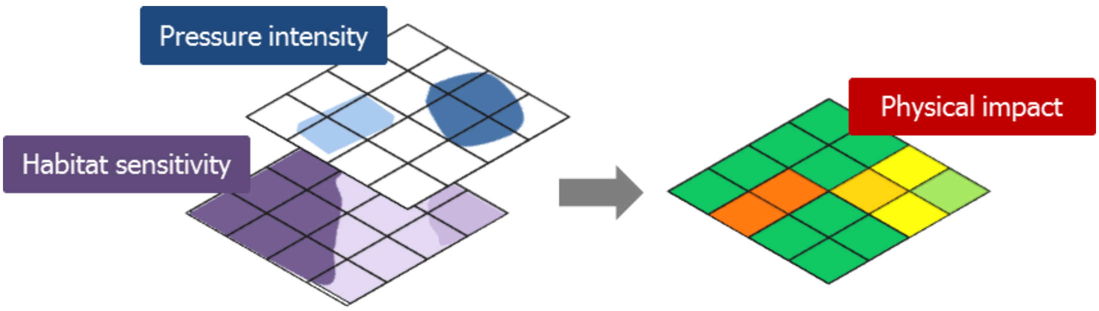
Conceptual approach for the assessment of indicator 6.1.2: 'Extent of the seabed significantly affected by human activities for the different substrate types'

Report within the R & D project 'Compilation and assessment of selected anthropogenic pressures in the context of the Marine Strategy Framework Directive'



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1.1 Summary

1.1.1 Objective

Within the framework of the research and development project 'Compilation and assessment of selected anthropogenic pressures in the context of the Marine Strategy Framework Directive' BioConsult Schuchardt & Scholle GbR was commissioned with the development of a concept to assess indicator 6.1.2: 'Extent of the seabed significantly affected by human activities for the different substrate types'. This work was also funded by the Bundesamt für Naturschutz. This report is the preliminary draft of a methodology for the national assessment concept and also presents suggestions for setting baselines and targets for the Good Environmental Status. Results of the first application of the proposed concept for the German Exclusive Economic Zone of the North Sea are shown and discussed.

1.1.2 Methodology

Identification of human activities and pressures

Human activities affecting the seabed and their impacts are described. Activities are assigned to predefined pressures based on specifications by the MSFD: Physical loss (sealing, smothering) and physical damage (selective extraction, abrasion, changes in siltation). Anthropogenic activities considered in the EEZ of the North Sea are bottom trawling, permanent offshore installations, aggregate extraction and pipelines. In order to assess the spatial extent of pressures the area affected by each activity is defined. The temporal extent is determined by means of a five-step scale ranging from rare (once per reporting period) to persistent (permanent installation or more than three times per year). Each pressure is visualized separately on a GIS-based map.

Assessment of habitat sensitivity

The MSFD differentiates between 'predominant' (broad-scale habitats based on EUNIS level 3) and 'special habitats' (habitats protected under EU, regional or national legislation). Based on a preliminary map on sediments and Natura 2000 habitats, three predominant and three special habitats are identified in the EEZ of the North Sea.

The method to assess habitat sensitivity is mainly adopted from the MarLIN approach developed by Tyler-Walters et al. (2001). The sensitivity of ecosystem components is determined by two aspects: the ability to withstand disturbance or stress (resistance or tolerance) and the ability and time needed to recover from a perturbation and return to the previous state (resilience or recoverability). Resistance and recovery time are categorized in relation to each pressure both for the physical habitat features and the characteristic species. Information on the potential impact of physical disturbance and the response of specific habitats and species is based on evidence as far as available. A decision matrix is used to automate the combination of resistance and recoverability and to obtain sensitivity categories for the physical habitat and the characteristic species. The highest (i.e. most sensitive) rank assigned to either habitat structure or species determines the overall habitat sensitivity.

Characteristic species used for the sensitivity assessment of benthic habitats in the EEZ were mainly those identified by Rachor & Nehmer (2003) for the classification of benthic communities in the south-eastern North Sea. This selection of characteristic species is assumed as a preliminarily approach for the initial application of the methodology. For future assessments it is proposed to mainly refer to results of an ongoing habitat mapping project, which also should provide information on characteristic species of benthic habitats.

It should be noted that the assessment is based on current distribution and extent of species and habitats and their sensitivity. These results allow the distinction to be made between habitats of varying sensitivity that are subject to physical pressures. In some areas sensitive species may have already been replaced by opportunistic and less sensitive species due to the long-lasting pressures on benthic habitats. Thus it has to be kept in mind that the indicator is not able to assess historical damage.

Physical impacts on benthic habitats

The degree of physical impact on a habitat is a product of its sensitivity and the exposure to a specific pressure. An impact assessment thus requires the linkage of sensitivity information with pressure data. A matrix combining pressure intensity in terms of the temporal extent and habitat sensitivity supports the classification in nine categories of physical impact. A percentage value is assigned to each rank which should provide an approximation of the relative impact on the habitat with regard to e.g. habitat structure, species richness, abundance or biomass. Due to the different nature of the pressures 'selective extraction', 'abrasion' and 'changes in siltation', for each of these physical damage pressures a separate impact matrix is provided in order to include a weighting factor in the impact assessment. 'Sealing' and 'smothering' are persistent pressures which are associated with an impact that destroys habitat structures as well as benthic organisms. The habitat is not expected to recover, thus sealing and smothering always result in a very high impact or total loss of habitat (100%).

In order to determine the cumulative physical impact on a particular habitat, the separate impact maps have to be summarised. Most approaches to assess cumulative impacts assume additive effects for lack of knowledge on actual responses of benthic habitats. It is proposed to follow this practice as the physical pressures regarded here are assumed to affect habitat structure and suitability in a similar mode. This means that percentages for overlapping physical impacts are added up with 100 % (total loss) as maximum value. The cumulative physical impact is calculated from the proportion of area impacted (A, [%]) for each habitat and the corresponding degree of impact (I, [%]) as derived from the impact matrices. The cumulative impact (CI, [%]) for each habitat results from the sum of individual values for the relative impact on habitat:

$$CI = \sum I \times A / 100 \ [\%]$$

High values of cumulative impact indicate either pressures with considerable temporal and spatial extent or habitats with high sensitivity towards the occurring pressures. The cumulative impact value may range from 0% which would be a habitat completely without impacts to 100% meaning the total loss of the habitat.

This method provides the advantage of easily comparing the different impacts of the pressures physical loss (reduction in extent) and physical damage (impairment of condition) and results in a single percentage value of physical degradation for each habitat.

1.1.3 Application of assessment concept

A first application of the proposed assessment concept was carried out for the German EEZ of the North Sea. Data used for the assessment were VMS data from 2006, the area extracted in 2005 / 2006 and permanent offshore installations under construction or in operation in 2013.

Pressures in the EEZ

In terms of area, 'abrasion' caused by bottom trawling is the main pressure which covers nearly the complete seabed of the EEZ (98.9 %). Areas without abrasion are solely the construction sites of offshore wind farms as well as operational wind farms. Areas subject to physical loss currently account for less than 0.01 % of the total area. The pressure 'changes in siltation' affects 1 % of the EEZ with the predominant activity being the construction of offshore wind farms. Selective extraction in 2005 / 2006 was restricted to an area of 0.02 % of the EEZ.

Impacts which interfere with each other are areas with aggregate extraction and bottom trawling as well as pipelines and bottom trawling. Other human uses are mutually exclusive, for example construction works and bottom trawling or operational wind farms, where fishing is excluded.

Cumulative physical impact on benthic habitats

The calculated cumulative impact values range from 13.3 % for sandbanks on the Borkum Reef Ground / Sylter Outer Reef to 43.2 % for reef habitats. The cumulative impact of predominant habitats adds up to 28.3 % for sublittoral sand, 35.8 % for sublittoral mud and 35.7 % for sublittoral coarse sediment. For the special habitat 'species-rich habitats on coarse sands, gravel or shell debris' an impact value of 28.5 % is calculated and for the separately assessed sandbank at the Doggerbank the cumulative impact accounts for 33.8 %.

The impact values mainly arise from high impacts of bottom trawling. Major parts of the benthic habitats are fished more than once a year, e.g. 50 % of the widespread sand habitats are subject to trawling more than once per year. The comparatively low cumulative impact value for ‘other sandbanks’ originates from the lower fishing pressure on the Borkum Reef Ground in 2006, where nearly 70 % of the sandbank area was trawled less than once a year. The high impact value for reefs is mainly caused by the high sensitivity towards ‘abrasion’ determined for this habitat.

Physical impacts on marine protected areas

The physical impact of the individual pressures has been calculated for benthic habitats in marine protected areas as well.

Sylter Outer Reef: The cumulative impact on benthic habitats in the Sylter Outer Reef ranges from 21.8 % for the predominant habitat ‘sublittoral sand’ to 52.9 % for ‘sublittoral mud’. High impact values were also calculated for ‘sublittoral coarse sediment’ (37.9 %), ‘sandbanks’ (41.9 %) and ‘reefs’ (47.0 %) The wide range of cumulative impact values corresponds to varying fishing intensity in the Sylter Outer Reef. While large parts of the Natura 2000 site were fished with low intensity, other areas were subject to persistent fishing pressure of up to five times per year.

Borkum Reef Ground: The only physical pressure affecting benthic habitats at the Natura 2000 site Borkum Reef Ground is ‘abrasion’ caused by bottom trawling. In 2006, fishing intensity was comparatively low with generally less than once per year. With the exception of reef habitats, the cumulative impact values for habitats in the Borkum Reef Ground were likewise relatively low, varying from 5.4 % to 21.8 %. The habitat ‘sandbank’ which covers the major part of the protected site (75.1 %) holds the lowest cumulative impact value of 5.4 %. Due to the high sensitivity rank of reefs towards ‘abrasion’, the cumulative impact of this habitat type amounts to 35.4 %.

Doggerbank: The total area of the Doggerbank is subject to ‘abrasion’ by bottom trawling and is additionally crossed by three gas pipelines. The cumulative impact of the main habitat ‘sandbank’ (95.8 % of total area) at the Doggerbank accounts for 38.8 %. The impact values for ‘sublittoral sand’ amounts to 20.9 % and for ‘sublittoral mud’ 6.0 %. However, muddy habitats cover only 0.02 % of the total area.

1.1.4 Further development of the assessment concept

With the present report, the assessment concept is already at an advanced stage so as to allow for a good estimation of physical impacts on benthic habitats. In order to improve the results of future assessments several enhancements are suggested which include the improvement of sensitivity assessments, introduction of levels of confidence, analysis of possible linking between indicator 6.1.2 and ‘condition indicators’ and modification of the concept for coastal waters. For further assessments it should as well be tried to improve data base, especially on fishing pressure and aggregate extraction. In spite of these unresolved issues, the proposed methodology presents a major step for assessing cumulative physical impacts on benthic habitats. The concept provides a simple, cost-effective and informative method which is easily applicable to other marine regions.

1.2 Objective

According to the Marine Strategy Framework Directive (MSFD), the Good Environmental Status of Descriptor 6 is achieved when 'seafloor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected' (EC 2008). The objective is that human pressures on the seabed do not hinder the ecosystem components to retain their natural diversity, productivity and dynamic ecological processes, having regard to ecosystem resilience (EC 2010). The indicator 6.1.2 'Extent of the seabed significantly affected by human activities for the different substrate types' aims to address pressures causing physical damage or loss to seafloor habitats and to assess the proportion of habitat area permanently or temporarily affected by anthropogenic use. The assessment of the indicator integrates information on the spatial extent and intensity of physical pressures and on the spatial extent and sensitivity of benthic habitats.

Within the framework of the research and development project 'Compilation and assessment of selected anthropogenic pressures in the context of the Marine Strategy Framework Directive' BioConsult Schuchardt & Scholle GbR was commissioned with the development of a concept to assess indicator 6.1.2. This work was also funded by the Bundesamt für Naturschutz. This report is the preliminary draft of a methodology for the national assessment concept and also presents suggestions for setting baselines and targets for the Good Environmental Status. Results of the first application of the proposed concept for the German Exclusive Economic Zone of the North Sea are shown and discussed.

1.3 Rationale

The MSFD requires an analysis of the state of habitats and the distribution and intensity of anthropogenic pressures impacting upon them. National marine strategies should include an assessment of pressures and impacts arising from human activities in order to obtain a better understanding and management of those pressures and impacts with the objective of reducing them and to achieve or maintain Good Environmental Status in 2020.

OSPAR and HELCOM as Regional Seas Conventions in the area are currently developing indicators for the assessment of physical pressures and impacts on benthic habitats, both to cover the MSFD requirements and regional projects such as the Baltic Sea Action Plan. The general importance of these indicators is agreed among the experts of member states, however, work on them is still in progress and the respective indicators are not yet approved.

Indicator 6.1.2 is considered to be highly sensitive to physical pressures such as sealing, smothering, abrasion or extraction. The assessment of human activities allows for an adequate deduction and quantification of pressures and impacts on benthic ecosystems. Principally, the indicator should be applicable throughout the national waters and be able to assess all kinds of habitats, predominant as well as special habitat types. As it is designed as a pressure indicator, this presents the advantage of directly providing information on the cause of changes in ecosystem components. Pressure indicators are regarded as providing the evidence for the need of management and may offer the opportunity to appropriately manage human activities affecting the environment.

As the suggested approach for the assessment of indicator 6.1.2 is mainly based on modelling the impact by combining habitat sensitivity maps with spatial pressure data, it is considered to be highly cost efficient. Information on pressures and human activities should be available e.g. from projects requiring licensing procedures or from VMS data for bottom trawling. Sensitivity data may be derived from existing programmes such as monitoring for the Habitats Directive in the case of special habitat types. Once the methodology is established, further application needs only current data on localisation and quantification of the different physical pressures. Additional monitoring is currently not regarded as required for the assessment, although it may become necessary to calibrate the method and improve confidence in the results. Validation of the concept may be done by means of the condition indicators of Descriptor 6 or by directly monitoring different levels of known human impact.

The proposed concept is based on guidance provided by the European Commission and a literature review of existing scientific studies dealing with similar subjects. Current discussions regarding the implementation of the MSFD, taking place e.g. within the Regional Seas Conventions such as HELCOM and OSPAR were likewise considered.

1.4 Methodology

1.4.1 Principles

The parameter to be modelled and measured for the assessment of indicator 6.1.2 is the area of damaged and lost habitats. The approach proposed is based on modelling the impact by combining pressure-specific sensitivity maps for benthic habitats with data on the spatial and temporal extent of physical pressures. Habitat sensitivity is determined by resistance (the ability to withstand disturbance or stress) in relation to a specific pressure and recoverability following the disturbance. The responses of habitats to physical pressures are linked to assess the cumulative physical impact on habitats.

The suggested methodology refers to existing approaches for vulnerability or impact assessments, trying to combine already approved and accepted concepts with the requirements of indicator 6.1.2. The magnitude of pressures and the sensitivity of habitats are qualitatively expressed in ranks and these ranks are combined by means of a decision matrix. This standardisation shall ensure that the assessment is able to compare different pressures and the responses of different habitats. The scales proposed for the assessment concept are intended to reflect likely levels of intensities or damage and are to be used within the evidence base. The setting of categories is based on existing concepts for vulnerability assessments (e.g. Tyler-Walters et al. 2001, Tillin et al. 2010) as well as expert judgement. It may still prove necessary to revise or adjust the categorisation in the further development process of this indicator concept.

The proposed concept relies mainly on available scientific evidence, which enables the assessment process to be automated and thereby ensures its reproducibility. Expert judgement also plays an important role, e.g. in the setting of scales or in the case of insufficient data on pressures or habitats. Data are processed and visualised on maps by means of a Geographic Information System (GIS).

1.4.2 Anthropogenic activities and pressures

Human activities and associated pressures potentially causing physical damage to benthic habitats must be identified. Initially emphasis will be on activities in the German EEZ such as bottom trawling, offshore constructions or sediment extraction, however, the approach should also be able to encompass anthropogenic uses in coastal waters. An indicative list of human activities with the potential of physically disturbing the seabed is provided by the EC (2011).

Pressures resulting from anthropogenic activities can be described as changes in physical, chemical or biological properties of the environment compared with background levels or a reference condition. Depending on the intensity, pressures have the potential to cause direct or indirect impacts on the components of the ecosystem (WG GES 2011). Physical pressures on the seabed may alter the structure and functioning of marine habitats and thus indirectly affect the benthic community.

According to Annex III, table 2 of the Directive a distinction is made between physical loss, which relates to the spatial extent of the habitat and physical damage, which affects the condition of habitats. Physical loss is defined as a permanent or long-term alteration of the habitat by changing the natural substrate (smothering) or by conversion of marine to terrestrial or freshwater habitats (sealing). In contrast, physical damage refers to a disturbance of the habitat where the same or similar natural substrate is retained but its structure and biota are altered (MSCG 2012). Effects associated with physical damage according to the MSFD Annex III are changes in siltation, abrasion and selective extraction. Definitions of pressures are proposed based on existing definitions of physical disturbance by the MSFD, OSPAR (2012), Tyler-Walters et al. (2001) and Tillin et al. (2010) (Table 1-1).

Table 1-1: Proposed definitions of physical pressure, adapted from EC (2008) and OSPAR (2012).

Physical loss
Smothering – change to another seabed type
Permanent or long-term change of one marine habitat type to another marine habitat type, e.g. where soft sediments are replaced by hard or coarse substrates including artificial substrates. Alteration of habitat features will result in distinct changes in the benthic community.
Associated activities: offshore installations, scour protection, aggregate extraction, capital dredging, disposal of dredged material, coastal defence structures.
Sealing
Permanent loss of marine habitats to land or freshwater habitats or man-made constructions.
Associated activities: land claim, foundations of offshore installations.
Physical damage
Changes in siltation
Settling out of sediments suspended in the water column, accumulation or erosion of fine sediments on the seafloor (smothering).
Associated activities: offshore installations, land claim, coastal defence, extraction of aggregates, dredging.
Abrasion
Penetration or disturbance of sediments where there is limited or no loss of substrate from the system.
Associated activities: bottom trawling, anchoring.
Selective extraction – removal of substratum
Removal of substratum where the exposed sediment is of the same type. Changes of habitat structure are temporary and / or reversible; re-colonisation by a similar benthic community is possible after the extraction event.
Associated activities: extraction of aggregates, dredging.

1.4.2.1 Identification of activities and pressures in the German Exclusive Economic Zone

The assessment of indicator 6.1.2 requires a conceptual understanding of the potential impacts on benthic habitat structure and suitability caused by physical pressures. In this section human activities occurring in the German EEZ are described in terms of their geographical distribution and their physical or mechanical impact, which is considered to result from the spatial and temporal footprint of the associated pressures. Table 1-2 summarises the information from this chapter and links human activities in the German EEZ with the definitions of physical pressures from Table 1-1.

Bottom trawling

Demersal trawling takes place in large parts of the Baltic and North Sea. A survey regarding the effects of bottom trawls on the benthic fauna showed that only small areas of the North Sea are not regularly fished (Schroeder et al. 2008). Fishing activities are solely restricted in the three nautical mile zone in the Baltic Sea and the 'plaice box' in the North Sea, which is closed for larger beam trawlers (BSH 2009a, BSH 2009b). Fishing gears employed in the North Sea are mainly otter trawls in the northern part and large and heavily-rigged beam trawls in the southern part of the EEZ. The highest fishing intensity with 10 to 15 events per year was registered in coastal waters of the North Sea up to a distance of 25 km to the coast. Coastal fisheries are mostly carried out by small beam trawl vessels (< 300 hp) targeting shrimp, plaice and sole. Major parts of the German EEZ of the North Sea are currently fished once a year, while the maximum fishing intensity is approximately five events per year (Schroeder et al. 2008). In the Baltic Sea, fisheries with towed gear is less intense and mainly carried out by otter trawls, both inshore and offshore (Janssen et al. 2008, Pedersen et al. 2010).

Fishing with towed bottom gears causes physical disturbance of the sea bottom and therefore adversely affects benthic habitats and communities. Effects include the reduction of habitat complexity, alterations in sediment characteristics and removal of structuring features. The passage of the fishing gear over the seafloor disturbs the upper bottom layers thereby causing a re-suspension of sediments, re-mineralisation of nutrients and contaminants and re-sorting of sediment particles. Habitat structures are altered in terms of a homogenisation of the seabed, e.g. by flattening of sand ripples, removal of rocks or structuring organisms such as biogenic reefs, epibenthic fauna or burrows and mounds (Kaiser et al. 2002). Fining of sediments has been observed in areas with a high intensity of fishing with bottom-tending gears and may be a long-term consequence of the resuspension and settling of sediments following fishing events (BSH 2009a). Generally, effects in more dynamic habitats such as unconsolidated sediments in shallow waters are less severe than those occurring in structurally complex habitats (e.g. seagrass meadows, biogenic reefs) and habitats relatively undisturbed by natural perturbations (Kaiser et al. 2002).

The degree of mechanical disturbance of the seafloor has been observed to differ apart from sediment properties and natural disturbances also due to the fishing gear used. While otter trawling creates irregular features in the form of furrows on the seabed, beam trawling mainly leads to a flattening of bottom topography. The net opening of an otter trawler is maintained by trawl doors which cause furrows generally ranging from 1 to 5 cm but may reach up to 20 cm deep depending on the door weight and the substrate properties. Trawl door marks may disappear after several months in highly dynamic ecosystems but may also last up to five years in sheltered areas (FAO 2004). Additionally, large amounts of sediment are resuspended during otter trawling (ICES 2003).

Beam trawlers are equipped with tickler chains which are specifically designed to disturb the seabed surface along the whole width of the gear and penetrate the upper few centimetres of the sediment. The width of a beam trawl ranges from 4 to 12 m.

Observations on the persistence of beam trawl marks range from tracks disappeared after a few days in tidally exposed areas to several months or more in sheltered areas (FAO 2004).

Offshore wind farms

The production of offshore wind energy is currently one of the most important in terms of area utilisation, especially in the EEZ of the North Sea. At present 28 wind farms are authorised in the North Sea and three in the Baltic Sea. With the test field 'alpha ventus' and 'Bard Offshore 1'in the North Sea and 'Baltic 1' in the territorial waters of the Baltic Sea three wind farms are already in operation. Several others are currently under construction in the German North Sea (BSH 2013a). Applications for many more wind farms are being assessed by the regulatory authorities. In the EEZ of the North Sea, the offshore wind farms approved and applied for so far will occupy an area of more than 15% of the total surface area (Ammermann 2011).

An offshore wind farm generally comprises of different components affecting the seabed: foundations of the piles (e.g. monopiles, tripods or gravity base) and the converter platform, power cables to connect the piles and the converter platform and scour protection in form of rock or concrete mattresses. Additional installations such as substations may be needed (OSPAR 2006).

Physical impacts on the seabed arise from the construction phase and the physical presence of the installations. Construction works in form of dredging activities, piling or drilling and cable-laying operations will disturb the seafloor by mobilising sediments and temporary causing increased turbidity. The permanent submarine installations are accompanied by a loss of marine soft-bottom habitats due to the introduction of artificial hard substrates. In dynamic ecosystems scouring may impact an additional area (OSPAR 2006). Usually scour pits can be considered to be limited to within ten times the diameter of the obstacle. Cumulative effects of scouring around piles could not be observed. If scour protection is applied, materials are placed around the tower in a radius of around 25 m (Meissner & Sordyl 2006). Furthermore the erection of a wind farm may influence local hydrographical regime and sediment transport processes (OSPAR 2006).

Other permanent offshore installations

Other offshore installations means structures beside those erected in relation to offshore wind farms. These contain platforms for the exploitation of gas and marine research. The extraction of gas is carried out at present only to a small extent in the German North Sea with one active gas rig located near the Dogger Bank. Additionally two gas compressor platforms and several research platforms are operational in the North and Baltic Seas. Further research platforms are planned (BSH 2013b).

The main pressures affecting the seabed arise from the placement and physical presence of sub-marine structures. Effects on the marine environment are comparable to those exerted by wind farms and mainly include permanent habitat alterations by the foundation of structures and scour protection as well as temporary effects of construction works.

Cables and pipelines

Currently the German North Sea is crossed by six gas pipelines connecting gas rigs to each other and the mainland. With the Nord Stream pipeline there exists at present one gas pipeline in the Baltic Sea, two more are at the planning stage. Pipelines are usually laid directly on the sea floor without further coverage. Especially in shallow waters the pipeline may be placed in a trench to ensure its stability and mechanical protection. In this case a trench is dug where the pipeline is laid in and afterwards the trench will be filled back. Alternatively the pipeline can be secured by concrete mats or gravel. Usually pipelines are enclosed by a concrete casing and have a diameter of approximately 1.2 m (Herberg et al. 2007).

In addition to the gas pipelines a series of submarine cables is planned or already exists. Cables can be distinguished into data or telecommunication cables and power cables. In the German North Sea there are currently eight data cables in operation, in the Baltic Sea seven. With the NorNed cable between the Netherlands and Norway currently only one transit power cable in the German North Sea is in operation. In the Baltic Sea two transit power cables exist which connect Germany with Denmark and Sweden. Additionally in the North Sea the first high-voltage power cable to link offshore wind farms with the coast is already in operation, many more will be established in the near future (BSH 2013b).

Submarine cables are usually placed in a depth of approximately 1 m in the sea floor. Where cables cannot be buried, e.g. in areas of exposed bedrock or at intersections with other cables or pipelines, they are laid directly on the seabed and may be covered by a protective structure like rock armour (OSPAR 2008).

The installation of cables and pipelines results in physical disturbance of the seabed and associated impacts such as damage or displacement of benthic organisms, increased turbidity and alteration of sediment properties. The presence of pipelines, cables if not buried and protection structures represents the introduction of artificial hard substrates in prevalent soft-bottom habitats. Near-bottom currents may be influenced by pipelines or protection structures and thus alter sediment characteristics (OSPAR 2008). The footprint of cables and pipelines is dependent on the length, diameter and whether or not it is trenched.

Extraction of sand and gravel

In the German North Sea there are currently four areas licensed for the extraction of sand and gravel with a total area of 1.350 km². The area currently in use accounts for approximately 250 km² (BMU 2008). Large parts of the extraction sites are located in Natura 2000 sites where priority habitats such as reefs and permanently submerged sandbanks are present (BSH 2013b). In the North Sea, the area actually extracted in 2005 was 2.8 km², while in 2006 the area was extended to 6.6 km² (Schroeder et al. 2008). In the EEZ of the Baltic Sea currently no aggregate extraction takes place. The amount of material extracted in the North Sea varied between 1.4 and 36.2 million tonnes in the years 2005 to 2009. The maximum values resulted from the construction of the Jade-Weser Port in 2008/09 and were taken from the territorial waters (BLMP 2012).

Extraction takes place by means of suction dredging either with the vessel remaining stationary or while driving. In Germany most aggregate dredging is carried out by trailer suction dredging. This creates a series of longitudinal tracks, generally 2-3 m wide and up to 50 cm deep, as the drag head passes over the seabed. Sediment is mobilised and brought into suspension as the drag head disturbs the sediment surface and with the overflow of excess water back in the water column. Sometimes screening of the sediment takes place while dredging, e.g. particles of a certain size, mostly fine sand, are sorted out and returned to the water (Hill et al. 2011).

Anchor dredging, where the vessel remains stationary to extract deep deposits, is less common. In this way rounded pits of around 10 m depth and with a diameter of 10-50 m are produced. Although the disturbed area is much smaller compared to trailer dredging, morphological changes are much more severe (Hill et al. 2011).

The main impacts on the physical environment caused by aggregate extraction are alterations of the seabed topography, changes in sediment composition and mobilisation of particulate matter. High intensity dredging may result in a strongly disturbed topography with deep tracks and furrows remaining for several years (ICES 2009). A lowering of the seabed by up to 2-3 m may be a con-sequence of repeated dredging in the same area. Such changes in seabed topography may in turn lead to an altered hydrodynamic and sedimentation regime. Extraction sites are often characterised by a higher proportion of sediments with a small grain size. Changes in sediment composition may be caused by screening when finer particles are returned to the seabed, by overspill of water containing small sand particles or by the infilling of dredge tracks and furrows. Increased turbidity plumes of suspended material generate from the dredging activity on the seafloor, the overflow and screening, thereby extending the area subject to changes in sediment composition. Depending on local conditions and extraction method sediments may as well become coarser, e.g. by selective extraction of sand or when gravel deposits are being exposed beneath the surface layer of the seabed. The footprint of aggregate extraction activities can be assumed to cover an area of up to 2-3 km around the extraction site, depending on sediment type (ICES 2009, Hill et al 2011).

Table 1-2: Summary of human activities and associated physical pressures on sea floor integrity in the German EEZ.

Activity	**Geographic distribution**	**Pressure**	**Description of pressure**
Bottom trawling	throughout the North and Baltic Sea	abrasion	alteration of seabed topography: reduction in habitat complexity, changes in sediment characteristics, removal of physical and biological structures
Offshore wind farms	three wind farms in operation in Baltic and North Sea, 28 authorised, around 90 planned, mostly in the North Sea	sealing	physical presence of foundation: loss of marine habitat
		smothering	physical presence of structures (foundations, scour protection), introduction of artificial hard substrate, scouring
		changes in siltation	during construction: increased turbidity, resuspension of sediments, in operation: changes in sediment transport
Other permanent offshore installations	one gas rig in the North Sea, several research and gas compressor platforms in the North and Baltic Seas	sealing	physical presence of foundation: loss of marine habitat
		smothering	physical presence of structures (foundations, scour protection), introduction of artificial hard substrate, scouring
		changes in siltation	during construction: increased turbidity, resuspension of sediments, in operation: changes in sediment transport
Pipelines	six gas pipelines in the North Sea	smothering	physical presence of pipeline when not trenched, protection structures, introduction of artificial hard substrate
		changes in siltation	during pipeline-laying: increased turbidity, resuspension of sediments, in operation: changes in sediment transport when pipeline is not trenched
Cables	several telecommunication and power cables in the North and Baltic Sea, more power cables planned for wind farms	smothering	physical presence when cable is not buried, in the case of protection structures: physical presence, introduction of artificial hard substrate
		changes in siltation	burial of cable: increased turbidity, resuspension of sediments
Extraction of sand and gravel	several areas licensed for extraction in the North Sea	smothering	changes in sediment composition (sediments mostly become finer)
		selective extraction	removal of substrate, altered seabed topography: presence of tracks and furrows, lowering of seabed
		changes in siltation	during dredging activity: increased turbidity, resuspension of sediments

1.4.2.2 Spatial and temporal extent of pressures

Assessing the intensity of pressures involves information on both the spatial and temporal footprint of the related activities. Determination of the spatial extent should include data on the precise location of activities, e.g. the site of an offshore wind farm, combined with information on the area affected like the extent to which seabed is disturbed by smothering around a pile foundation.

Estimates for the spatial extent of pressures given in this section are based on literature describing the area subject to physical disturbance (e.g. Eastwood et al. 2007, de Vries et al. 2011, DEFRA 2012).

Sealing

Offshore wind farms: Sealing by offshore wind farms results from the placement of foundations for the wind turbines. Specifications for the base diameters of the different foundations show some variation. Monopiles have been chosen for most of the installed offshore wind farms to date. In OSPAR (2006) the diameter of a monopile is set at 4 to 6 m with the indication that towers of 5 m appear to be the dominant size. Approvals for the offshore wind farms planned in Germany usually estimate a diameter of 5 m for the area sealed by monopiles, some wind farms designs may possess even larger monopiles with 6 m diameter (e.g. wind farm 'Innogy') (BSH 2013a). Tripods (three legs) and jackets (four legs) are anchored by driven or drilled piles, typically ranging from 0.8 to 2.5 m in diameter. These types of foundations are used with larger turbines and may be located in deeper waters (EWEA 2009). Gravity based structures have also been used on several projects. Information on the diameter of gravity based foundations varies from 15 m (Meissner & Sordyl 2006) to 30 m (OSPAR 2006). Gravity based structures may also vary in shape, they may be circular or rectangular. Based on this data, to estimate the spatial footprint of sealing caused by the foundations of wind turbines the area of 20 m² per foundation is suggested. This would correspond to a monopile with a diameter of 5 m or a jacket with piles of 2.5 m. Tripods will generally have a smaller footprint while gravity based structures are usually significantly larger.

Other permanent offshore installations: Platforms for the extraction of oil and gas are usually founded on jacket structures with four or six piles. Research platforms may be jackets such as FINO 1 or monopiles like FINO 2 and 3. The average area sealed by different types of platforms is estimated at 15 m² as the general footprint of jackets and monopiles used for research platforms is believed to be smaller than for the foundations of wind turbines.

Smothering

Offshore wind farms / other permanent offshore installations: Scour protection is applied around monopiles and gravity based foundations and usually has a radius of 10 m for monopiles. Recent studies on scour development of off-shore wind farms indicate the effects of scour are locally restricted to the near vicinity of the piles (Orejas et al. 2005, Meissner & Sordyl 2006). Changes in sediment dynamics around 'alpha ventus' have been observed in a maximum distance of 60 m from the structure (Lambers-Huesmann & Zeiler 2011). Surveys at wind farms in the UK found scour pits around individual monopile foundations in highly mobile sediments developed to 100 m in diameter while at other, more stable sites scour pits reached only a diameter of 10 m (CEFAS 2006, DECC 2008). According to METOC Plc (2000), the area around a structure prone to local scour is usually expected to be approximately ten times the diameter of the structure. Around the FINO research platforms changes in sediment structure could be observed up to around 40 m in the direction of the main current (Orejas et al. 2005). Buffers used for the spatial assessment of offshore wind farms range from a diameter of 50 m (DEFRA 2012) to 100 m (Eastwood et al. 2007). Based on the studies conducted in the German offshore area and due to the fact that changes in sediment properties do not occur circular around a pile, a diameter of 50 m or an approximate area of 2000 m² is proposed for the spatial footprint of offshore wind turbines and other platforms. Physical loss (sealing and smothering) caused by an offshore wind farm with 80 turbines would thus add up to the total area loss of 0.16 km² (average size of an offshore wind farm: 40-50 km²).

<u>Cables and pipelines:</u> Some of the pipelines in German waters are completely trenched (e.g. the pipeline connecting the gas rig in the EEZ with the Dutch NOGAT pipeline) or at least in shallow waters. Furthermore, pipelines laid on mobile sediments may bury themselves and thus will not exert any pressure on the seabed (BSH 2009a). Therefore it is proposed to estimate the spatial footprint of pipelines by the mean diameter of 1.2 m and only in the EEZ where pipelines are usually not buried in sediment. The large majority of cables are buried, so that impacts are short-term only during construction. Physical loss occurs when the cable has to be protected by rock armour at locations with hard substrate or at intersections. The area thus altered is believed to be negligibly small and may not be properly assessed with the available geospatial data.

<u>Extraction of sand and gravel:</u> The effect of aggregate extraction on habitat structures depends on the method and intensity of dredging, the level of screening and sediment type (Hill et al. 2011). The pressure associated with extraction of sand and gravel could thus be 'smothering' (sediment composition and consequently habitat type changes) or 'selective extraction' (exposed sediment is of the same type). It is assumed that based on national legislation and by means of Environmental Impact Assessments significant changes of habitat types by dredging are prevented. Therefore the pressure associated with aggregate extraction is proposed to be 'selective extraction'.

Selective extraction

<u>Extraction of sand and gravel:</u> In the UK waters mineral mining activities are routinely monitored by an electronic monitoring system which automatically records at 30 s intervals. Dredging locations are then spatially aggregated into 50 x 50 m blocks and categorised from low to high intensity which is expressed as hours dredged (Eastwood et al. 2007). These data can be used to represent the direct spatial extent of aggregate dredging (Eastwood et al. 2007, DEFRA 2010). It would be essential to obtain

equally exact data for the German areas licensed for the extraction of sand and gravel, otherwise the spatial footprint of extraction cannot be assessed.

Abrasion

Bottom trawling: The most reliable source of positional data for fishing vessels and the one with the highest resolution is the EC vessel monitoring system (VMS). Since January 2012 this includes all vessels in excess of 12 m operating in European waters. Resolution and accuracy obtained by VMS data far exceed that of the ICES rectangle-based data formerly used to provide information on spatial and temporal trends in fishing effort (Lee et al. 2010).

Several methods have been developed and applied to estimate the spatial footprint of fishing effort. Main differences are the distinction between fishing and steaming according to the recorded speed and the method of converting VMS data points to an area describing fishing effort. The Bundesanstalt für Landwirtschaft und Ernährung (BLE) provides data processed by the von-Thünen institute in Hamburg so there is little influence on the methods used for calculating the spatial extent of fishing effort.

Changes in siltation

Offshore wind farms: Under the pressure 'changes in siltation' all impacts occurring during construction activities are subsumed. These include the disturbance, resuspension, erosion and accumulation of sediments caused by cable laying and foundation installation as well as by ship movement and anchoring. The extent of these activities is mostly very localized and depends on sediment type, grain size distribution and the hydrodynamic regime and thus can vary greatly between sites (OSPAR 2006). Even though the individual impacts are small-scale, it is proposed to define the wind farm area as a whole as impacted by changes in siltation, similar to the approach by HELCOM (2012).

Other permanent offshore installations: The construction of platforms for the exploration of oil or gas or for research purposes involves disturbances of the seabed as described above for wind farms. The extent of impacts is near-field and largely site- and project-specific. As a generalisation it is suggested to attribute a buffer of 100 m around the installation as the area impacted by construction activities.

Cables and pipelines: Laying of cables and pipelines leads to seabed disturbance and associated impacts of increased turbidity and alteration of sediments. The area affected by sediment plumes and smothering is generally limited to the near-field area along the construction corridor and depends on the method and device used and the amount of excavated and dumped sediment. Direct disturbance of the seabed occurs within 1-2 m on both sides of the trench. Impact modelling observed sediment deposition in a maximally 90-120 m wide cable corridor. Water quality effects may be noticed as far as 1 km, however, it is assumed that suspended sediment concentrations which occur during cable burial do not exceed naturally induced turbidity by tides, waves or currents (OSPAR 2008). Thus it is proposed to calculate with a buffer of 100 m for the placement of cables and pipelines.

Extraction of sand and gravel: Increased turbidity due to sediment plumes can be detected in an area of up to 3 km around the extraction site, depending on sediment properties (ICES 2009, Hill et al. 2011). The dispersal of suspended material can be estimated by using particle transport models (Eastwood et al. 2007). However, as a uniform particle size distribution is assumed across all sites, it is believed that this model simulates a precision which may be misleading. HELCOM (2012) adds a buffer of 2000 m to the geospatial data on extraction sites which seems to be an appropriate mean value for the accumulation of fine sediments. If data on the exact location of the extracted area could be obtained, it is therefore suggested to apply a buffer of 2000 m around the extraction site to cover changes in siltation.

Table 1-3: Spatial considerations for intensity of pressures occurring in the German EEZ.

Pressure	**Activity**	**Spatial footprint**
Sealing	offshore wind farms	average size foundation = 20 m²
	other permanent offshore installations	average size of foundation = 15 m²
Smothering	offshore wind farms, other permanent offshore installations	average size of substrate alteration around foundation = 2000 m²
	surface pipelines	length of pipeline with diameter of 1.2 m
Selective extraction	extraction of sand and gravel	actual dredged area
Abrasion	bottom trawling	grid with fishing activity (0/1) for each cell (VMS cells or ICES rectangle)
Changes in siltation	construction of offshore wind farm	area of offshore wind farm
	construction of other permanent offshore installations	100 m around installation
	construction of cables and pipelines	100 m wide corridor
	extraction of sand and gravel	2000 m around actual area dredged

The temporal extent describes the frequency or duration of a pressure, e.g. the number of trawling events per year. A classification of five categories is applied for each pressure, ranging from rare to persistent (Table 1-4). The scale is based on expert judgement and should reflect the actual frequency of pressures in the German EEZ. A pressure occurring more than three times per year is assumed to be persistent. For example, even in more tolerant habitats like sublittoral sand, bottom trawling four times a year results in a permanent disturbance without the possibility of recovery. Pressures associated with physical loss (sealing and smothering) are persistent and can therefore only be allocated to the highest category, which is equivalent to the highest intensity possible for physical damage. The reporting period is chosen as reference period since this is assumed to aid in reflecting effects of management measures.

Table 1-4: Scale for temporal extent of physical pressures.

Rank	Definition
rare	1 event per reporting period
occasional	> 1 -< 6 events per reporting period
regular	1 event per year
frequent	> 1-3 events per year
persistent	> 3 events per year / permanent installation

Data on distribution and temporal extent of physical pressures are used to create pressure maps by means of GIS layers. The spatial scale is dependent on the nature of data available for the assessment. Data with the highest possible resolution are preferred, e.g. for fisheries information from the EC vessel monitoring system (VMS). Each physical pressure is displayed on a separate map. Figure 1-1 summarises the necessary components and steps for the generation of pressure maps.

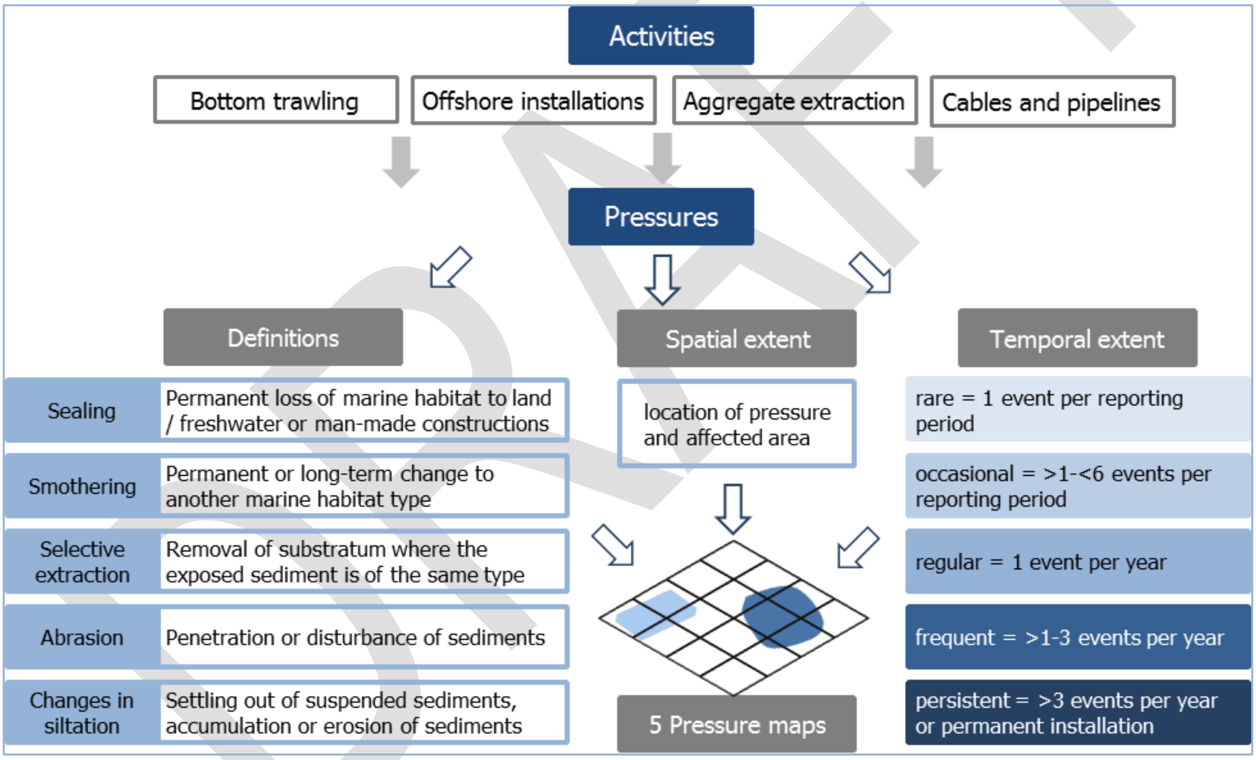

Figure 1-1: Human activities in the German EEZ and characterisation of associated pressures (own illustration).

1.4.3 Benthic habitats

1.4.3.1 Definition of habitat types

Annex III, table 1 of the MSFD provides an indicative list of habitat types:

- Predominant habitat types - The predominant seabed and water column habitat type(s) with a description of the characteristic physical and chemical features, such as depth, water temperature regime, currents and other water movements, salinity, structure and substrata composition of the seabed,
- Special habitat types - Identification and mapping of special habitat types, especially those recognised or identified under Community legislation (the Habitats Directive and the Birds Directive) or international conventions as being of special scientific or biodiversity interest,
- Habitat types meriting special reference - Habitats in areas which by virtue of their characteristics, location or strategic importance merit a particular reference. This may include areas subject to intense or specific pressures or areas which merit a specific protection regime.

Predominant habitats

The Commission Staff Working Paper (EC 2011) provides further instructions on definitions of habitat types. Predominant seabed habitat types are closely linked to level 3 of the EUNIS habitat classification scheme. Habitats are classified according to their depth (littoral, shallow, shelf, bathyal and abyssal) and their substrate. Substrates are differentiated into rock and biogenic reef and sediment habitats (coarse, sand, mud, mixed). Sublittoral sediments in the German EEZ of the North Sea classified according to EUNIS level 3 are as follows:

- A5.1 Sublittoral coarse sediment
- A5.2 Sublittoral sand
- A5.3 Sublittoral mud
- A5.4 Sublittoral mixed sediments

Special habitats

Special or listed habitat types refer to those identified under several regulatory frameworks such as the EU legislation or international conventions (EC 2011). Habitat types in German waters belonging to this category are therefore priority habitats of the Habitats Directive, protected biotopes according to § 30 BNatSchG (Federal Nature Conservation Act), the OSPAR list of threatened and/or declining species and habitats and the HELCOM red list of marine and coastal biotopes and biotope complexes. The following set of habitat types occurs in German coastal and marine waters:

- seagrass beds
- macrophyte meadows and beds
- *Mytilus edulis* beds

- sea-pen and burrowing megafauna communities
- *Sabellaria spinulosa* reefs
- shell gravel bottoms
- gravel bottoms with *Ophelia* species
- species-rich habitats on coarse sands, gravel or shell debris
- reefs
- sandbanks

Habitats in particular areas

Habitats in particular areas can include areas subject to specific or multiple pressures and are therefore likely to entail risks to marine biodiversity, marine ecosystems, human health or legitimate uses of the sea, or areas already designated or which should be designated due to various forms of spatial and management protection. Currently, particular habitats have neither been identified by the European Commission nor by the Regional Seas Conventions. In order to be consistent with other national environmental policies and to account for the ecological importance of protected areas it is proposed to consider these as habitats in particular areas on a national basis. With regard to benthic habitats this would be the designated Natura 2000 sites in the North and Baltic Seas. Habitats in particular areas will not be separately assessed, as Natura 2000 sites consist of both special and predominant habitats. Instead of that, a specific GES target should be proposed for these particular habitats in order to intensify national efforts for conservation of designated sites.

1.4.3.2 Sublittoral habitats in the German EEZ of the North Sea

According to Figge (1981), sediments in the German Bight are classified in several major areas: The Pleistocene Elbe valley, extending from the inner German Bight to the east of the Doggerbank, and the bordering plains west of this valley are characterized by fine sands with noticeable contents of silt and clay (5-50 %) and a comparatively even relief. Sediments of the Borkum Reef Ground west of the Pleistocene Elbe valley are more heterogeneous. The predominant medium and coarse sands are interspersed with gravel and small stones. With increasing water depth sediments change to medium and fine sands with a silt fraction of up to 10 %. The area east of the Pleistocene Elbe valley (Sylter Outer Reef, Amrum Outer Ground) is marked by a conspicuously heterogeneous distribution of marine sediments. Between typical relict sediments with coarse sands, gravel and stones fine and medium sands accumulate. The density of stones is generally higher compared to the Borkum Reef Ground. The predominant sediments of the Doggerbank are fine sands, partly mixed with shell debris and a minor fraction of silt and clay (BSH 2009a).

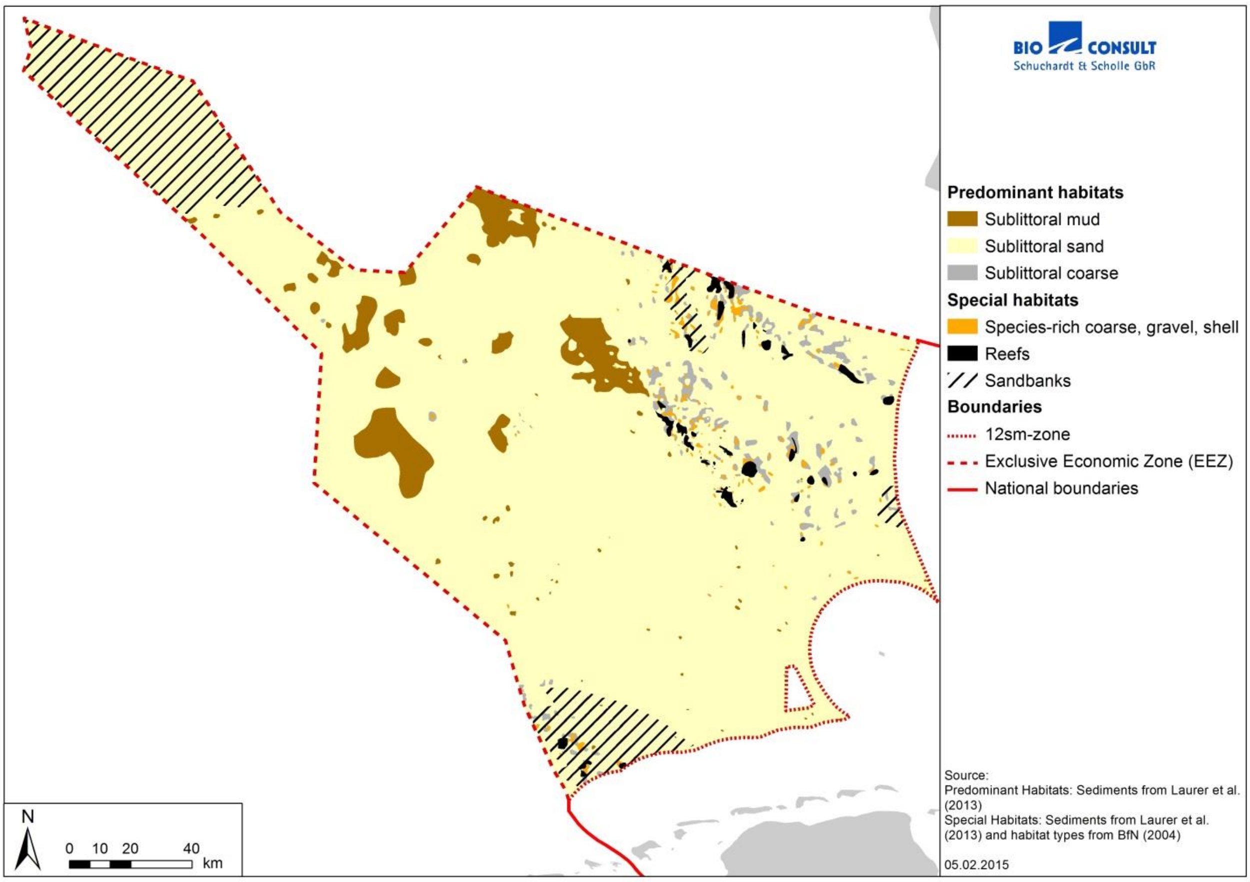

Figure 1-2: Distribution of predominant and special habitat types in the German EEZ of the North Sea.

Figure 1-2 shows the distribution of sediments in the German EEZ and the Natura 2000 habitat types. Based on this map, the following sublittoral predominant and special habitats have been identified in the German North Sea:

Predominant habitat types:

- Sublittoral sand
  This habitat type is widely distributed in the German Bight and contains all sediments with fine and muddy sands (silt and clay < 20 %).
- Sublittoral mud
  Larger areas of fine and sandy mud can be found in the central part of the German EEZ. The fraction of silt and clay exceeds 20 %.
- Sublittoral coarse sediment
  Small areas in the Borkum Reef Ground, Amrum Outer Ground and Sylter Outer Reef with medium to coarse sands.

Special habitat types:

- Reefs
  Geogenic reefs as defined by the Interpretation Manual of European Union Habi-

tats (EC 2013). Biogenic reefs have not yet been designated in the German North Sea.

- Sandbanks
  Sandbanks in the German EEZ are located at the Doggerbank, the Borkum Reef Ground and in the Sylter Outer Reef. They are defined according to the Interpretation Manual of European Union Habitats (EC 2013).
- Species-rich habitats on coarse sands, gravel or shell debris
  Small areas with mixed or unmixed sediments of coarse sands, gravel and shell debris.

1.4.3.3 Assessment of habitat sensitivity

For a particular pressure to have an impact on a habitat or community, these have to demonstrate a level of sensitivity to that pressure. In principle, sensitivity of ecosystem components is determined by two aspects: the ability to withstand disturbance or stress (resistance or tolerance) and the ability and time needed to recover from a perturbation and return to the previous state (resilience or recoverability). Highly sensitive species or habitats are therefore those which possess both low resistance and resilience (Environment Agency 2010). Basically, approaches to assess resistance and recovery time of habitats either rely on experts to allocate sensitivity categories to habitats based on given criteria (e.g. Halpern 2008, OSPAR 2009, HELCOM 2010, Andersen et al. 2011) or refer to evidence base or biological traits of selected species (e.g. McMath et al. 2000, Tyler-Walters et al. 2001). Expert judgement is however also required to choose species which are considered to be characteristic or important for the structure and function of the habitat. A more holistic approach which not only takes account of species sensitivities but also physico-chemical features such as substrate characteristics is delivered by Tillin et al. (2010). As there is a large number of existing approaches for assessing habitat sensitivities which are already approved and accepted, it is proposed to refer to the knowledge of these previous studies. Particular focus has been given to the MarLIN approach (Tyler-Walters et al. 2001), as it is mainly based on available evidence and includes a large database on benthic species features. The expanded concept by Tillin et al. (2010) has also been especially considered in the following suggestions for the sensitivity assessment of predominant and special habitats.

In general, sensitivity assessments focus mainly on the biological components of habitats. As benthic species play a crucial role in creating physical structures of the habitat (e.g. burrows or pits), it is considered that faunal sensitivity has to be a major part of any assessment of sensitivity to morphological impacts. At the same time the impact on the physical habitat, the modification following disturbance and the ability to recover from damage is regarded as important in order to assess sensitivity of the habitat as a whole. If habitat suitability is affected by the pressure, then recovery of the benthic community may not take place or may be delayed.

The proposed approach to define the sensitivity of habitats combines the assessment of both habitat structure and important species. In principal, the sensitivity assessment is closely related to the MarLIN approach described by Tyler-Walters et al. (2001): assessment of the resistance of a habitat or species in relation to a defined intensity of each pressure, assessment of the recoverability of the habitat or species and the combination of resistance and recoverability to derive an overall sensitivity rank for the particular habitat or species in relation to each pressure.

Habitat sensitivity by Tyler-Walters et al. (2001) is the result of the individual sensitivities of key or characteristic species. In the concept presented here an additional step is included: the physical impact on habitats is assessed with regard to the resistance in relation to a specific pressure and the recoverability following the disturbance. This sensitivity of physical habitat properties is combined with the sensitivities derived for representative species to obtain an overall sensitivity rank for the habitat. For the assessment of habitat sensitivity it is assumed that habitats are in an optimum reference state, i.e. habitat alterations due to previous anthropogenic activities are not considered.

Selection of characteristic species for the sensitivity assessment

Characteristic species used in the sensitivity assessment should be species which significantly influence the ecology of a particular habitat type. These could be species which provide a distinct habitat that supports an associated community, or are important for community functioning by interactions with other species, or species which are used for the definition of a habitat. The loss or degradation of one of these species would severely affect the viability, structure and function of the habitat and may result in the loss of the habitat or a changed classification. For example, the loss of *Sabellaria spinulosa* would lead to the loss of the habitat '*Sabellaria* reef'. The sea urchin *Echinus esculentus* is important for structure and function in geogenic reef communities due to its grazing activities. Most of the characteristic species used for the assessment are those that aid to classify a habitat type. As far as available, the characteristic species identified by Rachor & Nehmer (2003) for the classification of benthic communities in the south-eastern North Sea were adopted (see also chapter 1.7). The criteria applied by Rachor & Nehmer (2003, see also Rachor 2007) for the selection of characteristic species include dominance, presence, faithfulness in dominance and abundance and the contribution of discriminating species in a dissimilarity analysis. Other sources for the selection of characteristic species were Nehls et al. (2008) and BfN (2011). The selection of characteristic species for the sensitivity assessment is assumed as a preliminarily approach for the initial application of the methodology. For future assessments it is proposed to mainly refer to results of an ongoing habitat mapping project, which also should provide information on characteristic species of benthic habitats or to use the description of the reference state.

Resistance of the physical habitat and characteristic species

The resistance or tolerance of the physical properties and the characteristic species of a habitat should reflect the susceptibility to damage or loss as a result of a pressure on the seabed. The likely tolerance of the species or habitat is estimated with respect to a specified magnitude and duration of change in order to provide a standard level against which to assess resistance. Benchmarks for physical disturbance indicated by Tyler-Walters et al. (2001) largely correspond to the pressure definitions given in Table 1-1. The following definitions are used by the MarLIN approach and are adopted for the indicator concept:

- Substratum loss (= selective extraction): All of substratum occupied by the species or biotope under consideration is removed. A single event is assumed for sensitivity assessment. Once the activity or event has stopped (or between regular events) suitable substratum remains or is deposited. Species or community recovery assumes that the substratum within the habitat preferences of the original species or community is present.
- Physical disturbance or abrasion (= abrasion): Force equivalent to a standard scallop dredge landing on or being dragged across the seabed. A single event is assumed for assessment.
- Smothering (= changes in siltation): All of the population of a species or an area of a biotope is smothered by sediment to a depth of 5 cm above the substratum for one month.

The resistance of the physical habitat and the characteristic species is classified in four ranks, based on tolerance scales by Tyler-Walters et al. (2001) and IOW (2009) (Table 1-5).

Table 1-5: Scale for resistance of the physical habitat and characteristic species (adapted from Tyler-Walters et al. 2001).

Rank	Physical habitat	Characteristic species
low	Structure and function of physical habitat characteristics are altered completely or to a large extent.	The species population is likely to be killed / destroyed by single event of anthropogenic pressure.
intermediate	Significant alterations of physical habitat characteristics; essential structure and function are maintained.	Some individuals of a species population may be killed / destroyed by single event and the viability of a species population will be reduced.
high	Minor alterations of physical seabed characteristics, low impact on structure and function.	A species population is unlikely to be killed / destroyed by single event. However, the viability of a species population will be reduced.
tolerant	No negative effect detectable or positive effects on structure and function of physical habitat characteristics.	No negative effect detectable or positive effects on survival or viability of a species.

Recoverability of the physical habitat and characteristic species

Recoverability describes the ability of a habitat or species population to restore from damage sustained as a result of a physical impact on the seabed. Recoverability of organisms is especially dependent on the ability of the species to regenerate, regrow, recruit or recolonize and the extent of damage incurred. Recovery is only possible when the impact has stopped or has been removed.

Information on the potential impact of physical disturbance and the response of specific habitats and species is based on available evidence or expert judgement. Precedence is given to direct evidence of impacts such as information from targeted studies or experiments that looked at the effect of the specific factor on the habitat, the species or similar species. As a main source for the assessment of species resistance and recoverability, the MarLIN web site (MarLIN 2013) was used that provides detailed information on the sensitivity of selected species. Where information on characteristic species is not available, the relevant biological traits are inferred from similar species or congeners. As an additional source of information on species beside the MarLIN web site serves the 'Genus Trait Handbook' (MES 2008) or similar references. Tyler-Walter et al. (2001) also present simple decision trees to aid the resistance and recoverability assessment based on the available key information for the species like mobility, environmental position or reproductive biology. These decision trees provide a systematic and transparent approach to assessment and are described in full by Tyler-Walters et al. (2001).

The recoverability of the physical habitat or species is assessed against a five-step scale which has been adopted from Tyler-Walters et al. (2001) and Tillin et al. (2010) (Table 1-6).

Table 1-6: Scale for recoverability of the physical habitat and characteristic species (adapted from Tyler-Walters et al. 2001).

Rank	Definition
very low	full recovery not possible or will take over 25 years
low	full recovery within 10-25 years
moderate	full recovery within 2-10 years
high	full recovery within 1-2 years
very high	full recovery within 1 year

Overall habitat sensitivity

A decision matrix is used to automate the combination of intolerance and recoverability and to obtain sensitivity categories for the physical habitat and the characteristic species. The matrix has been adapted from Tyler-Walters et al. (2001) (Table 1-7).

Table 1-7: Matrix for the sensitivity of the physical habitat and characteristic species (adapted from Tyler-Walters et al. 2001).

Sensitivity		**Recoverability**				
		very low (>25 yr.)	low (>10-25 yr.)	moderate (>2-10 yr.)	high (1-2 yr.)	very high (<1 yr.)
Resistance	low	very high	high	intermediate	intermediate	low
	intermediate	high	high	intermediate	low	low
	high	intermediate	intermediate	low	low	very low
	tolerant	not sensitive	not sensitive	not sensitive	not sensitive	not sensitive

The overall sensitivity is derived from the sensitivity ranks of the physical habitat and the sensitivity of characteristic species. The highest (i.e. most sensitive) rank assigned to either habitat structure or species determines the overall habitat sensitivity. For example, if the habitat structure is judged to have an intermediate sensitivity but the characteristic species are highly sensitive, then the overall sensitivity of the habitat is reported as high. Figure 1-3 illustrates the methodology to assess habitat sensitivity and to generate pressure-specific sensitivity maps.

The physical pressures ‘smothering’ and ‘sealing’ are defined by a loss of substratum and therefore a loss of the habitat is implied. The habitat is not expected to recover unless the area is actively restored or any permanent structures are removed. Sealing and smothering are in addition associated with an impact which destroys habitat structures as well as benthic organisms. Therefore resistance is classified as low and recoverability as very low (>25 years) which means that all habitats are ranked as possessing a very high sensitivity towards the pressures sealing and smothering.

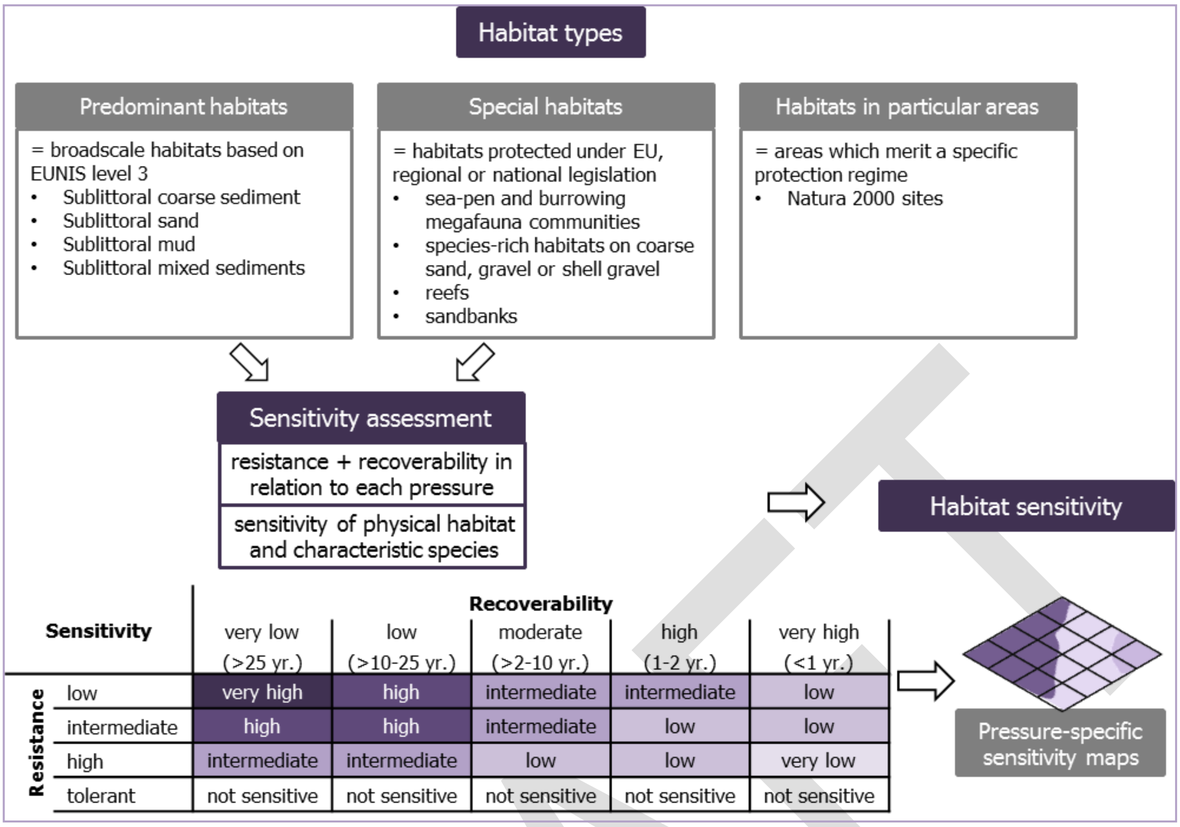

Figure 1-3: Sensitivity assessment of benthic habitats (own illustration).

In order to assess the proportion of benthic habitats perturbed by human activities, data on the distribution and extent of predominant and special habitats is required. For the application of the methodology to the German EEZ, a map with sediment distribution and the Natura 2000 habitat types is preliminarily used (Figure 1-2).

This habitat map is the best available map according to the current status of knowledge and ongoing discussions. However, some habitats cannot be identified according to this map, e.g. 'sublittoral mixed sediment' or 'sea-pen and burrowing megafauna communities'. Therefore in future assessments the habitat map shall be regularly updated with the latest state of research. It is also recommended to further refine predominant habitat types to EUNIS level 5 or 6 as far as possible. With the presently defined habitats on EUNIS level 3, a sensitivity assessment by means of characteristic species is difficult to achieve. EUNIS level 3 habitats are solely classified according to abiotic conditions like water depths and sediment type. At that level it is also not possible to identify habitats with high natural disturbance, e.g. areas with high current or tidal energy which may be more resistant towards physical pressures. An extensive habitat mapping project covering the German EEZ of the North Sea is currently under progress and should in the future provide information on habitat types and the associated characteristic species. For the present sensitivity assessment, the characteristic species of benthic assemblages defined by Rachor & Nehmer (2003) are used as a first approach to support the assessment of physical habitat properties with biological aspects (see chapter 1.7).

1.4.4 Physical impacts on habitats

The degree of physical impact on a habitat is a product of its sensitivity and the exposure to a specific pressure. An impact assessment thus requires the linkage of sensitivity information with pressure data. A matrix combining pressure intensity in terms of the temporal extent and habitat sensitivity supports the classification in nine categories of physical impact (Table 1-8). A percentage value is assigned to each rank which should provide an approximation of the relative impact on the habitat with regard to e.g. habitat structure, species richness, abundance or biomass. Due to the different nature of the pressures 'selective extraction', 'abrasion' and 'changes in siltation', for each of these physical damage pressures a separate impact matrix is provided in order to include a weighting factor in the impact assessment. 'Sealing' and 'smothering' are persistent pressures which are associated with an impact that destroys habitat structures as well as benthic organisms. The habitat is not expected to recover, thus sealing and smothering always result in a very high impact or total loss of habitat (100 %).

Table 1-8: Impact matrix combining habitat sensitivity and temporal extent of pressure.

Impact		**Habitat sensitivity**				
		very low	low	intermediate	high	very high
Temporal extent of pressure	rare	very low	very low-low	low	low-medium	medium
	occasional	very low-low	low	low-medium	medium	medium-high
	regular	low	low-medium	medium	medium-high	high
	frequent	low-medium	medium	medium-high	high	high-very high
	persistent	medium	medium-high	high	high-very high	very high

Pressure-impact relationships may be described by various types of functions, e.g. linear relation or logarithm function, and depend on the habitat or the life strategy of species. As a first approach to set up an impact matrix, the modelling results of Schroeder et al. (2008) were used as a basis. Schroeder et al. (2008) modelled fishery-induced mortality rates of selected benthic species with different ecotypes (r- and K-selected species of in- and epifauna) for the fishing gears beam and otter trawl (Figure 1-4).

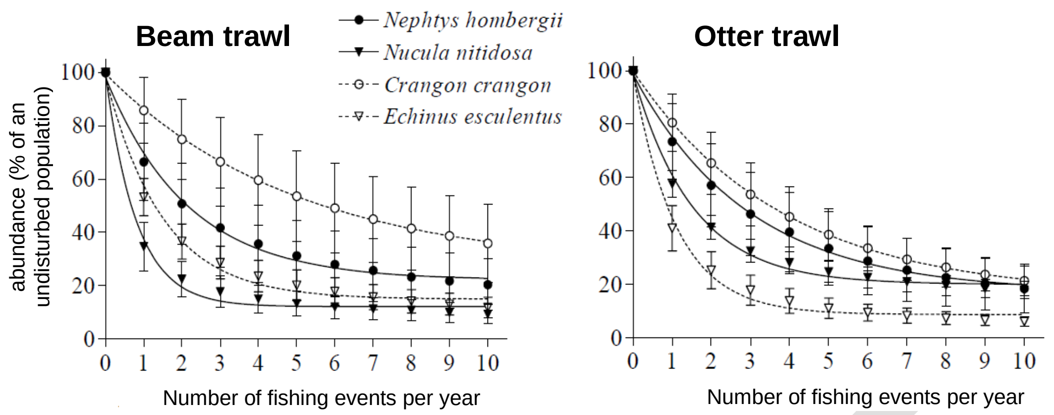

Figure 1-4: Percentage decrease in abundance of the benthic species *Nephtys hombergii*, *Nucula nitidosa*, *Crangon crangon* and *Echinus esculentus* induced by beam and otter trawling with different intensities per year (Schroeder et al. 2008).

For the development of an impact matrix, the decrease in abundance was averaged over the different species and gears to obtain a logarithmic curve for the physical impact of bottom trawling (Figure 1-5).

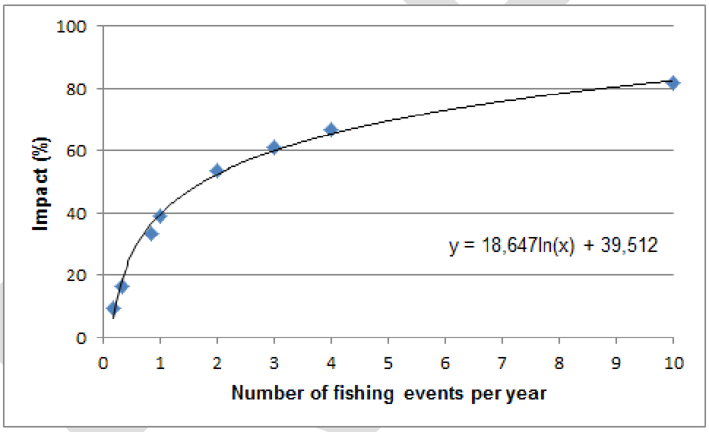

Figure 1-5: Estimated physical impact on benthic habitats by bottom trawling, based on decrease in abundance modelled by Schroeder et al. (2008).

In a second step the percentage values derived from the function were applied to the impact matrix combining sensitivity and temporal extent of pressure. Habitat sensitivity was set at intermediate with the respective temporal fishing intensities and then extrapolated to the very low and very high categories. For the impact matrices of the pressures ‘changes in siltation’ and ‘selective extraction’ weighting factors of 0.5 and 1.5 respectively were applied (Table 1-9).

Table 1-9: Values for relative impact on benthic habitats for the pressures ‘selective extraction’, ‘abrasion’ and ‘changes in siltation’.

Rank of impact	**Selective extraction**	**Abrasion**	**Changes in siltation**
very low	1%	0.5%	0.25%
very low – low	3%	2%	1%
low	9%	6%	3%
low – medium	44%	29%	15%
medium	59%	40%	20%
medium – high	85%	57%	28%
high	98%	65%	33%
high – very high	100%	80%	40%
very high	100%	100%	50%

1.4.5 Cumulative physical impacts on habitats

In order to determine the cumulative physical impact on a particular habitat, the five impact maps have to be summarised. Multiple pressures affecting a given location may vary in their cumulative impact. Several possible responses of habitats are discussed: Where pressure A causes the response ‘a’ from the habitat and pressure B the response ‘b’, then the cumulative effect under A + B conditions may be additive (a+b), antagonistic (<a+b) or synergistic (>a+b) (Crain et al. 2008). Most approaches to assess cumulative impacts assume additive effects for lack of knowledge on actual responses of benthic habitats. It is proposed to follow this practice as the physical pressures regarded here are assumed to affect habitat structure and suitability in a similar mode. This means that percentages for overlapping physical impacts are added up with 100 % (total loss) as maximum value. The cumulative physical impact is calculated from the proportion of area impacted (A, [%]) for each habitat and the corresponding degree of impact (I, [%]) as derived from the impact matrices. The cumulative impact (CI, [%]) for each habitat results from the sum of individual values for the relative impact on habitat:

$$CI = \sum I \times A / 100 \ [\%]$$

High values of cumulative impact indicate either pressures with considerable temporal and spatial extent or habitats with high sensitivity towards the occurring pressures. The cumulative impact value may range from 0% which would be a habitat completely without impacts to 100% meaning the total loss of the habitat.

This method provides the advantage of easily comparing the different impacts of the pressures physical loss (reduction in extent) and physical damage (impairment of condition) and results in a single percentage value of physical degradation for each habitat. Habitats and areas which are especially at risk by multiple pressures should be easily identified by this approach. Figure 1-6 briefly outlines the methodology to generate one map for the cumulative physical impact.

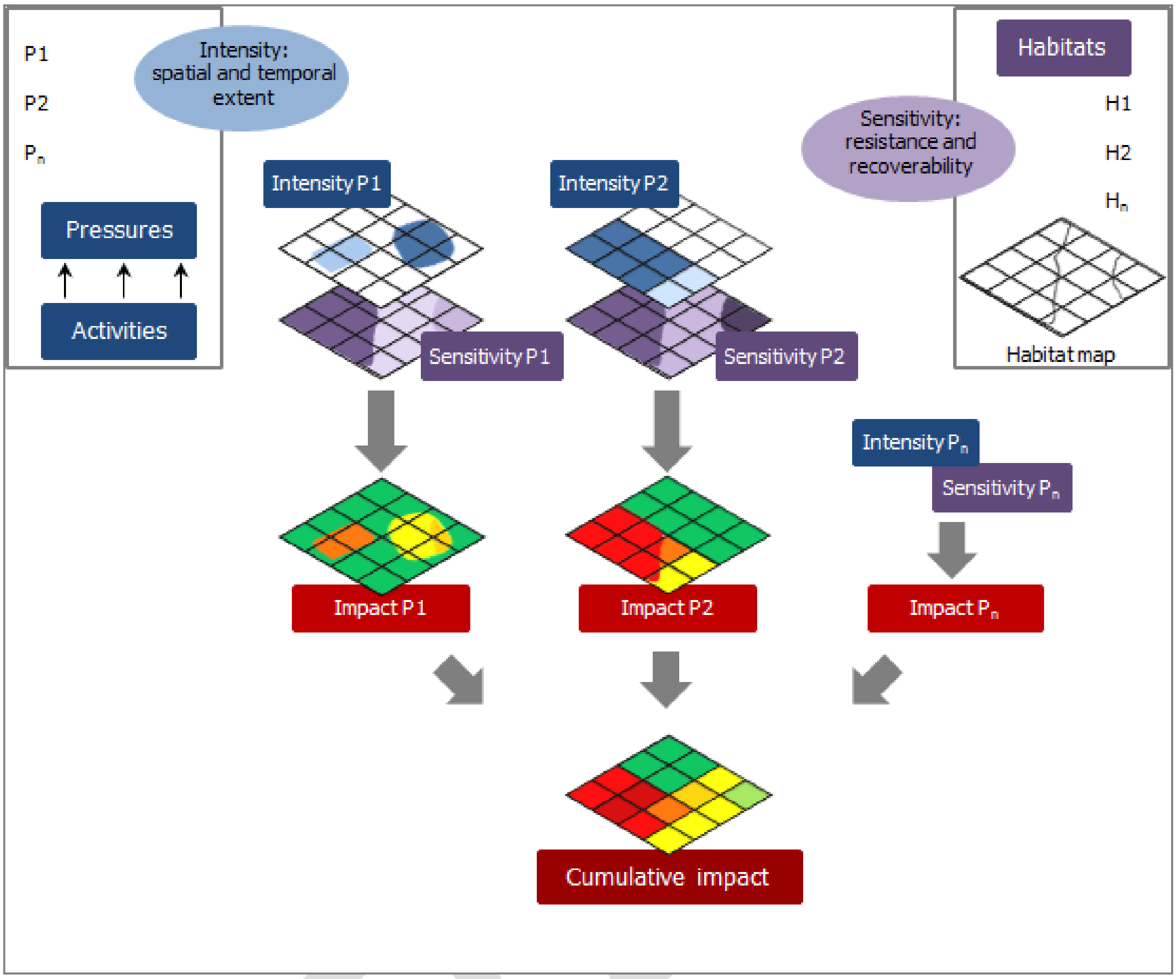

Figure 1-6: Assessment of cumulative physical impact by combining pressure intensity and habitat sensitivity (own illustration).

1.5 Application of assessment concept

1.5.1 Technical data

A first application of the proposed assessment concept was carried out for the German Exclusive Economic Zone (EEZ) of the North Sea. Anthropogenic activities considered are bottom trawling, permanent offshore installations, aggregate extraction and pipelines. Data formats and sources for human activities are described in Table 1-10. The habitat map used for the sensitivity assessment is based on the distribution of sediments in the German EEZ and the Natura 2000 habitat types (Figure 1-2). Data preparation and analysis was done with ArcGIS version 9.3.1.

Table 1-10: Data on human activities used for application of the assessment concept.

Activity	Data format	Data status	Data source
Bottom trawling	VMS data points, all fishing vessels > 15 m gear types: beam trawl <300 PS beam trawl >300 PS heavily rigged beam trawl > 300 PS otter / pair trawl area fished = temporal fishing effort x fishing speed x width of gear grid 100 x 100 m	2006	LANIS Habitat Mare, BfN method described in Schroeder et al. (2008)
Aggregate extraction	area in use for extraction	10/2013	CONTIS database, BSH
	area extracted	2005/2006	Schroeder et al. (2008)
Offshore wind farms	offshore wind farms in operation / under construction	10/2013	CONTIS database, BSH
Other offshore installations	installations for extractions of gas / research	10/2013	CONTIS database, BSH
Pipelines	pipelines in operation	10/2013	CONTIS database, BSH

1.5.2 Activities and pressures

Physical loss: sealing and smothering

The pressures 'sealing' and 'smothering' were combined as these pressures mostly arise from the same human activities and have the same temporal extent, i.e. they are persistent. Activities which are relevant with regard to physical loss are the foundations of offshore installations, scouring and scour protection around offshore installations and pipelines. The area impacted by physical loss is given in Table 1-11.

Table 1-11: Total area impacted by 'sealing' and 'smothering'.

Activity	Area impacted [km²]
Offshore wind farms	0.184
Research	0.006
Extraction of gas	0.004
Pipelines	1.052

Physical damage: selective extraction

Aggregate extraction is currently the only activity in the EEZ causing the pressure 'selective extraction'. At present there are three areas in use for sand and gravel extraction which are located in the Sylter Outer Reef. Data on actual areas dredged are difficult to obtain. For this first application it was only possible to use approximate data of extracted areas in 2005 and 2006 as transferred from Schroeder et al. (2008) (Figure 1-7). The description of the temporal extent of dredging activities is likewise only an approximation due to lack of data.

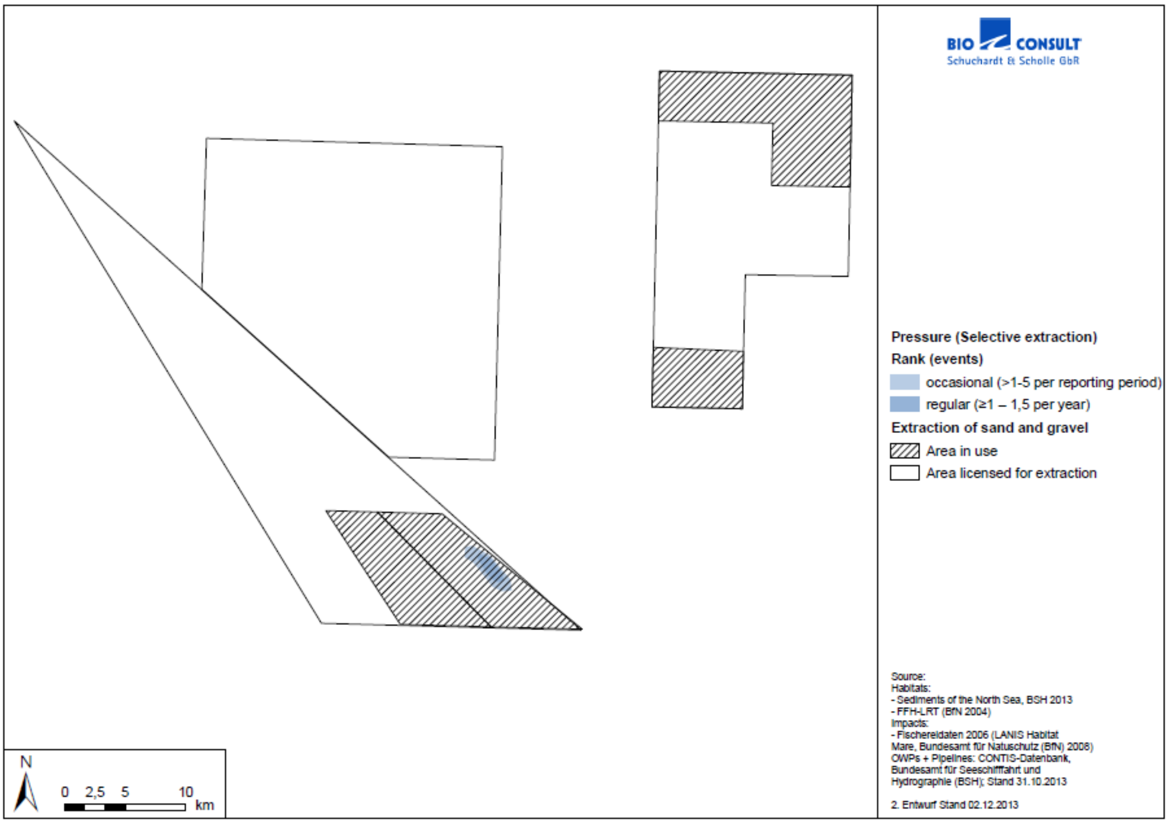

Figure 1-7: Pressure map for 'selective extraction' (detail of EEZ).

Physical damage: Abrasion

The pressure 'abrasion' in the German EEZ is caused by bottom trawling. Figure 1-8 shows the distribution and intensity of bottom trawling by beam and otter trawls in 2006.

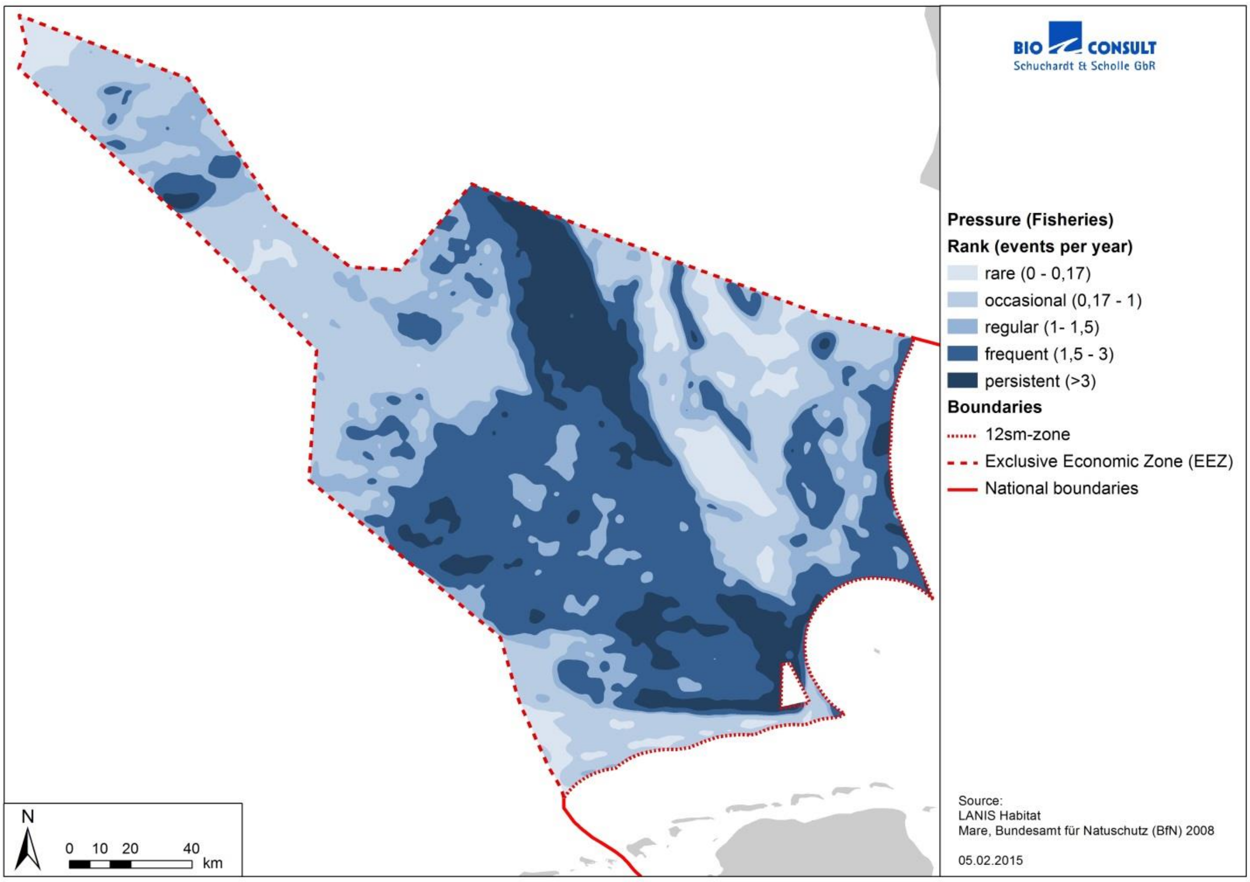

Figure 1-8: Pressure map for 'abrasion'.

Physical damage: Changes in siltation

'Changes in siltation' is a physical pressure associated with construction activities and dredging. Several construction works are currently ongoing in the German EEZ, mainly for offshore wind farms. Pressures resulting from the construction of power cables are not yet included in this assessment. For the extraction of sand and gravel the data from 2005 and 2006 were used with the uncertainties described for the pressure 'selective extraction' (Figure 1-9).

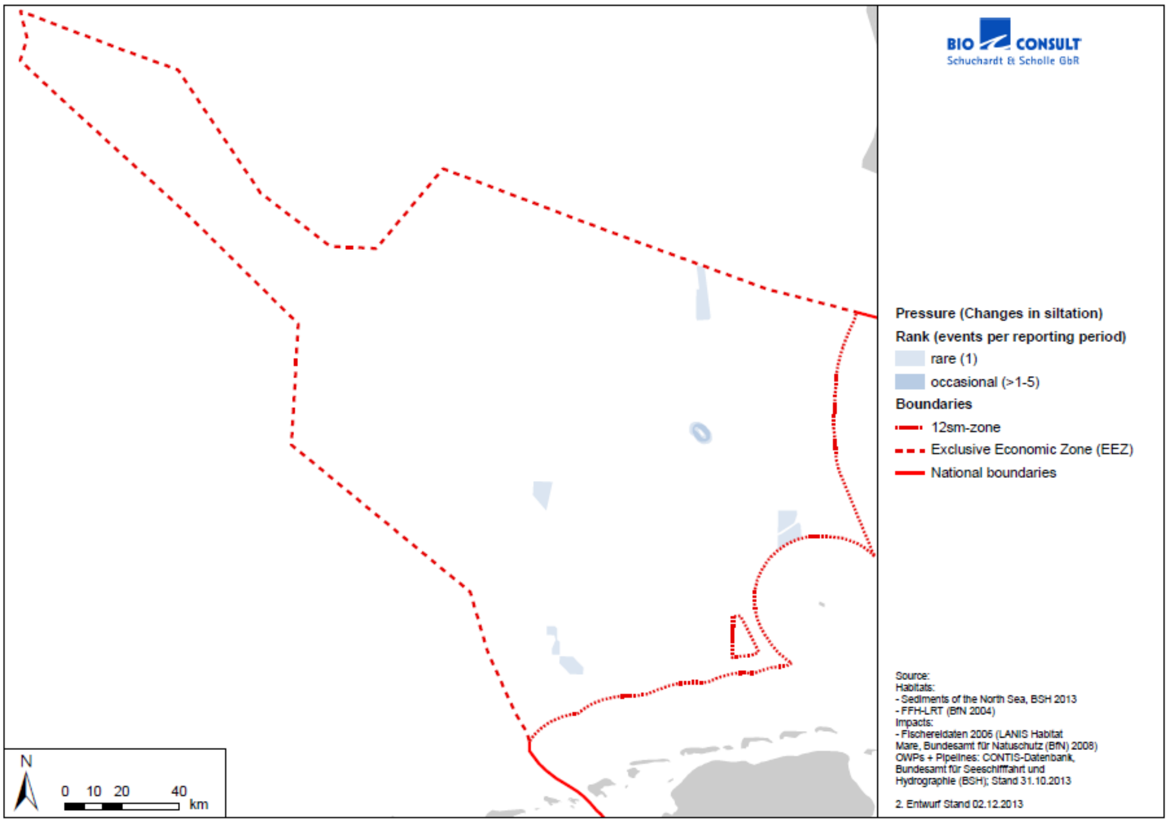

Figure 1-9: Pressure map for ‘changes in siltation‘.

1.5.3 Habitat sensitivity

Sensitivity maps were generated for each of the physical pressures according to the methodology described in chapter 1.4.3.3. The detailed assessments of the benthic habitats in the German EEZ are presented in chapter 1.7. Table 1-12 summarises the sensitivity ranks determined for the predominant and special habitats in the EEZ. The sandbank Doggerbank and further sandbanks on the Sylter Outer Reef and Borkum Reef Ground are listed separately as these habitats differ in their characteristic benthic communities. As an example, Figure 1-10 shows the sensitivity of benthic habitats towards the pressure ‘abrasion’.

Table 1-12: Summary of sensitivity ranks for benthic habitats in the German North Sea towards the physical loss and damage pressures.

	Sealing	Smothering	Selective extraction	Abrasion	Changes in siltation
Sublittoral sand	very high	very high	intermediate	low	very low
Sublittoral mud	very high	very high	not relevant	low	very low
Sublittoral coarse	very high	very high	intermediate	intermediate	low
Sandbanks (Doggerbank)	very high	very high	intermediate	intermediate	low
Other Sandbanks	very high	very high	intermediate	low	very low
Reefs	very high	very high	very high	high	intermediate
Species-rich coarse/gravel/shell	very high	very high	high	intermediate	low

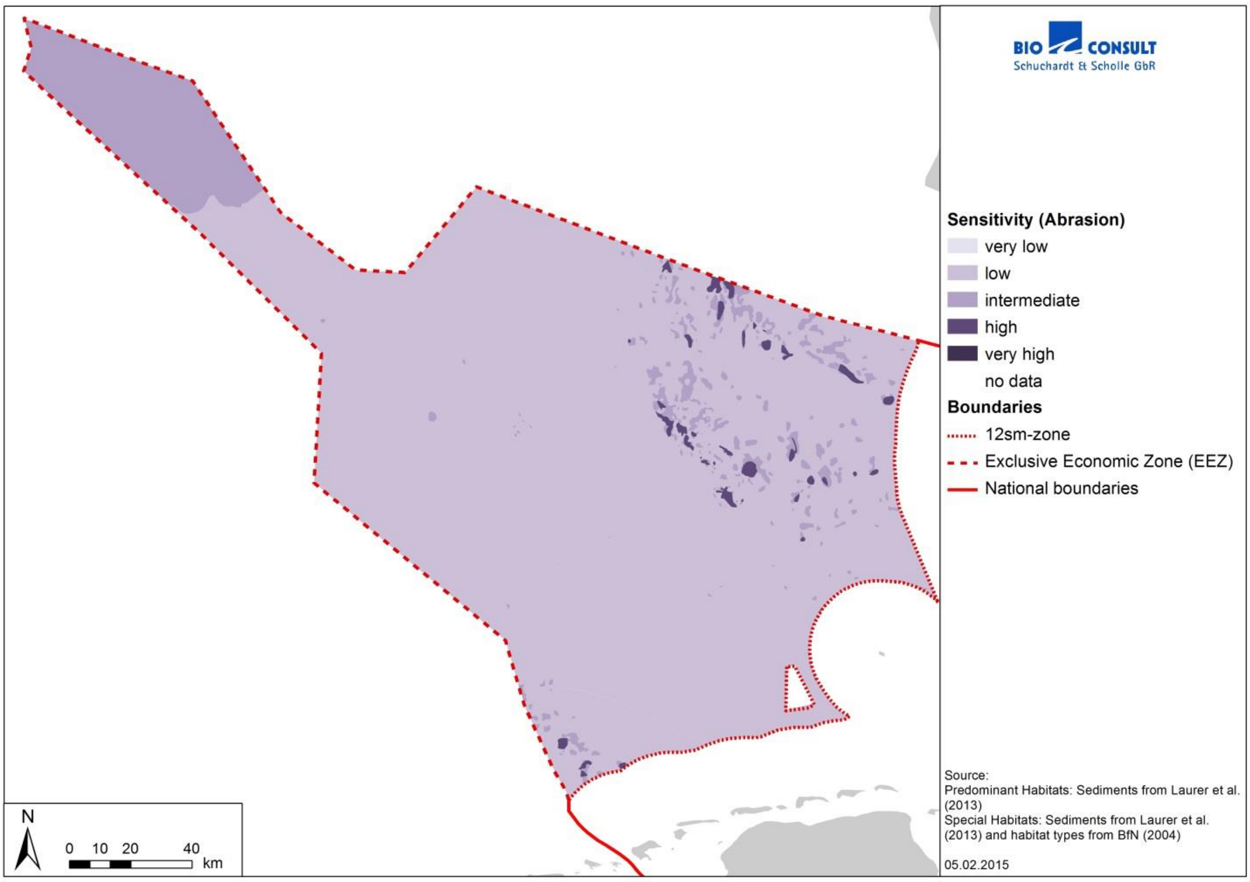

Figure 1-10: Habitat sensitivity towards the pressure ‘abrasion’.

1.5.4 Physical impact on benthic habitats

With the information from the pressure maps and the related habitat sensitivity maps combined, the potential impact of each of the pressures on benthic habitats is visualized. Figure 1-11 shows the impact map for the pressure ‘abrasion’ as an example. In

Table 1-14 and Table 1-15 the calculated absolute and relative area of benthic habitats impacted by each of the physical pressures is given.

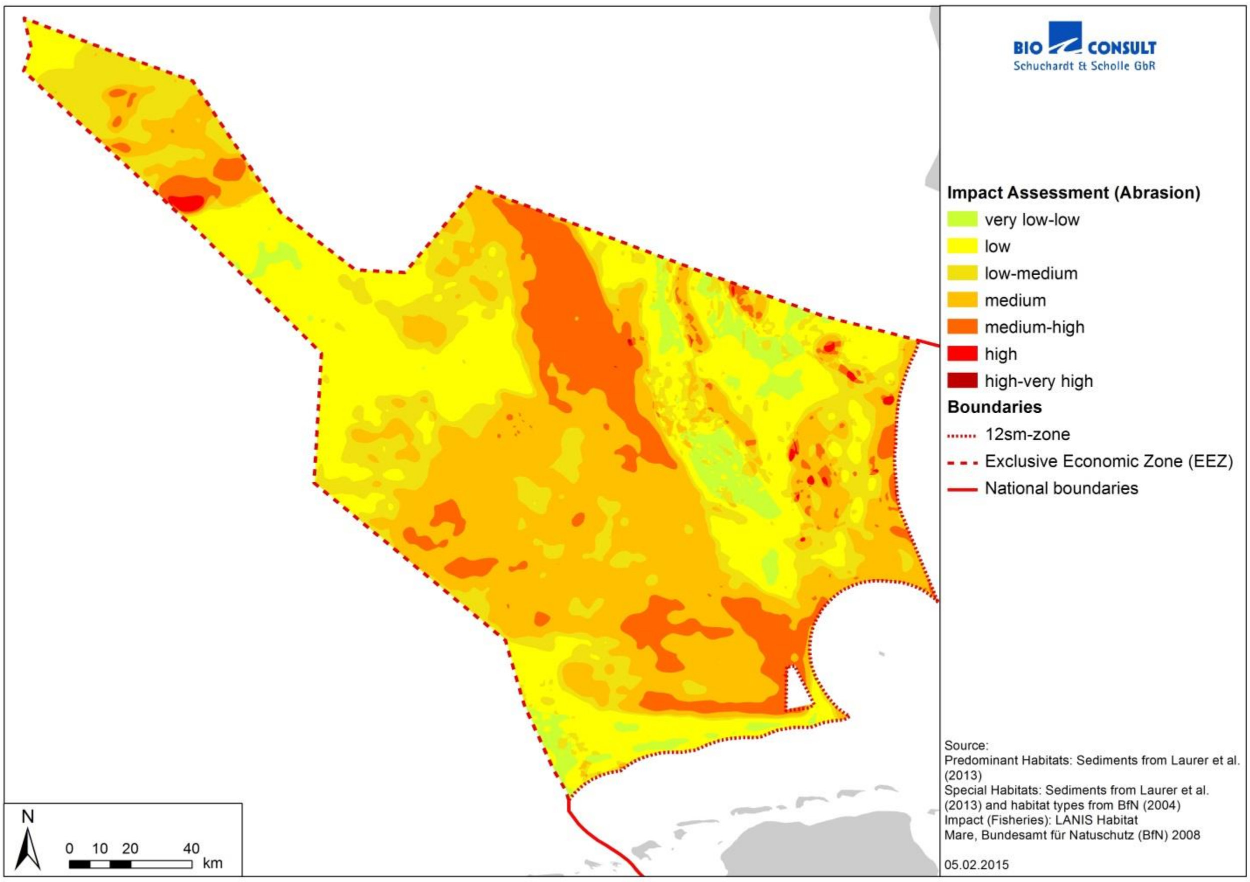

Figure 1-11: Impact on benthic habitats for the pressure 'abrasion'.

Table 1-13 summarises the total area of the German EEZ impacted by each of the physical pressures. In terms of area, 'abrasion' caused by bottom trawling is the main pressure which covers nearly the complete seabed of the EEZ (98.9 %). Areas without abrasion are solely the construction sites of offshore wind farms as well as operational wind farms. Areas subject to physical loss currently account for less than 0.01 % of the total area. The pressure 'changes in siltation' affects 1 % of the EEZ with the predominant activity being the construction of offshore wind farms. Selective extraction in 2005 / 2006 was restricted to an area of 0.02 % of the EEZ.

Table 1-13: Total area impacted by physical pressures in the German EEZ of the North Sea.

Pressure	**Area impacted [km²]**	**Area impacted [%]**
Sealing / smothering	1.2	<0.1
Selective extraction	6.3	<0.1
Abrasion	28142.8	98.9
Changes in siltation	283.3	1.0

Table 1-14: Area impacted (in km²) of benthic habitats in the German EEZ of the North Sea.

Habitat	**Pressure**	**Area impacted [km²]**									**Total area impacted [km²]**
		very low	very low – low	low	low – medium	medium	medium – high	high	high – very high	very high	
Sublittoral sand	Sealing / smothering	-	-	-	-	-	-	-	-	0.8	0.8
	Selective extraction	-	-	-	0.8	-	-	-	-	-	0.8
	Abrasion	-	1104.1	6424.1	3714.1	8538.7	2628.4	-	-	-	22409.5
	Changes in siltation	188.7	4.2	-	-	-	-	-	-	-	192.9
Sublittoral mud	Sealing / smothering	-	-	-	-	-	-	-	-	<0.1	<0.1
	Selective extraction	-	-	-	-	-	-	-	-	-	-
	Abrasion	-	0.9	310.5	273.0	385.6	453.6	-	-	-	142.,5
	Changes in siltation	0.2	-	-	-	-	-	-	-	-	0.2
Sublittoral coarse sedi-ment	Sealing / smothering	-	-	-	-	-	-	-	-	<0.1	<0.1
	Selective extraction	-	-	-	-	-	-	-	-	-	-
	Abrasion	-	-	55.7	230.9	121.1	121.7	10.2	-	-	539.5
	Changes in siltation	-	9.8	5.1	-	-	-	-	-	-	14.9
Sandbanks (Doggerbank)	Sealing / smothering	-	-	-	-	-	-	-	-	0.3	0.3
	Selective extraction	-	-	-	-	-	-	-	-	-	-
	Abrasion	-	-	230.7	1029.1	708.3	231.5	46.9	-	-	2246.6
	Changes in siltation	-	-	-	-	-	-	-	-	-	-
Other Sand-banks	Sealing / smothering	-	-	-	-	-	-	-	-	<0.1	<0.1
	Selective extraction	-	-	-	-	-	-	-	-	-	-
	Abrasion	-	194.3	571.3	86.1	182.6	16.9	-	-	-	1051.3
	Changes in siltation	44.8	-	-	-	-	-	-	-	-	44.8
Reefs	Sealing / smothering	-	-	-	-	-	-	-	-	-	<0.1
	Selective extraction	-	-	-	-	-	3.1	2.4	-	-	5.5
	Abrasion	-	-	-	109.2	62.8	25.6	39.4	1.2	-	238.2
	Changes in siltation	-	-	3.9	12.1	-	-	-	-	-	16.0
Species-rich coarse /gravel /shell	Sealing / smothering	-	-	-	-	-	-	-	-	<0.1	<0.1
	Selective extraction	-	-	-	-	-	-	-	-	-	-
	Abrasion	-	-	49.7	88.6	21.4	32.8	1.3	-	-	193.7
	Changes in siltation	-	9.3	1.1	-	-	-	-	-	-	10.4

Table 1-15: Area impacted (in %) of benthic habitats in the German EEZ of the North Sea.

Habitat	**Pressure**	**Area impacted [%]**									**Total area impacted [%]**
		very low	very low – low	low	low – medium	medium	medium – high	high	high – very high	very high	
Sublittoral sand	Sealing / smothering	-	-	-	-	-	-	-	-	<0.1	<0.1
	Selective extraction	-	-	-	<0.1	-	-	-	-	-	<0.1
	Abrasion	-	4.9	28.4	16.4	37.7	11.6	-	-	-	98.9
	Changes in siltation	0.8	<0.1	-	-	-	-	-	-	-	0.9
Sublittoral mud	Sealing / smothering	-	-	-	-	-	-	-	-	<0.1	<0.1
	Selective extraction	-	-	-	-	-	-	-	-	-	-
	Abrasion	-	0.1	21.7	19.1	27.0	31.8	-	-	-	99.7
	Changes in siltation	0.02	-	-	-	-	-	-	-	-	<0.1
Sublittoral coarse sedi-ment	Sealing / smothering	-	-	-	-	-	-	-	-	0.1	0.1
	Selective extraction	-	-	-	-	-	-	-	-	-	-
	Abrasion	-	-	10.2	42.2	22.1	22.3	1.9	-	-	98.7
	Changes in siltation	-	1.8	0.9	-	-	-	-	-	-	2.7
Sandbanks (Doggerbank)	Sealing / smothering	-	-	-	-	-	-	-	-	<0.1	<0.1
	Selective extraction	-	-	-	-	-	-	-	-	-	-
	Abrasion	-	-	10.3	45.8	31.5	10.3	2.1	-	-	100.0
	Changes in siltation	-	-	-	-	-	-	-	-	-	-
Other Sand-banks	Sealing / smothering	-	-	-	-	-	-	-	-	<0.1	<0.1
	Selective extraction	-	-	-	-	-	-	-	-	-	-
	Abrasion	-	17.7	52.0	7.8	16.6	1.5	-	-	-	95.7
	Changes in siltation	4.1	-	-	-	-	-	-	-	-	4.1
Reefs	Sealing / smothering	-	-	-	-	-	-	-	-	-	-
	Selective extraction	-	-	-	-	-	1.3	1.0	-	-	2.3
	Abrasion	-	-	-	45.4	26.1	10.7	16.4	0.5	-	99.1
	Changes in siltation	-	-	1.6	5.0	-	-	-	-	-	6.6
Species-rich coarse /gravel /shell	Sealing / smothering	-	-	-	-	-	-	-	-	<0.1	<0.1
	Selective extraction	-	-	-	-	-	-	-	-	-	-
	Abrasion	-	-	24.9	44.4	10.7	16.4	0.7	-	-	97.0
	Changes in siltation	-	4.6	0.6	-	-	-	-	-	-	5.2

1.5.5 Cumulative physical impact

The separate impact maps finally result in one cumulative impact map (Figure 1-12). The dominant physical pressure in the German EEZ is ‘abrasion’ caused by bottom trawling. Impacts which interfere with each other are areas with aggregate extraction and bottom trawling as well as pipelines and bottom trawling. Other human uses are mutually exclusive, for example construction works and bottom trawling or operational wind farms, where fishing is excluded. However, for the resulting cumulative impact it must be noted that fishing data are from 2006, where no wind farms were under construction. With several OWF areas excluded from trawling, it is possible that fishing effort has shifted to other areas and has actually increased elsewhere.

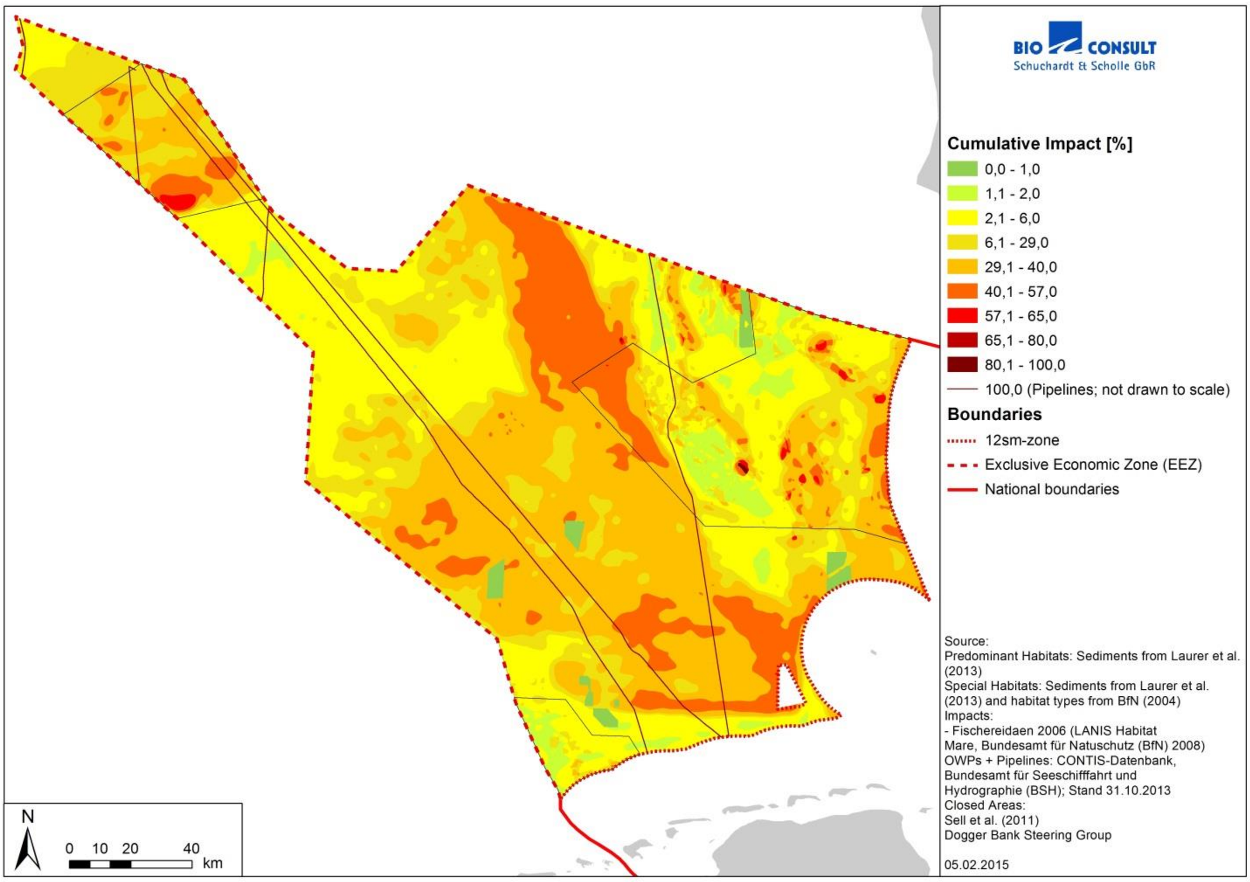

Figure 1-12: Cumulative physical impact on benthic habitats.

The cumulative physical impact has been calculated from the proportion of area impacted (A, [%]) for each habitat and the corresponding degree of impact (I, [%]) as derived from the impact matrices (see chapter 1.4.4). The cumulative impact (CI, [%]) for each habitat results from the sum of individual values for the relative impact on habitat:

$$CI = \sum I \times A / 100 \ [\%]$$

Table 1-16 gives an example for the calculation of the cumulative impact on the predominant habitat ‘sublittoral mud’.

Table 1-16: Calculation of cumulative impact as exemplified by the predominant habitat 'sublittoral mud'.

Pressure	**Rank of impact**	**Degree of impact (I [%])**	**Area impacted (A [%])**	**Relative impact on habitat (I x A /100 [%])**
Changes in siltation	very low	0.25	0.02	<0.01
Abrasion	very low - low	2	0.06	<0.01
Abrasion	low	6	21.74	1.3
Abrasion	low - medium	29	19.11	5.5
Abrasion	medium	40	27.00	10.8
Abrasion	medium - high	57	31.76	18.1
Sealing / smothering	very high	100	<0.01	<0.01
Cumulative impact (∑ Relative impact)				**35.8**

The resulting cumulative impact values are presented in Table 1-17. The calculated cumulative impact ranges from 13.3 % for sandbanks on the Borkum Reef Ground / Sylter Outer Reef to 43.2 % for reef habitats. The impact values mainly arise from high impacts of bottom trawling. Major parts of the benthic habitats are fished more than once a year, e.g. 50 % of the widespread sand habitats are subject to trawling more than once per year. The comparatively low cumulative impact value for 'other sandbanks' originates from the lower fishing pressure on the Borkum Reef Ground, where nearly 70 % of the sandbank area is trawled less than once a year. The high impact value for reefs is mainly caused by the high sensitivity towards 'abrasion' determined for this habitat.

Table 1-17: Calculated cumulative impact of physical loss and damage on benthic habitats.

Habitat	**Cumulative impact**
Sublittoral sand	28.3 %
Sublittoral mud	35.8 %
Sublittoral coarse sediment	35.7 %
Sandbanks (Doggerbank)	33.8 %
Other sandbanks	13.3 %
Reefs	43.2 %
Species-rich coarse/gravel/shell	28.5 %

1.5.6 Physical impacts on marine protected areas

The physical impact of the individual pressures has been calculated for benthic habitats in marine protected areas as well (Table 1-18, Table 1-19).

Sylter Outer Reef

The cumulative impact on benthic habitats in the Sylter Outer Reef ranges from 21.8 % for the predominant habitat ‘sublittoral sand’ to 52.9 % for ‘sublittoral mud’ (Table 1-20). High impact values were also calculated for ‘sublittoral coarse sediment’ (37.9 %), ‘sandbanks’ (41.9 %) and ‘reefs’ (47.0 %) The wide range of cumulative impact values corresponds to varying fishing intensity in the Sylter Outer Reef. While large parts of the Natura 2000 site were fished with low intensity, other areas were subject to persistent fishing pressure of up to five times per year.

Borkum Reef Ground

The only physical pressure affecting benthic habitats at the Natura 2000 site Borkum Reef Ground is ‘abrasion’ caused by bottom trawling. In 2006, fishing intensity was comparatively low with generally less than once per year. With the exception of reef habitats, the cumulative impact values for habitats in the Borkum Reef Ground were likewise relatively low, varying from 5.4 % to 21.8 % (Table 1-20). The habitat ‘sandbank’ which covers the major part of the protected site (75.1 %) holds the lowest cumulative impact value of 5.4 %. Due to the high sensitivity rank of reefs towards ‘abrasion’, the cumulative impact of this habitat type amounts to 35.4 %.

Doggerbank

The total area of the Doggerbank is subject to ‘abrasion’ by bottom trawling and is additionally crossed by three gas pipelines. The cumulative impact of the main habitat ‘sandbank’ (95.8 % of total area) at the Doggerbank accounts for 38.8 % (Table 1-20). The impact values for ‘sublittoral sand’ amounts to 20.9 % and for ‘sublittoral mud’ 6.0 %. However, muddy habitats cover only 0.02 % of the total area.

Table 1-18: Area impacted (in km²) of habitats in marine protected areas in the German EEZ of the North Sea.

Habitat	Pressure	Area impacted [km²]									Total area impacted [km²]
		very low	very low – low	low	low – medium	medium	medium – high	high	high – very high	very high	
Sylter Outer Reef											
Sublittoral sand	Sealing / smothering	-	-	-	-	-	-	-	-	0.1	0.1
	Selective extraction	-	-	-	0.8	-	-	-	-	-	0.8
	Abrasion	-	607.9	1595.3	855.2	1058.8	336.1	-	-	-	4453.3
	Changes in siltation	6.8	4.2	-	-	-	-	-	-	-	11.1
Sublittoral mud	Sealing / smothering	-	-	-	-	-	-	-	-	<0.1	<0.1
	Abrasion	-	0.6	1.5	-	26.4	106.5	-	-	-	135.0
Sublittoral coarse sediment	Sealing / smothering	-	-	-	-	-	-	-	-	<0.1	<0.1
	Abrasion	-	-	21.7	166.4	94.9	90.4	8.4	-	-	381.8
	Changes in siltation	-	2.5	5.1	-	-	-	-	-	-	7.6
Sandbanks	Abrasion	-	-	-	4.3	63.3	11.8	-	-	-	79.4
	Selective extraction	-	-	-	-	-	3.1	2.4	-	-	5.5
Reefs	Abrasion	-	-	-	62.1	39.0	17.9	34.5	<0.1	-	153.5
	Changes in siltation	-	-	4.7	12.1	-	-	-	-	-	16.8
Species-rich coarse /gravel /shell	Sealing / smothering	-	-	-	-	-	-	-	-	<0.1	<0.1
	Abrasion	-	-	21.5	47.7	12.9	14.5	0.3	-	-	96.8
	Changes in siltation	-	3.2	1.1	-	-	-	-	-	-	4.4
Borkum Reef Ground											
Sublittoral sand	Abrasion	-	34.3	30.2	6.3			-	-	-	70.8
Sublittoral mud	Abrasion	-		1.3				-	-	-	1.3
Sublitt. coarse	Abrasion	-		16.7	22.2	1.6		-	-	-	40.4
Sandbanks	Abrasion	-	142.0	307.6	12.1			-	-	-	461.8
Reefs	Abrasion	-			10.9	10.7	1.0	-	-	-	22.5
coarse /gravel	Abrasion	-		5.7	12.5	0.0		-	-	-	18.3
Doggerbank											
Sublittoral sand	Sealing / smothering	-	-	-	-	-	-	-	-	<0.1	<0.1
	Abrasion	-	-	33.8	19.4	16.2	1.1	-	-	-	70.5
Sublittoral mud	Abrasion	-	-	0.3	-	-	-	-	-	-	0.3
Sandbanks	Sealing / smothering	-	-	-	-	-	-	-	-	0.2	0.2
	Abrasion	-	-	1.2	631.8	701.8	231.5	46.9	-	-	1613.3

Table 1-19: Area impacted (in %) of habitats in marine protected areas in the German EEZ of the North Sea.

Habitat	Pressure	Area impacted [%]									Total area impacted [%]
		very low	very low – low	low	low – medium	medium	medium – high	high	high – very high	very high	
Sylter Outer Reef											
Sublittoral sand	Sealing / smothering	-	-	-	-	-	-	-	-	<0.1	<0.1
	Selective extraction	-	-	-	<0.1	-	-	-	-	-	<0.1
	Abrasion	-	13.7	35.8	19.2	23.8	7.5	-	-	-	100.0
	Changes in siltation	0.2	0.1	-	-	-	-	-	-	-	0.2
Sublittoral mud	Sealing / smothering	-	-	-	-	-	-	-	-	<0.1	<0.1
	Abrasion	-	0.5	1.1	-	19.6	78.9	-	-	-	100.0
Sublittoral coarse sedi-ment	Sealing / smothering	-	-	-	-	-	-	-	-	<0.1	<0.1
	Abrasion	-	-	5.7	43.6	24.9	23.7	2.2	-	-	100.0
	Changes in siltation	-	0.7	1.3	-	-	-	-	-	-	2.0
Sandbanks	Abrasion	-	-	-	5.5	79.6	14.9	-	-	-	100.0
	Selective extraction	-	-	-	-	-	2.0	1.6	-	-	3.5
Reefs	Abrasion	-	-	-	40.4	25.4	11.7	22.5	<0.1	-	100.0
	Changes in siltation	-	-	3.0	7.7	-	-	-	-	-	10.7
Species-rich coarse /gravel /shell	Sealing / smothering	-	-	-	-	-	-	-	-	<0.1	<0.1
	Abrasion	-	-	22.2	49.3	13.3	14.9	0.3	-	-	100.0
	Changes in siltation	-	3.3	1.2	-	-	-	-	-	-	4.5
Borkum Reef Ground											
Sublittoral sand	Abrasion	-	48.4	42.7	8.9			-	-	-	100.0
Sublittoral mud	Abrasion	-		100.0				-	-	-	100.0
Sublitt. coarse	Abrasion	-		41.2	54.9	3.9		-	-	-	100.0
Sandbanks	Abrasion	-	30.8	66.6	2.6			-	-	-	100.0
Reefs	Abrasion	-			48.2	47.4	4.3	-	-	-	100.0
coarse /gravel	Abrasion	-		31.2	68.7	0.1		-	-	-	100.0
Doggerbank											
Sublittoral sand	Sealing / smothering	-	-	-	-	-	-	-	-	<0.1	<0.1
	Abrasion	-	-	48.0	27.5	23.0	1.6	-	-	-	100.0
Sublittoral mud	Abrasion	-	-	100.0	-	-	-	-	-	-	100.0
Sandbanks	Sealing / smothering	-	-	-	-	-	-	-	-	0.3	0.3
	Abrasion	-	-	0.1	39.2	43.5	14.4	2.9	-	-	100.0

Table 1-20: Calculated cumulative impact of physical loss and damage on benthic habitats in marine protected areas.

Habitat	Proportion of total protected area (%)	Cumulative impact (%)
Sylter Outer Reef		
Sublittoral sand	84.0	21.8
Sublittoral mud	2.5	52.9
Sublittoral coarse sediment	7.3	37.9
Sandbanks	1.5	41.9
Reefs	2.9	47.0
Species-rich coarse/gravel/shell	1.8	29.7
Borkum Reef Ground		
Sublittoral sand	11.5	6.1
Sublittoral mud	0.2	6.0
Sublittoral coarse sediment	6.6	19.9
Sandbanks	75.1	5.4
Reefs	3.7	35.4
Species-rich coarse/gravel/shell	3.0	21.8
Doggerbank		
Sublittoral sand	4.2	20.9
Sublittoral mud	<0.1	6.0
Sandbanks	95.8	38.8

1.6 Further development of the assessment concept

With the present report a methodology for the national assessment of indicator 6.1.2 is proposed and successfully applied with current data of the German EEZ of the North Sea. In addition, suggestions have been made for setting of baselines and GES targets. The assessment concept is already at an advanced stage so as to allow for a good estimation of physical impacts on benthic habitats. It is acknowledged that the proposed modelling concept is a pragmatic approach which includes in some parts several assumptions and uncertainties. In order to improve the results of future assessments the following enhancements of the concept are suggested:

- Improvement of sensitivity assessment with results of currently ongoing habitat mapping project by the Bundesamt für Naturschutz (BfN),
- validation of the assessment concept with levels of confidence,

- analysis of possible linking between indicator 6.1.2 and indicators associated with criteria 6.2 'condition of benthic habitats',
- development of a reference state for benthic habitats in the German North Sea: the sensitivity assessment of habitats should ideally be based on the reference state,
- calibration of assessment concept: either by integration of 'condition indicators' or by directly monitoring different levels of known human impact and
- modification and application of the assessment concept for coastal waters.

For further assessments it should as well be tried to improve data base, especially on fishing pressure and aggregate extraction. In order to achieve a conclusive result for the assessment of GES, data on human activities should cover the corresponding reporting period of six years.

In spite of these unresolved issues, the proposed methodology presents a major step for assessing cumulative physical impacts on benthic habitats. The concept provides a simple, cost-effective and informative method which is easily applicable to other marine regions. The approach also enables to determine if the Good Environmental Status is achieved and offers the knowledge base to implement management actions.

1.7 Annex: Sensitivity assessment of benthic habitats

1.7.1 Characteristic species for the sensitivity assessment

Rachor & Nehmer (2003) identify seven large-scale benthic communities in the German EEZ of the North Sea, which are mainly discriminated according to prevailing substrate. Figure 1-13 shows the spatial distribution of the benthic associations described by Rachor & Nehmer (2003).

Rachor & Nehmer (2003) differentiate between several benthic associations in sandy habitats, but their analyses do not describe a separate community in muddy habitats. Characteristic species for the habitat type 'sublittoral sand' can thus be found in the *Nucula-nitidosa*-, the *Amphiura-filiformis*- and the *Tellina-fabula*-association. A further benthic community on sand, the *Bathyporeia-Tellina*-association, settles exclusively on the sandbank Doggerbank and therefore the corresponding characteristic species can be used to assess sensitivity in this area. The areas defined as 'sublittoral mud' are mainly settled by the *Amphiura-filiformis*-association, so this community is used for the biological sensitivity assessment of mud habitats. Coarse sediments in the south-eastern North Sea are settled by the *Goniadella-Spisula*-association. Rachor & Nehmer (2003) differentiate two variations of this association in the EEZ, which correspond to the definition of 'sublittoral coarse sediment' (*Goniadella-Spisula*-association on medium and coarse sands) and the special habitat type 'species-rich habitats on coarse sands, gravel or shell debris' (*Goniadella-Spisula*-association on coarse sands and gravel). Table 1-21 lists predominant and special habitat types and the corresponding benthic communities and associated characteristic species identified by Rachor & Nehmer (2003), which are preliminarily used for the sensitivity assessment. For the criteria applied for the selection of characteristic species see also Rachor

(2007). Rachor & Nehmer (2003) did not identify characteristic species for reef habitats, therefore the species list proposed by Nehls et al. (2008) is used. For the habitat 'species-rich habitats on coarse sands, gravel and shell debris' it is also referred to the mapping guidelines by the BfN (2011). Further information on the selection of characteristic species can be found in the respective chapters.

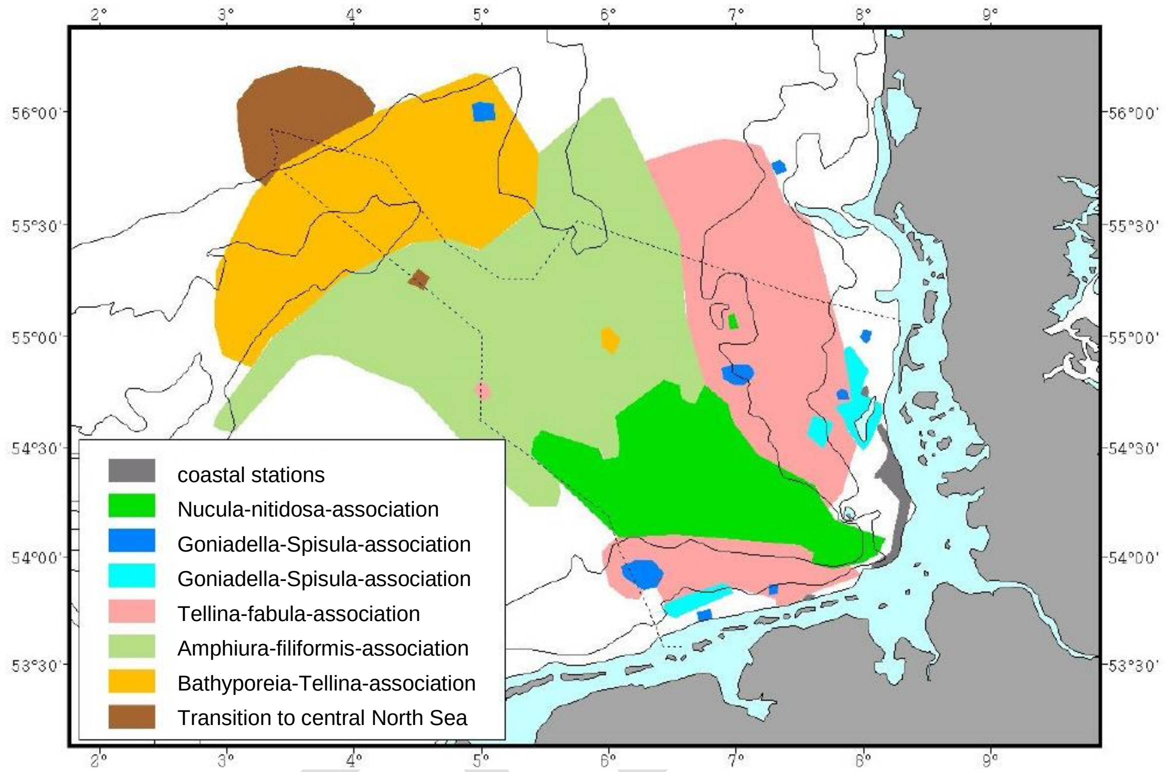

Figure 1-13: Spatial distribution of benthic assemblages in the German North Sea according to Rachor & Nehmer (2003).

Table 1-21: Habitat types in the German North Sea, the corresponding benthic associations according to Rachor & Nehmer (2003) and the characteristic species used for the sensitivity assessment

Habitat type	**Benthic association**	**Characteristic species**
Sublittoral sand	*Tellina-fabula*	*Magelona johnstoni* *Tellina fabula* *Urothoe poseidonis* *Bathyporeia guilliamsoniana*
	Nucula-nitidosa	*Nucula nitidosa* *Abra alba* *Scalibregma inflatum*
	Amphiura-filiformis	*Amphiura filiformis* *Mysella bidentata* *Harpinia antennaria* *Corbula gibba*
Sublittoral mud	*Amphiura-filiformis*	*Amphiura filiformis* *Mysella bidentata* *Harpinia antennaria*
Sublittoral coarse sediment	*Goniadella-Spisula*	*Aonides paucibranchiata* *Ophelia limacina* *Thracia* spp.
	Goniadella-Spisula on coarse and medium sands	*Goodallia triangularis* *Spisula solida* *Angulus tenuis*
Sandbanks	*Bathyporeia-Tellina* (Doggerbank)	*Amphiura brachiata* *Spiophanes bombyx* *Lanice conchilega* *Bathyporeia spp.* *Cerianthus lloydii* *Tellina fabula* *Spio decoratus*
	Tellina-fabula (Borkum Reef Ground, Sylter Outer Reef)	*Magelona johnstoni* *Tellina fabula* *Urothoe poseidonis* *Bathyporeia guilliamsoniana*
Reefs	-	*Leucosolenia botryoides* *Alcyonium digitatum* *Pomatoceros triquiter* *Flustra foliacea* *Balanus crenatus* *Pholas dactylus* *Cancer pagurus* *Echinus esculentus* *Ciona intestinalis*
Species-rich habitats on coarse sands, gravel or shell debris	*Goniadella-Spisula* on coarse sands and gravel	*Aonides paucibranchiata* *Branchiostoma lanceolatum* *Echinocyamus pusillus* *Spisula elliptica* *Pisione remota*

1.7.2 Sublittoral sand

According to Rachor & Nehmer (2003), the sublittoral sand habitats in the German EEZ are inhabited by several benthic associations. Species used for the assessment are characteristic species identified for the *Tellina-fabula*-, the *Nucula-nitidosa*- and the *Amphiura-filiformis*-association. These associations are treated separately, however, the overall sensitivity rank does not differ between the communities.

1.7.2.1 Selective extraction

Table 1-22: Sensitivity of sublittoral sand towards the pressure 'selective extraction'.

Selective extraction		Resistance	Recoverability	Sensitivity
Physical habitat		low	high	intermediate
Tellina fabula-association	*Tellina fabula*	low	moderate	intermediate
	Magelona johnstoni	low	high	intermediate
	Urothoe poseidonis	low	high	intermediate
	Bathyporeia guillamsioniana	low	high	intermediate
Habitat sensitivity sublittoral sand + *Tellina-fabula*-association				**intermediate**
*Nucula-nitidosa--*association	*Nucula nitidosa*	low	moderate	intermediate
	Abra alba	low	high	intermediate
	Scalibregma inflatum	low	high	intermediate
Habitat sensitivity sublittoral sand + *Nucula-nitidosa*-association				**intermediate**
*Amphiura-filiformis-*association	*Amphiura filiformis*	low	moderate	intermediate
	Mysella bidentata	low	high	intermediate
	Harpinia antennaria	low	not assessed	not assessed
	Corbula gibba	low	high	intermediate
Habitat sensitivity sublittoral sand + *Amphiura-filiformis*-association				**intermediate**

Physical habitat – explanatory notes

The extraction of sediment implies the complete removal of substrate by creating longitudinal tracks of generally 2-3 m width and up to 50 cm depth (trailer suction dredging) or rounded pits of around 10 m depth and with a diameter of 10-50 m (anchor dredging). Severe alterations of seabed topography and possibly also changes in sediment composition occur, therefore resistance to selective extraction is rated as low.

Physical seabed structures are supposed to have recovered when dredge tracks have disappeared and the original sediment composition is restored. Research on seabed recovery mostly focuses on observation of dredge furrows, while the recovery of sediment composition may take far longer but is less intense investigated. The disappearance of furrows may take place due to infilling where there is naturally high sediment transport or from dredging overflow. Existing furrows may also collapse or changed hydrodynamics may further erode dredge tracks. The infilling of furrows by fine sediment particles is associated with a decrease in sediment size and an increase in sediment instability and may thus prolong recovery time. Typical conditions for a fast recovery (months – 1 year) following extraction are high energy environments, fine sediments including sand, already disturbed communities and dominance of r-selected species, whereas slow recovery (years – decades) is predicted in moderate to low energy environments, with coarse sands, stable communities and a dominance of K-selected species. Additional factors influencing physical recovery are the method and intensity of dredging, the total area dredged and the extent of changes in sediment composition (Hill et al. 2011).

In the southern North Sea where tidal currents are generally strong, sand with a grain size up to 2 mm is mobile across the area during spring tides and may aid in the infilling of dredge tracks (Hill et al. 2011). Typical time-scales for the regeneration of dredge furrows in sandy substrates are in the range of months. In the German Baltic Sea in a shallow area of 8-10 m depth with fine to medium sands, furrows created by trailer suction dredging were observed to refill within months. In contrast, at another extraction site in the German Baltic Sea with fine sands in water depths between 14 and 21 m dredge tracks were still visible after ten years. At an extraction site west of Sylt stationary dredging was deployed creating pits of around 10 m depth and up to 2000 m in diameter. Bathymetric investigations revealed that only 10 % of the pits were refilled after cessation of dredging (ICES 2009).

Regarding the recoverability of sandy habitats in the areas licensed for extraction in the German North Sea considerable uncertainties remain. As investigation reports of the areas currently in use which could support the assessment are not available, the recovery time of sublittoral sand is preliminarily judged as high (1-2 years). The assessment is understood as precautionary, due to the sediment properties and the presumably moderate energy at the seabed, recovery of at least dredge tracks may as well be faster.

Characteristic species (*Tellina-fabula*-association) – explanatory notes

(Information on species characteristics is taken from the MarLIN web site unless otherwise stated)

The majority of species in the sublittoral sand is infaunal and would therefore be removed along with the substratum. Only some epifaunal and swimming species may be able to avoid the impact. The characteristic amphipods *Urothoe poseidonis* and *Bathyporeia guillamsioniana* settle the uppermost centimetres of sandy sediment and are thus also removed. Resident populations would be lost, so resistance for all characteristic species is assessed as low.

The bivalve *Tellina fabula* spawns at least once a year and has a protracted breeding period. The number of gametes is likely to be high with a larval phase of at least one month. The species therefore has high dispersal potential, however, post settlement development is not particularly rapid and the species may take two or more years to mature. Experimental data suggest that *Tellina fabula* would colonize available sediments in the year following environmental perturbation, but that a breeding population may take two or more years to establish. It is expected that full recovery would occur within five years and so recoverability is assessed as moderate.

The polychaete genus *Magelona* spp. displays characteristics typical of an r-selected species, i.e. rapid reproduction, short life span and high dispersal. The larval dispersal phase would potentially allow the species to colonize remote habitats. It is expected that populations of *Magelona* spp*.* would recover within two or three years and certainly within five years. Recoverability is therefore assessed as moderate.

Urothoe poseidonis is a small amphipod with moderate mobility which lives on the sediment surface and in shallow burrows. Sexual maturity is achieved at five month and a large number of reproductions with about 15 eggs per brood occur in a 15-day cycle during the breeding season between April and October. The genus thus has a relatively high fecundity and subsequent growth rate but a very limited dispersal potential (MES 2008). Recovery time is judged as high.

Repopulation of defaunated sediments by the amphipod *Bathyporeia* spp. is likely to be rapid. The genus is likely to have a high to very high capacity for recovery from many factors of disturbance. It is a short-lived genus which reaches maturity after six months and produces two generations within a year. There is no opportunity for larval dispersal as they are brooded, but adults are highly mobile in the water column and thus recovery potential is very high (MES 2008).

Characteristic species (*Nucula-nitidosa*-association) - explanatory notes

(Information on species characteristics is taken from the MarLIN web site unless otherwise stated)

The majority of species in sublittoral coarse sediment is infaunal and would therefore be removed along with the substratum. Only some epifaunal and swimming species may be able to avoid the impact. Resident populations of the benthic endofauna would be lost, so resistance for all characteristic species is assessed as low.

The life-span of the bivalve *Nucula nitidosa* ranges from 7-10 years with 2-3 years to reach sexual maturity. *Nucula nitidosa* reproduces in high numbers, but has a limited dispersal potential as larvae settle in the vicinity of the adults. Long-distance dispersal is potentially poor. If a population is removed from an area, it may take a long time for the area to be recolonized, depending on the local hydrography. Recoverability is assessed as moderate.

Abra alba spawns at least twice a year over a protracted breeding period, during which time an average sized animal of 11 mm can produce between 15000 to 17000 eggs. Such egg production ensures successful replacement of the population, despite high larval mortality which is characteristic of planktonic development. Timing of spawning and settlement suggests that the larval planktonic phase lasts at least a month, in which time the larvae may be transported over a considerable distance. In addition to dispersal via the plankton, dispersal of post-settlement juveniles may occur via byssus drifting and probably bedload transport. Experimental data suggest that *Abra alba* would colonize available sediments within the year following environmental perturbation. Summer settled recruits may grow very rapidly and spawn in the autumn, whilst autumn recruits experience delayed growth and may not reach maturity until the following spring/summer. In the worst instance, a breeding population may take up to two years to fully establish and so recoverability has been assessed to be high.

Little is known of the longevity, egg size or fecundity of *Scalibregma inflatum*. The sexes are separate and there is one spawning between October-December after which the adults die. The reproductive epitoke stage is pelagic for a short time but there is no true larval stage (MES 2008). It is estimated that *Scalibregma inflatum* has a high recoverability.

Characteristic species (*Amphiura-filiformis*-association) - explanatory notes

(Information on species characteristics is taken from the MarLIN web site unless otherwise stated)

Breeding of *Amphiura filiformis* is annual and in the UK one period of recruitment occurs in the autumn. The larvae of this species can disperse over considerable distances due to their long planktonic existence. Adults, although mobile, are not highly active. Some immigration of adults from nearby populations may be possible. However, it can take approximately 5-6 years for *Amphiura filiformis* to grow to maturity so population structure may not return to original levels for at least this length of time. Several studies observed high mortality rates of new settling *Amphiura filiformis* and low rates of recruitment. Therefore, it seems likely that after removal of all or most of the population recovery will be determined by the presence of suitable hydrodynamic forces providing new larvae. Once settled the population is likely to take longer than five years to return to maturity and so recoverability has been suggested to be moderate.

The bivalve *Mysella bidentata* has a generation time of one year, a relatively high fecundity and a planktonic larval phase. It is estimated that recoverability is high.

Information on the amphipod *Harpinia antennaria* is currently not sufficient to assess sensitivity.

The life span for individuals of *Corbula gibba* is about 1-2 years. It has a rapid growth rate in the first few months of its life and the ability to survive in a wide range of environmental conditions and the capacity to achieve high population densities. *Corbula gibba* is known to be a pioneer species in recolonization of defaunated seabeds. The settling time of larvae is variable and may change depending on location and may take several months. In Danish waters there were high mortalities of newly settled individuals during the first month of settling. Overall it is likely that this species has good powers of population recovery. A population that is reduced in extent or abundance could potentially recover within a few years, depending on recruitment. Its ability to recolonize defaunated area suggests that the population would recover in a relatively short period of time even if the population was removed. Recoverability is judged to be high.

1.7.2.2 Abrasion

Table 1-23: Sensitivity of sublittoral sand towards the pressure 'abrasion'.

Abrasion		Resistance	Recoverability	Sensitivity
Physical habitat		intermediate	very high	low
Tellina fabula-association	*Tellina fabula*	intermediate	high	low
	Magelona johnstoni	intermediate	high	low
	Urothoe poseidonis	intermediate	very high	low
	Bathyporeia guillamsioniana	tolerant	not relevant	not sensitive
Habitat sensitivity sublittoral sand + *Tellina-fabula*-association				**low**
Nucula-nitidosa-association	*Nucula nitidosa*	intermediate	high	low
	Abra alba	intermediate	very high	low
	Scalibregma inflatum	intermediate	high	low
Habitat sensitivity sublittoral sand + *Nucula-nitidosa*-association				**low**
Amphiura-filiformis-association	*Amphiura filiformis*	high	very high	very low
	Mysella bidentata	intermediate	high	low
	Harpinia antennaria	not assessed	not assessed	-
	Corbula gibba	intermediate	high	low
Habitat sensitivity sublittoral sand + *Amphiura-filiformis*-association				**low**

Physical habitat – explanatory notes

Impacts of fishing gears on sandy habitats include the removal of habitat complexity by flattening of biogenic structures or sand ripples, the penetration of sediment and smothering by resuspended sediment. Otter trawls generally disturb the upper 1-5 cm while beam trawls scour the sediment down to 8 cm (FAO 2004). Resistance towards abrasion is assessed as intermediate.

Physical restoration has been observed to be rapid (days to few months) in sandy habitats (Environment Agency 2010). In a study comparing the responses of various sediment types to physical disturbance, Dernie et al. (2003) found that clean sand communities had the most rapid recovery rate. Schwinghamer et al. (1996) examined the effect of otter trawls on habitats with fine and medium grained sand in the Grand Banks after trawling had stopped. The tracks left by the trawl doors were visible for at least ten weeks but not visible or only faintly visible after one year. Recoverability is therefore suggested to be very high.

Characteristic species (*Tellina-fabula*-association) – explanatory notes

(Information on species characteristics is taken from the MarLIN web site unless otherwise stated)

Despite their robust body form, bivalves are vulnerable to physical abrasion. *Tellina fabula* is a shallow burrower with a fragile shell and may be damaged by an impact with fishing gear so resistance is recorded as intermediate. As presumably not the whole population is affected, recoverability is assessed as high.

Magelona spp. is a small polychaete which exposes its palps at the surface while feeding. The species lives infaunally in sandy sediment, usually within a few centimetres of the sediment surface. Physical disturbance, such as dredging or dragging an anchor, would be likely to penetrate the upper few centimetres of the sediment and cause physical damage to *Magelona* spp. Resistance is therefore recorded as intermediate. Due to the rapid reproduction, short life span and high dispersal potential of *Magelona*, recoverability is recorded as high.

The amphipod *Urothoe poseidonis* burrows in the upper centimetres of sediment. It has a moderate mobility and may therefore be affected by fishing gears. Resistance is assessed as intermediate. The genus has a relatively high fecundity and subsequent growth rate so that potential recovery time is judged as very high (MES 2008).

Bathyporeia spp. are highly mobile amphipod species so that they are unlikely to be damaged by abrasion. Therefore, *Bathyporeia guillamsioniana* has been assessed as tolerant.

Characteristic species (*Nucula-nitidosa*-association) - explanatory notes

(Information on species characteristics is taken from the MarLIN web site unless otherwise stated)

Fishing for demersal species will disturb the surface layer of sediment and any protruding or shallow burrowing species. Even though the bivalve *Nucula nitidosa* has a small thick shell, it is probably vulnerable to physical damage from e.g. otter boards but its small size relative to the meshes of commercial trawls may ensure survival of at least a moderate proportion of disturbed individuals that pass through the nets. A manipulative field experiment in a fine muddy habitat reported a decline in the population density of *Nucula nitidosa* after five months of trawling disturbance, which remained significantly lower than the reference control area after ten months. Therefore resistance has been assessed as intermediate as mortality may occur, and recoverability has been assessed as high. The life-span of *Nucula nitidosa* ranges from 7-10 years with 2-3 years to reach sexual maturity. *Nucula nitidosa* reproduces in high numbers, but has a limited dispersal potential as larvae settle in the vicinity of the adults. Overall, *Nucula nitidosa* is likely to exhibit good local, within-population recruitment. Therefore, if the extent of abundance of a population is reduced, recoverability is likely to be high.

The bivalve *Abra alba* is a shallow burrower with a fragile shell and may be damaged by physical impact. Bergmann & Santbrink (2000) reported between <0.5%and 18% mortality of *Abra alba* due to trawling in the southern North Sea, depending on the type of trawl (12 m or 6 m beam trawl or otter trawl). They included *Abra alba* amongst their list of bivalve species most vulnerable to trawling. Therefore, resistance has been assessed to be intermediate. The life history characteristics of *Abra alba* and its widespread distribution contribute to its powers of recoverability. *Abra alba* spawns at least twice a year over a protracted breeding period, during which time an average sized animal of 11 mm can produce between 15000 to 17000 eggs. Such egg production ensures successful replacement of the population, despite high larval mortality which is characteristic of planktonic development. Timing of spawning and settlement suggests that the larval planktonic phase lasts at least a month, in which time the larvae may be transported over a considerable distance. In addition to dispersal via the plankton, dispersal of post-settlement juveniles may occur via byssus drifting and probably bedload transport. Recoverability is likely to be very high in instances where a proportion of the adult population survives.

Scalibregma inflatum is a small to medium sized polychaete worm which burrows in sediment. Infaunal polychaetes with little mobility are likely to be damaged by abrasion and suffer some degree of mortality. Resistance is judged as intermediate. Little is known of the longevity, egg size or fecundity of this species. The sexes are separate and there is one spawning between October-December after which the adults die. The reproductive epitoke stage is pelagic for a short time but there is no true larval stage (MES 2008). Providing that part of the population survives, *Scalibregma inflatum* is likely to have a high recoverability.

Characteristic species (*Amphiura-filiformis*-association) - explanatory notes

(Information on species characteristics is taken from the MarLIN web site unless otherwise stated)

Brittlestars have fragile arms which are likely to be damaged by abrasion. *Amphiura filiformis* burrows in the sediment and extends only its arms when feeding. Literature reviews suggest that *Amphiura* spp. may be less susceptible to beam trawl damage than other species like echinoids or tube dwelling amphipods and polychaetes. Brittlestars can tolerate considerable damage to arms and even the disk without suffering mortality and are capable of arm and even some disk regeneration. Resistance to abrasion is therefore recorded as high. Individuals can still function whilst regenerating a limb so recovery will be rapid.

Due to their small size, the bivalve *Mysella bidentata* may escape damage from trawling although they may experience increased predation before re-burrowing. *Mysella bidentata* is often preferentially found in the structured irrigated burrows of host species such as *Amphiura filiformis* and if the top layers of sediment are ploughed this structure will be lost. Resistance has been assessed as intermediate. Recovery is likely to be high.

Information on the amphipod *Harpinia antennaria* is currently not sufficient to assess sensitivity.

The small solid shells of *Corbula gibba* may be vulnerable to physical damage (from e.g. otter boards) However, the size of *Corbula gibba* relative to the meshes of commercial trawls may ensure survival of a moderate proportion of disturbed individuals that pass through them. Specimens exposed on the sediment surface would be at risk of predation. Experimental trawling studies resulted in varying mortality rates. Therefore a resistance of intermediate is recorded with a high recovery level.

1.7.2.3 Changes in siltation

Table 1-24: Sensitivity of sublittoral sand towards the pressure 'changes in siltation'.

Changes in siltation		Resistance	Recoverability	Sensitivity
Physical habitat		high	very high	very low
Tellina fabula-association	*Tellina fabula*	high	very high	very low
	Magelona johnstoni	high	very high	very low
	Urothoe poseidonis	high	very high	very low
	Bathyporeia guillamsioniana	high	very high	very low
Habitat sensitivity sublittoral sand + *Tellina-fabula*-association				**very low**
Nucula-nitidosa--association	*Nucula nitidosa*	high	very high	very low
	Abra alba	high	very high	very low
	Scalibregma inflatum	tolerant	not relevant	-
Habitat sensitivity sublittoral sand + *Nucula-nitidosa*-association				**very low**
Amphiura-filiformis-association	*Amphiura filiformis*	high	very high	very low
	Mysella bidentata	high	very high	very low
	Harpinia antennaria	not assessed	not assessed	-
	Corbula gibba	high	very high	very low
Habitat sensitivity sublittoral sand + *Amphiura-filiformis*-association				**very low**

Physical habitat – explanatory notes

Sediment plumes generated by construction works or aggregate extraction may cause changes in habitat structure such as infilling of small pits by fine sediments, siltation within crevices or development of migratory sand ripples (Hill et al. 2011). Finer sediment particles remain in suspension longer than larger particulates and can disperse over a wider area. Suspended fine and medium sands require a few hours for resettlement whereas silty sediments may remain in suspension for a few days (OSPAR 2008). In habitats with strong seabed transport recovery may be fast as fine sediments are rapidly mobilized. Resistance of sublittoral sand habitats is therefore regarded as high and recovery time as very high.

Characteristic species (*Tellina-fabula*-association) – explanatory notes

(Information on species characteristics is taken from the MarLIN web site unless otherwise stated)

Tellina fabula is a shallow burrower in sandy sediments. It requires its inhalant siphon to be above the sediment surface for feeding and respiration. Smothering with 5 cm of sediment would temporarily halt feeding and respiration and requires the species to relocate to its preferred depth. *Tellina fabula* is an active burrower and would be expected to relocate with no mortality. However, growth and reproduction may be compromised and so resistance is assessed as high. Growth and reproduction would return to normal following relocation so recoverability is immediate.

Magelona spp. lives infaunally in fine sand and moves by burrowing. It deposit feeds at the surface by extending contractile palps from its burrow. An additional 5 cm layer of sediment would result in a temporary cessation of feeding activity, and therefore growth and reproduction are likely to be compromised. However, *Magelona* would be expected to quickly relocate to its favoured depth, with no mortality, and hence a high resistance is recorded. Once the animals have relocated to the surface, feeding activity should return to normal and therefore recoverability is suggested to be immediate.

Urothoe poseidonis is an amphipod burrowing in sediment which is likely to be able to accommodate deposition of sediment (MES 2008). The population may still suffer from reduced viability, so tolerance is assessed as high. Recoverability after smothering is assumed to be rapid.

The amphipod *Bathyporeia* spp. would probably be unaffected by an additional covering of sediment of a texture within its habitat preference, although there may be an energetic cost incurred by the additional burrowing activity required to attain a near-surface position for feeding and to swim. *Bathyporeia* spp. is likely to be more intolerant of smothering by both coarser and finer particles through which burrowing is likely to be hindered. Consequently, the resistance of *Bathyporeia guillamsoniana* to an increase in sedimentation has been assessed to be high. The species is likely to have a very high capacity for recovery.

Characteristic species (*Nucula-nitidosa*-association) - explanatory notes

(Information on species characteristics is taken from the MarLIN web site unless otherwise stated)

The bivalve *Nucula nitidosa* can tolerate anaerobic conditions for several days and is able to thrive in poorly aerated sediments. It is therefore suggested that this ability to tolerate anaerobic conditions and their mobility allows them to survive when covered by sediments. Therefore, a high resistance has been recorded. Recoverability is assumed to be very high.

Abra alba is a shallow burrower in muddy sediments. It requires its inhalant siphon to be above the sediment surface for feeding and respiration. Sudden smothering with 5 cm of sediment would temporarily halt feeding and respiration and requires the species to relocate to its preferred depth. As an active burrower *Abra alba* would be expected to relocate with no mortality. However, growth and reproduction may be compromised owing to energetic expenditure and so resistance has been assessed to be high. Growth and reproduction would return to normal following relocation so recoverability is recorded as very high.

The polychaete *Scalibregma inflatum* burrows in sediment and is a sub-surface deposit feeder exploiting detritus (MES 2008). Therefore the species is suggested to be tolerant of smothering.

Characteristic species (*Amphiura-filiformis*-association) - explanatory notes

(Information on species characteristics is taken from the MarLIN web site unless otherwise stated)

Amphiura filiformis is an infaunal species which can burrow and lives up to a depth of 4 cm within the sediment. Therefore, smothering by sediment of 5 cm is unlikely to have great effect although feeding and hence viability of the population may be reduced if the sediment is particularly fine and mobile. Since only sub-lethal effects are likely resistance is considered to be high. Recovery is likely to be rapid as individuals move up through the sediment to resume their position for feeding and any fine particles are removed.

The suspension feeding bivalve *Mysella bidentata* is capable of burrowing and unlikely to be significantly affected by the addition of 5 cm of sediment, providing the sediment was of similar consistency to the existing sediment. As the viability of the population may be reduced due to temporary cessation of feeding activity and additional energetic costs of relocation, resistance is assessed as high. Recoverability is likely to be rapid.

Information on the amphipod *Harpinia antennaria* is currently not sufficient to assess sensitivity.

Corbula gibba is a burrower in shallow muddy or sandy sediments and uses a byssus thread to attach to pieces of shell or rock in the sediment. It uses its short inhalant siphon above the sediment for feeding and respiration. If smothered *Corbula gibba* would most likely burrow up through the new sediment. *Corbula gibba* is also considered to be generally tolerant of prolonged oxygen deprivation. Laboratory studies on *Corbula gibba* have shown that they can survive up to 57 days in near anoxic conditions. However, sudden smothering of the sediment would halt feeding. Therefore, resistance has been assessed as high with an immediate recoverability level.

1.7.3 Sublittoral mud

1.7.3.1 Selective extraction

Selective extraction is a pressure currently not relevant in the sublittoral mud habitats of the North Sea EEZ. The human activity associated with selective extraction in offshore areas is aggregate extraction, which affects only sand and gravel habitats.

1.7.3.2 Abrasion

Table 1-25: Sensitivity of sublittoral mud towards the pressure ‘abrasion’.

Abrasion		Resistance	Recoverability	Sensitivity
Physical habitat		intermediate	high	low
Characteristic species	*Amphiura filiformis*	high	very high	very low
	Mysella bidentata	intermediate	high	low
	Harpinia antennaria	not assessed	not assessed	-
	Corbula gibba	intermediate	high	low
Habitat sensitivity				**low**

Physical habitat – explanatory notes

Towed demersal gears have been shown to alter the sedimentary characteristics of subtidal muddy sand/mud habitats by penetration of the sediment. Trawling alters the physical environment of the benthos by creating furrows or scar from trawl doors, scouring and flattening the seabed with ground rope and weights, and redistributing sediment and other material (Environment Agency 2010). Trawl doors may cause furrows of up to 20 cm deep depending on the door weight and the hardness of the sediment (FAO 2004). The resistance of sublittoral mud towards abrasion has therefore been assessed as intermediate. Trawl marks are likely to last longer in sheltered areas with fine sediments. Pits at muddier sites generally take longer to infill (and thus had less negative infilling rates) than those in sandier sites. Muddy sands were found to be very vulnerable to the impacts of fishing activities, with recovery times predicted to take from several months to years (Environment Agency 2010). The same trawl track could be identified for almost five years in a sandy mud area in Kiel Bay that is not exposed to tidal currents (FAO 2004). This long recovery time is due to the fact that mud habitats are mediated by a combination of physical, chemical and biological processes (compared to sand habitats that are dominated by physical processes) (Environment Agency 2010). Due to the prevailing hydrographical conditions in the muddy areas of the German EEZ, recoverability of mud habitats is estimated as high.

Characteristic species – explanatory notes

(Information on species characteristics is taken from the MarLIN web site unless otherwise stated)

Brittlestars have fragile arms which are likely to be damaged by abrasion. *Amphiura filiformis* burrows in the sediment and extends only its arms when feeding. Literature reviews suggest that *Amphiura* spp. may be less susceptible to beam trawl damage than other species like echinoids or tube dwelling amphipods and polychaetes. Brittlestars can tolerate considerable damage to arms and even the disk without suffering mortality and are capable of arm and even some disk regeneration. Resistance to abrasion is therefore recorded as high. Individuals can still function whilst regenerating a limb so recovery will be rapid.

Due to their small size, the bivalve *Mysella bidentata* may escape damage from trawling although they may experience increased predation before re-burrowing. *Mysella bidentata* is often preferentially found in the structured irrigated burrows of host species such as *Amphiura filiformis* and if the top layers of sediment are ploughed this structure will be lost. Resistance has been assessed as intermediate. Recovery is likely to be high.

Information on the amphipod *Harpinia antennaria* is currently not sufficient to assess sensitivity.

The small solid shells of *Corbula gibba* may be vulnerable to physical damage (from e.g. otter boards) However, the size of *Corbula gibba* relative to the meshes of commercial trawls may ensure survival of a moderate proportion of disturbed individuals that pass through them. Specimens exposed on the sediment surface would be at risk of predation. Experimental trawling studies resulted in varying mortality rates. Therefore a resistance of intermediate is recorded with a high recovery level.

1.7.3.3 Changes in siltation

Table 1-26: Sensitivity of sublittoral sand towards the pressure 'changes in siltation'.

Changes in siltation		Resistance	Recoverability	Sensitivity
Physical habitat		high	very high	very low
Characteristic species	*Amphiura filiformis*	high	very high	very low
	Mysella bidentata	high	very high	very low
	Harpinia antennaria	not assessed	not assessed	-
	Corbula gibba	high	very high	very low
Habitat sensitivity				**very low**

Physical habitat – explanatory notes

Increased sedimentation mostly involves fine sediment particles which are similar to substrate size in sublittoral mud habitats. Therefore effects on habitat structure and benthic communities are assumed to be only small-scale. Resistance is judged to be high and recoverability is assumed to be very high.

Characteristic species – explanatory notes

(Information on species characteristics is taken from the MarLIN web site unless otherwise stated)

Amphiura filiformis is an infaunal species which can burrow and lives up to a depth of 4 cm within the sediment. Therefore, smothering by sediment of 5 cm is unlikely to have great effect although feeding and hence viability of the population may be reduced if the sediment is particularly fine and mobile. Since only sub-lethal effects are likely resistance is considered to be high. Recovery is likely to be rapid as individuals move up through the sediment to resume their position for feeding and any fine particles are removed.

The suspension feeding bivalve *Mysella bidentata* is capable of burrowing and unlikely to be significantly affected by the addition of 5 cm of sediment, providing the sediment was of similar consistency to the existing sediment. As the viability of the population may be reduced due to temporary cessation of feeding activity and additional energetic costs of relocation, resistance is assessed as high. Recoverability is likely to be rapid.

Information on the amphipod *Harpinia antennaria* is currently not sufficient to assess sensitivity.

Corbula gibba is a burrower in shallow muddy or sandy sediments and uses a byssus thread to attach to pieces of shell or rock in the sediment. It uses its short inhalant siphon above the sediment for feeding and respiration. If smothered *Corbula gibba* would most likely burrow up through the new sediment. *Corbula gibba* is also considered to be generally tolerant of prolonged oxygen deprivation. Laboratory studies on *Corbula gibba* have shown that they can survive up to 57 days in near anoxic conditions. However, sudden smothering of the sediment would halt feeding. Therefore, resistance has been assessed as high with an immediate recoverability level.

1.7.4 Sublittoral coarse sediment

1.7.4.1 Selective extraction

Table 1-27: Sensitivity of sublittoral coarse sediment towards the pressure ‘selective extraction’.

Selective extraction		Resistance	Recoverability	Sensitivity
Physical habitat		low	moderate	intermediate
Characteristic species	*Aonides paucibranchiata*	low	moderate	intermediate
	Ophelia limacina	low	moderate	intermediate
	Thracia spp.	low	moderate	intermediate
	Goodallia triangularis	not assessed	not assessed	not assessed
	Spisula solida	low	high	intermediate
	Angulus tenuis	low	moderate	intermediate
Habitat sensitivity				**intermediate**

Physical habitat – explanatory notes

The extraction of sediment implies the complete removal of substrate by creating longitudinal tracks of generally 2-3 m width and up to 50 cm depth (trailer suction dredging) or rounded pits of around 10 m depth and with a diameter of 10-50 m (anchor dredging). Severe alterations of seabed topography and possibly also changes in sediment composition occur, therefore resistance to selective extraction is rated as low.

Physical seabed structures are supposed to have recovered when dredge tracks have disappeared and the original sediment composition is restored. Research on seabed recovery mostly focuses on observation of dredge furrows, while the recovery of sediment composition may take far longer but is less intense investigated. Recovery takes the longest period of time at dredge sites characterised by coarse sediments (Hill et al. 2011). Observations from studies conducted in sandy gravel sediments reveal that the morphological behaviour of dredged tracks and pits varies significantly. In an area exposed to long-period waves, dredge tracks 0.3 – 0.5 m deep, in a gravelly substrate at a depth of 38 m, were found to disappear completely within eight months. In contrast, at an experimental dredged gravel site off Norfolk, UK, in 25 m of water, dredge tracks appeared to have been completely eroded well within three years of the cessation of dredging. Erosion of dredge tracks in areas of moderate wave exposure and tidal currents have been observed to take from three to more than seven years in gravelly sediments. In the latter case, however, infill resulted mainly from sand in transport. Especially in coarse sediments, the refill material may be finer grained than the material on the surrounding seabed, which could lead to a permanent change in benthic communities (Herrmann & Krause 1998). In the southern North Sea where tidal currents are generally strong, sand with a grain size up to 2 mm is mobile across the area during spring tides (Hill et al. 2011). Therefore it is assumed that recovery of coarse sediments after cessation of dredging is principally possible, but may take a few years. Recoverability is thus estimated as moderate.

Characteristic species – explanatory notes

(Information on species characteristics is taken from the MarLIN web site unless otherwise stated)

The majority of species in sublittoral coarse sediment is infaunal and would therefore be removed along with the substratum. Only some epifaunal and swimming species may be able to avoid the impact. Resident populations of the benthic endofauna would be lost, so resistance for all characteristic species is assessed as low.

Aonides paucibranchiata is a small-sized polychaete with limited mobility. The fecundity and dispersal potential of this genus is low (larval duration 2-10 days), so recolonisation from sources outside a disturbed area is likely to be slow. Recoverability is estimated to be moderate (MES 2008).

The life-span of *Ophelia limacina* is 6-10 years and adults mature at 1-2 years. The sexes are separate and eggs are fertilised externally after spawning in July-August. The duration of the larval stage is 2-10 days with settlement occurring between June and November. Little is known of the fecundity of this genus, but the relatively short planktonic phase and long life-span of the adult suggests an intermediate potential for recolonisation and subsequent recovery of biomass (MES 2008).

It is not possible to estimate the regeneration and dispersal potential of *Thracia* spp., but the genus is long-lived (>10 years) and slow-growing and probably has a relatively low recoverability following disturbance (MES 2008). It is estimated that recovery will last more than two years but will be completed within ten years. Therefore recoverability is judged to be moderate.

Information on the bivalve *Goodallia triangularis* is currently not sufficient to assess sensitivity.

The bivalve *Spisula solida* can live up to ten years. Individuals are sexually mature at 1 year, regardless of their size. The sexes of *Spisula* are separate and both show a synchrony in gametogenic development and spawning. Gametogenesis starts in September when temperatures decrease and spawning begins in February. Larvae can remain in the water column for several weeks, allowing fairly wide dispersal. The potential recovery of this bivalve is high and is often recorded amongst the first colonizers of sediments disturbed by dredging.

Little information is available on biological traits of *Angulus tenuis*, therefore sensitivity of the closely related species *Angulus (Tellina) fabula* is used as reference: The bivalve *Tellina fabula* spawns at least once a year and has a protracted breeding period. The number of gametes is likely to be high with a larval phase of at least one month. The species therefore has high dispersal potential, however, post settlement development is not particularly rapid and the species may take two or more years to mature. Experimental data suggest that *Tellina fabula* would colonize available sediments in the year following environmental perturbation, but that a breeding population may take two or more years to establish. It is expected that full recovery would occur within five years and so recoverability is assessed as moderate.

1.7.4.2 Abrasion

Table 1-28: Sensitivity of sublittoral coarse sediment towards the pressure 'abrasion'.

Abrasion		Resistance	Recoverability	Sensitivity
Physical habitat		intermediate	very high	low
Characteristic species	*Aonides paucibranchiata*	intermediate	high	low
	Ophelia limacina	intermediate	moderate	intermediate
	Thracia spp.	intermediate	high	low
	Goodallia triangularis	not assessed	not assessed	not assessed
	Spisula solida	intermediate	high	low
	Angulus tenuis	intermediate	high	low
Habitat sensitivity				**intermediate**

Physical habitat – explanatory notes

Impacts of fishing gears on habitats with coarse sands include the smoothing of the seafloor by flattening of biogenic structures or sand ripples, the penetration of sediment, smothering by resuspended sediment and displaced or overturned gravel (Environment Agency 2010). Otter trawls generally disturb the upper 1-5 cm while beam trawls scour the sediment down to 8 cm (FAO 2004). Resistance towards abrasion is assessed as intermediate.

Recovery time in gravel habitats has been predicted to be in the order of ten years, while physical restoration of sandy habitats has been observed to be rapid (days to few months) (Environment Agency 2010). The visible dredge marks from towed gear have been shown to be relatively short lived, lasting no more than a year in coarse sediments. As the habitat regard here predominantly consists of medium to coarse sands, recoverability is judged to be very high.

Characteristic species – explanatory notes

(Information on species characteristics is taken from the MarLIN web site unless otherwise stated)

Little is known about the life history of the polychaete worm *Aonides paucibranchiata* but its size and morphology suggest that it is likely to be vulnerable to physical disturbance. Infaunal polychaetes with little mobility are likely to be damaged by abrasion and suffer some degree of mortality. Resistance is judged as intermediate. As a short-lived animal with small body size, it is likely to recover adult biomass relatively quickly following colonisation by juveniles (MES 2008). Providing that part of the population survives, *Aonides paucibranchiata* is likely to have a high recoverability.

As an infaunal surface deposit feeder, part of the *Ophelia limacina* population is likely to be damaged or killed by a trawling event. Resistance is therefore assumed to be intermediate. The relatively short planktonic phase and therefore low dispersal potential and long life-span of the adult suggests the recoverability to be moderate.

The bivalve genus *Thracia* spp. burrows deeply in coarse sands and fine gravels and may thus escape the passing of a trawl. However, some individuals, especially juveniles, may suffer damage and may even be killed. Therefore resistance is estimated as intermediate. It is not possible to estimate the regeneration and dispersal potential of *Thracia* spp., but the genus is long-lived (>10 years) and slow-growing and probably has a relatively low recoverability following disturbance (MES 2008). As it is assumed that only a small part of the population is damaged, recoverability is estimated to be high.

Information on the bivalve *Goodallia triangularis* is currently not sufficient to assess sensitivity.

Fishing for demersal species will disturb the surface layer of sediment and any protruding or shallow burrowing species. Experimental trawls showed that 93% of the uncaught *Spisula solida* were undamaged, as they were well protected by their thick shells, and only 1% died. The impacts caused by a fishing dredge significantly increased the number of exposed *Spisula solida* clams and the abundance of potential predators. The impact of the dredge increased the time needed for *Spisula solida* to rebury, which rendered them vulnerable to predation for longer periods. Resistance has been assessed as intermediate as mortality may occur and recoverability has been assessed as high.

Little information is available on biological traits of *Angulus tenuis*, therefore sensitivity of the closely related species *Angulus (Tellina) fabula* is used as reference: Despite their robust body form, bivalves are vulnerable to physical abrasion. *Tellina fabula* is a shallow burrower with a fragile shell and may be damaged by an impact with fishing gear so resistance is recorded as intermediate. As presumably not the whole population is affected, recoverability is assessed as high.

1.7.4.3 Changes in siltation

Table 1-29: Sensitivity of sublittoral coarse sediment towards the pressure 'changes in siltation'.

Changes in siltation		Resistance	Recoverability	Sensitivity
Physical habitat		intermediate	very high	low
Characteristic species	*Aonides paucibranchiata*	high	very high	very low
	Ophelia limacina	high	very high	very low
	Thracia spp.	intermediate	high	low
	Goodallia triangularis	not assessed	not assessed	not assessed
	Spisula solida	intermediate	high	low
	Angulus tenuis	high	very high	very low
Habitat sensitivity				**low**

Physical habitat – explanatory notes

Sediment plumes generated by construction works or aggregate extraction may cause changes in habitat structure such as infilling of small pits by fine sediments, siltation within crevices or development of migratory sand ripples (Hill et al. 2011). Finer sediment particles remain in suspension longer than larger particulates and can disperse over a wider area. Suspended fine and medium sands require a few hours for resettlement whereas silty sediments may remain in suspension for a few days (OSPAR 2008). As suspended particles tend to be significantly finer than the prevailing coarse sands, changes in sediment composition are supposed to be more distinct than e.g. in mud habitats. Resistance of sublittoral coarse sediment is therefore regarded as intermediate. Recovery is dependent on seabed transport, wave and tidal energy. It is estimated to be very high in coarse sediments.

Characteristic species – explanatory notes

(Information on species characteristics is taken from the MarLIN web site unless otherwise stated)

Aonides paucibranchiata is a small deposit feeding polychaete with limited mobility. The species lives in a loosely constructed tube or is free-living (MES 2008). An additional 5 cm layer of sediment would result in a temporary cessation of feeding activity, and therefore growth and reproduction are likely to be compromised. However, spionids would be expected to quickly relocate to its favoured depth, with no mortality, and hence a high resistance is recorded. Recoverability will probably be very high.

The polychaete *Ophelia limacina* reaches 3-10 cm in length and burrows in unconsolidated mixed to medium coarse sands where it is a deposit-feeder exploiting diatoms & detritus within the sediments*. Ophelia* has moderate mobility within the surface deposits, and is likely to be able to accommodate moderate deposition of sediment (MES 2008). Resistance is judged to be high and recoverability very high.

The bivalve *Thracia* spp. is a deep-burrowing form that lives in sand, gravel and mud where it lives as a suspension-feeder on phytoplankton and detritus in the water column. It has very limited mobility and therefore it cannot be excluded that some mortality of individuals may occur. Resistance is therefore precautionarily estimated as intermediate and recovery as high.

Information on the bivalve *Goodallia triangularis* is currently not sufficient to assess sensitivity.

Spisula solida is a fast burrowing bivalve and suspension feeder. If *Spisula solida* were covered by sediments it would be able to reposition itself within the sediment. Fahy et al. (2003) noted that in a clam bed in Ireland, where part of the bed has silted up, numbers of *Spisula solida* and the size of the clam patch were reduced. Therefore resistance has been assessed as intermediate to reflect the reduction in the size of the clam bed and *Spisula* numbers. Recoverability is assessed as high.

Little information is available on biological traits of *Angulus tenuis*, therefore sensitivity of the closely related species *Angulus (Tellina) fabula* is used as reference: *Tellina fabula* is a shallow burrower in sandy sediments. It requires its inhalant siphon to be above the sediment surface for feeding and respiration. Smothering with 5 cm of sediment would temporarily halt feeding and respiration and requires the species to relocate to its preferred depth. *Tellina fabula* is an active burrower and would be expected to relocate with no mortality. However, growth and reproduction may be compromised and so resistance is assessed as high. Growth and reproduction would return to normal following relocation so recoverability is immediate.

1.7.5 Sandbanks

1.7.5.1 Definition of sandbanks

Sandbanks are elevated, elongated, rounded or irregular topographic features, permanently submerged and predominantly surrounded by deeper water. They consist mainly of sandy sediments, but larger grain sizes, including boulders and cobbles, or smaller grain sizes including mud may also be present on a sandbank (EC 2013)

Sandbanks of notable size in the German North Sea include the Dogger Bank and the smaller Amrum Outer Ground. The Borkum Reef Ground is an example of a sandbank with cobble fields and stony or gravelly areas constituting reef-like structures.

1.7.5.2 Characteristic species

In the German EEZ four sandbank areas have been identified. These vary according to prevailing hydrological and sediment conditions, thus producing different benthic communities. It is not possible to use a uniform list of characteristic species for all sandbank locations. Sandbanks in the Borkum Reef Ground and the Sylter Outer Reef predominantly consist of fine sands with the *Tellina fabula*-association with small areas of coarse sands and reefs. Therefore it is proposed that for the sensitivity assessment ranks assigned to the predominant habitat 'sublittorals sand' with the *Tellina-fabula*-association are used.

The sandbank on the Doggerbank is characterized by fine sediments and the *Bathyporeia-Tellina*-association. Characterising species for this habitat according to Rachor & Nehmer (2003) are: *Spiophanes bombyx*, *Lanice conchilega*, *Bathyporeia elegans*, *Amphiura brachiata*, *Cerianthus loydii*, *Tellina fabula*, *Bathyporeia nana* and *Spio decorata.* The only species which fulfills all criteria for a characteristic species is the brittlestar *Amphiura brachiata*. In order to have a more comprehensive assessment for the habitat, the other characterizing species were also used for the determination of the sensitivity rank for the habitat.

1.7.5.3 Selective extraction

Table 1-30: Sensitivity of sandbanks (Doggerbank) towards the pressure 'selective extraction'.

Selective extraction		Resistance	Recoverability	Sensitivity
Physical habitat		low	high	intermediate
Characteristic species	*Spiophanes bombyx*	low	high	intermediate
	Lanice conchilega	low	high	intermediate
	Bathyporeia spp.	low	high	intermediate
	Amphiura brachiata	low	moderate	intermediate
	Cerianthus lloydii	low	moderate	intermediate
	Tellina fabula	low	moderate	intermediate
	Spio decoratus	low	high	intermediate
Habitat sensitivity				**intermediate**

Physical habitat – explanatory notes

The extraction of sediment implies the complete removal of substrate by creating longitudinal tracks of generally 2-3 m width and up to 50 cm depth (trailer suction dredging) or rounded pits of around 10 m depth and with a diameter of 10-50 m (anchor dredging). Severe alterations of seabed topography and possibly also changes in sediment composition occur, therefore resistance to selective extraction is rated as low.

Physical seabed structures are supposed to have recovered when dredge tracks have disappeared and the original sediment composition is restored. Research on seabed recovery mostly focuses on observation of dredge furrows, while the recovery of sediment composition may take far longer but is less intense investigated. The disappearance of furrows may take place due to infilling where there is naturally high sediment transport or from dredging overflow. Existing furrows may also collapse or changed hydrodynamics may further erode dredge tracks. The infilling of furrows by fine sediment particles is associated with a decrease in sediment size and an increase in sediment instability and may thus prolong recovery time. Typical conditions for a fast recovery (months – 1 year) following extraction are high energy environments, fine sediments including sand, already disturbed communities and dominance of r-selected species, whereas slow recovery (years – decades) is predicted in moderate to low energy environments, with coarse sands, stable communities and a dominance of K-selected species. Additional factors influencing physical recovery are the method and intensity of dredging, the total area dredged and the extent of changes in sediment composition (Hill et al. 2011).

In the southern North Sea where tidal currents are generally strong, sand with a grain size up to 2 mm is mobile across the area during spring tides and may aid in the infilling of dredge tracks (Hill et al. 2011). Typical time-scales for the regeneration of dredge furrows in sandy substrates are in the range of months. In the German Baltic Sea in a shallow area of 8-10 m depth with fine to medium sands, furrows created by trailer suction dredging were observed to refill within months. In contrast, at another extraction site in the German Baltic Sea with fine sands in water depths between 14 and 21 m dredge tracks were still visible after ten years. At an extraction site west of Sylt stationary dredging was deployed creating pits of around 10 m depth and up to 2000 m in diameter. Bathymetric investigations revealed that only 10 % of the pits were refilled after cessation of dredging (ICES 2009).

Regarding the recoverability of sandy habitats in the areas licensed for extraction in the German North Sea considerable uncertainties remain. As investigation reports of the areas currently in use which could support the assessment are not available, the recovery time of sandbanks is preliminarily judged as high (1-2 years). The assessment is understood as precautionary, due to the sediment properties and the presumably moderate energy at the seabed, recovery of at least dredge tracks may as well be faster.

Characteristic species – explanatory notes

(Information on species characteristics is taken from the MarLIN web site unless otherwise stated)

The majority of species in the sublittoral sand is infaunal and would therefore be removed along with the substratum. Only some epifaunal and swimming species may be able to avoid the impact. The characteristic amphipods *Bathyporeia elegans* and *B. nana* settle the uppermost centimetres of sandy sediment and are thus also removed. Resident populations would be lost, so resistance for all characteristic species is assessed as low.

The polychaete *Spiophanes bombyx* is regarded as a typical 'r' selecting species with a short life span, high dispersal potential and high reproductive rate. It is often found at the early successional stages of variable, unstable habitats that it is quick to colonize following perturbation. Its larval dispersal phase may allow the species to colonize remote habitats. Recoverability is therefore estimated as high.

The sand mason *Lanice conchilega* lives for about 1 year at which point reproduction occurs between April-June. The female releases around 160,000 eggs and these are fertilised at the sediment surface. The larva spends about 8 weeks in a planktotrophic phase during which time a proto-tube develops before the post-larva sinks to the seabed. It has a capacity to disperse over considerable distances and can be found in dense communities. The relatively short life-span suggests that restoration of the biomass is achieved within one year following initial recolonisation by the juveniles. This species has a high recoverability.

Repopulation of defaunated sediments by the amphipod *Bathyporeia* spp. is likely to be rapid. The genus is likely to have a high to very high capacity for recovery from many factors of disturbance. It is a short-lived genus which reaches maturity after six months and produces two generations within a year. There is no opportunity for larval dispersal as they are brooded, but adults are highly mobile in the water column and thus recovery potential is high (MES 2008).

The genus *Amphiura* is a relatively long-lived and slow-growing brittlestar with a life-span of 10 to 20 years. Breeding is annual and larvae can disperse over considerable distances due to their long planktonic existence. Adults, although mobile, are not highly active. Some immigration of adults from nearby populations may be possible. However, it can take approximately 5-6 years for *Amphiura* to grow to maturity so population structure may not return to original levels for at least this length of time. Therefore, it seems likely that after removal of all or most of the population recovery will be determined by the presence of suitable hydrodynamic forces providing new larvae. Once settled the population is likely to take longer than five years to return to maturity and so recoverability of *Amphiura brachiata* has been suggested to be moderate.

The tubiculous sea anemone *Cerianthus lloydii* is a long-lived anemone with a life-span of as much as 11-20 years. The age at sexual maturity and fecundity is unknown. Fertilisation is external fertilisation and the larvae are pelagic. The dispersal potential may therefore be high, although without information on the fecundity, it is not possible to estimate the recolonisation potential for this genus. The long life-span and slow growth of this anemone suggests that it has a low rate of restoration of the biomass following recolonisation. Recoverability is estimated as moderate.

The bivalve *Tellina fabula* spawns at least once a year and has a protracted breeding period. The number of gametes is likely to be high with a larval phase of at least one month. The species therefore has high dispersal potential, however, post settlement development is not particularly rapid and the species may take two or more years to mature. Experimental data suggest that *Tellina fabula* would colonize available sediments in the year following environmental perturbation, but that a breeding population may take two or more years to establish. It is expected that full recovery would occur within five years and so recoverability is assessed as moderate.

Spio is a short-lived genus with a life-span of about one year. Sexual maturity is achieved at 2-3 months. The sexes are separate and approximately 250 eggs are fertilised externally during two reproductive periods (April-June & August-September). The embryos are brooded in the tube and then released as lecithotrophic larvae that spend about 4 weeks in the plankton. Settlement is from June-August. The dispersal potential is high and the relatively short generation time and rapid growth rate suggests that restoration of the biomass is achieved soon after settlement. This genus has a high recoverability.

1.7.5.4 Abrasion

Table 1-31: Sensitivity of sandbanks (Doggerbank) towards the pressure 'abrasion'.

Abrasion		Resistance	Recoverability	Sensitivity
Physical habitat		intermediate	very high	low
Characteristic species	*Spiophanes bombyx*	intermediate	very high	low
	Lanice conchilega	intermediate	very high	low
	Bathyporeia spp.	tolerant	not relevant	not sensitive
	Amphiura brachiata	high	very high	very low
	Cerianthus lloydii	intermediate	moderate	intermediate
	Tellina fabula	intermediate	high	low
	Spio decoratus	intermediate	very high	low
Habitat sensitivity				**intermediate**

Physical habitat – explanatory notes

Impacts of fishing gears on sandy habitats include the removal of habitat complexity by flattening of biogenic structures or sand ripples, the penetration of sediment and smothering by resuspended sediment. Otter trawls generally disturb the upper 1-5 cm while beam trawls scour the sediment down to 8 cm (FAO 2004). Resistance towards abrasion is assessed as intermediate.

Physical restoration has been observed to be rapid (days to few months) in sandy habitats (Environment Agency 2010). In a study comparing the responses of various sediment types to physical disturbance, Dernie et al. (2003) found that clean sand communities had the most rapid recovery rate. Schwinghamer et al. (1996) examined the effect of otter trawls on habitats with fine and medium grained sand in the Grand Banks after trawling had stopped. The tracks left by the trawl doors were visible for at least ten weeks but not visible or only faintly visible after one year. Recoverability is therefore suggested to be very high.

Characteristic species – explanatory notes

(Information on species characteristics is taken from the MarLIN web site unless otherwise stated)

Spiophanes bombyx is a soft bodied organism that exposes its palps at the surface while feeding. It lives infaunally in sandy sediment and any physical disturbance that penetrates the sediment, for example dredging or dragging an anchor, would lead to physical damage of *Spiophanes bombyx*. Bergman & Hup (1992) reported a 40-60% decrease in the total density of *Spiophanes bombyx* after 3 trawling events. Therefore, a resistance of intermediate has been recorded. Jennings & Kaiser (1995) suggested that the top few centimetres of the sediment were usually occupied by opportunistic species, such as spionids, capitellid polychaetes and amphipods, which were able to recolonize disturbed areas quickly. They further suggested that this surface community would probably recover within 6 -12 months. Therefore, a recoverability of very high has been recorded.

Lanice conchilega is a medium-large polychaete worm belonging to the Family Terebellidae. It reaches a length of 25-30cm and forms a characteristic tube of sand-grains ending at the head end in a tuft of sandy filaments that project from the surface of the sediment. It is likely that the species is damaged and killed by abrasion. Therefore resistance is assessed as intermediate. Due to their high reproductive and larval dispersal potential, recoverability is estimated to be very high.

Bathyporeia spp*.* are highly mobile amphipod species so that they are unlikely to be damaged by abrasion. Therefore, resistance has been assessed as tolerant.

Brittlestars have fragile arms which are likely to be damaged by abrasion. *Amphiura* spp*.* burrows in the sediment and extends only its arms when feeding. Literature reviews suggest that *Amphiura* spp. may be less susceptible to beam trawl damage than other species like echinoids or tube dwelling amphipods and polychaetes. Brittlestars can tolerate considerable damage to arms and even the disk without suffering mortality and are capable of arm and even some disk regeneration. Resistance to abrasion is therefore recorded as high. Individuals can still function whilst regenerating a limb so recovery will be rapid.

Cerianthus lloydii is a brownish, tube-dwelling anemone up to 15 cm long. The mouth and tentacles project above the surface of the sand from the soft tube, which can be up to 40 cm long and is permanently buried. It is able to retract rapidly into the tube to avoid physical disturbance. Withdrawn burrowing anemones are likely to reappear and dislodged individuals reburrow. However, it cannot be ruled out that some individuals may be damaged by trawling. Damaged anemones may be subject to predation by fish or other animals. Therefore resistance is assessed as intermediate. *Cerianthus lloydii* has a life-span of 11-20 years. The age at sexual maturity and fecundity is unknown. Fertilisation is external and the larvae are pelagic (MES 2008). The dispersal potential may therefore be high, although without information on the fecundity and due to the long life-span and slow growth of this anemone recoverability is assessed as moderate.

Despite their robust body form, bivalves are vulnerable to physical abrasion. *Tellina fabula* is a shallow burrower with a fragile shell and may be damaged by an impact with fishing gear so resistance is recorded as intermediate. As presumably not the whole population is affected, recoverability is assessed as high.

Spio spp. is a small polychaete with 2-5cm in body length and lives in burrows in sand where it feeds as a surface deposit-feeder on detritus and diatoms. Adult worms can burrow up to 10 cm down and may escape the disturbance. Juveniles can only burrow up to 2 cm into the sediment and are likely to be affected. A resistance of intermediate has therefore been recorded. It is reported that the total density of spionids actually increased with increased fishing disturbance, presumably due to their ability to colonize newly exposed substratum. Recoverability has been recorded as very high.

1.7.5.5 Changes in siltation

Table 1-32: Sensitivity of sandbanks (Doggerbank) towards the pressure 'changes in siltation'.

Changes in siltation		Resistance	Recoverability	Sensitivity
Physical habitat		high	very high	very low
Characteristic species	*Spiophanes bombyx*	high	very high	very low
	Lanice conchilega	intermediate	very high	low
	Bathyporeia spp.	high	very high	very low
	Amphiura brachiata	high	very high	very low
	Cerianthus lloydii	intermediate	high	low
	Tellina fabula	high	very high	very low
	Spio decoratus	high	very high	very low
Habitat sensitivity				**low**

Physical habitat – explanatory notes

Sediment plumes generated by construction works or aggregate extraction may cause changes in habitat structure such as infilling of small pits by fine sediments, siltation within crevices or development of migratory sand ripples (Hill et al. 2011). Finer sediment particles remain in suspension longer than larger particulates and can disperse over a wider area. Suspended fine and medium sands require a few hours for resettlement whereas silty sediments may remain in suspension for a few days (OSPAR 2008). In habitats with strong seabed transport recovery may be fast as fine sediments are rapidly mobilized. Resistance of sandbank habitats is therefore regarded as high and recovery time as very high.

Characteristic species – explanatory notes

(Information on species characteristics is taken from the MarLIN web site unless otherwise stated)

Spiophanes bombyx lives in the sediment and uses sediment grains to make its tube. It is likely that *Spiophanes bombyx* will be able to move up through any extra sediment, therefore resistance has been recorded as high. Recovery is likely to be immediate.

Lanice conchilega forms a characteristic tube of sand-grains ending at the head end in a tuft of sandy filaments that project from the surface of the sediment. The worm feeds on particulate matter on the sediment surface captured by a crown of tentacles. *Lanice conchilega* is capable of movement only within the tube and is likely to be vulnerable to deposition of sediment (MES 2008). Resistance has been assessed as intermediate and recoverability as very high.

The amphipod *Bathyporeia* spp. would probably be unaffected by an additional covering of sediment of a texture within its habitat preference, although there may be an energetic cost incurred by the additional burrowing activity required to attain a near-surface position for feeding and to swim. *Bathyporeia* spp*.* is likely to be more intolerant of smothering by both coarser and finer particles through which burrowing is likely to be hindered. Consequently, the resistance of *Bathyporeia* spp*.* to an increase in sedimentation has been assessed to be high. The genus is likely to have a very high capacity for recovery.

Amphiura spp*.*is an infaunal genus which can burrow and lives up to a depth of 4 cm within the sediment. Therefore, smothering by sediment of 5 cm is unlikely to have a great effect although feeding and hence viability of the population may be reduced if the sediment is particularly fine and mobile. Since only sub-lethal effects are likely resistance is considered to be high. Recovery is likely to be rapid as individuals move up through the sediment to resume their position for feeding and any fine particles are removed.

Cerianthus lloydii occurs in muddy sediments, so is likely to be tolerant of some smothering by suspended sediment. With a maximum height of only 3 cm above the sediment, the species will be completely smothered by the benchmark level of 5 cm of sediment. *Cerianthus lloydii* may be able to move by a limited amount and to rise above the smothering material. However, it is also likely that some individuals may die and so resistance is reported to be intermediate. Recoverability is assumed to be high.

Tellina fabula is a shallow burrower in sandy sediments. It requires its inhalant siphon to be above the sediment surface for feeding and respiration. Smothering with 5 cm of sediment would temporarily halt feeding and respiration and requires the species to relocate to its preferred depth. *Tellina fabula* is an active burrower and would be expected to relocate with no mortality. However, growth and reproduction may be compromised and so resistance is assessed as high. Growth and reproduction would return to normal following relocation so recoverability is immediate.

Spio spp*.* lives in the sediment and uses sediment grains to make its tube. It is likely that *Spio* spp*.* will be able to move up through any extra sediment, therefore resistance has been recorded as high. Recoverability will probably be very high.

1.7.6 Reefs

1.7.6.1 Definition of reefs

Reefs can be either biogenic concretions or of geogenic origin. They are hard compact substrata on solid and soft bottoms, which arise from the sea floor in the sublittoral and littoral zone. Reefs may support a zonation of benthic communities of algae and animal species as well as concretions and corallogenic concretions (EC 2013).

Sites of outstanding ecological value in the North Sea include areas around the Borkum Reef Ground, the eastern flank of the Elbe glacial valley, and the Steingrund reef off Helgoland (Nehls et al. 2008). Biogenic reefs have not yet been designated in the German North Sea.

1.7.6.2 Characteristic species

According to Nehls et al. (2008) criteria for characteristic reef species are:

- presence >50 % at the stations of a subarea
- preference for hard substrate
- longevity

Characteristic species identified by Nehls et al. (2008) for the Borkum Reef Ground and the Sylter Outer Reef are:

Table 1-33: Characteristic species of reef habitats in the German North Sea (Nehls et al. 2008). Species selected for the sensitivity assessment are printed in bold.

Porifera	***Leucosolenia botryoides***
Cnidaria	*Metridium senile*
Cnidaria	***Alcyonium digitatum***
Cnidaria	*Alcyonium glomeratum*
Cnidaria	*Sertularia cupressina*
Polychaeta	***Pomatoceros triquiter***
Bryozoa	***Flustra foliacea***
Crustacea - Cirripedia	*Balanus balanus*
Crustacea - Cirripedia	***Balanus crenatus***
Crustacea - Cirripedia	*Balanus improvisus*
Bivalvia	***Pholas dactylus***
Crustacea – Amphipoda	*Caprella linearis*
Crustacea - Decapoda	*Galathea strigosa*
Crustacea - Decapoda	*Galathea squamosa*
Crustacea - Decapoda	***Cancer pagurus***
Echinodermata	***Echinus esculentus***

Ascidiacea	***Ciona intestinalis***
Ascidiacea	Ascidiella scabra

For the sensitivity assessment one species was chosen from each class, except for Crustacea, where a barnacle species and a decapod crustacean were selected.

1.7.6.3 Selective extraction

Some of the reef structures in the Sylter Outer Ground are situated within designated areas for aggregate extraction. Especially areas with gravel or smaller stones may be affected by the pressure selective extraction.

Table 1-34: Sensitivity of reefs towards the pressure 'selective extraction'.

Selective extraction		Resistance	Recoverability	Sensitivity
Physical habitat		low	very low	very high
Characteristic species	*Leucosolenia botryoides*	low	low	high
	Alcyonidium digitatum	low	moderate	intermediate
	Pomatoceros triqueter	low	high	intermediate
	Flustra foliacea	low	moderate	intermediate
	Balanus crenatus	low	very high	low
	Pholas dactylus	low	moderate	intermediate
	Cancer pagurus	intermediate	moderate	intermediate
	Echinus esculentus	low	moderate	intermediate
	Ciona intestinalis	low	moderate	intermediate
Habitat sensitivity				**very high**

Physical habitat – explanatory notes

The extraction of sediment implies the complete removal of substrate and attached organisms. Severe alterations of seabed topography occur, therefore resistance to selective extraction is rated as low. Regeneration of gravel and rock substrata by hydrodynamic or other processes is not possible (Herrmann & Krause 1998), thus the recovery of the reef habitat with the associated benthic fauna will not take place.

Characteristic species – explanatory notes

(Information on species characteristics is taken from the MarLIN web site unless otherwise stated)

The majority of characteristic species in reef habitats is sessile and attached to the substrate and would therefore be removed by aggregate dredging. Only some epifaunal and swimming species may be able to avoid the impact. Resident populations of the benthic endo- and sessile epifauna would be lost, so resistance for these species is assessed as low.

Specific information on the reproduction or dispersal abilities of the sponge *Leucosolenia botryoides* is not available. Most sponges however, tend to be slow growing and long lived, so precautionarily recoverability is assessed as low.

It is likely that the octocoral *Alcyonium digitatum* has a high recovery potential. Its reproductive strategy is to 'broadcast' gametes into the water for fertilization indicates that fecundity is high. The combination of spawning in winter and that the larvae may have a long pelagic life allows a considerable length of time for the planulae to disperse (recruits from other populations can replace impacted populations), settle and metamorphose ahead of the spring plankton bloom. Young *Alcyonium digitatum* will consequently be able to take advantage of an abundant food resource in spring and be well developed before the appearance of other forms which may compete for the same substrata. In addition because the planulae do not feed whilst in the pelagic zone they do not suffer by being released at the time of minimum plankton density. They may also benefit by the scarcity of predatory zooplankton which would otherwise prey upon them. However, the life span of *Alcyonium digitatum* certainly exceeds 20 years as colonies have been followed for 28 years in marked plots and sexual maturity is reached at 2-3 years. The species has a relatively slow growth rate and therefore recovery to adult biomass is likely to take many years. Recoverability is assessed as moderate.

The encrusting polychaete *Pomatoceros triqueter* is fairly widespread, reaches sexual maturity within 4 months and longevity has been recorded to be between 1.5 and 4 years. Larvae are pelagic for about 2-3 weeks in the summer and about 2 months in the winter, enabling them to disperse widely. Recovery is therefore likely to be high.

Recovery of the bryozoan *Flustra foliacea* will depend on recruitment from other populations and is assessed as high. The brooded, lecithotrophic larvae of bryozoans have a short pelagic life time of several hours to about 12 hours. Recruitment is dependent on the supply of suitable, stable, hard substrata. *Flustra foliacea* colonies are perennial, and potentially highly fecund when large. In the strong currents occupied by *Flustra foliacea* populations many larvae are probably swept away, either to colonize other substrata or lost. Recruitment may be enhanced in areas subject to sediment abrasion, where less tolerant species are removed, making more substratum available for colonization, especially if larvae release in spring coincides with the end of winter storms. Once settled, new colonies take at least 1 year to develop erect growth and 1-2 years to reach maturity, depending on environmental conditions. Where the population was removed, recruitment would depend on the proximity of other populations or individuals and the hydrographic regime, and is likely to be more protracted, taking up to 5 years. In areas isolated by either by distance or hydrographic regime, *Flustra foliacea* may take longer to recolonize. Recoverability is recorded to be moderate.

The barnacle *Balanus crenatus* is an important early colonizer of sublittoral rock surfaces and it heavily colonized a site that was dredged for gravel within 7 months. Therefore recovery is predicted to be very high.

Provided a similar substratum remains and there is larval availability, recolonization of the boring bivalve *Pholas dactylus* is likely to occur and so recovery within five years should be possible, though maybe not to previous abundance. Recoverability is estimated to be moderate.

Substrate removal is likely to remove a proportion of *Cancer pagurus* although some will escape. Those that escape undamaged will quickly recolonize whatever seabed remains and migrate to new habitats if necessary. Female *Cancer pagurus* have high fecundity of 0.25-3 million eggs per spawning but mortality of larvae is high. Since juveniles spend the first 3 years post-settlement in the intertidal, recovery of an adult population from a mortality event is likely to take several years. If *Cancer pagurus* were to be completely eradicated from an area, repopulation would occur by larval input from surrounding areas and adult migration. Therefore a resistance of intermediate and a recoverability of moderate have been recorded.

Sea urchins like *Echinus esculentus* are slow moving and unlikely to escape removal of their substratum. Sea urchin recruitment is sporadic and dependent on location but populations would probably recover within 5 years, except in locations isolated by geography or hydrography. *Echinus esculentus* has a high larval dispersal potential but is slow to mature and it would take up to 8 years for adult biomass to be restored.

Adult individuals of the sea squirt *Ciona intestinalis* are sessile and so cannot contribute to recovery through active immigration. Rafting by adults attached to floating objects or shipping may form an important mechanism for recolonization. Dispersal through attachment to ships is believed to be the main reason behind the widespread global distribution. Otherwise, dispersal is mediated by the larval stage. Larval recruitment from other populations may be restricted by the larvae being retained near the adults in mucus threads. Settling time of the larva is quite short - usually a few hours so dispersal may be limited. No information is available regarding the fecundity of this species. Reproductive frequency and longevity varies from semelparous and annual to iteroparous and living 2-3 years depending on depth and salinity (in Sweden at least). Reproduction (in Plymouth) is recorded as occurring all year round. Recoverability is assessed to be moderate.

1.7.6.4 Abrasion

Table 1-35: Sensitivity of reefs towards the pressure ‘abrasion’.

Abrasion		Resistance	Recoverability	Sensitivity
Physical habitat		intermediate	very low	high
Characteristic species	*Leucosolenia botryoides*	intermediate	moderate	intermediate
	Alcyonium digitatum	intermediate	moderate	intermediate
	Pomatoceros triqueter	intermediate	very high	low
	Flustra foliacea	intermediate	moderate	intermediate
	Balanus crenatus	intermediate	very high	low
	Pholas dactylus	intermediate	moderate	intermediate
	Cancer pagurus	intermediate	moderate	intermediate
	Echinus esculentus	low	moderate	intermediate
	Ciona intestinalis	low	moderate	intermediate
Habitat sensitivity				**high**

Physical habitat – explanatory notes

Geogenic reef habitats in the German EEZ of the North Sea are fished with heavily-rigged beam trawls, which often damages or even destroys habitat structures (BfN 2012). Even though hard substrates are relatively resistant to physical damage from towed gears, fishing with mobile gears may result in modification of the substratum, including removal of shell debris, cobbles and rocks and the movement of boulders. Recovery of the benthic reef species will depend on the life-history characteristics of the species affected, including the ability of damaged adults to repair or regenerate lost or damaged parts and the ability of larvae to reach and recolonize the habitat. Re-establishment of long-lived, slow-growing species in which maturity occurs late will be slower than for smaller species with faster life cycles (MarLIN 2013). However, a pre-condition for the recovery of the benthic community is the presence of hard substrate for settlement, which may be partly removed. Resistance is assessed as intermediate and recovery of hard substrata is predicted to be very low.

Characteristic species – explanatory notes

(Information on species characteristics is taken from the MarLIN web site unless otherwise stated)

Specific information on the biological traits of the sponge *Leucosolenia botryoides* is not available. *Leucosolenia botryoides* is a very delicate, soft, white, tubular sponge that grows to up 2 cm wide and 1 cm thick. Abrasion may physically damage or dislodge the sponge, therefore resistance is judged as intermediate. Regarding reproduction and dispersal abilities of this species no information is available. Sponges may also regrow from tissue remaining in crevices or other irregularities and that were not affected by the abrasion. Precautionarily recoverability is estimated as moderate.

The octocoral *Alcyonium digitatum* is prone to damage and abrasion by fishing gears e.g. rock hopper otter trawls and dredges that are designed to penetrate the sea bed. In addition, the anchoring of boats for purposes of recreational diving may cause cumulative damage in heavily visited sites. Veale et al., 2000 reported that the abundance, biomass and production of epifaunal assemblages, including *Alcyonium digitatum*, decreased with increasing fishing effort. A resistance rank of intermediate is recorded as it is likely that the proportion of the population on vertical slopes and under overhangs will be unaffected by mechanical abrasion. The populations inhabiting horizontal surfaces at greater depths are at risk from abrasion. However, the fact that *Alcyonium digitatum* is more abundant on high fishing effort grounds suggests that this seemingly fragile species is more resistant to abrasive disturbance than might be assumed, presumably owing to the ability for the replacement of senescent cells and regeneration of damaged tissue in addition to the early larval colonization of available substrata. Due to the relatively slow growth of the species, recoverability is estimated as moderate.

Pomatoceros triqueter has a hard calcareous tube that is resistant to sand and gravel abrasion. Hiscock (1983) noted that a community, under conditions of scour and abrasion from stones and boulders moved by storms, developed into a community consisting of fast growing species such as *Pomatoceros triqueter*. Off Chesil Bank, the epifaunal community dominated by *Pomatoceros triqueter*, *Balanus crenatus* and *Electra pilosa*, decreased in cover in October, was scoured away in winter storms, and was recolonized in May to June. Warner (1985) reported that the community did not contain any persistent individuals, being dominated by rapidly colonizing organisms. But, while larval recruitment was patchy and varied between the years studied, recruitment was sufficiently predictable to result in a dynamic stability and a similar community was present in 1979, 1980, and 1983. Scour due to winter storms is probably greater than the benchmark level. Scour and abrasion will probably remove a proportion of the population, suggesting a resistance of intermediate. However, it demonstrates rapid growth and recruitment so that it recoverability is assumed to be very high. The abundance of *Pomatoceros triqueter* may increase due to decreased competition from other species.

Flustra foliacea is tolerant of sediment abrasion but physical disturbance by fishing gear has been shown to adversely affect emergent epifaunal communities. Although *Flustra foliacea* is flexible, physical disturbance by a passing scallop dredge is likely to damage fronds and remove some colonies, suggesting a resistance of intermediate. Colonies on hard substrata are probably less vulnerable to fishing activity but would probably be damaged or partially removed. Colonies growing on rocks, cobbles and shells on coarse grounds, may be removed by a scallop dredge and therefore be highly intolerant. Overall, local recruitment is probably good and a damaged or reduced population may recover its numbers and percentage cover in less than 5 years. Recoverability is therefore assessed as moderate.

Balanus crenatus would probably be crushed by a heavy force, such as an anchor landing on it. However, it is small and individuals in fissures and crevices would probably survive. Resistance is assessed as intermediate. The species has a high dispersal and colonization potential as well as fast growth rates. Recovery is predicted to be very high.

The shell of *Pholas dactylus* is thin and brittle so a force, equivalent to a 5-10 kg anchor and its chain being dropped or a passing scallop dredge, is likely to result in death. However, because the common piddock lives within a burrow in soft rock, generally only those individuals close to the surface will be damaged by an abrasive force or physical disturbance. Therefore, a resistance of intermediate has been recorded to represent the possible loss of a proportion of the population. Recolonization of the affected area by pelagic larvae is likely to occur and with several months spawning every year recovery within five years is expected.

Berried *Cancer pagurus* are likely to be disturbed by dredging and trawls as they are relatively immotile and spend most of their time half buried in the sediment. Abrasion is also likely to make *Cancer pagurus* vulnerable to Burn Spot Disease which may cause some mortality. *Cancer pagurus* is often damaged or killed if struck by a dredge and annual mortality can be as much as 14% of the population. *Cancer pagurus* is a rather brittle animal, easily damaged or killed by heavy impacts, and a resistance of intermediate has been recorded because, although a high proportion of individuals die as a result of abrasion, the whole population is unlikely to be affected. Recoverability is assessed to be moderate.

Species with fragile tests such as *Echinus esculentus* were reported to suffer badly as a result of impact with passing scallop or queen scallop dredges. Adults can repair non-lethal damage to the test and spines can be re-grown but most dredge impact is likely to be lethal. Schroeder et al. (2008) reported on fishery-induced mortality of *Echinus esculentus* reaching up to 50 %. Resistance has therefore been assessed as low. Sea urchin recruitment is sporadic and dependent on location but populations would probably recover within 5 years, except in locations isolated by geography or hydrography. *Echinus esculentus* has a high larval dispersal potential but is slow to mature and it would take several years for adult biomass to be restored.

Ciona intestinalis is a large ascidian, with a soft, retractile body. Physical disturbance by a passing dredge is likely to cause physical damage and death. Therefore, a resistance of low has been recorded. Recoverability is assessed to be moderate.

1.7.6.5 Changes in siltation

Table 1-36: Sensitivity of reefs towards the pressure 'changes in siltation'.

Changes in siltation		Resistance	Recoverability	Sensitivity
Physical habitat		intermediate	high	low
Characteristic species	*Leucosolenia botryoides*	intermediate	moderate	intermediate
	Alcyonium digitatum	intermediate	high	low
	Pomatoceros triqueter	low	high	intermediate
	Flustra foliacea	tolerant	not relevant	not sensitive
	Balanus crenatus	low	very high	low
	Pholas dactylus	high	very high	very low
	Cancer pagurus	high	very high	very low
	Echinus esculentus	intermediate	high	low
	Ciona intestinalis	intermediate	high	low
Habitat sensitivity				**intermediate**

Physical habitat – explanatory notes

Smothering of sediment will significantly change the habitat structure. Animals may be affected by the prevention of feeding, reduction in growth and reproduction, interference with respiration and potentially localized anoxia and interference with larval settlement. Tall erect species may survive due to their size, while some hydroids may survive as dormant stages. But encrusting sponge species and ascidians are likely to be damaged or killed by smothering, while vertical surfaces and overhangs will provide refuges from the effects of the factor (MarLIN 2013). Resistance is estimated as intermediate. Recoverability strongly depends on the prevailing hydrodynamic regime. In high energy environments deposits will be rapidly removed, while in environments with low and moderate current energy, as prevails in large parts of the German North Sea, recovery may take more than one year (Hill et al. 2011). Recoverability is therefore predicted as high.

Characteristic species – explanatory notes

(Information on species characteristics is taken from the MarLIN web site unless otherwise stated)

Leucosolenia botryoides is a very delicate, soft, white, tubular sponge that grows to up 2 cm wide and 1 cm thick. Accumulation of a few centimetres of sediment smothers the sponge. Increases in deposition of suspended sediment may interfere with feeding, clogging pores and channels etc. Many sponges have cleaning mechanisms for dealing with siltation such as sloughing of outer cells or mucus production. However, there may be significant inhibition of feeding and respiration and small colonies may suffer mortality if de-oxygenation below the silt occurs. Resistance is assessed as intermediate and recoverability due to lack of information on reproductive potential as moderate as a precautionary approach.

Alcyonium digitatum is permanently attached to the surface of rocky substrata. Thus it would be unable to avoid the deposition of a smothering layer of material up to a depth of 5 cm. Some colonies can attain a height of up to 20 cm so would still be able to expand tentacles and columns of the polyps to filter feed, and materials may be sloughed off with a large amount of mucous. Smaller / younger colonies that initially form encrustation's between 5 and 10 mm thick are likely to be killed by smothering as respiration is likely to be hindered and a resistance of intermediate is recorded. Recoverability is assessed to be high.

Smothering with a 5 cm layer of sediment would completely cover the tubes of *Pomatoceros triqueter* that usually lie flat against the surface of the rock. It is also likely that too much sediment on the surface of rocks or shells would prevent settlement of larvae and impair the long term survival of populations. Resistance has been assessed to be low. Recoverability is likely to be high.

Flustra foliacea dominated communities were reported to form in, and hence tolerate, areas subject to sediment transport (mainly sand) and periodic, temporary, submergence by thin layers of sand (ca <5 cm). In some cases, *Flustra foliacea* was seen to be partially buried by sand. It is likely that *Flustra foliacea* would withstand smothering by 5 cm of sediment for a month. Large colonies are likely to be >6 cm in height and exposed autozooids will be able to feed, providing food for the rest of the colony. Therefore, not sensitive has been recorded.

Balanus crenatus can withstand covering by silt provided that the cirri can extend above the silt layer but smothering by 5 cm of sediment would prevent feeding and could cause death. Resistance is therefore judged to be low. The species has a high dispersal and colonization potential as well as fast growth rates. Recovery is predicted to be very high.

Resistance to smothering is expected to be high because feeding apparatus can be cleared of particles although this will be energetically costly. Experimental work with *Pholas dactylus* showed that large particles can either be rejected immediately in the pseudofaeces or passed very quickly through the gut. In Exmouth, Knight (1984) found *Pholas dactylus* covered in a layer of sand and in Eastbourne individuals live under a layer of sand with siphons protruding at the surface. Recoverability is estimated to be very high.

The crab *Cancer pagurus* is able to escape from under silt and migrate away from an area. Smothering is unlikely to cause mortality therefore a resistance of high has been recorded. Recovery is predicted to be very high.

The adults of the sea urchin *Echinus esculentus* are slow moving and unlikely to be able to avoid smothering. A 5 cm layer of sediment is likely to affect smaller specimens more than large specimens. Smothered individuals are unlikely to be able to move through sediment. However, individuals are unlikely to starve within a month. A layer of sediment may interfere with larval settlement. Resistance is assessed to be intermediate and recoverability as high.

The ascidian *Ciona intestinalis* is permanently attached to the substratum and is an active suspension feeder. Because the adults reach up to 15 cm in length and frequently inhabit vertical surfaces, smothering with 5 cm of sediment will probably only affect a proportion of the population. Resistance is judged as intermediate and recoverability as high.

1.7.7 Species-rich habitats on coarse sands, gravel or shell gravel

1.7.7.1 Definition

Coarse sediments in the south-eastern North Sea are settled by the *Goniadella-Spisula*-association. Rachor & Nehmer (2003) differentiate two variations of this association in the EEZ. Characteristic species for both are *Ophelia limacina*, *Aonides paucibranchiata* and *Thracia* spp. The species-rich association can be found on coarse sands and gravel, e.g. in the Borkum Reef Ground, the Amrum Outer Ground and the Sylter Outer Reef. Rachor & Nehmer (2003) identified only one characteristic species for this habitat, the lancelet *Branchiostoma lanceolatum*.

This habitat type comprises mixed or unmixed sediments of coarse sands, gravel and shell debris, which are settled by a specific, species-rich endofauna and benthic community. Characteristic species according to the mapping guidelines of the BfN (2011) are: *Aonides paucibranchiata*, *Branchiostoma lanceolatum*, *Polygordius* spp., *Protodorvillea kefersteini*, *Echinocyamus pusillus*, *Spisula elliptica* and *Pisione remota*. These species should also be used in the sensitivity assessment, however, little information on biological traits is currently available especially for the small polychaetes.

1.7.7.2 Selective extraction

Table 1-37: Sensitivity of species-rich habitats on coarse sands, gravel or shell gravel towards the pressure 'selective extraction'.

Selective extraction		Resistance	Recoverability	Sensitivity
Physical habitat		low	low	high
Characteristic species	*Aonides paucibranchiata*	low	moderate	intermediate
	Branchiostoma lanceolatum	low	moderate	intermediate
	Pisione remota	low	moderate	intermediate
	Echinocyamus pusillus	low	moderate	intermediate
	Spisula elliptica	low	high	intermediate
Habitat sensitivity				**high**

Physical habitat – explanatory notes

The extraction of sediment implies the complete removal of substrate by creating longitudinal tracks of generally 2-3 m width and up to 50 cm depth (trailer suction dredging) or rounded pits of around 10 m depth and with a diameter of 10-50 m (anchor dredging). Severe alterations of seabed topography and possibly also changes in sediment composition occur, therefore resistance to selective extraction is rated as low.

Physical seabed structures are supposed to have recovered when dredge tracks have disappeared and the original sediment composition is restored. Research on seabed recovery mostly focuses on observation of dredge furrows, while the recovery of sediment composition may take far longer but is less intense investigated. Recovery takes the longest period of time at dredge sites characterised by coarse sediments (Hill et al. 2011). Observations from studies conducted in sandy gravel sediments reveal that the morphological behaviour of dredged tracks and pits varies significantly. In an area exposed to long-period waves, dredge tracks 0.3–0.5 m deep, in a gravelly substrate at a depth of 38 m, were found to disappear completely within eight months. In contrast, at an experimental dredged gravel site off Norfolk, UK, in 25 m of water, dredge tracks appeared to have been completely eroded well within three years of the cessation of dredging. Erosion of dredge tracks in areas of moderate wave exposure and tidal currents have been observed to take from three to more than seven years in gravelly sediments. In the latter case, however, infill resulted mainly from sand in transport. Especially in coarse sediments, the refill material may be finer grained than the material on the surrounding seabed, which could lead to a permanent change in benthic communities (Herrmann & Krause 1998). In the southern North Sea where tidal currents are generally strong, sand with a grain size up to 2 mm is mobile across the area during spring tides (Hill et al. 2011). However, the regeneration of gravel may not be possible, as there are no hydrodynamic mechanisms known to restore gravel or stony habitats (Herrmann & Krause 1998). As there is the risk of at least part of the habitat being lost, recoverability is recorded as low.

Characteristic species – explanatory notes

(Information on species characteristics is taken from the MarLIN web site unless otherwise stated)

The majority of species in coarse sands, gravel or shell debris habitats is infaunal and would therefore be removed along with the substratum. Only some epifaunal and swimming species may be able to avoid the impact. Resident populations of the benthic endofauna would be lost, so resistance for all characteristic species is assessed as low.

Aonides paucibranchiata is a small-sized polychaete with limited mobility. The fecundity and dispersal potential of this genus is low (larval duration 2-10 days), so recolonisation from sources outside a disturbed area is likely to be slow. Recoverability is estimated to be moderate (MES 2008).

For lancelets in general, it is supposed that they are iteroparous (reproducing more than once in a lifetime), spawning repeatedly in their several-year lifetime, but only once per breeding season. Fuentes et al. (2007) studied the spawning behavior of the European Lancelet *Branchiostoma lanceolatum* along the Mediterranean coast of southern France. They found that spawning occurs from around mid-May to early July, but varies from year to year (EOL 2013). No information is available on potential of larval dispersal, therefore recoverability has been assessed as moderate.

Pisione remota lives for 3-5 years and is likely to reach maturity after one year. Reproduction is from August-September and fertilisation is internal after which planktonic larvae are released into the water column. There is very little information on the length of the larval phase. It is probable that this genus has a moderate recoverability based on the presence of a pelagic dispersal phase, but more information is required on fecundity and larval biology to have confidence in this assessment (MES 2008).

Echinocyamus pusillus is small and only lives for 1-3 years, reaching sexual maturity after one year. There is little information available on its fecundity. Reproduction is external and the planktotrophic larvae occur in the plankton from March to September indicating a high dispersal potential. Once the sediment has become colonised, the abundance and biomass of *Echinocyamus pusillus* could be expected to recover within 3 years.

Little information is available on biological traits of *Spisula elliptica*, therefore sensitivity of the closely related species *Spisula solida* is used as reference. The bivalve *Spisula solida* can live up to ten years. Individuals are sexually mature at 1 year, regardless of their size. The sexes of *Spisula* are separate and both show a synchrony in gametogenic development and spawning. Gametogenesis starts in September when temperatures decrease and spawning begins in February. Larvae can remain in the water column for several weeks, allowing fairly wide dispersal. The potential recovery of this bivalve is high and is often recorded amongst the first colonizers of sediments disturbed by dredging.

1.7.7.3 Abrasion

Table 1-38: Sensitivity of species-rich habitats on coarse sands, gravel or shell gravel towards the pressure 'abrasion'.

Abrasion		Resistance	Recoverability	Sensitivity
Physical habitat		intermediate	moderate	intermediate
Characteristic species	*Aonides paucibranchiata*	intermediate	high	low
	Branchiostoma lanceolatum	intermediate	high	low
	Pisione remota	intermediate	high	low
	Echinocyamus pusillus	intermediate	high	low
	Spisula elliptica	intermediate	high	low
Habitat sensitivity				**intermediate**

Physical habitat – explanatory notes

Impacts of fishing gears on habitats with coarse sands include the smoothing of the seafloor by flattening of biogenic structures or sand ripples, the penetration of sediment, smothering by resuspended sediment and displaced or overturned gravel (Environment Agency 2010). Otter trawls generally disturb the upper 1-5 cm while beam trawls scour the sediment down to 8 cm (FAO 2004). Resistance towards abrasion is assessed as intermediate.

Recovery time in gravel habitats has been predicted to be in the order of ten years, while physical restoration of sandy habitats has been observed to be rapid (days to few months) (Environment Agency 2010). The visible dredge marks from towed gear have been shown to be relatively short lived, lasting no more than a year in coarse sediments. Monitoring of a 'closed area' of gravel habitat on Georges Bank, showed that five years after closure of the area to high levels of scallop fishing, the biomass and abundances of certain taxa (including crabs, molluscs, polychaetes and echinoderms) were still increasing. As such, the authors predicted that the recovery time for gravel habitats was in the order of ten years. Similar recovery rates were observed during 10 years of monitoring of a gravelly habitat off the Isle of Man following closure to scallop dredging. The authors speculate that the slow rate of recolonization of gravel habitat by structure-forming epifauna (sponges, bryozoans, anemones, hydroids, colonial tube worms) following fishing disturbance may be due to factors such as the low survival of recruits of these species, due to intermittent burial of the gravel by migrating sands, and the presence of high numbers of scavengers (crabs, echinoderms, nudibranchs, gastropods), the abundance of which increased rapidly on the gravel post disturbance. Hence, this suggests that the recovery of these habitats may be slower than individual life history traits predict. Recoverability is assessed as moderate.

Characteristic species – explanatory notes

(Information on species characteristics is taken from the MarLIN web site unless otherwise stated)

Little is known about the life history of the polychaete worm *Aonides paucibranchiata* but its size and morphology suggest that it is likely to be vulnerable to physical disturbance. Infaunal polychaetes with little mobility are likely to be damaged by abrasion and suffer some degree of mortality. Resistance is judged as intermediate. As a short-lived animal with small body size, it is likely to recover adult biomass relatively quickly following colonisation by juveniles (MES 2008). Providing that part of the population survives, *Aonides paucibranchiata* is likely to have a high recoverability.

Although the lancelet *Branchiostoma lanceolatum* is able to swim, most of the time is spent partially buried in the sand filtering microscopic food particles from the water. Disturbance and penetration of the sediment is likely to damage or kill some individuals of the population. Resistance is therefore judged to be intermediate. Recoverability is assessed as high.

Pisione remota is a small free-living polychaete with a body length of 1.5 cm and lives burrowed in coarse sand where it is a carnivore feeding on small invertebrates. It has some mobility but may be vulnerable to abrasion and physical disturbance. Resistance is estimated to be intermediate and recoverability as high.

The sea urchin *Echinocyamus pusillus* has a fragile shell which may be damaged by abrasion. Resistance is assessed as intermediate and recoverability as high.

Little information is available on biological traits of *Spisula elliptica*, therefore sensitivity of the closely related species *Spisula solida* is used as reference. Fishing for demersal species will disturb the surface layer of sediment and any protruding or shallow burrowing species. Experimental trawls showed that 93% of the uncaught *Spisula solida* were undamaged, as they were well protected by their thick shells, and only 1% died. The impacts caused by a fishing dredge significantly increased the number of exposed *Spisula solida* clams and the abundance of potential predators. The impact of the dredge increased the time needed for *Spisula solida* to rebury, which rendered them vulnerable to predation for longer periods. Resistance has been assessed as intermediate as mortality may occur and recoverability has been assessed as high.

1.7.7.4 Changes in siltation

Table 1-39: Sensitivity of species-rich habitats on coarse sands, gravel or shell gravel towards the pressure 'changes in siltation'.

Changes in siltation		Resistance	Recoverability	Sensitivity
Physical habitat		intermediate	very high	low
Characteristic species	*Aonides paucibranchiata*	high	very high	very low
	Branchiostoma lanceolatum	high	very high	very low
	Pisione remota	high	very high	very low
	Echinocyamus pusillus	high	very high	very low
	Spisula elliptica	intermediate	high	low
Habitat sensitivity				**low**

Physical habitat – explanatory notes

Sediment plumes generated by construction works or aggregate extraction may cause changes in habitat structure such as infilling of small pits by fine sediments or siltation within crevices (Hill et al. 2011). Finer sediment particles remain in suspension longer than larger particulates and can disperse over a wider area. As suspended particles tend to be significantly finer than the prevailing coarse sands and gravels, changes in sediment composition are supposed to be more distinct than e.g. in mud habitats. Resistance of coarse sands, gravel and shell debris habitats is therefore regarded as intermediate. Recovery is dependent on seabed transport, wave and tidal energy. It is estimated to be very high in coarse sediments.

Characteristic species – explanatory notes

(Information on species characteristics is taken from the MarLIN web site unless otherwise stated)

Aonides paucibranchiata is a small deposit feeding polychaete with limited mobility. The species lives in a loosely constructed tube or is free-living (MES 2008). An additional 5 cm layer of sediment would result in a temporary cessation of feeding activity, and therefore growth and reproduction are likely to be compromised. However, *Aonides paucibranchiata* would be expected to quickly relocate to its favoured depth, with no mortality, and hence a high resistance is recorded. Recoverability will probably be very high.

Information on the impact of smothering to the lancelet Branchiostoma lanceolatum is not available. However, as a species burrowing in sediment, it is likely to be able to accommodate deposition of sediment. The population may still suffer from reduced viability, so tolerance is assessed as high. Recoverability is assumed to be rapid.

The burrowing polychaete *Pisione remota* may be able to accommodate deposition of small quantities of sediment, probably with some additional energetic costs (MES 2008). Resistance is estimated as high and recoverability as very high.

The sensitivity of *Echinocyamus pusillus* to sedimentation is difficult to assess due the paucity of information but as a burrowing species it is likely to be able to resurface through thin veneers of sediment (MES 2008). Resistance is assessed as high and recoverability as very high.

Little information is available on biological traits of *Spisula elliptica*, therefore sensitivity of the closely related species *Spisula solida* is used as reference. *Spisula solida* is a fast burrowing bivalve and suspension feeder. If *Spisula solida* were covered by sediments it would be able to reposition itself within the sediment. Fahy et al. (2003) noted that in a clam bed in Ireland, where part of the bed has silted up, numbers of *Spisula solida* and the size of the clam patch were reduced. Therefore resistance has been assessed as intermediate to reflect the reduction in the size of the clam bed and *Spisula* numbers. Recoverability is assessed as high.

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