Gaining Better Geospatial Knowledge about the Marine Biodiversity by Using Harmonized Data Models, Adequate Cartographic Visualizations and by Providing Easy Access

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Abstract. In order to successfully bring together the marine biodiversity data of various origins, common data models need to be developed. The manifold data then need to be visualized adequately following cartographic principles. In order to transfer the spatial biodiversity information to experts, decision makers as well as the general public an easy access to the data visualizations is required. Here, Web services based on international standards such as OGC and INSPIRE present the appropriate way. Consequently, harmonized data models, adequate cartographic visualizations as well as an easy data access are prerequisites for a profound acquisition, analysis and use of geospatial knowledge about the marine biodiversity in the German EEZ.

Keywords: Cartographic Visualization, Coastal and Marine Data, Exclusive Economic Zone (EEZ), Marine Biodiversity, Monitoring Data, Nature Conservation

1. Introduction

Marine and coastal ecosystems comprise a high diversity of species, although it is expected that the majority of marine species are yet to be discovered (Burke et al. 2001). Pressures from human activities, however, are globally on the rise causing a decline of population abundance and bearing the threat of species extinction (Baillie et al. 2004). In order to efficiently protect the marine biodiversity including natural marine habitats, detailed knowledge is required about the subjects of protection themselves as well as about impacts caused by anthropogenic uses (Narberhaus et al. 2012). At the global scale though, knowledge about the geographic distribution of threatened marine species is not comprehensive (Baillie et al. 2004). Data are often missing because their acquisition is significantly more difficult for marine ecosystems as compared to terrestrial ecosystems where a wide range of detailed geospatial data sets exist. This is especially the case for areas beyond the territorial seas, where water depths are higher.

Germany's Federal Agency for Nature Conservation (BfN) has established several programms to monitor the marine biodiversity focusing on Germany's Exclusive Economic Zone (EEZ) of the North Sea and the Baltic Sea, i.e. the area between 12 sm and 200 sm off the baseline (see *figure 1*). Species monitoring includes mammals, with a special attention to the harbour porpoise (*Phocoena phocoena*) (cf. Gilles et al. 2011), certain sea birds (cf. Markones & Garthe 2011) and benthic communities (cf. Darr & Zettler 2011) which are protected under the Habitats and Birds directives. In addition, a cadastre of marine habitats is under development. Methods applied during the assessment include visual surveys from aircrafts and ships, the collection of grab samples, and the use of both stationary and portable acoustic detectors such as porpoise detectors (POD), side scan sonar (SSS) or Hydrophones. While the agency itself conducts between three to four ship surveys annually, most data are collected by different commissioned research institutes.

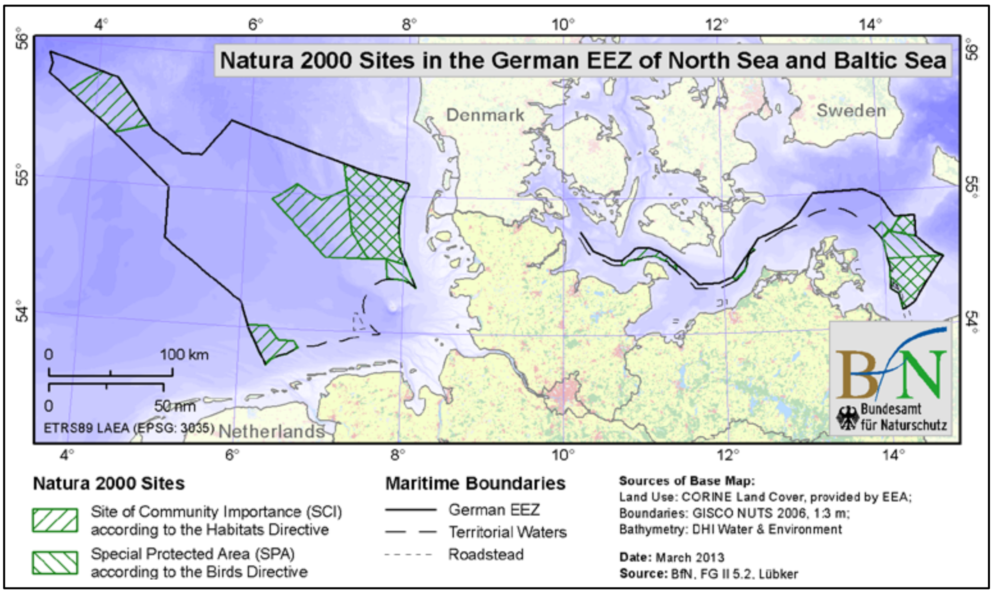

Figure 1. Location of Natura 2000 Sites in the German Exclusive Economic Zone (EEZ) of North Sea and Baltic Sea.

Due to the federal system of Germany the marine areas up to 12 sm are administered by the coastal state authorities. Consequently, marine biodiversity monitoring is here mainly conducted by the different state authorities (cf. e.g. Romahn et al. 2008, Dähne et al. 2011). Therefore, the monitoring information from state and federal authorities needs to be brought together. The consolidation of different data sources has become even more important since the Marine Strategy Framework Directive (MSFD; 2008/56/EC) came into force. The directive requires an intensification of marine monitoring activities for the ongoing assessment of the environmental status of all marine waters of the Member States of the European Union, coordinated reporting and installed coherent monitoring programmes by 2015, respectively (Krause et al. 2011).

2. Harmonized Data Models

An increasing amount of marine biodiversity monitoring data that cover distinct parts of the marine ecosystem and that are collected by different institutes need to be harmonized in order to be easily comparable. On the side of the collection of monitoring data coordinated monitoring concepts have been agreed by federal and state authorities as presented in the monitoring manual of the German Marine Monitoring Programme (BLMP). Quality assurance standards (cf. Schilling 2012) are not yet available for all monitoring methods and are currently under development for the missing types of marine biodiversity assessments and will be binding for measuring institutions once they have been agreed.

For data management, though, harmonization is still the exception rather than the rule. This includes data models used in underlying databases for storing qualified raw data as well as models used for result data that is aggregated over time and, when appropriate, space and Web services built upon these data. Moreover, time periods as well as reference grids used vary amongst the different institutions involved as well as within them.

Therefore, standardized data models are currently being designed at BfN for different marine biodiversity monitoring programms. A particularity of the relational models is that the geometry used for spatial aggregation is kept separately from the actual monitoring data (see *figure 2*). With this approach a redundant storage of geometry data is avoided and monitoring institutions need to report attribute data only. In addition, the approach is very flexible in the use of different grid systems and grid cell resolutions. Requirements of the INSPIRE directive are already taken into consideration but with preference to simplicity the data models are not fully compliant yet. Compatibility is instead ensured at the level of the Web services.

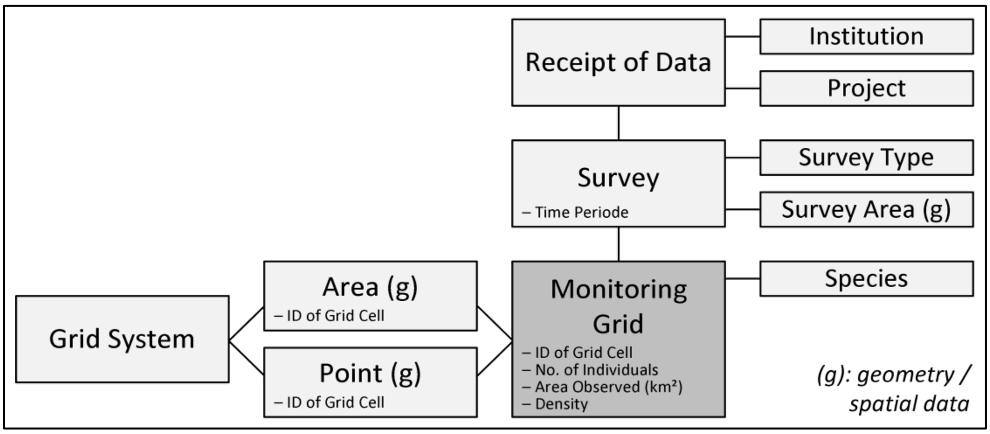

Figure 2. Schematic representation of a standardized data model designed for marine biodiversity monitoring data (simplified).

3. Cartographic Visualization

As second prerequisite to successfully transfer the spatial biodiversity information to the target audience, adequate cartographic means need to be developed for the visualization of the marine biodiversity monitoring data. Once such a system is established, the comparability between different time periods as well as between different species is granted, regardless of the origin of the data. For spatial aggregation the hierarchically organized pan-European reference grid (Annoni 2005) is preferred. It is based on the ETRS89 Lambert Azimuthal Equal-Area (LAEA) coordinate reference system and therefore suitable for area comparisons. The grid system is compliant to the INSPIRE specification on geographical grid systems (cf. TWG-RS 2010) and recommended for European reporting obligations such as required by the MSFD (cf. EEA 2012).

In case of the distribution and abundance of mammals and sea birds the data is aggregated using the European reference grid in the 10x10 km^2 resolution (see *figure 3*). Aggregation in time is dependent on expert opinion and differs for the distinct species groups and species. Aggregated monitoring results are visualized as graded colour grid cells and alternatively as proportional point symbols in order to guarantee a consistent symbolization. Additional information on species monitoring is provided such as the relative area coverage of individual grid cells, here used as an indicator for accuracy. Other punctiform symbols e.g. indicate sightings of harbour porpoise mother and child pairs. In case of habitat mapping a spatially discrete representation is more meaningful.

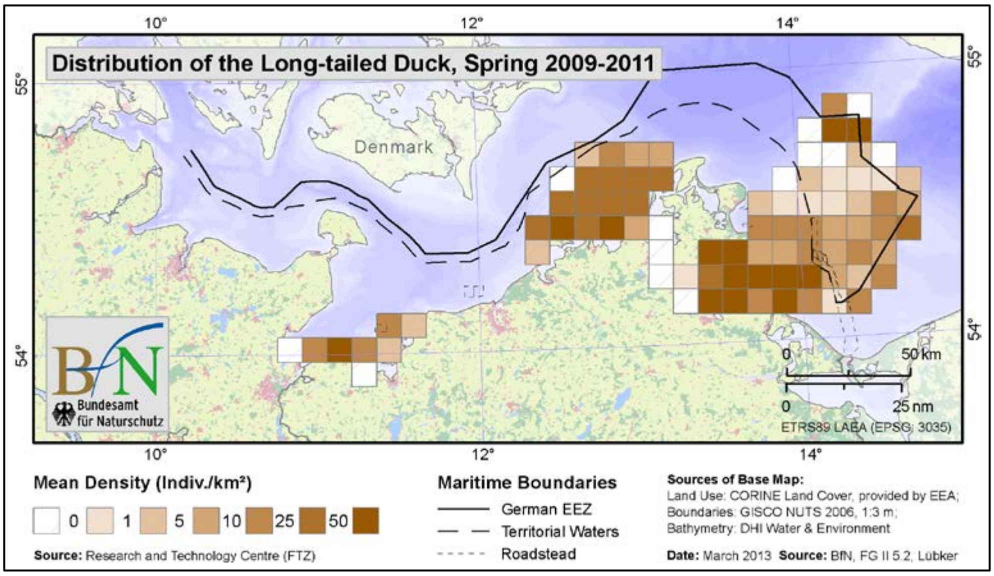

Figure 3. Visualization of sea bird distributions (here: Long-tailed Duck, *Clangula hyemalis*) aggregated over three time periods and based on the 10x10 km^2 pan-European reference grid.

4. Easy Access

The third prerequisite for a successful acquisition of geospatial knowledge on marine biodiversity is to provide easy access to the data and information. For the marine biodiversity data, BfN is following two approaches that complement each other very well.

On the one hand, an in-house solution is currently being developed that consists of a web-based intranet tool (see *figure 4 top*). Here, the agency's geospatial data is consolidated within a single point of entry. The application allows an easy access to the information, an easy comparison of information, to perform geospatial queries in time and space, and an overlay with other marine data sets (via OGC web services). Using the tool, marine ecologists can retrieve tailored information from the monitoring data that they can use to assess the condition and the development of the marine biodiversity.

On the other hand, OGC compliant Web services are provided for the aggregated result data sets. Where necessary, the Web map and Web feature services (WMS/WFS) are provided compliant with the requirements of INSPIRE. The structure of these Web services is coordinated between the federal and state authorities involved in an ongoing process of harmonization.

Metadata for these Web services will be available via the agency's standardized Catalogue Service for the Web (CSW) gateway starting from the second half of this year. These Web services are integrated into the Marine Data Infrastructure Germany (MDI-DE) (see Lübker et al. in this book). With the publicly accessible MDI-DE portal (www.mdi-de.org) a single access point is provided for marine geospatial data hold by the various federal and state authorities (see *figure 4 bottom*). Here, the data can therefore be overlaid with marine data from other thematic domains such as the protection of the marine environment and coastal engineering. Marine biodiversity data is thus brought into a broader context allowing to draw connections between the distinct thematic domains.

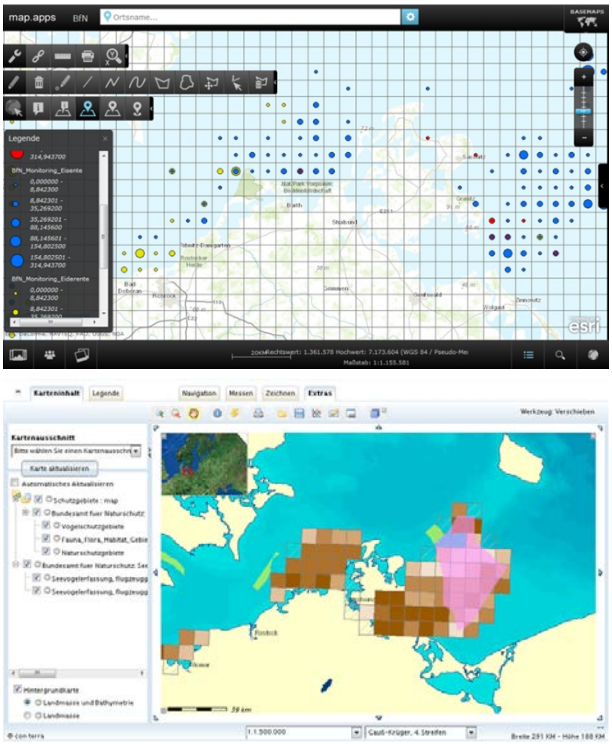

Figure 4. Screenshots of the in-house web-based intranet tool (top) and the portal of the Marine Data Infrastructure Germany (bottom).

5. Conclusion

It can be concluded that for providing an overview on marine biodiversity geospatial data three main steps are required. First, harmonization of data management is a prerequisite for an easy comparison of monitoring data originating from different sources. Second, cartographic means are needed to adequately visualize the results from analysed field data to explore changes over space and time. Finally, an easy access to the data is needed in order to transfer this information to experts, decision makers as well as the general public.

With the help of the approach outlined here the acquisition, analysis and use of geospatial knowledge on marine biodiversity in the German EEZ is facilitated to a high degree. Such geospatial information can be the basis for developing management plans for marine protected areas. Such sound data underpins proper protection of marine biodiversity and the conservation of natural marine habitats. In addition, by bringing together data from different sources reporting obligations as required by the MSFD are facilitated. Finally, a successful process to expand marine geospatial biodiversity knowledge including data harmonization of various measuring and responsible institutions, adequate visualization for their needs and the provision of easy access to all collaborators require substantial real world efforts and must be considered as an iterative open ended process.

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