Seabed features in Mecklenburg Bight based on Side-Scan Sonar Imagery

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ABSTRACT: Mecklenburg Bight (Baltic Sea) has various natural, geomorphological and sedimentological features reflecting hydrodynamic processes, sediment dynamics, biological activities and coastal development. This area is also strongly influenced by human activities like military exercises, professional fishing, dumping of dredged material and touristic activities. Bedforms such as small subaquatic dunes and sediment transport patterns, as well as features resulting from anthropogenic disturbances of the seafloor have been identified using hydroacoustic mapping techniques. A catalogue was prepared, showing different disturbances of natural seafloor conditions due to anthropogenic pressure. The sustainability of these features will be discussed.

1 INTRODUCTION

Nowadays, coastal areas are used in many different ways. They can be under natural protection, allowing no anthropogenic activity, or they can be heavily used by different type of industries. This use often has an impact on seafloor conditions. The inner Mecklenburg Bight (SW Baltic Sea, Germany, Fig. 1) is a confined area, where all these different activities are archived in the seafloor conditions. Here, anthropogenic activities such as trawling, anchoring due to military and touristic activities, dumping of dredged material and others activities can be observed in the seabed environment.

Side-scan Sonars (SSS) are hydroacoustic devices which are suitable tools for mapping sea bottom properties. They emit and collect high-frequency acoustic pulses which are scattered back from the seafloor. The intensity of sound scattered from obstacles on the seafloor, from the sediment due to its properties, from benthic organisms or other features gives a picture of the characteristics of the seafloor. The backscatter is affected by the local geometry of ensonification, the physical seabed characteristics and the intrinsic properties of the seafloor (Blondel, 2009). Therefore, the compilation of numerous backscatter measurements results in an image of backscatter intensities, providing information of the substrate characteristics. Furthermore, the characterisation of SSS imagery may be used to identify dynamical processes controlling seabed morphology by observing bedforms and surface sediment distribution patterns.

This work aims to provide a catalogue of SSS images of the seafloor in the area of inner Mecklenburg Bight and to identify distinctive features in a shallow water environment under the influence of human activities.

2 STUDY AREA

The hydroacoustic surveys are distributed in an area of approximately 1.260 km^2 in the Mecklenburg Bight (Fig. 1), located in the south-western Baltic Sea with a maximum depth of -28 m NHN. Lübeck Bight and Neustadt Bight are part of Mecklenburg Bight and the present morphology is the

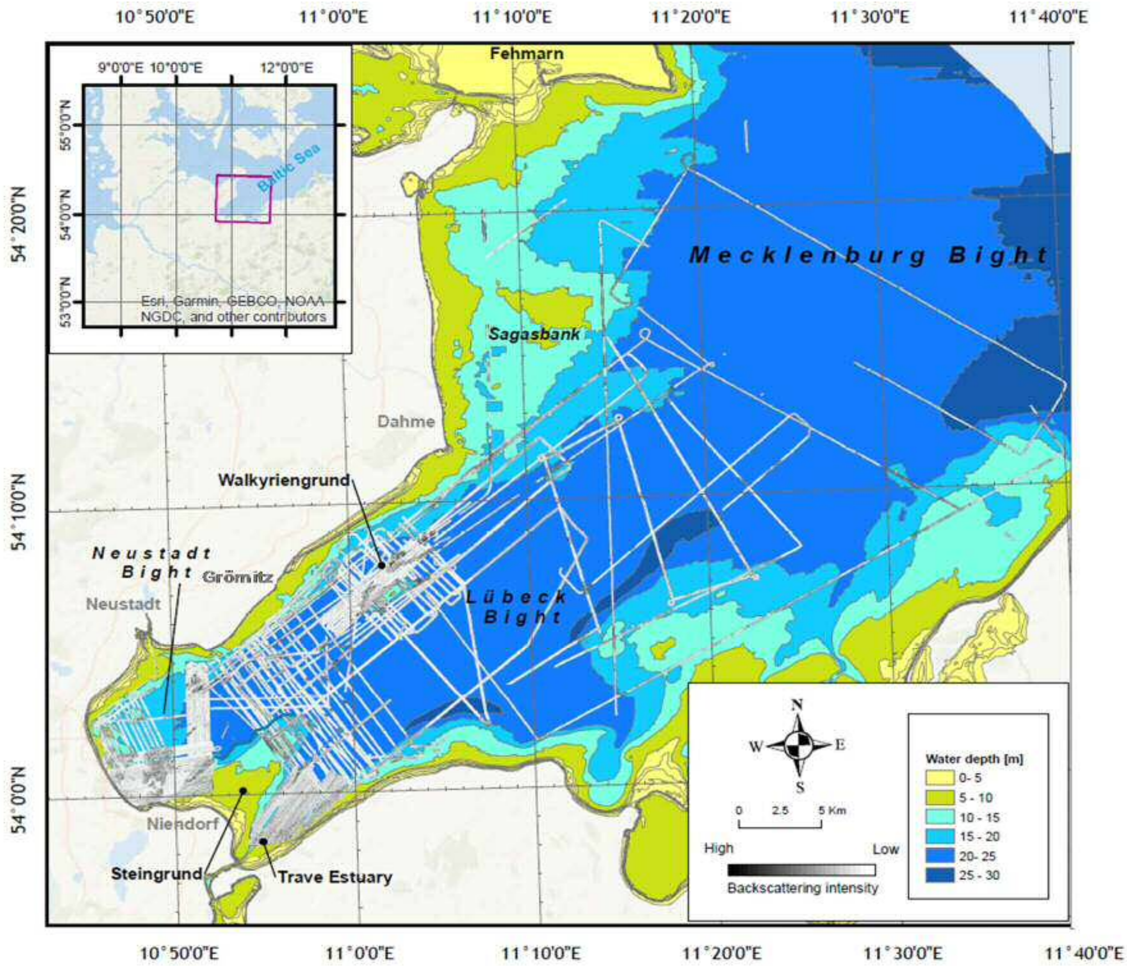

Figure 1 Location of the study area and side-scan sonar survey lines. Bathymetry source: BSH (www.geoseaportal.de).

result of various depositional processes occurring since the late Pleistocene deglaciation (Schwarzer et al., 2003). Wide areas of the seafloor are built up of Pleistocene deposits, mainly glacial till (Niedermeyer et al., 2011). Common features in the area are active cliffs alternating with lowlands which are fronted by nearshore bars. Additional morphological features include abrasion platforms in front of cliffs, submarine channels, detached abrasion platforms and the Trave River which empties into Lübeck Bight.

All abrasion platforms are predominantly composed of soft boulder clay of Pleistocene origin, sometimes with intermediary melt water deposits (Schrottke et al., 2006). On these platforms stones are occurring. Active cliffs and abrasion platforms are supporting the nearshore environment with sediment.

The surface sediment distribution in Mecklenburg Bight is a function of geological prerequisites, water depth, energy input due to waves and resulting currents. Significant wave height can reach 3.12 m in between a 10 years return period (Fröhle, 2000) or a maximum height of 5.5 m during storms from NE (Dette & Stephan, 1979). In deeper areas, muddy material predominates while the shallower areas on detached shoals and along the coast are dominated by coarse sediment including boulders. Also, lag deposits cover large areas of the seafloor especially in areas close to the coast and down to water depths of about -20 m NHN like NE of Sagasbank or NW of Steingrund

(Fig. 1). They are the result of the abrasion of the underlying till and mainly consist of gravel, stones and boulders, often surrounded by well-sorted fine to medium sand (Zeiler et al., 2008).

Walkyriengrund is a protected natural marine structure with typical communities of reefs and sandbanks (according to FFH regulations) located in central Lübeck Bight. It is a shoal rising up to about -5 m NHN water depth. This shoal is densely covered by boulders, benthic macrophytes such as *Laminaria saccharina* and the seagrass *Zostera marina*, as well as mussel beds of *Mytilus edulis*, which provide a marine invertebrate habitat and substrate (Christiansen & Körner, 2013).

In addition, Lübeck Bight is a busy area due to harbours and marinas, a shipyard, the mouth of the Trave River and the multiple activities developed in the regions which include dredging, anchoring, dumping of material, fishing and testing military devices.

2 METHODS

Mosaic generation is based on SSS raw data obtained from different cruises carried out during student exercises since 2001 (for database see Fig. 1). The acoustic devices employed are the Teledyne Benthos Dual Frequency 1624 (100 and 400 kHz), the Side-Scan Sonar Benthos C3D (200 kHz) and the Klein 595 Dual Frequency (100 kHz and 500 kHz). All systems were towed behind the ship with a vessel speed of 4-5 knots and with altitudes which equals 10 % of the range which was applied. However, in shallow areas, the altitude sometimes was only 3 m above the seafloor. The SSS towfish was fixed underneath a larger buoyancy to maintain the system in a stable position, minimising the effect of ship motion (Schwarzer et al., 1996). In general, the survey profiles were recorded with a range between 50 and 100 m to each side.

Data was recorded in digital form employing the software package ISIS (Triton Elics Int.). This allowed to construct georeferenced mosaics of the investigated seafloor. Corrections due to the distance of the fish to the seabed (the slant range) and layback/offset were settled according to survey characteristics. The raw data in extended Triton Format (.xtf) was processed in Sonar Wiz 7.0.

Due to the complexity in the compilation of data with different frequencies and gain settings obtained from different devices, individual files for every cruise were exported as GeoTIFF files with 0.25 m resolution and consequently assembled and characterised in ArcGIS 10.1.

3 RESULTS

The seabed features observed in the SSS images in Mecklenburg Bight include bedforms and human-induced seabed structures which are generated on a variety of seafloor types ranging from mud to boulders fields.

Bedforms such as small subaqueous dunes according to Ashley (1990) were found at the end of the abrasion platform, offshore of the Trave river mouth. They are found in depth of about -20 m NHN and they have sinuous to tongue-shaped crestlines (linguoid) with variable wavelengths from 1 m and 3.5 m. In sandy areas offshore Dahme (Fig. 2a) between -15 m and -20 m NHN small subaqueous dunes are asymmetrical and present straight crests partly showing bifurcation with wavelengths up to 1.5 m. Also, on the Walkyriengrund, a ripple field showed small subaqueous dunes straight to sinuous-crested with wavelengths between 0.5 to 1.1 m.

Other features recognised in the SSS images in Lübeck Bight consist of high-backscattering elongated, sinuous- structures composed of coarse material (Fig. 2b). Probably, these structures are related to bends of mussel beds of *Mytilus edilus* observed in video profiles.

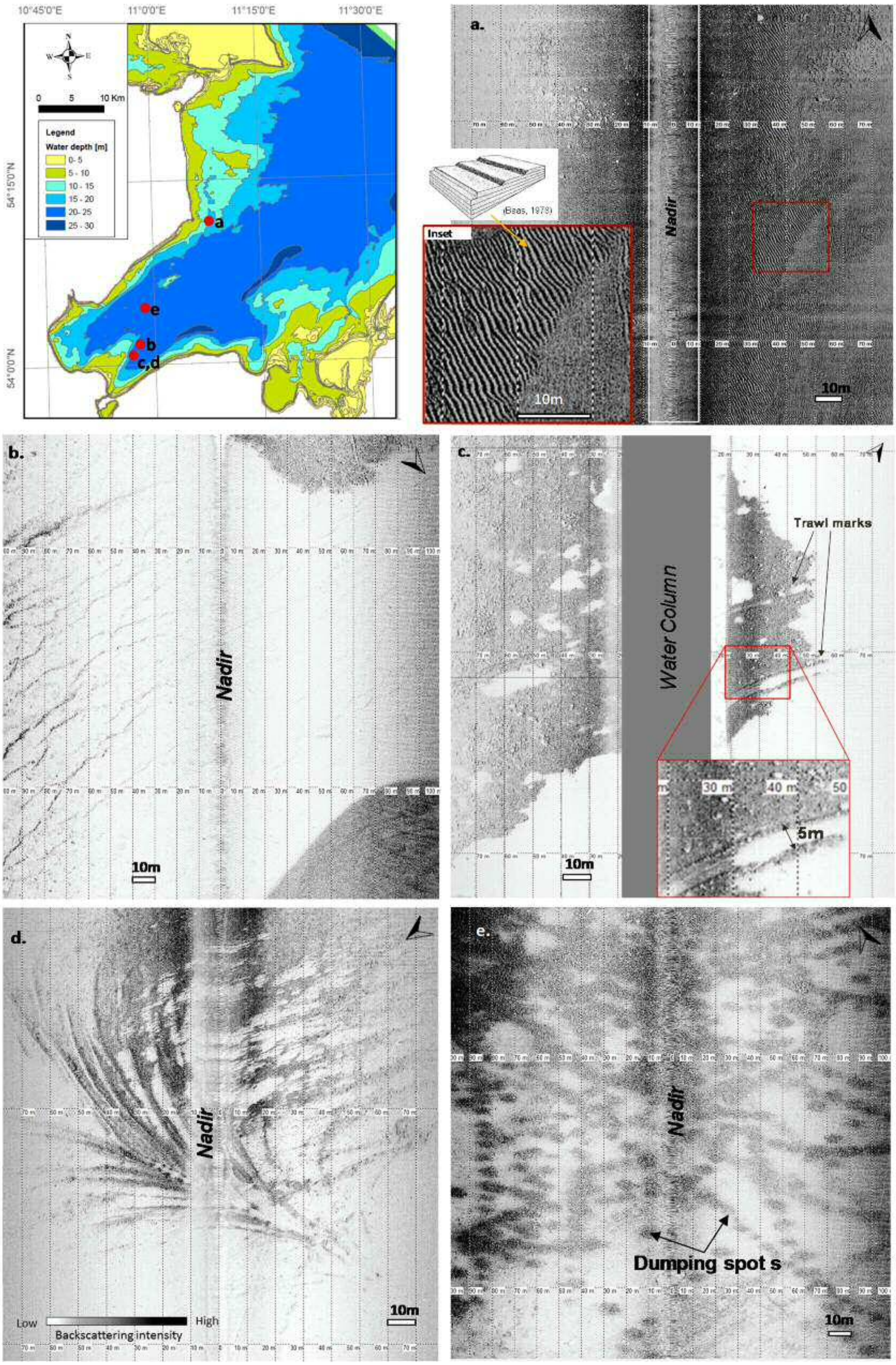

Figure 2 High resolution acoustic images showing a) bedforms, frequency: 400 kHz b) elongated bends of coarse material, c) trawl marks, d) anchor scars and e) dumping spots.

The source of the coarser material forming the elongated bends might be associated with the higher backscattering area of the nearby region (see Fig. 2b). Thus, probably the elongated bends are the result of deposition of shells and shell fragments transported from elevated areas during storm conditions. They are building a settlement of new and active communities on the surficial sediment layer and provide a new hardground for other species.

On the other hand, anthropogenic activities such as trawling or anchoring also influence the interaction between water flow and seabed surface by sediment reworking and redistribution, furrow formation and sometimes scouring affecting the seafloor severely. Particularly in Lübeck Bight, sonographs demonstrate strong seabed sediment disturbance (Figs 2c-e). Fishing activities using bottom contact gears such as otter trawlers, demersal seiners, beam trawlers, and dredgers have a significant impact on the seafloor. During the trawling operation, a trawl is towed behind the ship over long distances. It is weighed down on the seafloor by heavy steel doors, and the resulting erosion creates linear parallel features or furrows (Fig. 2c). The seafloor vulnerability to the trawling impact depends on sedimentological conditions and consolidation, geomorphological gradient, benthic fauna, sedimentation rates and the degree of reworking of sediments. Consequently, seabed disturbance includes scouring, furrow formation, creating roughness, increase in surface relief, flattening of ripples, sediment mobilisation, seabed smoothing, boulder displacement, and sediment penetration (Eigaard et al., 2016).

Similarly, anchoring creates furrows, reworks and redistributes strongly the sediment (Fig. 2d). The purpose of anchoring is to attach a ship to the seabed at a specific location, avoiding vessel drifting due to wind, waves or currents, which happens quite often in the military exercise area. The operation consists in dropping the anchor attached by the anchor chain. When the anchor hits the bottom, it is embedded into the seabed. As the ship is moving due to currents, the anchor also moves, dragging all sediment around it. Thus, anchoring affects the seabed morphology, creating depressions and redistributing sediment.

Additionally, the SSS images show distinctive conical and elliptical geometries which have been related to dumping sites in Lübeck Bight, east of Neustadt and Grömitz and south of Walkyriengrund in water depths of about -22 m NHN (Fig. 2e). These features are the result of dumping, and their morphology depends on multiple factors such as: the ship velocity, currents, the type of material, and water depths. Dumping areas can include dredged or excavated soil from sea or land, mainly from the dredging of harbours or harbour entrances. Old dumping sites might contain weapons, munitions and warfare agents. Today, dumped munitions and warfare agents are in different stages of decomposition which is a risk for the marine ecosystem due to corrosion (Brenner et al., 2017).

4 CONCLUSIONS

SSS technique has a high potential to identify natural and anthropogenic features on the seabed. The SSS constitutes a useful tool to image the seafloor letting us recognise the spatial distribution and character of different sediment types, bedforms and objects. Small subaqueous dunes were found in depths between - 10 to -25 m NHN with variable wavelengths and with straight to tongue-shaped crestlines. Furthermore, the acoustic imagery showed traces of intense human activity in the study area. Trawling marks, anchor scars and distinct conical to elliptical features were recognised in the acoustic images suggesting that anthropogenic activities strongly modify the seabed. As trawling marks cross fine-grained cohesive material and coarse-grained sediment, it can be easily observed that the disturbance last for a much longer time in the muddy deposits. With the growing demand of maritime traffic, touristic use and economic development these disturbances might increase.

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