each based on two triangular diagrams. The patterns within the triangles of both systems differ, as does the emphasis placed on gravel. For example, in the system described by Shepard, gravelly sediments have more than 10 percent gravel; in Folk's system, slightly gravelly sediments have as little as 0.01 percent gravel. Folk's classification scheme stresses gravel because its concentration is a function of the highest current velocity at the time of deposition, together with the maximum grain size of the detritus that is available; Shepard's classification scheme emphasizes the ratios of sand, silt, and clay because they reflect sorting and reworking (Poppe et al., 2005). Shepard's classification scheme was subsequently modified by Schlee (1973).

Because of the existing different classification schemes, working with analog sediment maps is a difficult task. After the digitalization it is required to approximate the classification schemes to a consolidated scale. This, chapter includes North Sea data distribution maps about surface sediment maps. The range of values with regard to the fraction is related to Wentworth (1922), the relationship between the size fractions is realized following the Folk (1954) classification.

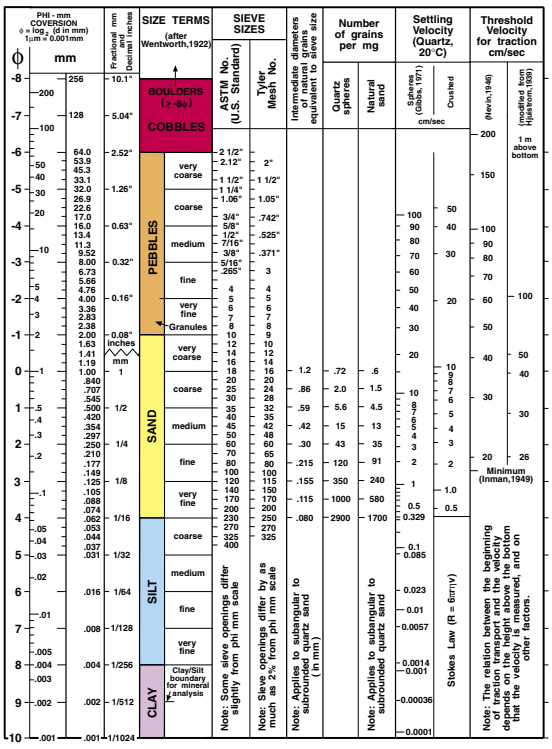
Classification systems



http://pubs.usgs.gov/of/2006/1046/htmldocs/images/folk.gif



http://pubs.usgs.gov/of/2006/1046/htmldocs/images/shephard.gif



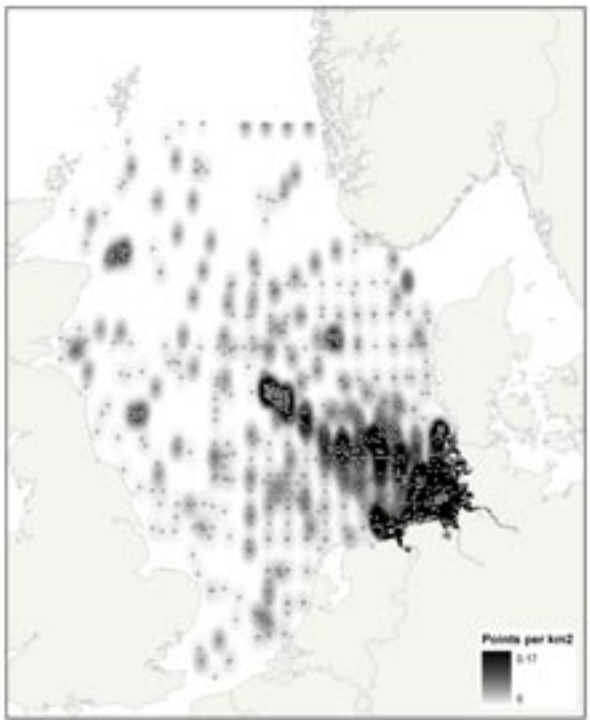
Wentworth fractions (1922)

Sediment grain sizes 0 - 63 µm distribution (1982-2002)

The map presents the portion (g/kg) of the grain size fraction 0-63 µm in the North Sea. It was generated within the BMBF/DFG-project MarGIS. Raw data provider: MUDAB.

Surface sediments 0 - 63 µm (1982-2002)

Density map of measurements

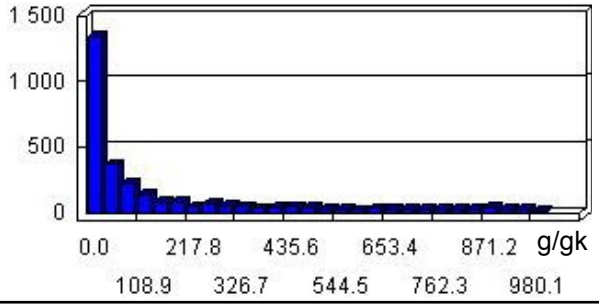


Data summary

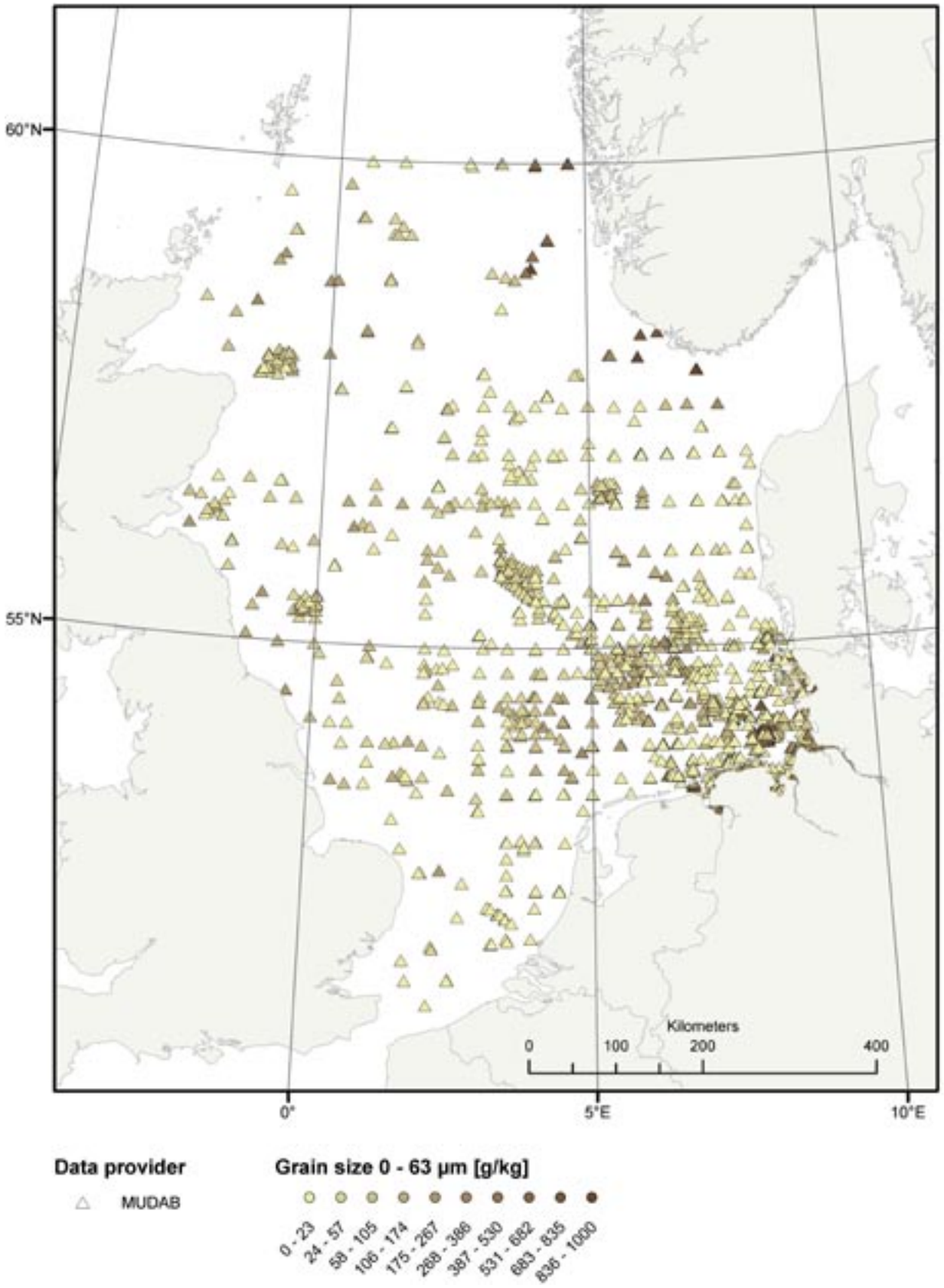
Count:	2957
Minimum:	0
Maximum:	1000
Sum:	510190.26
Mean:	172.536442
Standard Deviation:	251.316841

Frequency distribution

Counts



Sediment grain sizes 0 - 63 µm (1982-2002)

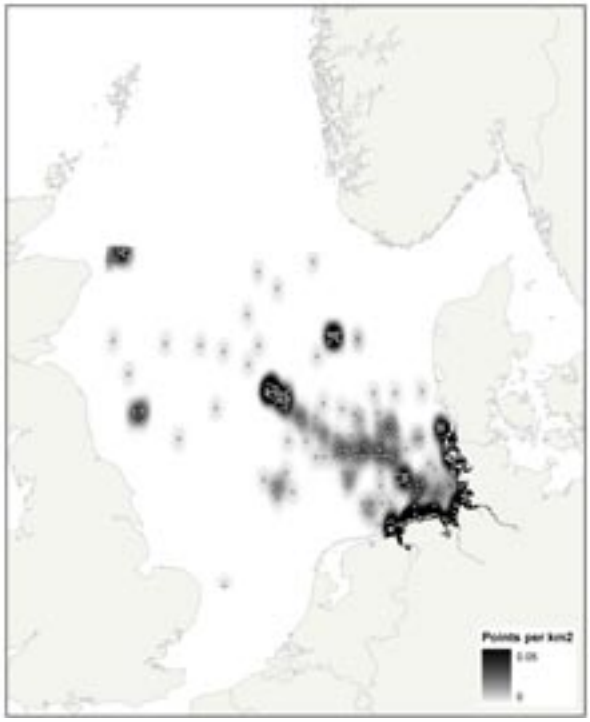


Sediment grain sizes 63 - 2000 µm distribution (1982-2002)

The map presents the portion (g/kg) of the grain size fraction 63 - 2000 µm in the North Sea. It was generated within the BMBF/DFG-project MarGIS. Raw data provider: MUDAB.

Surface sediments 63 - 2000 µm (1982-2002)

Density map of measurements

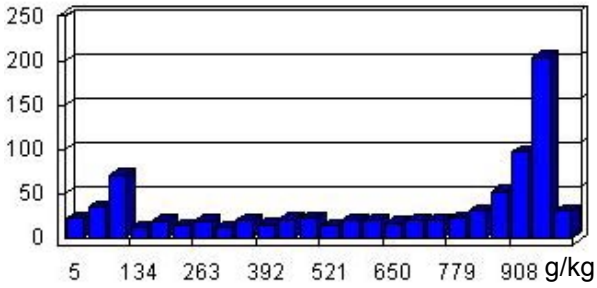


Data summary

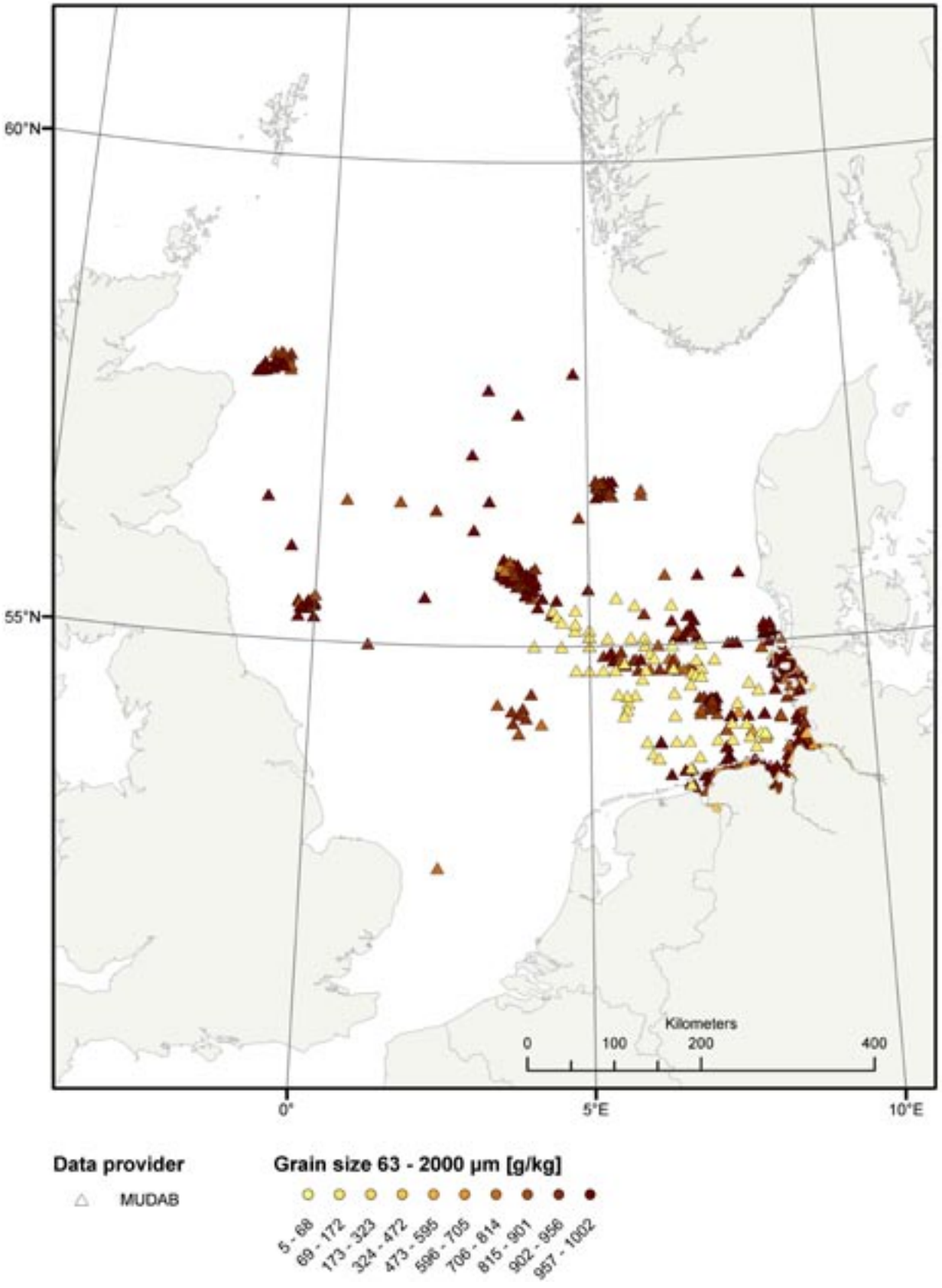
Count:	816
Minimum:	5
Maximum:	1002
Sum:	538005.97
Mean:	659.321042
Standard Deviation:	340.662754

Frequency distribution

Counts

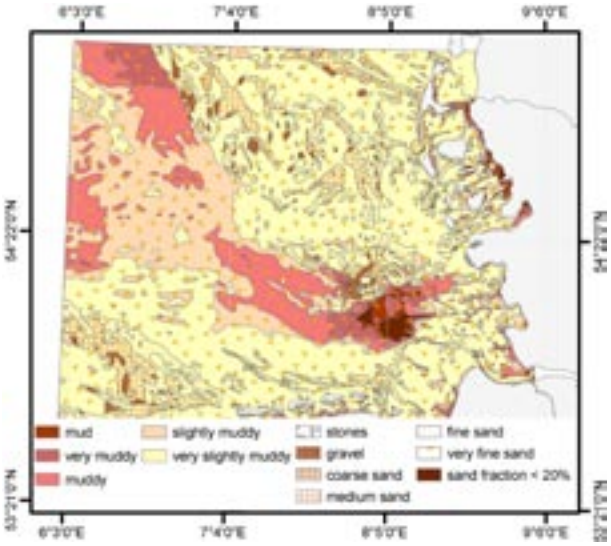


Sediment grain sizes 63 - 2000 µm (1982-2002)

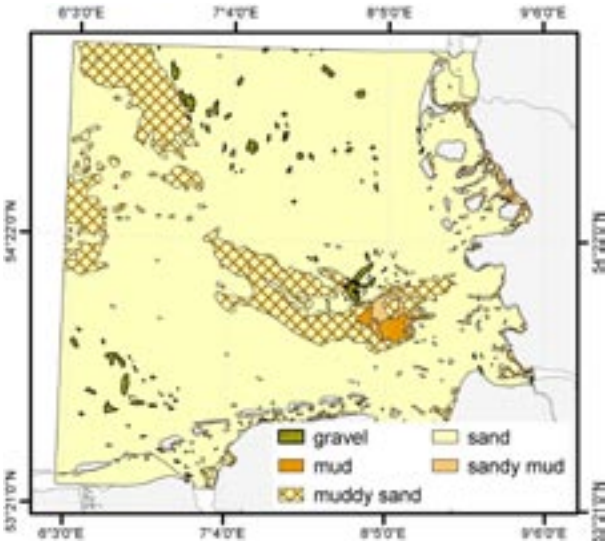


Aggregating sediment maps of different resolutions

The data density of this important parameter was not sufficient for a satisfying North Sea wide interpolation. Therefore, several existing maps had to be joined to cover the entire area. Although very detailed and high resolution sedimentological maps were generated and made available by the BSH, GEUS as well as other institutes and authorities, maps providing an overview of 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. 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. The overview map is shown in the lowest common scale, the Folk sediment classification (Folk, 1954).

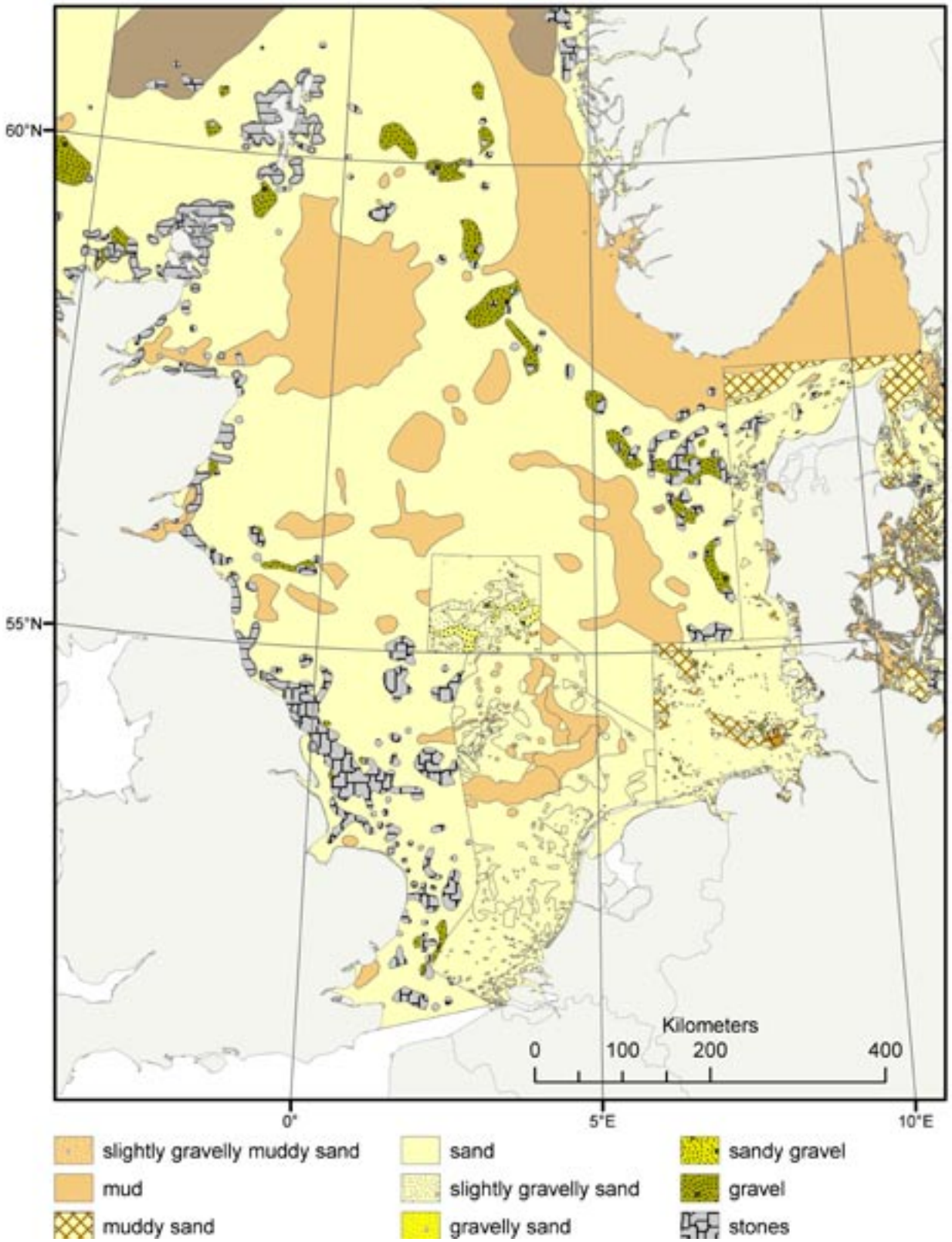


Original sediment map of the German Bight (Figge, 1981) applying the Wentworth (1922) classification scheme.



Aggregated sediment map of the German Bight (after Figge, 1981) applying the Folk (1954) classification scheme.

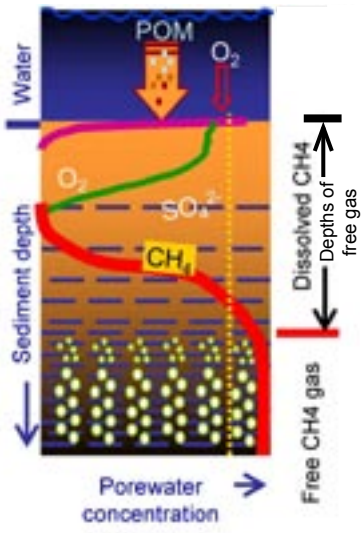
Aggregated sediment map of the North Sea



Dutch Continental Shelf (RGD, 1986)
Denmark (GEUS, 1992)
International Quarternary Map of Europe (BA für Bodenforschung/UNESCO, 1970)
German Bight (Figge, 1981)
Dogger Bank (BGS, 1977-1993)
Oyster Ground (BGS, 1977-1993)

Thematic Maps - Methane related themes

Worldwide, several coastal environments are characterized by high methane concentration in surface sediments. This is due to high organic carbon contents and the resulting formation of methane (CH_4), caused by burial of fresh plankton material and organic matter derived by rivers and surface run off.
In the sediment, methane is produced by microbial degradation of organic matter beneath the sulphate-methane transition zone. At times, the production of methane is intensive enough to enable free gas escape into the water column. Closer to the sea floor, above the sulphate-methane transitional zone and near the sediment-water-boundary, the microbial decomposition of CH_4 takes place and microbial consortia live on the breakdown of methane.



Distribution of pockmarks and shallow gas areas

Data description:
Free Shallow Gas (North Sea, Skagerrak, Kattegat, W. Baltic Sea) (polygons)

Collected data from different sources for the North Sea, Skagerrak, Kattegat, Western Baltic Sea: areas where free shallow gas accumulations in marine sediments have been reported.

Lineage statement:
Digitizing of published data (georeferenced maps).

Sources:

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The Millenium Atlas: Petroleum Geology of the Central and Northern North Sea [Armour,A., Bathurst,P., Evans,D., Gammage,J., Hickey,C. - Org. / Evans,D., Graham,C., Armour,A., Bathurst,P. - Eds.] - The Geological Society of London, 2003 / Copyright: The Millenium Atlas Company Ltd. 2003 / Chap. 16 by Fyfe,A., Gregersen,U., Jordt,H., Rundberg,Y., Eidvin,T., Evans,D., Stewart,D., Hovland,M., Andresen,P. „Oligocene to Holocene“ pp. 279-287 [Fig. 16.17].

Limitations of use:
Data created as task within the EU-project METROL, restrictive use.

Data description:
Pockmarks in the North Sea (polygons)

Areas where numerous pockmarks occur in contrast to areas without any occurrence.

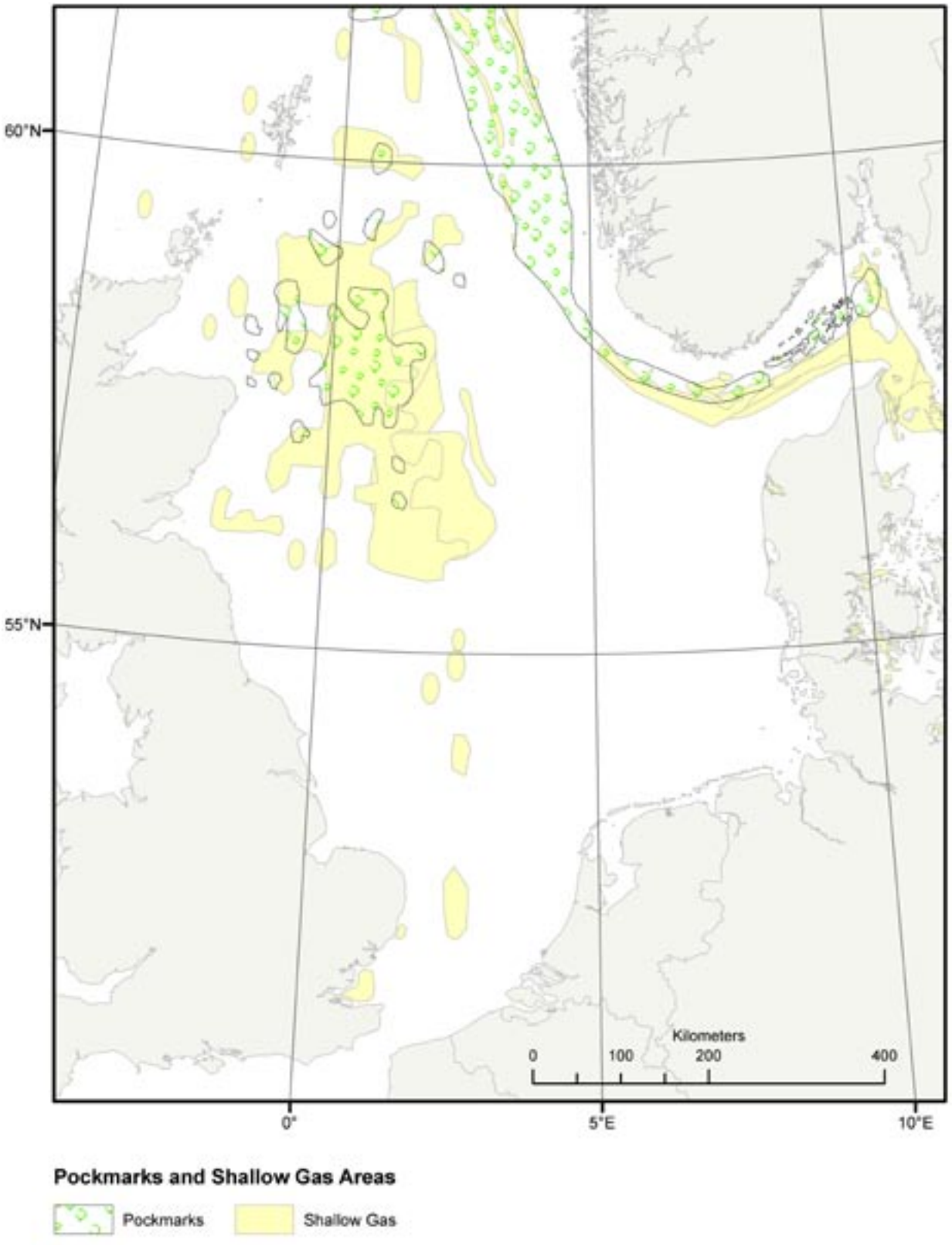
Lineage statement:
Digitizing of published data (georeferenced map).

Source:

Hovland,M. (2002): On the self-sealing nature of marine seeps. Continental Shelf Research 22, pp. 2387-2394.

Limitations of use:
Data created as task within the EU-project METROL, restrictive use.

Pockmarks and shallow gas areas



Distribution of hydrocarbons and pipelines

Data description:
Pipelines in the North Sea (lines)

Digitizing of georeferenced maps. Primary source was a shapefile downloaded from DEAL Data. This file was augmented for the whole North Sea by using third party information on maps.

Sources:

DEAL-Data Registry for UK Offshore Oil & Gas, downloadable data (incl. shapefiles) from www.ukdeal.co.uk (download from Sept. 2003).

„United Kingdom Oil and Gas activity“, Wallmap, Aug. 2003, by dti (download via DEAL).

Norwegian Petroleum Directorate / Reports (via internet, www.npd.no).

Statoil ASA, Stavanger, Norway.

Data for each pipeline not fully completed yet due to different degrees of information content in the third party sources.

Limitations of use:
Data created as task within the EU-project METROL, restrictive use.

Data description:
Offshore hydrocarbon deposits (Oil, gas and Ccondensates) (polygons)

Neither the owners of original data nor the processor accept responsibility for the accuracy of any data. Use of data is at the sole risk of the user.

Lineage statement:
Digitizing of data information on georeferenced maps.

Sources:

DEAL-Data Registry for UK Offshore Oil & Gas, downloadable data (incl. shapefiles) from www.ukdeal.co.uk (download from Sept. 2003).

„United Kingdom Oil and Gas activity“, Wallmap, Aug. 2003, by dti (download via DEAL).

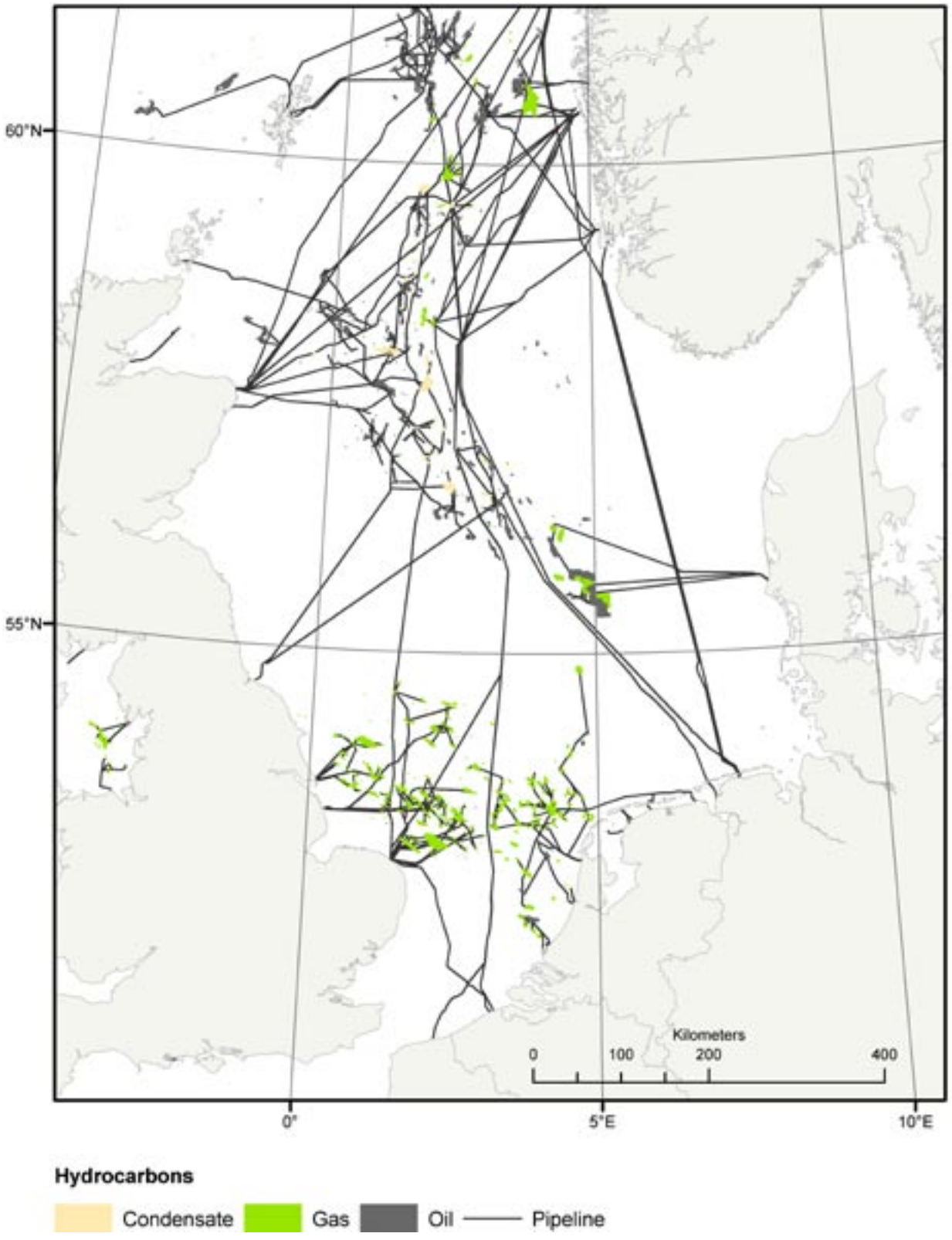
Norwegian Petroleum Directorate / Reports (via internet, www.npd.no).

Aardgasstromen in Nederland - prognose voor de periode 2002 tot 2011, Nederlands Instituut voor Geowetenschappen TNO, Utrecht, NL.

Danish Energy Authority, Amaliengade 44, DK-1256 Kobenhavn / Reports (via internet, www.ens.dk).

Limitations of use:
Data created as task within the EU-project METROL, restrictive use.

Hydrocarbons and pipelines



Distribution of earthquakes

Data description:
Earthquakes (poygons)

Epicenters of earthquakes in marine regions of North Europe as detected and reported by several authorities of different countries.

Current Status: Danish and southwestern Norwegian Region covered.

Digitizing of published data on maps after georeferencing. Not completed. Only Danish area is incorporated at the moment.

Source:
Gregersen,S., Leth,J., Lind,G., Lykke-Andersen,H. (1996): Earthquake activity and its relationship with geologically recent motion in Denmark.
Tectonophysics 257, pp. 265-273.

Limitations of use:
Data created as task within the EU-project METROL, restrictive use.

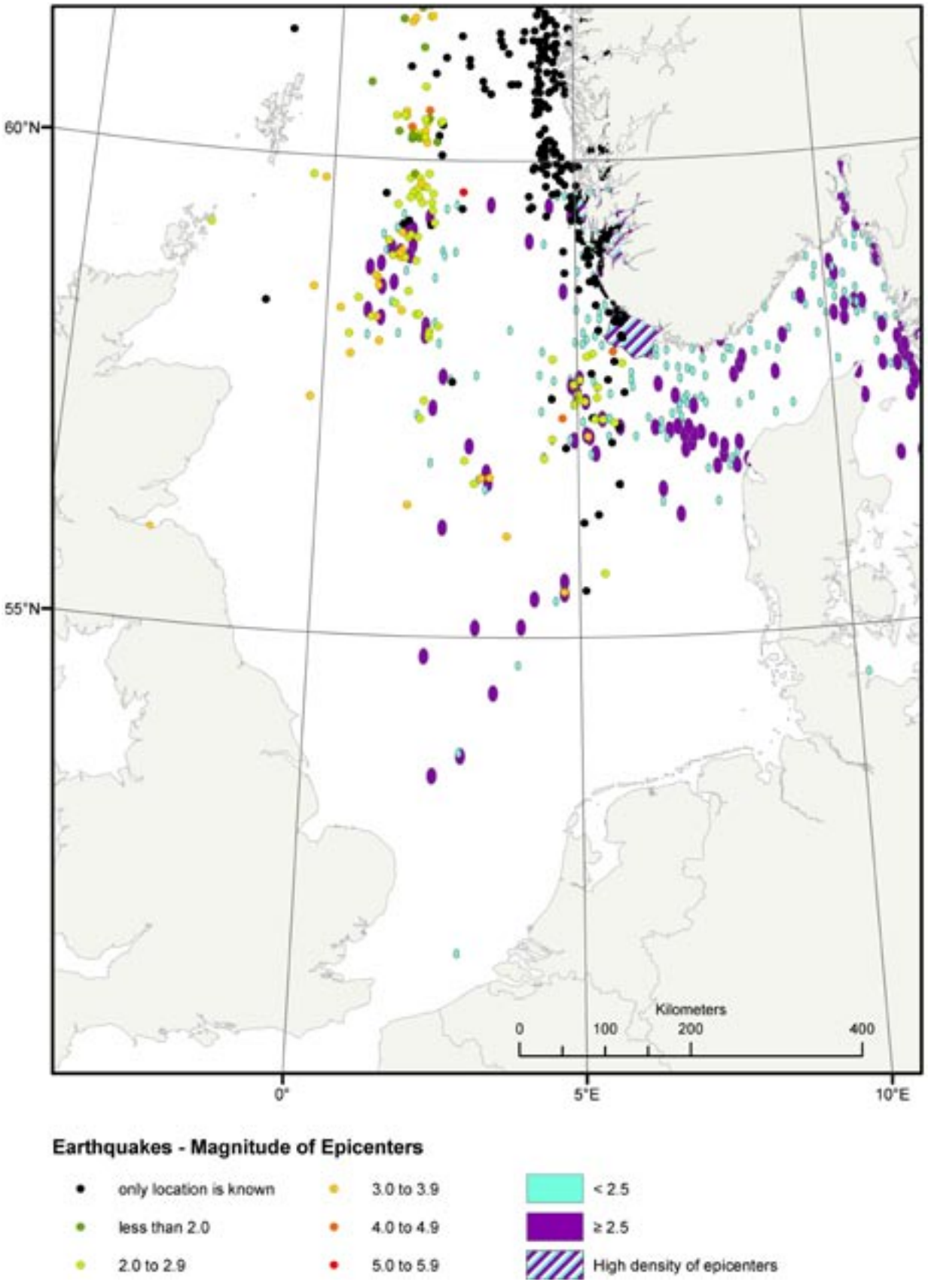
Data description:
Earthquakes (points)

Locations, magnitudes and focal depths of earthquakes in the North Sea. For UK Sector: only locations with magnitudes > 2.0 were given by data source (= British Geological Survey - BGS).

Source:
British Geological Survey (BGS).
Data was supplied on a map which was digitized and georeferenced. Data points were digitized from the map and attributed with data about magnitude and focal depths of earthquakes.

Limitations of use:
Data created as task within the EU-project METROL, restrictive use.

Earthquakes



Distribution of tectonic faults and structures

Data description:
Faults (lines)

Image of the main faults in the North Sea as a tectonic overview. The main tectonic inventory is given which means that not all mapped structures outcrop at the seabed surface. Most of them are covered with sediments of variable thicknesses.

Limitations of use:
Digitizing of georeferenced maps. These maps are already generalized and not of the quality of small scale geological maps. Accuracy of positioning within approx. few tens up to few hundreds of meters.

Digitizing of georeferenced published general maps of large scales.

Sources:

Glennie, K.W. (ed.) 1998: Petroleum Geology of the North Sea, 4th edition. Blackwell Science Ltd.

EU-project SCOPE - www.scope.ruc.dk, image of the geology of the Baltic Shield.

Winterhalter,B. (2001): The BASYS coring site in the North Central Baltic Sea Basin - a geological description. Baltica 14, pp. 9-17.

Pharaoh,T.C. & TESZ Project Core Group (2000): EUROPROBE “Trans-European Suture Zone“ project. EUROPROBE News 13, pp. 4-5.

Data description:
Structures (polygons)

Overview of the main basement geology in the North and the Baltic sea. Precambrian, caledonian and variscan basement elements (with or without cover of younger sediments) are distinguished.

Limitations of use:
Digitized information from general maps intended as overview maps, no large-scale high-resolution maps. Accuracy of the digitized borders are within approx. some tens of meters up to 100 m.
Data created as task within the EU-project METROL, restrictive use.

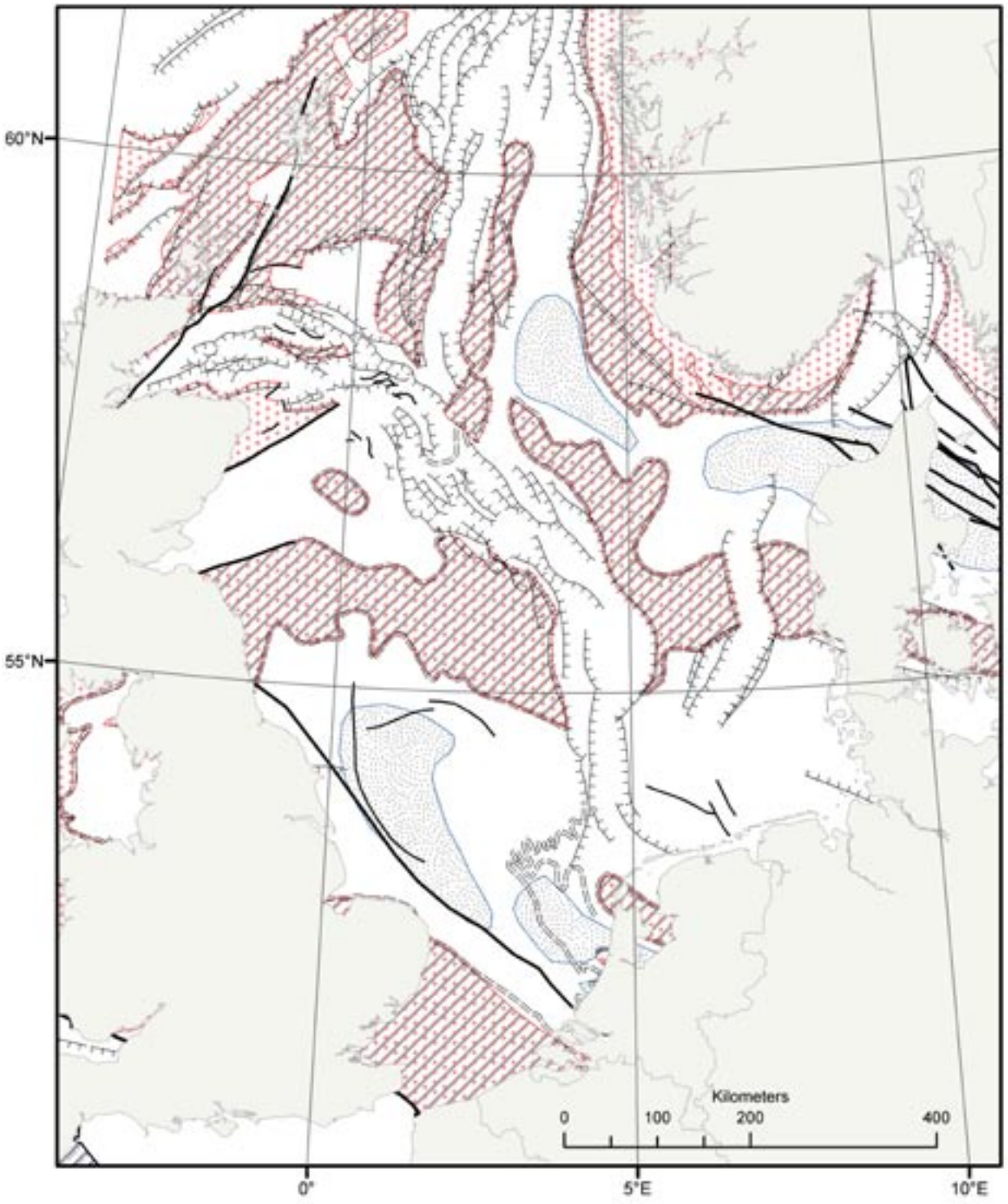
Digitizing of information given in maps, which have been georeferenced first. Original maps are overviews, not highly precise geological large-scale maps.

Sources:

Glennie, K.W. (ed.) 1998: Petroleum Geology of the North Sea, 4th edition. Blackwell Science Ltd.

Walter,R. - Geologie von Mitteleuropa, 6th edition, E. Schweizerbart´sche Verlagsbuchhandlung Nägele und Obermiller, 1995.

Tectonic faults and structures



Exploration of gas containing sediments

The Carboniferous is a major division of the geologic timescale that extends from the end of the Devonian period, about 359.2 ± 2.5 Ma (million years ago), to the beginning of the Permian period, about 299.0 ± 0.8 Ma (ICS, 2004). Concerning the North Sea, the Carboniferous is important due to remaining hydrocarbon inventories. The exploration of gas in the southern North Sea is almost concluded; most of the major accumulations in the Rotliegendes reservoir have already been found and mostly exploited. Future exploration must increasingly focus on the deeper and more complex Carboniferous reservoir sections.

Data description:
Carboniferous (polygons)

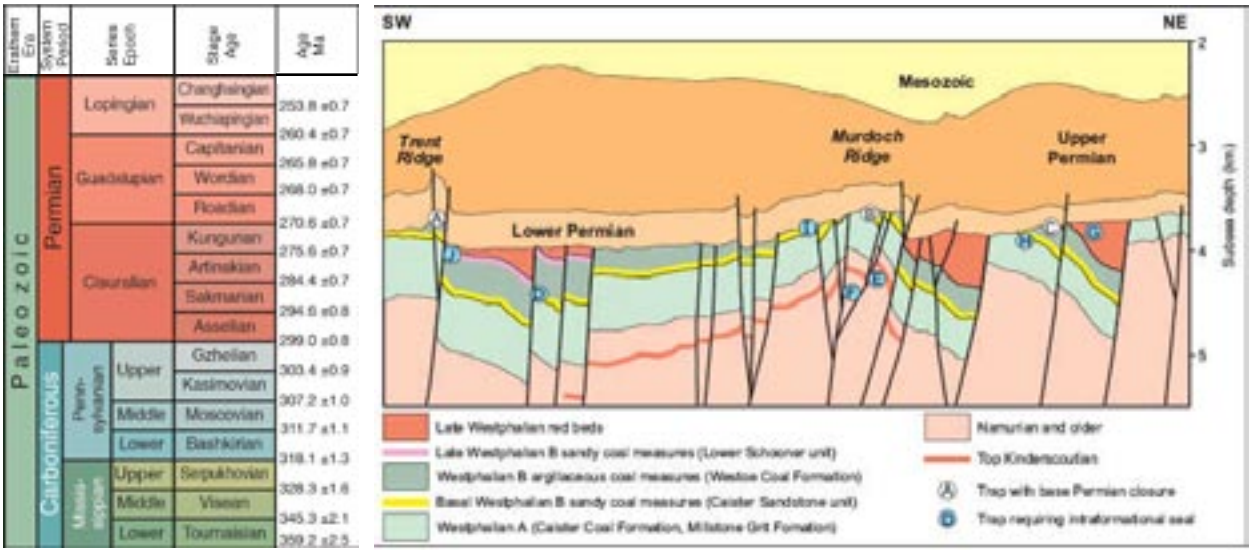
Rough outline of the areal extent of gas-prone Carboniferous source and reservoir rocks.
Mapped area is already represented as rough outline in the source. Digitized border lines are not for high precision use in dekameter scale.

Limitations of use:
Data created as task within the EU-project METROL, restrictive use.

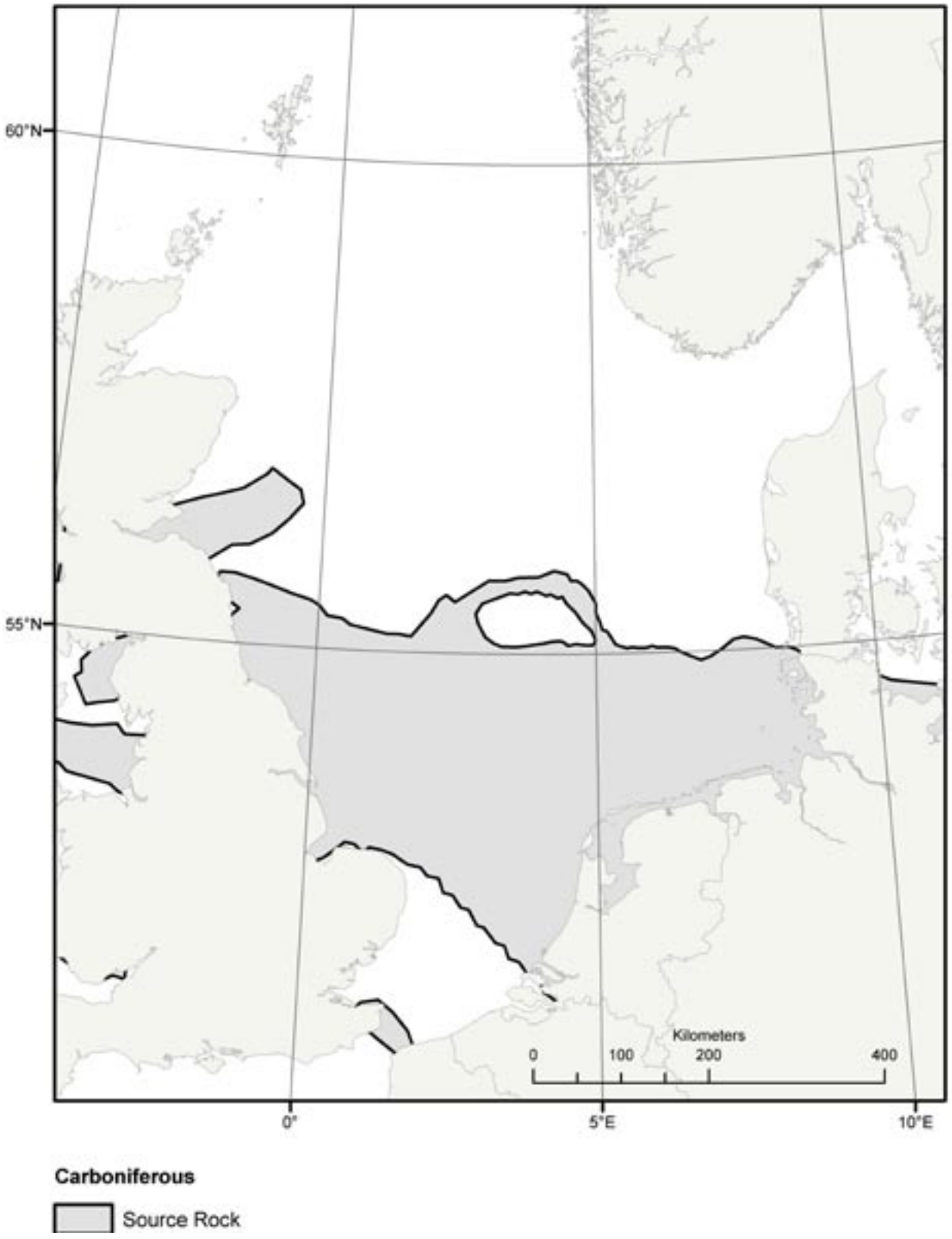
Source:
Petroleum Geology of the North Sea - Basic concepts and recent advances. - K.W. Glennie (Ed.).- Fourth Editionm, 1998. Blackwell Science. ISBN 0-632-03845-4 / Fig. 2.17, p. 64
Digitizing of figures after georeferencing, addition of meta data as given in the source.

Additional information

From: Cameron, Munns & Stoker: „Remaining hydrocarbon exploration potential of the Carboniferous fairway, UK southern North Sea“ Fig. 16. Geoseismic section illustrating examples of Carboniferous trap styles.



Carboniferous



Rotliegend - 299 million years - 257.3 million year ago

The Rotliegend is the older section of the Permian, which began before approximately 299 million years and ended approximately 257.3 million years ago. The younger part is called the *hangenden* (younger) Zechstein. In Germany it is common to separate the Permian only into two sections (older designation: Dyas, i.e. *The Spli*t). Internationally, the Permian is three-divided.

Data description:
Rotliegend (polygons)

Rough outline of the areal extent of Rotliegend reservoir and seal rocks.

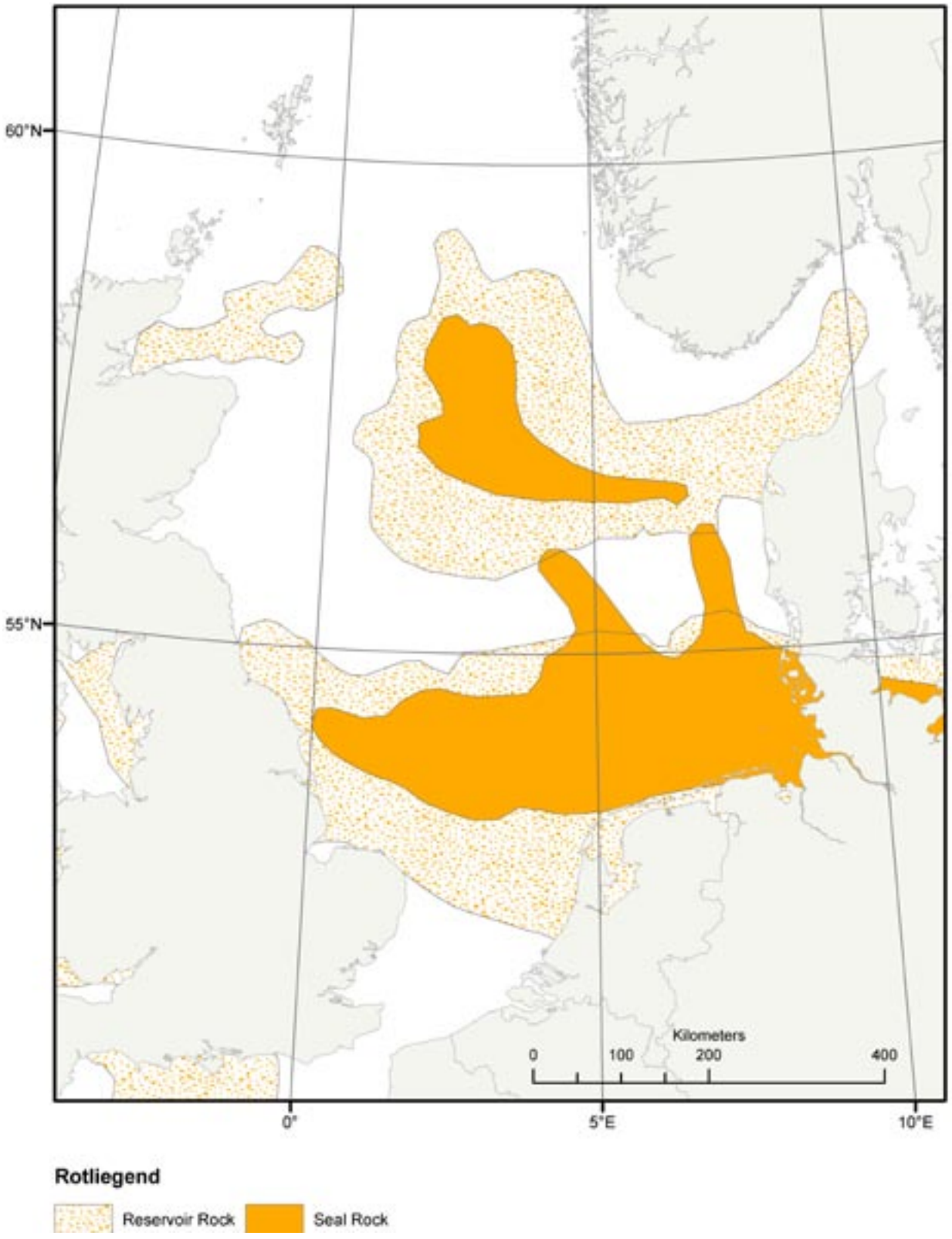
Mapped area is already represented as rough outline in the source. Digitized border lines are not for high precision use in dekameter scale.

Source:
Petroleum Geology of the North Sea - Basic concepts and recent advances. - K.W. Glennie (Ed.).- Fourth Editionm, 1998. Blackwell Science. ISBN 0-632-03845-4 / Fig. 2.17, p. 64.

Digitizing of figures after georeferencing, addition of meta data as given in the source.

Limitations of use:
Data created as task within the EU-project METROL, restrictive use.

Rotliegend


60°N
55°N
0°
5°E
10°E
Kilometers
0
100
200
400
Rotliegend
Reservoir Rock
Seal Rock

Zechstein - 257.3 million years - 251 million year ago

Zechstein is a geological formation of Late Permian age located in the European Permian Basin which stretches from the East Coast of England to Northern Poland.

The Zechstein consists of five cycles of evaporite rocks, (Halite, Anhydrite, Dolomite and shales) labelled Z1 to Z5 respectively. The Zechstein has significant economic importance in the North Sea oil province. In the southern gas basin it forms the main cap rock to the gas fields with Rotliegend reservoirs. Zechstein salt becomes diapric, becoming salt domes which form the structure for several oil fields.

The evaporite rocks of the Zechstein formation were laid down by the Zechstein Sea, an epicontinental or epeiric sea that existed for the last five to seven million years of the Permian Period. The Zechstein Sea occupied the region of what is now the North Sea, plus lowland areas of Britain and the north European plain through Germany and Poland. The eventual disappearance of the Zechstein Sea was part of a general marine regression that preceeded and accompanied the Permian-Triassic extinction (Glennie, 1998; Moores and Whitmore Fairbridge 1997).

Data description:
Zechstein (polygons)

Rough outline of the areal extent of Zechstein evaporite seals and salt diapirs, pillows and walls in the North Sea Area.

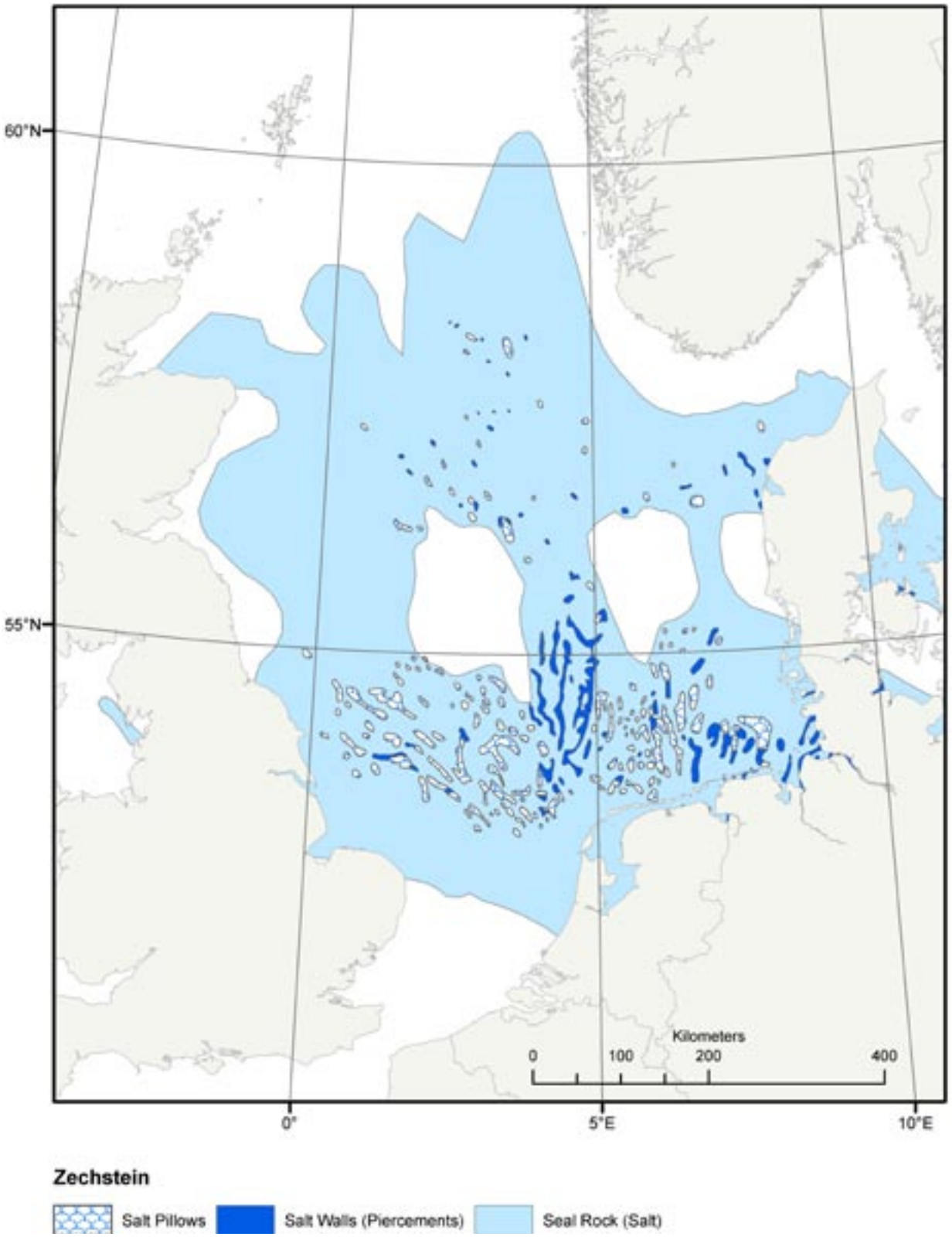
Limitations of use:
Mapped area is already represented as rough outline in the source. Digitized border lines are not for high precision use in dekameter scale.
Data created as task within the EU-project METROL, restrictive use.

Source:

Petroleum Geology of the North Sea - Basic concepts and recent advances. - K.W. Glennie (Ed.).- Fourth Editionm, 1998. Blackwell Science. ISBN 0-632-03845-4 / Fig. 2.17, p. 64.

Digitizing of figures after georeferencing, addition of meta data as given in the source.

Zechstein


60°N
55°N
0°
5°E
10°E
Kilometers
0
100
200
400
Zechstein
Salt Pillows
Salt Walls (Piercements)
Seal Rock (Salt)

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