Technical Report

Devolopment, analysis and publication of stakeholder oriented data and information within the MARLIN System

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(Technial report of the project ANsätze zur Kostenreduzierung bei der ERhebung von Monitoringdaten für Offshore Vorhaben (ANKER), **Arbeitspaket BENTHOS**; FKZ 0325921)

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1. Aim

The aim is to provide data and information on benthos and demersal fish species by the MARLIN information system. This information was designed by stakeholder-oriented needs for scientific advice related to offshore wind farm monitoring, marine spatial planning and conservation related regulations. All information is published via a web application of the MARLIN system.

2. Introduction

Marine ecosystems provide a number of ecosystem services, primarily living and non-living resources, means of transport, waste disposal and processing, leisure and recreational space. The intense use of our coastal systems has led to an increase of human pressures, such as transport, sand extraction and dumping, laying of cable, plumbing and pipelines, eutrophication, pollution, fisheries and, more recently, the use for marine renewable energy by the area-intense offshore windfarms (Atkins et al. 2011, Lindeboom et al. 2015). Every kind of human utilisation is in a way an interference with the respective ecosystem (Vitousek et al. 1997). Nowadays, marine ecosystem management and environmental protection aim at a sustainable use of our coastal areas and such management approaches are therefore implemented in national guidelines such as the marine strategy framework directive (MSFD), marine spatial planning (MSP) and regulations related to offshore wind farm construction and operation.

The benthos provides numerous ecologically and societally-important services, i.e. being a food source for economically important fish species, services related to biogeochemical processes (e.g. long-term carbon storage) and the biodiversity of the benthos itself (Dannheim et al. 2019). A sustainable management of marine resources requires sound research on basic benthic properties. Knowledge on the spatial and temporal scales of benthic species population dynamics and distribution is inevitable. Thereby, it is most important to understand and consider scales that are ecologically relevant (Wilding et al. 2017). The interactions between benthos and pressures can act from local to regional scales, as well as seasonal, annual and long-term variability on a temporal scale. Knowledge on the natural spatial and temporal variability of the benthos, i.e. the ‘natural corridors of variation’, is an indispensable prerequisite to discriminate anthropogenic impacts from the natural background variability. This impacts our understanding on how the benthos responds to pressures, how we determine the level of change and ultimately, whether there are any effects.

During the last decade, AWI and BSH have already cooperated in several projects providing information on benthos and demersal fish (e.g. via GeoSeaPoral) (StUKplus[1]: see Dannheim et al. 2013, BSH-AWI project[2]: see Dannheim et al. 2016, WebBenthosI[3]: see Dannheim et

[1] StUKplus project "Joint evaluation of data on benthos and fish for ecological effect monitoring at the offshore test field "alpha ventus"
[2] BSH-AWI project "Evaluation approaches for regional planning and approval procedures with regard to the benthic system and habitat structures"
[3] WebBenthosI project “ Nature compatible developments at sea (NavES) - Offshore research: Provision of environmental information from research projects and monitoring of offshore wind farms - Extension and updating of the existing technical information system and the web-based service for benthos data“

al. 2015). The ANKER project has built on this knowledge. For the first time, MARLIN provides a scientifically sound base for new scientific applications of large-scale and long-term data sets by multidisciplinary research in the German Bight in order to support scientific advice. Spatial and temporal analysis of benthic data provides information and explains natural benthic variability or to what extend planned activities might affect the benthic system. Thus basic and specific information on benthos and demersal fish are provided based on stakeholder needs.

Much information on benthos and demersal fish is frequently required as standard products from different stakeholders, e.g. for reports or as scientific base for effect analysis for environmental impact assessments or temporal and spatial variability e.g. in the context of marine spatial planning. In order to fulfil these enquiries of stakeholders (authorities, institutes, consultant companies, applicants of offshore wind farms, external planers) in the future with the MARLIN system, we developed and determined functional requirements of MARLIN as stakeholder-taylored information by specific user stories and use cases. These functional requirements for MARLIN in relation to environmental impact assessements, marine spatial planning and conservation needs were listed as products, i.e. data turned into information by graphs, tables or maps. Each product was defined by a product description including the scientific benthic aim of this product, the technical implementation in MARLIN and the final outcome and product view. After all product requirements and descriptions were settled, the products were implemented in MARLIN and tested in cooperation between BSH and AWI.

3. Technical development and implementation

A variety of frequently asked information was based on stakeholder needs and expertise of information needed from legacy projects related to the ANKER project. The use cases and user stories formed the scienitific justification of product selection. Products were allocated to different scientific biological themes which were collected based on stakeholder interests:

- Environmental factors, mainly sediment
- Distribution of individual benthic or fish species
- Sum parameters such as abundance and biomass data
- Inquiries related to biodiversity questions
- Endangered species, i.e. red list, §30 BNatschG and OSPAR species
- Distribution and dynamics of non-indigenous species
- Offshore wind farm turbine related analysis
- Multivariate community analysis
- Functional traits analysis

The technical requirements for the database of MARLIN are high, as to ensure that thematic, spatial and temporal data can be independently selected, as well as in a combination of those. Further requirements were that MARLIN provides tools beyond the biological data, e.g. statistical analysis tools to calculate diversity or geostatistical tools. Information is provided in different formats such as geodata (maps as vectors and raster data), graphics and tables.

Several overarching product classes within MARLIN were defined:

- Individual tables (views) of data and metadata

- Standardised overview tables and lists of data and metadata
- Geodata and map products
- Statistical analysis

Several topics were identified which are relevant fort he biological themes. These were

- Analysis in geographically predetermined regions, i.e. freely selectable areas on maps
- Analyis of classified areas (project and reference area of offshore wind farms, sediment tye)
- Temporal analysis, i.e. analysis on seasons and different years of investigaion in classified areas
- Analysis on different faunistic groups (infauna, epifauna, epifouling communities)
- Analysis on device related monitoring depending on the distance to the wind farm device

In general, the information systems of MARLIN and CRITTERBASE were partly restructured to fulfill the needs for product generation. Thus raw data are not selected any longer on station based data but on single grabs. This was an important change to data representation as natural variabilty is better described by single grabs. The developed tool thus has to be able to select single hauls and allocate them to the stations (e.g. for specific sum requests) and to calculate and standardise the abundance or biomass per area (e.g. m^{-2}), i.e. to link biological parameter to the sampled area in the database.

These topics, biological themes and product classes were defined by user stories and use cases and summarised in a list of 105 products for benthic invertebrates and demerstal fish. The products will be made available to the enduseres by a web application of MARLIN. In the following one example on a work flow of such one product is demonstrated.

3.1. Workflow Example

Before technical implementation in MARLIN, for each product a detailed product description was developed including the specific conditions and analysis for each product. As an example, the product description of the product ‘Mean biomass (g/m²) of single species of the infauna/epifauna’ is shown exemplarily (Figure 1). Here, the analysis of species mean biomass is a map product.

The first part of the product decription (Figure 1) defines the user story accomplished by stakeholder interest. The second part focuses on the methods which define the selection of data in the data information system and how the mean biomass should be calculated based on the raw data in the information system.

Produkt-Steckbrief

ID	Titel
B_005	*Mittlere Biomasse (g/m^2) von einzelnen Arten der Infauna/Epifauna*

Projekt:	Status:	Stand vom:	Letzte Änderung (Bearbeiter/in):
ANKER	ENTWURF	21.02.2017	Jennifer Dannheim, AWI

Fachl. erstellt von: Jennifer Dannheim, AWI

BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

1. User Story - Kurzbeschreibung und fachliche Darstellung der Arbeitsschritte

Darstellung der mittleren Biomasse (g/m^2) einer Art (Taxon) der Infauna/Epifauna in einem gewählten Gebiet anhand gerasterer Daten in einer Verbreitungskarte

Kurzbeschreibung

Als [Rolle] möchte ich [Wunsch], um [Nutzen].

Arbeitsschritte

1. …
2. …
3. …

2. Methode

Biologische Daten der Samples auf $1m^2$ standardisieren, Mittelwert aller Werte zur gewünschten Art in einer Gridzelle berechnen und für die gesamte AWZ auf Basis der Gridzellen in einem Raster/Shapefile ausgeben

Selektion nach Gerät:

SELECT(gearcategory) (hiernach wird entschieden Infauna/Epifauna)

Selektion aller Samples für Absenzdaten:

SELECT alle sampleid mit lon_start, lat_start

Berechnung der Biomasse für Arten:

Akzeptierter Artname

SEARCH(taxon) vergleiche mit (taxon_accepted) → ersetze taxon mit taxon_accepted

DESELECT(sum_wet) entspricht n/a

DESELECT(lifestage) entspricht "JUV" und "LAR" durch Verknüpfung zu lifestageid und lifestage

Flächenbezogene Biomasse pro $1m^2$:

BIOMASSE ($g\ m^{-2}$) = sum_wet des taxon_accepted / sampledarea für jede sampleid

INCLUDE alle sampleid (mit lon_start, lat_start), i.e. BIOMASSE für Absenzdaten

Geographische Verschneidung

Eingang:

- EEA reference grid, Germany (Infauna: 5km, Epifauna: 10km)
- AWZ-shp: SELECT alle sampleid, die innerhalb des shp-Files liegen
- File: BIOMASSE (inkl. alle sampleid) über lon_start und lat_start geographisch verorten

Mittelwertberechnung

Pro Gridzelle: Mittelwert (BIOMASSE) = SUM(BIOMASSE) / Anzahl(sampleid) aller in der Gridzelle liegender sampleid

Figure 1: Workflow example of a product description in the theme product 'Single species distribution' based on mean biomass as georeferenced presentation /map product.

Produkt-Steckbrief

ID	Titel		
B_005	***Mittlere Biomasse (g/m²) von einzelnen Arten der Infauna/Epifauna***		
Projekt: ANKER	Status: ENTWURF	Stand vom: 21.02.2017	Letzte Änderung (Bearbeiter/in): Jennifer Dannheim, AWI

BSH
BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

3. Technische Umsetzung Benötigte Daten / Attribute

Benötigte Tabellen:

- Tabelle sample
- Tabelle gear
- Tabelle population
- Tabelle taxon
- Tabelle lifestage

Benötigte Attribute:

Tabelle sample: sampleid, gearid, lon_start, lat_start, sampled_area
Tabelle gear: gearid, gearcategory
Tabelle population: sampleid, taxon, sum_wet, livestage
Tabelle taxon: taxon_name, taxon_accepted
Tabelle lifestage: lifestageid, lifestage

Benötigte GIS-files (extern):

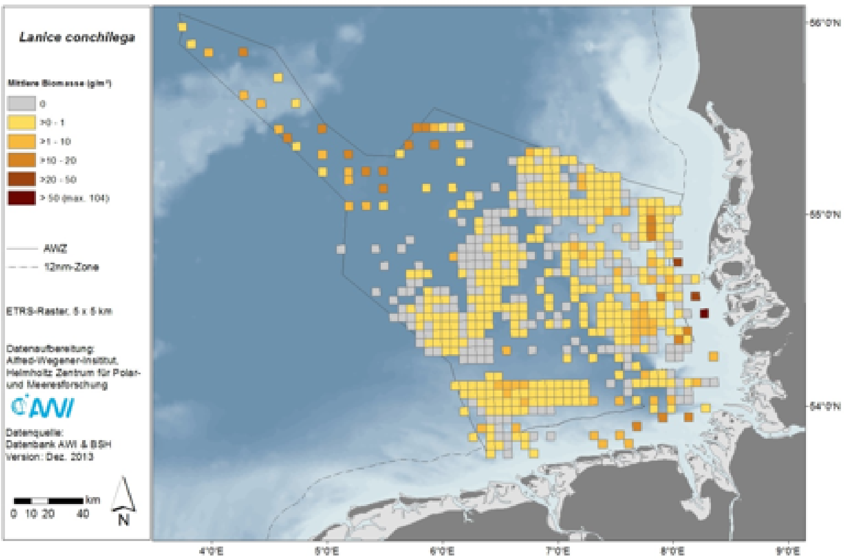
- EEA reference grid, Germany
- Shp-file Deutsche AWZ

Figure 1 ff: Workflow example of a product description in the theme product 'Single species distribution' based on mean biomass as georeferenced presentation /map product.

The third part of the product decription (Figure 1) focuses on the technical implementation, i.e. the tables and attributed needed from the database within MARLIN as well as external files and data needed. The last part of the description defines the definition of the product presentation. In this example, it is the distribution of the sand mason worm (*Lanice conchilega*) with its biomass in the German Exclusive Economy Zone.

Produkt-Steckbrief				
ID *B_005*	*Titel* **Mittlere Biomasse (g/m²) von einzelnen Arten der Infauna/Epifauna**			BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE
Projekt: ANKER	*Status:* ENTWURF	*Stand vom:* 21.02.2017	*Letzte Änderung (Bearbeiter/in):* Jennifer Dannheim, AWI	

4. Ausgabeprodukt



Die Karten sollten mit folgenden Metadaten geliefert werden:
- Aus Tabelle sampleid: date_start pro Gridzelle der ersten und letzten Probennahme
- evt. Anzahl sampleID pro Gridzelle

Mögliches Format:
- Raster, Shapefile, georeferenziertes TIFF

Wie groß ist die generierte Datenmenge?
ca. 300.000-800.000 Zeilen

- In welchen Zyklus muss das Produkt erstellt werden (z.B. aggregierte Dichtekarte 1-2 im Jahr)?
- kommt auf die Datenlieferung von neuen Daten durch das BSH an

Institution, fachl. Geprüft durch:	BSH, genehmigt durch:	
(Datum, Institution, Unterschrift)	(Datum, Unterschrift)	

Figure 1 ff: Workflow example of a product description in the theme product 'Single species distribution' based on mean biomass as georeferenced presentation /map product.

4. Results and discussion

In the ANKER project, 105 product dscriptions based on the stakeholder needs were developed based on the user stories and use cases which were developed in close collaboration with BSH. In the following, the biological themes with the allocated products are introduced. These are the main results for the project and the scientific base for the outputs of the MARLIN system.

4.1. Realised products in the MARLIN system

The MARLIN web application for products enables a straitforward selection (Figure 2) of the biological or environmental topics (start, see Figure 2 upper part), several filter functions, e.g. epifauna/infauna by gears, single species or protection state filter (subject, see Figure 2), thereafter the area (spatial filter) and the time (temporal selection) can be selected. The last tab guides the user to the requested product which is provided as a preview and concurrently as a download of the product as zip-folder. Selection decisions for the various products are always displayed on the right side for orientation (Figure 2).

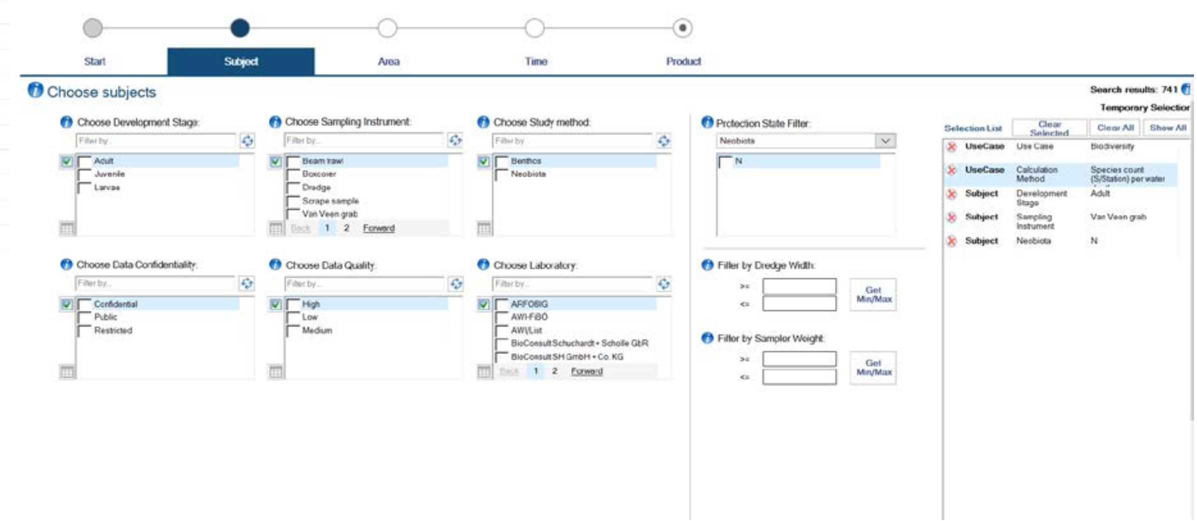


Figure 2: Overview on MARLIN web application (screenshot). Upper level Median grain size (µm) in the project (analysis) area and reference area of an offshore wind farm. Screenshot from MARLIN application.

As a baseline for the benthic system, MARLIN provides products related to environmental parameters. Those were primarily related to sediment such as mean percentage part of grain size fractions (after DIN4022), median grain size and sediment differences between offshore wind farm project area and reference area (Figure 3).

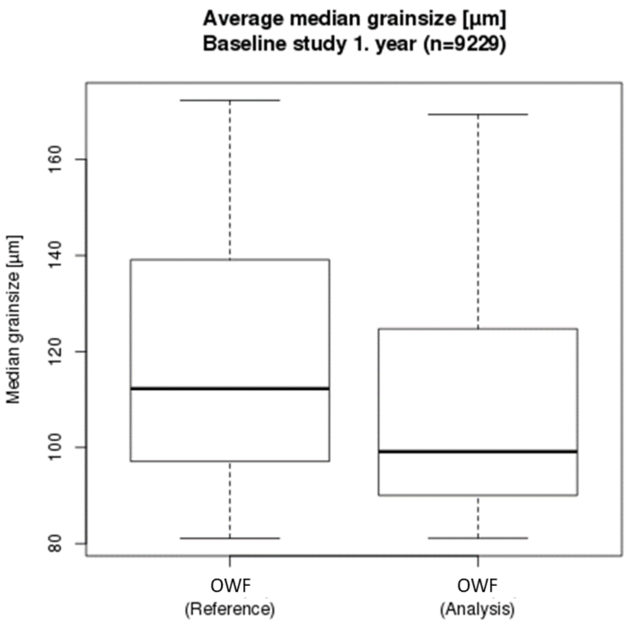


Figure 3: Median grain size (µm) in the project (analysis) area and reference area of an offshore wind farm. Screenshot from MARLIN application.

Frequently asked information by stakeholders are single species distribution of macrobenthic invertebrates and demersal fish. Within the MARLIN system, the user can select for single species and evaluate the abundance and biomass for example in the German Bight (map product), or in the project and reference area of a wind farm, or how distribution changes along environmental gradients (Figure 4).

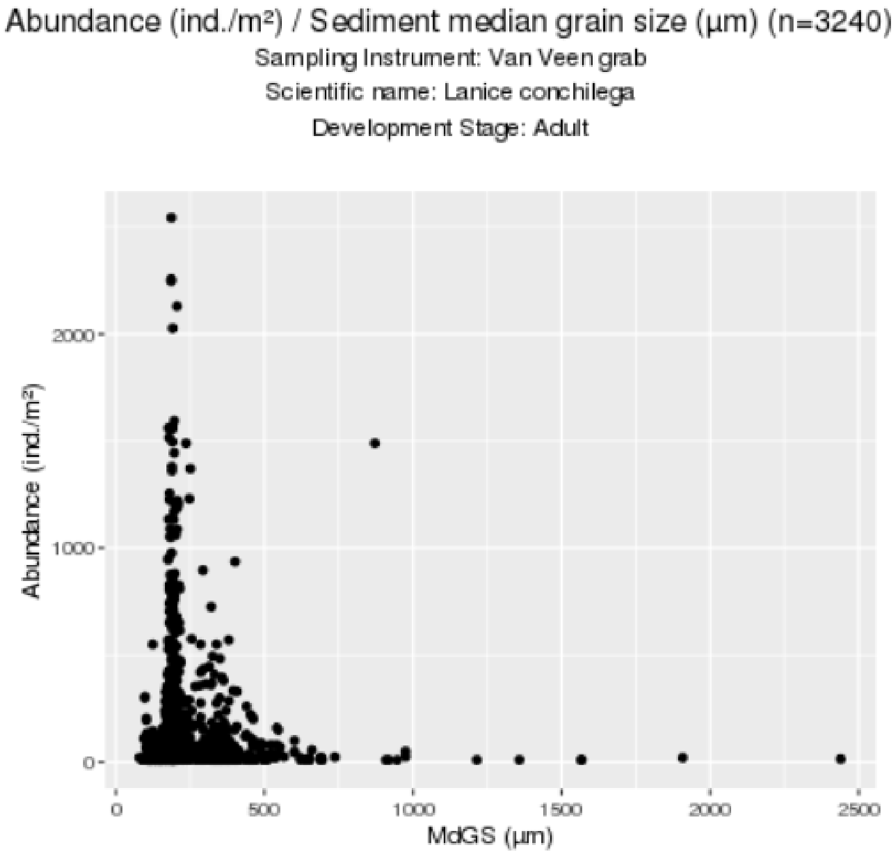


Figure 4: Abundance (m^{-2}) of the species *Lanice conchilega* depending on sediment median grain size (MdGS, µm) in the German Bight, North Sea. Screenshot from MARLIN application.

MARLIN also provides an overview on summarising queries which include the total biomass or abundance of benthos or demersal fish (map products, see example Figure 5), of taxonomic groups (Crustacea, Echinodermata, Polychaeta etc.), of single stations, of project and reference area in offshore wind farms, of different sediment types. Further, dominance relations (%) of abundance and biomass of species are available for stations and different areas.

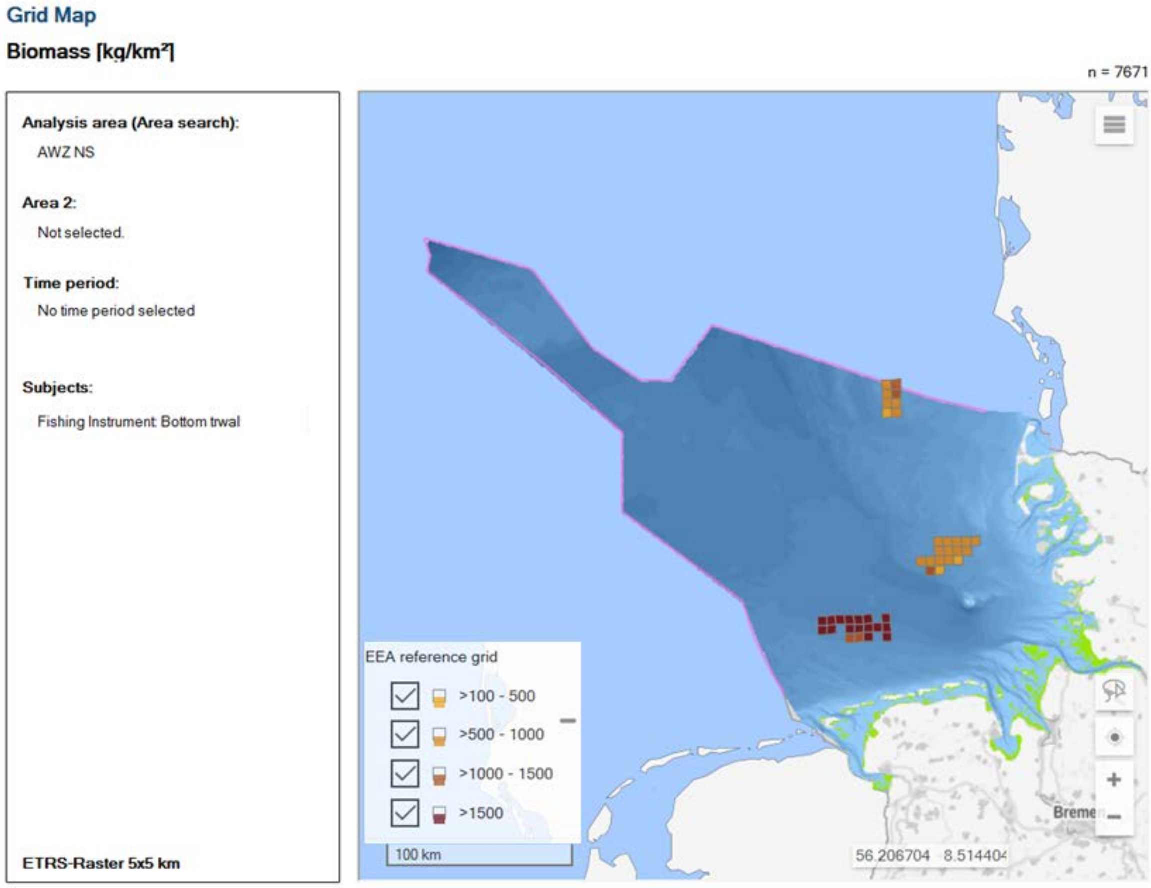


Figure 5: Total biomass (kg m^{-2}) of demersal fish in the German Bight, North Sea. Screenshot from MARLIN application.

Biodiversity queries are a fundamental measurement for studies such as environmental impact assessments, habitat monitoring (e.g. habitat directive, marine strategy framework directive) or marine spatial planning. Thus, MARLIN offers a large range of different products. Biodiversity parameters include total number of taxa (species richness) also devided by taxonomic groups (Crustacea, Echinodermata, Polychaeta etc.), diversity (e.g. Shannen Wiener index, see example in Figure 6), eveness, frequency of occurrence of species (%) and species lists. These parameters are demonstrated per station, in project and reference areas of wind farms, for different sediment types and depending on median grain size and water depth.

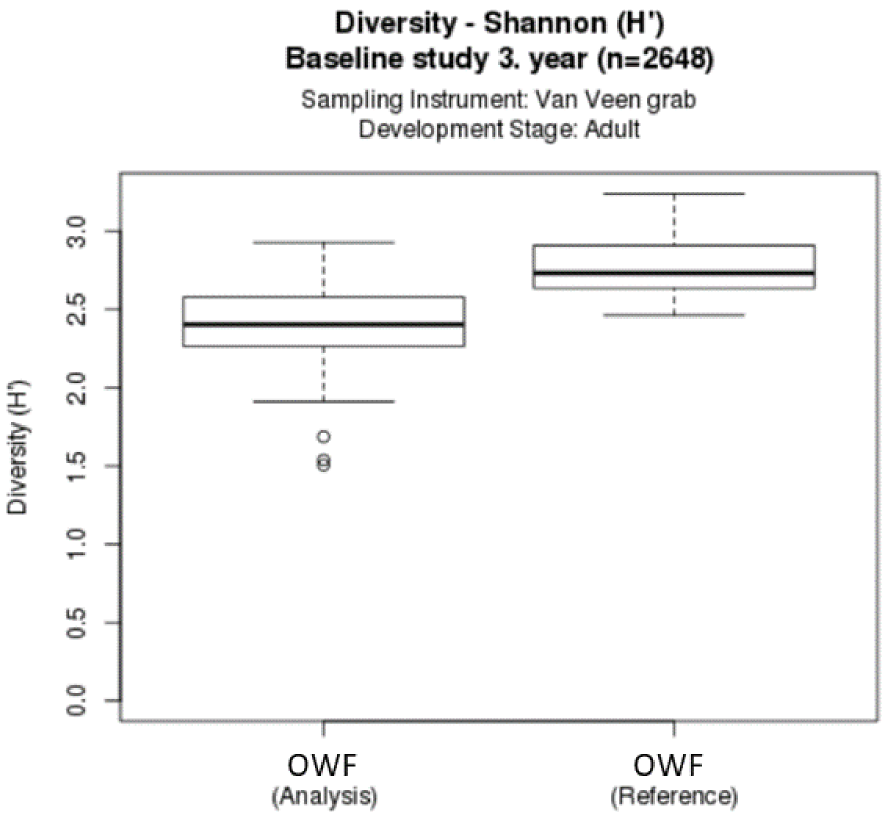


Figure 6: Diversity (H) of the infauna (macrobenthic invertebrates) in the project and reference area of an offshore wind farm in the German Bight, North Sea. Screenshot from MARLIN application.

As important as biodiversity measures, are measures related to endgangered species queries. As the taxonomic reference list in the MARLIN system covers several species attributes that cover species classification according to their endangerment, a range of products is provided in MARLIN. These cover the assignment of species to the German red list, §30 BNatschG and OSPAR species. All products are available as number of character species for §30 BNatschG, of OSPAR species and of total red list species or species per red list category (see example in Figure 7). Number of species are available per station, per taxonomic groups (Crustacea, Echinodermata, Polychaeta etc.), per project and reference areas of wind farms or related to different habitat types.

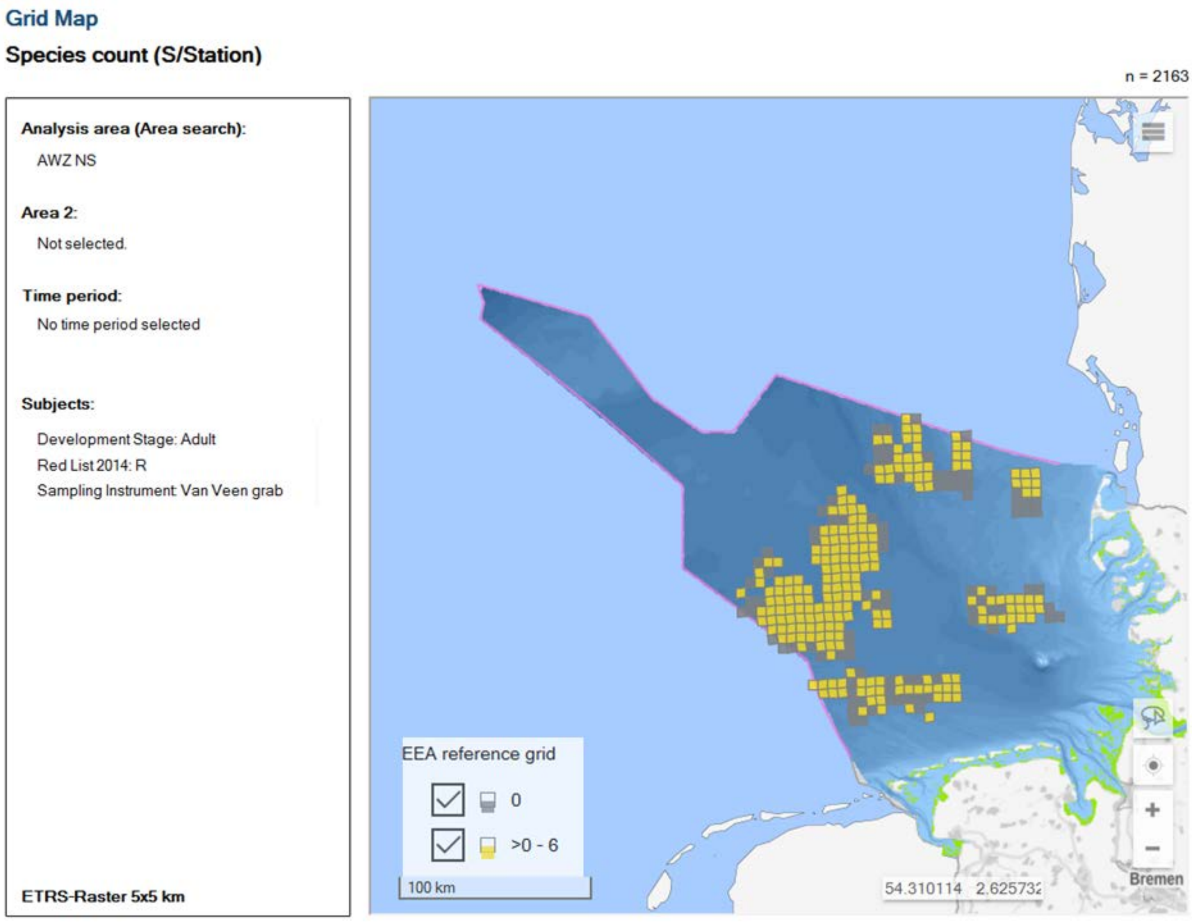


Figure 7: Spatial distribution of number of red list species (S/station) of category R (extremely rare) on a 5 km grid in the in the German Bight, North Sea. Screenshot from MARLIN application.

Non-indigenous species, their spatial and temporal distribution, are also covered in the MARLIN system. Products are available for the number of non-indigneous species per station, in project and reference area of wind farms and on different sediment types. Further, the abundance and biomass of single non-indigenous species is provided, as well as the number of species separately for taxonomic groups. Figure 8 gives an example of the distribution of number of neobiota species depending on sediment median grain size.

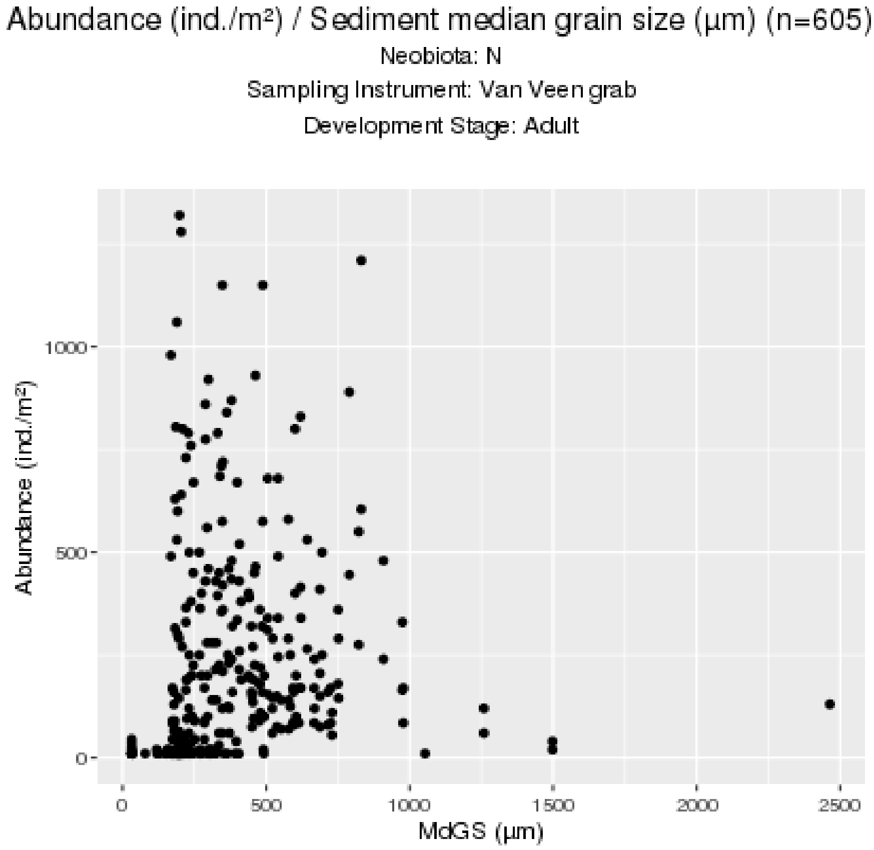


Figure 8: Abundance (m^{-2}) of non-indigenous species depending on the sediment median grain size (MdGS, µm) in the in the German Bight, North Sea. Screenshot from MARLIN application.

For all biological themes, products covering device related analysis are available and similar to the presented summary and biodiversity queries, but focus on the analysis of the distance to the wind energy device.

4.2. Limitation of automated products related to multivariate community analysis

There are several products related to multivariate analysis such as

- Analysis of the occurrence of character species (e.g. according to Rachor & Nehmer 2003)
- Community analyses by identifying similarities between stations based on species composition and their abundance/biomass between project and reference areas, different sediment types over time

While the analysis of character species from Rachor & Nehmer (2003) has been implemented in the MARLIN system by additional attributes in the taxon reference system (see Kloss et al. 2020), the automated multivariate analysis of communities is beyond the possibilities of the MARLIN automated information supply. In order to provide such multifactorial community statistics, the information system needs to calculate a similarity matrix (e.g. Bray Curtis similarity, Euclidean distance) based on the species occurrence and species abundance or biomass, respectively. Bray Curtis similarity is calculated as

$$D_{1,2} = \frac{\sum_{j=1}^{S} abs(x_{1j} - y_{2j})}{\sum_{j=1}^{S} (x_{1j} + y_{2j})}$$

where $D_{1,2}$ is the similarity between two stations, x_{1j} the (transformed) abundance/biomass of species j at the station 1 and x_{2j} the (transformed) abundance/biomass of the species j at the station 2. S = total species number.

Common derived products are graphs of cluster analysis or multidimensional scaling as well as statistical tests on significant differences between communities (e.g. ANOSIM, analysis of similarity). Classical programms that are able to undertake these analyses are PRIMER (Clarke & Gorley 2001) or the R package VEGAN (Oksanen et al. 2019).

The automation of multivariate analyses is generally not possible. Particularly if it comes to differentiating habitats or habitat types from each other. Two examples are given here for explanation. Using a similarity matrix, an MDS was generated by the program Primer. The two data sets used here (RN, AUT) comprise as subsets less than 10 % of all data in MARLIN and CRITTERBASE. The habitat types or benthic communities were investigated and defined in Rachor & Nehmer (2003) for the German Bight. Therefore, the stations of the RN data set are clearly assigned to one habitat type (RN commun) (see example below). The second dataset (AUT) could not be clearly assigned to communities (see Figure 9, stations with #NV), since the increasing number of stations blurs the transitions between communities.

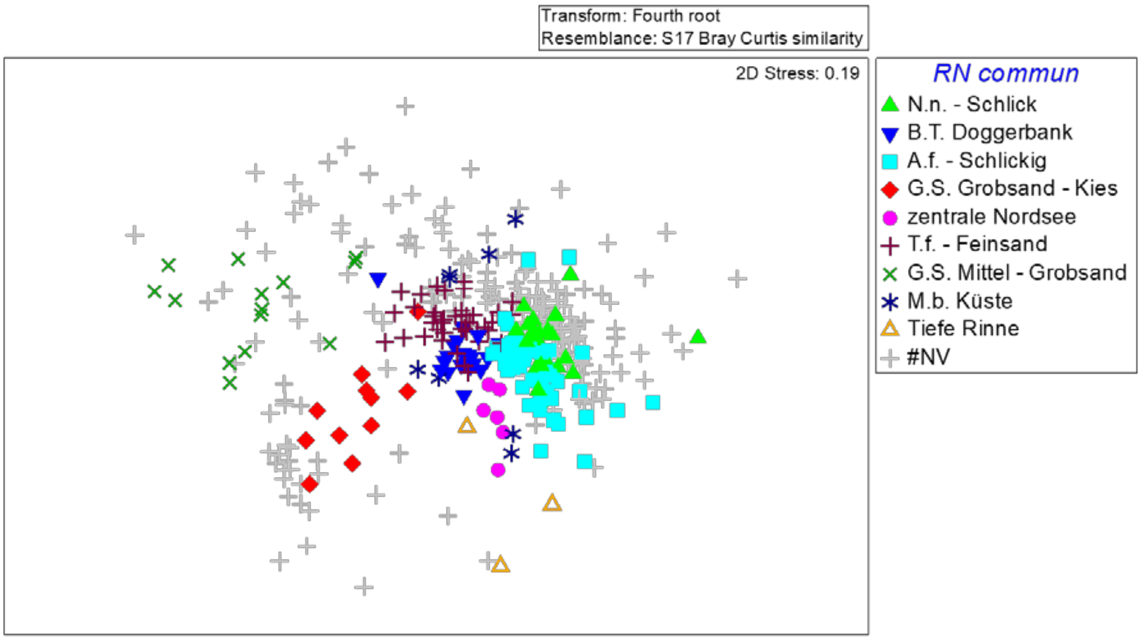


Figure 9: Multidimensional scaling (MDS) of communities defined after Rachor & Nehmer (2003) based on two data sets (RN, AUT). Here, the original allocation oft he station to the communities is shown (RN commun).

If the data of the two datasets are automatically or statistically reclassified based on the program, the lower example shows 56 bentic communities (see Figure 10, separation of communities at 40% Bray-Curtis-similarity), instead of the defined nine communities in the German Bight.

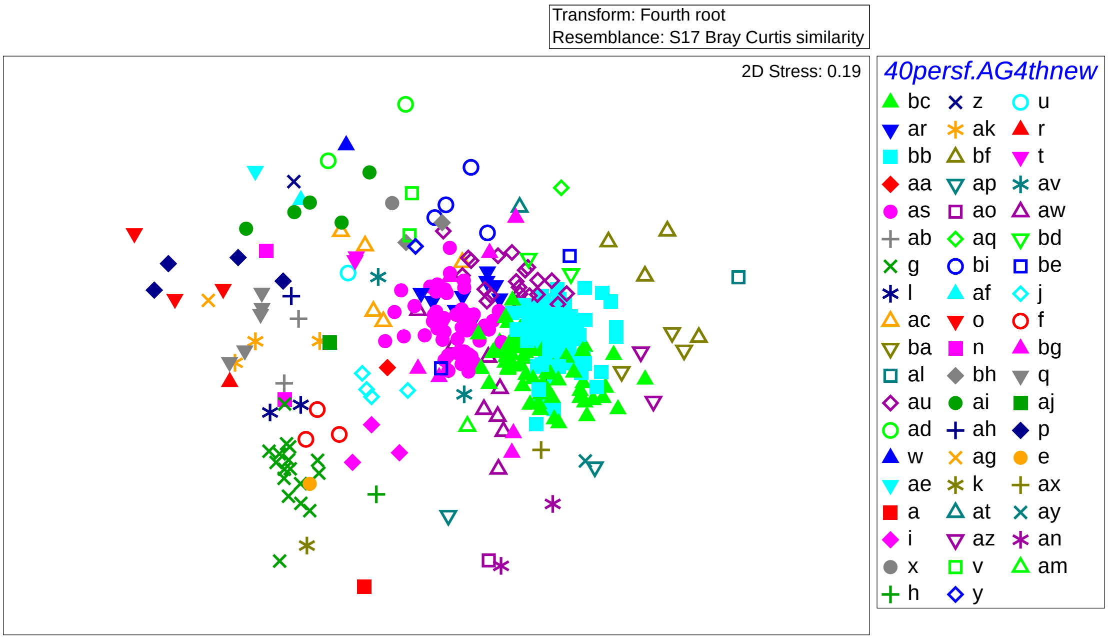


Figure 10: Multidimensional scaling (MDS) of communities based on two datasets (RN, AUT). Here, the statistically calculated classification of communities according to the 40% similarity (Bray-Curtis-Similarität) is shown.

The purely mathematical separation of communities does not correspond to the ecological natural conditions. Therefore, multivariate community analyses, especially of large datasets, cannot be provided fully automated via MARLIN as a product. However, the distribution of character species is available in MARLIN. Further, it is possible to provide an automated generation of the similarity matrix based on Bray-Curtis-similarity which is an ongoing initiative in MARLIN. This scientific base could then be used by exploring multivariate benthic patterns with statistical anaylsis tool by scientific experts. However, scientific judgment and expertise is needed to generate scientific sound multivariate analysis.

Within the framework of the ANKER project more than 100 different products are made available by the MARLIN web application. These products on spatial and temporal distribution of benthos and demersal fish are frequently requested by stakeholders. This important and unique web-portal for benthic information serves thus as a knowledge base for different tasks in relation to environmental impact assessements, marine spatial planning and conservation issues.

5. Supplementary material

All product descriptions are attached to the main report as digital Annex (see zip-package AP8.zip). An overview on use-cases and user stories, as well as a glossary accompanying the product description is also included in the Annex (AP8.zip).

6. Literature

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