ENERGINET - DANISH OFFSHORE WIND 2030

Cable Burial Risk Assessment

Kattegat - Grenå South Export Cable Route

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Cable Burial Risk Assessment

Kattegat - Grenå South Export Cable Route

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SUMMARY

Intertek Energy & Water (Intertek) has been appointed by Energinet to conduct a Cable Burial Risk Assessment (CBRA) study for the marine sections of the Kattegat - Grenå South cable route.

Sediment Mobility

Sediment mobility in itself does not pose a threat to a submarine cable but it can lead to issues with the thermal conductivity of cables (over burial), and exposure of cables (scour); Over burial should be accounted for in the design phase of the cables and is usually dealt with by increasing, universally or locally, the cross-sectional area of the cables. Burial under excess soil can change the thermal properties of the soil and cause hotspots along the cable, while exposure increases the risk of damage due to external aggressors such as trawling and anchoring and potentially mechanical damage from free spans.

There are a number of areas within the 1500m corridor where there are bedforms present which could be mobile.

For the purposes of depth of lowering all depths recommended in this report are assumed to be measured against a horizontal plane which has been determined to be non-mobile and after any required route engineering has been undertaken to flatten mobile sediments.

Fishing Risk

The review of the fishing indicated areas of mobile and static fishing gear along the entire cable route. No fishing protection or exclusion areas from fishing activity were reported.

Moreover, as the entire route is within water depth ranges in which mobile gear fishing could take place, we recommend the cables are given sufficient protection from fishing gear interaction in all sections of the route. The Carbon Trust's guidance indicates that penetration of fishing gear into the seabed is limited to a maximum of 0.3 m penetration even in soft sediment based on previous literature research. Allowing for a Factor of Safety (FoS) of 2 means Recommended Minimum Depth of Lowering (RMDOL) based on fishing risk only would result in a value of 0.60m.

Anchoring Risk

Vessel Automatic Identification System (AIS) data has been used to determine the size and quantity of vessels which operate in the vicinity of the cable route. Vessels are grouped into size categories based on their deadweight tonnage (DWT) from Band A (0-100 DWT) to Band K (325K-450K DWT) and an appropriate associated anchor size is assigned to each band. Analysis of this data determines the probability of anchor-cable interactions for each vessel banding and thus the size of anchor which must be protected against in order to reduce risk to the cable to As Low as Reasonably Practical (ALARP).

The probabilistic assessment calculates the annual failure probability of 42.65% for the entire route (based on anchor risk alone) if surface laid. This value equates to a return period of 2.34 years and a failure probability over the (40 year) lifetime of 100%. This is not an acceptable level of risk. Areas with the highest risk of Annual Failure include zone 13, 8, 10 and 2. These zones are areas of high vessel traffic thus; increased anchor drag risk. The lowest PA zones of risk are zones 12 and 3 given the low vessel traffic reducing all risk of anchor strike.

Note, the key reasons why anchor risk is not the key determinant in most zones is due to both the relatively light vessel densities and also the prevalent presence of soils which prevent anchors from penetrating very deeply.

Recommended Minimum Depth of Lowering (RMDOL)

The above approach results in a RMDOL varying from 0.65m to 2m. If these RMDOL values are achieved and maintained over the course of the cable lifetime then this would result in an annual failure rate of 0.00966% which equates to a return period of ~10,352 years and a failure probability over the (40 year) lifetime of 0.39% - i.e. "Event rarely expected to occur".

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GLOSSARY

AIS
Automatic Identification System

ALARP
As Low As Reasonably Practical

BGS
British Geological Survey

CBRA
Cable Burial Risk Assessment

CPT
Cone Penetration Test

DMA
Danish Maritime Authority

DNV
Det Norske Veritas

DoL
Depth of Lowering

DoC
Depth of Cover

DTM
Digital Terrain Model

DWT
Deadweight Tonnage

EMODnet
European Marine Observation and Data Network

EU
European Union

F&S
Fishing and Shipping

FoS
Factor of Safety

GS
Grab Sample

hr
Hour

ICES
International Council for the Exploration of the Sea

IACS
International Association of Classification Societies

IMO
International Maritime Organisation

Intertek
Intertek Energy and Water

kg
Kilogram

KP
Kilometre Positions

kPa
Kilopascal

m
Metre

MAIB
Marine Accident Investigation Branch

MBES
Multi-Beam Echo Sounder

MMO
Marine Management Organisation

MPa
Megapascal

MPA
Marine Protected Area

MSFD
Marine Strategy Framework Directive

MTTF
Mean Time of Failure

nm
Nautical Miles

NTZ
No-Take Zone

O&M
Operation and Maintenance

PPA
Partially Protected Area

PCI
Project of Common Interest

RMDOL
Recommended Minimum Depth of Lowering

SAR
Swept Area Ratio

SBP
Sub-Bottom Profiler

SI
Seabed Index

SSS
Side Scan Sonar

TAC
Total Allowable Catch

TDOL
Target Depth of Lowering

ToP
Top of the Product

VC
Vibro-Core

yr
Year

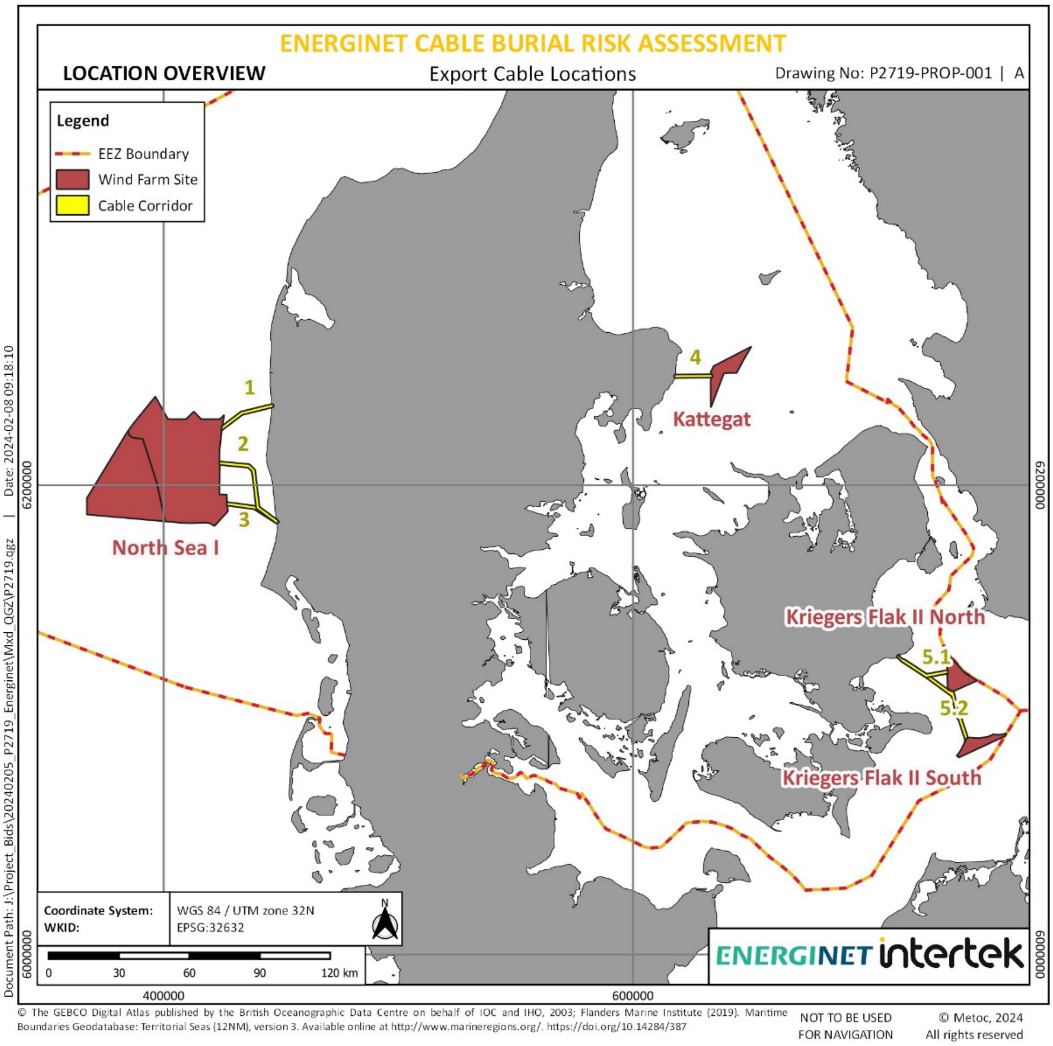
1. INTRODUCTION

Intertek Energy & Water (Intertek) has been appointed by Energinet to conduct a Cable Burial Risk Assessment (CBRA) study for the marine sections of the Kattegat - Grenå South cable route.

1.1 Project Background

Denmark is developing further offshore wind energy areas and related infrastructure in the Danish North Sea, the inner Danish Waters, and the Danish Baltic Sea as per a decision made by the Danish Parliament in 2022. It is understood that five main subsea cable connections will connect the offshore wind energy in the areas of North Sea I, Kattegat, and Kriegers Flak II to the Danish mainland. There will be three cable routes from North Sea I, one from Kattegat, and one from Kriegers Flak II as illustrated in the below overview map.

Figure 1-1 Danish Offshore Wind 2030 Investigated Offshore Wind Farm Areas and the Associated Export Cable Corridors (1500m wide)



It is understood that the width of the corridors for the route survey is 1500 m. Energinet anticipates that at least two cables are planned for each corridor. The length of the routes is detailed below in **Table 1-1**.

Table 1-1 Kattegat - Grenå South Export Cable Route

No.	Cable Route	Length [km]
4	Kattegat - Grenå South	Ca. 15 km

1.2 Revision List

This is second issue based on comments from Energinet – Revision 1

1.3 Scope of Work

Intertek has undertaken a thorough analysis and assessment of threats and risks concerning the integrity of the subsea cable throughout its lifetime. We have utilised the geophysical and geotechnical route survey data provided, along with available archive data. We have combined various elements detailed below such as threat identification, frequency analysis, failure assessment, risk assessment, to determine our recommendation for sufficient depth of lowering for installation and operation.

The purpose of this report is to identify any potential areas where activities, such as shipping and fishing, may pose a risk to the integrity of the installed cable and thus derive recommended depth of lowering along the route based on these threats.

The probabilistic method described by the Carbon Trust and used within this report relates to amount of time a vessel spends within a critical distance of the cable and the probability that a vessel might have an incident where the deployment of an anchor is necessary. When an event is certain to occur, its probability is 1.

Assumptions used are considered conservative and 'realistic worst case' which produces higher probabilities than would likely be the case. This enables the route and installation methods to be considered with a higher margin of safety.

Threat Identification:
Intertek completed the identification of an array of potential threats, including but not limited to foundering vessels, dropped objects, anchors, grounding ships, fishing activities, construction undertakings from neighbouring projects, and extraction of raw materials.

Frequency Analysis:
Following the threat identification process, a frequency analysis to evaluate the probability of events associated with identified threats, segmenting the analysis into 100-meter cable sections, was completed. The outcome presented through a series of detailed charts and tables for each individually identified threat, providing a clear understanding of the associated risks.

Failure Assessment:
Based on the frequency analysis and assessment the probability of failure in the event of any encountered threats was calculated. This assessment took into account factors such as the amount of cover on top of the asset and the likelihood of cable failure relative to the frequency of encounters with each identified threat type, ensuring a comprehensive evaluation of potential failure scenarios.

Risk Assessment:
A comprehensive risk assessment, quantifying the total probability of failure (PoF) along the cable route was undertaken.

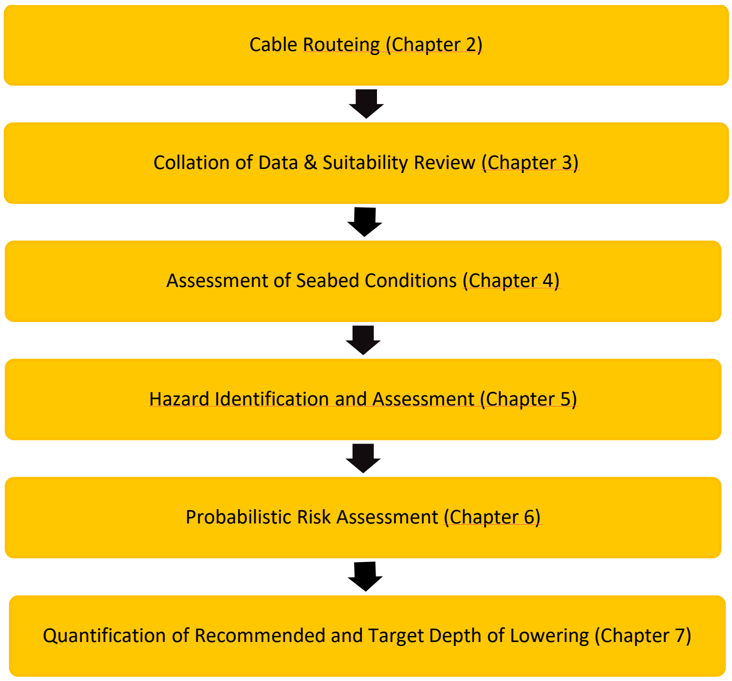
PoF at intervals of 1 failure per 10,000 years was discussed, determined and agreed by Energinet on the 19/03/2024 as a target failure that provides a robust level of protection. As per Energinet's suggestion, Intertek has used the DNV risk assessment guidelines (see Table 6-6) aiming for a Category 2 risk " Event rarely expected to occur" that encompasses a 1 in 10,000 PoF.

Additionally, Intertek have provided a representation illustrating how PoF varies with cable depth of lowering. This facilitates informed decision-making regarding risk mitigation strategies.

Recommended Depth of Lowering:
Drawing insights from the risk assessment, Intertek propose a recommended depth of lowering tailored to mitigate the identified risks posed by external threats. This depth of lowering (DoL) varies along the cable route to account for specific risk profiles, ensuring optimal protection of the asset throughout its operational lifespan.

The CBRA study presented in this report has been undertaken following the Carbon Trust's proposed methodology (Carbon Trust, Feb 2015) and steps (see **Figure 1-2**).

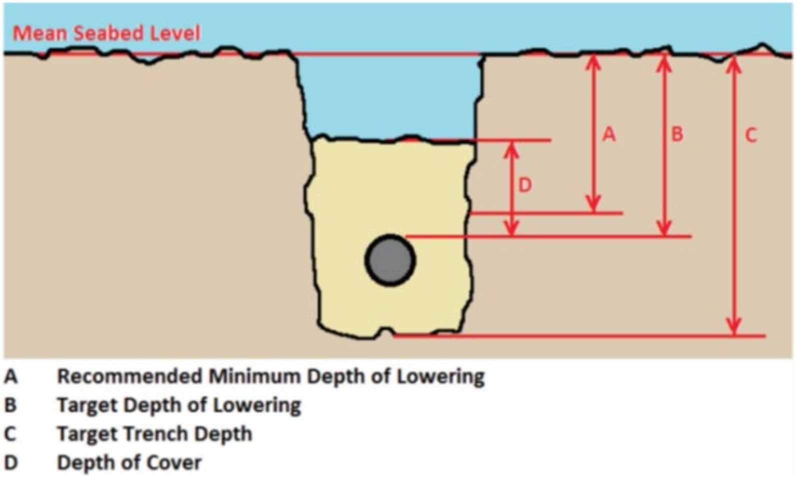
Figure 1-2 Burial Risk Assessment Method Flowchart in Line with Carbon Trust CTC835 Guideline



1.4 Definition of Trenching Parameter

Intertek has used the Carbon Trust's definition of Depth of Lowering (DOL) for this study. This is illustrated in **Figure 1-3.**

Figure 1-3 Definition of Burial Terms used in Report



Recommended Minimum Depth of Lowering (RMDOL)
This is the minimum DOL recommended for protection from the external threats. It is the direct output of the fishing risk assessment and the probabilistic anchor risk assessment and includes a factor of safety (FoS).

Target Depth of Lowering (TDOL)
This is the depth that will be specified as the target depth to the cable installation contractor. TDOL is a depth which makes best use of what is achievable by industry standard burial tools to gain additional depth beyond RMDOL without incurring a step change in costs. Target DOL is also a practical application of depth which considers the effect burial depth has on tool stability.

Target Trench Depth
This is the trench depth cable installation contractors determine is required to meet TDOL. This is driven by cable properties and the selected trenching tool and is usually the diameter of the cable plus between 0.1 m and 0.4 m beyond the TDOL.

Depth of Cover (DoC)
The thickness of material on top of the cable after trenching. DoC can vary depending on the sediment type and tidal cycles I.E in areas of fine sand or in stormy locations

1.5 Relevant Data

Data obtained from the geophysical and geotechnical campaigns and other relevant data sources are presented in **Table 1-2** below.

Table 1-2 Data Used in the CBRA

Data Type	Name	Information
Survey Bathymetry	KT_ECR2_MBES_XYZ_025m.xyz	0.5m resolution bathymetry over a 1500m survey corridor
	KT_ECR2_CONTOURS_LIN.shp	0.5m bathymetry contours over the extent of the survey corridor
Open-Source Bathymetry	EMODnet Bathymetry	EMODnet Digital Terrain Model (DTM) is generated for European sea regions from selected bathy survey data sets (1975 to 2013 using SBES & MBES) and composite DTMs, while gaps with no data coverage are completed by integrating the GEBCO Digital Bathymetry. 200m Resolution
AIS Data	Intertek_Data_Extent_201708_to_201807	5-minute time series data of shipping from 07/02/2023 to 06/02/2024 +/- 5nm either side of the route centreline provided by Exmile Solutions Ltd
Geology	Shallow Geological Isopach	Draft shallow geological isopach interpreted from sub-bottom profiler data and correlated with side scan sonar imagery and bathymetric digital terrain model data
Geotechnical Samples	Vibrocore, Cone Penetrometer Tests and grab sample logs	Draft geotechnical sample logs from Vibrocore (VC), Cone Penetration Test (CPT) and Grab Sample (GS)
Desktop Study	Screening of seabed geological conditions for the offshore wind farm area Kattegat II and the adjacent cable corridor area	Geological desktop study of the area undertaken by GEUS
Fishing Intensity	EMODnet	Datasets on fishing intensity in the EU waters by sea basin, created every year by the International Council for the Exploration of the Sea (ICES). In the 2020 Cogea started to collect and harmonize them according to the EMOdnet Human Activities dataset schema. This dataset is updated yearly. The fisheries overview data concern the spatial distribution of average annual fishing effort (mW fishing hours) by ecoregion and by gear type. Fishing effort data are only shown for vessels >12 m having VMS.
Registry information on fishing vessels	Danish Ship Register (DAS)	General registry of the Danish fishing fleet including information on registered vessels by fishing area, method, base port, length, power, etc.
Annual Report on Danish Fisheries	Danish Fisheries Agency	Annual statistics for marine fisheries for 2022 including information on FAO area of catch and species.

1.6 Limitations

The Cable Burial Risk Assessment analysis presented herein has been undertaken using the data listed in **Table 1-2** provided at the time of analysis. It is important to note that, as of the completion of this analysis and the writing of this report, the geophysical interpretation, geotechnical factual and integrated reports were not available from the survey contractor. Additionally, no alignment charts were available. Intertek's analysis of the soils conditions along the route is based solely on the analysis of the draft geotechnical coring and cone penetrometer logs.

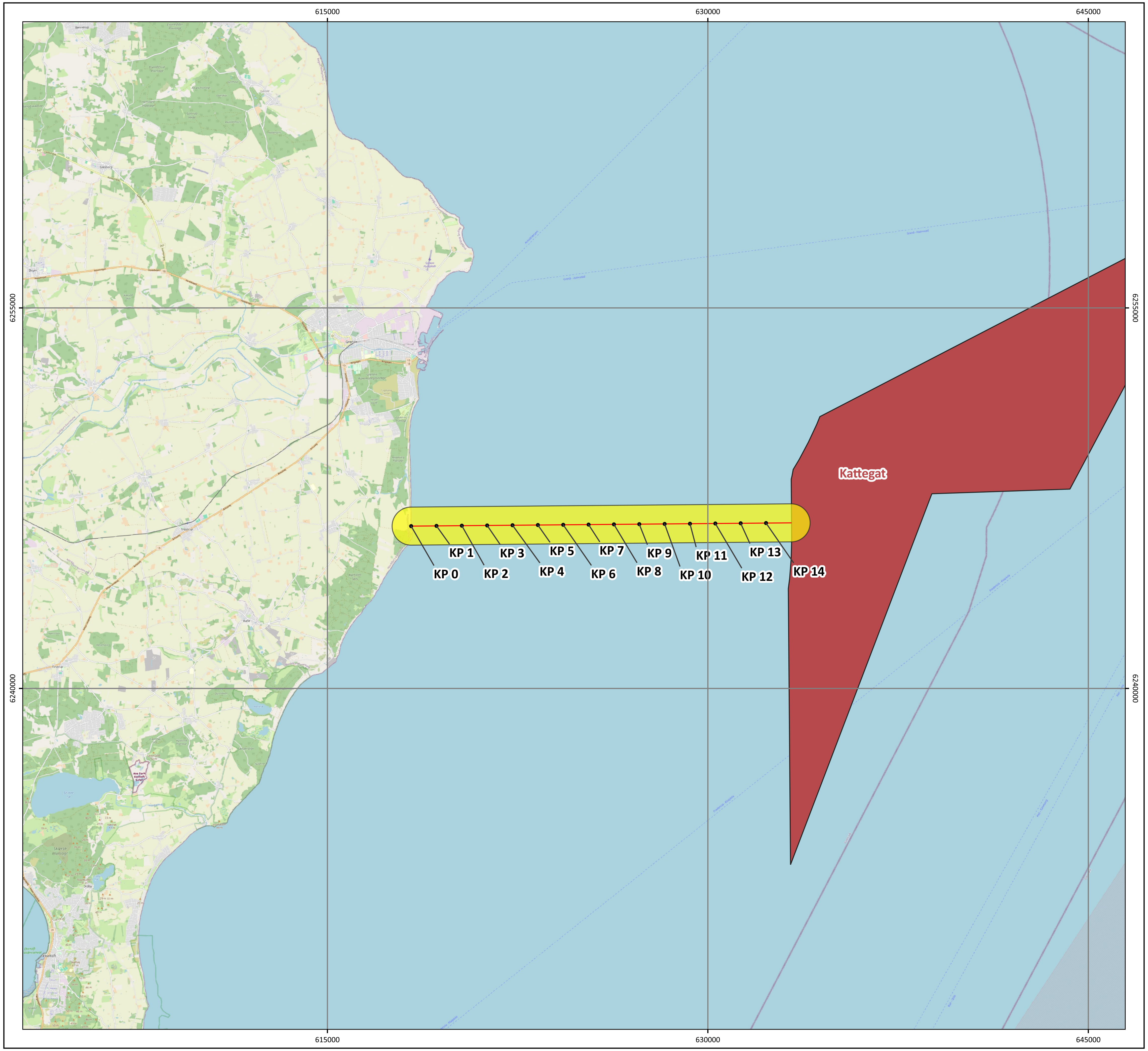
This report reflects the most current understanding of the site conditions. It should be noted that the analysis does not take into account future shipping patterns that will result from the construction of the windfarm since to many variables will be assumed for this verification and was not part of the initial methodology. Future revisions of this report may be necessary once the completed geophysical and geotechnical interpretation becomes available for review and integration into the analysis, and as shipping patterns evolve.

2. CABLE ROUTEING

Export cable route was received from Energinet as part of the data package. The export cable route extends from landfall location to the planned offshore wind location at KP15. See **Figure 2-1**

Kilometre Positions (KP) were calculated using a tool in ArcGIS using the provided survey centreline shapefile.

The cable corridor surveyed was 1500m.



CABLE BURIAL RISK ASSESSMENT KATTEGAT - GRENÅ SOUTH - CBRA

LOCATION OVERVIEW

Cable Route

Drawing No: P2719E-LOC-001 | B

Legend

- KP
- Cable Route
- Cable Corridor (1.5km)
- Wind Farm Site

N

NOT TO BE USED FOR NAVIGATION

Date	2024-06-19 12:46:28
Coordinate System	ETRS89 / UTM zone 32N
WKID	EPSG:25832
Scale @A3	1:150,000
Data Sources	ENERGINET; NUTS
File Reference	J:\P2719\Mxd_QGZ\P2719E\01_LOC \P2719E_LOC.qgz
Created By	Lewis Castle
Reviewed By	Emma Langley
Approved By	Stephane Theurich

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0 2 4 6 8 km

3. COLLATION OF DATA AND SUITABILITY REVIEW

This section provides an overview of the bathymetrical and geological data along the surveyed corridor, based on the interpretation of the geophysical and geotechnical data. All data obtained from the geophysical and geotechnical survey has been correlated with each other, and the output from this has been compared to the existing data sources.

3.1 Bathymetric Data

The seabed topography along the route is characterised by the presence of areas of mobile sediments, outcrop of bedrock, boulders, linear features such as furrows or striations of coarser sediment and varying relief. The knowledge of these features is critical to any cable installation feasibility study. This section describes the existing bathymetry data in the study area and the resolution and quality of each dataset.

Sources for the bathymetry datasets can be found in Section 1.5 and is summarised below:

- EMODnet Bathymetry – 100m resolution
- Survey Data – 0.5m resolution bathymetric soundings
- Survey Data – 0.5m bathymetry contours

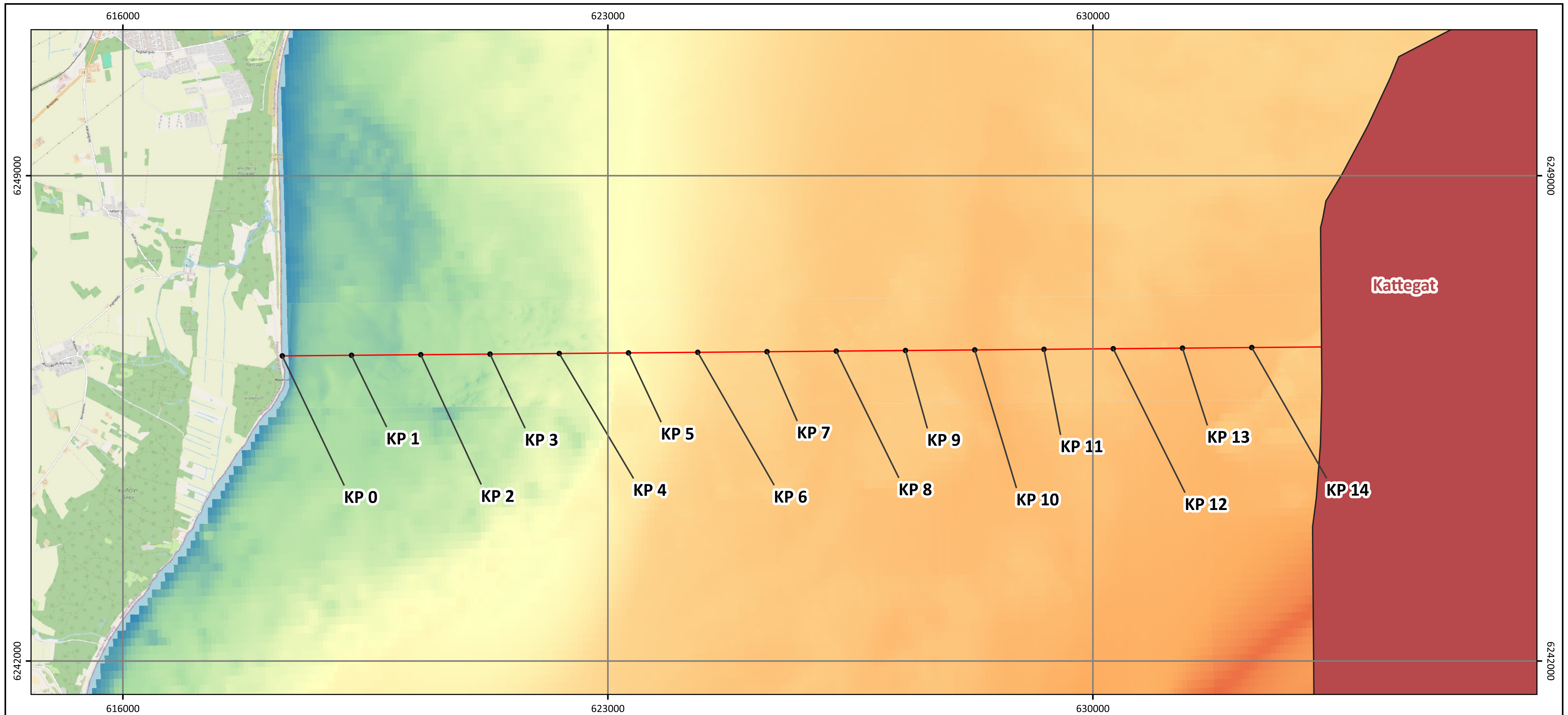
The open-source data (EMODnet Bathymetry) was used to define the route centreline for survey. These sources provide a good overview of the surrounding area and highlight large features such as sandwaves. There is good overall correlation between the open-source data and the acquired high resolution survey data.

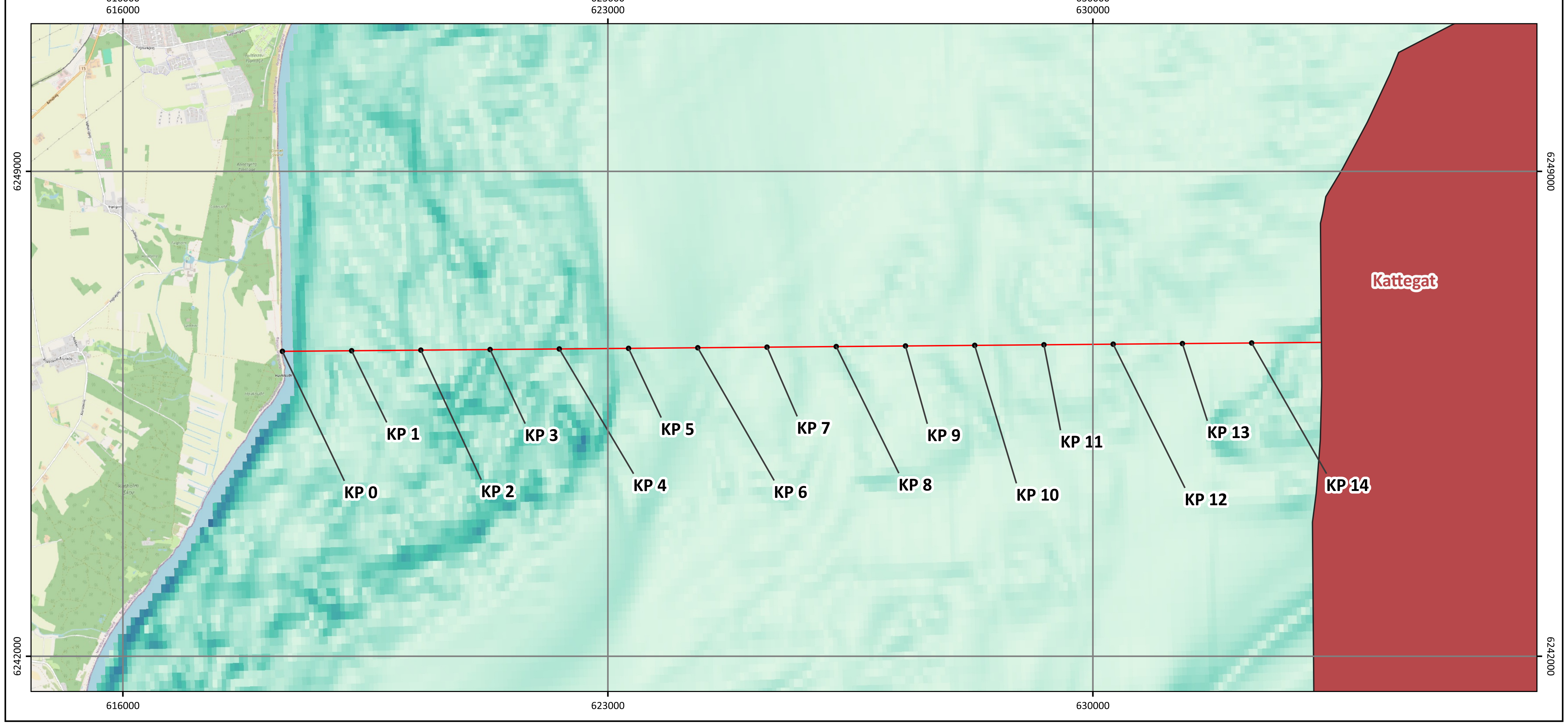
3.1.1 Suitability of Data

The bathymetric soundings obtained for this study is of very high quality and processed to a high resolution (0.5m). It has highlighted areas of shoaling, potential areas of sediment mobility, areas of outcrop and in some cases confirmed the presence of wrecks and obstructions.

The offshore dataset provided by EMODnet is a dataset suitable to show water depths, areas of shoaling and bathymetric lows. The low-resolution dataset confirms the presence of larger features in the study area, but its resolution is too low to determine any migration rate of mobile bedforms. The acquired, bathymetric data could be used to provide this insight, if compared to a similar, but temporally different data set.

An example of the typical slopes encountered within the survey corridor has been provided by the survey contractor and shown in **Table 3-1**. The zones were derived from the geological zonation and then refined taking into account the shipping patterns. The bathymetry profile of the cable route is displayed in **Figure 3-2.**





CABLE BURIAL RISK ASSESSMENT KATTEGAT - GRENÅ SOUTH - CBRA

BATHYMETRY

Bathymetry Along Cable Route

Drawing No: P2719E-BATH-001	B

Legend

N

- KP
- Cable Route
- Wind Farm Site

Bathymetry (m below LAT)

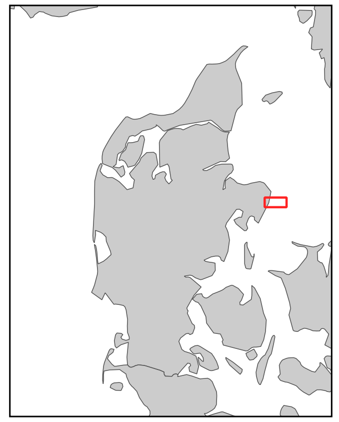
0

-30

Seabed Slope (Degrees)

0

2



NOT TO BE USED FOR NAVIGATION

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File Reference	J:\P2719\Mxd_QGZ\P2719E\01_LOC \P2719E_LOC.qgz
Created By	Lewis Castle
Reviewed By	Emma Langley
Approved By	Stephane Theurich

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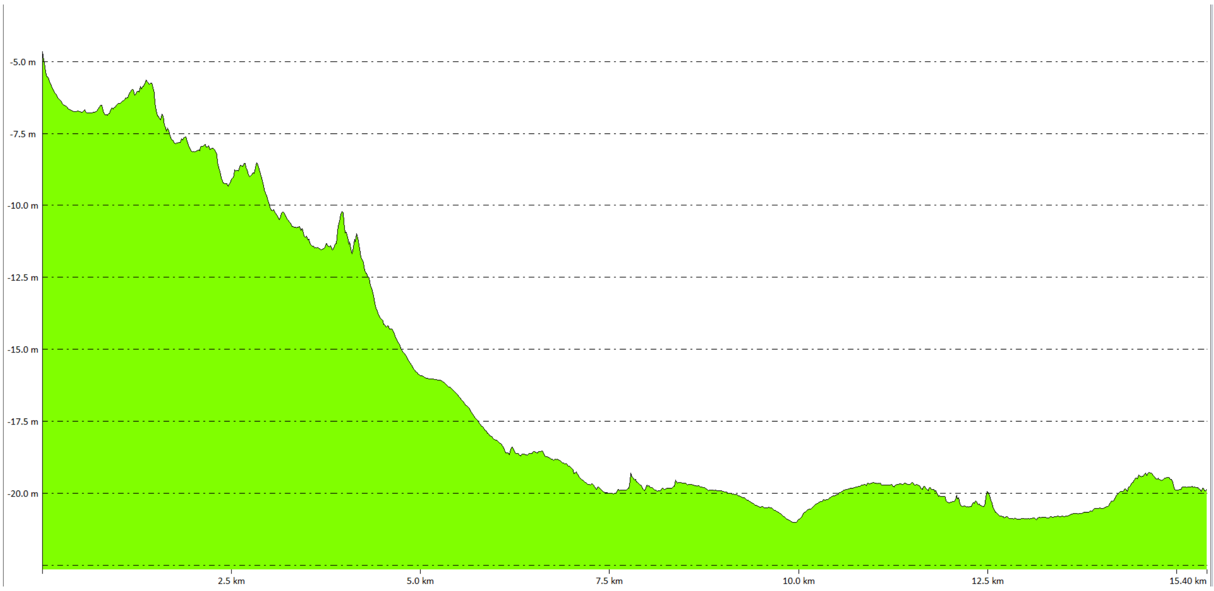
0 1 2 3 4 km

The bathymetric metadata and Digital Terrain Model data products have been derived from the EMODnet Bathymetry portal - http://www.emodnet-bathymetry.eu.; © EuroGeographics, © TurkStat.; © Energinet;

Figure 3-2 Bathymetric Profile along the Cable Route Centreline (West - East)



3.2 Geophysical Data

The geophysical data was surveyed by GEOxyz, producing the following data sets. Side scan sonar (SSS) data has been used for interpretation of surficial geology, identification of seabed features, and to select contacts. Sediment classes distinguished from SSS imagery are correlated with grab sample, vibrocore (VC) and cone penetration test (CPT) results. Topographical features identified from SSS records have been correlated with bathymetric digital terrain models processed from the bathymetric sounds acquired using the multibeam echo sounder (MBES). Shallow geology interpretations are based on sub-bottom profiler (SBP) data correlated with the geotechnical sampling results. SSS and MBES data is also used to corroborate the SBP data interpretation in the uppermost layers. Magnetometer records collected during the survey are used to identify cables and ferrous objects on the seafloor within the survey corridor.

It should be noted that Intertek did not do any of the initial geophysical interpretation. Furthermore, not all the data was available at the time of writing this CBRA (see section 3.2.2.)

3.2.1 Geophysical Survey

3.2.1.1 Bathymetry and Seabed Morphology

The route is generally characterised by gradually sloping seabed from the landfall to the end of the route. The maximum depth along the route is 21m at KP10. Moderate gradients are generally associated with areas of mobile bedforms, comprising of megaripples and sandwaves. Mobile bedforms are present in discreet areas within the corridor length.

3.2.1.2 Seabed Sediments and Features

The surficial sediments vary mainly between very loose SAND to low strength CLAY.

The interpretation of surficial sediment types was derived from the acoustic character of the SSS data, and the interpretations were aided by MBES bathymetric 3D surfaces and SBP data. During the review of the SSS survey data, higher intensity sonar returns (darker grey to black colours) were interpreted as relatively coarser grained sediments, and lower intensity sonar returns (lighter grey colours) were interpreted as relatively finer grained sediments. Bathymetric data was used to correct the interpretation for the effects of seabed slope on sonar returns. The correlation with the geotechnical results was initially based on the field logs and further verified with the final geotechnical results.

Seabed sediment classifications are as follows in **Table 3-1.**

Table 3-1 Seabed Sediment Classification from SSS Data

Acoustic Description	Interpretation
Low to medium acoustic reflectivity. Slightly grainy texture.	SILT and SAND The ratio between sand and silt can vary within this sediment type. The sediment often has a patchy appearance due to variation of the dominating sediment fraction.
Low to medium acoustic reflectivity. Slightly grainy to grainy texture with point source reflectors.	SILT Predominantly silt, may have minor fractions of clay, sand and/or gravel.
Medium acoustic reflectivity, slightly grainy texture.	SAND Predominantly sand, may have minor fractions of clay, silt and/or gravel.
Medium to high acoustic reflectivity. Slightly grainy to grainy texture, coarse texture in places.	Gravelly SAND to sandy GRAVEL The ratio between SAND and GRAVEL can vary within this sediment type.
High acoustic reflectivity. Grainy to coarse texture.	GRAVEL Predominantly gravel, may have minor fractions of clay, silt and/or sand.
Medium to high acoustic reflectivity. Exhibits relief and texture.	BEDROCK Comprises outcrops of crystalline bedrock

Seabed Feature Classifications are as follows in **Table 3-2**.

Table 3-2 Seabed Feature Classification

Interpreted Seabed Feature	Criteria[1]
Ripples	Wave length <15 m, Height <1.0 m
Megaripples	Wave length 15-25 m, Height 1-3 m
Sandwaves	Wave length 25-200 m, Height >3 m
Boulder Field Occasional boulders All >0.5 m	Concentration of 10 to 20 boulders within a maximum area of 100 x 100 m
Boulder Field Numerous boulders All >0.5 m	Concentration of >20 boulders within a maximum area of 100 x 100 m
Trawl Mark Area	Concentration of numerous trawl marks
Current Lineation	Current lineation

[1] Note, there is no standard for bedform descriptions. Criteria presented in **Table 3-2** are as defined by route survey contractor. Alternative criteria are also common.

3.2.1.4 Shallow Geological Features

The shallow geology along the route is characterised by variations of units of SAND, SAND overlying CLAY, CLAY overlying SAND and CLAY units. No subcropping or outcropping bedrock was noted from the analysis of the geotechnical information provided.

The classifications of the shallow geology have been derived through a combination of analysis and interpretation of the acoustic character of the SBP data and was modified according to the geotechnical results. A comparison with available background information was made and broken down into major sediment types along the route (**Table 3-3**).

Table 3-3 Shallow Geology Soil Types and Lithology

Sediment Type	Acoustic Characters	Lithological Variation
Veneer	-	Veneer of mobile sediments not resolved in seismic data (generally <0.5 m). SAND Occasionally SILT. Veneer of reworked sediment by winnowing of fines often present of top of TILL.
Sand	Acoustically homogeneous to layered, low to medium amplitude recent sediments present at seabed. Base often medium to high amplitude indicating presence of coarser sediment	Fine to coarse SAND. May locally contain shells, pebbles, cobbles and pockets of SILT, CLAY and GRAVEL. Commonly forming mobile sediment.
Till	Either heterogeneous with acoustic character indicating the presence clay with sand layers and possible coarser sediments, and boulders or Limited or no acoustic penetration.	Possible glacial deposit / till or diamicton. Unsorted sediment, soft to stiff clay with interbeds of sand, and layers/lenses of coarse sand and gravel. May contain pebbles, cobbles, and boulders.

3.2.2 Suitability of Geophysical Data

It is understood that the client requested early delivery of CBRA before the full geophysical survey data and reports are/were available therefore, they were not used in this project. Therefore, the geophysical data provided for this study is mixture of suitable and not usable;

Seabed features were provided in the form of a shapefiles that were of medium quality highlighting some of the seabed features present. Similarly, surficial deposits and SBP isopach's were deemed of good quality and were useable for this project.

However, SSS mosaics were not provided and the RAW SBP was unusable with no TIFS provided.

The final geophysical survey report was not provided.

3.3 Geotechnical Data

The geotechnical survey, undertaken by GEO, consisted of vibrocore samples (VC) and cone penetration tests (CPT).

In total, 19 CPT locations were carried out, with 6 re-attempts required.

For the vibrocores, a total of 16 locations were carried out with 6 re-attempts required.

3.3.1 Vibrocores

The vibrocores were recovered using electrically powered vibrocoring units. The corers were fitted with 6m long core barrel and used clear PVC 100mm OD liner. A 'basket-spring type' core catcher was fitted above the cutting shoe, in the base of the vibrocore barrel, to maximise retention of the penetrated sediment during retraction from the seabed and subsequent retrieval of the unit to the vessel deck.

During VC operations, there were instances of re-attempts being required largely due to initial poor recovery. Poor penetration and subsequent low material recovery were generally a function of dense to very dense coarse granular material or high strength cohesive material being encountered.

3.3.2 Cone Penetration Testing

CPTs were carried out to a maximum depth of 5.5m using 10cm2 electric piezocones operated from a seabed CPT unit.

The aim at each CPT location was to reach the target penetration depth of 6m. Re-attempts were required due to either initial failure to reach the required depth, concern with the overall test application class, or due to electrical power and/or communication issues with the seabed CPT unit.

3.3.3 Suitability of Geotechnical Data

Each VC and CPT log are clearly presented and provided the relevant geological information at each location.

3.4 Installation Constraints Identified from Available Data

- Extensive surficial boulder fields were identified by Intertek from the bathymetric data.
- No bedrock outcrops/subcrops were identified from the geotechnical logs.
- No third-party infrastructure to cross.
- Mobile sediments ranging from ripples to megaripples and occasional sandwaves, with associated local gradients, are present on sections of the route.

3.5 AIS Shipping Data

3.5.1 Methodology

AIS (Automatic Identification System) is an automatic tracking system used on ships for identifying and locating vessels by electronically exchanging data with other nearby ships and AIS base stations and satellites. The International Maritime Organisation (IMO) requires AIS to be fitted aboard international voyaging ships with gross tonnage of 300 or more tons, and all passenger ships regardless of size. This would cover almost all commercial vessels and most private vessels that would be of risk to the cable; however, some smaller fishing vessels could be missing from the AIS dataset.

Information provided by the AIS equipment usually consists of unique identification number for each vessel, vessel name, vessel type, vessel position, course, and speed. Other attributes like vessel deadweight tonnage and draught may be completed by the AIS supplier.

To quantify the anchoring risk to the cable, Intertek procured historical AIS data for a 12-month period (Exmile Solutions, 2024) between February 2023 and February 2024. Data were comprised of both terrestrial (AIS-T) and satellite derived (AIS-S) sources. Each record included a series of standardised attributes, as detailed in **Table 3-4**. This wide study area allows a clear insight into vessel movements by vessel type/size in the surrounding geography.

Table 3-4 Standard Attributes used During DATA Processing

Parameter	Format	Description
MMSI	Numerical	Maritime Mobile Service Identify number, unique to each vessel
Vessel Name	Text	Name given to the vessel
Vessel Type	Text	Category assigned to the type of ship (e.g. Fishing, Cargo, Tanker, Pleasure craft)
Status	Numerical	Code given
Speed	Numerical	Travelling speed (knots)
Longitude	Numerical	Longitude of the ship's position
Latitude	Numerical	Latitude of the ship's position
Course	Numerical	Direction the ship is travelling
Heading	Numerical	Direction the ship is facing
Timestamp (UTC)	Date and time	Time and date of the ship's location
Length	Numerical	Length of the vessel (meters)
Draught (mx10)	Numerical	Distance between the sea level and keel of the vessel
SWT	Numerical	Carrying capacity of the vessel (tonnes)

3.5.2 Data Sources, Gaps and Omissions

The data sources for this section are shown below in **Table 3-5.**

Table 3-5 AIS Data Sources

Type of Data	Source	Description
Automatic Identification system (AIS)	Exmile Solutions	Information of individual ship locations from land and satellite-based receivers from 7/2/23 to 6/2/24.

As an initial quality control measure, a gap analysis was undertaken removing duplicated entries of a ship’s position where the same timestamp was reported. The procedure also involved using public databases to fill in missing attributes including vessel length, vessel type and deadweight tonnage. Although a significant portion of the vessels had missing DWT values, these were accounted for by aggregating vessel types into broader and more meaningful categories, reducing the number of classes from 60 to 13. The broad categories were selected to be consistent with the classes reported on the EMODnet Human Activities portal (European Comission, 2024). The translation from the original vessel types into the EMODnet Human Activities classes is demonstrated in **Table F-1 in Appendix F**.

Once aggregated, an empirical relationship was established between vessel length and deadweight tonnage for each new vessel type. (See section 6.2).From here, records that were missing information on a vessel’s deadweight tonnage could be inferred by applying the formula to the vessel length. Records where key attributes could not be sourced from public databases or inferred through empirical formulae were omitted from the analysis as they would not be successfully sorted into anchor band categories for the CBRA. .

To ensure the best resolution for the data and future CBRA, data was interpolated from a 5-minute time step to a 1-minute time step using an in-house application. The interpolation process produced regular points between vessel pings with time intervals exceeding 1 minute. Vessel density grids for the area were produced by overlaying a square grid comprising 0.5 km^2 cells to determine the density of track lines on an overall, yearly/seasonal basis.

3.5.3 AIS Analysis

3.5.3.1 Vessel Traffic

The main vessel traffic crossing the proposed cable route is in the form of tanker, tug, passenger, pleasure crafts, sailing, cargo, fishing vessels, and service. **Figure 3-3** below shows the total vessel density for 12 months.

Seasonal variations show the highest months of vessel traffic are present in Winter (Jan – Mar). The lowest months are in the Autumn (Oct – Dec). The seasonal and vessel heat maps are presented in **Appendix D**.

3.5.3.2 Anchorages

No anchorages were identified in the vicinity of the cable route.

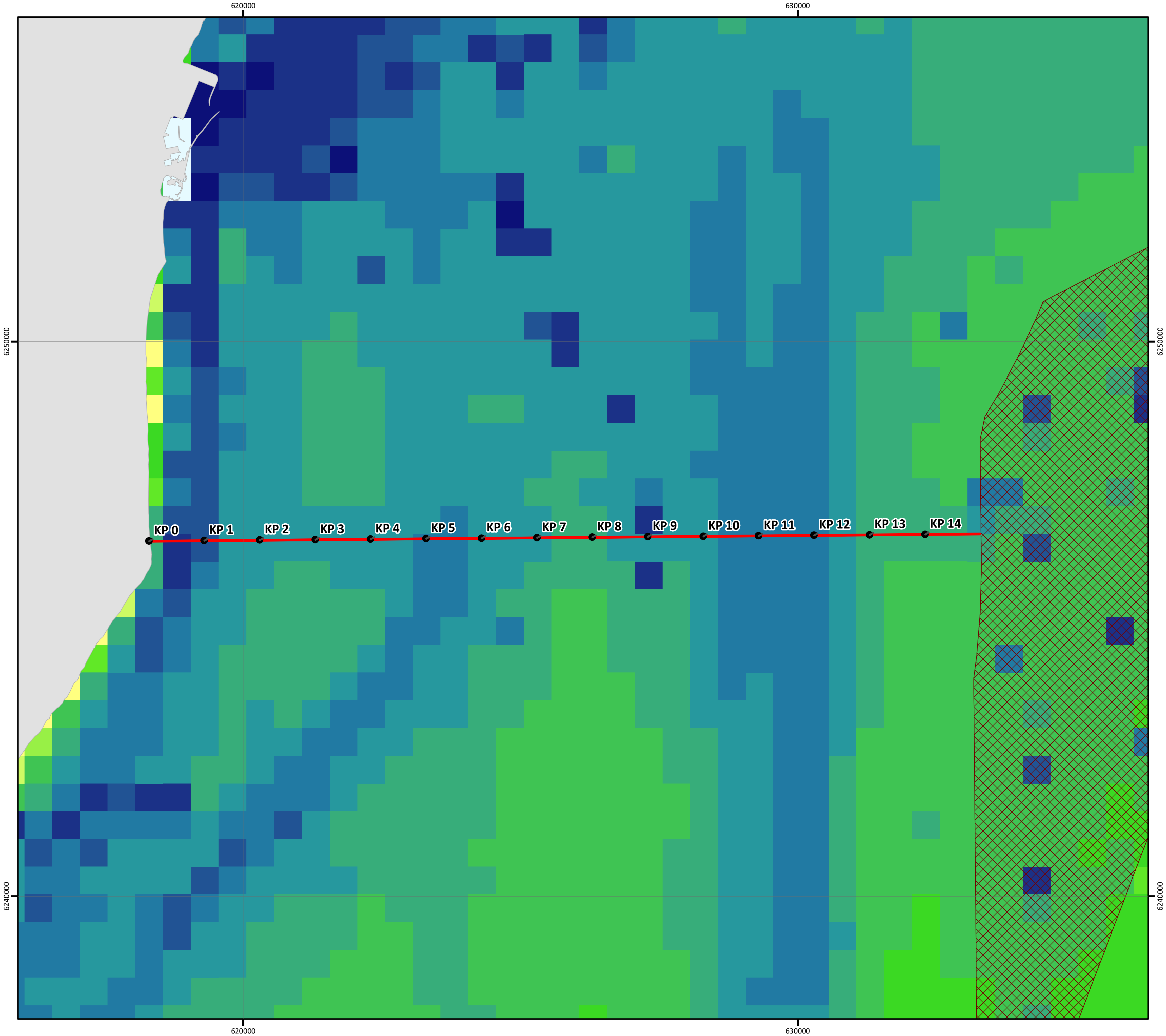
3.6 Vessel Incident Data

For this study, Intertek has reviewed information from the Danish Maritime Accident Investigation Board available on Home (dmaib.com). No investigations or accidents were reported in 2024 near the Kattegat - Grenå South cable corridor.

CABLE BURIAL RISK ASSESSMENT
KATTEGAT - GRENÅ SOUTH - CBRA

AUTOMATIC IDENTIFICATION SYSTEM (AIS)
Vessel Density (February 2023 - February 2024)

Drawing No: P2719E-AIS-001	B



Legend

- KP
- Cable Route
- Wind Farm Site

Vessel Density (Duration per Year)

- < 15 minutes
- 15 - 30 minutes
- 30 - 45 minutes
- 45 mins - 1 hour
- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week
- > 1 week

N W E S

NOTE: Not to be used for Navigation

Date	19 June 2024
Coordinate System	ETRS 1989 UTM Zone 32N
Projection	Transverse Mercator
Datum	ETRS 1989
Data Source	ESRI; NUTS; ENERGINET
File Reference	J:\P2719\Mxd_QGZ\P2719E\02_AIS\ P2719E-AIS-001.mxd
Created By	Lewis Castle
Reviewed By	Emma Langley
Approved By	Stephane Theurich

ENERGINET intertek

0 1 2 3 4 km

4. ASSESSMENT OF SEABED CONDITIONS

This section presents the breakdown of the Kattegat - Grenå South cable route based on distinct seabed conditions based on our review of the available geotechnical and regional geological data.

Intertek reviewed the provided cone penetrometer test (CPT) logs and the associated core logs to interpret a ground model along the route centreline. The following shear strength classification for cohesive soils and the relative densities classifications for non-cohesive soils are presented below in **Table 4-1** and **Table 4-2**

If a unit comprised of CLAY with thin band of SAND then this band was omitted. This creates conservatism in our analysis of the potential anchor penetration. In the absence of isopachs indicating a change of unit (e.g. unit pinching out) transition was made at an equal distance between the geotechnical samples.

Table 4-3 shows the Geotechnical zones created for the CBRA

Table 4-1 Interpreted Undrained Shear Strength Parameter and Classification

Descriptive term	Shear Strength Range (kPa)
extremely low	<10
very low	10 to 20
low	20 to 40
medium	40 to 75
high	75 to 150
very high	150 to 300

Table 4-2 Interpreted Relative Density Parameter and Classification

Descriptive Term (Relative Density)	Cone Resistance Range (MPa)
very loose	<2.5
loose	2.5 to 5
medium dense	5 to 10
dense	10 to 20
very dense	>20

Table 4-3 Geotechnical Zones

Zone	Comments/Assumptions	Start KP	End KP
1	0.2m of Very Loose Sand, 0.2m of Loose Sand, Overlying Medium Dense Sands	0	4.05
2	0.1m of Low Strength Clay, 1m, of Very Loose sand Overlying Loose Sand	4.05	6.57
3	0.1 of Low Strength Clay, 0.35 of Very Loose Sand Overlying Low Strength Clay	6.57	8.38
4	1.1 of Very Loose Sand, 0.1 of Loose sand, Overlying Medium Dense Sand	8.38	9.09
5	0.1 of Very Low Strength Clay, 0.3 of Very Loose sand overlying Low Strength Clay	9.09	10.77
6	0.1 of Very Low Strength Clay, 0.8m of Very Loose Sand, 0.5 Low Strength Clay	10.77	11.61
7	0.15 of Very Loose sand, 0.15 of Loose sand, overling Medium Dense Sand	11.61	12.45
8	0.05 of Very Low strength Clay, 0.4 of Very Loose Sand, overlying 1.5m of Low Strength Clay	12.45	15

5. RISK IDENTIFICATION AND ASSESSMENT

To specify an appropriate DOL for the Kattegat - Grenå South cable, Intertek conducted a risk identification and assessment considering both the likelihood and severity of the most common external threats to the cable.

Risks that pose a threat to installed marine cables can be classified as either natural or anthropogenic risks. The following sections describe the most common risks affecting marine cables.

The completed Risk Register is provided in **Appendix B**.

5.1 Natural Hazards

5.1.1 Sediment Mobility

Sediment mobility in itself does not pose a threat to a submarine cable but it can lead to issues with the thermal conductivity of cables (over burial), and exposure of cables (scour); burial under excess sediment can change the thermal properties of the soil and cause hotspots along the cable, while exposure increases the risk of damage due to external aggressors such as trawling and anchoring and potentially mechanical damage from free spans. Over burial should be considered at the cable design phase upon the analysis of the sediment movement.

There are several areas within the Kattegat - Grenå South 1500m corridor where there are bedforms present which could be mobile.

The first indication of mobile bedforms can be seen between KP 2.5 and KP 2.9 The bedforms are up to 0.7m high and have a wavelength of up to 120m. Smaller megaripples (height ~0.25m, wavelength ~14m) are located on the larger bedforms.

For further details of mobile features interpreted along the Kattegat - Grenå South corridor please see GEOxyz's Geophysical Report.

For the purposes of DOL targets (RMDOL & TDOL) all depths recommended in this report are assumed to be measured against a horizontal plane which has been determined to be non-mobile and after any required mobile bedform engineering has been undertaken to flatten mobile sediments.

5.1.2 Waves and Currents

Waves and currents may cause abrasion and stress to an exposed cable where it crosses over rock or rough terrain. Sufficient burial and protection of a subsea cable will reduce the risk of waves and currents to a negligible level.

In addition, wave/currents can mobilise sediment which may lead to increase in the thermal environment for cables if burial depth increases. Sediment mobilisation can also lead to exposure of the cable through de-burial, causing loss of protection against external aggressors.

5.1.3 Extreme Weather

Extreme weather is unexpected, unusual, unpredictable, severe or unseasonal weather and involves weather at the extremes of the historical distribution. While the Kattegat - Grenå South cable is geographically in a relatively weather-stable area, sufficient depth of lowering and protection will be required to deal with the effects of extreme weather such as excessive scour and extensive movement of mobile sediments. For the purposes of burial targets (RMDOL & TDOL) all depths recommended in this report are assumed to be measured against a horizontal plane which has been determined to be non-mobile and after any required mobile bedform engineering has been undertaken to flatten mobile sediments.

5.1.4 Outcropping Bedrock

Bedrock and hard sediment are considered an issue when the seabed proves to have properties that affect, and effectively inhibit, the use of the common trenching methods.

Bedrock and hard sediment may cause problems with reaching the required burial depth. In addition, topographical irregularities in bedrock or hard sediment may cause freespan, point load, and abrasion. Methods to avoid problems with bedrock or hard sediment include appropriate micro-routing, deployment of heavier trenching machines, or the installation of additional cable protection.

There was no evidence of outcropping bedrock within the Kattegat - Grenå South route corridor in the data provided.

5.1.5 Other Geohazards

Geohazards are geological states that may lead to risk and damage, induced by natural processes or human activity. Marine geohazards include any feature or process that could harm, endanger, or affect seafloor facilities, cables, pipelines etc. Marine geohazards can be a local and / or regional site and soil conditions having a potential to develop into seafloor failure events, which cause losses of life or damage to health, environment or field installations (Camargo *et al.*, Feb 2019).

Various geological processes and features can induce hazards. Some of the more well known, due to their high destructive power are earthquakes, volcanoes, landslides, and associated tsunamis. Others generally do not cause direct damage to societies but can affect engineered structures. These include pockmarks, mud volcanoes, and mobile bedforms. Some manifest themselves on the surface of the seafloor, while others occur in the subsurface.

No evidence of volcanos or landslides were identified in the literature or the provided survey data. Minor earthquakes have been identified within the wider region (Gregersen *et al*.,1998).

5.2 Anthropogenic Hazards

5.2.1 Shipping

Shipping represents an anchoring hazard to a cable on or in the seabed. Vessels that drop their anchors have the potential to interact with the cables if the anchor is dragged along the cable route or dropped directly on the cable. Ships in transit do not typically anchor under normal conditions and planned anchoring normally takes place within a designated area. Contact with an anchor is often catastrophic for the cable as the forces applied by a moving anchor can be extremely large. The anchoring hazard may result from:

- Insufficient protection.
- Emergency anchoring (where an anchor is deployed to prevent collision or grounding).
- Accidental anchoring (where an anchor falls unexpectedly from a vessel due to equipment impact or operator error). Accidental anchoring is accentuated by proximity to a port where, for navigational reasons such as the traffic density, proximity of obstructions, shallow waters and other vessels, anchors are more likely to be readied for deployment.
- A vessel being anchored inadequately (where an anchor is deployed but drags longer than necessary along the seabed prior to embedment).

All charted anchorage areas were identified and avoided as part of the routing study hence accidental anchoring and inadequate anchoring are not relevant to this study. Please refer to **Appendix F** for additional information on Navigation and Shipping in the vicinity of the cable route.

5.2.1.1 Unintentional anchor drags

Intertek is aware that in some cases, unintentional anchor drags are feasible as a potential hazard. However, Intertek has not investigated these deployments, especially for large commercials vessel.

The unintentional anchoring risk for large commercial vessels carrying anchors capable of causing significant damage to a buried cable is considered extremely low. Vessels of this size are usually fitted with secure anchor mechanisms and the redundancy of machinery installed to prevent such a mechanical failure accusing is high (DNV, 2010).

Similarly, the impact of unintentional deployment on smaller leisure vessels is harder to quantify given smaller sizes of anchors and different mechanisms to secure anchors during transit.

Intertek has reviewed literature on this topic and has not been able to determine the likely hood of intentional anchor drop and drag risk. Therefore, the risk of accidental anchor deployment for these vessels is not considered probable enough to include in our assessment

5.2.1.2 Ports and Harbours

There are numerous ports and harbours within and in proximity to the study area, ranging from large ferry and goods ports to small fishing and recreational harbours.

The main ports identified within the 30 km of the cable corridor area are as follows:

- Port of Aarhus
- Port of Grenaa
- Port of Ebeltoft
- Port of Helsingør (Elsinore)
- Port of Helsingborg
- Port of Skagen

EMODNet data highlights vessel density and tracklines of vessels transiting the area from additional ports further than 30 km. These are included given the traffic arising from these ports influencing the study area.

5.2.2 Summary of Shipping Related Features

Shipping related features within the study area are outlined below.

5.2.2.1 Wrecks

There are a total of 270 wrecks within 30 km of the cable corridor (Admiralty, 2024). The largest documented wreck in the area, the Ukrainian Aster wreck, is 78m long and 13m wide. The closest documented wreck to the cable corridor is approximately 100m away.

5.2.2.2 Dredging and Water Disposal

There are two dredge site locations which are located within 5 km of the cable corridor. There are also three dredge spoil dumping grounds located within 7 km of the area. There is one water discharge point within 10 km of the cable corridor (EMODnet, 2024).

5.2.2.3 Lighthouses

There are seven lighthouses within 30 km of the cable corridor (EMODnet, 2024). Gjerrild and Fornæs are located on the east coast, along with Ebeltoft Vig, Ebeltoft W and Ebeltoft N of which are west-facing. There is also a lighthouse located on Hjelm, a small unpopulated Danish island in the Kattegat 10 km east from Ebeltoft. The Sjaellans Rev N lighthouse is located on a reef in Zealand extending from the Sjællands-Odde peninsula.

5.2.2.4 Anchorage

The closest anchorages to the cable corridor are Port of Grenna and Port of Ebeltoft. The main anchorages outside the study area are Port of Helsingør, Port of Helsingbord and Port of Skagen.

5.2.2.5 Energy

At the time of writing, no oil and gas platforms or nuclear energy plants are within the study area. Anholt OWF is approximately 16 km from the cable corridor and Hesselø OWF is just over 30 km from the cable corridor (EMODnet, 2024). No cables, pipelines or similar infrastructure have been identified crossing the study area.

5.2.3 Fishing Gear Interaction

Fishing is a risk to the cable as certain fishing activities and gear are in contact with and/or penetrate the seabed. Literature review and analysis of data has shown that there are benthic fishing activities (dredging, trawling, netting) in proximity to the cable route. It is difficult to determine specific types of gear used so the depth of lowering and protection methods are derived from the maximum depth of penetration from fishing.

Further information on the fishing gear and activities in the vicinity of the cable route are provided in **Appendix F**.

5.2.3.1 Overview

There are over 2700 fishing vessels containing 1900 crew and supporting approximately 8000 jobs in Denmark (Ministry of Food, Agriculture and Fisheries, 2024). This of the report presents the fishing study of the Grenå South cable corridor. The fishing study has been carried out without consultation, however the following key European and Danish Sea fishing organisations were identified as being relevant to the area:

- Baltic Fishermen’s Association
- European Association of Fish Producers Organisations (EAPO)
- The Pelagic Advisory Council (AC)
- North Sea AC
- European Bottom Fisheries Alliance (EBFA)
- Association of Sustainable Fisheries (ASF)
- International Coalition of Fisheries Association (ICFA)
- European Fisheries Alliance (EUFA)
- Ministry of Environment and Food
- Ministry for Business
- Danish Fisheries Association (DFA)

5.2.3.2 Data Sources

The principal sources of data and information used in the complication of the fishing section are outlined in **Table 5-1** below.

Table 5-1 Fishing Study Principal Data Sources and Information

Type of Data	Source	Description
AIS (Automative Identification System)	Danish Maritime Authority (DMA)	Data with information on the position of fishing vessels 15 m and over in total length collected by the Danish Maritime Authority.
Fishing Intensity	EMODnet	Datasets on fishing intensity in the EU waters by sea basin, created every year by the International Council for the Exploration of the Sea (ICES). In the 2020 Cogea started to collect and harmonize them according to the EMOdnet Human Activities dataset schema. This dataset is updated yearly. The fisheries overview data concern the spatial distribution of average annual fishing effort (mW fishing hours) by ecoregion and by gear type. Fishing effort data are only shown for vessels >12 m having VMS.
Fishing Effort (Total Swept Area Ratio)	Technical University of Denmark	Annual Swept Area Ratio (SAR) and the Percentage Unfished Area (PUA) for various fishing gears and selected areas.

5.2.3.3 Data Gaps

Vessels under 12 meters are not included in the AIS data (positional records) that has been used to inform this study. Although these smaller vessels must be taken into account for Navigational Risk Assessment (NRA) and the impact on other sea users, they are not seen as a major risk factor to the assets. The majority of fishing vessels potentially active in area of relevance to the Project that are less than 12 m in length are minor artisanal vessels and to a lesser extent longliners and purse seiners. The fishing gear used by these vessels have limited potential to cause negative interactions with subsea cables. Therefore, this lack of data is not seen as a hindrance to the conclusions of the report with regard to risks to the Project during its operational phase.

The presence of fishing vessels under 12 m in length, particularly those that operate static gears, may result in conflict with the Project during early surveys and installation works. It is recommended that local fisheries organisations are consulted with to gather information on vessels not captured in the AIS dataset that are potentially active in the area of the Project.

5.2.4 Dredging/Aggregate Extraction/Subsea Mining/Dumping

No dredging, aggregate extraction, subsea mining or dumping areas were observed in the vicinity of the cable corridor

5.2.5 Other Cables

No third-party assets were identified from the survey data provided or within the cable corridor.

5.3 Risk Assessment and Evaluation Criteria

In this section, the risk acceptance criteria are discussed to allow implementation of the results of the probability of failure and consequence of failure assessment. The key output of this risk register being a probabilistic assessment of the risk to the cable after burial options are completed to a specified depth of lowering.

Table 5-2 shows the risk matrix that we developed for the purpose of this project. The generic meaning of the colour code is indicated in the legend below the table. The principle works as follows: an event, such as a cable failure, has a probability of happening, and has a severity. The combination gives a location in the risk matrix and from that follows required next steps.

Table 5-2 Risk Matrix

		Likelihood				
		Rare (1)	**Unlikely (2)**	**Possible (3)**	**Likely (4)**	**Almost Certain (5)**
Severity	**Insignificant (1)**	1	2	3	4	5
	Minor (2)	2	4	6	8	10
	Moderate (3)	3	6	9	12	15
	Major (4)	4	8	12	16	20
	Severe (5)	5	10	15	20	25

Dark green	Broadly acceptable
Light green	ALARP low
Yellow	ALARP medium
Orange	ALARP high
Red	Intolerable

The severities are defined for two different categories, cost and performance, as shown in **Table 5-3**, while the definition of the likelihood is shown in **Table 5-4**.

Table 5-3 Severity Definition

			Severity				
Category	**Cost**		**Insignificant (1)**	**Minor (2)**	**Moderate (3)**	**Major (4)**	**Severe (5)**
			Less than €59K	**€59k - €590K**	**€590K - €11.82M**	**€11.82M – €236.45M**	**10% CAPEX (>€236.45M)**
	Performance	**Availability**	Increased surveillance	Increased maintenance Occasional duration limits (days) at peak	One substantial outage +major intervention Regular duration limits (hours) at peak capacity	Between one and eight 6-month outages Between 1 and 10% capacity loss	10% availability drop through project lifetime (eg > eight 6-month outages in 40 years) > 10% max capacity loss
		Derating	Rare minor derating in a short period of time.	Routine minor derating for short period of time.	Minor derating for extended period.	Substantial derating for significant period of time.	Significant permanent derating.

Table 5-4 Likelihood Definition

	Description	Probability of event in the lifetime (40 years)	Probability of event per year range
Rare (1)	Although they are conceivable, not expected to occur. "Plausible but not known occurrences in industry".	0% - 2%	0.00% - 0.05%
Unlikely (2)	Incidents of this nature are uncommon but there is a chance that they may occur.	2%-10%	0.05% - 0.26%
Possible (3)	This may happen.	10%- 25%	0.26% - 0.72%
Likely (4)	Likely to experience in the near-future.	25%- 75%	0.72% - 3.41%
Almost Certain (5)	Will occur or is already occurring. "Probability within the life time of the project (i.e. several known occurrences per year)."	75%-100%	3.41% - 100.00%

5.4 Risk Mitigation

There are several remedial methods of protection that can be considered to reduce the risk to the cable. The principal method of protection for most modern cable systems is burial into the seabed. In general, an activity must penetrate through the material above the burial to interact with the cable.

It may be noted that there are instances in which utility crossings, joints, HDD exits or extremely hard soil conditions (e.g., bedrock) preclude burial or reduce the depth achievable. In such instances, there are three primary means of remedial protection which can be used:

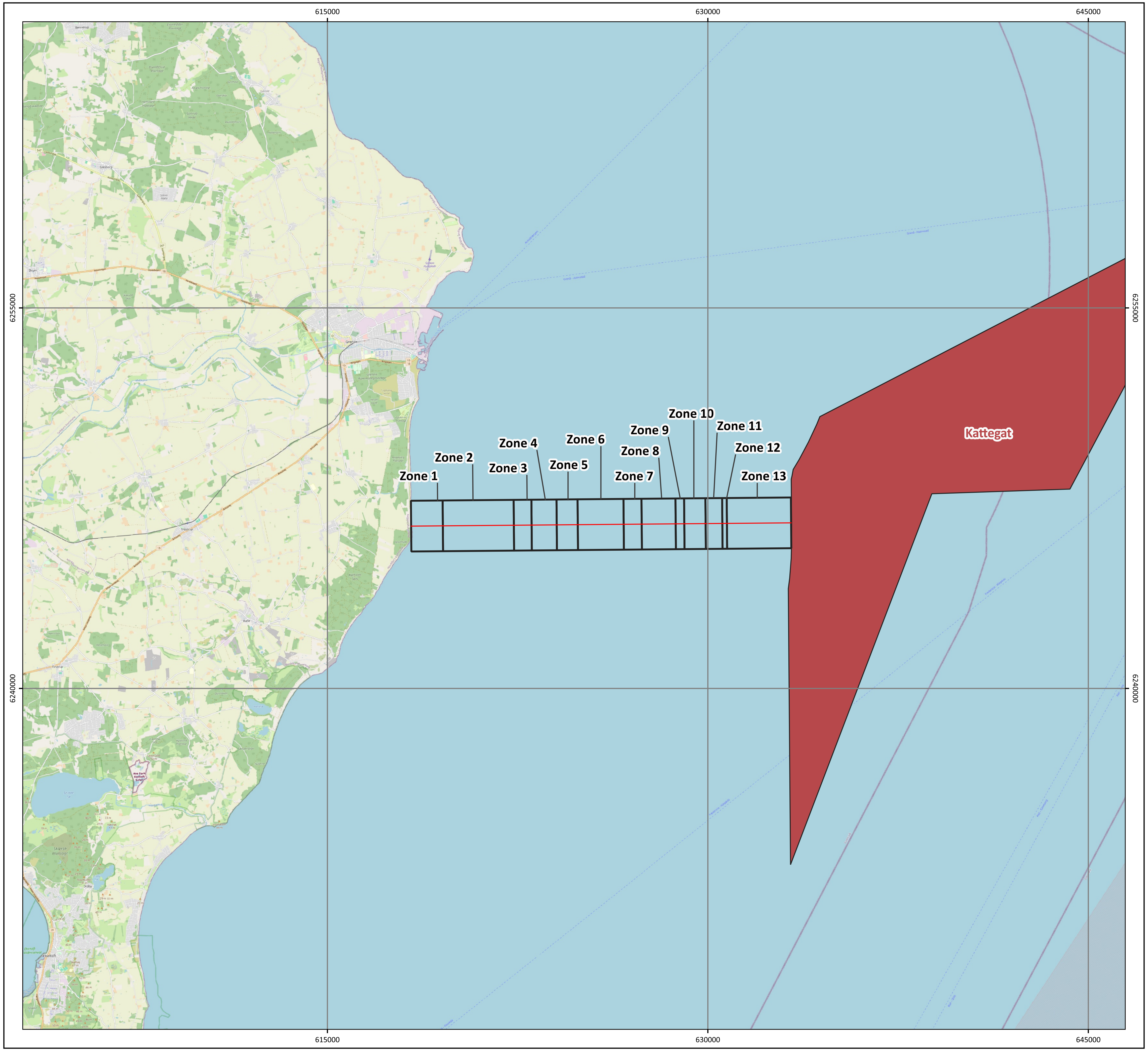
- Concrete mattresses
- Rock placement
- Articulated shell

5.5 Final Route Segmentation

The final route segmentation used for the probabilistic assessment was segmented according to changes in risk profile resulting from changes in:

- Seabed geology
- External risk factors (e.g. Anchoring risk variation by location and water depth)

The final cable segmentation for the cable route is presented in the Cable Burial Risk Assessment (CBRA) Summary Table (**Section 7**) and in **Figure 5-1**.



CABLE BURIAL RISK ASSESSMENT KATTEGAT - GRENÅ SOUTH - CBRA

LOCATION OVERVIEW

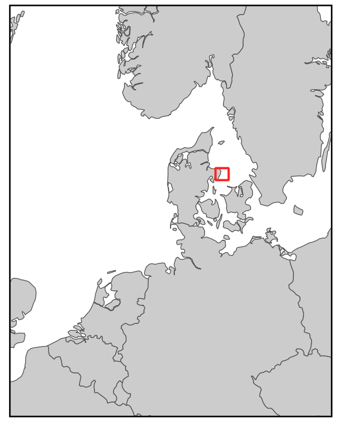
CBRA Zones

Drawing No: P2719E-LOC-003	A

Legend

- Cable Route
- CBRA Zone
- Cable Corridor (1.5km)
- Wind Farm Site

N



NOT TO BE USED FOR NAVIGATION

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Data Sources	ENERGINET; NUTS
File Reference	J:\P2719\Mxd_QGZ\P2719E\01_LOC \P2719E_LOC.qgz
Created By	Lewis Castle
Reviewed By	Emma Langley
Approved By	Stephane Theurich

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0 2 4 6 8 km

6. PROBABILISTIC RISK ASSESSMENT

This section describes the methodology and results used to assess the fishing and anchoring risk the Kattegat - Grenå South cable system.

All relevant factors are assessed for a cable route on a section-by-section basis.

6.1 Fishing Risk Assessment Methodology

The review of the fishing assessment indicated mobile and static fishing areas present along the entire cable route. No fishing protection or areas excluded from fishing activity were reported.

Moreover, as the entire route is within water depth range in which mobile gear fishing could take place, we recommend the cable is given sufficient protection from potential fishing gear interaction along the entire route.

The Carbon Trust' guidance indicates that penetration of fishing gear into the seabed is limited to a maximum of 0.3 m penetration even in soft sediment based on previous literature research.

Adding a FoS of 2 to account for measurement errors and deformation of soil beneath fishing gear gives a RMDOL of 0.60m for fishing risk alone.

6.2 Vessel and Anchors Bands

To facilitate easier analysis of the vessel traffic, the vessels were grouped into seven deadweight tonnage bands. This allowed a set range of anchor sizes to be used to characterise those carried by shipping fleets in the tonnage bands. This is shown below in **Table 6-1**

The vessels' DWT were calculated from the vessel length data supplied in the AIS data. The methodology to calculate the vessels' DWT is as follows:

1. Create a list of all unique vessels present in the AIS data set.

For each vessel category (Cargo, Tanker, Passenger, etc) research the DWT information online (https://www.marinetraffic.com/) using vessel MMSI number for a sufficient set of vessels per category (30 to 50 vessels' DWT were researched online per category).

2. For each vessel category, plot the DWT vs Length and derive a conservative power trendline that fits the distribution of data points.

Based on the above process, the following empirical formulas were derived by Intertek and used to calculate the vessels' DWT:

$$DWT_{cargo} = 0.0017 \times L^{3.2551}$$

$$DWT_{Tanker} = 0.0025 \times L^{3.175}$$

$$DWT_{Passenger}{}^{2} = 0.0583 \times L^{2.1278}$$

$$DWT_{Vessel<70m} = 0.0009 \times L^{3.3717}$$

Where:

DWT = Vessel deadweight tonnage (tonnes)

L = Vessel length (m)

The plots from which the above empirical formulas have been derived are provided in **Appendix D.**

Once the vessel deadweight tonnage is known, the theoretical anchor mass can be calculated by the following empirical formula proposed by Luger as referenced in the Submarine Power Cables book by Worzyk, (this is recognised as an acceptable approach by the Carbon Trust's CTC-835):

$$y = 7 \times 10^{-13}x^3 - 6 \times 10^{-7}x^2 + 0.1635x + 2162.2$$

Where:

y = Anchor mass (kg)

x = Vessel deadweight tonnage (upper DWT boundary of each band) (tonnes)

The Carbon Trust's guidance shows the Luger formula to be a good fit with the International Association of Classification Societies (IACS) rules for vessel DWT between 10,000 and at least up to 100,000. Thus, for the vessel Band with a DWT up to 10,000 (Bands A & B), Intertek has used the estimated anchor size from Table 9 of Ref 1, for Bands C-E we have used Luger's formula and for Bands F-G we have used a chart from a presentation given by Luger.

We then used an anchor catalogue to select realistic stockless anchor dimensions based on the theoretical anchor mass calculated. The "Hall" pattern anchor is used for Bands A-E and "Spek" is used for Bands F and G as these are typical stockless anchors in common use, especially on older vessels. These types of anchors have a relatively long fluke length for its unit mass and a large opening angle, which equates to more penetration for a given fluke length.

[2] The relationship between DWT and vessel length would normally be expected to be closer to the cube of the length than the square. However, as demonstrated in the **Appendix D**, the formula is a good fit to the data set obtained from research.

Table 6-1 Vessel and Anchor Size Bands

Band Name	Vessel DWT [Tonnes]	Vessel DWT (Tonnes)	Calculated Theoretical Anchor Mass [kg]	Selected Anchor Mass [kg]
Band A[3]	0.00	100.00	335	300
Band B	100.00	1,000.00	524	570
Band C	1,000.00	3,500.00	1,302	1,290
Band D	3,500.00	10,000.00	2,388	2,460
Band E	10,000.00	30,000.00	6,546	6,900
Band F	30,000.00	60,000.00	9,963	9,900
Band G	60,000.00	100,000.00	13,212	13,500
Band H	100,000.00	150,000.00	16,917	17,800
Band I	150,000.00	200,000.00	18,583	20,000
Band J	200,000.00	325,000.00	22,167	20,000
Band K	325,000.00	450,000.00	18,025	20,000

6.3 Probabilistic Model

Intertek have developed a robust probabilistic assessment to determine the probability of interaction between an anchor and an installed cable based on local data for shipping traffic intensities, derived from historical AIS data. The model predicts the probability of a buried cable being struck because of anchoring. The probability of cable-anchor interaction decreases as DoL is increased beyond the maximum penetration depth of each anchor size.

The method takes account of:

- shipping traffic intensity by vessel size;
- probability of engine failure;
- probability of an emergency anchor deployment;
- dragging distance of an anchor; and
- protection factor provided by soils.

The assessment provides the annual probability of a failure, which can in turn be used to calculate the mean time to failure (MTTF) due to anchoring. It should be recognised that it does not predict a failure time and that failure in year one is equally as likely as in any subsequent year.

The probabilities are calculated for a range of vessel and anchor sizes. The anchor size for the upper end of the vessel tonnage band is used, as indicated in **Table 6-1**.

The probability of failure of the cable because of damage caused by emergency anchoring is calculated using the following equation:

[3] Within this band there are a significant number of vessels present that are too small to carry an anchor of this mass. As such, the selected anchor mass represents a conservative approach

$$P_{anchor\ damage\ per\ km} = K \times P_{loss} \times P_{deploy} \times P_{fa}$$

Where:

$P_{anchor\ damage\ per\ km}$	= probability of anchor damage on cable (-/year.km^{-1})
K	= total number of ship hours in sample box (hr/year.km^{-2})
P_{loss}	= probability of engine failure (-/engine hour)
P_{deploy}	= probability of anchor operation (-)
P_{fa}	= protection factor (-)

Zones of Interest

A vessel does not immediately drop an anchor when it encounters engine problems. It drifts for a period while trying to recover from the engine problem. If unrecoverable, it slows down to below approximately 1 knot before dropping an anchor. Anchoring at speeds above 1 knot will most likely lead to vessel structural damage. Defining a Zone of Interest which is greater than just directly adjacent to the cable route allows for a potential period spent drifting while trying to recover the engine and/or slow down sufficiently to allow anchoring to take place. This means that the cables will not only be affected by vessels that are directly above it.

The Zones of Interest for the cable routes for each individual cable segments are defined as a 2km buffer around each segment. **Figure 5-1** shows the cable route segments and associated Zones of Interest used.

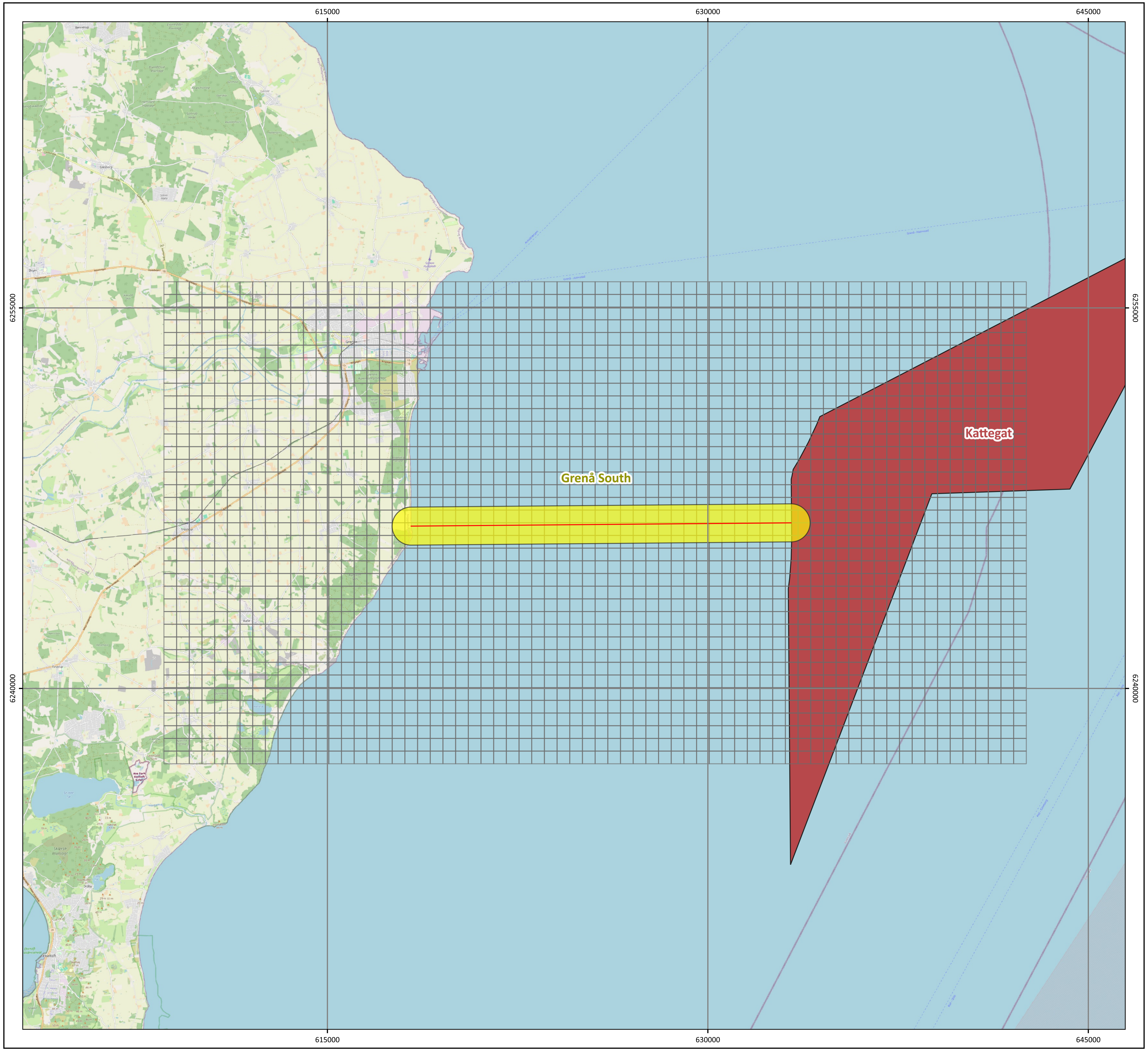
CABLE BURIAL RISK ASSESSMENT
KATTEGAT - GRENÅ SOUTH - CBRA
LOCATION OVERVIEW

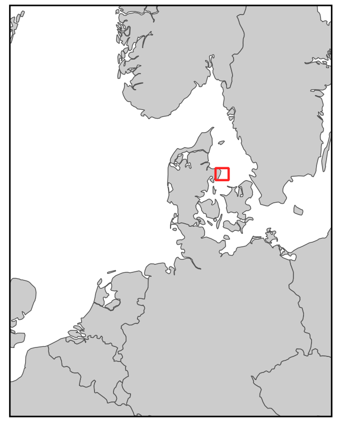
Fishnet Grid Extent

Drawing No: P2719E-LOC-002	A

Legend

- Cable Route
- FIshnet Grid (0.5km²)
- Cable Corridor (1.5km)
- Wind Farm Site





NOT TO BE USED FOR NAVIGATION

Date	2024-05-15 11:55:19
Coordinate System	ETRS89 / UTM zone 32N
WKID	EPSG:25832
Scale @A3	1:150,000
Data Sources	ENERGINET; NUTS
File Reference	J:\P2719\Mxd_QGZ\P2719E\01_LOC \P2719E_LOC.qgz
Created By	Lewis Castle
Reviewed By	Emma Langley
Approved By	Stephane Theurich

ENERGINET intertek

0 2 4 6 8 km

K - Total number of ship hours in sample box

This can be obtained by interrogating the historical AIS data. The AIS data has been interpolated to provide a location every 1 minute.

A fishnet grid at 0.5 km^2 resolution was created and intersected with the interpolated points. The sum of vessel hours was represented within each grid cell. Each zone of the cable route was intersected with the 0.5km^2 grid cells and all these values were used to represent each the vessel/hours/year/km^2 for the route within that zone. This value is then multiplied by the drag distance(m)/1000m. The fishnet grid is shown above in **Figure 6-1.**

The Drag distance (D_{ship}) is defined by the following equation derived from the carbon trust (Carbon Trust, 2015).

$$D_{ship} = \frac{m * V_{ship}^2}{4 * UHC}$$

Where:

D_{ship}	= Distance Travelled by the anchor in order to be a threat to the cable (m)
m	= Vessel mass as displacement (tons)
V_{ship}	= Ship speed when anchor is deployed (m/s)
UHC	= Ultimate Holding Capacity of the Anchor (tons)

In this case, displacement has been derived from the Carbon Trusts (Carbon Trust, 2015) methodology and vessel speed is assumed to be 2 knots based on industry standards. Intertek is aware the 4 knots is recorded as per the Carbon Trust's guidelines if vessel speed is not known, however 2 knots is used as a very conservative approach, since slower vessels are more likely to drop anchor.

UHC has been derived from Sotra's Anchor and chain handbook (Sorta, 2021). The handbook used provides three different UHC equations for different Seabed types (Sand and Clay, Medium Clay and Very soft clay and Mud), therefore three different UHC values have been used based on seabed geology. UHC and D_{ship} values per vessel bands are presented in **Table 6-2**.

Table 6-2 UHC and D_{ship} Values per Vessel Band

Band Name	Vessel DWT [Tonnes]		Displacement of Vessels [T]	UHC - SAND and clay [mT]	UHC - Medium Clay [mT]	UHC Very soft clay and mud [mT]	Dship SAND and clay [m]	Dship Medium Clay [m]	Dship Soft clay and mud [m]
Band A	0.00	100.00	170.00	23.78	18.50	13.21	7.1477	9.1899	12.8658
Band B	100.00	1,000.00	1,700.00	37.76	33.39	23.85	45.0250	50.9162	71.2827
Band C	1,000.00	3,500.00	5,100.00	85.45	70.78	50.56	59.6843	72.0509	100.8713
Band D	3,500.00	10,000.00	17,000.00	162.95	128.19	91.56	104.3262	132.6174	185.6644
Band E	10,000.00	30,000.00	51,000.00	457.06	331.08	236.48	111.5837	154.0427	215.6597
Band F	30,000.00	60,000.00	102,000.00	655.78	461.50	329.64	155.5409	221.0181	309.4253
Band G	60,000.00	100,000.00	170,000.00	894.24	613.90	438.50	190.1056	276.9197	387.6876
Band H	100,000.00	150,000.00	255,000.00	1179.07	791.73	565.52	216.2718	322.0815	450.9141
Band I	150,000.00	200,000.00	340,000.00	1324.80	881.32	629.52	256.6425	385.7832	540.0965
Band J	200,000.00	325,000.00	552,500.00	1324.80	881.32	629.52	417.0441	626.8977	877.6567
Band K	325,000.00	450,000.00	828,750.00	1324.80	881.32	629.52	625.5661	940.3465	1316.4851

Vessel density numbers are provided in **Appendix D**.

P_{loss} - Probability of engine failure
This is taken from a report compiled by DNV (Det Norske Veritas) for the Marine & Coastguard Agency for coastal waters around the UK. The value used in the calculations is 0.00015 / hr (equivalent to an average of 1.3 / yr of continuous vessel operation). In general, this figure is probably somewhat conservative.

P_{deploy} - Probability of anchor operation:
The anchor will not be dropped in every emergency situation. This depends on the local geography, local bathymetry and the Vessel Master's knowledge.

Table 6-3 provides the P_{deploy} factors which have been applied in this CBRA.

Table 6-3 P_{deploy} Values by Vessel Band and Water Depth

Water Depth (m)	P_{deploy}						
	Band A	Band B	Band C	Band D	Band E	Band F	Band G
0-50	0.5	0.5	0.5	0.5	0.5	0.5	0.5
50-75	0.05	0.05	0.1	0.1	0.1	0.1	0.1
75-100	0	0	0.05	0.05	0.05	0.05	0.05
>100	0	0	0	0	0	0	0

P_{fa} - Protection factor:
This considers the protection offered by soil cover. P_{fa} is a combination between the anchor penetration depth in different soil condition and the actual cable DOL and is either 0 or 1. If the cable DoL is greater than the maximum anchor penetration depth (including FoS) for a given anchor size then P_{fa} equals to 0 for that anchor size. Conversely, if cable DoL is less than or equals to the anchor penetration depth (including FoS) for a given anchor size then P_{fa} equals to 1 for that anchor size.

Anchor penetration depths for SANDS and CLAYS (or SAND/CLAY mixes) are typically calculated by taking the sine of the fluke opening angle and multiplying by the fluke length (for Hall anchors this is 45°). This is due to observations that anchor shanks are typically supported by the soil as they are dragged over it. However, EXTREMELY LOW STRENGTH SILTS and CLAYS (i.e. with shear strength <10kPa) are unable to support the shank and as such penetration can be significantly deeper – 3 times the sine 45° of fluke length is typically used in the industry (note these soils are not present on the route). In addition, industry understanding is that HIGH STRENGTH CLAYS (≥100kPa) prevent flukes penetrating at all and where soils with shear strength of this level or above are present on the route in underlying layers we have designated the depth they are at as the maximum depth any anchor will penetrate to.

As above, the industry typically applies Sin 45° of fluke length to calculate anchor penetration in SANDS. However, trials in the German Bight in 2013 suggest that in SANDS anchor penetration are less than previously thought. This report concluded that a 11.5t Hall anchor would have a maximum depth of penetration of 1m in VERY LOOSE SAND, 0.79m in LOOSE SAND and 0.40m in a MEDIUM DENSE SAND which are less than the theoretical value of 1.17m calculated by Sin 45° of fluke length. In addition, the report indicates extrapolation of results to anchors of different size using a scaling factor is valid.

Normally the fluke angle is fixed between 30° to 50°, the lower angle, i.e. less penetration is used in areas of sand or hard or stiff clays, the higher fluke angle, more penetration, is used for holding in softer consolidated clays and provides a greater resistance force (DNV, 2015).

Thus, for each anchor size defined in **Table 6-1** , Intertek calculated the theoretical anchor penetration depth and used the results outlined in the German Bight Anchor Penetration Trials report to scale these anchor penetration depths to more realistic values for areas of SAND sediment type. Areas of SAND sediment type which were dense or very dense were considered as medium dense for the purposes of calculating anchor penetration depths.

A Factor of Safety of 1.5 has been applied on the anchor penetration depths to consider:

- Uncertainty in anchor sizing;
- Uncertainty of soil type; and
- Deformation of the soil beneath the maximum penetration depth.

In addition, all final maximum penetration depths have been rounded up to the closet 5cm to avoid implying a level of accuracy which is not justified. Results of anchor penetration calculations by soil category, without and with the Factor of Safety are provided in **Table 6-4** and **Table 6-5** respectively.

In addition (and as can be expected), there are a number of zones in which there is a surficial sediment layer which has soil properties which vary significantly from the underlying layers. To account for this, we have defined all layers which are present within the soils depths which are relevant to the burial of the cable. Anchor penetration has then been first calculated for the top layer (Layer 1) and if the anchor penetrates through this layer into the underlying layer, then a second calculation has been undertaken to determine penetration depth in Layer 2. The method for calculating Layer 2 penetration is as follows:

- Calculate the remaining anchor penetration potential (in percentage terms) for each anchor size after it has penetrated Layer 1 (e.g. in LOOSE SAND a Band C anchor will penetrate 0.75m, if the top layer is 0.50m then the anchor has ~33% of its penetrating potential remaining after penetrating through Layer 1).
- Multiply the remaining anchor penetration by the maximum anchor penetration in Layer 2 to derive the Layer 2 penetration depth (e.g. in MEDIUM DENSE SAND a Band C anchor will penetrate 0.40m. If only ~33% of its penetrating potential remains after penetrating through Layer 1 then this equates to ~0.13cm penetration into Layer 2).

Thus, total penetration is calculated by adding the penetration thicknesses for Layer 1 and (where applicable) Layer 2 and 3 together.

Table 6-4 Anchor Sizes and Anchor Penetration Depth by Soil Category

Band Name	Selected Anchor Mass [kg]	Theoretical anchor penetration value [m]	Scaled Anchor Penetration by Soil Category [m]					
			VERY LOOSE SAND	LOOSE SAND	MEDIUM DENSE SAND	EXTREMELY LOW STRENGTH CLAY (<10 kPa)	MEDIUM STRENGTH CLAY (≥10 to <75 kPa)	HIGH STRENGTH CLAY (≥75 kPa)
Band A	300	0.35	0.30	0.24	0.12	1.05	0.35	0.18
Band B	570	0.44	0.38	0.30	0.15	1.33	0.44	0.22
Band C	1,290	0.57	0.49	0.39	0.20	1.72	0.57	0.29
Band D	2,460	0.71	0.61	0.48	0.24	2.14	0.71	0.36
Band E	6,900	1.00	0.85	0.68	0.34	3.01	1.00	0.50
Band F	9,900	1.13	0.96	0.76	0.38	3.39	1.13	0.57
Band G	13,500	1.13	0.96	0.76	0.39	3.40	1.13	0.57
Band H	17,800	1.25	1.06	0.84	0.43	3.75	1.25	0.63
Band I	20,000	1.28	1.09	0.86	0.44	3.84	1.28	0.64
Band J	20,000	1.28	1.09	0.86	0.44	3.84	1.28	0.64
Band K	20,000	1.28	1.09	0.86	0.44	3.84	1.28	0.64

Table 6-5 Anchor Sizes and ANCHOR penetration Depth by Soil Category Including a Factor of Safety of 1.5

Band Name	Selected Anchor Mass [kg]	Theoretical Anchor Penetration Value [m]	Scaled Anchor Penetration by Soil Category (incl. FoS of 1.5 & rounded up to nearest 0.05m) [m]					
			VERY LOOSE SAND	LOOSE SAND	MEDIUM DENSE SAND	EXTREMELY LOW STRENGTH CLAY (<10 kPa)	MEDIUM STRENGTH CLAY (≥10 to <75 kPa)	HIGH STRENGTH CLAY (≥75 kPa)
Band A	300	0.35	0.45	0.40	0.20	1.60	0.55	0.30
Band B	570	0.44	0.60	0.45	0.25	2.00	0.70	0.35
Band C	1,290	0.57	0.75	0.60	0.30	2.60	0.90	0.45
Band D	2,460	0.71	0.95	0.75	0.40	3.25	1.10	0.55
Band E	6,900	1.00	1.30	1.05	0.55	4.55	1.55	0.80
Band F	9,900	1.13	1.45	1.15	0.60	5.10	1.70	0.85
Band G	13,500	1.13	1.45	1.15	0.60	5.10	1.70	0.85
Band H	17,800	1.25	1.60	1.30	0.65	5.65	1.90	0.95
Band I	20,000	1.28	1.65	1.30	0.70	5.80	1.95	1.00
Band J	20,000	1.28	1.65	1.30	0.70	5.80	1.95	1.00
Band K	20,000	1.28	1.65	1.30	0.70	5.80	1.95	1.00

6.4 Identification of the Acceptable Risk

6.4.1 Project Requirement

Quantify the depth of lowering to achieve a total probability of failure (PoF) along the cable route of 1 failure per 10,000 years.

6.4.2 Calculations of Probability

The calculation for probability of a cable strike for the entire cable system is given by:

$$P_{anchor\ damage,total\ system} = \sum P_{anchor\ damage\ per\ km}$$

Where:

$P_{anchor\ damage,total\ system}$ = probability of anchor damage for the entire cable route (-/year)

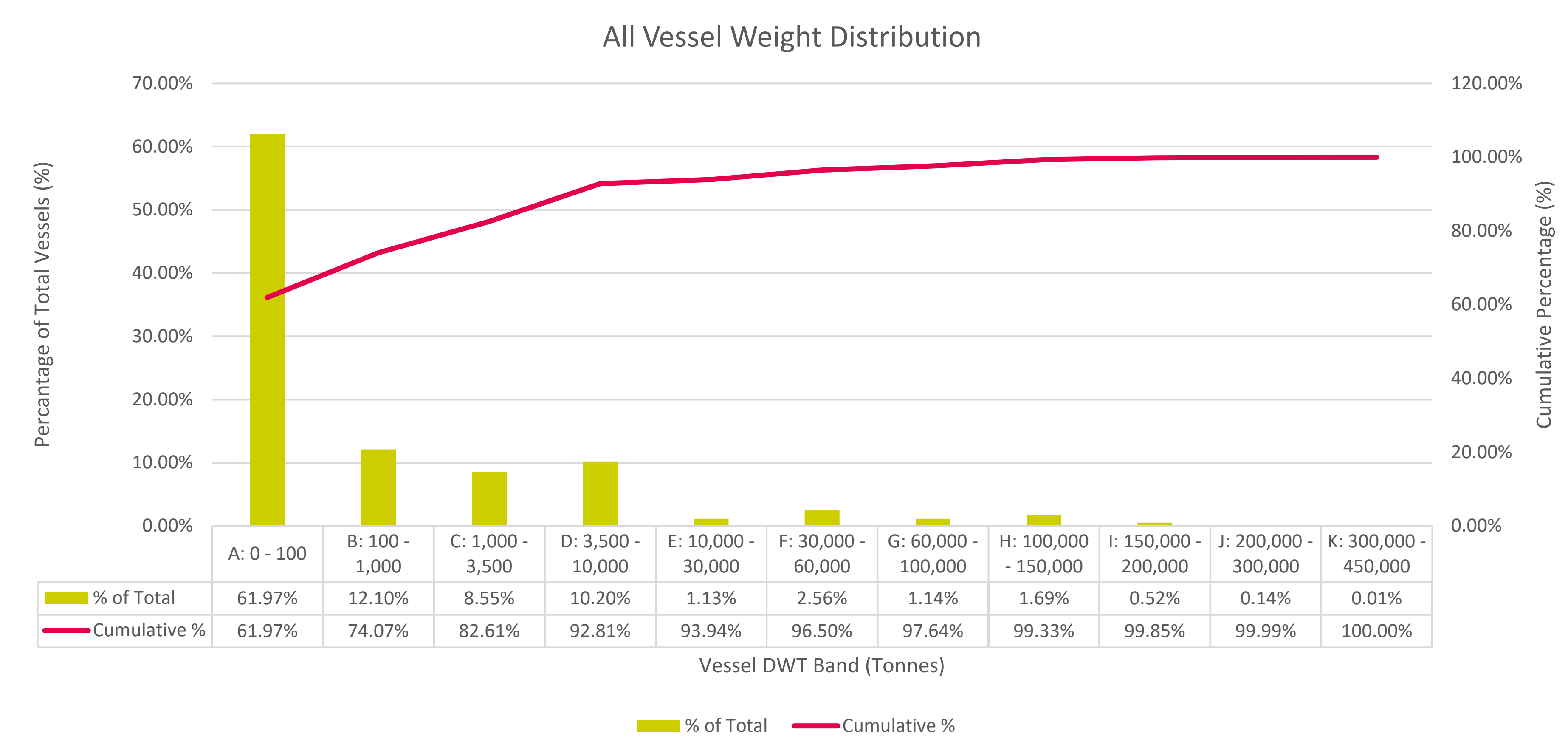
As recommended by the Carbon Trust's guideline, Intertek used an iterative approach to identify a burial depth which results in a "target" residual risk to overall cable system.

The iterative step can be described as follows:

3. Calculate the value of $P_{anchor\ damage,total\ system}$ for all vessels with a surface-laid cable.
4. Identify the value of $P_{anchor\ damage,total\ system}$ that would be acceptable to the stakeholders.
5. Goal-seek RMDOL which achieves this tolerable level.
6. If the RMDOL is considered impractical the acceptable level of risk should be re-considered.

Figure 6-2 shows vessel size distribution by DWT. Naturally, vessel densities are overwhelmingly composed of smaller vessels, so risk reduces significantly as DOL increases over and above the penetration depths of anchor sizes associated with smaller vessels.

Figure 6-2 Overview of Vessel Size Distribution



	A: 0 - 100	B: 100 - 1,000	C: 1,000 - 3,500	D: 3,500 - 10,000	E: 10,000 - 30,000	F: 30,000 - 60,000	G: 60,000 - 100,000	H: 100,000 - 150,000	I: 150,000 - 200,000	J: 200,000 - 300,000	K: 300,000 - 450,000
% of Total	61.97%	12.10%	8.55%	10.20%	1.13%	2.56%	1.14%	1.69%	0.52%	0.14%	0.01%
Cumulative %	61.97%	74.07%	82.61%	92.81%	93.94%	96.50%	97.64%	99.33%	99.85%	99.99%	100.00%

6.5 Probabilistic Risk Assessment Results

For this risk assessment the DNV 2005 risk levels were assigned to the probabilities. **Table 6-6** provides the DNV risk classification (DNV, 2005).

Table 6-6 DNV Risk Classification Used

DNV Risk Classification	Description	Return Periods (Years)
Cat 1	Low frequency that event considered negligible	>1 in 100,000
Cat 2	Event rarely expected to occur	1 in 10,000 to 1 in 100,000
Cat 3	Event individually not expected to happen, but when summarised over a large number of assets have the credibility to happen once a year	1 in 1,000 to 1 in 10,000
Cat 4	Event individually may be expected to occur during the lifetime of the cable	1 in 100 to 1 in 1,000
Cat 5	Event individually may be expected to occur more than once during lifetime	<1 in 100

6.5.2 Results of Surface Laid Cable

Table 6-7 presents segment annual failure for a surface laid cable.

Table 6-7 Zone Annual Failure for Surface Laid Cable

PA Zone	$P_{anchor\ damage}$
1	4.03E-03
2	1.64E-02
3	1.28E-03
4	2.44E-03
5	2.82E-03
6	9.13E-03
7	2.89E-03
8	1.81E-02
9	2.85E-03
10	1.60E-02
11	5.45E-03
12	9.42E-05
13	4.53E-02
Annual Failure Probability for Entire route	**42.65%**
Return Period (years)	**2.34**
Failure Probability in the lifetime (40 years)	**100.00%**

The probabilistic assessment calculates the annual failure probability of 42.65% for the entire route (based on anchor risk alone) if surface laid. This value equates to a return period of 2.34 years and a failure probability over the (40 year) lifetime of 100%.

Areas with the highest risk of Annual Failure include zone 13, 8, 10 and 2. These PA zones are areas of high vessel traffic thus; increased anchor drag risk.

The lowest PA zones of risk are zones 12 and 3 given the low vessel traffic reducing all risk of anchor strike.

6.5.3 Results for Recommended Minimum DOL

A RMDOL was derived on a zone basis to mitigate the risk from anchoring from the selected vessel band in order to achieve an overall acceptable risk of 1 failure per 10,000 years. The tables below present the RMDOL and associated annual failure probability for the following 12 scenarios:

1. Scenario 1: Protection against vessels in Band A
2. Scenario 2: Protection against vessels in Bands A to B
3. Scenario 3: Protection against vessels in Bands A to C
4. Scenario 4: Protection against vessels in Bands A to D
5. Scenario 5: Protection against vessels in Bands A to E
6. Scenario 6: Protection against vessels in Bands A to F
7. Scenario 7: Protection against vessels in Bands A to G
8. Scenario 8: Protection against vessels in Bands A to H
9. Scenario 9: Protection against vessels in Bands A to I
10. Scenario 10: Protection against vessels in Bands A to J
11. Scenario 11: Protection against vessels in Bands A to K
12. Scenario 12: Selected protection section by section

As can be seen in the provided scenarios, anchoring risk is concentrated in Zone 9, both in terms of vessel traffic density and also size of associated vessels. This is followed by Zone6 and Zone 1.

Note, the key reasons why anchor risk is not the key determinant in most zones is due to both the relatively light vessel densities and also the prevalent presence of soils which prevent anchors from penetrating very deeply.

The above approach results in a RMDOL varying from 0.65m to 2m. If these RMDOL values are achieved and maintained over the course of the cable lifetime then this would result in an annual failure rate of 0.00966% which equates to a return period of ~10,352 years and a failure probability over the (40 year) lifetime of 0.39% - i.e. “Event rarely expected to occur.”.

7. CBRA ASSESSMENT

Zone ID, KP and Length					Water Depth (m below LAT)			Known Co-Located Infrastructure/ Obstacles	Geophysical/Geotechnical Data													Shipping Data (Anchoring Assessment)			Fishing Data		Recommended Minimum Depth of Lowering (m)
GIS ID	Zone ID	Start KP	End KP	Length km	MAX	MIN	Mean		Layer 1 Dominant Sediment Type	Layer 1 Thickness (m)	Layer 1 Categorisation for Anchor Penetration Calculation	Layer 2 Dominant Sediment Type	Layer 2 Thickness (m)	Layer 2 Categorisation for Anchor Penetration Calculation	Layer 3 Dominant Sediment Type	Layer 3 Thickness (m)	Layer 3 Categorisation for Anchor Penetration Calculation	Mobile Features (where applicable)	Geotechnical Data			Risk from Anchoring (Vessel Bands Present)	Shipping Buffer Size (m)	Recommended DoL for Protection against Anchor Strike (including Factor of Safety of 1.5 & rounded up to nearest 0.05m) (m)	Presence of Fishing	Recommended DoL for Protection against Fishing Gear (including Factor of Safety of 2) (m)	
																			CPT	VC	Grabs						
1	1	0.00	1.25	1.25	8.7	1.6	6.4	None present	SAND	0.2	VERY LOOSE SAND	SAND	0.2	LOOSE SAND	SAND	1	MEDIUM DENSE SAND	YES	GT_CPT_080a GT_CPT_080b GT_CPT_081a	GT_VC_080a GT_VC_081a		Yes	2,000	0.65	Yes	0.60	0.65
2	2	1.25	4.05	2.80	13.9	4.6	8.8	None present	SAND	0.2	VERY LOOSE SAND	SAND	0.2	LOOSE SAND	SAND	1	MEDIUM DENSE SAND	YES	GT_CPT_080a GT_CPT_080b GT_CPT_081a	GT_VC_080a GT_VC_081a		Yes	2,000	1.35	Yes	0.60	1.35
3	3	4.05	4.75	0.70	16.2	8.1	12.7	None present	CLAY/TILL/SILT	0.1	EXTREMELY LOW STRENGTH CLAY	SAND	1	VERY LOOSE SAND	CLAY/TILL/SILT	1	LOOSE SAND	NO	GT_CPT_082 GT_CPT_083 GT_CPT_084 GT_CPT_084a	GT_VC_082 GT_VC_084a		Yes	2,000	1.15	Yes	0.60	1.15
4	4	4.75	5.74	0.99	17.6	13.0	15.8	None present	CLAY/TILL/SILT	0.1	EXTREMELY LOW STRENGTH CLAY	SAND	1	VERY LOOSE SAND	CLAY/TILL/SILT	1	LOOSE SAND	NO	GT_CPT_082 GT_CPT_083 GT_CPT_084 GT_CPT_084a	GT_VC_082 GT_VC_084a		Yes	2,000	1.25	Yes	0.60	1.25
5	5	5.74	6.57	0.83	19.3	16.2	17.9	None present	CLAY/TILL/SILT	0.1	EXTREMELY LOW STRENGTH CLAY	SAND	1	VERY LOOSE SAND	CLAY/TILL/SILT	1	LOOSE SAND	NO	GT_CPT_082 GT_CPT_083 GT_CPT_084 GT_CPT_084a	GT_VC_082 GT_VC_084a		Yes	2,000	1.75	Yes	0.60	1.75
6	6	6.57	8.38	1.81	20.6	17.6	19.5	None present	CLAY/TILL/SILT	0.1	EXTREMELY LOW STRENGTH CLAY	SAND	0.35	VERY LOOSE SAND	SAND	1.3	LOW STRENGTH CLAY	NO	GT_CPT_085	GT_VC_085		Yes	2,000	1.40	Yes	0.60	1.40
7	7	8.38	9.09	0.71	20.3	18.2	19.7	None present	SAND	1.1	VERY LOOSE SAND	SAND	0.1	LOOSE SAND	SAND	0.6	MEDIUM DENSE SAND	NO	GT_CPT_86 GT_CPT_87	GT_VC_86 GT_VC_87		Yes	2,000	1.40	Yes	0.60	1.40
8	8	9.09	10.43	1.34	21.3	18.5	20.3	None present	CLAY/TILL/SILT	0.1	EXTREMELY LOW STRENGTH CLAY	SAND	0.3	VERY LOOSE SAND	CLAY/TILL/SILT	1.6	MEDIUM STRENGTH CLAY	NO	GT_CPT_088 GT_CPT_089	GT_VC_088 GT_VC_089a		Yes	2,000	2.00	Yes	0.60	2.00
9	9	10.43	10.77	0.34	20.9	19.0	20.2	None present	CLAY/TILL/SILT	0.1	EXTREMELY LOW STRENGTH CLAY	SAND	0.3	VERY LOOSE SAND	CLAY/TILL/SILT	1.6	MEDIUM STRENGTH CLAY	NO	GT_CPT_088 GT_CPT_089	GT_VC_088 GT_VC_089a		Yes	2,000	1.95	Yes	0.60	1.95
10	10	10.77	11.61	0.84	20.6	18.4	19.8	None present	CLAY/TILL/SILT	0.1	EXTREMELY LOW STRENGTH CLAY	SAND	0.8	VERY LOOSE SAND	CLAY/TILL/SILT	0.75	MEDIUM STRENGTH CLAY	NO	GT_CPT_090a GT_CPT_090b	GT_VC_090b		Yes	2,000	2.00	Yes	0.60	2.00
11	11	11.61	12.27	0.66	20.8	18.6	19.9	None present	SAND	0.15	VERY LOOSE SAND	SAND	0.15	LOOSE SAND	SAND	1.1	MEDIUM DENSE SAND	NO	GT_CPT_091	GT_VC_091		Yes	2,000	0.90	Yes	0.60	0.90
12	12	12.27	12.45	0.18	20.9	18.6	20.3	None present	SAND	0.15	VERY LOOSE SAND	SAND	0.15	LOOSE SAND	SAND	1.1	MEDIUM DENSE SAND	NO	GT_CPT_091	GT_VC_091		Yes	2,000	0.85	Yes	0.60	0.85
13	13	12.45	15.00	2.55	21.2	18.2	20.6	None present	CLAY/TILL/SILT	0.05	EXTREMELY LOW STRENGTH CLAY	SAND	0.4	VERY LOOSE SAND	CLAY/TILL/SILT	1.5	MEDIUM STRENGTH CLAY	NO	GT_CPT_092 GT_CPT_093 GT_CPT_094 GT_CPT_095	GT_VC_092 GT_VC_093 GT_VC_094 GT_VC_095		Yes	2,000	1.95	Yes	0.60	1.95

8. CONCLUSION AND RECOMMENDATIONS

The cable burial risk assessment has shown that the following hazards are present along the Kattegat - Grenå South cable route:

Sediment Mobility
Sediment mobility in itself does not pose a threat to a submarine cable but it can lead to issues with the thermal conductivity of cables (over burial), and exposure of cables (scour); Over burial should be accounted for in the design phase of the cables and is usually dealt with by increasing, universally or locally, the cross-sectional area of the cables. Burial under excess soil can change the thermal properties of the soil and cause hotspots along the cable, while exposure increases the risk of damage due to external aggressors such as trawling and anchoring and potentially mechanical damage from free spans.

There are a number of areas within the 1500m corridor where there are bedforms present which could be mobile. For the purposes of depth of lowering all depths recommended in this report are assumed to be measured against a horizontal plane which has been determined to be non-mobile and after any required route engineering has been undertaken to flatten mobile sediments.

Fishing Risk
The review of the fishing indicated areas of mobile and static fishing gear along the entire cable route. No fishing protection or exclusion areas from fishing activity were reported.

Moreover, as the entire route is within water depth ranges in which mobile gear fishing could take place, we recommend the cables are given sufficient protection from fishing gear interaction in all sections of the route. The Carbon Trust's guidance indicates that penetration of fishing gear into the seabed is limited to a maximum of 0.3 m penetration even in soft sediment based on previous literature research. Allowing for a FoS of 2 means RMDOL based on fishing risk only would result in a value of 0.60m.

Anchoring Risk
Vessel Automatic Identification System (AIS) data has been used to determine the size and quantity of vessels which operate in the vicinity of the cable route. Vessels are grouped into size categories based on their deadweight tonnage (DWT) from Band A (0-100 DWT) to Band K (325K-450K DWT) and an appropriate associated anchor size is assigned to each band. Analysis of this data determines the probability of anchor-cable interactions for each vessel banding and thus the size of anchor which must be protected against in order to reduce risk to the cable to ALARP.

The probabilistic assessment calculates the annual failure probability of 42.65% for the entire route (based on anchor risk alone) if surface laid. This value equates to a return period of 2.34 years and a failure probability over the (40 year) lifetime of 100%. This is not an acceptable level of risk. Areas with the highest risk of Annual Failure include zone 13, 8, 10 and 2. These PA zones are areas of high vessel traffic thus; increased anchor drag risk. The lowest PA zones of risk are zones 12 and 3 given the low vessel traffic reducing all risk of anchor strike.

Note, the key reasons why anchor risk is not the key determinant in most zones is due to both the relatively light vessel densities and also the prevalent presence of soils which prevent anchors from penetrating very deeply.

Recommended Minimum Depth of Lowering (RMDOL)
The above approach results in a RMDOL varying from 0.65m to 2m. If these RMDOL values are achieved and maintained over the course of the cable lifetime then this would result in an annual failure rate of 0.00966% which equates to a return period of ~10,352 years and a failure probability over the (40 year) lifetime of 0.39% - i.e. "Event rarely expected to occur.".

REFERENCES

1 Admiralty (2024) Marine Data Portal. Available at: https://datahub.admiralty.co.uk/portal/apps/sites/#/marine-data-portal [Accessed: April 2024].

2 Ager, O., 2008. Buccinum undatum Common whelk. [Online] Available at: https://www.marlin.ac.uk/species/detail/1560 [Accessed April 2024]

3 Anchor Catalogue http://www.sotra.net/catalogue/2016/index.html)

4 Anchor Tests German Bight, Deltares, 2013

5 Baltic Wind, 2022. The growing role of the Port of Grenaa for Danish and Swedish wind farms. [Online] Available at: https://balticwind.eu/the-growing-role-of-the-port-of-grenaa-for-danish-and-swedish-wind-farms [Accessed March 2024].

6 Bergström, U. et al., 2022. Long-term effects of no-take zones in Swedish waters. Aqua Reports.

7 Bergström, U., Sköld, M., Wennhage, H. & Wikström, A., 2016. Ecological effects of no-take zones in Sweden's coastal and marine areas.. Aqua reports.

8 Camargo et. al. (Feb 2019), *Marine Geohazards: A Bibliometric-Based Review*, Geosciences 9, no. 2: 100

9 Carbon Trust (Dec 2019), Application Guide for the Specification of the Depth of Lowering Using the Cable Burial Risk Assessment (CBRA) Methodology, CTC857

10 Carbon Trust (Feb 2015), Cable Burial Risk Assessment Methodology - Guidance for the Preparation of Cable Burial Depth of Lowering Specification, CTC835

11 Danish Maritime Authority, 2020. New Shipping Routes in Kattegat and Skagerrak

12 Deloitte, 2022. Grenaa Havn Annual Report 2022

13 Developments in anchor technology and anchor penetration in the seabed, Dirk Luger, GeoDelft Presentation, Bremen, DK, 23 March 2006

14 DNV (Oct 2010), Risk Assessment of Pipeline Protection, DNV_RP_F107

15 DTU, 2024. The seafloor footprint of Danish fishing. [Online] Available at: https://ono.dtuaqua.dk/DDFAM/ [Accessed April 2024].

16 Du, L., Goerlandt, F. & Kujala, P., 2020. Review and analysis of methods for assessing. Reliability Engineering and System Safety, Issue 200.

17 Ebeltoft Havn, 2016. Port of Ebeltoft. [Online] Available at: http://ebeltofthavn.subsites.syddjurs.dk/om-os/ebeltoft-havn [Accessed March 2024].

18 Ebeltoft Havn, 2018. *Expansion of the port.* [Online] Available at: http://ebeltofthavn.subsites.syddjurs.dk/om-os/udvidelse-af-havnen [Accessed March 2024].

19 EMODNet (200m resolution), http://portal.emodnetbathymetry.eu/

20 EMODnet (March 2019), *EU Vessel Density Map Detailed Method, Human Activities Shipping Density Methodology Version 1.5*, available from: 'https://www.emodnet-humanactivities.eu/documents/Vessel%20density%20maps_method_v1.5.pdf', accessed 06 July 2020.

21 EMODnet Map Viewer (2024) European Marine Observation and Data Network (emodnet). Available at: https://emodnet.ec.europa.eu/geoviewer/ [Accessed: April 2024].

22 European Commission, 2022. *Fisheries conservation: Reinforced protection for 11 vulnerable sites in the North Sea (Kattegat).* [Online] Available at: news-37588-etude-peche-new-economics-foundation.pdf (actu-environnement.com) [Accessed April 2024].

23 European Parliament (2023) Fact Sheets on the European Union | European Parliament. Available at: https://www.europarl.europa.eu/factsheets/en/sheet/125/maritime-transport-traffic-and-safety-rules. [Accessed: April 2024].

24 European Sea Ports Organisation. (2023). Port of Aarhus. Retrieved from https://www.espo.be/port/port-of-aarhus

25 Eurostat, 2023. *Passengers embarked and disembarked in the top 20 EU ports.* [Online] Available at: https://ec.europa.eu/eurostat/databrowser/view/mar_mp_aa_pphd$defaultview/default/table?lang=en [Accessed March 2024].

26 Exmile Solutions, 2024 AIS data at 5-minute time series data of shipping from 07/02/2023 to 06/02/2024

27 Expansion of Port of Aarhus Approved: A Historic Milestone. https://www.portofaarhus.dk/en/nyheder/havneudvidelse-i-aarhus-vedtaget-en-historisk-milepael.

28 Expansion project Port of Aarhus - Ultimate Software. https://www.ultimatemaritimelogistics.com/en/insights/news/expansion-project-port-of-aarhus/.

29 FindaPort, 2023. *Port of Helsingor, Denmark.* [Online] Available at: https://www.findaport.com/port-of-helsingor [Accessed March 2024].

30 Foda M A, Hunt J R, Chou H T, (1993) A nonlinear model for the fluidization of marine mud by waves. American Geophysical Union, Journal of Geophysical Research, 58(C4): 7 039 - 7 047.

31 GEOxyz, 2024. Bathymetry

32 GEOxyz, 2024. Geotechnical Report and VC & CPT logs

33 GEOxyz, 2024. Geotechnical Sample Locations Shapefile

34 Gisselbæk, T., 2019. *Ask the Experts: Shipping* [Interview] 2019.

35 Gregersen, S., Hjelme, J., & Hjortenberg, E. (1998). EARTHQUAKES IN DENMARK. Bulletin of The Geological Society of Denmark, 44, 115-127.

36 Grenaa Havn, 2023. *Gateway to Kattegat.* [Online] Available at: https://grenaahavn.dk/en/om-os/porten-til-kattegat/ [Accessed March 2024].

37 Grimvall, A. & Larsson, K., 2014. Mapping shipping intensity and routes in the Baltic Sea. *Swedish Institute for the Marine Environment..*

38 HELCOM (Baltic Marine Environment Protection Commission), 2018. Report on shipping. *HELCOM.*

39 Helsinborgs Hamn, 2024a. *New Container Terminal 2030.* [Online] Available at: https://www.port.helsingborg.se/en/about-port-helsingborg/new-container-terminal-2028/ [Accessed March 2024].

40 Helsingborgs Hamn, 2020. *Our harbours.* [Online] Available at: https://www.port.helsingborg.se/en/sea-services/our-harbours/ [Accessed March 2024].

41 Helsingborgs Hamn, 2024b. *Record year for The Port of Helsingborg.* [Online] Available at: https://www.port.helsingborg.se/en/2022/01/24/record-year-for-the-port-of-helsingborg/?doing_wp_cron=1711548316.4921939373016357421875 [Accessed March 2024].

42 Helsingor Havne, 2023. *Velkommen.* [Online] [Accessed https://www.helsingor-havne.dk/ March 2024].

43 Hill, J. & Sabatini, M., 2008. *Nephrops norvegicus Norway lobster.* [Online] Available at: https://www.marlin.ac.uk/species/detail/1672

44 Holcomb, R.T.; Searle, R.C. (March 1991), *Large landslides from oceanic volcanoes*. Mar. Geotechnol. 1991, 10, 19–32.

45 ICES, 2023. *Official Nominal Catches 2006-2021.* [Online] Available at: http://ices.dk/data/dataset-collections/Pages/Fish-catch-and-stock-assessment.aspx [Accessed April 2024].

46 ICES, 2024. *ICES-FishMap.* [Online] Available at: https://www.ices.dk/about-ICES/projects/EU-RFP/Pages/ICES-FIshMap.aspx [Accessed April 2024].

47 International Maritime Organization, 2017. Routeing Measures and Mandatory Ship Reporting Systems - General overview for establishment of traffic separation scheme and other routeing measures in the

vicinity of Kattegat between Denmark and Sweden. *NCSR.*

48 International Transport Forum, 2019. ITF Transport Outlook 2019. *Paris: OECD Publishing.*

49 Lager & Transport, 2023. *Havn takes the next step in the hinterland.* [Online] Available at: https://grenaahavn.dk/wp-content/uploads/LT823_14-15_Grenaa-Havn.pdf [Accessed March 2024].

50 Langhorne, D N, (1978). Offshore Engineering and Navigational Problems - The Relevance of Sandwave Research. Published by the Society for Underwater Technology in Conjunction with the Institute of Oceanographic Sciences. 21 pages.

51 Langhorne, D. N. (1977), *Sandwave research and its relevance to present day navigation and engineering problems*, Institute of Oceanographic Sciences internal document, 19. Wormley, Surrey, UK. Institute of Oceanographic Sciences

52 Lecq, L., 2021. Lecq, L. Mapping Maritime Risk in the Kattegat Using the Automatic Identification System. *MS thesis.*

53 Lunne, R, Robertson, P K, and Powell, J J M (1997). Cone penetration testing in geotechnical practice. E & FN Spon. 312 pages.

54 Mandke et al., (March 1995), *Evaluation of Hurricane-induced damage to offshore pipelines*. Available from (https://www.bsee.gov/sites/bsee.gov/files/tap-technical-assessment-program//201aa-hurricane-andrew.pdf), accessed 20 July 2020.

55 Marine & Coastguard Agency, DNV 2005

56 Marine Insight, 2023. *6 Major Ports in Denmark.* [Online]
Available at: https://www.marineinsight.com/know-more/6-major-ports-in-denmark/
[Accessed March 2024].

57 Marine Stewardship Council (2020), *Common Fishing Gear Types*, (https://www.msc.org/what-we-are-doing/our-approach/fishing-methods-and-gear-types/), accessed 21 September 2020.

58 Marine Stewardship Council, 2024a. *Blue mussel (Mytilus edulis).* [Online] Available at: https://fisheries.msc.org/en/fisheries/havsodlarna-swedish-west-coast-rope-grown-mussel-fishery/
[Accessed April 2024].

59 Marine Stewardship Council, 2024b. *Nephrops (Nephrops norvegicus).* [Online] Available at: https://fisheries.msc.org/en/fisheries/danish-and-swedish-nephrops/#:~:text=The%20fishery%20operates%20around%20Skagerrak,extending%20forward%20from%20the%20opening.
[Accessed April 2024].

60 Ministry of Food, Agriculture and Fisheries (2024) Commercial Fisheries. Available at: https://fiskeristyrelsen.dk/english/commercial-fisheries#c83618 [Accessed: April 2024].

61 Munich RE (March 2017), The Year in Figures, available from (https://www.munichre.com/topics-online/en/climate-change-and-natural-disasters/natural-disasters/overview-natural-catastrophe-2016.html), accessed 20 July 2020.

62 Neal, K. & Wilson, E., 2008. *Cancer pagurus Edible crab.* [Online] Available at: https://www.marlin.ac.uk/species/detail/1179

63 NIRAS, 2022. Hesselø Offshore Wind Farm - Fisheries Technical Report, s.l.: s.n.

64 Oceana, 2018. Conservation proposals for ecologically important areas in the Baltic Sea, s.l.: s.n.

65 ØRESUNDSLINJEN, 2024. *Book between Helsingborg and Helsingør.* [Online] Available at: https://www.oresundslinjen.dk/ [Accessed March 2024].

66 Port of Aarhus. (2023). About us. Retrieved from https://www.portofaarhus.dk/en/about-us/

67 Port of Ebeltoft in Denmark, 2024. *Ebeltoft (Port).* [Online]
Available at: https://www.vesseltracker.com/en/Port/Ebeltoft/Dashboard.html
[Accessed March 2024].

68 Port of Grenaa, 2023. *Gateway to Kattegat.* [Online] Available at: https://grenaahavn.dk/en/om-os/porten-til-kattegat/
[Accessed March 2024].

69 Port of Grenaa, 2024. *New ferry ramp for Sweden traffic.* [Online] Available at: https://grenaahavn.dk/en/grenaa-havn-fastholder-energitillaeg-copy-copy/
[Accessed March 2024].

70 Port of Skagen, 2016. *The Port of Skagen.* [Online] Available at: http://www.portofskagen.com/
[Accessed March 2024].

71 Port of Skagen, 2021. *Expansion of the Port.* [Online] Available at: http://www.portofskagen.com/en/expansion-of-the-port#:~:text=The%20Port%20of%20Skagen%20expands,fishing%20industry%20and%20related%20industries. [Accessed March 2024].

72 Port of Skagen, 2022a. *Maritime Business Hub of Scandinavia.* [Online] Available at: http://www.portofskagen.com/Admin/Public/DWSDownload.aspx?File=%2fFiles%2fFiles%2fDokumenter%2fFolder%2fPort_of_Skagen_2021_WEB.pdf [Accessed March 2024].

73 Port of Skagen, 2022b. *Statistics.* [Online] Available at: http://www.portofskagen.com/en/port-of-scandinavia/statistics
[Accessed March 2024].

74 Port of the future. https://www.portofaarhus.dk/en/om-aarhus-havn/fremtidens-havn.

75 Robertson, PK, Campanella, RG, Gillespie, D and Greig J (1986) *Use of Piezometer Cone data. In-Situ'86 Use of Insitu testing in Geotechnical Engineering*, GSP 6, ASCE, Reston, VA, Specialty Publication, pp 1263-1280.

76 Seafish (2022) Basic fishing methods. Available at: https://www.seafish.org/document/?id=9f2fcd97-8bef-4c28-9185-b219b8eedf8a [Accessed: Jan 2024].

77 Serviceteam Skagen, 2022. *About Port of Skagen.* [Online] Available at: https://www.serviceteamskagen.dk/en/about-port-of-skagen/
[Accessed March 2024].

78 SHIPNEXT, 2024a. *Elsinore Port.* [Online] Available at: https://shipnext.com/port/58234a79821bd20e38598979
[Accessed March 2024].

79 SHIPNEXT, 2024b. *Grenaa Port.* [Online] Available at: https://shipnext.com/port/5823a294821bd20e38598ad1
[Accessed March 2024].

80 SHIPNEXT, 2024c. *Helsingborg Port.* [Online] Available at: https://shipnext.com/port/5821a57f0dd99d0cf03f0747
[Accessed March 2024].

81 SHIPNEXT, 2024d. *Ebeltoft Port.* [Online] Available at: https://shipnext.com/port/ebeltoft-dkebt-dnk
[Accessed March 2024].

82 Sköld, M. et al., 2018. Effects of chronic bottom trawling on soft-seafloor macrofauna in the Kattegat. *Marine Ecology Progress Series,* Issue 586, pp. 41-55.

83 State of Green, 2014. *Port of Grenaa.* [Online] Available at: https://stateofgreen.com/en/solution-providers/port-of-grenaa/
[Accessed March 2024].

84 Statistics Denmark, 2024. *StatBank Denmark.* [Online] Available at: https://www.dst.dk/en/
[Accessed March 2024].

85 Staudigel, H. & Clague, D., (Oct 2015), The *Geological History of Deep-Sea Volcanoes: Biosphere, Hydrosphere, and Lithosphere Interactions*, Oceanography 23(1):58–71, https://doi.org/10.5670/oceanog.2010.62.

86 Submarine Power Cables - Design, Installation, Repair, Environmental Aspects, Worzyk, T, 2009

87 The Danish Environmental Protection Agency, 2017. *Natura 2000-basisanalyse*

88 The port of Aarhus. https://www.the-intl.com/post/the-port-of-aarhus.

89 Tran, N. & Haasis, H., 2015. An empirical study of fleet expansion and growth of ship. *International Journal of Production Economics,* Volume 159.

90 Tunnel Contact, 2021. *Two new tunnels between Sweden and Denmark are planned.* [Online]

Available at: https://tunnelcontact.com/discussion/view/28243/two-new-tunnels-between-sweden-and-denmark-are-planned-both-between-helsingborg-and-helsingor [Accessed March 2024].

91 Tyler-Walters, H., 2008. *Mytilus edulis Common mussel.* [Online] Available at: https://www.marlin.ac.uk/species/detail/1421

92 Ungfors, A., 2008. Fisheries biology of the edible crab (Cancer pagurus) in the Kattegat and the Skagerak. Implications for Sustainable Management.

93 Vessel DWT, *https://www.marinetraffic.com/*

94 VisitAarhus, 2024. *Ebeltoft Traffic Port and Marina.* [Online]
Available at: https://www.visitaarhus.com/aarhus-region/plan-your-trip/ebeltoft-traffic-port-and-marina-gdk606024
[Accessed March 2024].

95 Whitehouse, R.J.S.; Damgaard, J.S.; Langhorne, D.N. (2000). *Sandwaves and seabed engineering; the application to submarine cables*, in: Trentesaux, A. et al. Marine Sandwave Dynamics, International Workshop, March 23-24 2000, University of Lille 1, France. Proceedings.In: Trentesaux, A.; Garlan, T. (Ed.) (2000). Marine Sandwave Dynamics, International Workshop, March 23-24 2000, University of Lille 1, France. Proceedings. Université de Lille 1: Lille. ISBN 2-11-088263-8. 240 pp.

APPENDIX A

Geotechnical Boundaries

Table A-1 Geotechnical Boundaries

Zone	Comments/Assumptions	Start KP	End KP	Segment Distance (km)
1	0.2m of Very Loose Sand, 0.2m of Loose Sand, Overlying Medium Dense Sands	0	4.05	4.05
2	0.1m m of Low Strength Clay, 1m, of Very Loose Sand Overlying Loose Sand	4.05	6.57	2.52
3	0.1 of Low Strength Clay, 0.35 of Very Loose Sand Overlying Low Strength Clay	6.57	8.38	1.81
4	1.1 of Very Loose Sand, 0.1 of Loose sand, Overlying Medium Dense Sand	8.38	9.09	0.71
5	0.1 of Very Low Strength Clay, 0.3 of Very Loose Sand Overlying Low Strength Clay	9.09	10.77	1.68
6	0.1 of Very Low Strength Clay, 0.8m of Very Loose Sand, 0.5 Low Strength Clay	10.77	11.61	0.84
7	0.15 of Very Loose Sand, 0.15 of Loose sand, overlying Medium Dense Sand	11.61	12.45	0.84
8	0.05 of Very Low strength Clay, 0.4 of Very Loose Sand, overlying 1.5m of Low Strength Clay	12.45	15	2.55

APPENDIX B

Risk Register

Table B-1 Risk Register

Hazard log Ref No.	Hazard Class	Hazard Description (potential)	Risk Description	Initial Risk Rating			Mitigation	Residual Risk Rating		
				Likelihood	Severity	Risk rating		Likelihood	Severity	Risk rating
Natural										
1.A	Bathymetry	Sandwaves sections are present along the cable route which present extreme slopes.	Risk to trencher operation during installation. Not applicable as installation risk not considered here. **Not Scored.**							
1.B	Bathymetry	Sandwaves sections are present along the cable route.	Sandwave sections are mobile which risks long-term asset protection (i.e. from vortex induced vibration and/or exposure to external aggressors) should free-spans develop or burial reduce to insufficient levels. **Assessed under 11. Mobile Sediment.**							
2	Seabed topography	Uneven seabed topography may lead to more variable burial requirements.	Local burial depth may be adjusted upwards by sandwaves that return after installation resulting in degraded thermal performance leading to potential derating.	4	2	8	Ensure cable's design can tolerate increased burial depths from returning sandwaves after installation.	1	2	2
3	Seabed obstructions	Obstruction will result in section out of burial specification.	Not applicable, only applicable to as-built cable. **Not scored**							
4	Shallow gas	Represent a danger to vessels / personnel.	Applicable to installation and as-built cable but not to present CBRA. **Not scored.**							
5	Currents / waves	Abrasion, stress and fatigue where cable crosses rock/rough terrain. Can induce loading on cable connectors. Can mobilise sediment exposing cables to further primary hazards. Metocean conditions likely to impact on surface laid cable and also influence sediment mobility.	Risk associated with protection for rocky terrain is design specific, thus outside CBRA scope. **Not scored.** See hazard No.13 for risk from Mobile Sediment. For surface laid there would be potential for damage from wave/current actions, predominantly in shallow waters.	2	3	6	CBRA to include consideration of wave/current action should surface laid be acceptable from anthropogenic threats. For protection in rocky areas, a design risk assessment would be required. Hydro-sedimentary study to be undertaken to determine risk of sediment accretion or erosion along the route. Vertical reference level to be revised if required by results of study.	1	2	2
6	Fish bites	Can damage insulation: historically mainly occurred with telegraph cables but recent occurrences have been noted occasionally.	Only applicable to subsea telecom cables. Not plausible threat to a power cable.							

Hazard log Ref No.	Hazard Class	Hazard Description (potential)	Risk Description	Initial Risk Rating			Mitigation	Residual Risk Rating		
				Likelihood	Severity	Risk rating		Likelihood	Severity	Risk rating
7.A	Hurricane / Storm surge / Extreme Weather	Can cause a shallow buried asset to be unburied due to hydrostatic forces or erosion of the seabed / formation of depressions; alternatively can lead to over burial through accretion.	Asset becomes vulnerable to risks such as fish and shipping. Additionally deburial may cause damage (strains and stresses) to the asset. See hazard No.13 for risk from increased burial depth (Mobile Sediment).	3	3	9	Recommended to undertake a Hydro-Sedimentary Study to determine risk of erosion or accretion on the route due to strong waves or currents. Outputs of this study should feed into the calculation of the vertical reference level which Recommend Minimum and Target Depth of Lowering is measured against. Cable designed to accommodate for greater levels of burial than level buried to, to accommodate more onerous thermal environment caused by either sandwave movement or accretion.	3	2	6
7.B		Soil liquefaction	Risk of mechanical stress for cable on interface locations with structures (HDD entry point, j-tube bellmouth). Risk of overheating if cable sinks deeper than design allows for. Risk of free-spanning cable if depressions form.	2	3	6	Recommended to undertake detailed Hydro-sedimentary Study to determine potential for wave-induced soil liquefaction. Consider use of bend restrictors in accordance with risk as identified by details engineering design. Cable designed to accommodate for greater levels of burial than level buried to, to accommodate more onerous thermal environment caused by either sandwave movement, accretion, or else greater burial through liquefaction. Cables monitored by Distributed Temperature Sensing (DTS)/Distributed Acoustic Sensing (DAS) and regular condition surveys to give early warning of reduction in sediment cover. Ensuring cable specific gravity is as close as possible to that of liquefied soils.	2	1	2

Hazard log Ref No.	Hazard Class	Hazard Description (potential)	Risk Description	Initial Risk Rating			Mitigation	Residual Risk Rating		
				Likelihood	Severity	Risk rating		Likelihood	Severity	Risk rating
7.C		Cause submarine landslides or turbidity currents reducing sediment cover exposing cables to primary risk.	Review of literature and the results of the seabed survey indicates that significant hazards of this nature are not expected along the cable's route though this should be confirmed by a detailed Geohazard Study.	1	3	3	Recommended to undertake detailed Geohazard Study.	1	3	3
8.A	Submarine earthquakes	Cause submarine landslides or turbidity currents reducing sediment cover exposing cables to primary risk.	Review of literature and the results of the seabed survey indicates that significant hazards of this nature are not expected along the cable's route though this should be confirmed by a detailed Geohazard Study.	1	3	3	Recommended to undertake detailed Geohazard Study.	1	3	3
8.B	Submarine earthquakes	Shifting geological layers along a fault line	Damage to asset caused by strains and stresses	1	4	4	Risk is at ALARP as there is no evidence of faults along the export cable route.	1	3	3
8.C	Submarine earthquakes	Soil liquefaction	Risk of mechanical stress for cable on interface locations with structures (j-tube bellmouth). Risk of overheating if cable sinks deeper than design allows for. Risk of free-spanning cable if depressions form.	2	3	6	Undertake detailed Geohazard Study to determine potential for earthquake-induced soil liquefaction (note, study has been undertaken). Consider use of bend restrictors in accordance with risk as identified by details engineering design. Cable designed to accommodate for greater levels of burial than level buried to, to accommodate more onerous thermal environment caused by either sandwave movement, accretion, or else greater burial through liquefaction. Cables monitored by Distributed Temperature Sensing (DTS)/Distributed Acoustic Sensing (DAS) and regular condition surveys to give early warning of reduction in sediment cover. Ensuring cable specific gravity is as close as possible to that of liquefied soils.	2	1	2
9	Submarine volcanoes	Directly impact cables through contact or trigger submarine landslides (see above).	None present at site. **Not scored.**							

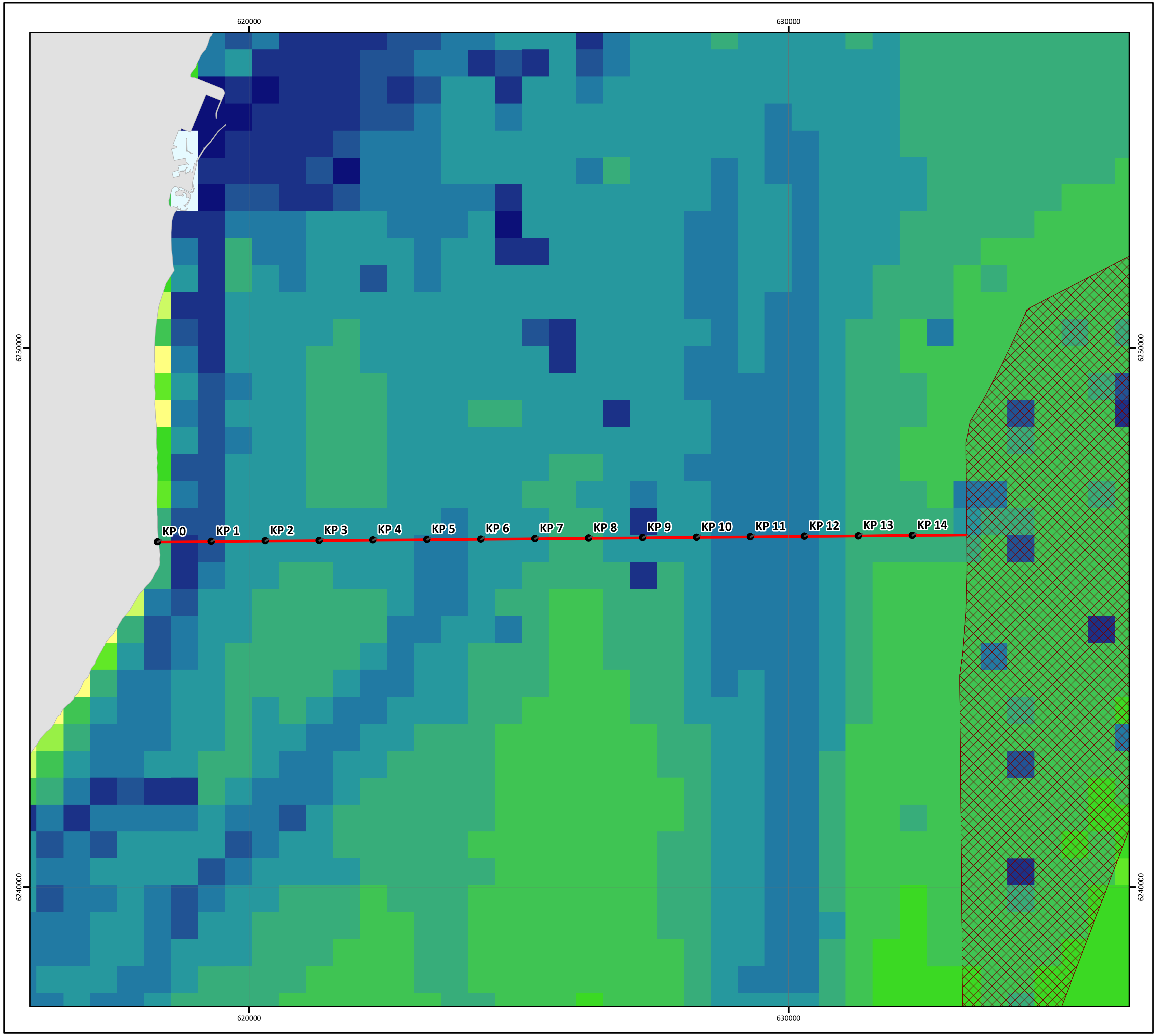
Hazard log Ref No.	Hazard Class	Hazard Description (potential)	Risk Description	Initial Risk Rating			Mitigation	Residual Risk Rating		
				Likelihood	Severity	Risk rating		Likelihood	Severity	Risk rating
10	Icebergs	Can directly impact on cables in shallow water depth as they scour the seabed. Not anticipated along the cable's route.	Not plausible. **Not scored.**							
Soil Conditions										
11	Mobile Sediment	Sand Wave or megaripple mobility could cause deburial or increased burial of the cable.	Potential mobile sediments identified from review of data for leading to uncertainties to actual burial depth at any time. The risk is that information gaps concerning the extent of sediment mobility means that the recommended DOL contingency is either too low or too high. The consequence is either lower protection or higher CAPEX.	3	3	9	Determination of accurate vertical reference level and DOL to reduce risk to ALARP. Cable designed to accommodate for greater levels of burial than level buried to, to accommodate more onerous thermal environment caused by either sandwave movement, accretion, or else greater burial through liquefaction. Cables monitored by Distributed Temperature Sensing (DTS)/Distributed Acoustic Sensing (DAS) and regular condition surveys to give early warning of reduction in sediment cover.	2	3	6
12	Variable ground conditions	Outcropping or subcropping rock, cemented / over consolidated soils, coral reef, weak layers, sapropels, very low strength soils, salt piercements, shallow gas, supersaturated soils, aggressive soils or soils with pyrite formation can affect the degree of burial or the ease of burial of a cable.	Very Low Strength CLAY as a top layer of various thicknesses is present on the route may present a risk during trenching due to sinkage or loss of traction during installation.	3	2	6	Undertake capacity bearing assessment of soil and select appropriate burial tool.	2	2	4
13	Thermal Variability	Soils which have a significant difference in thermal properties compared with surrounding soils.	Cable thermal environment as determined by geotechnical site investigation campaign is not accurate leading to either oversizing or under-sizing of cable core.	3	3	9	Close work and information exchange between site survey lead and cable design lead to ensure risk of thermal variability in soils from received figures is understood and accounted for in cable design. Use of competent personnel and rigorous internal QC process before each decision point in project lifecycle.	2	3	6
Anthropogenic										

Hazard log Ref No.	Hazard Class	Hazard Description (potential)	Risk Description	Initial Risk Rating			Mitigation	Residual Risk Rating		
				Likelihood	Severity	Risk rating		Likelihood	Severity	Risk rating
14a	Fishing	Snagging of cables with fishing gear and damage during retrieval of gear. Seabed interacting gear reducing sediment coverage above cable.	Due to inaccurate characterisation of presence of mobile fishing types there is a risk of misunderstanding the risk of mechanical damage to the installed cable. Consequence is misspecification of recommended minimum depth of lowering leading to either greater CAPEX or greater risk of damage to the installed cable. Leads to requirement to inspect and potentially to repair. Other consequence is cable outage and increase of monitoring requirements.	1	1	1	No further mitigation expected. Base case assumes sufficient burial to protect from known regional fishing threats applied to the whole cable route.	1	1	1
14b		Objects including drums discarded by fishing vessels penetrate the seabed and strike the cable and/or deform the seabed above the cable sufficiently enough to cause damage to the cable.	Discarded objects including drums have been observed on the cable route in the geophysical survey data and are understood to have originated from local fishing vessels. Likelihood of a direct strike is considered low but if occurred in area where soil strength is low then a large enough object could penetrate deeper than the 30cm maximum penetration depth assumed for the fishing assessment.	1	3	3	Undertake a specialist study into the risk of dropped objects on route. As part of study engage with the local fishing industry to gain understanding of the types of objects discarded and the circumstances of their disposal. If study concludes penetration >30cm is sufficient risk to the cables in any sections of the route then increase burial depth accordingly (while noting the 2 FOS already applied to the maximum fishing depth).	1	1	1
15.A	Shipping/Anchoring	Snagging of cables during normal or emergency anchoring procedures.	Due to inaccurate characterisation of shipping or soils there is a risk of misunderstanding the risk of mechanical damage to the installed cable. Consequence is misspecification of recommended minimum DOL leading to either greater CAPEX or greater risk of damage to the installed cable. Leads to requirement to inspect and potentially to repair. Other consequence is cable outage and increase of monitoring requirements.	3	3	9	Revise the CBRA following receipt of survey data, or significant changes to shipping patterns. (scored on a basis of shipping pattern changes).	1	3	3
15.B			Due to cable design for a return period of 25 years, there is a residual risk of mechanical damage.	1	2	2	No further mitigation required.	1	2	2

Hazard log Ref No.	Hazard Class	Hazard Description (potential)	Risk Description	Initial Risk Rating			Mitigation	Residual Risk Rating		
				Likelihood	Severity	Risk rating		Likelihood	Severity	Risk rating
16	Dredging / Aggregate Extraction / Subsea Mining / Dumping	Direct contact to the cable from the dredging equipment or reduction in seabed cover increasing risk to cable.	Damage to cable caused by activities and or increased unplanned for exposure leading to a cable strike by third-party aggressors.	2	3	6	Ensure cable is not installed in areas where dredging / Aggregate Extraction / Subsea Mining / Dumping areas are permitted. Or alternatively ensure risk is identified and designed for.	1	3	3
17	Renewable Energy Areas	Direct contact to the cable from offshore windfarm construction activities	The cable route avoids offshore windfarm areas **Not scored.**							
18	Other cables, umbilical, Pipelines	Reduced depth of lowering at crossing and/or proximity of third-party operation.	Cable and pipeline crossings identified along the route. Outside of CBRA scope, thus **not scored.**							
19	Misc. Activities	Such as construction, rock dumping, marine surveys, leisure activities. Any activity that directly interacts with the seabed and reduces the seabed cover.	Misc., activities are outside of the CBRA scope. **Not scored.**							
20	Exclusions physical	Defence and acts of aggressions.	Outside CBRA scope, thus **not scored.**							
21	Exclusions planning	Updated information which significantly changes the recommendations of the CBRA	Potential to require re-routing outside of survey corridor. **Not scored.**							

APPENDIX C

Vessel Density Heat Maps



CABLE BURIAL RISK ASSESSMENT
KATTEGAT - GRENÅ SOUTH - CBRA

AUTOMATIC IDENTIFICATION SYSTEM (AIS)
Vessel Density (February 2023 - February 2024)

Drawing No: P2719E-AIS-001	B

Legend

- KP
- Cable Route
- Wind Farm Site

Vessel Density (Duration per Year)

- < 15 minutes
- 15 - 30 minutes
- 30 - 45 minutes
- 45 mins - 1 hour
- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week
- > 1 week

N W E S

NOTE: Not to be used for Navigation

Date	19 June 2024
Coordinate System	ETRS 1989 UTM Zone 32N
Projection	Transverse Mercator
Datum	ETRS 1989
Data Source	ESRI; NUTS; ENERGINET
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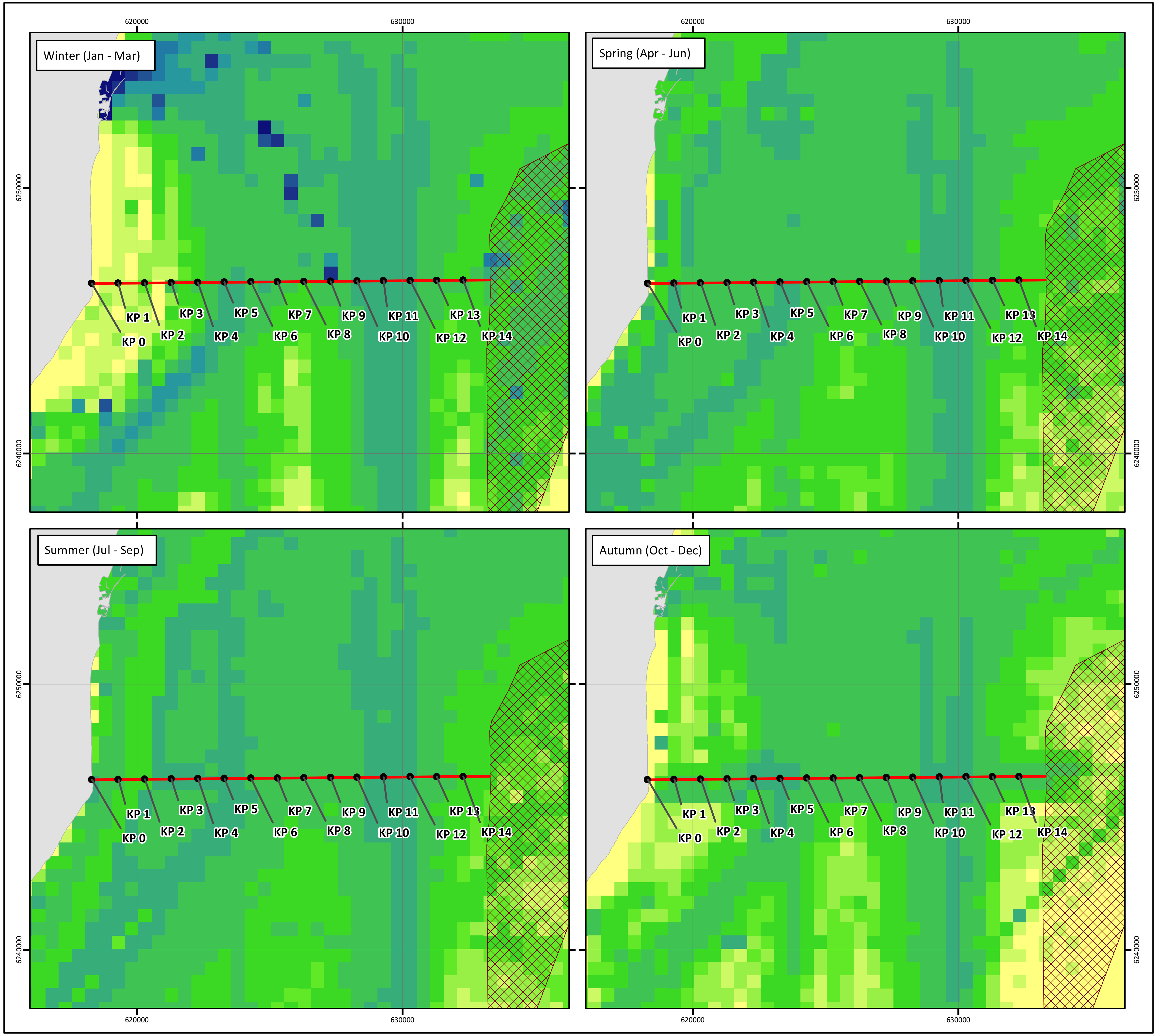
Created By	Lewis Castle
Reviewed By	Emma Langley
Approved By	Stephane Theurich

ENERGINET intertek

0 1 2 3 4 km



CABLE BURIAL RISK ASSESSMENT
KATTEGAT - GRENÅ SOUTH - CBRA

AUTOMATIC IDENTIFICATION SYSTEM (AIS)
Vessel Density by Season

Drawing No: P2719E-AIS-002 | **B**

Legend

- KP
- Cable Route
- Wind Farm Site

Vessel Density (Duration per Year)

- < 15 minutes
- 15 - 30 minutes
- 30 - 45 minutes
- 45 mins - 1 hour
- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week
- > 1 week

N W E S

NOTE: Not to be used for Navigation

Date	19 June 2024
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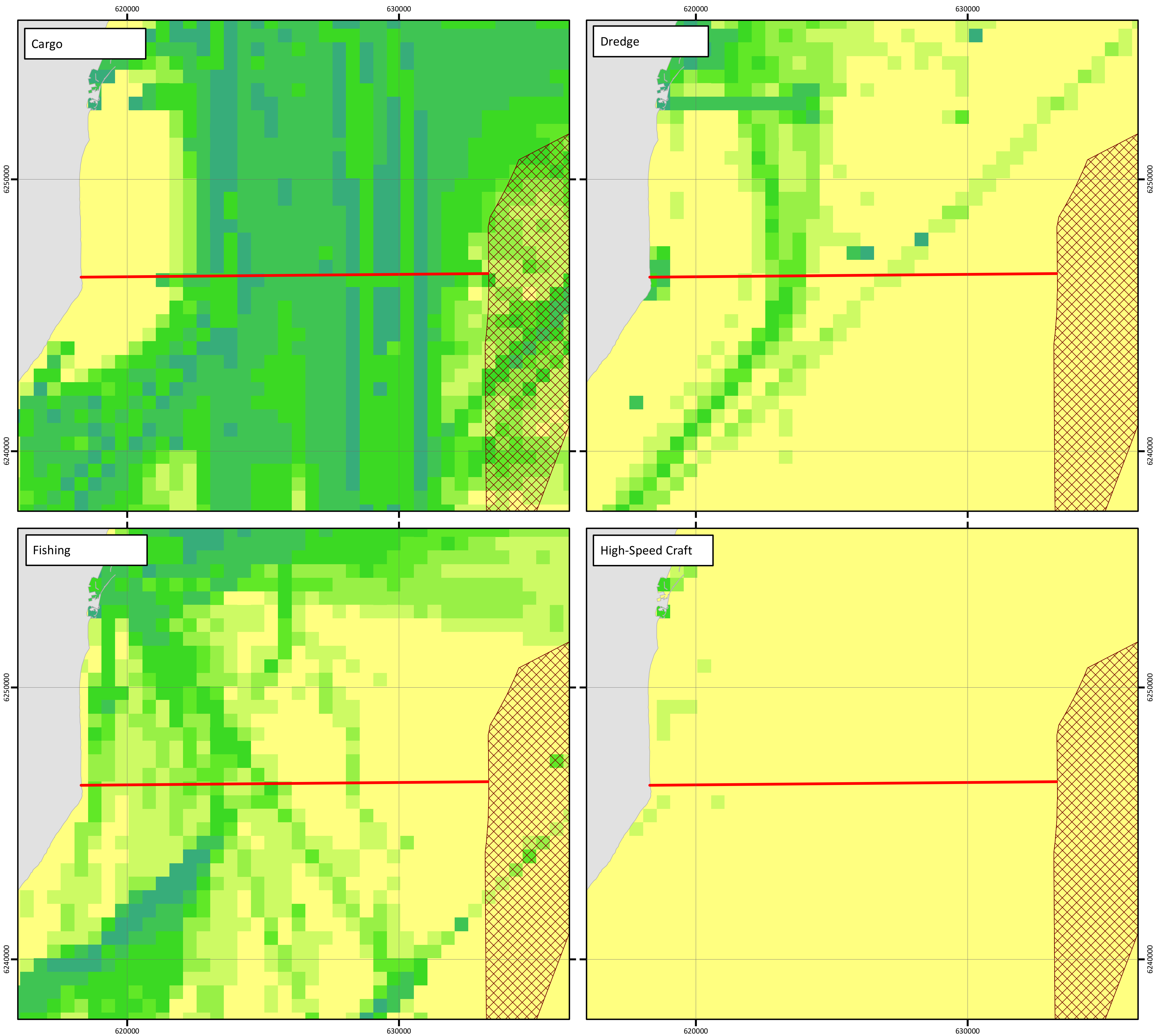
Created By	Lewis Castle
Reviewed By	Emma Langley
Approved By	Stephane Theurich

ENERGINET intertek

0 1 2 3 4 km



CABLE BURIAL RISK ASSESSMENT
KATTEGAT - GRENÅ SOUTH - CBRA

AUTOMATIC IDENTIFICATION SYSTEM (AIS)
Annual Vessel Density by Type - Sheet 1 of 4

Drawing No: P2719E-AIS-003	A

Legend

- Cable Route
- Wind Farm Site

Vessel Density (Duration per Year)

- < 15 minutes
- 15 - 30 minutes
- 30 - 45 minutes
- 45 mins - 1 hour
- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week
- > 1 week

N W E S

NOTE: Not to be used for Navigation

Date	23 May 2024
Coordinate System	ETRS 1989 UTM Zone 32N
Projection	Transverse Mercator
Datum	ETRS 1989
Data Source	ESRI; NUTS; ENERGINET
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Created By	Lewis Castle
Reviewed By	Emma Langley
Approved By	Stephane Theurich

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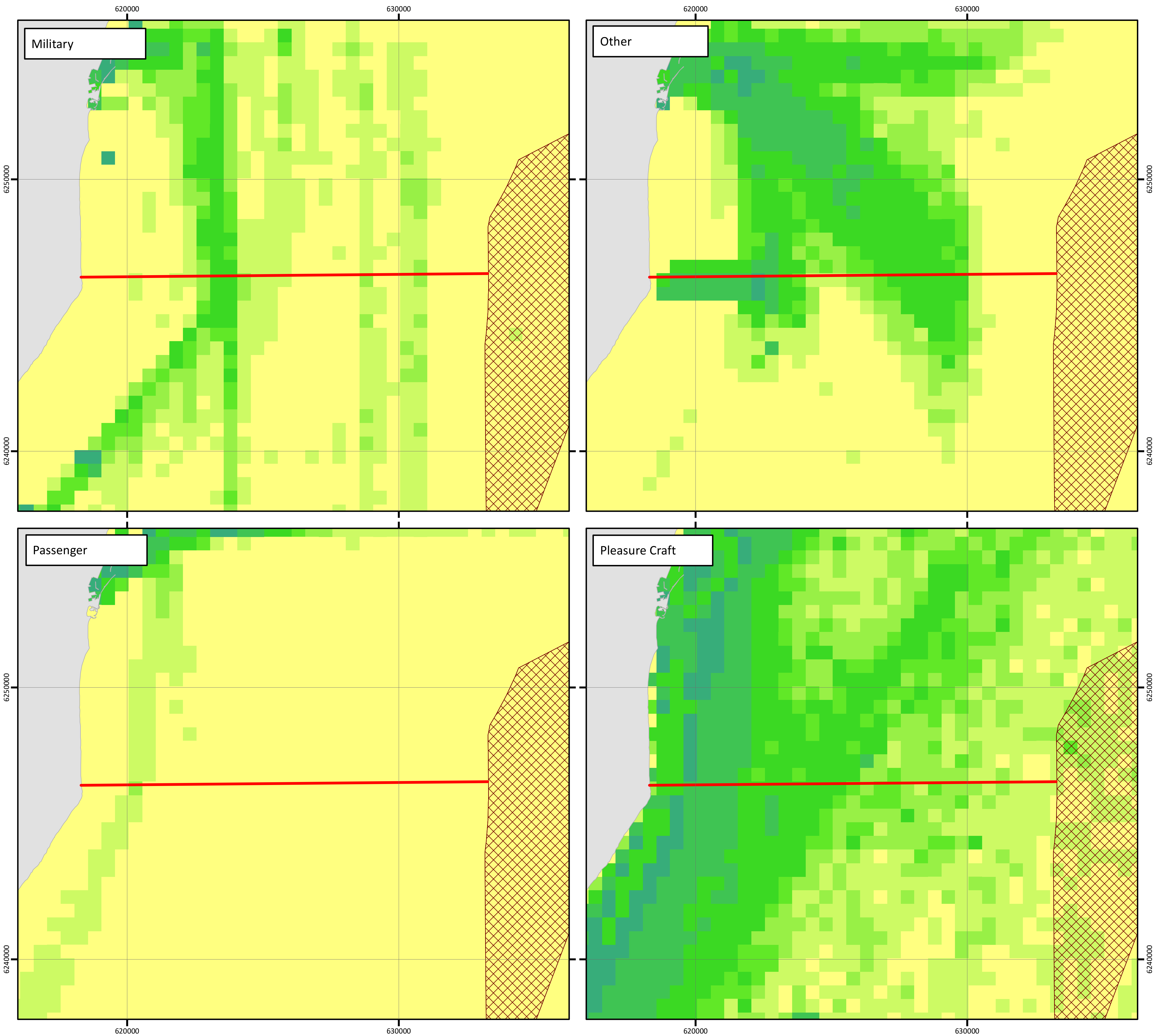
km 0 1 2 3 4



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CABLE BURIAL RISK ASSESSMENT
KATTEGAT - GRENÅ SOUTH - CBRA

AUTOMATIC IDENTIFICATION SYSTEM (AIS)
Annual Vessel Density by Type - Sheet 2 of 4

Drawing No: P2719E-AIS-004	A

Legend

- Cable Route
- Wind Farm Site

Vessel Density (Duration per Year)

- < 15 minutes
- 15 - 30 minutes
- 30 - 45 minutes
- 45 mins - 1 hour
- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week
- > 1 week

N W E S

NOTE: Not to be used for Navigation

Date	23 May 2024
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Projection	Transverse Mercator
Datum	ETRS 1989
Data Source	ESRI; NUTS; ENERGINET
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Created By	Lewis Castle
Reviewed By	Emma Langley
Approved By	Stephane Theurich

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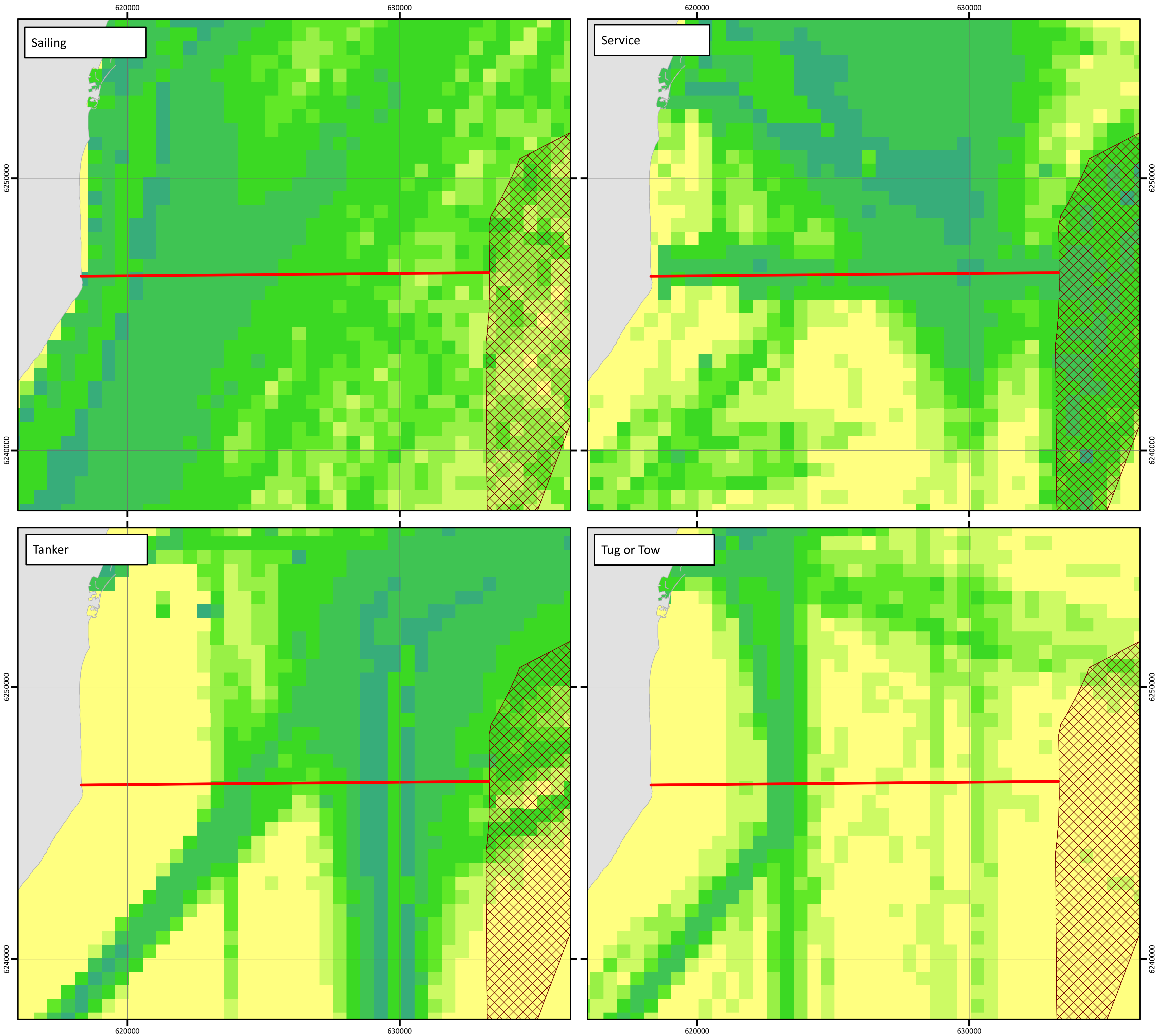
km 0 1 2 3 4

CABLE BURIAL RISK ASSESSMENT
KATTEGAT - GRENÅ SOUTH - CBRA

AUTOMATIC IDENTIFICATION SYSTEM (AIS)
Annual Vessel Density by Type - Sheet 3 of 4

Drawing No: P2719E-AIS-005	A



Legend

- Cable Route
- Wind Farm Site

Vessel Density (Duration per Year)

- < 15 minutes
- 15 - 30 minutes
- 30 - 45 minutes
- 45 mins - 1 hour
- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week
- > 1 week

N
W E
S

NOTE: Not to be used for Navigation

Date	23 May 2024
Coordinate System	ETRS 1989 UTM Zone 32N
Projection	Transverse Mercator
Datum	ETRS 1989
Data Source	ESRI; NUTS; ENERGINET
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Created By	Lewis Castle
Reviewed By	Emma Langley
Approved By	Stephane Theurich

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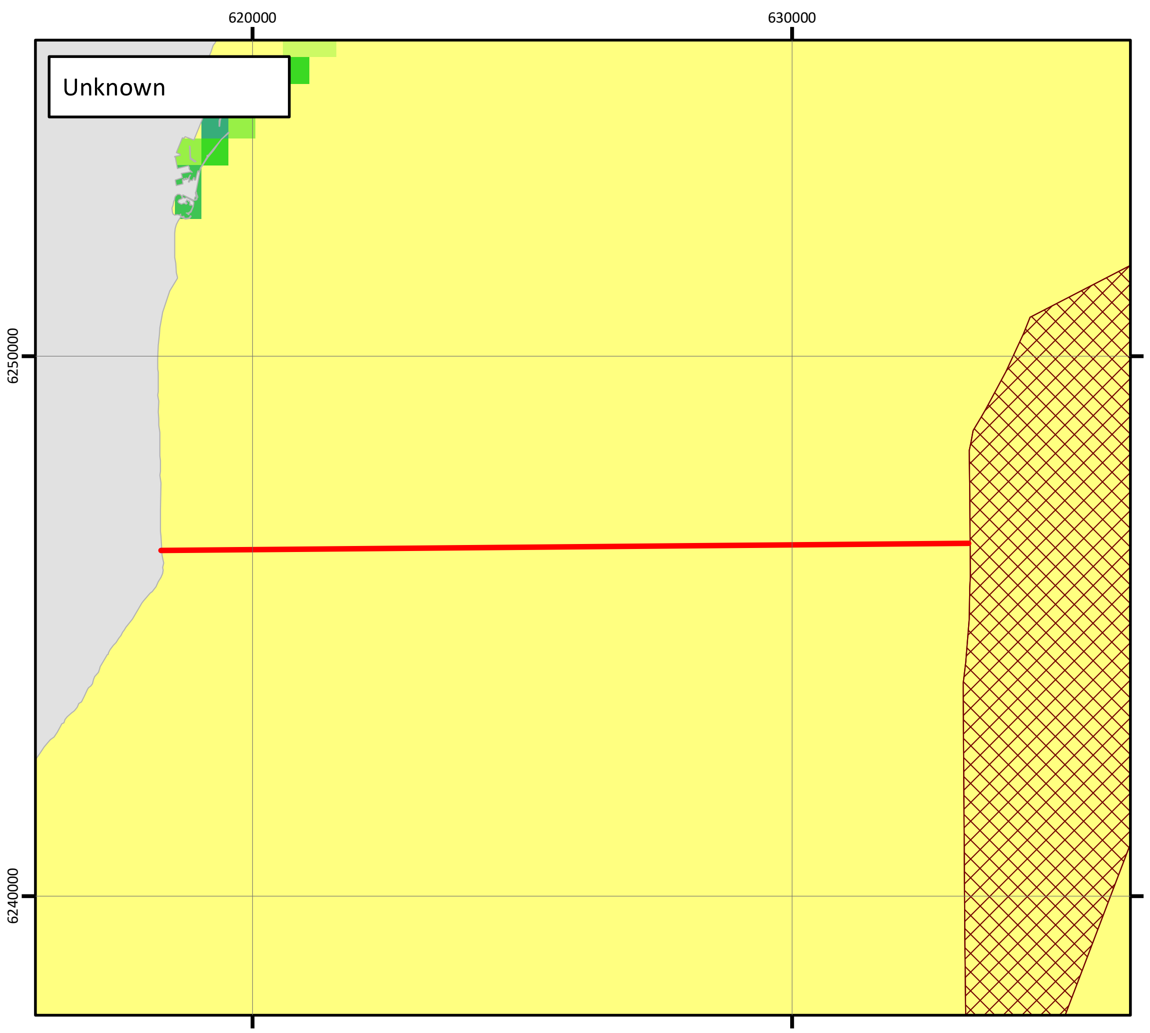
km
0 1 2 3 4



CABLE BURIAL RISK ASSESSMENT
KATTEGAT - GRENÅ SOUTH - CBRA

AUTOMATIC IDENTIFICATION SYSTEM (AIS)
Annual Vessel Density by Type - Sheet 4 of 4

Drawing No: P2719E-AIS-006	A

Legend

- Cable Route
- Wind Farm Site

Vessel Density (Duration per Year)

- < 15 minutes
- 15 - 30 minutes
- 30 - 45 minutes
- 45 mins - 1 hour
- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week
- > 1 week

N W E S

NOTE: Not to be used for Navigation

Date	23 May 2024
Coordinate System	ETRS 1989 UTM Zone 32N
Projection	Transverse Mercator
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Data Source	ESRI; NUTS; ENERGINET
File Reference	J:\P2719\Mxd_QGZ\P2719E\02_AIS\ P2719E-AIS-006.mxd
Created By	Lewis Castle
Reviewed By	Emma Langley
Approved By	Stephane Theurich

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km 0 1 2 3 4

APPENDIX D

Vessel Density

Table D-1 Vessel Density

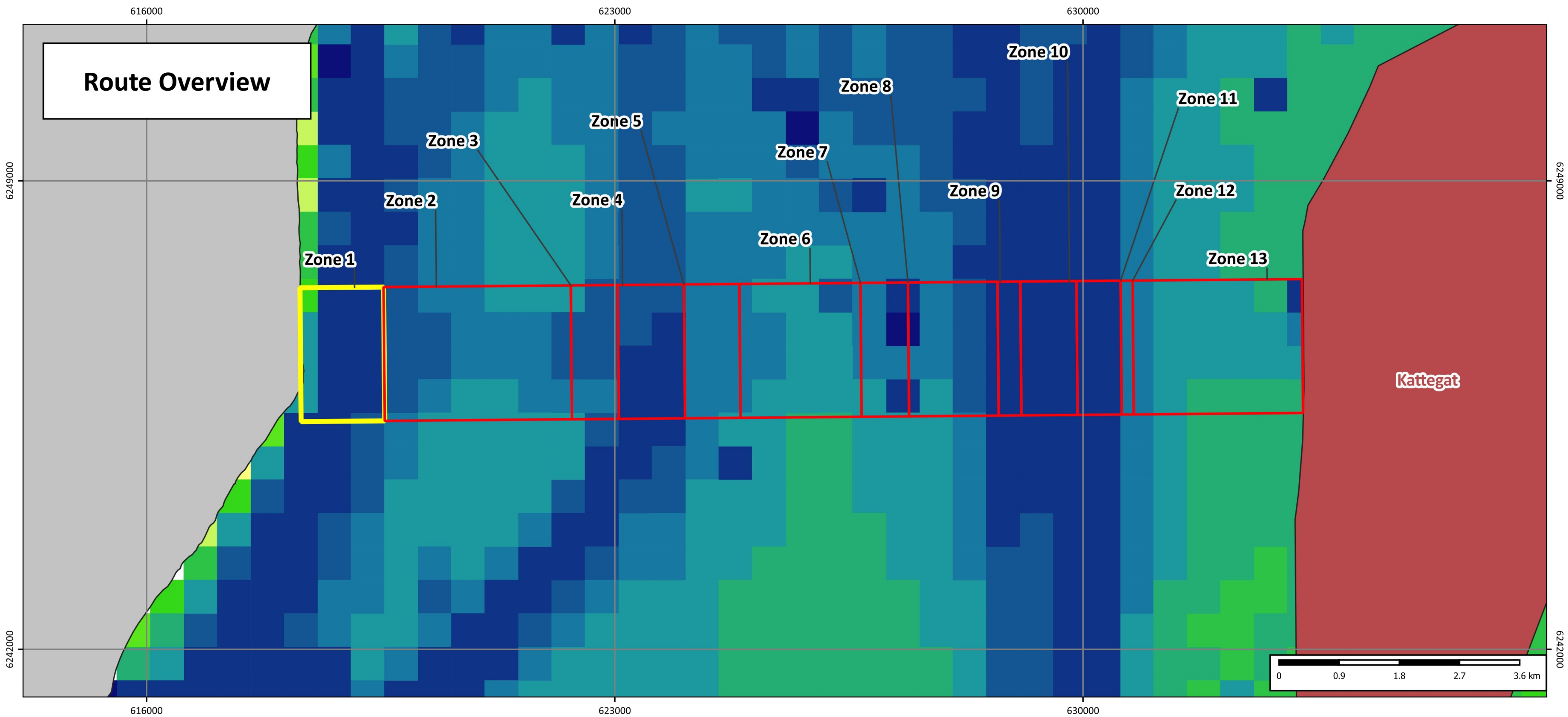
Zone identification	KP Range		Water Depth Range (m)			K - Sample box vessel densities								
						Band A	Band B	Band C	Band D	Band E	Band F	Band G	Band H	Band I
	From	To	Max	Min	Mean	[hr/km2/yr]	[hr/km2/yr]	[hr/km2/yr]	[hr/km2/yr]	[hr/km2/yr]	[hr/km2/yr]	[hr/km2/yr]	[hr/km2/yr]	[hr/km2/yr]
1	0.000	1.250	8.670	1.600	6.381	375.02	2.28	6.82	0.78	0.08	0.00	0.00	0.00	0.00
2	1.250	4.050	13.910	4.580	8.767	320.20	31.97	6.73	3.67	0.28	0.00	0.00	0.00	0.00
3	4.050	4.750	16.220	8.060	12.742	69.83	31.68	7.92	3.78	0.10	0.00	0.00	0.00	0.00
4	4.750	5.740	17.550	12.960	15.765	58.53	49.08	49.75	50.20	3.70	0.05	0.00	0.00	0.00
5	5.740	6.570	19.250	16.200	17.941	35.93	18.77	20.60	37.32	3.10	0.90	0.33	0.00	0.00
6	6.570	8.380	20.550	17.640	19.467	76.28	26.42	26.87	36.18	4.25	2.78	1.23	0.27	0.02
7	8.380	9.090	20.250	18.190	19.712	30.72	10.32	102.82	59.25	1.80	3.28	0.98	0.82	1.15
8	9.090	10.430	21.330	18.520	20.336	67.15	20.28	18.20	52.23	5.78	17.70	8.15	11.17	4.12
9	10.430	10.770	20.910	19.000	20.154	19.03	7.43	9.62	20.98	2.52	10.37	4.33	8.35	2.22
10	10.770	11.610	20.560	18.430	19.807	48.20	13.08	9.35	19.37	5.12	40.27	18.57	30.73	7.78
11	11.610	12.270	20.770	18.610	19.937	26.80	13.45	18.68	40.40	5.38	29.78	15.00	20.37	5.87
12	12.270	12.450	20.910	18.590	20.261	4.90	3.25	3.55	5.88	1.50	2.55	2.03	2.97	0.57
13	12.450	15.000	21.230	18.210	20.552	43.38	38.47	19.05	17.53	2.28	11.17	11.87	30.33	5.72

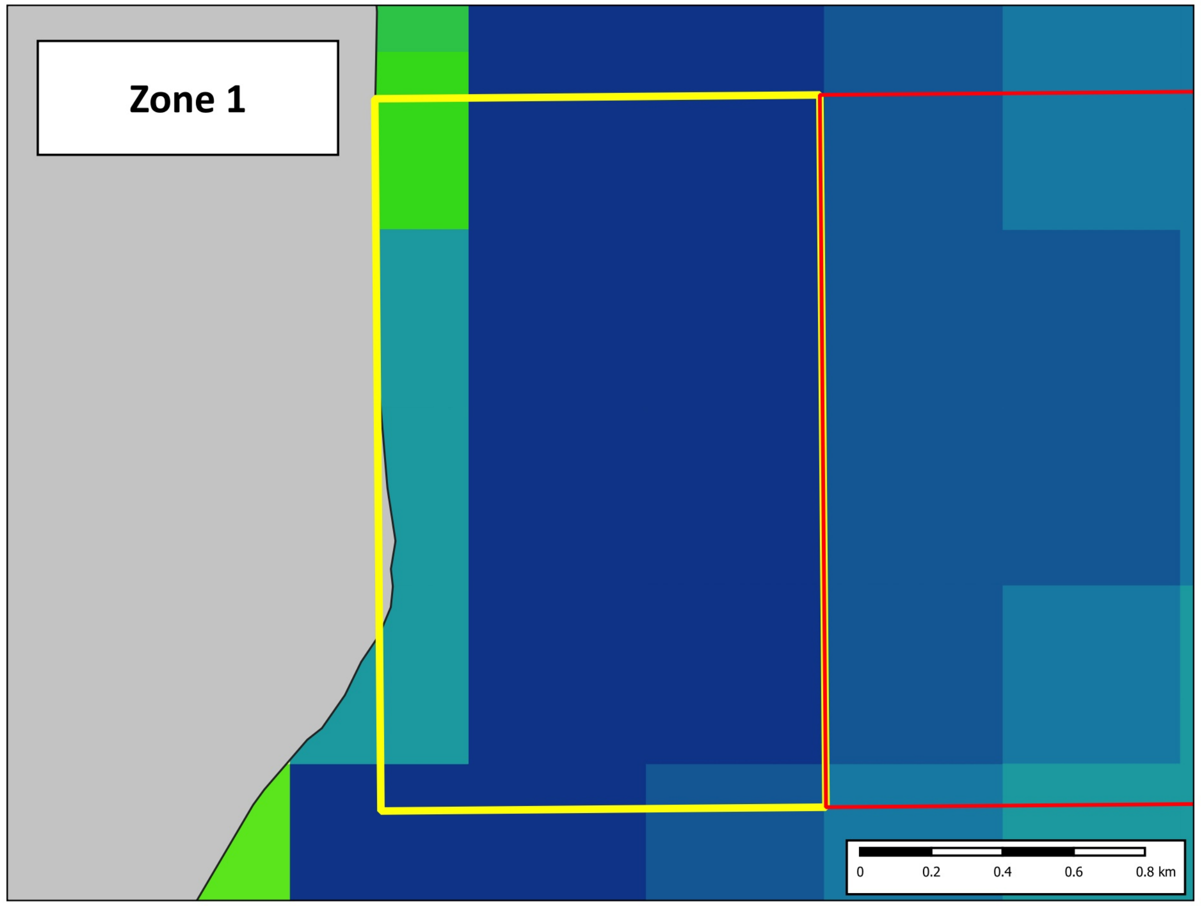
CABLE BURIAL RISK ASSESSMENT KATTEGAT - GRENÅ SOUTH - CBRA

CABLE BURIAL RISK ASSESSMENT

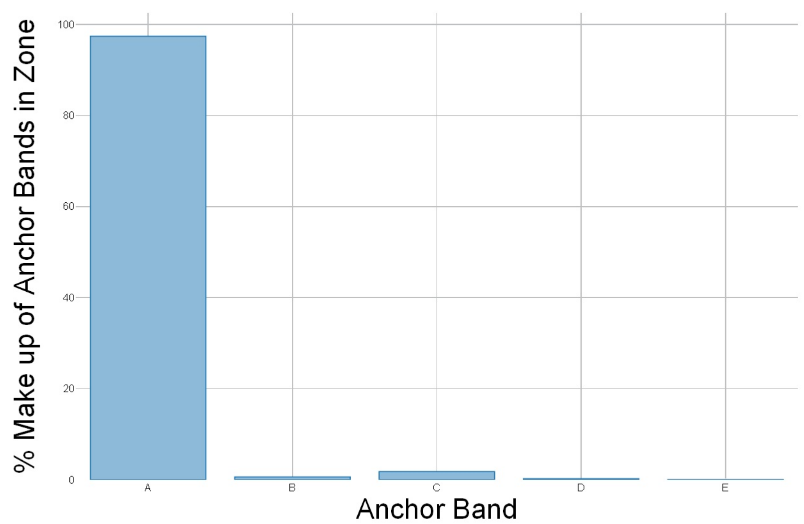
Anchor Band Statistics - Zone 1

Drawing No: P2719E-CBRA-001_1	A





Anchor Band Statistics by Zone - Zone 1



Legend

N

CBRA Zone

- Zone of Interest
- CBRA Zone

Vessel Density (Duration per year)

- < 15 mins
- 15 - 30 mins
- 30 - 45 mins
- 45 mins - 1 hour
- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week
- > 1 week

Legend - Inset

Vessel Density (Duration per year)

- < 15 mins
- 45 mins - 1 hour
- 1 - 2 hours
- 2 - 6 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week

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Scale @A3	1:75,000
Data Sources	NUTS; ENERGINET
File Reference	J:\P2719\Mxd_QGZ\P2719E\04_CBRA \P2719E_CBRA.qgz
Created By	Lewis Castle
Reviewed By	Emma Langley
Approved By	Stephane Theurich

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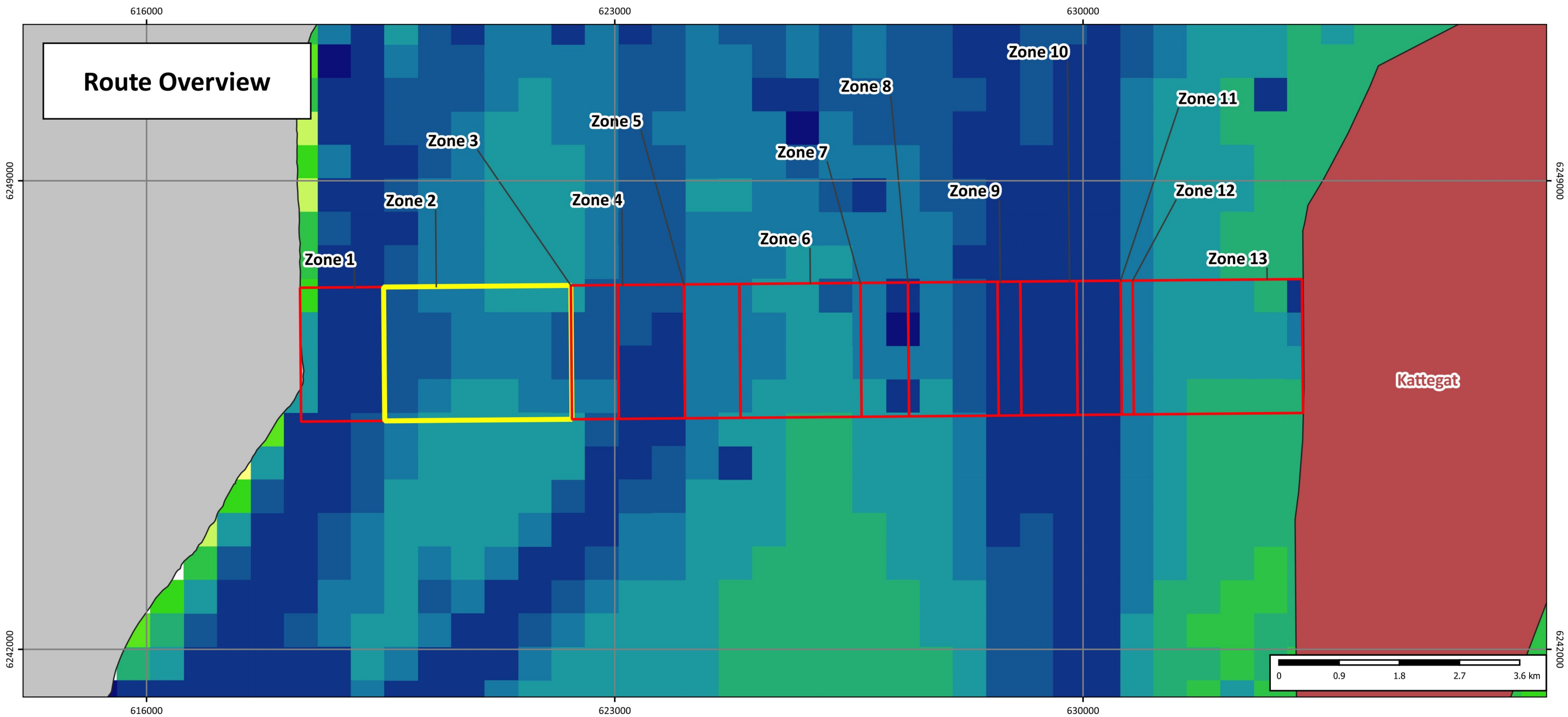
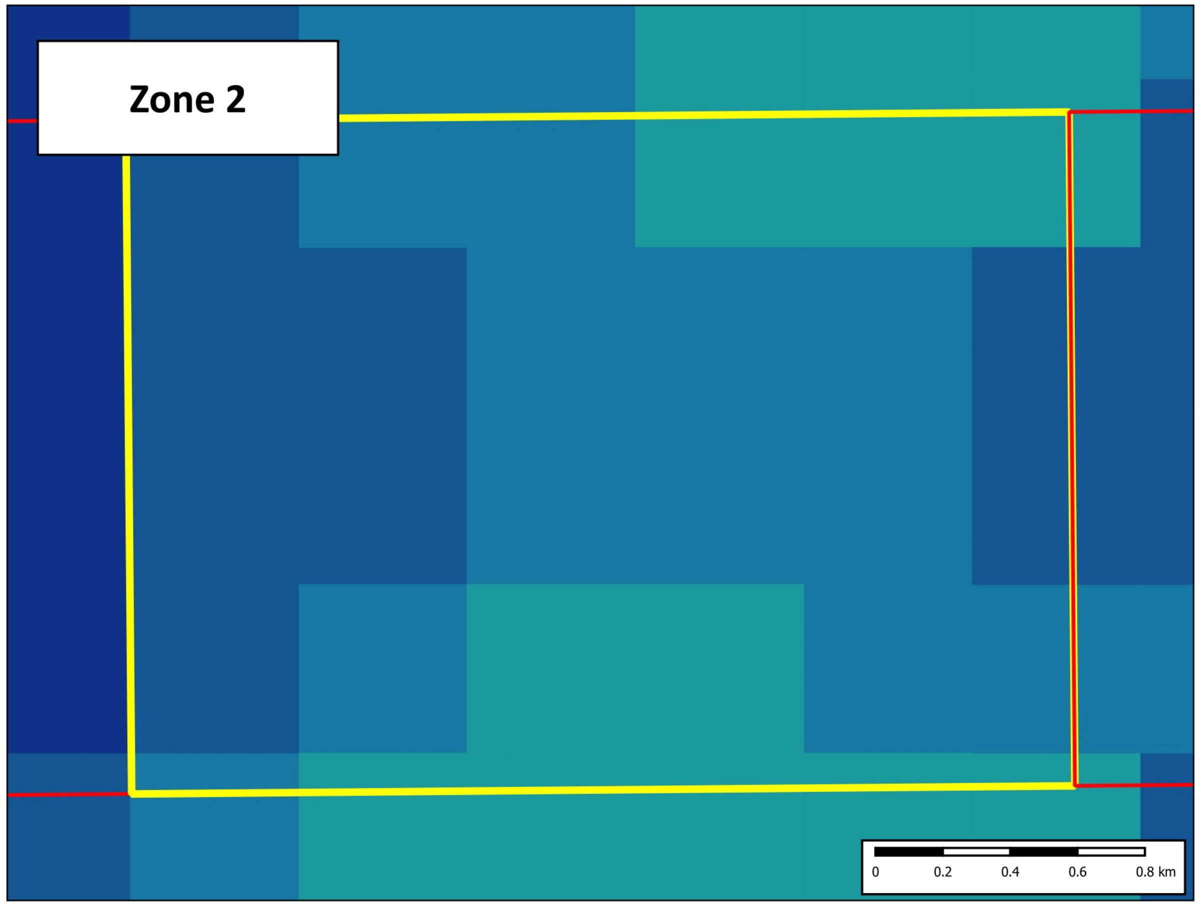
CABLE BURIAL RISK ASSESSMENT KATTEGAT - GRENÅ SOUTH - CBRA

CABLE BURIAL RISK ASSESSMENT

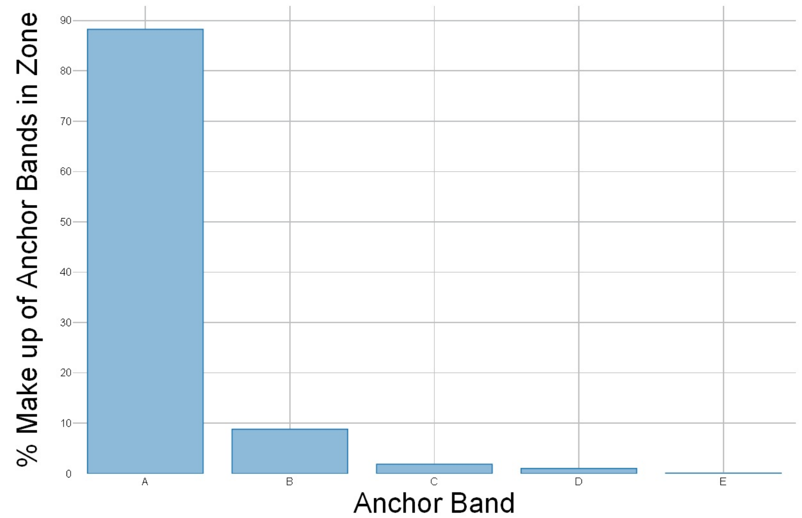
Anchor Band Statistics - Zone 2

Drawing No: P2719E-CBRA-001_2 | A





Anchor Band Statistics by Zone - Zone 2



Legend

CBRA Zone

- Zone of Interest
- CBRA Zone

Vessel Density (Duration per year)

- < 15 mins
- 15 - 30 mins
- 30 - 45 mins
- 45 mins - 1 hour
- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week
- > 1 week

N

Legend - Inset

Vessel Density (Duration per year)

- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week

Date	2024-05-24 13:17:03
Coordinate System	ETRS89 / UTM zone 32N
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Data Sources	NUTS; ENERGINET
File Reference	J:\P2719\Mxd_QGZ\P2719E\04_CBRA \P2719E_CBRA.qgz
Created By	Lewis Castle
Reviewed By	Emma Langley
Approved By	Stephane Theurich

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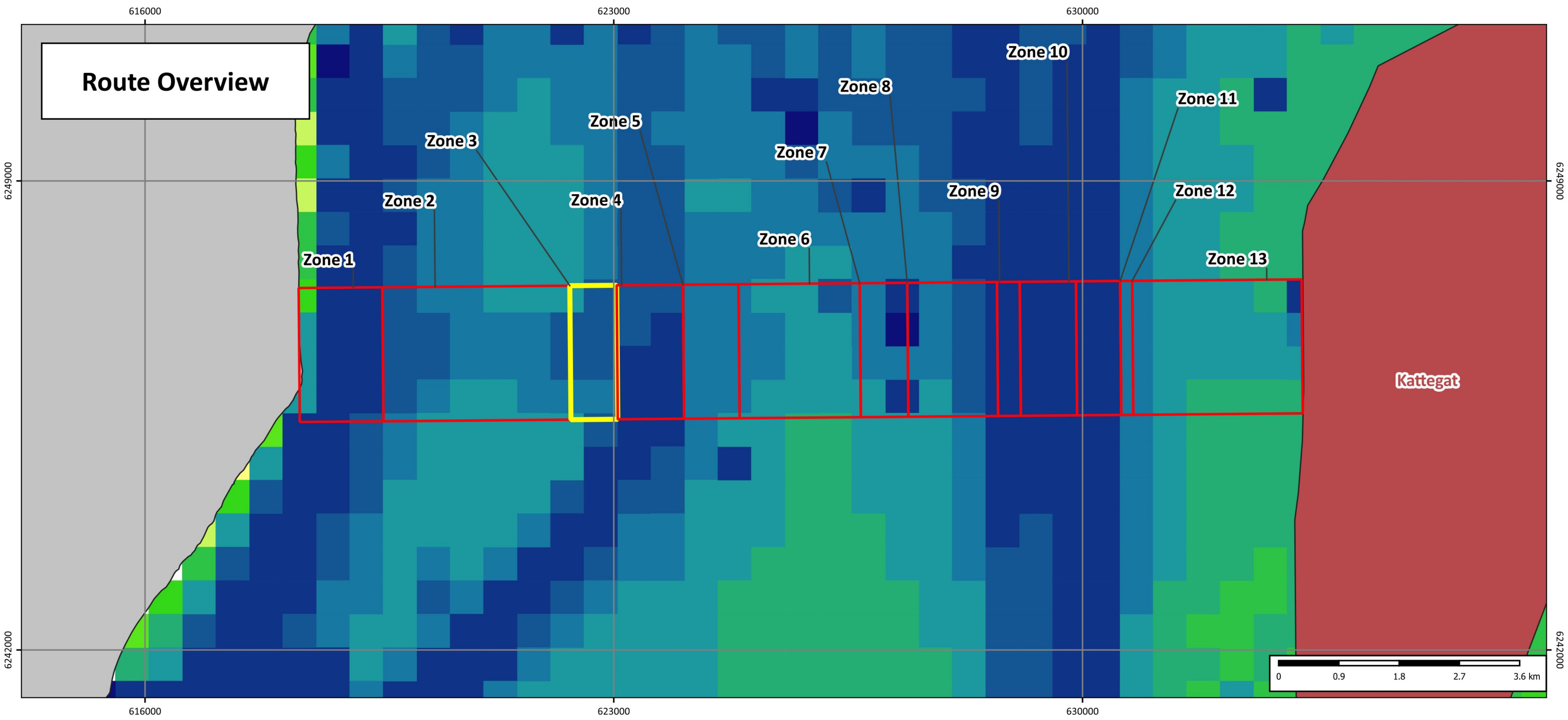
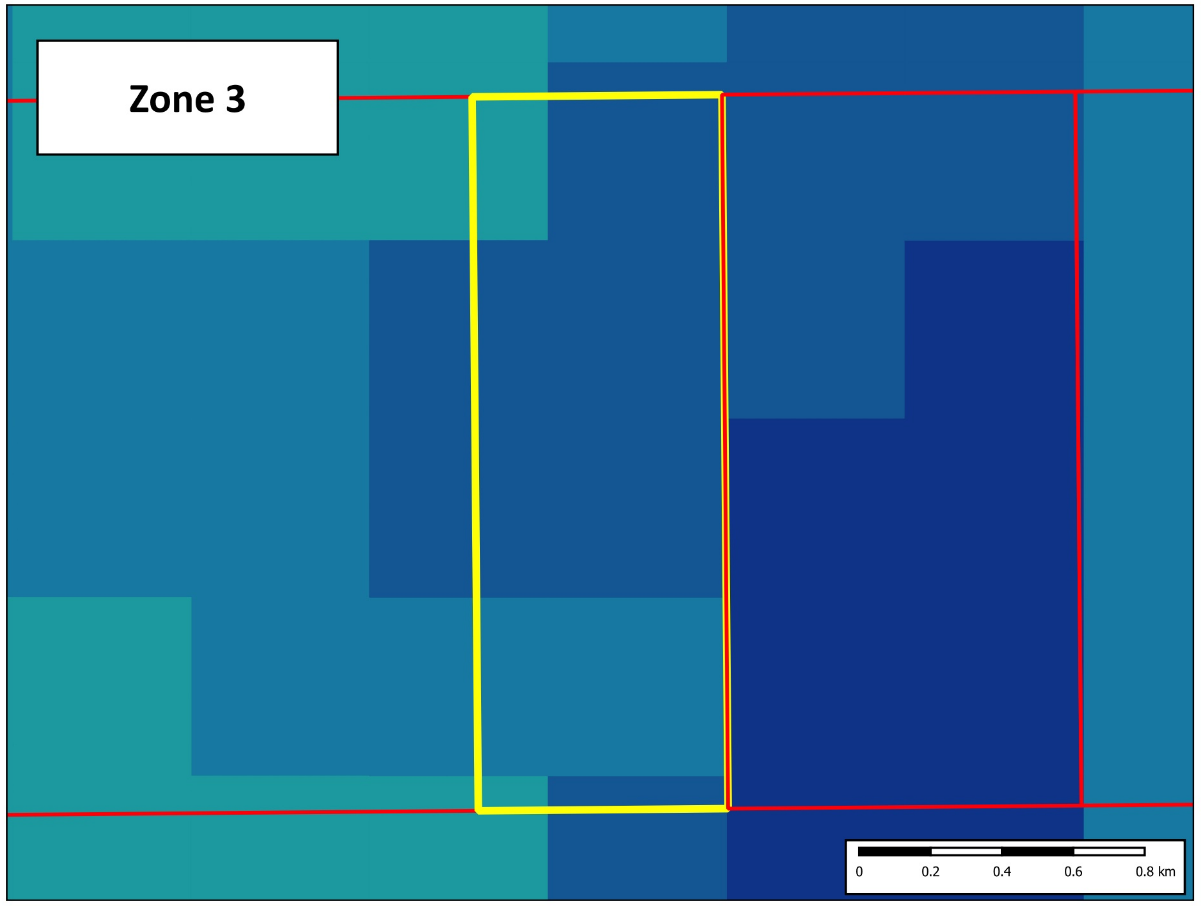
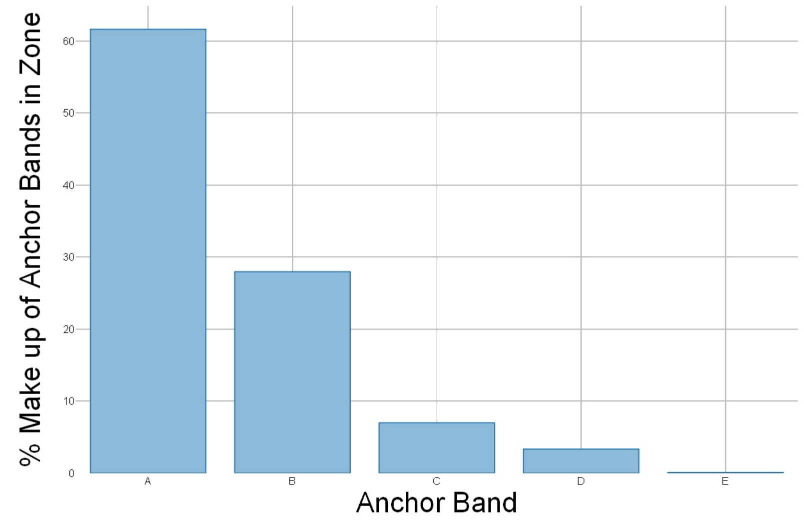




Anchor Band Statistics by Zone - Zone 3



CABLE BURIAL RISK ASSESSMENT KATTEGAT - GRENÅ SOUTH - CBRA

CABLE BURIAL RISK ASSESSMENT

Anchor Band Statistics - Zone 3

Drawing No: P2719E-CBRA-001_3 | A

Legend

N

CBRA Zone

- Zone of Interest
- CBRA Zone

Vessel Density (Duration per year)

- < 15 mins
- 15 - 30 mins
- 30 - 45 mins
- 45 mins - 1 hour
- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week
- > 1 week

Legend - Inset

Vessel Density (Duration per year)

- 12 - 24 hours
- 36 - 48 hours
- 24 - 36 hours
- 48 hours - 1 week

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Created By	Lewis Castle
Reviewed By	Emma Langley
Approved By	Stephane Theurich

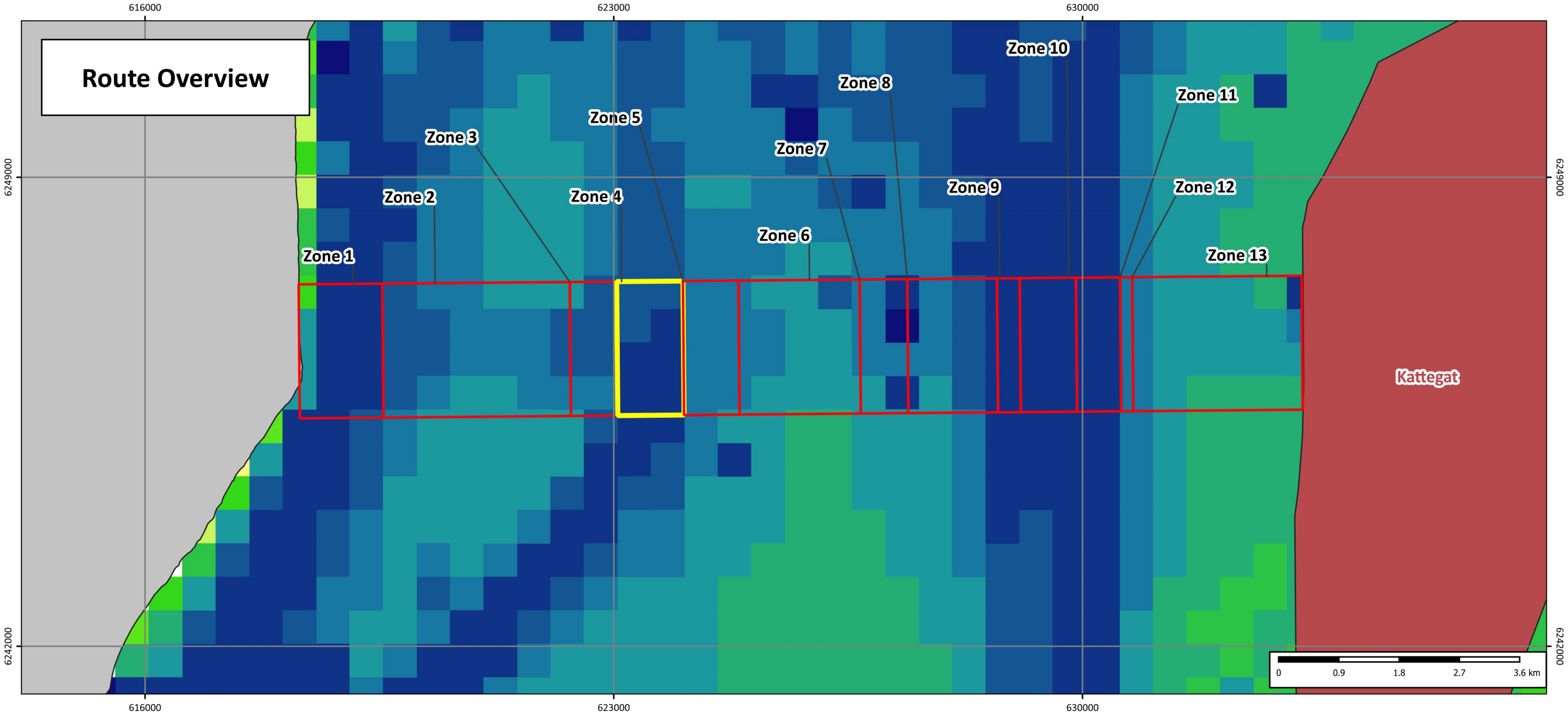
CABLE BURIAL RISK ASSESSMENT KATTEGAT - GRENÅ SOUTH - CBRA

CABLE BURIAL RISK ASSESSMENT

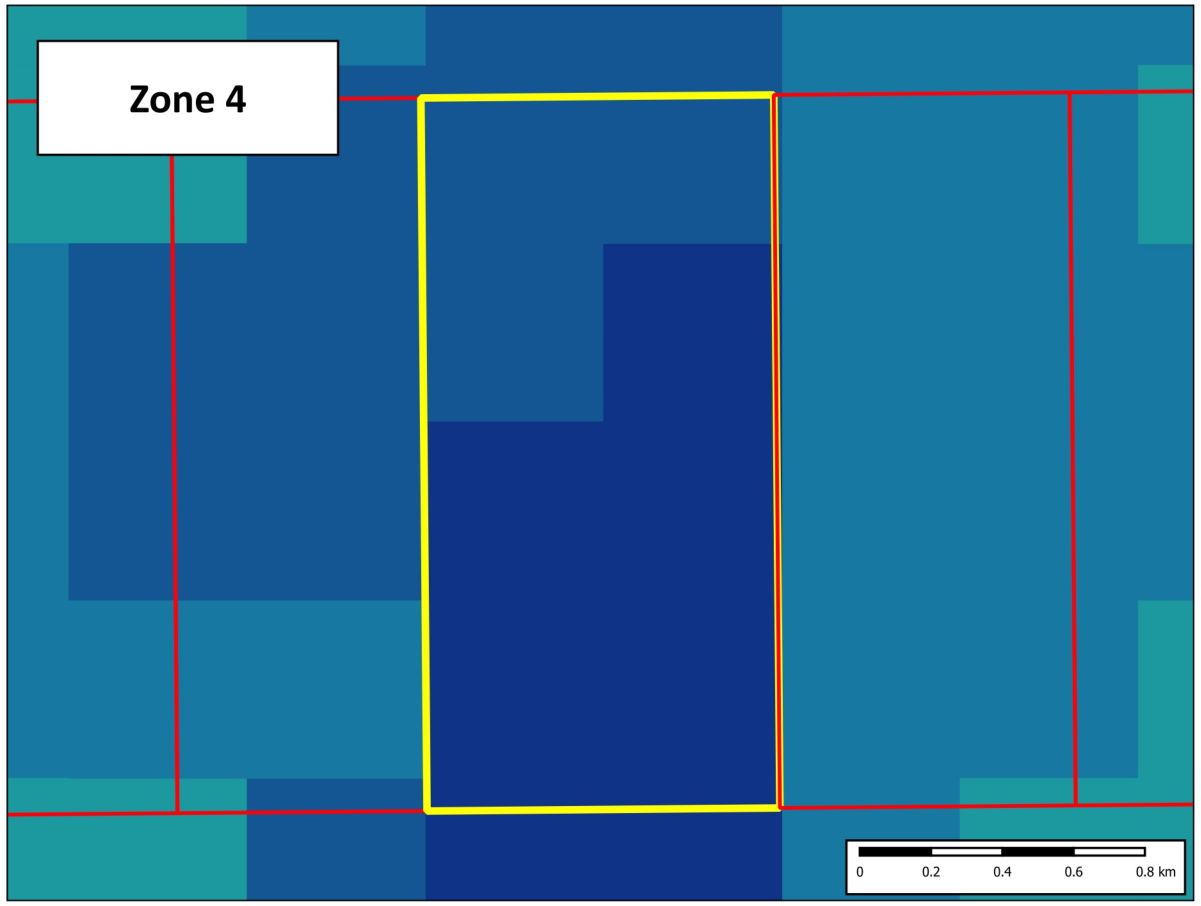
Anchor Band Statistics - Zone 4

Drawing No: P2719E-CBRA-001_4 | A

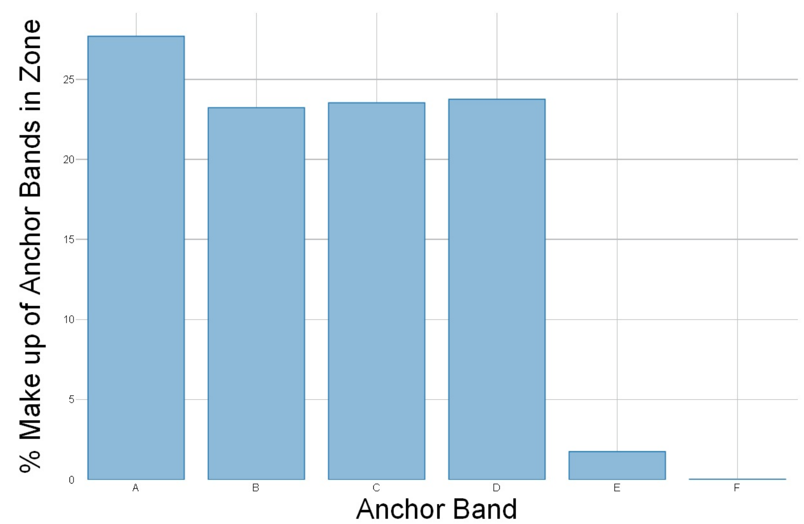
Route Overview



Zone 4



Anchor Band Statistics by Zone - Zone 4



Legend

N

CBRA Zone

- Zone of Interest
- CBRA Zone

Vessel Density (Duration per year)

- < 15 mins
- 15 - 30 mins
- 30 - 45 mins
- 45 mins - 1 hour
- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week
- > 1 week

Legend - Inset

Vessel Density (Duration per year)

- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week

Date	2024-05-24 13:19:38
Coordinate System	ETRS89 / UTM zone 32N
WKID	EPSG:25832
Scale @A3	1:75,000
Data Sources	NUTS; ENERGINET
File Reference	J:\P2719\Mxd_QGZ\P2719E\04_CBRA \P2719E_CBRA.qgz
Created By	Lewis Castle
Reviewed By	Emma Langley
Approved By	Stephane Theurich

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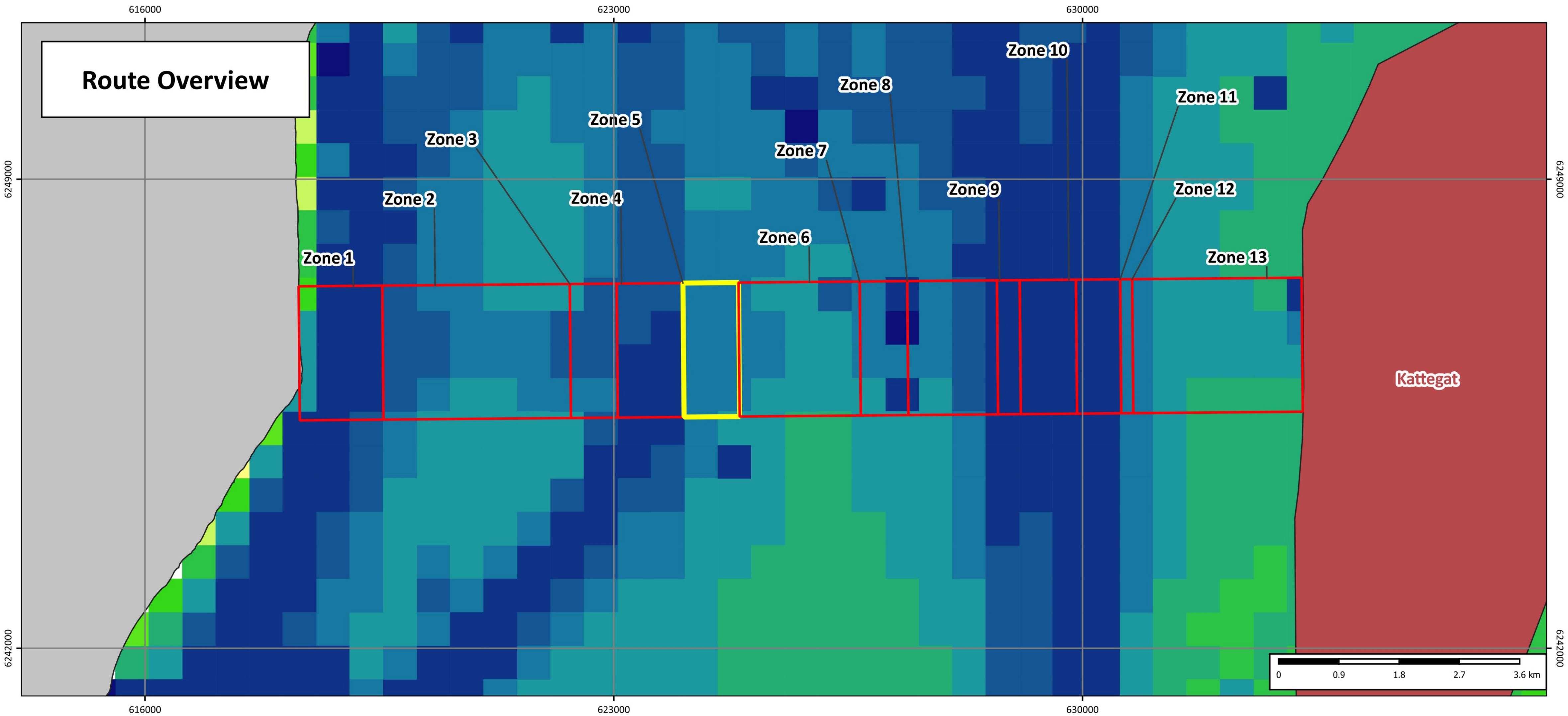
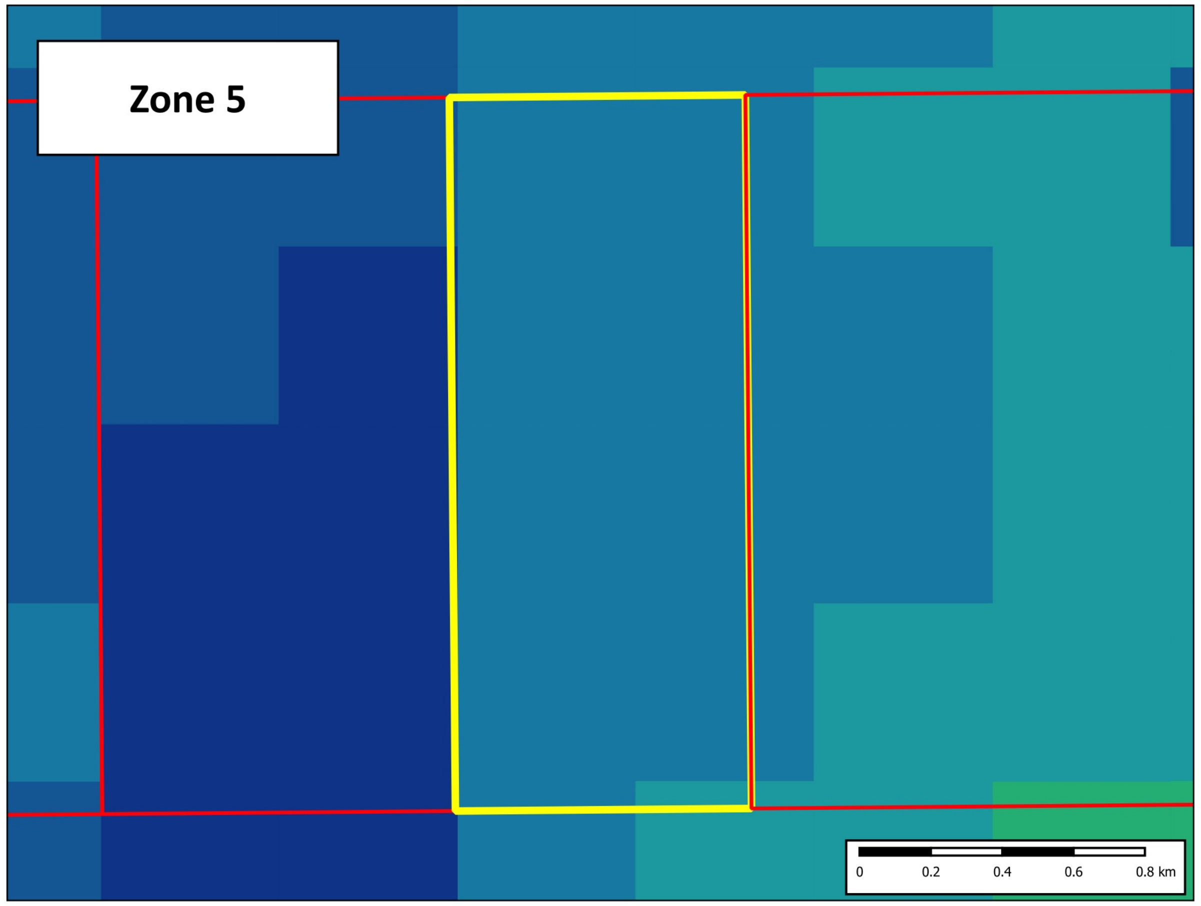
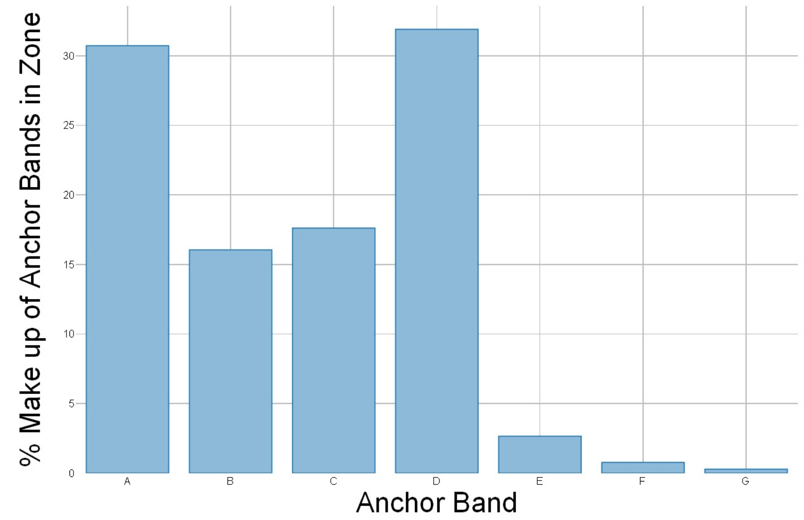




Anchor Band Statistics by Zone - Zone 5



CABLE BURIAL RISK ASSESSMENT KATTEGAT - GRENÅ SOUTH - CBRA

CABLE BURIAL RISK ASSESSMENT

Anchor Band Statistics - Zone 5

Drawing No: P2719E-CBRA-001_5 | A

Legend

N

CBRA Zone

- Zone of Interest
- CBRA Zone

Vessel Density (Duration per year)

- < 15 mins
- 15 - 30 mins
- 30 - 45 mins
- 45 mins - 1 hour
- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week
- > 1 week

Legend - Inset

Vessel Density (Duration per year)

- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week

Date	2024-05-24 13:21:00
Coordinate System	ETRS89 / UTM zone 32N
WKID	EPSG:25832
Scale @A3	1:75,000
Data Sources	NUTS; ENERGINET
File Reference	J:\P2719\Mxd_QGZ\P2719E\04_CBRA \P2719E_CBRA.qgz
Created By	Lewis Castle
Reviewed By	Emma Langley
Approved By	Stephane Theurich

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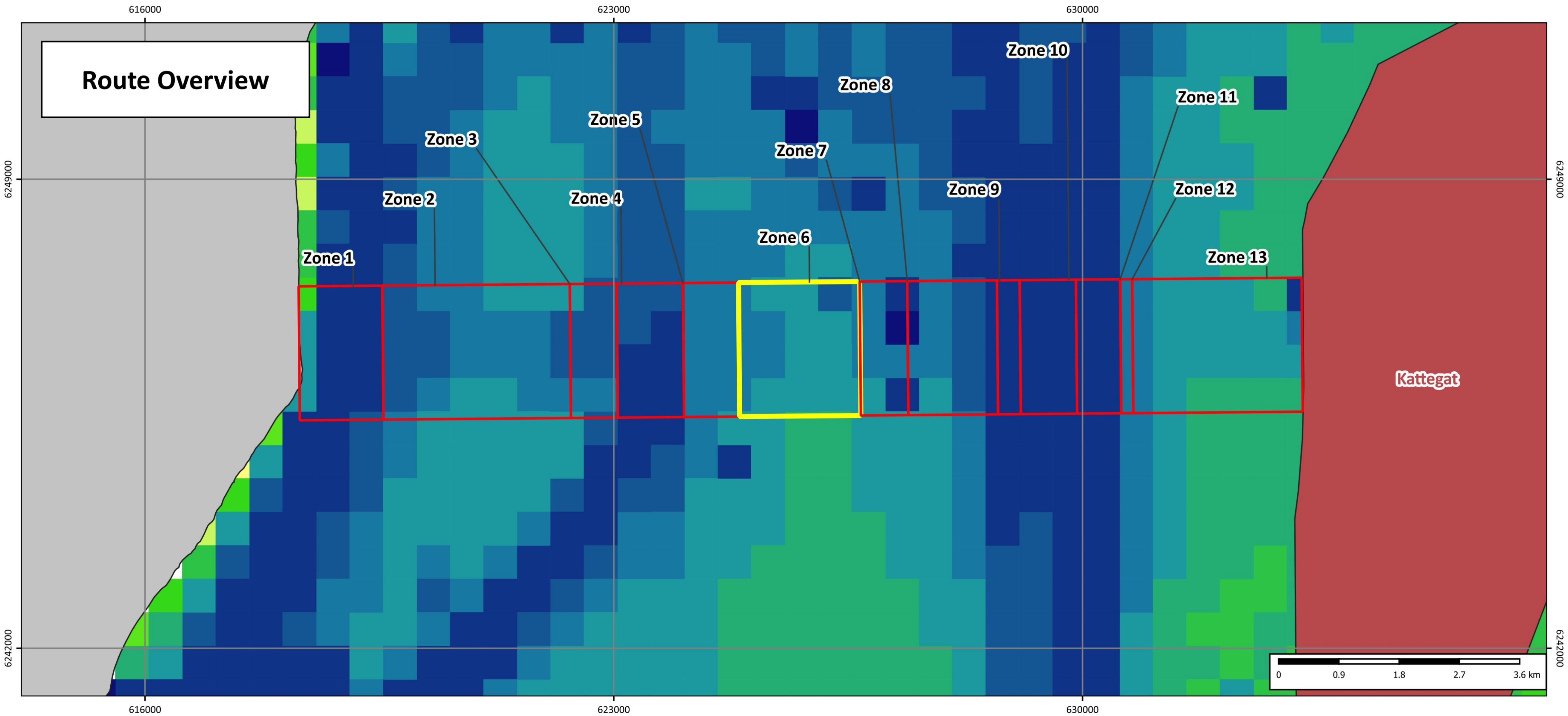
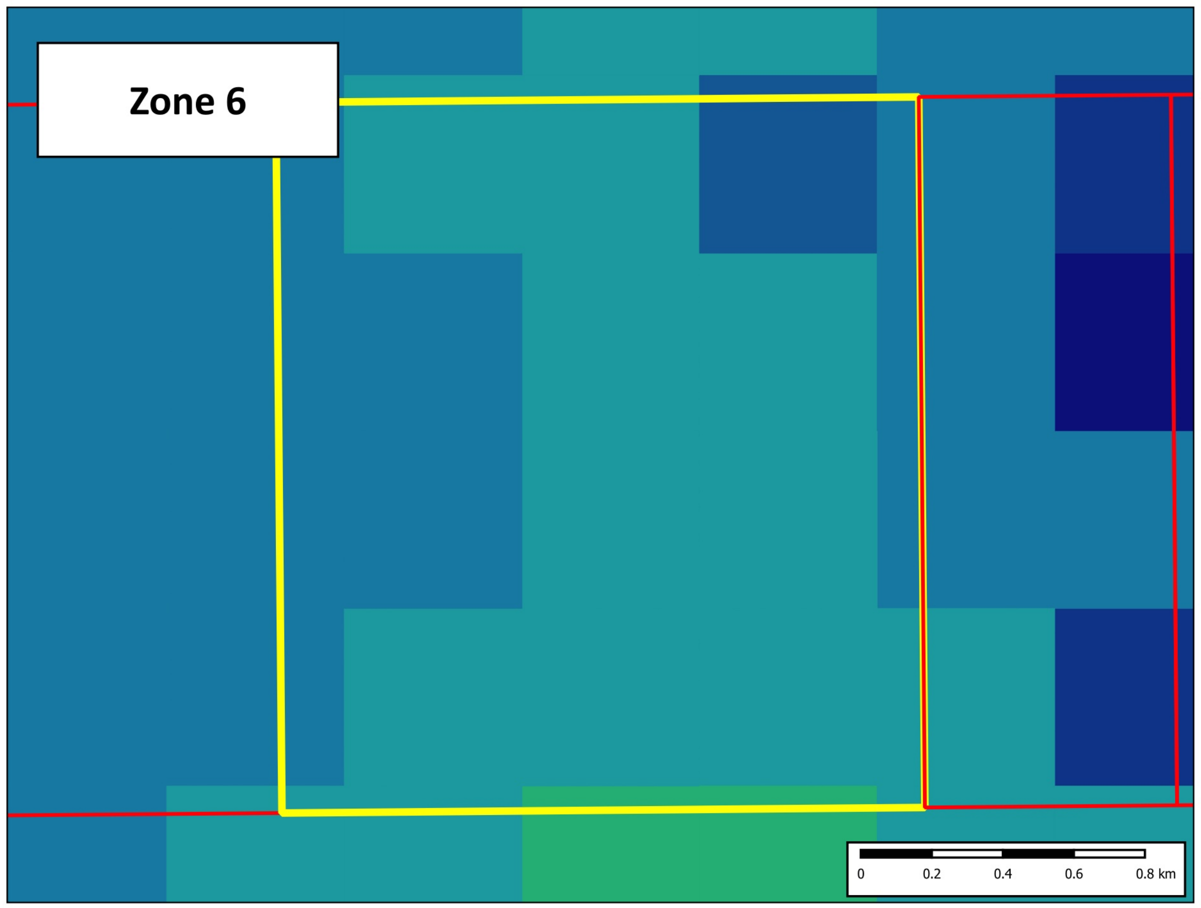
Anchor Band Statistics - Zone 6

Drawing No: P2719E-CBRA-001_6 | A

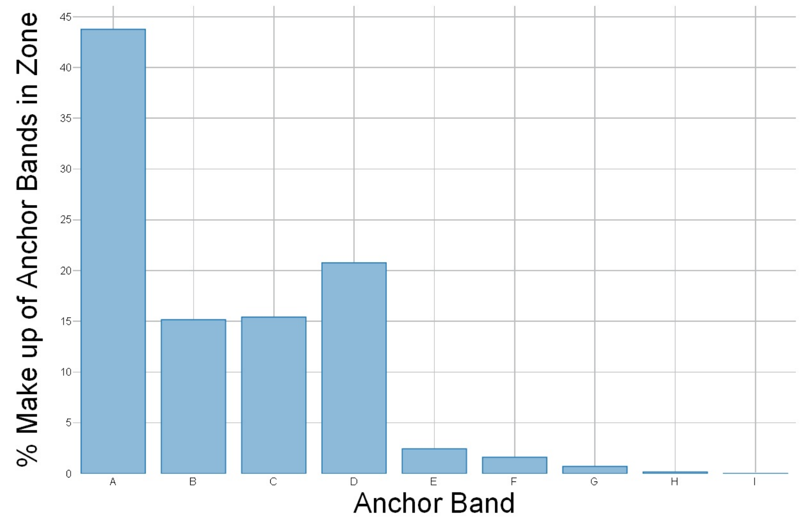
Route Overview



Zone 6



Anchor Band Statistics by Zone - Zone 6



Legend

N

CBRA Zone

- Zone of Interest
- CBRA Zone

Vessel Density (Duration per year)

- < 15 mins
- 15 - 30 mins
- 30 - 45 mins
- 45 mins - 1 hour
- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week
- > 1 week

Legend - Inset

Vessel Density (Duration per year)

- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week
- > 1 week

Date	2024-05-24 13:22:51
Coordinate System	ETRS89 / UTM zone 32N
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Data Sources	NUTS; ENERGINET
File Reference	J:\P2719\Mxd_QGZ\P2719E\04_CBRA \P2719E_CBRA.qgz
Created By	Lewis Castle
Reviewed By	Emma Langley
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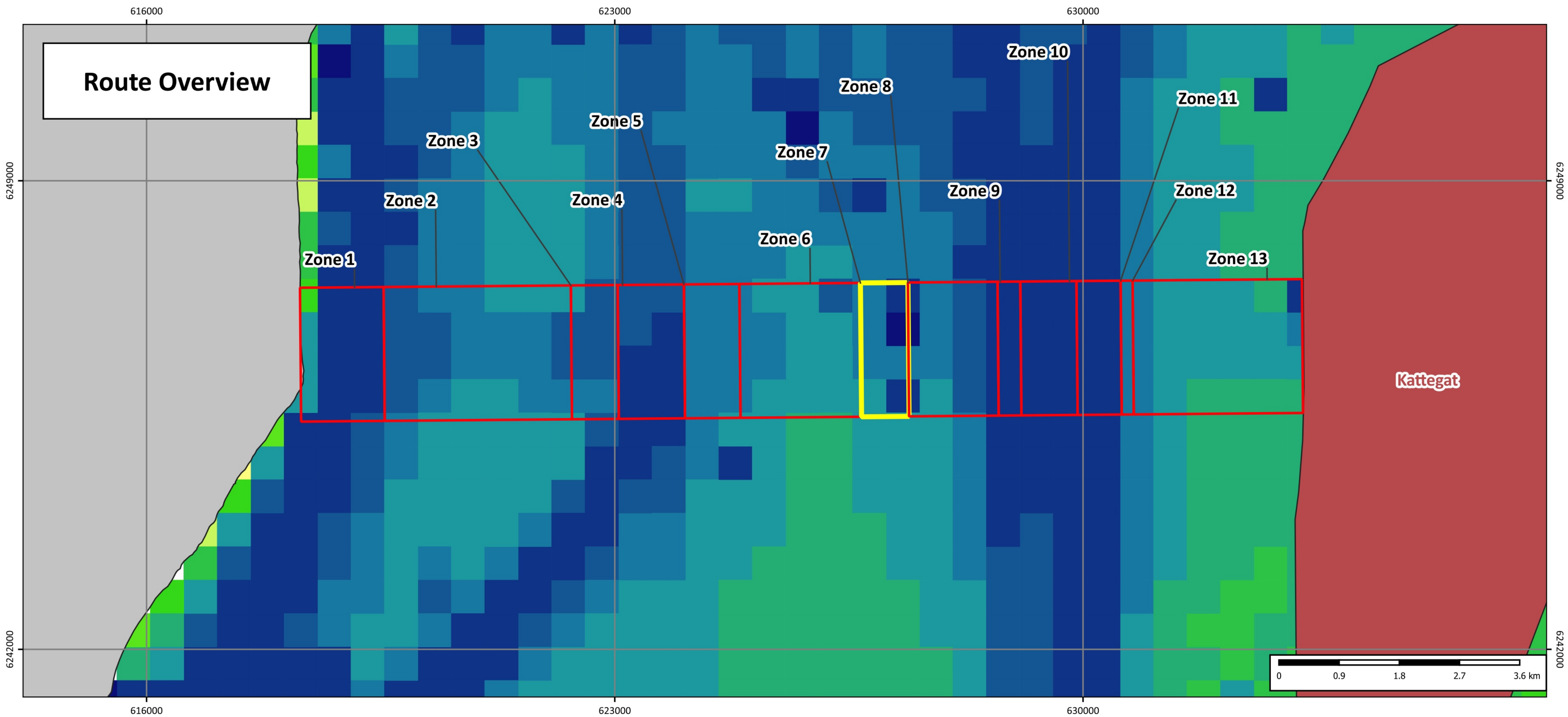
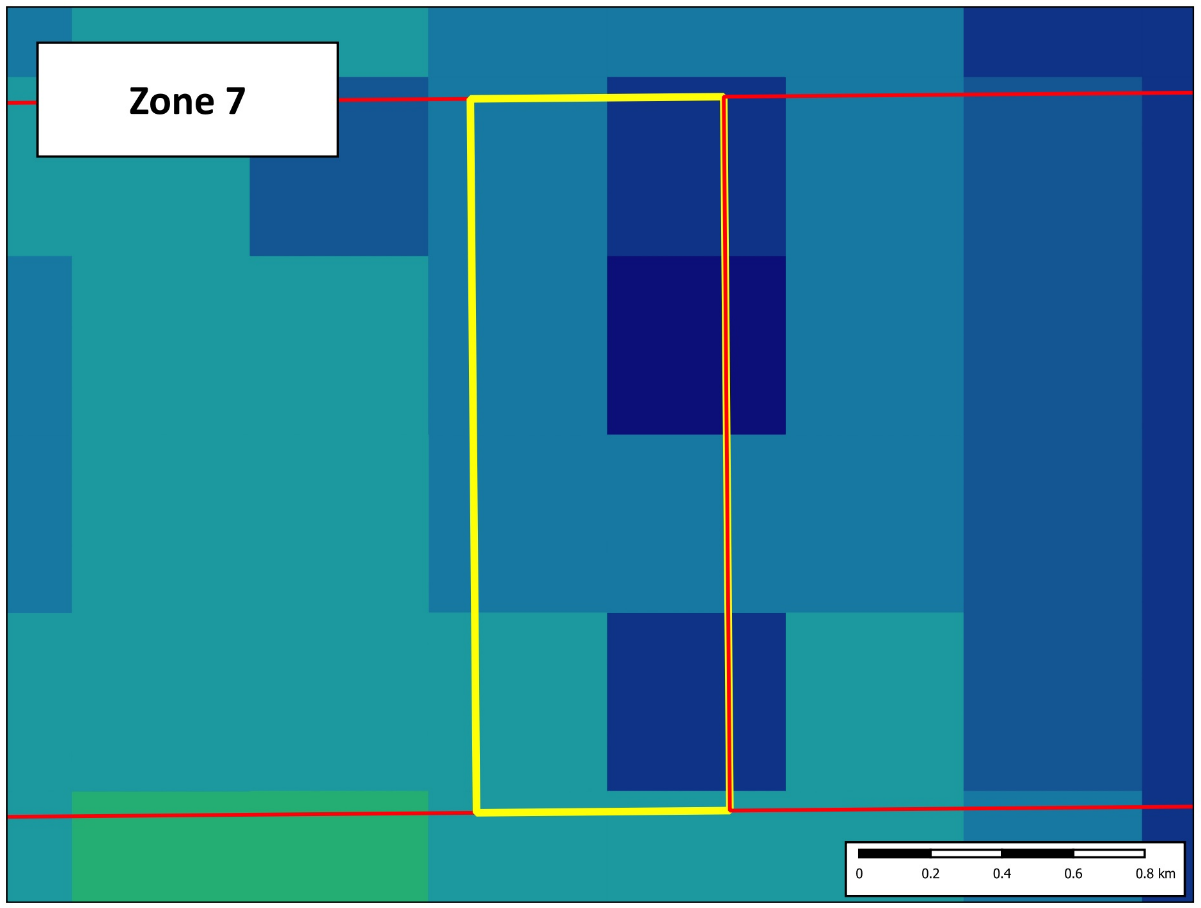
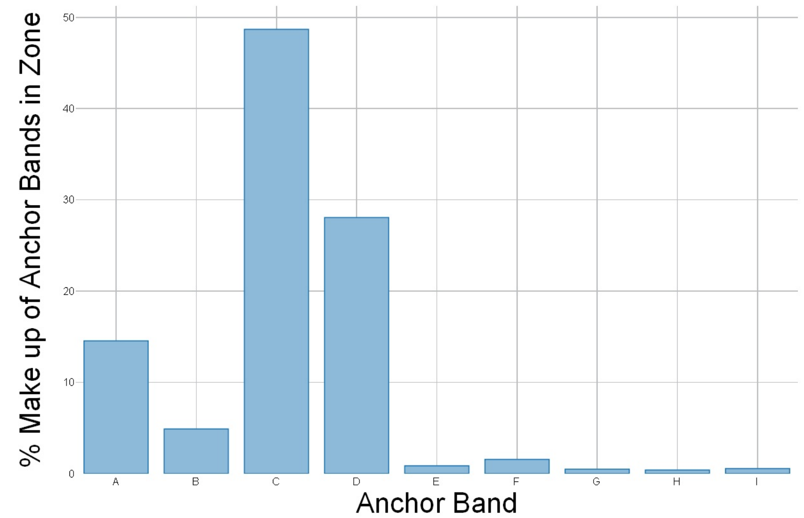
Anchor Band Statistics - Zone 7

Drawing No: P2719E-CBRA-001_7	A





Anchor Band Statistics by Zone - Zone 7



Legend

CBRA Zone

- Zone of Interest
- CBRA Zone

Vessel Density (Duration per year)

- < 15 mins
- 15 - 30 mins
- 30 - 45 mins
- 45 mins - 1 hour
- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week
- > 1 week

N

Legend - Inset

Vessel Density (Duration per year)

- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week
- > 1 week

Date	2024-05-24 13:24:37
Coordinate System	ETRS89 / UTM zone 32N
WKID	EPSG:25832
Scale @A3	1:75,000
Data Sources	NUTS; ENERGINET
File Reference	J:\P2719\Mxd_QGZ\P2719E\04_CBRA \P2719E_CBRA.qgz
Created By	Lewis Castle
Reviewed By	Emma Langley
Approved By	Stephane Theurich

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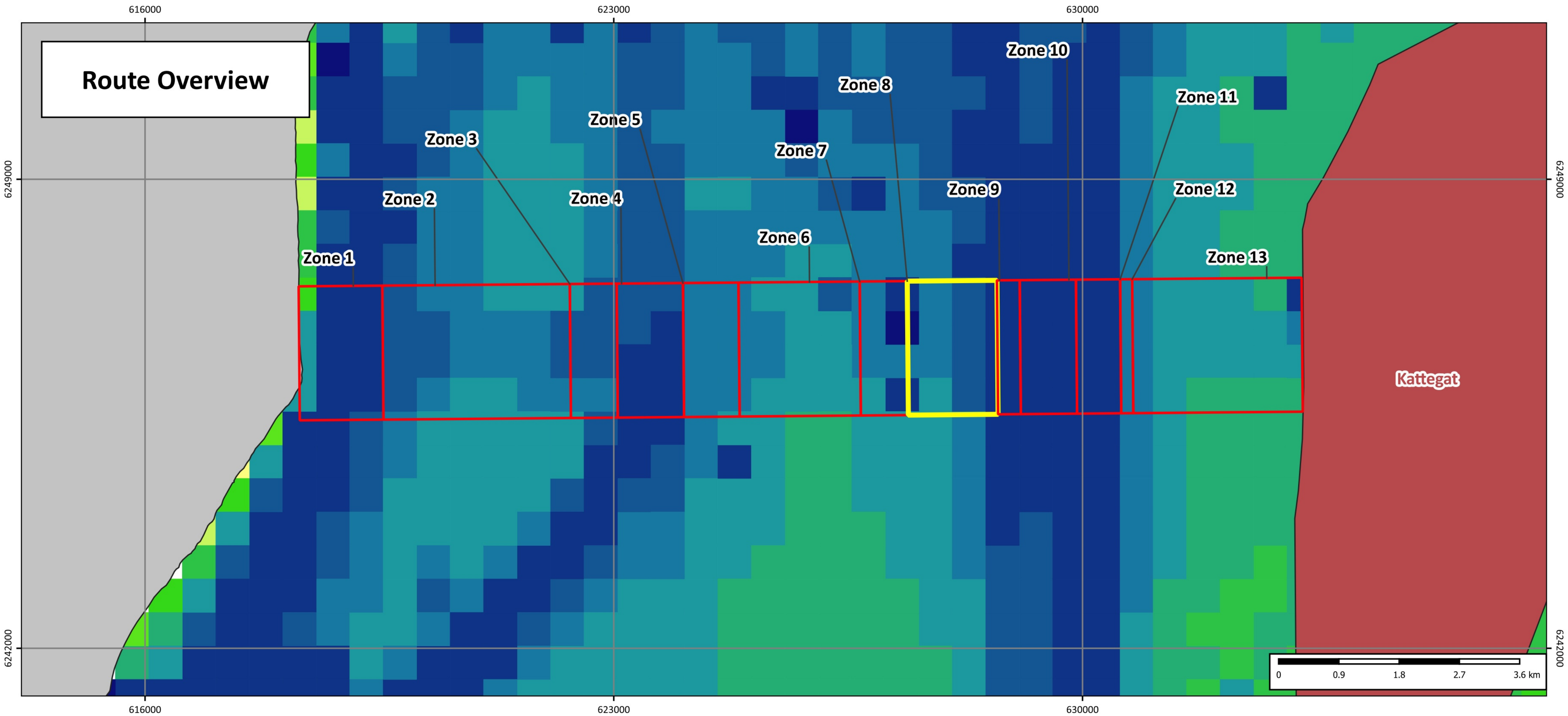
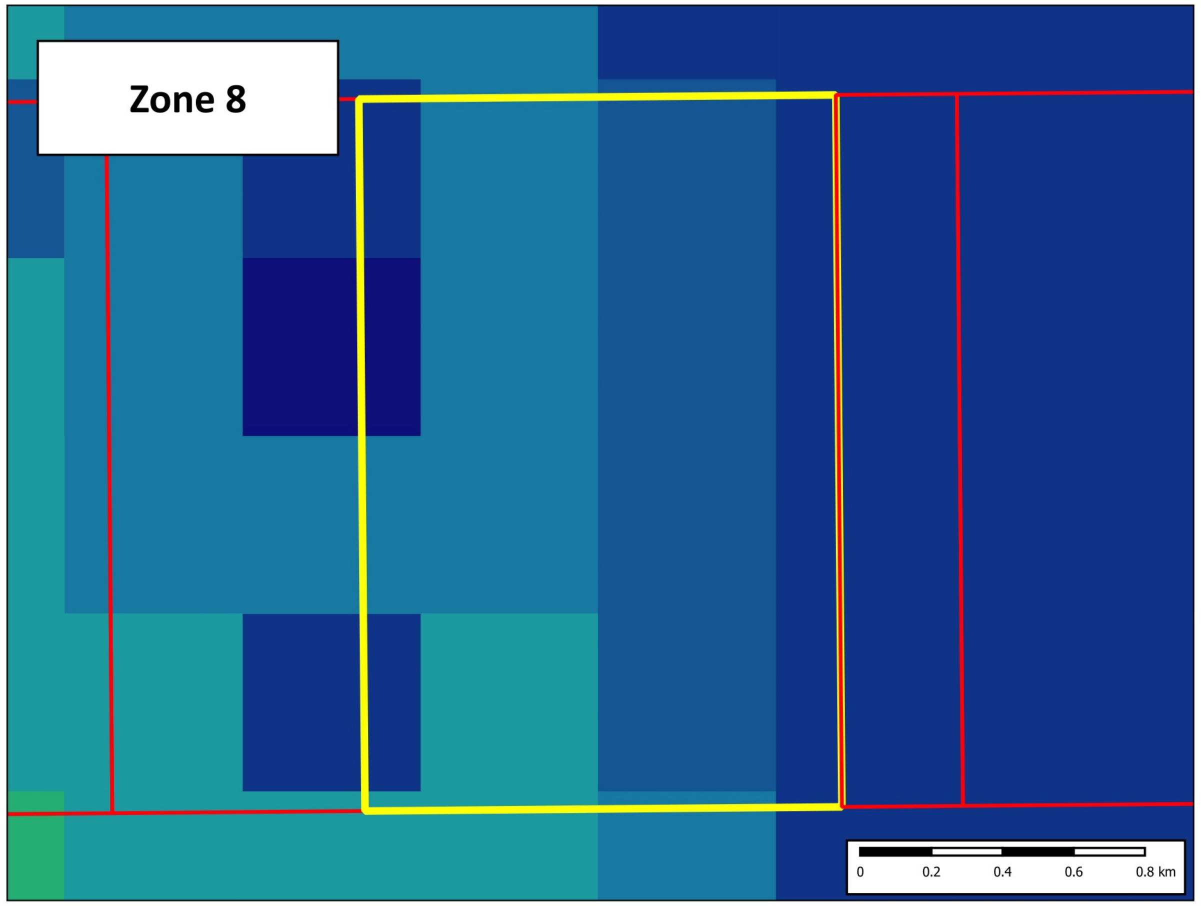
CABLE BURIAL RISK ASSESSMENT

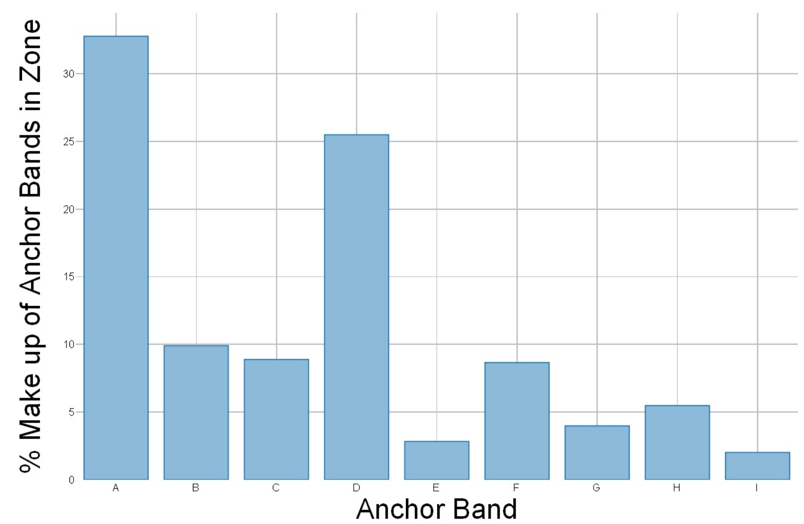
Anchor Band Statistics - Zone 8

Drawing No: P2719E-CBRA-001_8	A





Anchor Band Statistics by Zone - Zone 8



Legend

N

CBRA Zone

- Zone of Interest
- CBRA Zone

Vessel Density (Duration per year)

- < 15 mins
- 15 - 30 mins
- 30 - 45 mins
- 45 mins - 1 hour
- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week
- \> 1 week

Legend - Inset

Vessel Density (Duration per year)

- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week
- \> 1 week

Date	2024-05-24 13:27:31
Coordinate System	ETRS89 / UTM zone 32N
WKID	EPSG:25832
Scale @A3	1:75,000
Data Sources	NUTS; ENERGINET
File Reference	J:\P2719\Mxd_QGZ\P2719E\04_CBRA\P2719E_CBRA.qgz
Created By	Lewis Castle
Reviewed By	Emma Langley
Approved By	Stephane Theurich

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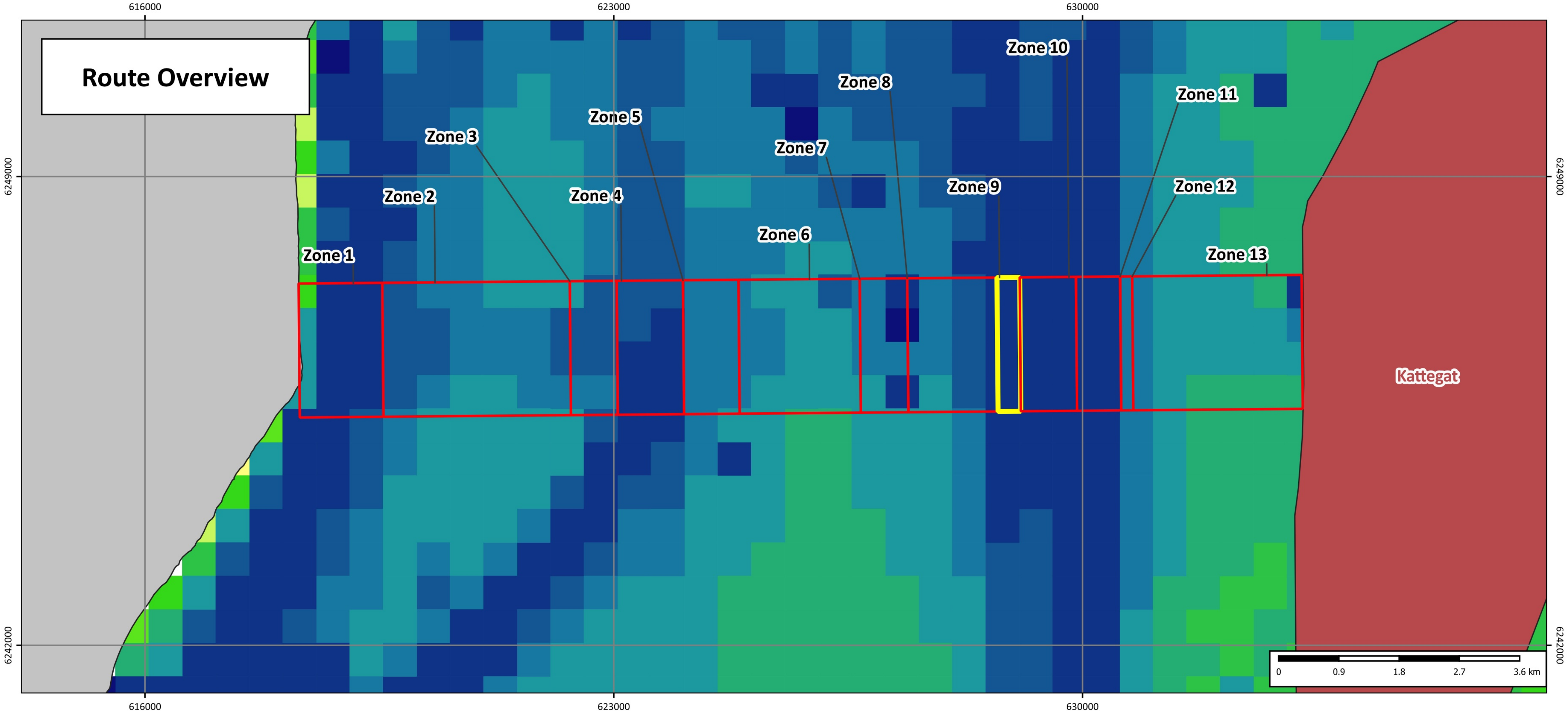
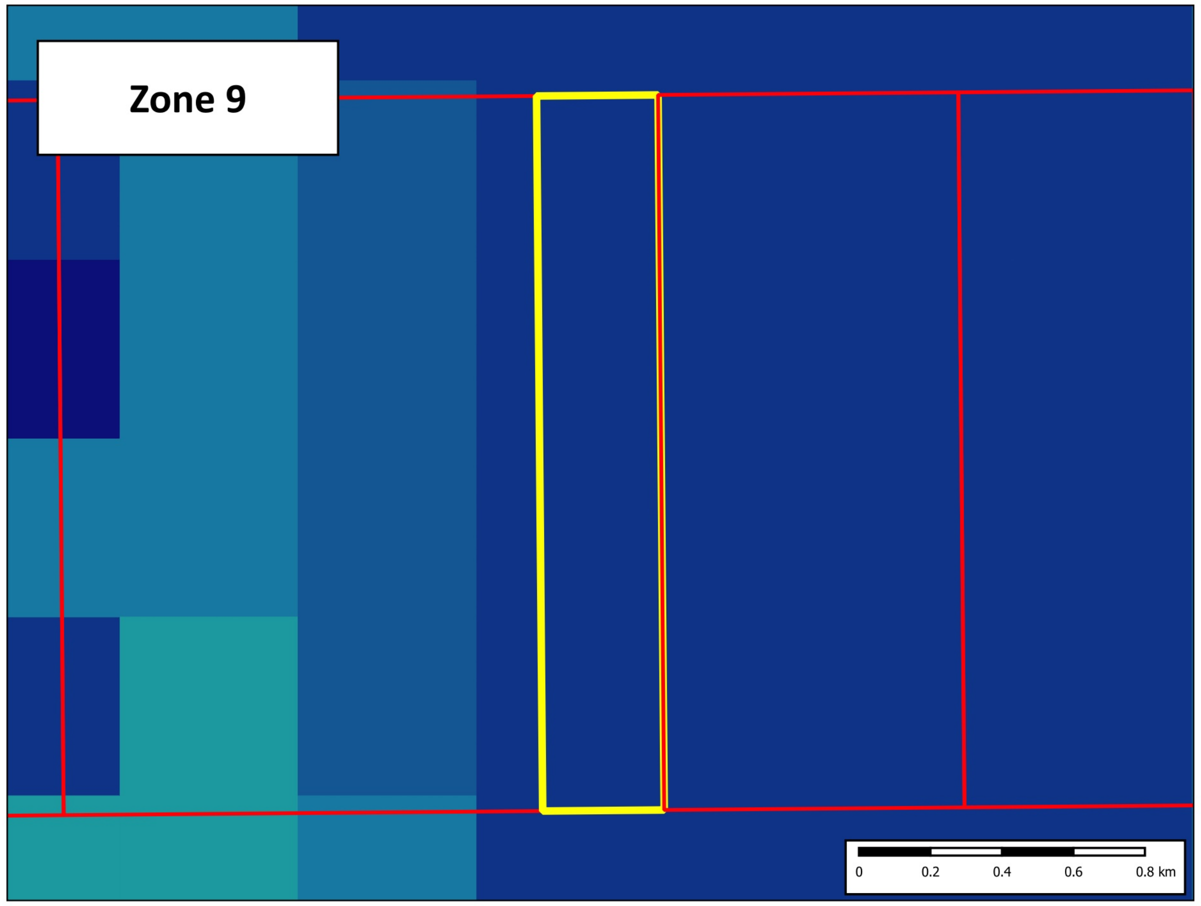
CABLE BURIAL RISK ASSESSMENT KATTEGAT - GRENÅ SOUTH - CBRA

CABLE BURIAL RISK ASSESSMENT

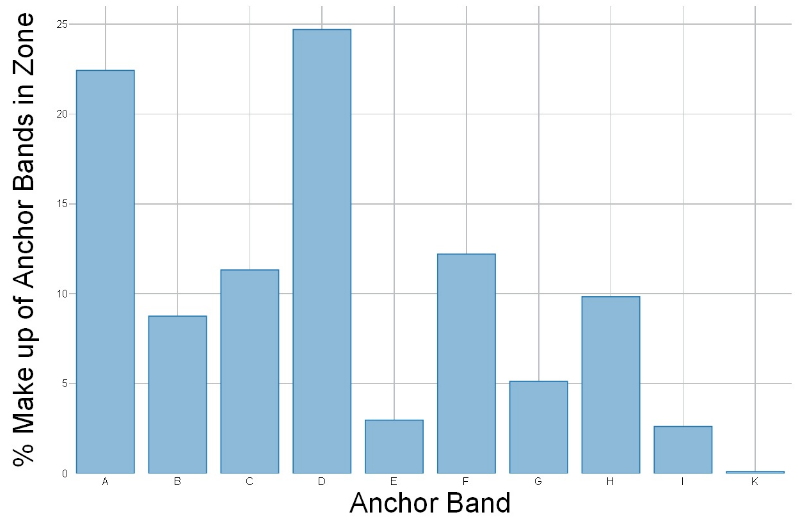
Anchor Band Statistics - Zone 9

Drawing No: P2719E-CBRA-001_9	A





Anchor Band Statistics by Zone - Zone 9



Legend

CBRA Zone

- Zone of Interest
- CBRA Zone

Vessel Density (Duration per year)

- < 15 mins
- 15 - 30 mins
- 30 - 45 mins
- 45 mins - 1 hour
- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week
- > 1 week

N

Legend - Inset

Vessel Density (Duration per year)

- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week
- > 1 week

Date	2024-05-24 13:29:14
Coordinate System	ETRS89 / UTM zone 32N
WKID	EPSG:25832
Scale @A3	1:75,000
Data Sources	NUTS; ENERGINET
File Reference	J:\P2719\Mxd_QGZ\P2719E\04_CBRA \P2719E_CBRA.qgz
Created By	Lewis Castle
Reviewed By	Emma Langley
Approved By	Stephane Theurich

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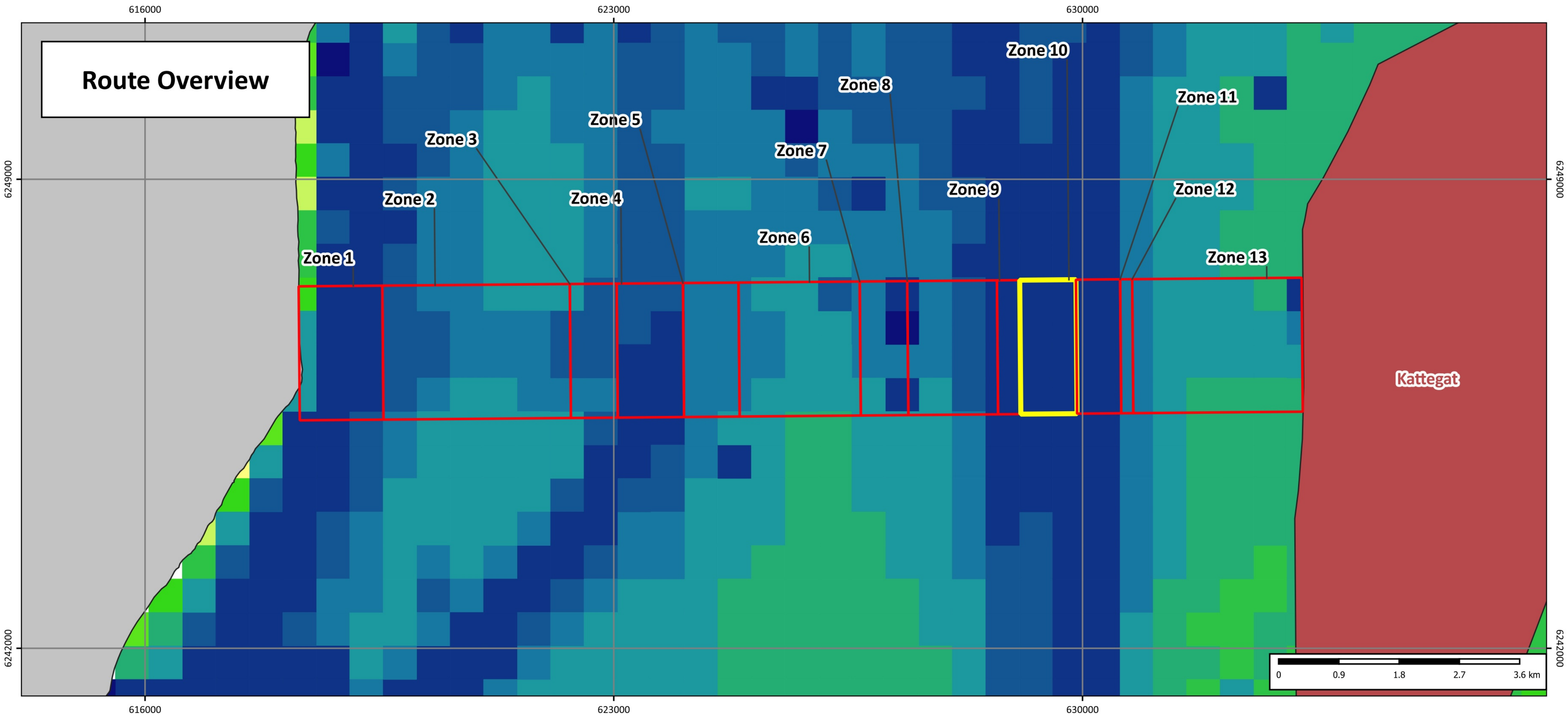
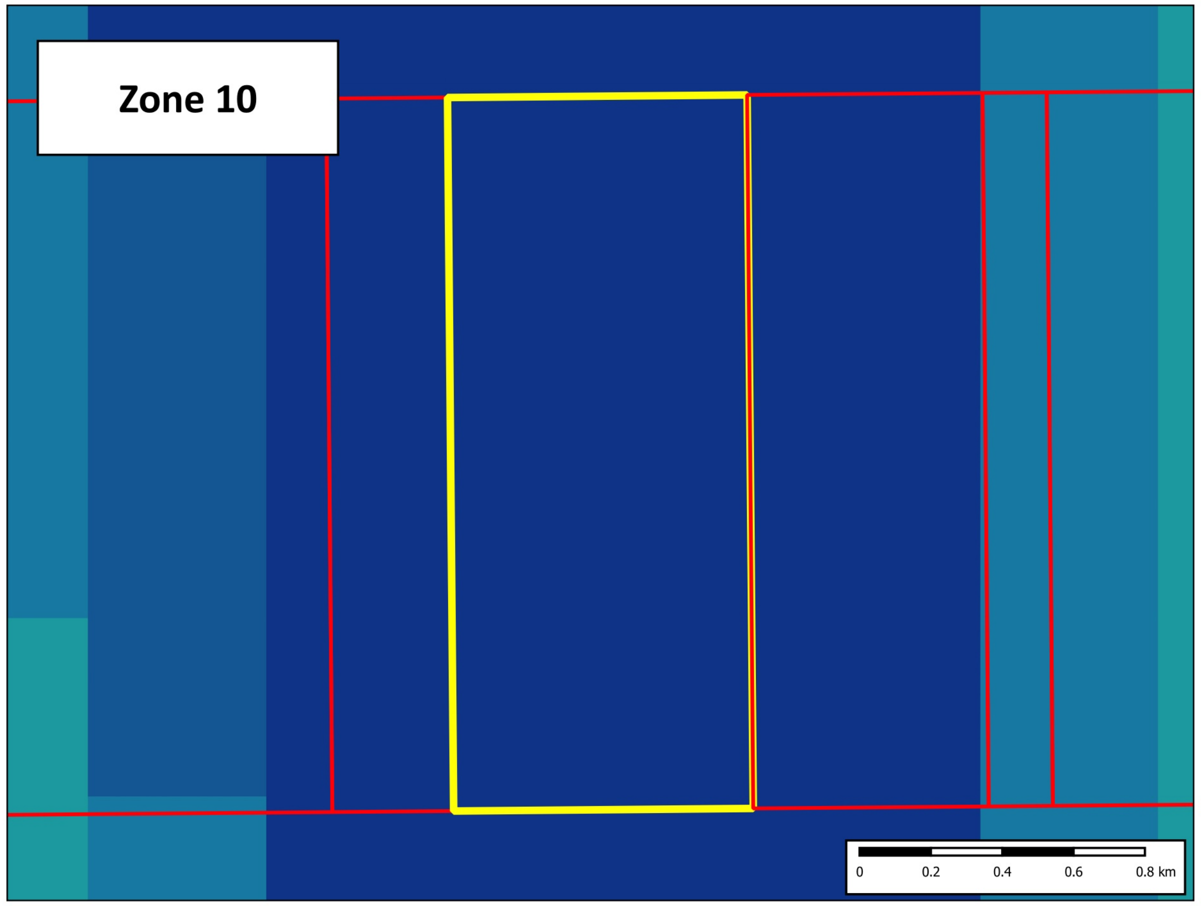
CABLE BURIAL RISK ASSESSMENT

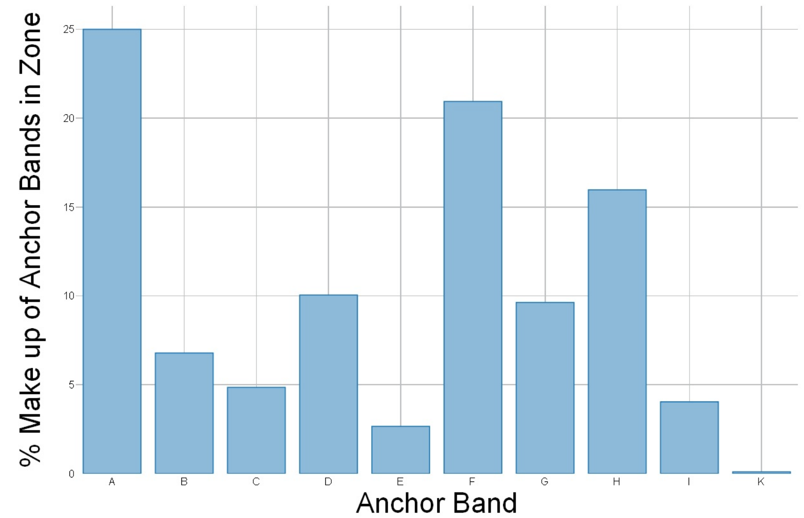
Anchor Band Statistics - Zone 10

Drawing No: P2719E-CBRA-001_10 | A





Anchor Band Statistics by Zone - Zone 10



Legend

N

CBRA Zone

- Zone of Interest
- CBRA Zone

Vessel Density (Duration per year)

- < 15 mins
- 15 - 30 mins
- 30 - 45 mins
- 45 mins - 1 hour
- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week
- > 1 week

Legend - Inset

Vessel Density (Duration per year)

- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week

Date	2024-05-24 13:31:04
Coordinate System	ETRS89 / UTM zone 32N
WKID	EPSG:25832
Scale @A3	1:75,000
Data Sources	NUTS; ENERGINET
File Reference	J:\P2719\Mxd_QGZ\P2719E\04_CBRA \P2719E_CBRA.qgz
Created By	Lewis Castle
Reviewed By	Emma Langley
Approved By	Stephane Theurich

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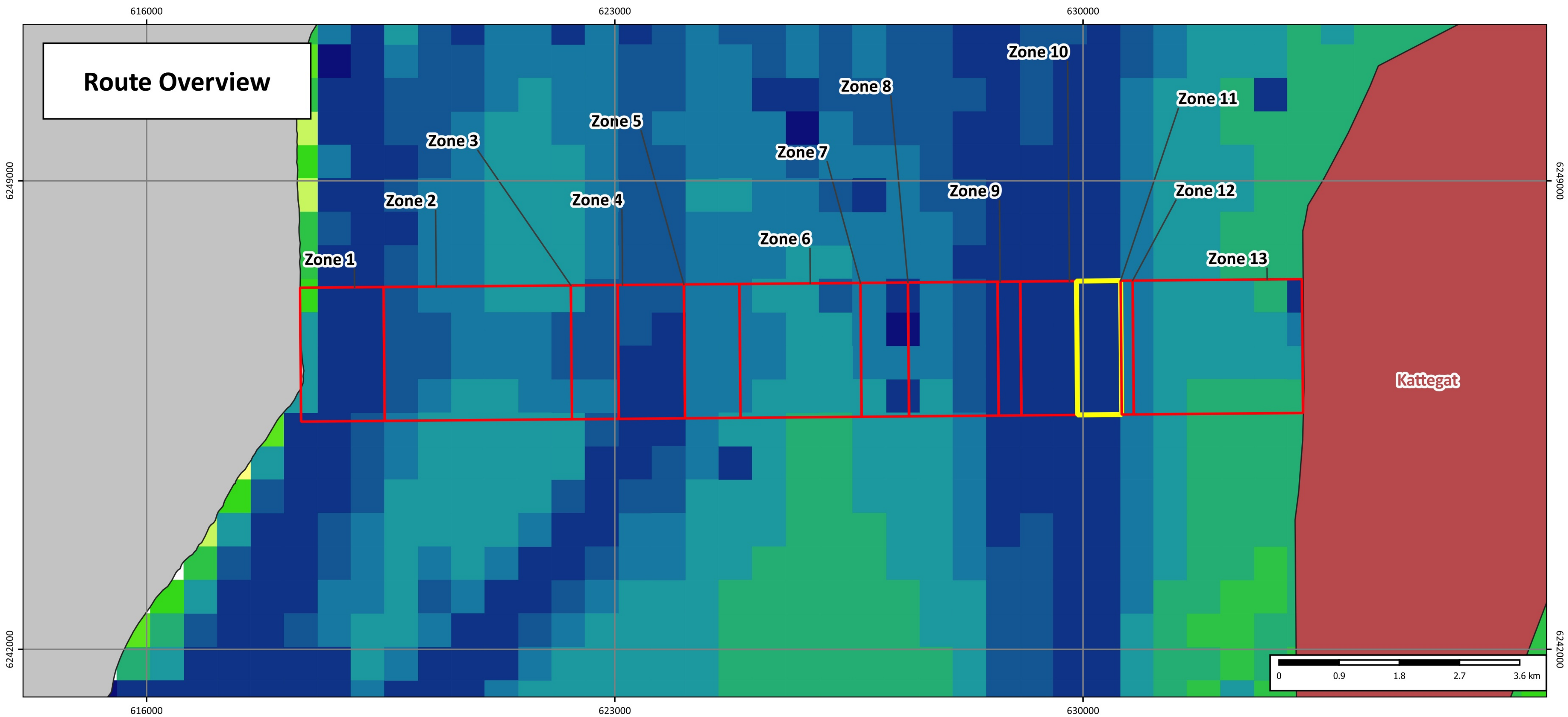
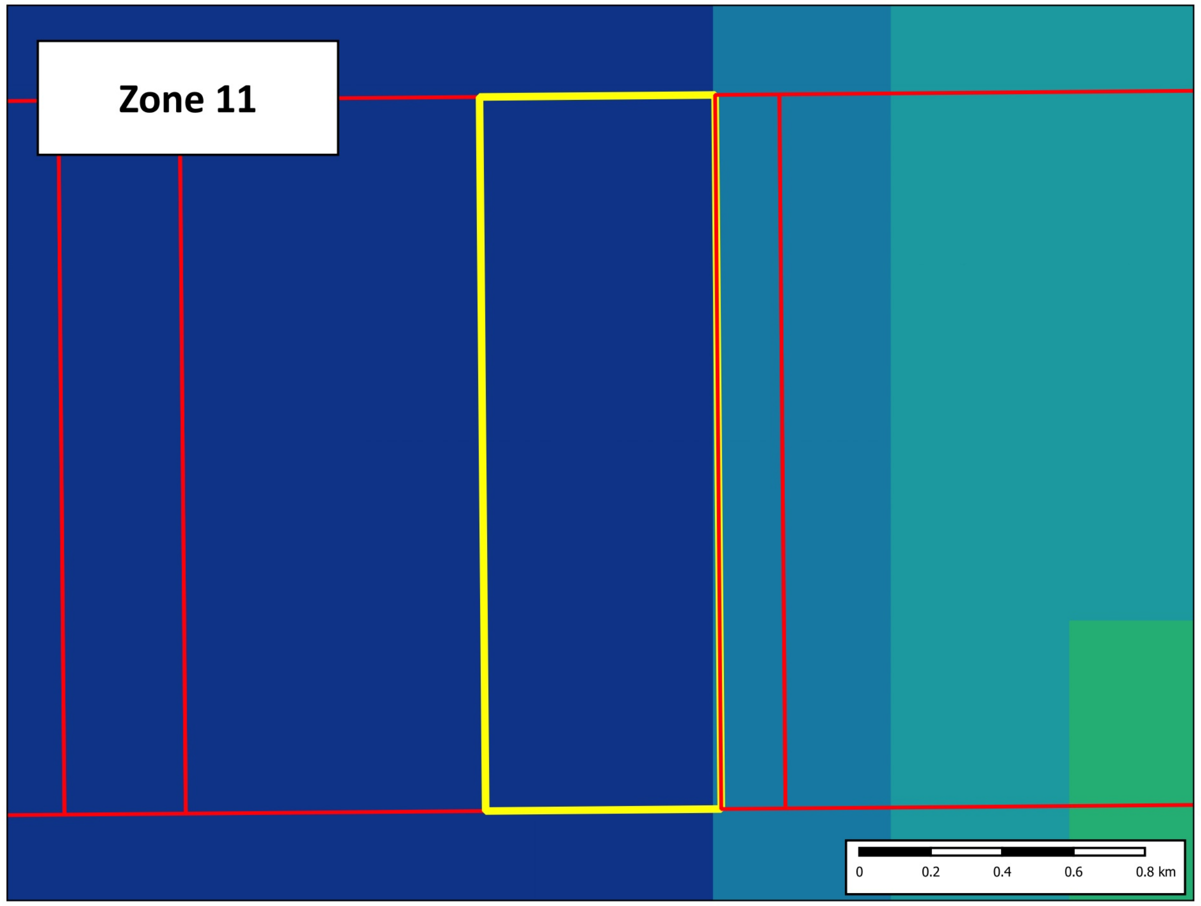
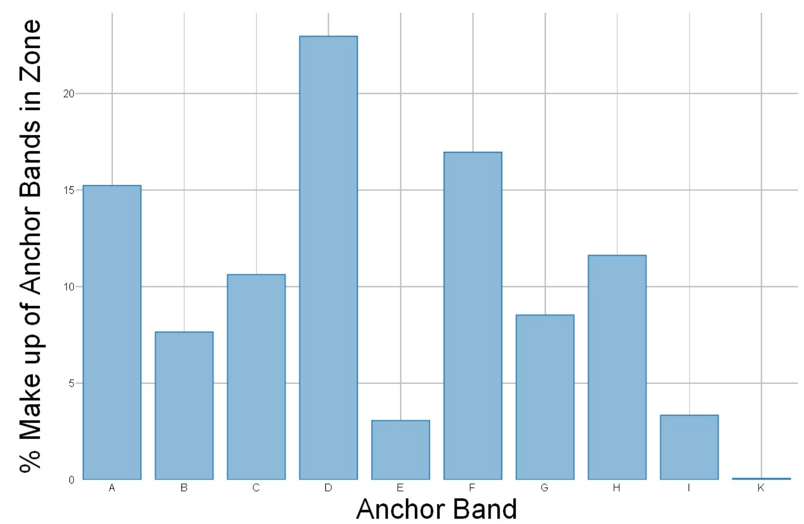




Anchor Band Statistics by Zone - Zone 11



CABLE BURIAL RISK ASSESSMENT KATTEGAT - GRENÅ SOUTH - CBRA

CABLE BURIAL RISK ASSESSMENT

Anchor Band Statistics - Zone 11

Drawing No: P2719E-CBRA-001_11	A

Legend

CBRA Zone

- Zone of Interest
- CBRA Zone

Vessel Density (Duration per year)

- < 15 mins
- 15 - 30 mins
- 30 - 45 mins
- 45 mins - 1 hour
- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week
- > 1 week

N

Legend - Inset

Vessel Density (Duration per year)

- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 48 hours - 1 week

Date	2024-05-24 13:32:23
Coordinate System	ETRS89 / UTM zone 32N
WKID	EPSG:25832
Scale @A3	1:75,000
Data Sources	NUTS; ENERGINET
File Reference	J:\P2719\Mxd_QGZ\P2719E\04_CBRA \P2719E_CBRA.qgz
Created By	Lewis Castle
Reviewed By	Emma Langley
Approved By	Stephane Theurich

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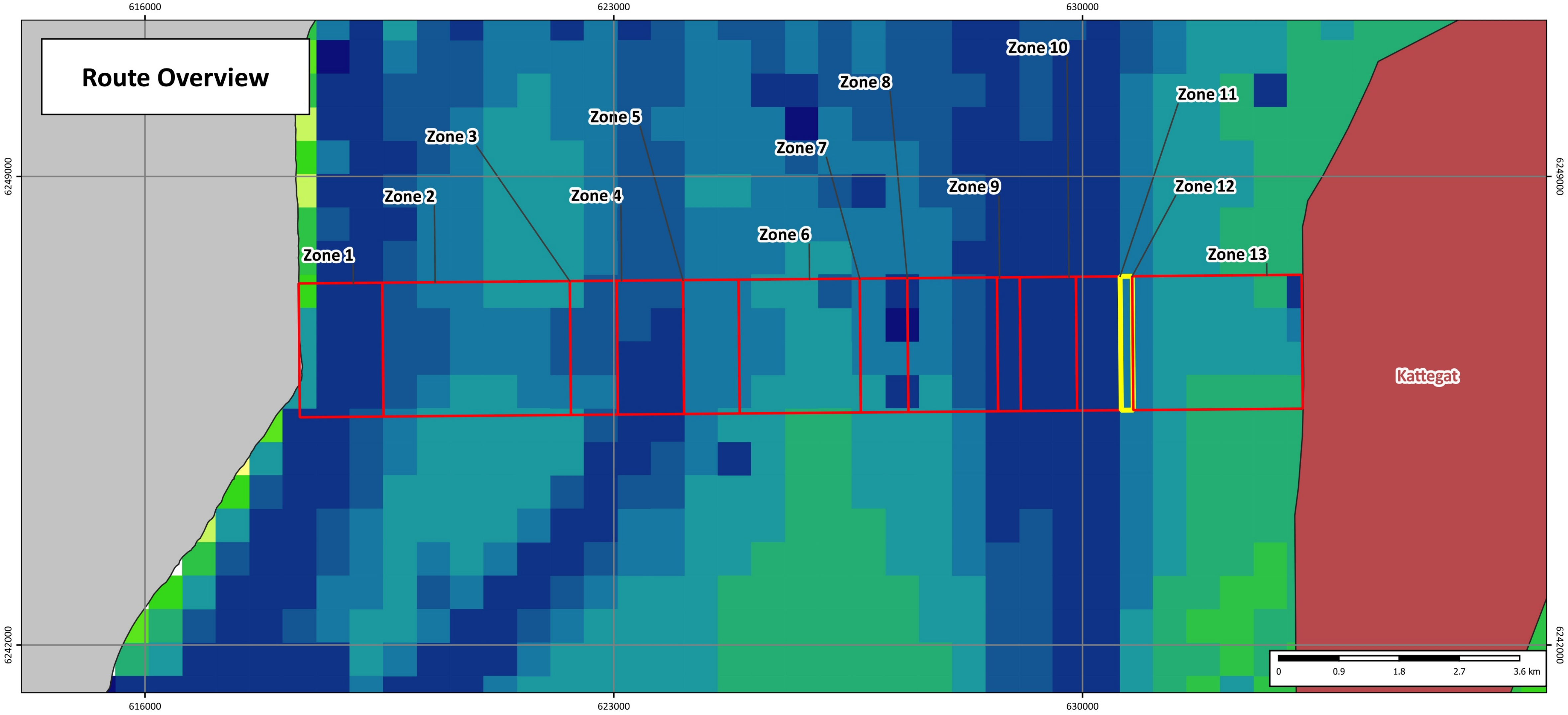
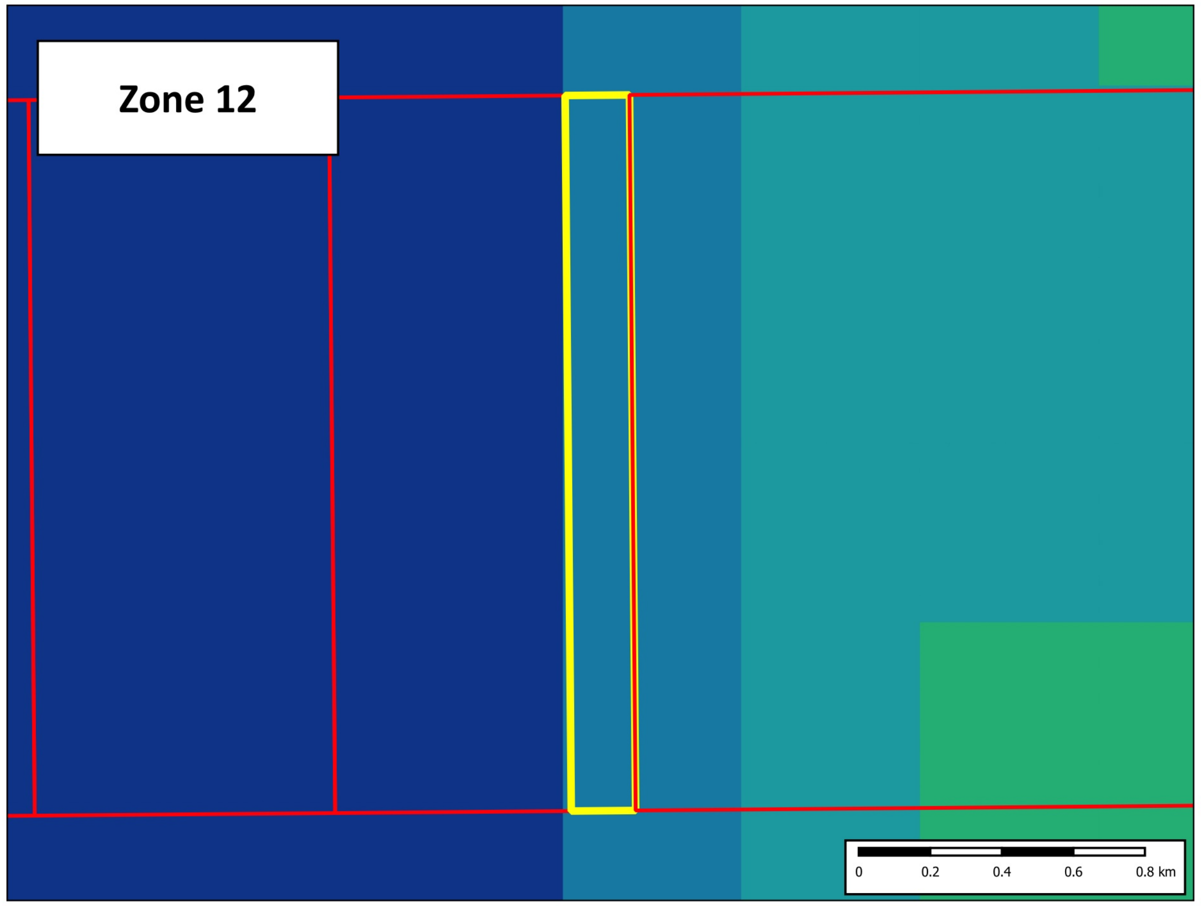
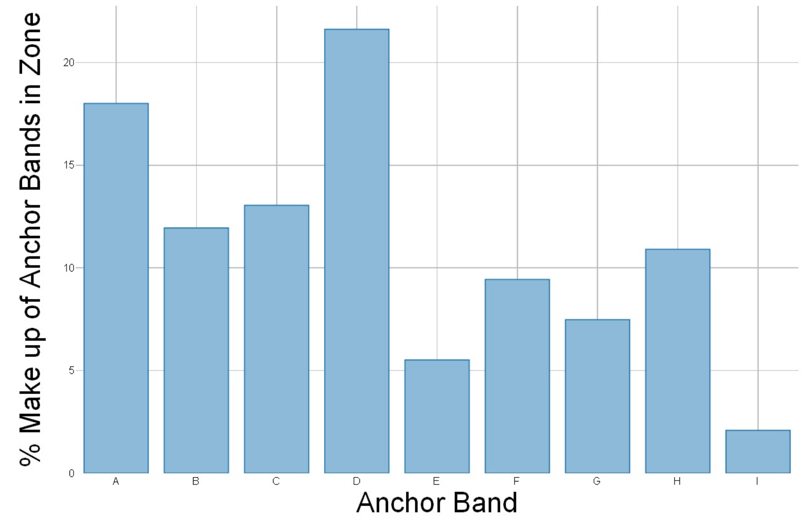




Anchor Band Statistics by Zone - Zone 12



CABLE BURIAL RISK ASSESSMENT KATTEGAT - GRENÅ SOUTH - CBRA

CABLE BURIAL RISK ASSESSMENT

Anchor Band Statistics - Zone 12

Drawing No: P2719E-CBRA-001_12	A

Legend

N

CBRA Zone

- Zone of Interest
- CBRA Zone

Vessel Density (Duration per year)

- < 15 mins
- 15 - 30 mins
- 30 - 45 mins
- 45 mins - 1 hour
- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week
- > 1 week

Legend - Inset

Vessel Density (Duration per year)

- 6 - 12 hours
- 24 - 36 hours
- 12 - 24 hours
- 48 hours - 1 week

Date	2024-05-24 13:34:20
Coordinate System	ETRS89 / UTM zone 32N
WKID	EPSG:25832
Scale @A3	1:75,000
Data Sources	NUTS; ENERGINET
File Reference	J:\P2719\Mxd_QGZ\P2719E\04_CBRA \P2719E_CBRA.qgz
Created By	Lewis Castle
Reviewed By	Emma Langley
Approved By	Stephane Theurich

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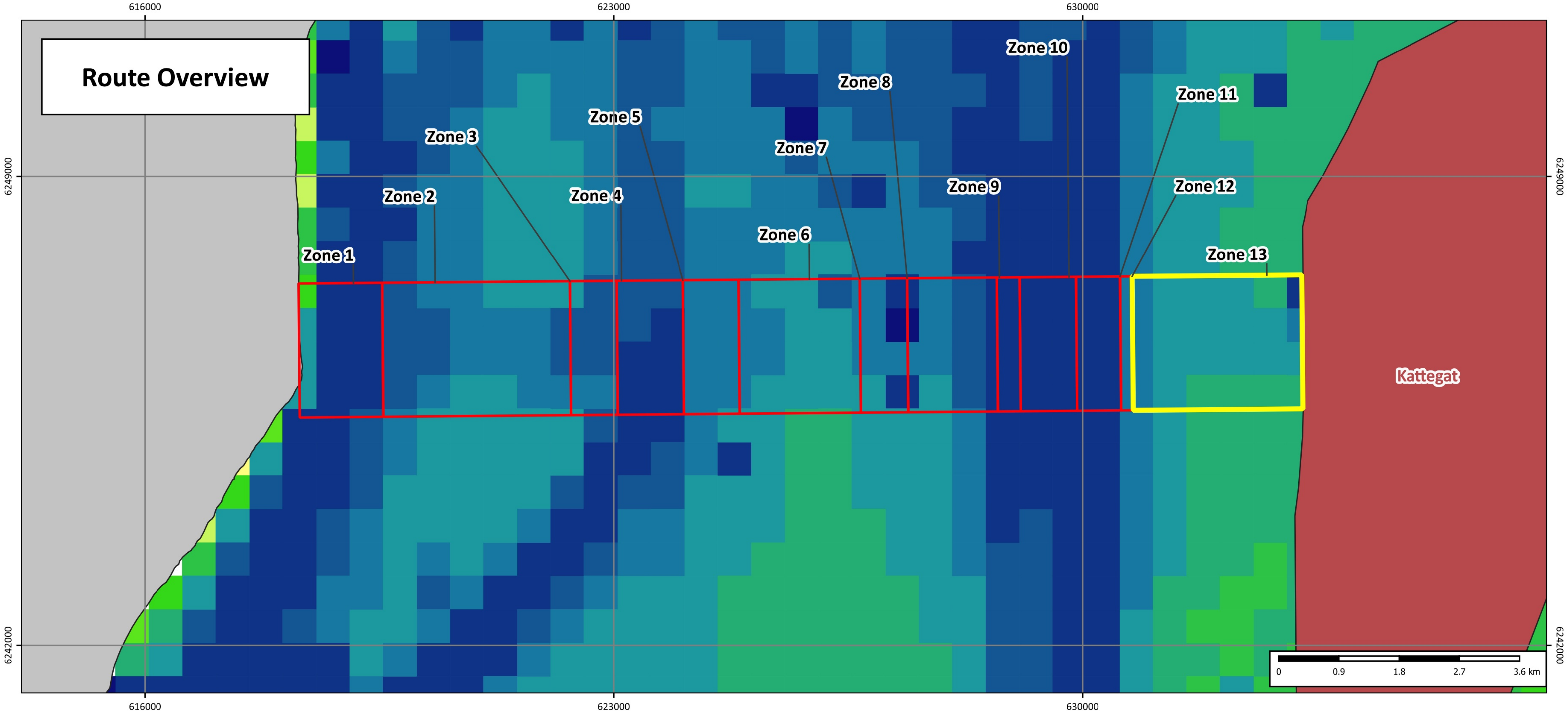
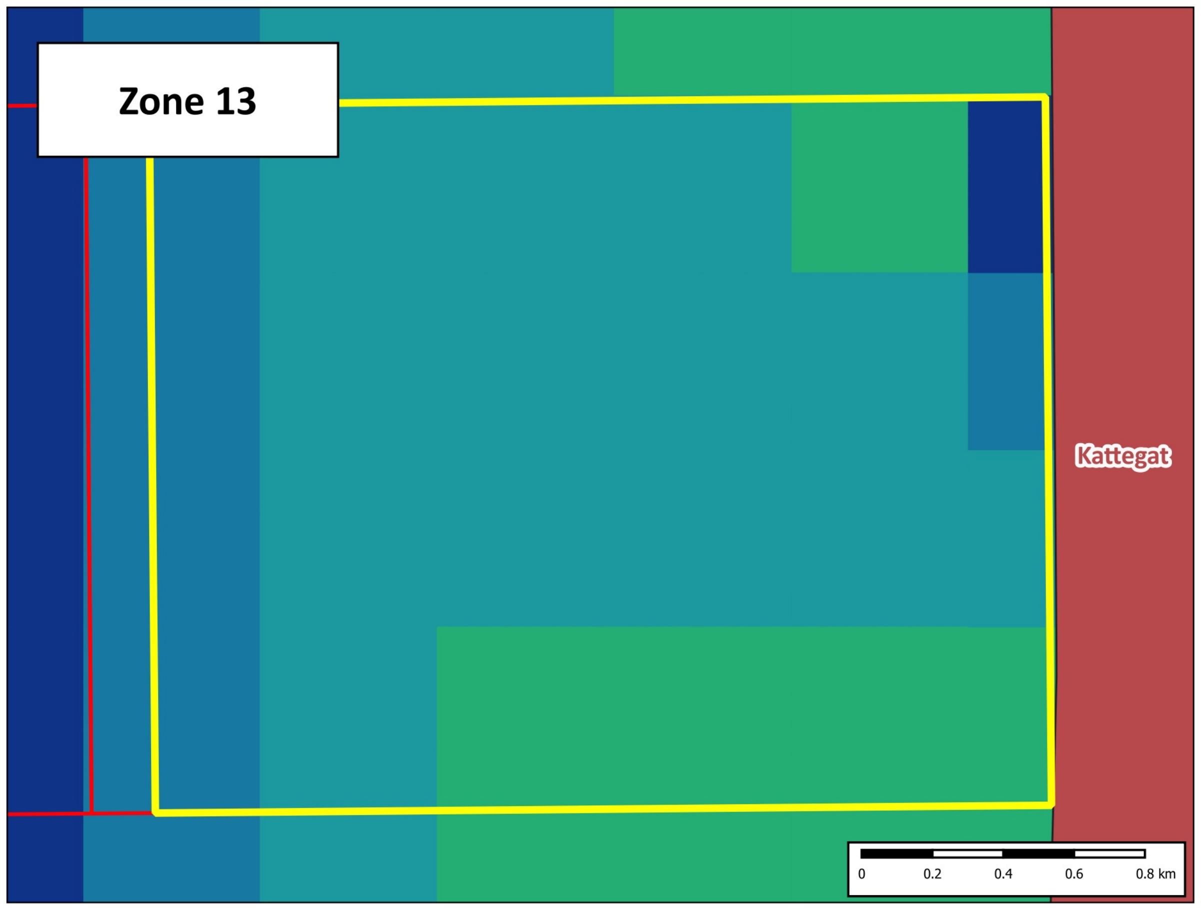
CABLE BURIAL RISK ASSESSMENT KATTEGAT - GRENÅ SOUTH - CBRA

CABLE BURIAL RISK ASSESSMENT

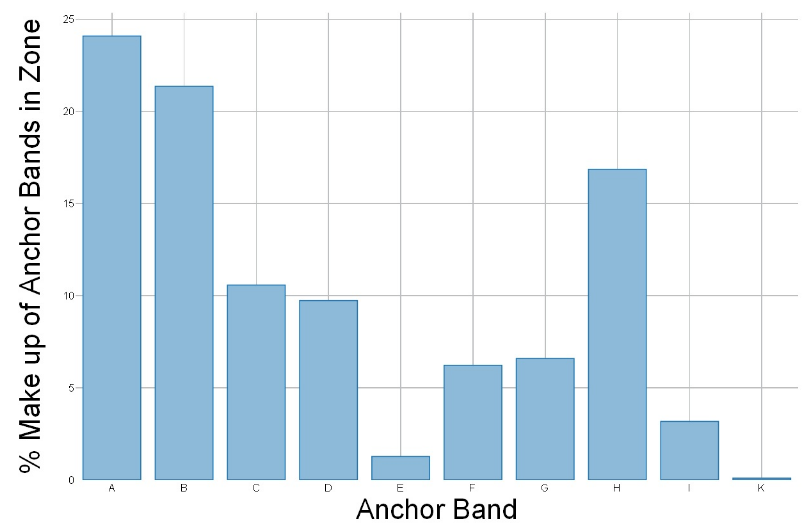
Anchor Band Statistics - Zone 13

Drawing No: P2719E-CBRA-001_13 | A





Anchor Band Statistics by Zone - Zone 13



Legend

CBRA Zone

- Zone of Interest
- CBRA Zone

Vessel Density (Duration per year)

- < 15 mins
- 15 - 30 mins
- 30 - 45 mins
- 45 mins - 1 hour
- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week
- > 1 week

N

Legend - Inset

Vessel Density (Duration per year)

- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 48 hours - 1 week

Date	2024-05-24 13:35:22
Coordinate System	ETRS89 / UTM zone 32N
WKID	EPSG:25832
Scale @A3	1:75,000
Data Sources	NUTS; ENERGINET
File Reference	J:\P2719\Mxd_QGZ\P2719E\04_CBRA \P2719E_CBRA.qgz
Created By	Lewis Castle
Reviewed By	Emma Langley
Approved By	Stephane Theurich

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APPENDIX E

Probabilistic Risk Assessment

Table E-1 Probabilistic Results for Each Scenario

Zone	Scenario 1 - Protection against Band A: Recommended Minimum DoL (m)	Scenario 1: Segment annual failure probability $P_{anchor\ damage}$	Scenario 2 - Protection against Bands A to B: Recommended Minimum DoL (m)	Scenario 2: Segment annual failure probability $P_{anchor\ damage}$	Scenario 3 - Protection against Bands A to C: Recommended Minimum DoL (m)	Scenario 3: Segment annual failure probability $P_{anchor\ damage}$	Scenario 4 - Protection against Bands A to D: Recommended Minimum DoL (m)	Scenario 4: Segment annual failure probability $P_{anchor\ damage}$
1	0.45	1.04E-04	0.50	8.04E-05	0.55	9.07E-06	0.65	8.72E-07
2	0.55	1.93E-03	0.70	4.84E-04	0.85	1.79E-04	1.05	1.28E-05
3	0.55	4.92E-04	0.75	1.34E-04	0.90	4.40E-05	1.15	1.13E-06
4	0.45	1.76E-03	0.60	1.20E-03	0.75	6.23E-04	0.95	4.33E-05
5	0.55	1.96E-03	0.75	1.50E-03	0.95	1.01E-03	1.15	1.05E-04
6	0.50	5.13E-03	0.65	3.75E-03	0.80	2.34E-03	1.00	4.48E-04
7	0.45	2.47E-03	0.60	2.32E-03	0.75	9.20E-04	0.95	1.10E-04
8	0.55	1.21E-02	0.75	1.04E-02	0.95	8.75E-03	1.15	4.14E-03
9	0.55	2.21E-03	0.75	1.96E-03	0.95	1.64E-03	1.15	9.35E-04
10	0.55	1.20E-02	0.70	1.09E-02	0.85	1.01E-02	1.05	8.51E-03
11	0.40	4.62E-03	0.45	4.20E-03	0.50	3.62E-03	0.60	2.37E-03
12	0.40	7.73E-05	0.45	6.60E-05	0.50	5.37E-05	0.60	3.33E-05
13	0.50	3.44E-02	0.70	2.47E-02	0.90	1.99E-02	1.10	1.55E-02
Annual Failure Probability for Entire route	7.93%		6.17%		4.92%		3.22%	
Return Period (years)	12.62		16.22		20.32		31.05	
Failure Probability in the lifetime (40 years)	96.32%		92.16%		86.71%		73.00%	

Zone	Scenario 5 - Protection against Bands A to E: Recommended Minimum DoL (m)	Scenario 5: Segment annual failure probability $P_{anchor\ damage}$	Scenario 6 - Protection against Bands A to F: Recommended Minimum DoL (m)	Scenario 6: Segment annual failure probability $P_{anchor\ damage}$	Scenario 7 - Protection against Bands A to G: Recommended Minimum DoL (m)	Scenario 7: Segment annual failure probability $P_{anchor\ damage}$	Scenario 8 - Protection against Bands A to H: Recommended Minimum DoL (m)	Scenario 8: Segment annual failure probability $P_{anchor\ damage}$
1	0.80	0.00E+00	0.85	0.00E+00	0.85	0.00E+00	0.90	0.00E+00
2	1.35	0.00E+00	1.45	0.00E+00	1.45	0.00E+00	1.60	0.00E+00
3	1.55	0.00E+00	1.75	0.00E+00	1.75	0.00E+00	1.95	0.00E+00
4	1.25	5.77E-07	1.30	0.00E+00	1.30	0.00E+00	1.40	0.00E+00
5	1.60	2.98E-05	1.75	0.00E+00	1.75	0.00E+00	1.95	0.00E+00
6	1.30	2.25E-04	1.40	1.48E-05	1.40	1.48E-05	1.55	0.00E+00
7	1.25	8.52E-05	1.30	2.69E-05	1.30	2.69E-05	1.40	0.00E+00
8	1.60	3.63E-03	1.75	1.35E-03	1.75	1.35E-03	1.95	3.64E-04
9	1.60	8.51E-04	1.75	3.58E-04	1.75	3.58E-04	1.95	7.72E-05
10	1.50	8.09E-03	1.65	3.21E-03	1.65	3.21E-03	1.85	6.61E-04
11	0.75	2.20E-03	0.80	8.16E-04	0.80	8.16E-04	0.85	1.85E-04
12	0.75	2.81E-05	0.80	1.22E-05	0.80	1.22E-05	0.85	1.96E-06
13	1.55	1.49E-02	1.70	9.12E-03	1.70	9.12E-03	1.90	1.48E-03
Annual Failure Probability for Entire route	3.01%		1.49%		1.49%		0.28%	
Return Period (years)	33.27		67.09		67.09		360.97	
Failure Probability in the lifetime (40 years)	70.50%		45.16%		45.16%		10.50%	

Zone	Scenario 9 - Protection against Bands A to I: Recommended Minimum DoL (m)	Scenario 9: Segment annual failure probability $P_{anchor\ damage}$	Scenario 10 - Protection against Bands A to J: Recommended Minimum DoL (m)	Scenario 10: Segment annual failure probability $P_{anchor\ damage}$	Scenario 11- Protection against Bands A to K: Recommended Minimum DoL (m)	Scenario 11: Segment annual failure probability $P_{anchor\ damage}$	Scenario 12 - Selected Protection Section by Section: Recommended Minimum DoL (m)	Scenario 12: Segment annual failure probability $P_{anchor\ damage}$
1	0.95	0.00E+00	0.95	0.00E+00	0.95	0.00E+00	0.65	8.72E-07
2	1.60	0.00E+00	1.60	0.00E+00	1.60	0.00E+00	1.35	0.00E+00
3	2.00	0.00E+00	2.00	0.00E+00	2.00	0.00E+00	1.15	1.13E-06
4	1.40	0.00E+00	1.40	0.00E+00	1.40	0.00E+00	1.25	5.77E-07
5	2.00	0.00E+00	2.00	0.00E+00	2.00	0.00E+00	1.75	0.00E+00
6	1.55	0.00E+00	1.55	0.00E+00	1.55	0.00E+00	1.40	1.48E-05
7	1.40	0.00E+00	1.40	0.00E+00	1.40	0.00E+00	1.40	0.00E+00
8	2.00	0.00E+00	2.00	0.00E+00	2.00	0.00E+00	2.00	0.00E+00
9	2.00	0.00E+00	2.00	0.00E+00	2.00	0.00E+00	1.95	7.72E-05
10	1.90	0.00E+00	1.90	0.00E+00	1.90	0.00E+00	2.00	0.00E+00
11	0.90	0.00E+00	0.90	0.00E+00	0.90	0.00E+00	0.90	0.00E+00
12	0.90	0.00E+00	0.90	0.00E+00	0.90	0.00E+00	0.85	1.96E-06
13	1.95	0.00E+00	1.95	0.00E+00	1.95	0.00E+00	1.95	0.00E+00
Annual Failure Probability for Entire route	0.00%		0.00%		0.00E+00		9.66E-05	
Return Period (years)	∞		∞		∞		10352.53	
Failure Probability in the lifetime (40 years)	0.00%		0.00%		0.00%		0.39%	

Table E-2 Probabilistic Results for Each Zone in 0.25m Increments

Zone	Selected Protection Section by Section at 0.25m: DoL (m)	Segment annual failure probability $P_{anchor\ damage}$	Selected Protection Section by Section at 0.50m: DoL (m)	Segment annual failure probability $P_{anchor\ damage}$	Selected Protection Section by Section at 0.75m: DoL (m)	Segment annual failure probability $P_{anchor\ damage}$	Selected Protection Section by Section at 1.00m: DoL (m)	Segment annual failure probability $P_{anchor\ damage}$	Selected Protection Section by Section at 1.25m: DoL (m)	Segment annual failure probability $P_{anchor\ damage}$	Selected Protection Section by Section at 1.50m: DoL (m)	Segment annual failure probability $P_{anchor\ damage}$	Selected Protection Section by Section at 1.75m: DoL (m)	Segment annual failure probability $P_{anchor\ damage}$	Selected Protection Section by Section at 2.00m: DoL (m)	Segment annual failure probability $P_{anchor\ damage}$
1	0.25	4.03E-03	0.50	8.04E-05	0.75	8.72E-07	1.00	0.00E+00	1.25	0.00E+00	1.50	0.00E+00	1.75	0.00E+00	2.00	0.00E+00
2	0.25	1.64E-02	0.50	1.64E-02	0.75	4.84E-04	1.00	1.79E-04	1.25	1.28E-05	1.50	0.00E+00	1.75	0.00E+00	2.00	0.00E+00
3	0.25	1.28E-03	0.50	1.28E-03	0.75	1.34E-04	1.00	4.40E-05	1.25	1.13E-06	1.50	1.13E-06	1.75	0.00E+00	2.00	0.00E+00
4	0.25	2.44E-03	0.50	1.76E-03	0.75	6.23E-04	1.00	4.33E-05	1.25	5.77E-07	1.50	0.00E+00	1.75	0.00E+00	2.00	0.00E+00
5	0.25	2.82E-03	0.50	2.82E-03	0.75	1.50E-03	1.00	1.01E-03	1.25	1.05E-04	1.50	1.05E-04	1.75	0.00E+00	2.00	0.00E+00
6	0.25	9.13E-03	0.50	5.13E-03	0.75	3.75E-03	1.00	4.48E-04	1.25	4.48E-04	1.50	1.48E-05	1.75	0.00E+00	2.00	0.00E+00
7	0.25	2.89E-03	0.50	2.47E-03	0.75	9.20E-04	1.00	1.10E-04	1.25	8.52E-05	1.50	0.00E+00	1.75	0.00E+00	2.00	0.00E+00
8	0.25	1.81E-02	0.50	1.81E-02	0.75	1.04E-02	1.00	8.75E-03	1.25	4.14E-03	1.50	4.14E-03	1.75	1.35E-03	2.00	0.00E+00
9	0.25	2.85E-03	0.50	2.85E-03	0.75	1.96E-03	1.00	1.64E-03	1.25	9.35E-04	1.50	9.35E-04	1.75	3.58E-04	2.00	0.00E+00
10	0.25	1.60E-02	0.50	1.60E-02	0.75	1.09E-02	1.00	1.01E-02	1.25	8.51E-03	1.50	8.09E-03	1.75	3.21E-03	2.00	0.00E+00
11	0.25	5.45E-03	0.50	3.62E-03	0.75	2.20E-03	1.00	0.00E+00	1.25	0.00E+00	1.50	0.00E+00	1.75	0.00E+00	2.00	0.00E+00
12	0.25	9.42E-05	0.50	5.37E-05	0.75	2.81E-05	1.00	0.00E+00	1.25	0.00E+00	1.50	0.00E+00	1.75	0.00E+00	2.00	0.00E+00
13	0.25	4.53E-02	0.50	3.44E-02	0.75	2.47E-02	1.00	1.99E-02	1.25	1.55E-02	1.50	1.55E-02	1.75	9.12E-03	2.00	0.00E+00
Annual Failure Probability for Entire route	12.6764%		10.4938%		5.7557%		4.2242%		2.9733%		2.8777%		1.4035%		0.0000%	
Return Period (years)	7.89		9.53		17.37		23.67		33.63		34.75		71.25		∞	
Failure Probability in the lifetime (40 years)	99.56%		98.81%		90.66%		82.21%		70.10%		68.90%		43.18%		0.00%	

APPENDIX F

Navigation and Shipping

F.1 AIS INFORMATION

F.1.1 EMODnet Human Activities Classes Translations

Table F-1 EMODnet Human Activities Classes Translations

Original Vessel Type	Aggregated Category Consistent with EMODnet Human Activities
Asphalt/Bitumen Tanker	Tanker
Bulk Carrier	Cargo
Cargo	Cargo
Cargo/Containership	Cargo
Cement Carrier	Cargo
Chemical Tanker	Tanker
Container Ship	Cargo
Crude Oil Tanker	Tanker
Dive Vessel	Dredging or underwater operations
Dredger	Dredging or underwater operations
Exhibition Ship	Other
Fish Carrier	Cargo
Fishery Research Vessel	Service
Fishing	Fishing
Fishing Vessel	Fishing
General Cargo	Cargo
High Speed Craft	High-speed craft
Houseboat	Pleasure craft
Inland; Motor Freighter	Cargo
Inland; Passenger Ship; Ferry; Cruise ship	Passenger
Inland; Pleasure Craft; >20 metres	Pleasure craft
Inland; Unknown	Unknown
Light; without Sectors	Other
Livestock Carrier	Cargo
LNG Tanker	Tanker
Local Vessel	Other
LPG Tanker	Tanker
Military Ops	Military
Naval/Naval Auxiliary Vessel	Military
NULL	Unknown
Offshore Supply Ship	Service
Oil Products Tanker	Tanker
Oil/Chemical Tanker	Tanker
Other	Other

Original Vessel Type	Aggregated Category Consistent with EMODnet Human Activities
Passenger	Passenger
Passenger Ship	Passenger
Passenger/Cargo Ship	Passenger
Pilot Vessel	Service
Pleasure Craft	Pleasure craft
Port Tender	Service
Research/Survey Vessel	Service
Reserved	Other
Ro-Ro Cargo	Cargo
Ro-Ro/Container Carrier	Cargo
Ro-Ro/Passenger Ship	Passenger
Safe Water	Other
Sailing Vessel	Sailing
Salvage/Rescue Vessel	Service
SAR	Service
SAR Aircraft	REMOVE
Special Vessel	Other
Supply Vessel	Service
Tanker	Tanker
Trawler	Fishing
Tug	Tug or Towing
Unspecified	Unknown
Unspecified	Sailing
Vehicles Carrier	Cargo
Work Vessel	Service
Yacht	Sailing

F.2 PORTS

F.2.1 Port of Aarhus

The Port of Aarhus, located in Denmark, is the largest container port in the country and one of the most significant in Northern Europe. Established in 1845, it has evolved into a major hub for maritime trade and logistics, handling a substantial portion of Denmark's container traffic. The port features advanced facilities, including state-of-the-art container terminals, extensive warehousing, and efficient logistics services, making it a key player in international shipping and trade. It also boasts deep-water quays capable of accommodating some of the world's largest container vessels. The strategic location of the Port of Aarhus, coupled with its modern infrastructure, contributes to its pivotal role in the Scandinavian and Baltic regions' supply chains (Port of Aarhus, 2023; European Sea Ports Organisation, 2023).

F.2.2 Port of Grenaa

The Port of Grenaa is a major industrial and commercial port on the east coast of the Jutlandic peninsula and is Denmark's most central deep-water port. It is located approximately 16 km north west of the Kattegat wind farm site. The Port of Grenaa is opened all year round and exports include grain, seed, stone and paper. Imports include coal, phosphates, saltpetre, oil, chemicals, wood pellets, wood chips, paper pulp, logs (SHIPNEXT, 2024b). The port is one of Denmark's leading industrial ports for offshore and onshore wind projects (State of Green, 2014). Ferry routes between Grenaa and Sweden have existed at this port for over 60 years (Grenaa Havn, 2023). Over 1000 vessels and 1,450,000t of cargo are handled annually (Marine Insight, 2023).

F.2.3 Port of Ebeltoft

The Port of Ebeltoft is located on the east coast of Jutland approximately 30 km west of the Kattegat wind farm site and consists of a ferry harbour (SHIPNEXT, 2024d). It is owned by Syddjurs Municipality and consists of a basin for yachts and a smaller harbour basin (Ebeltoft Havn, 2016). The harbour consists of a concrete pier for larger vessels up to 45 m in length, 10 m in width and a depth of 4.3 m (VisitAarhus, 2024). There is also a fishing port 2.5nm to the south of which is used by sailing vessels, high-speed craft and pleasure craft (Port of Ebeltoft in Denmark, 2024).

F.2.4 Port of Helsingør (Elsinore)

The Port of Helsingør (Elsinore), located on the north east coast of Zealand, is a commercial harbour, ferry and cruise port managed by the Helsingør Port Authority (Helsingor Havne, 2023). It is situated 96 km north west of the Kattegat wind farm site and has facilities for a small amount of woodchip, stone and gravel import of which is discharged directly to lorries (FindaPort, 2023). There is a car ferry line between Helsingør and Helsingborg Sweden, of which has over 70 departures in each direction every day (ØRESUNDSLINJEN, 2024).

F.2.5 Port of Helsingborg

The Port of Helsinborg is located 100 km north west of the Kattegat wind farm site and is situated on the coast of Sweden between Kattegat and the Baltic Sea. It is Sweden's main ferry port and consists of four commercial harbours including the north, west, south and bulk harbours. The bulk harbour is privately owned and is operated by the Port of Helsinborg (SHIPNEXT, 2024c). The south harbour handles a variety of imports and exports are handled including grains, tomato paste, sheet steel, metals and paper rolls (Helsingborgs Hamn, 2020). It is also a destination for cruise ships. The west harbour features three container cranes and one mobile crane and enables transports directly from ship to railway. There is also a dock for bulk cargo such as chemicals, oil, industrial products, food, wood pellets, containers and trailers. The north harbour is dominated by ferry traffic between Helsingborg and Elsinore, Denmark (Helsingborgs Hamn, 2020). Approximately 46,500 vessels are handled annually with over 8 million tonnes of cargo (Helsingborgs Hamn, 2020; SHIPNEXT, 2024c).

F.2.6 Port of Skagen

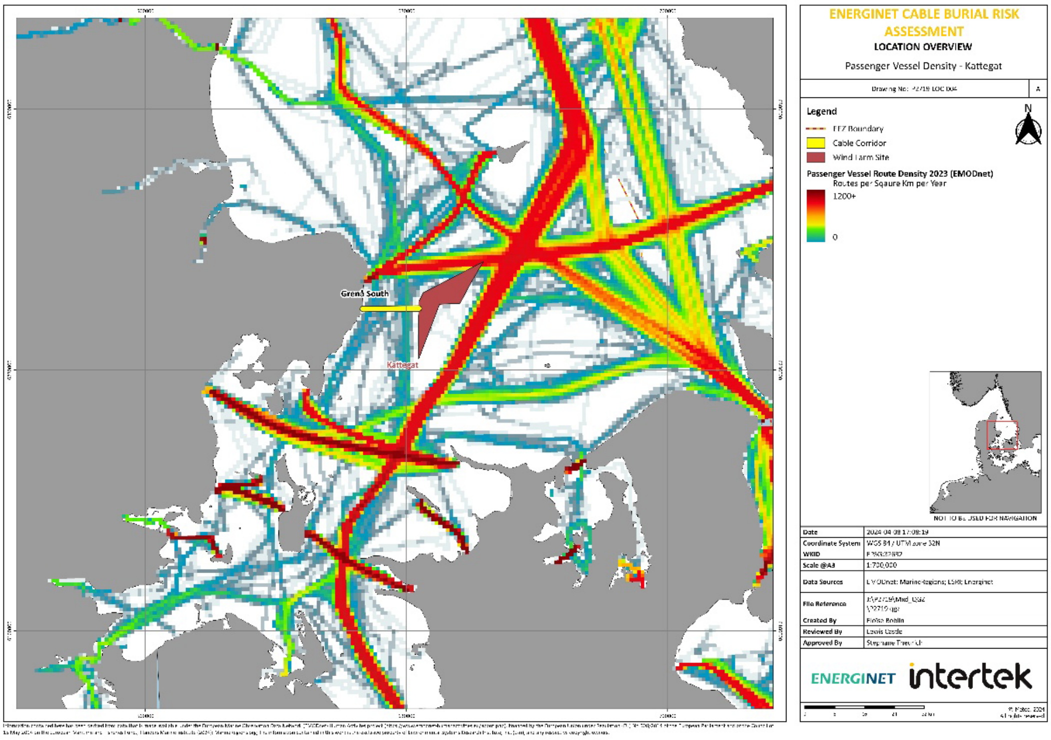
The Port of Skagen is located in the north of Denmark, 153 km north of the Kattegat wind farm site and is Denmark's largest fishing harbour. It is Europe's largest landing port for pelagic fish, with 6000 landings annually (Port of Skagen, 2016). In 2020, a total of 290,000t of fish was landed with a value of 991 million DKK (Port of Skagen, 2022a). The port is used by large cargo vessels and tankers and over 650 bunkering and cargo ships visit the port every year (Serviceteam Skagen, 2022). In 2020, over 600 vessels called at Skagen to unload or load cargo or to receive service or ship repair (Port of Skagen, 2022a). The port has been a member of the local cruise network since 1999 and has recently been adapted to accommodate large international cruise ships (Port of Skagen, 2016).

F.3 PORT ACTIVITIES AND GROWTH PLAN

F.3.1 Ferry and Passenger vessel routes

The below images illustrate the ferry and passenger vessel routes in the vicinity of the proposed cable route corridor.

Figure F-1 Passenger Vessel Route Density



The future trends for the Port of Aarhus, Denmark's largest commercial port, are quite promising. Here are some key points:

A broad political majority in the Aarhus City Council has approved an expansion of the Port of Aarhus[1]. This expansion is considered a historic milestone as it secures the future of the port and supports the need for more space and quayside capacity (Port of Aarhus, 2024). The total expansion will be 84 hectares, distributed over stages (The International, 2024).

Along with the port expansion, a so-called Dry Port will be developed west of Aarhus (Port of Aarhus, 2024). This will serve as an efficient logistics center with buildings to ensure supply chains to the port's customers (Port of Aarhus, 2024).

The port expansion project includes a number of new initiatives and green measures for both the climate and the marine environment (Port of Aarhus, 2024). For instance, the port aims to offset one-to-one for the CO_2 emissions generated by the construction of the expansion by 2030 (Port of Aarhus, 2024).

The Port of Aarhus is working on a proposal called Aarhus Blueline, which aims to increase biodiversity in Aarhus Bay by turning the upcoming pier into a nature and biodiversity area (Port of Aarhus, 2024).

The Aarhus Port Authority has a strategy that focuses on sustainable energy, industry, innovation & infrastructure, sustainable cities & communities, and life at sea (Ultimate Maritime Logistics, 2024).

These trends indicate a future of growth and sustainability for the Port of Aarhus. The port is not only expanding its physical capacity but also making significant strides in environmental sustainability and biodiversity.

F.3.2 Port of Grenaa

A current focus area for the Port of Grenaa is to remain an attractive player for future projects such as near and offshore wind farms including Kattegat (Deloitte, 2022). In recent years, the port has grown from a small fishing port to an international hub with a wide variety of capabilities such as bulk activities. It now has the capacity to serve the offshore wind market with ideal access to Denmark, Sweden and Northern Europe. The construction of the Anholt OWF in 2013 earned the port national and international recognition (Gisselbæk, 2019).

In 2020 the Denmark Maritime Authority announced the Grenaa port expansion project as the port had surpasses its capacity in 2018 and 2019 (Marine Insight, 2023). Following the COVID-19 pandemic, supply crisis, war in Ukraine and high inflation, the port became more cautious regarding port expansion strategies (Lager & Transport, 2023). This said, the port plans to build two new farm operation and maintenance (O&M) facilities as part of the port's infrastructure expansion (Baltic Wind, 2022). In addition, in 2023 a new lower ramp for Swedish traffic was installed (Port of Grenaa, 2024). The port is also looking to potentially acquire a land area of up to 200,000m2 in the northern end of the port in order to make it more attractive to those companies that are not necessarily dependent on location (Lager & Transport, 2023).

Table F-2 and **Table F-3** present an overview of ship calls and throughput of goods in Grenaa port. **Figure F-2** shows the location of port of Grenaa shipping and ferry lanes.

Table F-2 Call of cargo ships and cruiser ships on the Port of Grenaa (Statistics Denmark, 2024)

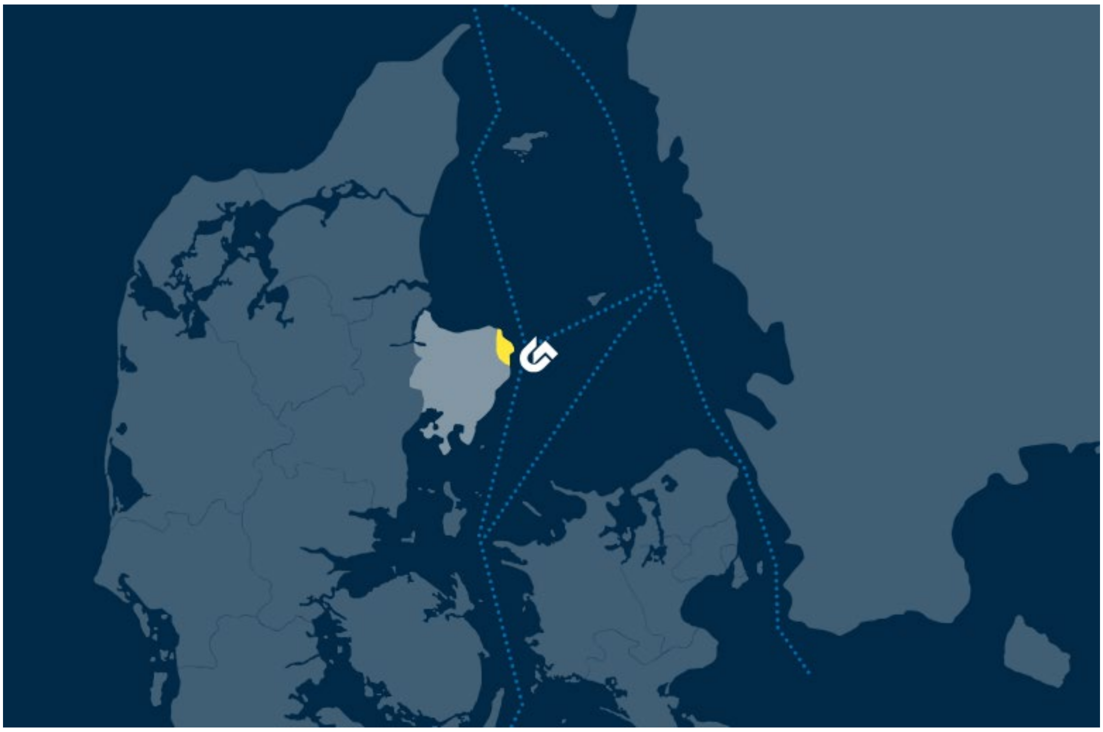
Year	2017	2018	2019	2020	2021	2022
Container ships	1	0	0	0	1	0
Bulk carriers	164	189	148	148	153	159
Reefer ships	0	0	0	0	0	0
Tankers	65	75	56	53	60	61
Special ships	1	3	4	22	19	13
Other general cargo ships	31	26	31	24	24	32
Barges	0	10	1	1	3	8
Cruiser ships	0	0	0	0	0	0
Cargo Ships and Cruise Ships Total	262	303	240	248	260	273

Table F-3 Call of vessels, passengers and throughput of goods in the Port of Grenaa (Statistics Denmark, 2024)

Year	2017	2018	2019	2020	2021	2022
Ships calling at port	1107	1161	1064	1103	1095	1107
Passengers, domestic traffic	27	29	31	31	37	33
Passengers, international traffic	155	151	146	54	59	97

Year	2017	2018	2019	2020	2021	2022
Throughput of goods, domestic traffic	184	194	153	162	179	202
Throughput of goods, international traffic	1231	1312	1138	1177	1200	1313

Figure F-2 Port of Grenaa Ferry and Shipping Lanes (Port of Grenaa, 2023)



F.3.3 Port of Ebeltoft

In 2018, Ebeltoft Traffic and Marina extended the floating bridge by 20 metres in order to create 10 new berths, of which are mainly used by sailors (Ebeltoft Havn, 2018). **Table F-4** presents an overview of call of vessels, passengers and throughput of good in the Port of Ebeltoft.

Table F-4 Call of vessels, passengers and throughput of goods in the Port of Ebeltoft (Statistics Denmark, 2024)

Year	2017	2018	2019	2020	2021	2022
Ships calling at port	98	97	93	72	131	142
Passengers, domestic traffic	79	81	108	69	146	157
Passengers, international traffic	0	0	0	0	0	0
Throughput of goods, domestic traffic	0	0	1	0	1	1
Throughput of goods, international traffic	0	0	0	0	0	0

F.3.4 Port of Helsingør (Elsinore)

There are no current plans to expand the port, however the connection of Sweden and Denmark via a series of tunnels has been proposed including road and rail tunnels (Tunnel Contact, 2021). A summary of call of vessels, passengers and throughput of goods in Helsingør port is provided in **Table F-5** along with a summary of passengers embarked and disembarked in **Table F-6**

Table F-5 Call of vessels, passengers and throughput of goods in the Port of Helsingør (Eurostat, 2023)

Year	2017	2018	2019	2020	2021	2022
Ships calling at port	28120	28922	28074	22254	21689	24327
Passengers, domestic traffic	0	0	0	0	0	0
Passengers, international traffic	7310	7152	7105	3548	3985	6268
Throughput of goods, domestic traffic	0	0	0	0	0	0
Throughput of goods, international traffic	4982	5184	5088	5060	5462	5590

Table F-6 Passengers embarked and disembarked in the Port of Helsingør (Eurostat, 2023)

Year	2017	2018	2019	2020	2021	2022
Passengers	7,310	7,152	7,105	3,548	3,985	6,268

F.3.5 Helsingborg

Projections suggest a demand for an increase in container operations in Helsingborg. It is for this reason that a new container terminal will be developed by 2030 in the southern part of the port (Helsinborgs Hamn, 2024a).

Cargo volumes in the port of Helsingborg have increased from 7.9 million tons in 2019 to 8.2 million tons in 2021. Ferry cargo and traffic also increased, along with passengers. An increase in bulk handling for pellets used as energy in heating systems was observed in 2021, due to the cold weather conditions in southern Sweden. The total volume of dry bulk has decreased slightly while liquid bulk good have seen an increase of five percent since 2019 (Helsingborgs Hamn, 2024b). A summary of passenger embarked and disembarked in Helsingborg port is present in **Table F-7**.

Table F-7 Passengers embarked and disembarked in the Port of Helsingborg (Eurostat, 2023)

Year	2017	2018	2019	2020	2021	2022
Passengers	7,319	7,136	7,153	3,562	4,009	6,318

F.3.6 Port of Skagen

In 2019 the Skagen DryPort was founded, offering a vacant commercial area of 25,000 square metres. The port of Skagen is a growing port and expansion was completed in March 2021 (Port of Skagen, 2022a). This expansion added a new land area of 190,000m2 and 1050m of new quay creating improved infrastructure for the customers of the port, mainly focusing on fishing (Port of Skagen, 2021). Ship arrivals, freight turnover, fish landings and cruise calls are displayed in **Table F-8**, **Figures F-3** to **F-6**.

Table F-8 Call of vessels, passengers and throughput of goods in the Port of Skagen (Port of Skagen, 2022b)

Year	2017	2018	2019	2020	2021	2022
Ships calling at port	496	608	508	654	642	592
Passengers, domestic traffic	0	0	0	0	0	0
Passengers, international traffic	0	0	0	0	0	0
Throughput of goods, domestic traffic	39	71	64	71	116	82
Throughput of goods, international traffic	159	279	249	293	194	208

Figure F-3 Arrival of Ships in the Port of Skagen (unit stk/piece) (Port of Skagen, 2022b

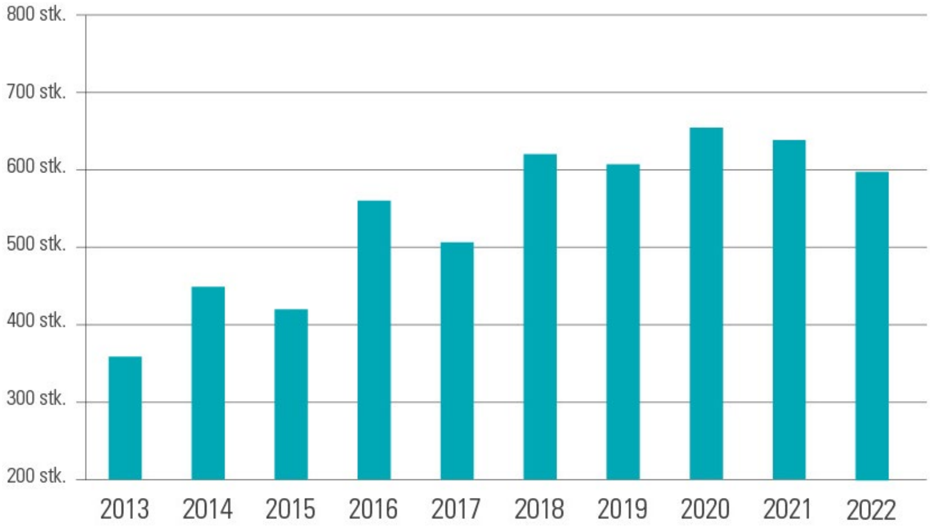


Figure F-4 Freight Turnover of the Port of Skagen (Port of Skagen, 2022b)

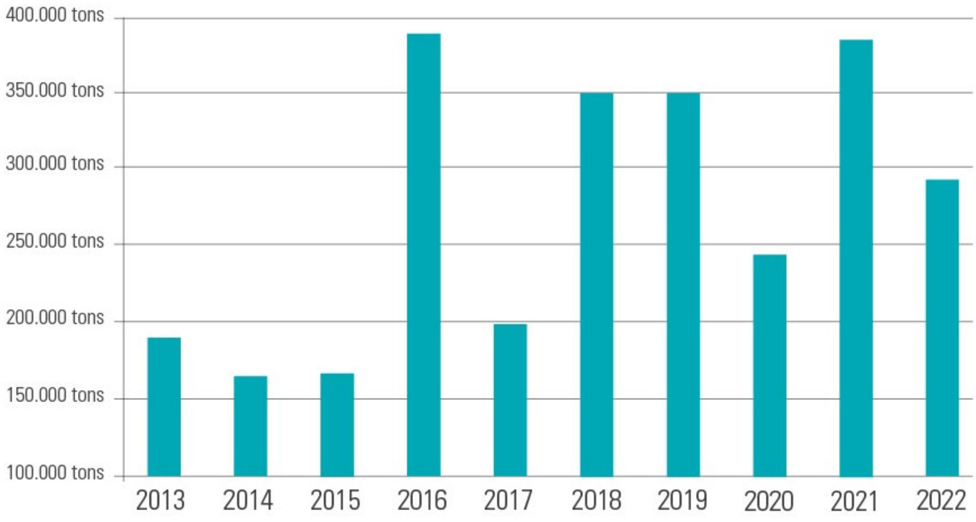


Figure F-5 Industrial Fish Landing at the Port of Skagen (Quantity/Mænge and Value/Værdi) (Port of Skagen, 2022b)

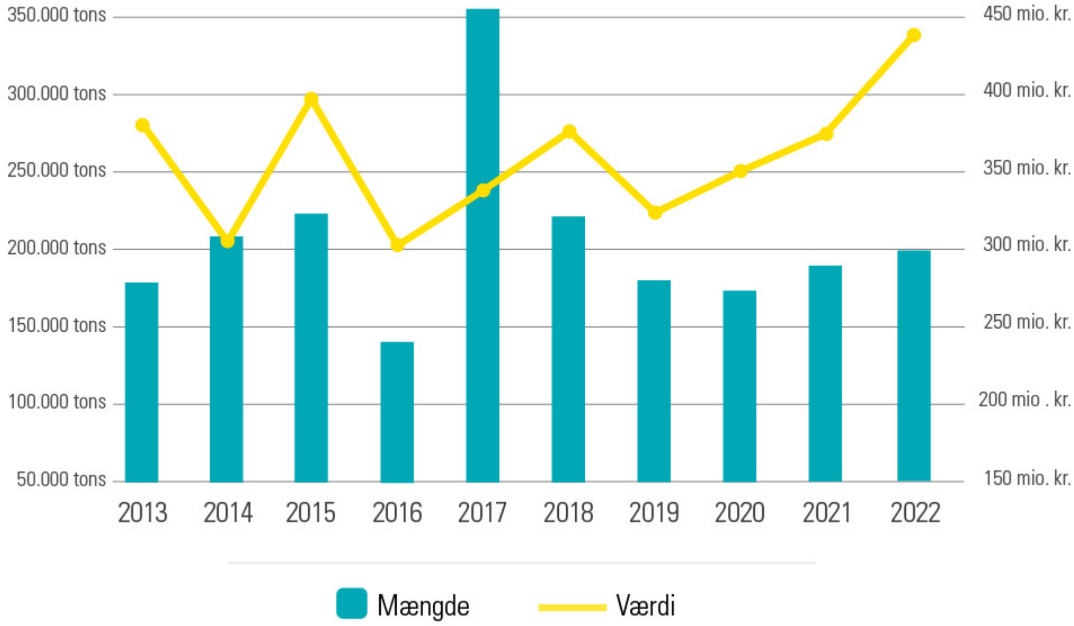
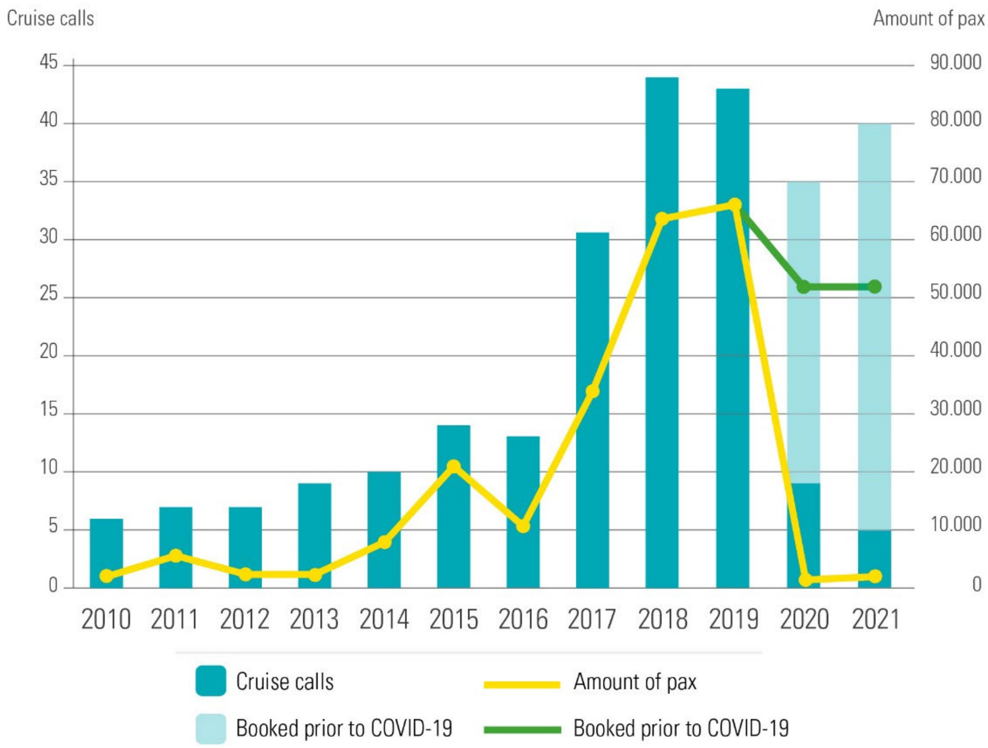


Figure F-6 Cruise Calls and Amount of Pax at the Port of Skagen before and after COVID-19 (Port of Skagen, 2022b)



F.4 NAVIGATION ACTIVITY

Navigation data has been analysed from marine traffic, as well as other public data presenting the following patterns below.

F.4.1 Global

The demand for global transport and seaborne trade is showing an upward trend along with vessel traffic intensities (International Transport Forum, 2019). Vessels are becoming larger with deeper draughts in order to fulfil this demand (Tran & Haasis, 2015). The development of OWF's, designation of Marine Protected Areas (MPAs) and maritime recreation are increasing pressures on the use of sea space (Lecq, 2021).

F.4.2 Kattegat Sea

The Kattegat Sea is a shallow sea area (mean depth 27m) and features very high vessel traffic densities and has some of the world's busiest shipping lanes (Sköld, et al., 2018). The Kattegat Sea links the North Sea and the Baltic Sea and can be very difficult to navigate (Lecq, 2021). The strait has heavy international vessel traffic, with nearly 75,000 ship passages in 2019 (Grimvall & Larsson, 2014). The shipping routes through the Kattegat feature heavier use than the Baltic Sea, and practically no part of the Kattegat area is free of vessel traffic (HELCOM (Baltic Marine Environment Protection Commission), 2018). The shipping routes are mainly used by tankers and cargo ships as well as high speed passenger crafts, ferries and fishing vessels (International Maritime Organization, 2017). The Kattegat, however, limits navigation due to shallow waters. This has resulted in a relatively high number of groundings (HELCOM (Baltic Marine Environment Protection Commission), 2018). High vessel traffic densities and difficult navigational conditions have also led to a high number of ship collisions in the Kattegat (Du, et al., 2020). This, combined with the hive of nautical activity in the nearby Baltic Sea, led to the development of a new shipping route system as of 2020 (Danish Maritime Authority, 2020).

F.5 MARITIME REGULATIONS AND NAVIGATIONAL RULES

Numerous regulations and rules are present within the study area and across the Kattegat Sea.

F.5.1 Global and EU Regulations

Danish waters are influenced by global and EU regulations.

International regulations are governed by the International Maritime Organisation (IMO). Key conventions include; SOLAS - International Convention for the Safety of Life at Sea, MARPOL - International Convention for the Prevention of Pollution from Ships, ISPS - the International Ship and Port Facility Security Code and STCW - International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (IMO, 2023). Other laws relating to maritime safety Further information can be found on the International Maritime Organization website: https://www.imo.org/en/about/Conventions/Pages/ListOfConventions.aspx.

EU regulations cover numerous topics including training and qualifications, Marine equipment, Security on ships, Passenger ship safety and digital maritime systems (European Parliment, 2023). Further information on EU laws and regulations can be found on the EU website: https://www.europarl.europa.eu/factsheets/en/sheet/125/maritime-transport-traffic-and-safety-rules.

Summary of relevant law is presented in **Table F-9**.

Table F-9 Summary of Relevant Global and EU Regulations

Governing Body	Convention Topic	Regulation
IMO	Maritime safety and security and ship/port interface	Convention on the International Regulations for Preventing Collisions at Sea (COLREG), 1972 Convention on Facilitation of International Maritime Traffic (FAL), 1965 International Convention on Load Lines(LL), 1966 International Convention on Maritime Search and Rescue(SAR), 1979 Convention for the Suppression of Unlawful Acts Against the Safety of Maritime Navigation(SUA), 1988, and Protocol for the Suppression of Unlawful Acts Against the Safety of Fixed Platforms located on the Continental Shelf (and the 2005 Protocols) International Convention for Safe Containers (CSC), 1972 Convention on the International Maritime Satellite Organization (IMSO C), 1976 The Torremolinos International Convention for the Safety of Fishing Vessels (SFV), 1977, superseded by the 1993 Torremolinos Protocol; Cape Town Agreement of 2012 on the Implementation of the Provisions of the 1993 Protocol relating to the Torremolinos International Convention for the Safety of Fishing Vessels International Convention on Standards of Training, Certification and Watchkeeping for Fishing Vessel Personnel (STCW-F), 1995 Special Trade Passenger Ships Agreement (STP), 1971 and Protocol on Space Requirements for Special Trade Passenger Ships, 1973
IMO	Marine pollution	International Convention Relating to Intervention on the High Seas in Cases of Oil Pollution Casualties (INTERVENTION), 1969

Governing Body	Convention Topic	Regulation
		Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter(LC), 1972 (and the 1996 London Protocol) International Convention on Oil Pollution Preparedness, Response and Co-operation(OPRC), 1990 Protocol on Preparedness, Response and Co-operation to pollution Incidents by Hazardous and Noxious Substances, 2000 (OPRC-HNS Protocol) International Convention on the Control of Harmful Anti-fouling Systems on Ships (AFS), 2001 International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004 The Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships, 2009
IMO	Liability and compensation	International Convention on Civil Liability for Oil Pollution Damage (CLC), 1969 1992 Protocol to the International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage (FUND 1992) Convention relating to Civil Liability in the Field of Maritime Carriage of Nuclear Material (NUCLEAR), 1971 Athens Convention relating to the Carriage of Passengers and their Luggage by Sea (PAL), 1974 Convention on Limitation of Liability for Maritime Claims(LLMC), 1976 International Convention on Liability and Compensation for Damage in Connection with the Carriage of Hazardous and Noxious Substances by Sea (HNS), 1996 (and its 2010 Protocol) International Convention on Civil Liability for Bunker Oil Pollution Damage, 2001 Nairobi International Convention on the Removal of Wrecks, 2007
EU	Training and qualifications	Directive 94/58/EC of 22 November 1994 Directive (EU) 2017/2397 of 12 December 2017
EU	Marine equipment	Directive 96/98/EC of 20 December 199
EU	Security on Ships and Port facility standards	The ISPS (International Ship and Port Facility Security)
EU	Passenger ship safety	Directive 94/57/EC of 22 November 1994. Directive 2009/45/EC of 6 May 2009, Directive 98/18/EC. Directive 98/41/EC of 18 June 1998 Directive (EU) 2019/1159 was published in the Official Journal on 12 July 2019. Directive (EU) 2017/2108 of 15 November 2017 Directive (EU) 2016/1629 of 14 September 2016
EU	Digital Maritime systems and services	Directive (EU) 2005/44/EC Directive 2010/65/EU of October 2010 Commission Delegated Regulation (EU) 2023/205 of November 2022

F.5.2 Danish Regulations

Denmark's has a comprehensive framework of maritime legislation to govern various aspects of maritime activities. Some of the main maritime legislation in Denmark includes:

1. **Merchant Shipping Act (Søloven)**: The Merchant Shipping Act regulates various aspects of Danish merchant shipping, including the registration of vessels, safety standards, crewing requirements, navigation, pollution prevention, and liability issues.
2. **Danish Maritime Authority (DMA) Regulations**: The Danish Maritime Authority issues regulations and guidelines covering a wide range of maritime matters, including ship safety, navigation, environmental protection, crewing standards, and port operations. These regulations are often aligned with international conventions and standards.
3. **Maritime Labor Law**: Denmark has legislation governing maritime labor matters, including seafarers' rights, employment conditions, wages, working hours, and health and safety standards onboard Danish-flagged vessels. These regulations typically comply with international labor conventions such as those established by the International Labour Organization (ILO).
4. **Environmental Regulations**: Denmark has stringent environmental regulations aimed at preventing pollution from ships and offshore installations. These regulations cover issues such as ballast water management, waste disposal, emissions control, and environmental impact assessments for maritime projects.
5. **Port Regulations**: Danish ports are governed by regulations covering port operations, infrastructure development, safety standards, port dues, and environmental management. These regulations ensure the efficient and safe operation of Danish ports while promoting trade and commerce.
6. **Offshore Energy Legislation**: Denmark has specific legislation governing offshore energy activities, including oil and gas exploration and production, offshore wind energy projects, and marine renewable energy developments. These regulations address licensing, safety standards, environmental impact assessments, and decommissioning requirements for offshore installations.
7. **Maritime Security Laws**: Denmark implements maritime security measures in accordance with international conventions and guidelines to enhance the security of ships, ports, and offshore installations against security threats such as piracy, terrorism, and smuggling.
8. **International Conventions and Treaties**: Denmark is a party to numerous international maritime conventions and treaties, including those established by the International Maritime Organization (IMO), International Labour Organization (ILO), International Convention for the Prevention of Pollution from Ships (MARPOL), and International Convention for the Safety of Life at Sea (SOLAS), among others. These conventions influence Danish maritime legislation and ensure alignment with international maritime standards and best practices.

APPENDIX G

Fishing Information

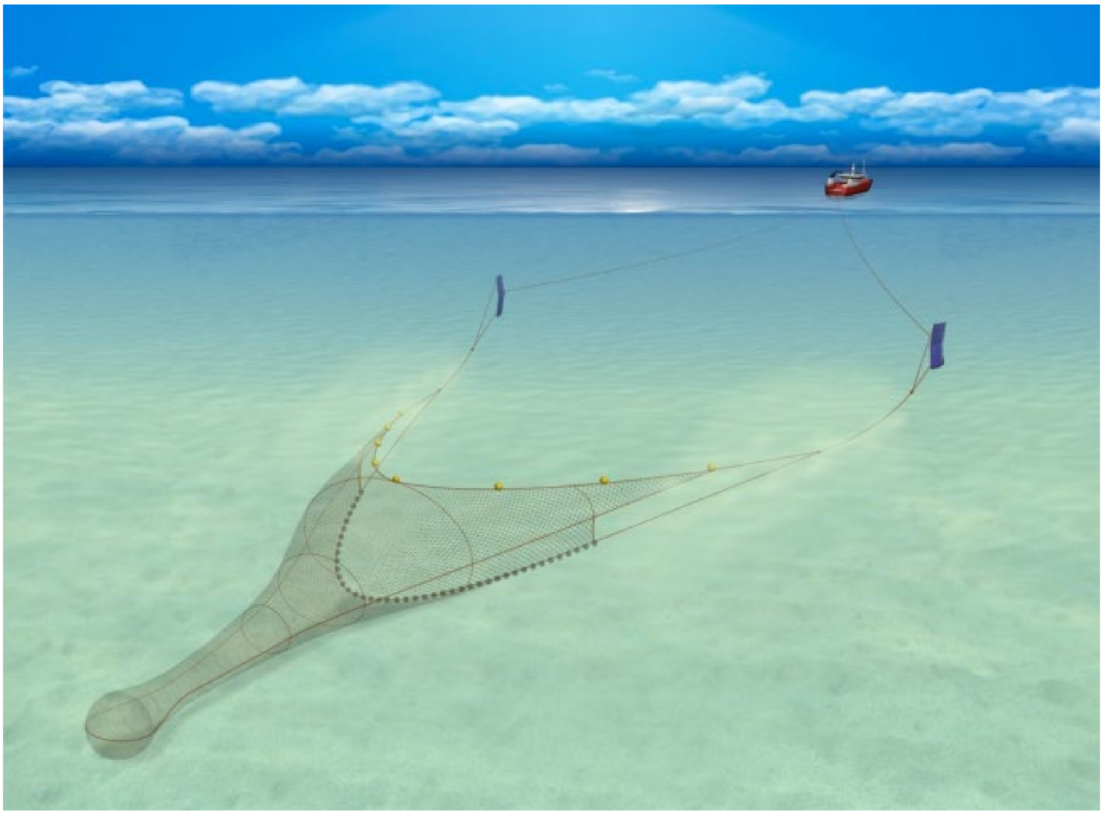
G.1 MAIN FISHING METHODS

The following provides information on the main types of fishing methods, operating patterns and vessels registered at ports in the proximity of the Project. It should be noted that no direct consultation with the fishing industry in respect of the cable route has been undertaken to collect data on fishing practices to inform this report. As such, the descriptions provided in the following sections are based on publicly available information and do not take account of feedback from the fishing industry on local practices.

G.1.1 Bottom-Otter Trawling

Bottom-otter trawling, **Figure G-1**, is the principal fishing gear used in the area, with Otter trawling consists of demersal trawling and the use of otter boards to maintain the opening of the net mouth (Seafish, 2022). Ropes, wires, bridles or sweeps are used to herd fish into the path of the net and allow a large area of seabed to be swept by the gear. Vessel speeds for active bottom trawling are roughly between 1 and 5 knots (NIRAS, 2022).

Figure G-1 Demersal Trawl Net on the Seabed (Seafish, 2022)



Bottom trawling has been ongoing in the Kattegat since early 1900 (Sköld, et al., 2018). The main target species of bottom-otter trawling in the proximity of Kattegat are Norway lobster, demersal fish, deep-water prawn, gadoid fish and flatfish (Sköld, et al., 2018; DTU, 2024). The fishery is dominated by otter trawling targeting Norway lobster, plaice, sole and cod and Denmark has the largest share of the Total Allowable Catch (TAC) of Norway lobster (Sköld, et al., 2018). A summary of otter trawling within the boundaries of the proposed Kattegat OWF is shown in **Table G-1**.

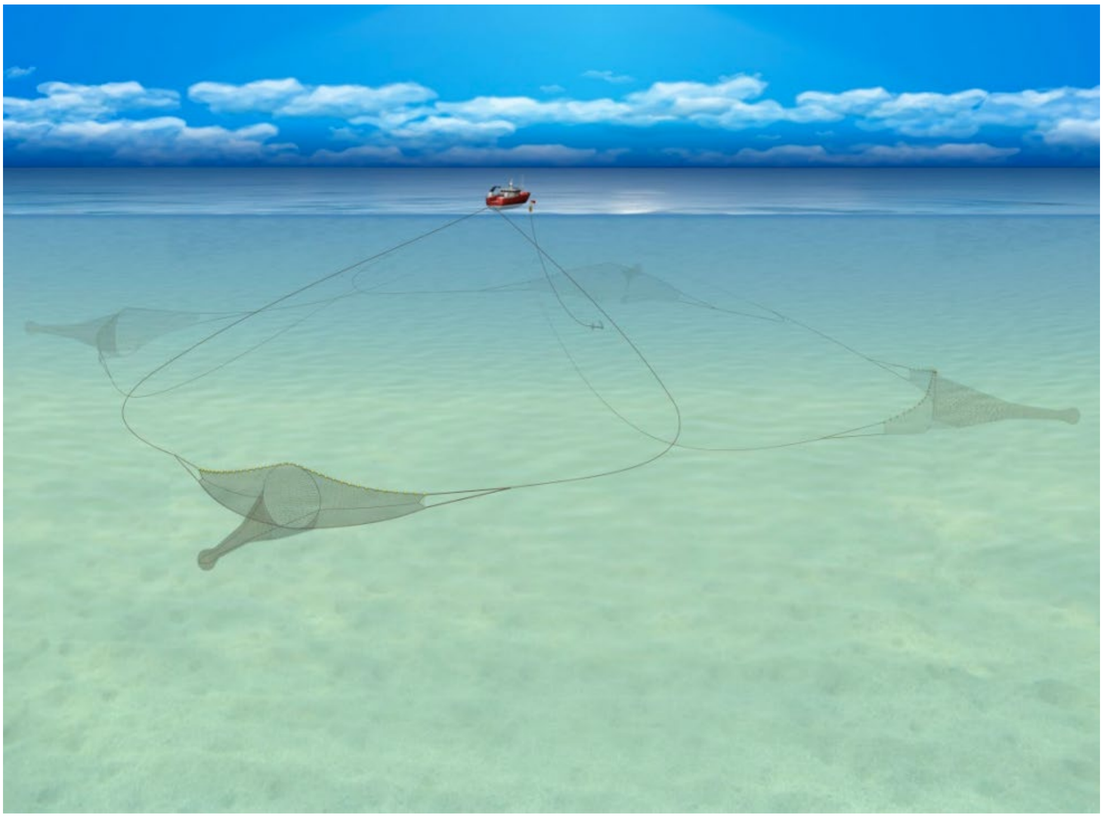
Table G-1 Fishing Activity Indicators within the proposed Kattegat OWF (DTU, 2024)

Year	Number of Vessels	Fishing Intensity (SAR)	Percentage Unfished Area (PUA)
2020	3	0.03	97%
2019	5	0.12	92%
2018	8	0.13	91%
2017	14	0.43	80%
2016	13	0.23	85%

G.1.2 Bottom Seines

Anchor seine, also known as Danish seine, fishing involves the use of long ropes on the seabed along with a circular net. When the ropes up, the movement herds demersal fish into the net (Seafish, 2022). Anchor seines vary to other seine gears due to the use of an anchor to moor the boat and the use of opposite end, to that of Scottish seines, of the seine net ropes upon collection. Anchor seine, shown in **Figure G-2**, originates in Denmark and mainly targets cod and plaice (DTU, 2024). Vessel speeds for active seine gears are roughly between 0.2 and 3 knots (NIRAS, 2022). Anchored seine net fishing is less prominent in the Kattegat than other gears, such as trawlers and gillnets and primarily targets cod and flatfish (NIRAS, 2022).

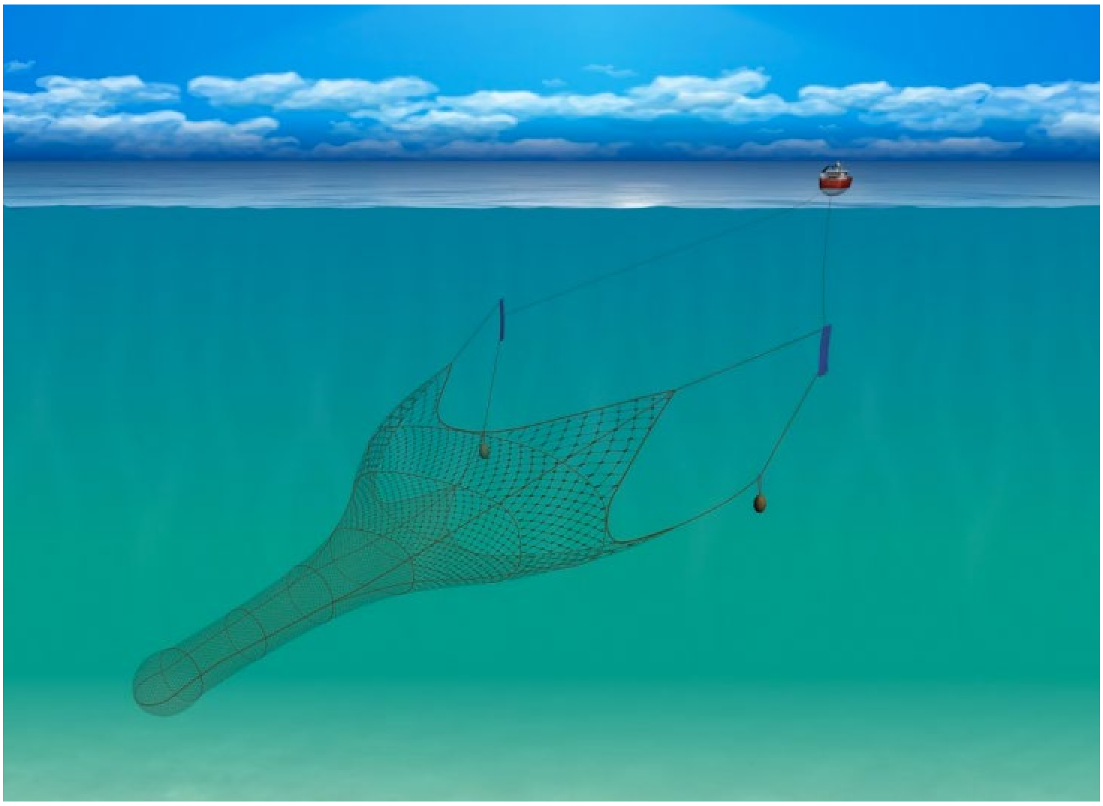
Figure G-2 Anchor Seining (Seafish, 2022)



G.1.3 Pelagic Trawls

Pelagic trawling, **Figure G-3**, involves trawling in mid-water in order to target shoaling fish species. Modern pelagic trawls consist of large meshes in the mouth and forward sections of the trawl, with four panels to enable a greater height than demersal trawling (Seafish, 2022). The mesh size of the net decreases as it gets closer to the cod-end of the trawl. Pelagic nets can be towed by two vessels, known as pair trawling, or by one vessel, known as single trawling. Vessel speeds for active pelagic trawling are roughly between 1 and 5 knots (NIRAS, 2022).

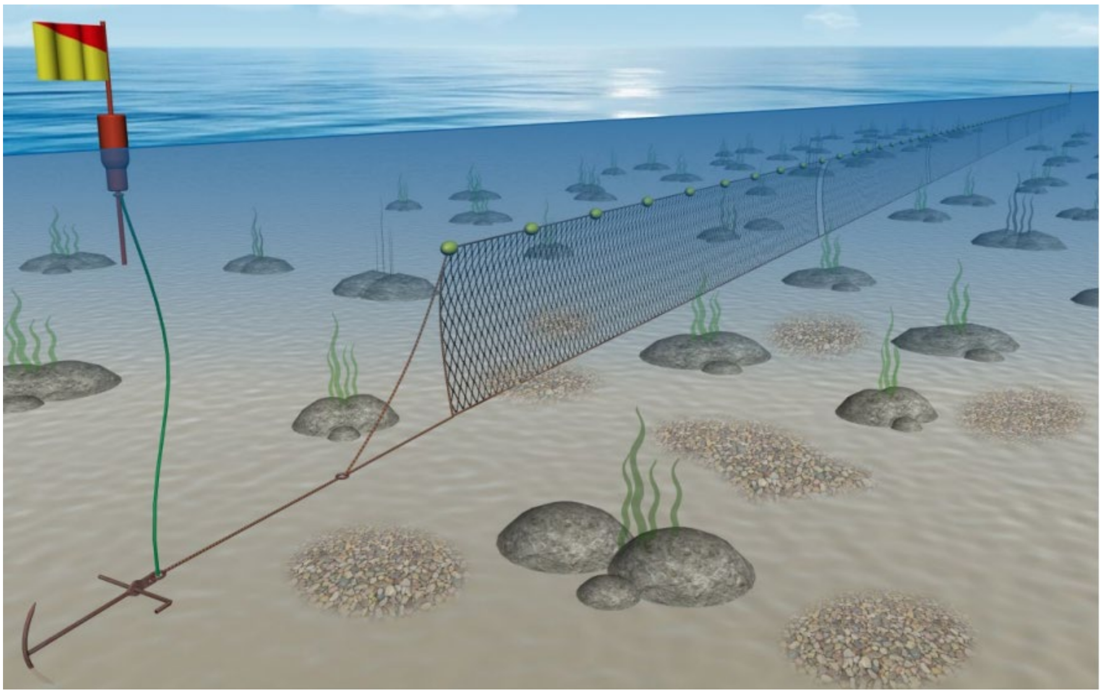
Figure G-3 Pelagic Single Trawling (Seafish, 2022)



G.1.4 Gill Nets

Gill net fisheries involve the use of passive gear consisting of panels of nets. Typically, gill nets are used along the bottom of the seafloor, as seen in **Figure G-4**, however can also be used in midwater. In the Kattegat, gill nets target flatfish, cod and lumpsuckers (NIRAS, 2022). Vessel speeds for gill net fishing are roughly between 0.4 and 5 knots (NIRAS, 2022).

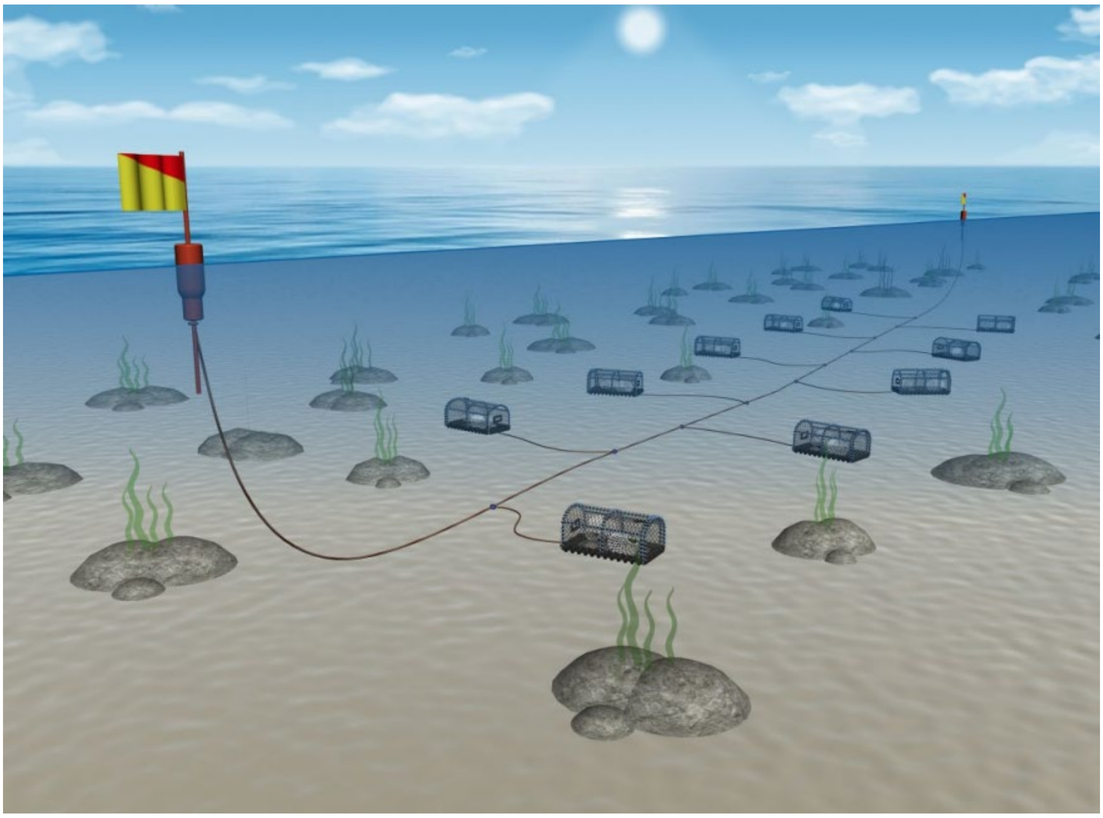
Figure G-4 Fleet of Gill Nets (Seafish, 2022)



G.1.5 Static Gear

Static gears such as pots, traps, hooks and line and fkye nets are also used in the Kattegat. In recent years the use of static gear has increased in Kattegat, mainly for shellfish and whelk fisheries (NIRAS, 2022). Whelk pots consist of plastic containers with a main entrance of which is near impossible to exit. Pots, as seen in **Figure G-5**, are mainly used to trap crabs and lobsters, including Nephrops. These static gears are often baited and left overnight (NIRAS, 2022; Seafish, 2022).

Figure G-5 Fleet of Pots (Seafish, 2022)



G.1.6 Danish Vessels

Total landings by Danish vessels has decreased in recent years (**Figure G-6)** and crustaceans and molluscs account for a large proportion of the catch by weight (**Figure G-7**).

Figure G-6 Total Fish Landings by Danish Vessels (Statistics Denmark, 2024)

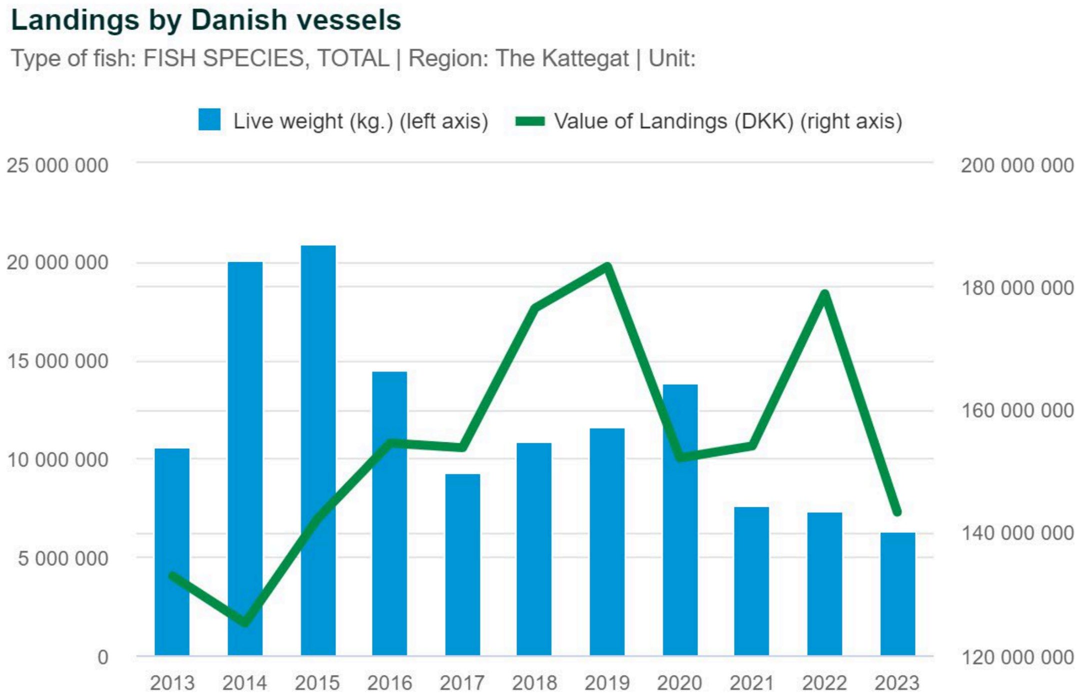
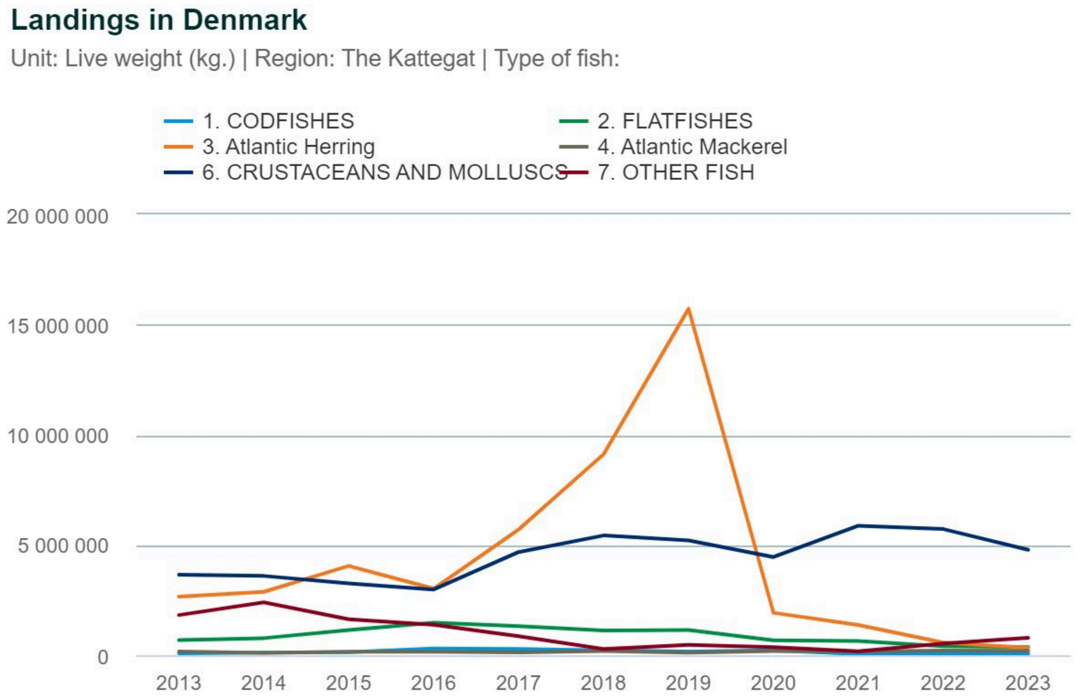


Figure G-7 Landings in Denmark for Various Fish (Statistics Denmark, 2024)



G.1.7 All Vessels

Catch data for Danish, German and Swedish vessels in the Kattegat is provided in **Table G-2** as annual Tonnes Live Weight (TLW) from 2017 to 2021 (ICES, 2023). As shown, pelagic fish such as Atlantic herring, European sprat, Atlantic mackerel, Atlantic cod and whiting account for a large proportion of the catch by weight. Demersal fish species, such as European plaice and common sole, as well as shellfish, such as Norway lobster, edible crab, blue mussels and whelk are also amongst the main target biota.

It should be noted that the catch data included above and in **Table G-2**, being for the whole Kattegat (ICES Area 27.3.a.21), may not be necessarily representative of the main species targeted in the exact area where the Project is located. Information on the principal species commercially exploited in the Kattegat has been reviewed ad is summarised in **Table G-3**.

Table G-2 IUCN Catch Data 2017 – 2021 (ICES, 2023)

Common Name	Latin Name	Tonnes Live Weight (TLW)				
		2021	2020	2019	2018	2017
Anglerfish	*Lophiidae*	0.0	0.8	0.0	0.0	0.0
Atlantic bluefin tuna	*Thunnus thynnus*	1.0	0.0	0.0	0.0	0.0
Atlantic bonito	*Sarda sarda*	0.0	0.0	0.0	0.0	1.0
Atlantic cod	*Gadus morhua*	25.7	69.7	82.3	207.8	283.8
Atlantic halibut	*Hippoglossus hippoglossus*	0.0	0.0	0.0	0.0	0.0
Atlantic herring	*Clupea harengus*	3054.9	3386.5	3227.0	7216.4	8336.6
Atlantic horse mackerel	*Trachurus trachurus*	1.7	4.2	1.2	5.6	11.1
Atlantic mackerel	*Scomber scombrus*	165.3	228.0	158.4	225.7	203.4
Atlantic salmon	*Salmo salar*	0.0	0.0	0.0	0.0	0.0
Atlantic searobins	*Prionotus spp*	0.0	0.0	0.0	0.0	0.0
Atlantic wolffish	*Anarhichas lupus*	0.0	0.0	0.0	0.0	0.5
Ballan wrasse	*Labrus bergylta*	0.0	0.0	0.0	0.0	0.0
Blonde ray	*Raja brachyura*	0.0	0.0	0.0	0.0	0.0
Blue mussel	*Mytilus edulis*	3777.0	2374.0	2639.0	2981.0	2818.0
Blue skate	*Raja batis*	1.0	0.0	0.0	0.0	0.0
Blue whiting	*Micromesistius poutassou*	0.0	0.0	0.0	0.1	0.0
Blue-leg swimcrab	*Liocarcinus depurator*	0.1	0.6	0.0	0.0	0.0
Brill	*Scophthalmus rhombus*	79.6	89.7	74.0	82.5	126.2
Catfish	*Anarhichas spp*	1.1	1.9	1.5	1.4	2.1
Cephalopods nei	*Cephalopoda*	8.0	6.0	1.0	8.0	4.0
Common dab	*Limanda limanda*	25.5	35.7	45.2	59.4	58.7
Common prawn	*Palaemon serratus*	6.0	10.0	19.0	14.0	30.0
Common sole	*Solea solea*	137.8	137.8	157.3	179.1	248.6
Common squids	*Loligo spp*	0.0	0.0	0.0	0.0	1.2

Common Name	Latin Name	Tonnes Live Weight (TLW)				
		2021	2020	2019	2018	2017
Cuckoo ray	*Raja naevus*	1.0	1.0	0.0	0.0	0.0
Cuckoo wrasse	*Labrus bimaculatus*	0.0	0.0	0.0	0.0	0.0
Cusk	*Brosme brosme*	0.0	0.0	0.0	0.0	0.0
Cuttlefishes nei	*Sepia spp*	0.0	0.0	0.0	0.0	0.0
Edible crab	*Cancer pagurus*	212.1	195.5	214.6	161.7	146.1
Eelpout	*Zoarces viviparus*	0.0	0.0	0.0	0.0	0.0
European anchovy	*Engraulis encrasicolus*	34.9	1.0	1.0	9.5	0.0
European eel	*Anguilla anguilla*	15.2	14.0	22.1	26.4	21.2
European flounder	*Platichthys flesus*	66.5	93.7	101.7	151.2	137.3
European flying squid	*Todarodes sagittatus*	0.0	0.0	0.0	0.0	0.0
European hake	*Merluccius merluccius*	12.5	10.6	7.5	8.3	11.2
European lobster	*Homarus gammarus*	7.9	10.4	8.6	3.8	4.0
European plaice	*Pleuronectes platessa*	216.5	329.1	365.7	531.4	796.2
European seabass	*Dicentrarchus labrax*	0.0	0.0	0.0	0.0	0.0
European sprat	*Sprattus sprattus*	792.8	8439.6	3680.6	2554.5	1163.9
European squid	*Loligo vulgaris*	0.0	0.0	0.0	3.0	0.0
Garfish	*Belone belone*	48.0	21.0	54.0	8.0	17.0
Gastropods	*Gastropoda*	0.0	2.0	12.0	0.0	0.0
Great Atlantic scallop	*Pecten maximus*	0.0	0.0	0.1	0.1	0.0
Greater weever	*Trachinus draco*	16.4	139.6	348.8	112.9	760.5
Greenland halibut	*Reinhardtius hippoglossoides*	0.0	0.0	0.0	0.0	0.0
Grey gurnard	*Eutrigla gurnardus*	1.6	1.6	5.1	4.4	6.6
Gurnards	*Triglidae*	0.0	0.0	0.0	0.0	0.0
Haddock	*Melanogrammus aeglefinus*	3.1	18.9	5.5	23.8	43.3
Harbour porpoise	*Phocoena phocoena*	0.0	0.0	0.0	0.0	0.0
Inshore squids	*Loliginidae*	0.4	0.6	0.1	1.3	0.0
John dory	*Zeus faber*	0.0	0.0	0.0	0.0	0.0
Lemon sole	*Microstomus kitt*	11.6	17.2	15.1	21.5	27.8

Common Name	Latin Name	Tonnes Live Weight (TLW)				
		2021	2020	2019	2018	2017
Ling	*Molva molva*	3.3	3.3	2.4	1.4	2.9
Long rough dab	*Hippoglossoides platessoides*	0.0	0.0	0.0	0.0	0.0
Lumpsucker	*Cyclopterus lumpus*	43.0	161.8	68.8	133.8	54.4
Marine crabs	*Brachyura*	6.0	3.1	5.0	6.0	10.0
Marine fishes	*Osteichthyes*	0.6	0.1	1.1	0.1	0.1
Monkfish	*Lophius piscatorius*	4.5	2.3	3.3	2.2	1.2
Mullets nei	*Mugilidae*	0.0	0.0	0.0	0.0	0.0
Northern pike	*Esox lucius*	0.0	0.0	0.0	0.0	0.0
Northern prawn	*Pandalus borealis*	36.5	73.8	13.1	6.0	20.7
Norway lobster	*Nephrops norvegicus*	2509.3	2530.7	3120.3	2886.0	2081.6
Norway pout	*Trisopterus esmarkii*	0.0	0.1	0.0	0.0	0.0
Octopus	*Octopodidae*	0.2	0.2	0.0	0.2	0.0
Pacific cupped oyster	*Crassostrea gigas*	0.0	0.0	2.0	0.0	0.0
Picked dogfish	*Squalus acanthias*	0.0	0.0	0.0	0.0	7.0
Pike-perch	*Sander lucioperca*	0.0	0.0	0.0	0.0	0.0
Pollack	*Pollachius pollachius*	0.1	4.8	1.2	2.8	7.4
Pollock	*Pollachius virens*	0.0	5.0	2.4	4.3	4.6
Poor cod	*Trisopterus minutus*	0.0	0.0	0.0	0.0	0.0
Rainbow trout	*Oncorhynchus mykiss*	0.0	0.0	0.0	0.0	0.0
Raja rays nei	*Raja spp*	0.0	1.0	1.0	2.0	2.1
Sailray	*Raja lintea*	1.0	0.0	0.0	0.0	0.0
Sandeel	*Ammodytes spp*	133.0	177.0	103.0	25.0	0.0
Sardine	*Sardina pilchardus*	1.0	0.0	0.0	0.0	0.0
Sea trout	*Salmo trutta*	0.1	0.2	0.1	0.1	0.1
Small-spotted catshark	*Scyliorhinus canicula*	0.0	0.0	0.0	0.0	0.0
Stone king crab	*Lithodes maja*	0.0	0.0	0.0	0.0	0.1
Subtruncate surf clam	*Spisula subtruncata*	0.0	0.0	0.0	0.0	0.3
Surmullet	*Mullus surmuletus*	0.0	0.0	0.0	0.0	0.0
Thicklip grey mullet	*Chelon labrosus*	0.0	0.0	0.0	0.0	0.0
Thornback ray	*Raja clavata*	0.0	0.0	0.0	0.0	0.0

Common Name	Latin Name	Tonnes Live Weight (TLW)				
		2021	**2020**	**2019**	**2018**	**2017**
Tope shark	*Galeorhinus galeus*	0.0	0.0	0.0	0.0	0.0
Tub gurnard	*Chelidonichthys lucerna*	4.0	2.0	0.0	1.0	1.0
Turbot	*Psetta maxima*	35.5	29.7	26.6	44.7	51.6
Various squid	*Loliginidae, Ommastrephidae*	0.0	0.8	0.0	0.0	0.0
Whelk	*Buccinum undatum*	74.0	69.2	81.0	184.1	204.0
Whiting	*Merlangius merlangus*	17.4	170.9	62.6	150.2	196.6
Witch flounder	*Glyptocephalus cynoglossus*	10.9	20.4	19.1	27.3	37.0

Table G-3 Information on Main Stocks Commercially Exploited in the Kattegat

Species	Habitat	Main Fishing Methods
Atlantic herring (*Clupea harengus*)	Pelagic fish found in seas to depths of 100m deep. The Kattegat remains on of the only areas with high concentrations for all age groups (ICES, 2024).	Mainly caught using trawling (mid-water, pair and otter trawls) (ICES, 2024).
Blue mussel (*Mytilus edulis*)	Found of hard substratum and in sandy mud from intertidal habitats to 5m (Tyler-Walters, 2008).	Farming in the form of long-line and smart farming (Marine Stewardship Council, 2024a).
European sprat (*Sprattus sprattus*)	Pelagic fish found largely up to 50 depth and in inshore waters. Most abundant in the Kattegat and North Sea (ICES, 2024).	Small-meshed trawling gear (ICES, 2024).
Norway lobster (*Nephrops norvegicus*)	Found in burrows in soft sediment mainly between 200 and 800m (Hill & Sabatini, 2008).	Bottom otter trawling (single, twin or pai) (Marine Stewardship Council, 2024b).
European plaice (*Pleuronectes platessa*)	Demersal flatfish found in areas of sandy sediments between 0 and 200m (ICES, 2024).	Beam trawling, Danish seines and gillnets. A by-catch in otter trawl fisheries (ICES, 2024).
Atlantic mackerel *(Scomber scombrus*)	Pelagic fish found in depths less than 200m (ICES, 2024).	Pelagic trawling (ICES, 2024),
Edible crab (*Cancer pagurus*)	Found on bedrock, boulders, coarse found and muddy sand to about 100m (Neal & Wilson, 2008).	Static gears close to shore but also offshore on the banks in Kattegat (Ungfors, 2008).

Species	Habitat	Main Fishing Methods
Atlantic cod (*Gadus morhua*)	Demersal fish, pelagic when juvenile, found in a variety of habitats up to 200m (ICES, 2024).	Mainly targeted by demersal trawl and gill net, however may be caught in virtually all demersal and pelagic fishing gears sometimes as by-catch (ICES, 2024).
Common sole (*Solea solea*)	Demersal fish found in sandy or muddy bottoms and largely restricted to water under 50m deep. Catch in Kattegat is dominated by 2 year old fish (ICES, 2024).	Requires heavy gear to be chased out and caught in trawls such as gill nets, beam trawlers and otter trawlers (ICES, 2024).
Whiting (*Merlangius merlangus*)	Pelagic fish commonly found in depths from 10 to 200m. Frequently found near the seafloor but also in midwater to pursue prey (ICES, 2024).	Caught in mixed trawl fisheries (ICES, 2024).
Whelk (*Buccinum undatum*)	Mainly subtidal down to 1200 and found on muddy sand, gravel and rock (Ager, 2008).	There is a significant fishery, which uses traps (Ager, 2008).

G.1.8 Applicable Law Regulating Fishing Activities

There are several No-Take Zones (NTZs) in the Kattegat. In 2009, a 464km2 year-round NTZ was establish surrounded by a 2600km2 partially protected area (PPA) (Bergström, et al., 2022). The total catches of Norway lobster and flatfish in this area have been maintained, however with substantially less bycatches of cod (Bergström, et al., 2016). Fishing is prohibited in the northern area (PPA-North) between January and March as this is the spawning period for cod. Selective fishing gear is permitted the rest of the year. Fishing is permitted all year round in the western area (PPA-West), however selective gear must be used between January and March. The same premises prevail in the southern area (PPA-South), however the period is February to March. The Surface Swept Area Ratio estimates (SAR) defines the swept area as the cumulative area contacted by bottom trawlers within a grid cell over one year. The SAR here is from ICES 2017-2020 data and averaged per year.

Two additional small NTZ's were establish at Vinga, Sweden in 2003. These are Tanneskar and Buskar of which are 1.2km2 and 3.2km2 respectively (Bergström, et al., 2022).

The proposed Kattegat OWF is situated in close proximity to several areas that are OSPAR MPA's and Natura 2000 sites. Schultz og Hastens Grund samt Briseis Flak is located directly next to the proposed OWF (EMODnet, 2024). In 2017, fisheries regulation was introduced to protect the reef areas from bottom-dragging fishing (The Danish Environmental Protection Agency, 2017). Bottom-dragging gear fishing continues on a small part of one reef. Two other MPA's/Natura 2000, Kobberhage kystarealer and Ålborg Bugt østlige del, are located within 30km of the cable corridor however no fisheries regulations are in place (Oceana, 2018). In 2022, a set of conservation measures protecting several Natura 2000 sites located in the Kattegat was adopted. This is reported to concern six MSFD areas and one Natura 2000 areas, as shown in **Figure G-8**, however official documentation has not been released (European Commission, 2022).

Figure G-8 MSFD and Natura 2000 sites in the Kattegat (European Commission, 2022)