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Navigational Risk Assessment Kattegat

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Environmental engineering consultancy services. The objective of the project is to perform marine environmental studies in order to describe the baseline conditions for offshore wind farms in the areas of Hesselø, Kriegers Flak II (North and South) and Kattegat in the Danish sector. The present report addresses the Navigational Risk Assessment for Kattegat Offshore Wind Farm.

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1 EXECUTIVE SUMMARY

1.1 Conclusions

On the basis of both quantitative study and the HAZID workshop the following conclusions by this study are:

- The construction and operation of the Kattegat offshore wind farm (KA OWF) leads to a noticeable increase in the expected number of allisions between ships and wind turbines. This is mainly related to vessels that intend to cross the OWF and may amount up to on average 1 incident per 100 years. For (commercial) ships that remain within the fairways outside the OWF, the frequency is estimated to be a factor of three lower. Such risk is acceptable if reduced to as low as reasonably practicable.
- The construction and operation of the KA OWF does not lead to a significant larger number of groundings in the area (less than 1%).
- The construction and operation of the KA OWF offshore wind farm leads to a noticeable increase in risk of ship/ship collisions, notably on the section of route "T" between Sjællands Rev and the crossing with the route between Grenaa and Halmstad. The increase in the number of expected ship-ship collisions due to KA OWF is between 6 and 7 per 1000 years. Such risk is acceptable if reduced to as low as reasonably practicable.
- The cumulative effect of KA OWF together with HES OWF (HES OWF is a planned OWF at a short distance (5 nautical miles) east of KA OWF) will be that the additional allision frequency becomes 1.6 incidents per 100 years and, in a worst case, additional collision risk may become close to 2 per 100 years.

1.2 Recommendations

On the basis of the studies, the following risk-reducing measures are proposed:

1. Eastbound ships or ferries from Grenaa to Halmstad should pass the KA OWF 1.5 NM north of the northernmost corner of the OWF to avoid masking of northbound ships east of (or departing from) the OWF. Investigate to provide additional marking (e.g. using RACON of the northern-most corner of KA OWF).
2. Ensure sufficient separation between ships and ferries heading east and west between Grenaa and Halmstad north of KA OWF to minimize the risk of collision.
3. Perform a detailed assessment of the navigational safety for the approach to Grenaa harbour, considering construction vessels, CTVs servicing Anholt OWF and (potentially) KA OWF and/or HES OWF, and other vessels (ferries) frequenting the harbour once details on construction and operation are known. Establish Work Vessel Coordination during construction, avoiding work traffic in leaving or entering the port during arrival and departure of ferries.
4. Ensure emergency response to stop WTGs when a drifting or uncontrolled ship threatens to collide with an OWF structure.
5. Investigate the need to establish additional coast-based Radar stations or AIS base-stations.
6. Avoid constructing and/or servicing KA OWF from a harbour that requires work vessels or CTVs, respectively, to cross route "T".
7. Investigate to mark all individual WTGs by beacons instead of only marking the perimeter of the OWF.
8. Consider the use of surveillance vessels to enforce the compliance with the prohibited work areas during the Construction Phase and to protect cable-laying vessels when crossing route "C".

9. Consider locating additional beacons (physically or as virtual AIS Aids to Navigation) along route “T” to mark the restricted construction zone outside the KA OWF perimeter during construction.
10. Exploit all possible communication channels to inform recreational sailors and fishermen about prohibited work areas and other temporary restrictions or arrangements.
11. Consider during construction to establish Work Vessel Co-ordination with all ship traffic close to KA OWF.
12. Consider to reserve or assign specific VHF channels for communication between work vessels, service vessels and Work Vessel Coordination.
13. Consider establishing dedicated corridors for work vessels from/to KA OWF.

2 INTRODUCTION

In order to accelerate the expansion of Danish offshore wind production, it was decided with the agreement on the Finance Act for 2022 to offer an additional 2 GW of offshore wind for establishment before the end of 2030. In addition, the parties behind the Climate Agreement on Green Power and Heat 2022 of 25 June 2022 (hereinafter Climate Agreement 2022) decided), that areas that can accommodate an additional 4 GW of offshore wind must be offered for establishment before the end of 2030. Most recently, a political agreement was concluded on 30 May 2023, which establishes the framework for the Climate Agreement 2022 with the development of 9 GW of offshore wind, which potentially can be increased to 14 GW or more if the concession winners – i.e. the tenderers who will set up the offshore wind turbines – use the freedom included in the agreement to establish capacity in addition to the tendered minimum capacity of 1 GW per tendered area.

In order to enable the realization of the political agreements on significantly more energy production from offshore wind before the end of 2030, the Danish Energy Agency has drawn up a plan for the establishment of offshore wind farms in three areas in the North Sea, the Kattegat and the Baltic Sea respectively.

The area for Kattegat Offshore Wind Farm (OWF) is located in Kattegat, approximately 20 kilometer east of Djursland and approximately 30 kilometers north of Zealand. The area for the OWF is approximately 122 km^2. The Kattegat OWF will be connected to land via subsea cables making landfall close to Grenaa.

Energinet has been requested by the Danish Energy Agency to perform a number of preliminary investigations for the planned Kattegat OWF east of Grenaa. As part of the studies, a navigational risk assessment shall be carried out.

This report presents the results of the quantitative navigational risk assessment. Prior to the quantitative analysis, a hazard identification workshop was held in November 2023. The overall approach for the navigational risk assessment follows hereby IMO's (International Maritime Organization) guidelines for evaluation of navigational safety assessment /6/.

In principle, a stepwise approach needs to be adopted meaning that results are presented after each step and evaluated together with the Danish Maritime Authority (DMA, Søfartsstyrelsen) whether the next step needs to be executed:

- Step 1: A frequency analysis based on ship traffic and proposed offshore wind farm layout is executed and results are presented to the Danish Maritime Authority.
- Step 2: If the Danish Maritime Authority does not find it possible to conclude from the results of the frequency analysis that the navigational risks will be acceptable, a consequence analysis must be executed and combined with the frequency results. The navigational risk assessment will then be updated with the resulting risk derived by combining the frequency and the consequence analyses.
- Step 3: If the Danish Maritime Authority cannot approve the estimated risk, possible risk reducing measures have to be identified, analysed, and adopted if considered feasible. This risk reduction process must continue until the risk reaches an acceptable level. Otherwise, it has to be concluded that the project will not be feasible when required to be associated with an acceptable ship collision risk.

This report presents the results of Step 1 for Kriegers Flak II North and South, applying the preliminary layout with the largest number of wind turbine, which would lead to the largest risk of allisions.

The HAZID workshop (the HAZID report is attached as Appendix A to this report) is to be considered as an integrated part of this study. The results of the HAZID are transferred into the frequency analysis and addressed in the conclusions. Risk assessments from the HAZID are updated to the extent that this is possible within the frequency analysis.

An issue mentioned during the HAZID workshop is the impact of the wind turbine structures on the radar, both ship based radar and the coastal Radar stations used for Vessel Traffic Service (VTS). This issue requires a separate assessment and is beyond the scope of this study.

2.1 Objectives

The purpose of the work package on maritime traffic and safety of navigation is to provide a description and mapping of the existing ship traffic in and around the offshore wind farm and based on this to undertake a navigational safety and risk assessment.

The navigational risk assessment will, to the extent applicable for this study, IMO's guidelines for Formal Safety Assessment (FSA) /6/, particularly step 1, Identification of hazards, and step 2, risk analysis. This will lead to recommendations, including proposals for risk reducing measures as covered by IMO's FSA step 3, but without full re-analysis or a Cost Benefit Analysis (CBA).

The main questions to be answered by the navigational risk assessment are:

- Does the offshore wind farm (OWF) lead to an unacceptable number of collisions between ships and wind turbines?
- Does the rearrangement of the shipping lead to an increased and intolerable number of groundings?
- Does the rearrangement of the shipping, including additional shipping in relation to construction and operation (maintenance) of the OWF lead to an increased and intolerable number of collisions between ships?

2.2 Limitations

The method to predict the frequency of allisions, collisions and groundings of ships is based on a probabilistic analysis. This is described in more detail in the model description in section 5.1. It shall be pointed out that the different scenarios to be analysed (the condition before establishment of the OWF and the condition after establishment of the OWF) is based on 1) the additional number of obstacles close to the shipping routes (the wind turbines) and 2) the redistribution of traffic routes in terms of number, width (lateral distribution), traffic density and waypoints. The probability of navigators not being able to avoid accidents in potentially hazardous situations is assumed not to be changed in the course of the assessments. But the OWF may have an effect on this probability (e.g. as identified during the HAZID). The probabilistic analysis does not account for these effects, neither positive nor negative. Such ignored effects are, but may not be limited to:

- The effects of the OWF on the situational awareness of navigators (e.g. the possibility of becoming confused or not expecting vessels to sail between the OWF structures).
- The effects of the OWF on the effectiveness of ship-based radar.
- The effect of an extension of, or changes in, coast-based traffic coordination (VTS, Work Vessel Coordination).
- The effect of surveillance ships or warnings issued by work vessels.
- The effect of additional navigational aids (buoys, virtual AIS).
- "Secondary" consequences, e.g. allisions with objects outside narrow fairways after performing evasive action to avoid collision.

As a consequence, this means that the probabilistic analysis cannot demonstrate the effectiveness of certain preventive measures, e.g. Work Vessel Coordination. It can only indicate that there may be waypoints (locations where fairways cross each other, merge, or change direction) with an increased risk of collision between crossing traffic, where such coordination may seem beneficial based on a qualitative assessment.

2.3 Abbreviations

AIS	Automatic Identification System	An AIS system transmits repeatedly the object's (e.g. a ship's) identification (MMSI), position, speed, direction, and other information via a VHF-radio transponder, to be used as a navigation and anti-collision tool, making the information visible to other ships and VTS. AIS is obligatory for ships over 300 gross tonnage, all passenger ships and for fishing vessels over 15 m. These ships require a "class A" transponder. AIS is voluntary for other ships that may use a "class B" transponder.
CTV	Crew Transfer Vessel	Vessels used to transfer service personnel to OWF installations. Most CTV's are classified as High Speed Craft (HSC)
DEA	Danish Energy Agency (Energistyrelsen, ENS)	
DMA	Danish Maritime Authority (Søfartsstyrelsen, SFS)	
EC	Export Cable	
ECC	Export Cable Corridors	
EIA	Environmental Impact Assessment (Vurdering af Virkning på Miljø, VVM)	Environmental Impact Assessment is a process of evaluating the expected environmental impacts of a proposed project or development, considering inter-related socio-economic, cultural, and human-health impacts, both beneficial and adverse. EIA is mandatory for certain projects according to national and EU-legislation.
EPA	Environmental Protection Agency (Miljøstyrelsen, MST)	
FSA	Formal Safety Assessment	Methodology for performing risk assessments. Within this report addressing the method following the IMO Guideline /6/
GIS	Geographical Information System	Digital system to represent data linked to a geographical position such as objects in maps. IWRAP allows to import data (e.g., location of structures) in GIS format.
HAZID	Hazard Identification	Method (typically using a workshop session with stakeholders) to identify possible hazards and risk for some activity.
HES OWF	Hesselø Offshore Wind Farm	
HSC	High Speed Craft	Includes fast ferries and most CTV-s are classified as HSC

IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities	
IDW	Inner Danish Waters	The three offshore wind farm projects: Kattegat, Hesselø and Kriegers Flak II (North and South)
IMO; IMO number	International Maritime Organization	The IMO ship identification number is a unique seven-digit number that is assigned to propelled, sea-going merchant ships of 100 GT and above upon keel laying except for: • Ships without mechanical means of propulsion • Pleasure yachts • Ships engaged on special service (e.g. lightships, SAR vessels) • Hopper barges • Hydrofoils, air cushion vehicles • Floating docks and structures classified in an analogous manner • Ships of war and troopships • Wooden ships
IWRAP	IALA Waterway Risk Assessment Program	IWRAP is a modelling tool useful for maritime risk assessment. IWRAP assist to estimate the frequency of collisions and groundings in each waterway based on information about traffic volume/composition, route geometry and bathymetry.
KA OWF	Kattegat Offshore Wind Farm	
KF II OWF	Kriegers Flak II Offshore Wind Farm (North and South)	
Landfall	Is where the cable transfers from sea to land	
MMSI	Maritime Mobile Service Identity	A Maritime Mobile Service Identity (MMSI) is a series of nine digits which are sent in digital form over a radio frequency channel to uniquely identify ship stations, ship earth stations, coast stations, coast earth stations, and group calls.
MSL	Mean Sea Level	
MSP	Marine Spatial Plan (Havplanen)	
NS1	North Sea I	The name of the offshore wind farm area (OWF) including all three subareas and the shipping corridors in between the three subareas
OSS	Offshore substation	Offshore structure (often a platform structure) collecting power connection from the individual wind turbines in an OWF, using a step-up transformer to enable a high voltage export of power to the coast.

OWF	Offshore Wind Farm (Offshore vindmøllepark)	
PA	Pre-investigation area	Gross area for the benthic survey. Within the pre-investigation area are the three wind farm areas (1-3), the three export cable routes (ERC's) and the shipping corridors between the three OFW areas.
Subareas		The wind farm area is subdivided into three subareas 1-3
TSS	Traffic Separation Scheme	A traffic separation scheme is a maritime traffic-management route-system ruled by IMO. It consists of two (outer) lines, two lanes with prescribed (opposite) sailing direction, and a separation zone in-between.
VMS	Vessel Monitoring System	Vessel Monitoring Systems (VMS) is a general term to describe systems that are used in commercial fishing to allow environmental and fisheries regulatory organizations to track and monitor the activities of fishing vessels. In Denmark VMS is based on Inmarsat-C transceivers and is obligatory for commercial fishing vessels over 12 m.
VTS	Vessel Traffic Service	Land-based service to assist navigation, typically in busy waters. In Danish waters, VTS is provided by the Danish Navy's Surveillance Unit (Søværnets Overvågningsenhed)
WTG	Wind Turbine Generator	

3 PROJECT DESCRIPTION

3.1 Description of area

The Kattegat OWF is marked yellow in Figure 1. The red area is the existing Anholt OWF and the green areas are the planned OWFs (Hesselø OWF and Kattegat Syd OWF west of the Swedish coast. /7//8//9/.

Cumulative effects of the OWFs have been taken into account during the HAZID workshop (Appendix D) and the future planned wind farms are therefore marked in Figure 1 /7/. This concerns Hesselø OWF. There are other planned parks with a greater distance to Kattegat OWF, notably west of the Swedish coast, where no cumulative effects are expected.

The most important shipping routes are marked in Figure 2. The intensity of traffic is derived from AIS registrations for 2022 which are made available via the Danish Maritime Authority (see section 4.3).

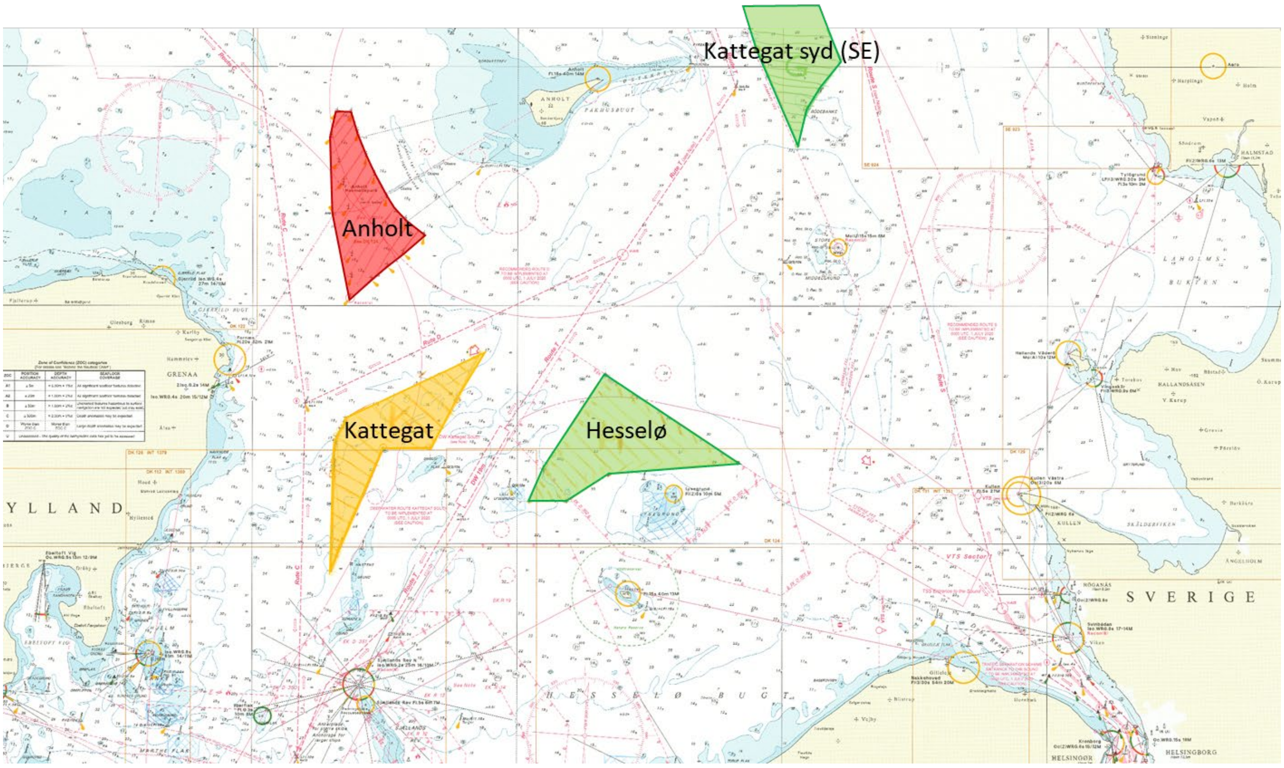

Figure 1 Position of the planned Kattegat OWF. The yellow area is analysed within this report, the red area is the existing Anholt OWF and green areas are future planned OWFs.

The area includes several marked routes for ships in transit /10/,/11/. Route "T" leads through the Storebælt to Skagerrak east of Anholt; Route S leads through Øresund to Skagerrak and meets route "T" east of Læsø. Route C leads from the Storebælt to the east coast of North Jutland past Grenaa and west of Læsø. Route D leads from the pilot meeting point east of Grenaa to route "T" in the direction of Anholt. The AIS registration shows that many ships sail directly from Grenaa to the beacon east of Anholt (i.e. they keep north of route D), while ships with greater draft (14-15 m) prefer to keep approx. 3 to 4 nautical miles south of route D, where there is greater depth, marked with an asterisk in Figure 2 (information received from DanPilot).

As part of route "T", there is a deep-water route in the middle between HES OWF and KA OWF, where ships with less draught (up to 10 m) keep to either side. In Øresund, there are several traffic separation zones (TSS), and traffic in Øresund is controlled by VTS (Vessel Traffic Service) "Soundrep", just like in Storebælt (VTS area "Beltrep"), where commercial vessels over 300 tons are required to report /10//11/.

There are also the ferry routes Grenaa-Anholt (typically one departure per day) and Grenaa-Halmstad (typically one or two departures per day). Both routes are north of HES OWF and will not be affected directly.

In the Marine Spatial Plan (MSP, Havplanen) for Danish waters some sea areas have been designated for other uses (extraction areas, landfill, aquaculture, fishing, etc.). At present, version 1.1 of the "Havplanen" is in consultation. The areas are therefore identified based on available charts. From this, areas have been identified which are, or can be used, as extraction areas. Most extraction areas indicated on charts of the Kattegat are within "Natura 2000" areas and are therefore no longer in use. The extraction area at Lille Lysegrund (570-BA) could be relevant (marked in Figure 2), but the AIS registration for 2022 does not show local ship movements that can be related to extraction, nor are there any current permits. The possibility of extraction expires at the end of 2025, just like for Lysegrund Syd (530-BA) and Lysegrund Sydøst (530-DA) /10/.

North of Sjælland, there are several of the Danish military training and shooting ranges. They stretch from the coast of Sjællands Odde and east of route "T" up to the southern border of the area designated for HES OWF, see Figure 2. The north-easternmost shooting area is "EK R 22 Hesselø Bugt". This area borders to the west to "EK R 19 MULTEX". The present layout has been defined by chart corrections issued October 2022 /16/, prior to this date there was a corridor between EK R 19 and the shooting ranges further north and east. There are several areas, all covered by the largest area "EK R 19 MULTEX" /10/. When drills or firing have been announced by navigational warnings, ship traffic will navigate around these areas. The Danish Defense Command has informed that EK R 22 will not be used for military exercises due to other local restrictions /18/.

Anholt OWF is serviced from Grenaa. This is visible in AIS registrations for passenger ships in Appendix B (service vessels are under AIS registered as passenger ships).

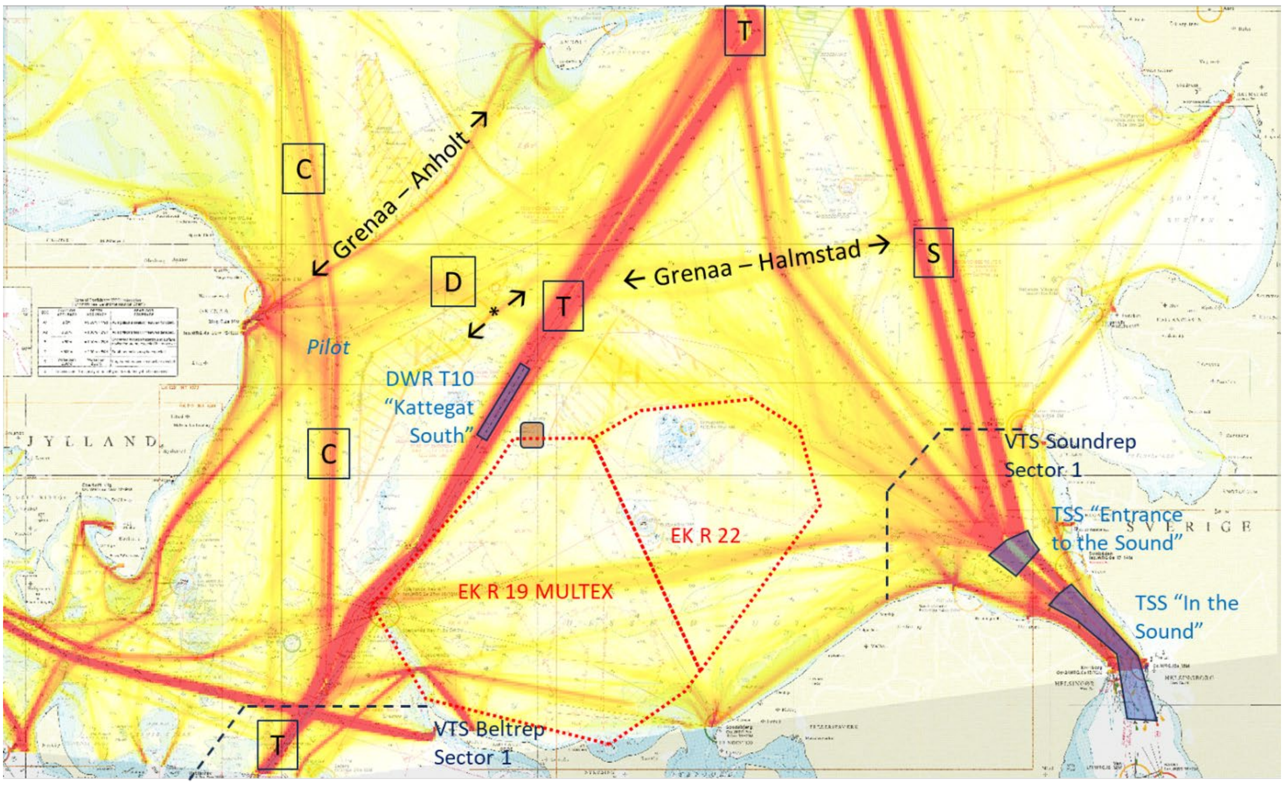

Figure 2 Traffic patterns based on AIS data and the most important ship and ferry routes. Blue with black outline marks Traffic Separation Zones (TSS) and Deep-Water Route (DWR); VTS areas are marked with black broken line, military shooting ranges are indicated by red dotted line. Extraction areas are marked with brown /10//11//12/, "pilot" refers to a pilot meeting point, the asterisk points at a narrow channel that can be navigated by (relatively) deep ships

3.2 Location of existing offshore wind turbine generators

The locations of the WTGs in the existing Danish OWFs are obtained from DEA /14/. This covers the existing Anholt OWF. The positions are listed in Appendix B.

For the sake of the allision analysis, the single positions are transferred to small hexagons with a radius of 13 m (distance between opposite corners) at sea level.

3.3 Wind turbine generator locations for Kattegat OWF

At present, the exact locations of the WTGs in the KA OWF area are not decided, but various alternative scenarios for WTG locations have been provided by Energinet to support the pre-investigations /8/. For the present navigational risk assessment, the "scenario Over Planting" is used, because the largest number of WTGs will pose the largest risk of allision, see Figure 3.

For the sake of allision analysis, the single positions are transferred to small hexagons with a radius of 13 m (distance between opposite corners) at sea level.

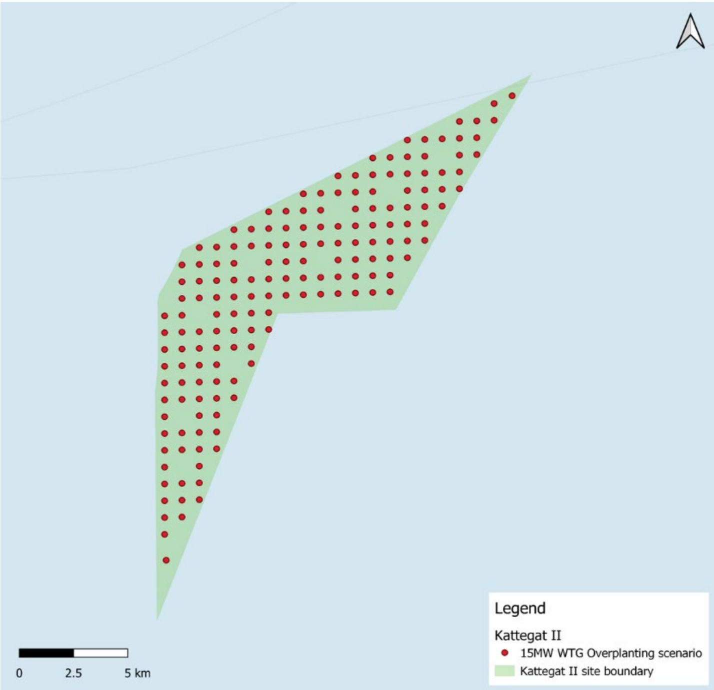

Figure 3 Kattegat OWF, scenario Over Planting, 164 WTGs /9/. Size of WTGs are not to scale.

3.4 Bathymetry

Bathymetry for Kattegat has been obtained from the BALANCE project /13/. Bathymetry is available as a raster set with a resolution of 200 m horizontal and 1 m vertical. Data has been transferred to a vector format to be imported into the IWRAP model. Only bathymetry down to 46 m depth has been imported (no ships with such draught are expected, and effectiveness of emergency anchoring to avoid drifting will not be significantly worse if larger depth would have been included), see Figure 4.

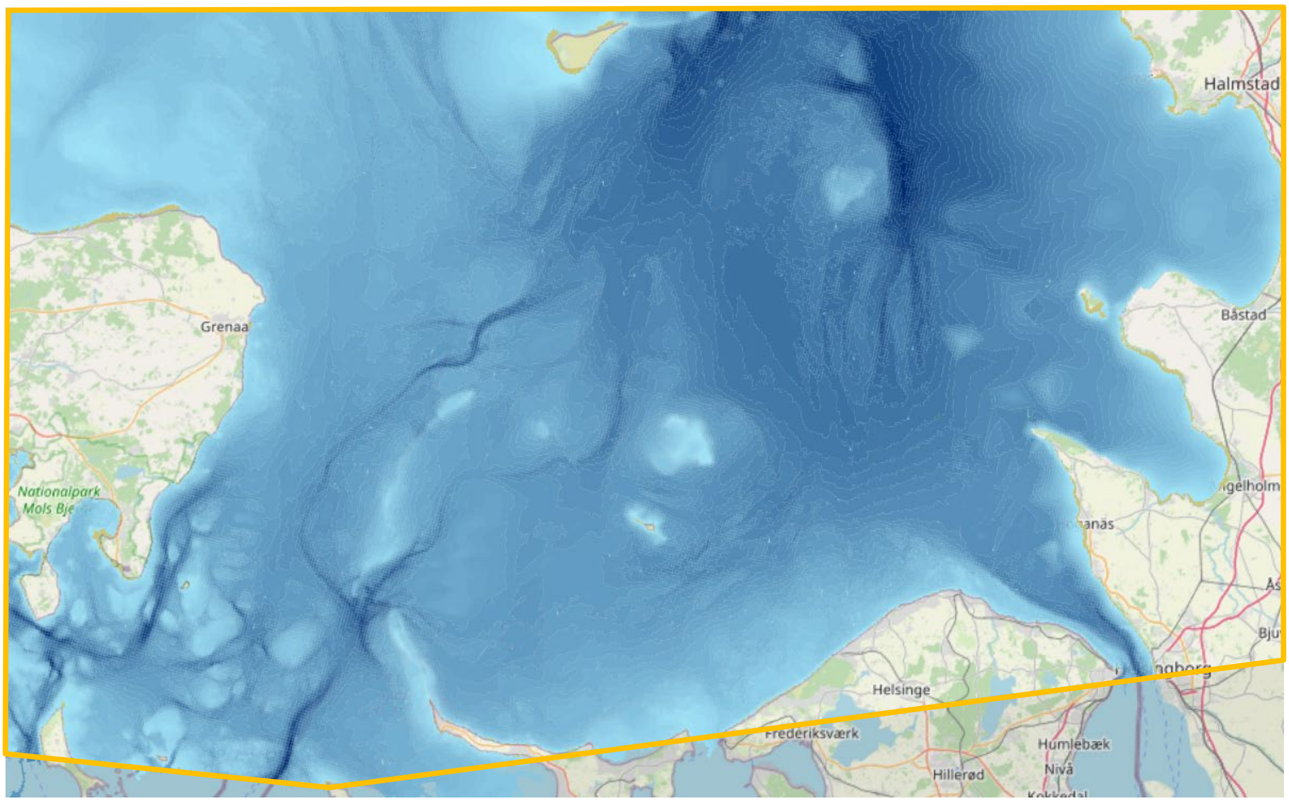

Figure 4 Bathymetry of Kattegat within study area (marked by an orange line). Lightest blue: depth 1 m; darkest blue: depth 46 m; interval 1 m. Olive green: less than 1 m (effectively 0).

3.5 Wind direction

The IWRAP software requires input concerning the frequency of drift directions. Drift direction frequency is assumed to be the same as the wind direction frequency, see Assumption C.2, Appendix C.

4 SHIP TRAFFIC DATA

4.1 Ship data collection (AIS)

The ship traffic is determined from the historical AIS data available at DMA /1/, using all data (twelve months) for 2022. The AIS data handled in the analysis is within the following geographic bounds (the model area):

- Northerly bound: 56°45.193'N (north of Anholt)
- Westerly bound: 10°26.623'E (Kaløvig)
- Easterly bound: 12°56.761'E (Swedish coast at Laholm)
- The southern boundary is cut off through the locations 56°03.655'N, 12°56.761'E (south-east corner), 55°55.154'N, 11°04.885'E (Sejerø Lighthouse) and 55°56.983'N, 10°26.623'E (Tunø By)

The model area is shown in Figure 2 (the area within the slightly darker margin). The area is chosen so that all relevant shipping that could reasonably interact with the HES OWF and/or KA OWF (by drifting or on erroneous course) is included.

The AIS data consists of records for each transmitted AIS message. Before uploading the AIS data into the IWRAP tool, the messages have been pre-processed to select the following ships and ship positions:

- MMSI number of nine digits starts with integer between 2 and 7 (i.e., only ship-related stations are included);
- Position is within the above boundaries;
- Speed Over Ground (SOG) is between 0.8 and 100 m/s;
- Navigational status is neither "At anchor" nor "Moored" nor "Aground";

Furthermore, records were adjusted to enable proper classification of ships in the IWRAP tool. If the transponder is Class B or ship type is "Pleasure", and if the ship length unknown (empty data field) then the ship length is set at 15 m and width at 4 m. This allows identification of the unknown ship types after being imported in IWRAP. Unknown ship types will be assigned "Other Ships" in IWRAP, and unknown ship length is default assigned to 50 m. Class B transponders are limited to pleasure vessels and fishing vessels. IWRAP does not read the transponder class, but by selecting unknown ships with 15 m length, ships that are likely to be pleasure vessels can be identified.

4.2 Ship types

When importing AIS data, the IWRAP software assigns the ship type to the data available in the AIS message. The data obtained from DMA does not contain ship types for all AIS messages (ship type "undefined"). IWRAP maps this to the category "Other ship." IWRAP applies ship categories (types) as in Table 1.

Ships are assigned to length classes of 25 m each (so 0-25 m, 25-50 m, 50-75 m, etc.) up to 400 m, or longer than 400 m.

The category "Other ship" is attempted to be minimized. For ships with IMO number, the ship type is assigned by:

- Applying data from a list issued by Lloyds, a list which was used for the previous risk assessments, updated up to 2015
- Applying data from SeaWeb (IHS Markit, 2021) to the remaining "other ships"

For the remaining "Other Ships", and ships without IMO number (e.g., naval vessels), data has been added manually using data from MarineTraffic (MarineTraffic, 2021). Such manual editing has been performed for all ships that have at least one trip in the model area.

The AIS data analysis leads to identification of 13953 unique ships performing 139604 single trips within the modelling area.

Table 1 Ship categories

IWRAP categories	Lumped categories in plots (e.g. as in Appendix A)
Crude oil tanker	Tankers
Oil products tanker	
Chemical tanker	
Gas tanker	
Container ship	Cargo
General cargo ship	
Bulk carrier	
Ro-Ro cargo ship	
Passenger ship	Passenger ships
Fast ferry	
Support ship	”Other”
Fishing ship	Fishing ships
Pleasure boat	Pleasure boats
Other ship	”Other”

4.2.1 VMS data

Commercial fishing ships shorter than 15 m do not need to use AIS. Commercial fishing ships above 12 m length need to use a VMS transponder. In principle, VMS data could be used in addition to AIS data. However, from earlier studies DNV concluded that there is considerable overlap between AIS data and VMS data, but the overlap cannot be removed, because VMS data supplied by Danish authorities is anonymous. Also, the AIS registrations show that the total number of fishing ships is small as compared to pleasure vessels, which have similar sailing patterns off the main fairways. Therefore, no attempt has been made to include VMS data.

4.3 Existing ship traffic patterns

The AIS data is imported into the IWRAP tool to provide a traffic density plot. The traffic density map shows the number of *passages* of ships through a small area (the cell size). It is not the same as a ship density plot (or heatmap): the traffic density does not depend on the ship’s speed, only on the number of passages or routes. (The *ship density* depends on speed: a ship at half the speed contributes twice to ship density because it will be present twice as long in the same area).

Traffic density plots are provided in Appendix A for all ships and as plots for separate categories:

- Cargo ships (which includes Container ships, General cargo ships, Bulk carriers and Ro-Ro cargo ships).
- Tanker ships (including Crude oil tankers, Oil products tankers, Chemical tanker, and Gas tankers)
- Passenger ships (including ships classified as fast ferries or High Speed Craft, most of the Crew Transfer Vessels used to service OWF installations are classified as HSC)
- Pleasure ships (both motor vessels and sailing vessels)
- Fishing ships.
- “Other ships” and Support ships. “Other ships” include e.g. naval (military) vessels, rescue craft and dredgers.

Note that in Appendix A both HES OWF and KA OWF are featured as being the “new” OWF in order to be able to share this appendix between the two studies.

Figure A 2 and Figure A 3 show that cargo and tanker ships mainly follow the main shipping routes, as expected. However, there is a noticeable cargo route from/to the Øresund to/from the east coast of Jutland passing south of the Anholt OWF, which is not noticeable for tankers. On the other hand, tankers more frequently navigate between the east of Grenaa (the pilot meeting point) and the cardinal buoy east of Østerrev (Anholt). Both tankers and cargo ships can be seen to use the narrow deeper passage (marked with an asterisk in Figure 2) to have sufficient keel clearance when required.

Passenger ships mainly follow the main shipping routes too. Figure A 4 also shows that service vessels (CTV-s) serve Anholt OWF from Grenaa harbour. Also, the ferry connections are clearly visible of which Grenaa-Halmstad is most relevant for this study.

Figure A 5 shows the fishing activities. Fishing activities concern about 280 unique vessels, and count for about 6% of all trips in the area. Fishing activities take place between Anholt and Gilleleje. There is little or no fishing activity overlapping with the provisioned area of KA OWF, crossing of the area seems to be related to ships in transit.

Figure A 6 shows that the routes of pleasure boats differ substantially from the commercial shipping routes and avoid the busy shipping routes T and S. The pleasure boats typically follow the coastlines, but otherwise are rather randomly distributed, also through the existing Anholt OWF (see also the assessment of pleasure boats crossing OWFs, Assumption C.4 in Appendix C). There are typical crossings of open water between marinas along the coast. Crossings passing KA OWF are between Grenaa and both Hundested and Gilleleje and crossings between Anholt and destinations in the Great Belt (e.g. Samsø). It shall be noted that the plot only shows movements of pleasure boats equipped with (and using) AIS. Section C.3 in Appendix C discusses the fraction of pleasure boats with AIS, but this does not affect Figure A 6 (the colours of the traffic density plots are relative to the maximum number of passage density of the ship category in question). Based on AIS registrations, pleasure boats account for about 6400 trips in the area, which may be multiplied by 8 (as per the analysis in. Section C.3 in Appendix C) to obtain a reasonable estimate of the total trips. Pleasure boats then account for between 70 and 75% of all trips in the area, but the majority of trips are close to the coast and do not interfere neither with the provisioned OWF nor with commercial ship traffic.

Figure A 7 shows the traffic density of “other ships”. “Other ships” represent about 13% of the trips performed by 6% of the unique ships. They are hard to be distinguished in the central area of the plot for all ships (Figure A 1), but the activity of pilot vessels stationed at Grenaa and Odden is clear. As an example, Figure 5 shows the around 700 separate trips performed in 2022 by a single pilot vessel, presumably stationed in Odden. It is noted that none of these trips are matched to a “leg” (see description of model, legs and waypoints below in section 5.2) which means that these ship movements are not included in the model predictions for incidents.

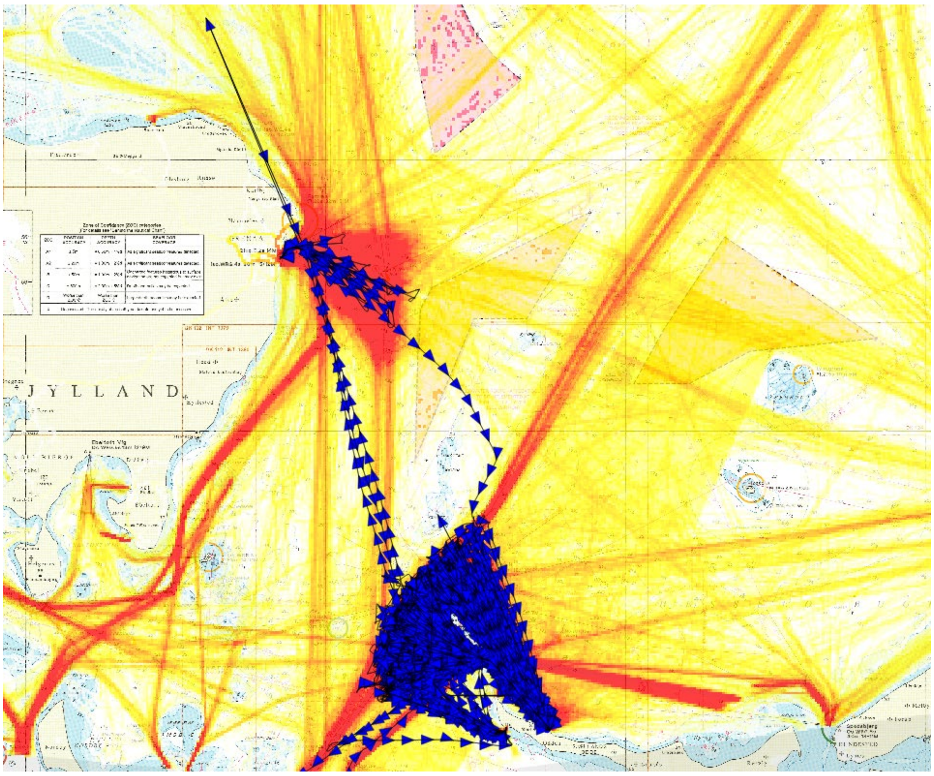

Figure 5 Trips by “Other ship” (MMSI 219023945 - PILOT II) in 2022

5 MODEL DESCRIPTION

The following describes the method for performing Step 1, the frequency analysis. The frequency analysis is based on acknowledged mathematical models typically used for such analyses and with input based on historical (statistical) data. The applied calculation tool IWRAP MKII is a part of the IALA Recommendation (IALA, 2009) on risk management.

5.1 Analysis tool

The IWRAP MKII software calculates the probability of allisions (collisions with fixed structures), collisions between ships or groundings for vessels operating on a specified route. The applied model for calculating the frequency of grounding or collision accident involves the use of a so-called causation probability that is multiplied onto a theoretically obtained number of grounding or collision candidates. The causation factor models the probability of the officer on the watch not reacting in time given that he is on collision course with another vessel (or – alternatively – on grounding course), see /2/,/3/ for detailed theoretical model description. The probabilistic model assumptions are summarised in Appendix C (section C.1).

A description of the ship traffic constitutes the central input for a navigational risk assessment. Automatic Identification System (AIS) data provides a detailed geographic and temporal description of the ship traffic in a region and has been used as the primary data basis. Because the predominant part of the ship traffic is following navigational routes, the modelling of the ship traffic and the associated models of the risk of collisions and groundings adopts a route-based description of the traffic.

The ship traffic description based on AIS is thus subsequently used as basis for definition of the routes in the probabilistic model in IWRAP MKII.

5.1.1 Type of collisions

The assessment considers a number of possible accidents:

- Collisions between ships:
    - Within a straight route: *overtaking* and *head-on* collisions
    - collisions when two routes cross each other, merge, or intersect each other in a bend of a fairway.
- Groundings or allisions (collision with a fixed structure) (both are handled in the same way):
    - Powered groundings/allisions:
        - Ships following the ordinary direct route at normal speed. Accidents in this category are mainly due to human error but may include ships subject to unexpected problems with the propulsion/steering system that occur in the vicinity of the fixed marine structure or the ground.
        - Ships that fail to change course at a given turning point near the obstacle. For the simulations presented herein, when legs are extending within 10° of each other's direction, no such failures are assumed (the fairway is assumed to go straight on and no change of course is deemed necessary), This is done to have some freedom in definition of legs and waypoints to cover as much traffic as possible without too many legs and waypoints.
    - Drifting groundings/allisions

For a detailed description of the model theory, reference is made to /3/.

5.2 Definition of routes and waypoints

As stated above, the model applies traffic routes and ships assigned to those routes. Within the modelling concept, routes exist of straight "legs" between waypoints. At waypoints, legs can change direction and/or merge, and/or divide into several legs. The analyst assigns ship traffic to legs, i.e. by describing the number movements per year of ships within a certain category and length class for that leg. Within this study the standard categories in the IWRAP tool are applied (Table 1):

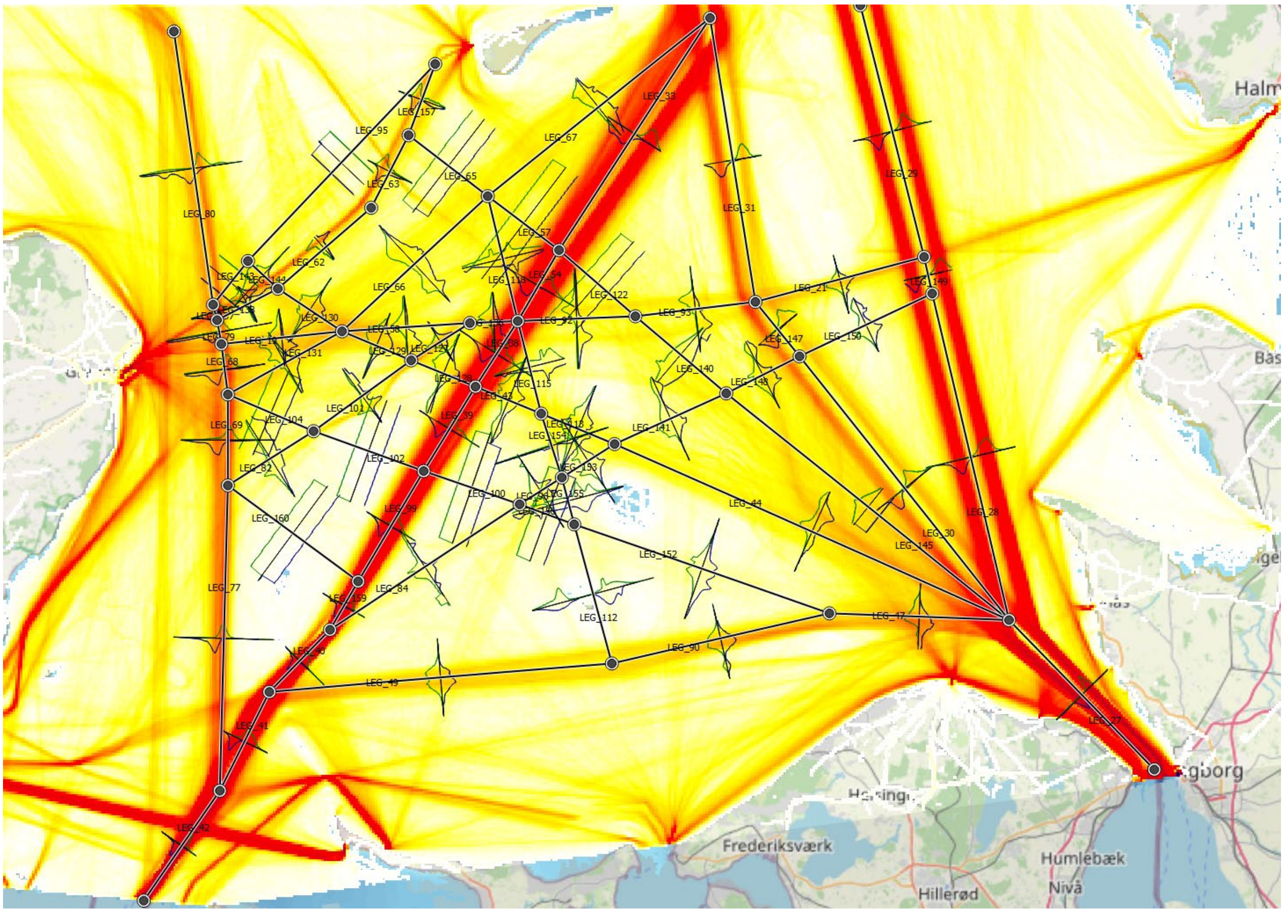

Figure 6 Definition of legs with lateral traffic distributions derived from AIS registrations.

The commercial version of IWRAP allows to use AIS data to automatically assign AIS registered ship movements to legs. The analyst defines the waypoints, the legs between the waypoints and the width of the legs. Furthermore, the analyst selects to what degree the ship movements shall be aligned (have the same direction) with the leg, and the distance beyond the waypoint for which allisions and groundings are calculated (when the ship does not turn at the waypoint).

For this assessment, an alignment of 25 degrees for all legs have been applied, which is relatively wide, but this is done to ensure that traffic with diverging directions (e.g. CTVs sailing from one harbour to all WTGs within an OWF) are captured within the leg. For a number of legs close to each other and with small angles between them, the alignment criterion has been decreased, this list is included in Appendix E.

There will be a part of the AIS registered ship movements that will not be assigned to a leg (see the remark on trips from a pilot vessel in section 4.3). Within the present version of IWRAP, there is no information what fraction of the ship movements is assigned to legs and what fraction is not. This is a rather important information, because the fraction that is not captured will not be included in the analysis. This is another reason to apply the wide degree for alignment, to include as many movements as possible. It is noted that the model results herewith are sensitive to the selection (density and direction) of waypoints and legs, and the leg width. This shall be kept in mind when comparing results with other analyses for the same area.

Figure 6 shows the AIS traffic density for all ship categories (see Section 4.3 and Appendix A) and the definition of legs. Each leg has a number. These legs are selected and defined considering the traffic density of "all" ships and individual lumped categories, notably passenger ships (including CTV's) and pleasure boats, to ensure that all relevant ship movements are covered. E.g. leg 95 runs parallel with legs 62 and 63 and represent pleasure boats sailing through the Anholt OWF

Where legs are crossing or come together (waypoints), ships may turn to another leg. The IWRAP tool collects the number of ships turning from one leg into another, thereby providing the data necessary to estimate the number of ships that inadvertently make a wrong (or no) turn.

In order to account for pleasure boats not equipped with AIS, the number of pleasure boats assigned to a leg has been multiplied by 8 for all legs as per Assumption C.3 (Appendix C).

There is no single or simple way of representing the ship-type distribution in the modelling area. A possible representation is shown in Table 2, where the traffic movements per year for all legs have been added up. As the length of the legs has not been accounted for, "short" legs have the same weight as "long" legs. The table includes the correction for pleasure boats by a factor of 8.

Table 2 Distribution of ship types for all legs

Ship type	Contribution to sum of traffic movements for all legs
Crude oil tanker	3.1%
Oil products tanker	16.2%
Chemical tanker	0.7%
Gas tanker	0.8%
Container ship	5.4%
General cargo ship	27.5%
Bulk carrier	5.2%
Ro-Ro cargo ship	4.3%
Passenger ship	6.7%
Fast ferry	0.2%
Support ship	2.3%
Fishing ship	1.8%
Pleasure boat	24.3%
Other ship	1.5%

5.2.1 Lateral distributions

The IWRAP tool calculates the lateral distribution of the ship traffic along the leg as a multimodal combination of (typical) normal and uniform distributions. Figure 6 shows the lateral distributions across each leg for north or west going ships (green) and for south or east going ships (blue) derived from the AIS registrations. The width of the distributions shows the selected width of the leg, used to select which ships from the AIS data belong to the leg. Assigned width as describes above is only used to limit the traffic assigned to the leg, the lateral (normal) distributions as used in the simulation can extend beyond the assigned width of the leg as visible in Figure 6. Note that the lateral distributions are normalized to the traffic along leg, so an equal height of the (peak of) the distribution does not indicate the same number of ships passing as along another leg. After first assessments, for a number of legs the distribution has been forced to be uniform. This ensures that there is no long "tail" of the distribution which would erroneously suggest interactions of the leg traffic with e.g. shallow grounds or obstacles (OWFs) far away from the leg centre line. Some distributions can indeed be bi-modal, e,g leg 112 shows that ships to/from Hundested are passing at both sides of Hesselø.

5.3 Definition of simulation scenarios

Three simulation scenarios are defined, as described in the following sections. These scenarios are:

- Base case scenario (present condition with traffic from 2022 AIS data)
- Construction-phase scenario, i.e. the condition during the installation and construction of the KA OWF
- Operational phase scenario, i.e. the condition when the KA OWF is in operation.

Furthermore, there is the scenario for the Cumulative effect i.e. the condition when both the KA OWF and the HES OWF are in operation. This scenario has not been separately simulated but has been assessed on the basis of the outcome of the operational phase scenarios for KA OWF and HES OWF /15/.

All traffic intensities are based on the 2022 AIS data, that is, future trends in shipping intensity, apart from changes incurred by the operation of the KF II OWF, are not accounted for.

5.3.1 Base case scenario

The base case simulation is based on the 2022 AIS traffic data and definition of legs and way points as shown in Figure 6. Ship traffic has not been adjusted apart from the general increase of pleasure boats by a factor of 8 as per Assumption C.3 (Appendix C) to account for pleasure boats not equipped with AIS.

Existing WTGs in Danish waters, notably Anholt OWF are included in the simulation, i.e. there will be estimated allisions with these existing WTGs in the modelling area for the base case. This means that the other scenarios will cover the cumulative effects between the existing WTGs and the KA OWF.

5.3.2 Construction Phase

For the construction phase, all WTG structures (in the over-planting scenario) of the KA OWF are all included in the simulation (for the allision simulation, there is no difference between foundations or complete WTG). This will provide a worst-case scenario result.

The construction phase is characterized by the fact that the KA OWF area is a work area and non-attending vessels are not permitted to enter this area. This means that all existing traffic must pass around or outside the area. This is modelled by the following changes made to the base case, see also re-routing on Figure 7:

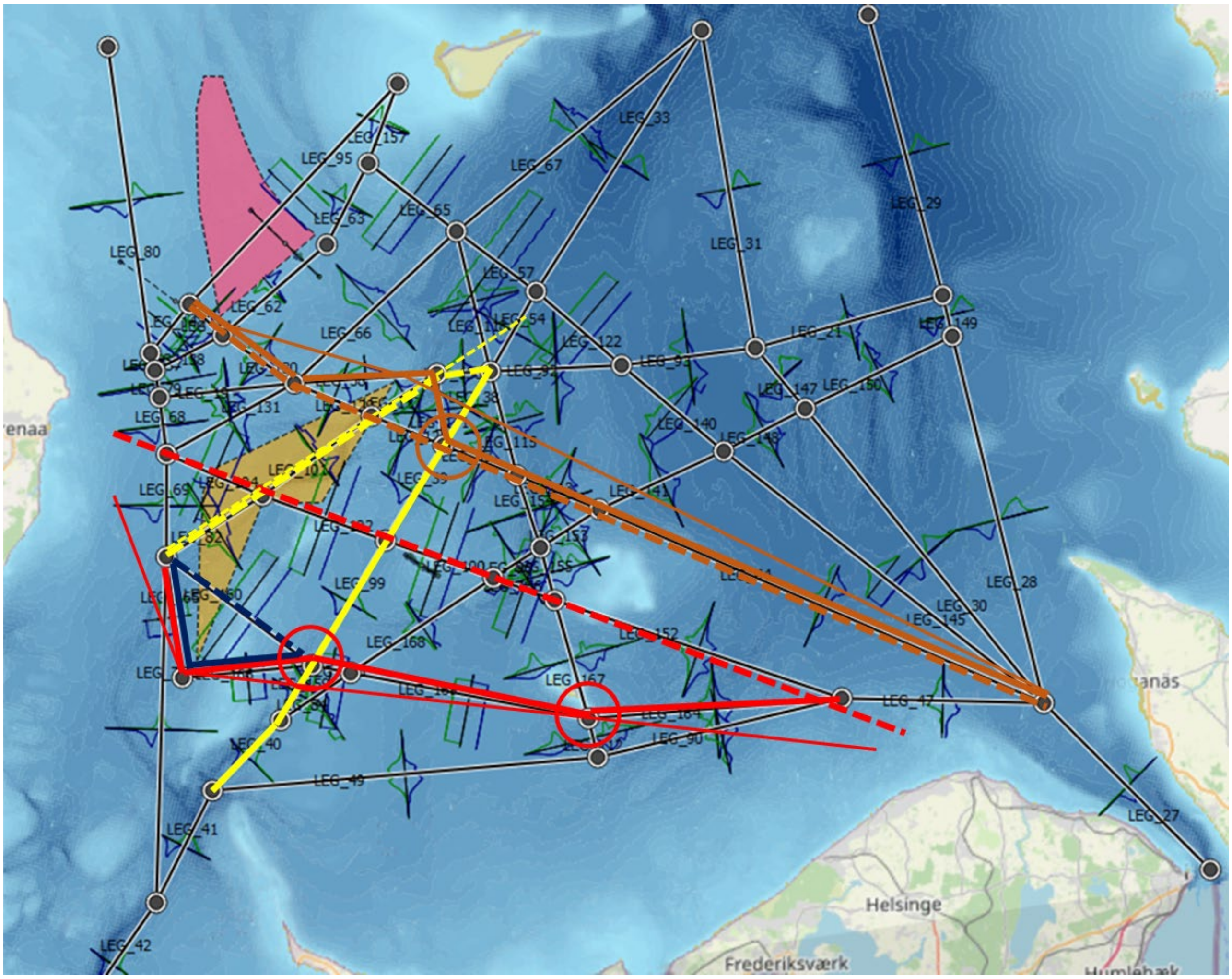

Figure 7 Construction phase. Broken lines are the original (Base Case) routes. Solid lines represent re-routing for the Construction phase scenario. Thin lines show the "real" (straight) routes, the thick lines the approximation in the model. Circles mark the waypoints where the bending incidents are suppressed to simulate the straight course.

A. All ships navigating about 2 to 3 nm south of route D through the narrow deep-water passage (marked by an asterisk in Figure 2) are assumed to move to route T rather than route D as there may be requirements to keel clearance, see the yellow routes in Figure 7. Note that this affects the operations of pilots from Grenaa as the pilot meeting point for these ships would move to Sjællands Rev.

B. Ships between Gilleleje and Grenaa can choose to pass the KA OWF around the north or the south corner. The detour around the northern corner of the KA OWF is 6.3 km (on a direct distance of about 91 km), and around the southern corner 6.9 km. For this study it is assumed ships navigate around the southern corner (because the route around the northern corner will be blocked when HES OWF is also installed). New legs and waypoints have been defined, see the red routes in Figure 7. The route definition is done by exploiting existing waypoints from the base case to ensure the best consistency between the different scenarios. This leads to routes in the model not being straight where they would be straight in reality. At "unrealistic" waypoints and bends in the model, the incidents due to bending have been suppressed by increasing the incident causation reduction factor for bending incidents from 1 to 100 at those waypoints (indicated by circles in Figure 7).

C. Ships between the southern corner of Anholt OWF and Øresund need to pass north of KA OWF with an extra change of course (brown routes in Figure 7). In in this case at one waypoint the bending incidents are suppressed too.

D. Some traffic (pleasure boats mainly) from Hundested to Grenaa pass the southern part of the KA OWF. This traffic has been re-routed along the same legs as ships from Gilleleje to Grenaa (dark blue in Figure 7)

E. The lateral distribution of the legs on the ferry route between Grenaa and Halmstad north of KA OWF (legs 58 and 92 in Figure 6) are changed so there is no interaction with the OWF. The distance between the leg centre line and the OWF is 500m; for leg 58, in east-bound direction, the lateral distribution is changed to a normal distribution with mean at -500m (i.e. north of the leg centreline) and standard deviation of 300 m. In west-bound direction the mean is set t 600m and standard deviation also at 300m, see Figure 8.

F. The route from Hundested to Anholt, with mainly pleasure boats, is assumed most sailors decide to pass east around HES OWF to avoid navigation along or across route T close to the DWR T10 between Lille Lysegrund and Briseis Flak, both detours are equally long. New legs 164 and 163 have been defined, merging with the route from Øresund to/from east of Anholt OWF. The route from Hundested to this route will be a straight course, and at the artificial bend between the new legs 164 and 163, the causation reduction factor for bending incidents is set to 100 to suppress bending incidents generated by the model.

G. The route from/to Gilleleje to/from Grenaa is moved to pass south of the KA OWF, with new legs (from west to east) 165, 166, 170, 169 and 164. The route definition is done by exploiting existing waypoints from the base case to ensure the best consistency between the different scenarios. This leads to routes in the model not being straight where they would be straight in reality. At “unrealistic” waypoints and bends in the model, the incidents due to bending have been suppressed by increasing the incident causation reduction factor for bending incidents from 1 to 100 at those waypoints (indicated by circles in Figure 7). The lateral distributions (as well as the ship traffic intensity) for legs 170, 169 and 164 have been copied from the Base Case legs 100, 156 and 152, respectively. The lateral distribution on the new legs 165 and 166 are uniform with a width not to interact with the southern corner of KA OWF, see Figure 8.

The construction phase scenario does not consider any extra traffic for construction purposes, as there is no information about neither intensity nor route (construction harbour is not known).

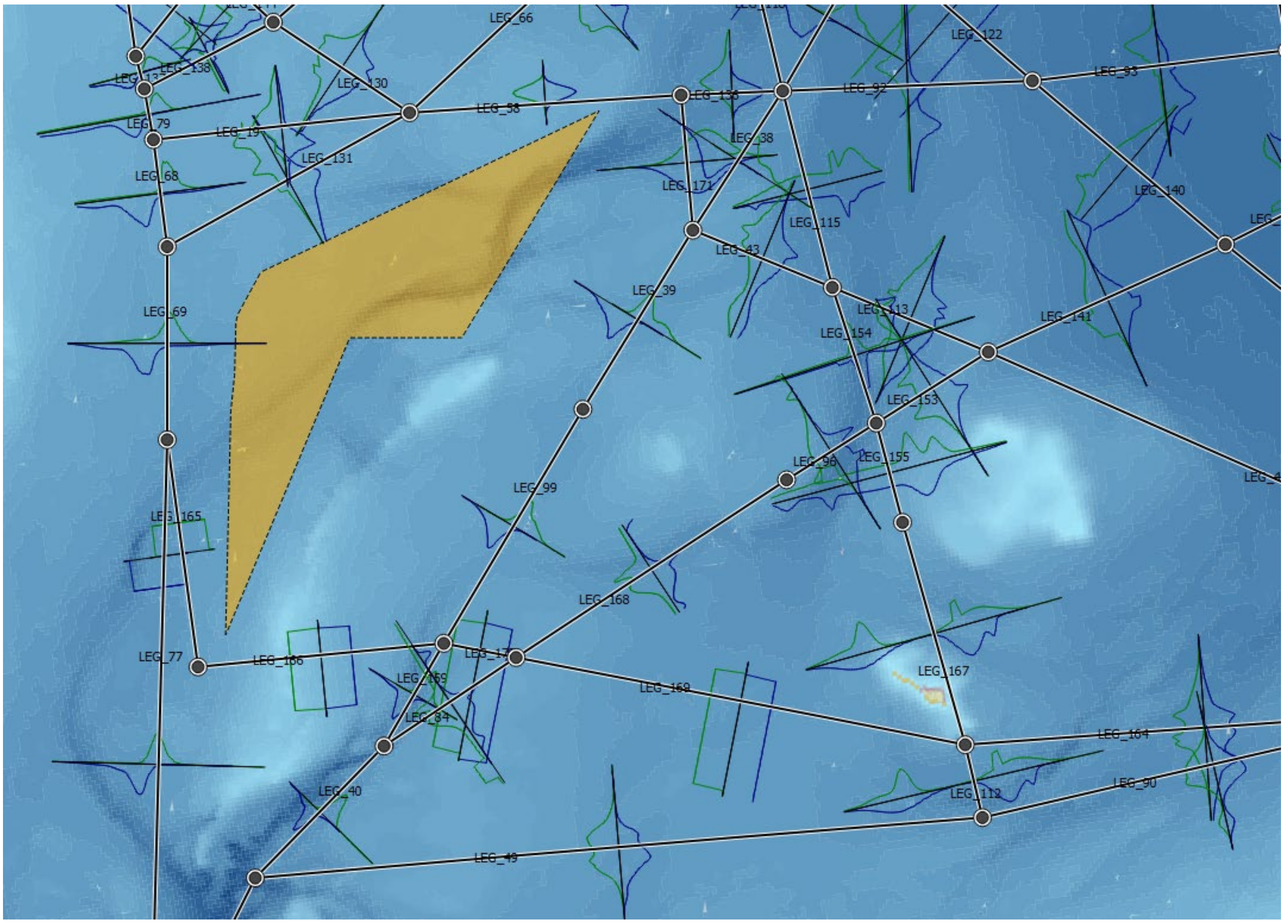

Figure 8 Adjustments of routes and lateral distributions around KA OWF during Construction Phase.

5.3.3 Operational phase scenario

The operational-phase scenario is based on the construction phase scenario but the original Base Case routes through the KA OWF allow for some traffic (in the model limited to pleasure boats and fishing ships) to pass through. The amount of traffic is based on the relative length of the de-route around the OWF as compared to the direct route as per Assumption C.4 in Appendix C. The routes with passing traffic are shown in Figure 9. The amount of pleasure boats and fishing ships passing KA OWF are included in Table 3. These amounts are of course taken out of the corresponding routes around KA OWF.

Note that the numerical analysis assumed that pleasure boats and fishing ships would behave similarly when choosing to pass or to take the detour. Later assessments show that fishing ships twice as often decide to pass the OWF, as per amendment to Assumption C.4 in Appendix C. The updated numbers are shown in parentheses in Table 3. This means that the total ship traffic through KA OWF is underestimated by less than 4%, the largest change (about 12%) is for the route between Øresund and West of Anholt OWF (brown route in Figure 9). This difference is not expected to significantly alter the risk of (collision with) other ship sailing outside the OWF However, the risk of allision between a fishing ship and a WTG inside the OWF is expected to increase by a factor 2. This will be addressed qualitatively when discussing the results.

In addition, CTVs servicing the 164 WTGs of KA OWF from Grenaa are included as 820 return trips along the purple route in Figure 9. Half of the CTVs are less than 25 m length, the other half between 25 and 50 m, which matches the distribution of the CTVs servicing Anholt OWF.

Table 3 Pleasure boats and fishing ships passing KA OWF during Operational Phase. Colours refer to colours of routes in Figure 7 (numbers in parentheses are updated after review of the number of fishing ships passing the OWF).

		Samsø - Anholt (S of route D) (yellow)	Hundested – Grenaa (dark blue)	Gilleleje – Grenaa (red)	Øresund -W. of Anholt OWF (brown)
Direct route (km)		97	75	91	83
Deroute (km)		2.9	1.9	7.8	0.5
Relative deroute		3.0%	3%	6.9%	0.6%
Fraction of ships passing OWF		23%	23%	36%	12%
Base Case	Pleasure Boats heading N or W	192	320	195	112
	Pleasure Boats heading S or E	100	352	251	92
	Fishing Ships heading N or W	1	8	14	7
	Fishing Ships heading S or E	5	3	7	6
Operational Phase (Passing OWF)	Pleasure Boats heading N or W	9	70	70	14
	Pleasure Boats heading S or E	18	77	90	11
	Fishing Ships heading N or W	0 (0)	1 (4)	5 (8)	1 (3)
	Fishing Ships heading S or E	1 (2)	0 (1)	3 (4)	1 (2)

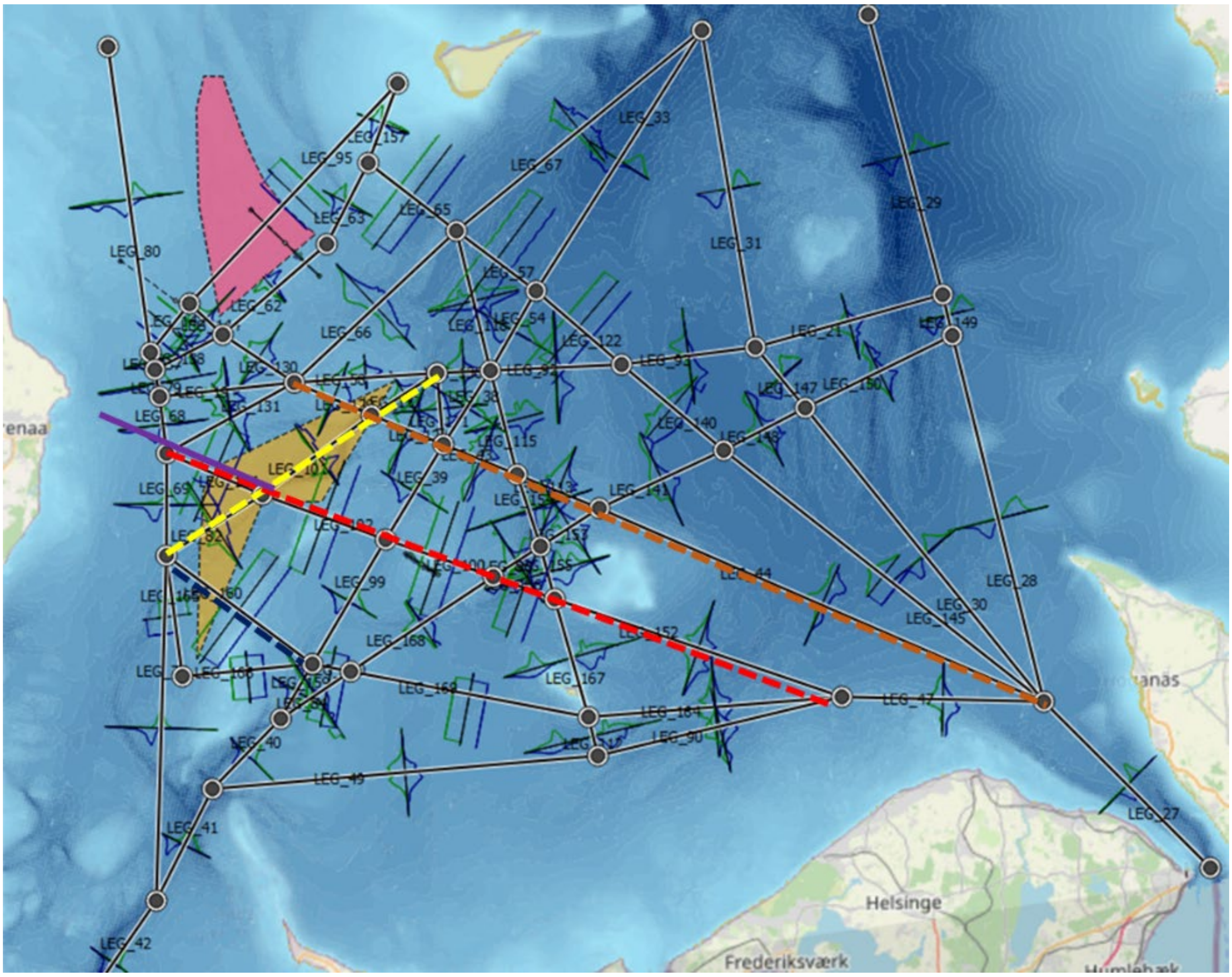

Figure 9 Operational phase. A fraction of the pleasure boats and fishing ships from the original routes (see also Figure 7), have been reinstated as per Table 3. Purple line indicates CTVs servicing KA OWF from Grenaa.

6 RESULTS

The results of the assessment are presented as comparisons between the three scenarios. The cumulative effects for the combined operation of KA OWF and HES OWF is discussed in chapter 7 The absolute number of expected incidents or accidents depends heavily on the model assumptions (notably on the definition of legs and waypoints and also on the default causation factors), whereas the comparative results are less biased by these assumptions.

The results are presented as total results for the modelling area. This provides a valid comparison with respect to the number of allisions with existing and/or new WTGs, but when considering the impact on ship-ship collisions, results will be dominated by the transit routes with most traffic, also those at a distance from KA OWF (e.g. the route through Øresund). Similar arguments hold for groundings. Therefore, it will be reported at what locations there will be changes in the collision risk.

A summary of results for the modelling area is presented in Table 4. The Table shows the absolute results for the modelling area and the changes as compared to the Base Case Scenario, both in absolute expected number of incidents per year, and the relative increase for the type of incident.

It can be concluded that the impact on groundings is limited, both in absolute and relative terms.

In relative terms the number of allisions increases most as can be expected by the increase of the number of WTGs in the modelling area, but the increase is modest as compared to the existing risk of allision with the Anholt OWF.

The increase in the number of collision incidents is of the same number as the increase of the number of allisions. Merging and crossing incidents are expected to remain the same (or drop a little), while incidents due to overtaking, head-on and bending increase.

The details of results per ship category and/or route will be discussed in the next sections.

Table 4 Summary of results for the modelling area

Type of incident	Expected number of incidents per year / *Expected averaged number of years between incidents*			Increase (incidents per year)		Relative increase	
	Base Case	Construction	Operational	Construction	Operational	Construction	Operational
Powered Groundings	0.91 / *1.1*	0.91 / *1.1*	0.92 / *1.1*	0.000	0.001	0.0%	0.1%
Drifting Groundings	0.405 / *2.5*	0.407 / *2.5*	0.407 / *2.5*	0.003	0.002	0.7%	0.6%
Total Groundings	1.32 / *0.8*	1.32 / *0.8*	1.32 / *0.8*	0.003	0.003	0.2%	0.2%
Powered Allisions	0.047 / *21*	0.049 / *20*	0.054 / *18.5*	0.002	0.007	3%	15%
Drifting Allisions	0.0028 / *357*	0.0047 / *213*	0.0047 / *213*	0.0020	0.0019	71%	70%
Total Allisions	0.050 / *20*	0.054 / *18.5*	0.059 / *16.9*	0.004	0.009	7%	18%
Overtaking	0.066 / *15.2*	0.068 / *14.7*	0.068 / *14.7*	0.002	0.002	3.0%	2.9%
HeadOn	0.014 / *71*	0.015 / *67*	0.015 / *67*	0.001	0.001	7.1%	6.8%
Crossing	0.026 / *38*	0.026 / *38*	0.026 / *38*	0.000	0.000	0%	-1%
Merging	0.014 / *71*	0.014 / *71*	0.014 / *71*	0.000	0.000	-0.2%	0%
Bend	0.050 / *20*	0.054 / *18.5*	0.053 / *18.5*	0.004	0.004	7%	7%
Total Collisions	0.170 / *5.9*	0.177 / *5.6*	0.177 / *5.6*	0.007	0.006	3.9%	3.7%

6.1 Allisions

The base case allisions relate to the existing OWF in the modelling area. Figure 10 shows the relative probability of allisions with the WTGs of Anholt OWF. IWRAP expects for the Anholt OWF about 5 allision per 100 years (probability 0.051 per year). Pleasure boats account for 93% of these allisions and most of them (96%) are powered allisions, and relate to the sailing from Grenaa to Anholt, both through and around the Anholt OWF. In contrast, for tankers and cargo vessels, powered allisions account for only half of the allisions.

Note that this study does not address the potential impact of high ships (superstructures or masts) with rotor blades outside the foundation base of about 13 m diameter.

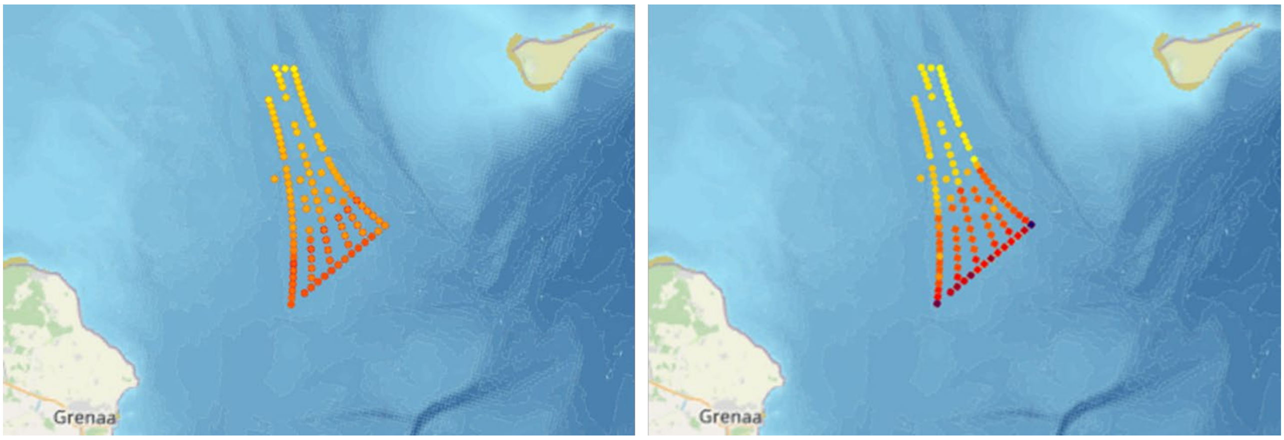

Figure 10 Base Case Scenario Allisions. Left: drifting allisions, right: powered allisions for Anholt OWF

As per Table 4, during construction phase (and with all WTGs foundations installed) of KA OWF the allisions risk in the modelling area increases only by 7%, or the added probability (frequency) of allision during construction is $4{\cdot}10^{-3}$ per year. There is a limited increase (3%) in the number of powered allisions during the Construction Phase, and drifting allisions increase by about 70%.

However, these (limited) increases are biassed by the contribution of pleasure boats sailing through Anholt OWF, and this number does not increase since when during installation pleasure boats will not pass the KA OWF. Table 5 shows the allision results in the same format as Table 4, but excluding pleasure boats, now showing significant increases, expecting additional 3 allision incidents per 1000 years (not considering pleasure boats) related to the KA OWF.

Table 5 Summary of allision results excluding pleasure boats

Type of incident	Expected number of incidents per year / *Expected averaged number of years between incidents*			Increase (incidents per year)		Relative increase	
	Base Case	Construction	Operational	Construction	Operational	Construction	Operational
Powered Allisions	0.0020 / *500*	0.0035 / *286*	0.0037 / *270*	0.0015	0.0017	72%	86%
Drifting Allisions	0.0008 / *1250*	0.0021 / *476*	0.0021 / *476*	0.0013	0.0013	155%	155%
Total Allisions	0.0028 / *357*	0.0055 / *182*	0.0058 / *172*	0.0027	0.0030	96%	106%

The detailed comparison of the number of allisions is included in Table 6 and Figure 11. The increase of drifting allisions is mainly caused by drifting of ships on route C just west of the KA OWF (the route between the Great Belt/Aarhus and the pilot meeting point east of Grenaa) and to a lesser degree of ships on route T east of KA OWF.

For tankers and cargo ships, the (relative) increase in allisions is substantial, as can be seen from Figure 11 and Table 6 notably for Oil Product tankers and General Cargo.

There is no difference between the Construction Phase and the Operational Phase, except for Fishing ships and Pleasure boats expecting to cross (to some extent) through the KA OWF in the Operational phase and the additional CTVs (fast ferries) servicing KA OWF. Other vessels may also pass the KA OWF, but that has not been included in the simulation. It is expected that there will be about 0.005 and 0.0002 additional allisions per year due to pleasure boats and fishing ships, respectively, passing through the KA OWF in the Operational phase. The above number for fishing ship comes from the numerical analysis, assuming that fishing ships and pleasure boats behave similarly when choosing to pass an OWF, later assessment shows that fishing ships will twice as often chose to pass an OWF, see the discussion in section 5.3.3. Based on that assessment, the additional number of allisions for fishing ships may be twice as high, i.e. 0.0008 on average per year.

Service trips for CTVs are added with 820 return rips in total and this is forecasted to lead to an expected frequency of 0.00008 per year. Most of these allisions are powered allisions. This number may be questioned because the CTVs are deliberately attending the OWF and crews will be experienced to navigate within the OWF. This risk is considered to be the OWF's operator risk.

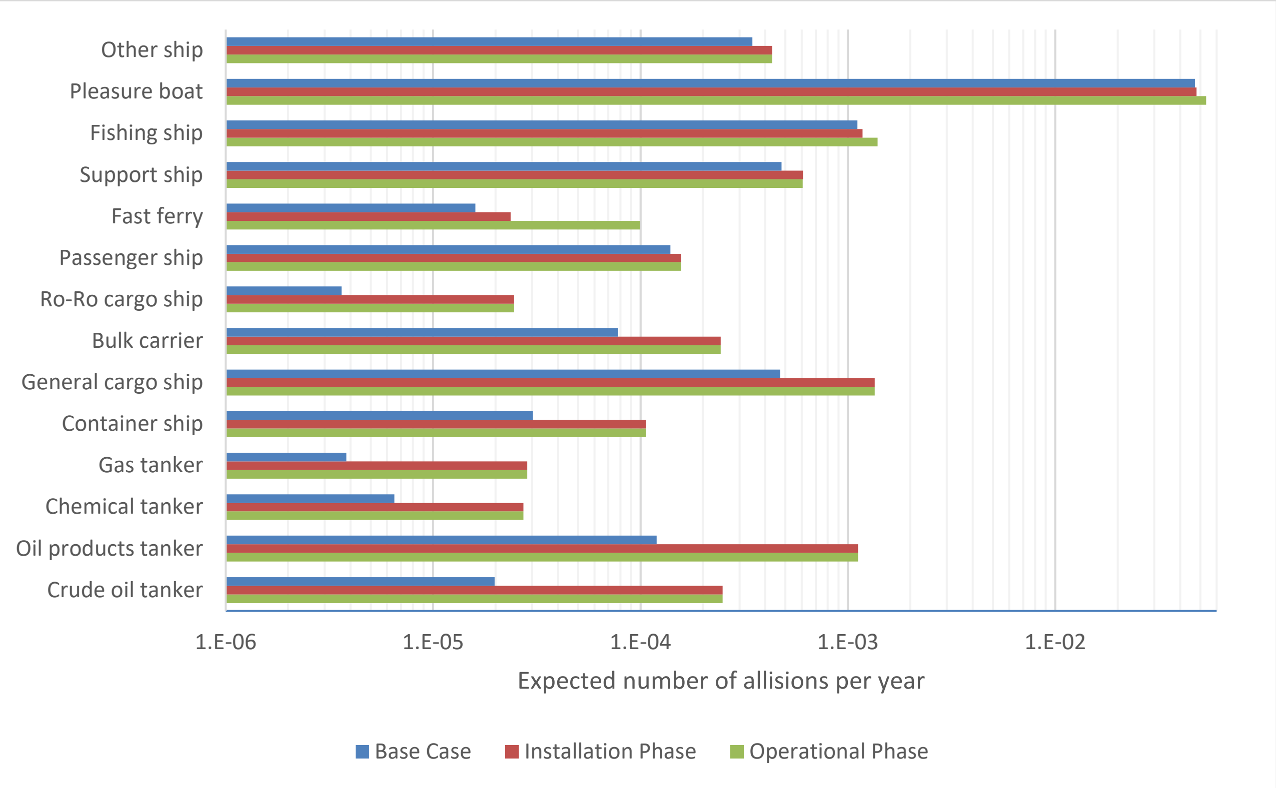

Figure 11 Total allisions

In Table 6 the two highest number of allisions have been marked bold (Base Case column), and so have the largest absolute and relative increases from Base Case to Construction Phase and Operational Phase.

Table 6 Total (Powered and drifting) allisions in the modelling area

Ship category	Expected number of allisions per year / *Expected averaged number of years between allisions*			Increase (incidents per year)		Relative increase	
	Base Case	Construction	Operational	Construction	Operational	Construction	Operational
Crude oil tanker	1.98E-05 / *50500*	2.49E-04 / *4020*	2.49E-04 / *4020*	2.29E-04	2.29E-04	**1158%**	**1159%**
Oil products tanker	1.20E-04 / *8330*	1.12E-03 / *893*	1.12E-03 / *893*	**9.99E-04**	**1.00E-03**	**834%**	**834%**
Chemical tanker	6.50E-06 / *154000*	2.73E-05 / *36600*	2.73E-05 / *36600*	2.08E-05	2.08E-05	320%	320%
Gas tanker	3.82E-06 / *262000*	2.85E-05 / *35100*	2.85E-05 / *35100*	2.46E-05	2.47E-05	645%	645%
Container ship	3.02E-05 / *33100*	1.06E-04 / *9430*	1.06E-04 / *9430*	7.61E-05	7.61E-05	252%	252%
General cargo ship	4.72E-04 / *2120*	1.35E-03 / *741*	1.35E-03 / *741*	**8.73E-04**	8.73E-04	185%	185%
Bulk carrier	7.82E-05 / *12800*	2.44E-04 / *4100*	2.44E-04 / *4100*	1.65E-04	1.65E-04	212%	212%
Ro-Ro cargo ship	3.61E-06 / *277000*	2.46E-05 / *40700*	2.46E-05 / *40700*	2.10E-05	2.10E-05	581%	582%
Passenger ship	1.39E-04 / *7200*	1.57E-04 / *6370*	1.57E-04 / *6370*	1.74E-05	1.73E-05	12%	12%
Fast ferry	1.60E-05 / *62500*	2.37E-05 / *42200*	9.94E-05 / *10100*	7.70E-06	8.34E-05*	48%	522%*
Support ship	4.80E-04 / *2080*	6.07E-04 / *1650*	6.06E-04 / *1650*	1.28E-04	1.27E-04	27%	26%
Fishing ship	**1.11E-03 /** ***901***	1.18E-03 / *847*	1.39E-03 (1.6E-03**) / *719 (620**)*	6.44E-05	2.78E-04 (5E-04**)	6%	25% (44%**)
Pleasure boat	**4.72E-02 /** ***21.2***	4.80E-02 / *20.8*	5.33E-02 / *18.8*	8.54E-04	**6.16E-03**	2%	13%
Other ship	3.46E-04 / *2890*	4.32E-04 / *2320*	4.32E-04 / *2320*	8.60E-05	8.58E-05	25%	25%
Total	5.00E-02 / *20.0*	5.36E-02 / *18.5*	5.92E-02 / *16.9*	3.57E-03	9.16E-03	7%	18%

)* Operator's risk

)** Qualitative estimates based on updated assessment of number of fishing ships passing HES OWF

Figure 12 shows the distribution of drifting and powered allisions during the construction phase. The north and west side of KA OWF seems to be most exposed to allision due to proximity of routes C and D.

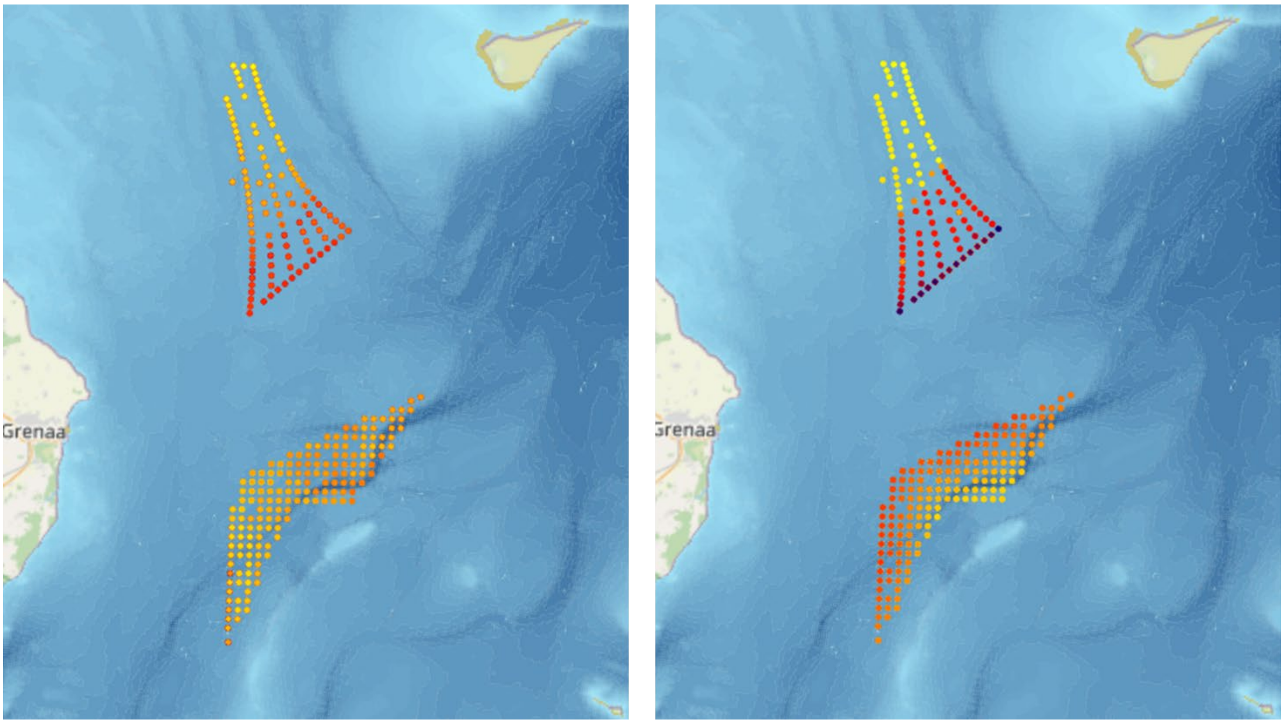

Figure 12 Construction Phase Scenario Allisions. Left: drifting allisions, right: powered allisions

Figure 13 shows the distribution of drifting and powered allisions during the operational phase. By comparison with Figure 12, it can be seen that the passing of pleasure boats, fishing ships and attending CTVs increases the powered allisions within the KA OWF (Cf. yellow and dark blue dashed routes in Figure 7).

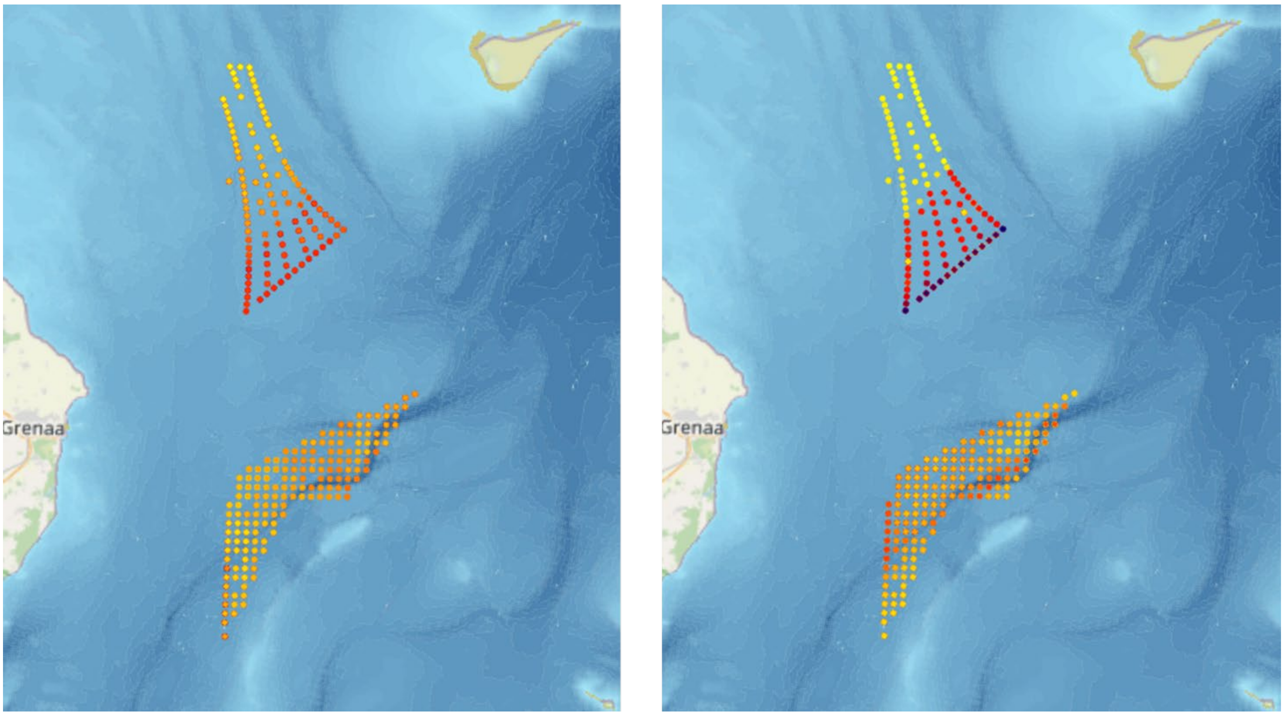

Figure 13 Operational Phase Scenario Allisions. Left: drifting allisions, right: powered allisions (Colours are scaled with the maximum incident frequency and therefore colours cannot be directly compared with Figure 12)

6.2 Groundings

The Kattegat waters are characterized by shallow areas and banks with deep water fairways crossing between and passing at short distances from these banks. Groundings occur both on these banks and the coasts surrounding the modelling area, see Figure 14.

The comparison of the number of groundings is included in Table 7. IWRAP expects one to two groundings in the modelling area per year, about 32% caused by General Cargo ships followed by pleasure boats (24%) and Oil Product Tankers (19%).

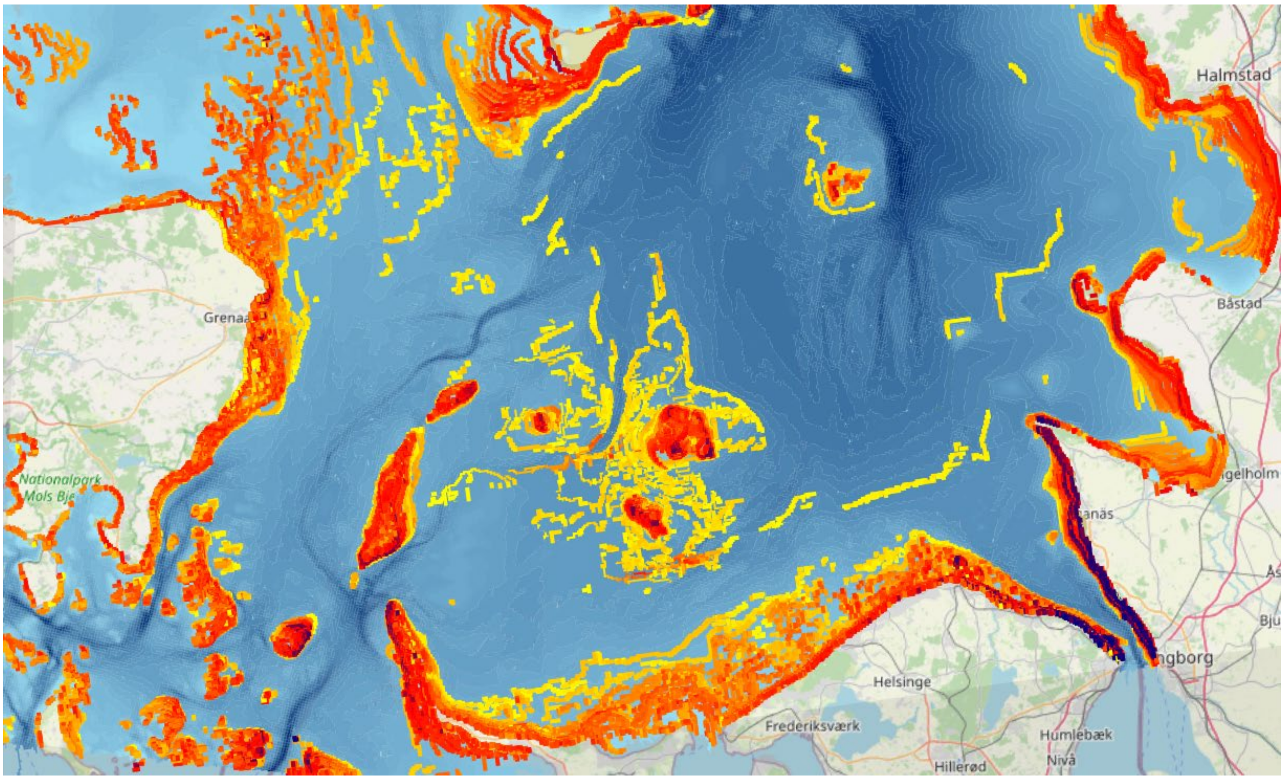

Figure 14 Base Case Scenario Groundings. Total groundings

Table 7 Total (Powered and drifting) groundings in the modelling area

Ship category	Expected number of groundings per year / *Expected averaged number of years between groundings*			Increase (incidents per year)		Relative increase	
	Base Case	Construction	Operational	Construction	Operational	Construction	Operational
Crude oil tanker	3.56E-02 / *28*	3.58E-02 / *28*	3.57E-02 / *28*	2.02E-04	1.76E-04	0.6%	0.5%
Oil products tanker	2.56E-01 / *3.9*	2.56E-01 / *3.9*	2.57E-01 / *3.9*	1.99E-04	2.51E-04	0.1%	0.1%
Chemical tanker	9.38E-03 / *107*	9.37E-03 / *107*	9.38E-03 / *107*	-4.26E-06	3.57E-06	0.0%	0.0%
Gas tanker	1.39E-02 / *72*	1.39E-02 / *72*	1.39E-02 / *72*	-2.98E-06	-2.64E-06	0.0%	0.0%
Container ship	7.24E-02 / *13.8*	7.23E-02 / *13.8*	7.23E-02 / *13.8*	-8.90E-05	-6.73E-05	-0.1%	-0.1%
General cargo ship	***4.19E-01 / 2.4***	4.19E-01 / *2.4*	4.20E-01 / *2.4*	3.63E-04	6.05E-04	0.1%	0.1%
Bulk carrier	7.83E-02 / *12.8*	7.83E-02 / *12.8*	7.83E-02 / *12.8*	1.05E-06	4.96E-06	0.0%	0.0%

Ro-Ro cargo ship	4.33E-02 / *23*	4.33E-02 / *23*	4.33E-02 / *23*	-3.87E-06	-3.80E-06	0.0%	0.0%
Passenger ship	4.44E-03 / *225*	4.43E-03 / *226*	4.43E-03 / *226*	-4.94E-06	-5.14E-06	-0.1%	-0.1%
Fast ferry	9.16E-05 / *10900*	9.15E-05 / *10900*	2.83E-04 / *3530*	-5.40E-08	1.92E-04	-0.1%	209%
Support ship	2.93E-02 / *34*	2.95E-02 / *34*	2.95E-02 / *34*	1.64E-04	1.65E-04	0.6%	0.6%
Fishing ship	2.12E-02 / *47*	2.10E-02 / *48*	2.10E-02 / *48*	-2.84E-04	-2.50E-04	-1.3%	-1.2%
Pleasure boat	3.18E-01 / *3.1*	3.20E-01 / *3.1*	3.19E-01 / *3.1*	***1.94E-03***	***1.42E-03***	0.6%	0.4%
Other ship	1.78E-02 / *56*	1.82E-02 / *55*	1.82E-02 / *55*	4.25E-04	4.12E-04	***2.4%***	***2.3%***
Total	1.32 / *0.76*	1.32 / *0.76*	1.32 / *0.76*	2.90E-03	2.90E-03	0.2%	0.2%

The increase of the number of groundings during installation and operation of KA OWF is predicted to be 0.2% on average. The largest increase in absolute terms is for pleasure boats, due to the routing between Gilleleje and Grenaa south of KA OWF, passing Hesselø. The relative increase of groundings by large crude oil tankers (larger than the increase for general cargo ships) may be due to the re-routing of ships originally using the deep-water passage south of route D, this has not been assessed further.

6.3 Collisions

From Table 4 it appears that the total number of collisions increases by a few percent when the KA OWF is being constructed or operational. Crossing and Bending incidents remain almost the same, but incidents along straight legs (Head-on and Overtaking collisions) increase as well as collisions due to bending (or lacking to do so). Figure 15 shows the waypoints where the collisions due to crossing, merging or bending either significantly increase (red symbols) or decrease (cyan symbols). Note that these differences are based on the absolute changes, not the percentages.

Head-on and overtaking collisions in absolute numbers increase most along route T between Sjællands Rev and the crossing with the route between Grenaa and Halmstad. The increase is (depending on where along the route, in the southern part the fairway is narrower) between 13% and 21% for Head-on collisions and between 16% and 41% for overtaking collisions. The simulations predict additional one (1) head-on and two (2) overtaking collisions per 1000 years for the construction and operational phase of KA OWF along this part of route T.

The largest relative increase of head-on and overtaking collisions is on the route between Grenaa and Halmstad, at the leg just north of KA OWF. The AIS registrations show that at present the ferries heading east and west are fairly separated. Due to KA OWF, the traffic heading east has to move about 1500 m north leading to overlap (at least in the simulation, see section 5.3.2, E) of the opposite shipping traffic. Head-on collisions increase by a factor more than 100, overtaking accidents by a factor more than 20. In absolute terms, at this segment of the route, collisions are expected to happen more than once every 10 000 years. There are no navigational (depth) limitations to move the whole fairway further north around KA OWF, but it will require an extra course change if the ferries need to stay clear of Store Middelgrund and the wreckage that lies close to those banks (according to the navigational charts).

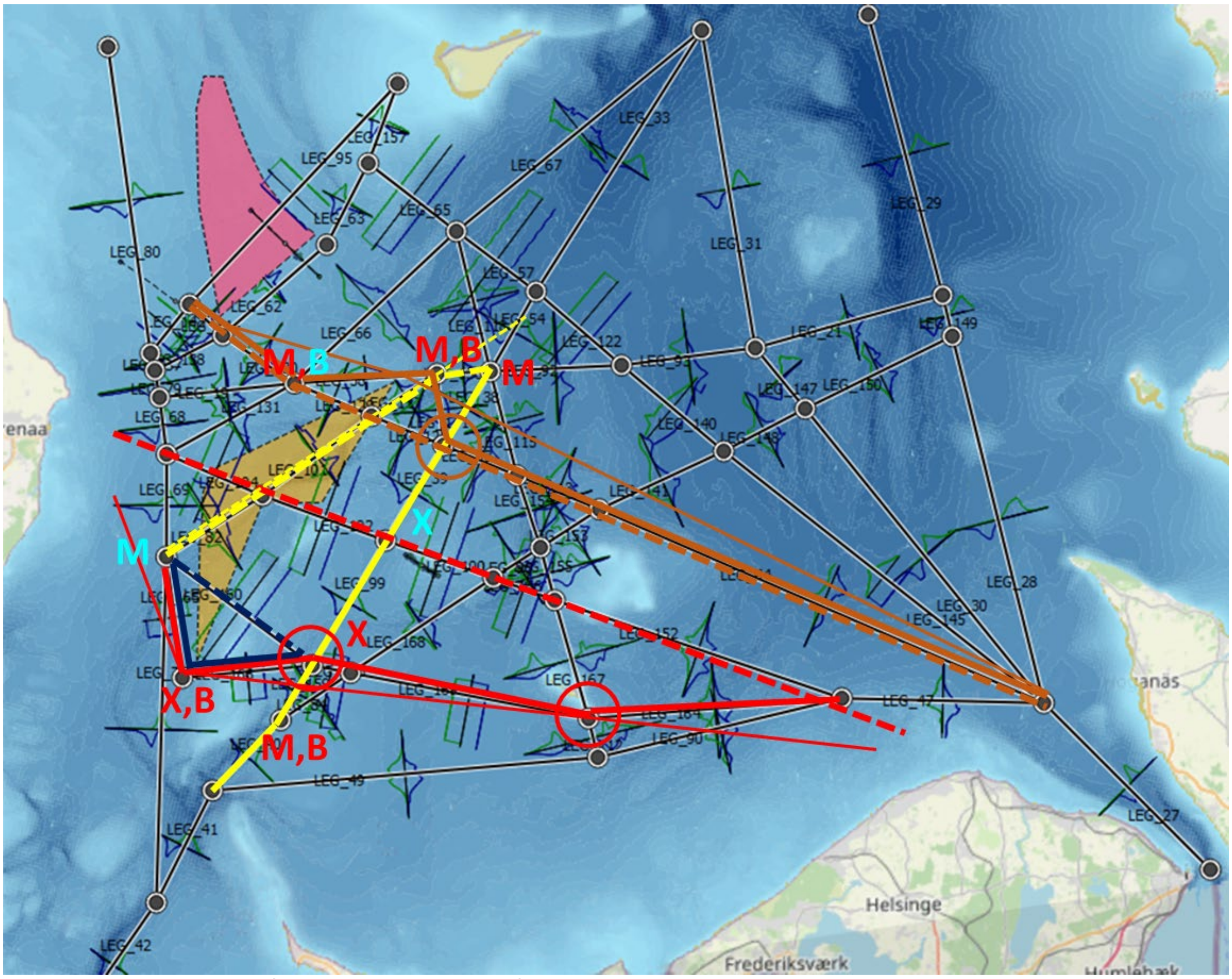

Figure 15 Assessment of changes in number of collisions at way point (crossing, merging, bending). Dashed lines indicate Base Case routes (existing traffic), drawn lines show re-routing around KA OWF. During Operational Phase fraction of original pleasure boats and fishing ships will use the existing routes (now through the KA OWF). Red letters point at waypoints where incidents increase, turquoise (cyan) letters where incidents decrease, B=Bending incidents, M=Merging incidents, X=crossing incidents.

6.4 Updated risk table from HAZID workshop

During the HAZID workshop (the full report is included in Appendix D) the identified hazards were risk ranked. This risk ranking has been updated with the results from the quantified assessment as described in the sections above. The main columns from the HAZID sheet, as included in Appendix D, are copied into Table 8, and the column with expected event frequencies has been updated with the information from the quantified study to the extent possible (see for limitations section 2.2). The Risk Ranking (color coding "red, yellow, green") is updated as well. In Table 8, 4th column from left (frequency class), frequency estimates that have been unchanged from the HAZID assessment are coloured light blue. In case the updated frequency is lower, the cell is marked light green, and in case it has been increased, the cell is pink. In case the cell is white, it means that the quantitative study did not provide information to update the HAZID assessment.

Hazard IDs 6, 7B, 8, 24B, 29, 30, 34, 35, 47, 50, 51 and 52 have not been risk-ranked during the HAZID and have not been included in Table 8. These hazards relate e.g. to the impact of the WTGs on radar and other means of communication, extraction areas, SAR helicopters, weather conditions during construction, and some issues related to vessels used during construction, which are not covered by this general navigational safety study. The HAZID was performed simultaneously for HES OWF and KA OWF, and other missing Hazard IDs address issues that are applicable to KA OWF or address cumulative effects.

The following hazards could not be updated:

- Hazard ID 16: Allision with WTG blades have not been modelled. This issue applies to pleasure boats (sailing boats) which have a mast height above the free height of the wings.
- Hazard ID 20: Transformer platforms have not been included in the assessment.
- Hazard ID 26: The impact of limited situation awareness has not been quantified, see section 2.2.This hazard is separately discussed in section 6.4.1 below.
- Hazard ID 31: The impact of limited situation awareness in combination with reduced coverage of ship radar has not been quantified, see section 2.2. This hazard is separately discussed in section 6.4.1 below.
- Hazard ID 32: The operation of SAR helicopters is not part of the navigational simulation.
- Hazard ID 36: The effect of the restricted work zone of 500 m has not been quantified. The lateral distribution of traffic along route T derived from the AIS registrations does not suggest that there will be a conflict with the KA OWF area including the additional restricted work zone. Infringement of the additional restricted work zone would only appear as cause for an incident if construction vessels in this zone would have been simulated.
- Hazard ID 38: The effect of the restricted work zone of 500 m has not been quantified. The lateral distribution of traffic along route C derived from the AIS registrations does not suggest that there will be a conflict with the KA OWF area including the additional restricted work zone. Traffic following route D is laterally spread and should be able to keep sufficient distance from KA OWF area including the additional restricted work zone. Infringement of the additional restricted work zone would only appear as cause for an incident if construction vessels in this zone would have been simulated.
- Hazard ID 41 and 42 Vessels used for construction have not been included in the assessment.
- Hazard ID 29, 33 and 34: The effect of surveillance ships or not complying with regulations has not been quantified, see section 2.2.
- Hazard ID 45: The risk of collision with a slowly moving working vessel crossing fairways has not been included in the simulation.
- Hazard ID 48: Vessels used for construction have not been included in the assessment. The approach to Grenaa has not been modelled in detail. Such simulation can be performed once details on construction-related ship traffic is available.
- Hazard ID 49: The effect of surveillance ships or not complying with regulations has not been quantified, see section 2.2.

It is noted that the updated information does not leave any hazards to be “unacceptable” (red), remaining unacceptable hazards relate to construction-related traffic operating from Hundested and crossing route T (which can be avoided by selecting a construction harbour west of route T) and the traffic density at Grenaa harbour during construction, which can be mitigated by vessel coordination. Both hazards can be investigated further once details about construction activities are known.

Table 8 Summary of updated HAZID hazard sheet (original HAZID sheet included in Appendix D). In the column "frequency", light blue indicates no change as compared to HAZID assessment, light green: the frequency has been lowered, and pink; the frequency has been increased.

Hazard-ID	Cause/Event	Hazard/Incident	Frequency	M.F.	Severity - Person	Severity – Property	Severity - Environme	Risk
	Operation Phase							
2	Ships in transit. Insufficient distance to wind farm from route T to both Hesselø and/or Kattegat	Ship-ship collision	3	1	3	2	2	6
3	Ships in transit. Insufficient distance to wind farm from route T to both Hesselø and/or Kattegat	Ship-turbine collision	3	1	2	2	2	5
4	Insufficient distance to wind farm	Ship-ship or ship-turbine collision	3	1	3	2	2	6
5	Ferry route currently crosses through the northern part of the pre-investigation area Kattegat. Insufficient distance to wind farm	Ship-turbine collision	2	1	4	2	2	6
7A	Larger ships (e.g., tankers) come close to Grenaa to get a pilot and continue towards the Great Belt. Larger ships from/to Aarhus may sail through Hjelmdyb. Concentration of ships west of the wind farm. Insufficient distance to wind farm	Ship-turbine collision	3	1	3	3	4	7
10	Most leisure boats from Grenaa to Zealand will likely sail south of Kattegat, creating more traffic on surrounding routes.	More concentrated sailing. Conflict between large ships and pleasure/fishing vessels	3	1	3	2	1	6
13	Large ships: Drifting ships, blackout	Ship-turbine collision	3	1	2	2	2	5
14	Passenger ships: Drifting ships, blackout	Ship-turbine collision	4	0.1	4	2	2	7
15	Smaller ships: Drifting ships, blackout	Ship-turbine collision	3	0.1	3	2	1	5
16	(Larger) sailing boat gets too close to the turbine	Blade hits mast	2	1	3	2	1	5
17	Large ships: Direct collision	Ship-turbine collision	3	1	2	2	2	5
18	Passenger ships: Direct collision	Turbine breaks down onto ship, blade hits ship.	2	1	4	2	2	6
19	Smaller ships: Direct collision		3	1	3	2	1	6
20	Direct collision	Ship-transformer platform collision	2	1	2	2	2	4
21	Service vessel: Collision with smaller other vessels	Ship-ship collision	2	1	3	2	2	5
22	Service vessel: Collision with large vessels	Ship-ship collision	2	1	4	2	2	6
24A	Service vessel: Maintenance traffic from Hundested or similar port on the north coast of Zealand to Kattegat	Crosses route T. Risk of ship-ship collision	3*	1	4	2	2	7
25	Large ship: More traffic on routes due to wind turbine areas.	Grounding. Evasive manoeuvre of larger ship. E.g., Lille Lysegrund Briseis Flak. Hastens Grund Schultz's Grund	2	1	2	2	1	4
26	Smaller ships crossing route T from the wind farm.	Collision with larger ship due to lack of situational awareness due to wind farm	3	1	3	2	1	6
27	Smaller ships crossing route T from the wind farm.	Grounding of larger ship due to evasive manoeuvre	2	1	2	2	1	4

28	Shift of smaller ship traffic south of Kattegat crossing route T.	Ships must pass Hastensgrund, risk of grounding	2	1	2	2	1	4
31	Eastbound ferries crossing route T must give way to northbound traffic and maintain course and speed for southbound traffic. Concern that the radar image may be disturbed and that there is insufficient manoeuvring space.	Ship-ship collision	2	1	4			6
32	SAR with helicopter.	Helicopter must navigate between turbines (under poor weather conditions)	1	1	3	0	0	4
33	Tanker	Collision with tanker	3	1	2	2	4	7
	Construction Phase							
36	Area reserved for construction work is larger (typically 500m) than the turbine area and comes too close to route T.	Less space on route T, risk of grounding	4	1	2	2	1	6
38	Area reserved for construction work is larger than the turbine area and comes close to routes C and/or D	Less space on routes, northbound traffic will move west. Ship-ship collision	3	1	3	2	2	6
41	Work traffic from Grenaa port to Kattegat and possibly for Hesselø	Collision between ships	4	1	3	2	2	7
42	Work traffic from Hundested port to Kattegat	Collision between ships (route T must be crossed)	5	1	3	2	2	8
44	Concentration of traffic as it is not possible to sail through the work area. General traffic is displaced to the north	Increased risk of ship-ship collision	4	1	3	2	2	7
45	Cable work to and from the park/land possibly south of Grenaa	Work ships cross and work on route	4	1	3	2	2	7
48	Ferry traffic in and out of Grenaa, arrival and departure of 6 passengers per day in Grenaa. Construction phase very busy.	Collision between ships	4	1	4	2	2	8
49	Prohibited zone in the construction phase for the work area.	Sailing into the work area, especially pleasure boats	4	1	3	2	1	7

*) Based on an assessment of the CTVs crossing route T from Grenaa to service HES OWF, see /15/.

6.4.1 Risk of collision due to OWF structures masking ships on collision course

Hazards 26 and 31 address the possibility of OWF structures hiding ships sailing behind or within the OWF. In general, this is addressed by PIANC /17/ section 4.2.1 “COLREG 7c) Risk of collision", discussing ships departing an OWF, where ships on the main route may have difficulty to assess the collision potential (Closest Point of Approach) by radar's difficulty to discriminate between fixed and moving targets inside the OWF. PIANC /17/ recommends that ships should keep a distance of 1.5 NM from an OWF to have sufficient time to respond to ships departing from within or from behind an OWF.

With respect to route T, the distance between the most westward sailing, south-bound ships on route T and the KA OWF is 2.4 NM, which exceeds the PIANC minimum of 1.5 NM. It is not expected that fast CTVs will cross in this direction (see recommendation No 6 in section 8.2).

The distance from the KA OWF to centreline of route C is 1.7 NM, but the distance to the most eastward sailing, north-bound ships is 1.2 NM. Crossing ships on this route include the fast CTVs returning to Grenaa.

Most critical is the passage of the ferries from Grenaa to Halmstad, crossing the ships from Gilleleje heading to the west of Anholt OWF. The northernmost point of KA OWF is only 0.5 NM from the (present) centreline of the ferry route, see also discussion in section 5.3.2 under "E". This leads to recommendation No 1 in section 8.2.

7 CUMULATIVE EFFECTS OF OPERATION OF HESSELØ AND KATTEGAT OFFSHORE WIND FARMS

Within the southern part of Danish Kattegat, two OWFs are planned, KA OWF and HES OWF. These planned OWF areas are very close (5 nautical miles) and cumulative effects on navigational safety can be expected, especially with respect to re-routing of ship traffic around both OWFs. This chapter provides and assessment of the cumulative effects based on the quantitative studies for KA OWF in this report and HES OWF (/15/). The assessment is limited to the operational phase because it is considered unlikely that both OWFs will be constructed at the same time and the order of construction is unknown too.

7.1 Re-routing of ship traffic

Re-routing of traffic will be handled in a similar way as the scenario definitions in section 5.3 and based on the same elements as described in section 5.3.3 and the corresponding section in /15/, see Figure 16.

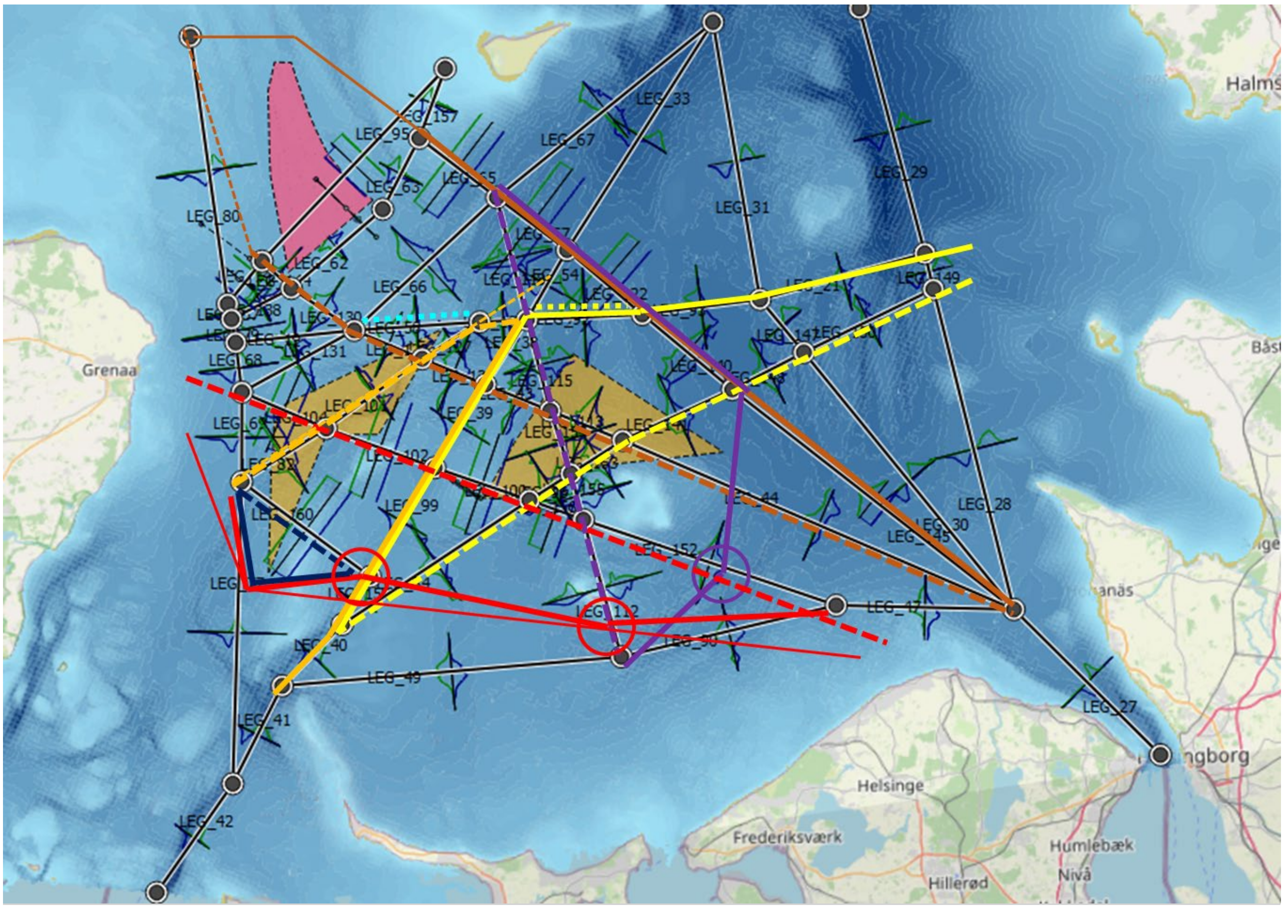

Figure 16. Cumulative changes in ship traffic for the operational phase of HES OWF and KA OWF. Broken lines represent the original (Base Case) routes, solid lines represent re-routing around the OWFs, dotted lines indicate legs where the lateral distributions have been adjusted to avoid the OWFs, circles represent waypoints where actual routes will be straight (as indicated by thin lines)

A. The traffic on the route from/to Øresund to/from the west of Anholt OWF (east coast of Jutland/Aalborg) is moved to the (existing) route from/to Øresund passing between the island Anholt and Anholt OWF (brown routes in Figure 16)

B. The traffic on the route from Sjællands Rev to/from Halmstad is moved to route T until the crossing with the ferry route Grenaa-Halmstad, where it will follow this route (yellow routes in Figure 16).

C. The route from Hundested to Anholt, with mainly pleasure boats, is moved to pass east around HES OWF, merging with the route from Øresund to/from east of Anholt OWF (purple routes in Figure 16). The route from Hundested to this merging point will be a straight course and the waypoint marked with a purple circle in Figure 16 is artificial and does not represent a change of course.

D. The ships navigating about 2 to 3 nm south of route D through the narrow deep-water passage (marked by an asterisk in Figure 2) is moved to route T as there may be requirements to keel clearance, see the orange routes in Figure 16. Note that this affects the operations of pilots from Grenaa.

E. Ships between Gilleleje and Grenaa will pass the KA OWF around the south corner. The "real" route will exist of a straight leg between the southern corner of KA OWF and Gilelleje (passing south of Hesselø), see the thin red line in Figure 16. Within the model, the red legs in Figure 16 exploit existing waypoints from the Base Case, and waypoints marked with a red circle are artificial and do not represent a change of course.

F. Some traffic (pleasure boats mainly) from Hundested to Grenaa pass the southern part of the KA OWF. This traffic has been re-routed along the same legs as ships from Gilleleje to Grenaa (dark blue in Figure 16)

G. The lateral distribution of the legs on the ferry route between Grenaa and Halmstad north of KA OWF and HES OWF (marked by yellow and cyan dotted lines in Figure 16) are changed so that the traffic passes outside the OWFs, for details see this report section 5.3.2 E as well as in /15/, also section 5.3.2 E.

The above re-routing will apply to (large) commercial vessels. Pleasure boats and fishing ships may decide to pass through the OWF as per Assumption C.4 in Appendix C. The passing traffic is estimated in Table 9. Numbers in parentheses are updated estimates as per amendment to Assumption C.4 in Appendix C (see also the discussion in section 5.3.3). The updated numbers mean that the total ship traffic through both OWFs is underestimated by about 8%. The largest change (about 26%) is for the route between Øresund and West of Anholt OWF (brown route in Figure 16). This difference is not expected to change significantly the risk of (collision with) other ship sailing outside the OWF, but the risk of allision between a fishing ship and a WTG inside the OWF is expected to increase by a factor 1.7. Table 10 includes updated total allision frequency accounting for the updated number of fishing ships passing the OWFs by summing the adjustments made for the individual studies.

Table 9 Pleasure boats and fishing ships passing KA OWF and/or HES OWF during Operational Phase. Colours refer to colours of routes in Figure 16 (numbers in parentheses are updated after review of the number of fishing ships passing the OWF).

		Samsø - Anholt (S of route D) (orange)	Hundested – Grenaa (dark blue)	Gilleleje – Grenaa (red)	Øresund - W. of Anholt OWF (brown)	Sjællands Rev (Århus) - Halmstad (yellow)	Hundested – Anholt (purple)
Direct route (km)		97	75	91	112	154	86
Deroute (km)		2.9	1.9	7.8	4.5	31*	6
Relative deroute		3.0%	3%	6.9%	4.1%	20%	6.9%
Fraction of ships passing OWF		23%	23%	36%	27%	52%	33%
Base Case	Pleasure Boats heading N or W	192	320	195	127	51	462
	Pleasure Boats heading S or E	100	352	251	163	16	444
	Fishing Ships heading N or W	1	8	14	55	6	75
	Fishing Ships heading S or E	5	3	7	37	8	75
Operational Phase (Passing OWF)	Pleasure Boats heading N or W	9	70	70	34	26	153
	Pleasure Boats heading S or E	18	77	90	42	8	147
	Fishing Ships heading N or W	0 (0)	1 (4)	5 (8)	15 (27)	3 (4)	25 (40)
	Fishing Ships heading S or E	1 (2)	0 (1)	3 (4)	10 (18)	4 (5)	25 (40)

*) Via route south of Lysegrund

Some of the changes in the cumulative case are as for HES OWF, and will cause similar effects on navigational safety, some are as for KA OWF, and some changes will have cumulative effects.

The re-routing of traffic between Øresund and Jutland (brown route in Figure 16) and between Hundestad and Anholt (purple route) will be as for HES OWF. The re-routing of traffic between Gilleleje and Grenaa (red and dark blue routes) will be as for KA OWF. Cumulative effects relate to re-routing towards route T (between Sjællands Rev and Halmstad, the yellow route, and the route through the deep passage south of route D, the orange route) and the ferry route between Grenaa and Halmstad, north of both OWFs.

7.2 Expected number of allisions

As both drifting and powered allisions will be simulated as individual events, the results of the separate calculations for HES OWF and KA OWF may be added, at least for the ship traffic along the routes not crossing the OWFs. There will be some "shadowing" effect of the OWFs (if a ship hits a WTG, it will not hit another one) for (mainly drifting) ships either sailing east of HES OWF or west of KA OWF that reduces the cumulative number of allisions a bit.

The crossing of the southern-most corner of HES OWF on the route between Gilleleje and Grenaa (the dashed red route in Figure 16) was not included in the simulation for HES OWF, so allisions due to such crossing are not covered. The de-route distance around this corner is very short and it is expected that few ships will decide to pass through that corner.

The estimated number of allisions for the cumulative case are presented in Table 10. It is estimated that both OWFs may lead to commercial vessels colliding with an WTG of one of the new OWFs 5 to 6 times in 1000 years, about equally shared between powered and drifting allisions and 2 out of these 6 allisions will involve a fishing ship, considering that fishing ships are expected to pass through the OWFs twice as often as a pleasure boat.

Table 10 Estimated number of allisions when both HES OWF and KA OWF are in operation.

	Base Case (Incidents per year) / *Expected averaged number of years between incidents*	Estimated cumulative increase (Incidents per year)	Relative estimated cumulative increase
Powered Allisions all ships	0.047 / *21*	0.013	28%
Drifting Allisions all ships	0.003 / *330*	0.003	105%
Total Allisions	0.050 / *20*	0.016 (0.017**)	32% (34%**)
Powered Allisions excl. Pleasure boats	0.002 / *500*	0.003	141%
Drifting Allisions excl. Pleasure boats	0.001 / *1000*	0.002	247%
Total Allisions excl. Pleasure boats	0.003 / *330*	0.005 (0.006**)	172% (200%**)

)** Qualitative estimates based on updated assessment of number of fishing ships passing HES and KA OWF

7.3 Expected number of groundings

Neither HES OWF nor KA OWF leads to significant increase in groundings. The width of route T north of Sjællands Rev and between KA OWF and HES OWF is limited by shallow waters more than it is limited by both OWFs, and it is therefore not expected that both OWFs together will lead to significantly more groundings, especially not for commercial vessels. An exception might be for Crude oil tankers, where an increase up to about 1% may be possible, corresponding to one additional crude oil tanker grounding per 10 000 years (in the Base Case 3 to 4 groundings per 100 years are predicted).

7.4 Expected number of collisions

The number of collisions in a fairway depend on the traffic intensity, width of the fairway, number of course changes, amount of traffic crossing or merging, the angle of crossing, and differences in speed and size between vessels. Both planned OWFs lead to a concentration of traffic along fewer fairways and extra course changes. Some crossings disappear where fairways are abandoned, other crossings appear or become more trafficked. In the cumulative case, both the route between Sjællands Rev and Halmstad and the deep-water passage south of route D move to route T, which is already a busy and at some places narrow fairway.

A conservative estimate of the increase in collisions has been made by collecting, per leg and per waypoint, the increased collision risk, ignoring legs or waypoints where the risk decreased as compared to the Base Case, and adding these data for the HES OWF and KA OWF. The results are presented in Table 11. This estimate shows that in the worst case the cumulative effect of HES OWF and KA OWF are an additional 2 collisions per 100 years.

Table 11. Conservative estimated number of collisions when both HES OWF and KA OWF are in operation.

	Base Case (Incidents per year) / *Expected averaged number of years between incidents*	Estimated cumulative increase (Incidents per year)	Relative estimated cumulative increase
Overtaking	0.066 / *15*	0.003	4%
Head-On	0.014 / *71*	0.002	14%
Crossing	0.026 / *38*	0.002	7%
Merging	0.014 / *71*	0.0002	1%
Bend	0.050 / *20*	0.012	23%
Total Collisions	0.170 / *6*	0.019	11%

Figure 17 shows the waypoints where it may be expected that the number of collisions (due to crossing, merging or crossing) increase. Most of the additional collisions will happen along route T between Sjællands Rev and the ferry route between Grenaa and Halmstad. That includes the slight bending north of Sjællands Rev (southern-most point of the yellow route). The increase is due to the increased traffic intensity, rather than the proximity of the OWFs.

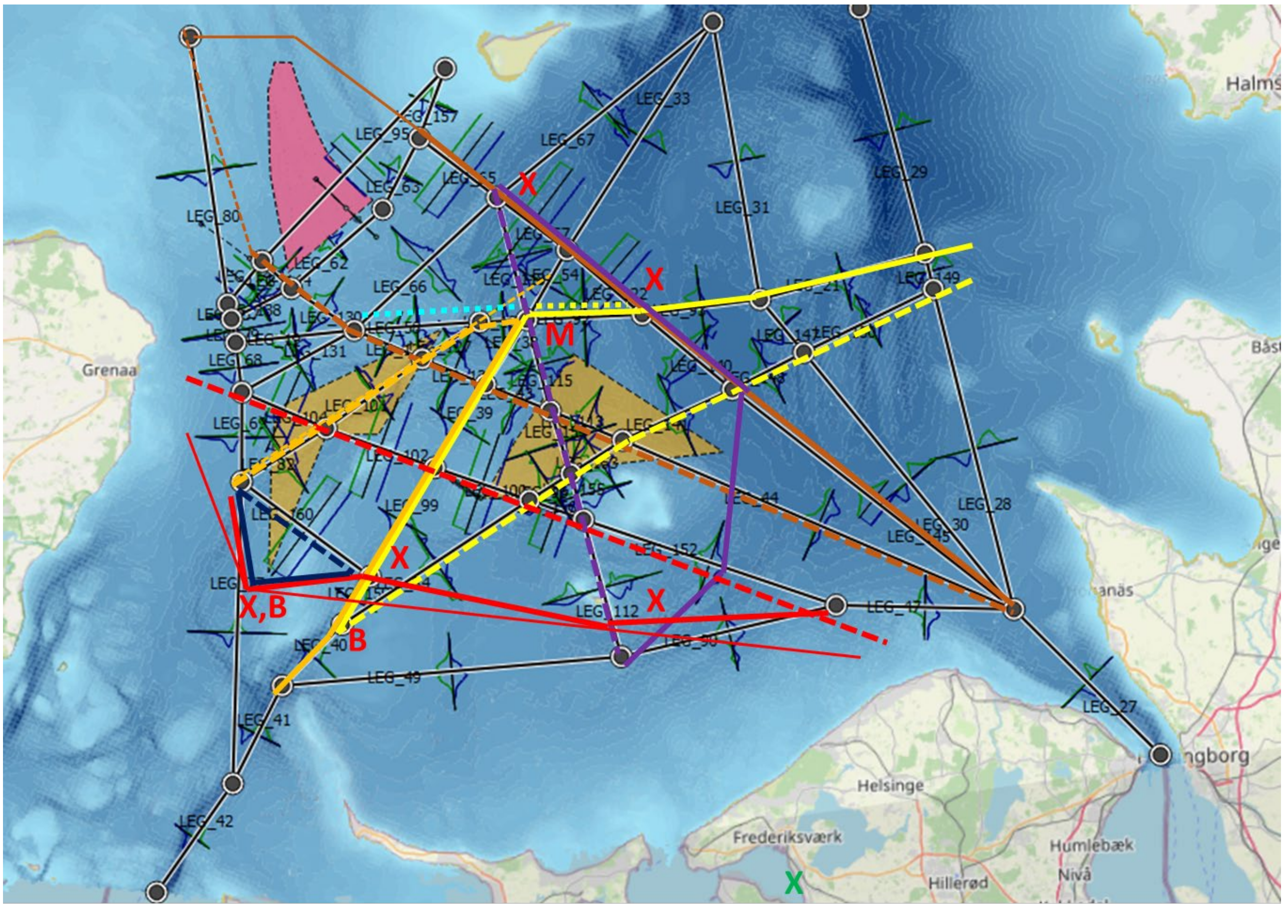

Figure 17 Assessment of changes in number of collisions at waypoints (crossing, merging, bending) for the cumulative case. Red letters point at waypoints where incidents are expected to increase, B=Bending incidents, M=Merging incidents, X=Crossing incidents.

7.5 Updated risk table from HAZID workshop

The HAZID table (see Appendix D) includes two hazards addressing the cumulative effects, viz. Hazard ID 37 and Hazard ID 43. Both hazards address the Construction Phase. During the HAZID it was stated that it is very unlikely that both OWFs will be constructed simultaneously and the assessment in this chapter only considered the operational phase as a consequence. With respect to Hazard ID 37 we refer to the note regarding Hazard ID 36, and for Hazard ID 43 to the notes regarding Hazard IDs 41 and 48, all in section 6.4. The latter hazard can be assessed in detail when the construction process and number of vessels involved in construction are known.

8 CONCLUSIONS AND RECOMMENDATIONS

8.1 Discussion of the results

The questions to be answered by this study are:

- Does the wind farm lead to an intolerable number of allisions between ships and wind turbines?
- Does the rearrangement of the shipping lead to an increased and intolerable number of groundings?
- Does the rearrangement of the shipping lead to an increased and unacceptable number of collisions between ships?

8.1.1 Allisions between ships and offshore wind turbine generators

The HAZID study (Appendix D, Table 8) addresses the hazard of ships colliding into WTGs. The additional number of allisions during operation of KA OWF amounts to about 1 incident per 100 years, of which the majority (two thirds) involves pleasure boats, mainly due to boats sailing across the KA OWF. Among the other ship-types, most allisions will be by Oil product tankers and General cargo ships, both with 1 expected allision per 1000 years. These risks are considered acceptable if reduced to as low as reasonably practicable.

The probability of allision of a passenger ship remains improbable, in the order of 2 incidents per 100 000 years.

8.1.2 Change in number of groundings

The data in Table 4 and Table 7 show a very small increase (less than 1%) in the number of groundings during construction and operation of the KA OWF. This cannot be considered a significant change, and it is concluded that the KA OWF and the related change of shipping patterns does not affect the risk of grounding.

8.1.3 Change in number of ship-ship collisions

The data in Table 4 and section 6.3 show that the increase in risk due to collisions is in the same order as the risk of allision. The increase occurs mainly along route T due to re-routing of ships originally sailing though the KA OWF, increasing the traffic intensity along that route. An additional 6 to 7 collisions per 1000 years are expected. These risks are considered acceptable if reduced to as low as reasonably practicable.

8.1.4 Cumulative effects with HES OWF

Chapter 7 addresses the cumulative effects between KA OWF and HES OWF during operation. The total number of allisions may rise from 9 to 16 incidents per 1000 years but when pleasure boats are ignored the number rises from only 3 to about 5 incidents per 1000 years. The additional risk of grounding remains insignificant. A worst-case assessment of the cumulative impact on ship-ship collision suggests the total number may rise from 6 to 20 incidents per 1000 years.

8.2 Recommendations

On the basis of both the HAZID workshop and findings from the quantitative study, the following three (3) risk mitigating measures are proposed:

1. Eastbound ships or ferries from Grenaa to Halmstad should preferably pass the KA OWF 1.5 NM north of the northernmost corner of the OWF to avoid masking of northbound ships east of (or departing from) the OWF. Investigate to provide additional marking (e.g. using RACON) of the northern-most corner of KA OWF.
2. Ensure sufficient separation between ships and ferries heading east and west between Grenaa and Halmstad north of KA OWF to minimize the risk of collision.
3. Perform a detailed assessment of the navigational safety for the approach to Grenaa harbour, considering construction vessels, CTVs servicing Anholt OWF and (potentially) KA OWF and/or HES OWF, and other vessels (ferries) frequenting the harbour once details on construction and operation are known. Establish Work

Vessel Coordination during construction, avoiding work traffic in leaving or entering the port during arrival and departure of ferries.

The following general recommendations were already identified during the HAZID study and are summarized for completeness (more details are included in Appendix D)

4. Ensure emergency response to stop WTGs when a drifting or uncontrolled ship threatens to collide with a OWF structure.
5. Investigate the need to establish additional coast-based Radar stations or AIS base-stations.
6. Avoid constructing and/or servicing KA OWF from a harbour that requires work vessels or CTVs, respectively, to cross route “T”.
7. Investigate to mark all individual WTGs by beacons instead of only marking the perimeter of the OWF.
8. Consider the use of surveillance vessels to enforce the compliance with the prohibited work areas during the Construction Phase and to protect cable-laying vessels when crossing route “C”.
9. Consider locating additional beacons (physically or as virtual AIS Aids to Navigation) along route “T” to mark the restricted construction zone outside the KA OWF perimeter during construction.
10. Exploit all possible communication channels to inform recreational sailors and fishermen about prohibited work areas and other temporary restrictions or arrangements.
11. Consider during construction to establish Work Vessel Co-ordination with all ship traffic close to KA OWF.
12. Consider to reserve or assign specific VHF channels for communication between work vessels, service vessels and Work Vessel Coordination.
13. Consider establishing dedicated corridors for work vessels from/to KA OWF.

With respect to the HAZID recommendation to establish temporary corridors for pleasure boats and other non-attending vessels to pass through KA OWF during construction, the following is noted. The additional sailing distances for detours around the KA OWF are limited (7% at maximum) and the quantitative study does not indicate that ship-ship collision risk is (significantly) lower when passing through the OWF as compared to following the alternative route around the OWF. The benefit of this measure as compared to efforts may be limited.

9 REFERENCES

/1/ Danish Maritime Agency, 2023, Index of /aisdata Retrieved from Søfartstyrelsen: web.ais.dk/aisdata/ files: *aisdk-2022-01.zip* to *aisdk-2022-12.zip*

/2/ IALA. (2009). IALA Recommendation O-134 on the IALA Risk Management Tool for Ports and Restricted Waterways. 2. Edition: International Association of Marine Aids to Navigation and Lighthouse Authorities.

/3/ IALA. (2014). IWRAP-Theory. Retrieved from Wiki/IWRAP: https://www.iala-aism.org/wiki/iwrap/index.php/Theory

/4/ IHS Markit. (2023). Seaweb Ships. Retrieved from SeaWeb: https://ihsmarkit.com/products/sea-web-vessel-search.html

/5/ MarineTraffic. (2023). MarineTraffic Vessels Database. Retrieved from MarineTraffic: https://www.marinetraffic.com

/6/ IMO, 2018, REVISED GUIDELINES FOR FORMAL SAFETY ASSESSMENT (FSA) FOR USE IN THE IMO RULE-MAKING PROCESS, MSC-MEPC.2/Circ.12/Rev.2

/7/ www.4coffshore.com (subscription) data extracted October 2023

/8/ COWI, Doc No A245595-OFW-VO002, MERE HAVVIND 2030 - KRIEGERS FLAK II AND KATTEGAT II - WIND FARM LAYOUT SCENARIOS, 2023-02-15

/9/ COWI, Doc No A245595-OFW-Ekstra001, HESSELØ OFFSHORE WIND FARM LAYOUT - WIND FARM LAYOUT SCENARIOS, 2023-02-01

/10/ Geodatastyrelsen, Nautical Chart DK 102, Kattegat S-lige del, 14th Ed. Apr. 2020

/11/ The Danish Maritime Authority, 'Navigation through Danish Waters', www.soefartsstyrelsen.dk/Media/E/B/Navigation_through_Danish_waters.pdf, Version 15, Sep. 2022

/12/ MARIS https://raastofindvinding.dk/

/13/ Dataset "Bathymetry of the Baltic Sea" obtained from http://archive.iwlearn.net/helcom.fi/GIS/BalanceData/en_GB/main/index.html,

/14/ Stamdataregister for vindkraftanlæg ultimo januar 2022, excel file downloaded from https://ens.dk/service/statistik-data-noegletal-og-kort/data-oversigt-over-energisektoren , download 2023-12-04

/15/ DNV, WP F Navigational Risk Assessment Hesselø, Report no.: 2109655 (Rev. D, 2024)

/16/ Danish Geodata Agency, Danish Chart Corrections 42/2022, October 26, 2022 (Corrections no. 399-427)

/17/ PIANC Report No. 161 Interaction between offshore wind farms and maritime navigation, PIANC Maritime Navigation Commission, 2018 https://www.pianc.org/publication/interaction-between-offshore-wind-farms-and-maritime-navigation/

/18/ Forsvarskommandoen, email FKO-O-J35K13 Lone Stylsvig to DNV, Nijs Jan Duijm, 2024-10-28, 12:35

APPENDIX A. EXISTING SHIPPING PATTERNS

Figure A 1 Traffic density all ship types.

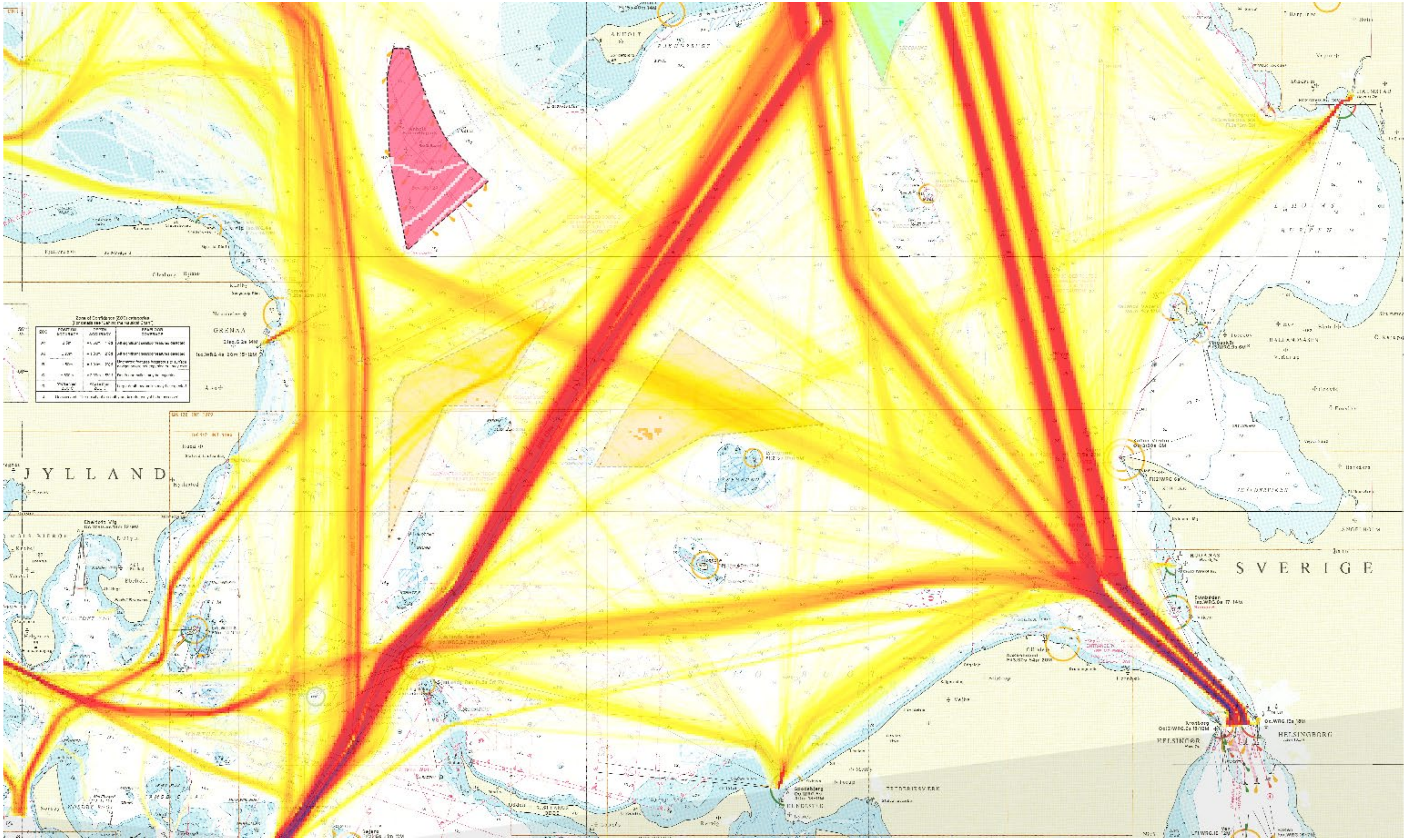

Figure A 2 Traffic density cargo ships (Container ship, General cargo ship, Bulk carrier, Ro-Ro cargo ship)

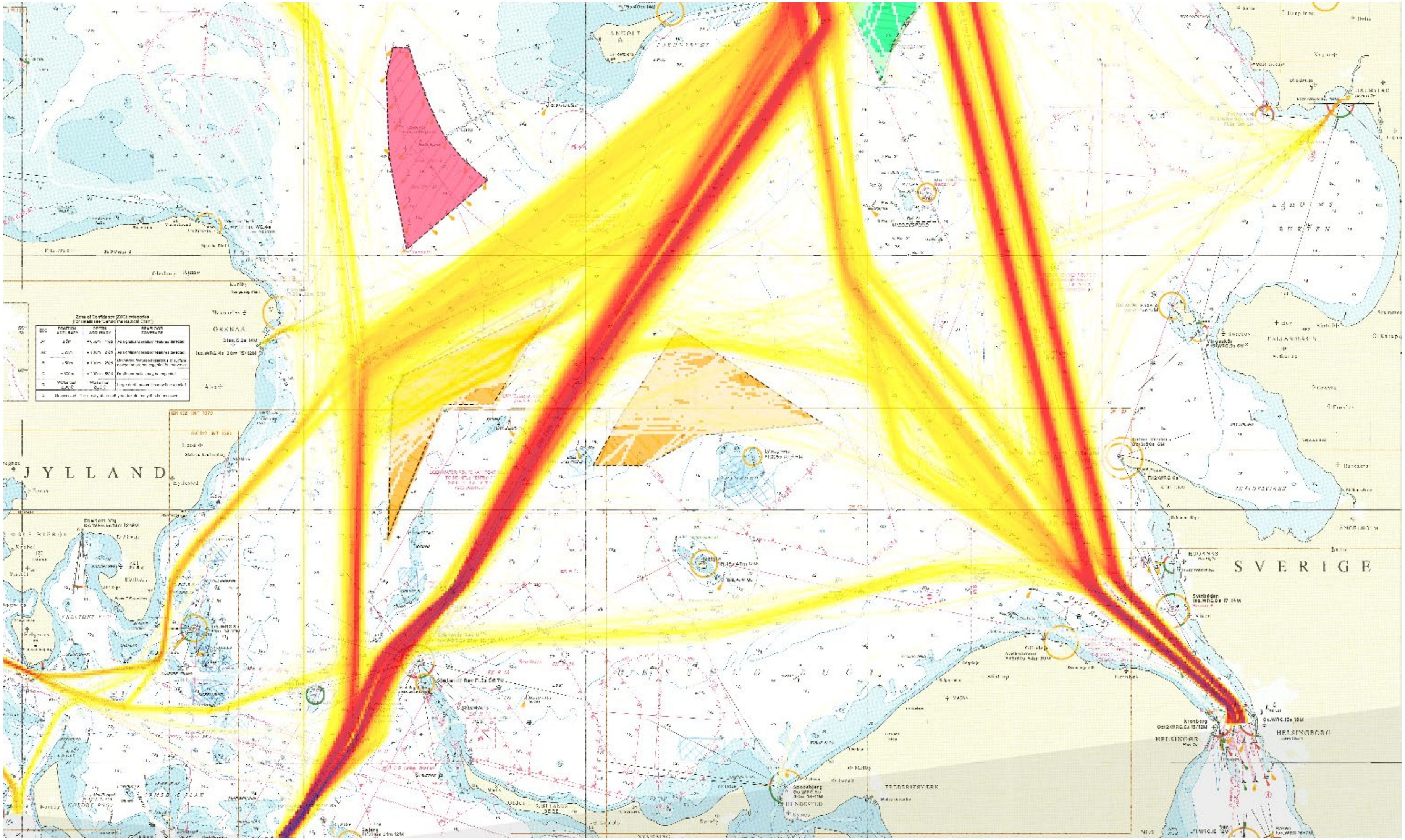

Figure A 3 Traffic density Tanker ships (Crude oil tanker, oil products tanker, Chemical tanker, Gas tanker)

Figure A 4 Traffic density Passenger ships (Passenger ship, Fast ferry)

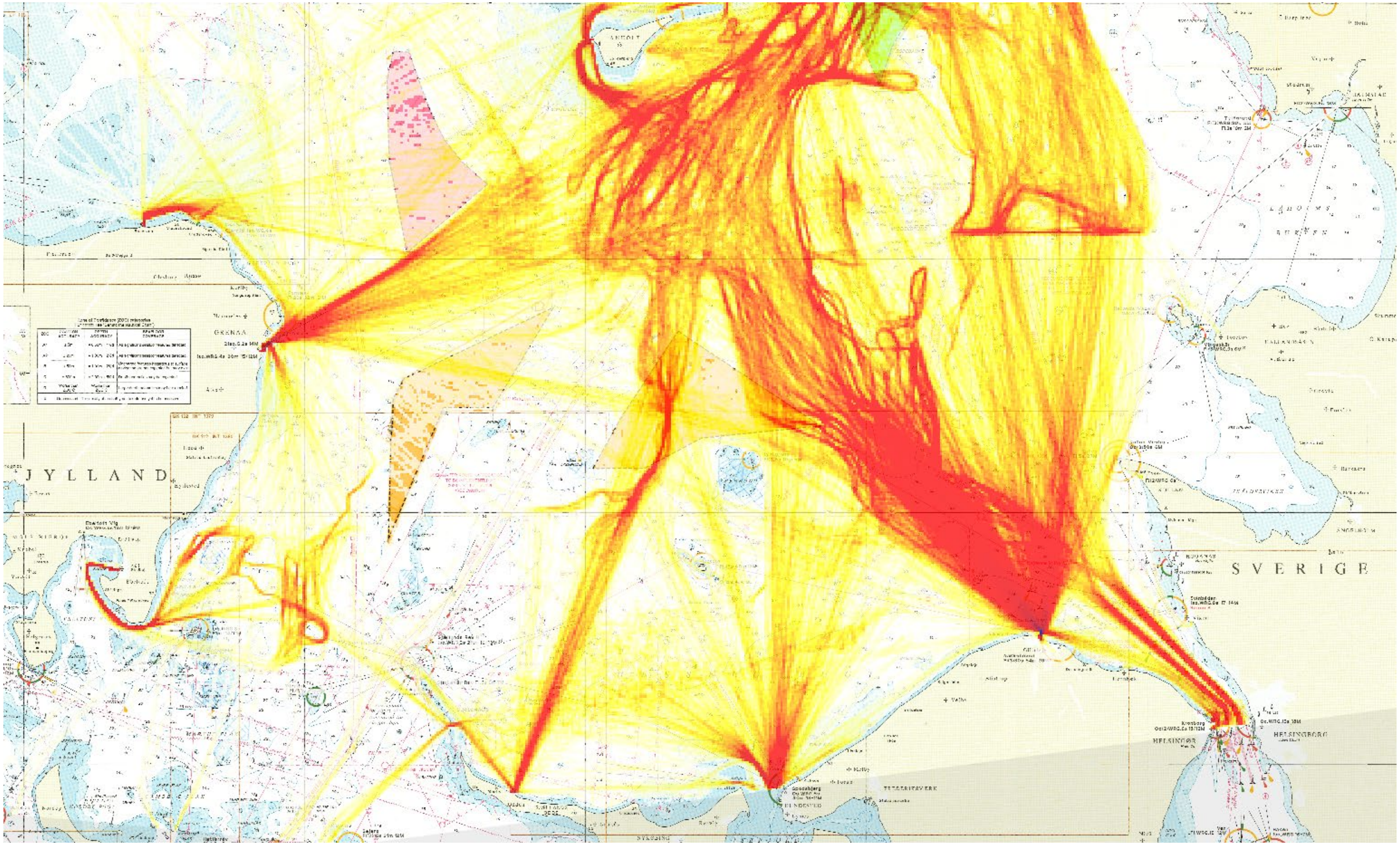

Figure A 5 Traffic density Fishing ships

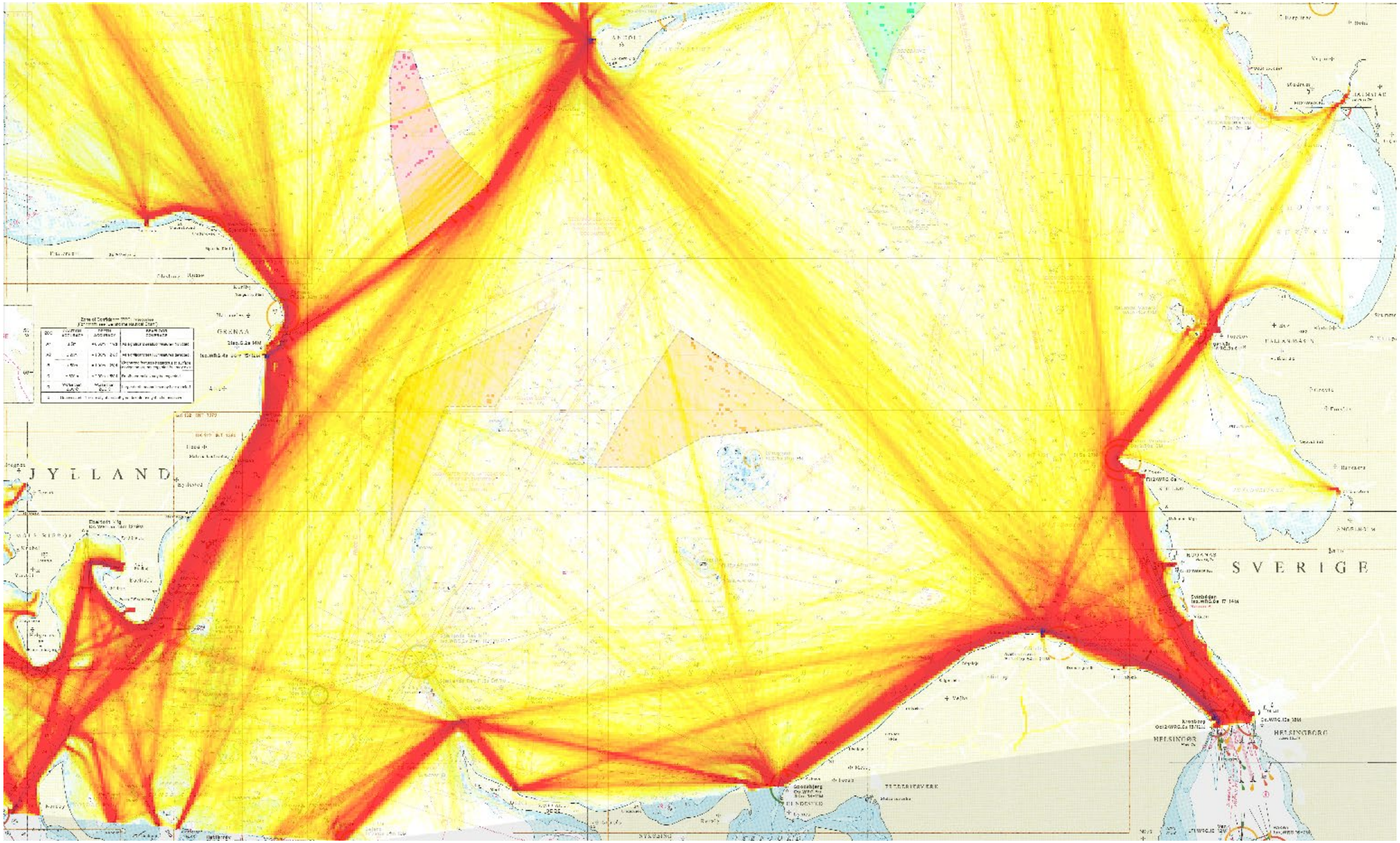

Figure A 6 Traffic density Pleasure boats

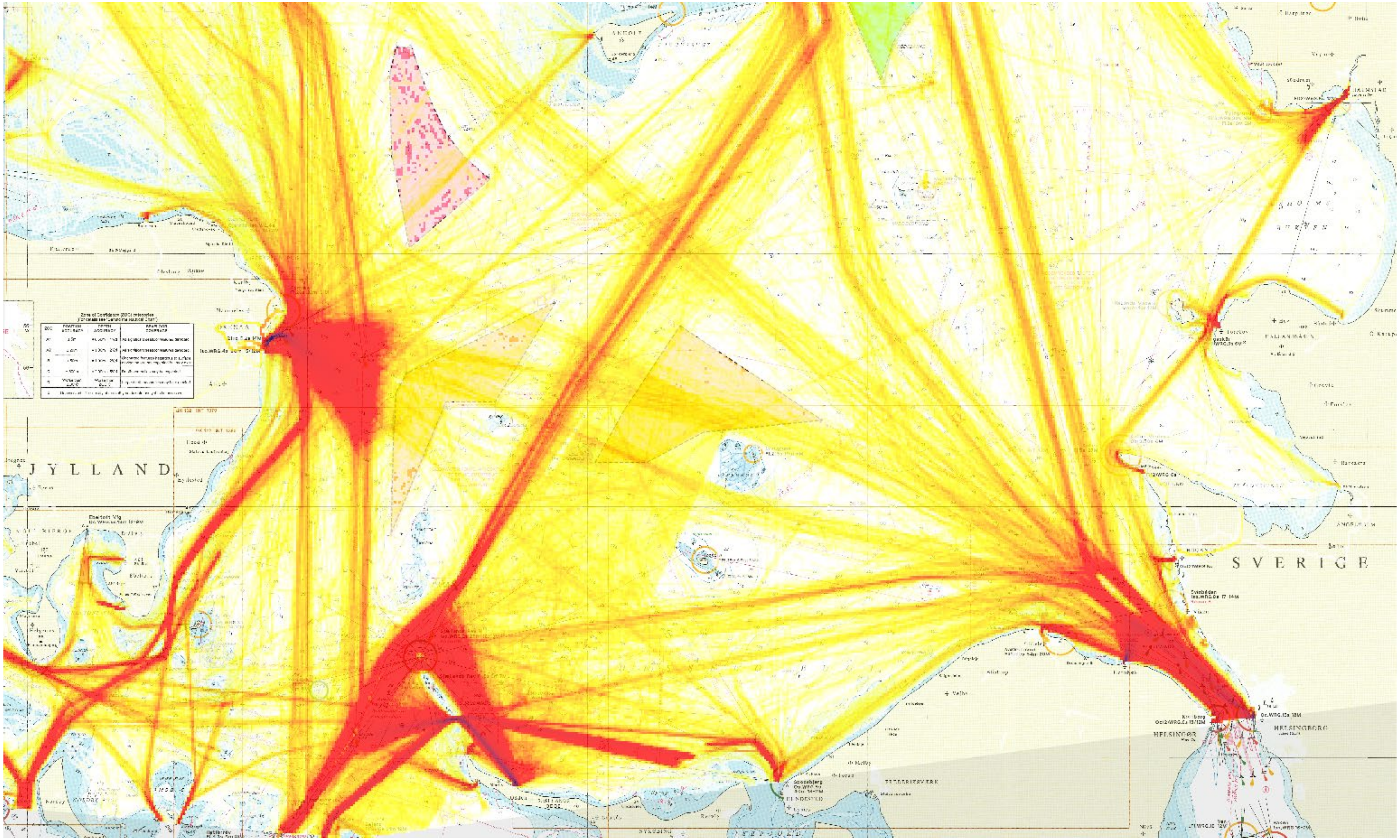

Figure A 7 Traffic density Other ships (Support ships, Other ships)

APPENDIX B. OWF TURBINE POSITIONS

Danish existing wind-turbine positions, position coordinates according to UTM 32 Euref89

Object ID	Easting	Northing
Ukendt 570715000000088650	625628	6135118
Ukendt 570715000000088674	625193	6135008
Ukendt 570715000000088681	624757	6134898
Ukendt 570715000000088698	624321	6134788
Ukendt 570715000000088704	623885	6134678
Ukendt 570715000000088711	623448	6134568
Ukendt 570715000000088728	623012	6134457
Kriegers Flak 570715000001542588	744149	6108859
Kriegers Flak 570715000001542595	741899	6107869
Kriegers Flak 570715000001542601	743789	6107689
Kriegers Flak 570715000001542618	740639	6107234
Kriegers Flak 570715000001542625	743609	6106429
Kriegers Flak 570715000001542632	740549	6105979
Kriegers Flak 570715000001542649	743789	6105169
Kriegers Flak 570715000001542656	740369	6104899
Kriegers Flak 570715000001542663	740459	6103819
Kriegers Flak 570715000001542670	744149	6103639
Kriegers Flak 570715000001542687	740459	6102739
Kriegers Flak 570715000001542694	744419	6102559
Kriegers Flak 570715000001542700	740189	6101749
Kriegers Flak 570715000001542717	744056	6101294
Kriegers Flak 570715000001542724	740639	6100669
Kriegers Flak 570715000001542731	745949	6100406
Kriegers Flak 570715000001542748	743788	6099673
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Object ID	Easting	Northing
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Kriegers Flak 570715000001542977	759093	6105316
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Object ID	Easting	Northing
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Anholt 1 570715000000257032	634479	6267234
Anholt 1 570715000000257049	634479	6267855
Anholt 1 570715000000257056	634471	6268476
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Anholt 1 570715000000257087	634395	6270338
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Anholt 1 570715000000257155	633837	6275158
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Object ID	Easting	Northing
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Anholt 1 570715000000257551	635052	6278430
Anholt 1 570715000000257568	634769	6279241
Anholt 1 570715000000257575	634309	6280530
Anholt 1 570715000000257582	634072	6281189
Anholt 1 570715000000257599	633166	6283679
Anholt 1 570715000000257605	632816	6284616
Anholt 1 570715000000257612	632598	6285195
Anholt 1 570715000000257629	632384	6285755
Anholt 1 570715000000257636	632069	6286316
Anholt 1 570715000000257643	638560	6268538
Anholt 1 570715000000257650	639155	6269079
Anholt 1 570715000000257667	639751	6269619
Anholt 1 570715000000257674	639421	6270433
Anholt 1 570715000000257681	639089	6271245
Anholt 1 570715000000257698	638755	6272056
Anholt 1 570715000000257704	638418	6272866
Anholt 1 570715000000257711	637736	6274483
Anholt 1 570715000000257728	637391	6275290
Anholt 1 570715000000257735	636695	6276901
Anholt 1 570715000000257742	632985	6286311
Anholt 1 570715000000257759	640346	6270160
Anholt 1 570715000000257766	640942	6270701
Anholt 1 570715000000257773	641537	6271242
Anholt 1 570715000000257780	640698	6271605
Anholt 1 570715000000257797	640183	6272260
Anholt 1 570715000000257803	639695	6272935
Anholt 1 570715000000257810	639236	6273630
Anholt 1 570715000000257827	638806	6274344

Object ID	Easting	Northing
Anholt 1 570715000000257834	642115	6271767
Anholt 1 570715000000257841	642718	6272315
Anholt 1 570715000000257858	642154	6272717
Anholt 1 570715000000257865	641594	6273136
Anholt 1 570715000000257872	641053	6273574
Anholt 1 570715000000257889	640527	6274034
Anholt 1 570715000000257896	640021	6274513
Anholt 1 570715000000257902	639533	6275013
Anholt 1 570715000000257919	639029	6275572
Anholt 1 570715000000257926	638563	6276134
Anholt 1 570715000000257933	638205	6276600
Anholt 1 570715000000257940	637861	6277079
Anholt 1 570715000000257957	637534	6277568
Anholt 1 570715000000257964	637254	6278095
Anholt 1 570715000000257971	636711	6279161
Anholt 1 570715000000257988	636451	6279695
Anholt 1 570715000000257995	636196	6280232
Anholt 1 570715000000258008	635705	6281314
Anholt 1 570715000000258015	635469	6281859
Anholt 1 570715000000258022	635239	6282406
Anholt 1 570715000000258039	635015	6282956
Anholt 1 570715000000258046	634797	6283509
Anholt 1 570715000000258053	634585	6284064
Anholt 1 570715000000258060	634380	6284621
Anholt 1 570715000000258077	634181	6285181
Anholt 1 570715000000258084	633988	6285743
Anholt 1 570715000000258091	633802	6286307
Ukendt 570715000000023972	584396	6203077
Ukendt 570715000000023989	584396	6203277

Object ID	Easting	Northing
Ukendt 570715000000023996	584395	6203477
Ukendt 570715000000024009	584391	6203679
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Ukendt 570715000000024023	584796	6203010
Ukendt 570715000000024030	584795	6203211
Ukendt 570715000000024047	584793	6203411
Ukendt 570715000000024054	584792	6203611
Ukendt 570715000000024061	584791	6203811
Offshore 570715000001592651	599466	6175756
Uoplyst 570714700000003592	730459	6179565
Uoplyst 570714700000003608	730499	6179386
Uoplyst 570714700000003615	730535	6179207
Uoplyst 570714700000003622	730568	6179027
Uoplyst 570714700000003639	730597	6178847
Uoplyst 570714700000003646	730624	6178665
Uoplyst 570714700000003653	730647	6178484
Uoplyst 570714700000003660	730666	6178300
Uoplyst 570714700000003677	730683	6178120
Uoplyst 570714700000003684	730696	6177937
Uoplyst 570714700000013713	730705	6177755
Uoplyst 570714700000013720	730712	6177572
Uoplyst 570714700000013737	730715	6177389
Uoplyst 570714700000013744	730714	6177206
Uoplyst 570714700000013751	730711	6177023
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Uoplyst 570714700000013782	730680	6176475
Uoplyst 570714700000013799	730662	6176293
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APPENDIX C. ASSUMPTION REGISTER

C.1 Probabilistic Model Assumptions

Revision / Date	Cf. Earlier studies as per 2021, adopted for MH2030 studies 2024-01-10 (Fast Ferry causation reduction)
Purpose	Definition of the probabilistic parameters in the IWRAP tool
Description	**Human failure relevant parameters** (see tables below)

Human failure relevant parameters

Ship-ship collision incidents	**Causation factors**
Merging	1.3E-4 *(IWRAP default)*
Crossing	1.3E-4 *(IWRAP default)*
Bend	1.3E-4 *(IWRAP default)*
Head-on	0.5E-4 *(IWRAP default)*
Overtaking	1.1E-4 *(IWRAP default)*
Area moving	0.5E-4 *(IWRAP default)*
Area stationary	0.5E-4 *(IWRAP default)*
Ship grounding incidents	
Grounding - forget to turn	1.6E-4 *(IWRAP default)*
Ship-turbine collision incidents	
Collision - forget to turn	1.6E-4 *(IWRAP default, as for grounding)*
Ship type specific reductions	**Causation reduction factors**
Passenger ships	20 *(IWRAP default)*
Fast ferries	1 (IWRAP default is 20), see justification

Machine failure relevant parameters

Drift speed	1 knot(s) *(IWRAP default)*
Probability of successful anchoring	0.98 (*Assessment by Søfartstyrelsen based on seabed conditions*)
Max. anchor depth	7 times design draught *(IWRAP default)*
Min. anchor distance from ground	3 times ship length *(IWRAP default)*
Probability of self-repair	0 for $t < 0.25$ hour $1 - \frac{1}{1.5(t-0.25)+1}$ for $t > 0.25$ hour
Blackout frequencies	
RoRo and passenger ships	0.1 per year *(IWRAP default)*
Other vessels	1.75 per year *(IWRAP default)*

Impact	The calculated incident frequencies are linearly proportional with the causation factors
Justification/ References	/1/ IWRAP Mk II, Basic Modelling Principles for Prediction of Collision and Grounding Frequencies, (draft working document), Rev. 4, 2008.03.09, Peter Friis-Hansen, Technical University of Denmark. /2/ IWRAP Mk2 Extended v6.6.0 (software)

	The causation reduction for Fast Ferries (High Speed Craft) has been reduced to 1 (i.e., no reduction) as the relevant HSC operations in the study areas (Kattegat and Western Baltic) are mainly limited to the Crew Transfer Vessels servicing the OWFs, normally transporting no more than 20 passengers. This assumption is supported by the preliminary conclusions of the Dutch Safety Board concerning the fatal accident involving Fast Ferry “De Tiger” and water taxi (comparable to Crew Transfer Vessel) “Stormloper”, 2023-10-21 near Terschelling, NL.
Prepared by	Nijs Jan Duijm
Review	Lasse Sahlberg-Nielsen

C.2 Drift directions

Revision / Date	First Issue / 2024-01-16
Purpose	IWRAP requires probabilities for drift directions
Description	Drift directions are derived from wind data from the Global Wind Atlas /1/. As likelihood and consequence of drifting is largest for high wind speeds (storm), the probabilities have been taken from the wind speed rose (showing the relative contribution to the averaged windspeed from each wind direction) rather than the wind frequency rose (the distribution of wind direction occurrence). This data is distributed over 12 sectors, IWRAP uses 8 drift directions, so the data is redistributed:

Kriegers Flak (55.13493°N, 12.85675°E)						
Data from Global Wind Atlas			Transferred to 8 sectors			
12 sectors	Center (degr.)	Fraction of yearly averaged windspeed	8 sectors	Center (degr.)	Fraction of yearly averaged windspeed	Drift direction
1	0	0.03	1	0	0.05	S
2	30	0.02	2	45	0.05	SW
3	60	0.05	3	90	0.13	W
4	90	0.09	4	135	0.09	NW
5	120	0.08	5	180	0.12	N
6	150	0.06	6	225	0.19	NE
7	180	0.06	7	270	0.29	E
8	210	0.11	8	315	0.09	SE
9	240	0.17				
10	270	0.2				
11	300	0.09				
12	330	0.05				
Sum		101%	Sum		101%	

Kattegat (56.386543°N, 11.66748°E)						
Data from Global Wind Atlas			Transferred to 8 sectors			
12 sectors	Center (degr.)	Fraction of yearly averaged windspeed	8 sectors	Center (degr.)	Fraction of yearly averaged windspeed	Drift direction
1	0	0.04	1	0	0.06	S
2	30	0.02	2	45	0.04	SW
3	60	0.04	3	90	0.11	W
4	90	0.07	4	135	0.10	NW
5	120	0.08	5	180	0.14	N
6	150	0.07	6	225	0.21	NE
7	180	0.07	7	270	0.25	E
8	210	0.14	8	315	0.09	SE
9	240	0.17				

	<table><tr><td>10</td><td>270</td><td>0.16</td><td></td><td></td><td></td><td></td></tr><tr><td>11</td><td>300</td><td>0.1</td><td></td><td></td><td></td><td></td></tr><tr><td>12</td><td>330</td><td>0.04</td><td></td><td></td><td></td><td></td></tr><tr><td>Sum</td><td></td><td>100%</td><td>Sum</td><td></td><td>100%</td><td></td></tr></table>
Impact	The distribution of drift direction affects the number of drifting allisions in relation to the location of the structure and the traffic leg
Justification/ References	/1/ https://globalwindatlas.info/en/ /2/ IWRAP Mk II, Basic Modelling Principles for Prediction of Collision and Grounding Frequencies, (draft working document), Rev. 4, 2008.03.09, Peter Friis-Hansen, Technical University of Denmark.
Prepared by	Nijs Jan Duijm
Review	Lasse Sahlberg-Nielsen

C.3 Fraction of Pleasure Vessels using AIS

Revision / Date	First Issue / 2023-03-16
Purpose	AIS is not obligatory for smaller vessels such as Pleasure Vessels (including smaller fishing vessels and other small commercial craft). In order to include a realistic number of pleasure vessel in the assessment, it is necessary to assume what fraction of pleasure vessels is using AIS
Description	According to the Lynetteholm report /1/, comparison of visual observations of Pleasure Vessel passages and AIS data for 6 days in August 2018 and September 2019 through channels close to Copenhagen, the number of visually observed vessels is 10.4 +/- 3.4 times the number of vessels observed by AIS. This number (10.4) will be applied for “domestic” Pleasure Vessels (Pleasure Vessels not registered in Austria, Belgium, Germany, Netherlands or Switzerland). For foreign pleasure vessels (from A, B, D, NL or S), a factor of 2.8 will be used following an analysis of foreign ships visiting Klintholm Harbour (See justification below) For the Kattegat model area, the AIS data as analysed by IWRAP shows 33478 pleasure Vessel Trips. According to the country code of the MMSI numbers, 10411 trips, i.e. 31%, have been by foreign vessels (Austria, Belgium, Germany, Netherlands, Switzerland). Therefore, it is estimated that the actual number of Pleasure Vessel trips in the Kattegat area is 0.31*2,8 + 0.69*10.4 = **8.0** times the number of trips as registered by AIS. The uncertainty range is between 5.6 and 10.4. For the Kriegers Flak model area, the AIS data as analysed by IWRAP shows 35006 pleasure Vessel Trips. According to the country code of the MMSI numbers, 17221 trips, i.e. 49%, have been by foreign vessels (Austria, Belgium, Germany, Netherlands, Switzerland). Therefore, it is estimated that the actual number of Pleasure Vessel trips in the Kattegat area is 0.49*2.8 + 0.51*10.4 = **6.7** times the number of trips as registered by AIS. The uncertainty range is between 4.8 and 8.4.
Impact	The number of Pleasure Vessel relate linearly to the number of incidents related to Pleasure Vessels.
Justification/ References	/1/ Ramboll, SEJLADSANALYSE FOR LYNETTEHOLM – BAGGRUNDSRAPPORT, Doc ID 1100038380-1940442988-101, 2020 /2/ Emails Rigo Jørgensen Klintholm havn, to DNV, dated 2024-01-10 8:28 and 9:59 *Justification on factor for foreign Pleasure vessels:* Klintholm Harbour is frequently visited by foreign guests from mainly Germany, but also Austria, Belgium, The Netherlands and Switzerland. For these countries, the Klintholm Harbour master has registered the overnight stays in 2022, being 7105 nights /2/. By comparing these numbers with the AIS registrations (using the country code as included in the MMSI number) of Pleasure Vessels visiting Klintholm Harbour, it can be estimated how many of the foreign ships apply AIS. Figure C.3-18 shows the passage line used for the analysis.

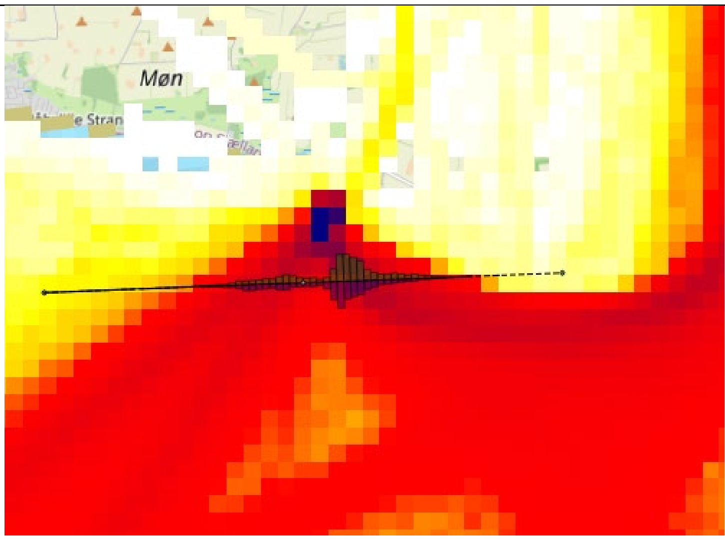


Figure C.3-18 Passage line south of Klintholm Harbour. The traffic density shows pleasure vessels, the distribution along the passage line shows all ships.

In order to relate the passages to the number of stays and nights, the passages of ships have been arranged, so arrivals (north going passage) and departures (south going passage) of single ships have been paired. For these pairs, the number of nights can be extracted on the basis of time of passage. Some passages could not be paired (e.g. because ships have kept close to coastline to the west, or had AIS turned off during arrival or departure, or AIS analysis did not identify passage). Results of the analysis is in Table C.3-12. An outlier of a stay duration of 44 days (Figure C.3-19) has been subtracted from the number of nights from paired arrivals and departures.

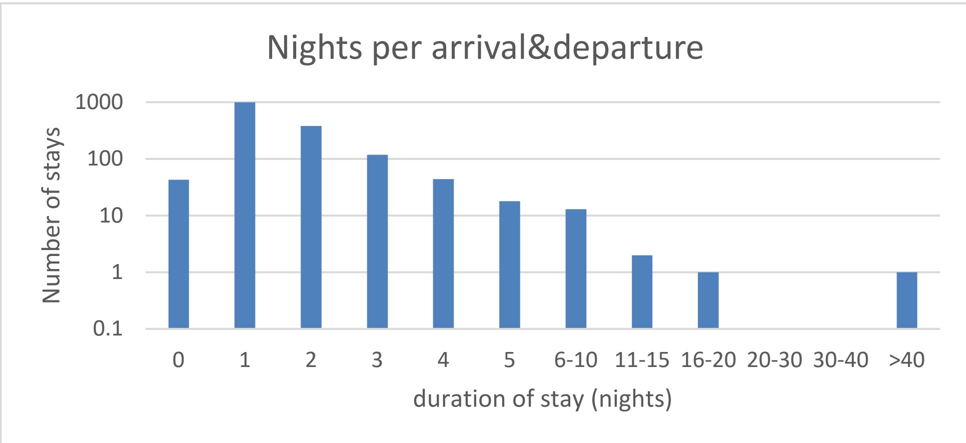


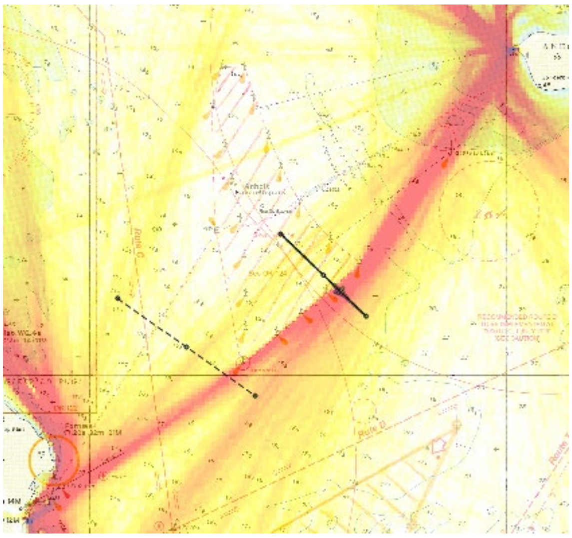
Figure C.3-19 Distribution of duration of stay per visit of AIS-equipped pleasure vessels (from A, B, D, NL or S). The duration of >40 days is considered erroneous (departure not registered correctly)

Table C.3-12 Analysis of AIS arrivals and departures at Klintholm Harbour in 2022

Total registered guest nights (Klintholm Harbour)	7105
Nights from paired arrivals and departures (AIS)	2510
Paired arrivals and departures (AIS)	1616

<table>
<tr><td></td><td>
<table>
<tr><td>Averaged nights per stay for paired arrivals and departures</td><td>1.55</td></tr>
<tr><td>Unpaired arrivals or departures (AIS), sum</td><td>230</td></tr>
<tr><td>Corresponding overnight stays of unpaired arrivals or departures</td><td>357*</td></tr>
<tr><td>Expected total overnight stays (AIS)</td><td>2867</td></tr>
<tr><td colspan="2">Ratio between registered guest nights and nights w/AIS</td></tr>
<tr><td>Best estimate</td><td>2.5*</td></tr>
<tr><td>Highest estimate (conservative)</td><td>2.8* **</td></tr>
</table>
*) It is assumed that the average duration of a stay of foreign pleasure vessels without AIS or unpaired visits with AIS is the same as for the vessels with paired visits with AIS, 1.55 night per stay.
**) the highest estimate is based on paired arrivals and departures only.
As it is not intended to underestimate the number of total pleasure vessels, a factor of 2.8 will be used for the foreign pleasure vessels (vessels from A, B, D, NL and S).
</td></tr>
<tr><td>Prepared by</td><td>Nijs Jan Duijm</td></tr>
<tr><td>Review</td><td>Lasse Sahlberg-Nielsen</td></tr>
</table>

C.4 Number of Pleasure Vessels crossing OWF

Revision / Date	First Issue / 2024-01-09 *Fishing ship analysis added / 2024-10-29*
Purpose	Estimating how many Pleasure Vessels will decide to cross an OWF rather than sail around
Description	The fraction of Pleasure Vessels that decide to cross though an OWF rather than sailing around the OWF is calculated based on the relative increase in sailing distance with this formula, where the extra sailing distance is the difference between the length of the route around the OWF and the shortest sailing distance through the OWF: $$Fraction = \left(\frac{extra\ sailing\ distance}{shortest\ sailing\ distance\ through\ OWF}\right)^{0.4135}$$
Impact	Sailing through an OWF will lead to more allisions with OWF structures
Justification/ References	From AIS data for 2022 for the Kattegat area it can be deducted how many ships are passing through the Anholt OWF rather than passing to the south of the OWF when sailing between the harbours of Grenaa and Anholt. The traffic was analysed using a “passage line”, Figure C.4-20 and Figure C.4-21.  **Figure C.4-20 Traffic density plot between Grenaa Harbour and Anholt Harbour for the whole year 2022, showing most traffic (including ferries) passing south of the Anholt OWF. The black line indicates the passage line for which the analysis is made. Density plot shows Pleasure Vessels; passage line distribution shows all ships.**

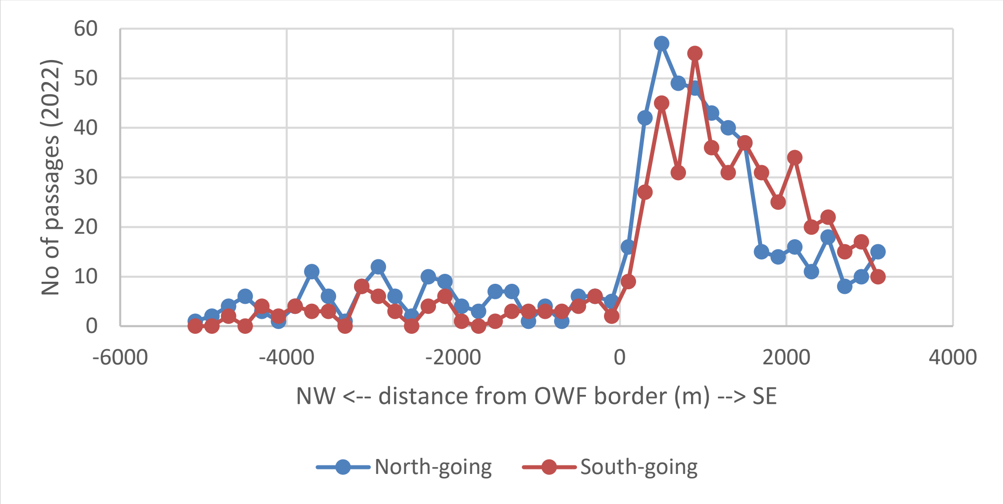


Figure C.4-21 Distribution of Pleasure Vessels crossing the passage line.

In total 130 and 71 Pleasure Vessels passed through OWF in northerly and southerly direction, respectively (between -5200 and 0 m in Figure C.4-21) against 361 and 327 vessels passing outside the OWF (between 0 and 2000 m). So, between 18% and 26% passed through the OWF.

It is expected that the longer the detour around the OWF, the more boats will decide to cross the OWF instead. There will be other factors determining this decision, including means of propulsion (sailing boats tending to avoid dirty wind inside the OWF) and sailing conditions (e.g., wind direction).

Detour length can be considered relative and absolute. The direct route from Grenaa to Anholt harbour crossing the OWF is 23.4 NM, whereas the route around the OWF would take 24.3 NM, i.e., an extra distance of 0.9 NM (absolute) or 3.8% (relative).

No other data is available, and further assumptions are speculative, but here it is assumed that when the sailing distance is doubled (relative), all boats will decide to cross. For this case, given a sailing speed of 5 to 10 knots, this would mean that a crossing of 3 to 5 hours would become 6 to 10 hours. These two points (a fraction of 26% with a relative increase of distance of 3.8% and a fraction of 100% at a doubling of the distance) are fitted with a power function with exponent 0.4135, Figure C.4-22

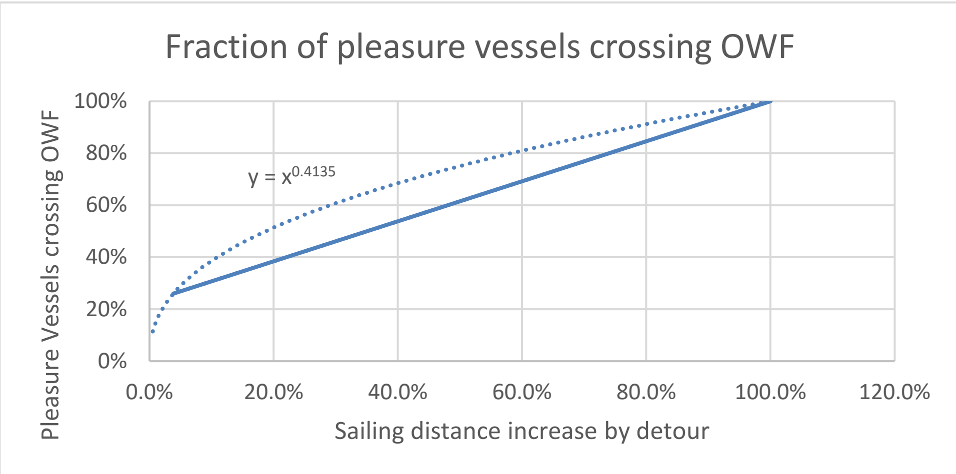


Figure C.4-22 relation between fraction crossing OWF and extra sailing distance.

After review of the report Rev C, the Danish Maritime Authorities questioned the above data for fishing ships, based on observations that about half of the fishing ships pass the OWF. DNV has used the same passage data to review the data for fishing ships

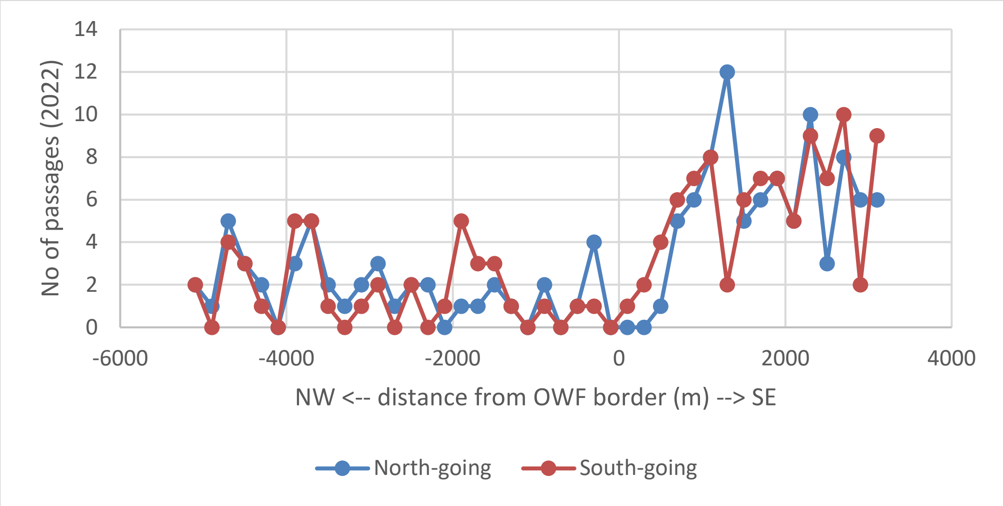


Figure C.4-23 Distribution of Fishing ships crossing the passage line.

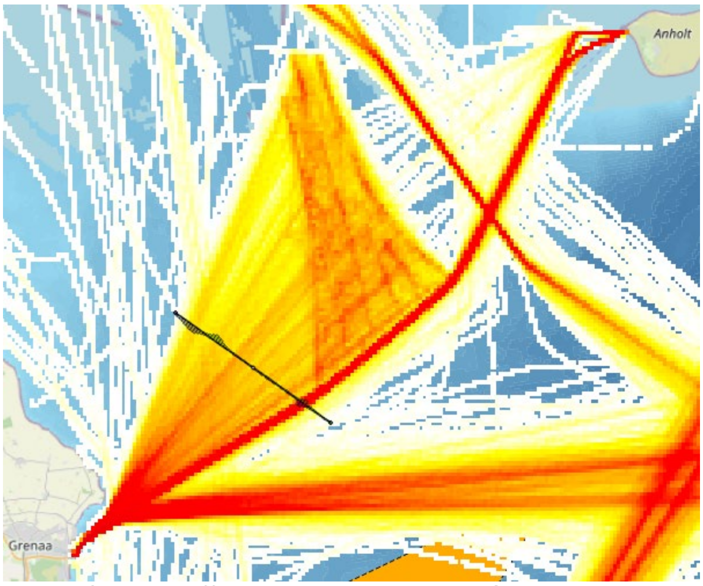
In total 46 and 42 Fishing ships passed through OWF in northerly and southerly direction, respectively (between -5200 and 0 m in Figure C.4-21) against 50 vessels passing outside the OWF (between 0 and 2000 m) in each direction. So, between 48% and 46% passed through the OWF, which means twice as many fishing ships seem to choose OWF to pass the Anholt OWF rather than to follow the detour as pleasure vessels, or expressed differently and operational for all relative detours, the percentage of fishing ships that will follow the detour is (based on this data) 0.7 times the percentage of pleasure boats that will follow the detour around the OWF.

A review of the data for HES OWF and KA OWF show that the total number of ships (pleasure vessels and fishing ships) passing the OWFs during the operational phase should be increased by:

- *Kattegat: less than 4%, worst leg (Øresund-W. of Anholt OWF) about 12%, on average 2 times more fishing ships passing than assumed.*
- *Hesselø: about 13%, worst leg (Øresund-W. of Anholt OWF) about 26%, on average 1.6 times more fishing ships passing than assumed.*
- *Cumulative case: about 8%, worst leg (Øresund-W. of Anholt OWF) about 26%)), on average 1.7 times more fishing ships passing than assumed.*

Prepared by	Nijs Jan Duijm
Review	Lasse Sahlberg-Nielsen

C.5 Number of Crew Transfer Vessel operations for new OWF

Revision / Date	First Issue / 2024-01-09 Updated / 2024-02-22 – data from Kriegers Flak I added
Purpose	Estimating additional service traffic generated by new OWFs
Description	Crew Transfer Vessels classified as “Fast Ferry” (HSC – High Speed Craft) are expected to perform 5 return trips per year per wind turbine. Average speed of a CTV during transit is 17 m/s
Impact	Additional ship traffic crossing existing shipping routes may cause additional incidents
Justification/ References	AIS data for 2022 in the Kattegat area show CTV’s servicing Anholt OWF from Grenaa Harbour. This traffic was analysed across a “passage line”,  **Figure C.5-24 Traffic density plot between Grenaa Harbour and Anholt OWF for the whole year 2022. The black line indicates the passage line for which the analysis is made. Density plot shows passenger ships (including HSC); passage line distribution shows all ships.** Three Crew Boats, with AIS classification “Fast Ferry” (HSC – High Speed Craft) were identified, performing 533 north going passages and 570 south going passages. It is assumed that the highest number corresponds with the number of visits, and representative for the service traffic (some of the outbound trips may have been passing outside the passage line) The OWF exists of 111 wind turbines of 3.6 MW each. This suggests that an OWF generates about 5 service trips per year per wind turbine. This will be used to estimate the additional service vessel traffic generated by new OWFs. There is quite some difference in average speed for outbound (north going) and inbound (south-going) service traffic, 11.9 and 16.6 m/s, respectively. For the new traffic, an average speed of 17 m/s will be assumed (high speed being more hazardous)

	As additional evidence the study for Kriegers Flak shows that HSC to existing Kriegers Flak I (Leg 39 in the IWRAP model) include 343 HSC trips west bound, and 346 trips east bound. Given 72 turbines in Kriegers Flak I OWF, 360 trips would correspond to 5 trips per turbine.
Prepared by	Nijs Jan Duijm
Review	Lasse Sahlberg-Nielsen

C.6 Mapping trips to legs

Revision / Date	First Issue / 2023-03-16
Purpose	Generate traffic distribution along legs from AIS data, IWRAP Extract Model Data
Description	The width of legs is defined manually, attempting to ensure that all relevant traffic is covered by a leg. Parameters used for extracting model data: Season: not used (IWRAP default) Angle: 25 Degr (IWRAP default is 10 degr.) Bin size: 100 m Max time: 900 s (IWRAP default, maximum time between AIS records, if time is longer new trip is started) Min calculated speed: Disabled (IWRAP default) Max calculated speed: 100 kn (IWRAP default) Max distance: 4000 m (IWRAP default, maximum distance between AIS record, if longer new trip is started) Calculated geographical boundary used (IWRAP default) New algorithm disabled (IWRAP default)
Impact	The traffic assigned to legs will be used for the calculation of number of incidents. It is important to ensure that a maximum amount of traffic that can cause incidents is assigned to a leg, traffic not assigned to a leg will not be included in the calculations
Justification/ References	The angle is set at 25 degrees, so that also reasonable misalignment between leg direction and course still leads to assignment to that leg. Especially relevant to Pleasure Vessel traffic not aligned with leg definition.
Prepared by	Nijs Jan Duijm
Review	Lasse Sahlberg-Nielsen

APPENDIX D. **HAZID REPORT**

The HAZID report is included as a pdf-attachment to this pdf file.

APPENDIX E. APPENDIX E NON-DEFAULT LEG SPECIFICATIONS

Leg alignment.

For the following legs, necessary alignment of trips with the leg of less than the default value of 25° are applied:

Leg number	alignment within (°)
LEG_19	20
LEG_30	15
LEG_33	15
LEG_38	20
LEG_44	15
LEG_47	15
LEG_49	15
LEG_54	15
LEG_58	15
LEG_63	10
LEG_67	15
LEG_89	15
LEG_95	15
LEG_127	15
LEG_129	15
LEG_131	20
LEG_136	30 (wider)
LEG_138	15
LEG_143	15
LEG_157	10

Leg lateral distribution

For the following legs, the application of a uniform lateral distribution has been enforced:

Leg number	Distribution
LEG_57	Uniform
LEG_65	Uniform
LEG_102	uniform
LEG_104	uniform
LEG_122	Uniform
LEG_156	uniform
LEG_160	uniform

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DNV is the independent expert in risk management and assurance, operating in more than 100 countries. Through its broad experience and deep expertise DNV advances safety and sustainable performance, sets industry benchmarks, and inspires and invents solutions.

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Driven by its purpose, to safeguard life, property, and the environment, DNV helps tackle the challenges and global transformations facing its customers and the world today and is a trusted voice for many of the world's most successful and forward-thinking companies.