Part II: Site selection procedure

Chapter 3

Interpretation, identification and ecological assessment of the NATURA 2000 habitats "sandbank" and "reef"

Dieter Boedeker, Jochen C. Krause and Henning von Nordheim

German Federal Agency for Nature Conservation, branch office: Isle of Vilm

Abstract

In the German Exclusive Economic Zone (EEZ), the marine natural habitats *reefs* (NATURA 2000 code 1170) and *sandbanks which are slightly covered by sea water all the time* (1110) are found throughout the North Sea and the Baltic Sea. They serve several important functions, such as offering protection for rare and threatened species, as well as hosting important and threatened biotopes. Both habitat types occur in nearshore coastal waters as well as in offshore waters. Calculations show that with around 79% of all German North Sea sandbank habitats and with ca. 61% of those in the Baltic Sea, the majority of this habitat is situated in offshore waters of the German EEZ and the minority in the coastal waters of the Territorial Sea. The same situation applies for reefs in the North Sea (ca. 53% in the EEZ), whereas the majority of Baltic Sea reefs is situated closer to the coast (73% in the Territorial Sea). A great portion of the German EEZ sandbank habitats (64% North Sea, 99% Baltic Sea) and reef habitats (73% North Sea, 57% Baltic Sea) are included in the German offshore NATURA 2000 site nominations.

1 Introduction

According to the Habitats Directive of the European Union (EU), natural habitats of Annex I to the Directive, but also several animal and plant species of Annex II and IV are to be protected by EU Member States as Special Areas of Conservation (SACs). Together with the Special Protection Areas (SPAs) classified under the EU Birds Directive, they form the coherent European system of protected areas entitled NATURA 2000.

This article focuses on the identification and selection process of marine habitats in the German EEZ. The basic definitions and further mapping notes for all NATURA 2000 natural habitats are laid out in the *Interpretation Manual of European Union Habitats*. However, in the marine environment the application of the Habitats Directive has remained more difficult than originally expected, especially as regards the identification and selection of natural habitats in the offshore areas. EU-Member states had to face several gaps and deficiencies in the Interpretation Manual (e.g., imprecise habitat definitions) and in the applicability of the Habitats Directive for the offshore areas of the Member States as well (missing several threatened marine biotope types and species in the Annexes). To address these and other offshore marine issues, the EU Commission established in 2003 a marine expert working group (MEWG). According to the Terms of Reference of this group, the experts should propose, among other issues, new definitions of marine natural habitats, the best means of locating and assessing these habitats, and a site selection rationale.

Although preparatory work had been conducted for some years in Germany, the full national application of the Habitats- and Birds Directives in the German EEZ started only in 2002, directly after the legal basis was established through an amendment of the Federal German Nature Conservation Act.

In the following, methods that were applied for identifying and assessing offshore natural Annex I (Habitats Directive) habitats in the German EEZ are explained. Several scientific projects were carried out or commissioned by the German Federal Agency for Nature Conservation (BfN) under the umbrella of the *HabitatMareNATURA2000* project of BfN.

2 Definition of marine habitats in the German EEZ

Other than animal and plant species, Annex I habitats are not clearly determined by their names. For that reason the Scientific Working Group set up by the Habitats Committee of the European Commission issued

the *Interpretation Manual of European Union Habitats* to further define and describe the habitats. The first version was published in 1994, and an amended version of 2003 anticipated the accession of 10 new EU Member States in 2004 (EC 2003). In the German EEZ, only two marine natural habitats are known to be present (Balzer et al. 2002):

- Sandbanks which are slightly covered by sea water all the time (NATURA 2000 Code 1110); and,
- Reefs (NATURA 2000 Code 1170).

The authors have only recently received information on existing gas vents in the German North Sea and Baltic Sea. Whether they belong to the natural habitat "Submarine structures made by leaking gases" (NATURA 2000 code 1180) could not yet be ascertained (Kudrass 2004, pers. comm., Schlüter 2005, pers. comm.).

2.1 Interpretation Manual of European Union Habitats

The basic definitions and further mapping notes for all NATURA 2000 natural habitats are laid out in the *Interpretation Manual of European Union Habitats* (EC 2003). It provides the following basic definitions for the natural habitats sandbank and reef relevant for the German EEZ:

Sandbanks which are slightly covered by sea water all the time

"Sublittoral[1] sandbanks, permanently submerged. Water depth is seldom more than 20 m below Chart Datum. Non-vegetated sandbanks or sandbanks with vegetation belonging to the *Zosteretum marinae* and *Cymodoceion nodosae*."

Reefs

"Submarine, or exposed at low tide, rocky substrates and biogenic concretions, which arise from the sea floor in the sublittoral zone but may extend into the littoral zone[2] where there is an uninterrupted zonation of plant and animal communities. These reefs generally support a zonation of benthic communities of algae and animal species including concretions, encrustations and corallogenic concretions.

[1] Sublittoral: zone between the low-tide mark and the edge of the continental shelf.
[2] Littoral zone: zone between the tide marks (also intertidal zone).

In northern Baltic areas, the upper shallow water filamentous algal-zone with great annual succession is normally well developed on gently sloping shores. *Fucus vesiculosus* is submerged at depth of 0.5–6 m in the sublittoral zone. A red algae zone occurs below the *Fucus* zone at depth of about 5 m to 10 m."

2.2 Application of the Interpretation Manual in Germany

In April 2002, the German Federal Nature Conservation Act (Bundesnaturchutzgesetz, BNatSchG) was amended. Article 38 of the Act established the legal basis and statutory necessity for the implementation of NATURA 2000 also in the EEZ of the North Sea and the Baltic Sea, areas that fall within federal jurisdiction. Before that time, the selection of German marine sites could be directed only within the Territorial Sea (up to 12 nautical miles), where the coastal states (Länder) have jurisdiction for the NATURA 2000 site selection.

The new legal situation led to a reconsideration of the national classifications of sandbanks and reefs in Germany (Ssymank et al. 1998) in order to adapt them to the specific conditions of offshore areas (EEZ). In anticipation of this change, as early as 2001 BfN began discussions with national and international marine experts. Within this process two scientific events can be highlighted:

1 In close cooperation with the European Commission (Nature & Biodiversity Unit, DG ENVIRONMENT), BfN conducted an European workshop on the *Application of NATURA 2000 in the Marine Environment* from 27 June to 1 July 2001 at the International Academy for Nature Conservation (INA) on the Isle of Vilm (Germany). By sharing experiences and expertise, this workshop aimed at guiding the implementation of the EU Habitats and Birds Directives in the marine environment, including discussions on definitions for natural marine habitats (Boedeker and von Nordheim 2002). One widely accepted general result of the workshop was that Annex I did not sufficiently reflect threatened marine habitats for EU waters. In addition, it was a common view that there was no scientific argument to restrict the eligible depth of a sandbank, and finally it was stated clearly that the wording in the Interpretation Manual (EC 2003), "seldom deeper than 20 m" does not actually exclude selecting sites for sandbanks below 20 m. In the North

[3] The Summary Record (in German) can be downloaded from: http://www.bfn.de/marinehabitate/en/downloads/berichte/Statusseminar_AWZ-Forschung_2002.zip

Sea, in particular, sandbanks or parts of it with high ecological value are known to occur in waters deeper than 20 metres.

2 In September 2002, BfN organised a national status seminar bringing together scientists who were commissioned to work on the implementation of NATURA 2000 in the German EEZ.[3] The participants discussed, among other things, the habitat definitions, and compiled more concrete applicable national characterisations and mapping notes for marine natural habitats.

The results of these workshops and the ongoing discussion within the MEWG formed the scientific basis for a reconsideration and modification of the German interpretations of sandbank and reef habitats, summarised in following text boxes.

Characteristic structural attributes for the identification of the natural habitat "Sandbanks which are slightly covered by sea water all the time"

- Sandbanks are sandy ridges that clearly rise above their surroundings.
- They must be permanently submerged and be mainly surrounded by deeper water.
- Their substrate is primarily a sand to gravel mix with a minimum thickness of 30 to 40 cm to provide habitats for typical sandy bottom communities, but patches of larger grain sizes, including boulders and cobbles may also be present on a sandbank as well as lower portions of mud.
- They are often free of vegetation, or only sparsely covered by macrophyte vegetation.
- Sandbanks can be found in association with mudflats and sandflats (1140) as well as with reefs (1170).
- Banks where sandy sediments occur in a layer over hard substrata are classed as sandbanks if the associated biota are dependent on the sand rather than the underlying hard substrata.

Characteristic structural attributes for the identification of the natural habitat "Reef"

- Reefs are submarine, or exposed at low tide, they rise mildly to

prominently above the seafloor, and are topographically distinct from the surrounding seafloor, e.g., forming or emerging from a submarine sill, bank, slope or ridge.
- Geogenic reefs are characterised by benthic species that settle on hard compact substrata such as rocks or stones, moraine ridges with block, and stones surrounded by glacial till.
- Existing biogenic reefs in German waters include *Sabellaria* reefs[4] and mussel banks, that settle on solid and soft seabeds. Natural oyster beds were known to occur through to the beginning of the 20th century, but were extirpated (Nehring 2003).
- Reefs can be found in association with "sandbanks which are slightly covered by sea water all the time" (1110) and with mudflats and sandflats (1140).
- Reefs which are partly covered by mobile sediments should be classed as reefs if the associated biota are dependent on the rock rather than the overlying sediment.

3 Identification, ecological assessment and delimitation of natural marine habitats in the German EEZ

BfN used existing scientific expertise, including the results of previously concluded research projects (Rachor and Nehmer 2003, Gosselck et al. 1998), as well as thematic maps (e.g., Figge 1981, Nielsen 1992, LANU 1998, Geologische Karte MV 1994) for a preliminary assessment of the distribution of bottom sediments and of the marine species and communities in the German North Sea and Baltic Sea. Additionally, national and international red lists provided information on what degree species and biotopes were rare, declining or threatened (Riecken et al. 1994, von Nordheim et al. 1996, von Nordheim and Merck 1995, Merck and von Nordheim 1996, von Nordheim and Boedeker 1998).

In 2001, first sites of special ecological value in the North Sea and Baltic Sea and an initial distribution of marine Annex I natural habitats in the German Baltic Sea (Balzer et al. 2002) were published by BfN (Boedeker et al. 2001a, 2001b). This was the basis for new research within the *HabitatMareNATURA2000* project which started thereafter to determine the location of additional reefs and sandbanks, particularly in those areas

[4] Sublittoral habitat of the North Sea, in the Wadden Sea area threatened by complete destruction (Nordheim et al. 1996), not known in German offshore areas (Vorberg 1998).

where previous information gave first indications that such natural habitats were likely to be present. Therefore, in areas of special ecological value with insufficient information on sediments, additional analysis of the seafloor was carried out by the Institute of Geo-Science of Kiel University. The surveys included the following methods:

- hydro-acoustic mapping tools (multibeam, or sidescan sonar) to provide bathymetry and/or seabed character (see chapter 6); and,
- groundtruthing with a video sledge and/or seabed substratum sampling with grabs and corers.

Figure 1. All field work was supported by the SCUBA divers of the Federal Agency for Nature Conservation (photo BfN © Krause & Hübner)

In order to assess whether a morphologically recognisable bank-like structure would qualify as sandbank or reef habitat, it was further necessary to examine its biology. Existing biological data, particularly for the benthos, was amassed to identify the presence of red listed species and biotopes. In case no historical or actual information on the distribution of benthic species or communities existed, specific projects commissioned to the Baltic Sea Research Institute, Warnemünde and the Alfred Wegener – Institute, Bremerhaven provided further expert assessment (see chapters 7 and 8).

Finally, all relevant spatial data were summarised and transferred into the Geographic Information System (GIS) at BfN. Biological data were overlaid upon physical data with the goal of identifying sandbank and reef habitats.

The following sections, 3.1 and 3.2, contain detailed descriptions of the scientific steps that were undertaken in order to map these marine Annex I natural habitats in the German EEZ.

3.1 Identification, ecological assessment and delimitation of sandbank habitats

The selection criteria for Annex I habitats are given in Annex III of the Habitats Directive (see chapter 4). Before these criteria could be applied, BfN had to identify the almost complete suite of potential sandbanks in the German EEZ. Thus, the following steps were undertaken:

1 A 3D-Model of the seafloor was produced by using a TIN (Triangular Irregular Network) and a GIS (see chapter 5). In such a way, structures which rise above the sea floor, like sandbanks, could be recognised more easily than just from two-dimensional charts. The model delivered also necessary information on morphological properties of submarine structures, such as levelness, bank character, exposure gradient and orientation which could be queried from GIS. From these, several banks could be identified within the German offshore area as basis for the next steps. Because the scale of the different data sets varied widely (between 1:20,000 and 1:500,000), the spatial resolution of the different modelled layers also varied. Therefore, a minimum size of 1 km^2 had to be set as a threshold for any area to be identified as a bank (see chapter 5).
2 BfN overlaid the resulting modelled layer of banks with various sediment data sets from grab samples, sidescan sonar data, and digital geological maps. With this overlay a draft set of sandy banks was produced which however did not yet contain any information on their biology.
3 Finally, (sandy) bank polygons were matched with available information on benthic infaunal species (see chapters 7 and 8) and, as were available, marine benthic biotope types according to Riecken et al. (1994). Additional BfN data came from recent underwater video evaluations of all potential sandbanks, grab sampling and/or observations by SCUBA dives.

Figure 2 illustrates one such GIS map overlay for the easternmost part of the German Baltic Sea. The model layers shown in the figure are:

- boundaries of potential sandbanks (see chapter 5), i.e., banks according to the result of the TIN model compilation (green lines);
- location of grab samples where the marine amphipod *Bathyporeia* sp. was found (see chapter 8). Its habitat in the Baltic Sea is restricted to fine to medium sand in the shallow sublittoral (black points);
- qualifying sandbanks, representing the overlap of *Bathyporeia* sp. and the modelled bathymetric banks (yellow shaded polygons).

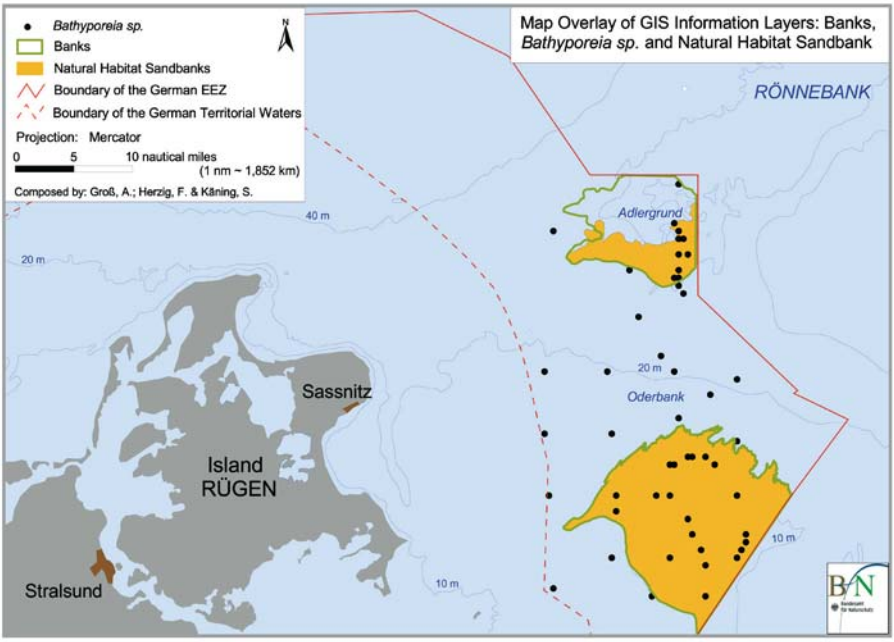

Figure 2. Map overlay of GIS information layers: structural bank boundaries, occurrence of the amphipod *Bathyporeia* sp. and polygons of the natural habitat sandbank for the *Adler Ground* and the *Odra Bank* in the German EEZ of the *Pommeranian Bay*

The two areas which thus qualify as sandbanks are the *Adler Ground* (*Adlergrund*) and the *Odra Bank* (*Oderbank*). The *Odra Bank* is a pure sandbank and the structural bank boundary is the same as what was identified with the overlay; whereas for the *Adler Ground*, its upper parts qualify as natural reef habitat, but not as sandbank. According to Zettler (pers. comm. 2005), the abundances of *Bathyporeia* were higher on the sandbank habitats of *Odra Bank* and *Adler Ground* compared to the shallower and more level sea bed in between both sites.

In summary, it was found that sandbank habitat type as at Annex I of the Directive is spread throughout the North Sea and Baltic Sea. It occurs in inner marine waters, in nearshore coastal waters, as well as further offshore in the EEZ. In the North Sea, it is frequently associated with sand flats, with the outer parts of large estuaries, as well as with reefs. Ripple

[5] Biocoenoses: associations of organisms living together in a certain habitat.

markings found on many sandbanks indicate a dynamic environment on the top of these banks caused by e.g. currents. The substrate diversity provides a variety of biotope types (Riecken et al. 1994) and, in turn, a corresponding wide spectrum of species (see chapters 7 and 8). Numerous typical sandy bottom biocoenoses[5] that develop interdependently with sediment type (fine, medium and coarse sand) and water depth have been distinguished. The sandbank habitat accommodates an array of well-known species that are recognisable on the sediment surface, while many other organisms live hidden in the deeper layers of the substrate, or as tiny creatures in the spaces between the sand grains (*interstitial fauna*) preferably in the upper sediment layers. Areas with alternating sand types, where different biocoenoses occur adjacent to one another, appear to be especially worthy of protection. In the overall ecological assessment of the sandbank habitats, the following important ecological functions were considered according to the criteria of Annex III Habitats Directive (see chapter 4):

- importance as habitat for rare, threatened or declining benthic organisms, e.g., *Bathyporeia* sp., *Travisia forbesii*, *Cerastoderma* sp. (Baltic Sea), *Spisula* sp., *Glyceria* sp., and *Lagis koreni* (North Sea);
- importance as stepping-stone for the expansion of bottom organisms into other parts of the seas and thereby preventing isolation and genetic depletion of populations (e.g,. the *Doggerbank*);
- importance as regeneration and recolonisation reservoir after catastrophic oxygen depletion events with mass-mortality in deeper marine areas or similar catastrophes during iced winters in nearshore shallow waters, (e.g., *Odra Bank* and *Adler Ground*);
- importance as feeding, resting and nursery grounds for demersal fish species and marine mammals; and,
- importance as feeding habitat for resting and wintering seabirds, e.g., sea ducks (incl. common scoter) and loons.

The above assessment resulted in a set of sandbank habitats found to be worthy of protection, and led to the following areas being selected for protection according to their representativity, conservation status and value, restoration possibilities and size:

For the North Sea:

- *Borkum Reef Ground* (*Borkum-Riffgrund*) with bank like elevations of the shelf and high sediment dynamics;
- *Amrum Bank* with representative parameter values for this natural habitat (figure 3);
- *Doggerbank* with glacial relicts.

Figure 3. *Amrum Bank* (North Sea) with sea stars (*Asterias rubens*) on its surface (photo BfN © Krause & Hübner)

Figure 4. *Fehmarn Belt* (Baltic Sea), top of a subaquatic dune (sandbank subtype megaripple) with sea star (photo BfN © Krause & Hübner)

For the Baltic Sea:

- *Fehmarn Belt* with dynamic subaquatic dunes (figure 4);
- *Adler Ground* with bank-like elevations; and
- *Odra Bank* as a submerged former dune.

Boundaries were generally drawn at the transition from the slopes of the bank into the surrounding plains and/or at the transition of typical sandbank biotopes to other non-typical biocoenoses. Boundaries which ended up in shallow or coastal areas were demarcated by a straight line.

3.2 Identification, ecological assessment and delimitation of reef habitats

The guiding principles for the identification and pre-selection of reef habitats were in principle similar to those for sandbanks:

1 Potential reefs were identified by interpretation of thematic maps and the analysis of scientific data and literature reviews. In order to achieve a comprehensive suite of potential reef sites in the German EEZ, all locations with glacial tills, biogenic hard substrates (e.g., mussel beds), and fields of boulders and blocks along submarine moraine ridges were incorporated into the GIS. Figure 5 illustrates such a GIS-supported analysis. On the basis of a sediment distribution map, those areas which indicated hard bottom substrates were chosen for additional closer investigations by sidescan sonar surveys (green profiles). The red shaded polygons show the resulting "potential reefs" (not all sidescan sonar profiles and no video profiles are shown in the figure).

2 In those identified potential reef areas where no field work had yet been done, the following research approach was taken:
   - assessment of grain sizes of cobble fields with underwater video recordings (laser measurement), and in some areas, scientific diving;
   - ascertainment of biological features through bottom dredge trawls (benthic samplings), and/or video profiles, and in some areas scientific diving;
   - photo and video documentation of habitat types by video profiling and scientific diving.

3 The last step was to achieve a complete suite of ecologically valuable reefs which also reflect, in a representative way, the different ecological forms and features of the habitat types according to Annex III of the Habitats Directive. The following forms of reef habitats occur in the German EEZ:

   North Sea:
   - Reefs in the form of boulder or cobble fields, which arise from the seafloor (typical for the central part of *Sylt Outer Reef* (*Sylter Außenriff*), figure 6).
   - Stony reef bands along the slope of the glacial Elbe Valley (*Sylt Outer Reef*, figure 7).
   - Scattered stony reefs (*Borkum Reef Ground*).

   Baltic Sea:
   - Stony reefs and mussel beds at the slopes of e.g., *Fehmarn Belt* with high salinity (up to 25 psu) and with macrophyte vegetation (figure 8); *Kadet Trench* (*Kadetrinne*) representing "deeper reefs" with a medium salinity of 10 to 18 psu (figure 9).

- Reefs in the form of boulder or cobble fields, which arise on thetop of a shallow bank e.g., (*Adler Ground*, with low salinity and rich macrophyte vegetation (figure 10).
- Stony reefs and mussel beds on a deeper bank with low salinity and without macrophyte vegetation (*Rønne Bank* (*Rönnebank*)).

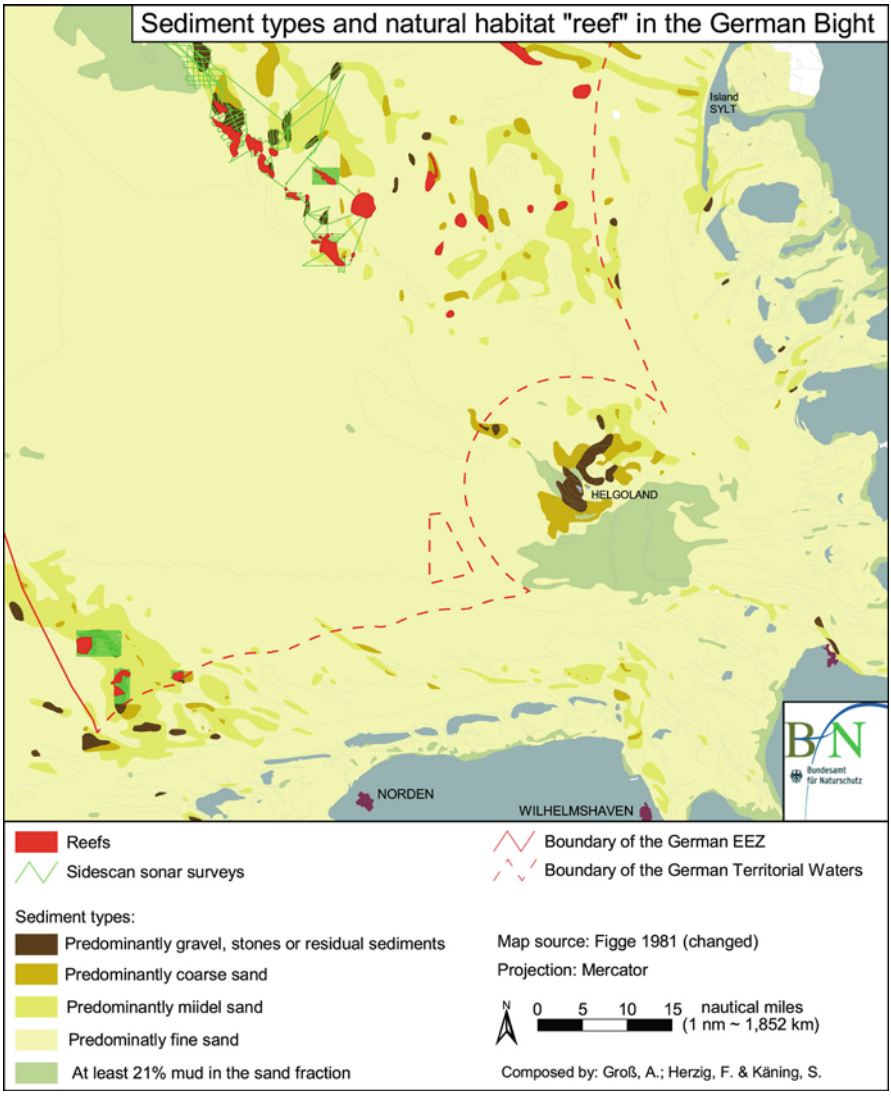

Figure 5. Sidescan sonar survey as basis for the identification of the natural habitat reef. Sediment data modified from data provided by BSH

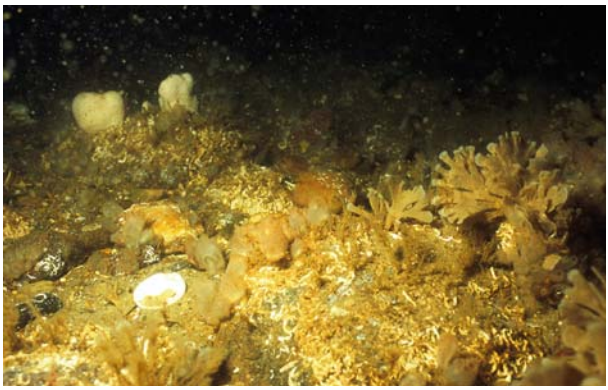

Figure 6. Typical species on top of a North Sea stony reef (e.g., *Alcyonium* sp., *Pomatocerus triqueter*, *Flustra* sp. and *Cionia* sp.)at *Sylt Outer Reef* (photo BfN © Krause & Hübner)

Figure 7. North Sea stony reef at the slopes of the ancient glacial Elbe Valley with typical epifauna (e.g., *Pomatocerus triqueter* and *Metridium senile*) (photo BfN © Krause & Hübner)

Figure 8. Baltic high-salinity reef community on stony reef (e.g., *Laminaria saccharina* and *Dendrodoa* sp.) at the slope of *Fehmarn Belt* (photo BfN © Krause & Hübner)

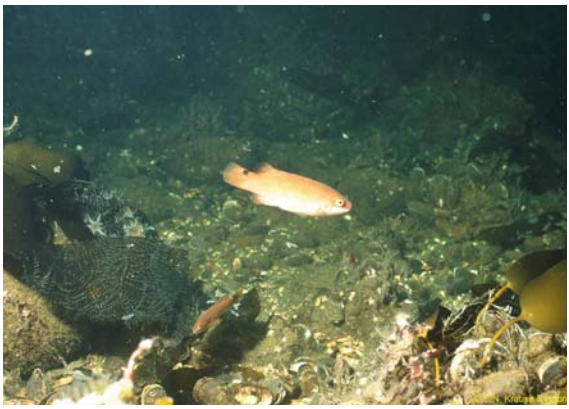

Figure 9. Baltic medium-salinity reef community on stony reef (with e.g., Hydrozoa, *Laminaria saccharina* and *Ctenolabrus rupestris*) at the slopes of *Kadet Trench* (photo BfN © Krause & Hübner)

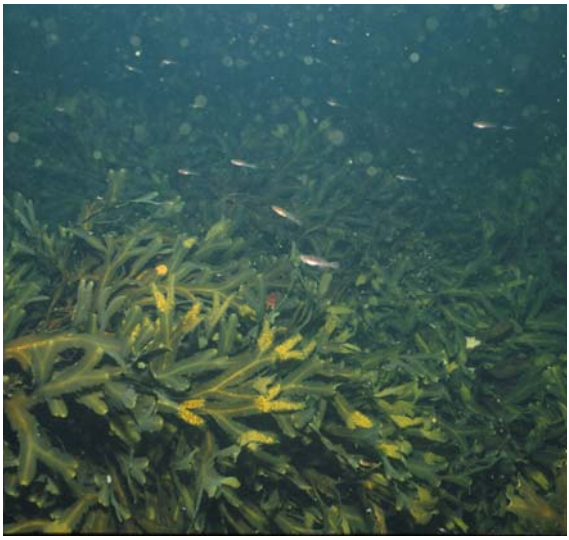

Figure 10. Baltic low-salinity reef community (*Fucus serratus* – stands with *Gobius flavescens*) on top of *Adler Ground* (photo BfN © Krause & Hübner)

4 Spatial distribution and protection of natural marine habitats in the German North Sea and Baltic Sea

In the German EEZ, sandbanks and reef habitats have been thoroughly investigated within the BfN research programme *HabitatMare-NATURA2000* since 2002, as a substantial scientific deepening of the preliminary works in the 1990s. It became clear that these habitats are spread throughout the German North Sea and Baltic Sea. They occur in inner marine waters, in nearshore coastal waters, as well as further offshore, in the EEZ. Table 1 provides data on the spatial extend of the two natural habitat types in the German North Sea and Baltic Sea. Figure 11 illustrates the distribution of the natural habitats sandbank and reef in the German EEZ of the North Sea and Baltic Sea.

Table 1. Sandbank and reef habitats in the German North Sea and Baltic Sea (numbers indicate area covered in hectares)

Natural habitat	North Sea (EEZ+ territorial Sea)	Baltic Sea (EEZ+ territorial Sea)	North Sea (EEZ)	Baltic Sea (EEZ)
Sandbanks total	438,555	94,195	347,995	57,129
Sandbanks inside pSCIs[6]	273,190	69,143	223,190	57,094
Reefs total	45,283	171,996	24,081	46,377
Reefs inside pSCIs	24,560	40,772	17,627	26,459

[6] pSCI: proposed Site of Community Importance

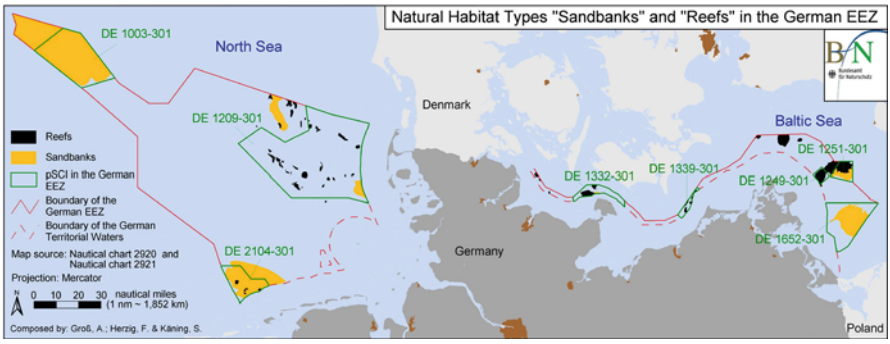

Figure 11. Occurrence of the Natural Annex I Habitats "Sandbanks which are slightly covered by sea water all the time" (NATURA 2000-Code 1110) and "Reefs" (NATURA 2000-Code 1170) in the EEZ of the German North Sea and Baltic Sea

The source for the number values in table 1 is the BfN NATURA 2000-database, which stores data from the coastal "Länder" (States) and data collected by BfN itself. The calculations show that with around 79% of all German North Sea sandbank habitats and with ca. 61% of those in the Baltic Sea, the majority portion of this habitat is situated in the German EEZ, whereas the minority is found in the coastal waters of the German Territorial Sea. The same situation applies for reefs in the North Sea (ca. 53% in the EEZ), whereas the majority of Baltic Sea reefs (73%) is situated closer to the coast in the Territorial Sea.

The research results indicate that sandbank and reef habitats serve several important ecological functions, such as offering protection for rare and threatened species as well as providing breeding, nursery, feeding and resting habitats. Furthermore, they host important biotope types and communities of marine animal and plant species. Areas with alternating substrates where different biocoenoses occur adjacent to one another appeared to be especially worthy of protection. Consequently, a great portion of the sandbank habitats (64% North Sea, 99% Baltic Sea) and reef habitats (73% North Sea, 57% Baltic Sea) are comprised in the pSCIs and thus are nominated as NATURA 2000 Marine Protected Areas (MPAs) (see chapter 4).

References

Balzer S, Boedeker D, Hauke U (2002) Interpretation, Abgrenzung und Erfassung der marinen und Küsten-Lebensraumtypen nach Anhang I der FFH-Richtlinie in Deutschland. Natur und Landschaft, 77 (1):20–28

Boedeker D, von Nordheim H (2002) Application of NATURA 2000 in the Marine Environment. BfN-Skripten 56. Bundesamt für Naturschutz, Bonn. http://www.bfn.de/09/natura2000marin.pdf

Boedeker D, Herrmann U, Hübner P, Kias M, Merck T, Rachor E, von Nordheim H (2001a) Ökologisch besonders wertvolle marine Gebiete im deutschen Nordseebereich. BfN-Map: 2. überarbeitete Auflage http://www.bfn.de/marinehabitate/en/downloads/Nordsee.pdf

Boedeker D, Herrmann U, Hübner P, Kias M, Meißner J, von Nordheim H (2001b) Ökologisch besonders wertvolle marine Gebiete im deutschen Ostseebereich. BfN-Map: 2. überarbeitete Auflage http://www.bfn.de/marinehabitate/en/downloads/Ostsee.pdf

EC (2003) Interpretation manual of European Union habitats. EUR 25. European Commission (DG Environment), Brussels

Figge K (1981) Sedimentverteilung in der Deutschen Bucht – Karte Nr. 2900, Deutsches Hydrographisches Institut, Hamburg

Geologische Karte MV (1994) Geologische Karte Mecklenburg-Vorpommern 1:500.000. Geologisches Landesamt Mecklenburg-Vorpommern

Gosselck F, Bönsch R and Kreuzberg M (1998) Fachgutachten über wissenschaftliche Grundlagen zur Ausweisung und zum Management mariner OFFSHORE-Schutzgebiete im Bereich der Hoheitsgewässer und der AWZ Deutschlands in der Ostsee und deren Integration in das System von "Baltic Sea Protected Areas". FuE-Vorhaben im Auftrag des Bundesamtes für Naturschutz

LANU (Landesamt für Natur und Umwelt) (Hrsg.) (1998) Geologische Karte von Schleswig-Holstein 1:500.000. Flintbek

Merck T, von Nordheim H (1996) (eds) Rote Listen und Artenlisten der Tiere und Pflanzen des deutschen Meeres- und Küstenbereichs der Ostsee. Schriften-reihe für Landschaftspflege und Naturschutz, Heft 48

Nehring S (2003) Gebietsfremde Arten in den deutschen Gewässern – ein Risiko für die Biodiversität. Alien species in German waters – a risk for biodiversity. Schriftenreihe des BMVEL „Angewandte Wissenschaft", Heft 498:40–52

Nielsen PE (ed) (1992) Map on Bottom Sediments around Denmark and Western Sweden. Geological Survey of Denmark Kortserie nr. 38; Geological Survey of Sweden. Serie Ba nr. 48

Rachor E, Nehmer P (2003) Erfassung und Bewertung ökologisch wertvoller Lebensräume in der Nordsee. Abschlussbericht für das F+E-Vorhaben FKZ 899 85 310 (Bundesamt für Naturschutz). Alfred-Wegener-Institut für Polar- und Meeresforschung, Bremerhaven

Riecken U, Ries U, Ssymank A (1994) Rote Liste der gefährdeten Biotoptypen der Bundesrepublik Deutschland. Schriften-reihe für Landschaftspflege und Naturschutz, Heft 41

Ssymank A, Hauke U, Rückriem C, Schröder E (1998) Das europäische Schutzgebietssystem Natura 2000. BfN-Handbuch zur Umsetzung der Fauna-Flora-Habitat-Richtlinie (92/43/EWG) und der Vogelschutzrichtlinie (79/409/EWG). – Schriftenreihe für Landschaftspflege und Naturschutz 53

von Nordheim H, Boedeker D (eds) (1998): Red List of Marine and Coastal Biotopes and Biotope Complexes of the Baltic Sea, Belt Sea and Kattegat – Including a comprehensive description and classification system for all Baltic Marine and Coastal Biotopes. HELCOM-Baltic Sea Environ-ment Proceedings No. 75. Helsinki Commission

von Nordheim H, Norden Andersen O, Thiessen J (eds.) (1996) Red Lists of Biotopes, Flora and Fauna of the Trilateral Wadden Sea Area 1995. Helgol. Meeres-untersuchungen. 50 (suppl.)

von Nordheim H, Merck T (eds) (1995) Rote Liste der Biotoptypen, Tier- und Pflanzenarten des deutschen Wattenmeer- und Nordseebereichs. Schriften-reihe für Landschaftspflege und Naturschutz, Heft 44

Vorberg R (1998) Sandkorallenriffe. In: Umweltatlas Wattenmeer Band I. Nordfriesisches und Dithmarscher Wattenmeer. Landesamt für den Nationalpark Schleswig-Holsteinisches Wattenmeer, Umweltbundesamt (Hrsg.) – Ulmer. 96–97