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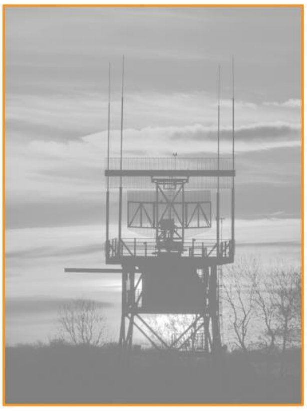
OX2

SAFETY DISTANCE ANALYSIS FOR THE TRITON WIND FARM: CALCULATING DISTANCES BETWEEN OFFSHORE WIND FARMS AND SHIPPING LANES



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EXECUTIVE SUMMARY

Safe, navigable distances must be applied between offshore windfarms and shipping lanes (IMO routeing measures or clearways) to allow for basic safety manoeuvres to occur (such as anchoring and round turns) and to protect vessels and turbines from damage. These zones therefore mitigate the risk of incidents at sea and create a safer, navigable environment.

OX2 have commissioned Marine and Risk Consultants Ltd to undertake a project assessing the necessary distances required between the offshore windfarm and shipping lanes. The project has been divided into three lots:

1. Presenting guidelines and actual distances between offshore windfarms and shipping lanes.
2. Assessing acceptable risk and distances needed between offshore windfarms and shipping lanes.
3. Calculating acceptable distances for three OX2 projects and quantifying impacts on navigational safety.

This assessment considered the Triton offshore windfarm and calculated the necessary distance between the offshore windfarm and the shipping lanes that surround it. The findings of this assessment were as follows:

Traffic Density

The traffic density around Triton was moderate/high with an average of 156 vessels per day within 10nm. The densest region was located within shipping lane A located to the east/south of Triton at approximately 36 vessels per day. Traffic surrounding Triton primarily travels to the north and east of the wind farm within the designated traffic lanes that form the traffic separation scheme.

Vessel Sizes

Most vessels within 10nm of Triton range between 80-90m LOA with 9,593 transits within that category over the 12-month data period. The largest frequent ship was the 323m passenger ship MSC SEAVIEW which was used as a baseline for the calculating the necessary room required for vessels to manoeuvre between the offshore windfarm and shipping lane. This was calculated at approximately 0.87nm. The largest vessels are seen to use the full width of the lanes and transit within the routeing measures designated. The lanes are of sufficient width for vessels to have adequate room to complete a round turn.

Environmental Conditions

Prevailing winds are west to south-westerly at a maximum speed of 17.78m/s to 20.32m/s and the maximum tidal heights estimated across the Baltic for a 100-year period are 23cm. Therefore, as tidal drift is negligible, mariner expertise suggests a prevailing west to south-westerly wind would be of little concern due to the adequate sea room around the OWF for vessels to drift.

Ocean Uses

The closest IMO routeing measure is the traffic lane that forms part of the TSS in Bornholmsgat approximately 0.25nm east of the boundary. The site is approximately 9.35nm from the closest renewable energy installation, the Baltic Two wind farm. The closest navigation hazards are the firing practice area south of Triton at a CPA of approximately 1.22nm and the precautionary area that forms part of the TTS to the east approximately 1.50nm from the Triton boundary.

Traffic Profile

A total of 9,900 vessels (79,319 tracks) transited within the data extent during the assessed period. A total of 1,379 vessels (3,153 tracks) vessels intersected the boundary across the 12-month data period which is an average of 9 vessel tracks per day. A total of 2,702 recreational vessel tracks were within 10nm of the Triton offshore windfarm and 779 tracks were made by fishing vessels within 10nm of Triton. Approximately 59% of tracks were produced by cargo vessels, 18% by tankers, 13% by passenger vessels, 5% were by recreational vessels, 4% by other category vessels, and 1% were by fishing vessels.

Shipping Lanes

9 shipping lanes were identified within the vicinity of the Triton OWF, 4 were located within existing routeing measures and the remaining 5 were clearways. 4 out of the 9 90th percentile lanes identified (A, C, E, and G) were located under 0.5nm of the Triton wind farm boundary. The highest number of commercial vessels per day was lane A (Traffic Lane) with an average of 36 vessels per day.

Radar Interference

Radar interference is dependent on the situation, with the most common impact being reflected energy cluttering the operating display. Guidance on mitigating radar interference suggests a zone of 0.8nm is sufficient to reduce the effects on vessels radars and larger vessels must plan their voyages and allow for a 2nm zone between themselves and the adjacent offshore windfarm providing adequate safe sea room exists.

Conclusion

This assessment has considered a range of factors that would contribute to the in-situ designation of a safety zone around the Triton offshore windfarm. Based on analysis of the surrounding area and vessel traffic, the evidence suggests that a minimum safety distance of 0.5nm from the closest point of approach to the Triton offshore windfarm boundary is likely tolerable within the navigation risk profile of the development. The Triton OWF boundary and indicative turbine layout would therefore require substantial adjustment to the east section and west section border to adhere to the safe distance suggested above.

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ABBREVIATIONS

Abbreviation	Detail
AIS	Automatic Identification System
ALARP	As Low as Reasonably Practicable
COLREG	International Regulations for Preventing Collisions at Sea
CPA	Closest Point of Approach
DW	Deep-Water
EEZ	Exclusive Economic Zones
GPRS	General Provisions on Ships' Routeing
HSC	High Speed Craft
IMO	International Maritime Organisation
ISM	International Safety Management
ITZ	Inshore Traffic Zone
km^2	Square Kilometres
LOA	Length Over-all
m	Meter
Marico Marine	Marine and Risk Consultants Ltd
MCA	Maritime and Coastguard Agency
MGN	Marine Guidance Note
MSP	Marine Spatial Planning
nm	Nautical Mile
NRA	Navigation Risk Assessment
OREI	Offshore Renewable Energy Installation
OWF	Offshore Wind Farm
SOLAS	Safety of Life at Sea
TSS	Traffic Separation Scheme
UNCLOS	United Nations Convention on the Law of the Sea
VHF	Very High Frequency
WGS	World Geodetic System
WTG	Wind Turbine Generator

TERMINOLOGY

Term	Definition
ALARP	Refers to a level of risk that is neither negligibly low nor intolerable high. ALARP is actually the attribute of a risk, for which further investment of resources for risk reduction is not justifiable. The principle of ALARP is employed for the risk assessment procedure. Risks should be As Low As Reasonably Practicable. It means that accidental events whose risks fall within this region have to be reduced unless there is a disproportionate cost to the benefits obtained.[1]
Allision	The striking of one ship against a stationary object such as a berth, Aid to Navigation, Offshore structure or vessel at anchor or stopped and making no way through the water. Offshore structures could include OFW infrastructure such as wind turbines or their foundations.
Area to be Avoided	An area within defined limits in which either navigation is particularly hazardous or it is exceptionally important to avoid casualties and which should be avoided by all ships, or by certain classes of ships.
Clearway	A clearway is a section of open sea that connects TSSs or commonly gets used by vessels to transit. Clearways are not formally defined by boundaries and are identified using AIS tracks.
COLREGS	Otherwise referred to as the "Rules of the Road" or RoR, the COLREGS were adopted by the IMO to mandate the rules to be followed by ships and other vessels at sea in order to prevent collisions between two or more vessels.
CPA	The closest point of approach is the minimum distance a vessel transits past a static object (e.g. OWF).
Deep Water (DW) Route	A route within defined limits which has been accurately surveyed for clearance of sea bottom and submerged articles.
IMO	The IMO is the United Nations specialized agency with responsibility for the safety and security of shipping and the prevention of marine and atmospheric pollution by ships.
Inshore Traffic Zone (ITZ)	A designated area between the landward boundary of a traffic separation scheme and the adjacent coast.

[1] IMO (2018) MSC-MEPC.2/Circ.12/Rev.2 dated 9 April 2018, 'Revised Guidelines for Formal Safety Assessment (FSA) in the IMO Rule-Making Process'

Marine Casualty	An event, or a sequence of events, that has resulted in any of the following which has occurred directly in connection with the operations of a ship: 1. the death of, or serious injury to, a person; 2. the loss of a person from a ship; 3. the loss, presumed loss or abandonment of a ship; 4. material damage to a ship; 5. the stranding or disabling of a ship, or the involvement of a ship in a collision; 6. material damage to marine infrastructure external to a ship, that could seriously endanger the safety of the ship, another ship or an individual; or 7. severe damage to the environment, or the potential for severe damage to the environment, brought about by the damage of a ship or ships.
Precautionary Area	An area within defined limits where ships must navigate with particular caution and within which the direction of flow of traffic may be recommended.
Recommended Route	A route of undefined width, for the convenience of ships in transit, which is often marked by centreline buoys.
Roundabout	A separation point or circular separation zone and a circular traffic lane within defined limits.
Safety Zone/Distance	Refers to the distance between an OWF and shipping lane. Also referred to as a safe, navigable distance.
Separation Zone or Line	A zone or line separating traffic lanes in which ships are proceeding in opposite or nearly opposite directions; or separating a traffic lane from the adjacent sea area; or separating traffic lanes designated for particular classes of ship proceeding in the same direction.
Shipping Lane	Shipping lanes are popular routes used by vessels to transit ocean space, these can be either clearways or defined by the IMO in the IMO routeing Guide. Such a description could apply to a DW Route, ITZ, Recommended Route or Traffic Lane (whether within a TSS or otherwise).
Traffic Lane	An area within defined limits in which one-way traffic is established. Natural obstacles, including those forming separation zones, may constitute a boundary.
TSS	A routeing measure aimed at the separation of opposing streams of traffic by appropriate means and by the establishment of traffic lanes. TSSs' that have been adopted by the IMO are included in in the IMO Routeing Guide.

MARICO MARINE

Marico Marine is an independent maritime consultancy and technology company based in Southampton, UK and Wellington, New Zealand, providing shipping, navigation and risk management expertise to the marine, ports, and offshore energy sectors, worldwide. With a diverse and multi-disciplined team, Marico Marine offers a unique blend of quantitative analyses supported by practical maritime experience founded on a wealth of knowledge and technical innovation.

Marico Marine have over 20 years of experience in providing consultancy services and over 10 years' experience working at the interface between maritime, shipping, and offshore renewables, focusing on the assessment and quantification of marine and navigation risk. From feasibility to decommissioning, Marico Marine can provide maritime expertise throughout all stages of a project lifecycle, fusing professional mariner experience with contemporary maritime analytics to provide additional assurance and value to outputs delivered.

Marico Marine have undertaken a great many navigation risk assessments in support of offshore renewable projects across the UK and Europe to regulatory requirements and guidelines. Projects are supported by the development and implementation of geospatial and probabilistic tools and models to inform quantitative navigation risk assessments.

1 INTRODUCTION

It is important to ensure that a safe navigable distance is maintained between the boundary of an Offshore Wind Farm (OWF) and an adjacent shipping lane to prevent allision between vessels and OWF infrastructure and to provide sufficient sea-room for vessels to:

- Execute collision avoidance manoeuvres in compliance with the COLREGs;
- Safely complete an extraordinary or emergency manoeuvre such as a “round turn” where a vessel is required to change her heading through a full 360˚;
- Increase the vessel’s safety margin from navigational hazards owing to sideways drift of ship as a result of the prevailing wind, sea, swell or current conditions at the location;
- Safely anchor at a location clear of traffic congestion if required; or
- Execute a man-overboard recovery.

OX2 have commissioned Marine and Risk Consultants Ltd (Marico Marine) to determine a tolerable safety distance zone between the Triton OWF and adjacent shipping lanes in the southern Baltic Sea. This report will:

1. Profile vessel traffic within the area and consider the contributing factors for safety distances;
2. Consider appropriate international guidance; and
3. Determine an appropriate safety distance zone for the Triton OWF.

This assessment explores the safety distances in situ and analyses the distances necessary to create a safe maritime environment in the vicinity of the Triton OWF.

Please note: This document ought to be used in conjunction with existing Nautical Risk Analysis documents and Guidelines for Distances Between Offshore Wind Farms and Shipping Lanes (Lot 1) created by Marico Marine.

2 STUDY OBJECTIVES

This document has been created to support the wider works of the Triton OWF project and should be considered with guidance outlined within lot 1[2]. The report evaluates the contributing factors to safe, navigable distances (**Section 3**) that were identified within lot 1 to support and justify distances allocated between shipping lanes and the Triton OWF. This assessment utilises one-year's worth of AIS data and considers sea-space factors, environmental conditions, and guidance to determine and recommend safe, navigable distances within the vicinity of the Triton OWF.

The objectives of this document are as follows:

- Determine factors that contribute to safe distances between OWF and shipping lanes using the guidance outlined in lot 1;
- Analyse shipping movements in the vicinity of Triton by type, size, and activity;
- Analyse ocean uses within the vicinity of Triton including Traffic Separation Scheme (TSS), other developments, anchorages, etc;
- Identify the principal shipping routes within the study area and in the vicinity of Triton;
- Using findings and legislation, determine if the distances around Triton are safe; and
- Recommend mitigation and safe distances around the development.

2.1 DATA SOURCES

The principal data source in this assessment is provided from the Automatic Identification System (AIS). The following section outlines data type, extent, and duration of the dataset.

2.1.1 Automatic Identification System Data

In 2000, the International Maritime Organisation (IMO) adopted a new requirement as part of a revised Chapter V of Safety of Life at Sea (SOLAS) for ships to be fitted with an AIS receiver. The system aims to improve a mariner's awareness of other vessels by augmenting radar, visual and sound as collision avoidance tools. AIS broadcasts key information about a vessel (such as its identity, position, type, speed, and course) at regular intervals through Very High Frequency (VHF) radio waves.

AIS exists in two forms, Class A and Class B: the former is fitted in all vessels required to carry AIS under SOLAS; the latter is on a voluntary basis by non-SOLAS vessels such as recreational craft and commercial fishing vessels less than 15m in length.

[2] Guidelines for Distances Between Offshore Wind Farms and Shipping Lanes, Marico Marine, 2022

Regulation 19 of SOLAS Chapter V sets out the navigational equipment to be carried on board ships according to ship type, and AIS is required on:

- All ships greater than or equal to 300 gross tonnage and engaged on international voyages;
- Cargo ships greater than or equal to 500 gross tonnage not engaged on international voyages; and
- All passenger ships irrespective of size.

2.1.2 Data Timeframe and Extent

An AIS vessel traffic dataset was sourced for the 12-month period between 1 May 2021 and 30 April 2022. The extent of the data (based on a 20nm buffer of Triton) is shown on **Figure 1** and is as follows:

- Latitude between 55.506479 (55° 30' 23.32" N) and 54.769287 (54° 46' 9.43" N) Decimal Degrees (WGS 1984); and
- Longitude between 12.875797 (12° 52' 32.86" E) and 14.666562 (14° 39' 59.62" E) Decimal Degrees (WGS 1984).

The dataset is composed of terrestrial AIS vessel positions. The dataset was of sufficient duration to identify any seasonality and to provide a reliable sample of vessel traffic in the area. The extent of the dataset was large enough to include not only the study area and the local vicinity, but also to overcome some of the limitations of AIS data.

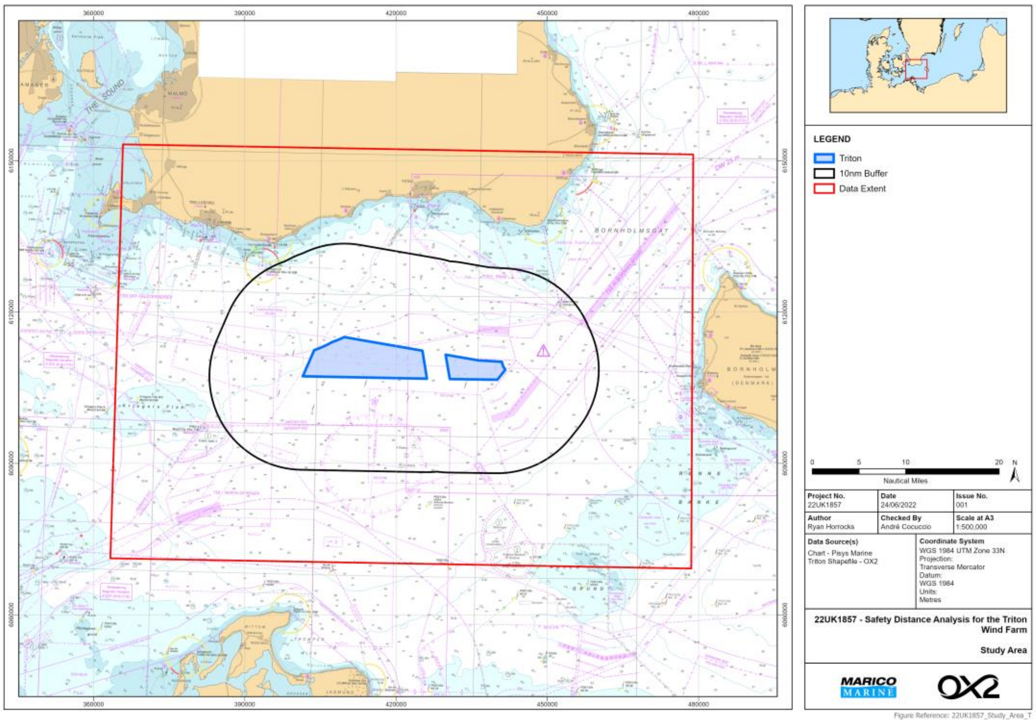

Figure 1 – Triton OWF Study Area.

2.1.3 Triton Data Overview

Supplied by OX2 were two datasets that were used as the basis for calculating the distances between the OWF and the shipping lanes that surround it. The two datasets supplied are shown in **Figure 2** and are as follows:

- Triton Offshore Windfarm Boundary; and
- Indicative Triton Wind Turbine Generator (WTG) positions.

The Triton OWF is approximately 195.32km² for both sections combined. This shapefile was used as a baseline for conducting the safety distance analysis. The WTG data contains information on **example turbine positions** to give a general look as to how the farm could be laid out.

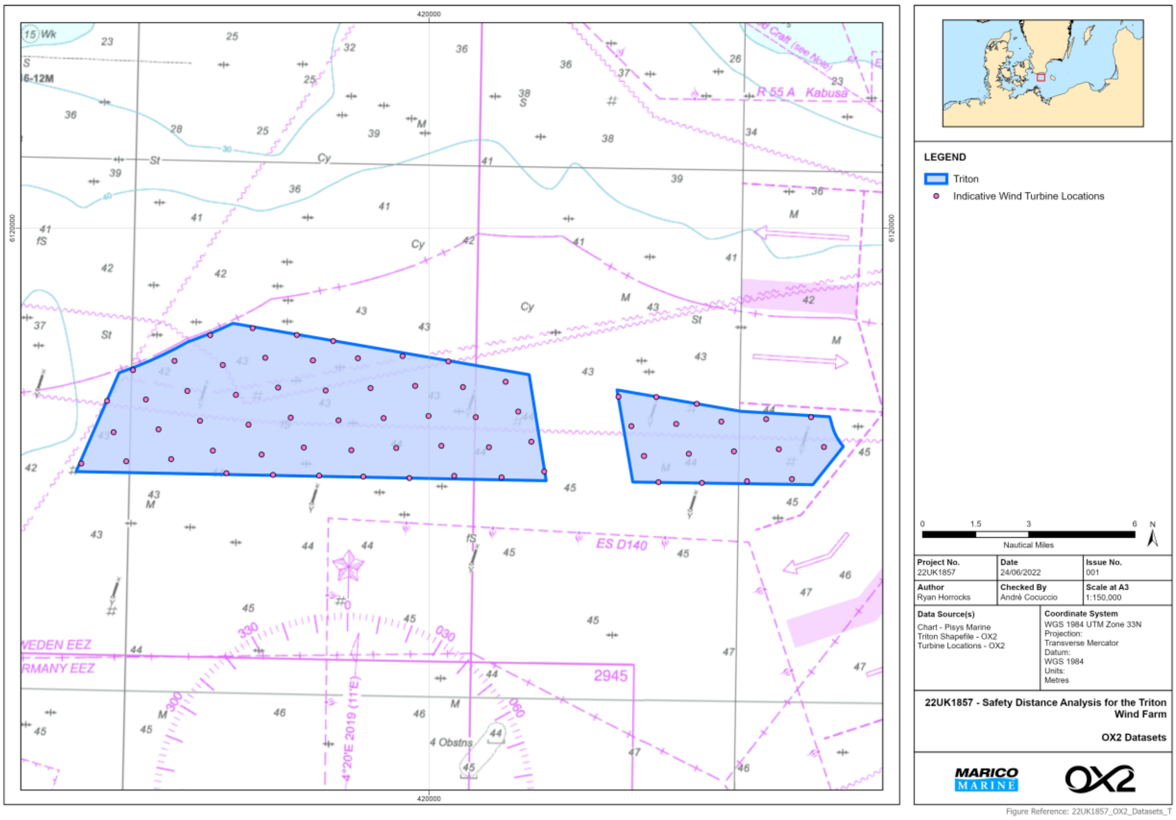

Figure 2 – OX2 Datasets.

3 CONTRIBUTING FACTORS TO SAFE DISTANCE ANALYSIS

This section analyses the factors that contribute to calculating safe distances. Using legislation, guidance, and mariner expertise, Marico Marine have identified the following as being the main factors for consideration when determining safe distances between OWF and shipping lanes:

Table 1 – Factors taken into consideration when determining safe distance between OWF and shipping lanes.

Factors to consider when calculating safety distances
Traffic Density
Vessel Sizes
Environmental Conditions
Ocean Uses
Traffic Profile
Shipping Lanes
Radar Interference

3.1 TRAFFIC DENSITY

Vessel transit density is a measure of the number of individual vessel transits through a localised area. Once a vessel departs, a new transit is recorded until she reaches her destination, and her speed drops below 0.5 knots for a significant period, after which, any future movements are counted as a new transit. **Figure 3** shows the vessel transit density of all vessel types in the 12-month data period. Density in the area surrounding Triton is moderate to high. The north and west borders of Triton have the highest density in the region with over 20 tracks per day and are located within 1nm of the wind farm. These areas are shipping lanes: the east is an IMO shipping lane travelling south and the north is a clearway connecting two Traffic Separation Schemes (TSS), both of which have a predominance of cargo and tanker vessel tracks. The least dense region within 10nm is the area south of the windfarm, which lies between lanes A and G as seen in **Section 3.7** with 0-0.25 vessels tracks per day.

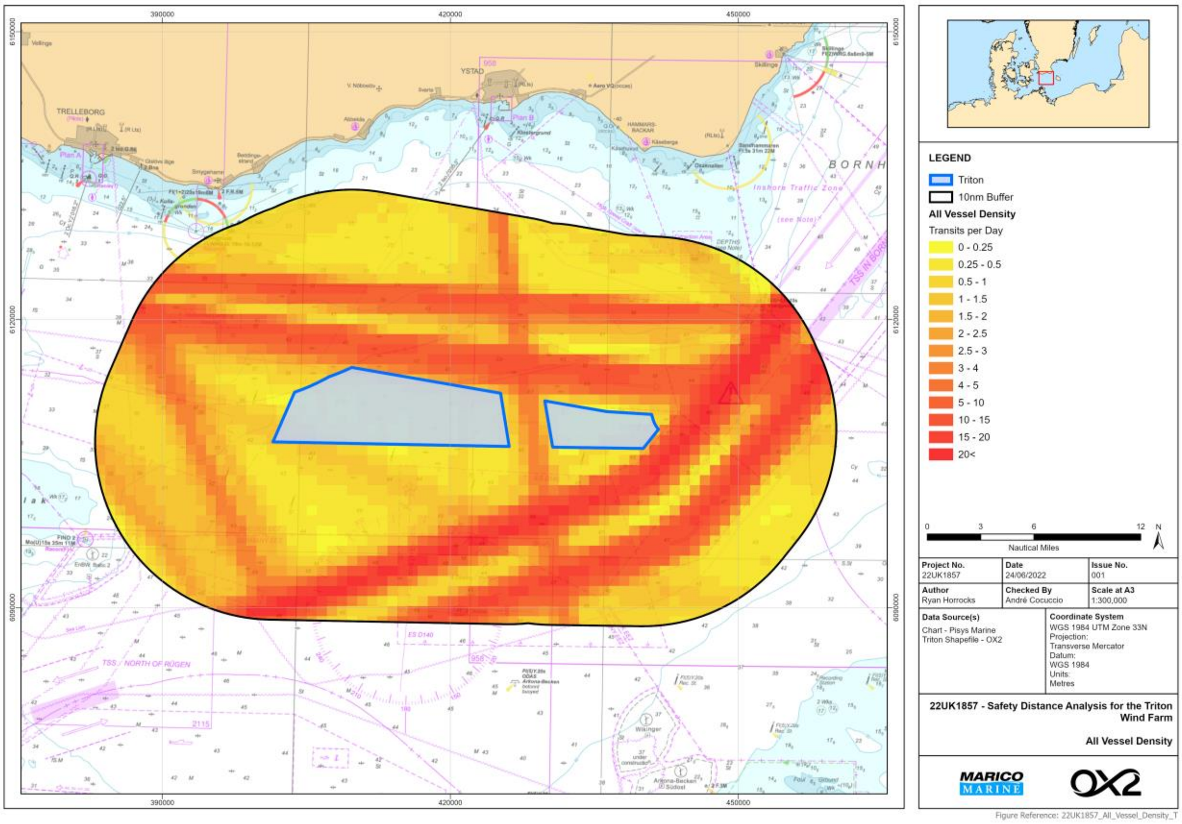

Figure 3 – All vessel density within 10nm of the Triton OWF.

All vessels transiting within 10nm of the Triton OWF were extracted. A simple filter was used to identify unique transits; if the same vessel was recorded within 10nm of Triton within 24 hours, it was counted as being a single transit. Additionally, if a vessel, such as a standby safety vessel, was noted transiting to a location where it remained for a duration of days, only the transit to/from site was included within the analysis.

Figure 4 and **Figure 5** demonstrate vessel traffic within 10nm of Triton over the 12-month data period. July 2021 was the busiest month with 5,640 tracks and 01/05/2021 was the busiest day with 249 tracks. Within both figures, some summer and winter seasonality to vessel traffic can be observed with the summer period showing more transits than the winter. An average of approximately 156 vessel tracks per day were recorded within 10nm.

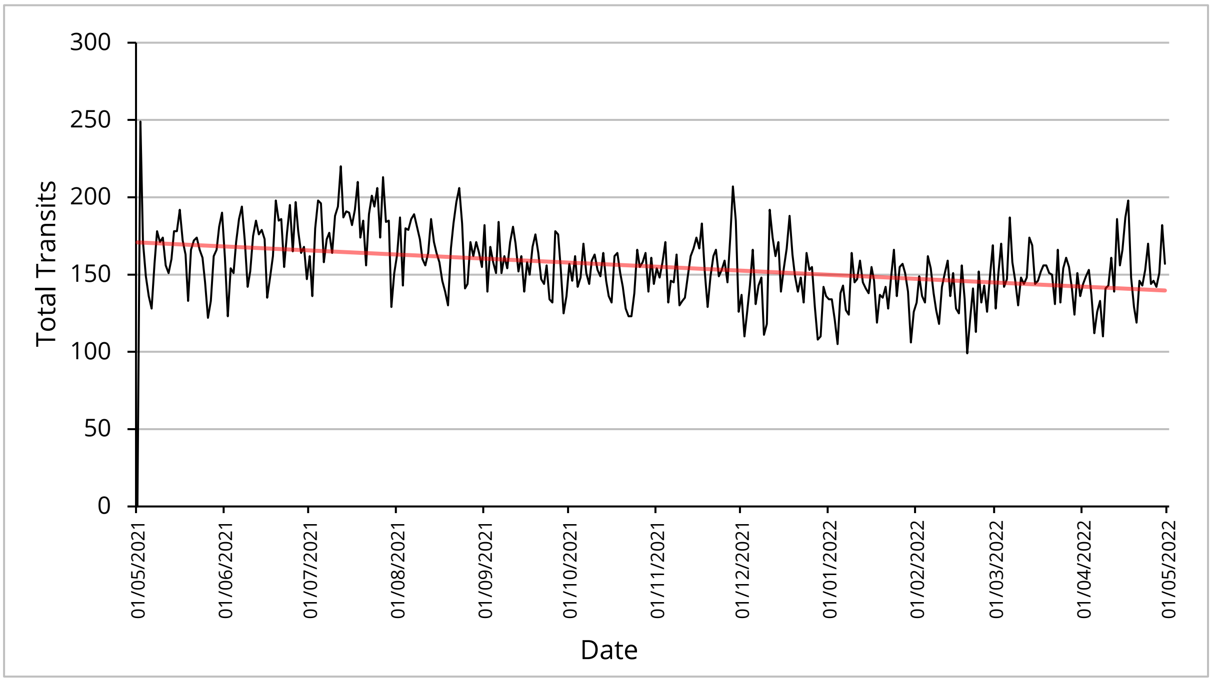

Figure 4 – Transits per day within 10nm of the Triton OWF.

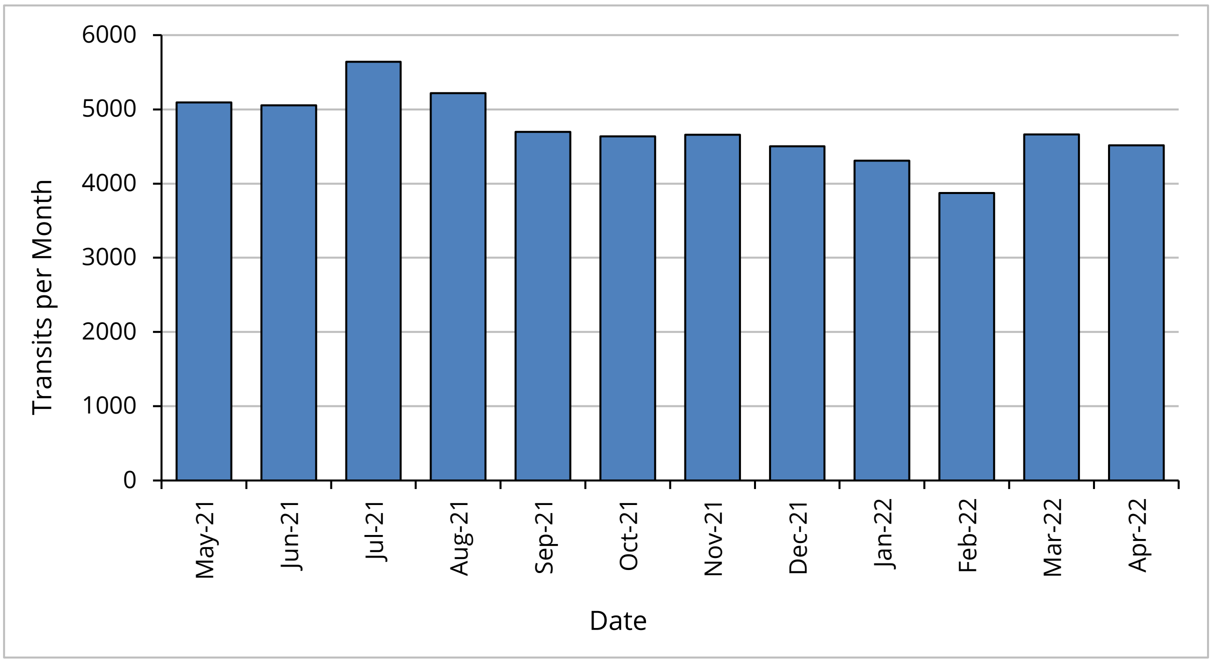

Figure 5 – Transits per month within 10nm of the Triton OWF.

3.2 VESSEL SIZES

Figure 6 shows vessel tracks differentiated by length. As described below, most vessels are commercial reflecting the predominance of vessel lengths between 80m and 250m (see Figure 7). The most common Length Over-All (LOA) for vessels within 10nm is 80-90m with 9,593 transits over the 12-month data period which are primarily commercial vessels. The smaller vessels (recreational and fishing) with lengths between 0 and 60m are seen to transit further from the OWF boundary and towards the south coast of Sweden. Most large vessels (>260m) are seen to transit the shipping lanes which have been identified in Section 3.7. The largest length vessel within 10nm was the 400m container ship MSC DIANA which transited across the clearways and TSS to the south and east of Triton.

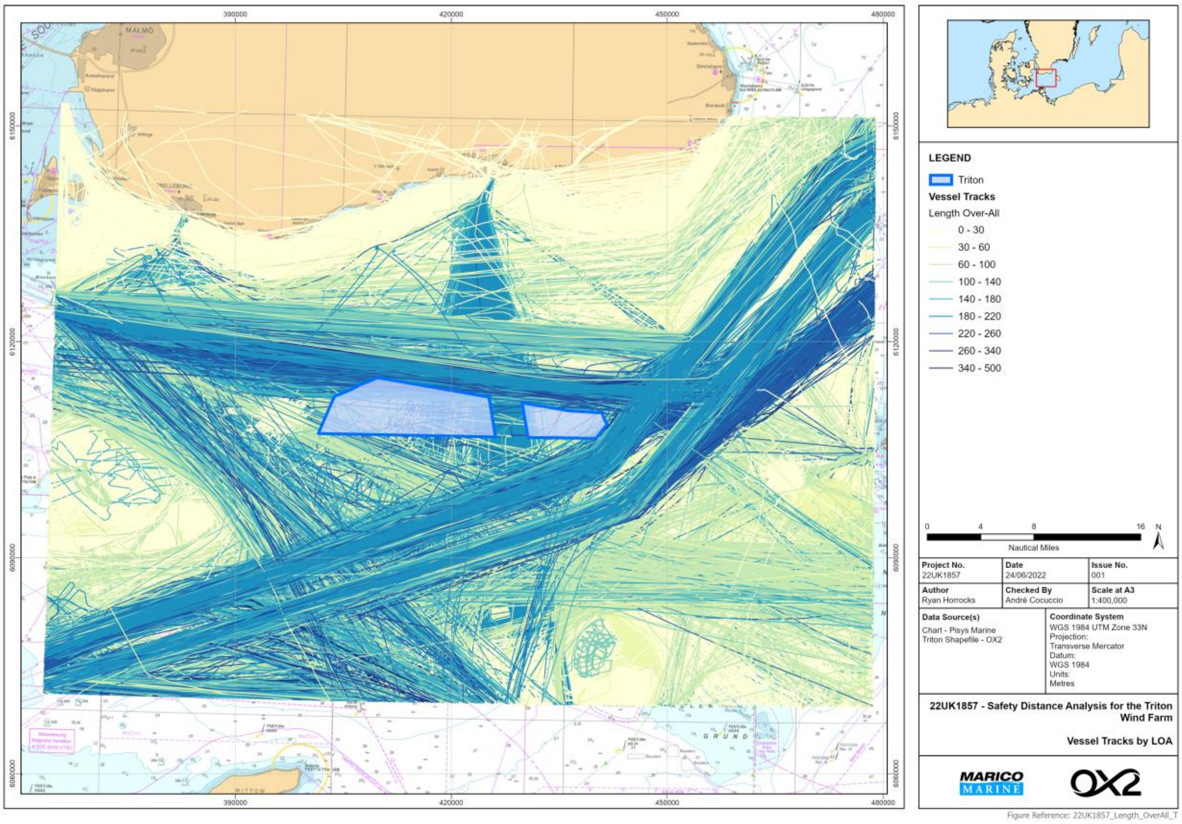

Figure 6 – Vessel tracks by LOA.

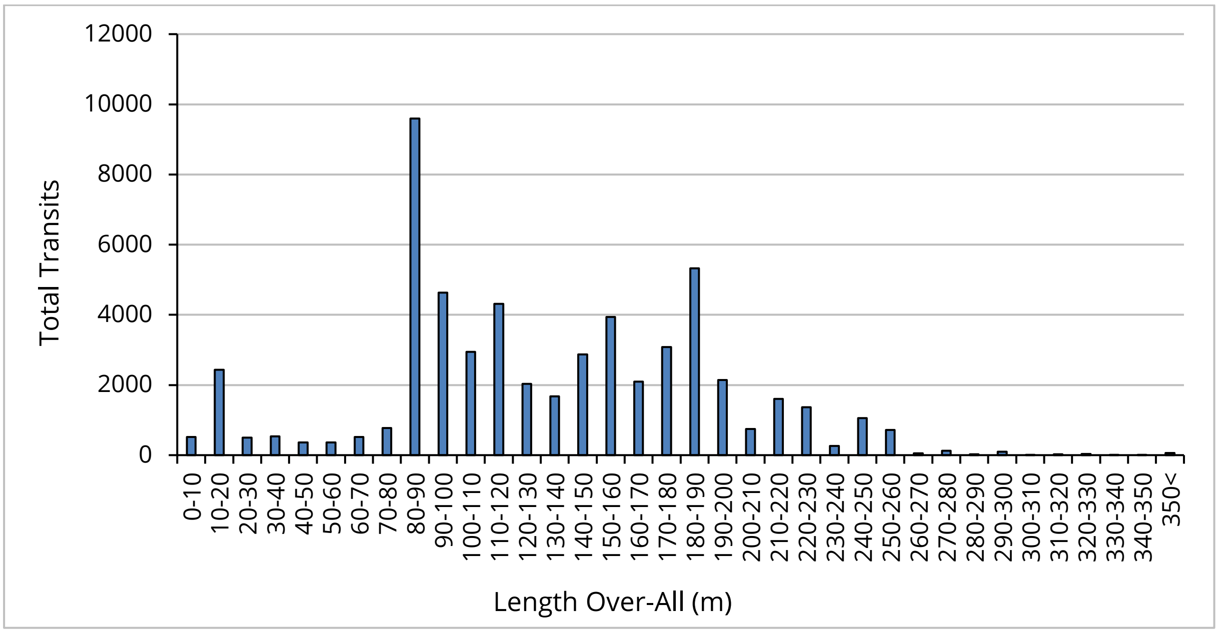

Figure 7 – Transits by LOA within 10nm of the Triton OWF.

3.3 MANOEUVRABILITY

To abide by the *International Regulations for Preventing Collisions at Sea* (COLREG) rule 8, and the *General Provisions on Ships' Routeing* (GPRS), Amendment 3.14, there must be substantial sea room for vessels to undertake evasive manoeuvres and course corrections when faced with the possibility of collision. Much of the guidance on safety distances recommends 6 ship lengths for a vessel to complete a round turn between an OWF and a shipping lane. According to the IMO *Standards for Ship Manoeuvrability*, the turning circle of a vessel advance should not exceed 4.5 ship lengths and the tactical diameter of a turn should not exceed 5 ship lengths.[3] Therefore, with the largest frequent vessel being the 323m passenger ship, the MSC SEAVIEW, the necessary room for a ship of this size to complete a round turn would be approximately 0.87nm.

As per the *International Safety Management code* (ISM) and SOLAS chapter V Regulation 34-1, a master reserves the right to make overriding decisions with regards to safety and protection of the environment such as pollution prevention. The *United Nations Convention on the Law of the Sea* (UNLCOS) states that vessels have freedom of navigation in the high seas and Exclusive Economic Zones (EEZ) and a right of innocent passage through terrestrial seas and contiguous zones. Therefore, vessels are not confined to clearways and could transit between the turbines of a windfarm for safety manoeuvres. Although, it would be an offence under section 23 of the *Petroleum Act 1987* if a vessel were to travel within the 500m safety zone for construction or the 50m zones for maintenance and operational phases. This act is implemented for all installations which project above the sea at any state of the tide.

[3] ANNEX 6 RESOLUTION MSC.137(76) (adopted on 4 December 2002) STANDARDS FOR SHIP MANOEUVRABILITY

3.4 ENVIRONMENTAL CONDITIONS

The wind conditions around Triton are represented by the wind rose in **Figure 8** and the location of the wind rose is illustrated in **Figure 9**. The wind rose is based on wind data from 2000 – 2019 for the area around Triton and was produced by DHI in 2021 and discussed within the nautical risk assessment produced by Swedish consultants SSPA. The rose shows a west to south-westerly to west prevailing wind at a maximum speed of 17.78m/s to 20.32m/s.

Due to the limited availability of tidal data within the area, a desk-based study was undertaken to determine the maximum tidal range for the Baltic Sea. A peer-reviewed paper from the Institute of Oceanology in Russia entitled 'Tides in Three Enclosed Basins: The Baltic, Black, and Caspian Sea' concluded that the maximum tidal heights estimated for a 100-year period are 23cm across the Baltic.[4] A statement by the Baltic Sea Hydrographic Commission suggests that differences in tides may be caused by strong wind, variation in atmospheric pressure, and seasonal changes in the amount of water discharged by rivers. These factors can influence the water level to change by approximately 1m from the mean sea level.

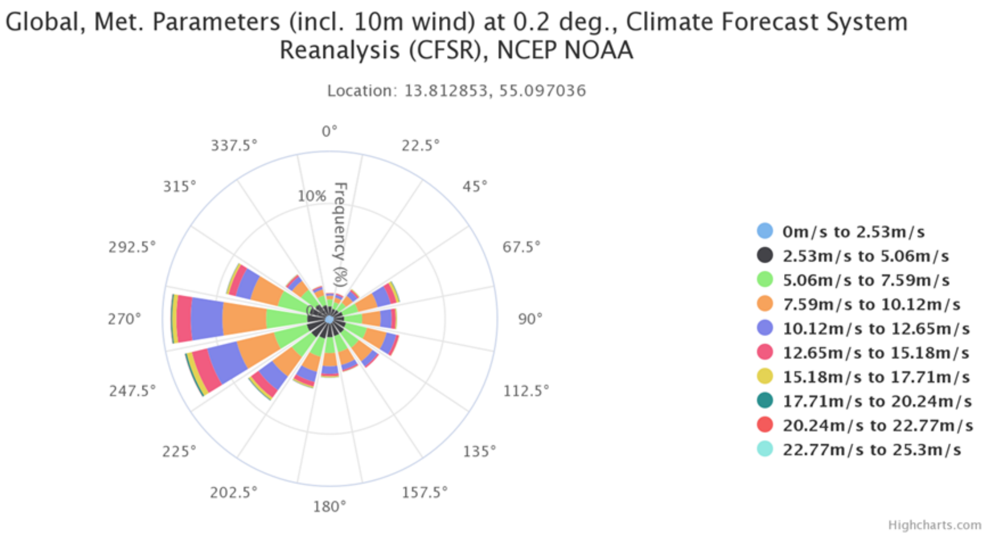

Figure 8 – Wind Rose (SSPA)

[4] Medvedev, I.P., Rabinovich, A.B. and Kulikov, E.A., 2016. Tides in three enclosed basins: The Baltic, Black, and Caspian seas. Frontiers in Marine Science, 3, p.46.

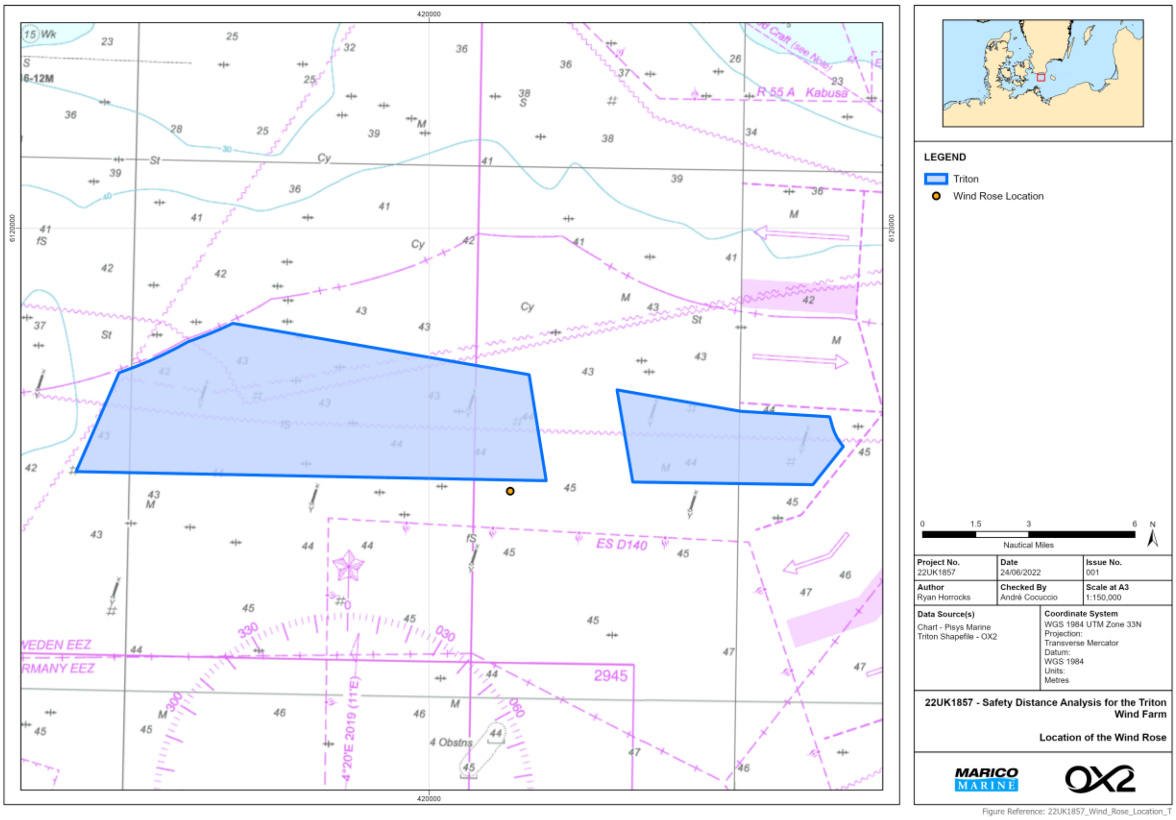

Figure 9 – Location of the Wind Rose.

3.5 OCEAN USES

Figure 10 shows the different types of ocean uses within the vicinity of the Triton OWF. The closest IMO routeing measures are traffic lanes approximately 0.25nm to the east and north of the west segment of Triton which form part of the TSS in Bornholmsgat. These lanes are connected to more IMO traffic lanes by clearways, one of which runs parallel to the north of the wind farm, and one travels southwest and northeast to and from the TSS north of Rügen. The TSS filters vessels that are travelling to/from the sound and to/from the north of Denmark that travel between the south coast of Sweden and Bornholmsgat. These lanes have defined limits and one-way traffic.

Triton is approximately 21.12nm from Bornholmsgat and 12.14nm from the south coast of Sweden. The site is approximately 9.35nm from the closest renewable energy installation, the Baltic Two wind farm. The closest navigation hazards are the firing practice area south of Triton a CPA of approximately 1.22nm and the precautionary area that forms part of the TTS to the east approximately 1.50nm from the Triton boundary. There are multiple wrecks and obstructions within the area although these are at depths that make them of little concern to mariners. The shallowest water depth within 10nm of Triton are the waters of the coast of Beddingestrand approximately 9.54nm north of the development at 13.00m. The site is approximately 13.99nm for the nearest pilot boarding station with no designated anchorages identified in the area.

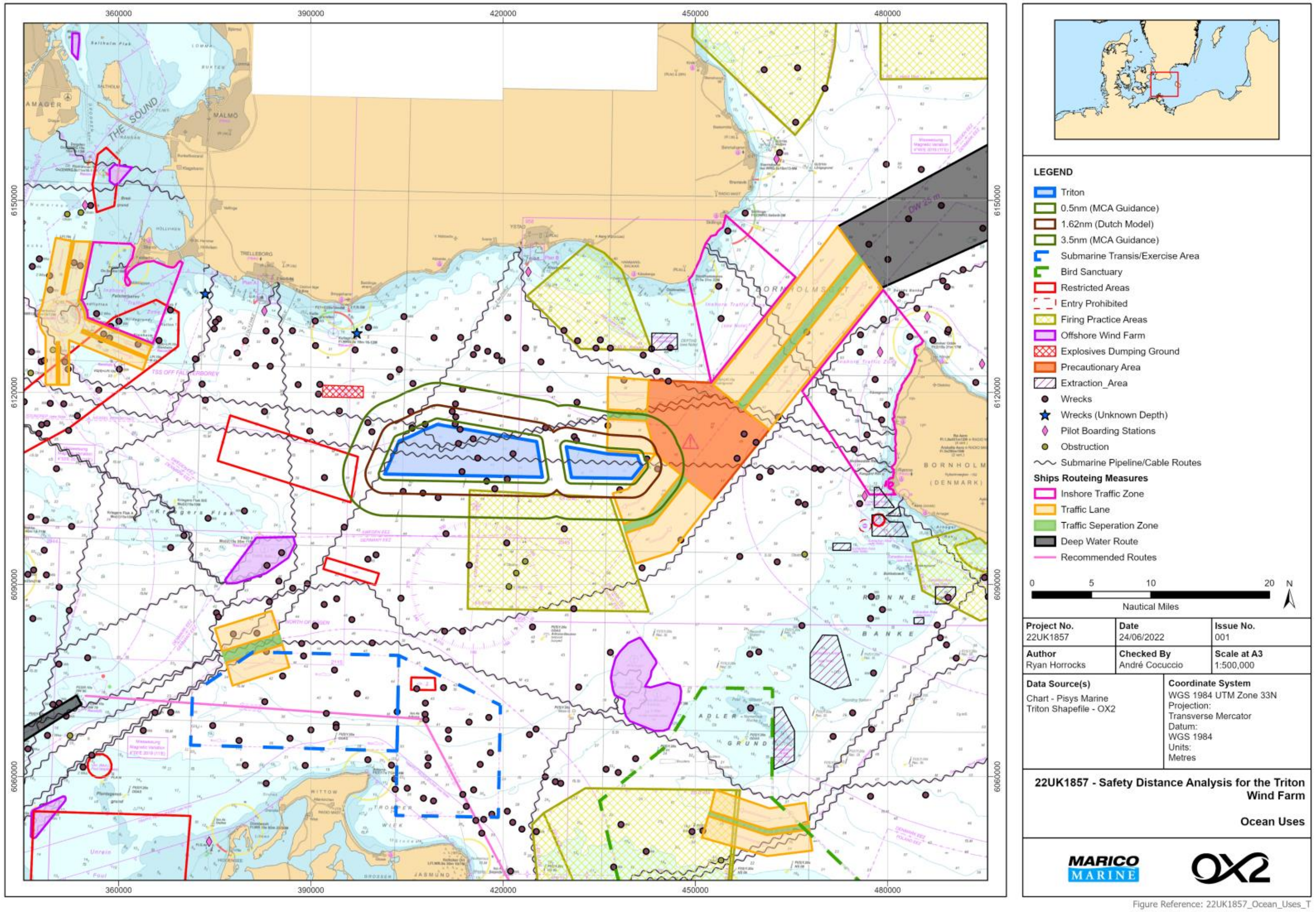

Figure 10 - Ocean uses within the vicinity of the Triton OWF.

3.6 TRAFFIC PROFILE

The tracks of all vessel traffic within the data extent are illustrated in **Figure 11**. A total of 9,900 vessels (79,319 tracks) transited within the data extent during the assessed period. A total of 1,379 vessels (3,153 tracks) intersected the Triton OWF boundaries across the 12-month data period which is an average of 9 vessel tracks per day. The majority of vessels that intersected the Triton OWF boundary were cargo vessels which accounted for 39% of all 3,153 tracks recorded.

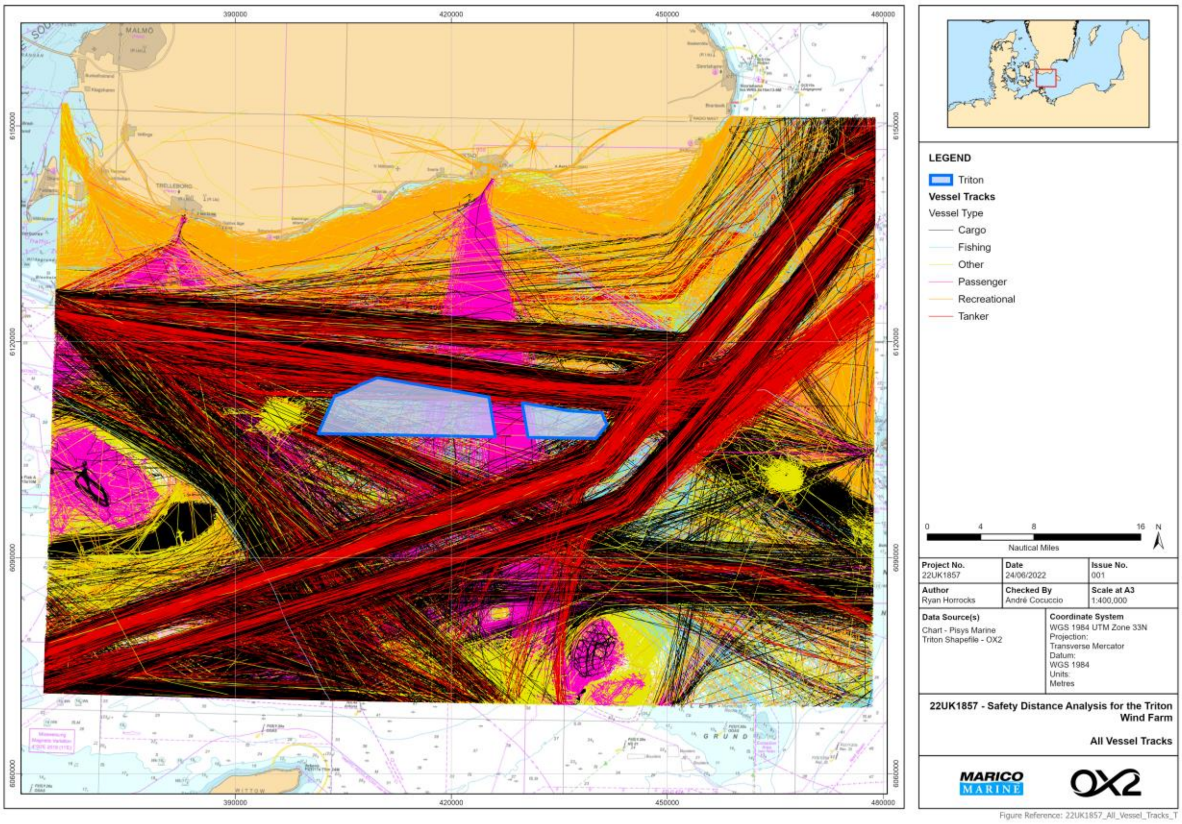

Figure 11 – All vessel tracks.

3.6.1 Recreational Vessel Tracks

Figure 12 demonstrates recreational vessel tracks which include sailing, non-commercial motorboats, superyachts, and tall ships. While many recreational craft carry AIS on a voluntary basis, they are not required to do so. Therefore, they are likely to be under-represented in the analysis. Recreational vessel AIS data may be of poorer quality as Class A commercial vessel data is preferentially collected over smaller Class B vessels. This may result in early termination of transits as is noted within **Figure 12**. A total of 2,702 recreational vessel tracks were recorded within 10nm of the Triton OWF, of which, 459 tracks intersected the Triton OWF boundary over the 12-month data period.

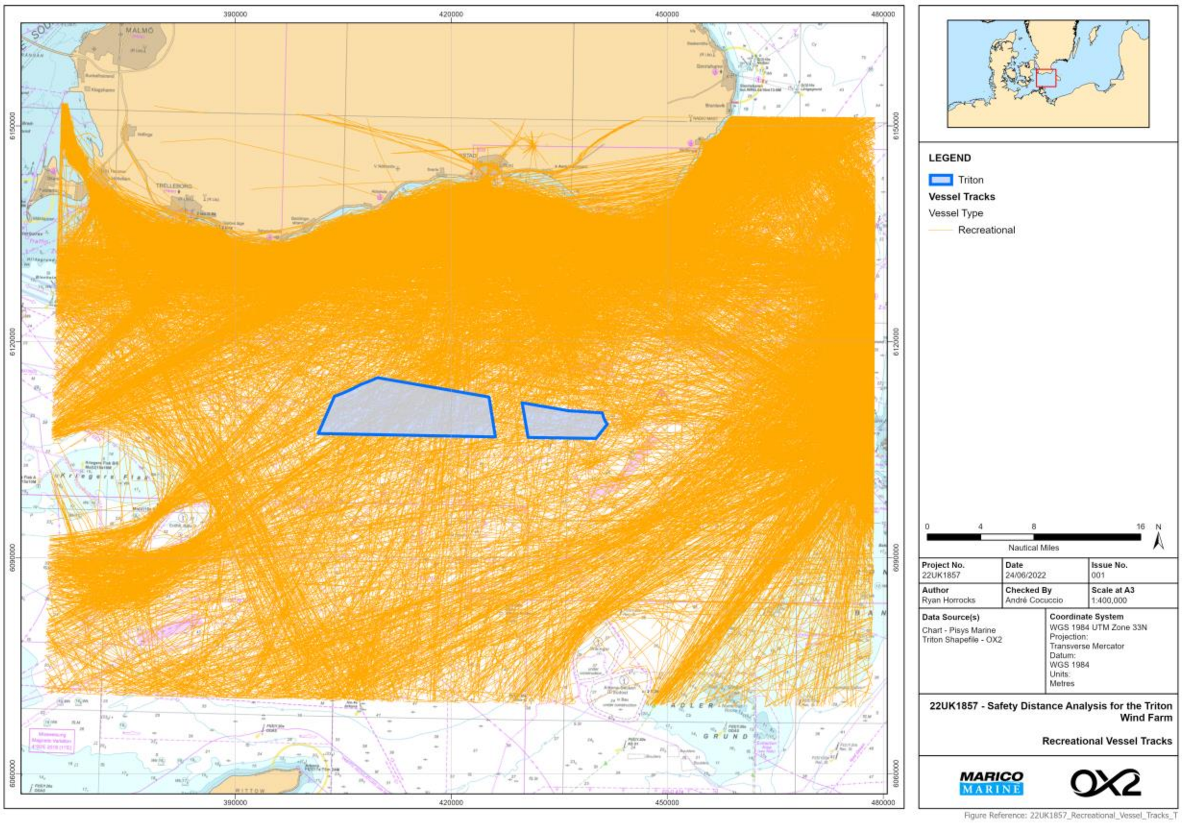

Figure 12 – Recreational vessel tracks.

3.6.2 Fishing Vessel Tracks

Fishing activity near to Triton is seen to be low. Most fishing vessels are not required to carry AIS under SOLAS Chapter V but vessels longer than 15 metres in length are required to carry AIS under EU regulations. Fishing vessel tracks are shown in **Figure 13**. A total of 779 tracks were recorded by fishing vessels within 10nm of Triton, 108 of which intersected the Triton OWF boundary. The ARNE TISELIUS had the most transits over the course of the 12-month data period, with 13 within 10nm.

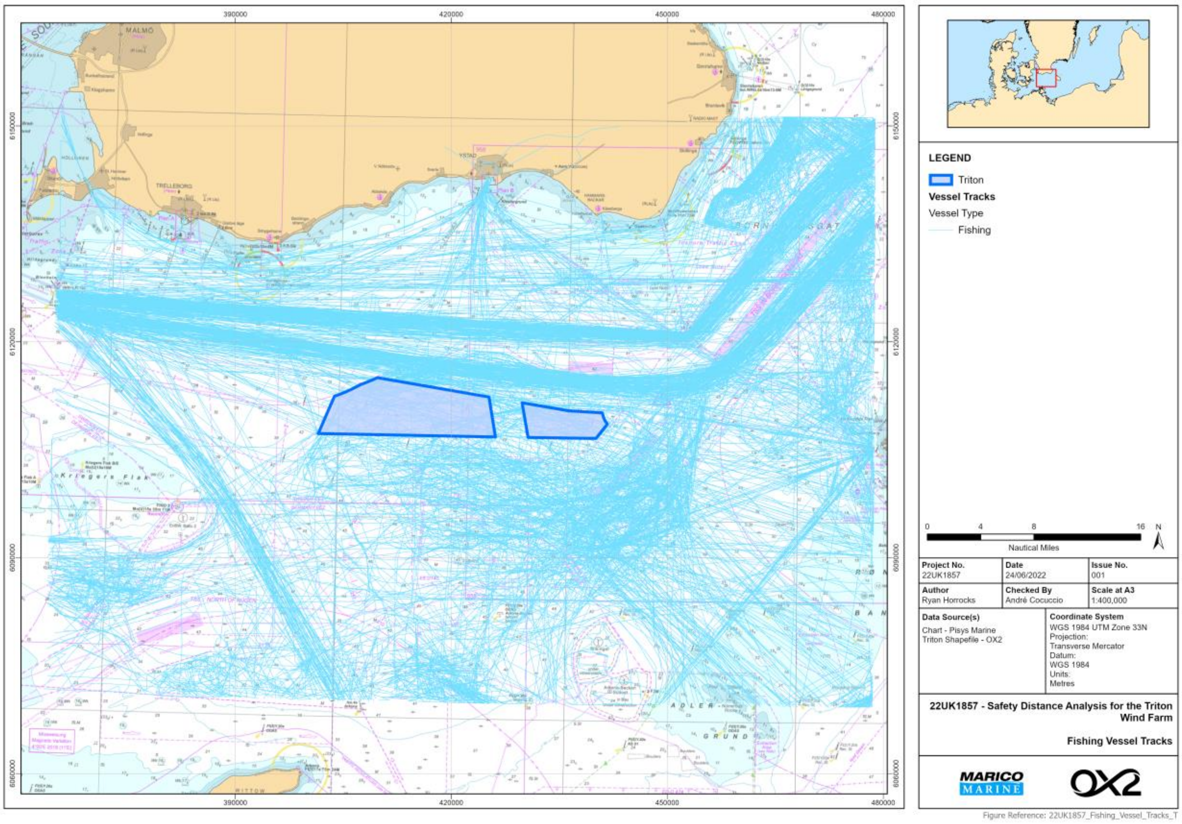

Figure 13 – Fishing vessel tracks.

3.6.3 Commercial Vessel Tracks

In total, 51,019 (33,480 Cargo, 10,271 Tanker, 7,268 Passenger) tracks were made by commercial vessels in the 12-month data period within 10nm. Commercial tracks are shown within **Figure 14**. Approximately 49,607 (97%) of tracks were recorded transiting the 90% routes outlined in **Section 3.7** with 14,752 or 29% of all tracks transiting in the south-bound clearway and traffic lane to the east of Triton (Lane A) and 11,484 or 23% of all tracks transiting in the north-bound clearway and traffic lane to the east of Triton (Lane B). A total of 2,421 vessels (or approximately 7 per day) intersected the Triton OWF boundary.

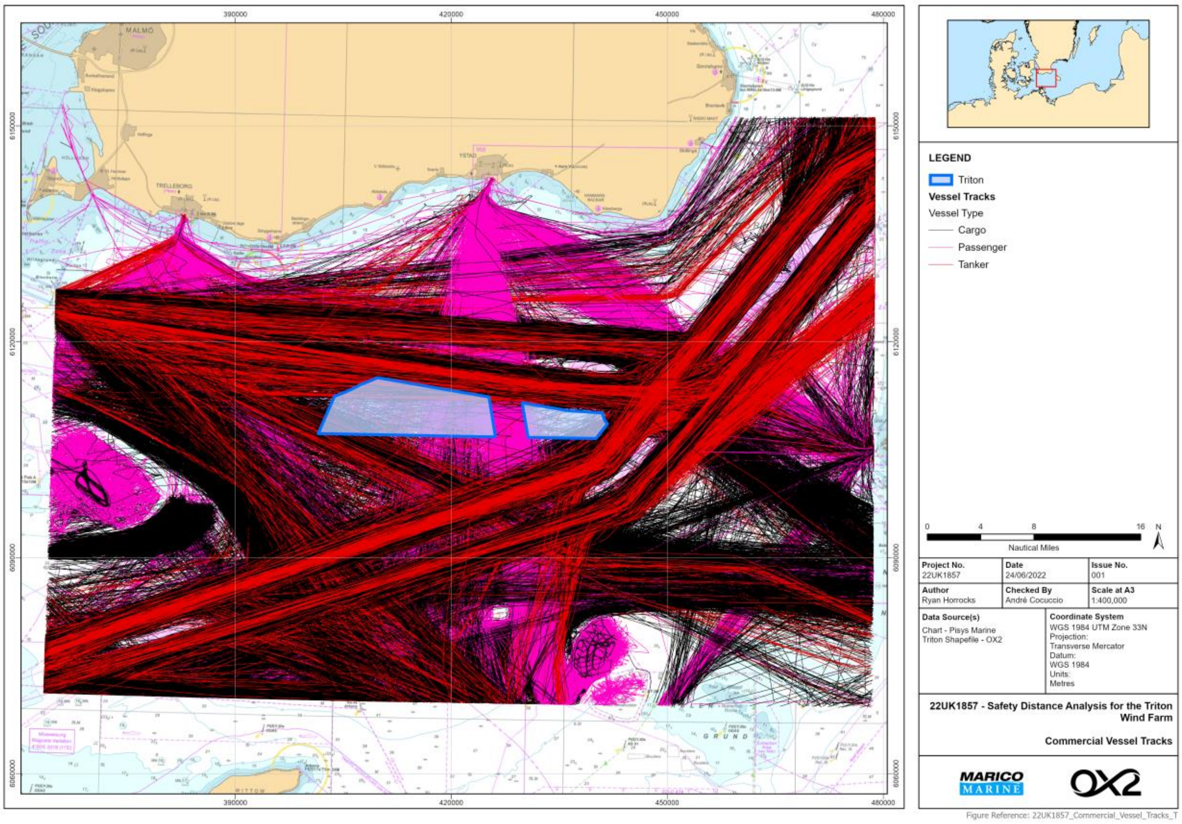

Figure 14 – Commercial vessel tracks.

3.6.4 Other Vessel Tracks

The tracks of other category vessels are shown within **Figure 15**. A total of 2,361 tracks were recorded by other vessels, most of which being Reefer vessels which accounted for 678 (29%) of all tracks. A total of 165 tracks intersected the Triton OWF boundary.

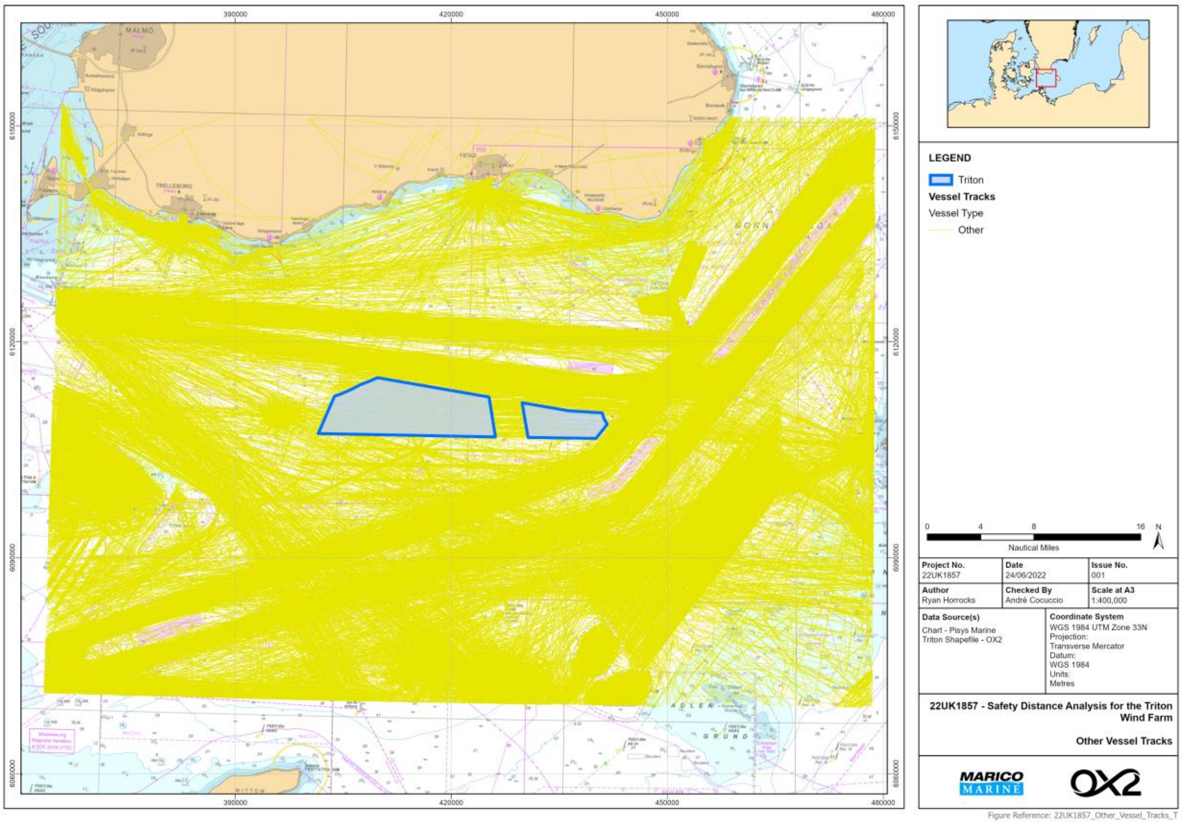

Figure 15 – Other Vessel Tracks.

In total, 56,861 vessel tracks were recorded within 10nm of the Triton OWF over the 12-month data period, comprising 7,824 unique vessels. Of these 7,824, approximately 47% were by cargo vessels, 23% by recreational vessels, 19% by tankers, 7% by other category vessels, 2% were by fishing vessels, and 2% by passenger vessels. In terms of tracks, approximately 59% were produced by cargo vessels, 18% by tankers, 13% by passenger vessels, 5% were by recreational vessels, 4% by other category vessels, and 1% were by fishing vessels, (see **Figure 16**).

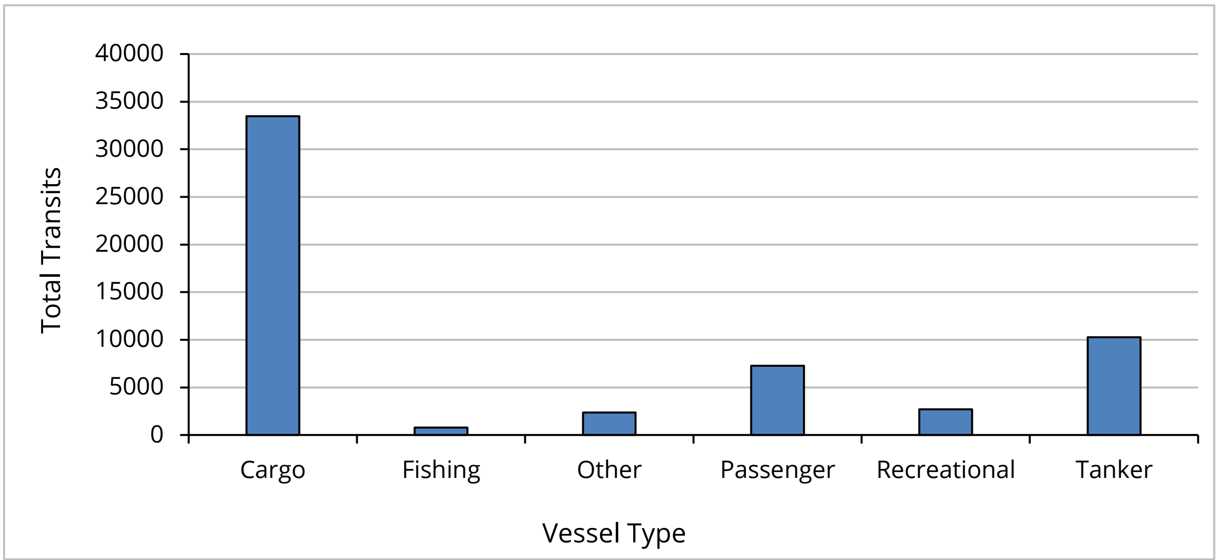

Figure 16 – Transits by vessel type within 10nm of the Triton OWF.

3.7 SHIPPING LANES

An assessment of vessel routeing was undertaken to establish the potential impact that the Triton OWF could have on commercial traffic routeing. 90^{th} percentile shipping lanes were identified using commercial vessel AIS tracks. These lanes determine where the majority of vessel traffic travels through a given shipping lane and are allocated using the percentages of traffic generated from the gate analysis tool as seen in **Figure 18** and **Figure 19**. Route ID, 90^{th} percentile shipping lanes, and shipping lanes as defined in the Swedish Marine Spatial Plan (MSP) can be seen in **Figure 17**. The Closest Point of Approach (CPA) method was used to determine the distance between the turbines/OWF boundary and the shipping lanes. The lane width, CPA, and description can be found in **Table 1**.

9 shipping lanes were identified within the vicinity of the Triton OWF, of which, 4 were located within existing routeing measures and the remaining 5 were clearways. Lanes A and B located to the east/southeast of Triton and C and D located to the north of Triton are IMO traffic lanes which form part of the TSS in Bornholmsgat to the east and north of the west site of Triton. These lanes also connect more IMO traffic lanes by clearways, one of which runs parallel to the north of the wind farm and leads to the roundabout south of the Sound, and one travels southwest and northeast to and from the TSS north of Rügen. These lanes are moderately busy with approximately 17 to 36 transits per day. Lanes I and G both located to the southwest of Triton are low-use lanes with approximately 2 to 4 transits per day that both travel to and from the TSS roundabout south of the Sound. Vessels travelling to and from ports on the south side of Sweden will typically transit through low-use lanes E, F, and H. These lanes range from approximately 9 to 10 transits per day and are popular ferry routes. 4 out of the 9 90th percentile lanes identified (A, C, E, and G) were located under 0.5nm of the Triton wind farm boundary. The CPA and widths of all lanes can be found in **Table 1**. Most lanes identified were found within the shipping lanes as defined by the Swedish MSP with the exception of lanes I, H, and G.

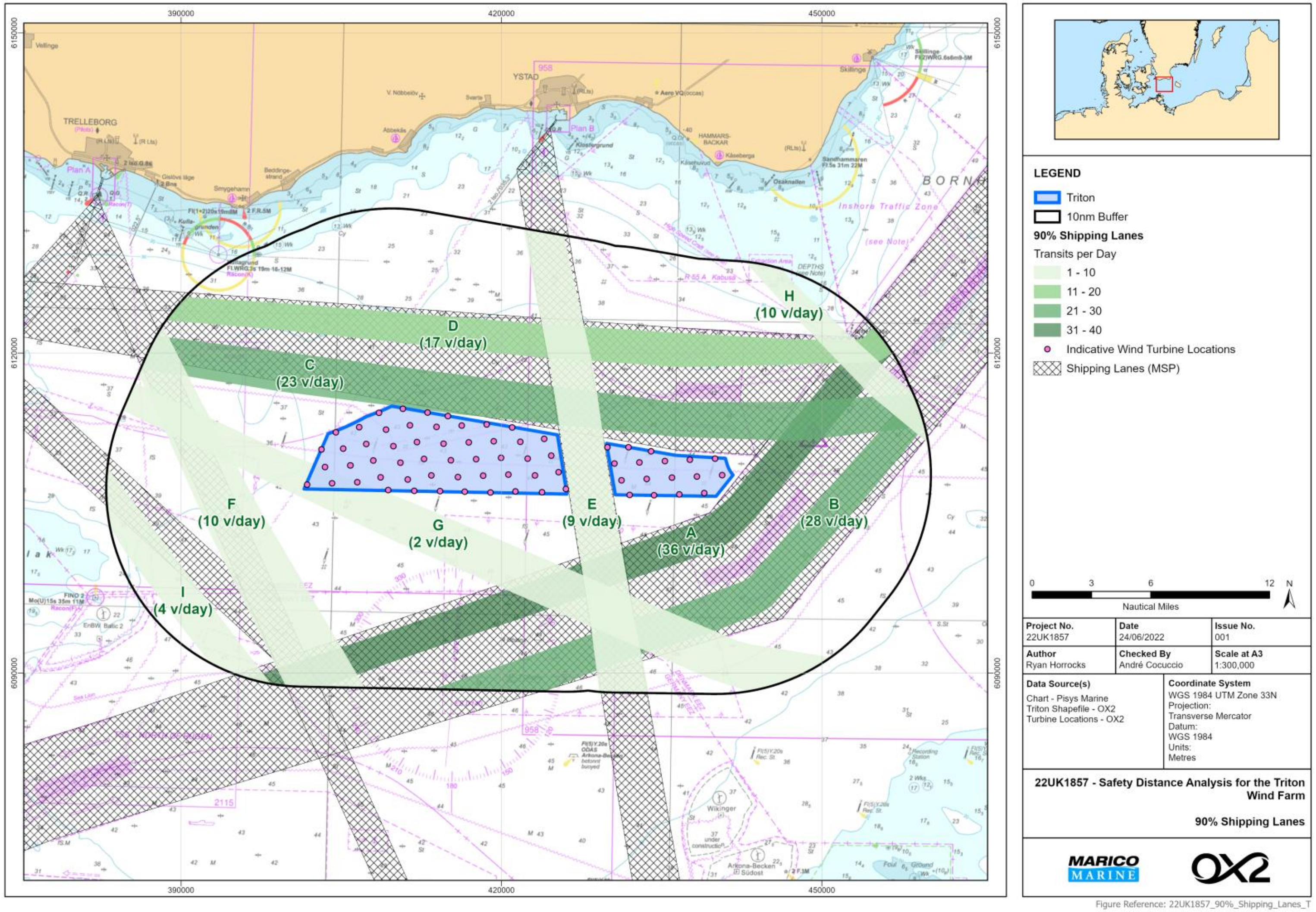

Figure 17 – 90th percentile analysis for clearways around the Triton OWF.

Table 2 – Closest point of approach for each shipping lane identified.

Lane	CPA (nm) from OWF Boundary	Narrowest Lane Width (nm)	Av. No. of Commercial Tracks per Day	Description
A	0.50	1.52	36	A southbound traffic lane/clearway that forms part of the TSS in Bornholmsgat and connects this TSS to the TSS north of Rügen. This lane is predominantly cargo and tanker vessels.
B	3.99	1.62	28	A northbound traffic lane/clearway that forms part of the TSS in Bornholmsgat and connects this TSS to the TSS north of Rügen. This lane is predominantly cargo and tanker vessels.
C	0.00	1.75	23	An eastbound traffic lane/clearway that forms part of the TSS in Bornholmsgat and connects this TSS to the roundabout south of the Sound. This lane is predominantly cargo and tanker vessels.
D	3.25	1.26	17	A westbound traffic lane/clearway that forms part of the TSS in Bornholmsgat and connects this TSS to the roundabout below the Sound. This lane is predominantly cargo and tanker vessels.
E	0.12	1.97	9	Popular ferry route that primarily ro-ro passenger ships transit between Ystad and Świnoujście.
F	2.46	2.20	10	Popular ferry route that primarily ro-ro passenger ships transit between Trelleborg to Sassnitz.
G	0.00	1.53	2	A low-use lane primarily used by cargo and tanker vessels to travel from the roundabout south of the Sound to ports in the east Baltic Sea south of Bornholmsgat.
H	7.51	1.13	10	Popular ferry route that primarily High Speed Craft (HSC) transit between Ystad and Rønne.
I	7.33	1.81	4	A low-use lane primarily used by cargo and tanker vessels to travel from the roundabout south of the Sound to the south of the Baltic Sea towards Świnoujście.

Gate analysis is a tool used by Marico Marine to examine the frequency and direction of traffic through a linear 'gate'. Transects of known distance are created perpendicular to a shipping lane and columns created depending upon the frequency and direction (course) of vessel tracks passing through the gate. For each column, a percentile is created to determine the percentage of traffic within that lane that travels through a given column over the AIS data period.

Figure 18, Figure 19, Figure 20, and Figure 21 all show the gate analysis for the CPA to the Triton boundary of the four lanes under 0.5nm (A, C, E, and G). Traffic within lane A is consistent with the traffic using the full width of the 90th percentile. The majority of vessel traffic within lane C transits towards the north of the lane and away from the boundary of the wind farm. Lanes E and G are bi-directional lanes where most of the traffic is seen to transit through the centre.

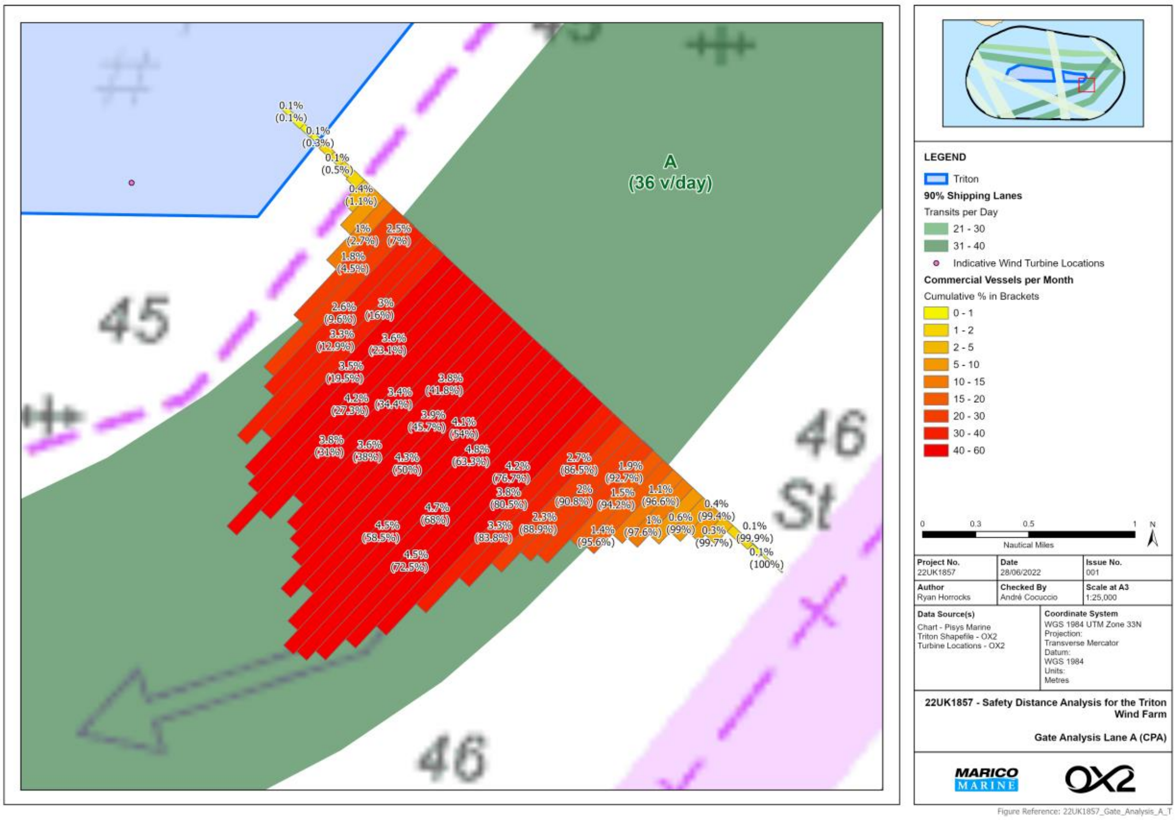

Figure 18 – CPA Route A.

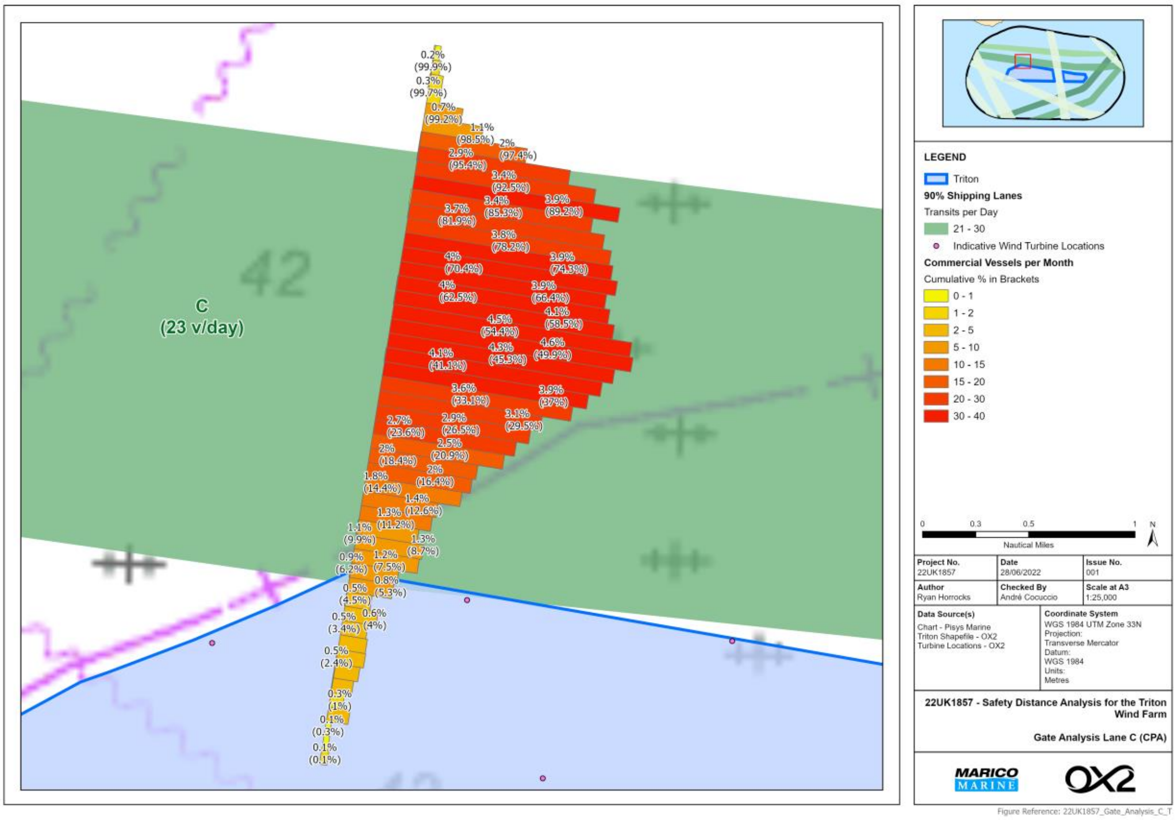

Figure 19 – CPA Route C.

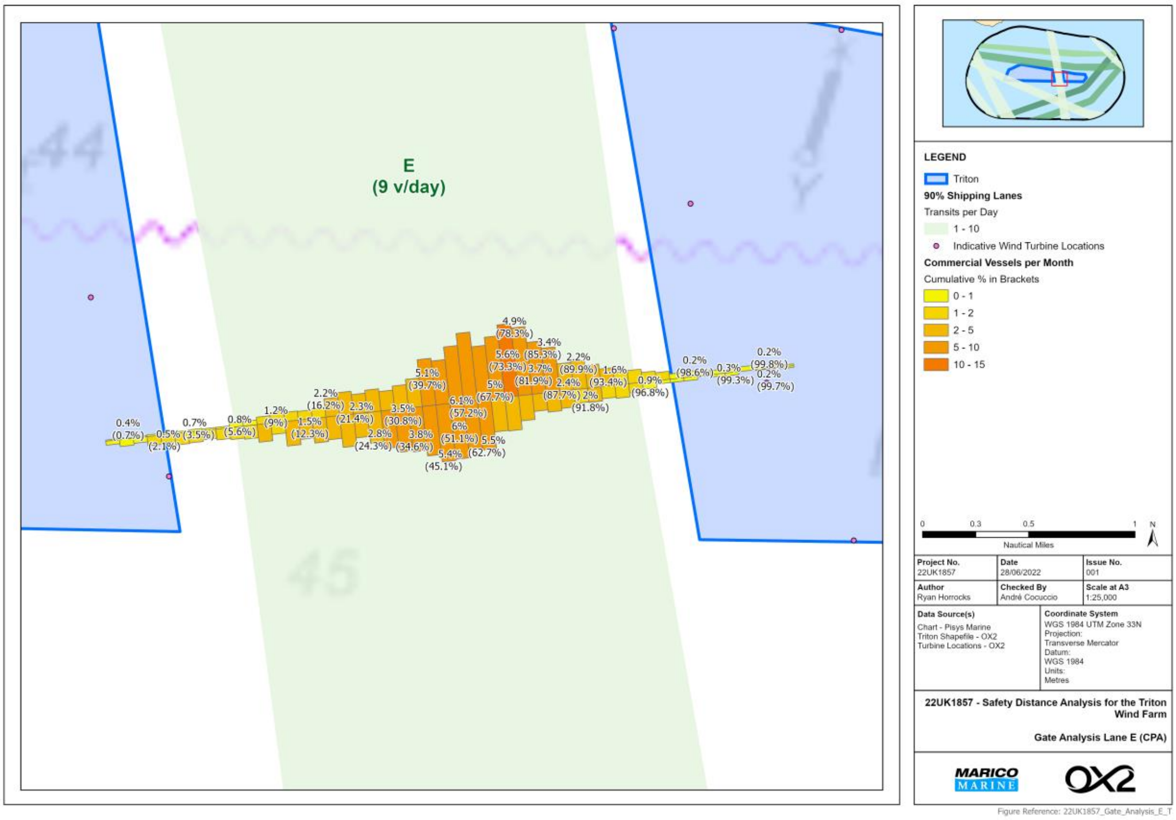

Figure 20 – CPA Route E.

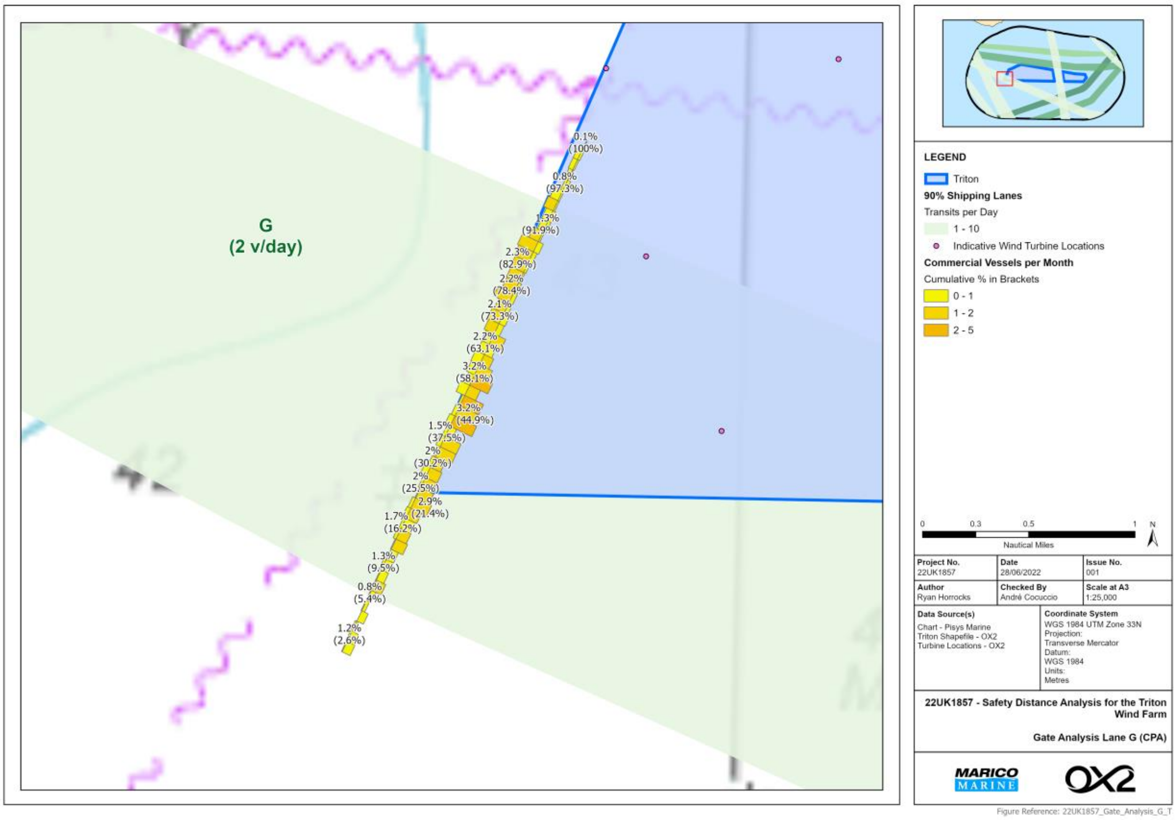

Figure 21 – CPA Route G.

3.8 RADAR INTERFERENCE

Radar interference is caused by structures and objects blocking signals or reflecting them causing false targets, clutter, and reflections to show up on the display. A contributor to radar interference is WTGs. A recent study by The National Academies of Sciences, Engineering, and Medicine suggests that radar interference is dependent on the situation, with the most common impact being reflected energy cluttering the operating display.[5] The document also recommends solid-state Doppler radars to mitigate the interference as they filter signals based on Doppler frequency.

Guidance on mitigating radar interference suggests a zone of 0.8nm is sufficient to reduce the effects on vessels radars. Maritime Coastguard Agency (MCA) guidance stated within Marine Guidance Note (MCN) 372[6] suggests larger vessels must plan their voyages and allow for a 2nm zone between themselves and the adjacent OWF providing adequate safe sea room exists as smaller vessels and buoys may get lost as targets. With regards to Triton, the shipping lanes have adequate room to allow larger vessels to plan their voyages efficiently and mitigate radar interference.

[5] National Academies of Sciences, Engineering, and Medicine, 2022. Wind Turbine Generator Impacts to Marine Vessel Radar.

[6] MCA MGN 372 Offshore Renewable Energy Installations (OREIs): Guidance to Mariners Operating in the Vicinity of UK OREIs.

4 GUIDANCE

This section outlines the key guidance associated with determining safety distances in relation to the Triton OWF. The distances that are suggested or calculated by the guidance below are determined using expertise from mariners and industry professionals. They require intelligent application and are used on a case-by-case basis. The guidance has been implemented in relation to the Triton OWF using the factors that contribute to the calculation of safety distances outlined and analysed above.

4.1 MCA

In 2004, the Greater Wash wind farm developers approached the MCA with the intention to seek guidance on the inter-relationship of wind farms to shipping routes. This was to consider spatial planning factors early when optimising their turbine layout. Consequently, the MCA produced a method on guidance for distances between shipping traffic and offshore wind farms within the MCA's MGN 654 considering international guidance and standards for safety distances and navigational safety within their design. The method is composed of a template that outlines the acceptable distances and the level of risk considered acceptable with each. The template suggests a 0.5nm distance as the minimum distance for when ALARP is applied, with a 3.5nm distance considered broadly acceptable. More information on the MCA guidance can be found within Lot 1.

The guidance suggests that distances are calculated between the turbine boundary and an IMO routeing measure (or a 90% shipping lane in the absence of a TSS). **Figure 22**, **Figure 23**, and **Figure 24** show how the Triton OWF complies with the MCA guidance. The figures show the distances suggested by the MCA within a buffer around the Triton OWF boundary, the 90th percentile lanes identified in **Section 3.7** and the traffic lanes within the TSS to the east of Triton. As a TSS is present, the guidance suggests that the calculations should be calculated from its borders.

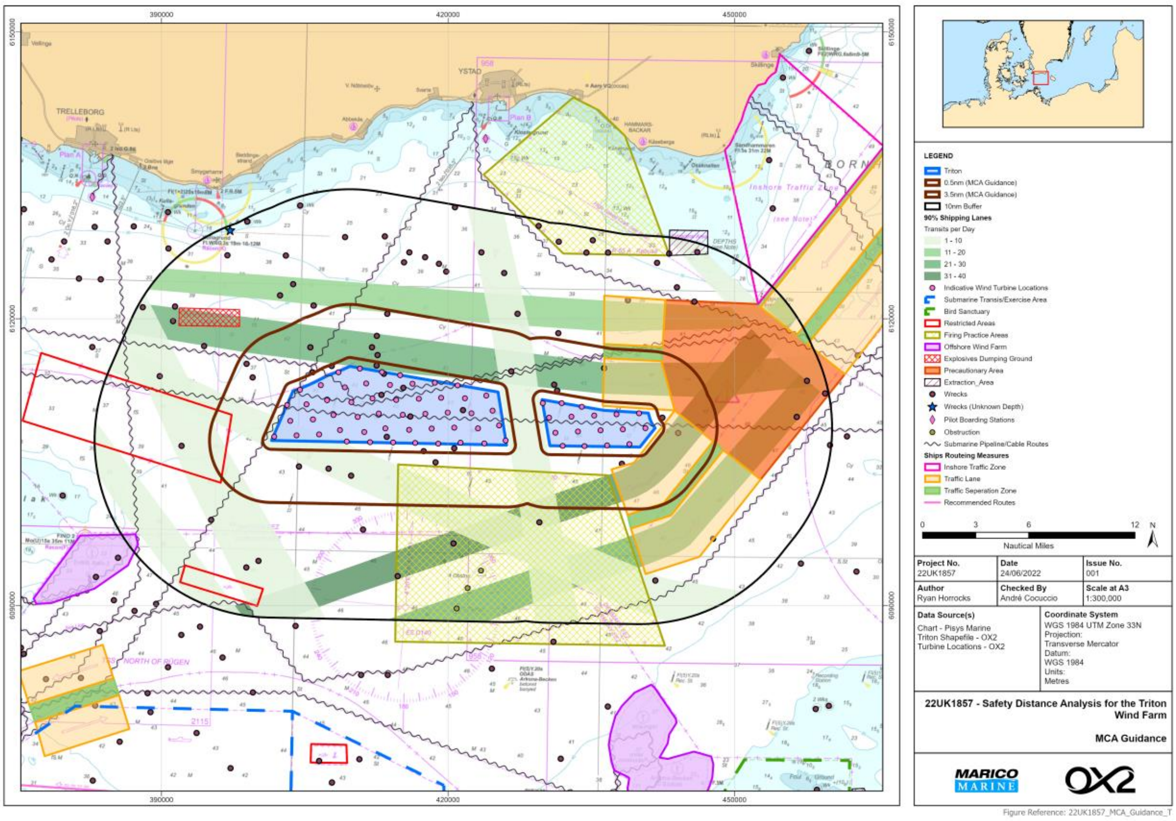

Figure 22 – MCA MGN 654 guidance on appropriate safety zones calculated from the OWF boundary.

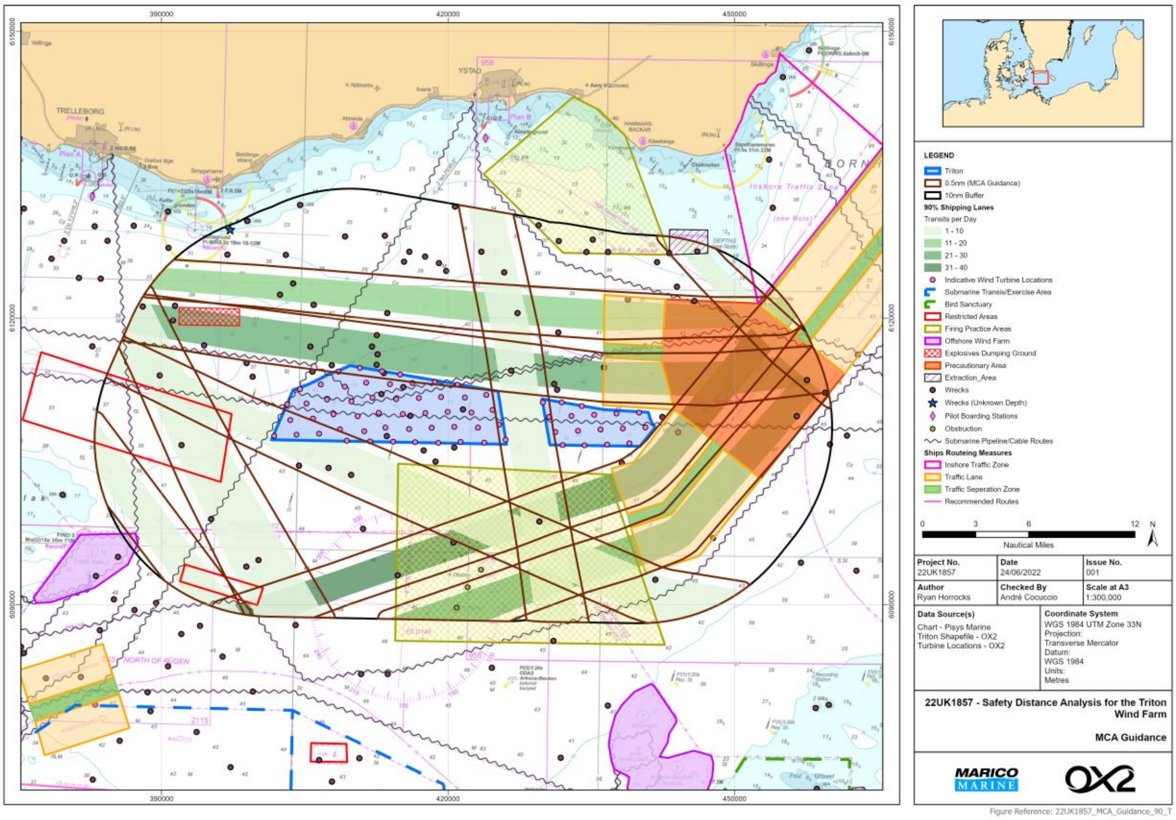

Figure 23 - MCA MGN 654 guidance on appropriate safety zones calculated from the 90th percentile lanes.

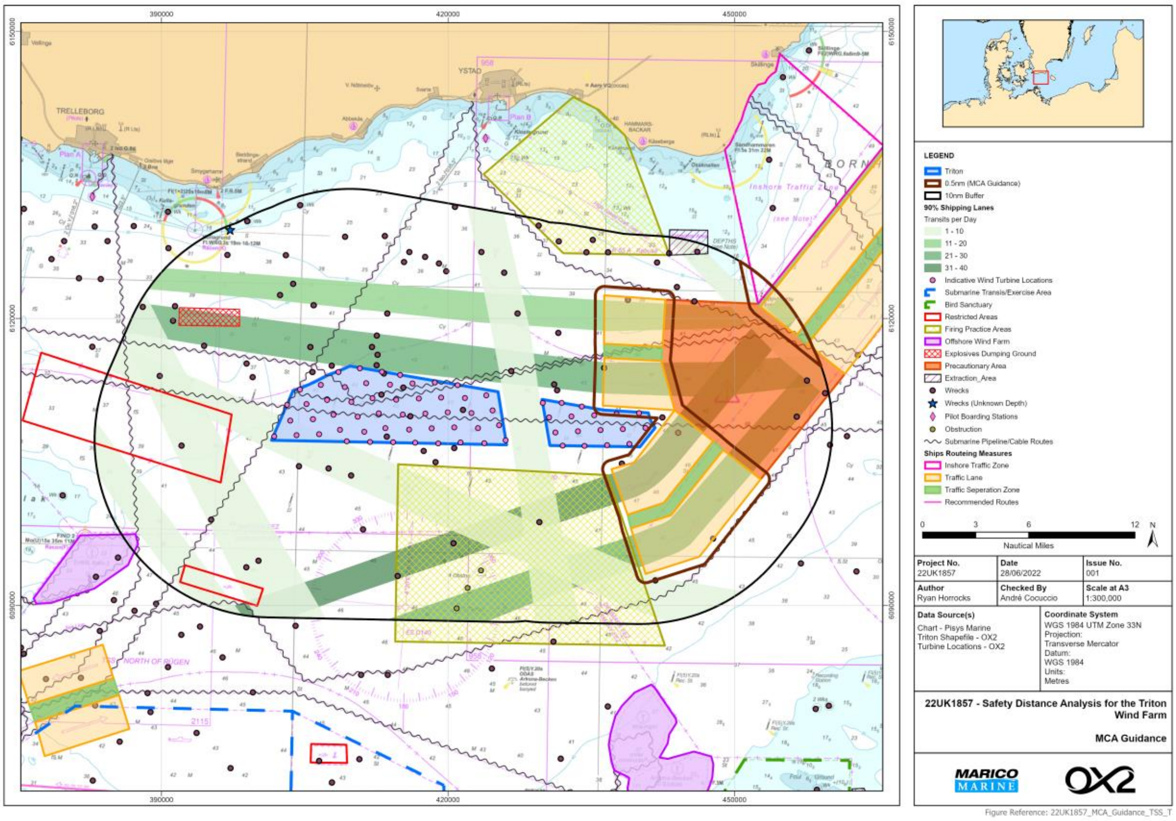

Figure 24 - MCA MGN 654 guidance on appropriate safety zones calculated from the traffic lane border.

4.1.1 UK Case Study

Figure 25 shows both Gwynt y Mor sites with buffer zones detailing the different guidance distances. Cargo and Tanker vessel density using 2019 AIS data has also been shown within a 5nm buffer to indicate clearways and popular routes.

Both Gwynt y Mor sites combined are approximately 68.03km². The OWF are separated by approximately 0.53nm. The two IMO Traffic Lanes with a width of 1.80nm with a Separation Zone of 1nm (4.6nm) are approximately 0.46nm at the CPA. Although the lane boundary is less than 0.5nm, the commercial vessel density shows most of the traffic (1.5 - 2 cargo and tanker vessels per day) transits 0.68nm at the CPA from the OWF boundary. The closest clearway is the entrance of the Traffic Lane on the East site which is approximately 0.72nm from the site boundary. The sites therefore do not comply with MCA guidance, PIANC guidance or the Dutch model.

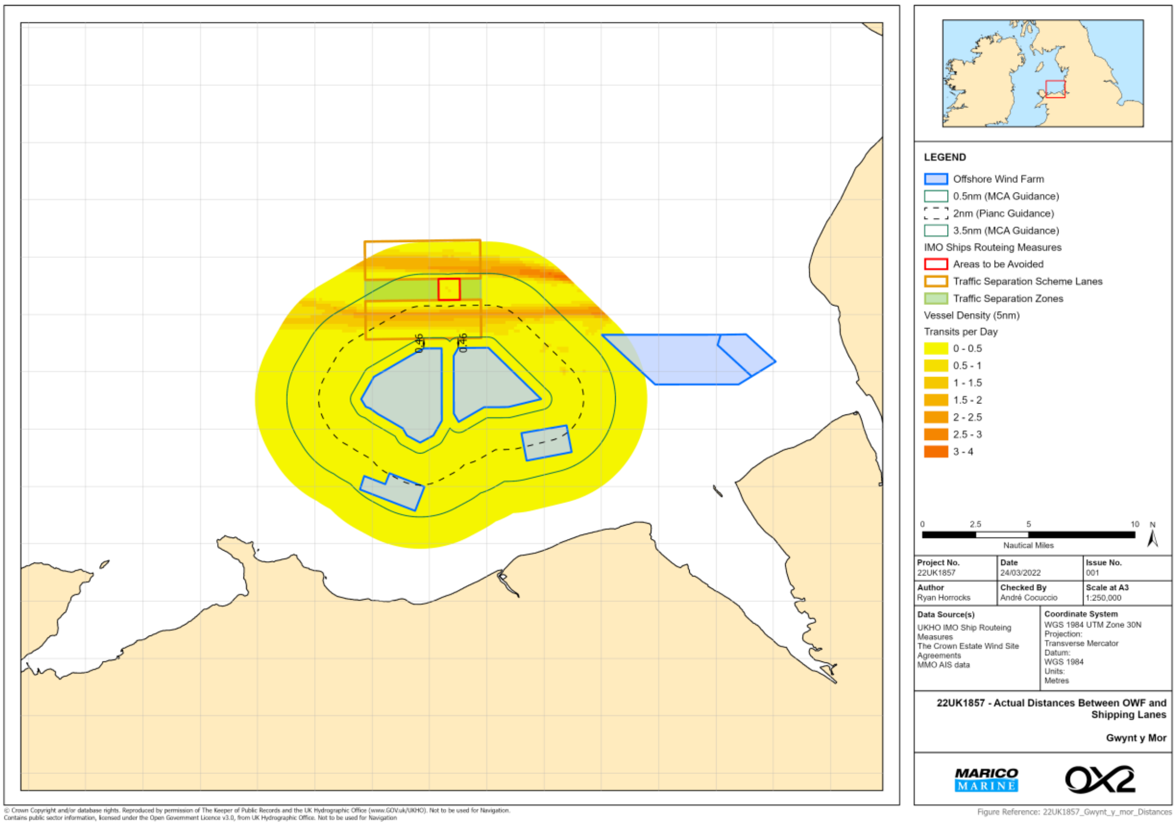

Figure 25 – Gwynt y Mor OWF Safety Distances.

4.2 THE DUTCH MODEL/PIANC

The Design Criterion: Distance Between Shipping Routes and Wind Farms, previously referred to as the *Assessment Framework for Defining Safe Distances Between Shipping Lanes and OWF* [7], is a Dutch system for calculating the necessary space needed for safe navigation between an OWF and a shipping lane. The concept was originally developed in the White Paper on Offshore Wind Energy (2014) which was a partial review of the Dutch National Water Plan but has since been remodelled within the Policy Document on the North Sea 2016 – 2021.

Produced in 2018, the PIANC document '*Interactions Between Offshore Wind Farms and Maritime Navigation*' provides guidance and recommendations on the minimum distances between shipping lanes for OWF to minimise navigational risk.

The Dutch policy document and the PIANC guidance both suggest the same formula for calculating safe distances between OWF and shipping lanes which can be seen below:

6 Lengths (Largest, Frequent Vessel) + 500m Safety Zone + 0.3nm Starboard buffer

Calculations were conducted from the Triton boundary and the TSS in Bornholmsgat as per the Dutch whitepaper recommendations. The Dutch whitepaper recommendation of using "Standard Ship" as a basis for the calculations was also used. The Standard Ship is a vessel whose size is not exceeded by 98.5% of all ships which transit the route in question. To adhere to this guidance, the largest frequent vessel that transits the shipping lanes around Triton is the MSC SEAVIEW passenger ship which is 323m LOA and transited the area 28 times, was used to conduct calculations. The calculations are shown in **Table 3** and illustrated in **Figure 26** and **Figure 27**.

Table 3 – Calculations for the Triton OWF.

Attribute	Value
6 Ship Lengths: 323*6 = 1,938m	1.05nm
500m safety Zone	0.27nm
Starboard buffer	0.30nm
Total:	1.62nm

[7] Government of the Netherlands White Paper on Offshore Wind Energy Partial review of the National Water Plan Holland Coast and area north of the Wadden Islands, 2014

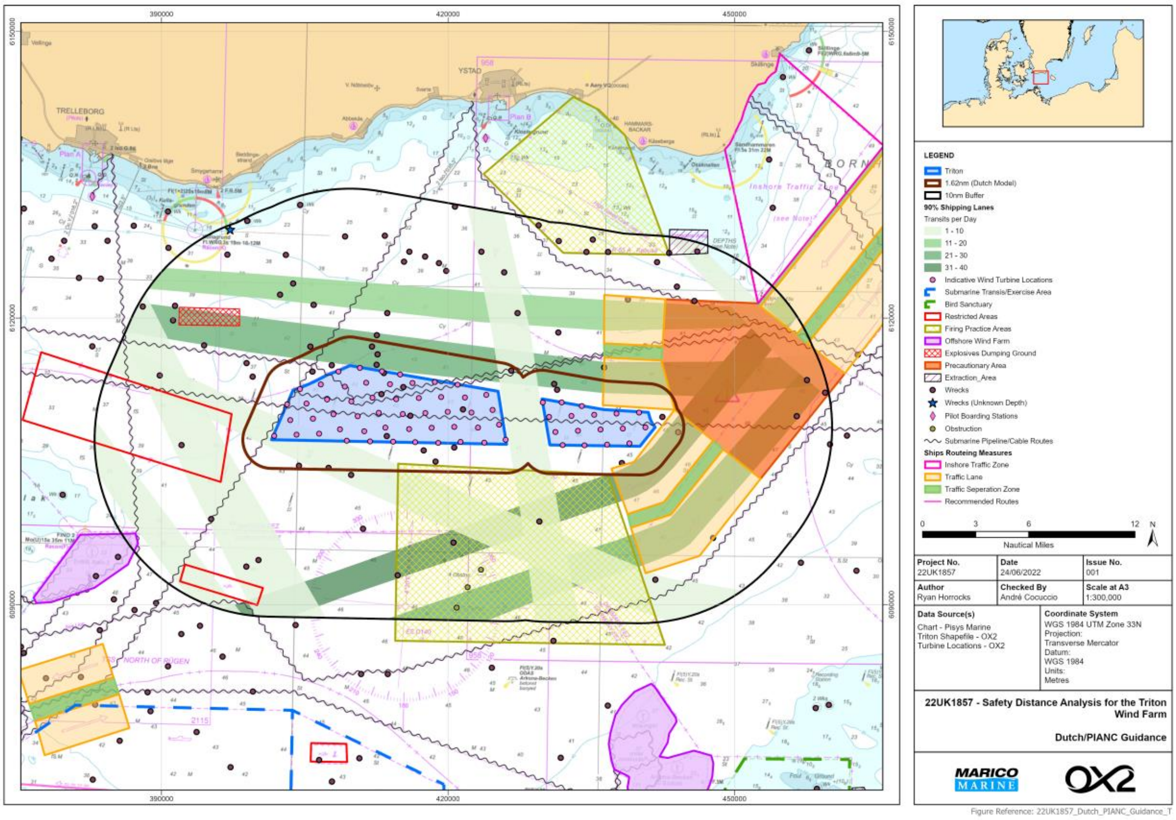

Figure 26 – Dutch/PIANC guidance for calculating safety zones calculated from the Triton boundary.

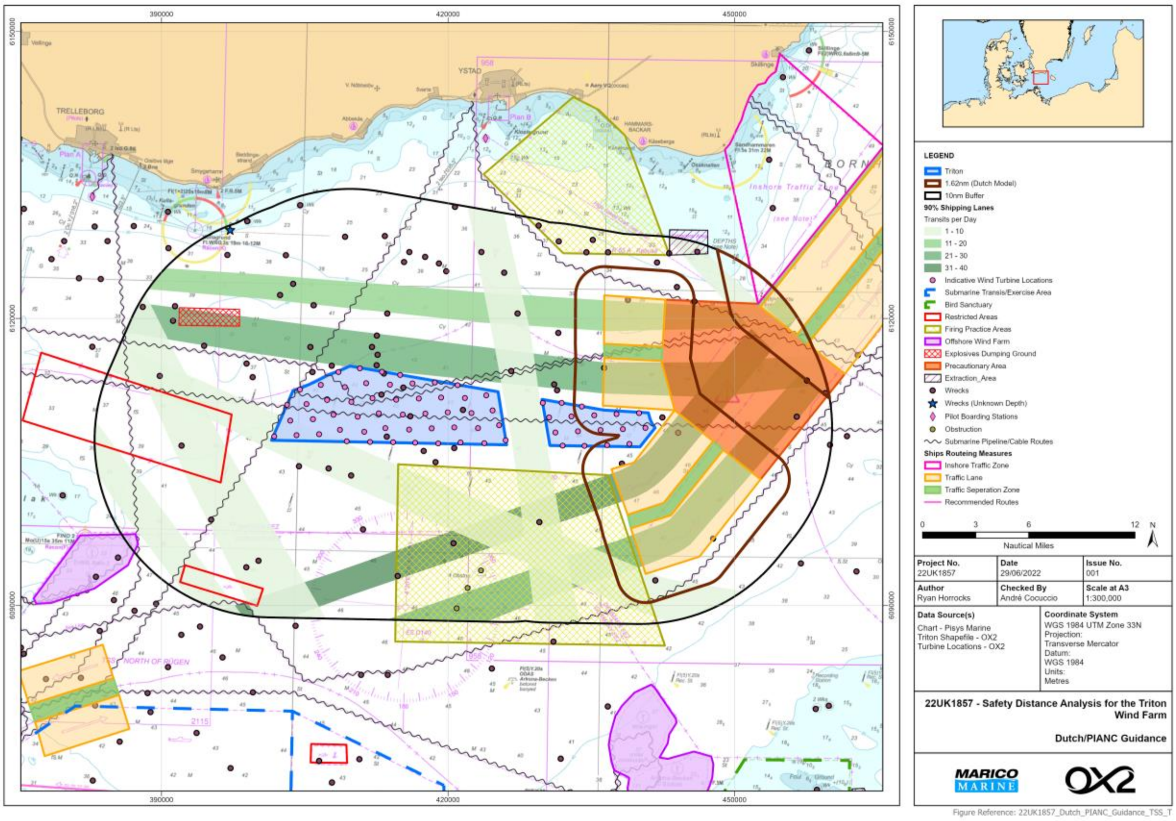

Figure 27 – Dutch/PIANC guidance for calculating safety zones calculated from the traffic lane boarder.

5 SUMMARY

This study has determined that:

5.1 TRAFFIC DENSITY

- The traffic density within 10nm of Triton is moderate/high with the densest region reaching over 20 vessels per day;
- Traffic surrounding Triton primarily travels to the east/southeast and north of the wind farm within the traffic lanes/clearways;
- The highest density within the busiest 90th percentile lane (A) is over 20 transits per day; and
- An average of 156 vessels per day travel within 10nm of the Triton boundary. The traffic within 10nm shows some summer and winter seasonality with the summer period showing more transits than the winter.

5.2 VESSEL SIZES

- Most vessels range between 80-90m LOA with 9,593 transits within that category over the 12-month data period within 10nm;
- The largest vessel recorded was the 400m container ship MSC DIANA; the largest frequent vessel recorded was the 323m passenger ship MSC SEAVIEW with 28 transits across the data extent;
- Larger vessels are seen to transit primarily within the routeing measures to the east/southeast and north of the boundary;
- With a turning circle of 5 ship lengths and the largest, frequent recorded ship of 323m, the necessary room required for vessels to manoeuvre between the OWF and shipping lane is approximately 0.87nm; and
- For a standard ship of 250m, the necessary room required for vessels to manoeuvre between the Triton OWF and shipping lane is approximately 0.67nm.

5.3 ENVIRONMENTAL CONDITIONS

- Prevailing winds are west to south-westerly at a maximum speed of 17.78m/s to 20.32m/s; and
- The maximum tidal heights estimated across the Baltic for a 100-year period are 23cm.

5.4 OCEAN USES

- The closest IMO routeing measure is the traffic lane that forms part of the TSS in Bornholmsgat approximately 0.25nm east of the boundary;
- The site is approximately 9.35nm from the closest renewable energy installation, the Baltic Two wind farm; and

- The closest navigation hazards are the firing practice area south of Triton a CPA of approximately 1.22nm and the precautionary area that forms part of the TTS to the east approximately 1.50nm from the Triton boundary.

5.5 TRAFFIC PROFILE

- A total of 9,900 vessels (79,319 tracks) transited within the data extent during the assessed period. A total of 1,379 vessels (3,153 tracks) vessels intersected the boundary across the 12-month data period which is an average of 9 vessel tracks per day;
- A total of 2,702 recreational vessel tracks were within 10nm of the Triton OWF, of which, 459 tracks intersected the boundaries area over the 12-month data period;
- A total of 779 tracks were made by fishing vessels within 10nm of Triton, 108 of which intersected the OWF boundaries; and
- In terms of tracks, approximately 59% were produced by cargo vessels, 18% by tankers, 13% by passenger vessels, 5% were by recreational vessels, 4% by other category vessels, and 1% were by fishing vessels.

5.6 SHIPPING LANES

- 9 shipping lanes were identified within the vicinity of the Triton OWF, 4 were located within existing routeing measures and the remaining 5 were clearways;
- 4 out of the 9 90^{th} percentile lanes identified (A, C, E, and G) were located under 0.5nm of the Triton wind farm boundary;
- The CPA for all the lanes identified were lanes C and G which intersected the Triton boundary;
- The highest number of commercial vessels per day was lane A (traffic lane/clearway) with an average of 36 vessels per day; and
- Traffic within lane A is consistent with the traffic using the full width of the 90th percentile. The majority of vessel traffic within lane C transits towards the north of the lane and away from the boundary of the wind farm. Lanes E and G are bi-directional lanes where most of the traffic is seen to transit through the centre.

5.7 RADAR INTERFERENCE

- Guidance on mitigating radar interference suggests a zone of 0.8nm is sufficient to reduce the effects on vessels radars and larger vessels must plan their voyages and allow for a 2nm zone between themselves and the adjacent OWF providing adequate safe sea room exists; and
- Radar interference is dependent on the situation, with the most common impact being reflected energy cluttering the operating display.

6 CONCLUSION

Based on the evidence presented, this assessment can conclude that:

- Traffic Density – within the vicinity of Triton is considered moderate/high;
- Vessel Sizes – Larger vessels are seen to use the full width of the lanes although most vessel traffic travels down the centre of the 90th percentile lanes identified with the exception of lane A;
- Environmental Conditions – as tidal drift is negligible, mariner expertise suggests a prevailing west/south-westerly wind would be of little concern due to the adequate sea room around the OWF for vessels to drift;
- Ocean Uses – The closest navigation hazards are the firing practice area south of Triton a CPA of approximately 1.22nm and the precautionary area that forms part of the TTS to the east approximately 1.50nm from the Triton boundary. These are of minimal concern to the designation of the safety zones;
- Traffic Profile - Cargo vessels represent the principal vessel type (59%) within 10nm of the OWF. Fishing and recreational vessels constitute 6% of vessel types within 10nm of the OWF making them of limited interest when considering safety distances;
- Shipping Lanes – the 90% percentile lanes are moderately/highly transited and are all wide enough to allow vessels to manoeuvre; and
- Radar Interference – can be mitigated providing larger vessels transit towards the centre of the shipping lanes and densities of fishing and recreational vessels do not increase.

This assessment has considered a range of factors that would contribute to the in-situ designation of a safety zone around the Triton OWF. Based on analysis of the surrounding area and vessel traffic, the evidence suggests that a **minimum safety distance of 0.5nm** from the closest point of approach to the Triton OWF boundary is likely tolerable within the navigation risk profile of the development. The Triton OWF boundary and indicative turbine layout would therefore require substantial adjustment to the east section and west section border to adhere to the safe distance suggested above.

This determination is made on the basis that:

- The busy traffic lanes/clearways adjacent to the OWF have been identified in shipping lanes under Sweden's MSP;
- All lanes are of sufficient width for vessels to manoeuvre and plan voyages to mitigate radar interference.
- 90th Percentile Gate analysis has revealed that the majority of vessel transits take place mid-way through the most of the shipping lanes identified;
- Five of the nine 90th Percentile shipping lanes (A, B, D, F, H, and I) were located over 0.5nm away from the OWF limit;
- Consequently, a minimum safety distance of 0.5nm:

  - Exists between the proposed OWF boundary and where the bulk of traffic transits through the 90th Percentile shipping lanes;

- This falls in line with guidance issued by the UK's Maritime and Coastguard Agency, citing that 0.5nm is the minimum safety distance acceptable once the navigational risk profile of the development is reduced to 'as low as reasonably practicable' or ALARP.

Although the 90th percentile lanes in the vicinity of the TSS are a) of an adequate distance from the boundary, b) a sufficient width for vessels to manoeuvre, and c) the lanes themselves are of a sufficient width for vessels to manoeuvre (with the narrowest point of the traffic lanes being approximately 2.70nm), the guidance outlined within Lot 1 suggests that safety distances should be calculated from an IMO routeing measure with a defined limit. Triton's border currently sits at 0.25nm away from the closest TSS border and would therefore require adjustment to comply with the safe distance suggested above (See **Figure 24**). Although this distance has been deemed tolerable based on the analysis, the Swedish Maritime Authority must decide whether they are willing to accept the level of risk presented by having a windfarm 0.25nm away from a traffic lane boarder, or whether it would be appropriate and necessary to consider amending the IMO's routeing measure in this instance.

7 FUTURE WORK

It is Marico Marine's recommendation that a full Navigation Risk Assessment (NRA) is undertaken once turbine design and layout has been finalised. The determined safety zone of 0.5nm would feature within this assessment as one of the proposed mitigation measures and support the de-risking of the site to ALARP ensuring an adequate level of navigational safety is maintained during site construction & operation.

Annex A IWRAP Calculations (SSPA)

CALCULATION OF BASIC GROUNDING, COLLISION AND ALLISION PROBABILITY

The IWRAP Mk2 (IALA Waterway Risk Assessment Program) is used to assess whether and how the wind farm may affect the likelihood of grounding and collision between ships and to estimate the likelihood of ships sailing or drifting into the wind farm.

Based on AIS data, traffic in the current area is modelled by defining vessel routes, known as legs, and nodes, known as waypoints, to resemble the current marine traffic pattern. The legs run between two waypoints, and several legs can be linked to each waypoint to define where vessel routes intersect or converge. In the programme, based on the AIS registrations, a statistical distribution is calculated for each leg, which describes how far from the centre line the ships have manoeuvred (lateral distribution).

The software uses AIS data to calculate the likelihood of collisions along the respective leg and at defined waypoints. The probability of grounding in the vicinity of the vessel leg is also calculated along defined depth curves and land contours. The model is also be supplemented with a wind farm in order to calculate the likelihood of so-called allisions with the wind farm, i.e. ships sailing or drifting into the wind farm. **Figure 5.1** shows the IWRAP model on which the calculations are based.

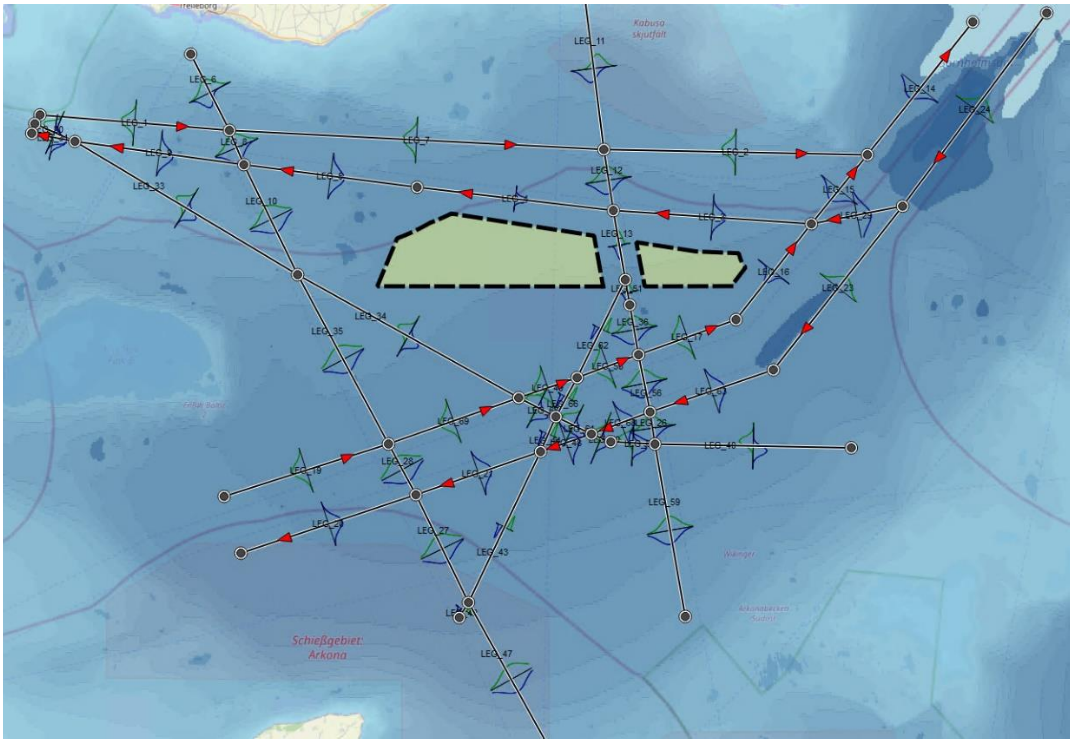

Figure 5.1 IWRAP model for calculating the probability of grounding, collisions and alloys. For each leg in the model, the lateral distribution of traffic is shown with a green (westbound traffic) and blue (eastbound traffic) curve, respectively. On many of the defined "legs", the traffic only goes in one direction. The red arrows in the figure indicate in which direction there is no traffic.

The direction a vessel will drift is primarily influenced by the wind direction. The IWRAP model has therefore been supplemented with a probability of different drift directions, based on wind statistics for the area. The prevailing wind direction of the area in question is south-west – west, see Figure 5.2, which means that vessels suffering from blackout scenarios will in most cases drift north-northeast-east.

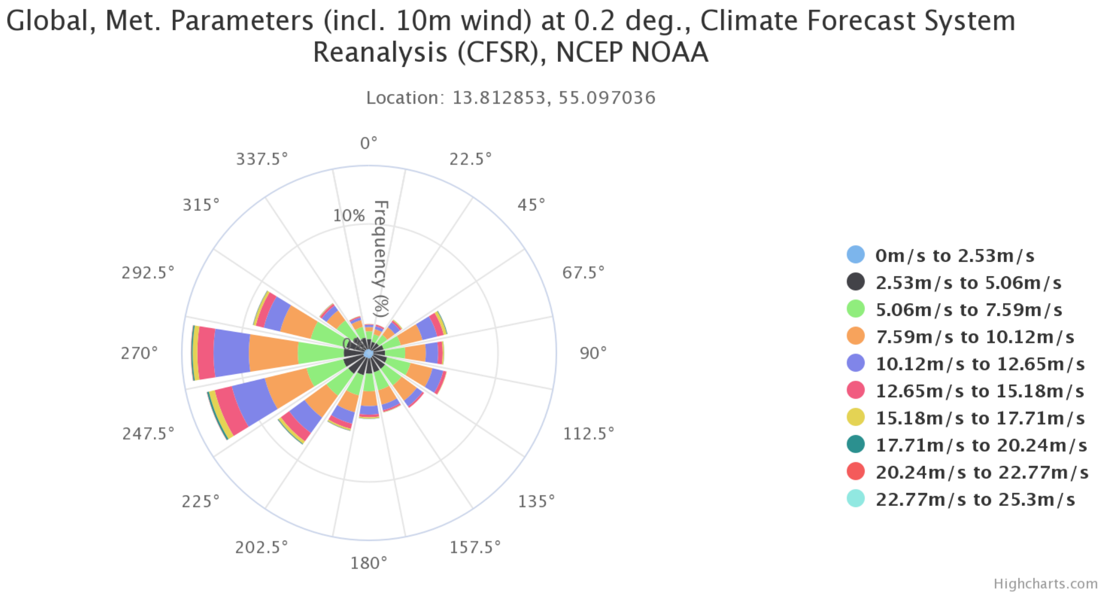

Figure 5.2 Wind rose based on wind data from 2000–2019 for the area around Triton.

In addition to the prevailing wind directions, the direction of marine currents also affects the course of events in scenarios with drifting grounding and drifting allisions. The speed of the marine currents is generally moderate in the waters in question, and their direction may vary temporarily depending on the prevailing weather situation. The effect of current is not taken into account in the IWRAP calculations presented, but the ocean currents in the area in question can be said to be dominated by the northbound Baltic current that transports Baltic Sea water to the North Sea.

The mathematical model is based on a probabilistic model where geometrical conditions define a number of so-called collision/grounding candidates, i.e. vessels on collision course and vessels drifting in the direction of potential grounding. The number of candidates is multiplied by empirically determined causation factors, which represent the probability that a dangerous course, caused by technical or human errors, will not be corrected in time and thus lead to collision or grounding. Different causation factors are used for different types of collision and grounding scenarios and are characterised as follows:

Collisions (between two vessels) – depending on where they occur are categorised as:

- *head-on* – collision between meeting vessels;
- *overtaking* – collision when overtaking in the same lane;
- *crossing* – collision when lanes cross each other;

- *merging* – collisions at node points where lanes converge; or
- *bend* – collisions at node points where the shipping lane bends.

Grounding is characterised as either:

- *Powered grounding* – when the ship grounds due to human error while under power; or
- *Drifting grounding* – when the ship is drifting due to technical fault that has caused a blackout and the engines are not operating.

Allisions are characterised in the same way as grounding:

- *Powered allision* – when the vessel enters the wind farm due to human error while under power; or
- *Drifting allision* – when the ship is drifting due to technical fault that has caused a blackout and the engines are not operating.

For the reported numerical values for collisions, grounding and allisions differences are calculated using the default values available for the various causation factors and the results have not been correlated with recorded incident statistics in the waters in question. This means that the reported values should not be interpreted as absolute numbers but should only be analysed from a comparative perspective to identify any significant differences between the current incident probabilities and those that can be expected to occur after the wind farm has been established.

Calculations have been carried out for three different traffic scenarios:

- Scenario 1: "*base case*"
  - Based on traffic patterns and traffic intensity for 1 July 2020 to 31 December 2020.
- Scenario 2: 2030
  - With a traffic increase of 20% from today's traffic / scenario 1.

In order to be able to see the potential impact of the wind farm, five traffic scenarios are made for all various calculations:

- A: Without wind farm.
  - Constitutes a zero alternative and is calculated to be able to compare how accident probabilities are affected by an establishment. The model intends to reflect the current traffic pattern in the area.
- B: With wind farm and safety distance (SD) 500 m from the outer edge of the traffic lane.
  - Refers to the case when a wind farm has been established. The traffic pattern does not change compared to case A
- C: With wind farm, safety distance 500 m from the outer edge of the traffic lane congestion of traffic at the passage near the park
  - The risk identification identified the risk that ship traffic passing on the lanes in the immediate vicinity of the park will be congested when more vessels in these lanes

choose a route slightly further from the park. In calculating case C, it is therefore assumed that ship traffic maintains a minimum distance of 1 nm to the wind farm. This also shifts the lateral centre of this traffic away from the wind farm and closer to the traffic in the opposite direction.

- D: With wind farm, reduced extent - safety distance 1,000 m from the outer edge of the traffic lane.
  - Refers to the case when a wind farm has been established. However, the park in case D has been reduced so that a minimum distance of 1,000 m (cf. 500 m in cases B and C) is maintained to the outer edge of the surrounding traffic lanes. The traffic pattern does not change compared to case A.
- E: With wind farm, reduced extent - safety distance 1,000 m from the outer edge of the traffic lane, congestion of traffic when passing near a park (Similar to case C).
  - The same distribution of wind farms as in case D. As in case C, the ship traffic that passes on the lanes in the immediate vicinity of the park is assumed to be crowded when more vessels in these lanes choose a route slightly further from the park. However, the congestion of traffic will be less when the wind farm is reduced and a safety distance of 1,000 m is maintained.

For each calculation, the probability of groundings, collisions and alliances with the wind farm is presented in tabular form, see Table 5.1 - Table 5.2. The results are illustrated in diagrams in Figure 5.3 and Figure 5.4

Table 5.1 Estimated probabilities (incidents / year) for Scenario 1; traffic corresponding to 2020. E indicates the ten-power factor, for example E-04 = 10–4.

SCENARIO 1	A	B	C	D	E
	No wind farm	500 m SD	500 m SD congestion	1000 m SD	1000 m SD congestion
Powered Grounding	1,1E-02	1,1E-02	1,1E-02	1,1E-02	1,1E-02
Drifting Grounding	8,5E-02	8,0E-02	8,1E-02	8,1E-02	8,1E-02
Total Groundings	9,5E-02	9,1E-02	9,2E-02	9,1E-02	9,1E-02
Powered Allision	---	3,2E-02	3,5E-06	8,6E-03	5,7E-05
Drifting Allision	---	1,4E-01	1,1E-01	1,2E-01	1,0E-01
Total Allisions	0,0E+00	1,7E-01	1,1E-01	1,3E-01	1,0E-01
Overtaking	3,8E-02	3,8E-02	4,4E-02	3,8E-02	4,0E-02
HeadOn	2,9E-04	2,9E-04	3,0E-04	2,9E-04	3,0E-04
Crossing	5,4E-02	5,4E-02	5,4E-02	5,4E-02	5,4E-02
Merging	1,8E-02	1,8E-02	1,8E-02	1,8E-02	1,8E-02
Bend	4,9E-05	4,3E-05	4,3E-05	4,3E-05	4,3E-05
Total Collisions	1,1E-01	1,1E-01	1,2E-01	1,1E-01	1,1E-01
Total Accidents	2,1E-01	3,7E-01	3,2E-01	3,3E-01	3,1E-01

Table 5.2 Estimated probabilities (incidents / year) for Scenario 2; traffic corresponding to 2020 + 20%. E indicates the ten power factor, for example E-04 = 10^{-4}.

SCENARIO 2	A	B	C	D	E
	No wind farm	500 m SD	500 m SD congestion	1000 SD	1000 SD congestion
Powered Grounding	1,3E-02	1,3E-02	1,3E-02	1,3E-02	1,3E-02
Drifting Grounding	1,0E-01	9,7E-02	9,7E-02	9,7E-02	9,7E-02
Total Groundings	1,1E-01	1,1E-01	1,1E-01	1,1E-01	1,1E-01
Powered Allision	---	3,8E-02	4,2E-06	1,0E-02	6,9E-05
Drifting Allision	---	1,7E-01	1,3E-01	1,4E-01	1,3E-01
Total Allisions	0,0E+00	2,0E-01	1,3E-01	1,5E-01	1,3E-01
Overtaking	5,5E-02	5,5E-02	6,3E-02	5,5E-02	5,7E-02
HeadOn	4,2E-04	4,2E-04	4,3E-04	4,2E-04	4,3E-04
Crossing	7,8E-02	7,8E-02	7,8E-02	7,8E-02	7,8E-02
Merging	2,6E-02	2,6E-02	2,6E-02	2,6E-02	2,6E-02
Bend	6,2E-05	6,2E-05	6,2E-05	6,2E-05	6,2E-05
Total Collisions	1,6E-01	1,6E-01	1,7E-01	1,6E-01	1,6E-01
Total Accidents	2,7E-01	4,7E-01	4,1E-01	4,2E-01	4,0E-01

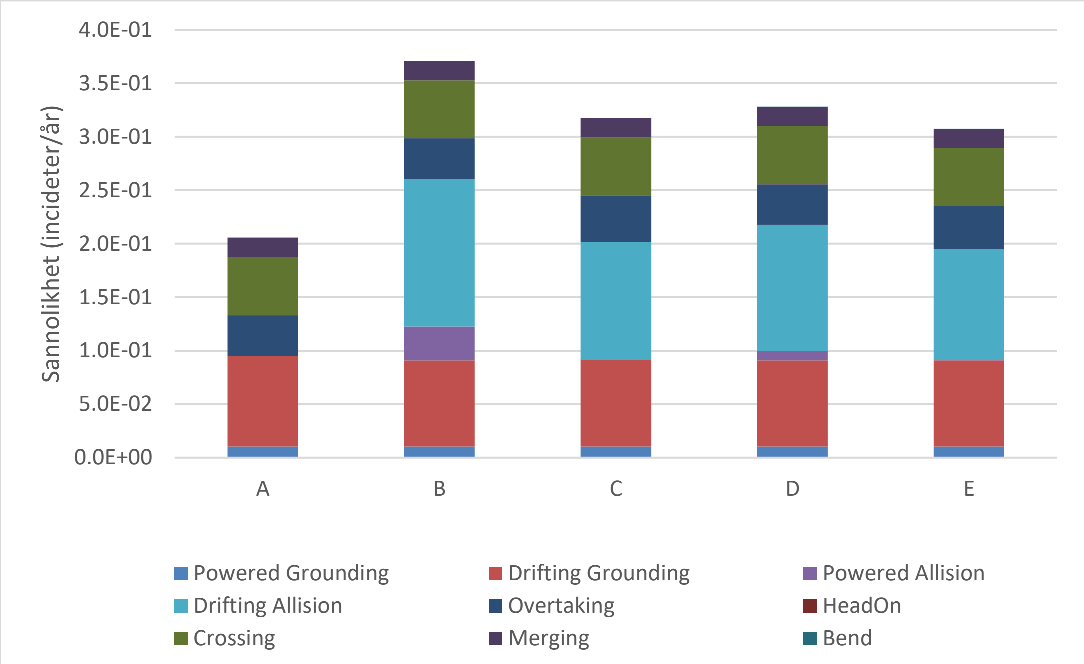

Figure 5.3 Estimated probabilities for traffic scenario 1.

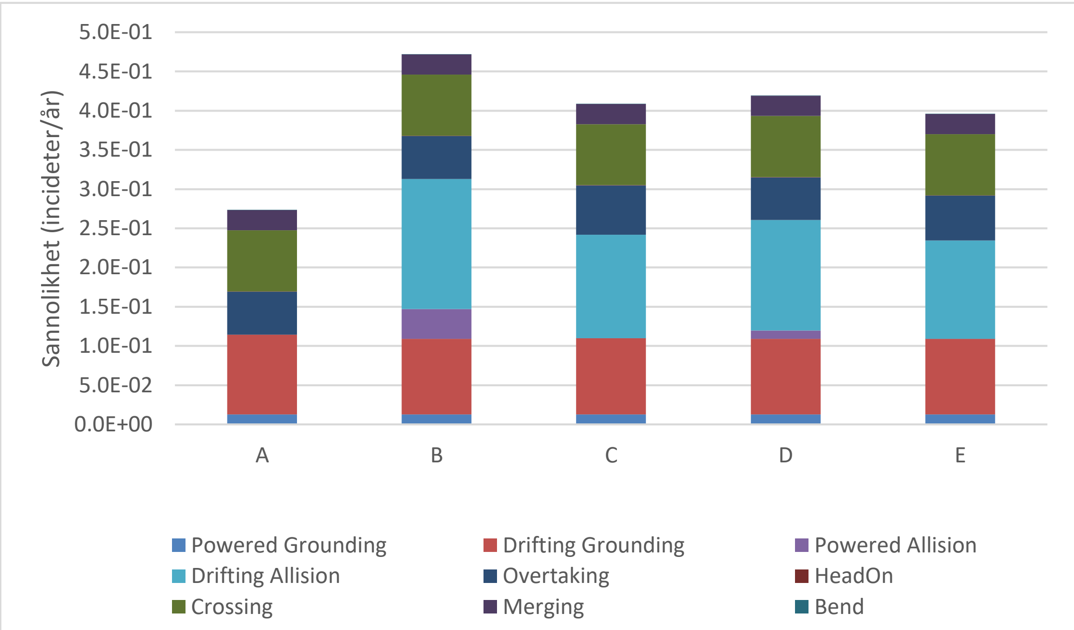

Figure 5.4 Estimated probabilities for traffic scenario 2.