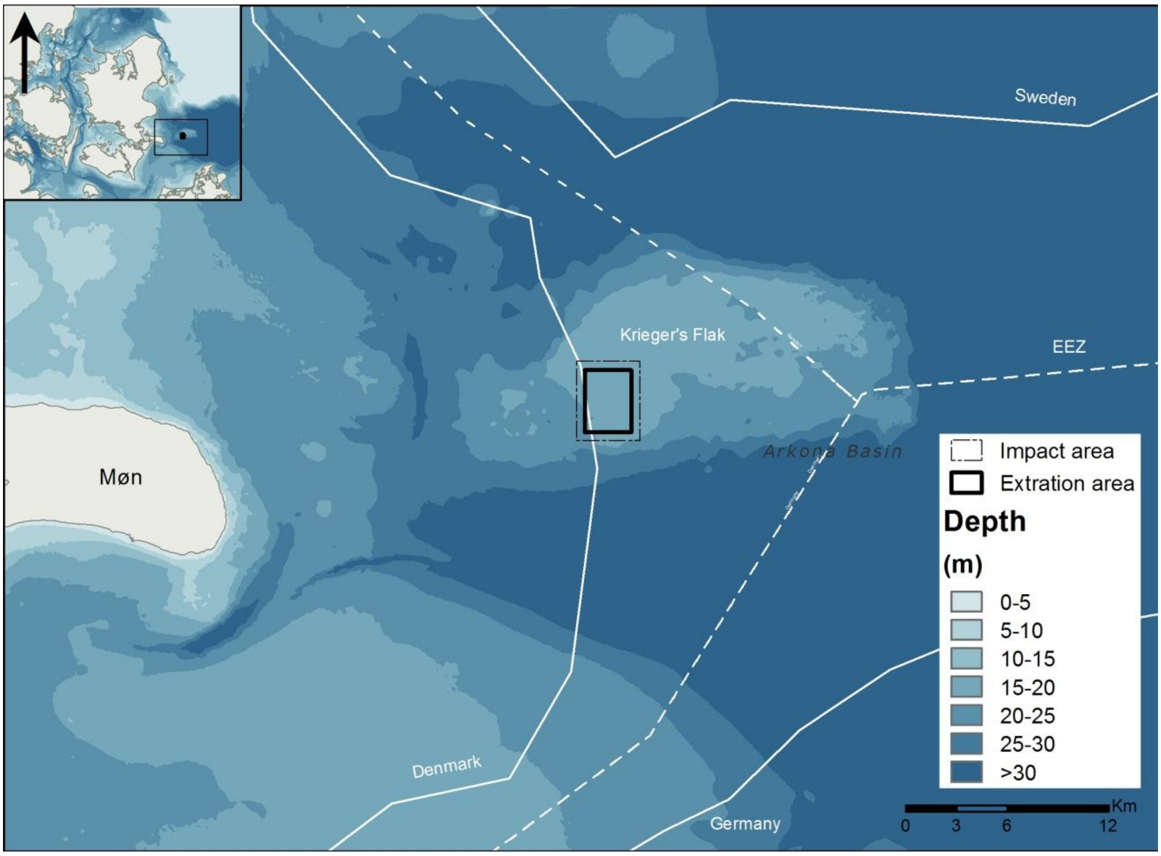
Final Report

FEHMARNBELT FIXED LINK
Marine Biology Services (FEMA)

Environmental Impact Assessment (EIA) of Sand Extraction at Krieger's Flak

E2TR0027



Prepared for: Femern A/S
By: DHI/IOW/Marilim Consortium
in association with Cefas and DTU Aqua

Responsible editor:
FEMA consortium / co DHI
Agern Allé 5
DK-2970 Hørsholm
Denmark

FEMA Project Director: Hanne Kaas, DHI
www.dhigroup.com

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ACRONYMS AND ABBREVIATIONS

AFDW: Ash Free Dry Weight

AIS: Automatic Identification System (for ship traffic)

BS: Baltic Sea

Cd: Cadmium

Cr: Chromium

Cu: Copper

D50: Median Grain Size

DW: Dry Weight

EEZ: Exclusive Economic Zone

EIA: Environmental Impact Assessment (in Danish VVM)

EPA: Environmental Nature Agency

H Ac: Higher Action Level (SQG used by the Danish EPA, concentrations above H Ac are considered problematic)

Hg: Mercury

L Ac: Lower Action Level (SQG used by the Danish EPA, concentrations below L Ac are considered unproblematic)

LOI: Loss On Ignition (equivivalent to organic content)

Ni: Nickel

OSPAR: Oslo and Paris Commission

PAH: Polynuclear Aromatic hydrocarbons

Pb: Lead

PCB: Polychlorinated Biphenyl

PSU: Practical Salinity Unit

PTS: Permanent threshold shifts (hearing loss in mammals)

Sn: Tin

SQG: Sediment quality guidelines

TBT: Tributyltin

TN: Total Nitrogen

TP: Total Phosphorus

TTS: Temporary threshold shifts (hearing loss in mammals)

VMS: Vessel Monitoring System

VVM: Vurdering af Virkninger på Miljøet

Year 2014: “year 0”; Year 2015: “year 1”; etc.

Zn: Zink

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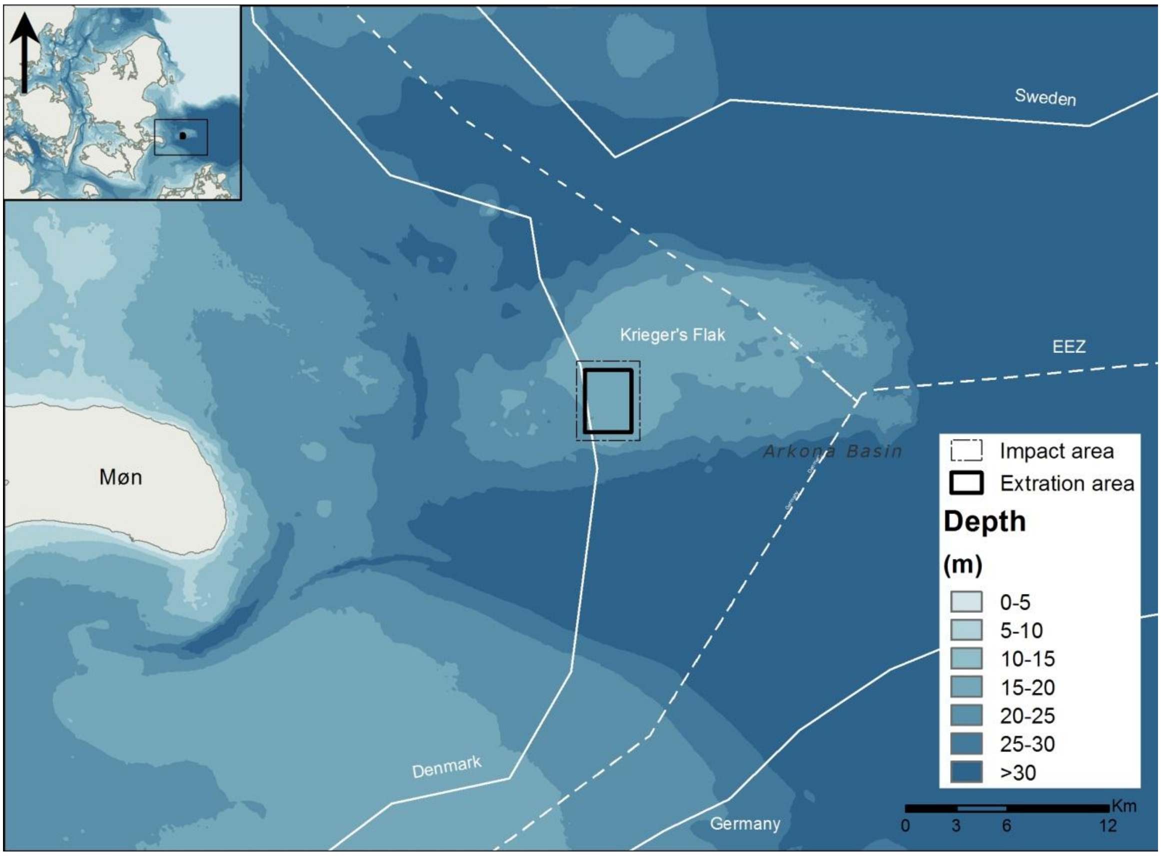
Note to the reader:
In this report the time for start of construction is artificially set to 1 October 2014 for the tunnel and 1 January 2015 for the bridge alternative. In the Danish EIA (VVM) and the German EIA (UVS/LBP) absolute year references are not used. Instead the time references are relative to start of construction works. In the VVM the same time reference is used for tunnel and bridge, i.e. year 0 corresponds to 2014/start of tunnel construction; year 1 corresponds to 2015/start of bridge construction etc. In the UVS/LBP individual time references are used for tunnel and bridge, i.e. for tunnel construction year 1 is equivalent to 2014 (construction starts 1 October in year 1) and for bridge construction year 1 is equivalent to 2015 (construction starts 1st January).

EXECUTIVE SUMMARY

Introduction

Denmark and Germany are planning a Fixed Link between Denmark and Germany across the Fehmarnbelt. One important part of this work is to prepare an Environmental Impact Assessment, EIA (in Denmark VVM and in Germany UVS) in order to get approval of the project by the authorities in Denmark and Germany. This report is a part of a number of background reports forming the base of the Environmental Impact Assessment (EIA) for the Fehmarnbelt Fixed Link.

Sand and gravel is required for construction and backfill of both selected alternatives, a cable stayed bridge and an immersed tunnel. Two areas have been designated for sand extraction by Femern A/S: Krieger's Flak and Rønne Banke. According to the sand extraction plan for the Fehmarnbelt Fixed Link 6 mill m^3 of sand for the backfilling of the tunnel trench are expected to be extracted from Krieger's Flak.



Location of Krieger's Flak.

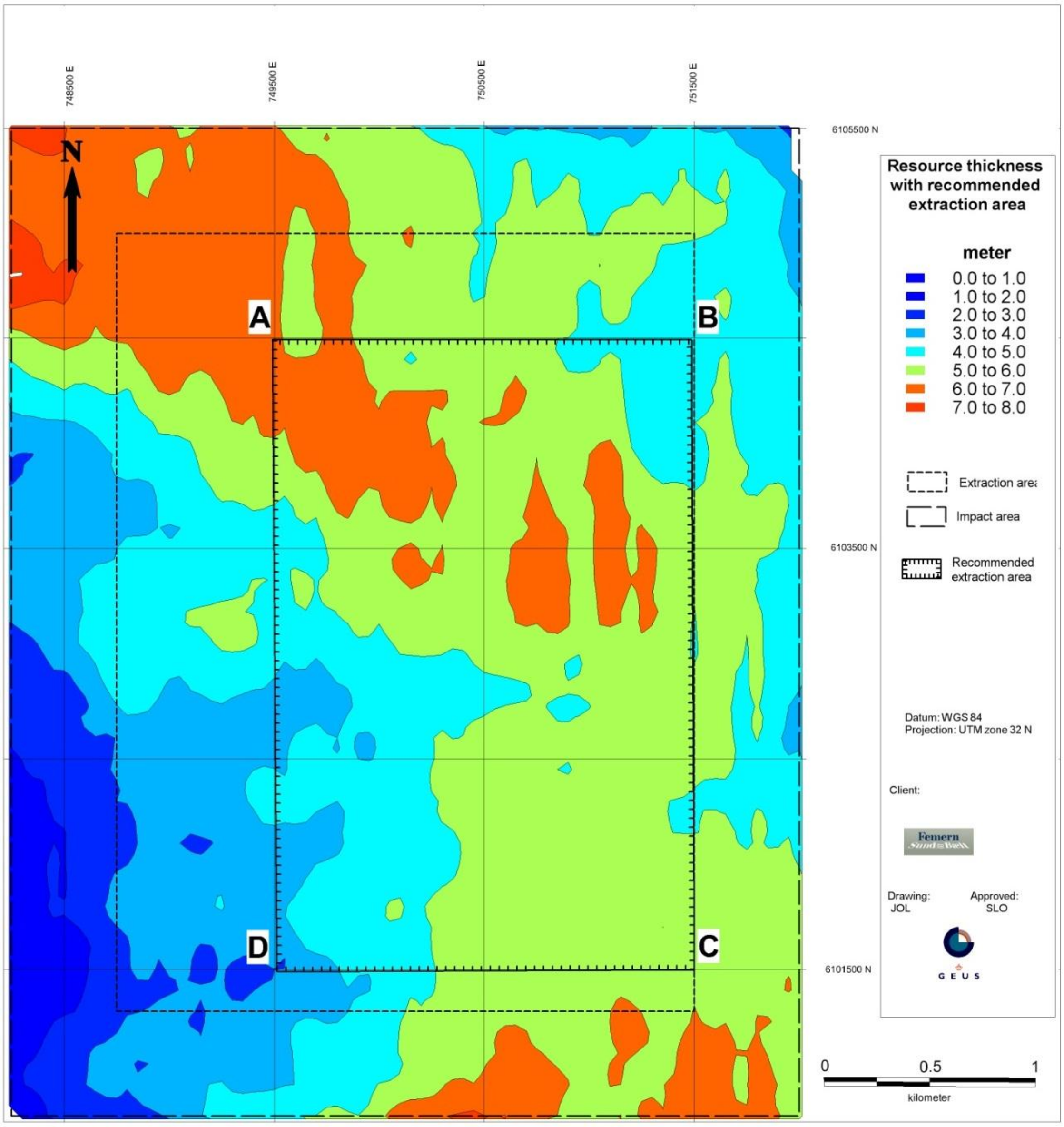
The present report covers the mapping of the sand resource, a baseline description and an impact assessment of the sand extraction at Krieger's Flak. Furthermore the impact assessment contains a screening of a possible impact on the Natura 2000 area outside the coast of Møn.

In July-August 2011, new seismic data and seabed samples were acquired with the purpose of mapping resources and describing the biological conditions in the investigation area at Krieger's Flak. Baseline conditions were described combining new data with existing information. Seismic data have been used to map resources, seabed sediment and substrate types. The physical and biological conditions have been described to assess the possible impacts caused by sand extraction, sediment spill, sedimentation of spill, traffic and noise on the environmental factors water quality, benthic flora and fauna and fishery in and around the planned sand extraction area. The EIA study describes the predicted short- and longterm impacts on the environment.

Project areas

Krieger’s Flak is located in the Baltic Sea, 30 km east of the island Møn. It is a part of a large resource area which has previously been exploited for larger construction projects. The designated extraction area at Krieger’s Flak is approximately 10 km^2. The investigated area includes a surrounding 500 m impact zone and the total area is approximately 17.5 km^2.

Resource mapping and sand extraction plan



Resource thickness of Krieger’s Flak including the sub-area recommended for extraction.

Resource

The resource at Krieger's Flak is part of an elongated shaped sandy ridge with sand thickness up to 7 m mainly deposited as coastal spit deposits of sand, gravel and scattered stones. The uppermost 1 m of Recent to Sub-Recent marine sand is continuously reworked due to wave and current activity. The available resource in the designated area is approximately 40 mill m^3.

Extraction area

To minimize the physical and biological impacts it has been suggested that the required backfilling material can be produced in a sub-area of 2 x 3 km (6 km^2) where 1-2 m of the seabed can be extracted. The resource thickness in the sub-area is more than 4 m (see map with resource thickness).

Dredging

The sand extraction from Krieger's Flak is recommended to take place by trailing hopper suction dredgers. The capacity of this type of dredger is typical 2,000-6,000 m^3 corresponding to 1,500 to 4,200 m^3 sand. If a 6,000 m^3 dredger is used, about 1,428 cargos of sand will be transported from Krieger's Flak to the Fehmarnbelt construction site, and if a 10,000 m^3 dredger is used 800 cargos will be needed. The trailing suction method leaves the seabed with dredging scars of 1-2 m width and 0.5 to 1 m depth. The sand extraction will be a steady operation following the dredging and backfilling plans for the tunnel trench. According to the plan the activities will take place between June 2016 and November 2018.

Alternative areas

Two alternative resource areas to the Krieger's Flak are known from the German continental shelf in the Baltic region: Plantagenet Ground and the Adler Ground. The areas are partly Habitat and Bird Protection sites and the resources are for local use (beach nourishment). Five alternative resource areas are known on the Danish continental shelf in the Baltic region: Vejsnæs Flak, Keldsnor, Rødbyhavn, Gedser and Gedser Rev. Both the German and the Danish resources are dedicated for local use. More intensive investigations are required if additional resources within these areas should be made available for the construction of the Fehmarnbelt Fixed Link.

The construction of the Fehmarnbelt Fixed Link with raw materials onshore sand and gravel pits have been investigated. The southern part of the Zeeland and surrounding islands has estimated to have approximately 12.5 millm^3 resources left in sand and gravel pits. By 2013 less than 10 mill m^3 is left and these materials are planned for local use for construction works and buildings. Hence onshore materials are not an available resource for the Fehmarnbelt Fixed Link.

0-Alternative

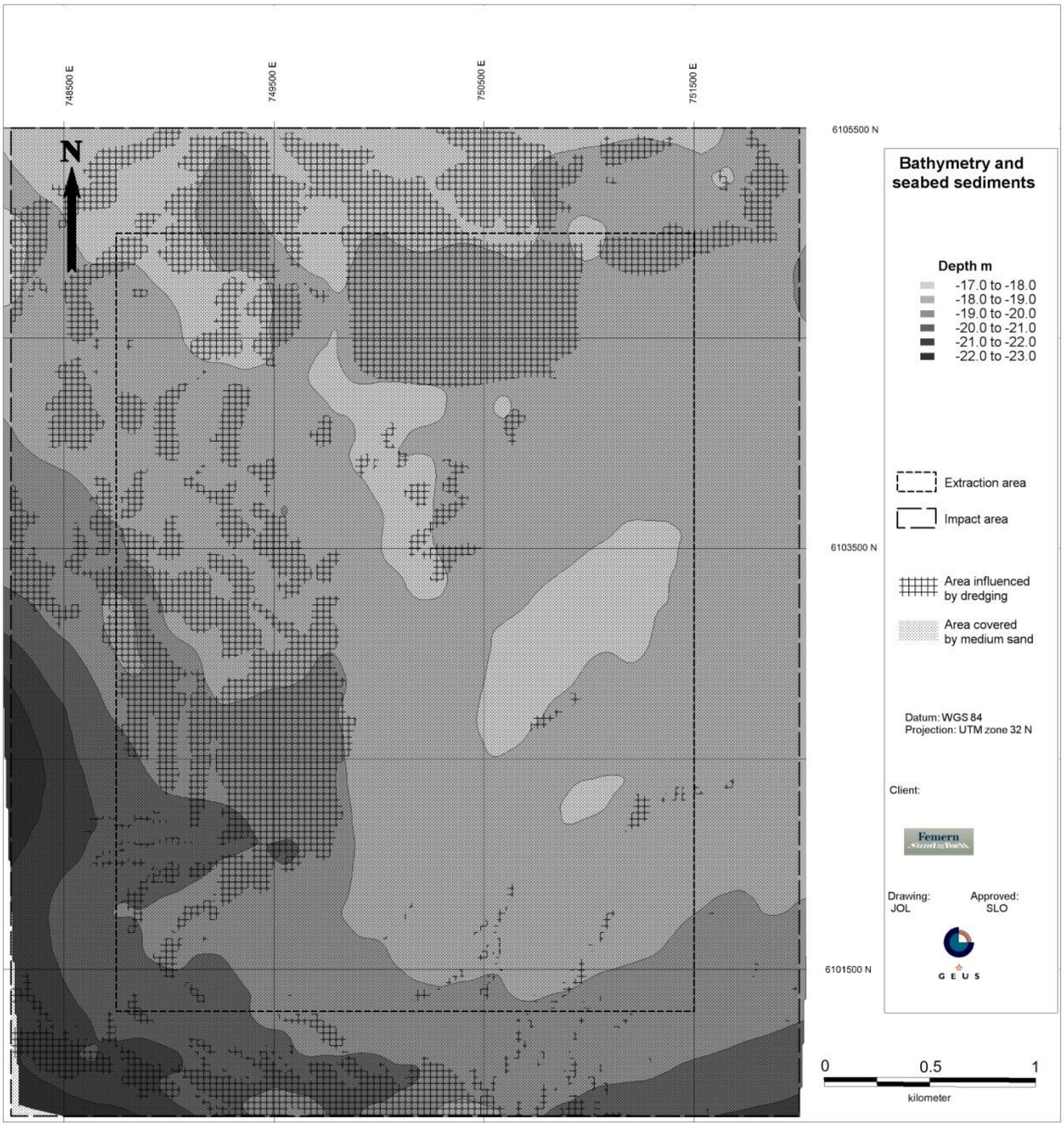
In case of not building the Femarnbelt Fixed Link there will be no effect on the marine environment from sand extraction.

Baseline description

Seabed, bathymetri and sand transport processes.

To characterize and classify the seabed sediment acoustic data were acquired by use of a side scan sonar system. The data were used for seabed classification subdividing the seabed into classes of different reflectivity. To confirm the initial classification ground truthing at selected stations was performed in August 2011 using Van Veen grab and video inspections. The stations were the same stations as the ones used at the fauna sample sites. The seabed in the extraction area and the surrounding 500 m impact area is classified as substrate type 1, medium grained sand with an average grain size between 0.2 and 0.5 mm with some content of gravel and coarser fractions. Recent dredging activities have taken place in the northwestern part of the extraction and impact area leaving the seabed with plenty of scars and spill cones from the sand extraction activities. In these areas deposits of gravel and cobbles have accumulated in a patchy pattern after the sand fraction of the resource has been extracted. The latter seabed type is in this context considered as an artificial substrate type as a result of human activities.

The water depth in the area is between 18 and 21.5 m, and up to 23 m in the 500 m impact zone.



Seabed sediment map of Krieger's Flak showing the general medium grain size sandy seabed and areas of lag deposits of gravel and cobbles.

Sand transport processes

The sediment transport has been estimated based on data on currents and waves. The resulting sediment transport conditions are presented in the table below.

Transport capacity [m3/m/year] for the sand extraction area at Krieger's Flak.

Wave height H_S [m]	**Peak wave period, T_p [s]**	**Current speed [m/s]**	**Yearly durati-on [%]**	**Water depth [m] 18**	**20**
				Transport capacity [m³/m/year]	
1	5	0.05	58	0	0
2	6	0.1	13	0	0
3	7	0.18	1.7	0.1	0.02
4	7.5	0.25	0.2	0.11	0.06
Total annual transport capacity				0.21	0.08

The current regime at Krieger's Flak is very weak and the current speed is below 0.2 m/s in 99.6% of the time. A current speed of 0.2 m/s is needed to initiate transport of sand at the seabed.

The wave action is also important with regard to sand transport processes. The predominant waves are from W to SW and from easterly directions. The main current direction is towards WSW, which is related to outward flow from the Baltic Sea. The inward flow causes E to SE-ward direction. The current speed at Krieger's Flak is below 0.2 m/s in 99.6% of the time.

Water quality

Relevant hydrographic and water quality data are available from a near-coastal station east of Møn (Hjelm Bugt "0901008") sampled monthly during 1990-1997 under NOVANA Programme and also sampled monthly under the Fehmarn Link Baseline study (Station H131, formerly known as Kadett Trench station). Additional hydrographic and oxygen data collected in the Swedish sector of Kriegers Flak in 2002 and 2003 in connections with an Environmental Impact Assessment for a Wind Farm at Krieger's Flak (Sweden offshore wind AB 2007) provided data from near the sand mining site.

On a yearly basis, the salinity is stable at 7-9 PSU in the upper part of the water column. Density stratification occurs regularly during calm periods in summer and is reinforced by thermoclines located between 10 and 15 m. Temperature in surface water varies seasonally between 0 and 20 °C, but falls below 0 in cold winters In bottom water (18-22 m) temperature only rarely exceeds 15 °C.

During winter, spring and early summer concentration of dissolved oxygen in bottom water is saturated (or near-saturated) with concentrations varying between 7 and 11 mg/l depending on temperature. During summer and early autumn (July-September) oxygen in bottom water becomes under-saturated if stable density stratification is established. Results from the baseline study are confirmed by the NOVANA monitoring and samplings in the Swedish sector of Krieger's Flak.

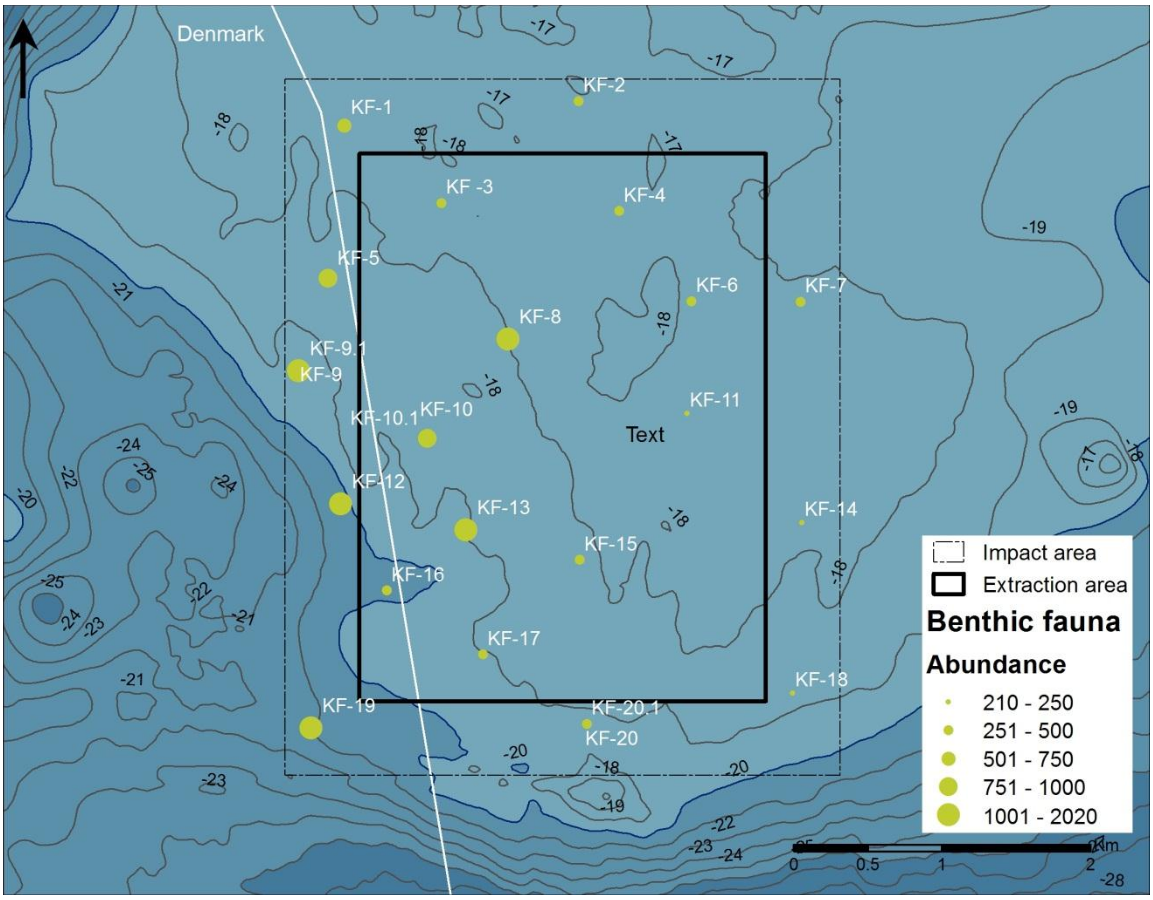
At the station H131 TN varied between 16–24 µmol/l without particular trends through the water column and year (2009-2010). TP was in the same period 0.5-1 µmol/l in the entire water column with the lowest observations in the summer period. Spring bloom occurred in March (2009) and early April 2010 with peak concenntrations reaching 6-8 µg/l. A prolonged autumn bloom (mid-August through

November) was recorded in 2009 and less pronounced in 2010. Averaged over the two years the yearly concentration was 1.5 µg/l.

Benthic Fauna

Quantitative samples of the benthic fauna and subsamples of the surface sediment were collected at 20 stations at Krieger's Flak in August 2011.

The species richness is characteristic for shallow, low saline areas in the Baltic Sea. The abundance and biomass of the benthic fauna were low and dominated by a few species of polychaetes (*Pygospio elegans* and *Marenzelleria viridis*) and bivalves (*Mytilus edulis, Mya arenaria* and *Macoma balthica*).



Abundance of the benthic fauna at Krieger's Flak in August 2011.

The abundance of the benthic fauna was between 210 and 2,020 m^{-2}. The abundance was above 1,000 m^{-2} at a number of stations mostly located in the western part of the survey area. The biomass was between 0.190 and 13.26 g AFDW m^{-2}. The biomass was highest at stations K-12 and K-13 located in the deeper south-western part of the survey area.

The impact area is characterised by a limited range of water depth and uniform sediment with a low content of organic matter. The species richness is characteristic for shallow, low saline areas of the Baltic Sea. The community of the area resembles the Cerastoderma community. The abundance and biomass of the benthic fauna were low and dominated by a few species of polychaetes (*Pygospio elegans* and *Marenzelleria viridis*) and bivalves (*Mytilus edulis, Mya arenaria* and *Macoma balthica*). The similarity of the benthic fauna was high and only slightly different at a few stations due to a high abundance and biomass of *Mytilus edulis*. The Macoma

(Cerastoderma) community is typically found at all depths in The Baltic Sea and is widely distributed in the surrounding areas.

Benthic vegetation

Macroalgae was not observed within the impact area, which is the extraction area plus the surrounding 500 m impact zone.

Outside the impact area (along transects) only very few small single macroalgae of the genus Laminaria spp. was observed. The very limited is most likely due to lack of substrate on which the flora can grow as the area primarily consists of sand.

A thin layer of algea was observed on top of the sediment at most sampling stations. The layer most likely consisted of a mixture of sedimented algae and benthic microalgae.

Fish

Fish surveys were not undertaken in connections to this investigation thus the baseline description of the fish community in the extraction area of Krieger's Flak has been based on both general knowledge, literature on fish in the Baltic Sea and on fish surveys undertaken in the Swedish and German parts of Krieger's Flak.

Species diversity is low in the Baltic Sea due to its character as a geologically very young brackish sea with a prehistory as a freshwater lake. Many species are precluded due to the low oxygen levels and to fluctuating and progressively lower salinities as one move from the outer to the innermost parts.

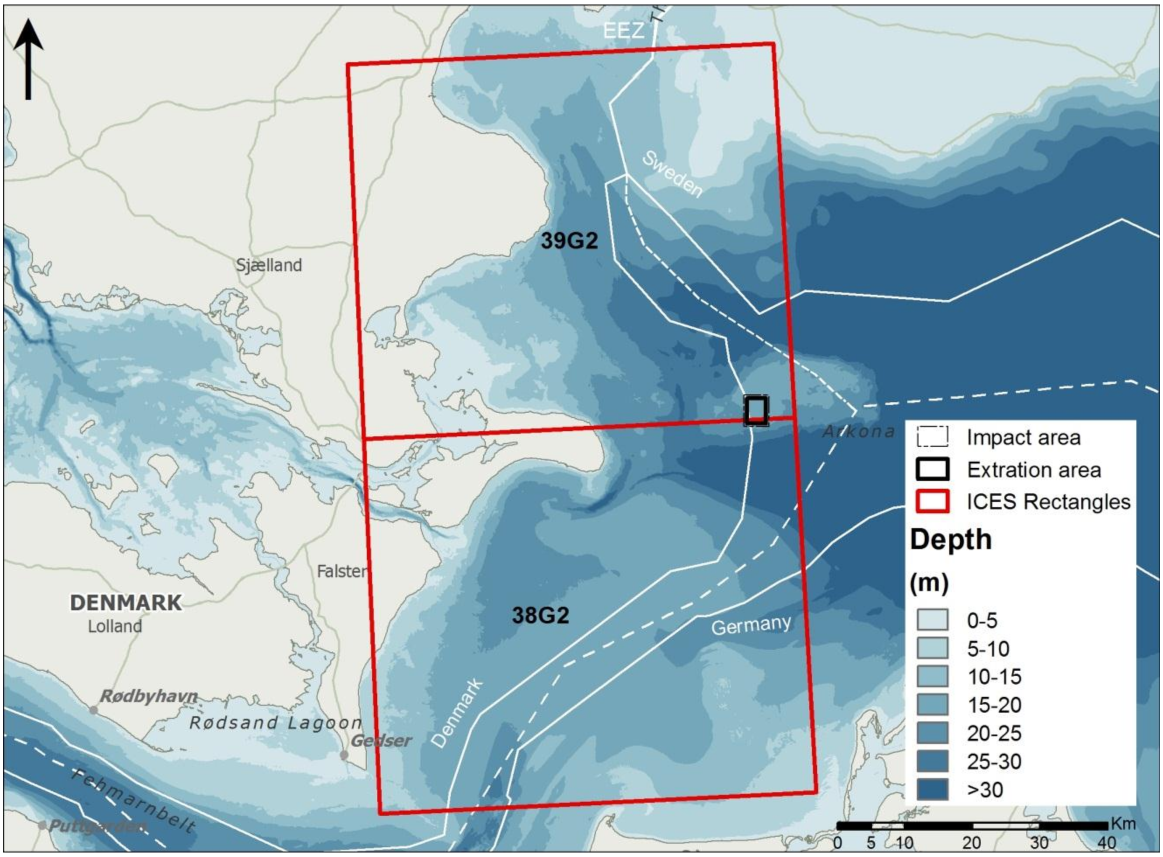
In total 41 fish species are registered in the Krieger's Flak area of which 28 spend their entire life cycle in the Baltic Sea area - 5 species are anadromous, spawning and growing up in rivers running into the Baltic Sea. Three species: the catadromous eel and the highly migratory lumpsucker and garfish spend significant parts of their life outside the Baltic Sea. The remaining 10 species also only occur sporadically, and have their main distribution outside the Baltic Sea.

The fish community found in the Krieger's Flak-area can be divided into two categories: pelagic fish living near the surface or in the water column: Herring, sprat, salmon, trout, garfish, sandeel (pelagic in daytime), twaite shad, and demersal (benthic) fish species living in, on or close to the seabed: Cod, sandeel (in night and in wintertime), flatfish-species, eel and lumpsucker (demersal when feeding, pelagic during migration), bull-rout, gobies (transparent goby partly pelagic). Most of the demersal species prefer sandy seabeds with stones, mussel banks, sea grass and algae. Sandy bottoms are preferred by flatfishes and sandeels – especially important to the sandeels because of their burrowing mode of life, living in the bottom during night and in wintertime.

Twaite shad, river lamprey, autumn spawning herring, salmon, cod, eel and sea snail, are included in the HELCOM List of threatened species and categorised as endangered. Salmon, twaid shad and river lamprey are also listed in annex II and V of the Habitats Directive.

Fisheries

The fisheries in the Baltic are divided by the international fishery zones where national and international fishery regulations and quotas apply and catch data are separated. These zones: ICES rectangles (approx. 30 x 30 nm) are used to form the boundaries for the presentation of the official commercial fisheries data. The proposed area for sand extraction at Krieger's Flak is situated in two ICES rectangles: 39G2 (78%) and 38G2 (22%). The sand extraction area constitutes less than 1% of the area of an ICES rectangle.

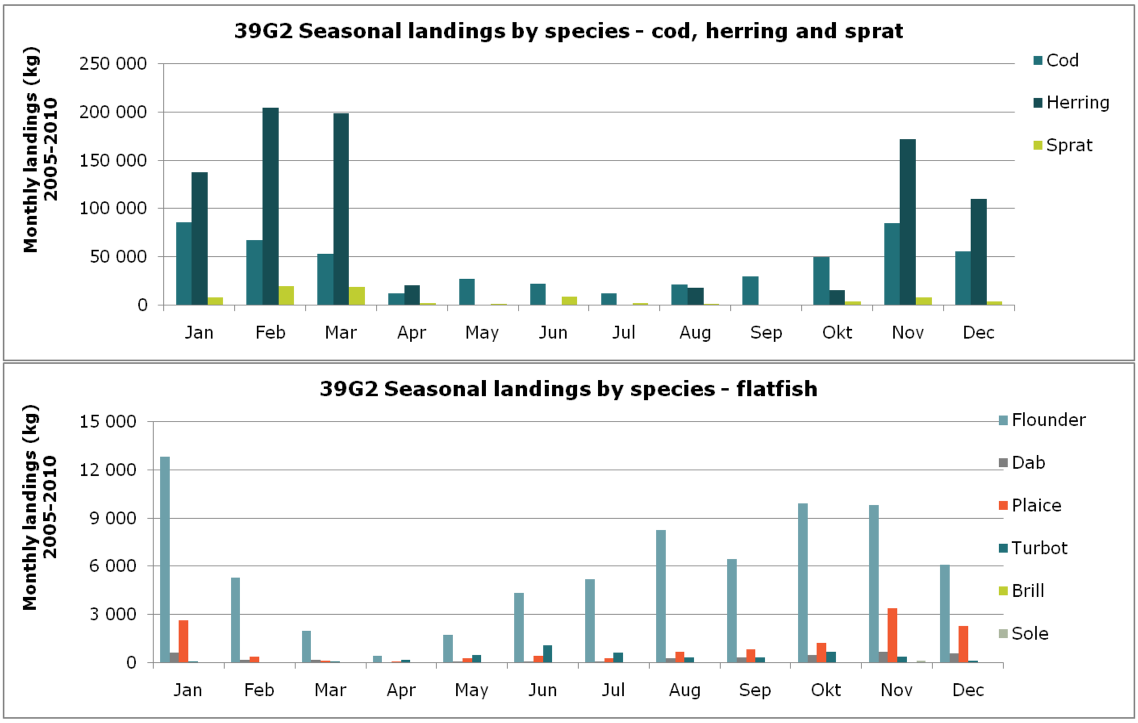


The ICES statistical rectangles 38G2 and 39G2 in the Western Baltic Sea. The proposed extraction area is represented by a black rectangle in the south-eastern corner of 39G2.

The total landings from ICES 38G2 have decreased from 6,800 tons (43 mill DKK) in 2005 to 1,500 tons (18 mill DKK) in 2010. Landings from ICES 39G2 have fluctuated between 1,500-2,100 tons (10-20 mill DKK in value) over the last 6 years.

More than 70% of the total landings are from the trawl fisheries. The values of the landings, however, represent less than 50% of the total value of the landings. Landings from gill netters have been constantly declining during the period 2005-2010 to a present low level.

The seasonality of the landings from ICES 39G2 show that a large majority of landings are from trawl fishing and that most of the trawling and partly the gill nets fishery activity is taking place between November and March.



Seasonal landings of the most important fish species from ICES 39G2 (Danish Directorate of Fisheries – logbook registration).

Monthly landings of cod and herring are at their highest level between October and March. Flatfish species are landed throughout most of the year except from a minimum between March and May.

The value of cod landings is 3 times higher than the landings of all the other species combined. Herring is the second most important species after cod with a total value to the fisheries 10 times greater than that of sprat.

According to Vessel Monitoring System (VMS) data (VMS, installed on ships ≥15 m) and the trawl fishermen's electronically saved trawl tracks a significant trawling route passes through the proposed extraction area. Almost no fishery with larger gill netters is taking place inside the extraction area due to the gill netters usually use areas that have many stones and boulders as well as wrecks where trawling cannot be undertaken.

The number of small vessels (8-15 m) operating in the area is greater than the number of large vessels (≥15 m). A relative indication of the fishing activity for larger vessels (≥15 m) within the extraction area according to VMS in the extraction area indicate the fishing activity has decreased during the last 3 years to a low level representing less than one fourth of the 2005-2007-level. The relative importance of the extraction area has varied from 1.5 – 5.6% of the total fishing activity in ICES 39G2.

Birds

The available historic and recent data on the occurrence of waterbirds at Krieger's Flak unambiguously document that no species occur regularly in the area in concentrations of international importance. The most important occurrence of waterbirds is the concentration of Long-tailed Duck which regularly exceeds 10,000 birds in winter and spring. Other sea ducks seem to use the area irregularly, while pelagic species like auks and gulls use the area more regularly. Aggregations of large gulls are typically associated with intensive fishing activities.

The diversity of bird migration can be quite high, as shown by counts of visual migration at Krieger's Flak (65 days German part) in which 116 species were observed.

Marine mammals

The inner Danish waters and south-western Baltic Sea are inhabited by three species of marine mammals; the harbour porpoise (*Phocoena phocoena*), the harbour seal (*Phoca vitulina vitulina*) and the grey seal (*Halichoerus grypus*). Even though porpoises are relatively abundant in Danish waters they decline rapidly throughout the Danish and German part of the Baltic Sea from west to east. Harbour porpoises are most likely rare in the areas of Krieger's Flak. Movements of tagged grey seals from the haul-out site on Rødsand indicate that Krieger's Flak is crossed regularly by animals as they move between Rødsand and feeding areas in the northern parts of the Baltic Proper.

Marine archaeology

According to the database of the Heritage Agency of Denmark 3 wrecks are registered within the excavation area and 4 wrecks within the 500 m impact area. Two of these wrecks have been recognized from GEUS side scan sonar survey in July 2011. It is recommended that the sand extraction can be limited to a sub-area of 2 x 3 km (6 km^2) where 1-2 m of the upper seabed can be extracted. Due to the fact that the extracted part of the seabed by that is limited to the Litorina sand, the layers of potential marine archaeological interest such as potential submerged Stone Age settlements will not be affected, because layers from this period are expected to be covered by approximately 4 m of sand in the area.

Material assets, ammunition and recreational interests

There are no cables in the sand extraction area, thus it is not likely that ammunition will occur.

There are no major ship traffic routes passing through the sand extraction area. Recreational ship traffic can pass through Krieger's Flak, but no marinas are found close to the area.

Project pressures

Several pressures have been identified to have a possible impact on the sub-factors in the area.

Loss of seabed (sediments and benthic habitats)

The sand extraction will be conducted by a trailing suction hopper dredger. The dredger will continue dredging until it is filled. This means that excess (overflow) water and excess sediment will be flowing from the dredger during dredging. This type of dredging will lead to a loss of sediment and benthic habitats in the area where extraction takes place. The total extraction area is approximately 10 km^2, and hence a similar magnitude of sediment and benthic habitats will be lost.

Increase in suspended sediment and deposition

When the sand is extracted, sediment is spilled. Dispersal and deposition of the spilled sediment particles depend on the size of the particles and the hydrodynamic conditions. The general pattern is that the finer particles; e.g. silt-clay, are carried further away than larger because they have a relatively lower settling velocities.

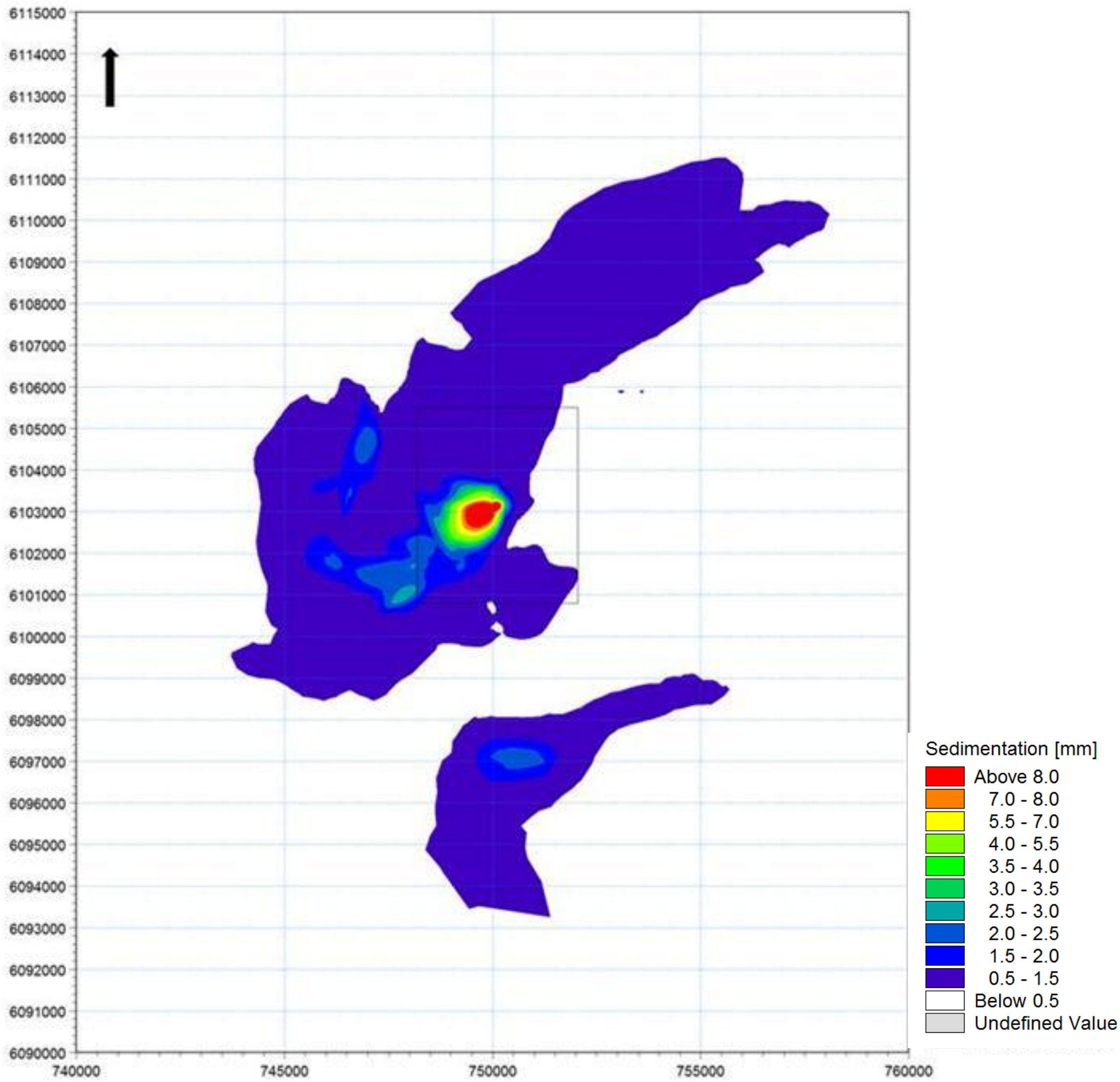
Exceedance for suspended sediment concentration (SSC) is assessed using the thresholds 2 mg/l, 10 and 15 mg/l. Exceedance is expressed as the time within a selected period, where the SSC exceeds these thresholds. SSC exceedance is assessed for surface (depth 0-1 m below surface) and bottom layers (depth 0-1 m above bottom), respectively. Furthermore, the calculation of exceedance is limited to the productive period May-August.

The overall results from the modelling are that the generated plume is quickly dispersed. This means that high SSC concentrations are mainly observed close to the centre of dredging site and that the concentration becomes below 2 mg/l within a few days.

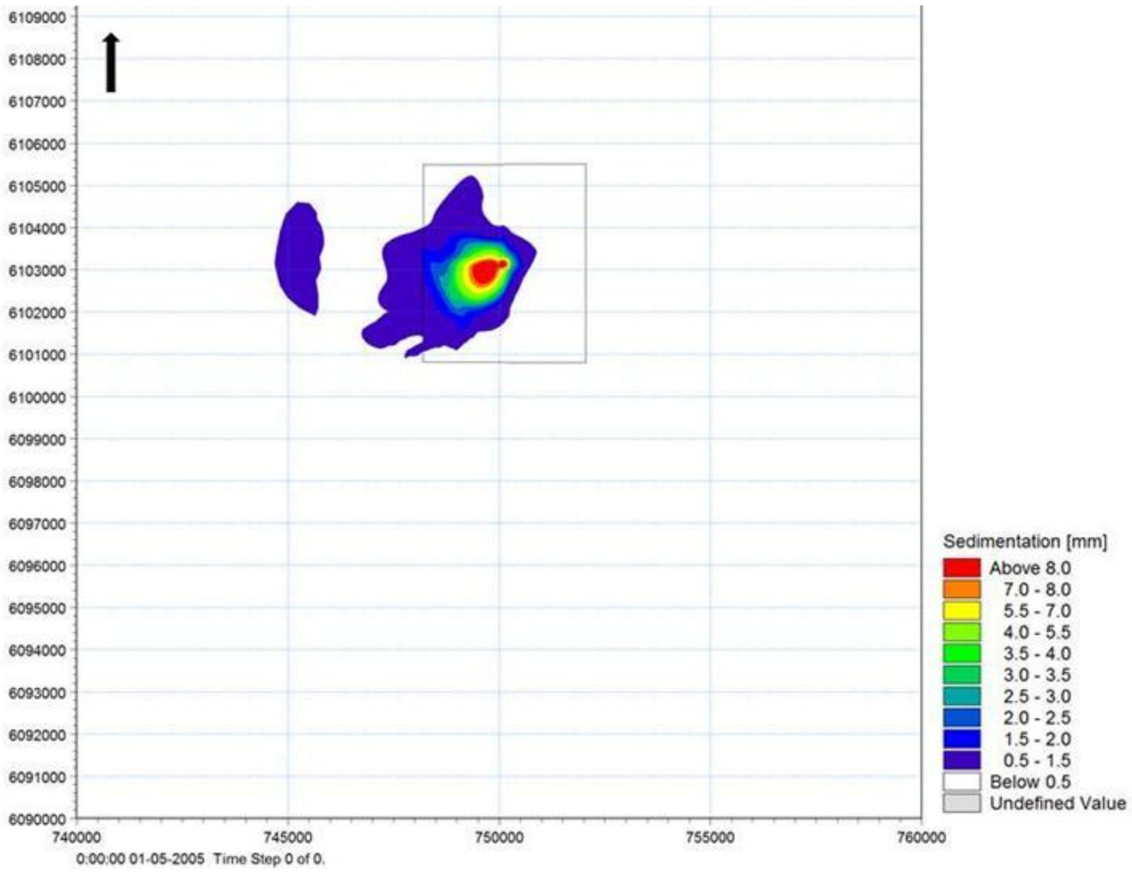
The SSC concentration at the surface is always below 10 mg/l, and is found less than 1.5 km from the dredging site. Concentrations between 2-10 mg/l occur closer to the dredgning site. In total, SSC levels exceeding 2 mg/l occur in less than 3% of the time (~4 days) and in most of the area in 1-2 % of the time. Close to the source, the SSC exceeds within a distance of 1 km, the 2 mg/l limit about 5 % of the time (~6 days). Maximum plume extension is about 5 km for the 2 mg/l exceedance limit and about 3 and 2 km for the 10 mg/l and 15 mg/l exceedance limits, respectively.

The SSC concentration at the bottom never exceeds the threshold of 15 mg/l. The plume of 10 mg/l is always localised very close (less than 100 m) and is found less than 10% of the time. Maximum plume extension for the 2 mg/l threshold is in the order of one kilometre. In summary, concentrations rarely exceeds values higher than 2 mg/l at the bottom and plumes only occur less than 10 % of the time.

The model results of the deposition shows that the highest accumulation of deposited material is found up to 1 km from the dredger, with an accumulation height of up to 8-9 mm (summer period). Depositied sediment of less than 3 mm is found in a larger area around the extracted area (see figure below). The sediment is generally transported towards west due to the prevalent current resulting in some but lower deposition in the west of the source. Looking at the whole year, accumulation occurs in a deeper area south of the extraction area with values of about 0.5-2 mm.



The maximum net sedimentation of sediment below 63 µm in millimetres for the full model year. Extraction area marked with a black rectangle.



The maximum net sedimentation of sediment below 63 µm in millimetres at the end of the summer period 1/5 to 1/9. Extraction area marked with a black rectangle.

Organic material, nutrients and toxic substances

The content of organic material was measured in sediment samples and was found very low. The concentration of nutrients and toxic substances depend on the content of organic material and was therefore also found very low.

Noise and air pollution

The primary noise sources on a dredger are the diesel motors that provide propulsion to the dredge. In addition there would be secondary noise sources such as generators, pumps and gearboxes. It is expected, that the dredger used for this operation will have a sound power level of 114 dB(A) or less. For the purposes of this report a Trailing suction Hopper Dredger has conservatively been assumed to have a sound power level of 114 dB(A) and at a distance of 2 km from the dredger the noise level is calculated to be 27 dB(A).

There are no indicative limit values for noise from dredging activities, but in recreation areas the limit is 40 dB (A) during the night time. Considering that the Krieger's Flak is located app. 30 km from the nearest coastline at Møn, the noise from the dredging operation is regarded not to give rise to noise onshore. The primary receptors of noise are birds (noise in air) and fish and marine mammals (underwater noise).

Underwater noise from the sand extraction is also a factor, which can impact fish, and mammals. The underwater noise levels from Trailing Suction Hopper Dredgers are usually 186-188 dB re 1 μPa rms with the main energy between 100 and 500 Hz. The impact on underwater noise will be dealt with in the assessment on the respective factors.

Ship emission and air pollution in connection with dredging and transport of sand extracted from the seabed at Krieger's Flak 30 km east of the cost of Møn Island in the Baltic Sea, is calculated for an expected volume of 6 mill m^3. Trailing hopper dredgers with different capacity and performance with load capacity at 2,000, 2,600, 6,000 and 10,000 m^3 have been used in the calculations. Total emissions cover dredging at Krieger's Flak, transport between Krieger's Flak and the construction site at the Fehmarnbelt Fixed Link, off-loading and return to Krieger's Flak in ballast.

The total emissions of CO_2 are calculated to most likely to be between 26,600 and 30,600 tonnes, depending on dredger size.

Impact assessment

Coastal morphology

The coast nearest to the extraction area is the coast of Møn which is located less than 30 km away from the extraction area towards WSW. It is concluded that there will be no impact on the coastal stability along the east coast of Møn.

Seabed morphology

The original seabed in the sand extraction area will be completely removed down to an average depth of 0.5 to 1.0 m. The composition of the seabed following the sand extraction is assumed to be the same as for the initial seabed because the thickness of the available sand resource in the extraction area is thicker than the extracted layer and because all extracted material is recovered in the hopper of the dredger, which means that no coarse materials, such as pebbles, are returned to the seabed. Due to the sand processes at Krieger's Flak, the seabed will be smoothed out to a relatively smooth surface after 5 to 10 years, but with scattered local areas dominated with coarse fractions and the remaining areas dominated by medium well sorted sand resembling the pre-project conditions. The sand ripples will come back over most of the seabed within the 5 to 10 year period.

Toxic substances

Toxic substances are bound to organic compounds and very fine particles of the sediments. The concentration of toxic substances in the sediments at Krieger's Flak has therefore been related to the content of organic matter. Depending on presence of local pollutant sources and the sedimentary conditions, marine sediments may contain toxic substances that potentially can be released during dredging and hence impact the aquatic environment.

All concentrations of toxic substances in the sediment at the shallow Krieger's Flak is found to be lower than the accepted background values for sediment set by OSPAR and or the Danish EPA. There is therefore no impact on the marine environment due to release of toxic substances from dredging activities.

Water quality

The impact on the water quality is in general low. No signigifcant impacts are predicted for the general nutrient and oxygen regime and processes, as foreseeable changes in the hydrodynamics and seabed morphology are limited. There is a risk of increasing oxygen deficiency in dredging scars due to accumulation of organic matters. The impact is limited to the dredging scars and therefore assessed to be insignificant.

Benthic fauna

The loss of benthic fauna habitat will correspond to the area exploited for sand extraction; i.e. the maximal lost area will be 10 km^2. The loss of fauna in this area will be total as the upper approximately 1 m of sediment will be removed.

Re-colonisation of the seabed after ended dredging activities, will take place by migration of adult species and settling of larvae from nearby unaffected areas. The nature of the area that they are re-colonising will similar to pre-project conditions. Most of the species, which are abundant at Krieger's Flak, especially polychaetes and oligochaetes (which accounts for 73 % of the abundance and 9.2 % of the biomass) have a relatively short life cycle and will most likely re-establish after one or two growth seasons. Mussels (which account for 23 % of the abundance and 90% of the biomass) have a longer life cycle and re-establishment will take longer. *Macoma balthica* and *Mytilus edulis* have a generation time of approximately 2-4 years while *Mya arenaria* have a generation time of 2-5 years. The re-colonisation could be hampered by the seabed recovery process. However this is assessed to be so slow that it cannot be expected to influence the faunal re-colonisation. Re-establishment of the biodiversity and biomass of the benthic fauna community in the impacted area will therefore most likely take place within 5 years after dredging has stopped.

Suitable criteria for the impact on the benthic fauna from increased suspended sediment (SSC) from sediment spill has also been discussed and defined in the EIA for Fehmarnbelt Fixed Link (FEMA 2013c). These criteria have been adopted in the present EIA. The threshold for no impact is defined as 25 mg/l (FEMA 2013c); meaning that the benthic fauna can cope with an increase in SSC (exceedance) below this limit. The sediment plumes at the bottom are always localised within 1 km from the extraction source and the SCC values never exceed 15 mg/l. There is hence no impact on the benthic fauna as a result of the increased SSC.

In the EIA for the benthic fauna communities of Fehmarnbelt, a set of criteria for the pressure deposition has been defined on the basis of scientific literature and expert judgements (FEMA 2013c). In this connection it has been established that deposition below 3 mm, regardless of the duration of the deposition, the rate of deposition and the fauna community, will have no impact on the benthic fauna.

As the maximum deposition 1.5 – 2 km away from the extraction source is less than 3 mm at any point in time, it is therefore concluded that deposition will not impact the fauna outside the extraction area significantly.

As mentioned above some impacts on oxygen levels in the dredging scars cannot be excluded. The possible impact is limited in area and it is therefore concluded that it pose an insignificant risk to the benthic fauna.

Benthic vegetation

There is only very limited quantities of macroalgae present in the impact area or in the vicinity, the impact on the macroalgae will be negligible. The observed thin layer of sedimented algae and benthic microalgae will be lost when the seabed is extracted. The generation time of small microalgae is very fast (days) and the algae will recolonize very fast after the extraction has ended. The impact on the microalgae is insignificant.

Fish

In summary, increase in suspended sediment from the sediment plumes and in noise in periods of intense dredging activity and heavy ship traffic may affect fish in the extraction area and lead to periodical decreases in their abundance in the area. However, fish will with great probability return to the area and an impact on the local fish populations over a longer period is unlikely. However, it cannot be ruled out that intensive activity during spawning periods, in particular for stationary species and species with specific habitat or seabed substrate demands (sand eel, sculpins and gobies etc.) will experience a period (approximately 1-5 years) with non-permanent, negative impact on local populations.

Substrate removal, and to a lesser extent deposition in the extraction area will have a considerable, but temporary impact of approximately 1 to 5 years on the prey for demersal fish species.

Fishery

The impact on the trawl and net fishery within the extraction period (days) is only minor, because fish allocates to other areas, from where they can be fished. Furthermore, if the extraction periods is planned to avoid the periods where possible fishing for migratory fish is present which reduces the impact on the trawl fishery in the area.

When the extraction period has ended the loss of benthic habitat and loss of food for the fish within the extraction area can lead to changes in fish distribution. The duration of this impact is maximal 5 years, where after the food source is expected to have recovered. There is an impact on the trawl fishery due to this substrate removal. The impact is reversible (5 years) and it is expected that the fish stocks in the area will be re-established. The impact on net-fishery is negligible because the impact is limited to the extraction area, where net-fishing does not take place.

The impact on trawl and net-fishery due to suspended sediment and noise is very limited because the impact on the fish stocks is very small.

An impact on the undertaking of fisheries is only short term (during the extraction period). The extent of this impact will depend on when and for how long the extraction vessel will be in trawling routes and whether there will be zones restricting the fisheries during this time. Regardless of the extent the impact is only expected to only over a short time period (days).

In previous projects with extractions of material from the seabed at Krieger's Flak (2004-2005) a close and continual contact with active fishermen in the area, or eventually with a person with fishery knowledge on board the dredging vessel, has shown that this could be a positive measure to reduce the level of possible conflicts.

Birds

Sediment dispersal affecting available food supplies of fish and foraging conditions for diving waterbirds is estimated to be small-scale. Simulations of the dispersal of suspended matter showed that the generated plume due to extraction operations is quickly dispersed, and the plume was mainly located within the extraction area limits and only visible a few days in total. The plume is only detected further away at low concentrations (2-10 mg/l), but only around 2 or 3 km from the dredging area and only about 1-2% of the time and the impact is assessed as being negligible.

Given the broad front migration of waterbirds at the site, collision risks to migrating waterbirds from the dredging vessel can be expected to be at a low level with no or minor impact on the populations passing the site.

Mammals

The extraction activities will inevitable cause sediment dispersal affecting the transparency of the local areas. The extension/propagation of the plumes is strongly dependent on the local current conditions at the time of construction. However, considering the results of the sediment spill modelling sediment plumes are not expected to cause any direct impact on seals and porpoises. The effects on availability of prey, especially juvenile fish are assessed as minor. However, since the affected areas are expected to be very small compared to the total area available to the animals on Krieger's Flak and the duration of the impact is short, no significant negative impact due to sediment dispersal are expected.

Material assets: Cables, ammunition, navigation, recreational interests and marine archaeology

There are no cables in the extraction area and ammunition is nok likely to occur.

Only a smaller amount of ship traffic passes Krieger's Flak so minor impact may occur for this traffic as they may change their sailing route during the extraction period. This is also the case for recreational ship traffic.

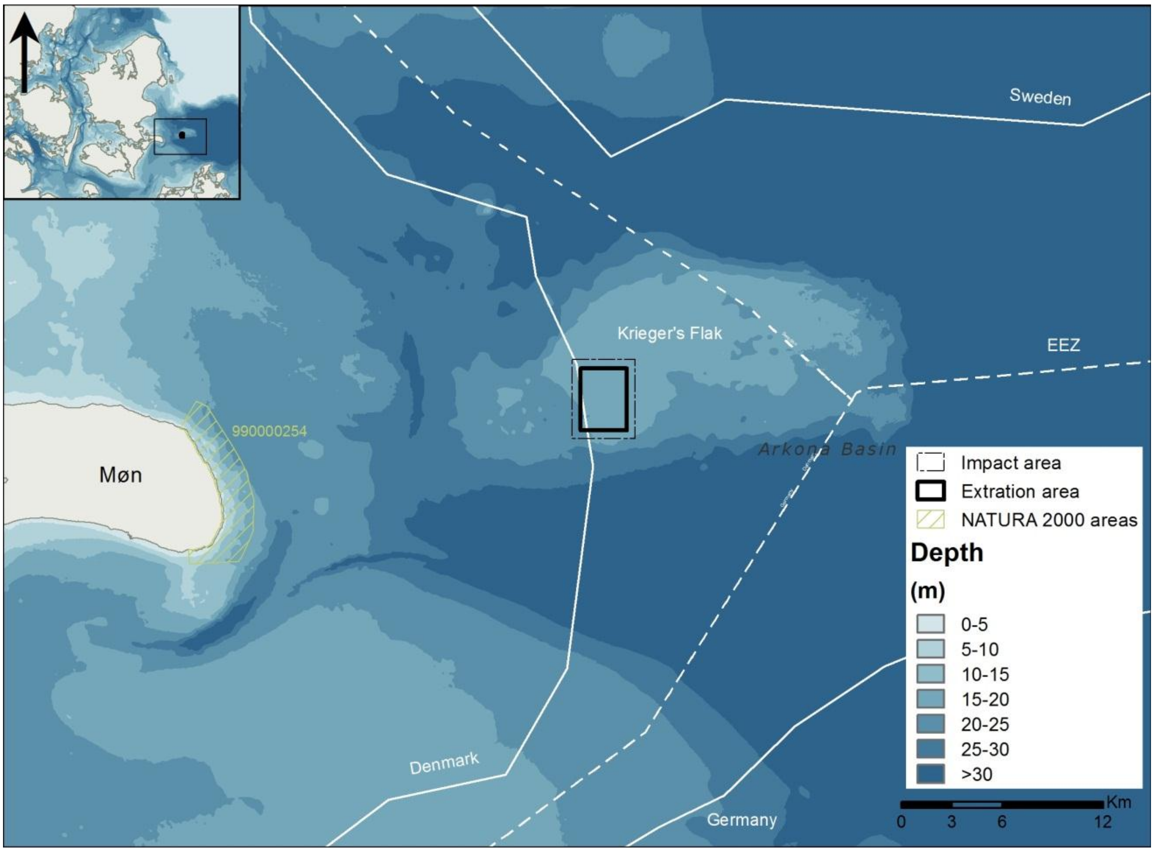
Within the extraction area three ship wrecks are registered in database hold by Heritage Agency of Denmark. However, all three wrecks are located outside the area recommended for extraction.

NATURA 2000

The Natura 2000 site 171 includes the habitat site H207 Klinteskov Kalkgrund, which is situated approximately 30 km west of the sand extraction area. The site covers an area of 2,994 ha. The marine designation basis for the designated area is the habitat types: Sandbanks which are slightly covered by sea water all the time (1110) and Reefs (1170).

Environmental pressures on the habitats and the associated flora and fauna has to be taken into consideration for the planned sand extraction at Krieger's Flak although all pressures are regarded as temporary.

Model simulations of suspended sediment concentrations (SSC) and deposition of sediment show that the SSC and deposition area is far from the Natura 2000 site 171 Klinteskov and Kalkgrund near the island of Møn. Impact from Krieger's Flak sand extractions is very unlikely and the impact on the Natura 2000 area and the designation basis is insignificant. It is therefore not necessary to prepare an appropriate assessment.



Natura 2000 site 171 (DK 990000254), including the habitat site H207-Klinteskov Kalkgrund.

Monitoring programme

A monitoring programme has been suggested in connection with the extraction project.

1 INTRODUCTION

1.1 Background

For the construction of the fixed link between Denmark and Germany across the Fehmarnbelt there is a demand for sand and gravel resources.

Based on the existing information of the marine sand and gravel resource distribution in the Baltic Sea, Femern A/S has pointed out Krieger's Flak east of Zeeland and Rønne Banke southwest of the island of Bornholm as potential extraction areas for the construction works.

In relation to previous construction projects (the Øresund Bridge and the Amager Strandpark projects), the resources at Krieger's Flak have been investigated and exploited. The volume of the Krieger's Flak resources was in these projects estimated to comprise several hundred million m^3 of sand and gravel as a whole (Leth 1992, Jensen and Leth 1992, Lomholt and Jensen 1993).

Prior to the selection of a potential extraction area for the Fehmarnbelt project, GEUS has performed an evaluation for Femern A/S of potential resource areas to be used as backfill materials (Jensen 2009). The evaluation was based on existing data from Danish and German offshore areas and concluded that Krieger's Flak will comply with the volume and quality of sand needed. Based on the investigation an extraction area was designated. The area is approximately 10 km^2 and including a surrounding impact zone of 500 m (*BEK 1452 of 2009/12/15*) the area is approximately 17.5 km^2 (Figure 2.1).

The need for sand for the tunnel solution is 6 million m^3 fill for backfilling of the tunnel trench and 1 mill m^3 for the tunnel or bridge element production. The precondition for this EIA is that all the 6 mill m^3 backfill material is extracted from the Krieger's Flak. The 1 million m^3 is planned to be dredged at Rønne Banke. During this study new data have been acquired using seismic and acoustic methods followed by video and diver inspections and collection of sediment samples by a grab in order to document the volume and quality of the resource. Furthermore, the biological condition of the resource area was investigated. The stations from the sediment and the benthic fauna and flora study were identical.

The present report presents the EIA study investigating and assessing possible impacts on the environment from the sand extraction at Krieger's Flak. The EIA for the Rønne Banke extraction is reported in a separate report.

The resource mapping and the data sampling for the EIA have been executed in compliance with the departmental order of raw material "Bekendtgørelse af lov om råstoffer" (lov nr. 950 of 24/09/2009) § 20 together with the departmental order on permission to investigate and extract raw material from the seabed etc. "Bekendtgørelse om ansøgning om tilladelse til efterforskning og indvinding af råstoffer fra havbunden samt indberetning af efterforskningsdata og indvundne råstoffer" (bek. nr. 1452 of 15/12/2009).

The EIA is carried out in compliance with Bek. 1452 of 15/12/2009 and the dept. order bek. nr. 126 of 04/03/1999 with changes bek. 1454 of 11/12/2007. The project is covered by § 1, stk. 1, pkt. 2, on raw material extraction of more than 5 mill m^3 in total.

Screening of the potential impact on the Natura 2000-sites has been performed in compliance with the Habitats Directive which has been implemented in Danish law and administration through the departmental order "Bekendtgørelse om udpegning og administration af internationale naturbeskyttelsesområder samt beskyttelse af visse arter (bek. nr. 408 of 01/05/2007).

Earlier studies of the Danish part of Krieger's Flak have been conducted in connection with sand extraction for the Øresund Bridge and the construction of the Amager Strand recreational area (Øresundskonsortiet 2000 and Amager Strandpark I/S 2005). Furthermore the Swedish and German parts have been investigated as in connection with EIAs of wind mill parks. The results of these studies are included in the present EIA study where relevant (Sweden offshore wind A/S 2007, IFAÖ 2003).

1.2 Objectives

The objective of the present study is to conduct relevant surveys to acquire data on the quality and volume of the Krieger's Flak resource and to evaluate if the requirements for the backfilling of the tunnel can be fulfilled. Furthermore, a compilation of existing information and a description of the present water quality and biological conditions (the baseline) are assessed with respect to possible impacts caused by sand extraction, sediment spill, deposition of spill, traffic and noise on water quality, flora and fauna including fishery.

1.3 Organisation of the report

The report is divided into two parts presenting the results from the seismic and acoustic mapping of the sand resources in the first part, and the second part presenting the baseline description and the environmental impacts in relation to a possible sand extraction at Krieger's Flak.

Studies of possible spillage from the dredging activities and possible impacts on local habitats from the sand extraction operations on Krieger's Flak have been assessed by FEHY (FEHY 2011). The key results are included in this report.

2 PROJECT DESCRIPTION

The need of sand fill for backfilling of the seabed is 6 mill m^3. Based on previous and new studies it is concluded that a designated extraction area of approximately 10 km^2 at Krieger's Flak will comply with the volume and quality of sand needed for the project.

2.1 Krieger's Flak

Krieger's Flak is located approximately 30 km east of the island Møn (Figure 2.1). The water depths are between 18 and 22 m. The distance to the construction site of the Fehmarnbelt Fixed Link is 120 km.

The Flak is a huge sandy formation with a layer thickness of up to 8 m. The initial deposition started in the late Weichselian, but the main part of the resources is coastal deposits of sand and gravel mainly formed as spits attached to the glacial landscape. The upper 1 m of the resource is related to the succeeding postglacial transgression. Most likely these deposits have been reworked several times due to the oscillating shore level during the late and postglacial period which consequently, in general, has resulted in the deposition of very well-sorted sandy sediment.

2.2 Methods and equipment used for sand extraction

The sand extraction can be performed by use of dredging vessels either stationary suction hopper dredging or by trailing suction hopper dredging. Both are hydraulic methods where water and sediment is sucked up via a tube by means of centrifugal pumps. Trailing suction hopper dredging will be used as far as the bottom conditions allow. Based on previous investigations and similar dredging activities in Danish waters it is expected that the extraction at Krieger's Flak exclusively can be performed by trailing suction hopper dredging. The capacity of this type of dredger is typical 2,000 - 10,000 m^3 corresponding to 1,500 to 7,500 m^3 sand. If a 6,000 m^3 dredger is used about 1,428 cargos of sand is to be transported from Krieger's Flak to the Fehmarnbelt Fixed Link construction site. If a 10,000 m^3 dredger is used 800 cargos is to be transported. After loading the dredging vessel with sand the load is transported to the construction area either by the dredging vessel itself or by reloading to barges for transport.

The trailing suction hopper dredging vessel is loading while the dredging vessel slowly moves forward with a speed of typically 2 km/h. The trailing suction method leaves the seabed with dredging scars of 1-2 m width and 0.5 - 1 m depth. This method is specifically applicable where the resource is relatively thin but has a wide areal distribution. To ensure a rational production procedure and maneuvering for the vessel the resource area should have a considerable extent. The method has become the most common in Denmark for the production of sand and gravel.

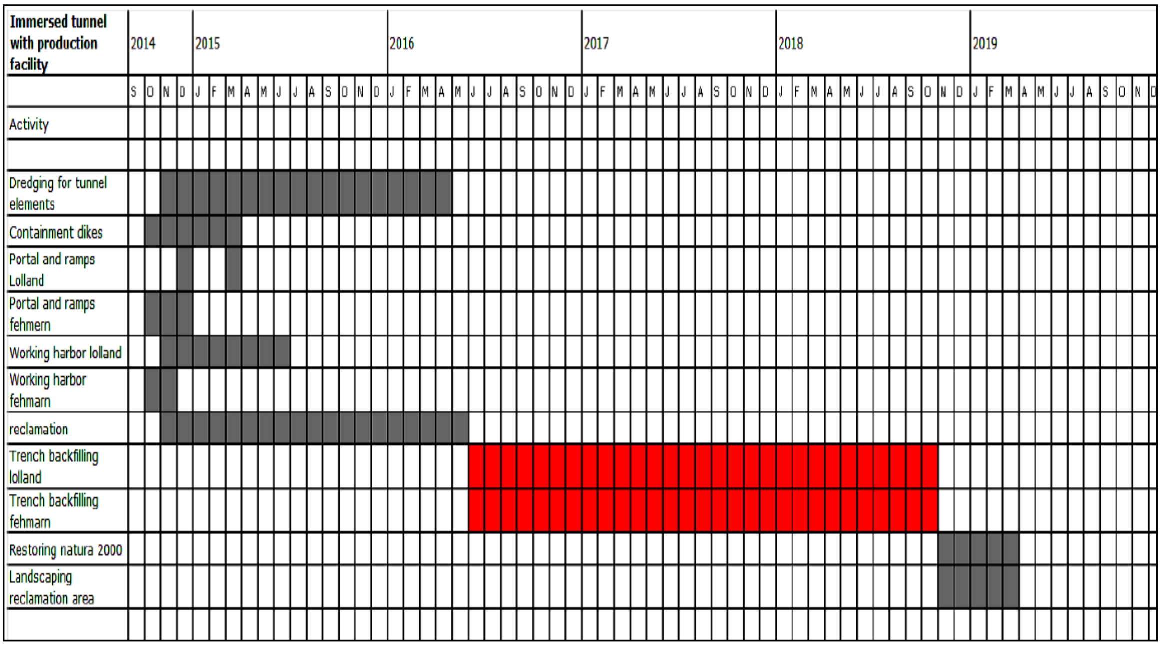
It is expected that the dredger will work continuously day and night. When the dredger is full, the sand is transported to the project site, after which the dredger returns to the extraction site and repeats the dredging activity. This will give 3 extractions per 24 hours.

2.3 The dredging plan

The dredging is planned to take place between June 2016 and November 2018. The overall time schedule for sand extraction is shown in Table 2.1. It is expected that the extraction at Krieger's Flak exclusively can be performed by trailing suction hopper dredging.

The sand extraction will be a steady operation following the project plans. However, the operation will be subject to downtime caused by the weather and thus the dredging rates will in periods be higher to keep the time schedule.

Table 2.1 Time schedule for dredging activities. Red area indicates the activities related to the backfilling of the tunnel trench.



2.4 Area of investigation

The designated extraction area is situated at the southwestern part of Krieger's Flak (coordinates shown in Tabel 2.2). Based on previous and new studies it is concluded that an extraction area of approximately 10 km^2 at Krieger's Flak will comply with the volume and quality of sand needed for the project.

Tabel 2.2 Coordinates for the extraction area at Krieger's Flak (excl.impact zone)

Longitude	Latitude
12° 53.5521	55° 01.7685
12° 56.1235	55° 01.6879
12° 53.3598	54° 59.7795
12° 55.9313	54° 59.6957

In agreement with the ministerial regulation of exploration and exploitation of marine raw materials issued by the Danish Ministry of Environment (*BEK 1452 of 2009/12/15)*, the environmental assessment study will apart from the extraction area include an impact zone of 500 m surrounding the extraction area. This is called the impact area and covers 17.5 km^2.

The two areas are shown in Figure 2.1.

For some of the environmental factor it has been considered relevant to go beyond the area indicated in Figure 2.1. The extent of investigation for these cases is given in the relevant sections.

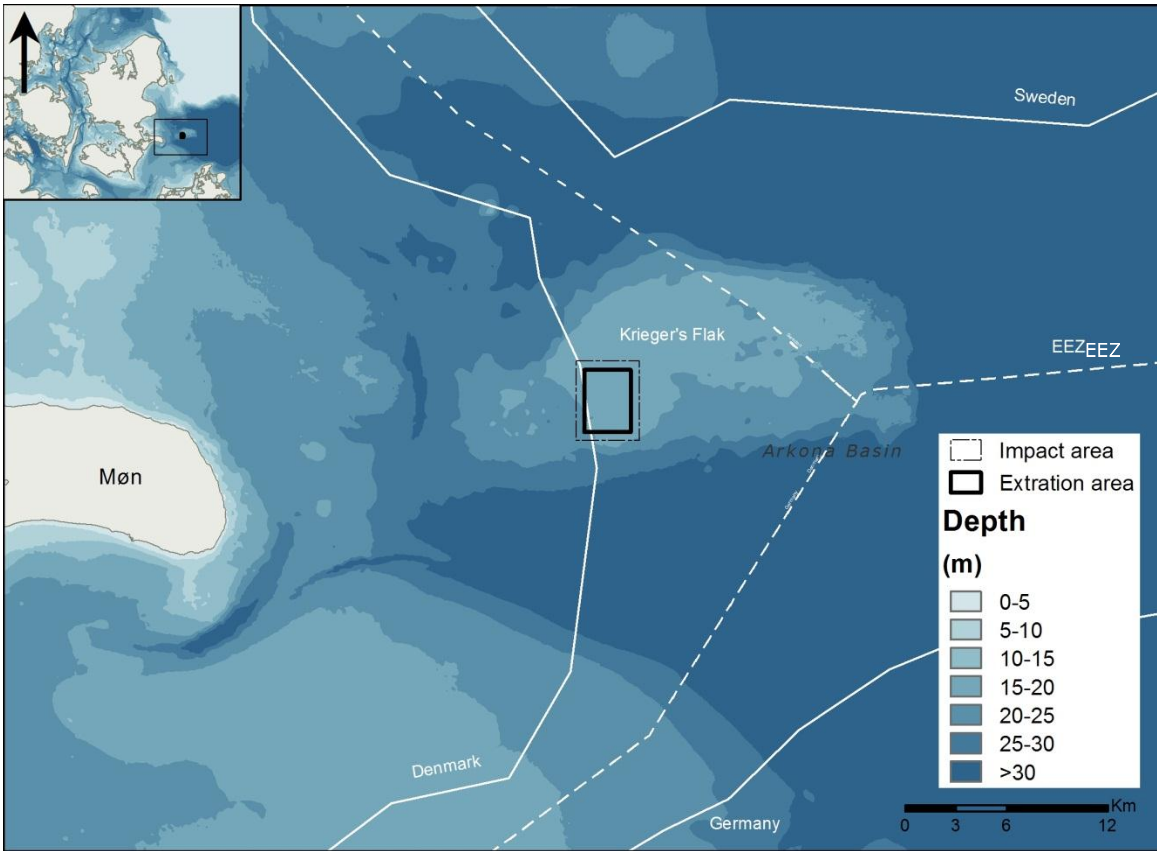


Figure 2.1 Area map of Krieger's Flak showing the extraction and impact areas.

2.5 Sand resource mapping at Krieger's Flak

GEUS performed a seismic/acoustic survey during July 2011 to document the distribution, volume, composition and quality of the resource pointed out for the Fehmarnbelt project. The survey vessel *"JHC-Miljø"* was used as platform for the survey. The survey lines were planned as a grid of parallel lines with a spacing of 75 m and in addition 7 crosslines in a 900 m grid. In total approximately 265 line kilometres has been surveyed (Figure 2.2).

To optimize the geological information of the resource two high resolution seismic systems were used in parallel: 1) The GeoSpark 200 sparker system (frequence interval 500-2000 Hz) with a penetration of 10-20 m and a vertical resolution of about 0.5 m; and 2) The combined Teledyne/Benthos SIS-1625 Chirp (1-10 kHz)/sidescan sonar system providing information of the uppermost part of the seabed with a penetration of 5-10 m and a vertical resolution in decimetres. As part of the post-processing the chirp data were converted to SEGY format to fulfil the required format for the interpretation software. Technical details on the seismic systems are compiled in Appendix E.

The newly acquired seismic data have been used to delineate the resource within the extraction and impact area. Processing and interpretation was done digitally by use of the interpretation software Geographix. The seabed and the lower horizon of the resource were digitized and the resulting (x,y,z) files exported as ASCII files from Geographix. The resource thickness was subsequently gridded using the MapInfo VerticalMapper gridding software. The resulting grid cell size used is 50 m.

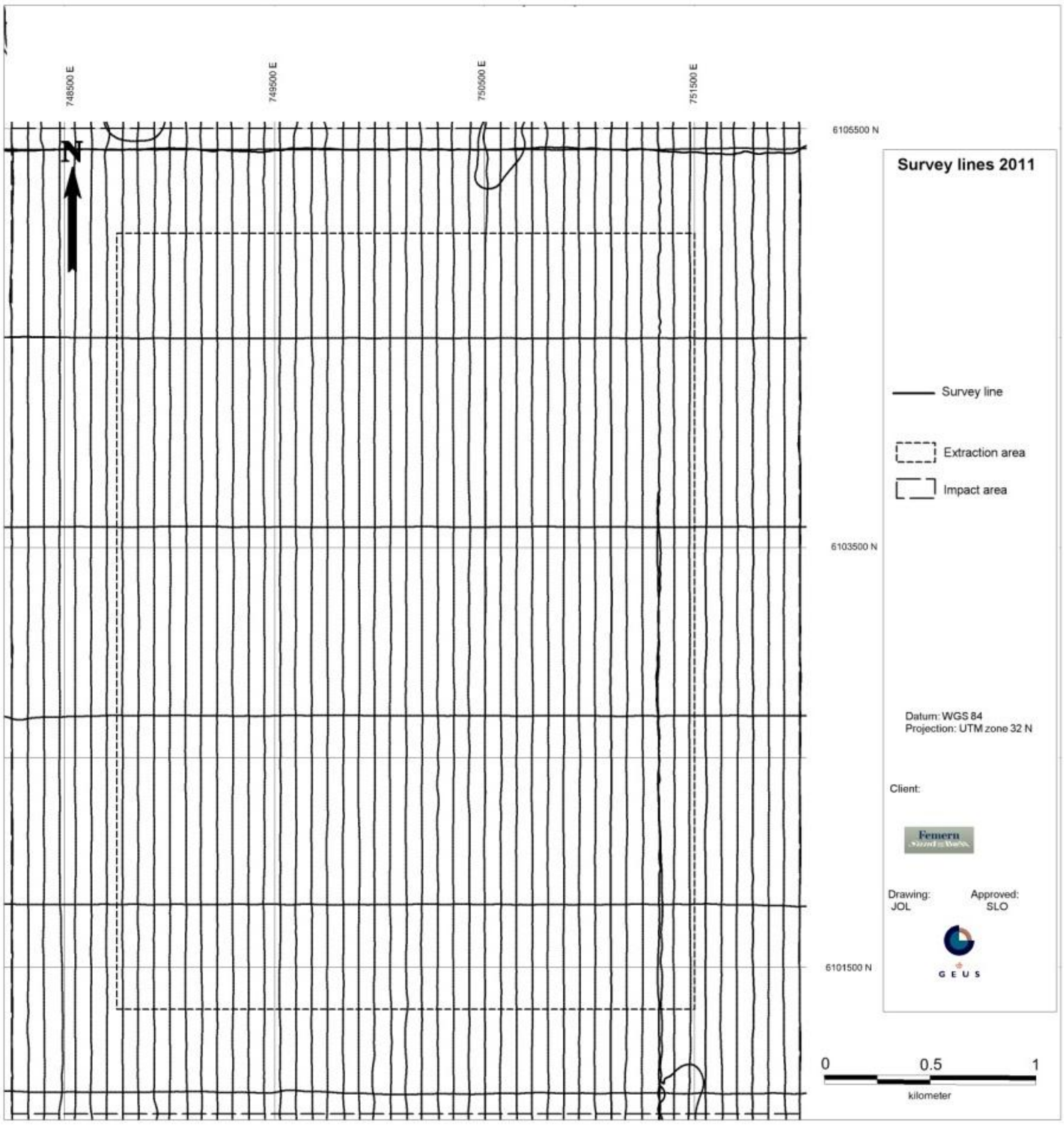


Figure 2.2 Survey lines covering the extraction and impact areas area of investigation at Krieger's Flak. Figure also found in A3 in appendix F

2.5.1 Bathymetry data

Bathymetric data were acquired continuously along all the survey lines using the ships Atlas Deso 25 single beam echosounder system. The logged data were corrected to the reference datum online. By that the post-processing included only filtering of outliers. All data were merged into a (x,y,z)-file and subsequently gridded by use of MapInfo Vertical Mapper software using the "Inverse distance weighting" interpolation method. The resulting bathymetric map is shown in Figure 2.3. The depth within the extraction area varies between 18 and 21.5 m with a general but slight deepening from the north to the south. In the impact area the depth increases further to about 23 m to the southwest and the southeast.

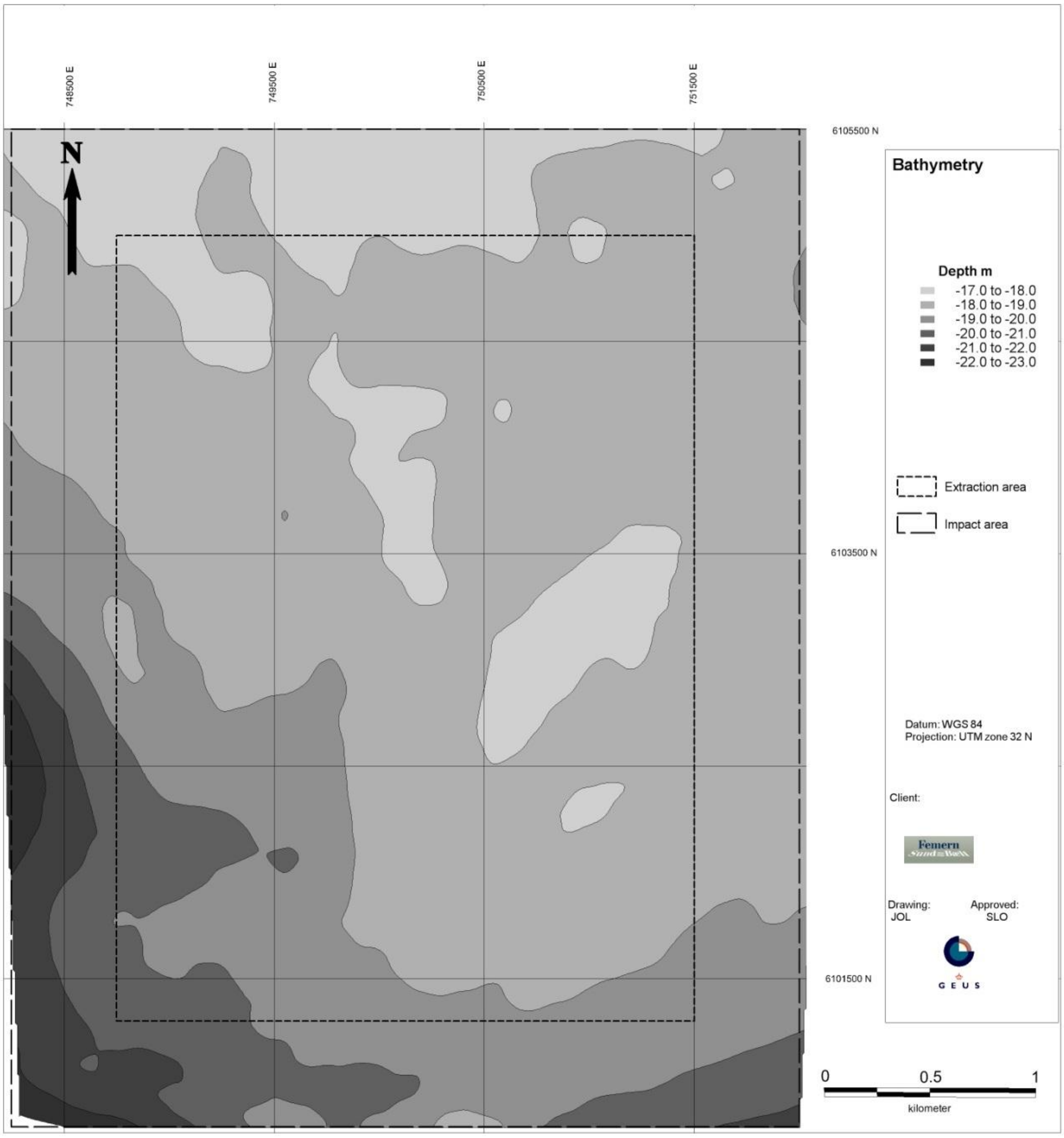


Figure 2.3 Bathymetry map of the Krieger's Flak area in 1 m depth intervals. Figure also found in A3 in appendix F

2.5.2 Side scan sonar mapping

To characterize and classify the seabed sediment with full coverage acoustic data were acquired by use of a dual frequency side scan sonar (Teledyne/Benthos SIS-1625 system 100/400 kHz) covering 100 m to each side of the survey tracks ensuring a 125% coverage of the seabed (Figure 2.2). The side scan data were stored as XTF-files onboard using the Triton-ISIS-software. During the post-processing the XTF-files were converted to geo-tiff files using the TritonMap software. Subsequently these geotiff-files representing the individual side scan lines were merged into a side scan mosaic (Figure 2.4) which was used for seabed classification subdividing the seabed into classes of different reflectivity. To verify the initial classification ground truthing at selected stations was performed by DHI in connection with this EIA in August 2011 using Van Veen grab and video inspections. The stations were the same stations as those used at the fauna sample sites (Figure 4.9). The ground truthing results showed that overall two seabed types are present which were used for calibrating and verifying the acoustic seabed classification.

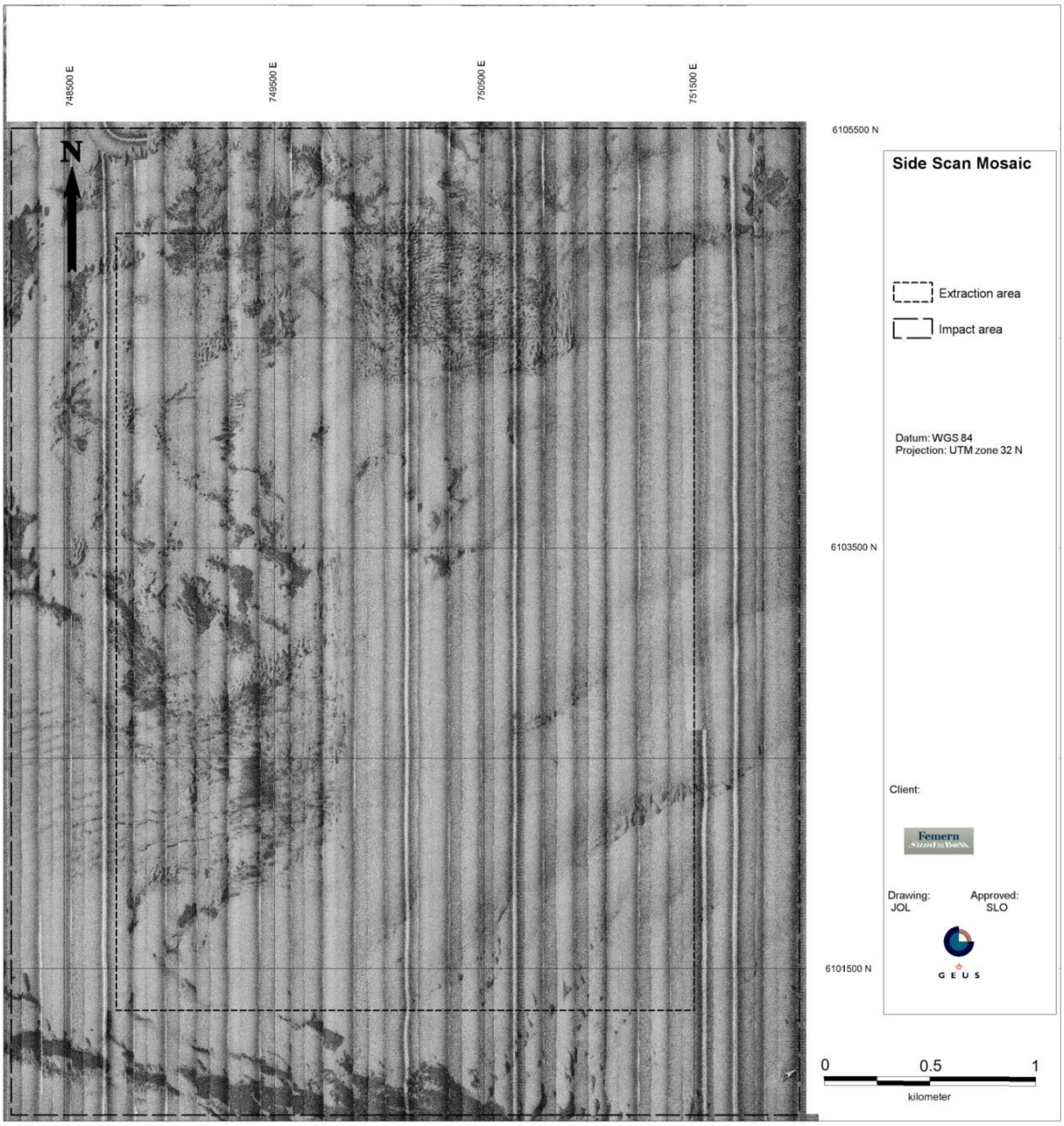


Figure 2.4 Side scan sonar mosaic of the Krieger's Flak area. Light coloured area reflect sandy seabed. Dark coloured areas reflect previous dredging area with the presence of lag deposits of gravel and cobbles. Figure also found in A3 in appendix F.

2.5.3 Resources and extraction

The resource area at Krieger's Flak is part of a huge sandy ridge with sand thickness up to 8 m within the impact zone. The resource is distributed with an elongated shaped body with a maximum thickness of up to 7 m in a northwestern-southeastern direction in the central part within the extraction area (Figure 2.5). The resource is thinning to the southwest and northeast with thicknesses of less than 4 m.

Seismic cross-sections from the sparker source illustrate in a north-south and east-west section the shape of the resource and furthermore the inclining bedding planes yielding evidences of a spit-like depositional environment (Figure 2.6). High reflective inclining seimic reflectors indicate that coarse material (gravel and stones) has accumulated along the bedding planes in a high energy current regime. The coarse grained sediment now constitutes the lag deposit in the previous dredging areas, which was recognised from the seabed classification.

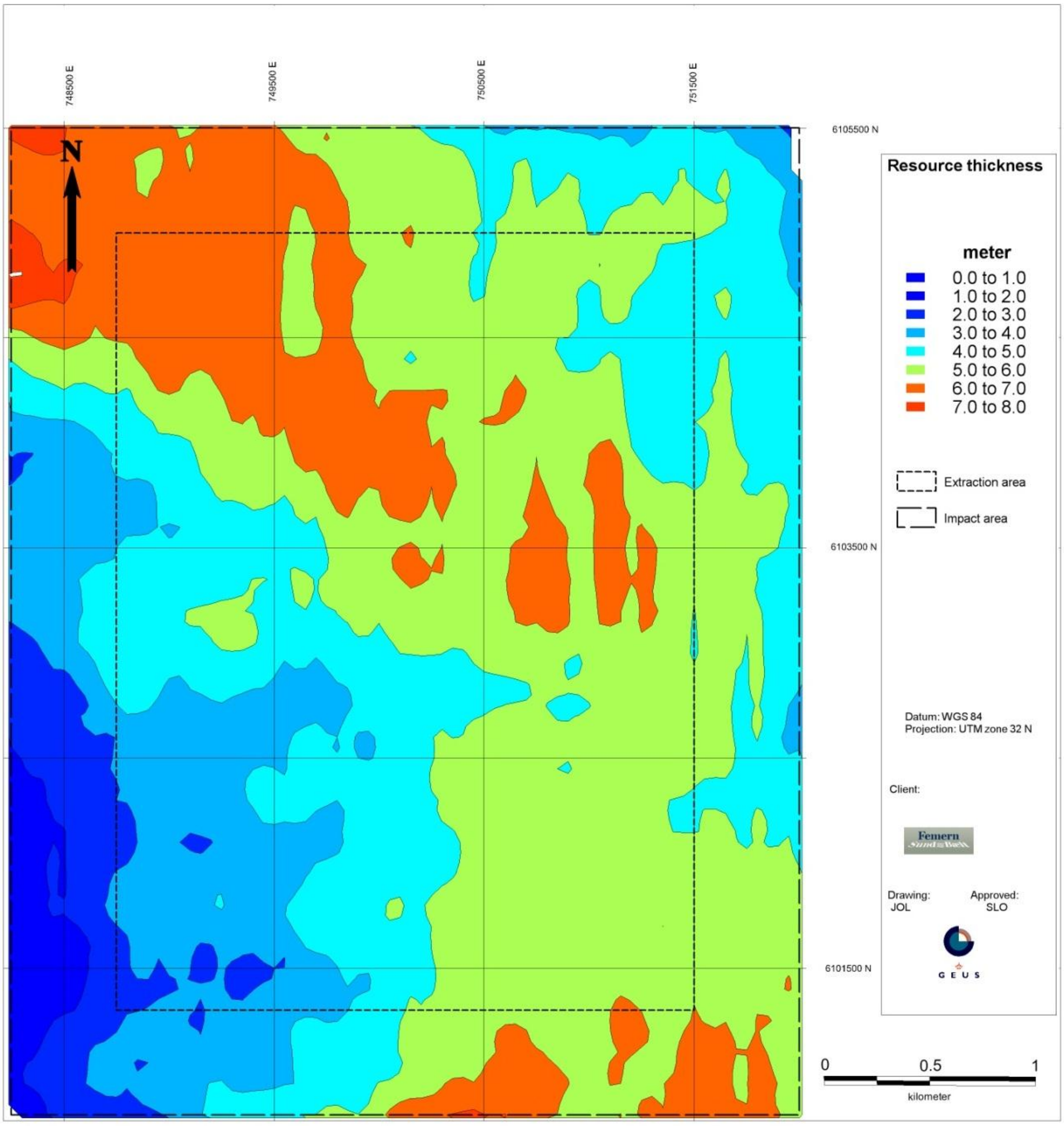


Figure 2.5 Resource thickness map of Krieger's Flak. Figure also found in A3 in appendix F.

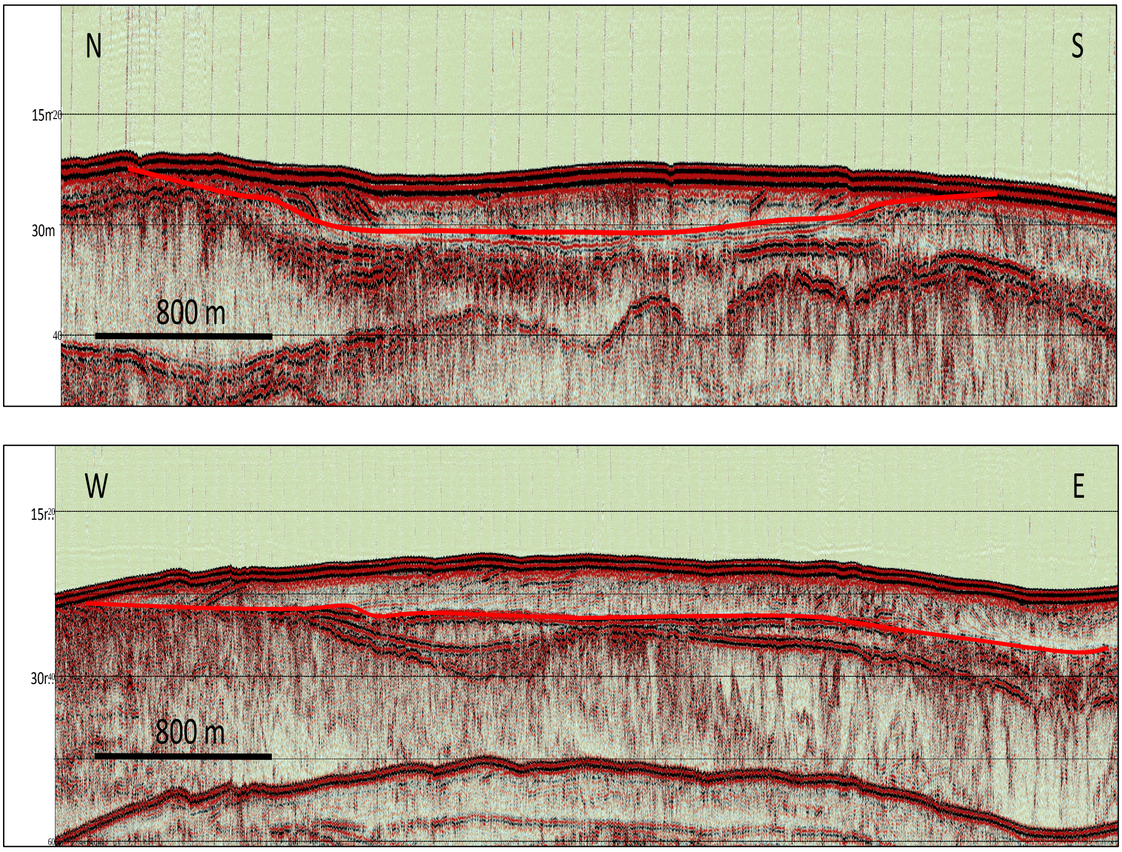


Figure 2.6 Two seismic cross sections of the extraction area at Krieger's Flak showing the up to 7 m thick sandy resource (above the red line) and the inclining reflectors indicating the presence of gravel and stones.

The specification and availability of the resource is specified Table 2.3. The accumulated resource within the extraction area has been calculated to a total of approximately 50 mill m^3. In the calculation of the actual available resource (Table 2.3 column 4) it is anticipated that a residual sediment layer of about 1m is left behind after completing the extraction taking into account that certain parts of the resource might have a content of gravel and stones along bedding planes. This might reduce the volume of the available sand resource from 50 mill m^3 to 40 mill m^3.

Table 2.3 Specifications of the mapped resource within the extraction area at Krieger's Flak.

1 **Thickness interval (m)**	2 **Volume (10^3 m^3)**	3 **Accumulated vol. (10^3 m^3)**	4 **Resource (10^3 m^3)**
0-1	9,898	9,898	0
1-2	9,898	19,796	9,898
2-3	9,888	29,684	19,786
3-4	9,272	38,956	29,058
4-5	7,432	46,388	36,490
5-6	3,670	50,058	40,160
6-7	417	50,475	40,577
Total	**0**	**50,475**	**40,577**

1: Resource thickness by 1 m intervals. 2: Volume of intervals, 1,000 m^3.

3: Accumulated available resource, 1,000 m^3. 4: Actual available resource per depth interval, 1,000 m^3

3 ALTERNATIVE RESOURCES AND RAW MATERIAL MARKET

In this chapter alternative areas for extraction of 6 mill m^3 sand fill for the construction of the Fehmarnbelt Fixed Link are described and assessed. The 0-alternative is the alternative when the construction of the Fehmarnbelt Fixed Link is not carried out. The description of the alternative resources is based on Jensen (2009). Marine alternative areas for the extraction are local designated marine sand extraction areas on the German and Danish continental shelf in the Baltic region.

In general, the German and the Danish resources are dedicated for local use in the region and more intensively investigations are required if an increase in resources inside these areas should be mapped and made available for construction of the Fehmarnbelt Fixed Link. Both quality and volume of producible resource in the areas are uncertain.

3.1 Marine resources in the German sector

On the German continental shelf in the Baltic region two well-known sand resource areas are described: Plantagenet Ground and Adler Ground (Figure 3.1).

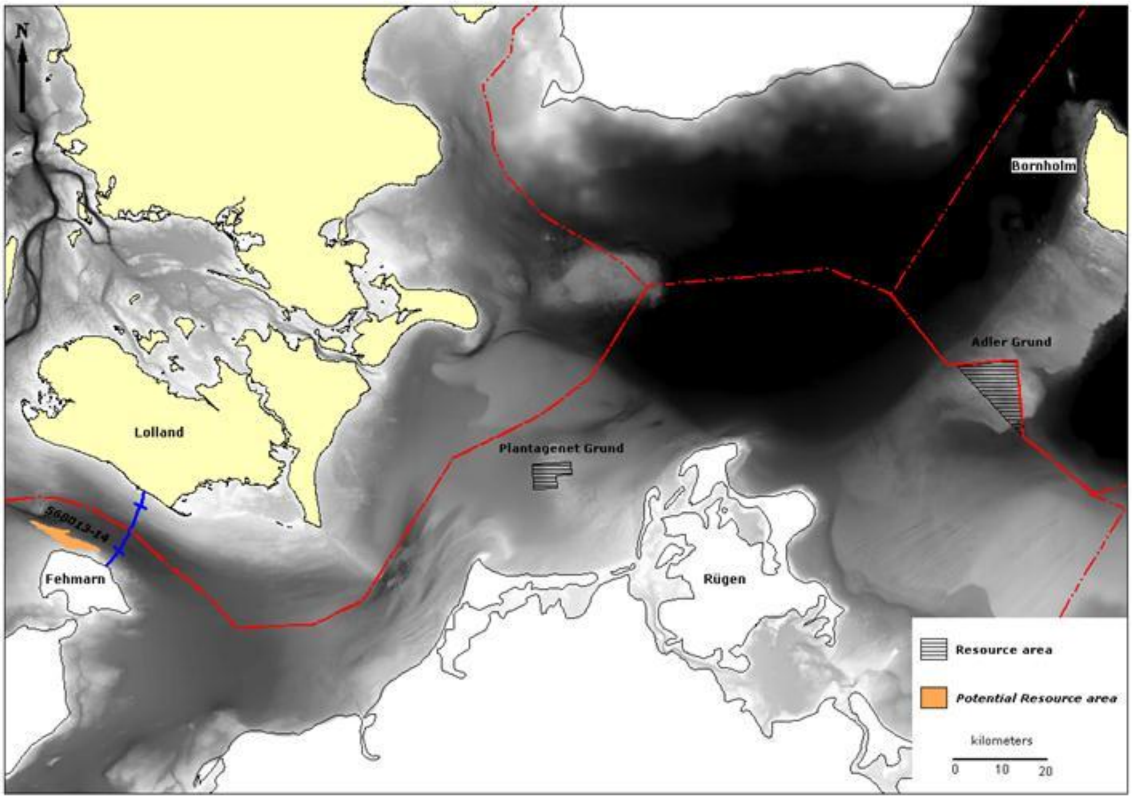


Figure 3.1 Sand extraction resource areas in the German sector. Blue line indicates the alignment of the Fehmarnbelt Fixed Link.

The Plantagenet Ground near the Rügen Island is a sand and gravel resource of 10 mill m^3. The distance from the area to the Fehmarnbelt Fixed Link is approximately 110 km. The area is partly covered by a Habitat and Bird protection and the resources are used for beach nourishment.

The Adler Ground south west of the Bornholm Island sand and gravel resource of 10 mill m^3. The distance from the area to the Fehmarnbelt Fixed Link is approximately 220 km. The area is partly covered by SAC and SPA restrictions.

Furthermore two potential sand resource areas are described nearby the Fehmarnbelt Fixed Link corridor: Resource area 568013 and 568014 (marked as potential resource area at Figure 3.1). The two areas have sand resources of the magnitude of respectively 30 and 45 mill m^3 (Table 3.1). The resources are fine to medium grained sand. Both areas are conservation areas covered by SAC and SPA restrictions. The distance from these areas to the construction site are less than 20 km.

Table 3.1 Details of the two resource areas nearby the Fehmarnbelt Link corridor.

Area	**Res. volume**	**Res. thickness**	**Water depth**	**Resource quality**	**Comments**
	mill m^3	m	M		
568013	30	2 – 5	7- 15	Sand Fine-Medium	Environmental Protection
568014	45	1 – 2	15 – 25	Sand Medium-Coarse	Environmental Protection

3.2 *Marine resources in the Danish sector*

On the Danish continental shelf in the Baltic region five existing resource areas are located within a distance of 55 km from the construction area: Vejsnæs Flak, Keldsnor, Rødbyhavn, Gedser and Gedser Rev.

The accumulated resource of these areas is approximately 1 mill m^3 of sand (Figure 3.2). Additional resources of between 5 and 10 mill m^3 are documented, but to exploit this resource more documentation of the resource volume and quality are required and an increase in production from the five areas has to pass the parliament. None of the areas are covered by SAC and SPA restrictions.

Further 13 potential sand resource areas (Table 3.2) are mapped in the Fehmarnbelt region. The resource thickness varies between 1 and 3 m. Therefore, if 1 m should be left at the seabed, to preserve the original habitats, the potential resource will decrease drastically.

Three potential resource areas are located near the construction site for Fehmarnbelt link (Figure 3.2). The areas named 568009, 568010 and 568011 hold an estimated potential resource in total of 10 mill m^3. They have been characterized as a sand wave field with a resource thickness of 1-3 m. The resource area needs thorough investigations but most likely the results with show less available resource volume for dredging than estimated in Jensen (2009).

Table 3.2 Potential sand resource areas in the Fehmarnbelt region. (Res. = Resource).

Area	**Res. volume**	**Res. thickness**	**Water depth**	**Ressource quality**	**Comments**

	mill m^3	m	m		
568001	30	2	10 - 20	Sand Fine-Medium	Existing dredging
568002	20	1	6 - 10	Sand Medium	Cables and Ferries
568003	2	1	4 - 8	Sand Fine-Medium	Shallow Water
568004	2	1	4 - 6	Sand Fine-Medium	Wind Farm
568005	2	1	6 - 8	Sand Fine-Medium	Wind Farm
568006	10	1	6- 8	Sand Fine-Medium	Wind Farm
568007	15	2	4 - 10	Sand Fine-Medium	Wind Farm
568009-11	10	1 – 3	12- 18	Sand Medium	Fehmarnbelt trace
568012	3	1 – 2	18 - 22	Sand	Uncertain ressource
568015	10	2	18 - 24	Sand Fine-Medium	Environmental Protection
568016a	5 - 10	2	12 - 18	Sand Fine-Medium Coarse	Environmental Protection
568016b	3	1 – 2	8 - 12	Sand – gravel	Environmental protection
568017	3	1	15	Sand	

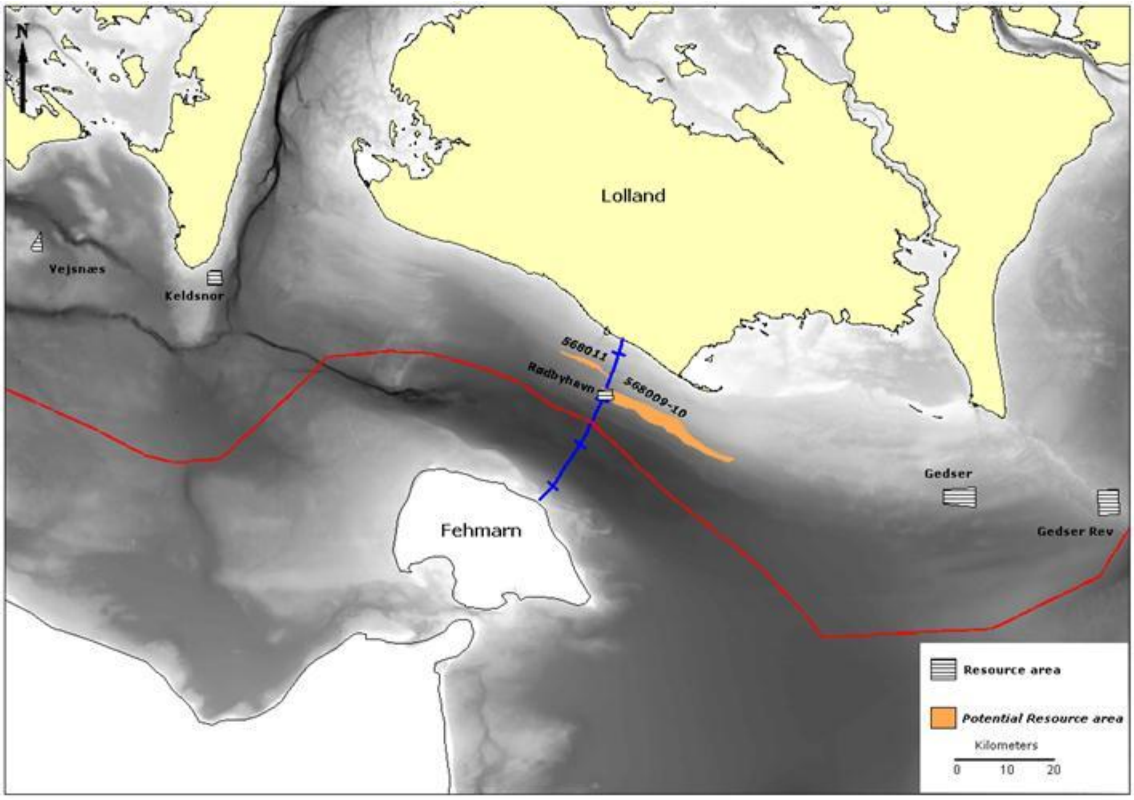


Figure 3.2 Resource areas in the Danish sector. Blue line indicates the alignment of the Fehmarnbelt Fixed Link.

3.3 Onshore resources in the Danish sector

An alternative to marine sand extraction is to retrieve the required raw materials or construction of the Fehmarnbelt Fixed Link onshore from local sand and gravel pits. Available raw material resources in the southern part of the Danish island Zeeland and surrounding islands have been estimated in 2006 and constituted approximately 12.5 mill m^3 resources left in sand and gravel pits (Lomholt and Jacobsen 2006). Most of the onshore production, 0.5 mill m^3 per year, is used for high quality concrete. The resources left in 2013 are most likely less than 10 mill m^3 - assuming that no new onshore resources have been discovered since 2006 as the probability of this is low.

Considering the total demand for fill and aggregate materials for the construction Fehmarnbelt Fixed Link of 6 mill m^3 sand and the requirement for materials for local constructions and buildings, it can be concluded that onshore materials are not a possibility for the resource demand for the Fehmarnbelt Fixed Link.

3.4 Other resources

Sand and gravel resources from the fixed link, such as dredged material from the tunnel trench or other project structures cannot be used as backfill material etc., The material does not live up to the standards and requirements needed for the resources.

3.5 0-Alternative

In case of not building the Fehmarnbelt Fixed Link there will be no effect on the marine environment from sand extraction.

4 BASELINE DESCRIPTION

4.1 Seabed, bathymetry and sand transport

4.1.1 Seabed substrates

Previous sediment analyses (Leth 1992, Lomholt and Jensen 1993) indicate that the seabed sediment of the Krieger's Flak resource area consists of well sorted homogeneous medium sand. This has been confirmed by the results from the present study. The seabed conditions were surveyed during the field campaigns in July and August 2011 including a full coverage side scan sonar mapping and ground truthing. For details and results of the field work see Chapter 2.

By integrating the acoustic data set and the ground truth data, the seabed has been classified into substrates/nature types following the classification system required by Danish Nature Agency (Naturstyrelsen):

- Type 1: Sand: Areas comprising primarily of sandy substrates with variable amounts of ribbons etc. < 1% gravel and pebbles

- Type 2: Sand, gravel and pebbles: Areas comprising primarily of sand with variable amounts of gravel and pebbles, and with few scattered stones, < 5%.

- Type 3: Sand, gravel, pebbles and scattered stones covering 5 < 25%: Areas comprising of mixed substrates with sand, gravel and pebbles with variable amount of larger stones.

- Type 4: Stones covering more than 25%: Areas dominated by larger stones (stone reefs) with variable amounts of sand, gravel and pebbles.

Based on the interpretation of the side scan data the seabed was classified as a sandy seabed with scattered sand ripples recognized in a limited area to the southwest. The sediment samples as well as the video inspection of the seabed confirm the sandy seabed. In addition the video recordings show that almost the entire seabed is covered by ripples in the order of magnitude of decimetres. The presence of ripples is suggested to be due to wave action (see photo in Figure 4.3 and Appendix D). The resolution of the mapping is 50x50 m, which has been found to be optimal for interpretations of sidescan data (Leth & Al-Hamdani 2012). By that the seabed of the investigation area can be classified as nature type 1, medium grained sand with an average grain size between 0.2 and 0.5 mm with some content of gravel and coarser fractions.

Previous dredging activities have taken place in the northwestern part of the investigation area leaving the seabed with plenty of scars and spill cones from the sand extraction activities. In these areas lag deposits of gravel and cobbles have accumulated in a patchy pattern. The video recordings and sediment samples confirm the presence of scattered stones up to 10 cm in diameter, partly buried by loose sand (see Figure 4.2 and Appendix D). The stones originate from the underlying coastal spit and beach ridge deposits where coarse grained sediment accumulated along the bedding planes. In general, the cobbles are covered by blue mussels (*Mytilus edulis)*.

The substrate/nature type 3 is in this context considered as an artificial type resulting from human activities. In the resulting seabed map this type is indicated as areas influenced by dredging (Figure 4.1).

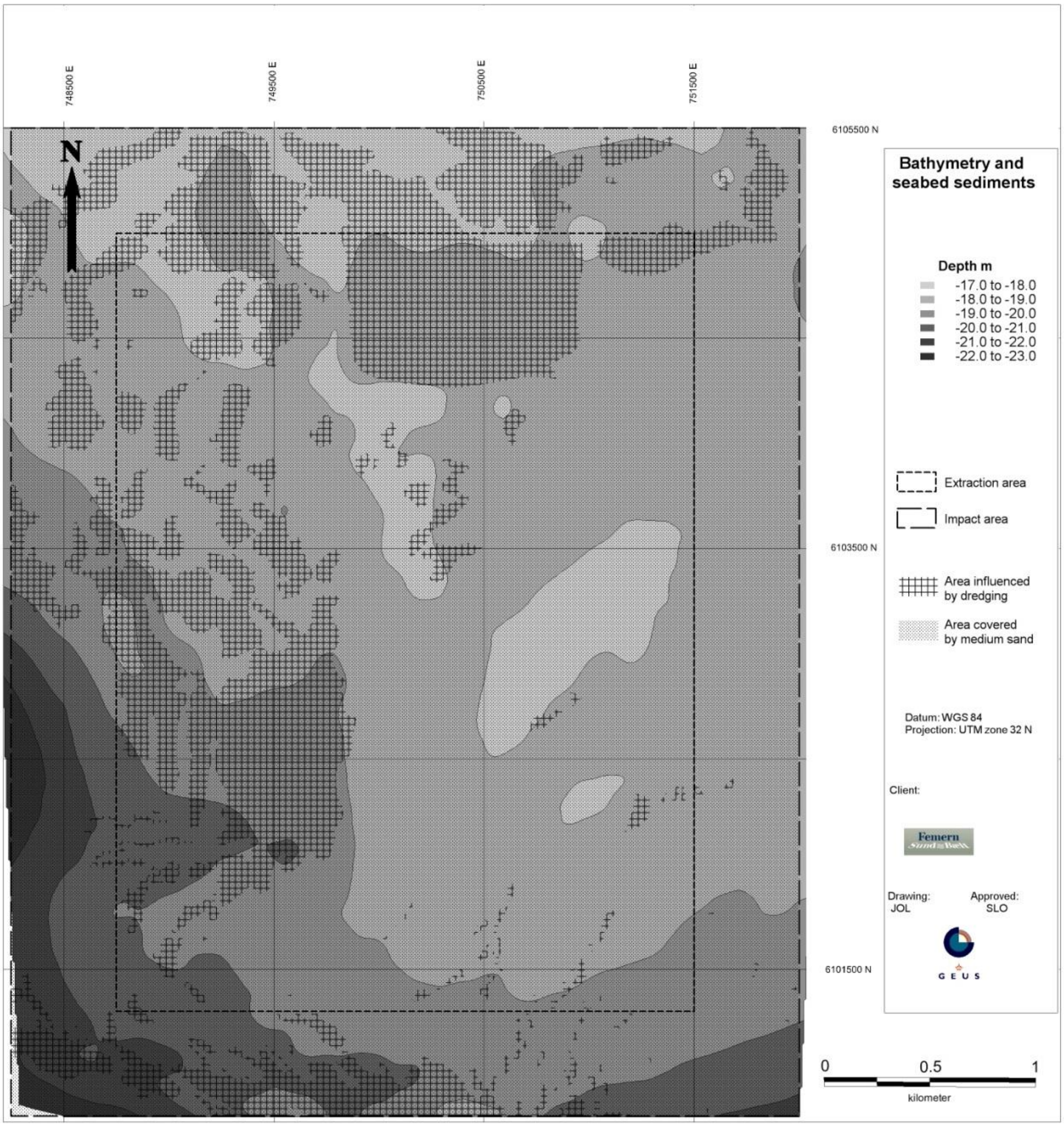


Figure 4.1 Seabed sediment map of Impact area at Krieger's Flak showing the general medium grain size sandy seabed and areas of lag deposits of gravel and cobbles. Figure also found in A3 in appendix F.

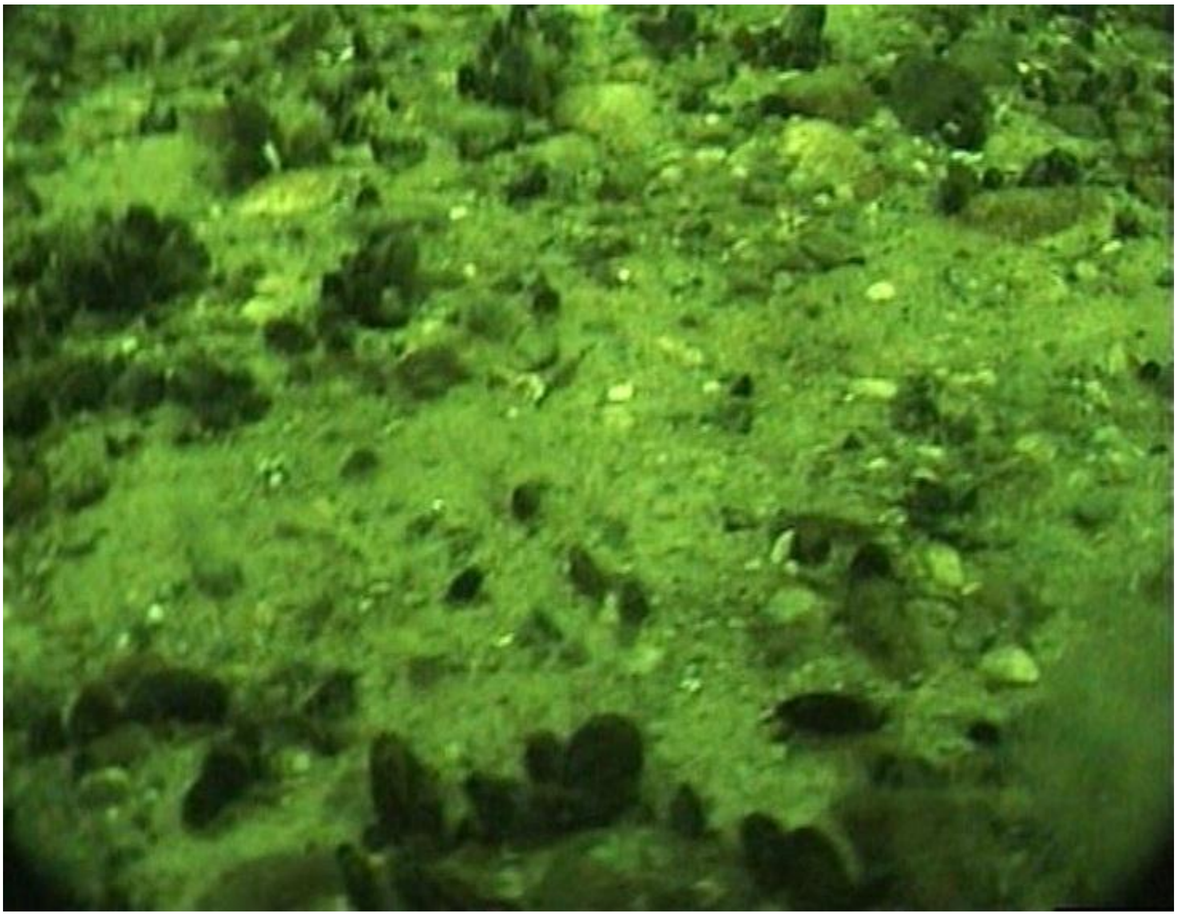


Figure 4.2 Seabed of lag deposits in the northwestern part of the impact area showing gravel and scattered stones and mussels. Photo from video inspection.

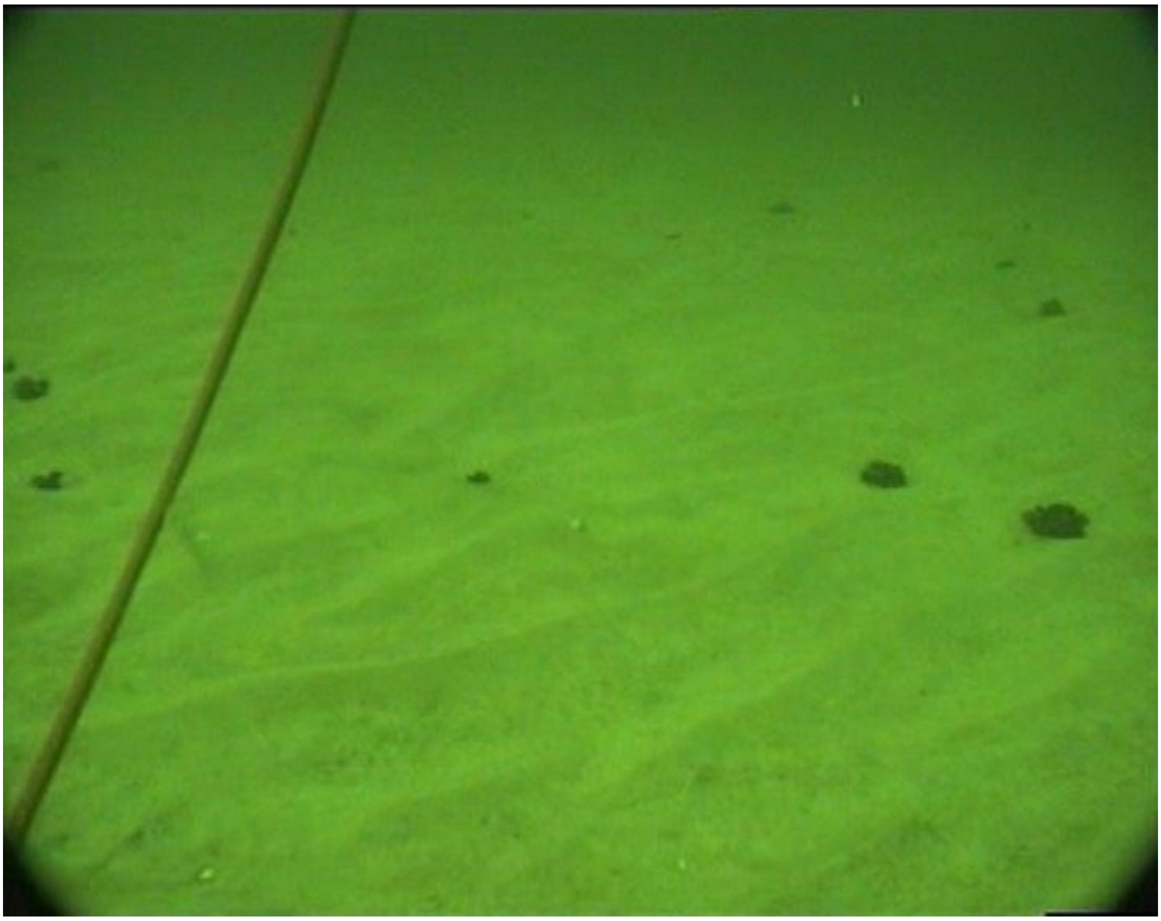


Figure 4.3 Sandy seabed type with ripples of the extraction area at Krieger's Flak. Scattered occurrence of mussel clusters is seen as black spots. Photo from video inspection.

4.1.2 Bathymetry

The transition from the Arkona Basin to Krieger's Flak is characterized by a slope where the water depths rise from a maximum depth of 50 m in the Arkona Basin to water depths in the magnitude of 20 m at Krieger's Flak. The general bathymetry of the Krieger's Flak and the surrounding area is shown in Figure 4.4. A detailed bathymetric mapping was performed by GEUS in July 2011 as part of the resource mapping (see Chapter 2). The resulting bathymetry from this survey indicates that the water depth in the sand extraction area varies between 18 and 21.5 m though with water depths up to 23 m in the 500 m impact zone.

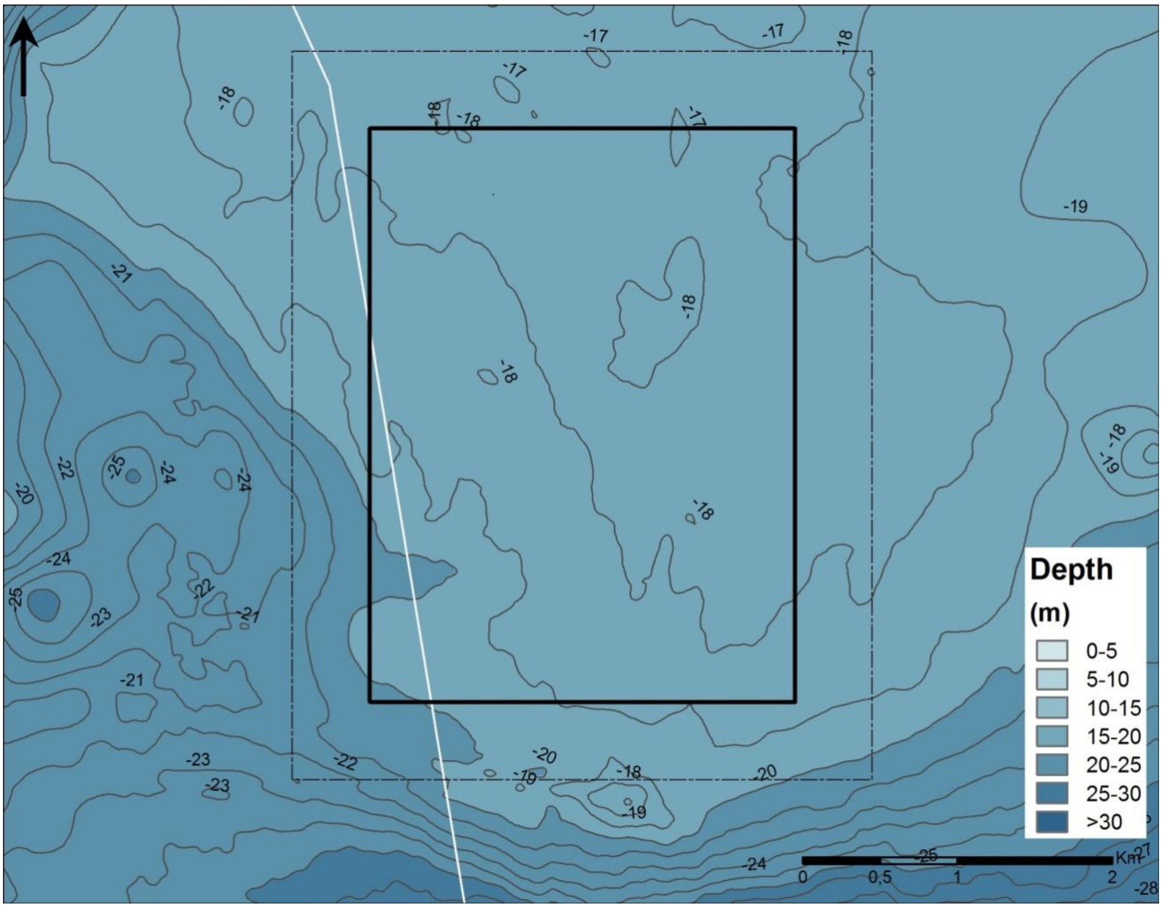


Figure 4.4 Bathymetri map of the extraction and impact area including the surrounding seabed. For details see Figure 2.3. White line indicates the Danish border.

4.1.3 Sand transport processes

The transport capacity in the extraction area has been computed using the sediment transport module MIKE 21ST (Mike by DHI 2011). The ST model is based on a deterministic intra-wave formulation of sediment transport computation which calculates the sediment transport rate on basis of given flow and wave fields and it is able to resolve the effects of sediment characteristics such a grain size distribution, sediment fall velocity and density. The following data have been used as basis for the computations:

- Depths of the area, two characteristic depths of 18 and 20 m have been used
- An average mean grain size of d_{50} = 0.45 mm
- Characteristic wave and current conditions and their durations have been extracted from Table 4.1 and Table 4.2 (see below).

Wave conditions

The sand transport conditions depend among other things on the wave conditions. Wave conditions, to be used as basis for transport computations, have been extracted from the regional model runs conducted in connection with the baseline assessment of the Fehmarnbelt Fixed Link (FEHY 2013b) Data cover the period 1 January 1989 to 30 April 2010. They are extracted for the model cells covering the extraction and 500 m impact area. A wave rose from Krieger's Flak is presented in

Figure 4.5. The data behind the wave rose are shown in Table 4.1 giving the wave heights vs. directions.

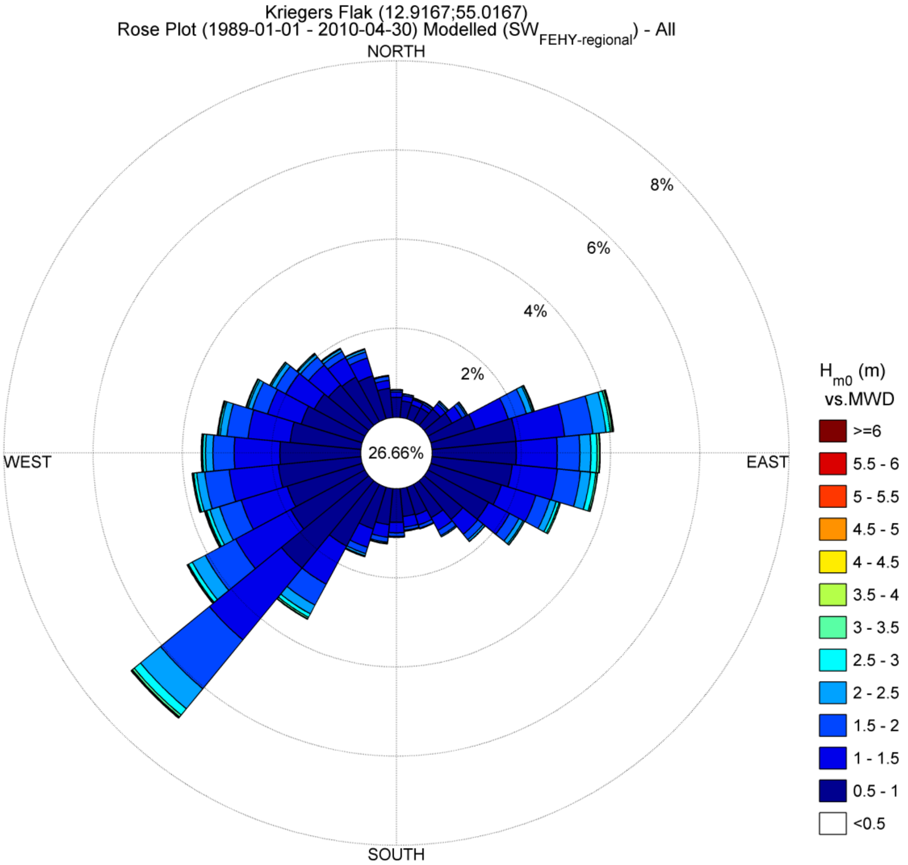


Figure 4.5 Wave rose form Krieger's Flak for the period: 1.1.1989 to 30.04.2010. From FEHY Regional SW model (FEHY 2013b).

The predominant waves are from W to SW and from easterly directions (Figure 4.5).

Table 4.1 Percentage occurrence of wave heights vs. directions from Krieger's Flak 1 January 1989 to 30 April 2010

Kriegers Flak (12.9167;55.0167)
Percentage Occurence (1989-01-01 - 2010-04-30) Modelled ($SW_{FEHY\text{-}regional}$) - All

H_{m0} (m)

MWD (°N-from)	[0-0.5[	[0.5-1[	[1-1.5[	[1.5-2[	[2-2.5[	[2.5-3[	[3-3.5[	[3.5-4[	[4-4.5[	[4.5-5[	[5-5.5[	[5.5-6[	[6-6.5[	Total	Accum
[-5.625-5.625[	0.551	0.449	0.122	0.042	0.011	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	1.178	1.178
[5.625-16.875[	0.458	0.374	0.121	0.035	0.007	0.001	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.999	2.177
[16.875-28.125[	0.432	0.329	0.120	0.029	0.012	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.928	3.106
[28.125-39.375[	0.386	0.346	0.097	0.044	0.010	0.005	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.888	3.993
[39.375-50.625[	0.372	0.474	0.148	0.051	0.032	0.007	0.001	0.000	0.000	0.000	0.000	0.000	0.000	1.085	5.078
[50.625-61.875[	0.462	0.610	0.252	0.101	0.034	0.009	0.003	0.001	0.000	0.000	0.000	0.000	0.000	1.471	6.550
[61.875-73.125[	0.689	1.038	0.781	0.424	0.132	0.033	0.016	0.004	0.003	0.000	0.000	0.000	0.000	3.122	9.671
[73.125-84.375[	0.977	1.892	1.094	0.635	0.297	0.099	0.042	0.016	0.011	0.003	0.002	0.000	0.000	5.069	14.740
[84.375-95.625[	0.933	1.887	0.919	0.506	0.248	0.140	0.055	0.011	0.005	0.000	0.000	0.000	0.000	4.702	19.442
[95.625-106.875[	0.912	1.808	1.014	0.523	0.226	0.117	0.035	0.008	0.002	0.000	0.000	0.000	0.000	4.644	24.086
[106.875-118.125[	0.989	1.656	0.810	0.328	0.150	0.066	0.033	0.002	0.000	0.000	0.000	0.000	0.000	4.034	28.120
[118.125-129.375[	0.925	1.541	0.533	0.239	0.104	0.034	0.005	0.001	0.000	0.000	0.000	0.000	0.000	3.382	31.502
[129.375-140.625[	0.855	1.125	0.433	0.157	0.051	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.630	34.132
[140.625-151.875[	0.715	0.845	0.321	0.135	0.032	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.052	36.184
[151.875-163.125[	0.641	0.651	0.235	0.078	0.016	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.622	37.805
[163.125-174.375[	0.638	0.630	0.241	0.068	0.022	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.604	39.409
[174.375-185.625[	0.633	0.755	0.234	0.082	0.017	0.000	0.002	0.001	0.000	0.000	0.000	0.000	0.000	1.725	41.134
[185.625-196.875[	0.663	0.814	0.283	0.112	0.027	0.010	0.003	0.005	0.000	0.000	0.000	0.000	0.000	1.916	43.050
[196.875-208.125[	0.888	0.978	0.434	0.148	0.051	0.017	0.005	0.004	0.000	0.000	0.000	0.000	0.000	2.524	45.574
[208.125-219.375[	1.080	1.570	0.965	0.534	0.221	0.087	0.039	0.011	0.005	0.000	0.000	0.000	0.000	4.512	50.087
[219.375-230.625[	1.405	2.537	2.087	1.416	0.582	0.185	0.054	0.019	0.010	0.004	0.003	0.001	0.000	8.301	58.387
[230.625-241.875[	1.178	1.885	1.403	0.771	0.328	0.097	0.026	0.007	0.002	0.002	0.001	0.002	0.000	5.701	64.089
[241.875-253.125[	1.143	1.758	1.077	0.510	0.225	0.077	0.027	0.016	0.003	0.001	0.001	0.001	0.001	4.839	68.927
[253.125-264.375[	1.190	1.860	1.106	0.549	0.184	0.067	0.024	0.009	0.003	0.000	0.001	0.001	0.000	4.993	73.920
[264.375-275.625[	1.125	1.813	1.024	0.476	0.166	0.062	0.024	0.009	0.003	0.000	0.001	0.000	0.000	4.703	78.622
[275.625-286.875[	1.045	1.596	0.946	0.477	0.152	0.039	0.014	0.011	0.002	0.001	0.000	0.000	0.000	4.283	82.905
[286.875-298.125[	0.942	1.431	0.787	0.356	0.099	0.036	0.014	0.004	0.001	0.000	0.000	0.000	0.000	3.670	86.576
[298.125-309.375[	0.911	1.289	0.727	0.258	0.104	0.033	0.009	0.003	0.000	0.000	0.000	0.000	0.000	3.334	89.909
[309.375-320.625[	0.921	1.173	0.582	0.231	0.076	0.027	0.004	0.001	0.001	0.000	0.000	0.000	0.000	3.017	92.927
[320.625-331.875[	0.876	1.130	0.499	0.154	0.062	0.017	0.004	0.003	0.002	0.000	0.000	0.000	0.000	2.745	95.672
[331.875-343.125[	0.919	1.011	0.418	0.141	0.058	0.013	0.003	0.001	0.001	0.000	0.000	0.000	0.000	2.565	98.237
[343.125-354.375[	0.809	0.659	0.180	0.091	0.014	0.007	0.002	0.000	0.000	0.000	0.000	0.000	0.000	1.763	100.000
Total	26.664	37.915	19.995	9.701	3.754	1.305	0.446	0.145	0.052	0.011	0.008	0.003	0.001	100.000	0.000
Accum	26.664	64.579	84.575	94.275	98.029	99.334	99.779	99.925	99.977	99.988	99.996	99.999	100.000	0.000	0.000

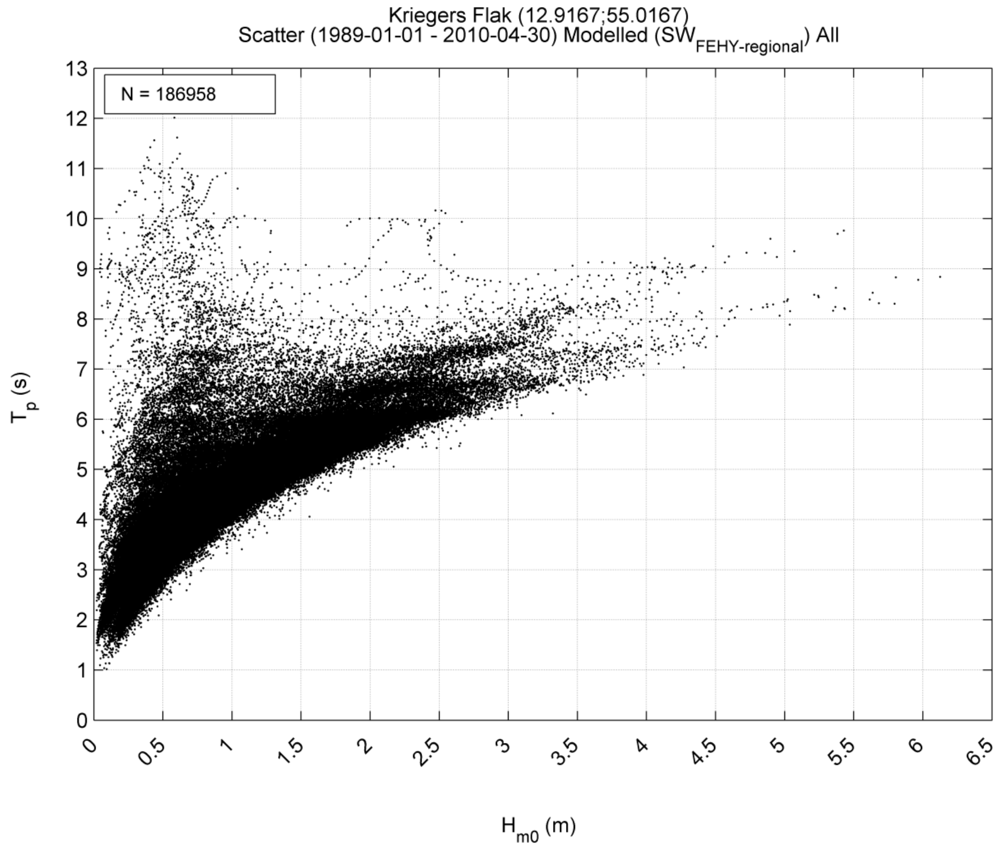


Figure 4.6 Scatted diagram of Hm0=Hs Significant wave height vs. Tp=wave peak from Krieger's Flak. Data from 1 January 1989 to 30 April 2010, extracted from the regional modelling conducted by FEHY (2013b).

Current conditions

Sand transport contitions depend also on the current conditions. Consequently, current conditions, to be used as basis for the sediment transport computations, have been extracted from FEHY (2013a) regional modeling, which covers the period 1 January 1989 to 30 April 2010. Data covering the extract and 500 m impact area have been extracted. The directional distribution of depth averaged currents, a so-called current rose, is presented in Figure 4.7. The sediment transport program calculates a current profile based on the depth averaged current taking into account the turbulence generated by waves and current.

It is seen that the main current direction is towards WSW, which is related to outward flow form the Baltic Sea. The inward flow causes currents in the direction interval E to SE.

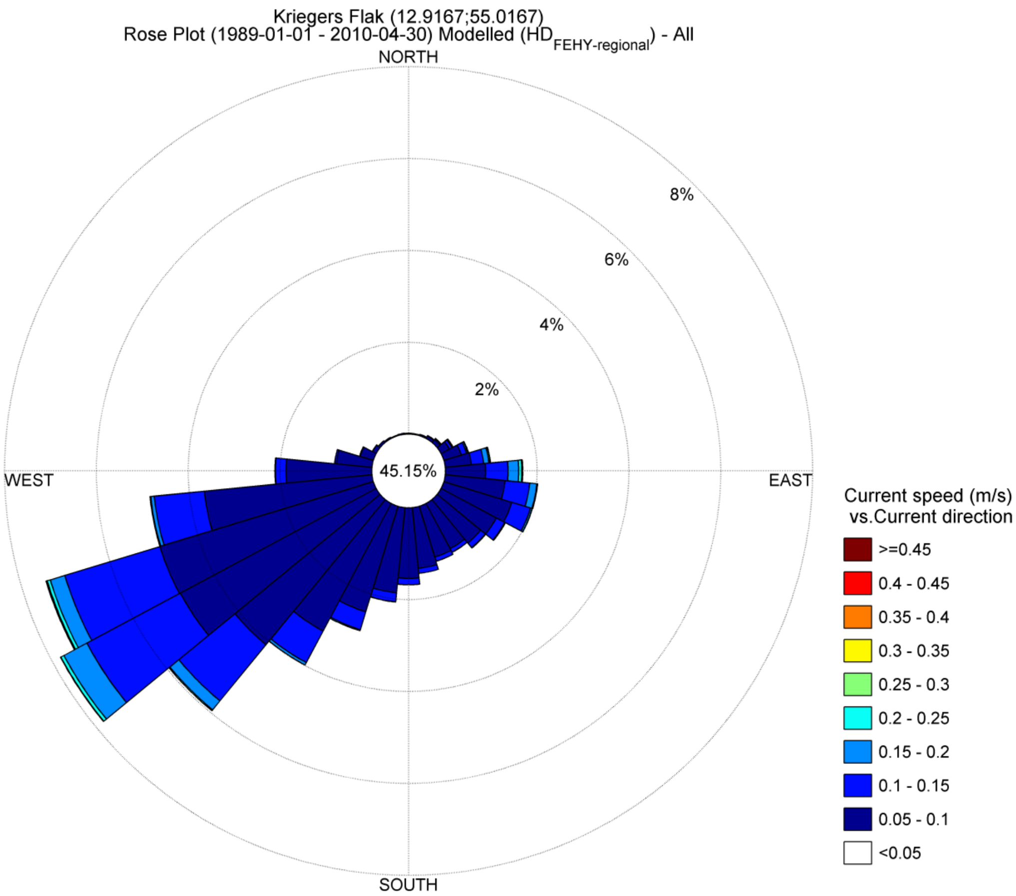


Figure 4.7 Current rose for Krieger's Flak for the period 1.01.1989 to 30.04.2010, from FEHY regional HD model: FEHY (2013a).

A table presenting the percentage distribution of current speeds vs. directions is presented Table 4.2.

It is seen that the current regime at Krieger's Flak is very mild, it is e.g. seen that the current speed is below 0.2 m/s in 99.6% of the time. This indicates a low transport regime although some transport takes place as demonstrated in the following transport computations.

Transport conditions

The transport conditions at Krieger's Flak has been computed with DHI's MIKE 21ST module (Sediment Transport module) for representative durations of waves and currents extracted from Table 4.1 and Table 4.2 using sand parameters characteristic for Krieger's Flak. The results are presented in Table 4.3. It should be noted that the impact of waves on the sand transport is of secondary importance compared to the current at deep waters. `

Table 4.2 Scatter diagram of depth averaged current speeds vs. direction at Krieger's Flak, 1 January 1989 to 30 March 2010.

Kriegers Flak (12.9167;55.0167)
Percentage Occurence (1989-01-01 - 2010-04-30) Modelled ($HD_{FEHY\text{-}regional}$) - All

Current speed (m/s)

Current direction (°N-to)	[0-0.05[	[0.05-0.1[	[0.1-0.15[	[0.15-0.2[	[0.2-0.25[	[0.25-0.3[	[0.3-0.35[	[0.35-0.4[	[0.4-0.45[	[0.45-0.5[	Total	Accum
[-5.625-5.625[	0.267	0.020	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.290	0.290
[5.625-16.875[	0.275	0.018	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.297	0.587
[16.875-28.125[	0.303	0.030	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.339	0.926
[28.125-39.375[	0.372	0.064	0.011	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.448	1.374
[39.375-50.625[	0.414	0.085	0.026	0.006	0.001	0.001	0.000	0.000	0.000	0.000	0.533	1.907
[50.625-61.875[	0.548	0.209	0.061	0.016	0.013	0.003	0.000	0.000	0.000	0.000	0.850	2.757
[61.875-73.125[	0.642	0.399	0.120	0.030	0.014	0.001	0.000	0.000	0.000	0.000	1.207	3.964
[73.125-84.375[	0.689	0.572	0.269	0.115	0.024	0.007	0.004	0.001	0.000	0.000	1.682	5.646
[84.375-95.625[	0.955	0.875	0.490	0.232	0.070	0.016	0.006	0.000	0.000	0.000	2.643	8.289
[95.625-106.875[	1.266	1.308	0.542	0.157	0.017	0.002	0.000	0.000	0.000	0.000	3.291	11.580
[106.875-118.125[	1.429	1.545	0.429	0.041	0.005	0.000	0.000	0.000	0.000	0.000	3.449	15.029
[118.125-129.375[	1.727	1.363	0.208	0.017	0.002	0.000	0.000	0.000	0.000	0.000	3.316	18.345
[129.375-140.625[	1.818	1.229	0.130	0.009	0.004	0.000	0.000	0.000	0.000	0.000	3.190	21.535
[140.625-151.875[	1.916	1.116	0.092	0.002	0.001	0.000	0.000	0.000	0.000	0.000	3.127	24.662
[151.875-163.125[	2.081	1.157	0.097	0.001	0.000	0.000	0.000	0.000	0.000	0.000	3.336	27.998
[163.125-174.375[	2.205	1.328	0.112	0.000	0.000	0.000	0.000	0.000	0.000	0.000	3.644	31.642
[174.375-185.625[	2.332	1.536	0.140	0.001	0.000	0.000	0.000	0.000	0.000	0.000	4.008	35.650
[185.625-196.875[	2.451	1.862	0.199	0.007	0.000	0.000	0.000	0.000	0.000	0.000	4.520	40.170
[196.875-208.125[	2.574	2.403	0.408	0.027	0.000	0.000	0.000	0.000	0.000	0.000	5.412	45.582
[208.125-219.375[	2.773	3.150	0.779	0.060	0.003	0.000	0.000	0.000	0.000	0.000	6.765	52.346
[219.375-230.625[	2.994	4.093	1.581	0.251	0.026	0.001	0.000	0.000	0.000	0.000	8.946	61.293
[230.625-241.875[	3.162	4.837	2.310	0.566	0.074	0.009	0.001	0.001	0.000	0.000	10.959	72.252
[241.875-253.125[	2.968	4.859	2.167	0.331	0.070	0.017	0.006	0.003	0.001	0.000	10.420	82.672
[253.125-264.375[	2.436	3.669	1.098	0.075	0.013	0.003	0.001	0.001	0.001	0.000	7.295	89.967
[264.375-275.625[	2.039	1.871	0.233	0.007	0.000	0.000	0.000	0.000	0.000	0.000	4.151	94.119
[275.625-286.875[	1.470	0.783	0.039	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.292	96.410
[286.875-298.125[	0.995	0.306	0.014	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.315	97.725
[298.125-309.375[	0.650	0.097	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.750	98.476
[309.375-320.625[	0.462	0.051	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.514	98.990
[320.625-331.875[	0.367	0.030	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.397	99.387
[331.875-343.125[	0.301	0.018	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.319	99.706
[343.125-354.375[	0.266	0.028	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.294	100.000
Total	45.148	40.911	11.570	1.951	0.336	0.060	0.017	0.005	0.001	0.000	100.000	0.000
Accum	45.148	86.060	97.629	99.581	99.917	99.977	99.994	99.999	100.000	100.000	0.000	0.000

Table 4.3 Transport capacity [m³/m/year] for the sand extraction area at Krieger's Flak. Representative wave heights and current speeds extracted from Table 4.1 and Table 4.2.

Wave height H_S [m]	Peak wave period, T_p [s]	Current speed [m/s]	Yearly duration [%]	Water depth [m] 18	20
				Transport capacity [m³/m/year]	
1	5	0.05	58	0	0
2	6	0.1	13	0	0
3	7	0.18	1.7	0.1	0.02
4	7.5	0.25	0.2	0.11	0.06
Total annual transport capacity				**0.21**	**0.08**

The above computations have demonstrated that there is hardly any transport under normal conditions in the sand extraction area but that there is some sand transport capacity during rare events. The fact that the bulk of the transport takes place during extreme events is a normal transport pattern. The magnitude of the yearly transport capacity decides the speed of the regeneration process but the regeneration of the seabed cannot be computed exactly, because the detailed characteristics of the seabed following the sand extraction are unknown. This is the reason why the methodology for evaluation of the regeneration is based on simplified computations of the transport capacity. It is evaluated that the uncertainty introduced by computing transport capacities on basis of characteristic depths, average seabed sediment characteristics and characteristic wave and current conditions are of minor importance relative to the uncertainty introduced by the lack of information about seabed characteristics. On basis of the above computations and considerations it is concluded that the computed amount of transport is sufficient to regenerate the seabed following the sand extraction over some years.

4.2 Toxic substances in seabed sediment

Toxic substances are bound to organic compounds and very fine particles of the sediments.

To survey the occurrence of organic matter in the extraction and 500 m impact area, samples of surface sediment (down to 5 cm) were collected in August 2011 and analysed for organic content (LOI) and dry weight (DW) (see Appendix A). The results of the analyses show that the organic content (LOI) is between 0.09 and 0.24 % DW (Table 4.5). Furthermore, the median grain size (D50) is between 0.226 and 0.355 mm; classified as medium sand.

The sediment in the extraction and impact areas does thus contain very little organic material and fine particles which potentially can carry toxic substances. Consequently, chemical analyses of the sediment have not been executed. Deduced from the scarcity of organic material, the content is expected to be below detection limit (FEMA 2013a, Herut and Sandler 2006).

Concentration of toxic substances in Baltic Sea has been measured in samples relatively near to Krieger's Flak at the Arkona W sampling station in connection with the Danish monitoring programme NOVANA. These data confirm that the concentrations of toxic substance are low at Krieger's Flak.

Data from the Arkona W (Figure 4.9), have been retrieved from the National Database for Marine Data, MADS (DMU web database 2011) for the period 2008 (most recent data in the database) where regular sampling took place. The Arkona W is a relatively deep sampling station (45 m) and functions as a sediment trap for fine particles. Hence, it is expected that toxic substances will accumulate in this area and that the concentration of toxic substances is thereby higher in this area than in the shallow areas of Krieger's Flak.

In Table 4.4 the concentrations measured in 2008 at Arkona W sampling stations has been corrected for the organic content (LOI) from the sampling at Krieger's Flak to make data from current project comparable to the sediment quality guidelines given by "Oslo and Paris Commission to protect the NE Atlantic against pollution", OSPAR (2009) and the Danish EPA (BLST 2008). The OSPAR values are based on unpolluted background concentrations. To correct the data, the concentration of toxic substances have been calculated per LOI for Arkona W and then multiplied with the LOI for the samples at Krieger's Flak. The estimation is hence a worse case value for Krieger's Flak, as it is not a trap for sediment and adhered toxic substances.

The evaluation of pollutant levels in sediments is usually based on so called sediment quality guidelines (SQG) that are derived based on three different approaches: 1) definition of criteria from data sets from toxicity experiments with polluted sediment (toxicological criteria), 2) definition of criteria based on data from unpolluted sediments (background levels) or 3) a combination of both approaches. In Table 4.4 a selection of SQG is listed that are accepted by environmental authorities and that includes some of the lowest criteria values available. OSPAR (2009) values are based on background concentrations and accepted exceedance from background concentrations, while the Danish EPA (BLST 2008) values are based on both toxicological and background data. Danish authorities operate with two sets of criteria values, Lower Action level (L Ac) and Higher Action level (H Ac), where values below L Ac are considered unproblematic.

*Table 4.4 Sediment quality guidelines (OSPAR (absolute) values from OSPAR (2009); Danish EPA values from BLST 2008). LOI = loss on ignition *Data from 2001, **sum of 9 compounds (given in BLST 2008).*

		Arkona W 2008	**Krieger's Flak - corrected for LOI**	**OSPAR**	**Danish L Ac**	**Danish H Ac**
PAH (total)**	mg/kg	2.4	0.02	0.35	3	30
PCB (total) (2001)	µg/kg	2.3*	0.02	1.09	20	200
TBT	µg Sn/kg	1.77	0.02	0	7	200
Cd	mg/kg	0.77	0.01	0.37	0.4	2.5
Cu	mg/kg	53.45	0.55	27	20	90
Hg	mg/kg	0.46*	0	0.07	0.25	1
Ni	mg/kg	44.35	0.45	36	30	60
Pb	mg/kg	95.95	0.99	38	40	200
Zn	mg/kg	149.5	1.55	122	130	500
Average LOI (2011)		15.6 (14.9*)	0.1615			

The calculated concentrations of toxic substances at Krieger's Flak are all below the accepted threshold values given by OSPAR as well as the Danish EPA. The concentration of TBT is very close to the OSPAR threshold (0.02 µg Sn/kg) but compared to the Danish EPA thresholds, TBT is a factor 1000 lower than the L Ac and is therefore not considered problematic.

4.3 Salinity, temperature and water quality

Relevant hydrographic and water quality data are available from a near-coastal station east of Møn (Hjelm Bugt "0901008") sampled monthly during 1990-1997 and in 2006 under NOVANA Programme and also sampled monthly under the Fehmarn Link Baseline study in 2009-2010 Station H131). Data from the monitoring programme was retrieved from the MADS database (DCE web database 2012). Additionally, hydrographic and oxygen data collected in the Swedish sector of Kriegers Flak in 2002 and 2003 in connections with an Environmental Impact Assessment for a Wind Farm at Krieger's Flak (Sweden offshore wind AB 2007) provided data from near the sand mining site. The mentioned stations are together considered to give a representative description of the conditions in the part of the Baltic Sea where Kriegers Flak is located and thereby also the conditions at the extraction site.

Salinity
On a yearly basis, the salinity at Hjelms Bugt is stable at 7-9 PSU in the upper part of the water column. Density stratification occurs regularly during calm periods in summer and is reinforced by a more shallow thermoclines located between 10 and 15 m (Figure 6.1). Observations in 2002 and 2003 of the Swedish and German part of Krieger's Flak show similar conditions; the salinity in the surface waters was between 7.6 and 8.6 PSU (Sweden offshore wind AB 2007) increasing to 13-18 PSU below 20m. The density stratification occurs usually in 18-25 m depth.

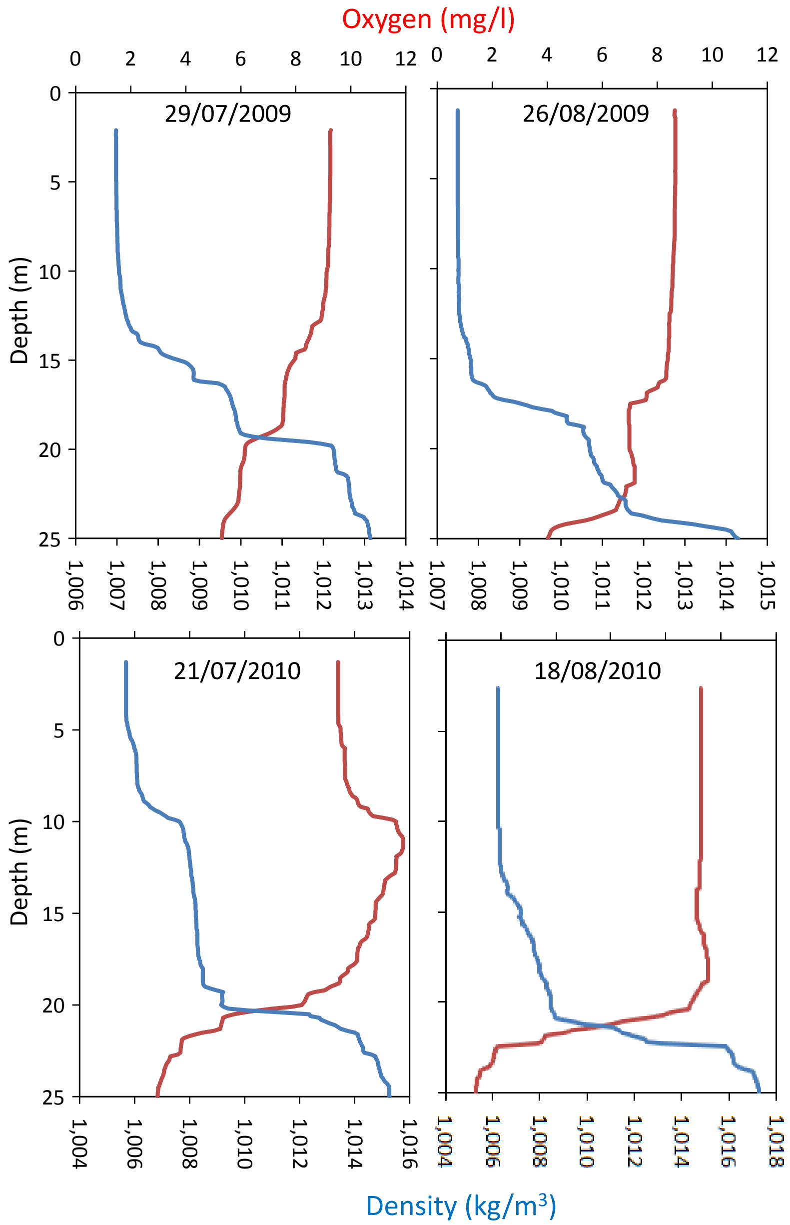


Figure 4.8 Depth profile of seawater density (blue) and dissolved oxygen (red) sampled at station H131 (Hjelm Bugt) during Fehmarnbelt baseline study.

Temperature
Temperature in surface water at Hjelm Bugt varies seasonally between 0 and 20 °C, but falls below 0 in cold winters. In the bottom water (18-22 m) temperature only rarely exceeds 15 °C. Data are supported by observation in the EIA report by Sweden offshore wind AB (2007).

Oxygen
During winter, spring and early summer in 2009-2010, concentration of dissolved oxygen in bottom water is saturated (or near-saturated) with concentrations varying between 7 and 11 mg/l depending on temperature. During summer and early autumn (July-September) oxygen in bottom water becomes under-saturated if stable density stratification is established (Figure 6.1). Results from the baseline study

are confirmed by the NOVANA monitoring; the water column is usually stratified with an increasing salinity below 17-18 m in 39 out of 46 CTD profiles sampled during July-September (1990-1997, 2006). In addition, the oxygen was reduced in waters below 18 m when the water column was stratified (Figure 4.8). On few occasion, water was supersaturated with oxygen when subsurface algal bloom occurred conciding with secondary pycnocline located at 10-13 m (Figure 6.1).

The presence of a seasonal (summer) density stratification at 18-22m and depressed oxygen concentreation in the area is supported by samplings in the Swedish sector of Krieger's Flak carried out during summer and autumn 2002 and 2003 (Sweden offshore wind AB 2007).

Nutrients
The concentration of total nitrogen (TN) and total phosphorous (TP) has also been measured during the Fehmarnbelt baseline study. At the station H131 TN varied between 16–24 µmol/l without particular trends through the water column and year (2009-2010). TP was in the same period 0.5-1 µmol/l in the entire water column with the lowest observations in the summer period.

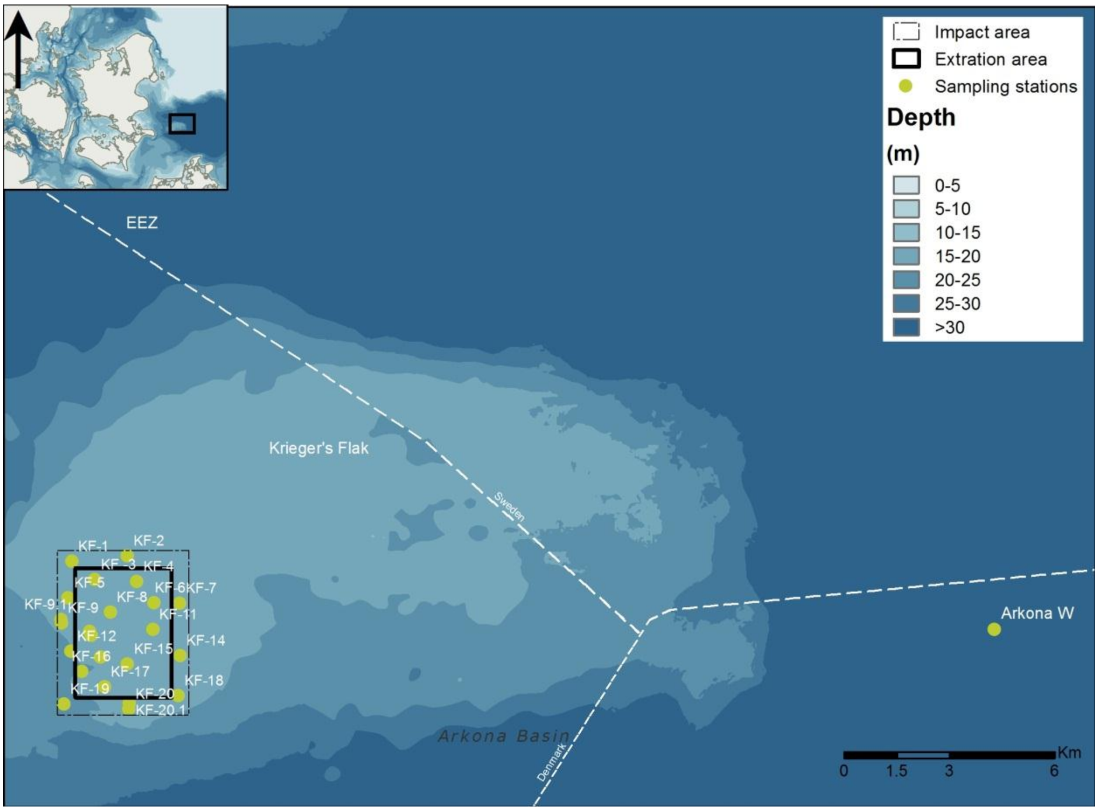
Chlorophyll a
Chlorophyll-a was measured monthly at H131 during Fehmarnbelt baseline study (2009-2010). Spring bloom occurred in March (2009) and early April 2010 with peak concenntrations reaching 6-8 µg/l. A prolonged autumn bloom (mid-August through November) was recorded in 2009 and less pronounced in 2010. Averaged over the two years the yearly concentration was 1.5 µg/l. Measurements of chlorophyll were not a part of the monitoring in connections to the EIA at the Swedish part of Krieger's Flak (Sweden offshore wind AB 2007).

4.4 Benthic fauna

The baseline description for benthic fauna is based on a field survey conducted at Krieger's Flak in August 2011. The results are compared with earlier investigations.

Quantitative samples of the benthic fauna and subsamples of the surface sediment were collected at 20 stations at Krieger's Flak in August 2011 (Figure 4.9).

The methods of sampling and analysis are described in Appendix A and the results of the surveys are summarised in tables in Appendix B, Appendix C and Appendix D.



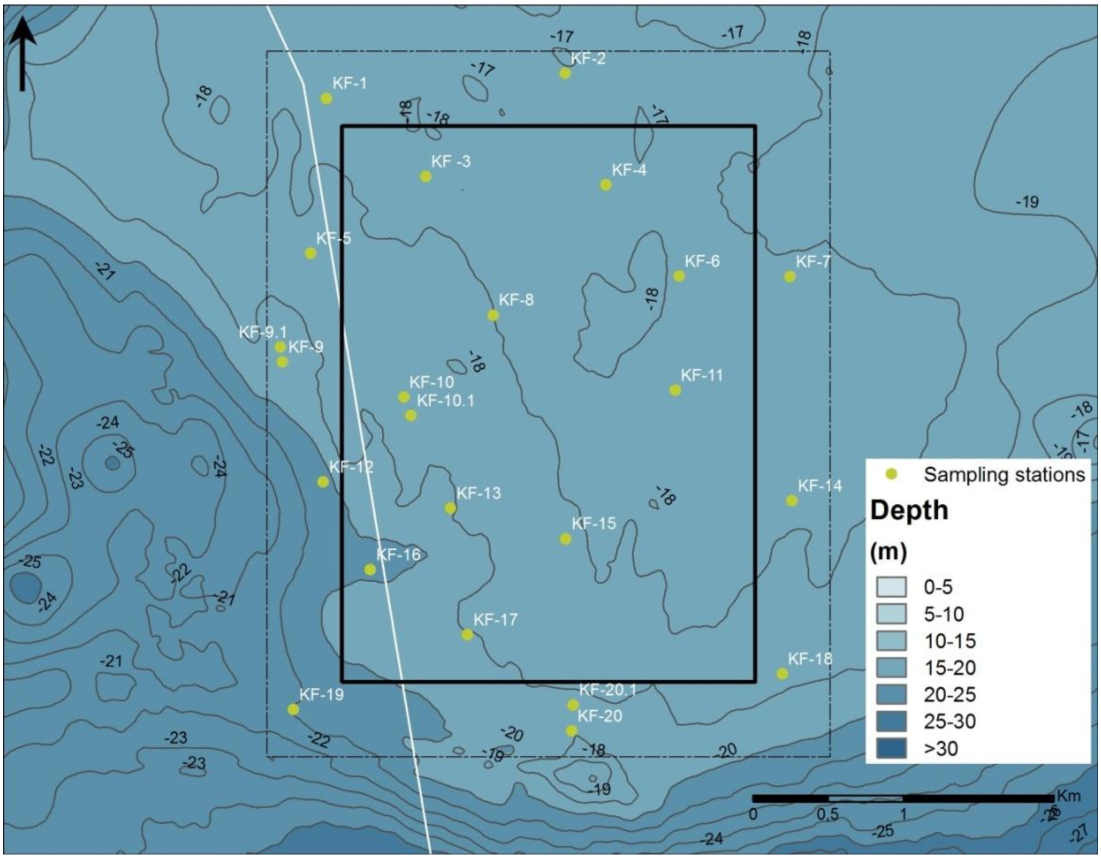


Figure 4.9 Map of the location of the benthic fauna stations together with the Arkona W NOVANA station (top). Detailed map of the location of the benthic fauna stations at Krieger's Flak visited in August 2011 (bottom). White line indicates the Danish border. Solid black square indicates extraction area and dashed line indicates impact area.

4.4.1 Number of species, abundance and biomass

Number of species

A total of 20 species and one higher taxon (Oligochaeta) was recorded at Krieger's Flak. The number of species depends on the number of samples (area of the sea-bed) collected. However, as appears from Figure 4.10, the sampling program was adequate to describe the species present in this shallow, low saline area of the Baltic Sea.

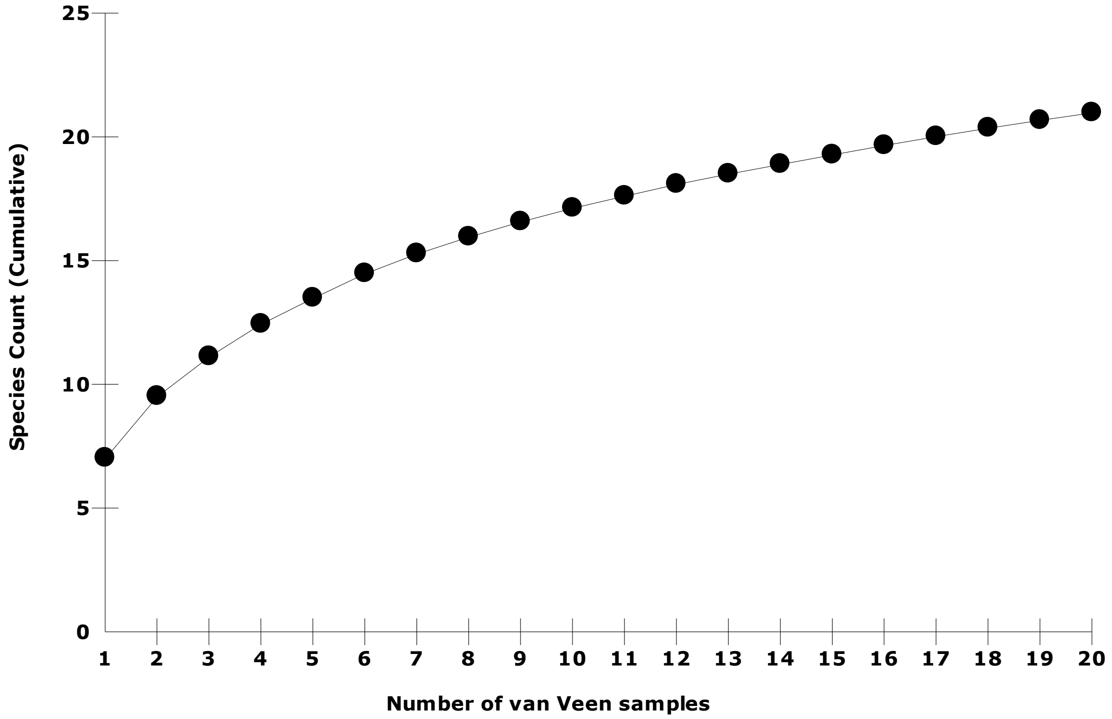


Figure 4.10 Cumulative number of species vs. number of van Veen samples collected at Krieger's Flak in August 2011.

The number of species was between 4 and 12 per 0.1 m^{-2} at the stations (Table 4.5).

Table 4.5 Water depth, number of species, abundance and biomass in AFDW (ash free dry weight) of the benthic fauna; and dry weight (DW), loss on ignition (LOI) and median grain size (D50) measured in the surface sediment of the extraction and 500 m impact area at Krieger's Flak in August 2011.

Station	Depth	Number of species	Abundance	Biomass	DW	LOI	D50
	M	0.1 m^{-2}	m^{-2}	g AFDW m^{-2}	% WW	% DW	mm
K-01	17.9	9	670	2.418	78	0.14	0.318
K-02	17.5	6	270	9.002	86	0.09	0.345
K-03	17.9	6	380	3.558	69	0.16	0.226
K-04	18.0	7	360	1.298	80	0.19	0.294
K-05	18.5	12	970	6.920	79	0.17	0.299
K-06	18.4	6	280	1.709	82	0.11	0.318
K-07	18.5	7	500	1.139	80	0.16	0.331
K-08	18.7	8	1,070	1.355	79	0.18	0.294

Station	Depth	Number of species	Abun-dance	Biomass	DW	LOI	D50
	M	0.1 m^{-2}	m^{-2}	g AFDW m^{-2}	% WW	% DW	mm
K-09-1	19.7	8	1,400	0.513	81	0.16	0.280
K-10-1	18.5	8	820	0.865	80	0.16	0.304
K-11	17.8	5	240	1.305	80	0.15	0.355
K-12	20.8	10	1,420	13.264	80	0.14	0.303
K-13	19.4	8	1,390	13.058	81	0.19	0.345
K-14	18.5	5	210	1.158	82	0.14	0.350
K-15	18.5	5	440	2.378	80	0.16	0.311
K-16	20.5	4	480	0.190	80	0.17	0.295
K-17	19.6	6	360	0.821	81	0.16	0.322
K-18	19.5	6	230	0.960	82	0.19	0.331
K-19	20.1	9	2,020	1.236	79	0.24	0.234
K-20-1	19.5	6	420	1.312	82	0.17	0.324
Range	**17.5-20.8**	**4-12**	**210-2,020**	**0.190-13.26**	**69-86**	**0.09-0.24**	**0.226-0.355**

Abundance

The abundance of the benthic fauna was between 210 and 2020 individual's m^{-2} (Table 4.5). Abundance above 1,000 individual's m^{-2} only occurred at a number of stations located in the western part of the survey area (Figure 4.11).

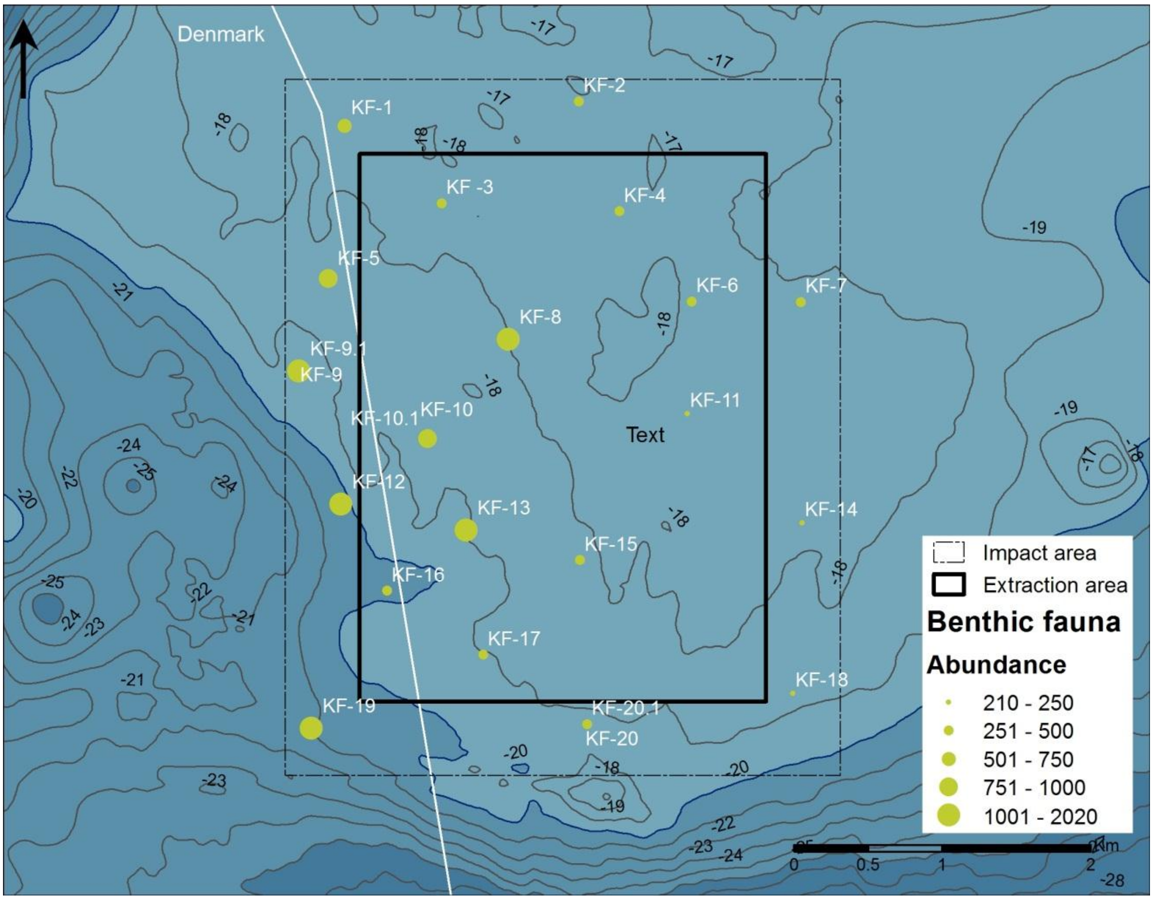


Figure 4.11 Abundance of the benthic fauna in the extraction and 500 m impact zone at Krieger's Flak in August 2011. White line indicates the Danish border.

Biomass

The benthic biomass was between 0.190 and 13.26 g AFDW m^{-2} (Table 4.5). The biomass was highest at stations K-12 and K-13 located in the southwestern part of the survey area.

4.4.2 *Common and dominant species*

The average abundance and biomass of the benthic fauna is summarized in Table 4.6.

Table 4.6 Average abundance and biomass of the species recorded at Krieger's Flak in August 2011.

Species	Abundance (m^{-2})	% of Abundance	Biomass (gAFDW m^{-2})	% of Biomass
Polychaetes				
Alitta succinea	2	0.22	0.0033	0.10
Bylgides sarsi	6	0.86	0.0051	0.16
Hediste diversicolor	19	2.73	0.1144	3.55
Marenzelleria viridis	212	**30.44**	0.1059	3.29
Ophelia rathkei	1	0.14	0.0001	0.00
Pygospio elegans	262	**37.62**	0.0584	1.81
Scoloplos armiger	1	0.07	0.0013	0.04
Travisia forbesii	3	0.43	0.0072	0.22
Oligochaeta	13	1.87	0.0011	0.04
Bivalves				

Species	Abundance (m^{-2})	% of Abundance	Biomass (gAFDW m^{-2})	% of Biomass
Cerastoderma edule	1	0.07	0.0124	0.38
Cerastoderma glaucum	4	0.50	0.1032	3.20
Macoma balthica	34	4.81	0.7654	**23.75**
Mya arenaria	26	3.66	1.0358	**32.14**
Mytilus edulis	99	**14.14**	0.9941	**30.84**
Gastropoda				
Hydrobia ulvae	10	1.36	0.0035	0.11
Crustaceans				
Bathyporeia pilosa	3	0.36	0.0015	0.04
Diastylis lucifera	1	0.07	0.0001	0.00
Diastylis rathkei	1	0.07	0.0006	0.02
Gammarus salinus	3	0.36	0.0041	0.13
Gammarus zaddachi	1	0.07	0.0010	0.03
Neomysis integer	1	0.14	0.0046	0.14
Total	**697**	**100**	**3.223**	**100**

Polychaetes and oligochaetes

Polychaetes and oligochaetes were the most diverse taxonomic group and eight species was recorded. The polychaetes accounted for 73% of the benthic abundance and 9.2% of the biomass.

The sedentary tube building *Pygospio elegans* was present at all stations and accounted for 38% of the average benthic abundance and 1.8% of the biomass (Table 4.6). The average abundance of the species was 262 m^{-2} and the range between 70 m^{-2} and 950 m^{-2} (Appendix B).

The spionid polychaete *Marenzelleria viridis* was the second most abundant species and accounted for 30 % of the average benthic abundance and 3.3 % of the biomass. The species was present at all stations (Appendix B). The average abundance of *Marenzelleria viridis* was 212 m^{-2} and the range between 50 m^{-2} and 850 m^{-2}. The high abundance of *Merenzelleria viridis* is remarkable because this species is non-indigenous (alien) and introduced to European waters in recent years, probably via ballast water from the core area at the east coast of America (Kirkegaard 1996). *Marenzelleria viridis* was first recorded in England in 1979 and in Holland in 1983 (Jensen and Knudsen 2005). Since the first appearance in the southern Baltic in 1985 *Marenzelleria viridis* has dispersed rapidly and was recorded in the Gulf of Finland in 1990 and in the Åland archipelago in 1993 (Perus and Bonsdorff 2004, Hietanen et al. 2007).

Hediste (Nereis) diversicolor was recorded at most stations but the densities were below 50 m^{-2}. The species accounted for 3.6% of the average biomass due to the large size (Appendix C). The distribution of the remaining five species of polychaetes was scattered. These species contributed only little to the benthic abundance and biomass were low (Appendix B and Appendix C). Unidentified species of oligochaetes were scattered and the abundance low (Appendix B).

Bivalves

The five species recorded accounted for 23% of the benthic abundance and 90% of the biomass (Table 4.6). The Baltic tellin *Macoma balthica* was one of the most common species of bivalves and recorded at 70% of the stations. However, the abundance was mostly low and the species accounted in average for 5% of the abundance and 24% of the biomass (Appendix B). The population was dominated by older year classes (age is related to the shell length). Figure 4.12 shows the number of species versus shell length. The distribution of the year classes is relevant for determining the recovery time after a possible impact a project. The older the community structure is the longer recovery time

Mya arenaria was the most common species and recorded at 90% of the stations. The abundance was mostly low and the species accouted for 4% of the average abundance, but 32% of the biomass (Appendix B and Appendix C). The population was dominated by young bivalves, but older year classes were also present (Figure 4.12).

The distribution of the Blue mussel (*Mytilus edulis*) was patchy and the species was recorded at less than half of the stations. The mussels accounted for 14% of the average abundance and 31% of the biomass. However, the species was only recorded in larger numbers (>100 m^{-2}) at four stations (K-01, K-05, K-12 and K-13) in the western part of the survey area. According to the side scan surveys, the sediment of this area appears to be slightly different and may be affected by previous sand extraction. Underwater video records supported that Blue mussels were in particular common and abundant in the western area. The shell length of most of the mussels was between 5 mm and 15 mm (Figure 4.12).

The cockles (*Cerastoderma glaucum* and *Cerastoderma edule*) were scarce and only one specimen of the marine species *Cerastoderma edule* was recorded. The species accounted for less than 1 % of the average benthic abundance and 3.5% of the biomass. The cockles population consisted of older year classes of approximately 3 to 4 years (Boyden 1972) (Figure 4.12).

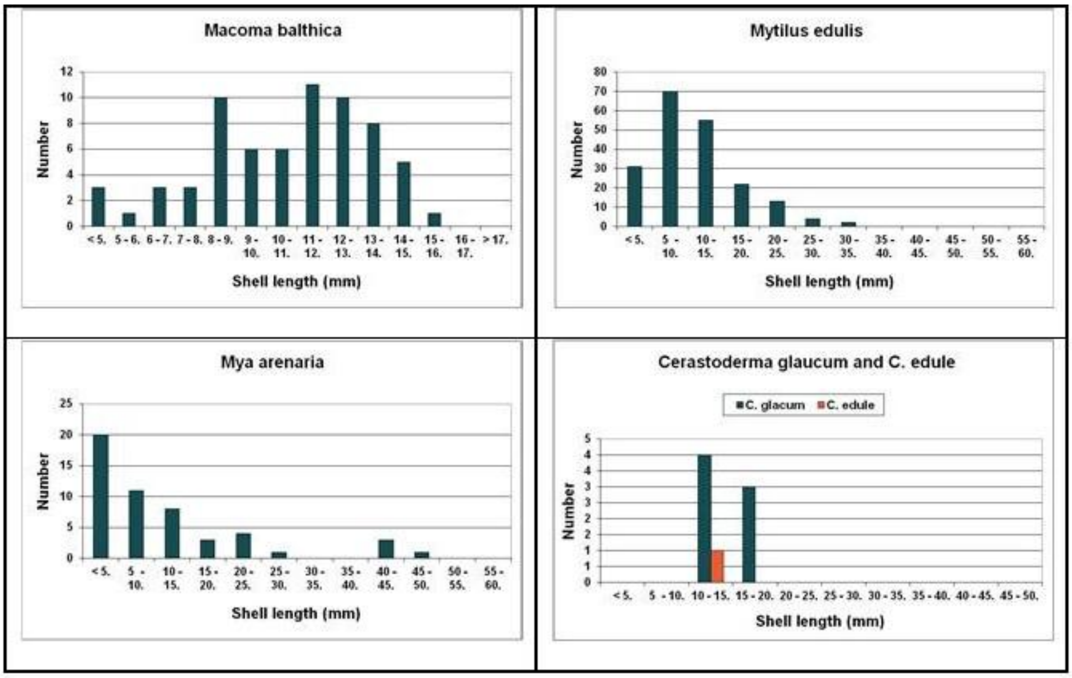


Figure 4.12 Shell length distribution of Macoma balthica, Mya arenaria, Mytilus edulis, Cerastoderma glaucum and Cerastoderma edule.

Gastropoda

The mud snail (*Hydrobia ulvae*) was scarce and the abundance very low (Table 4.6).

Crustaceans

Crustaceans were the second most diverse taxonomic group. However, the six species were scarce and only accounted for 1% of the average benthic abundance and less than 0.5% of the biomass.

4.4.3 Structure of the benthic community

The abundance and the biomass can be used to evaluate the ecological characteristics of the benthic fauna at Krieger's Flak and using multivariate analysis give an indication on the community structures within the sampling area.

Analysis based on abundance

The results of a classification and ordination are presented in Figure 4.13 and Figure 4.14, respectively.

The similarity between the benthic fauna samples was high and more than 50% at all stations. However, a cluster analysis shows that the sampling stations may be separated into three different clusters. The three clusters of stations are characterised in Table 4.7.

Table 4.7 Characterization of the similarity and average abundance of the species, which contributed 90% to the similarity in Cluster I, II and III in August 2011. Based on SIMPER (Clarke and Gorley 2001). Bold: species contributing mostly to the similarity.

Variables	Cluster I	Cluster II	Cluster III
Similarity	66.6%	76.5	71.1
Stations: number	5	2	13
Water depth (m)	19.3 (17.9-20.8)	19.1 (18.5-19.6)	19.9 (17.5-20.5)
Abundance (m^{-2})	1170 (670-1420)	400 (360-440)	1220 (210-2020)
Species contributing 90%			
Marenzelleria viridis	**310 (21.8)**	130 (28.2)	186 (25.7)
Pygospio elegans	296 (20.5)	**200 (34.0)**	**258 (28.0)**
Mytilus edulis	364 (18.6)		
Bylgides sarsi	24 (11.0)		
Hediste diversicolor	20 (6.8)		21 (16.5)
Mya arenaria	36 (6.6)	35 (21.4)	20 (13.8)
Hydrobia ulvae	24 (6.1)		
Bathyporeia pilosa		10 (16.3)	
Macoma balthica			33 (12.0)

Cluster I includes five stations (K-01, K-05, K-09-1, K-12 and K-13) in the western part of the area cfr. Figure 4.9. The benthic fauna is characterized by a high abundance of polychaetes (*Marenzelleria viridis* and *Pygospio elegans*) and Blue mussels (M*ytilus edulis*), which contributed mostly to the similarity at the stations.

Cluster II includes two stations (K-15 and K-17) in the southern part of the extraction area (Figure 4.9). The abundance was low and in addition to *Mya arenaria*, the same species of polychaetes as at Cluster I stations contributed mostly to the similarity. The dis-similarity between the benthic fauna at Cluster I and Cluster II stations was caused by the absence or a lower abundance of a number of species at Cluster II station contrary to Cluster I stations e.g. the absence of *Mytilus edulis*, *Macoma balthica* and *Hediste diversicolor*.

Cluster III includes all the remaining stations distributed in most of extraction area and in the impact zone north, east and south of the extraction area. The benthic fauna at Cluster II and Cluster III stations was similar but the abundance was highest at Cluster III stations.

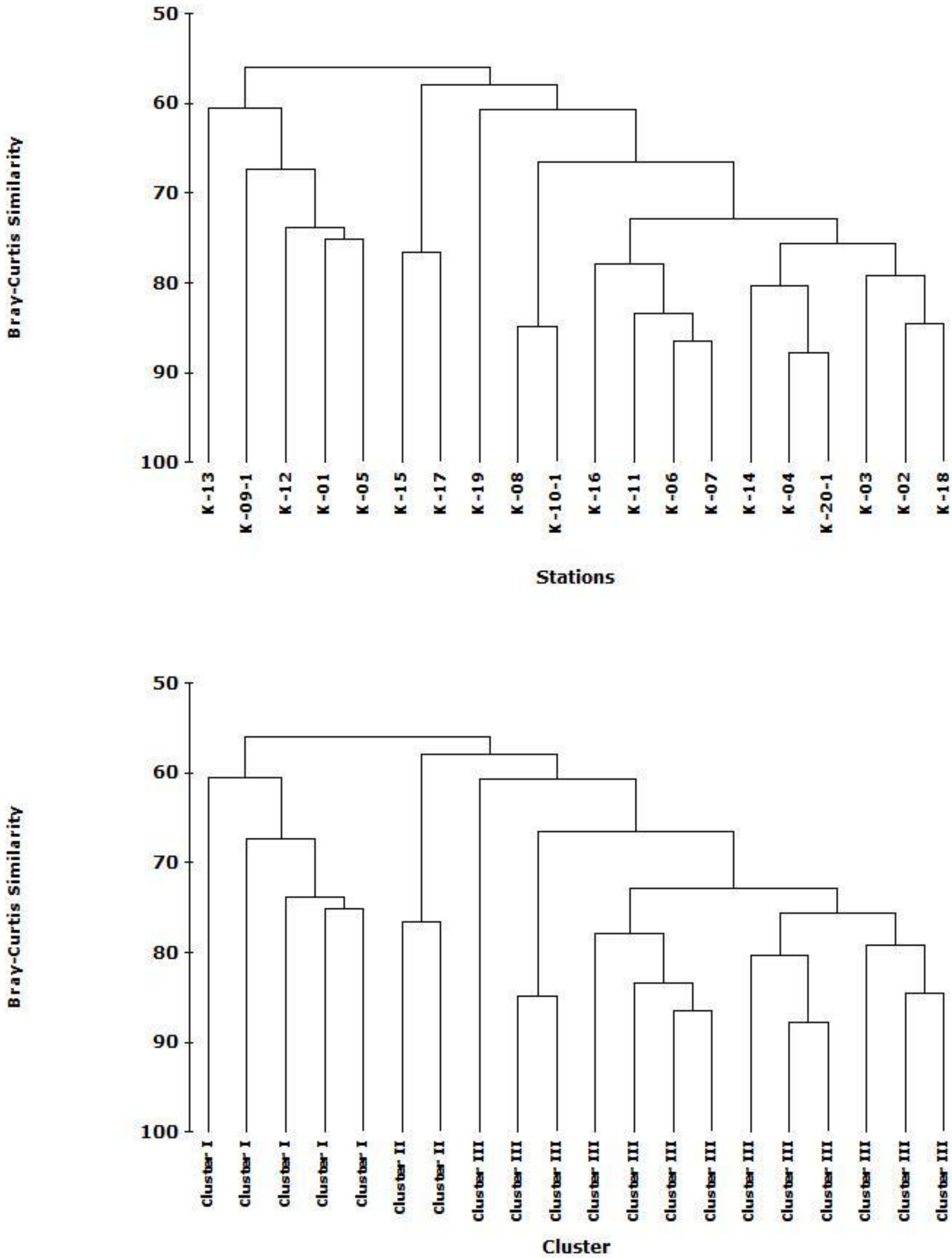


Figure 4.13 Results of classification based on abundance of the species at the stations in August 2011. Stations (top) and delineation of three clusters of stations (bottom).

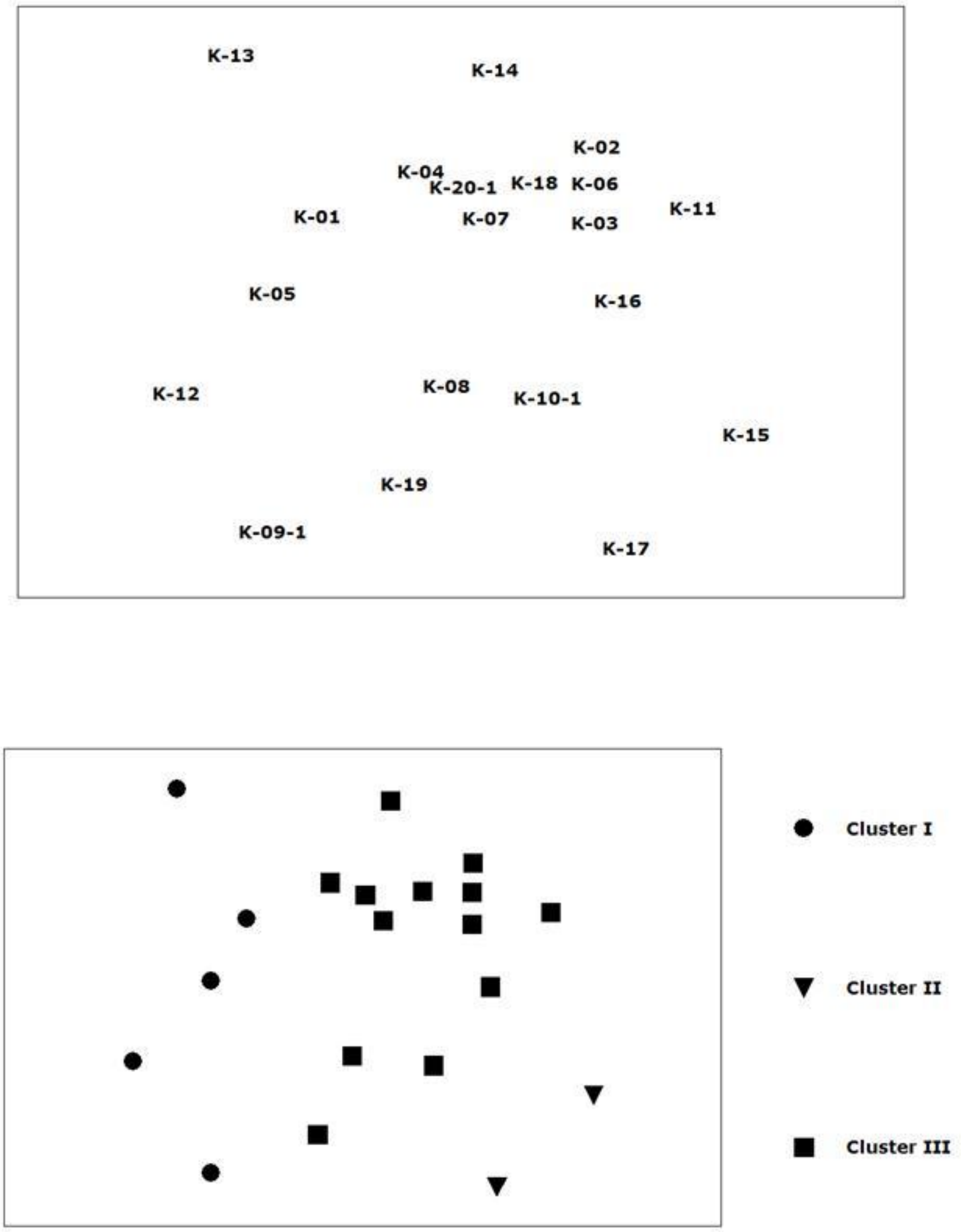


Figure 4.14 Results of ordination based on abundance of the species at the stations in August 2011. Stations (top) and delineation of three clusters of stations (bottom). Stress = 0.15.

Analysis based on biomass

The results of classification and ordination are presented in Figure 4.15 and Figure 4.16, respectively.

The results of the analysis based on abundance and biomass was mostly similar. The similarity of the benthic fauna was more than 40%; i.e. a little lower than the results of the analysis based on abundance. Three clusters of stations may be separated. The three clusters of stations are characterised in Table 4.8.

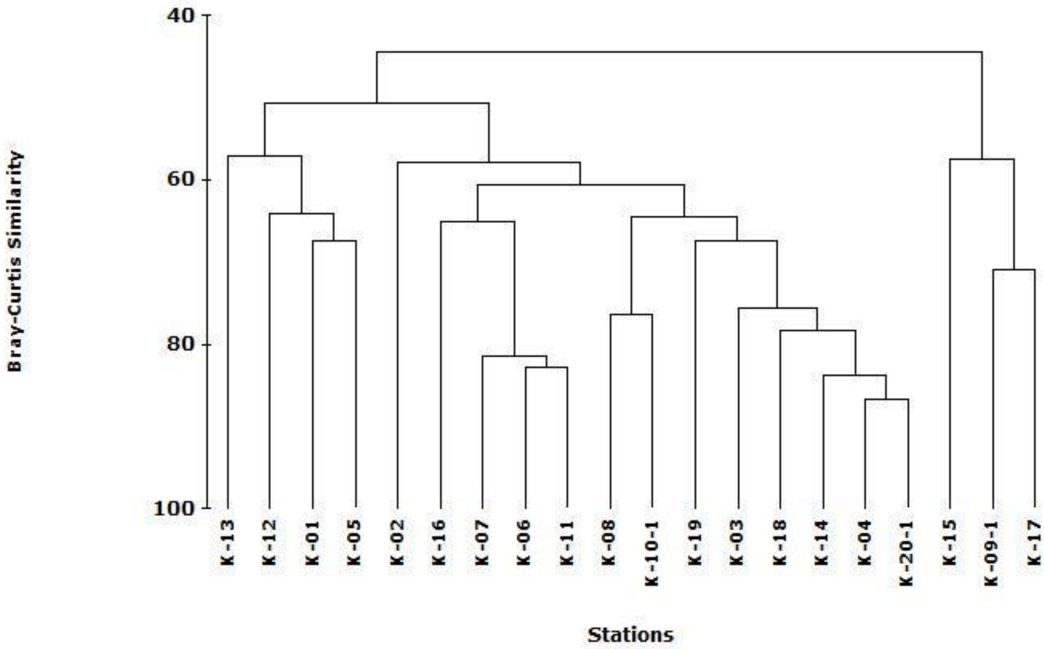
Table 4.8 Characterization of the similarity and average biomass of the species, which contributed 90 % to the similarity at Cluster I, II and III in August 2011. Based on SIMPER(Clarke and Gorley 2001). Bold: species contributing most to the similarity.

Variables	Cluster I	Cluster II	Cluster III
Similarity	61.1	61.9	64.8
Stations: number	4	3	13
Biomass (gA FDW m^{-2})	8.91 (2.41-13.26)	1.24 (0.51-2.38)	0.92 (0.19-9.00)
Species contributing 90%			
Mytilus edulis	**4.88 (34.2)**		
Marenzelleria viridis	0.7 (13.4)	0.06 (22.2)	**0.13 (22.8)**
Hediste diversicolor	0.11 (11.7)		0.14 (19.7)
Mya arenaria	1.71 (11.2)	**0.96 (37.3)**	0,85 (16.1)
Pygospio elegans	0.03 (9.6)	0.08 (22.7)	0.06 (17.2)
Macoma balthica	2.00 (8.8)		0.56 (20.5)
Bylgides sarsi	0.02 (7.4)		
Travisia forbesii		0.03 (7.3)	
Hydrobia ulvae		0.02 (5.8)	

Cluster I includes the same four stations as Cluster I stations based on abundance, except station K-09-1, which is included in Cluster II. The benthic fauna was characterised by a high biomass of *Mytilus edulis* and the species contributed mostly to the similarity at the stations.

Cluster II includes the same two stations as Cluster II based on abundance in addition to station K-09-1. The average biomass was lower than at cluster I stations and *Mya arenaria* and the abundant polychaetes (*Pygospio elegans* and *Marenzelleria viridis*) contributed mostly to the similarity.

Cluster III includes all the remaining stations and the stations were the same as the results of the analysis based on abundance. Polychaetes *(Marenzelleria viridis, Pygospio elegans* and *Hediste diversicolor*) and bivalves (*Macoma balthica* and *Mya arenaria*) contributed mostly to the similarity.



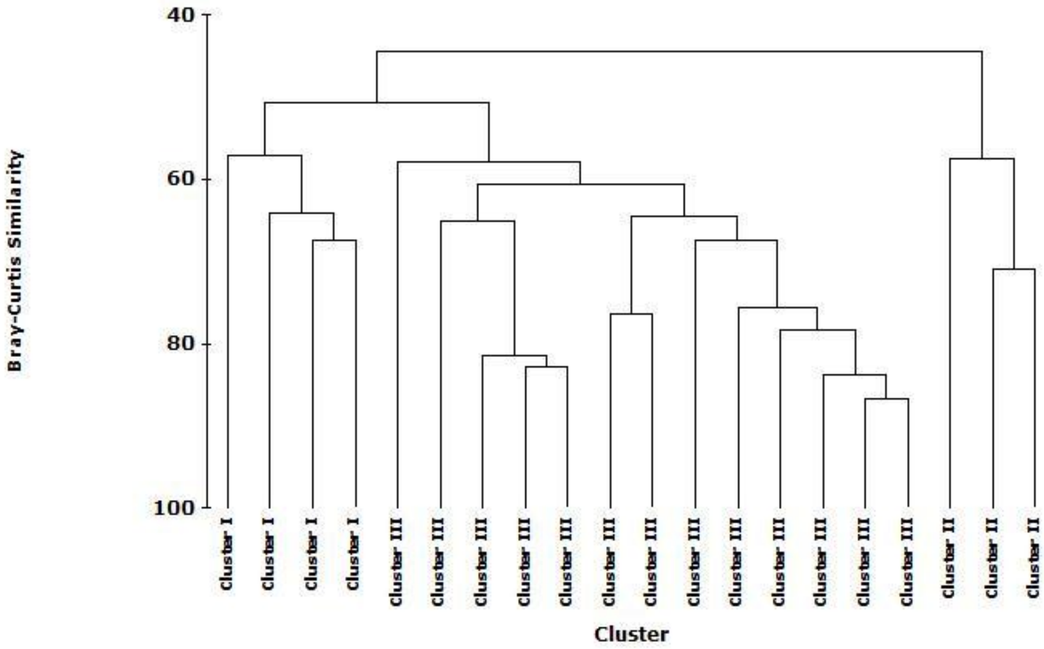


Figure 4.15 Results of classification based on biomass of the species at the stations in August 2011. Stations (top) and delineation of three clusters of stations (bottom).

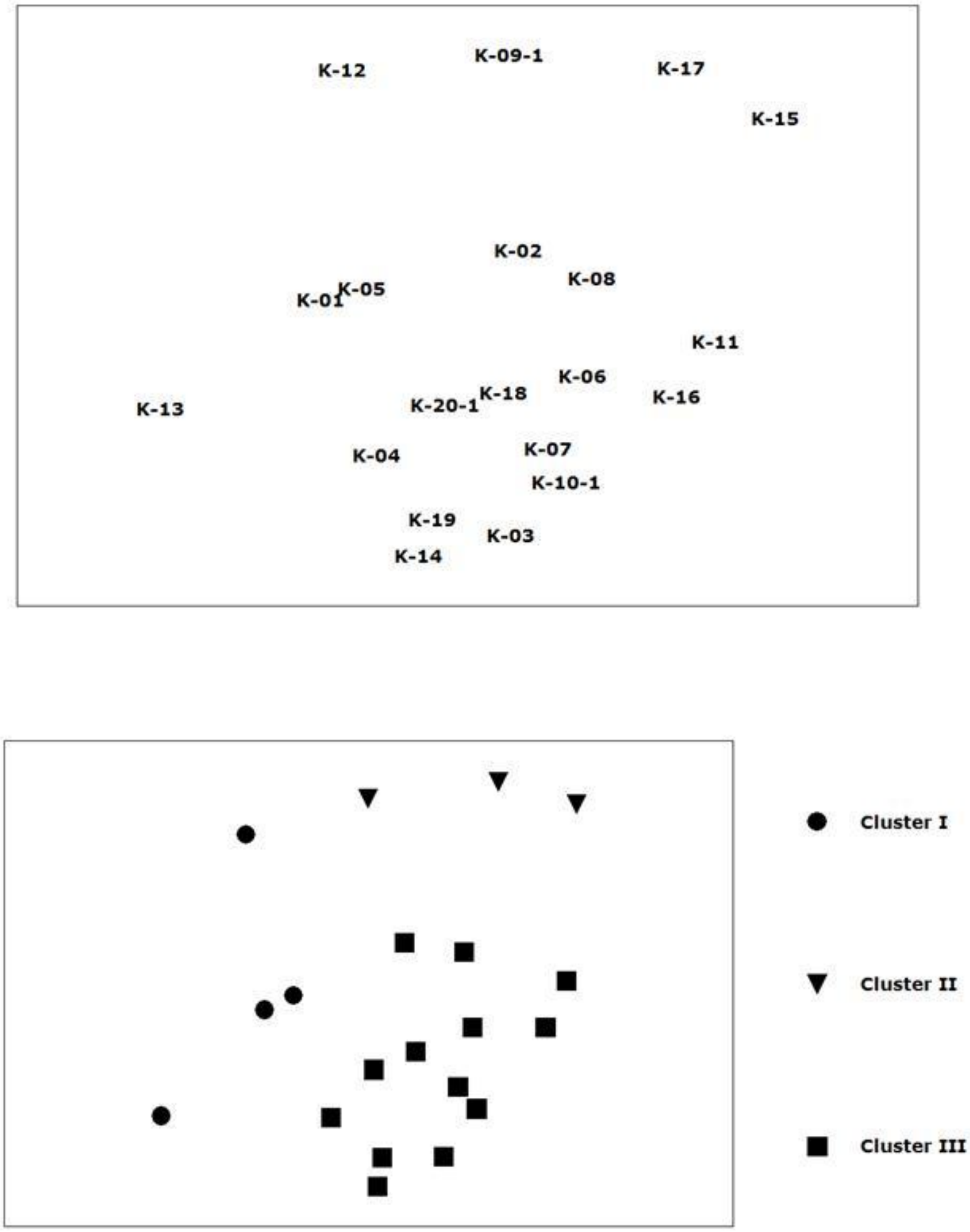


Figure 4.16 Results of ordination based on biomass of the species at the stations in August 2011. Stations (top) and delineation of three clusters of stations (bottom). Stress=0.16.

4.4.4 Importance of environmental factors

The structuring importance of water depth and the variables measured in the sediment (dry weight, loss on ignition and median grain size of the sediment) to the benthic community was analysed using BioEnvir (Clarke and Gorley 2001). The silt/clay fraction of the sediment was zero at all stations except at station K-3, where the content was 0.003% DW. The silt/clay fraction is therefore not included in the analysis.

The factors contributing to the structure of the benthic community were water depth and the median grain size of the sediment (based on the analysis of abundance). However, the importance of the factors was very low. This agrees with the limited depth range of the survey area of about 3 m and the uniform sediment with a low content of organic matter (Table 4.5). Furthermore there was no difference between in abundance or biomass with regard to the limited differences in water depths at the sampling stations, which supported the analysis.

The similarity of the benthic fauna is high and only 4-5 stations (Cluster I stations) in the western part of the area are slightly different due to a high abundance and biomass of Blue mussels (*Mytilus edulis*). Even though there is differences between the Cluster I stations and the remaining stations, the benthic fauna community at all stations resembles a shallow water community, which predominantly is found above a seasonal halocline and which is associated soft bottom that is muddy to sandy. This community has been defined in the baseline report for the Fehmarnbelt Fixed Link, FEMA 2013b and is named the Cerastoderma community. The slight difference in clusters might be due to a slightly changed sediment structure caused by previous extraction activities or the slight difference in water depth, but as mentioned in the above paragraph the contribution of this factor to the environmental importance is low. It is therefore not possible to explain, with certainty the small difference community structure.

The Cerastoderma community is historically called the Macoma community. The name Cerastoderma was adapted to reflect this characteristic species of the community, which is not abundant in many other communities. *Macoma balthica* is also present in the community (thereby the classical naming) but is also abundant in many other communities. Compared to the Cerastoderma community mapped in the Fehmarnbelt, the species richness is lower at Krieger's Flak which most likely is due to the lower salinities found at the Flak. This also explains why some of the species represented in the Fehmarnbelt investigation is not represented in the samples from Krieger's Flak, furthermore some variations within a defined community can occur (FEMA 2013b).

4.4.5 Development of the benthic fauna at Krieger's Flak

Comprehensive surveys of the benthic fauna at Krieger's Flak have been conducted earlier, before (1995), during (1996 and 1997) and after (1999) extraction of sand for the Øresund Fixed Link (Øresundskonsortiet 2000) and again in 2003 and 2005 before and after extraction of sand to Amager Strandpark (Amager Strandpark I/S 2005).

The qualitative and quantitative composition of the benthic fauna has changed over the years. The most remarkable changes are:

- A reduction of the benthic abundance
- A reduction of the mud snail *Hydrobia ulvae*
- An increase in the abundance of the polychaete *Marenzelleria viridis*

The average abundance of the benthic fauna until 2003 was mostly above 1000 m^{-2} and often 2000-4000 m^{-2}. The polychaete *Pygospio elegans* and the mud snail *Hydrobia ulvae* were the most abundant species. The average abundance in 2005 was below 1000 m^{-2} and the same is valid in 2011. The abundance of mud snails was low in 2005 and even lower in 2011.

A total of eight specimens of the polychaete *Marenzelleria viridis* were recorded in 1995-1999. This species was rather abundant in 2005 and the abundance has since increased.

The profound changes in the benthic fauna at Krieger's Flak since 1995 are not caused by sand extraction because the same changes are observed in adjacent areas (DHI Water & Environment 2006, DHI Water & Environment 2007), but could be because of other environmental factors, such as temperature, changes in salinity etc., but the actual cause of change is not known.

4.4.6 Summary

The impact area is characterised by a limited range of water depth and uniform sediment with a low content of organic matter. The species richness is characteristic for shallow, low saline areas of the Baltic Sea. The community of the area resembles the Cerastoderma community. The abundance and biomass of the benthic fauna were low and dominated by a few species of polychaetes (*Pygospio elegans* and *Marenzelleria viridis*) and bivalves (*Mytilus edulis, Mya arenaria* and *Macoma balthica*). The similarity of the benthic fauna was high and only slightly different at a few stations due to a high abundance and biomass of *Mytilus edulis*. The Macoma (Cerastoderma) community is typically found at all depths in The Baltic Sea and is widely distributed in the surrounding areas (Øresundskonsortiet 1995). The community has a recovery time of 2-5 years if destroyed (FEMA 2013a).

Other studies of benthic fauna at Krieger's Flak have shown higher species diversity than observed in the present investigation. In the EIA for wind farm at Krieger's Flak on the Swedish part, 90 species have been described (Sweden offshore Wind AB 2007) and in the EIA for a wind park in the German part of Krieger's Flak, 83 species were described (IFAÖ 2003). The large difference in species number is due to sampling depths and the consequently higher salinity, occurring in deeper waters of the Arkona Basin. At the shallow sampling stations in the Swedish part of Krieger's Flak, the same species are dominant as observed in the present investigation (Sweden offshore Wind AB 2007). Furthermore the species number is comparable low. The study indicates that the benthic fauna community is present throughout the shallow parts of Krieger's Flak.

4.5 Benthic vegetation

Video observations of flora and seabed structure were conducted in connections with the sampling of the benthic fauna and at the same 20 stations (Figure 4.17). Each station was recorded for one minute and the videos were analysed for the presence of benthic flora. Benthic vegetation is usually present in areas where there is hard substrate and where light is available, which is a water depths less than 20 meters (approximately). Because the water depths in connecting areas are less than 20 m, investigations of flora outside the impact area have been carried out. Observations were obtained along transects (Figure 4.17) by video, which was attached to a boat with a speed of 1.5 knot.

Macroalgae was not observed within the impact area, which is the extraction area plus the surrounding 500 m impact zone.

Outside the impact area (along transects) only very few small single macroalgae of the genus *Laminaria spp.* was observed. The very limited is most likely due to lack of substrate on which the flora can grow as the area primarily consists of sand.

Other studies on flora at Krieger's Flak have shown that macroalgae are present in areas where there is hard substrate (Sweden offshore Wind AB 2007) at depths shallower than 25 m. Below 25 m only very few algae were found.

A thin layer of algae was observed on top of the sediment at most sampling stations. The layer most likely consisted of a mixture of sedimented algae and benthic microalgae.

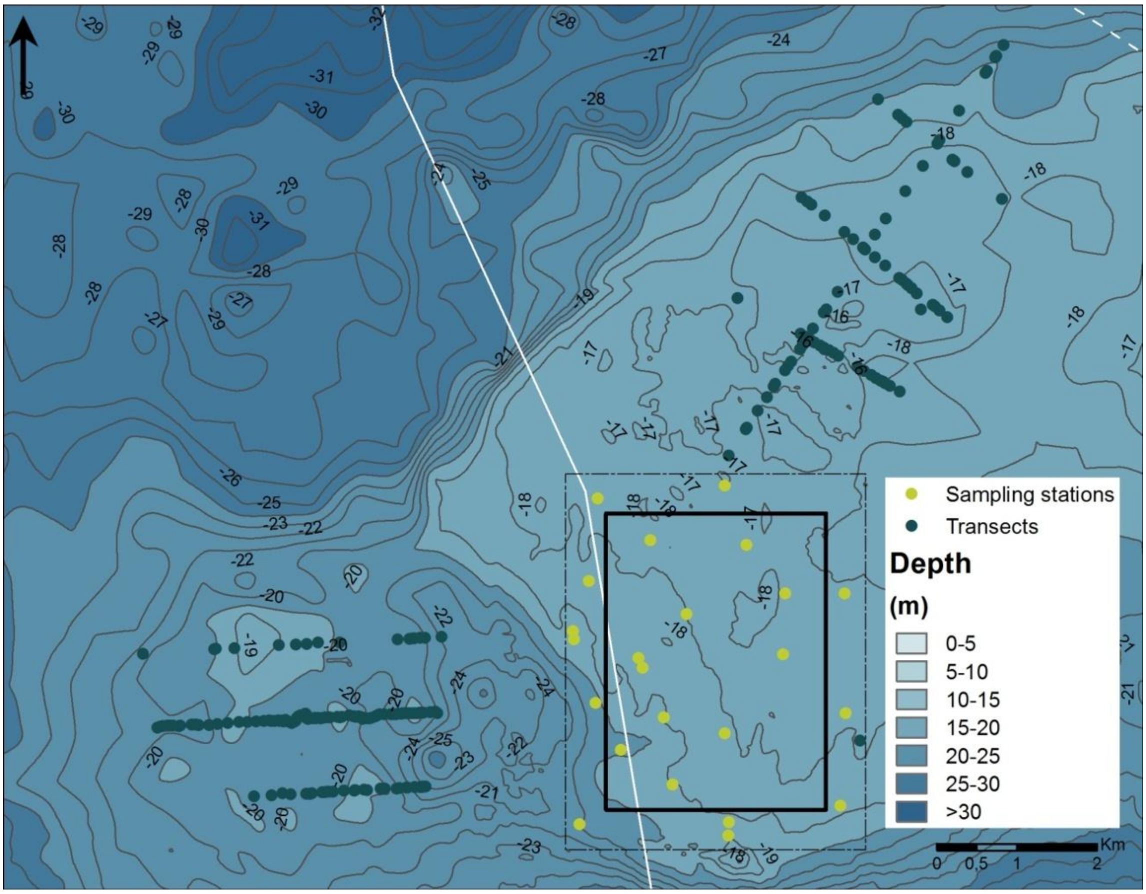


Figure 4.17 Transects for flora observations outside impact area and flora observations within the impact area at Krieger's Flak. White line indicates the Danish border.

4.6 Fish and fishery

4.6.1 Fish

Fish surveys were not undertaken in association with this report, thus the baseline description of the fish community in the extraction area of Krieger's Flak is based on both general knowledge and literature on fish in the Baltic Sea and on fish surveys undertaken in the Swedish and German parts of Krieger's Flak. The studies in the Swedish and German parts of Krieger's Flak are based on data collected in 2003-4. Since more recent data don't exist, these data are used as as basis for the assessment

Relatively little is known about species composition, habitats, genetic diversity, ecology and endangerment of the fish community of the Baltic Sea (HELCOM 2002). This is in particularly the case for fish species that are not exploited by the commercial fisheries.

Biodiversity is low in the Baltic Sea due to its geological character as a very young brackish sea with a prehistory of being a freshwater lake. Many species are precluded due to the low oxygen levels and to fluctuating and progressively lower salinities as one move from the outer to the innermost parts of the Baltic. Thus the number of marine species is higher in the Kattegat and the western Baltic Sea, while the number of freshwater species (40 species) is more predominant in the eastern and northern Baltic Sea (Thiel et al. 1996).

Herring (*Clupea harengus*), sprat (*Sprattus sprattus*) and cod (*Gadus morhua*) are the major commercial fish species of the Baltic Sea. The status of these stocks has been monitored for decades with the longest record available for the eastern Baltic cod; since the mid-1940s. The Baltic cod stocks peaked in the late 1970s and early 1980s. Since the 1980s, a climate-induced decrease in the cod reproductive volume, i.e., the amount of water with favourable conditions for successful hatching of cod eggs, has caused high cod egg mortality (ICES 2007a). This, together with very high fishing pressure, has resulted in low abundance of the cod stock since the early 1990s. However, some recovery in the eastern (east of Bornholm) cod spawning stock biomass has been observed during the past three years (ICES 2010). Reductions of the predation pressure by cod, accompanied by favourable hydrographical conditions, has allowed the sprat stock to increase since the late 1980s, which together with herring has strongly dominated the Baltic fish communities since then. This shift to domination by a pelagic fish community represents a profound change in the marine ecosystem, also called a "regime shift" (Alheit et al. 2005).

In periods with a strong inflow of new saline and oxygen-rich water from the North Sea various fish species migrate into the Baltic Sea. However, due to unfavourable environmental factors (essentially low salinity and temperature), these fish are unable to form self-sustaining populations in the Baltic Sea; they include, for example, such species as whiting (*Merlangus merlangus*), European anchovy (*Engrauli encrasicolus*) and mackerel (*Scomber scombrus*).

Distribution and reproduction of some important fish species
Cod (Gadus morhua) occur in two populations or stocks in the Baltic Sea: eastern and western Baltic cod. These populations overlap in ICES subdivision 24 west of Bornholm Island. Spawning in the western Cod stock takes place in deeper parts of the Western Baltic from January-April, somewhat earlier than the eastern stock (March-September) (Nissling and Westin 1997). In a report of German and Swedish fish investigations (Sweden Offshore Wind AB, 2007) it was concluded that Krieger's Flak "does not constitute a spawning or nursery area for cod".

Herring (Clupea harengus) occur in large schools throughout the Baltic Sea, with clearly distinct stocks in different areas. Herring tend to make seasonal migrations between coastal archipelagos and open sea areas, spending summer and winter in the open sea areas and staying closer to the coast in spring and autumn. Herring has adhesive eggs and spawn on the seabed or on vegetation in coastal areas which are sensitive to low oxygen concentrations and high concentrations of suspended solids. Since the early 1970s the spring spawning stocks have been dominating in the Baltic Sea, while the autumn spawning stocks strongly decreased. Main spawning period in Western Baltic/Krieger's Flak is from March-May (ICES 2007b).

Sprat (Sprattus sprattus) occur in large schools throughout the Baltic Sea, seeking out warmer water layers during different seasons and avoiding areas where water temperature drops to less than 2-3°C. Sprat is an open-sea species and spawning and the distribution of its planktonic eggs is restricted to deeper parts of the Baltic Sea (Baumann et al. 2006). According to Swedish authorities (Fiskeriverket 2008) spawning also takes place in more coastal areas (depth 10-40 m) of the Western Baltic Sea, where the spawning period is from March-August.

Sandeels (Ammodytes sp.) are distributed in most of the Baltic Sea, except in the Gulf of Bothnia, in coastal waters and at intermediate water depths offshore. It is most common in the Central and Western Baltic Sea. Sandeels are non-migratory species, living within sandy substrate during night and in winter and swimming in schools in the pelagic during day-time in summer. Sandeels lay their eggs in the sand, and the sand grains of a certain size adhere to them. A. marinus is a winter spawner and A. tobianus spawns in early spring and autumn (Whitehead et al.

1986). Sandeels constitutes an important part of the food for gadoids and other predatory fish.

Flounder (Plathichtys flesus) can be divided into two ecological distinct groups: one southern with pelagic eggs and one northern with demersal eggs. Flounder in the southern Baltic migrate between coastal feeding areas and spawn in the deep basins and have larger, pelagic eggs that are adapted to floating despite the low salinity. Flounder spawn in spring (ICES 2007c).

Turbot (Psetta maxima) are mainly stationary, but migrate in spring and autumn between shallow and deeper waters. Turbot is a summer spawner. Eggs are not buoyant at salinities below 20‰, which means that the eggs of Baltic Sea turbot are demersal instead of pelagic. Spawning takes place in relatively shallow waters (10-40 m) and the metamorphosing post larvae migrate towards shallower depths near the shore (Florin 2005).

Plaice (Pleuronectes platessa) spawn only in the relatively saline water of the Western Baltic Sea and the deeper areas in the Central Baltic. Spawning takes place in winter, from December-February. Eggs are pelagic (Florin 2005).

Dab (Pleuronectes limanda) spawn in the same areas as plaice, and also have pelagic eggs. Spawning takes place during the spring (Florin 2005).

Salmon (Salmo salar) is distributed throughout the Baltic, usually following its main prey: sprat and herring. Salmon spawns in rivers and streams with swift flowing water.

Eel (Anguilla Anguilla) enter the Baltic Sea as glass eels coming from the Atlantic Ocean. Recruitment has declined considerably over the last 25 years. Migration back to the Atlantic Ocean takes place from August to October. The swimming depth during migration is close to the surface however they dive to deeper water several times during the night hours (Westerberg et al. 2007).

Species known to occur in the Krieger's Flak area
Fish studies have been undertaken in the Swedish and German parts of Krieger's Flak in 2003-2004 by the German Institute "Institut für Angewante Ökologi" (IfAÖ) in association with "Sweden Offshore Wind AB" assessing the impact of establishing an offshore wind farm (Sweden Offshore Wind AB 2007). The results from these studies are assumed to reflect the fish species and communities in the Danish parts of Krieger's Flak where no fish studies have been undertaken.

Other sources of information on the fish assemblages in the Krieger's Flak area are the archives of the Danish Museum of Natural History, commercial fishery logbooks, interviews of fishermen and diverse literature from that part of the Baltic.

In total 41 fish species are registered in the Krieger's Flak area (Table 4.9) of which 28 spend their entire life cycle in the Baltic Sea area - 5 species are anadromous, spawning and growing up in rivers running into the Baltic Sea. Three species: the catadromous eel and the highly migratory lumpsucker and garfish spend significant parts of their life outside the Baltic Sea. The remaining 10 species also only occur sporadically, and have their main distribution outside the Baltic Sea.

The fish community found in the Krieger's Flak-area can be divided into two categories: pelagic fish living near the surface or in the water column: Herring, sprat, salmon, trout, garfish, sandeel (pelagic in daytime), twaite shad, and demersal (benthic) fish species living in, on or close to the seabed: Cod, sandeel (in night and in wintertime), flatfish-species, eel and lumpsucker (demersal when feeding, pelagic during migration), bull-rout, gobies (transparent goby partly pelagic). Most of the demersal species prefer sandy seabeds with stones, mussel banks, sea grass and algae. Sandy bottoms are preferred by flatfishes and sandeels – especially important to the sandeels because of their burrowing mode of life, living in the bottom during night and in wintertime.

Table 4.9 Fish species known to occur in ICES 38G2/39G2 including the Krieger's Flak. Species names given in bold: Species native to, and spawning in the Baltic Sea area (BS).

Species	**Habitat** (Whitehead et al., 1986)	**Reproduction**	**Ref.***
Cod *(Gadus morhua)*	Demersal or in intermediate (midwater) water layer	Pelagic eggs Spawning in BS	1,3, 4
Whiting *(Merlangius merlangus)*	Shallow water, usually 30-100 m, above the bottom often near surface	Pelagic eggs	3, 4
Saithe *(Pollachius virens)*	Offshore and inshore, midwater, in surface and bottom layer	Pelagic eggs	1,3
Haddock *(Melanogrammus aeglefinus)*	Offshore, benthic at 30-40 m depth, occasionally in midwater	Pelagic eggs	1,3
Hake *(Merluccius merluccius)*	Midwater	Pelagic eggs	1,3
Plaice *(Pleuronectes platessa)*	Demersal on mixed bottoms, from a few meters to about 100 m	Pelagic eggs Spawning in BS	1,3, 4
Dab *(Limanda limanda)*	Demersal on sandy bottoms, from a few meters to about 100 m	Pelagic eggs Spawning in BS	1,3, 4
Flounder *(Platichthys flesus)*	Demersal at shallow depths with soft bottoms	Pelagic eggs Spawning in BS	1,3, 4
Turbot *(Psetta maxima)*	Demersal on sandy and stony bottoms down to about 70 m	Demersal eggs Spawning in BS	1,3, 4
Brill *(Scophthalmus rhombus)*	Demersal on sandy bottoms, shallow waters	Pelagic eggs Spawning in BS	1,4
Lemon sole *(Microstomus kitt)*	Demersal on stony bottoms at 20-200 m	Pelagic eggs	1
Common sole *(Solea vulgaris)*	Demersal on sandy and muddy bottoms, from shallow waters down to 200 m	Pelagic eggs	1,4
Herring *(Clupea harengus)*	Pelagic, juveniles occurring in shallow water near spawning grounds, moving into deeper waters after two years	Demersal eggs Spawning in BS	1,3, 4
Sprat *(Sprattus sprattus)*	Pelagic, migrating between winter feeding and spring and summer spawning grounds	Pelagic eggs Spawning in BS	1,3
Atlantic mackerel *(Scomber*	Pelagic, migratory	Pelagic eggs	1,3

Species	Habitat (Whitehead et al., 1986)	Reproduction	Ref.*
scombrus)			
Garfish *(Belone belone)*	Pelagic, migratory	Demersal eggs Spawning in BS coastal areas	1
Horse mackerel *(Trachurus trachurus)*	Pelagic, migratory	Pelagic eggs	3
Lumpsucker *(Cyclopterus lumpus)*	Benthic on rocky bottoms usually between 50-150 m. Highly migratory	Demersal eggs, Moving inshore to spawn (also in BS)	1,3, 4
Lesser sand-eel *(Ammodytes tobianus)*	Inshore waters. Within sandy substrate areas during night and in winter. Swims in schools in the pelagic during day-time	Demersal eggs Spawning in BS	3
Sandeel *(Ammodytes sp.)*	Offshore *(A. marinus)* and inshore *(A. tobianus)* waters. Within sandy substrate during night and in winter. Swimming in schools in the pelagic during day-time	Demersal eggs Spawning in BS	1,4
Greater sand-eel *(Hyperoplus lanceolatus)*	Inshore and offshore to about 60 m depth. Commonly associated with *Ammodytes* species.	Demersal eggs Spawning in BS	1,3, 4
Sea snail *(Liparis liparis)*	Benthic in depths from sub tidal to less than 300 m	Demersal eggs Spawning in BS	3
Viviparous eelpout *(Zoarces viviparus)*	Benthic on rocky shores under stones and among algae, down to 40 m.	Viviparous Spawning in BS	3, 4
Rock gunnel *(Pholis gunnellus)*	Benthic, shallow waters but descending to deeper waters, especially in winter	Demersal eggs Spawning in BS	3
Goldsinny-wrasse *(Ctenolabrus rupestrus)*	Benthic on rocky, weed-covered shores, 1-50 m	Pelagic eggs Spawning in BS	3
Bull-rout *(Myoxocephalus scorpius)*	Benthic on rocky bottoms with sand or mud, 20-50 m	Demersal eggs Spawning in BS	3, 4
Hooknose *(Agonus cataphractus)*	Benthic in inshore waters, deeper in winter. Prefers sandy bottoms, rarely with stones	Demersal eggs Spawning in BS	3
Four-bearded rockling *(Rhinonemus cimbrius)*	Benthic on soft mud or sand, 20-650 m	Pelagic eggs Spawning in BS	3
Snake blenny *(Lumpenus lampretaeformis)*	Demersal on muddy bottoms from 30-200 m	Pelagic eggs Spawning in BS	3

Species	Habitat (Whitehead et al., 1986)	Reproduction	Ref.*
Three-spined stickleback *(Gasterosteus aculeatus)*	Estuaries and coastal waters, shoaling offshore outside breeding season (spring)	Demersal eggs Spawning in BS	3
Eel *(Anquilla anguilla)*	Demersal, Pelagic during migration	Catadromous Spawning outside BS	1,3
Striped red mullet *(Mullus surmuletus)*	Benthic on depths less than 100 m	Pelagic eggs	1,3
Transparent goby *(Aphia minuta)*	Nektonic, surface to 70-80 m, over sand, mud, eel-grass etc.	Demersal eggs Spawning in BS	3
Sand goby *(Pomatoschistus minutus)*	Benthic, inshore sand and muddy sand, shallow down to about 20 m	Demersal eggs Spawning in BS	3
Black goby *(Gobius niger)*	Benthic, inshore waters down to 50-75 m, on sand or mud, in sea-grass or algae	Demersal eggs Spawning in BS	3
Two-spotted goby *(Gobiusculus flavescens)*	Inshore, midwater around weed-grown structures down to 20 m	Demersal eggs Spawning in BS	3
Atlantic salmon *(Salmo salar)*	Pelagic, migratory	Anadromous Spawning in rivers	1,3
Sea trout *(Salmo trutta trutta)*	Pelagic, migratory	Anadromus Spawning in rivers	1,3
Smelt *(Osmerus eperlanus)*	Pelagic, migratory	Anadromous Spawning in rivers	3
Thicklip grey mullet *(Chelon labrosus)*	Pelagic, usually inshore	Pelagic eggs Spawning in BS	1,3
Twaite shad *(Alosa fallax)*	Pelagic, migratory	Anadromous Spawning in rivers	1,3
River lamprey *(Lampetra fluviatilis)*	Demersal, migratory	Anadromous Spawning in rivers	3

*References: 1) Logbooks 2005-2010, ICES rectangles 38G2/39G2. 2) Danish Museum of Natural History 3) Literature: IfAÖ in: Sweden Offshore Wind AB 2007; Janssen, et al. 2008; Thiel and Winkler 2007; Kloppmann et al. 2003, Thiel et al. 2008. 4) Interviews of fishermen, incl. fish samples. BS = Baltic Sea

Twaite shad, river lamprey, autumn spawning herring, salmon, cod, eel and sea snail, are included in the HELCOM List of threatened species and categorised as endangered (HELCOM 2007). Salmon, twaite shad and river lamprey are furthermore listed in annex II and V in the Habitats Directive.

4.6.2 *Fishery*

In the past 10 years, the overall landings of the Danish fisheries in the Western Baltic Sea have decreased by approximately 50%, but they still constitute an important part of the Danish fisheries.

Historically cod, herring and sprat have made up the vast majority of the catches. Diverse flatfish species, European eel, and salmon have also been targeted.

The fisheries in the Baltic are divided by the international fishery zones where national and international fishery regulations and quotas apply and catch data are separated. These zones: ICES rectangles (approx. 30 x 30 nm) are used to form the boundaries for the presentation of the official commercial fisheries data.

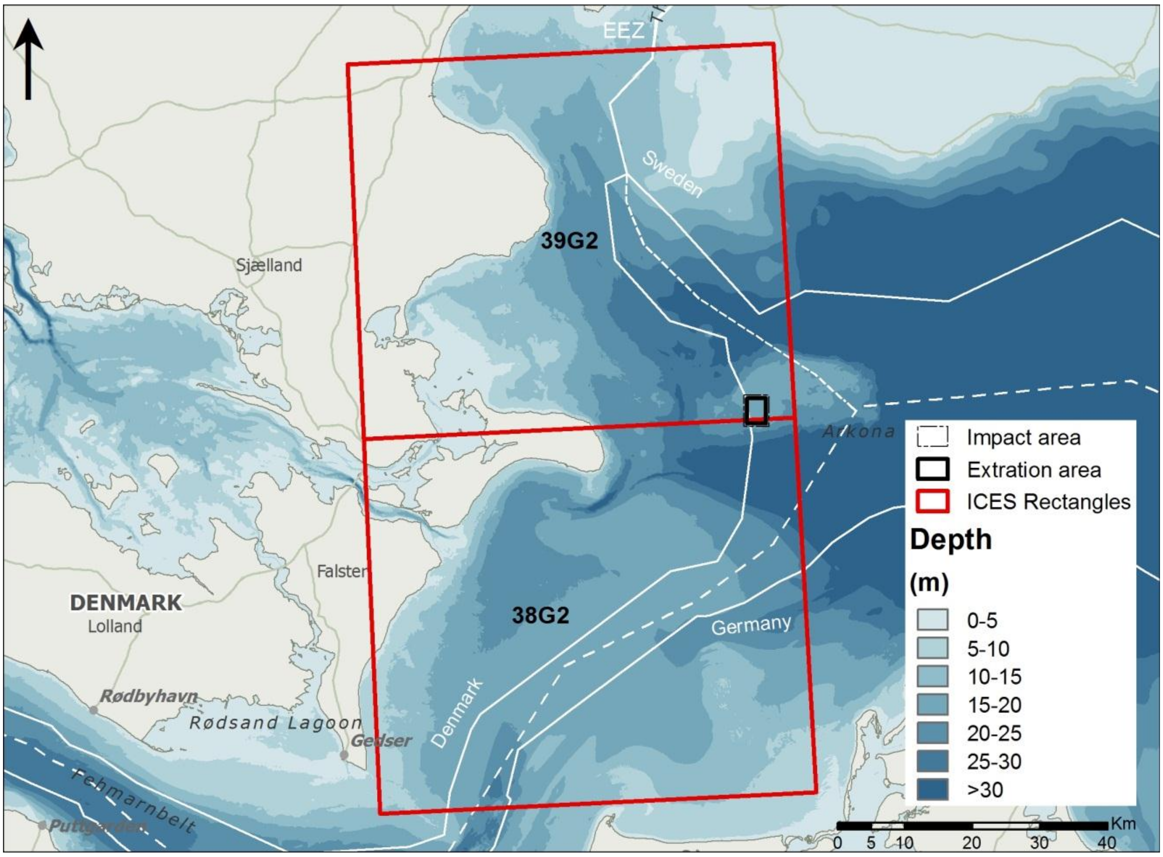


Figure 4.18 The ICES statistical rectangles 38G2 and 39G2 in the Western Baltic Sea. The proposed extraction area is represented by a black rectangle in the south-eastern corner of 39G2.

The proposed area for sand extraction at Krieger's Flak is situated in ICES rectangles 39G2 (78%) and 38G2 (22%) (Figure 4.18). Official data for landings and additional fleet statistics for these rectangles were obtained from the Danish Directorate for Fisheries. Data do not include information on vessels less than 8 m (less than 10 m before 2005) because these vessels are not required to fill out logbooks. However, because vessels of these lengths primarily fish in the vicinity of their home harbour and only catch a small part of the fish in the relevant ICES rectangle, the official catch statistics are considered to contain the essential fisheries information.

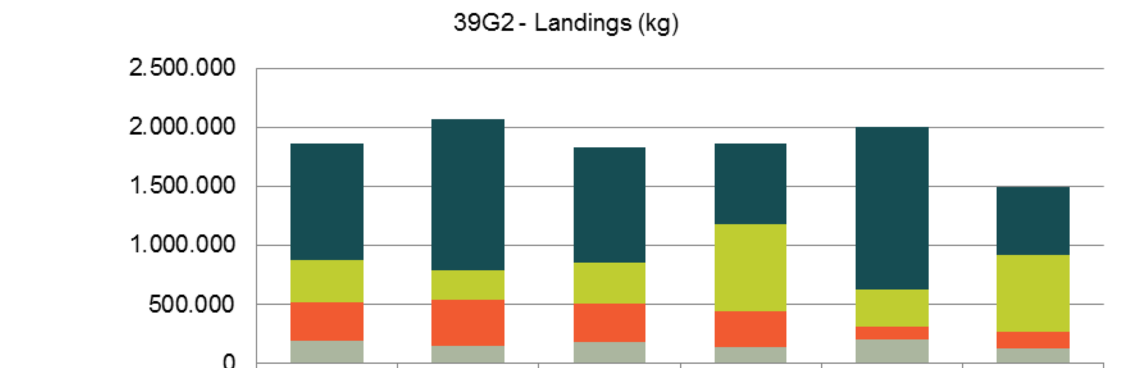
It is important to notice that the sand extraction area constitutes less than 1% of the area of an ICES rectangle.

In order to give a thorough description of the distribution of the fisheries, the Vessel Monitoring System (VMS) data were also obtained from the Danish Directorate for Fisheries. These data are only available from vessels ≥15 meters, and only since 2005.

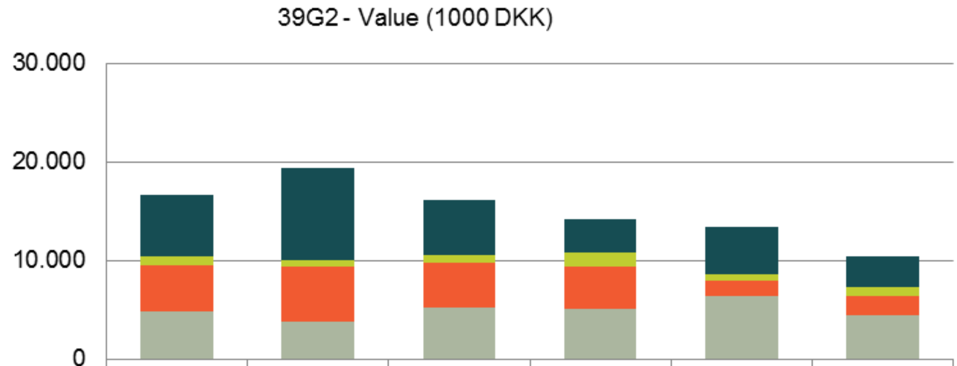
To supplement the official fishery statistics, which are bound by the spatial resolution of the ICES rectangles, group and individual consultation meetings were held with relevant Danish vessel owners and their representatives. Supplementary to VMS, plotter data were obtained from trawler-fishermen from Klintholm Harbour.

Landings and gear types
Because only approx. 22% of the extraction area is in ICES 38G2, these fishery data are not presented in tables or figures. Landings from this ICES rectangle have decreased from 6,800 tons (43 mill DKK) in 2005 to 1,500 tons (18 mill DKK) in 2010.

Landings from ICES 39G2 have fluctuated between 1,500-2,100 tons (10-20 mill DKK in value) over the last 6 years (Figure 4.19).



	2005	2006	2007	2008	2009	2010
Bottom trawl	990.848	1.280.397	982.296	679.740	1.381.458	570.964
Pelagic trawl	351.131	248.100	342.318	736.501	311.711	654.000
Seine nets	2.450	0	40	18.157	295	0
Gill/trammel nets	327.344	392.622	330.176	289.624	111.932	142.787
Other gear	192.570	143.048	180.030	134.455	197.062	121.063



	2005	2006	2007	2008	2009	2010
Bottom trawl	6.235	9.423	5.581	3.395	4.888	3.148
Pelagic trawl	881	563	776	1.429	625	885
Seine nets	34	0	1	268	2	0
Gill/trammel nets	4.668	5.562	4.509	4.009	1.564	1.923
Other gear	4.841	3.849	5.216	5.139	6.354	4.455

Figure 4.19 Annual (2005-2010) landings (kg) and their values (1000 DKK) from ICES 39G2 according to gear types (Danish Directorate of Fisheries – logbook and vessel registration FVM 2011).

The landings according to gear (Figure 4.20) show that the seine net fishery is negligible in the area. More than 70% of the total landings are from the trawl fisheries. The values of the landings, however, represent less than 50% of the total value of the landings. The relative low value of landings from trawlers is because their catch is primarily made up of pelagic species (herring, sprat and sandeel) which have a low kilo price. It should be noted that landings from "other gear" represents a relatively large and constant value – in recent years this has been around 50% of the total value. The gear group "other gear" primarily represents pound nets which are distributed along the coast and these landings are not relevant in assessing the impact of material extraction at Krieger's Flak. Landings from gill netters have been constantly declining during the period 2005-2010 to the present low level.

Seasonality of landings according to gear, value and fish species

The seasonality of the landings from ICES 39G2 (Figure 4.20) confirms that a large majority of landings are from trawl fishing and shows that most of the trawling activity is taking place in the last months and in the first months of the year (Nov-Mar) – during the winter season. Fishing with gill nets is more or less carried out in the same period.

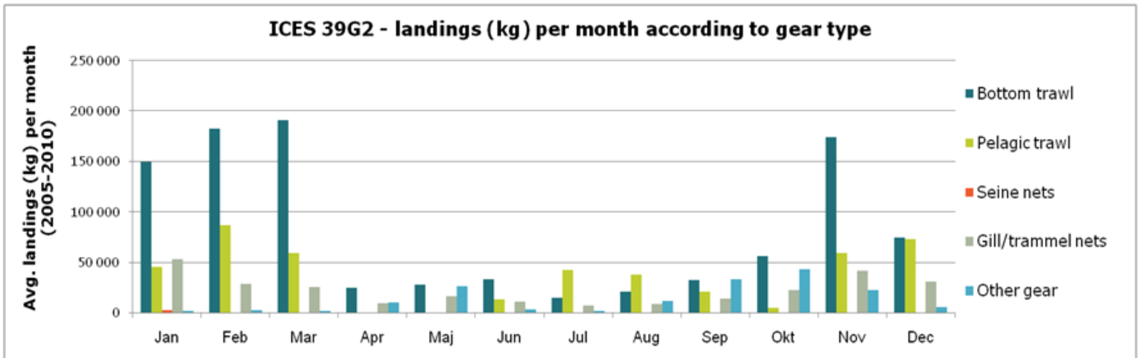


Figure 4.20 Average landings (kg) per month in ICES 39G2 according to gear type (Danish Directorate of Fisheries logbook and vessel registration FVM 2011)

The average monthly landings (2005-2010) for the most important commercial species for ICES rectangle 39G2 are given in Figure 4.21.

Monthly landings of cod and herring are at their highest level during the winter period (Oct-Mar). Flatfish species are landed throughout most of the year however landings are comparatively low during the spring (March-May).

The value of cod landings is 3 times greater than the landings of all the other species combined. Herring is the second most important species after cod with a total value to the fisheries 10 times greater than that of sprat.

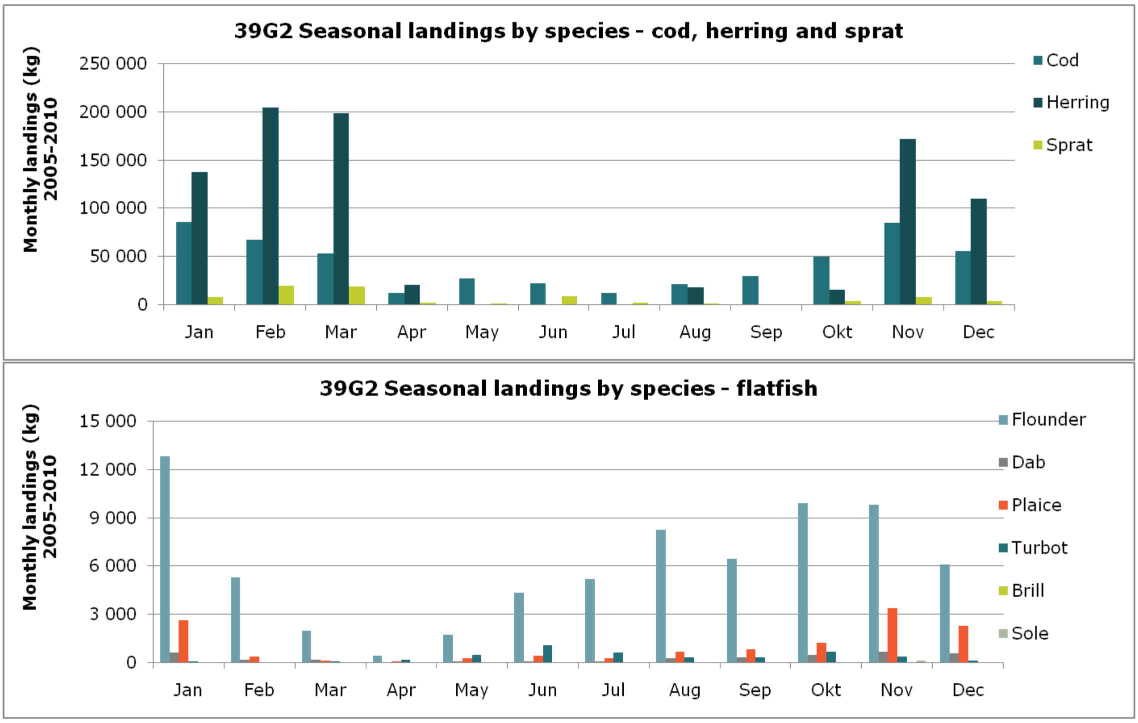


Figure 4.21 Seasonal landings of the most important fish species from ICES 39G2 (Danish Directorate of Fisheries – logbook registration FVM 2011).

Fishing activity according to size of vessel, gear type and basis harbour

The number of registered fishing trips can be used as a proxy for fishery activity in ICES 39G2. As mentioned earlier these data do not include vessels less than 8 m in length, which are generally not considered to participate in the fisheries in the extraction area.

The number of fishing trips has been decreasing since 2005 and at present is less than 50% of the levels in 2005/2006 (Table 4.10). The smaller fishing vessels (8-15 m) have undertaken more than 10 times the number of fishing trips than large vessels (≥15 m). Approximately 50% of the total numbers of fishing trips are undertaken by gillnetting vessels. Seine nets are almost not used in ICES 39G2. The gear category ”Other gear” generally represents the vessels that fish with pound nets near the coast – a fishery that is not relevant for the assessment of impacts at Krieger’s Flak.

Table 4.10 Number of registered fishing trips in ICES 39G2 (Danish vessels ≥ 8m) (Danish Directorate of Fisheries – logbook and vessel registration FVM 2011).

Year	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
8-15 meter	**2835**	**2759**	**1912**	**1784**	**1427**	**1272**
Bottom trawl	631	723	321	251	264	185
Gill nets	1798	1563	1043	1044	655	663
Pelagic trawl	12	0	0	0	0	22
Seine nets	0	0	1	1	0	0
Other gear	394	473	547	488	508	402
>15 meter	**273**	**341**	**243**	**176**	**97**	**111**
Bottom trawl	219	298	177	87	73	67
Gill nets	21	26	45	39	5	5
Pelagic trawl	30	14	21	29	18	38
Seine nets	2	0	0	21	1	0
Other gear	1	3	0	0	0	1
Total	**3108**	**3100**	**2155**	**1960**	**1524**	**1383**

According to logbook data for the period 2005-2010 vessels from Rødvig Harbour have annually landed approx. 40% of the total landings from ICES 39G2. Vessels with basis harbours in north and west Jutland have landed approx. 6%, while vessels from the nearby harbour of Klintholm only have landed 1.5% of the total landings. However, it should be noted that due to the length of trawling hauls and the proximity of the extraction area near both ICES 39G2 and 38G2, there is a large possibility that some landings from 39G2 could have been registered in ICES 38G2. Cod has been the most important species for vessels from all harbours except for "Other harbours" (Table 4.11). The large landings in "other harbours" including Rødvig Harbour is due to the coastal fisheries with pound nets – this is also the reason for the relatively large landings registered as unspecified (for example eel) in the table.

Table 4.11 Annual average landings from 2005-2010 according to vessels from the most important harbours and commercial species (Danish Directorate of Fisheries – logbook registration).

	Klintholm		**Rørvig**	
Species and groups	Landings (kg)	Value (DKK)	Landings (kg)	Value (DKK)
Cod	4,420	63,995	292,708	4,237,819
Herring/Sprat	23,567	47,638	206,774	393,661
Flatfish	567	5,362	57,938	430,333
Unspecified	236	1,704	189,524	2,275,375
Total	28,790	118,700	746,943	7,337,189

	Bornholm harbours		**West Jutland harbours**	
Species and groups	Landings (kg)	Value (DKK)	Landings (kg)	Value (DKK)
Cod	3,790	54,872	84,628	1,225,239
Herring/Sprat	0	0	18,333	37,107
Flatfish	5,264	40,271	10,495	71,079
Unspecified	3,512	4,763	4,343	109,645
Total	12,566	99,905	117,799	1,443,070

	Other harbours	
Species and groups	Landings (kg)	Value (DKK)
Cod	139,822	2,024,348
Herring/Sprat	709,359	1,390,192
Flatfish	18,797	172,914
Unspecified	76,961	2,539,154
Total	944,939	6,126,608

Fishing distribution according to VMS data

As of 2005, all Danish fishing vessels ≥15 m are required to operate a satellite-based vessel monitoring system (VMS) which registers the position of each vessel at regular time intervals. These data make it possible to map the distribution of fishing activity. Vessel speeds lower than 4.5 knots for trawlers, 2 knots for gill netters and 3 knots for seine netters are considered to indicate speeds when fishing activities are taking place.

The number of small vessels (8-15 m) operating in the area is greater than the number of large vessels (≥15 m) (see Figure 4.22).

It is well known that trawlers often fish along specific tracks which depend on the bottom topography, especially avoiding heterogeneous bottoms with stones and boulders which make fishing with bottom gear impossible or very difficult and full of risk of gear damage. Fisheries with stationary gear, primarily gill nets, are generally carried out in areas with mixed bottoms, partly because spatial conflicts with trawlers are minimal and because areas with structure such as stones and boulders on the bottom are good fishing areas.

A significant trawling route passes through the proposed extraction area as seen from the mapping of the fishing distribution on Krieger's Flak (Figure 4.22). Almost no fishery with larger gill netters is taking place inside the extraction area. The large gill netting vessels, the majority coming from west coast harbours, generally undertake their fisheries west of the extraction area and at a greater distance also north and east of the extraction area. A considerable seine net fishery is undertaken at a distance of 3-5 sea miles south of the extraction area during the winter period by vessels from the west coast of Jutland.

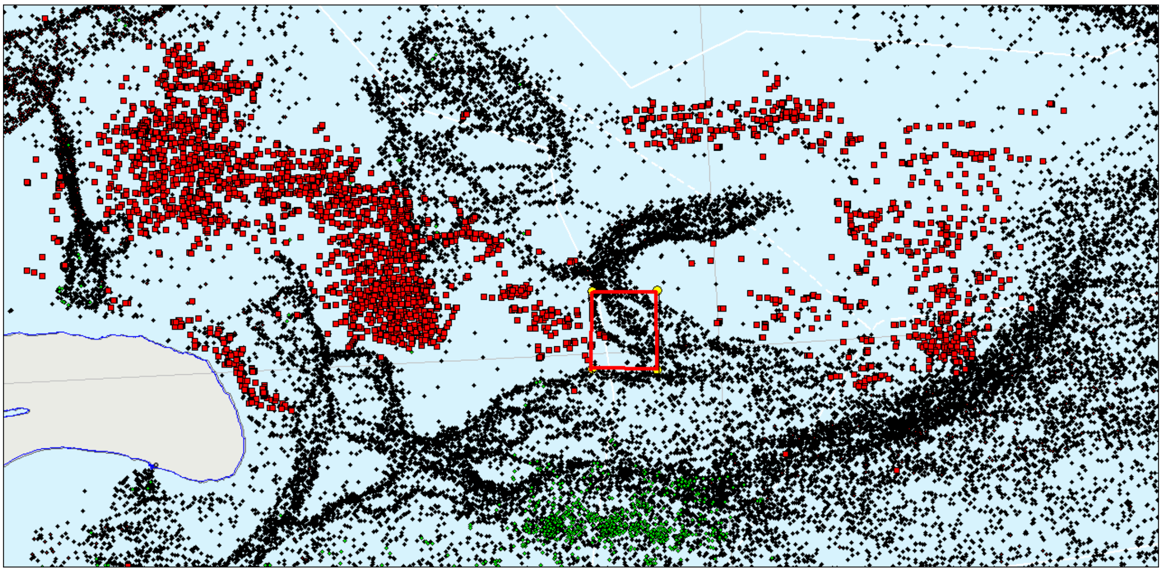


Figure 4.22 The distribution of the fishing activity of Danish trawlers (black dots), gill netters (red dots) and seiners (green dots) in the Baltic Sea east of Møn (ICES 38G2 and 39G2). The distribution of plots is derived from VMS data for vessels ≥15 m in the period 2005-2010. The proposed extraction area is represented by a red rectangle in the centre of the map.

A relative indication of the fishing activity for larger vessels (≥15 m) within the extraction area can be obtained by the number of VMS plots in the extraction area compared to the number of plots in the entire ICES 39G2 rectangle (Table 4.12). These data indicate the fishing activity in this area has decreased during the last 3 years to a low level representing less than one fourth of the 2005-2007-level. The relative importance of the extraction area has varied from 1.5 – 5.6% of the total fishing activity in ICES 39G2. It is important to note that this information only represents the larger vessels (≥15 m) in the area and does not indicate their landings. Similar data are not available for vessels less than 15 m, which account for approximately 60 % (average 2005-2010) of the total landings in ICES 39G2.

Table 4.12 Registered VMS plots (trawlers≥15 m) in the extraction area and in ICES 39G2.

Year	Extraction area	ICES 39G2	% effort in area
2005	86	2187	3,9
2006	46	3017	1,5
2007	97	2186	4,4
2008	32	812	3,9
2009	39	699	5,6
2010	12	432	2,8

Fishing activity according to information from fishermen
Some trawl fishermen electronically save their trawl tracks on map plotters and to a certain degree share these with each other. This is exemplified for the fishing area east of Møn including Krieger's Flak and the extraction area. This information supports the distribution of the fisheries indicated by VMS data, but also gives an indication of how the fisheries are practiced.

There is an intensive trawl fishery that is undertaken through the extraction area as it is also seen in Figure 4.22. Because of stones and boulders it is not possible or very difficult to trawl over the flak. Normally a trawl hauls last 3-5 hours where a trawler travels a distance of up to 20-35 kilometres. There are turning points in both the northern (pos. 13°03`Ø, 55°04,5`N) and southern (13°03,5`Ø, 54°59,5`N) parts of the flak.

The fisheries are undertaken only at night in the relatively shallow waters (17-20 m) with the main fishing season in the second half of the year. In the winter, cod and other commercial species migrate to deeper waters.

Within the last few years several trawlers (four in number) from Rødvig have developed a fishery after sandeel in the same area, where the main part of the catch is taken in the northern and western part of the flak. This fishery is undertaken during the day in the summer period.

The Gill net fishery cannot be undertaken in areas where there is an intensive trawl fishery and so gill netters usually use areas that have many stones and boulders as well as wrecks where trawling cannot be undertaken.. A number of smaller (8-15 m) gill netting vessels (approximately 10) from the local harbours on Zealand fish in the same area, and with some intensity on the flak. Some of these vessels periodically fish with long lines/hooks in the same area. Gill netting vessels less than 8 m fish are very seldom using the area. In general, the number of gill netting vessels has been decreasing considerably in recent years.

4.7 Birds

The extraction site does not house any local breeding waterbirds. Accordingly, the baseline description is focused on the occurrence of non-breeding waterbirds locally, and the regional characteristics of bird migration.

4.7.1 Non-breeding waterbirds

A recent review of wintering waterbird populations in the Baltic Sea based on coordinated censuses between 2007 and 2009 included the planned extraction site on Krieger's Flak (Skov et al. 2011). The censuses included the country-wide surveys undertaken in Danish waters during the winter 2007/08 (Petersen et al. 2010). In the Krieger's Flak area, including the extraction site, Long-tailed Duck *Clangula hyemalis* is the only common species (Figure 4.23 and Table 4.13). The area shallower than 20 m, including a large proportion of the part located in the Danish EEZ generally holds the highest densities of waterbirds. Danish waterbird monitoring data from 2004 and 2008 corroborate the findings for Long-tailed Duck. Gulls are common in the Krieger's Flak area, and most are associated with fishing activities. Less common species of waterbirds include Red-throated/Black-throated Diver *Gavia stellate/arctica* and Black Guillemots *Cepphus grylle*. Baseline surveys undertaken in relation to the planned wind farms on the Swedish and German parts of Krieger's Flak add more details on the use of waterbirds of the general area (IfAÖ 2003, Kube et al. 2004a and b), (Table 4.13).

Table 4.13 Reported densities and abundance of staging/feeding waterbirds at Krieger's Flak.

Species	**Skov et al. 2011** **Durinck et al. 1994**	**IfAÖ 2003** **Kube et al. 2004a and b.**
Red-throated/ Black-throated Diver (*Gavia stellate/arctica*)	Winter < 0.1 birds/km^2	0.1 - 0.37 birds/km^2
Common Eider (*Somateria mollissima*)	None in winter	1,000 birds during spring, late summer
Long-tailed Duck (*Clangula hyemalis*)	Winter 3 - 10 birds/km^2	Up to 10,000 birds during winter, spring
Common Scoter (*Melanitta nigra*)	None in winter	Irregular – peak density spring 0.45 birds/km^2
Velvet Scoter (*Melanitta fusca*)	None in winter	Uncommon
Little Gull (*Larus minutus*)	Winter < 0.01 birds/km^2	Up to 80 birds spring, autumn
Black-headed Gull (*Larus ridibundus*)	None in winter	Up to 50 birds spring, autumn
Common Gull (*Larus canus*)	Winter < 0.1 birds/km^2	Up to 500 birds winter, spring
Herring Gull (*Larus argentatus*)	Winter 1 – 4.99 birds/km2	Up to 3,000 birds winter, spring
Great Black-backed Gull (*Larus marinus*)	Winter < 0.1 birds/km^2	Up to 800 birds winter, spring, autumn
Razorbill (*Alca torda*)	Winter < 0.1 birds/km^2	Up to 500 birds winter, spring
Common Guillemot (*Uria aalge*)	Winter 0.1 – 0.99 birds/km^2	Up to 100 birds winter, spring
Black Guillemot (*Cepphus grylle*)	Winter 0.01 – 0.49 birds/km^2	Up to 130 birds winter

The review of waterbirds in the German EEZ by Garthe (2003) based on baseline surveys prior to development of marine wind farms adds the following details on regular occurrence of species of seabirds and seasonality on Krieger's Flak: Red-throated/Black-throated Divers (winter, spring), Common Eider (spring), Long-tailed Duck (winter, spring), Common Gull *Larus canus* (winter, spring), Herring Gull *Larus argentatus* (winter, spring, autumn), Great Black-backed Gull *Larus marinus* (winter, spring, autumn), Lesser Black-backed Gull *Larus fuscus* (spring, autumn), Common Guillemot *Uria aalge* (winter, spring), Razorbill *Alca torda* (winter, spring) and Black Guillemot (winter, spring).

Concluding, the available historic and recent data on the occurrence of waterbirds at Krieger's Flak unambiguously document that no species occur regularly in the area in concentrations of international importance. The most important occurrence of waterbirds is the concentration of Long-tailed Duck which regularly exceeds 10,000 birds in winter and spring. Given the densities of Long-tailed Ducks in the Danish part of Kriegers Flak the abundance here is likely to be of similar magnitude. Other seaducks seem to use the area irregularly, while pelagic species like auks and gulls use the area more regularly. Aggregations of large gulls are typically associated with intensive fishing activities.

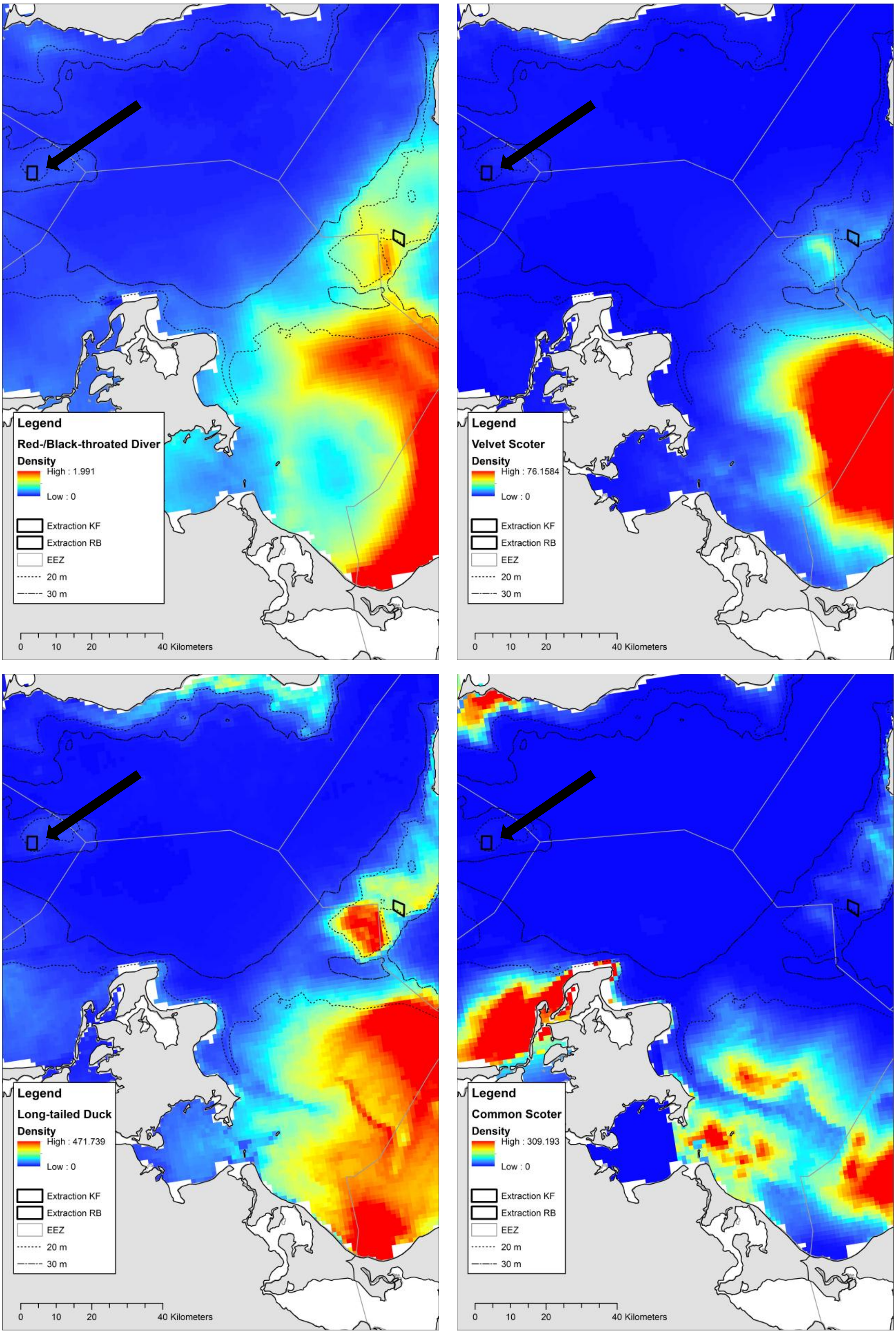


Figure 4.23 Distribution of selected species of waterbirds during winter in relation to the location of the sand extraction site. The map shows mean densities (birds per km^2) between 2007-2009; modelled on the basis of Danish, German, Swedish and Polish aerial and ship-based line transect data (Modified from Skov et al. 2011). KF: Kriegers Flak and RB: Rønne Banke. The extraction area is located at the arrow.

4.7.2 *Bird migration*

Baseline investigations undertaken in relation to the planned wind farms on the Swedish and German parts of Krieger's Flak and Adler Ground (Arkona Becken Südost, Ventotec Ost 2) have provided the main sources of recent information on the timing and intensity of bird migration through the Arkona Basin. The migration of waterbirds through the Arkona Basin seems mainly to take place over a relatively broad front, and is dominated by Common Eider, Barnacle Goose *Branta leucopsis* and Common Scoter. The radar study by Petterson (2003) from the Swedish south coast indicated that 30% of the waterbirds were moving within a distance of 10 km from the coast, while the remaining 70 % were dispersed over a wide front without any obvious use of specific corridors.

The migration of landbirds through the region is markedly different during day and night both with respect to dominating species and migration altitude. Recorded flight intensities during night indicate that the flux of birds peaks on very few nights (Kube et al. 2004b). During spring, nocturnal migration was most intense 5-6 hours after sunset, and during autumn 3-4 hours after sunset, indicating recruitment areas in Mecklenburg and southern Sweden, respectively (Kube et al. 2004b). Diurnal migration was less intense, and showed no obvious peaks.

The diversity of bird migration can be quite high, as shown by counts of visual migration at Krieger's Flak (65 days German part) in which 116 species were observed. The vertical distribution of migrating birds showed the same general trends documented by other studies that birds tend to fly at lower altitudes during head winds and at lower altitudes during the day as compared to during the night. Overall most bird echoes during night were recorded in the lower 200 m (IfAÖ 2003).

4.8 *Marine mammals*

The inner Danish waters and south-western Baltic Sea are inhabited by three species of marine mammals; the harbour porpoise (*Phocoena phocoena*), the harbour seal (*Phoca vitulina vitulina*) and the grey seal (*Halichoerus grypus*). All three species are piscivorous; hence most likely they feed regularly on fish in the areas where they occur.

4.8.1 *Harbour porpoise*

The harbour porpoise is a protected species and listed in the EU Habitat Directives Appendix IV. It is also a major animal of concern in the ASCOBANS agreement under the Bonn Convention. It is the most common cetacean in Danish waters, and is also the only cetacean known to use the Danish waters in all aspects of its life cycle.

Harbour porpoises have been observed in the Danish and German regions of the Baltic Sea through aerial and ship-based visual surveys, satellite-tagged individuals, passive acoustic monitoring using T-PODs and opportunistic observations (Figure 4.24 to Figure 4.29). Although none of these studies were designed specifically with the purpose to document the use of Krieger's Flak by marine mammals they provide general information about the occurrence of mammals in the region.

The large-scale visual and acoustic surveys of harbour porpoises in all European waters in the summers of 1994 and 2005 (Hammond et al. 2002, 2006) show that even though porpoises are relatively abundant in Danish waters the abundance decline rapidly throughout the Danish and German part of the Baltic Sea from west to east (Teilmann et al. 2008).

These studies indicate that porpoises occur in low density in the areas of Krieger’s Flak (Scheidat et al. 2008, Teilmann et al. 2008, Figure 4.25 to Figure 4.28.). There seems to be a slight difference between summer and winter distributions, with a small increase in likelihood of occurrence during the summer period (Figure 4.25, Teilmann et al. 2008).

This large-scale decrease in occurrence of porpoises east of the Darss sill is also evident from the passive acoustic monitoring data collected by (Verfuss et al. 2007) and shown in Figure 4.28. The passive acoustic monitoring data shown in Figure 4.28 were collected in 2005, but the same study also collected data during parts of 2002 as well as all of 2003 and 2004. The data from these years showed a very similar pattern to the one in 2005 (Verfuss et al. 2007). As the same pattern emerges from the visual and acoustic data the seasonal difference in abundance is judged as genuine, and not solely an artefact caused by more calm sighting conditions during summer. The decrease in the occurrence of harbour porpoises east of the Dars sill was further documented during the study of satellite tagged animals from the Belt Sea undertaken as part of the Fehmarnbelt Fixed Link baseline studies (Figure 4.29, Nehls et al 2012).

In summary it doesn’t appear that harbour porpoises occur in any substantial numbers in the Krieger’s Flak area. The designation of any individuals occasionally sighted there to a certain population is not possible at the moment. It is currently challenging to assign porpoises occurring at Kriegers Flak to any distinct population. Genetic studies by Wiemann et al. (2010) indicate that at least two genetically distinct populations occur in the Baltic Sea: one in the Skagerrak and another in the Belt Sea with seasonal overlaps in the Kattegat (see also Sveegaard et al. 2011). Although some further differences between individuals in the Belt Sea and the Inner Baltic were found, this was not statistically significant and did not justify the separation of a third genetically distinct population for the Inner Baltic. Porpoises occurring in the Krieger’s Flak area would thus belong to the population of the Belt Sea and Kattegat. This is supported by the FEMM telemetry studies that clearly showed that all position signals in the Krieger’s Flak area were from individuals that were caught in the Belt area (for a more detailed discussion, see FEMM Baseline report, Nehls et al. 2012).

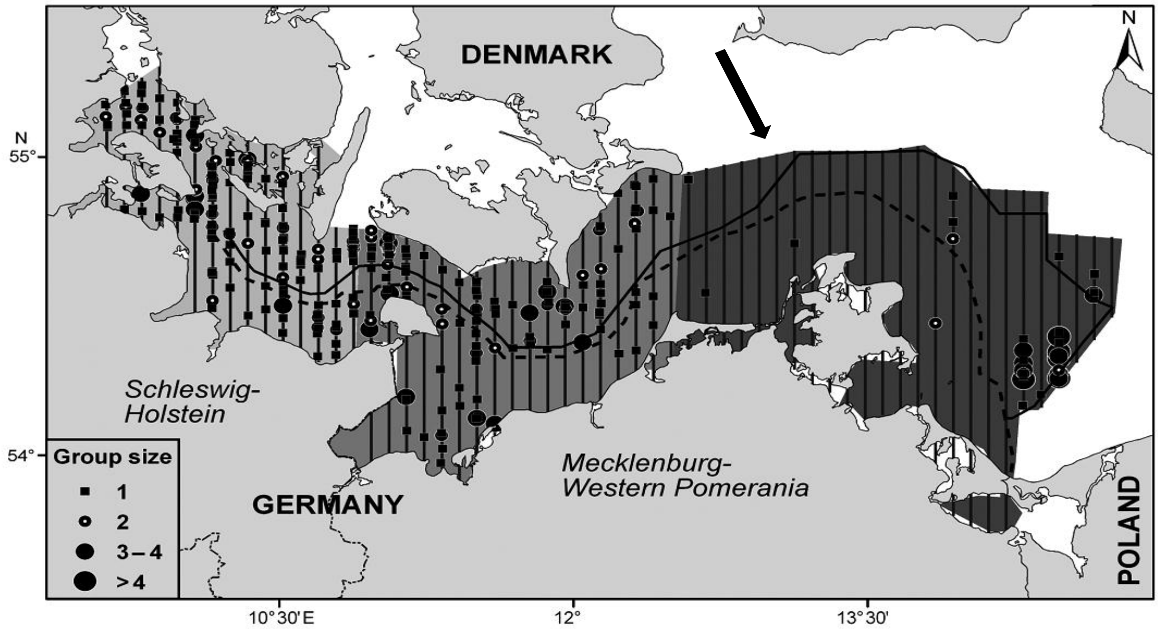


Figure 4.24 Aerial survey tracklines and visual observations of harbour porpoises in a study from Scheidat et al. (2008).

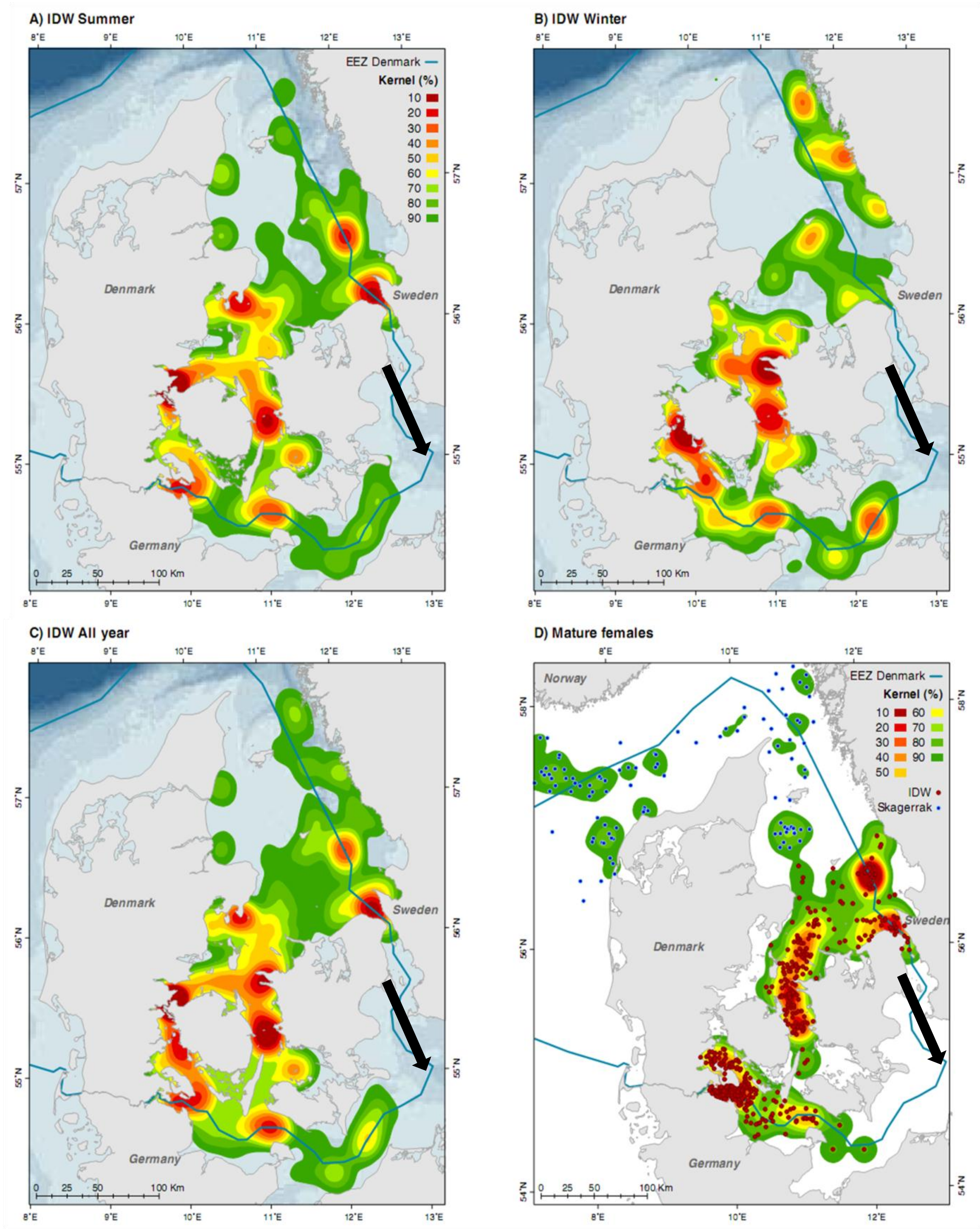


Figure 4.25 Seasonality in the distribution of harbour porpoises from satellite taggings of 37 animals in inner Danish waters 1997-2007. Colour scale is based on kernel density estimations in 10 intervals (the lower the % the higher density). A) Distribution during summer, B) Distribution during winter, C) All year distribution, and D) Kernel and transmitted locations for 8 of the satellite tracked individuals (tracked all year and all females). From: Teilmann et al. (2008); modified with indication of location of extraction area.

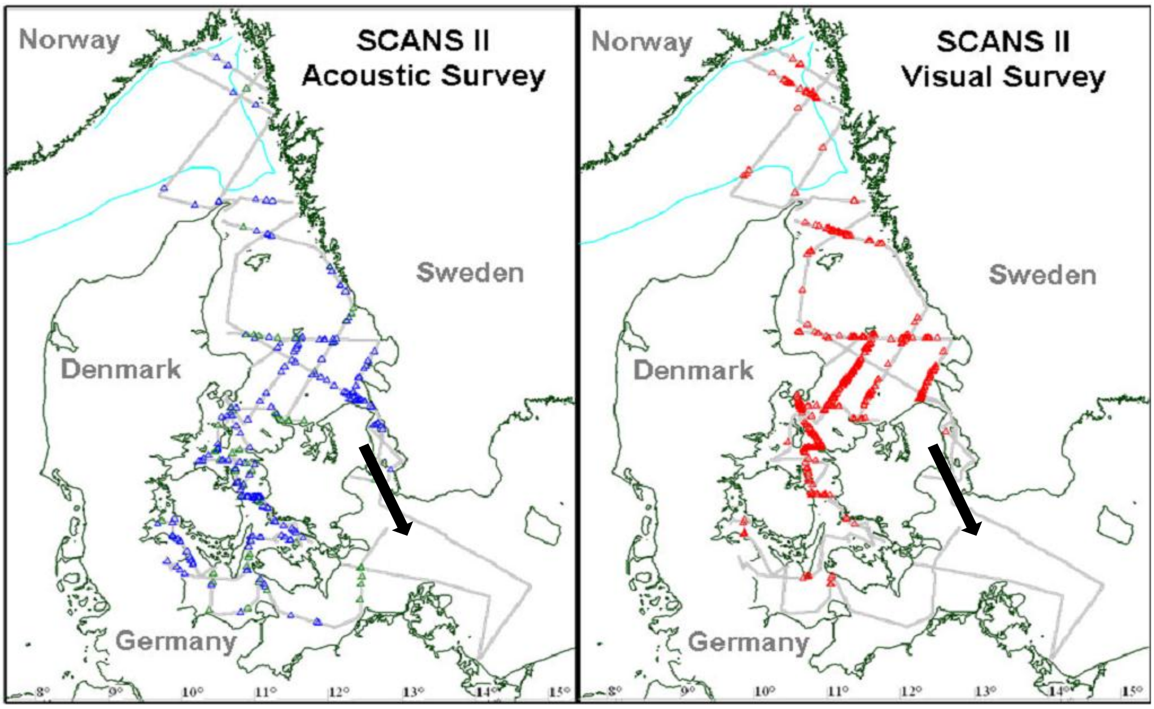


Figure 4.26 Survey plot from the vessel 'Skagerrak' during the SCANS-II survey 29th of June to 14th of July 2005. Acoustic detections are shown with blue triangles on the left panel. Visual sightings are shown with red triangles on the right panel. The sailed route is shown as a grey line. From Teilmann et al. (2008).

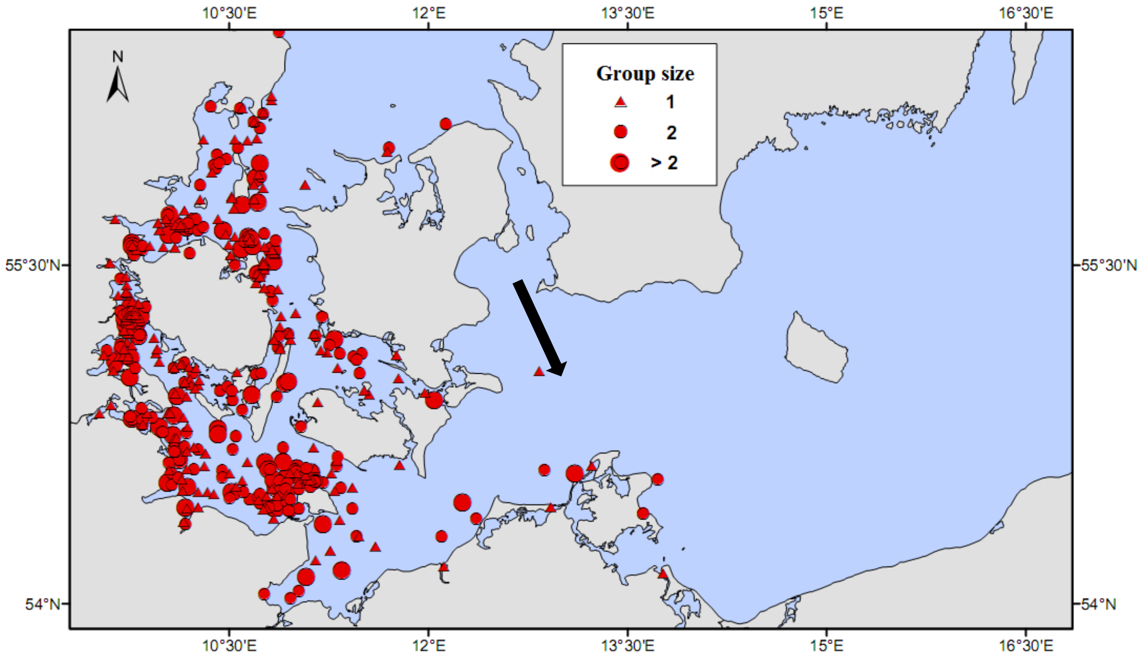


Figure 4.27 Anecdotal sightings of harbour porpoises in Danish and German Baltic Sea waters, 1980 to 2002. Modified after Gilles et al. (2006).

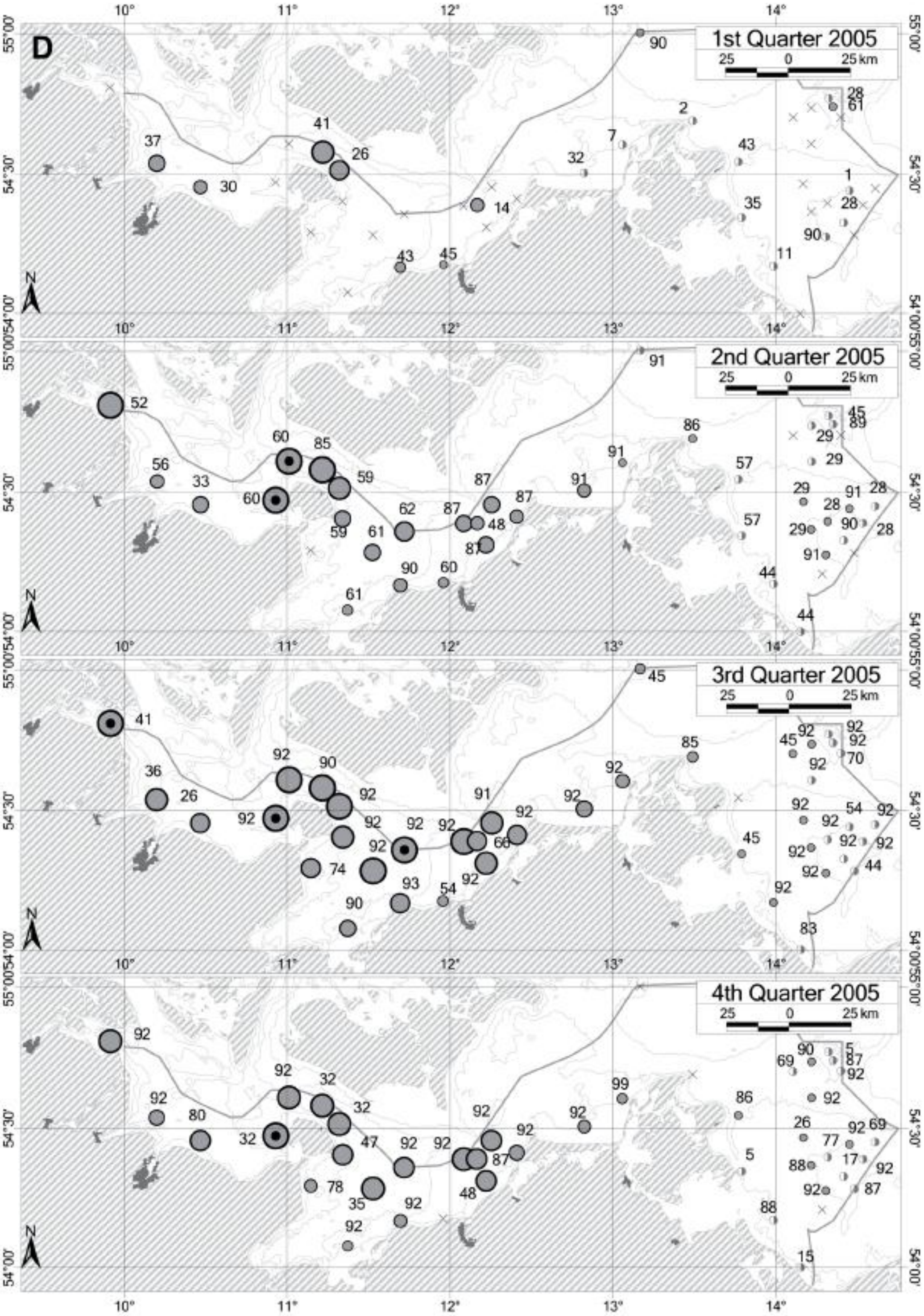


Figure 4.28 Spatial and seasonal distribution of harbour porpoises based on acoustic detections in Denmark and Germany using T-PODS. The data shown are the percentage of porpoise-positive days per monitoring period at the measuring positions for each quarter of the year in 2005. The size of the dots is proportional to the percentage. The number of monitoring days is given next to the dots. Measuring positions at which no data were gathered for the specific quarter are marked with grey crosses. Figures are from (Verfuss et al. 2007).

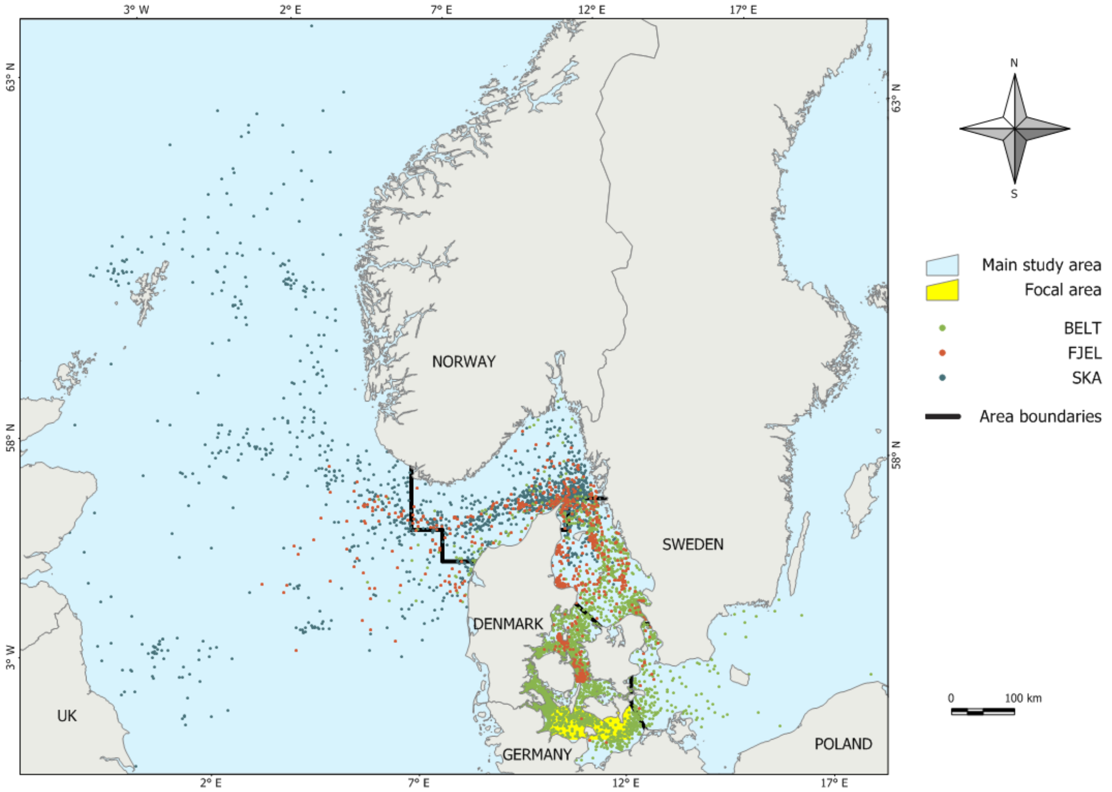


Figure 4.29 Filtered locations for all 82 harbour porpoises tagged between 1997 and 2010, coloured by tagging location. BELT (Belt Sea) = green; FJEL (Fjellerup) = orange; SKA (Skagerrak) = dark blue. The Fehmarnbelt focal study area is shown in yellow from Nehls et al (2012).

In summary, Krieger's Flak seems to be of little importance for Danish and German porpoises. However, individuals, either spending time in the area foraging or animals migrating eastward into the Baltic Sea might still be affected.

4.8.2 Harbour seals and grey seals

Harbour seals and grey seals are found throughout the Danish waters, where both species are known to breed (Olsen et al. 2010, Härkönen et al. 2007). Harbour seals have haul-outs at Falsterbo, Bøgestrømmen and Rødsand, within a few 100 km of Krieger's Flak, and grey seals have also been observed at all these haul-outs (Laursen 2001). Seasonal distribution of grey- and harbour seals are not known, but both species are known to be able to move considerable distances from the haul-out sites to foraging areas (Dietz et al. 2003, Sjöberg et al. 1995). Movements of tagged grey seals from the haul-out site on Rødsand indicate that Krieger's Flak is crossed regularly by animals as they move between Rødsand and feeding areas in the northern parts of the Baltic Proper (Dietz et al. 2003), Figure 4.29.

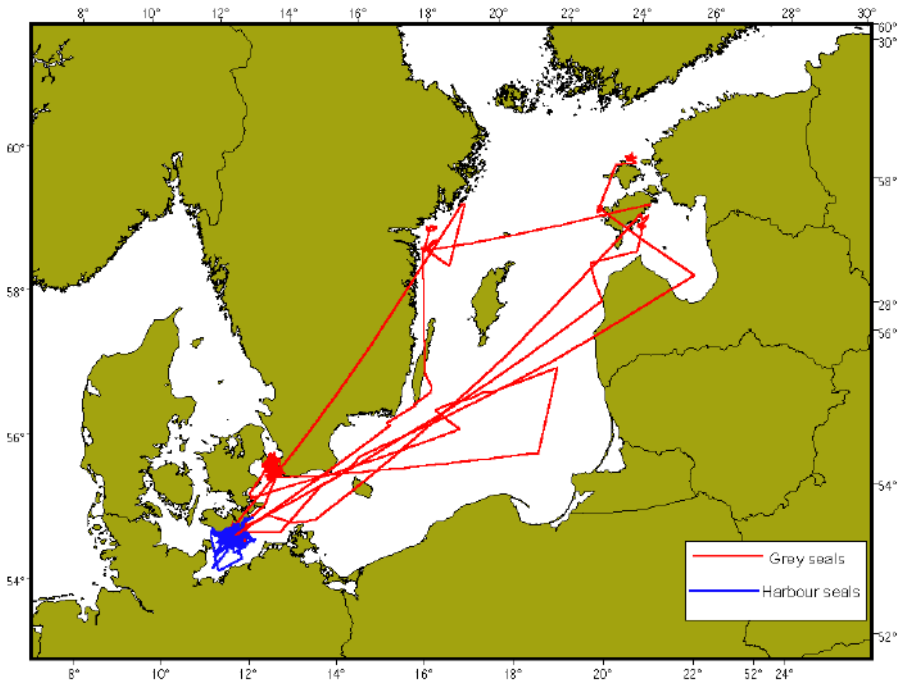


Figure 4.30 Movements of seals from Rødsand seal sanctuary from satellite taggings of six grey and four harbour seals 2001-2002. From: (Dietz et al. 2003).

For the FEMM study, 4 adult and one juvenile harbour seal where tagged and their movements documented for the study period 2009-2010. None of them was tracked in the Krieger's Flak area (see Figure 4.31). In addition two juvenile grey seals where tagged and although both of them covered relatively large distances during the tagging period (October 2009 – April 2010), no position fixes were obtained directly in the Krieger's Flak Area. Rather the animals covered areas nearby (see Nehls et al. 2012; Figure 4.31). Additional tagging was undertaken by NERI in 2010 on three grey seals and one harbour seal captured at Rødsand. The harbour seal moved west into the inner Danish waters. The three grey seals covered a large area with two of them showing repeated position fixes in the areas adjacent to Kriegers Flak (Figure 4.32). According to Nehls et al (2012) up to 200 harbour seals and 200 grey seals have been found to haul out at Falsterbo in Sweden, 40 km from the extraction area (data from 1990-2009), but there is no knowledge on whether Krieger's Flak is a foraging area for these animals. In summary, the occasional appearance of both harbour and grey seals in the Krieger's Flak area can't be ruled out.

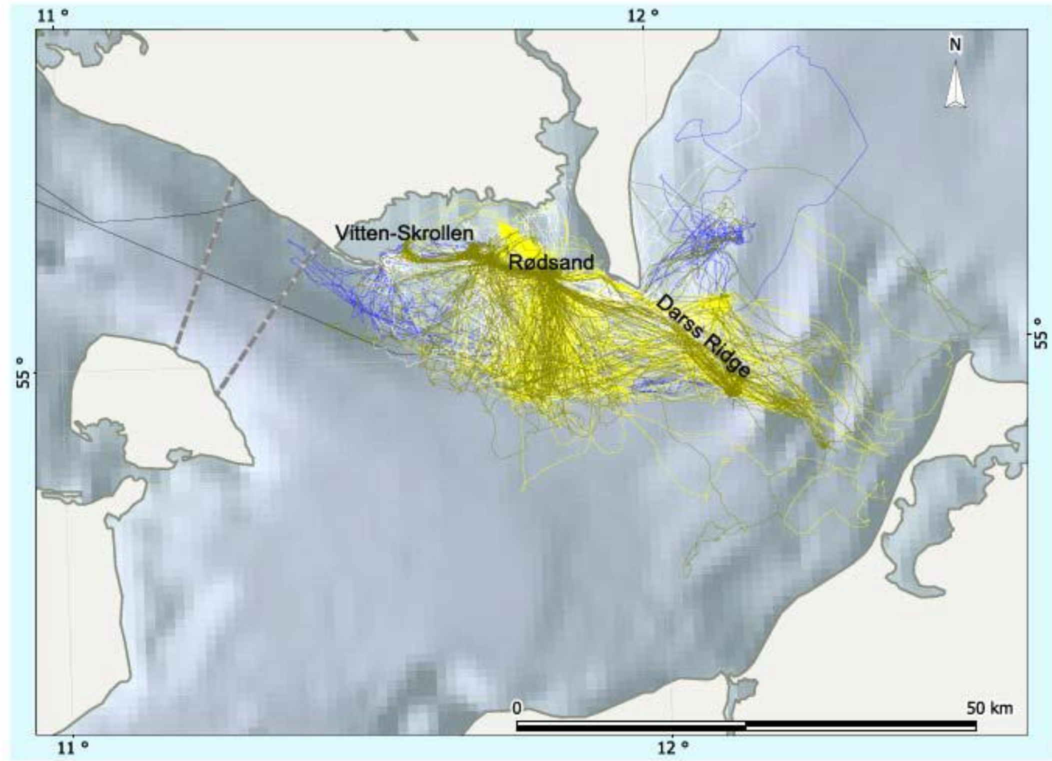


Figure 4.31 Combined tracks of 4 adult harbour seals tagged for the FEMM study (from Nehls et al. 2012)

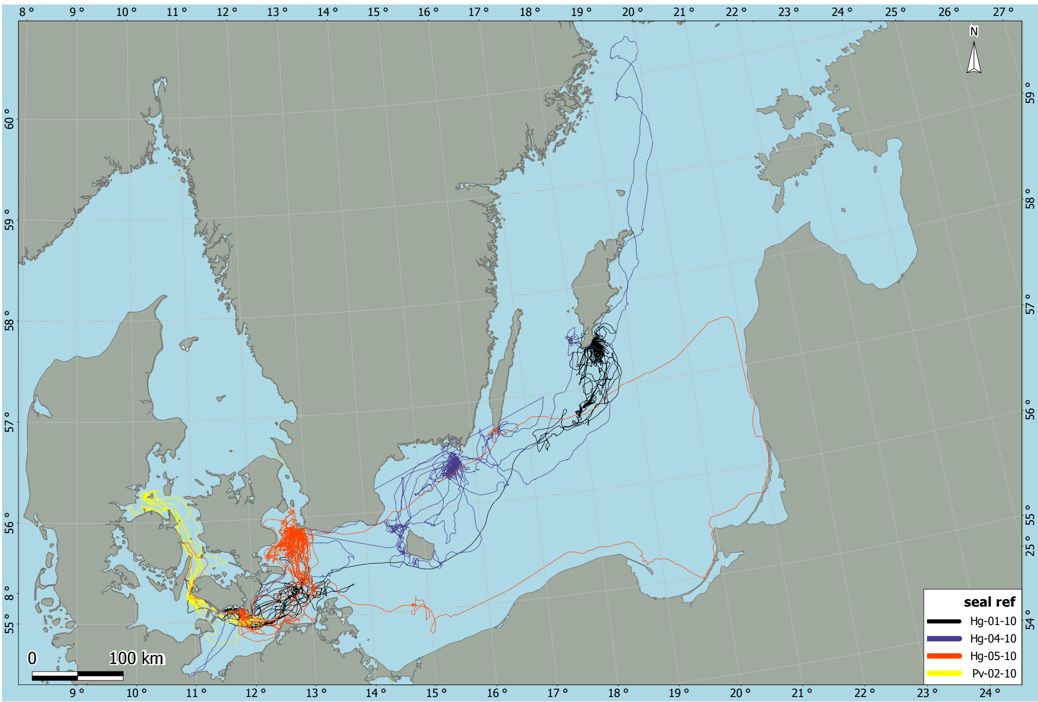


Figure 4.32 Tracks of the four seals (three grey – Hg; one harbour – Pv) tagged with GPS/GSM tags in 2010. Data supplied by The Crown Estate for FEMM (from Nehls et al. 2012)

4.9 Marine archaeology

The National Survey and Cadastre (Kort & Matrikelstyrelsen) has published charts showing wrecks in the Danish marine area. Chart no. 104 (Kort & Matrikelstyrelsen 2011). In addition The Heritage Agency of Denmark holds a database of registered wrecks in the Danish marine area. Data extracted from this database and plotted on Chart no. 104 show that 3 wrecks are registered within the extraction area and 4 wrecks within the 500 m impact area (Figure 4.33). Only two of these wrecks (The Heritage Agency of Denmark system no. 183387 and 183965/177923 - two system numbers for the same wreck) have been recognized from the side scan sonar survey. Figure 4.34 shows a side scan picture the wreck no. 183965/177923.

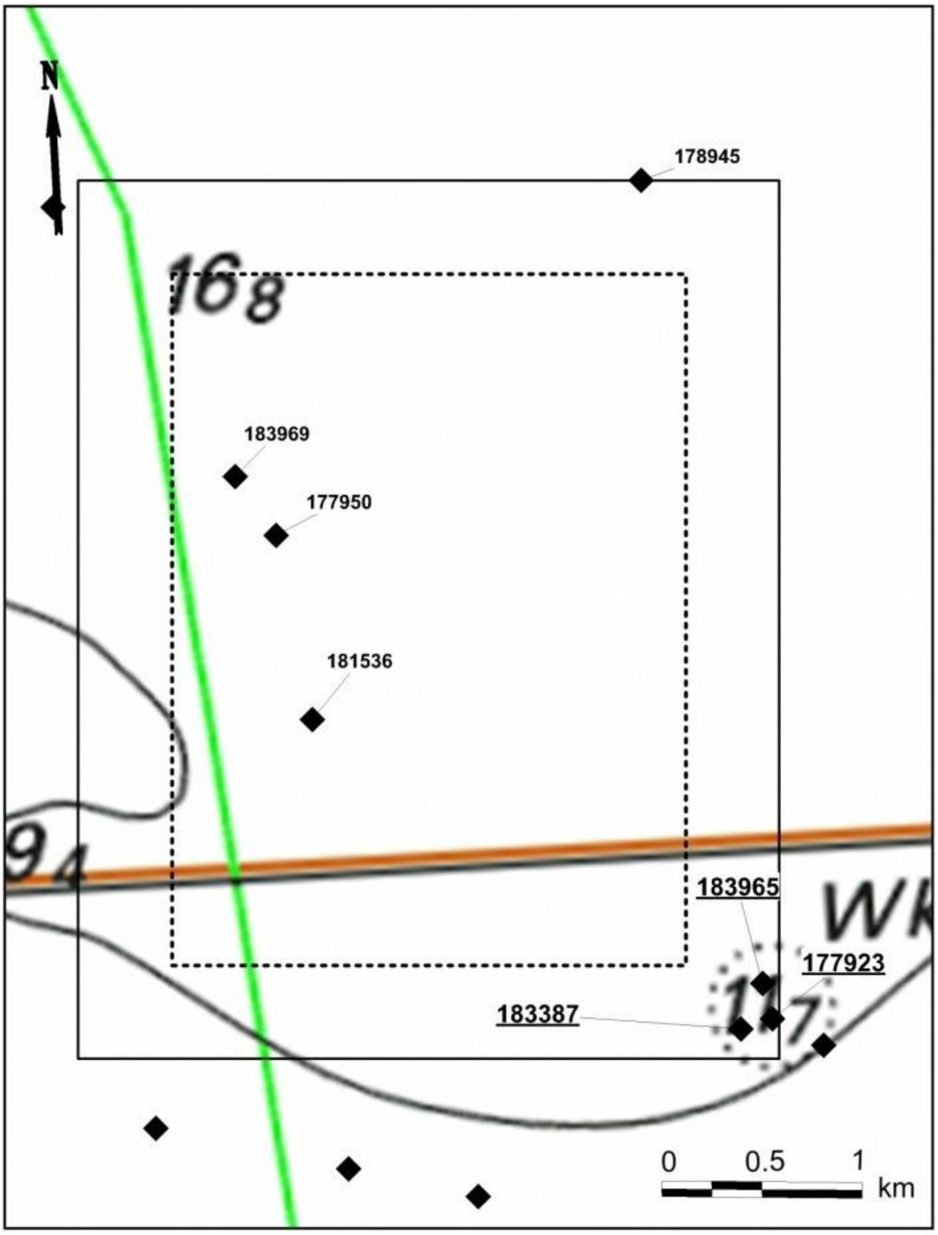


Figure 4.33 Wrecks in the extraction and impact areas registered by The Heritage Agency of Denmark. The underlined numbers indicate wrecks recognised on the side scan sonar data.

Magnetometer data have been acquired by GEUS during the survey in July 2011 but data processing was not a part of this EIA.

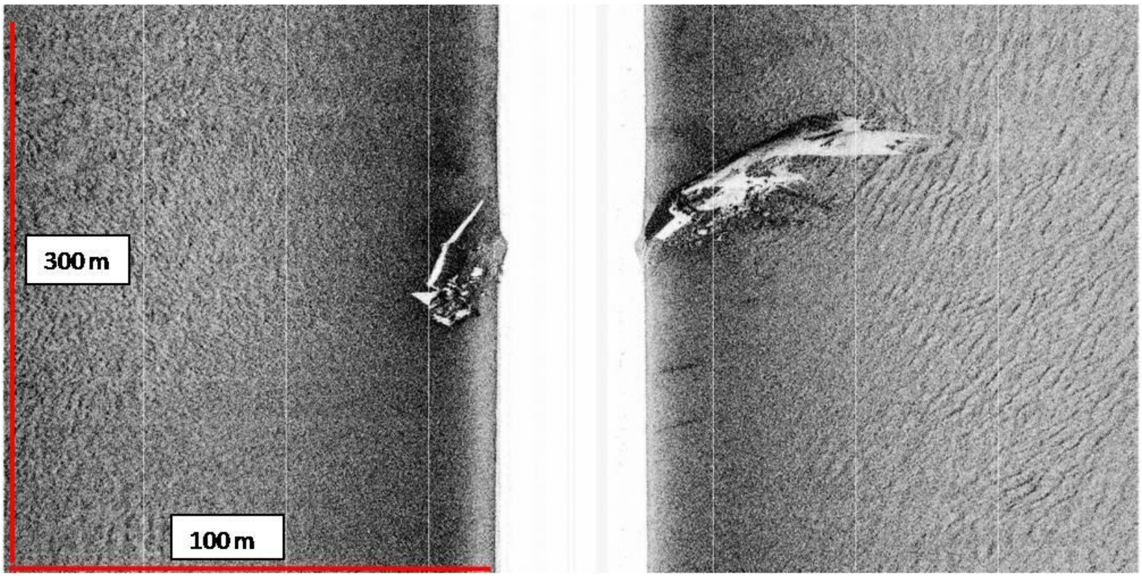


Figure 4.34 Wreck no. 183965/177923 according to The Heritage Agency of Denmark system. Side scan photo from the investigation conducted to survey sediment resources (see chapter 2).

No settlements have been registered within the extraction area. As there is 4 m of Littorina sand in the area, which is deposited on the layers with potential settlements, the settlements will not be impacted by the extraction activities. Hence, further investigations are not necessary.

4.10 Material assets, ammunition and recreational interests

4.10.1 Cables

The National Survey and Cadastre (Kort & Matrikelstyrelsen) has published charts with cabling in the Danish marine area. Chart no. 104 (Kort & Matrikelstyrelsen 2011) covers part of the Baltic Sea with Fehmarnbelt and the Sound. It covers also Krieger's Flak and shows that no cabling is present in the Krieger's Flak area.

4.10.2 Ammunition

Previous investigations at Krieger's Flak in connections with sand extraction for Amager Strandpark revealed few small fragments of ammunition (a few projectiles -sharp and not sharp- and cartridge cases) in the seabed, but other projects (e.g. for Øresund) did not reveal any fragments (GEUS 2012). Hence, the findings are sporadic.

4.10.3 Navigation

The Danish Maritime Safety Administration (Farvandsvæsenet) collects in a database information about the ship traffic pattern in the marine area based on AIS data (Automatic Identification System). The AIS collects the real-time ship locations.

Figure 4.35 shows the traffic pattern for 2009 based on AIS data transmitted by larger ships (Danish Maritime Safety Administration 2011). The chart covers the area between Sweden and Germany, west of Bornholm and west of Krieger's Flak. Krieger's Flak and Rønne Banke are marked on the chart. The main traffic routes passes around Krieger Flak, but do not cross Krieger Flak. However, a smaller amount of traffic passes Krieger Flak.

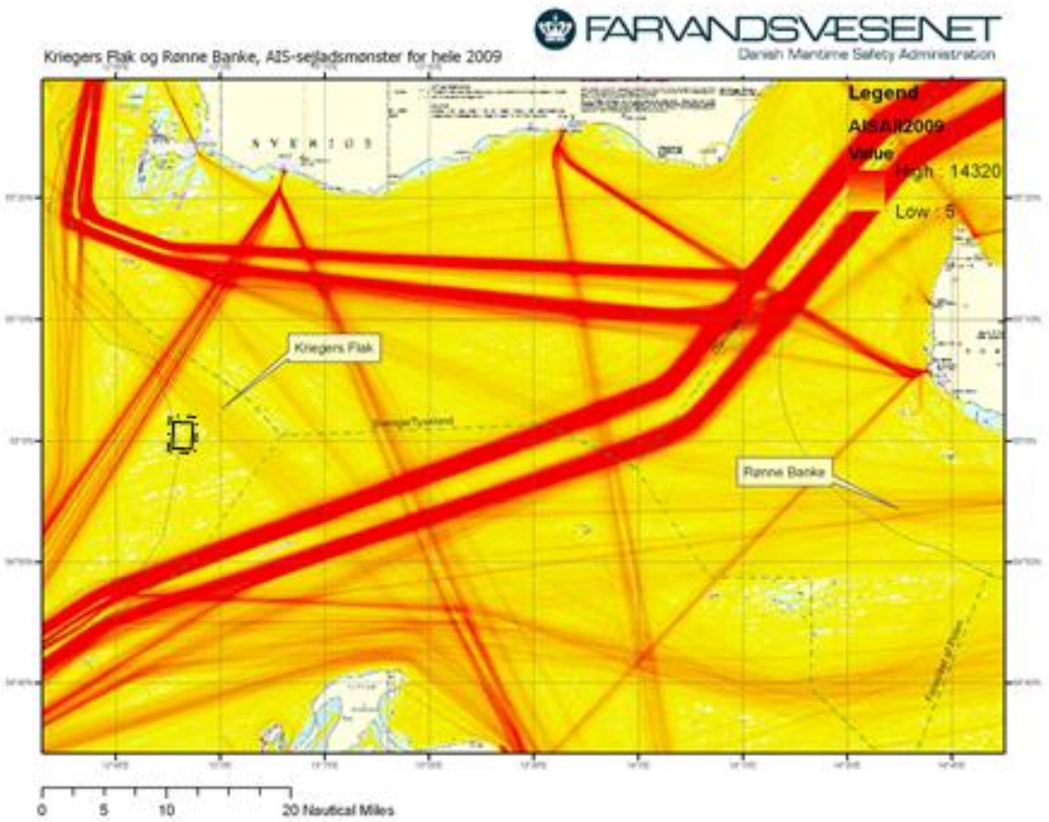


Figure 4.35 Ship traffic pattern south of Sweden and east of Bornholm. The sand extraction area is marked in black (Danish Maritime Safety Administration, Farvandsvæsenet (2011).

4.10.4 Recreational interests

Recreational interests in case of ship traffic can occur, but there are no marinas in the nearby areas.

5 PROJECT PRESSURES

Several pressures from the project have been identified to have a possible impact on the sub-factors in the area. Table 5.1 gives a presentation of all identified possible pressures from the sand extraction project. All pressures are temporary.

Table 5.1 Presentation of possible direct and indirect pressures from the sand mining project at Krieger's Flak.

Pressure
Loss of seabed (sediments and benthic habitats)
Increase in concentration of suspended sediment
Increased deposition
Increased release of organic material, nutrients and toxic substances
Increased noise and air pollution

5.1 Loss of seabed (sediments and benthic habitats)

The sand extraction will be conducted by a trailing suction hopper dredger. The dredger will continue dredging until it is filled. This means that excess (overflow) water and excess sediment will be flowing from the dredger during dredging. This type of dredging will lead to a loss of sediment and benthic habitats in the area where extraction takes place. The total extraction area is approximately 10 km2, and hence a similar magnitude of sediment and benthic habitats will be lost. As a maximum of 6 million m^3 of sediment shall be extracted, it is expected that the removed seabed will be of 0.5-1 m's depth.

5.2 Increase in suspended sediment and deposition

When the sand is extracted, sediment is spilled. Dispersal and deposition of the spilled sediment particles depend on the size of the particles and the hydrodynamic conditions. The general pattern is that the finer particles; e.g. silt-clay, are carried further away than larger because they have a relatively lower settling velocities.

- In order to quantify the sediment spill, the dispersal and deposition of sediment spill from dredging was computed using the Mike by DHI MT module (FEHY 2011). The temporal and spatial accumulation and resuspension of spilled sediments have been modelled for the project scenario (FEHY 2011) based on a dredging plan provided by Femern A/S. The results were available in time steps of 1 hour and with a spatial resolution of 100-5000 m. To achieve relevant data for the assessment, these data were post-processed. The average (1 h) size of the deposited sediment (cm) was extracted as well as the duration (in days, the exceedance) of the deposition. The same was done for the suspended sediment concentration. The following conditions form the basis of the simulations: A full model year simulates the dredging of 4.2 mill m^3 of the total expected extraction of 6.0 mill m^3 sand.

- Sediment spill was modelled in 8 hour cycles where spill occurred one hour per cycle.

- The spillage is 5% of the extracted sediment at the surface due to the overflow and 1% at the bottom (an assumption).

- The grain size distribution of the spill at the drag head is identical to the grain size distribution of seabed sediment.

- Only the fine material with d < 63 μm (clay-silt) is spilled in the overflow. Sediment fractions smaller than 63 μm will be dispersed, coarser particles are predicted to settled within dredging site (close to the dredged area, within 20 minutes after dredging) (FEHY 2011).

- The concentration of the fine fraction is 0.5% of the total sand content. This proportion is based on the observed structure of the sediment at the extraction site (FEHY 2011).

- The year 2005 has been used as hydrographical model year. Each year has identical hydrographical conditions. Year 2005 is in general considered representative and used in assessment in relation to the Fehmarnbelt Fixed Link (FEHY 2011).

Given the above conditions, the spill scenario simulates the maximum extraction rates expected, i.e. the extraction rates occurring when the trailing hopper suction dredgers are operating at their maximum capacity all year round for the model year (2005). The modelled results are hence a "worst case" result.

As the summer period from May to August is the productive period (growth season), the modelled data are shown for the summer period for the exceedance plots and for the deposition (deposition). The maximum deposition is shown for a full year period (2005) and for the summer period.

- The extraction is fixed in the centre of the extraction area, but the impact pressure will be extrapolated to cover the entire area for the environmental impact assessments.

Suspended sediment concentration

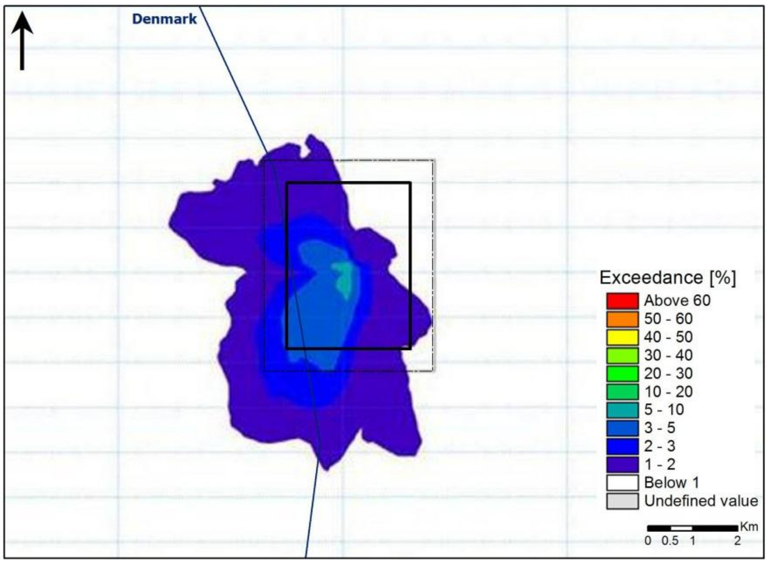
Exceedance for suspended sediment concentration (SSC) is assessed using the thresholds 2 mg/l, 10 and 15 mg/l. Exceedance is expressed as the time within a selected period, where the SSC exceeds these thresholds. SSC exceedance is assessed for surface (depth 0-1 m below surface) and bottom layers (depth 0-1 m above bottom), respectively. Furthermore, the calculation of exceedance is limited to the productive period May-August.

The overall results from the modelling are that the generated plume is quickly dispersed. This means that high SSC concentrations are mainly observed close to the centre of dredging site and that the concentration is below 2 mg/l within a few days.

Figure 5.1 presents the maps of exceedance time at the surface for the 2 mg/l, 10 mg/l and 15 mg/l thresholds, respectively, during the summer time. It is seen that the plume is mainly localised within the extraction area.

Less than 1.5 km from the dredging site, the SSC concentration at the surface is always below 10 mg/l while concentrations between 2-10 mg/l occur. In total, SSC levels exceeding 2 mg/l occur in less than 3% of the time (~4 days) and in most of the area in 1-2% of the time. Exceedance is not observed further away than 2 to 3 km.

Close to the source, the SSC exceeds within a distance of 1 km, the 2 mg/l limit about 5% of the time (~6 days). Maximum plume extension is about 5 km for the 2 mg/l exceedance limit and about 3 and 2 km for the 10 mg/l and 15 mg/l exceedance limits, respectively. Plume shape is almost identical for 10 and 15 mg/l and only exceedance plot for 10 mg/l is presented in Figure 5.1. In summary, the sediment is quickly dispersed at the surface under the influence of both currents and settling of the particles.



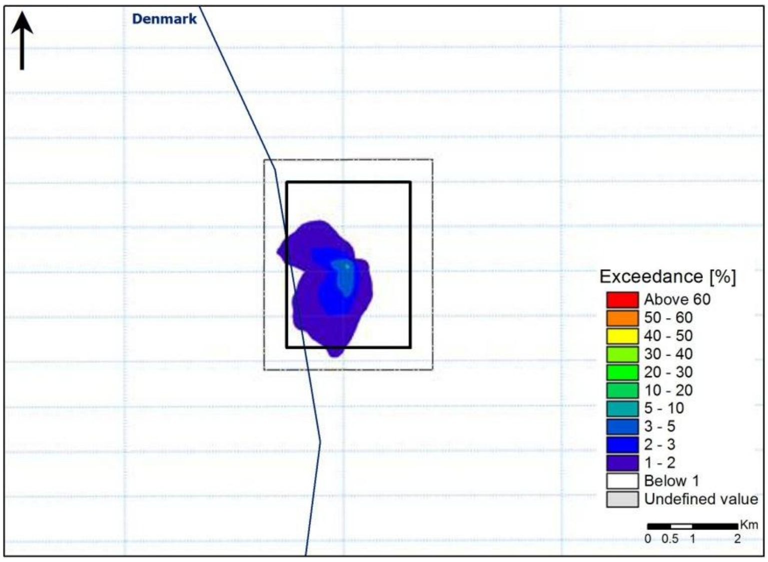


*Figure 5.1 Exceedance time for the period 1/5 to 1/9 (2005) for the surface (depth 0-1 m below surface) of **2 mg/l** (top) and **10 mg/l** (bottom) (FEHY 2011). Exceedance time is given as percentage days with SSC levels above the threshold in relation to the total number of days. Extraction area (500 m impact zone not included) is marked with a black rectangle. Numbers at axes indicate the scale in metres.*

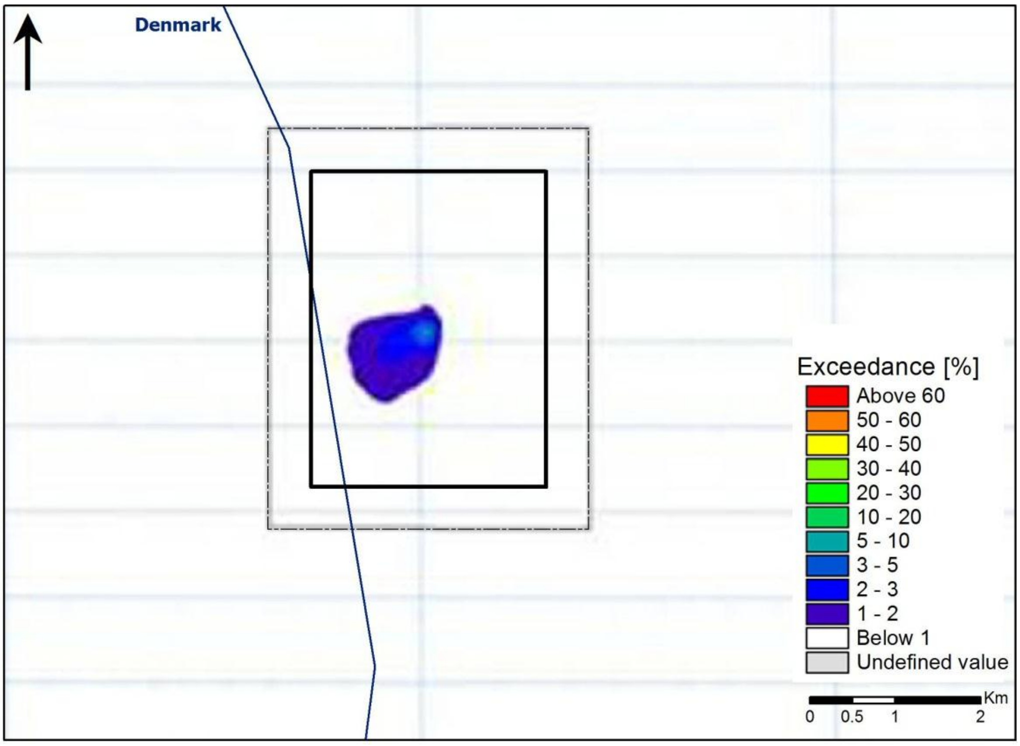


Figure 5.2 Exceedance time for the period 1/5 to 1/9 (2005) for the bottom (depth 0-1 m above bottom) of 2 mg/l (FEHY 2011). Exceedance time is given as percentage days with SSC levels above the threshold in relation to the total number of days. Extraction area is marked with a black rectangle. Numbers at axes indicate the scale in metres.

Figure 5.2 presents the maps of exceedance time at the bottom of 2 mg/l for the summer period. The extension of the plume for 10 mg/l is less than 200 m around the dredger and is not shown (FEHY 2011). The threshold 15 mg/l is not expected to be exceeded at the bottom (not shown). It is seen from the exceedance plot that the plume is always localised close to the source. Maximum plume extension for the 2 mg/l limit is in the order of one kilometre. Concentrations are rarely exceeding values higher than 2 mg/l at the bottom.

Deposition

The maximum deposition of sediment with sizes below 63 µm (clay-silt) in mm. The maximum deposition of sediment has been identified for a full year of continuous dredging and for continuous dredging during the summer period. The remaining sediment, above 63 µm, will deposit close to the source at an average thickness of 1.2 cm within 15-20 minutes after dredging. It is seen from the plots that for the summer period and for a full year, the highest accumulation of deposited material is localised approximately 1 km form the source with values up to 8-9 mm for the summer period. Farther than 1 km from the source the order of magnitude of the temporary maximum thickness of the deposited sediment varies from 1 to 2.5 mm for the one year period; occurring within 5 km from the source. For the summer period the maximum temporary deposition is mainly localized closer to the source with a smaller area outside to the west with a deposition of 1-2 mm. Maximum values are around 8 mm close to the source

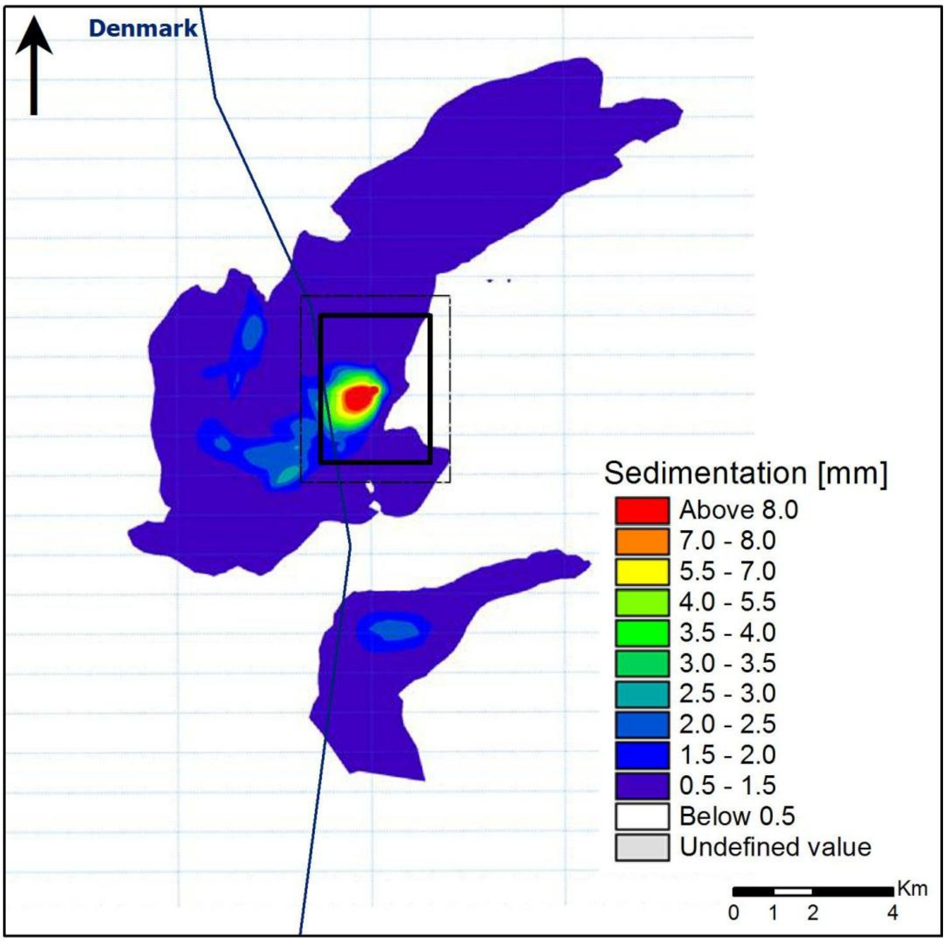


Figure 5.3 The maximum deposition of sediment below 63 µm in mm; extracted from the modelling results considering a full model year (FEHY 2011). Extraction area marked with a black rectangle.

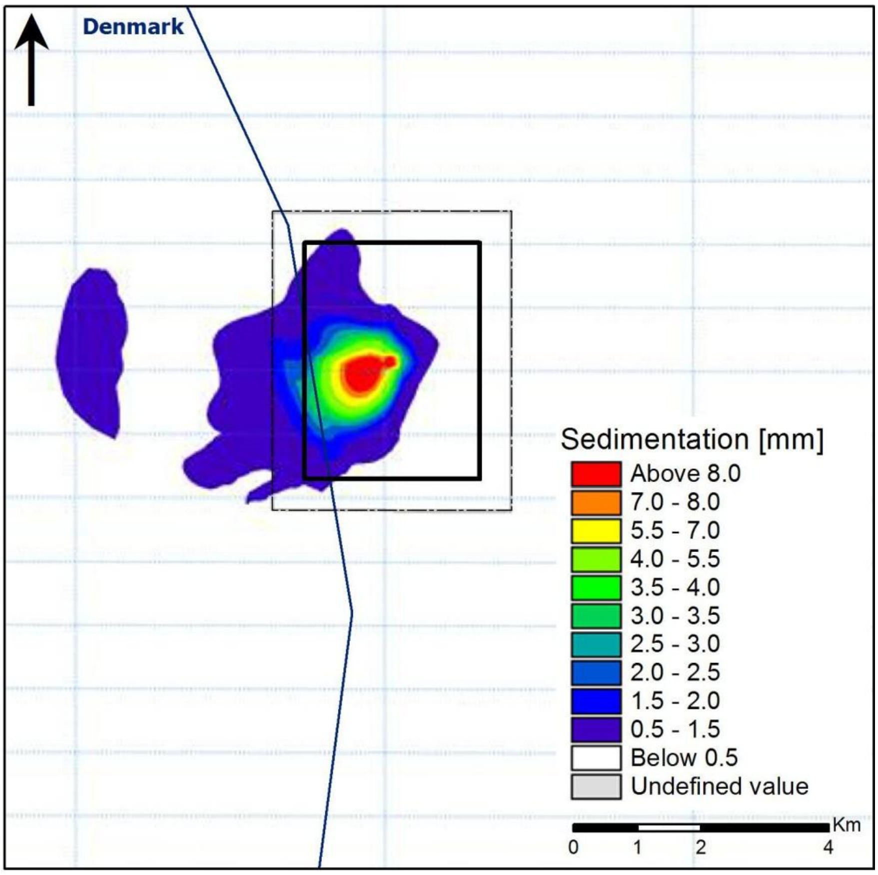


Figure 5.4 The maximum deposition of sediment below 63 µm in mm; extracted from the modelling results considering the summer period 1/5 to 1/9 (FEHY 2011). Extraction area marked with a black rectangle. Numbers at axes indicate the scale in metres.

5.3 Organic material, nutrients and toxic substances

Organic materials in the sediment can, if released to the water column, cause an increased decomposition of the organic material. This can, if the concentration is high, lead to an increased oxygen consumption and release of nutrients. Release of nutrients can increase the phytoplankton growth. Furthermore depending on the presence of local pollutant sources and the sedimentary conditions, marine sediments may contain a large number of toxic substances that potentially can be released during dredging and hence impact the aquatic environment.

The concentration of toxic substances in the sediments at Krieger's Flak will therefore be related to the content of organic matter (FEMA 2013a; Herut and Sandler 2006).

As seen in Table 4.5 (section 0) the content of organic material in the sediments (LOI) of the investigation area is very low (between 0.09 and 0.24% DW). The impact assessment based the low content of organic matter is given in section 6.3.

5.4 Noise

The primary noise sources on a dredger are the diesel motors that provide propulsion to the dredge. In addition there would be secondary noise sources such as generators, pumps and gearboxes. It is expected, that the dredger used for this operation will have a sound power level of 114 dB(A) or less. For the purposes of this report a Trailing suction Hopper Dredger has conservatively been assumed to have a sound power level of 114 dB(A) and at a distance of 2 km from the dredger the noise level is calculated to be 27 dB(A).

There are no indicative limit values for noise from dredging activities, but in recreation areas the limit is 40 dB (A) during the night time. Considering that the Krieger's Flak is located approximately 30 km from the nearest coastline at Møn, the noise from the dredging operation is regarded not to give rise to noise onshore. The primary receptors of noise in air are birds and seals and underwater noise fish and marine mammals.

Underwater noise from the sand extraction is also a factor, which can impact fish, and mammals. The underwater noise levels from Trailing Suction Hopper Dredgers are usually 186-188 dB re 1 µPa rms with the main energy between 100 and 500 Hz (CEDA 2011). The impact on underwater noise will be dealt with in the assessment on the respective factors.

5.5 Air pollution

Ship emission and air pollution in connection with dredging and transport of sand to the construction site of the Fehmarnbelt Fixed Link, is calculated for an expected volume of 6 mill m^3 (Trafikministeriet 1996). In addition the following references have also used been for the evaluation: (NERI 2008), (Olsen et al. 2009) and (ORBITAL 2010).

Total emissions cover dredging at Krieger's Flak, transport between Krieger's Flak and the construction site at the Fehmarnbelt Fixed Link, off-loading and return to Krieger's Flak in ballast.

The basis for the calculation is the average emission rates shown in Table 5.2. Trailing Hopper Dredgers with different capacity and performance with load capacity at 2,000, 2,600, 6,000 and 10,000 m^3 have been used in the calculations. Capacities of 6- or 10,000 are most likely to be used. The distance to the construction site is approximately 120 km.

Table 5.2 Total air pollution, extraction 6 mill m^3 sand at Krieger's Flak (Trafikministeriet 1996).

Krieger's Flak		**CO_2**	**NO_x**	**HC**	**SO_2**	**Particles**
		g/ton/km	g/ton/km	g/ton/km	g/ton/km	g/ton/km
Emission (average rates)		11.097	0.032	0.295	0.009	0.007
Offloading	Load capacity	CO_2	NO_x	HC	SO_2	Particles
	m^3	ton	ton	ton	ton	ton
	2,000	36,200	960	29	550	23
	2,600	42,000	1,120	34	640	26
	6,000	30,600	810	25	470	19
	10,000	26,600	700	22	400	17

The total emissions of CO_2, for the dredger sizes which are most likely to be used, are calculated to be between 26,600 and 30,500 tonnes. The total emission from Denmark was approximately 50 Megaton in 2008 (excluding shipping).

6 IMPACT ASSESSMENT

6.1 Environmental components assessed

Table 6.1 presents the factors, sub-factors and components assessed in connections to the project. The categorisation follows the guideline and assessment method used for the EIA for Fehmarnbelt Fixed Link. Some of the components are not relevant for this project and are marked NA.

Table 6.1 Assessed components and how they fit into the environmental factor framework as in the Fehmarnbelt Fixed Link.

Factor	Sub-factor	Components	Assessed/NA
Fauna and flora (including biodiversity)	Marine plankton	Planktonic flora Planktonic fauna Jellyfish	NA
	Marine benthic fauna	In- and epifauna communities including blue mussels	Assessed
	Marine fish	Migration Spawning Feeding/nursery	Assessed
	Marine mammals	Harbour Porpoise Harbour Seal Grey Seal	Assessed
	Birds	Non-breeding waterbirds Breeding waterbirds Bird Migration	Assessed
	Migrating bats	-	NA
Soil	Marine Soil (including marine landscape)	Seabed morphology Coastal Morphology Seabed Chemistry	Assessed Assessed Assessed
Water	Marine waters	Seawater Hydrography Seawater Quality	NA Assessed
Cultural heritage	Marine archaeology	-	Assessed
Other material assets	Other marine material assets	-	Assessed
Natura 2000	-	Designation basis	Assessed

Impact on the hydrography, plankton and migrating bats has not been assessed. Hydrography and plankton will not be impacted by the sand extraction because the project does not create barriers, which can change the water flow in the area. Furthermore the pressures from the project are so short-term and minor that a shadow effect, hydrographical changes, addition of nutrients or an increase in phytoplankton could not be measured. Knowledge on migrating bats across marine areas is very sparse. It is assumed, though that the bats migrate broadly (as birds) meaning that they use the entire marine area. Because the extraction is temporary and very local is not likely that there will be an impact on the migrating bats.

This impact assessment is part of the environmental impact assessment for the Fehmarnbelt Fixed Link. The criteria for assessing the impact for the sand extraction will to the extent it is possible be similar to the criteria used in Fehmarnbelt Fixed Link EIA. It will be stated in the section if a criterion is used. The assessment will be based on the magnitude of the pressures relevant to the component and factors on which the pressure acts. The assessment will be done based on expert judgement in a narrative and qualitatively way, weighting the pressure and the sensitivity of the component. The expert judgement will be based on the best available knowledge and scientific studies.

6.2 Changes in seabed and coastal morphology

6.2.1 Coastal morphology

The coast nearest to the extraction area is the coast of Møn, which is located less than 30 km away from the extraction area towards WSW.

There are three items to be considered in the assessment of the possible impact of the sand extraction on the coastal conditions:

a. Will the sand extraction directly undermine the coastal profile along the east coast of Møn?

b. Does the lowering of the seabed impact the wave conditions in the extraction area and?

c. Will a possible impact on the waves have an impact on the coast of Møn?

Ad. a: The sand extraction will not undermine the coastal profile because of the long distance to the shore and the relatively deep waters in the area between the coast and the extraction area.

Ad. b: The sand extraction in the extraction area will on the average lower the seabed with about 1.0 m, i.e. from a depth of about 20 to 23 m to about 21 to 24 m. This about 5% increase in the water depth over the dredging area of 10 km^2 will have insignificant impact on the wave conditions in the deepened area and absolutely no impact on the wave conditions more than 20 km away from the sand extraction area.

Ad. c: Only a very small percentage of the waves along the coast of Møn will have passed the dredging area, as only about 4 % of the waves comes from the direction interval pointing towards the dredging area. It can thus be concluded that the dredging at Krieger’s Flak does not change the wave conditions along the coast of Møn.

It can consequently be concluded that there will be no impact on the coastal stability along the east coast of Møn of the sand extraction at Krieger’s Flak.

6.2.2 Seabed morphology

The original seabed will be removed down to an average depth of 0.5 and 1 m where the dredging operation has taken place without individual specific trenching marks, see Section 2.2. The composition of the resource following the sand extraction is assumed to be the same as for the initial seabed because the thickness of the available sand resource in the extraction area is thicker than the extracted layer and because all extracted material is recovered in the hopper of the dredger, which means that no coarse materials, such as pebbles, are returned to the seabed.

The backfilling rate of sand extraction trenches in the seabed is proportional with the transport capacity of sand on the seabed as nearly all sand transported towards a trench will be trapped due to the smaller transport capacity in the trench compared to the transport capacity on the adjacent seabed. The transport capacity in the order of magnitude 0.1 to 0.2 m^3/m/year resulting mainly from very rough wave conditions typically occurring for a duration of a week per year. This transport capacity is so small that it will take many years before the irregular nature of the seabed resulting from the sand extraction has been smoothed out to an even seabed (which is also indicated by the observed marks from previous dredging activities). The transport processes will result in lowering of the high spots and filling of the local depressions (the dredging scars). The process of smoothing the high spots will leave the coarser fractions of the bed sediments whereas the finer fractions will be transported to the adjacent lower areas within the extraction area. This means that the seabed after 5 to 10 years will be smoothed out to a relatively smooth surface, but with scattered local areas dominated with coarse fractions and the remaining areas dominated by medium well sorted sand resembling the pre-project conditions. The sand ripples will come back over most of the seabed within the 5 to 10 year period.

6.3 Toxic substances

Sediment dredging and disposal activities in Denmark are regulated according to the concentration of toxic substances in the sediments. All concentrations of toxic substances in the sediment at the shallow Krieger's Flak is found to be lower than the accepted background values for sediment set by OSPAR (OSPAR 2009) except for TBT, which is on the other hand a factor 350 lower than the L Ac set by the Danish EPA (BLST 2008) and therefore considered unproblematic (see section 0). There is therefore no impact on the marine environment due to release of toxic substances from dredging activities.

6.4 Salinity, temperature, water quality

The changes in the seabed morphology are too limited to cause any changes in the hydrodynamic regime; meaning that there will be no changes in e.g. salinity, temperature, current and mixing. Consequently no hydrodynamic based changes in the general nutrient and oxygen regime and processes will occur.

Potentially, nutrient and oxygen concentration may also be affected by changes in the concentration of organic material due to release from dredged sediments. If large amounts of organic material is released to the water a re-oxidation of reduced substances (H_2S) can take place (FEMA 2013a), which reduced the oxygen concentration. As the sediments did not contain H_2S (the sediments was purely sand and not anoxic muddy sediments), this reduction will not lead to oxygen degradation. The degradation of the organic material can potentially lead to a minor decrease I oxygen concentration and a release of nutrients (FEMA 2013a). The low concentrations of organic material (between 0.09 and 0.24% DW) will most likely not give rise to perceptible effects on the concentration of oxygen, nutrients, or chlorophyll a concentrations. There will hence not be an impact on the marine environment due to changes in water quality.

An increase in the suspended sediment concentration (SSC) can potentially result in a reduction in light availability, which may impact the growth of phytoplankton.

However, it is not likely that the increase in SSC of 2 mg/l in approximately 5 % of the time or 15 mg/l in 1-2 % of the time will have any impact on the plankton growth.

Depending on the method of sand extraction and the environmental conditions at mining site, the activity may leave scars in the seafloor. Use of static suction hopper may leave deep depressions with propensity to collect organic material and develop anoxic conditions (Norden Andersen et al. 1992; Szymelfenig et al. 2006) while other method as the trailer suction hopper (as preferred in the Fehmanr Belt extraction) leave shallow furrows on the seafloor, linear, curved or crossing. In contrast to deep pits, shallow furrows are less prone to foster oxygen deficiency as they allow exchange of water in the pit. Still, depressions in the seafloor will increase risks of local oxygen reductions if the water column is stratified and the density stratification is located near to the seafloor.

As long as the water column is un-stratified or well-mixed, oxygen depletion at seafloor will be very unlikely. In well-mixed environments, oxygen that is consumed can be replenished by re-aeration from the atmosphere and oxygen produced by primary producers in the upper water layers.

Sand extraction at Krieger's Flak will take place within in the depth interval 18-21.5 m. As described in section 4.3 existing data suggest that oxygen deficiency in bottom water potentially can occur in the area, at 18- 25 m depth, below the stratified layer. Therefore, dredging furrows in the seabed at depths between 18 and 22 m are likely to intercept with stratification and if furrows collect organic matter during the summer period there will be an increasing risk for additional oxygen reductions in furrows. At present it is not known if furrows will accumulate organic matter and thereby lead to increase in oxygen uptake and it is not known if an additional oxygen uptake will affect oxygen concentration because the flushing in the furrows are not known. As the content of organic matter in the sediment at Kriegers is very low (Table 4.5, section 4.4), the risk of accumulation in the furrows is however expected to be very low too.

6.5 Benthic Fauna

Impact on benthic fauna from sand extraction the can be due to

- Loss of benthic habitat
- Increased deposition
- Increased suspended sediment concentration
- Oxygen deficiency

Loss of benthic fauna habitat
The loss of benthic fauna habitat will correspond to the area exploited for sand extraction; i.e. the maximal extracted area is 10 km^2. The loss of fauna in this area will be total as the upper approximately 0.5 - 1 m of sediment will be removed.

Re-colonisation of the seabed after ended dredging activities, will take place by migration of adult species and settling of larvae from nearby unaffected areas. The nature of the area that they are re-colonising will similar to pre-project conditions (Section 6.2.2). Most of the species, which are abundant at Krieger's Flak, especially polychaetes and oligochaetes (which accounts for 73% of the abundance and 9.2 % of the biomass) have a relatively short life cycle and will most likely re-establish after one or two growth seasons. Mussels (which account for 23% of the abundance and 90% of the biomass) have a longer life cycle and re-establishment will take longer. *Macoma balthica* and *Mytilus edulis* have a generation time of approximately 2-4 years while *Mya arenaria* have a generation time of 2-5 years. The re-colonisation could be hampered by the seabed recovery process. However this is assessed to be so slow (Section 6.2.2) that it cannot be expected to influence the faunal re-colonisation. Re-establishment of the biodiversity and biomass of the benthic fauna community in the impacted area will therefore most likely take place within 5 years after dredging has stopped.

The reestablishment of the seabed will not hamper the recolonisation process as the sand processes in the extraction area will resemble the existing seabed processses to which the benthic fauna is already adapted.

Suspended sediment concentration (SSC)
Several groups of benthic invertebrates can be affected by high SSC. Suspension-feeders such as mussels, clams and other bivalves, barnacles, or tunicates are most sensitive to high concentrations of SS, because the solids can dilute their primary food (i.e. phytoplankton) and overload the filter-feeding apparatus. In general, other feeding groups are less sensitive as long as other water quality issues such as dissolved oxygen and toxic substances are not affected negatively along with high SSC. High SSC can lead to reduced growth, in extreme cases also to negative growth. Depending on concentration, the consequence can be mortality if the duration is long compared to the typical turnover of body mass for a specific species and individual.

Suitable criteria for the impact on the benthic fauna from increased SSC has also been discussed and defined in the EIA for Fehmarnbelt Fixed Link (FEMA 2013c). These criteria have been adopted in the present EIA. The threshold for no impact is defined as 25 mg/l (FEMA 2013c); meaning that the benthic fauna can cope with an increase in SSC (exceedance) below this limit. As appears from the exceedance plot (Figure 5.2) the sediment plumes at the bottom are always localised within 1 km from the extraction source and the SCC values never exceed 15 mg/l. There is hence no impact on the benthic fauna as a result of the increased SSC.

Deposition
Generally, macrofauna can cope with the deposition levels occurring in their natural environment and will remain unaffected due to its burrowing/escaping ability (Miller et al. 2002, Gibbs and Hewitt 2004). The sensitivity to deposition does however vary with species, dependent on if they are sessile or mobile, the type of deposition (instant or gradually deposition) and type of deposited material (clay, sand etc.) (Essink 1999 and Lisbjerg et al. 2002).

In the EIA for the benthic fauna communities of Fehmarnbelt, a set of criteria for the pressure deposition has been defined on the basis of scientific literature and expert judgements (FEMA 2013c). In this connection it has been established that deposition below 3 mm, regardless of the duration of the deposition, the rate of deposition and the fauna community, will have no impact on the benthic fauna.

As the maximum deposition 1.5 – 2 km away from the extraction source is less than 3 mm at any point in time (Figure 5.4), it is therefore concluded that deposition will not impact the fauna outside the extraction area significantly.

Deposition of sand and the fine sand/silt fraction within the extraction area will mostly occur in areas where the benthic fauna has been directly affected by removal of the sediment and habitat loss. The deposition within the extraction area will therefore not add significantly to the impact on the benthic fauna.

Oxygen deficiency
As mentioned in section 6.4 a risk of additional oxygen reductions in the furrows or the dredging scares cannot be excluded. The area where this may occure is limited to the furrows/ dredging scares in the summer period. The possible impact on the benthic fauna is assessed to be insignificant due to the restricted area extension.

Overall conclusion
It is evident that the only significant pressure on the benthic fauna is the destruction of the seabed in the dredged areas. The area lost is estimated to be maximum 10 km^2. The impact is reversible and the fauna community will recover within 5 years.

There will be no impact on the benthic fauna outside the extracted areas.

6.6 Benthic vegetation

As there is only very limited quantities of macroalgae present in the impact area or in the vicinity, the impact on the macroalgae will be negligible.

The observed green thin layer, which consisted most likely of sedimented algae and benthic microalgae will be lost when the seabed is extracted. The growth rate of small microalgae is very fast (hours-days) and the algae will hence recolonize very fast after the extraction has ended. The impact on the microalgae is very limited.

An increase in suspended sediment concentration (SSC) can potentially result in a reduction in light availability, which may impact the growth benthic vegetation. It is not likely that the increase in SSC of 2 mg/l in approximately 5% of the time or 15 mg/l in 1-2% of the time will have any impact on the photosynthesis in the benthic vegetation.

6.7 Fish and Fishery

6.7.1 Fish
The potential physical and biological impact of sand and gravel extraction is site-specific depending upon numerous factors such as the extraction method employed, bottom current strength, sediment mobility and bottom topography. The most serious physical impacts potentially having implications to fish are:

- Loss of sediment and changes in seabed morphology
- Increase of suspended sediment concentration in the water column
- Increase of deposition
- Increase of underwater noise

In addition, dredging activities may cause changes in the existing biological community, which directly or indirectly influence the fish community in the area.

Alteration of seabed structure related to screening (returning of material to the sea floor) may also be an issue for some extraction projects but not the present (section 6.2).

In the following the impacts on fish of these pressures are assessed based on the expected or possible presence of the fish species and populations described in section 4.6.1.

Loss of sediment and changes in seabed morphology (habitats)
The most obvious impact of sand extraction is the removal of material from the seabed and the resulting destruction of its infaunal and epifaunal biota, which hence can impact the fish by removal of food resource. The assessment on benthic in- and epifauna is that the benthic fauna community will be reestablished within a 5-year period (section 6.5). It can be assumed that when the food resource has re-established the impact will be negligible. Within this period the impact on the fish species can be difficult to predict, as fish diets are often species specific although many fish are flexible in their choice of prey and eat and adapt to what is available. The impact on the fish is very low.

Besides having a possible effect on the food resources for fish, material extraction in an area can also have temporary effects on fish habitats. It is expected that the seabed and hence the habitat will be changed considerably during the extraction period but not significantly after extraction has ended as the seabed characteristics have not been change (Section 6.2.2). The impact of the temporary change in sea-bed species specific – for example, if the grain size of sediment is altered this could have a negative impact on sand eel species, if this species are present in the extraction area that have very specific habitat demands for the sand composition on the bottom. The sand eel species are non-migratory species, having very specific habitat demands for the substrates they live in, thus these species are particularly vulnerable to removal and changes in seabed material. Sandeels prefer sandy substrates with medium to coarse grain sizes (0.25-1.2 mm) (Jensen et al. 2003). Because sand eels contribute to the diet of many important gadoid species (cod, whiting etc.) as well as turbot a decrease in the sand eel stock size will potentially affect the stocks of other species in the area (ICES 1992). Since the substrate will not change after the dredging period has ended, the impact on sand eel is expected to be temporary. The impact in the within dredging period can be significant if sand eel is present.

Suspended sediment
The increase of suspended sediment in the water, i.e. in water turbidity, associated with the dredging process will periodically cause fish to avoid or move away from the area. Permanent effects of this are however not expected.

Computer simulations of extraction activities on Krieger's Flak have shown that the plumes from the extraction operation are generally quickly dispersed within a few days and that the levels are potentially low in comparison with natural background concentrations (section 5.2, FEHY 2011). Maximum plume extension at the surface is about 5 km for the 2 mg/l exceedance limit and about 3 and 2 km for the 10 mg/l and 15 mg/l exceedance limits, respectively. Maximum plume extension for the 2 mg/l limit at the bottom is in the order of 1 km (Figure 5.1 and Figure 5.2).

Two aspects of the SSC with regard to fish should be considered; avoidance and effects on egg and larvae.

Laboratory experiments for herring and cod have shown that they display avoidance response when silt and limestone particles are as low as 3 mg/l (Westerberg et al. 1996). Benthic fish such as flatfish species are much more tolerant of suspended material compared to pelagic species such as herring and sprat. For example, plaice have survived 14 days of exposure to 3000 mg/l of clay and silt. Some fish species may actually be attracted to the area by the "odour trail" of the crushed benthos. This effect is often observed by fishermen in areas heavily fished with beam trawls in the North Sea (pers. comm.) The concentration of suspended sediment is not necessarily the critical factor causing fish avoidance, but should be combined with the exposure time to give a true picture of the potential risk of the influence of suspended material (Newcombe and McDonald 1991). In connection with the EIA for the Fehmarnbelt Fixed Link, a threshold for avoidance behavior has been set at 10 mg/l suspended sediment for pelagic fish species such as herring, sprat, whiting and cod, while densities of 50 mg/l has been set for more benthic species such as flatfish and shallow water species. The threshold value for avoidance response by migrating silver eel is set to 100 mg/l (FeBEC 2011 in progress). Thus in very short periods during material extraction the more sensitive pelagic species might flee from or avoid an area of 2-3 km from the dredging site. However, because the suspended sediment levels potentially triggering an avoidance in fish (>10 mg/l) will only occur in 1-2% of the time of material extraction, the overall effect of this pressure is considered to be very limited in space and time and is hence negligible.

Early life stages of fish are usually more vulnerable to sediment plumes than adults because they generally are more sensitive to suspended material and less capable of escaping. Concentrations in the range of milligrams per liter can be lethal for eggs and larvae, while for juveniles and adults this effect is not expected until concentrations reach levels of grams per liter (Engell-Sørensen and Skyt 2002). Impacts of suspended material on fish eggs depend on whether they are spawned in the open water (pelagic eggs) or whether they are spawned on the seabed (benthic eggs) – eventually with parental care.

Sediment spill may affect benthic fish eggs by covering them and reducing oxygen flow. Other than reducing oxygen availability, sediment that adheres to pelagic fish eggs can also cause them to sink into depths and thereby into water layers that do not have the optimum oxygen conditions. Sediment-response experiments were performed as a part of the Fehmarnbelt Fixed Link impact assessment (Petereit and Franke 2011). In general, they concluded that exposure of cod, flounder and herring eggs to concentrations of 1,000 mg sediment/l had only a few significant impacts on their survival and overall fitness. Sediment free treatments did have on average higher survival and hatch rates; however this was not significant due to the high variability among replicates. Other experiments have shown that cod eggs exposed to 5 mg/l suspended sediment are still buoyant while exposure up to 100 mg/l suspended sediment will increase their mortality by significantly reducing egg buoyancy (Rönnbäck and Westerberg 1996). Furthermore Kiørboe et al. (1981) performed herring exposure experiments with different constant concentrations of suspended silt (5-300 mg/l) and a short-term high concentration (500 mg/l) of suspended silt at different stages of embryonic development and found embryonic development was unaffected. They stated that "as far as suspended particles are concerned, no harmful effects of dredging to herring spawning grounds are likely to occur". Since the duration of the relatively low concentrations of SSC is very limited in connections to the dredging activities, the impact on egg is regarded as very low to negligible.

Fish larvae use sight to localise their prey. Larvae of species such as plaice, sole, turbot and cod see their prey when they are within a distance of a few millimeters (one body length) and can survive a few days without food. The more turbid the water is, the more difficult it is for fish larvae to localise their prey (de Groot 1980, Johnston and Wildish 1982). Fine particles in water will also get caught in the gills of fish larvae and reduce oxygen uptake (de Groot 1980). At concentrations of 10 mg/l mortality rates of cod larvae have been observed to increase significantly (Westerberg et al. 1996). Since the duration of the 10 mg/l is very short, the impact on the fish larvae is very low and insignificant.

Deposition
The impact upon the benthic ecosystem of deposition of fine material is not normally as severe as that resulting from the direct removal of the substrate and its indigenous fauna (ICES 1992).

The prime risks of deposition are the smothering of fish eggs on spawning grounds. Sand eels lay their eggs in the sand and sand grains of a certain size adhere to them. When sand eel eggs are fully covered with fine material, the development of the embryo will be negatively affected resulting in less successful hatching rates (ICES 1992). Demersal eggs from other species such as turbot, herring, bullrout, gobies etc. may also be susceptible to smothering. There is, however, no information on whether these species spawn in the planned extraction area.

Analysis of maximum temporary deposition shows that at some point in time it is likely that up to one millimeter of fine sediment will deposited in a few spots south of the extraction area. This temporary deposition will subsequently be removed by re-suspension. Thus, deposition maps at the end of the modeled year show that there is practically no remaining deposition on the seabed outside the mining area (FEHY 2011). Thus, as the seabed and fauna community is reestablished over time it is not expected that there will be a permanent impact on the fish community inside the extraction area. Furthermore there will be neither temporary nor permanent impact on fish outside the extraction area.

Noise

The noise from ship traffic and excavation activities will typically be within the sound frequencies of (80-200 Hz and 130-200 dB) which can be perceived by most fish species. The distance in which different species can perceive sounds depends on background noise such as wind, currents and waves – measured to more than 100 dB at 10 Hz during calm conditions (Vella et al. 2001). During strong winds the background noise can be greater than the noise generated during sand extraction (Vella et al. 2001). In addition, the noise from ship traffic can be considerably greater (>150 dB at 100-1000 Hz) (Vella et al. 2001).

Fish species sensitive to sound such as herring and cod can hear intensive noise generated from structures at distances of several kilometers. Depending on the natural and man-made background noise, this could trigger an avoidance response. There is a large uncertainty of the noise levels generated by structures which can trigger avoidance responses of other fish species (flatfish species, sculpins etc.) which are less sensitive to noise.

Overall, avoidance reactions typically occur when fish are 100-200 m from vessels, but particularly noisy vessels may elicit an avoidance response at distances as great as 400 m (Mitson 1995).

In general, potential noise from the excavation vessels and extraction methods may create noise levels triggering some avoidance response by hearing sensitive fish in the near vicinity of extraction, but this will only be temporary and short-term and at most will probably displace fish only short distances from the noise source. The impact is thus negligible to minor.

Threatened and declining species

The species twaite shad, river lamprey, autumn spawning herring *(Clupeaharengus subsp.)*, salmon, cod, eel and sea snail, known to occur in the Krieger's Flak area, are included in the HELCOM list of threatened and declining species of lampreys and fishes (HELCOM 2007), and salmon twaid shad and river lamprey are listed in annex II and V in the Habitats Directive. All these species are widely distributed in the western Baltic and therefore Krieger's Flak is not considered to be an area of specific importance. Only the sea snail *(Liparis liparis)* and herring spawn in the regional marine environment and have demersal eggs that could potentially be affected by material extraction. However, at present there is no documentation that Krieger's Flak is a spawning area for either of these species.

Conclusion
In summary, increase in suspended sediment from the sediment plumes and in noise in periods of intense dredging activity and heavy ship traffic may affect fish in the extraction area and lead to periodical decreases in their abundance in the area. However, fish will with great probability return to the area and an impact on the local fish populations over a longer period is highly unlikely. However, it cannot be ruled out that intensive activity during spawning periods, in particular for stationary species and species with specific habitat or seabed substrate demands (sand eel, sculpins and gobies etc.) will experience a longer (approximately 1-5 years), but not permanent, negative impact on local populations.

Substrate removal, and to a lesser extent deposition in the extraction area will have a considerable, but temporary impact of approximately 1 to 5 years on the prey for demersal fish species. The minor increase in SSC will not have a significant impact on the egg, larvae or fish.

6.7.2 Fishery
The impact on the fisheries due to the dredging operations is a combination of the effects on the fishery resource (fish and shellfish) and on the fishermen's possibility to undertake their fisheries:

- Changes in the distribution of fishery resources (fish)
- Restriction of fishing activities
- Changes in the distribution of fishery with bottom trawl due to obstructions at the seabed

Changes in the distribution of fishery resources (fish)
Changes in distribution of fishery resources can be indirect because of the loss of benthic epi- and infauna or loss of fish habitats. The impact can also be due to noise, which forces the fish to other areas.

The conclusion on the impacts on the fish is given in section 6.5.1. It is concluded that substrate removal and to a lesser extent deposition in the extraction area will have a considerable, but temporary impact of approximately 1 to 5 years on the prey for demersal fish species. Impact from noise and increased suspended sediment concentration is limited.

Assessment of direct losses to fishermen arising from sand and gravel extraction depends entirely on the fishery concerned and the nature of the impacts on it. Only a fishery with trawl is undertaken in the extraction area on Krieger's Flak. A gill net fishery is undertaken in an area close to the extraction area to the West. There is no Danish seine net fishery in or near the extraction area and thus assessment of potential impacts to this type of fishery are not relevant.

It should be mentioned that some fishermen argue that the loss to the fisheries in these circumstances is due to a loss of access to traditional fishing grounds rather than a direct loss of fish. The fish (like the fisheries) will merely be redistributed elsewhere for a period of time. In some circumstances, however, fishermen know that a specific area supports an important, local seasonal fishery of migrating fish. In these circumstances any redistribution of fish or the fisheries may have economic consequences, and the best approach in these circumstances is to plan the timing of extraction operations to allow access to fishermen during this seasonal window.

The impact on the trawl and net fishery within the extraction period (days) is only minor, because fish allocates to other areas, from where they can be fished. Furthermore, if the extraction periods are planned so they avoid the periods where possible migratory fishing can take place; it reduces the impact on the trawl fishery in the area.

When the extraction period has ended the loss of benthic habitat and loss of food for the fish within the extraction area can lead to changes in fish distribution. The duration of this impact is maximal 5 years, where after the food source is expected to have recovered. There is an impact on the trawl fishery due to this substrate removal. The impact is reversible (5 years) and it is expected that the fish stocks in the area will be re-established. The impact on net-fishery is negligible because the impact is limited to the extraction area, where net-fishing does not take place.

The impact on trawl and net-fishery due to suspended sediment and noise is very limited because the impact on the fish stocks is very small (section 6.5.1).

Restrictions of fisheries
In connections with the sand extraction the fishery will be impacted during the sand extraction periods. Because of the risk of collision there will be zones around the extraction activities where fishery is not possible. Regardless of the extent the impact is only expected over a short time period (hours).

In previous projects with extractions of material from the seabed at Krieger's Flak (2004-2005) a close and continual contact with active fishermen in the area, or eventually with a person with fishery knowledge on board the dredging vessel, has shown that this could be a positive measure to reduce the level of possible conflicts.

Changes in the distribution of fishery with bottom trawl due to obstructions at the seabed
As mentioned earlier (section 2.2) all extracted material will be retained in the dredge hopper, and large boulders and stones will not be left at the seabed. Thus bottom trawls are not expected to be obstructed by stones and boulders in this extraction project.

6.8 Birds

In the following the assessment of impacts of the extraction activities on birds is outlined. The assessment is split into the following pressure caused directly by the project and by interaction with other environmental factors:

- localized habitat displacement caused by disturbance from the dredger,
- habitat change caused by reductions in available food supply due either to direct (extraction) or indirect (sediment dispersal) effects of the extraction works, and
- risk of collision with migrating birds.

6.8.1 Non-breeding waterbirds
Habitat displacement effects on waterbirds during sand extraction may vary as a function of the local densities of sensitive waterbird species which regularly use the site. Waterbirds respond in different ways to approaching vessels. While some species are attracted to vessels as they expect food (gulls following fishing vessels) other species show a negative response and flush if a vessel approaches at a certain distance. The response differs not only between species but also in relation to the status of a species in its annual cycle, the function of the area and social structure of waterbird assemblages. Waterbirds are especially sensitive during moult while reaction distances are smaller during the winter months (Thiel et al. 1992). Species like Common Scoter and divers exhibit large response distances of 1–2 km

(Bellebaum et al. 2006, Schwemmer et al. 2011). The response distance usually increases with flock size making large aggregations more vulnerable to disturbance.

Of the species occurring in medium or higher densities at the extraction site four (Red-throated Diver, Black-throated Diver, Long-tailed Duck, Black Guillemot) have been identified as being sensitive to disturbance (Table 6.2). Based on the available information about planned dredger activities it is assumed, that these species will be displaced within the given distance.

Table 6.2 Reported response of waterbirds to shipping (Bellebaum et al. 2006, Schwemmer et al. 2011).

Species	**Response to shipping**
Red-throated Diver (*Gavia stellata*)	1-2 km
Black-throated Diver (*Gavia arctica*)	1-2 km
Great Crested Grebe (*Podiceps cristatus*)	100-500 m
Red-necked Grebe (*Podiceps grisegena*)	100-500 m
Common Eider (*Somateria mollissima*)	100-500 m
Long-tailed Duck (*Clangula hyemalis*)	100-500 m
Common Scoter (*Melanitta nigra*)	1-2 km
Velvet Scoter (*Melanitta fusca*)	1-2 km
Razorbill (*Alca torda*)	100-500 m
Common Guillemot (*Uria aalge*)	100-500 m
Black Guillemot (*Cepphus grylle*)	100-500 m

As the numbers of waterbirds using the area shows strong seasonal variability, the potential habitat displacement of divers, Long-tailed Duck and Black Guillemot will depend on the timing of extraction activities with the largest impacts conceived during winter and spring (November-April). Given the impacted area (10 km^2) and densities of the sensitive species the number of birds which the dredger potentially will disturb will be in the range of less than 100 Long-tailed Ducks and single individuals of divers and Black Guillemots. Accordingly, the habitat displacement impacts on waterbirds in the extraction site will be very small.

The key food resources to waterbirds are mussels and fish. In the site the benthic fauna is dominated by mussels which comprise approximately 90 % of the total benthic biomass. During the extraction period no reduction in the biomass of mussels due to increased concentrations of suspended sediments are expected and disturbance effects on potential benthic prey organisms living in the extraction site are assessed as being limited. As the loss of removed seabed is maximum 10 km^2 the maximum number of impacted Long-tailed Ducks can be estimated at less than 100 individuals. As the recovery time of the mussels is expected to be 5 years, the impacted areas will have no long-term impacts on waterbirds.

Sediment dispersal affecting available food supplies of fish and foraging conditions for diving waterbirds is estimated to be small-scale. The simulations of the dispersal of suspended matter showed that the generated plume due to extraction operations is quickly dispersed, and the plume was mainly located within the extraction area limits and only visible a few days in total. The plume is only detected further away at low concentrations (2-10 mg/l), but only around 2 or 3 km from the dredging area and only about 1-2% of the time and the impact is assessed as being negligible.

6.8.2 Bird migration

The collision risk of generally flying and especially migrating birds is considered a problem particularly in the marine environment. There are no natural obstacles on the migration at sea; birds might be attracted by the lights of the vertical structures, which is a well-known phenomenon from various illuminated structures at sea; in addition, in particular slowly manoeuvring birds and birds flying in formations might misjudge or underestimate the risk; last but not least, in situations of low visibility or inclement weather birds might simply not be able to recognize ships and other the man-made structures, and show strong attraction responses to strong artificial lights.

Many studies on collisions with ships have reported that passerines are being killed in larger numbers than other birds. Large-scale mortality can often be related to the artificial lights used on ships, with strong omnidirectional light potentially attracting and killing the largest numbers of birds (Rich and Longcore 2005). Still, it's important to recall that passerines outnumber other bird species on migration by at least an order of magnitude, and hence the relative impact may not be highest for passerines. In fact, larger species may be more sensitive to collision with ships. Merkel and Johansen (2011) analysed light-induced killings of waterbirds in Greenland waters, and reported up to 88 casualties at a single ship per night. The rate of collision was clearly associated with increment weather conditions and low visibility. However, given the broad front migration of waterbirds at the site, collision risks to migrating waterbirds from the dredging vessel can be expected to be at a low level with no or minor impact on the populations passing the site.

6.9 Mammals

In the following the assessment of impacts of the extraction activities on marine mammals is outlined. The assessment is split into the following pressure caused directly by the project and by interaction with other environmental factors:

- Increased noise
- Increased suspended sediment
- Reduced prey availability

Increased Noise

It is planned that at Krieger's Flak, a Trailing Suction Hopper dredger will be used for the Sand Extraction. For this type of dredger, some measurements of acoustic emission are available (see ITAP 2007 and Robinson et al. 2011). According to them the sound produced by sand extraction is assumed to be of relatively low frequencies; with main energy below 1000 Hz, Figure 6.1, ITAP 2007) though recent investigations indicate that there may be higher frequencies when extracting gravels (Robinson et al. 2011). Figure 6.1 shows the frequency spectrum of the dredging sound in 1/3 octave bands. This kind of representation is suitable for impact assessments since in biological hearing systems, sound is integrated over several frequency filters that are app. 1/3 octave wide (see Thomsen et al. 2006). It can be seen that most sound energy is well below 1 kHz with a steady decline in sound pressure levels at higher frequencies.

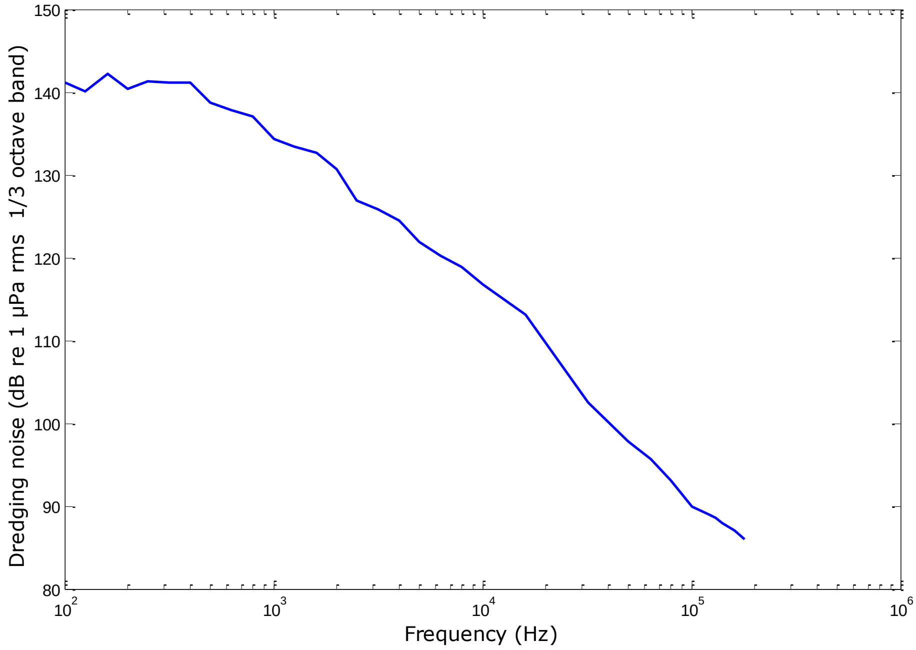


Figure 6.1 Underwater sound from the trailing suction hopper dredger Thor-R (modified from ITAP 2007, extrapolated from 40 to 100 kHz) measured at 300 m distance.

Sound use and hearing in harbour porpoises and harbour seals
The harbour porpoise uses sounds for echolocation and possibly for communication. Echolocation is used to navigate and forage. Harbour porpoise's echolocate by emitting intense ultrasonic clicks and listening for the returning echoes reflected by objects impinged by the sound. The frequency content of the sounds is centred around 130 kHz and has a source level of up to around 200 dB re 1µPa pp (Villadsgaard et al. 2007). There are indications that clicks are used for communication purposes as well, where the clicks are repeated in sequences of stereotyped repetition rates (Clausen et al. 2010).

The hearing capabilities of harbour porpoise have been investigated in several studies (Andersen 1970, Popov et al 1986, Kastelein et al. 2002). In addition to the thresholds of the audiograms harbour porpoise hearing is increasingly directional the higher the frequency. This improves their echolocation capabilities by making them less susceptible to background noise in directions other than the one of the returning echoes (Kastelein et al. 2005). For the impact assessment, the best way of describing hearing is by defining a masked detection threshold such as the one shown in Figure 6.2. For the harbour porpoises, the audiogram by Kastelein et al. (2002) has been used. Together with this the likely ambient sound spectrum at Krieger's Flak as taken from literature data for areas with high shipping has been documented. It can be seen that for lower frequencies (app. up to 800 Hz) detection of the sound by harbour porpoises is depending on the hearing sensitivity (= the red line in the graph). For the higher frequencies (> 800 Hz), detection is depending on the ambient sound levels as the ambient sound levels (blue line) are higher than the detection threshold in the audiogram in Figure 6.2.

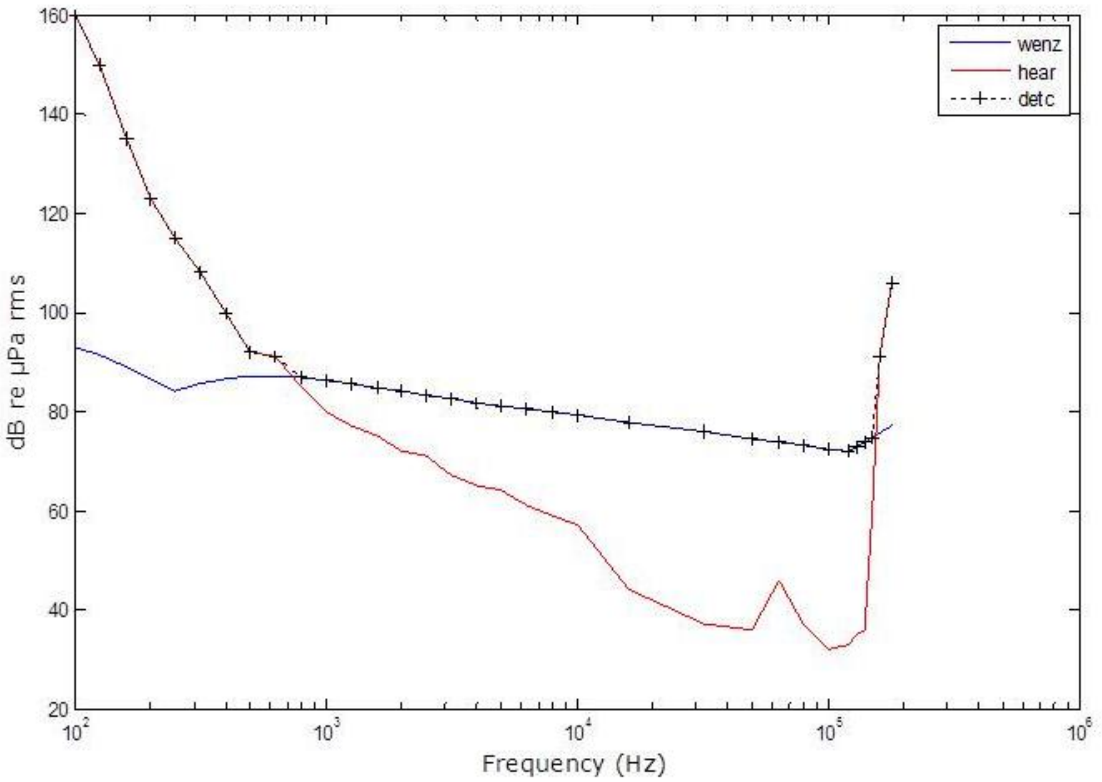


Figure 6.2 The masked detection threshold (+) for harbour porpoise. The red line indicates the audiogram of a harbour porpoise (modified from Kastelein 2002) and the blue line indicates the expected background noise at Krieger's Flak given by the Wenz curve for heavy shipping noise in shallow water. The background noise is measured in 1/3 octave bands.

During the mating season in the summer, male harbour seals maintain underwater territories through long-lasting low-frequency rumbles (van Parijs et al. 2000). Grey seals also use underwater sounds for communication both during and outside the mating season. Both these signals can be affected by noise.

Harbour seals are amphibious animals with acute hearing both in air and under water and their hearing has been studied extensively (Møhl 1968, Kastak and Schusterman 1998). The hearing of grey seals on the other hand has only been investigated in a single study (Ridgway and Joyce 1975). In the grey seal study auditory evoked potentials were used, which is not directly comparable to the psychophysical data obtained from harbour seals. Still, grey seal hearing abilities are assumed to be comparable to the hearing abilities of harbour seals (Schusterman 1981, Richardson et al. 1995) and hearing thresholds for harbour seals are generally recommended as a conservative estimate for the hearing thresholds of other phocids (Southall et al. 2007). The masked detection threshold for the harbour seal is given in Figure 6.3. It can be seen that for seals, that have a very good hearing in the lower frequencies, detection is solely depending on the ambient sound level.

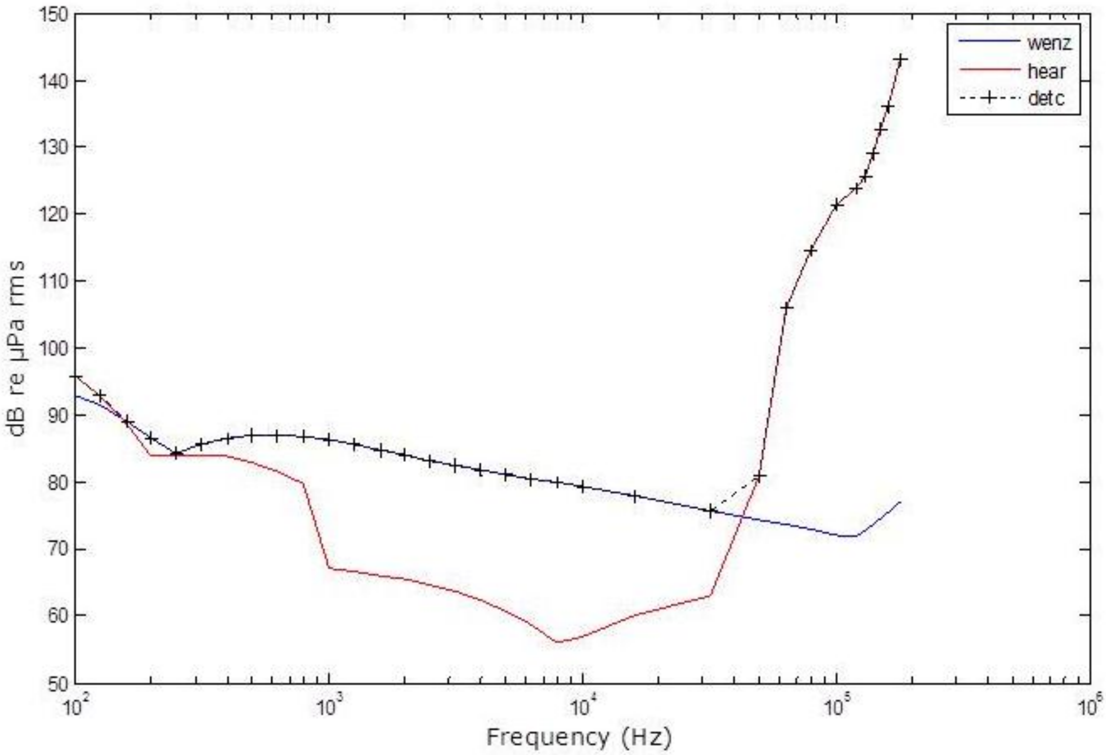


Figure 6.3 The masked detection threshold (+) for harbour seal. The red line indicates the audiogram of a harbour seal (modified from Kastak and Schusterman 1998, Møhl 1968) and the blue line indicates the expected background noise at Krieger's Flak given by the Wenz curve for heavy shipping noise in shallow water. The background noise is measured in 1/3 octave bands.

Estimated impact zones for sound

The effect of sound on marine mammals can be divided into four general categories that largely depend on the individual's proximity to the sound source:

- Detection
- Masking
- Behavioural changes
- Physical damages

It is important to realise that the limits of each zone of impact are not sharp and that there is a large overlap between the different zones. Furthermore, especially behavioural changes, masking and detection critically depends on the background noise level and the behavioural and physiological states of the animals.

In the first step, the detection thresholds of the sound source was obtained by comparing the masked detection threshold of the harbour porpoise and the harbour seal (see Figure 6.2, Figure 6.3) with the 1/3 octave sound from the source extrapolated to different distances. The ranges at which underwater sound sources can be detected by marine mammals are in many cases surprisingly large: for pile driving operations they can extend many tens or perhaps hundreds of kilometres (Thomsen et al. 2006; Tougaard et al. 2009).

In Figure 6.4 and Figure 6.5 the detection range for harbour porpoises and harbour seals is shown. It can be seen that – depending on the frequency – dredging sound can be detected over quite large ranges by both species with an overall larger detection zone for harbour seals compared to porpoises. Seals have a better hearing sensitivity at lower frequencies where the dredger has most acoustic energy than harbour porpoises.

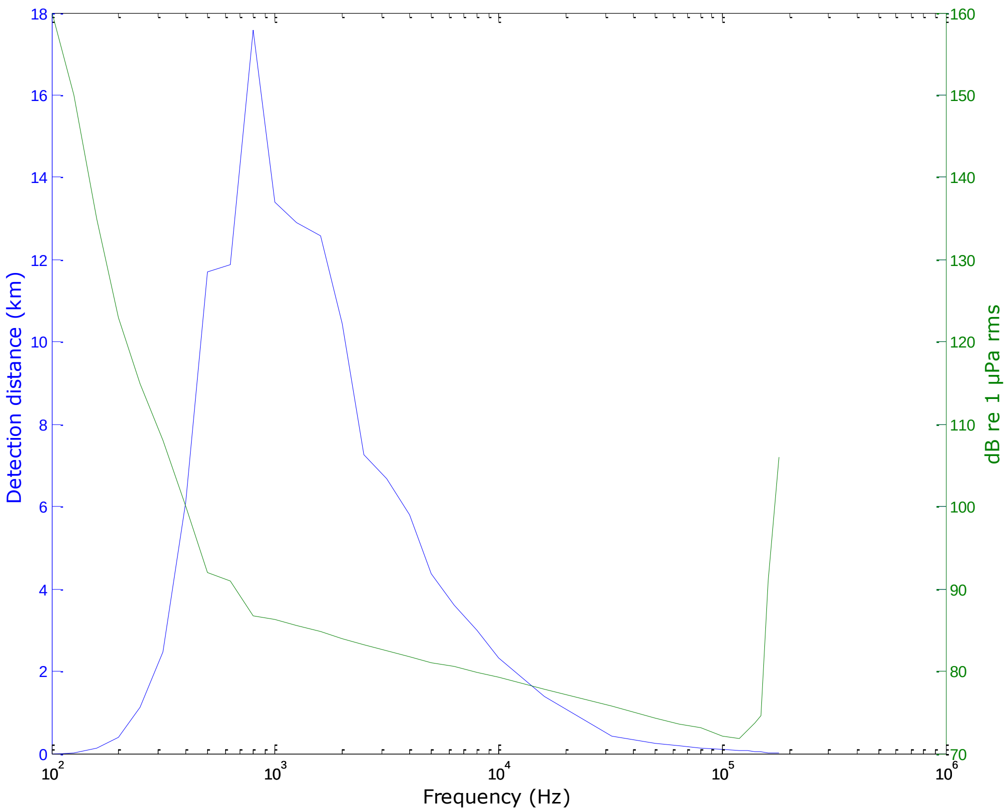


Figure 6.4 Dredging noise detection by the harbour porpoise. The green line is the masked hearing threshold (from Figure 5.7) and the blue line shows the detection distance for the different frequencies, calculated assuming spherical spreading and normal frequency dependent absorption, and also assuming that the dredging sound is detectable at distances where the background noise and the dredging sound is of the same intensity.

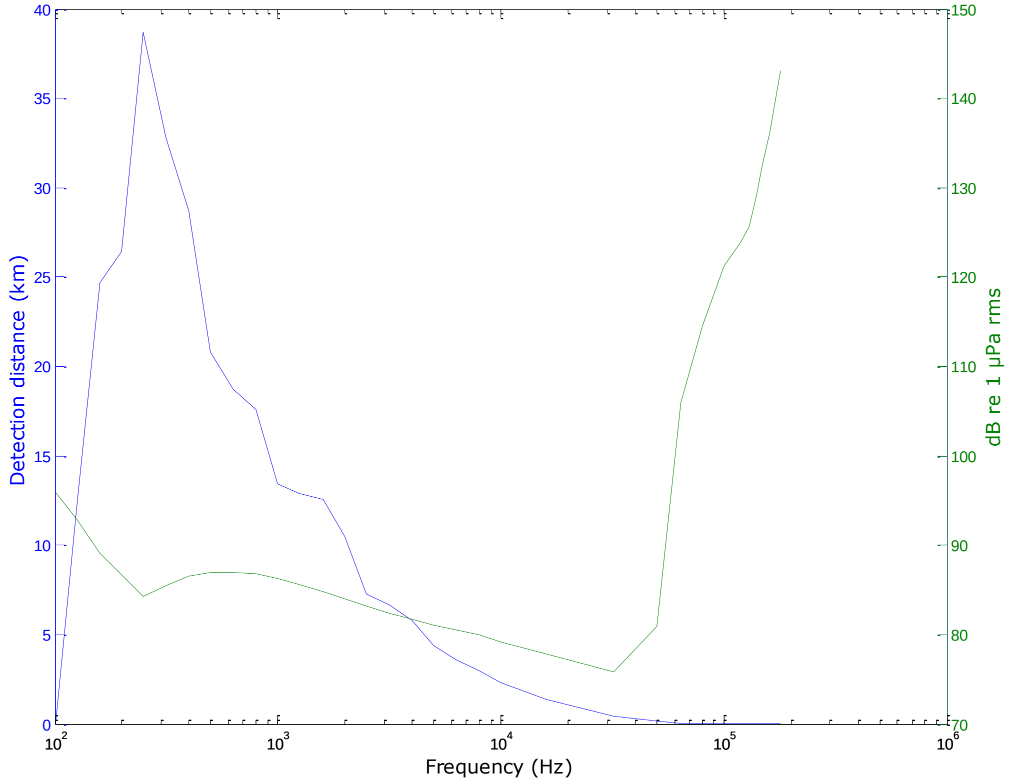


Figure 6.5 Dredging sound detection by the harbour seal. The green line is the masked hearing threshold and the blue line shows the detection distance for the different frequencies, calculated assuming spherical spreading and normal frequency dependent absorption, and also assuming that the dredging sound is detectable at distances where the background noise and the dredging sound is of the same intensity.

Masking of biological relevant signals by the dredging sound can happen anywhere in the detection zone. Harbour porpoises rely heavily on acoustic signals for all aspects of foraging and navigation but may also use acoustic signals during e.g., sexual displays. Masking of any of these signals may have serious consequences for the overall fitness of the animal. Yet, as porpoises use sounds in the ultrasonic range where dredging sound energy is potentially very minimal, harbour porpoise signals are not likely to be masked by dredging.

Seals, on the other hand, may rely heavily on their hearing for especially foraging and social interactions. Masking of relevant signals by noise can therefore have serious implications for seals. The range within which masking (i.e. the reduction in detection distance to a sound source due to increased levels of noise) takes place does not have a well-defined limit but depends very much on the strength of the signal to be detected by the animal and the frequency overlap between biological signal and noise. For seals it is especially communication signals that may be masked, but also signals important for navigation and prey detection can be affected. However, due to the uncertainty over signal strength in seals, no impact ranges for masking can be given.

The behavioural changes can potentially range from strong reactions such as panic or flight to more moderate reactions where the animal may orient itself towards the sound or move slowly away. However, behaviour is inherently difficult as the animals' reaction may depend on season, behavioural state, age, sex, as well as frequency and time structure of the sound causing behavioural changes. This does, however, not mean that behavioural changes should not be considered, since behavioural changes in some cases may be the only impact.

Southall et al. (2007) defines behaviour on a scale of 0 to 9, where 0 is no behavioural change and 9 is regular panic. This scale can be reduced to 3 categories based on the severity of the behavioural changes (≥6; 5-4; 3-0). For the harbour porpoise the exposure limits for behavioural changes given by Southall (2007) are 80 dB re 1 μPa rms for category 0-3, 100 dB re 1 μPa rms for category 5-4, and 120 dB re 1 μPa rms for category ≥6. Behavioural changes in seals caused by underwater sound are according to Southall et al. (2007) 120 dB re 1 μPa rms for the 0-3 category and 130 dB re 1 μPa (rms) for the 4-5 category. These values are all based on pulsed sounds but may give an indication of which levels can cause behavioural changes. Measurements in the nearby Fehmarnbelt Area indicate that ambient background noise levels in in the region are exceeding 120 dB re 1 μPa at many places. These levels are similar or in excess to the levels for behavioural changes in the higher category behaviour changes given by Southall et al. (2007). It is therefore unlikely that porpoises would react to sound at these levels. If the dredging sound exceeds these relatively high background noise levels, or if the sound at certain frequencies exceeds the masked threshold this could elicit behavioural changes (Table 6.3). If animals stay in an area where they are exposed to high noise levels it is likely that they habituate to these levels. Therefore, it is possible that any behavioural changes caused by dredging in Krieger's Flak with its supposedly relatively high background noise levels may be more similar to the lower category behaviours in Southall et al. (2007) even though the sound levels exceed the threshold for the higher categories. Recent research indicates that harbour porpoises leave areas during sand extraction at distances of at least 600 m. However, the reactions were relatively short term (Diederichs et al. 2010). The impact on the behaviour is regarded as insignificant.

Physical damages to the hearing apparatus lead to permanent changes in the animals' detection threshold (PTS) which are caused by the destruction of sensory cells in the inner ear. If hearing loss does occur it is usually only temporary (TTS) and the animal will regain its original detection abilities within a few hours. PTS has not been investigated in the harbour porpoise, but a study by Lucke et al. (2009) measured TTS in the harbour porpoise when exposed to a single sound pulse and found a TTS limit of 199.7 dB re 1 μPa pp. For harbour seals Southall et al. (2007) gives at PTS limit of 218 dB re 1 μPa peak (above which PTS may occur) for seals under water, this value is based on a study of a single animal. For seals under water the TTS limit defined by Southall et al. (2007) is 152 dB re 1 μPa rms and is, once again, based on studies of a single harbour seal (the same individual also used for the PTS data).

Table 6.3 lists the effects and the maximum range from the sound source at which behavioural and physical effects may occur. For both porpoises and seals TTS effects on single animals may take place at very short distances from the dredger. Given the low density of harbour porpoise on Krieger's Flak the number of animals potentially displaced by dredging activities will also be very small, and hence the habitat displacement impact will be negligible. No habitat displacement is predicted for seals. More long term behavioural implications of noise in the Baltic Sea have been investigated for the harbour porpoises during construction of the Nysted wind farm, and though the porpoises initially left the area (Carstensen 2006) there seems to be little long term effect of wind farms on the porpoise population (Nabe-Nielsen 2011). The impact is hence insignificant.

Table 6.3 Maximum distance for PTS, TTS, behavioural changes and detection of Thor-R assuming spherical spreading and frequency dependant absorption. Thresholds for PTS and TTS for harbour seals are from Southall et al. (2007) and TTS threshold for harbour porpoise is from Lucke et al. (2009).

Impact type	Threshold for harbour porpoise (dB re 1 µPa rms)	Maximum range	Threshold for harbour seal (and grey seal) (dB re 1 µPa rms)	Maximum range
PTS	-	-	218 (p)	-
TTS	200 (pp)	< 1 m	152	17 m
Behaviour ≥6	120	600 m	-	-
Behaviour 4-5	100	7 km	130	200 m
Behaviour 0-3	80	-	120	600 m
Detection		18 km		38 km

Suspended sediment and
The extraction activities will inevitable cause sediment dispersal affecting the transparency of the local areas. The extension/propagation of the plumes is strongly dependent on the local current conditions at the time of construction. However, sediment plumes are not expected to cause any direct impact on seals and porpoises, but may reduce the availability of prey, especially juvenile fish. However, since the affected areas are expected to be very small compared to the total area available to the animals on Krieger's Flak and the duration of the impact is short, the impact is regarded as insignificant.

Prey availability
The effect on availability of prey is assessed as very low. Especially juvenile fish are sensitive and some effect is expected during the extraction period (section 6.5.1). However, since the affected areas are expected to be very small compared to the total area available to the animals on Krieger's Flak and the duration of the impact is short, no significant negative impact due to sediment dispersal are expected.

Overall conclusion
The overall conclusion is that the impact on the marine mammals present in the area is very low and insignificant on a population level.

6.10 Marine archaeology

Within the extraction area three ship wrecks are registered in a database held by Heritage Agency of Denmark. Actions should be taken to provide information of wreck positions to the dredger captain to avoid destruction by the dredging activity. However, all three wrecks are located outside the area recommended for extraction. Ship wrecks outside the extraction area (including the two observed by the side scan study) will not be impacted by the project as no activities influencing the seabed will take place here. Furthermore, settlements have not been registered, nor will they be in risk of being impacted by the sand extraction due to the deep layer of sand, which has been deposited on topabove. No impact is therefore predicted for marine archaeology.

6.11 Material assets, ammunition and recreational interests

6.11.1 Cables
There are no cables in the extraction area.

6.11.2 Ammunition

It is assessed that there is no risk due to ammunition, as the findings at Krieger's Flak in connection with previous extraction activities have been very sporadic and sparse.

6.11.3 Navigation and recreational interests

The impact on the ship traffic due to dredging activities can be:

- Increase in ship traffic
- Change in sailing routes
- Risk of collision

Heavy ship traffic occurs in the Baltic Sea, but all the main traffic routes passes around Krieger's Flak. Sand extraction will generate a between 800 and 1,428 cargos of sand between the working area for the fixed link and Krieger's Flak (120 km) in a period of 2-3 years. Compared to the current ship traffic in Fehmarnbelt the increase is regarded as negligible (approximately 38,000 ships in 2010 and an additional 34,000 crossing ferries per year). A smaller amount of traffic passes across Krieger's Flak and minor impact may occur for this traffic as they may have to change their sailing route to avoid the extraction area. The risk of collision is regarded as low because there is sufficient of areas which the traffic can relocate to. The ship traffic in the area is not restricted to channels (fairways) within the extraction area and ship traffic can change sail routes.

The impact on navigation and recreational ship traffic is regarded as negligible.

7 NATURA 2000

7.1 Baseline description

Natura 2000 is a network of protected areas in the European Union. The network includes areas designated under the Habitats Directive and the Birds Directive. The aim of the network is to ensure favourable conservation status designation basis of the area. The designation basis is composed of a number of physical habitats and species.

The only Natura 2000 close to the extraction area is Danish site 171, Klinteskoven and Klinteskov Kalkgrund, which is located 20 km west of Krieger's Flaks (Figure 7.1). Natura 2000 site 171 includes habitat site H207 Klinteskov Kalkgrund containing the marine elements: Sandbanks which are slightly covered by sea water all the time (1110) and Reefs (1170) (Miljøministeriet 2011).

The nearest German Natura 2000 site is DE1339301 Kadetrinne, situated 53 km from the extraction area. The designation basis for the area is Reefs (1170) and Harbour porpoise (*Phocoena phocoena*). The Kadetrinne transverses the Darss ridge from SW to NE. It comprises of a number of small trenches (or ditches) which are down to 32 m deep. The flanks of these trenches are in many parts large stone reefs.

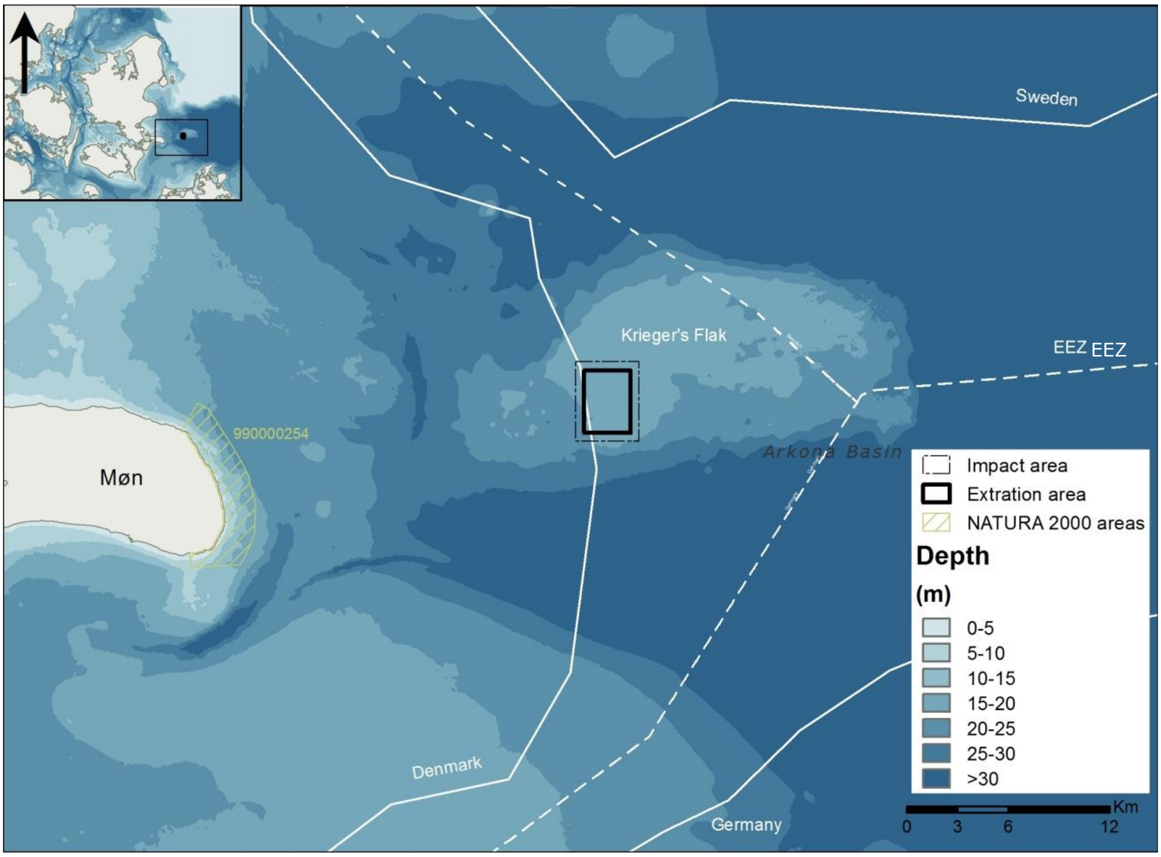


Figure 7.1 Natura 2000 site 171, habitat site H207 Klinteskov Kalkgrund.

7.2 Screening

7.2.1 Pressures on habitats

Klinteskoven and Klinteskov Kalkgrund

There are several environmental pressures on the habitats and the associated flora and fauna (no designated), which should be taken into consideration if the area will be used for sand extraction. All pressures are regarded as temporary.

One pressure have been identified as a potential threat to the Natura 2000 areas and the habitat types which forms the basis for the designation (*"Sandbanks, which are slightly covered by sea water all the time" (1110)* and *"Reefs" (1170)*:

- Excess deposition, which causes changes in the structure of the sandbanks and reefs;

Furthermore following pressures can potentially have an indirect impact on the associated flora and fauna:

- Changes in benthic flora communities on the sandbanks and reefs due to increased suspended sediment concentration and reduced light penetration;
- Changes in the benthic fauna community due to excess deposition and/or increased suspended sediment concentration;
- Changes in phytoplankton concentration due to released nutrients, which can change the water quality;
- Changes in flora and fauna communities due to released toxic substances and decreased oxygen concentration due to released organic material from dredged sediment.

None of these pressures are relevant pressure for the sand extraction project and impact from Krieger's Flak sand extractions is very unlikely and will therefore not affect the Natura 2000 area or the designation basis significantly. The maximal extension of the suspended sediment plume (areas with concentrations over 2 mg/l) is 5 km and hence far from the Natura 2000 area. The impact assessment on coastal morphology (section 6.2.1) documented that there will be no effects on the coast of Møn. Model simulations of suspended sediment concentrations (SSC) and deposition of sediment show that the SSC and deposition area is far from the Natura 2000 site 171 Klinteskov and Kalkgrund (section 5.2). Similarly, other pressures would not have long distance effects. Furthermore it should be noted that there is no risk of cumulative impacts on the Natura 2000 area with the fixed link, as the impacts from the extraction will be local. It is therefore not necessary to prepare an appropriate assessment.

Kadetrinne

The Kadetrinne is situated 53 km from the sand extraction area at Kriegers Flak. The maximal extension of the suspended sediment plume (areas with concentrations over 2 mg/l) is 5 km and hence there is not risk of impact on the reefs in the Natura 2000 area. The detection limit for Harbour porpoise (*Phocoena phocoena*) is 18 km and behavioural reactions are expected at distances much shorter than that (7 km and 600 m, respectively) (Table 6.3), thus the animals in the area will not hear the noise from the sand extraction 53 km away. There is therefores no risk of any significant impacts and it is therefore not necessary to prepare an appropriate assessment

8 CUMULATIVE IMPACTS

Cumulative impacts are defined as the aggregated impact from the Fehmarnbelt Link project and projects that are carried out at the same time. Projects, which may take place within the same geographical area, and at the same time has been considered although the exact timing and extension of the projects is uncertain.

The Danish Ministry of Climate, Energy and Building has recently published an update of the Danish Strategy for localisation of the future wind farms until 2025 (Danish Ministry of Climate, Energy and Building 2011). These plans include three wind parks at Krieger's Flak with a total capacity of 600 MW. It has recently been decided politically to establish an offshore wind park in the Danish part of Krieger's Flak. However, no implementation date is included in the plans. There is competing interest at Krieger's Flak because Krieger's Flak contains big resources for mining extraction. The present EIA describes the extraction of sand from Krieger's Flak. Agreement has been obtained between the Danish Energy Agency and the Nature Conservation Agency to allocate the central parts of Krieger's Flak for mining extraction. This means that the planned wind park will not affect the sand extraction at Krieger's Flak.

The German company EnBW (EnBW 2011) has got the permission to build a wind park named Baltic II in the German EEZ at the eastern part of Krieger Flak just south of the EEZ boarder with Sweden. The wind park will consist of 80 wind mills and is expected to be built from 2014. The expected date for operation is currently not known.

The sand extraction is planned to take place from June 2016 to November 2018 and since the windfarm projects at Krieger's Flak are either not scheduled or planned to begin construction in 2014, there is a risk of cumulative impacts. It is foreseen that there will be an impact on the benthic fauna in the locations of the planned wind parks (IFAÖ 2003 and Sweden offshore wind A/B 2007). The impact is limited to the areas close to the wind farms. In addition, the distance between the wind parks and the extraction area is large. The impacts from the current project on the benthic fauna communities and the consequently minor impacts on the fish will only be temporary and full recovery is expected within a time period of five years. Thus, cumulative impacts are not foreseeable netiher with respect to the benthic fauna nor fish and it is assessed that the mutual impact from the projects will not affect the ecological function of the concerned region of the Baltic Sea.

In summary, no significant cumulative impacts are likely between the sand extraction and the wind park projects

Since in the near future Krieger's Flak will be developed into a region with relatively intense human activities, this can cause disturbance and habitat displacement on waterbirds and marine mammals. Depending on the time schedules for constructing the wind farms these impacts will be augmented by the planned dredging activities. It is expected though that since the impact from the dredging activities is regarded as having negligible impact on the birds and mammals, the cumulative impact will also be negligible.

9 MITIGATION AND COMPENSATION

9.1 Sand Extraction Strategy

The volume of approximately 6 mill m^3 sand needed for the backfilling work can be produced in a sub-area of the designated extraction area to minimize the physical and biological impacts. Figure 9.1 shows a recommendation of such a sub-area and Table 9.1 gives the coordinates of the rectangle. The sub-area is 2 x 3 km (6 km^2; i.e. reducing the impacted area by 40 %). Limiting the extraction area requires that 1-2 m of the seabed can be extracted. At the recommended sub-area the resource thickness is more than 4 m. Thus, the extracted part of the seabed is constrained to the Litorina sand, and layers of potential marine archaeological interest, such as potential submerged Stone Age settlements, are not at risk as these layers are expected to be covered by approximately 4 m of sand.

Mitigation of impacts on fishery can be carried out by a close and continuous contact with active fishermen in the area, or with a person with knowledge on fishery onboard the dredging vessel; a measure which has proven to be able to reduce the level of possible conflicts.

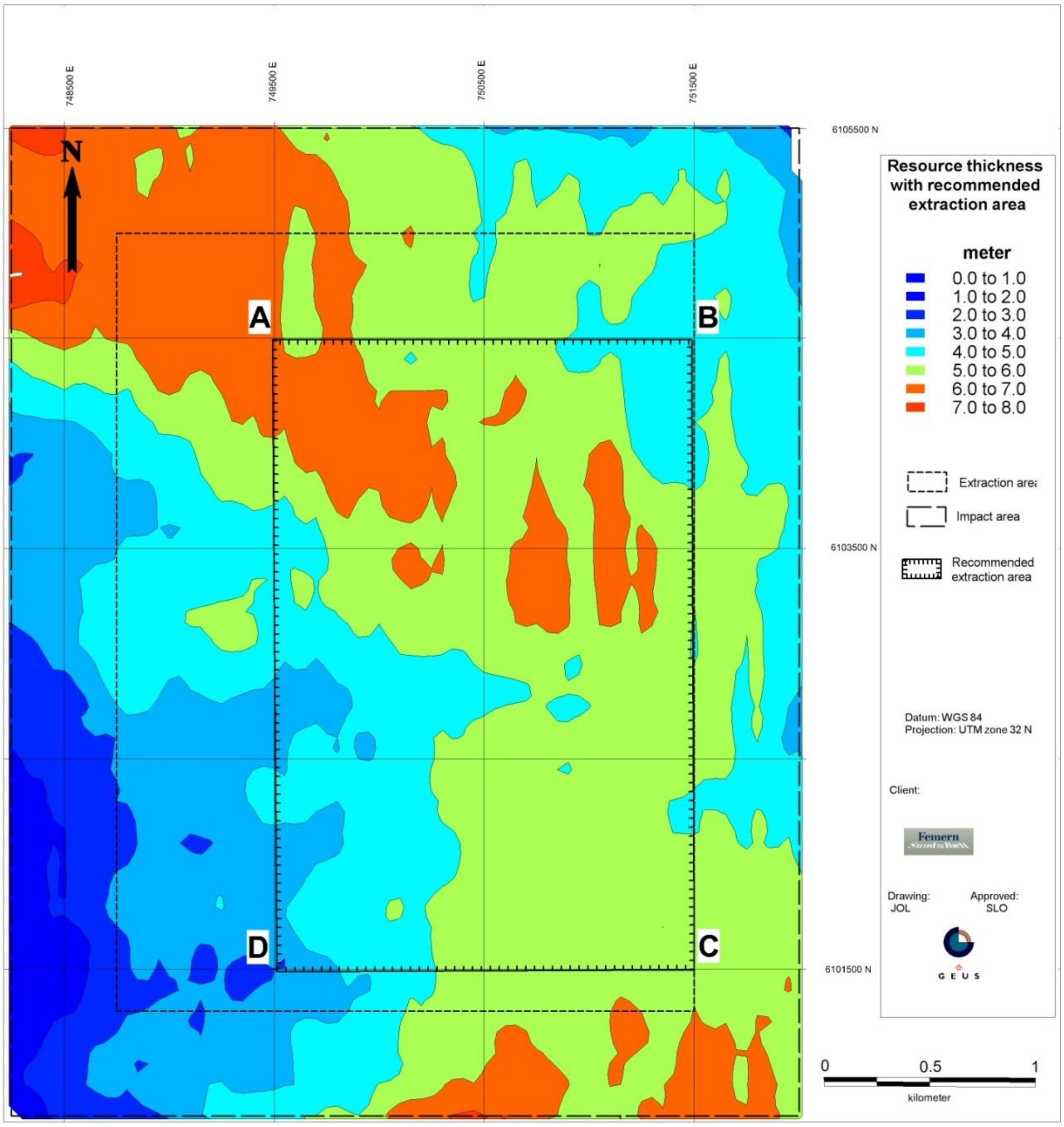


Figure 9.1 Resource thickness of Krieger's Flak including the sub-area recommended for extraction. Figure also found in A3 in appendix F.

Table 9.1 Coordinates for the recommended extraction area. The points refer to Figure 9.1

Recommended area	Easting	Northing	Longitude	Latitude
A	749500	6104500	12 54.22683	55 01.47707
B	751500	6104500	12 56.09949	55 01.41667
C	751500	6101500	12 55.94130	54 59.80294
D	749500	6101500	12 54.06989	54 54.06989

10 KNOWLEDGE GAPS

No major gaps which weaken the impact assessment are identified. This EIA is based on expert knowledge based on scientific references and on data collected as part of the baseline study. Some uncertainties linked to the background material or the related investigations have been observed and addressed in the relevant assessment sections.

11 MONITORING PROGRAMME

Femern has assessed that the monitoring programme at Krieger's Flak should contain the following:

Phase 1: Investigation of the environmental conditions before the extraction takes place.

The seabed shall be mapped by side sonar scan and video recordings along transects within the extraction area. Samples of sediments shall be taken for the evaluation of the physical and chemical conditions of the seabed. Besides this, benthic fauna samples shall be taken at sampling stations in the area. Furthermore, video monitoring of flora shall be done.

These investigations have already been carried out.

Phase 2: Surveillance of the environmental conditions during extraction

Investigations of water discharge from the overflow from the dredger by spot tests. The investigations are executed to verify that the assumptions for the predicted sediment spill calculations (spill rate, grain size distribution and settling velocities) are correct. This also contributes to the certainty about the environmental impact assessment.

Phase 3: Documentation of the environmental conditions immediately after ended extraction activities

Side scan and video inspections of the seabed shall be performed along transects in the areas and it can possibly, after agreement with the Danish Nature Agency, be used to document the reestatblishment of the seabed.

12 ENVIRONMENTAL IMPACTS AND OVERALL CONCLUSION

The overall conclusion on the environmental impact assessment is that there will be impacts on the marine environment within the extraction area. The impact is due to loss of seabed in dredged areas, which causes loss of the benthic fauna community and habitat of the area, which again indirectly leads to impacts on the fish, birds and fishery. The impacts are however considered insignificant as they are recovered within a five-year period after the end of extraction. For migratory birds and mammals noise and light from dredging activities will be disturbing. As they exploit an area much larger than the impact area, this impact is also insignificant.

The physical impact on the seabed will be limited to the dredged areas, i.e. a maximum of 10 km^2, and the impacts will be recovered within 5 to 10 years.

The most severe biological impact is loss of benthic fauna as a consequence of the loss of a maximum of 10 km^2 seabed. Compared to the wide occurrence of the fauna community of the area, the Cerastoderma community, the lost area is small. The recovery time for the benthic fauna is maximally 5 years.

The impact on the fish and fishery is in summary: The increase in suspended sediment from the sediment plumes and in noise in periods of intense dredging activity and heavy ship traffic may affect fish in the extraction area and lead to periodical decreases in their abundance in the area. However, fish will with great probability return to the area and an impact on the local fish populations over a longer period is highly unlikely. However, it cannot be ruled out that intensive activity during spawning periods, in particular for stationary species and species with specific habitat or seabed substrate demands (sand eel, sculpins and gobies etc.), will experience a longer (approximately 1-5 years), but not permanent, negative impact on local populations.

Substrate removal, and to a lesser extent deposition in the extraction area will have a considerable, but temporary impact of approximately 1 to 5 years on the prey for demersal fish species.

The impact on the trawl and net fishery within the extraction period (days) is only minor, because fish allocates to other areas, from where they can be fished. Furthermore, if the extraction period is planned to avoid the periods when possible fishing for migratory fish takes place, this will reduce the impact on the trawl fishery in the area.

When the extraction period has ended, the loss of benthic habitat and loss of food for the fish within the extraction area can lead to changes in fish distribution. The duration of this impact is maximally 5 years, whereupon the food source is expected to have recovered. There is an impact on the trawl fishery due to this substrate removal. The impact is reversible (5 years) and it is expected that the fish stocks in the area will be re-established. The impact on net-fishery is negligible because the impact is limited to the extraction area, where net-fishing does not take place.

The impact on trawl and net-fishery due to suspended sediment and noise is very limited because the impact on the fish stocks is very small.

An impact on the undertaking of fisheries is only short term (during the extraction period). The extent of this impact will depend on when and for how long the extraction vessel will be in trawling routes and whether there will be zones restricting the fisheries during this time. Regardless of the extent the impact is only expected to last a short period (days).

In previous projects with extractions of material from the seabed at Krieger's Flak (2004-2005) a close and continuous contact with active fishermen in the area, or eventually with a person with fishery knowledge on board the dredging vessel, has shown that this could be a positive measure to reduce the level of possible conflicts.

The waterbirds will temporarily be displaced from the extraction area due to habitat displacement and habitat change on the extraction site. However, considering the size of the area and the impact on the benthic fauna, the impact will be insignificant (less than 100 Long-tailed Ducks and single individuals of divers and Black Guillemots are predicted to be affected). The impacts will mainly take place during winter and spring (November-April). Depending on the use of artificial lights on the dredging vessel, collisions with migrating waterbirds and landbirds will take place during periods of low visibility. However, given the broad front migration at the site collision risks to migrating waterbirds from the dredging vessel should be expected to be at a low level.

The planned sand extraction activities on Krieger's Flak will have little impact on harbour porpoises and seals in the area. There are few animals in the area and the sound levels are not assumed to affect the animals except at very close range.

Ship traffic might be displaced in the dredging period. However, no major ship routes pass Krieger's Flak.

Finally, there is no impact on the Natura 2000 site 171 on the east coast of Møn, 30 km away from the extraction area. Neither the coastal morphology, nor the conservation status of the designated sand banks and reefs will be impacted.

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APPENDICES

A P P E N D I X   A

Sampling and analysis of baseline data on benthic biology

Survey programme

The benthic biology survey programme at Krieger's Flak included:

- Collection of quantitative samples of the benthic fauna at 20 stations
- Collection of sub-samples of surface sediment at 20 stations
- Biological screening based on underwater-video records at 20 stations; supportive to fauna sampling and applied for description of occurrence of benthic flora

Allocation of sampling stations

The 20 sampling and video survey stations were allocated in consultation with GEUS on the basis of the results of the surveys of the sediment types conducted by GEUS. The stations were placed with the aim to represent differences in seabed characteristics and water depths both in the extraction area (10 stations) and in the 500 m wide impact area (10 stations) around the extraction area.

At a meeting between Naturstyrelsen and Femern A/S the positions of the sampling stations were agreed upon before the field surveys was initiated.

However, during the field surveys, it proved necessary to move 3 stations (K-9, K-10 and K-20) to nearby alternative positions named K-9.1, K-10.1 and K-20.1 due to hard and stony bottom which could not be sampled (Table 1).

Table 1 Position and water depth at the surveys stations at Krieger's Flak in August 2011.

Station	Longitude WGS84	Latitude WGS84	Water depth m	Sampling depth cm
K-1	12° 53.465	55° 01.872	17.9	13
K-2	12° 54.959	55° 01.914	17.5	17
K-3	12° 54.054	55° 01.572	17.9	11
K-4	12° 55.175	55° 01.506	18.0	13
K-5	12° 53.310	55° 01.320	18.5	15
K-6	12° 55.600	55° 01.164	18.4	11
K-7	12° 56.291	55° 01.140	18.5	13
K-8	12° 54.427	55° 01.062	18.7	14
K-9.1	12° 53.090	55° 00.990	19.7	13
K-10.1	12° 53.880	55° 00.718	18.5	13
K-11	12° 55.535	55° 00.756	17.8	14
K-12	12° 53.310	55° 00.498	20.8	14
K-13	12° 54.094	55° 00.378	19.4	11
K-14	12° 56.224	55° 00.336	18.5	15
K-15	12° 54.801	55° 00.246	18.5	14
K-16	12° 53.571	55° 00.174	20.5	10
K-17	12° 54.156	54° 59.922	19.6	10
K-18	12° 56.103	54° 59.718	19.5	14
K-19	12° 53.044	54° 59.688	20.1	11
K-20.1	12° 54.789	54° 59.649	19.5	15

Sampling of benthic fauna and sediment

One (1) van Veen sample (unit area: 0.1 m^{-2}) was collected at each station. The quality of the sample was inspected through a lid on top of the sampler. The penetration of the grab sampler into the sediment was measured, cfr. Table 1. A sub-sample of the uppermost 5 cm of the sediment was collected in a marked plastic bag, stored in a cooling box and later frozen until analysis.

The sampler was opened and emptied into a tub. The structure, colour and stratification of the sediment were noted in a field log.

Water was added and the sediment was gently suspended and sieved through a 1 mm floating sieve. The sieving residue including the benthic fauna was transferred to a plastic bucket and fixated in 4 % buffered formaldehyde. The bucket was marked with area, date and station number on the outside and a note with similar information was placed inside the bucket.

The field surveys were conducted 18 august 2011 using the ship JHC-Miljø. The water depth at the stations was recorded from the echo-sounder of the ship.

Underwater-video surveys

In addition to the sampling of benthic fauna and sediment a biological screening of the seabed was conducted at the 20 stations (BEK nr. 1452 af 15/12/2009).

An underwater-video mounted on a frame was lowered close to the seabed. The quality was monitored on a screen and a record of 2-3 minutes duration was obtained while the ship was maintained in position as far as possible. The video-surveys were conducted 22 and 23 August 2011 using DHI's ship DHIVA.

Representative pictures at each station are presented in Appendix D.

Laboratory analysis – benthic fauna

The samples were analyzed at Dansk Biologisk Laboratorium. Dansk Biologisk Laboratorium is a part of the FEMA group. The fauna method has been harmonized in connections to the Femarnbelt Fixed Link baseline studies, and the used method is identical to the method use for the baseline study of the Fehmarnbelt area (FEMA 2011).

In short, each of the 20 samples was treated individually. The samples were sieved in a 0.5 mm sieve in order to remove formaldehyde before sorting. All animals were sorted out using a sorting lamp and the sorting efficiency was controlled using a low power microscope. The animals were identified to species level (except for Oligochaeta) and counted. The shell length of bivalves was measured with a digital caliper.

The total biomass of the individual species including shells of bivalves was determined as total wet weight, dry weight at 105°C in 18-24 hours or until stabile weight was reached and as ash free dry weight (AFDW) after burning in a muffle oven at 550°C for 2 hours.

Laboratory analysis – sediment

The samples were analysed at the DHI for the following variables:

- Dry weight (DW) - expressed in % of the wet weight (WW)
- Loss on ignition (LOI) - a measure of organic matter expressed in % DW
- Median grain size of the sediment (D_{50}) – expressed in µm
- Silt/clay fraction (SC) below 63 µm of the sediment – expressed in % DW

Dry weight and loss on ignition was analysed according to DS 204 and the mechanical sieve analysis and determination of median grain size and silt/clay fraction according to FEHY (2011).

Statistical analysis

The software package Primer v5 (Clarke and Gorley 2001) was used to analyze the structure of the benthic community based on fourth root transformed abundance and biomass data (AFDW) and Bray-Curtis similarity. Environmental data (depth and the variables measured in the sediment) were transformed (log x+1) and similarity calculated as Euclidean distance.

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A P P E N D I X   B

Benthic fauna - species and abundances

Taxa	Species	K-01	K-02	K-03	K-04	K-05	K-06
Polychaeta	*Alitta succinea*	0	0	0	0	0	0
Polychaeta	*Bylgides sarsi*	30	0	0	0	10	0
Polychaeta	*Hediste diversicolor*	20	10	30	50	30	10
Polychaeta	*Marenzelleria viridis*	150	50	80	120	330	130
Polychaeta	*Ophelia rathkei*	10	10	0	0	0	0
Polychaeta	*Pygospio elegans*	150	120	70	70	310	70
Polychaeta	*Scoloplos armiger*	0	0	0	0	0	0
Polychaeta	*Travisia forbesii*	0	0	0	0	0	0
Oligochaeta	Oligochaeta	0	0	0	20	10	0
Bivalvia	*Cerastoderma edule*	0	0	0	0	0	0
Bivalvia	*Cerastoderma glaucum*	0	0	0	0	10	20
Bivalvia	*Macoma balthica*	10	50	170	20	30	20
Bivalvia	*Mya arenaria*	10	30	20	10	50	30
Bivalvia	*Mytilus edulis*	280	0	0	70	160	0
Gastropoda	*Hydrobia ulvae*	10	0	0	0	10	0
Crustacea	*Bathyporeia pilosa*	0	0	10	0	0	0
Crustacea	*Diastylis lucifera*	0	0	0	0	0	0
Crustacea	*Diastylis rathkei*	0	0	0	0	0	0
Crustacea	*Gammarus salinus*	0	0	0	0	10	0
Crustacea	*Gammarus zaddachi*	0	0	0	0	10	0
Crustacea	*Neomysis integer*	0	0	0	0	0	0
Abundance (m^{-2})		**670**	**270**	**380**	**360**	**970**	**280**
Number of species (0.1 m^{-2})		**9**	**6**	**6**	**7**	**12**	**6**

	Species	K-07	K-08	K-09-1	K-10-1	K-11	K-12
Polychaeta	*Alitta succinea*	0	0	0	0	0	0
Polychaeta	*Bylgides sarsi*	0	0	50	0	0	20
Polychaeta	*Hediste diversicolor*	20	20	0	10	10	10
Polychaeta	*Marenzelleria viridis*	130	380	500	230	50	410
Polychaeta	*Ophelia rathkei*	0	0	0	0	0	0
Polychaeta	*Pygospio elegans*	300	580	600	450	150	330
Polychaeta	*Scoloplos armiger*	0	0	0	0	0	0
Polychaeta	*Travisia forbesii*	0	0	20	0	0	10
Oligochaeta	Oligochaeta	0	20	10	0	0	0
Bivalvia	*Cerastoderma edule*	0	0	0	0	0	0
Bivalvia	*Cerastoderma glaucum*	20	0	0	0	20	0
Bivalvia	*Macoma balthica*	10	10	0	30	0	0
Bivalvia	*Mya arenaria*	10	40	110	40	10	10
Bivalvia	*Mytilus edulis*	10	0	20	0	0	570
Gastropoda	*Hydrobia ulvae*	0	10	90	30	0	10
Crustacea	*Bathyporeia pilosa*	0	0	0	20	0	0
Crustacea	*Diastylis lucifera*	0	0	0	0	0	10
Crustacea	*Diastylis rathkei*	0	0	0	0	0	0
Crustacea	*Gammarus salinus*	0	0	0	0	0	40
Crustacea	*Gammarus zaddachi*	0	0	0	0	0	0
Crustacea	*Neomysis integer*	0	10	0	10	0	0
Abundance (m^{-2})		**500**	**1070**	**1400**	**820**	**240**	**1420**
Number of species (0.1 m^{-2})		**7**	**8**	**8**	**8**	**5**	**10**

Taxa	Species	K-13	K-14	K-15	K-16	K-17	K-18
Polychaeta	*Alitta succinea*	30	0	0	0	0	0
Polychaeta	*Bylgides sarsi*	10	0	0	0	0	0
Polychaeta	*Hediste diversicolor*	40	10	0	30	0	10
Polychaeta	*Marenzelleria viridis*	160	70	170	210	90	50
Polychaeta	*Ophelia rathkei*	0	0	0	0	0	0
Polychaeta	*Pygospio elegans*	90	100	210	230	190	90
Polychaeta	*Scoloplos armiger*	0	0	0	0	0	0
Polychaeta	*Travisia forbesii*	0	0	0	0	10	0
Oligochaeta	Oligochaeta	70	0	0	0	0	20
Bivalvia	*Cerastoderma edule*	0	0	10	0	0	0
Bivalvia	*Cerastoderma glaucum*	0	0	0	0	0	0
Bivalvia	*Macoma balthica*	200	20	0	0	0	30
Bivalvia	*Mya arenaria*	0	0	40	10	30	30
Bivalvia	*Mytilus edulis*	790	10	0	0	0	0
Gastropoda	*Hydrobia ulvae*	0	0	0	0	30	0
Crustacea	*Bathyporeia pilosa*	0	0	10	0	10	0
Crustacea	*Diastylis lucifera*	0	0	0	0	0	0
Crustacea	*Diastylis rathkei*	0	0	0	0	0	0
Crustacea	*Gammarus salinus*	0	0	0	0	0	0
Crustacea	*Gammarus zaddachi*	0	0	0	0	0	0
Crustacea	*Neomysis integer*	0	0	0	0	0	0
Abundance (m^{-2})		**1390**	**210**	**440**	**480**	**360**	**230**
Number of species (0.1 m^{-2})		**8**	**5**	**5**	**4**	**6**	**6**

Taxa	Species	K-19	K-20-1	AVR AB	% AVR AB	No. of Stations	% of Stations
Polychaeta	*Alitta succinea*	0	0	2	0.22	1	5
Polychaeta	*Bylgides sarsi*	0	0	6	0.86	5	25
Polychaeta	*Hediste diversicolor*	30	40	19	2.73	17	85
Polychaeta	*Marenzelleria viridis*	850	80	212	30.44	20	100
Polychaeta	*Ophelia rathkei*	0	0	1	0.14	2	10
Polychaeta	*Pygospio elegans*	950	180	262	37.62	20	100
Polychaeta	*Scoloplos armiger*	10	0	1	0.07	1	5
Polychaeta	*Travisia forbesii*	20	0	3	0.43	4	20
Oligochaeta	Oligochaeta	110	0	13	1.87	7	35
Bivalvia	*Cerastoderma edule*	0	0	1	0.07	1	5
Bivalvia	*Cerastoderma glaucum*	0	0	4	0.50	4	20
Bivalvia	*Macoma balthica*	30	40	34	4.81	14	70
Bivalvia	*Mya arenaria*	10	20	26	3.66	18	90
Bivalvia	*Mytilus edulis*	0	60	99	14.14	9	45
Gastropoda	*Hydrobia ulvae*	0	0	10	1.36	7	35
Crustacea	*Bathyporeia pilosa*	0	0	3	0.36	4	20
Crustacea	*Diastylis lucifera*	0	0	1	0.07	1	5
Crustacea	*Diastylis rathkei*	10	0	1	0.07	1	5
Crustacea	*Gammarus salinus*	0	0	3	0.36	2	10
Crustacea	*Gammarus zaddachi*	0	0	1	0.07	1	5
Crustacea	*Neomysis integer*	0	0	1	0.14	2	10
Abundance (m^{-2})		**2020**	**420**	**697**	**100**	**20**	**100**
Number of species (0.1 m^{-2})		**9**	**6**				

A P P E N D I X   C

Benthic fauna – species biomass

Taxa	Species	K-01	K-02	K-03	K-04	K-05	K-06
Polychaeta	*Alitta succinea*	0	0	0	0	0	0
Polychaeta	*Bylgides sarsi*	0.006	0	0	0	0.002	0
Polychaeta	*Hediste diversicolor*	0.176	0.006	0.453	0.293	0.212	0.105
Polychaeta	*Marenzelleria viridis*	0.062	0.010	0.074	0.153	0.094	0.046
Polychaeta	*Ophelia rathkei*	0.001	0.001	0	0	0	0
Polychaeta	*Pygospio elegans*	0.009	0.030	0.013	0.015	0.054	0.010
Polychaeta	*Scoloplos armiger*	0	0	0	0	0	0
Polychaeta	*Travisia forbesii*	0	0	0	0	0	0
Oligochaeta	Oligochaeta	0	0	0	0.001	0.001	0
Bivalvia	*Cerastoderma edule*	0	0	0	0	0	0
Bivalvia	*Cerastoderma glaucum*	0	0	0	0	0.141	0.624
Bivalvia	*Macoma balthica*	0.040	0.388	2.981	0.569	0.804	0.191
Bivalvia	*Mya arenaria*	0.137	8.567	0.030	0.005	4.259	0.733
Bivalvia	*Mytilus edulis*	1.984	0	0	0.262	1.323	0
Gastropoda	*Hydrobia ulvae*	0.003	0	0	0	0	0
Crustacea	*Bathyporeia pilosa*	0	0	0.007	0	0	0
Crustacea	*Diastylis lucifera*	0	0	0	0	0	0
Crustacea	*Diastylis rathkei*	0	0	0	0	0	0
Crustacea	*Gammarus salinus*	0	0	0	0	0.010	0
Crustacea	*Gammarus zaddachi*	0	0	0	0	0.020	0
Crustacea	*Neomysis integer*	0	0	0	0	0	0
Biomass (gAFDW m^{-2})		**2.418**	**9.002**	**3.558**	**1.298**	**6.920**	**1.709**

Taxa	Species	K-07	K-08	K-09-1	K-10-1	K-11	K-12
Polychaeta	*Alitta succinea*	0	0	0	0	0	0
Polychaeta	*Bylgides sarsi*	0	0	0.035	0	0	0.042
Polychaeta	*Hediste diversicolor*	0.070	0.015	0	0.080	0.059	0.008
Polychaeta	*Marenzelleria viridis*	0.250	0.111	0.075	0.162	0.128	0.109
Polychaeta	*Ophelia rathkei*	0	0	0	0	0	0
Polychaeta	*Pygospio elegans*	0.097	0.107	0.149	0.132	0.051	0.066
Polychaeta	*Scoloplos armiger*	0	0	0	0	0	0
Polychaeta	*Travisia forbesii*	0	0	0.039	0	0	0.034
Oligochaeta	Oligochaeta	0	0.005	0.003	0	0	0
Bivalvia	*Cerastoderma edule*	0	0	0	0	0	0
Bivalvia	*Cerastoderma glaucum*	0.587	0	0	0	0.712	0
Bivalvia	*Macoma balthica*	0.100	0.046	0	0.414	0	0
Bivalvia	*Mya arenaria*	0.033	1.003	0.183	0.027	0.355	2.448
Bivalvia	*Mytilus edulis*	0.002	0	0.013	0	0	10.481
Gastropoda	*Hydrobia ulvae*	0	0.006	0.016	0.008	0	0.003
Crustacea	*Bathyporeia pilosa*	0	0	0	0.011	0	0
Crustacea	*Diastylis lucifera*	0	0	0	0	0	0.001
Crustacea	*Diastylis rathkei*	0	0	0	0	0	0
Crustacea	*Gammarus salinus*	0	0	0	0	0	0.072
Crustacea	*Gammarus zaddachi*	0	0	0	0	0	0
Crustacea	*Neomysis integer*	0	0.062	0	0.031	0	0

Biomass (gAFDW m^{-2})		1.139	1.355	0.513	0.865	1.305	13.264
Taxa	**Species**	**K-13**	**K-14**	**K-15**	**K-16**	**K-17**	**K-18**
Polychaeta	*Alitta succinea*	0.066	0	0	0	0	0
Polychaeta	*Bylgides sarsi*	0.017	0	0	0	0	0
Polychaeta	*Hediste diversicolor*	0.041	0.444	0	0.035	0	0.023
Polychaeta	*Marenzelleria viridis*	0.033	0.160	0.062	0.060	0.030	0.150
Polychaeta	*Ophelia rathkei*	0	0	0	0	0	0
Polychaeta	*Pygospio elegans*	0.010	0.025	0.047	0.043	0.039	0.018
Polychaeta	*Scoloplos armiger*	0	0	0	0	0	0
Polychaeta	*Travisia forbesii*	0	0	0	0	0.039	0
Oligochaeta	Oligochaeta	0.004	0	0	0	0	0.001
Bivalvia	*Cerastoderma edule*	0	0	0.248	0	0	0
Bivalvia	*Cerastoderma glaucum*	0	0	0	0	0	0
Bivalvia	*Macoma balthica*	7.147	0.522	0	0	0	0.637
Bivalvia	*Mya arenaria*	0	0	2.017	0.052	0.672	0.131
Bivalvia	*Mytilus edulis*	5.740	0.007	0	0	0	0
Gastropoda	*Hydrobia ulvae*	0	0	0	0	0.034	0
Crustacea	*Bathyporeia pilosa*	0	0	0.004	0	0.007	0
Crustacea	*Diastylis lucifera*	0	0	0	0	0	0
Crustacea	*Diastylis rathkei*	0	0	0	0	0	0
Crustacea	*Gammarus salinus*	0	0	0	0	0	0
Crustacea	*Gammarus zaddachi*	0	0	0	0	0	0
Crustacea	*Neomysis integer*	0	0	0	0	0	0
Biomass (gAFDW m^{-2})		**13.058**	**1.158**	**2.378**	**0.190**	**0.821**	**0.960**

Taxa	Species	K-19	K-20-1	Average biomass	% Average biomass
Polychaeta	*Alitta succinea*	0	0	0.0033	0.10
Polychaeta	*Bylgides sarsi*	0	0	0.0051	0.16
Polychaeta	*Hediste diversicolor*	0.158	0.109	0.1144	3.55
Polychaeta	*Marenzelleria viridis*	0.224	0.125	0.1059	3.29
Polychaeta	*Ophelia rathkei*	0	0	0.0001	0.00
Polychaeta	*Pygospio elegans*	0.222	0.03	0.0584	1.81
Polychaeta	*Scoloplos armiger*	0.027	0	0.0013	0.04
Polychaeta	*Travisia forbesii*	0.033	0	0.0072	0.22
Oligochaeta	Oligochaeta	0.008	0	0.0011	0.04
Bivalvia	*Cerastoderma edule*	0	0	0.0124	0.38
Bivalvia	*Cerastoderma glaucum*	0	0	0.1032	3.20
Bivalvia	*Macoma balthica*	0.546	0.923	0.7654	23.75
Bivalvia	*Mya arenaria*	0.007	0.056	1.0358	32.14
Bivalvia	*Mytilus edulis*	0	0.069	0.9941	30.84
Gastropoda	*Hydrobia ulvae*	0	0	0.0035	0.11
Crustacea	*Bathyporeia pilosa*	0	0	0.0015	0.04
Crustacea	*Diastylis lucifera*	0	0	0.0001	0.00

Taxa	Species	K-19	K-20-1	Average biomass	% Average biomass
Crustacea	*Diastylis rathkei*	0.011	0	0.0006	0.02
Crustacea	*Gammarus salinus*	0	0	0.0041	0.13
Crustacea	*Gammarus zaddachi*	0	0	0.0010	0.03
Crustacea	*Neomysis integer*	0	0	0.0046	0.14
Biomass (gAFDW m-2)		**1.236**	**1.312**	**3.223**	**100**

A P P E N D I X   D

Sediment description and photos of sampling stations

Description of the seabed and pictures at the stations where underwater video were recorded 24 August 2011

Station	Water depth (m)	Description of the seabed (about 50 m²)
K-01	17.9	10 cm stones, 95 % fine sand, 5 % medium to coarse sand
K-02	17.5	95 % medium sand, 5 % coarse sand/ few small stones
K-03	17.9	10 cm stones, fine to coarse sand adn many shells
K-04	18.0	Stones and mussels, medium to coarse sand
K-05	18.5	90 % fine sand, 10 % coarse sand, small stones and shells
K-06	18.4	Fine to medium sand and shells
K-07	18.5	100 % very fine sand
K-08	18.7	Fine sand
K-09	20.0	Stones and mussels, 50 % coarse sand. Sample moved 100 m north as sampling was not possible
K-09.1	19.7	Fine sand and many worms
K-10	18.4	Only 5-15 cm stones and mussels. Sample moved 100 m south as sampling was not possible
K-10.1	18.5	Fine to medium sand
K-11	17.8	Fine to medium sand and mussels
K-12	20.8	Fine sand and blue mussels
K-13	19.4	Very stony. Sample ok. Medium to coarse sand and stones
K-14	18.5	Medium sand
K-15	18.5	Fine sand
K-16	20.5	Fine to medium sand and shells
K-17	19.6	Fine sand
K-18	19.5	90 % fine sand, 10 % medium sand in bottom (12 cm)
K-19	20.1	Very fine sand
K-20	19.9	10 cm stones and mussels. Sample moved 100 m north as sampling was not possible
K-20.1	19.5	90 % fine sand, 10 % medium sand, medium sand in bottom

Comments

The sand was fine at the surface (0-10 cm) in the southern part of the impact area, while the sand becomes more coarse below 10 cm (medium sand).

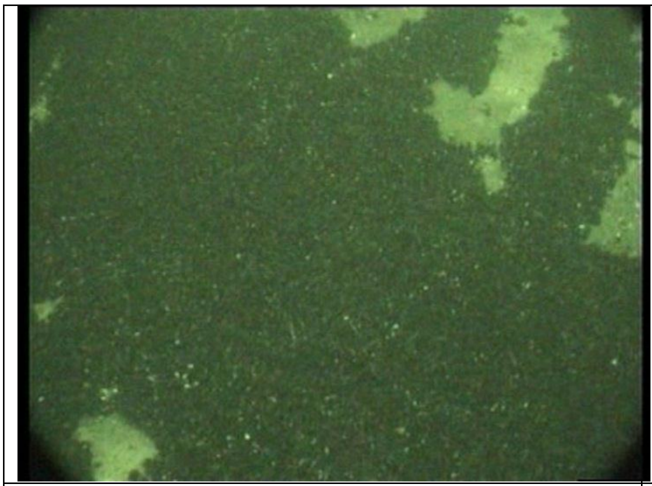
The (Van Veen) sampler was 0.1 m^2, and app. 1/3 to ½ filled. Samplings is representative for the sediment present. The colour of the sand is yellow-brown.

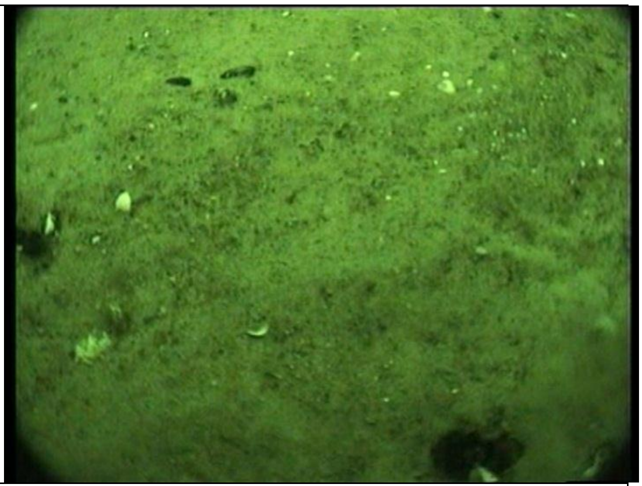
The northern part of the area is more stony, which resulted in multiple samples before it was successful.

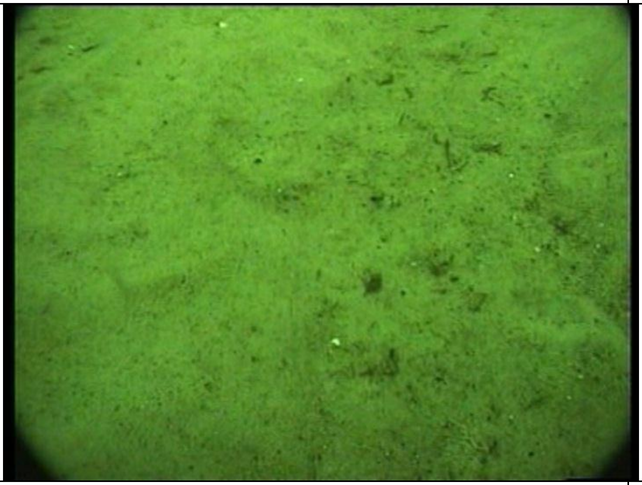
At three sampling stations (sample K-9, K-10 and K-20) samples had to be redone due to obstruction of the sampler (with stones). Sampling was moved 100 m. It was observed that the seabed was completely different at the new sampling stations.

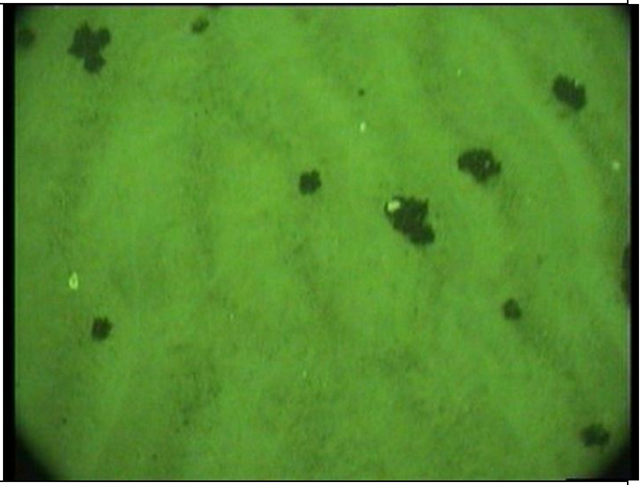
A thin layer of sedimented or benthic microalgae was observed on top of the sediments at most stations.

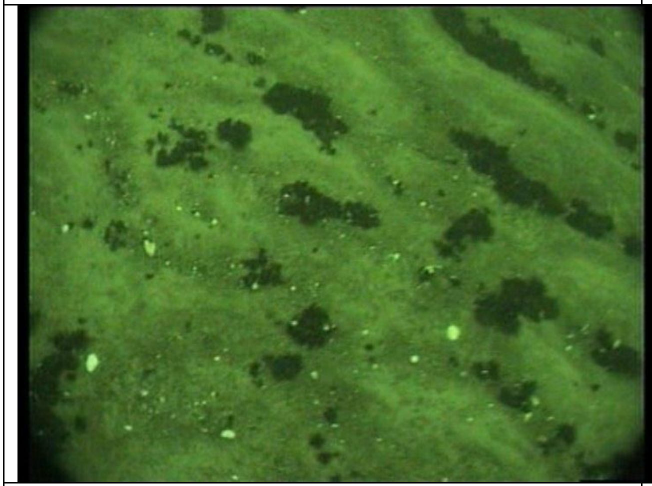
Two pictures from each record are presented below.

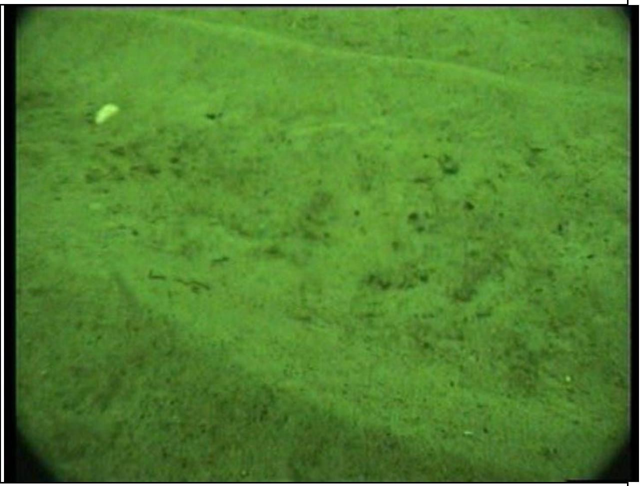

Krieger's Flak Station 1: Photo A

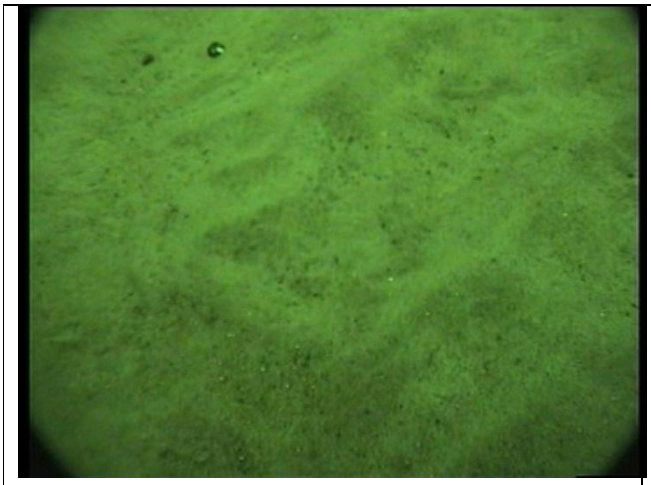

Krieger's Flak Station 1: Photo B


Krieger's FlakStation 2: Photo A

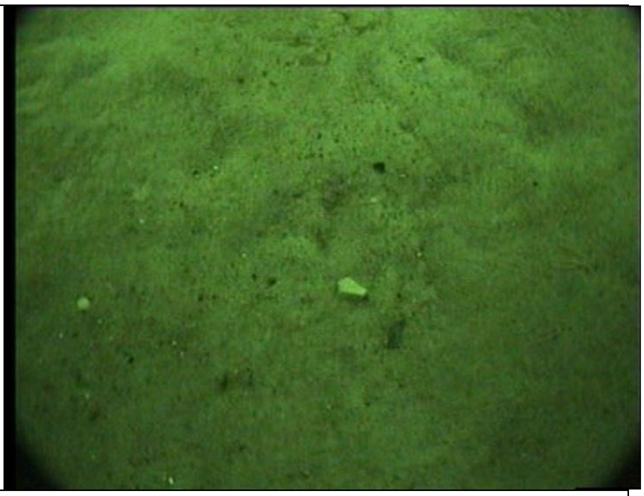

Krieger's Flak Station 2: Photo B


Krieger's Flak Station 3: Photo A

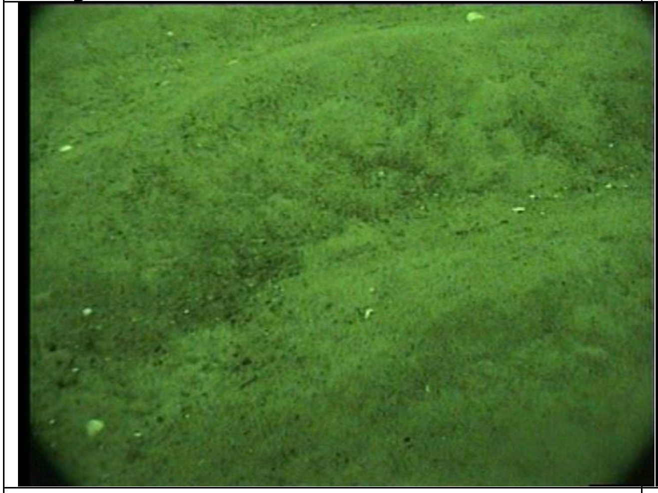

Krieger's Flak Station 3: Photo B



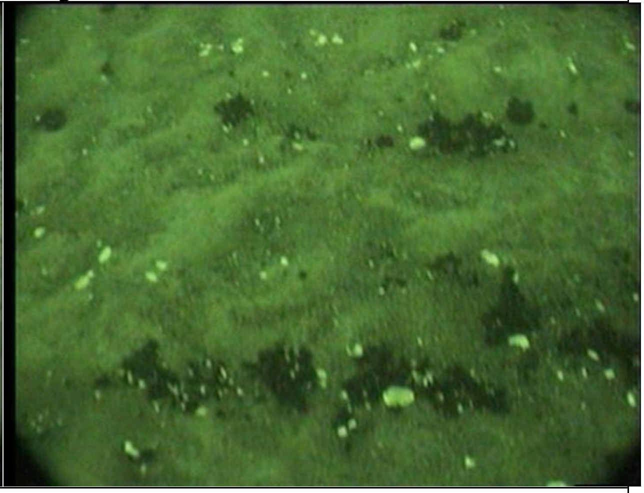
Krieger's Flak Station 4: Photo A



Krieger's Flak Station 4: Photo B

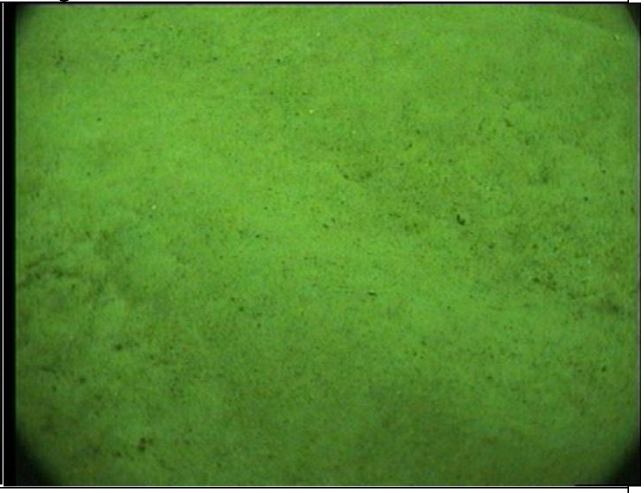


Krieger's Flak Station 5: Photo A

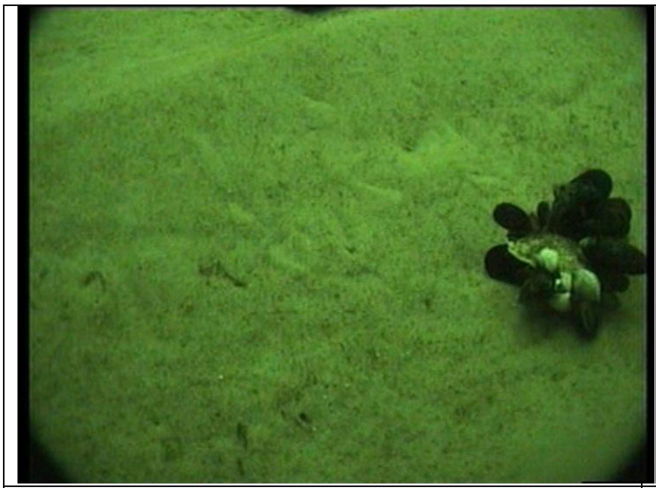
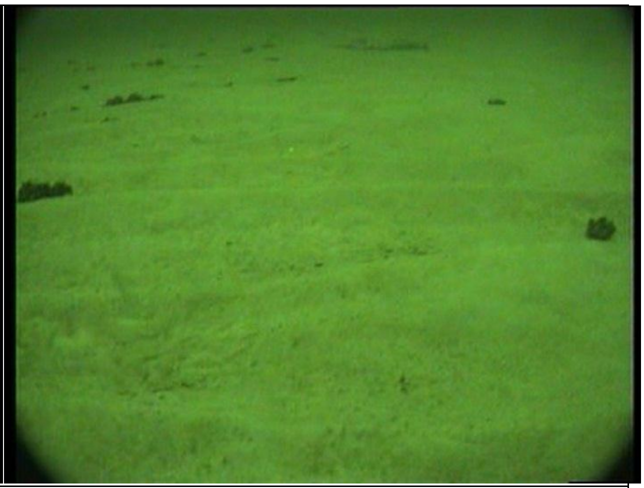
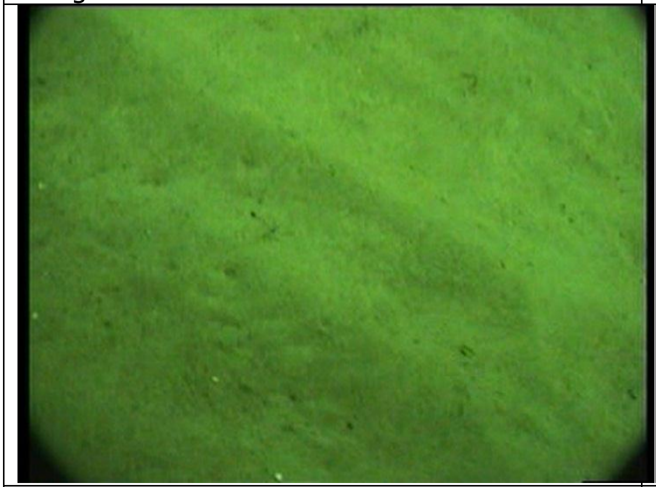
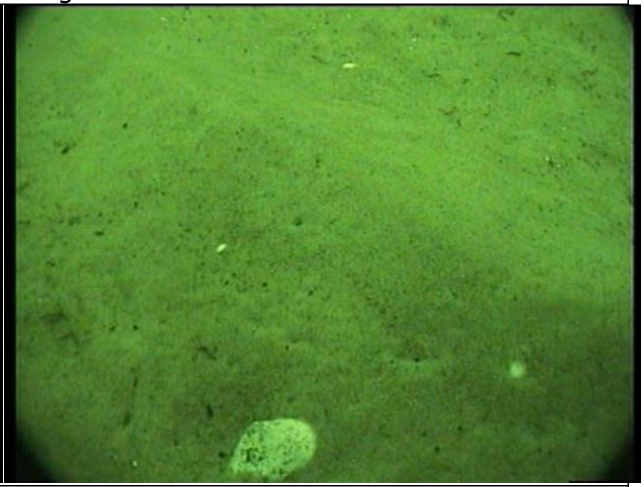
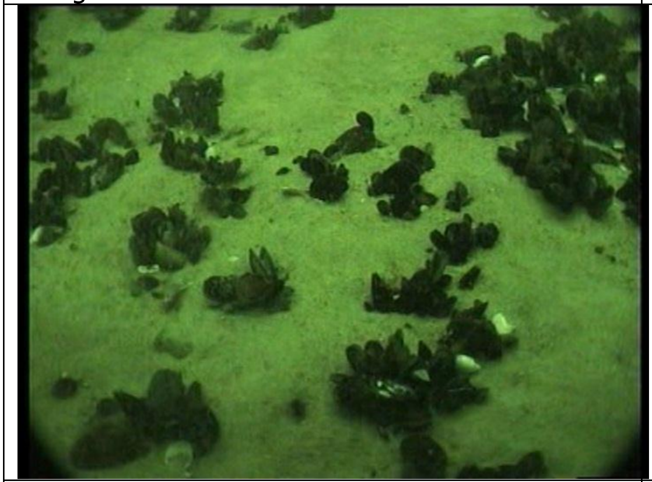
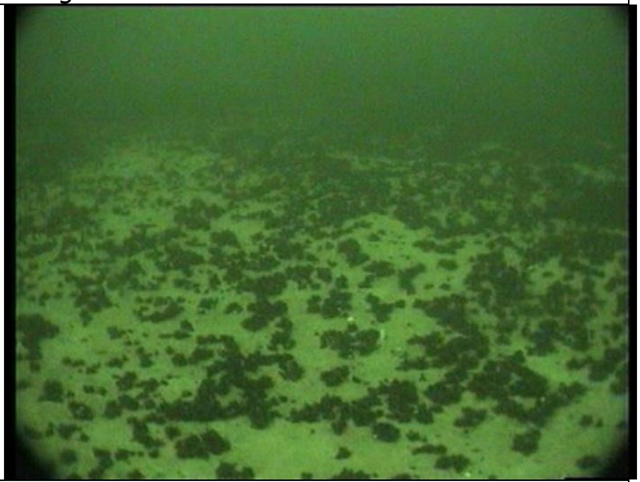


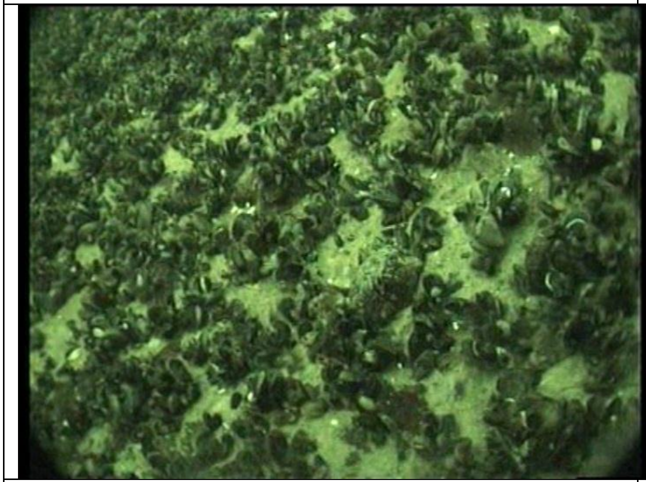
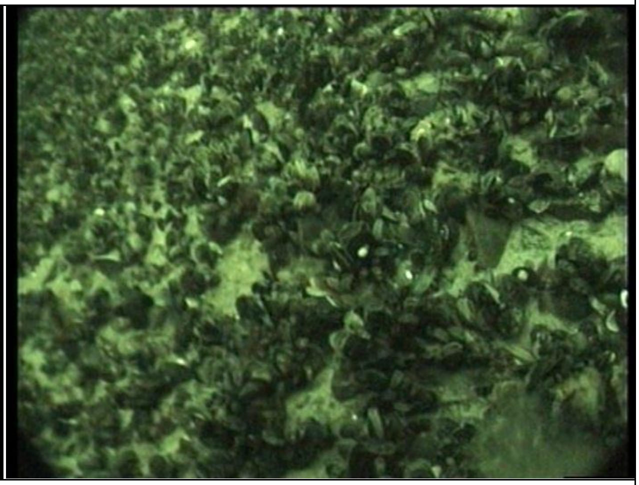
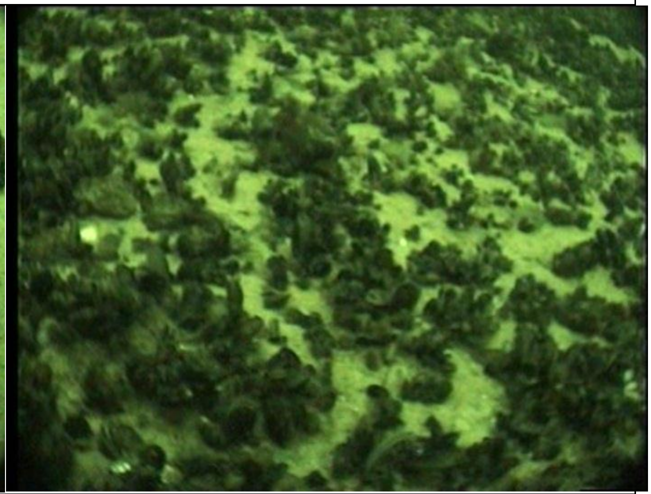
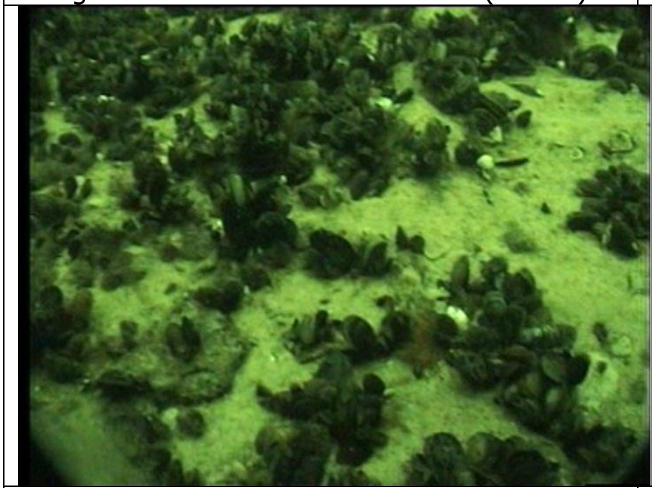
Krieger's Flak Station 5: Photo B

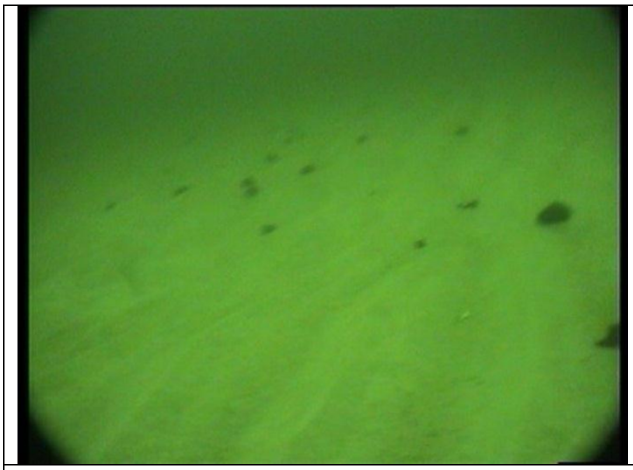
Krieger's Flak Station 6: Photo A



Krieger's Flak Station 6: Photo B

	
Krieger's Flak Station 7: Photo A	Krieger's Flak Station 7: Photo B
	
Krieger's Flak Station 8: Photo A	Krieger's Flak Station 8: Photo B
	
Krieger's Flak Station 9: Photo A	Krieger's Flak Station 9: Photo B

	
Krieger's Flak Station 9.1: Photo A	Krieger's Flak Station 9.1: Photo B
	
Krieger's Flak Station 10: Photo A (K10-3)	Krieger's Flak Station 10: Photo B (K10-4)
	
Krieger's Flak Station 10.1: Photo A (K-10.1-3)	Krieger's Flak Station 10: Photo B (K10.1-4)



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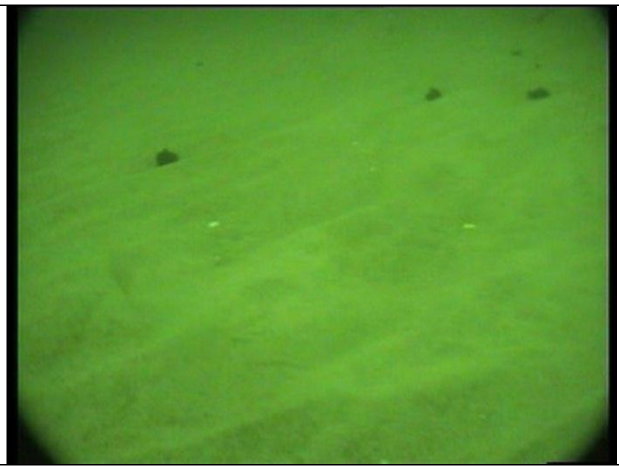

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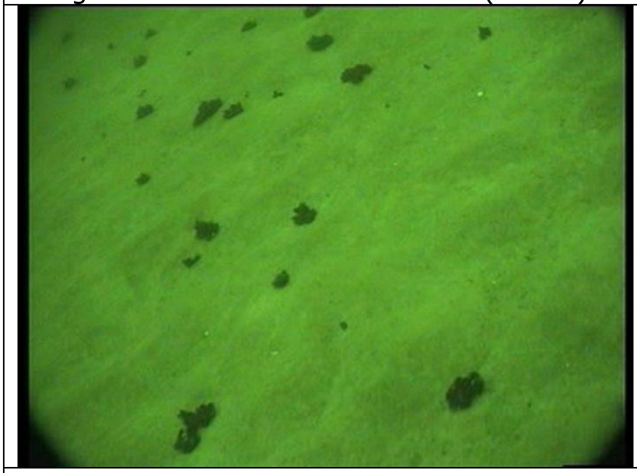

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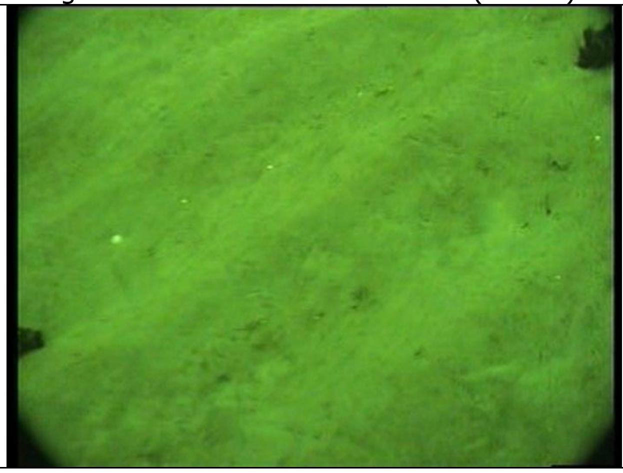

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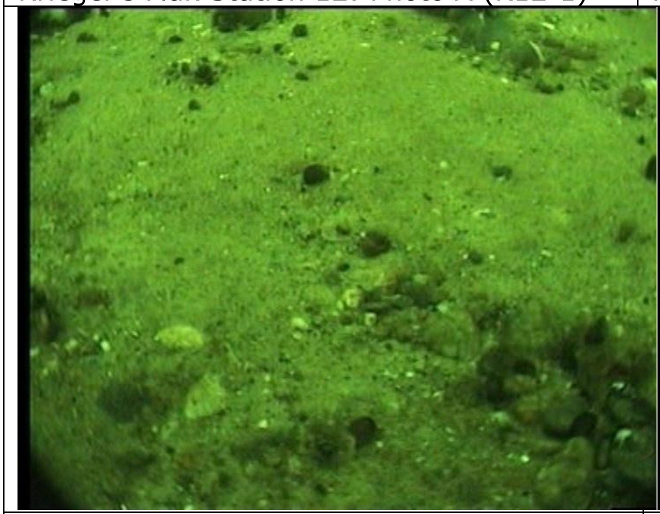

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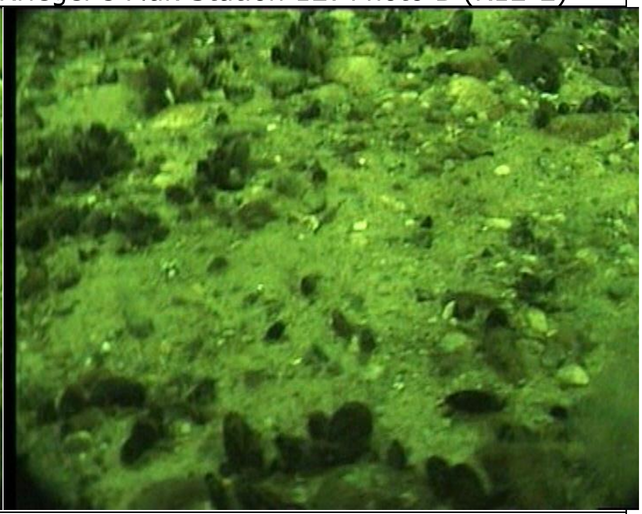

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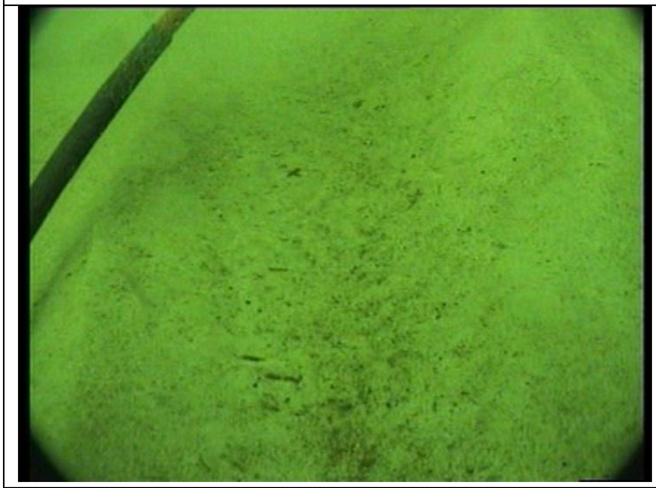	
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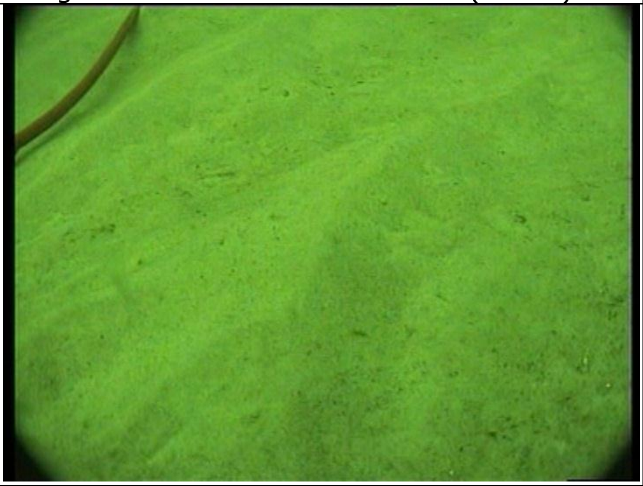	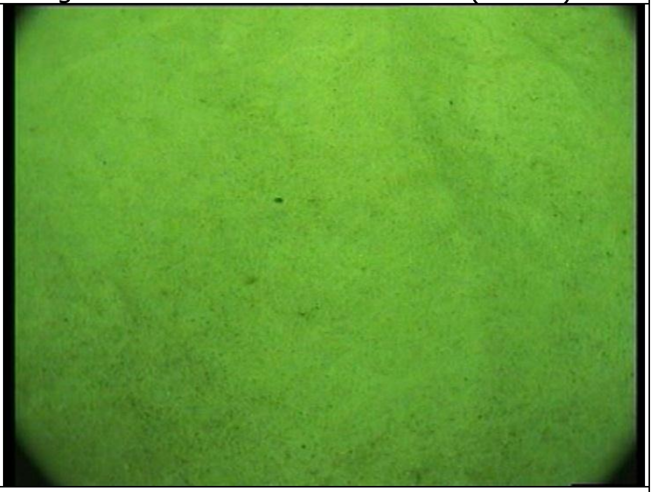
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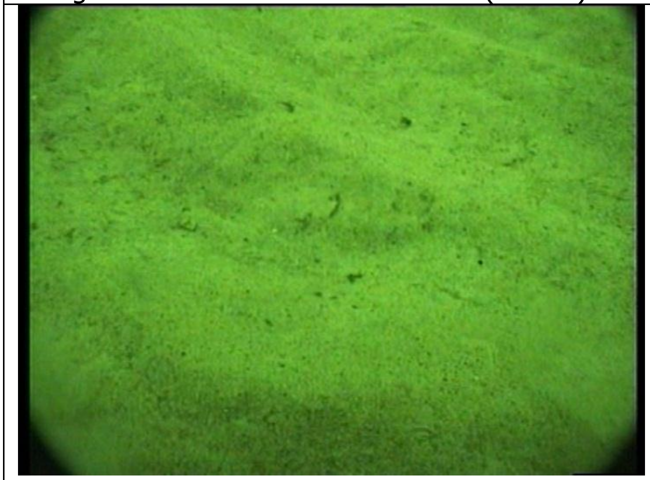	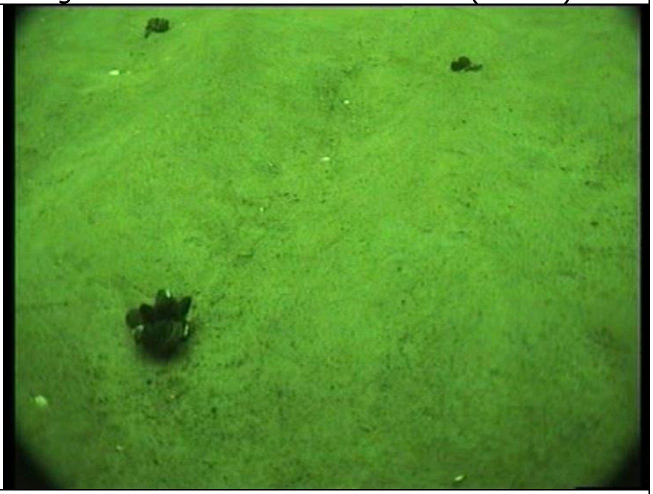
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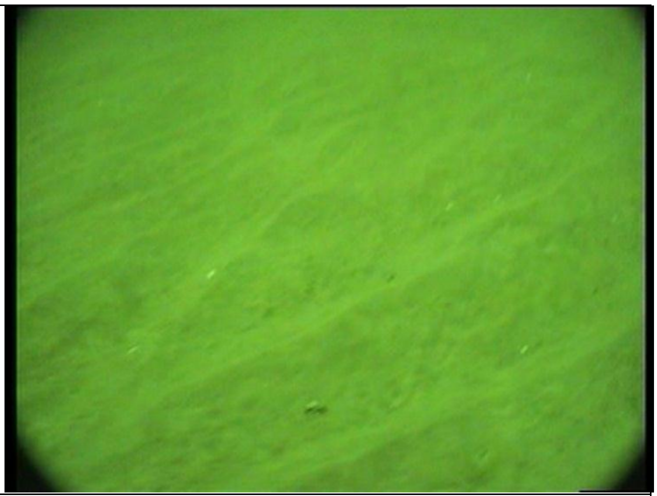

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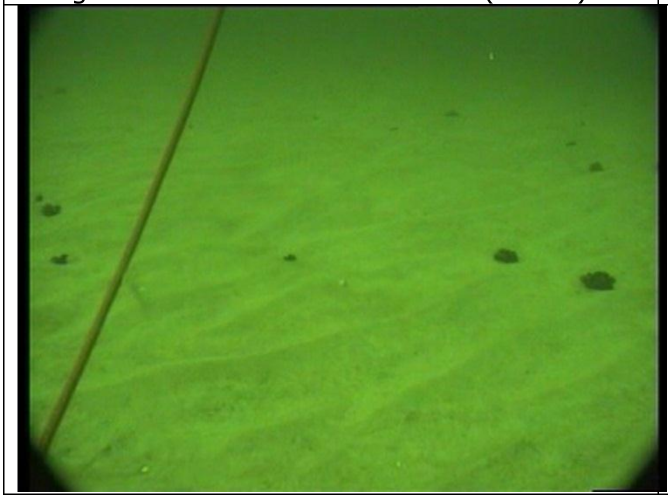

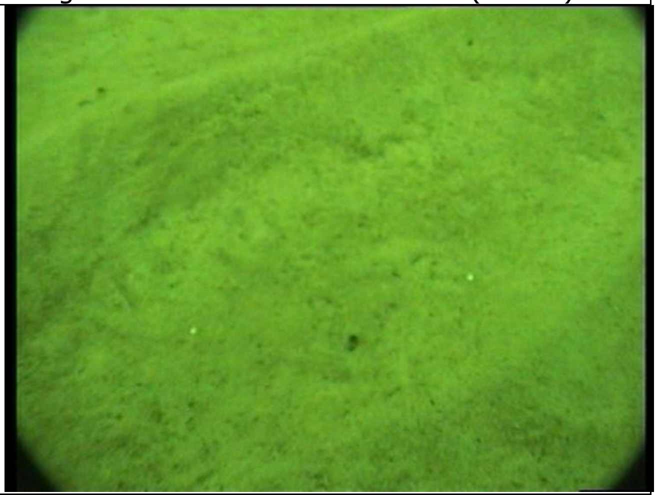

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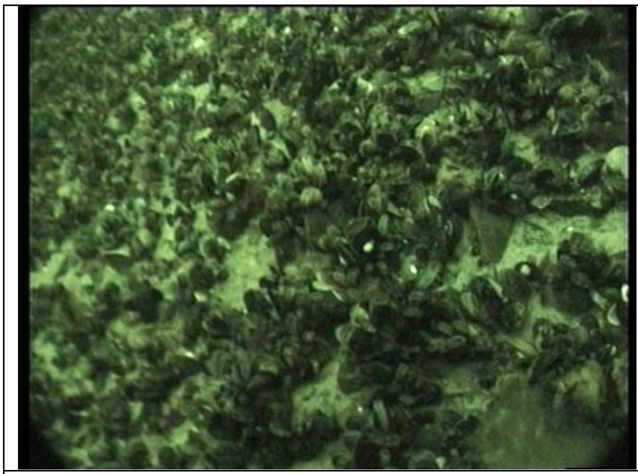

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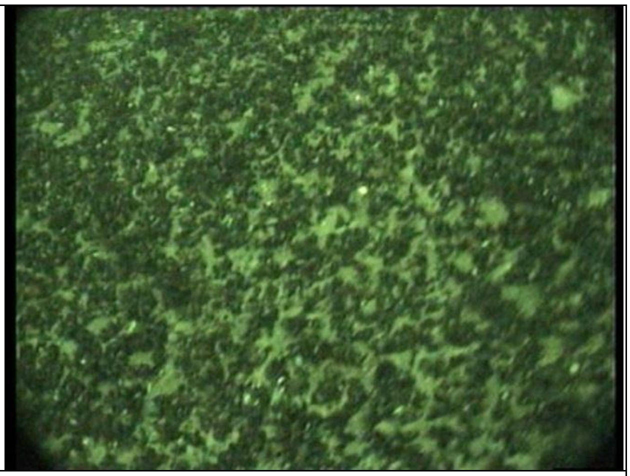

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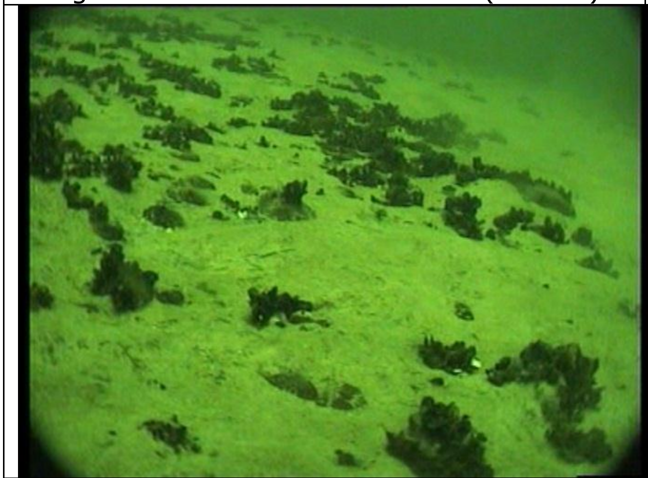
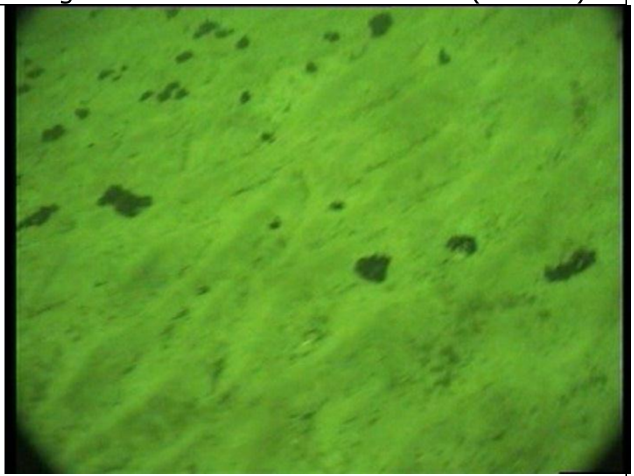
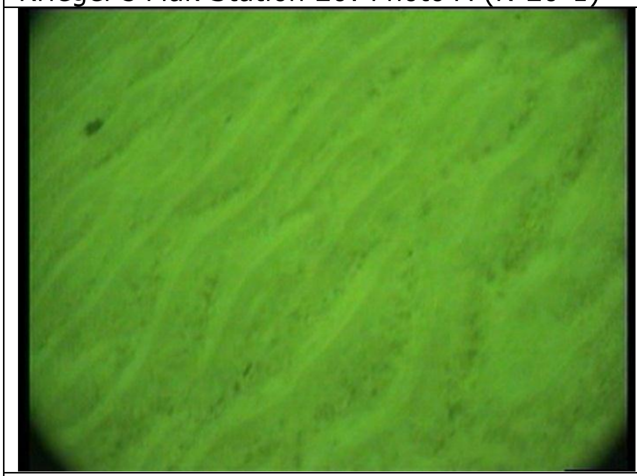


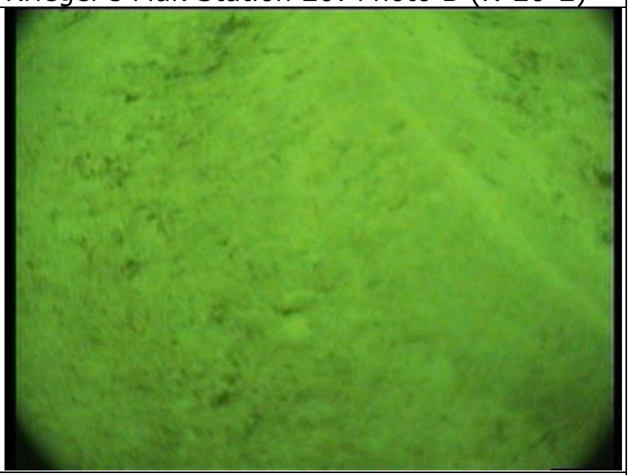
Krieger's Flak Station 20: Photo A (K-20-1)



Krieger's Flak Station 20: Photo B (K-20-2)



Krieger's Flak Station 20: Photo A (K-20.1-1)



Krieger's Flak Station 20: Photo B (K-20.1-2)

A P P E N D I X   E

Seismic/acoustic equipment specifications

SIS-1625 Seafloor Imaging System

SIDE SCAN SONAR/ PROFILER

Combined Chirp/CW Side Scan Sonar/ Sub-bottom Profiling System

The SIS-1625 Seafloor Imaging System has quickly become the industry standard for shallow water (<2000M) seafloor survey operations. This field proven, highly versatile survey tool offers a fully digital platform capable of collecting high resolution chirp side scan/sub-bottom data, as well as a full suite of customer selected sensor data. The high resolution, extended range chirp data and multiple data sensor capability provide the surveyor with a significant savings in instrument cost and survey time.

One Workstation

Topside system consists of:

- Chirp DSP based side scan sonar, operating at 100/400 kHz simultaneously, allows a full 1000 meter swath, with resolution equivalent to much higher frequency systems.
- Chirp DSP/CW based sub-bottom profiling, operating in the 1 to 10 kHz region, allows maximum sediment penetration with greatly improved resolution.
- Gain, TVG, image correction, color palette, and other programmable parameters are under trackball control.
- Digital interface provided for thermal graphic recorders.

One Tow Vehicle—TTV-290

The TTV-290 is a fully digital platform with standard Chirp side scan/sub-bottom transducer arrays, digital multiplexor, subsea electronics, and RS-232 ports for optional sensors.

- Hydrodynamically stable tow vehicle includes pitch, roll and heading sensors, optional position responder/ transponder, and other customer selected sensors.
- 0.5° side scan sonar horizontal radiation pattern,combined with broad band Chirp DSP match filter processing, provides optimal cross-track and along track resolution.
- Tow vehicle operates in depths up to 2000 meters.

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TELEDYNE BENTHOS
A Teledyne Technologies Company

49 Edgerton Drive • North Falmouth, MA 02556 USA
Tel: 508 563-1000 • Fax: 508 563-6444 • E-mail: info@benthos.com
www.benthos.com

SIS-1625 Seafloor Imaging System

One Cable—CL-160 Communications Link

The comm link was designed through a program to develop a full ocean depth telemetry module for a multisensor seafloor mapping system.

- Two-way communication with tow vehicle over single coax with digital high speed multiplexor. Standard cable length—up to 10,000 meters.
- Digital multiplexor for single coaxial tow cables. Communication rates: sonar data—up to 5 megabit/sec; uplink status—9600 bits/sec; downlink command—9600 bits/sec.

SPECIFICATIONS

CL-160 Shipboard Sub-System	
Chirp Processing:	Sonar/status control PC based workstation; 5-DSP based sonar matched filter processing channels.
Display:	High resolution video display.
Recording:	Large capacity hard drive, DVD writable, other..
Status Display:	Vehicle pitch, roll, heading (standard); speed, altitude, and depth (optional). Customer input ship position, vehicle position, event marks; all status data recorded.
Sonar Display:	Side scan port, starb; dual channel sub-bottom; all sonar data recorded.
Corrections:	Slant range and speed; beam angle/grazing angle.
Multiplexor:	Digital MUX for coaxial cables (ADSL).
Sonar Data:	up to 5 megabit/sec.
Uplink Status:	9600 bit/sec.
Downlink Command:	9600 bits/sec.
Power Supply:	110/220 VAC autosensing.
Side Scan	
Side Scan Transducers:	Multi-element array, dual channel 100/400 kHz 0.5° horizontal beam; 60° vertical beam.
Frequency:	100/400 kHz band swept FM; 4.5 cm resolution.
Processing:	Calibrated transmit waveform stored in ROM; match filter FFT digital signal processing.
Swath Selection:	25 meters to ±500 meters.
Sub-Bottom	
Transducer:	Transmit projector array; line array receiving hydrophone; 30° conical radiation pattern.
Frequency:	1 kHz to 10 kHz swept FM (4 KW output), synchronous with side scan.
Resolution:	5 cm.
Processing:	Calibrated transmit waveform stored in ROM; matched filter FFT digital signal processing.
Scale Selection:	25 meters to 500 meters full scale.
TTV-290 Tow Vehicle Sub-System	
Depth rating:	2000 meters.
Vehicle Dimensions:	18 inches (45 cm) OD x 64 inches (162.6 cm) long.
Weight:	In air: 300 lbs (136 Kg); in water: 170 lbs (77 Kg).

TELEDYNE BENTHOS
A Teledyne Technologies Company

49 Edgerton Drive • North Falmouth, MA 02556 USA
Tel: 508 563-1000 • Fax: 508 563-6444 • E-mail: info@benthos.com
www.benthos.com

Geo-Spark 200 Multi-tip Sparker

The GEO-SPARK series is a new generation of very high-resolution multi-tip sparkers and HV pulsed power supplies developed / manufactured by Geo-Resources Instruments.

The GEO-SPARK-200 source system is capable to acquire very high-resolution (< 30 cm) seismic profiles of the "shallow" sub-bottom strata. Depending on the energy level, the geology and water depth, the effective penetration can exceed 300 - 400 msec below seabed.

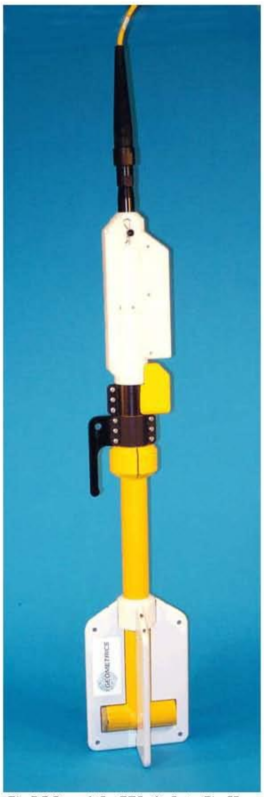
Specifications GEO-SPARK 200 Multi-tip Sparker

Dimensions:	H x W x D = 55 x 75 x 105 cm
Overall Weight	55 kg
Shipping	Standard Euro pallet / container 60 x 80 x 120 cm
Frame	Marine quality stainless steel (316)
	Entirely passivated c/w aluminium protection anodes
Array Depth	Adjustable from 10 cm to 40 cm below surface
Array Geometry	Planar configuration of 0.75 x 1.00 m for enhanced downward projection of acoustic energy
Number of Tips	Number of active Electrode Modules (1 - 4) corresponding to 50, 100, 150, or 200 tips can be selected onboard.
Diameter of Tips	Electrode Modules are available with: Small diameter tip, surface = 0.45 mm^2, for low power per tip Large diameter tips, surface = 2.50 mm^2 , for high power per tip
Energy Level	Recommended max energy per tip in PE mode: 3 Joule / tip for small diameter tips 12.5 Joule / tip for large diameter tips
Standard Configuration	For use with the Geo-Spark 1000 PPS, a combination of 2 modules with 50 small diameter tips plus 2 modules with 50 large diameter tips
Primary Pulse Length	Around 0.5 msec
Dominant Frequencies	Between 500 - 2000 Hz, depending on the selected energy level see attached spectra
PE Mode	The Geo-Spark 200 multi-tip sparker is specifically designed for operation with the Geo-Spark 1000 High Voltage Pulsed Power Supply in **Preserving Electrode Mode**. In this patented mode the electrodes have negative potential with respect to the frame (ground referenced). This mode reduces the **electrode wear to practically zero**.
HV Tow / Power Cable	Coaxial HV cable, Kevlar reinforced, double insulated, LOW EM emission
Material / Colour	High quality Polyurethane, orange
Outer Diameter:	27 mm
Bending Radius	400 mm
Weight	1.07 kg /m
Inner Cores	4 x 6 mm^2 PU insulated
Outer Braiding	1 x 25 mm^2 PU insulated
Strength Member	4 tons
Wet Termination	4 special HV connectors, each rated for 6 kV pulses of 5 kA
	1 flat stainless steel frame connector
Dry Termination	5 eye connectors to patch panel
Patch Panel	Heavy duty, custom-made HMPE distribution box for connection of HV cable to the Geo-Spark 1000 PPS, allows to connect each electrode module independently

GEOMETRICS

G-882 MARINE MAGNETOMETER

- ***CESIUM VAPOR HIGH PERFORMANCE – Highest detection range and probability of detecting all sized ferrous targets***
- ***NEW STREAMLINED DESIGN FOR TOW SAFETY – Low probability of fouling in lines or rocks***
- ***NEW QUICK CONVERSION FROM NOSE TOW TO CG TOW – Simply remove an aluminum locking pin, move tow point and reinsert. New built in easy carry handle!***
- ***NEW INTERNAL CM-221 COUNTER MODULE – Provides Flash Memory for storage of default parameters set by user***
- ***NEW ECHOSOUNDER / ALTIMETER OPTION***
- ***NEW DEPTH RATING – 4,000 psi !***
- ***HIGHEST SENSITIVITY IN THE INDUSTRY – 0.004 nT/Hz RMS with the internal CM-221 Mini-Counter***
- ***EASY PORTABILITY & HANDLING – no winch required, single man operation, only 44 lbs with 200 ft cable (without weights)***
- ***COMBINE TWO SYSTEMS FOR INCREASED COVERAGE – Internal CM-221 Mini-Counter provides multi-sensor data concatenation allowing side by side coverage which maximizes detection of small targets and reduces noise***



G-882 with Weight Collar Depth Option & Altimeter

Very high resolution Cesium Vapor performance is now available in a low cost, small size system for professional surveys in shallow or deep water. High sensitivity and sample rates are maintained for all applications. The well proven Cesium sensor is combined with a unique and new CM-221 Larmor counter and ruggedly packaged for small or large boat operation. Use your computer and standard printer with our MagLogLite™ software to log, display and print GPS position and magnetic field data. The G–882 is the lowest priced high performance full range marine magnetometer system ever offered.

The G-882 offers flexibility for operation from small boat, shallow water surveys as well as deep tow applications (4,000 psi rating, telemetry over steel coax available to 10Km). The G-882 also directly interfaces to all major Side Scan manufacturers for tandem tow configurations. Being small and lightweight (44 lbs net, without weights) it is easily deployed and operated by one person. But add several streamlined weight collars and the system can quickly weigh more than 100 lbs. for deep tow applications. Power may be supplied from a 24 to 30 VDC battery power or the included 110/220 VAC power supply. The tow cable employs high strength Kevlar strain member with a standard length of 200 ft (61 m) and optional cable length up to 500m with no telemetry required.
A rugged fiber-wound fiberglass housing is designed for operation is all parts of the world allowing sensor rotation for work in equatorial regions. The shipboard end of the tow cable is attached to an included junction box or optional on-board cable for quick and simple hookup to power and output of data into any Windows 98, ME, NT, 2000 or XP computer equipped with RS-232 serial ports.

The G-882 Cesium magnetometer provides the same operating sensitivity and sample rates as the larger deep tow model G-880. MagLogLite™ Logging Software is offered with each magnetometer and allows recording and display of data and position with Automatic Anomaly Detection and automatic anomaly printing on Windows™ printer! Additional options include: MagMap2000 plotting and contouring software and post acquisition processing software MagPick™ (free from our website.)

The G-882 system is particularly well suited for the detection and mapping of all sizes of ferrous objects. This includes anchors, chains, cables, pipelines, ballast stone and other scattered shipwreck debris, munitions of all sizes (UXO), aircraft, engines and any other object with magnetic expression. Objects as small as a 5 inch screwdriver are readily detected provided that the sensor is close to the seafloor and within practical detection range. (Refer to table at right).

The design of this high sensitivity G-882 marine unit is directed toward the largest number of user needs. It is intended to meet all marine requirements such as shallow survey, deep tow through long cables, integration with Side Scan Sonar systems and monitoring of fish depth and altitude.

Typical Detection Range For Common Objects

Ship 1000 tons	0.5 to 1 nT at 800 ft (244 m)
Anchor 20 tons	0.8 to 1.25 nT at 400 ft (120 m)
Automobile	1 to 2 nT at 100 ft (30 m)
Light Aircraft	0.5 to 2 nT at 40 ft (12 m)
Pipeline (12 inch)	1 to 2 nT at 200 ft (60 m)
Pipeline (6 inch)	1 to 2 nT at 100 ft (30 m)
100 KG of iron	1 to 2 nT at 50 ft (15 m)
100 lbs of iron	0.5 to 1 nT at 30 ft (9 m)
10 lbs of iron	0.5 to 1 nT at 20 ft (6 m)
1 lb of iron	0.5 to 1 nT at 10 ft (3 m)
Screwdriver 5 inch	0.5 to 2 nT at 12 ft (4 m)
1000 lb bomb	1 to 5 nT at 100 ft (30 m)
500 lb bomb	0.5 to 5 nT at 50 ft (16 m)
Grenade	0.5 to 2 nT at 10 ft (3 m)
20 mm shell	0.5 to 2 nT at 5 ft (1.8 m)

MODEL G-882 CESIUM MARINE MAGNETOMETER SYSTEM SPECIFICATIONS

Operating Principle:	Self-oscillating split-beam Cesium Vapor (non-radioactive)
Operating Range:	20,000 to 100,000 nT
Operating Zones:	The earth's field vector should be at an angle greater than 6° from the sensor's equator and greater than 6° away from the sensor's long axis. Automatic hemisphere switching.
CM-221 Counter Sensitivity:	<0.004 nT/√Hz rms. Up to 20 samples per second
Heading Error:	±1 nT (over entire 360° spin)
Absolute Accuracy:	<2 nT throughout range
Output:	RS-232 at 1,200 to 19,200 Baud
Mechanical:	
Sensor Fish:	Body 2.75 in. (7 cm) dia., 4.5 ft (1.37 m) long with fin assembly (11 in. cross width), 40 lbs. (18 kg) Includes Sensor and Electronics and 1 main weight. Additional collar weights are 14lbs (6.4kg) each, total of 5 capable
Tow Cable:	Kevlar Reinforced multiconductor tow cable. Breaking strength 3,600 lbs, 0.48 in OD, 200 ft maximum. Weighs 17 lbs (7.7 kg) with terminations.
Operating Temperature:	-30°F to +122°F (-35°C to +50°C)
Storage Temperature:	-48°F to +158°F (-45°C to +70°C)
Altitude:	Up to 30,000 ft (9,000 m)
Water Tight:	O-Ring sealed for up to 4,000 psi (9000 ft or 2750 m) depth operation
Power:	24 to 32 VDC, 0.75 amp at turn-on and 0.5 amp thereafter
Accessories:	
Standard:	View201 Utility Software operation manual and ship kit
Optional:	Telemetry to 10Km coax, gradiometer (longitudinal or transverse), reusable shipping case
MagLog Lite™ Software:	Logs, displays and prints Mag and GPS data at 10 Hz sample rate. Automatic anomaly detection and single sheet Windows printer support

SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE ***12/03***

GEOMETRICS

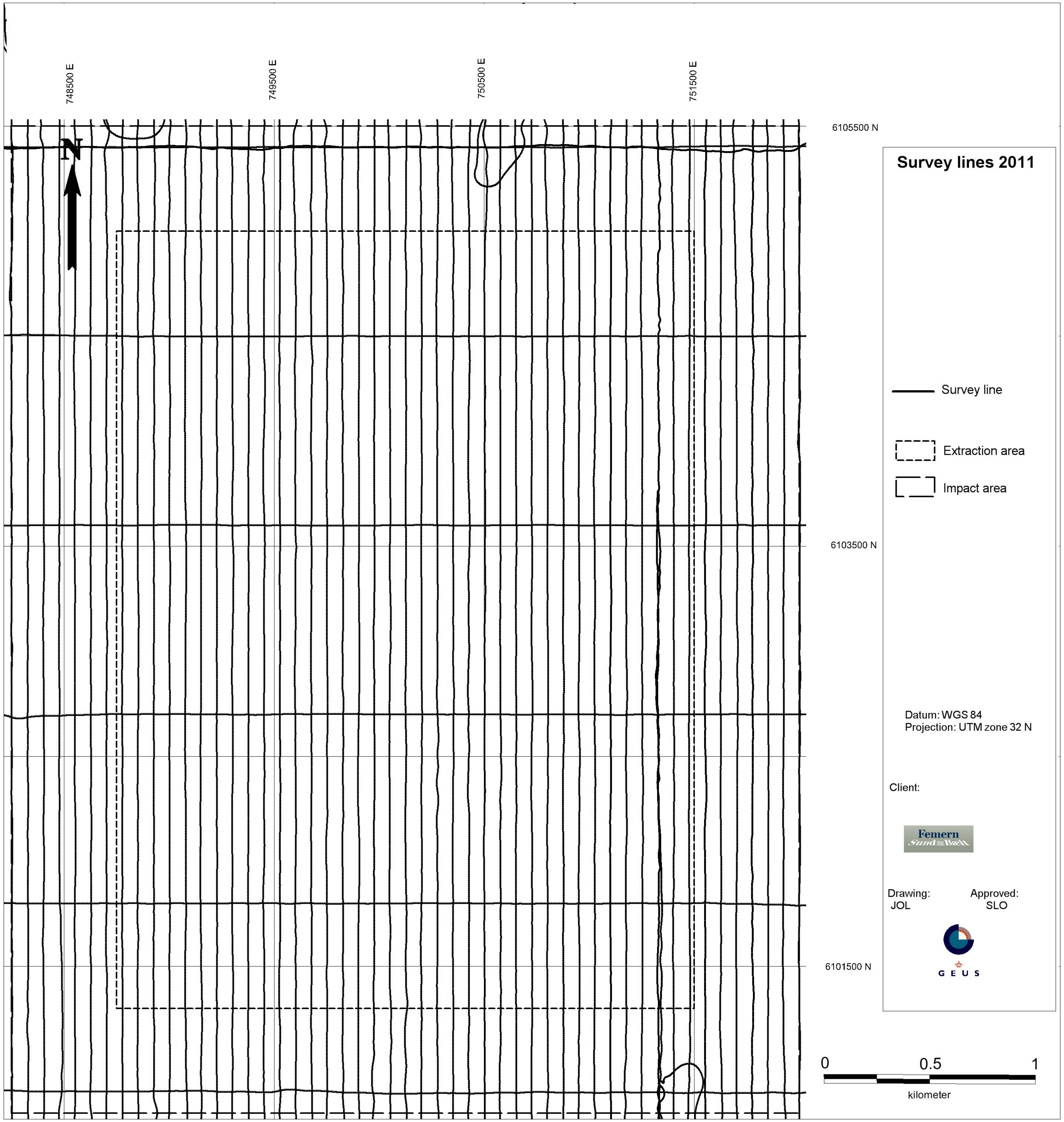
GEOMETRICS, INC. 2190 Fortune Drive, San Jose, California 95131
408-954-0522 □ Fax 408-954-0902 □ Internet: sales@mail.geometrics.com

GEOMETRICS Europe Manor Farm Cottage, Galley Lane, Great Brickhill, Bucks, England MK179AB □ 44-1525-261874 □ Fax 44-1525-261867

GEOMETRICS China Laurel Industrial Co. Inc. - Beijing Office, Room 2509-2511, Full Link Plaza #18 Chaoyangmenwai Dajie, Chaoyang District, Beijing, China 100020
10-6588-1126 (1127..1130), 10-6588-1132 □ Fax 010-6588-1162

A P P E N D I X   F

Survey, sediment and resource maps in A3-format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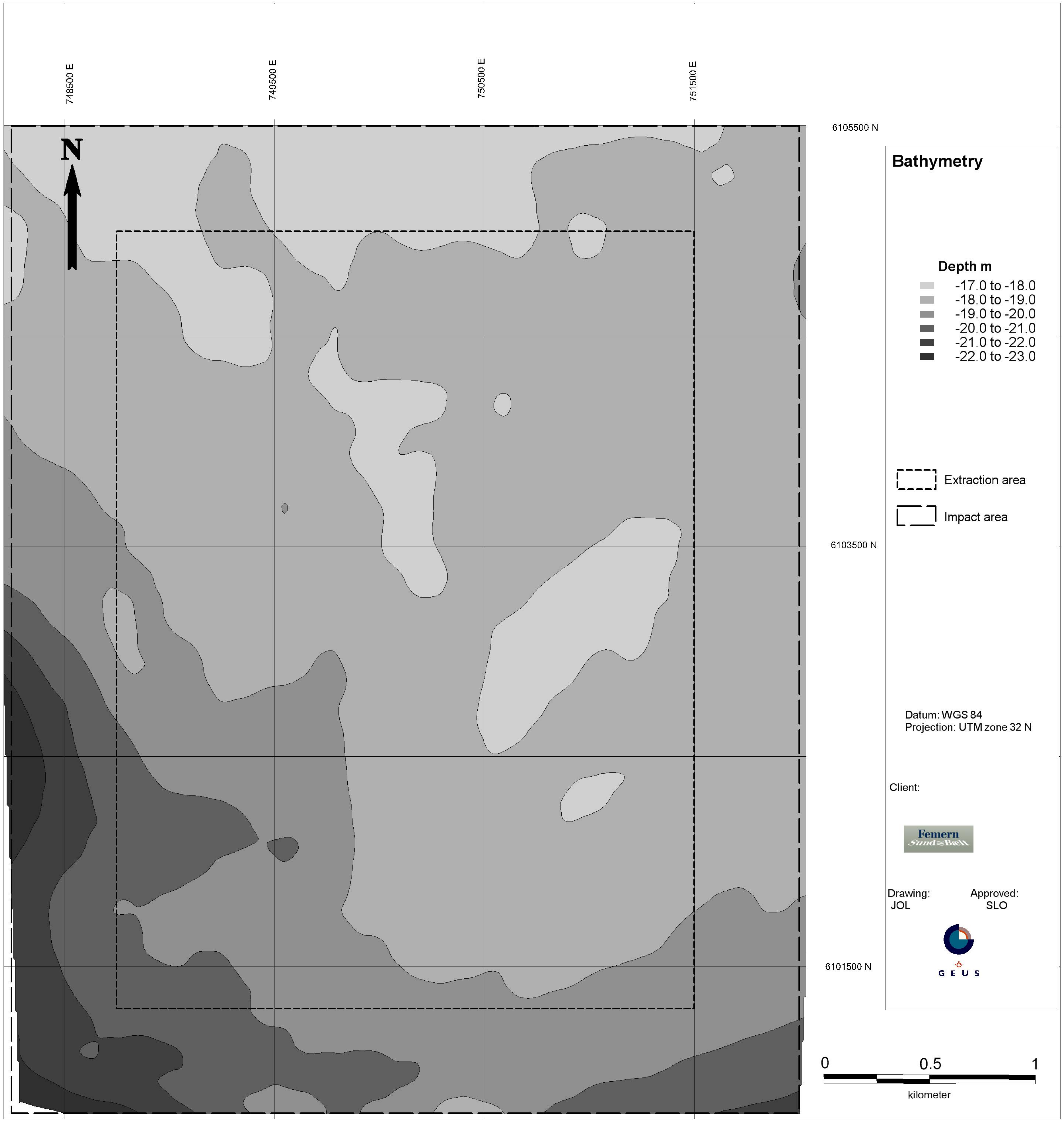
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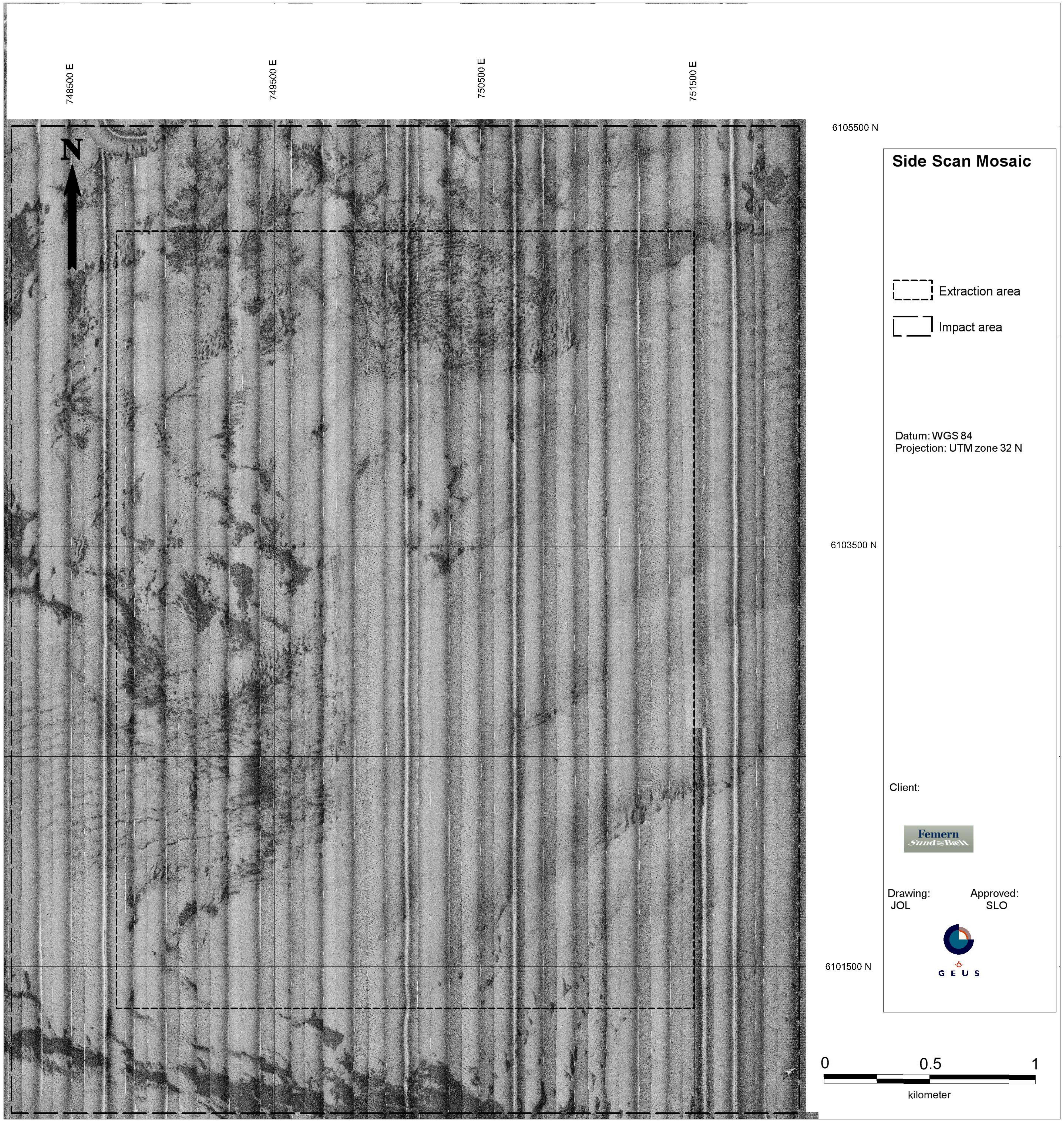
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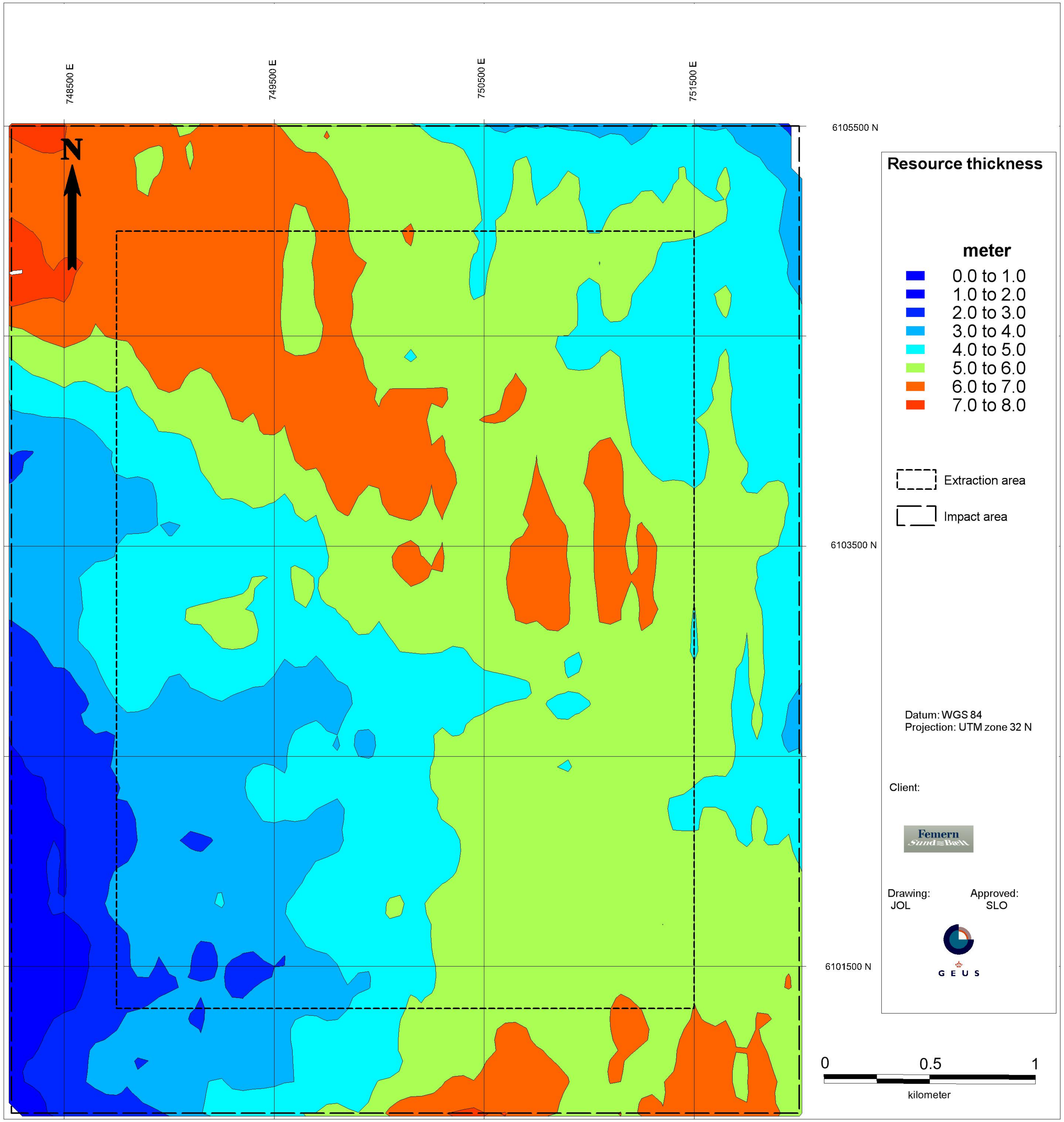
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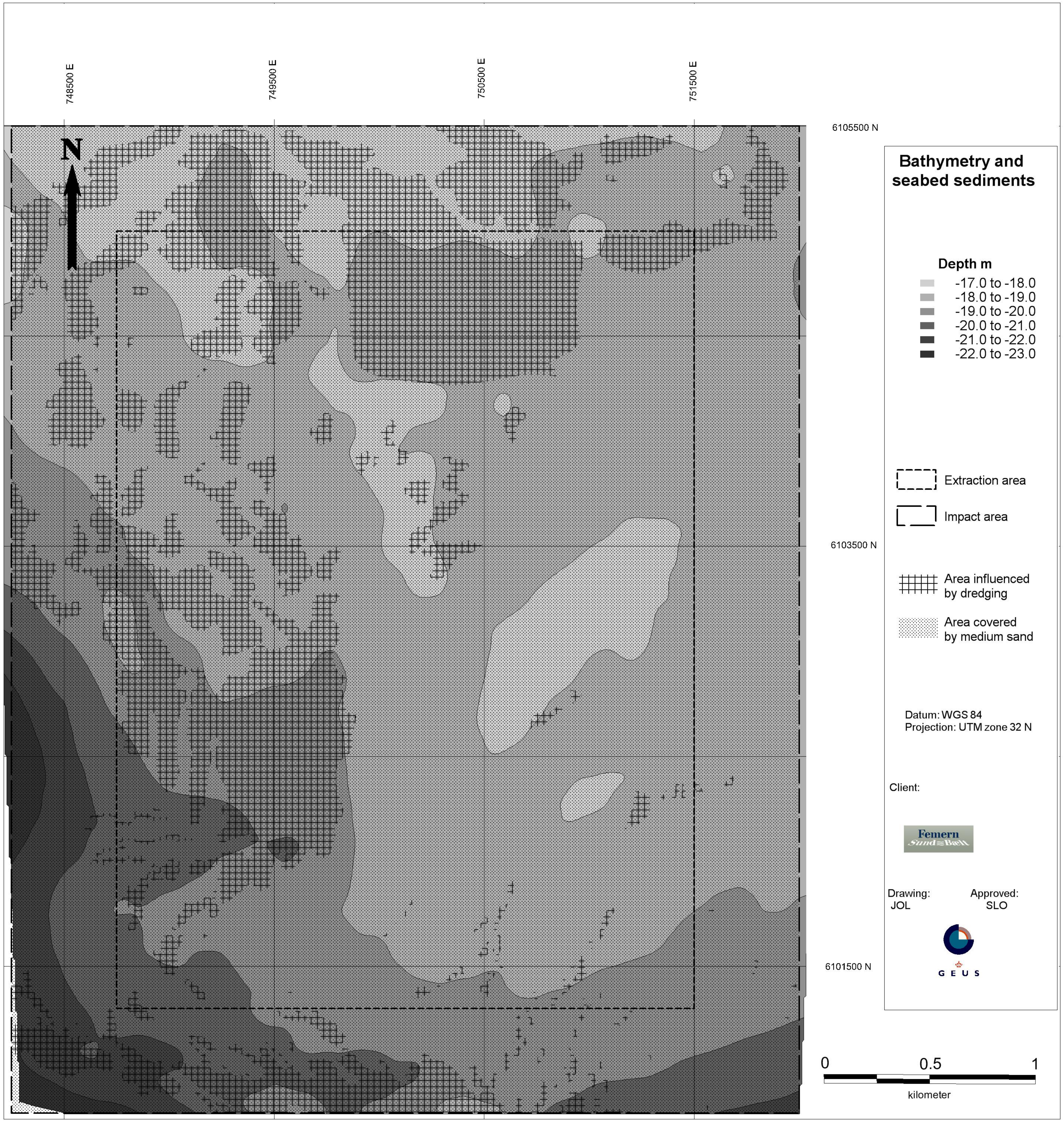
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751500 E
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Bathymetry and seabed sediments
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-19.0 to -20.0
-20.0 to -21.0
-21.0 to -22.0
-22.0 to -23.0
Extraction area
Impact area
Area influenced by dredging
Area covered by medium sand
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Projection: UTM zone 32 N
Client:
Femern Sund Bælt
Drawing: JOL
Approved: SLO
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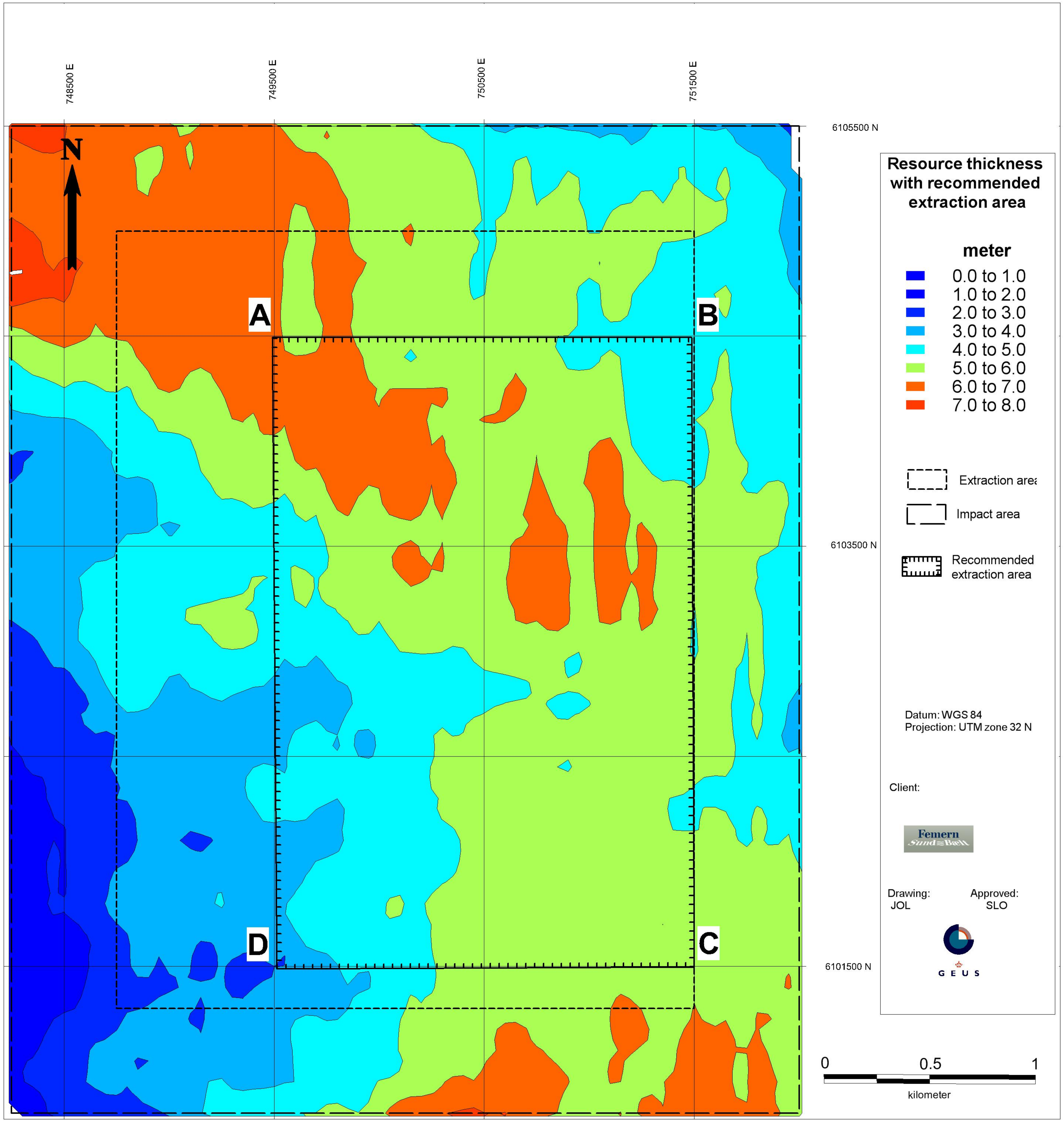
1
kilometer


748500 E
749500 E
750500 E
751500 E
6105500 N
6103500 N
6101500 N
N
A
B
C
D
Resource thickness with recommended extraction area
meter
0.0 to 1.0
1.0 to 2.0
2.0 to 3.0
3.0 to 4.0
4.0 to 5.0
5.0 to 6.0
6.0 to 7.0
7.0 to 8.0
Extraction area
Impact area
Recommended extraction area
Datum: WGS 84
Projection: UTM zone 32 N
Client:
Femern Sund Bælt
Drawing: JOL
Approved: SLO
GEUS
0
0.5
1
kilometer