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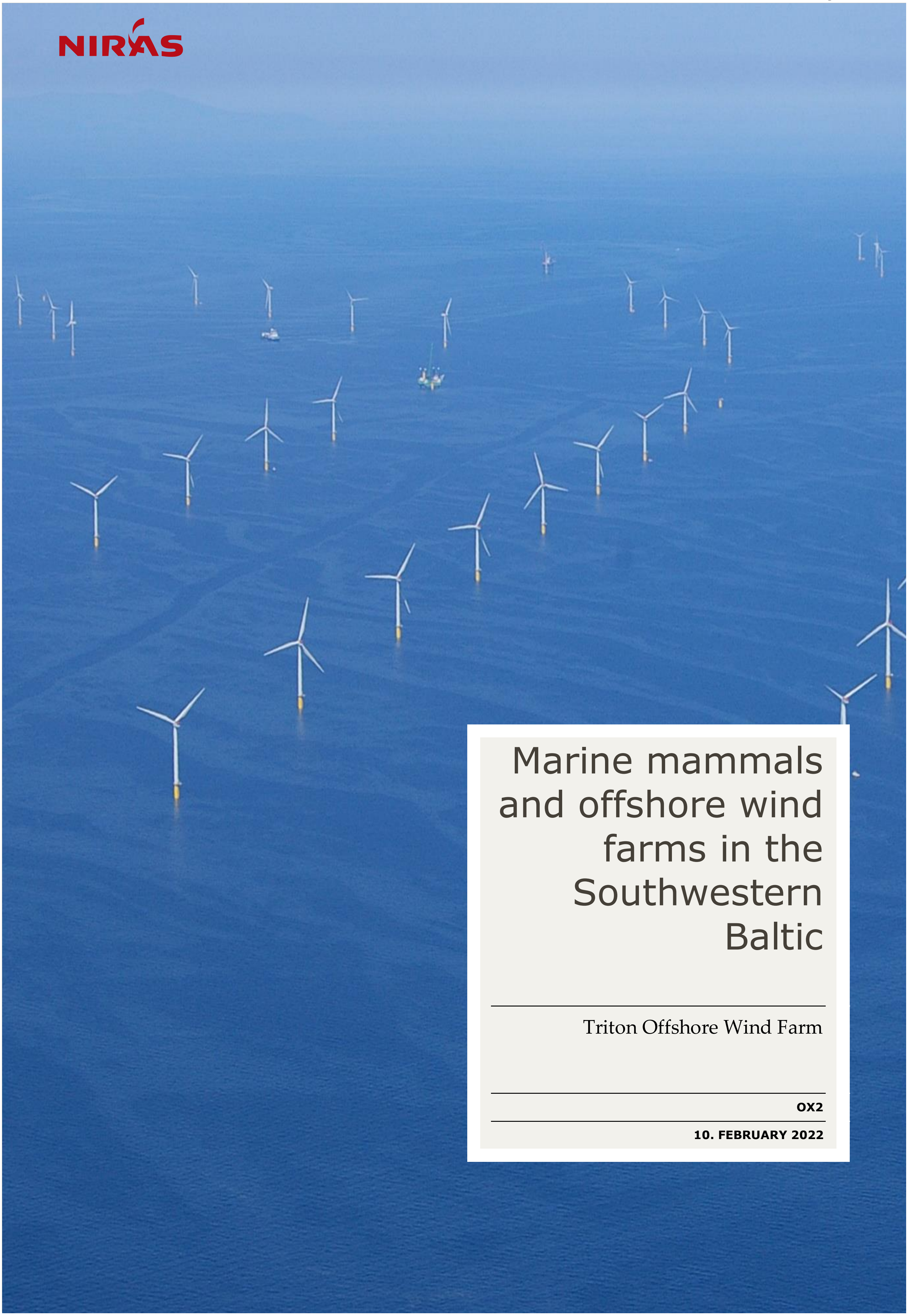

NIRAS

Marine mammals and offshore wind farms in the Southwestern Baltic

Triton Offshore Wind Farm

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Contents

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Summary

The Triton offshore wind farm is located off the south coast of Skåne, about 30 kilometers south of Ystad. The planned wind farm has an area of 250 km^2 excluding the planned export cable corridors for connection to shore. The depth in the area varies between 43 and 47 meters and the seabed sediments consists of soft bottom substrates, such as clay and muddy clay.

The wind farm is planned for a total rated power of approximately 1700-1900 MW and comprise of 68-129 wind turbines, array cables and offshore substations. The following foundation types are considered as viable options: Monopiles (with a bottom diameter of up to 14 meters), gravity based foundations (estimated to have a bottom diameter of up to 45 meters), 3-4 legged jacket (with up to 4.5 meter pinpiles or with suction buckets).

Surrounding the foundations, scour protection will be placed to avoid the development of scour holes. Inter array cables will connect the wind turbines to offshore substations. The voltage level in inter array cables will be 66 kV to 170 kV. Cables will be buried in the seabed. From the offshore substations, export cables will transmit electricity to shore. The voltage of export cables is most likely 220 kV or more. The operational lifetime of offshore wind farm is expected to be up to 45 years, and thereafter the windfarm will be decommissioned.

The aim of this report is to assess the environmental impact of the pre-investigation survey, construction, operation and decommissioning on the three most common marine mammal species in the development area for Triton offshore wind farm (harbour seals, grey seals, and harbour porpoises). The baseline description of marine mammals is based on existing knowledge, data from the passive acoustic monitoring of porpoises in the development area for Triton offshore wind farm, and on data from other projects near the development area for Triton offshore wind farm.

Abundance of marine mammals in the development area for Triton OWF

The development area for Triton offshore wind farm is located in a transition area, where harbour porpoises from both the Belt Sea population and the critically endangered Baltic Proper population may occur. The Belt Sea population is in favorable conservation status and consists of 42.000 animals, whereas the Baltic Proper population consists of approximately 500 animals and is in unfavorable conservation status. Recent studies of the Baltic Proper population, however, indicate that the population is slowly recovering. The development area for Triton offshore wind farm is at the border of both populations range and the development area is not assessed as being a particular suitable harbour porpoise habitat (supported by low porpoise densities), or a breeding ground for harbour porpoises. Porpoises from the Belt Sea population can occur in the area during all seasons, whereas individuals from the Baltic Proper population are only potentially found in the area during the winter period. During the winter period, it is still expected that the vast majority of harbour porpoises in the area are from the Belt Sea population, as it is far more numerous.

Based on the latest studies of the occurrence of harbour porpoises, it is estimated that the development area (and the immediate area) for Triton Offshore Wind Farm has a low significance for harbour porpoises (both porpoises from the Belt Sea population and porpoises from the Baltic Proper population).

One of the largest seal haul-out sites in the Southern Baltic Sea for both harbour seals and grey seals is located 50 km at Måkläppen to the northwest of the development area. It is expected that harbour seals and grey seals occur in the development area for Triton offshore wind farm, however the development area is considered to be of low/medium importance for harbour seals as well as grey seals, as neither species seems to use it as a particular feeding ground.

Impact from pre-investigation survey

Underwater noise during the pre-investigation survey for construction (seismic survey) and construction phase is considered by far the most important source of potential impacts on marine mammals.

Underwater noise from seismic surveys may cause behavioural avoidance responses, temporary threshold shift (TTS), and permanent threshold shift (PTS) in marine mammals. To assess the impact of underwater noise from a seismic survey, a detailed underwater noise modelling has been conducted. To reduce the impact from underwater noise from the seismic survey, a 30 minute soft start to full power should be applied, to ensure that porpoises and seals are not within the risk zone for TTS and PTS. Furthermore, passive acoustic monitoring should be applied as well as having marine mammal observers onboard the survey vessel to ensure that no marine mammals are in close proximity of the survey vessel at the onset of the seismic survey. If the seismic survey is interrupted, the onset of the seismic survey should include a soft start procedure.

Under the assumption that an appropriate soft start procedure is applied, the combined impact on the harbour porpoises, harbour seals and grey seals is assessed to be negligible to minor and without consequences for the short-term and long-term conservation status of the populations.

Impact from construction

Underwater noise from pile driving, if not mitigated, may cause behavioural avoidance responses, temporary threshold shift (TTS), and permanent threshold shift (PTS) in marine mammals. To assess the impact of underwater noise from pile driving a detailed underwater noise modelling has been conducted. In the modelling of impact ranges of underwater noise from pile driving it is assumed that a noise abatement system is used, with an efficiency corresponding to the attenuation achieved by application of a single Big Bubble Curtain (BBC). Piling without noise abatement systems is not considered as this is not deemed to be a realistic scenario. Furthermore, it is assumed that a soft start/ramp-up procedure is applied, where the intensity of the hammer energy is gradually increased. Application of BBC and soft start/ramp-up prevents PTS in both harbour porpoises and seals. Furthermore, even in a worst-case scenario, the impact range of TTS is very limited for both harbour porpoises (300 meter) and for seals (825 meter) and is assessed to cause a negligible impact on both harbour porpoises (both Belt Sea and the Baltic Sea population) and seals.

Noise levels exceeding the threshold for behavioural reactions may occur out to 11.6 km in the worst-case scenario. In this case 4-39 harbour porpoises from the Belt Sea population and less than 1 harbour porpoises from the critically endangered Baltic Proper population may be exposed to underwater noise levels that exceed the threshold for behavioural avoidance responses during installation of one monopile during the winter period. During the summer period porpoises from the Baltic Proper do not occur in the area, whereas 8-78 harbour porpoises form the Belt Sea population may be exposed to underwater noise levels exceeding the threshold for behavioural avoidance responses. In the worst-case scenario, underwater noise from pile driving of monopile will be present up to 6 hours of efficient piling per day for four months (129 days, if one pile is installed per day). However, the total period where foundation construction work takes place will be longer, as e.g. weather conditions can delay the construction work and it is expected that installation of one foundation will take 2 days leading to 260 days of foundation installation.

It is expected that harbour porpoises will avoid the construction site during pile driving and that they will return a few days to a few weeks after the pile driving is completed. As the development area for Triton offshore wind farm is located in an area of low importance for harbour porpoises, the overall assessment of impact of behavioural avoidance responses in harbour porpoises caused by underwater noise from pile driving is minor for the Belt Sea population all year round, minor for the Baltic Proper population during the winter period and negligible for the Baltic Proper population during the summer, as they are not expected to be in the southwestern part of the Baltic Sea in this period.

The impact of underwater noise from pile driving on harbour seals and grey seals is assessed as minor, as it is a limited area of the seals home range, in which the underwater noise exceeds the threshold for behavioural avoidance responses. In the worst-case scenario up to 7.5 % of the home range for harbour seals and 0.55 % of the home range for grey seals will be affected short-term. Seals are in general, considered to be more noise tolerant compared to harbour porpoises.

Since calculated estimates show that less than one Baltic Proper harbour porpoise may experience underwater noise levels above the behavioral threshold during pile driving in winter months, and that the development area is a low quality habitat for harbour porpoises overall, it is assessed that time restrictions for pile driving in the winter months are unnecessary.

In addition to underwater noise modelling with application of a mitigation system corresponding to a single big bubble curtain (BBC), underwater noise modelling has also been undertaken assuming the application of a mitigation system corresponding to a double big bubble curtain combined with a hydro sound damper (DBBC+HSD). The underwater noise modelling showed that no PTS or TTS will be elicited in any harbour porpoise. Noise levels exceeding the threshold for behavioural reactions may occur out to 6.7 km in the worst-case scenario. In this worst-case scenario it is estimated that 1-13 harbour porpoises from the Belt Sea population may be exposed to underwater noise levels exceeding the threshold for behavioural avoidance responses during installation of a monopile during the winter period. For the critically endangered Baltic Proper harbour porpoises the estimate is much less than 1 individual. Based on the underwater noise modelling which assumes the application of a mitigation system corresponding to a DBBC+ HSD, the impact assessment of behavioural avoidance responses in harbour porpoises is still minor for the Belt Sea population and still minor for the Baltic Proper population during the winter period. The impact of underwater noise from pile driving with application of DBBC+HSD on harbour seals and grey seals is assessed as minor. In the worst-case scenario up to 2.3 % of the home range for harbour seals and 0.17 % of the home range for grey seals will be affected short-term.

Other impacts such as habitat loss, sediment spillage and increased concentrations of suspended sediment are estimated to cause negligible to minor impact on marine mammals. According to several studies, both harbor porpoises and harbor seals as well as grey seals will quickly return to the development area when the construction of the offshore wind farm is completed and reach the same level as before the wind farm was built. Foundations and erosion protection of the foundations will form small artificial reefs, which can increase the biodiversity around the foundations and thus lead to a small improvement in the feeding opportunities of marine mammals.

Impact from operation

All potential impacts related to the operational phase of the wind farm are assessed as negligible to minor. This applies to underwater noise from the wind turbines in operation and maintenance traffic as well as to electromagnetic fields around the cables and permanent habitat changes by the introducing of hard bottom substrate at the wind turbine foundations. Underwater noise from the wind turbines in operation will only exceed the existing background noise level in close vicinity to each wind turbine. Regarding habitat changes the small direct habitat loss is accompanied by alterations that may lead to an improvement of the food resources for marine mammals (introduction of hard substrate, exclusion or regulation and limitation of fisheries).

Impact from decommissioning

Noise will occur in connection with the decommissioning work, although it is expected to be considerably less intensive compared to the construction phase, as there will be no pile driving activities. For other potential impacts during the decommissioning phase, it is expected that they will be smaller or equal to the impacts during the construction phase. The overall impact on marine mammals in the decommissioning phase is assessed to be negligible to minor.

Impact on Natura 2000 areas and annex IV species

The protection of harbour porpoises, harbour seals and grey seals is part of the conservation objectives for a large number of both Danish and Swedish marine Natura 2000 areas. There are several nearby Natura 2000 areas appointed to protect harbour porpoises. During pile driving of foundations, one of the nearby Natura 2000 areas "SE0430187 Sydvästskånes utsjövatten" appointed to protect both harbour porpoises, harbour seals and grey seals will be affected by underwater noise levels that exceed the threshold for behavioural avoidance responses. However this will only be in 12% of the Natura 2000 area with pile driving with application of a single big bubble curtain. There will be no risk of temporary thresholds shift or permanent threshold shift inside the Natura 2000 area. It is therefore assessed that construction of Triton offshore wind farm will not harm or have any negative impact on the short-term and long-term conservation status of harbour porpoise (both the Belt Sea population or the Baltic Proper population), harbour seals and grey seals in SE0430187 Sydvästskånes utsjövatten nor prevent fulfillment of the conservation objectives for harbour porpoises, harbour seals and grey seals in the Natura 2000 area SE0430187.

Underwater noise from seismic surveys may cause behavioural avoidance responses, temporary threshold shift (TTS), and permanent threshold shift (PTS) in marine mammals. Under the assumption that an appropriate soft start procedure is applied as a mitigation measure, the combined impact on the harbour porpoises, harbour seals and grey seal in the nearby Natura 2000 area, is assessed to be negligible to minor and without consequences for the short-term and long-term conservation status of the populations nor prevent fulfillment of the conservation objectives for harbour porpoises, harbour seals and grey seals in the Natura 2000 area SE0430187.

With application of the above-mentioned mitigation measures, the impact from seismic surveys, construction, operation and decommissioning of Triton offshore wind farm on individuals is assessed as limited and without risk of impact at population level. Construction, operation and decommissioning of Triton offshore wind farm does not give rise to either short-term or long-term consequences for the conservation status of harbour porpoises and thereby does not prevent maintenance of favorable conservation status for the Belt Sea population of harbour porpoises, harbour seals and grey seals inside or outside the Natura 2000 area SE0430187 Sydvästskånes utsjövatten. Furthermore, the construction, operation and decommissioning of Triton offshore wind farm does not give rise to either short-term or long-term consequences for the conservation status of harbour porpoises belonging to the Baltic Proper and thereby does not prevent fulfillment of favorable conservation status for the Baltic Proper population of harbour porpoises, inside or outside the Natura 2000 area SE0430187 Sydvästskånes utsjövatten. Construction, operation and decommissioning of Triton offshore wind farm will not prevent fulfillment of the conservation objectives for harbour porpoises, harbour seals and grey seals in the Natura 2000 area SE0430187.

Harbour porpoises are listed in Annex IV of the Habitats Directive and are therefore strictly protected wherever they occur. It is concluded that the Annex IV protection of harbour porpoises is maintained, as the project does not result in harbour porpoises being caught, killed, intentionally disturbed or having their breeding or resting areas damaged or destroyed. It is therefore assessed that the project will not affect the area's ecological functionality for harbour porpoises (both the Belt Sea population and the Baltic Proper population).

Applied mitigation measures

For the seismic survey, the following mitigation measures should be applied to reduce impact on marine mammals:

- The seismic survey should be started with a 30 minute soft start/ramp up to full power to ensure that porpoises and seals are not within the risk zone for TTS and PTS.
- Passive acoustic monitoring should be applied as well as observers should be onboard the survey vessel to ensure that no marine mammals are in close proximity of the survey vessel at the onset of the seismic survey.
- If the seismic survey is interrupted, the onset of the seismic survey should include a soft start procedure.

For pile driving, the following mitigation measures should be applied to reduce impact on marine mammals:

- Prior to commencing pile driving deterrence devises developed for harbour porpoises should be used in the required extent. Consultation with the relevant authority must take place (before the planned piling takes place) for decisions on methods, scope, and duration.
- Pile driving should be conducted with application of a soft start /ramp up procedure.
- Pile driving should be conducted with application of a noise abatement systems with an efficiency corresponding to the attenuation achieved by application of a Big Bubble Curtain (BBC) or more.

Svensk Sammanfattning

Vindparken Triton ligger inom Sveriges ekonomiska zon i sydvästra Östersjön. Området ligger utanför Skånes sydkust, cirka 30 kilometer söder om Ystad. Den planerade vindparken har en yta om 250 km^2 exklusive tillhörande korridorer för anslutning till land. Vattendjupet i vindparksområdet varierar mellan 43 och 47 meter. Havsbottensedimenten utgörs av mjuka bottensubstrat, så som lera och gyttjelera.

Vindparken är planerad att omfatta en total installerad effekt om cirka 1700-1900 MW och består av 68–129 vindkraftverk, ett internt kabelnät samt transformatorstationer. Vindkraftverken kommer att monteras på fundament. De fundamentstyper som anses vara genomförbara alternativ för förankring av vindkraftverken är: monopiles (med en bottendiameter på upp till 14 meter), gravitationsfundament (beräknas ha en bottendiameter på upp till 45 meter), fackverksfundament (med tre till fyra ben med upp till 4,5 meter i diameter på pålarna alternativt med sugkassuner).

Runt fundamenten kommer erosionsskydd att etableras för att undvika att sediment eroderar bort vid fundamenten. Det interna kabelnätet kommer att förbinda vindkraftverken i radialer till havsbaserade transformatorstationer. Spänningsnivån i det interna kabelnätet kommer vara 66 kV till 170 kV. Kablarna kommer grävas ner i havsbotten. Från transformatorstationen anläggs även kablar för överföring av elektricitet till land. Spänningen hos anslutningskablar beräknas vara 220 kV eller mer. Vindparken förväntas vara i drift upp till 45 år och därefter avvecklas.

Syftet med denna rapport är att bedöma miljökonsekvenserna från anläggningsundersökningar, anläggning, drift och avveckling för de tre vanligast förekommande marina däggdjuren i parkområdet för vindpark Triton (knubbsäl, gråsäl och tumlare). Bakgrundsinformationen om de marina däggdjuren baseras på befintlig kunskap, data från passiv akustisk övervakning av tumlare i parkområdet och data från andra projekt i närheten av parkområdet för vindpark Triton.

Förekomst av marina däggdjur i parkområdet för vindpark Triton

Parkområdet för vindpark Triton ligger i ett övergångsområde där tumlare från både Bälthavspopulationen och den kritiskt hotade Östersjöpopulationen kan förekomma. Bälthavspopulationen har en gynnsam bevarandestatus och består av cirka 42 000 djur, medan Östersjöpopulationen består av cirka 500 djur och har en icke gynnsam bevarandestatus. Nyligen genomförda studier av Östersjöpopulationen indikerar dock på att populationen långsamt återhämtar sig. Parkområdet för vindpark Triton ligger i gränsområdet för båda populationernas utbredning och projektområdet bedöms inte som ett lämpligt habitat (vilket stöds av den låga tätheten av tumlare) eller ett fortplantningsområde för tumlare. Tumlare från Bälthavspopulationen kan förekomma i området året om medan individer från Östersjöpopulationen bara potentiellt förekommer under vinterperioden. Under vintern förväntas det fortfarande att den stora majoriteten av tumlare i området tillhör Bälthavspopulationen eftersom de är så många fler.

Baserat på de senaste studierna av förekomst av tumlare uppskattas projektområdet för vindpark Triton ha låg betydelse för tumlare (från både Bälthavspopulationen och Östersjöpopulationen).

En av de största sälkolonierna (Måkläppen) i södra Östersjön för både knubbsäl och gråsäl ligger 50 kilometer nordväst om parkområdet för vindpark Triton. Knubbsälar och gråsälar förväntas förekomma i projektområdet för Triton, dock anses området ha låg/medelstor vikt för knubbsäl och gråsäl eftersom ingen av arterna verkar använda området som ett särskilt födosöksområde.

Påverkan från anläggningsundersökningar

Undervattensljud under anläggningsundersökningar (seismiska undersökningar) och anläggningsfasen anses vara den absolut viktigaste källan för potentiell påverkan på marina däggdjur.

Undervattensljud från seismiska undersökningar kan orsaka beteendeförändringar, tillfällig hörselnedsättning (TTS) och permanent hörselnedsättning (PTS) hos marina däggdjur. För att bedöma påverkan från undervattensljud från seismiska undersökningar har en detaljerad modellering av undervattensljud genomförts. För att minska påverkan från undervattensljud från de seismiska undersökningarna bör en 30 minuters mjuk uppstart tillämpas för att tillse att tumlarna och sälarna inte finns inom riskzonen för TTS och PTS. Dessutom bör passiv akustisk övervakning tillämpas och marina däggdjursobservatörer finnas ombord på undersökningsfartyget för att säkerställa att inga marina däggdjur befinner sig i nära anslutning till undersökningsfartyget när de seismiska undersökningarna startar. Om den seismiska undersökningen avbryts bör åter igen mjuk uppstart tillämpas vid återupptagandet.

Förutsatt att ett lämpligt förfarande för mjuk uppstart tillämpas bedöms den samlade påverkan på tumlare, knubbsäl och gråsäl vara försumbar till liten utan konsekvenser för populationernas bevarandestatus vare sig på kort eller lång sikt.

Påverkan under anläggning

Undervattensljud från pålning kan, utan bullerdämpande åtgärder, orsaka undvikandebeteende, tillfällig hörselnedsättning (TTS) och permanent hörselnedsättning (PTS) hos marina däggdjur. För att bedöma påverkan av undervattensljud från pålning har en detaljerad modellering av undervattensljud genomförts.

I modelleringen av påverkansavstånd från undervattensljud vid pålning har förutsatts att bullerdämpande åtgärder kommer att användas med en minskning av ljudet motsvarande användandet av en enkel bubbelgardin (Big Bubble Curtain, BBC). Pålning utan bullerdämpning har inte bedömts då pålning utan hänsynsåtgärder inte ansetts vara ett realistiskt scenario. Dessutom har det förutsatts att ett förfarande med mjuk uppstart och ramp up tillämpas, där intensiteten i hammarslagens energi gradvis ökar. Användandet av BBC och mjuk uppstart/ ramp up förhindrar PTS hos både tumlare och säl. Dessutom, även i worst case scenariot, blir påverkansavståndet för TTS väldigt begränsat för tumlare (300 meter) och säl (825 meter) och bedöms medföra försumbar konsekvens för både tumlare (både Bälthavs- och Östersjöpopulationen) och sälar.

Undervattensljud som kan medföra beteendepåverkan kan förekomma på ett avstånd upp till 11,6 kilometer i worst case scenariot. I worst case scenariot kan 4–39 tumlare från Bälthavspopulationen och mindre än en tumlare från den kritiskt hotade Östersjöpopulationen utsättas för undervattensljudnivåer som överstiger tröskelvärdet för undvikandebeteende under installationen av en monopile under vintern. Under sommaren förekommer inte tumlare från Östersjöpopulationen i detta område medan 8–78 tumlare från Bälthavspopulationen kan utsättas för undervattensljudnivåer som överstiger tröskelvärdet för undvikandebeteende. I worst case scenariot kommer undervattensljud från pålning av monopile fundament förekomma upp till sex timmar av effektivt pålningsarbete per dag under fyra månader (129 dagar) om ett fundament installeras per dag. Den totala perioden med anläggningsarbeten av fundament förväntas dock bli längre eftersom till exempel väderförhållanden kan försena anläggningsarbetet och det förväntas att installationen av ett fundament kommer ta två dagar vilket leder till 260 dagar med anläggning av fundament.

Tumlare förväntas undvika anläggningsområdet under pålningsarbeten och återvända efter några få dagar till veckor efter att pålningsarbetet är avslutat. Eftersom parkområdet för vindpark Triton ligger i ett område av låg betydelse för tumlare är den övergripande bedömningen av påverkan av undvikandebeteende hos tumlare orsakat av undervattensljud från pålningsarbeten liten för Bälthavspopulationen året om, liten för Östersjöpopulationen under vintern och försumbar för Östersjöpopulationen under sommaren, eftersom de inte förväntas befinna sig i den sydvästra delen av Östersjön under denna period.

Påverkan på knubbsäl och gråsäl av undervattensljud från pålningsarbeten bedöms som liten eftersom det är ett begränsat område av sälarnas hemområde där undervattensljuden överstiger gränsvärdet för beteendepåverkan. I worst case scenariot påverkas upp till 7,5 % av knubbsälarnas hemområde och 0,55 % av gråsälarnas hemområde kortvarigt. Sälar anses generellt vara mer tåliga för undervattensljud jämfört med tumlare.

Eftersom de beräknade uppskattningarna visar att färre än en Östersjötumlare kan utsättas för undervattensljud över tröskelvärdet för undvikandebeteende under pålningsarbeten under vintermånaderna och att parkområdet generellt är ett habitat med låg kvalité för tumlare bedöms tidsrestriktioner för pålningsarbeten under vintermånaderna inte vara nödvändiga.

Som tillägg till modelleringen av undervattensljud med bullerdämpande åtgärder motsvarande en enkel bubbelgardin (BBC) har även undervattensljud med bullerdämpande åtgärder motsvarande en dubbel bubbelgardin kombinerat med en hydro sound damper (DBBC+HSD) modellerats. Modelleringen av undervattensljud visade att inga tumlare då kommer att riskera varken PTS eller TTS. Undervattensljud som överskrider tröskelvärdet för undvikandebeteende kan förekomma upp till 6,7 km i worst case scenariot. I detta worst case scenario uppskattas 1–13 tumlare från Bälthavspopulationen kunna utsättas för undervattensljud som överstiger tröskelvärdet för undvikandebeteende under installationen av ett monopile fundament under vinterperioden. För tumlare från den kritiskt hotade Östersjöpopulationen är uppskattningen mycket mindre än en individ. Baserat på modelleringen av undervattensljud som förutsätter tillämpningen av bullerdämpande åtgärder motsvarande DBBC+HSD är bedömningen av undvikandebeteendet fortfarande liten för tumlare från Bälthavspopulationen och fortfarande liten för Östersjöpopulationen under vintern. Påverkan av undervattensljud från pålningsarbeten med bullerdämpning motsvarande DBBC+HSD bedöms för knubbsäl och gråsäl som liten. I worst case scenario bedöms upp till 2,3 % av knubbsälarnas och 0,17 % av gråsälarnas hemområden påverkas kortvarigt.

Annan påverkan så som habitatsförlust, sedimentspridning och ökade koncentrationer av suspenderade partiklar bedöms ge försumbar till liten påverkan på marina däggdjur. Enligt flera studier återvänder både tumlare, knubbsäl och gråsäl till vindparksområdet kort efter det att anläggningsarbetet har avslutats och når samma nivåer som innan vindparken byggts. Fundament och erosionsskydd kommer utgöra små artificiella rev som kan öka den biologiska mångfalden kring fundamenten och leda till en liten förbättring av födosöksmöjligheter för marina däggdjur.

Påverkan under drift

All potentiell påverkan förknippad med driftsfasen för vindparken bedöms som försumbar till liten. Detta gäller undervattensljud från vindkraftverken under drift och underhållstrafik liksom elektromagnetiska fält från kablarna samt permanenta förändringar av habitatet i och med införandet av hårda bottensubstrat vid vindkraftverkens fundament. Undervattensljud från vindkraftverk i drift kommer endast att överstiga den befintliga bakgrundsljudnivån i den absoluta närheten av varje vindkraftverk. Beträffande förändring av habitat åtföljs den lilla direkta habitatförlusten av förändringar som kan leda till en förbättring av födoresurserna för marina däggdjur (införandet av hårda substrat, uteslutning eller reglering och begränsning av fisket).

Påverkan under avveckling

Undervattensljud kommer förekomma under avvecklingen av vindparken dock förväntas ljudnivåerna vara betydligt lägre jämfört med anläggningsfasen eftersom det inte kommer förekomma pålningsarbeten. För andra potentiella effekter under avvecklingsfasen förväntas de vara mindre eller jämförbara med påverkan under anläggningsfasen. Den övergripande påverkan på marina däggdjur under avvecklingsfasen bedöms som försumbar till liten.

Påverkan på Natura 2000-områden och bilaga IV arter

Att skydda tumlare, knubbsäl och gråsäl är del av bevarandemålen för ett flertal marina Natura 2000-områden i både Sverige och Danmark. Det är flera närliggande Natura 2000-områden som har utsetts för att skydda tumlare. Under pålning av fundament kan ett av de närliggande Natura 2000-områdena, ” SE0430187 Sydvästskånes utsjövatten” utsett att skydda tumlare, knubbsäl och gråsäl, beröras av undervattensljud som överstiger gränsvärdet för beteendepåverkan. Dock bara 12% av Natura 2000-området vid pålning med enkel bubbelgardin. Det finns ingen risk för tillfällig eller permanent hörselnedsättning inom Natura 2000-området. Därför bedöms anläggningen av vindpark Triton inte skada eller negativt påverka, varken på kort eller lång sikt, bevarandestatusen för tumlare (från Bälthavspopulationen eller Östersjöpopulationen), knubbsäl eller gråsäl i SE0430187 Sydvästskånes utsjövatten eller förhindra att bevarandemålen uppfylls för tumlare, knubbsälar och gråsälar i Natura 2000-området SE0430187.

Undervattensljud från seismiska undersökningar kan orsaka undvikandebeteende, tillfällig hörselnedsättning (TTS) och permanent hörselnedsättning (PTS) hos marina däggdjur. Under antagandet att lämpligt förfarande med mjuk uppstart tillämpas som skyddsåtgärd bedöms den kombinerade påverkan på tumlare, knubbsäl och gråsäl i det närliggande Natura 2000-området bli försumbar till liten utan konsekvenser, varken på kort eller lång sikt, för bevarandestatusen för populationerna eller förhindra att bevarandemålen uppfylls för tumlare, knubbsäl eller gråsäl i Natura 2000-området SE0430187.

Med tillämpning av skyddsåtgärderna beskrivna ovan bedöms påverkan på individer från de seismiska undersökningarna, anläggningen, driften och avvecklingen av Triton vindpark som begränsad och utan risk för påverkan på populationsnivå. Anläggning, drift och avveckling av vindpark Triton ger varken kort- eller långsiktiga konsekvenser för tumlares bevarandestatus och förhindrar inte därmed upprätthållandet av en gynnsam bevarandestatus för Bälthavspopulationen av tumlare, knubbsälar och gråsälar inom eller utanför Natura 2000-området SE0430187 Sydvästskånes utsjövatten. Dessutom ger anläggningen, driften och avvecklingen av vindpark Triton inte upphov till vare sig kort- eller långsiktiga konsekvenser för bevarandestatusen för tumlare från Östersjöpopulationen och förhindrar därmed inte möjligheten att uppnå en gynnsam bevarandestatus för Östersjöpopulationen av tumlare inom eller utanför Natura 2000-området SE0430187 Sydvästskånes utsjövatten. Anläggning, drift och avveckling av vindpark Triton kommer inte att hindra uppfyllandet av bevarandemålen för tumlare, knubbsäl och gråsäl i Natura 2000-området SE0430187.

Tumlare är listade i Bilaga IV till Art- och habitatdirektivet och har därmed ett strikt skydd var än de förekommer. Slutsatsen är att Bilaga IV-skyddet av tumlare bibehålls eftersom projektet inte leder till att tumlare fångas, dödas, avsiktligt störs eller att deras häcknings- eller viloplatser skadas eller förstörs. Därmed bedöms projektet inte påverka områdets ekologiska funktion för tumlare (både Bälthavspopulationen och Östersjöpopulationen).

Tillämpade skyddsåtgärder
För de seismiska undersökningarna kommer följande skyddsåtgärder tillämpas för att minska påverkan på marina däggdjur:

- De seismiska undersökningarna bör stata med 30 minuter mjuk uppstart för att säkerställa att tumlare och sälar inte befinner sig inom riskzonen för TTS eller PTS.
- Passiv akustisk övervakning bör tillämpas, liksom observatörer bör vara ombord på undersökningsfartyget för att säkerställa att inga marina däggdjur befinner sig i närheten av undersökningsfartygen vid starten av de seismiska undersökningarna.
- Om de seismiska undersökningarna avbryts bör uppstarten inkludera ett förfarande med mjuk uppstart

För pålningsarbeten bör följande skyddsåtgärder tillämpas för att minska påverkan på marina däggdjur:

- Innan start av pålningsarbeten bör akustiska bortmotningsmetoder anpassade för tumlare användas i erforderlig omfattning. Samråd med tillsynsmyndigheten ska äga rum (innan den planerade pålningen äger rum) för beslut om metoder, omfattning och varaktighet.
- Pålningsarbeten bör genomföras med tillämpning av mjuk uppstart/ ramp up förfarande.
- Pålningsarbeten bör genomföras med tillämpning av bullerdämpande åtgärder med en effektivitet motsvarande den dämpning som uppnås med en enkel bubbelgardin (BBC) eller mer.

1 Introduction

OX2 AB plans to establish an offshore wind farm in the Southern Baltic Sea in Sweden’s exclusive economic zone off the coast of Skåne. The overall goal with the Triton offshore wind farm is to produce renewable electricity and thus contribute to achieving Sweden’s energy and climate goals and provide the society, especially in southern Sweden with competitive electricity.

This report presents the details of the Environmental Impact Assessment for marine mammals. The impacts of the offshore elements on marine mammals are differentiated according to installation, operation and decommissioning. Furthermore, potential mitigation and monitoring options are provided. The final layout of the wind farm is not yet defined, but the turbines will be distributed within a pre-investigation area that is referred to as "development area" in this report.

1.1 Objectives

Before assessing any impact of the planned wind farm Triton on marine mammals, basic knowledge about marine mammals use of the development area needs to be assessed, and potential disturbances have to be explained. In this report the occurrence, abundance and distribution of harbour porpoises, grey seals, harbour seals and other potentially occurring marine mammal species in the development area are presented in order to document the importance of the area. The description is based on existing knowledge/studies of marine mammals within the area. For further information about species specific behavior due to influences like noise, traffic, and habitat changes existing literature has been reviewed.

The specific objectives of this assessment are to:

- Describe and evaluate the importance of the development area for Triton offshore wind farm for marine mammals.

- Determine the potential impacts of installation, operation and decommissioning of the offshore elements of the development area for Triton offshore wind farm on the identified marine mammal species in the area, and to predict the significance of those impacts.

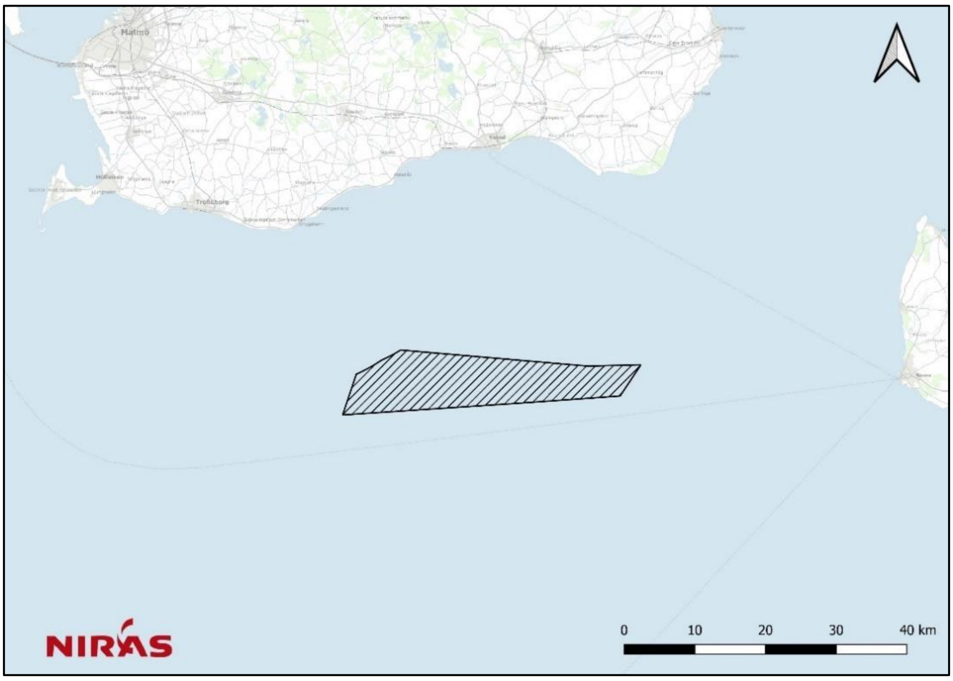
- Present a Habitats Regulations Assessment of the development area, including the Natura 2000 screening process, and an assessment of the conservation obligations for strictly protected species according to the Habitats Directive.

- Identify the potential for cumulative effects with other developments (e.g., other planned or present nearby offshore windfarms).

2 Project description

The Triton offshore wind farm is located within the Swedish exclusive economic zone in the southwestern Baltic Sea (Figure 2.1).

Figure 2.1: Development area for the offshore wind farm Triton.



The development area is located off the south coast of Skåne, about 30 kilometers south of Ystad. The planned wind farm has an area of 250 km^2 excluding the planned export cable corridors for connection to shore. The depth in the area varies between 43 and 47 meters and the sea floor sediments consist only of soft bottom substrates, such as clay and mud clay.

The wind farm is planned for a total rated power of approximately 1800 MW and comprise 68-129 wind turbines[1]. The wind turbines will be mounted on foundations. The following foundation types are considered as viable options for the detailed engineering of the offshore wind farm:

- Monopiles with a bottom diameter of up to 14 meters
- Gravity based foundations, estimated to have a bottom diameter of up to 45 meters.
- 3-4 legged jacket with up to 4.5 meter pin piles

Surrounding the foundation scour protection will be placed to avoid the development of scour holes. Inter array cables will connect the wind turbines to offshore substations. The voltage level in inter array cables will be 66 kV or higher. Cables are generally buried at a depth of 1 to 2 meters. From the offshore substations export cables

[1] The 68-129 turbines are to be seen as two scenarios used in the assessment in the EIA and not two final alternatives

will transmit the power to shore. The voltage of export cables is most likely 220 kV or more.

The operational lifetime of offshore wind farm is expected to 35 -40 years, and thereafter the windfarm will be decommissioned.

As the foundation type is not confirmed yet, a short description of all possible foundation variations is included. Furthermore, other parts of the installation procedures, which might be relevant for the impact assessment e.g., scour protection and cable laying procedures, are described briefly as well.

2.1 Turbines

Turbine size and dimension has not been finally determined. The wind farm area is planned for a total rated power of approximately 1800 MW consisting of 68-129 turbines, depending on the type and size of the chosen turbine.

The technical development in the offshore wind farm industry is moving forward at a high pace. Two possible design scenarios for the Triton offshore wind are shown in Table 2.1

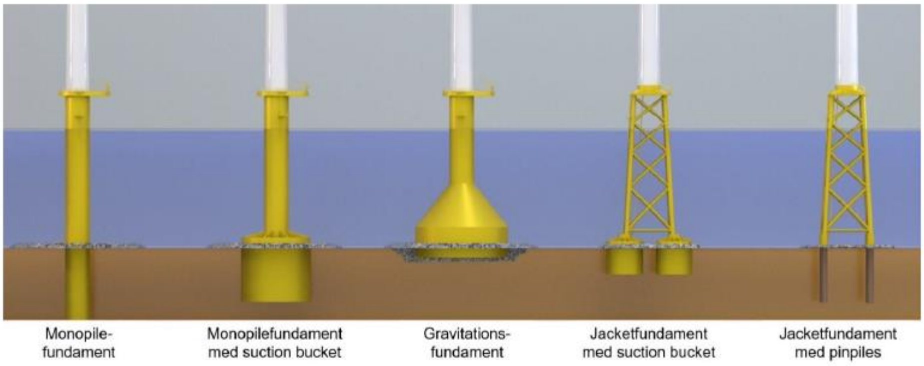
Table 2-1: Examples of the turbine dimensions.

	Example 1	Example 2
Capacity of the individual turbine	25 MW	15 MW
Total hight (m)	340	260
Number of turbines	68	129

2.2 Foundations

The turbines will be fixed in the seabed by one of the foundation types shown in Figure 2.2. Foundation types are dependent on turbine size, water depth and sediment characteristics. Based on the available technology, there are three basic types of foundations that are relevant for the Triton offshore wind farm: monopile foundations, concrete gravity foundations and jacket foundations. The foundations can also be combined as shown in Figure 2.2.

Figure 2.2: Examples of different foundations types fixed in the seabed.



Monopiles have been installed in a large number of wind farms in Europe. A monopile foundation is a steel pile, which is driven into the seabed.

Concrete gravity bases have been used successfully for wind farms since the early 1990s. Gravity base foundations are held in place mainly by their mass. Prior to the installation of concrete gravity bases, seabed preparations are required such as the removal of ground material and replacement by a stone bed.

Wind turbines can be erected on a jacket foundation. Jacket foundations are widely applied as they are often used in the oil and gas industry. They are therefore also applicable in deeper water. The jacket foundation itself has three or four main piers or legs. The legs have to be secured to the sea bottom and can be anchored in the seabed with either suction buckets or pin pile (three-four small monopiles).

The monobucket foundation is a relative new foundation type. It combines the main features of a gravity foundation and a monopile foundation.

2.3 Scour protection

Depending on the type of foundation used, ground conditions, and hydrodynamics, scour holes of different sizes can be formed around the base of a foundation. If the seabed is erodible and the flow is sufficiently strong, a scour hole is formed. Development of scour holes can affect the foundation structure’s stability.

In order to ensure the stability of the offshore wind turbines and to prevent serious damage, scour protection can be necessary.

2.4 Subsea cables

Subsea cables are necessary to connect the wind turbines and to transmit the electricity to land. For this, inner-array cables are necessary as well as export cables. The network of inner-array cables depends heavily on the number of wind turbines, as they can be 68 (large turbines) or 129 (smaller turbines). Based on the available technology, the inter-array cables can for example consist of 66 kV cables, which can transmit a total power of around 80 MW per cable. The voltage level of inter-array cables is expected to increase in the next five years to 220 kV or even higher.

All cables, both inter-array cables as well as export cables will be buried in the seabed to protect the cables from damage from fishery tools or anchors. Cables are buried at a depth of 1 to 2 meters. Different procedures are possible for cable-laying, and all are carried out by specialized vessels. Cables could also be protected by rock dumping. The width of this corridor would be 2-3 metres.

3 Method

To estimate the distribution and abundance of harbour porpoises, grey seals and harbour seals in the development area, existing literature and studies of marine mammals within and near the development area are used. In the mapping of marine mammals within and near the development area for Triton offshore wind farm, identifying which management units of the marine mammal species occurring is also attempted. This is important for assessing the project's possible effects at population level. In addition, the assessments of impact on harbour porpoises and seals are based on existing knowledge from previous wind farm development and supported by the latest available scientific research in the field.

3.1 Baseline description

During the past 20 years, several studies have been carried out on the distribution of harbour porpoises in inner Danish waters. The results of these studies are used in the description of existing conditions and occurrence of harbour porpoises in and near the development area of Triton Offshore Wind Farm. Although none of these studies have been performed specifically for the development area, several of the studies provide information on the presence of harbour porpoises and in some cases estimated densities of harbour porpoises in and near the development area for Triton offshore wind farm. Data from several studies were included in the description of harbour porpoises in and near the development area, such as the SCANS projects, a large-scale European cooperation on the counting of whales in the European part of the Atlantic. These surveys were done either from aircraft or ships, and were carried out in 1994, 2005, 2012 and 2016 (Hammond, et al., 2002; Hammond, et al., 2013; Hammond, et al., 2017; Viquerat, et al., 2013). In addition, the results from the SAMBAH project are included. This was a passive acoustic monitoring study in the Baltic Sea carried out from 2011-2013. CPODs were used to estimate the population size and distribution of the Baltic Proper population of harbour porpoises (SAMBAH, 2016). Here, one of the acoustic measuring stations was located just south of the development area for Triton Offshore Wind Farm, and one station placed inside the development area. Findings from the German part of the Western Baltic Sea (Gallus, et al., 2015) were used to support the data from SCANS and SAMBAH. Finally, data from a combination of aerial and ship surveys, and passive acoustic monitoring carried out in 2018-2019 in the German part of the Southern Baltic Proper just south of the Triton Wind Farm development area was also used to corroborate the findings of SCANS and SAMBAH (IBL Umweltplanung et al., 2020).

Since 1997, DCE, Aarhus University, has installed satellite transmitters on harbour porpoises in Danish waters (Teilmann, et al., 2008; Sveegaard, et al., 2011; Sveegaard, et al., 2015; Sveegaard, et al., 2018). This provides data that shows harbour porpoise distribution patterns on a more local scale, and the results of these studies will also be included in the description of the occurrence of harbour porpoises in and near the development area for Triton Offshore Wind Farm. In 2008, Aarhus University published the report "High density areas for Harbor porpoises in Danish waters" (Teilmann, et al., 2008). The report reviews the distribution of harbour porpoises and core areas in Danish waters, including the western part of the Baltic Sea. The data used in the report was from satellite-tagged harbour porpoises, counts from ships and aircraft, and acoustic recordings in the period 1997-2007. Since then, new data has been collected on the distribution of harbour porpoises from e.g. SCANS, SAMBAH and NOVANA, and in 2018 Aarhus University published an updated report on the distribution of harbour porpoises in Danish waters and core areas for the species (Sveegaard, et al., 2018). Sveegaard et al. (2018) includes both the existing knowledge as well as the latest data, summarizing all data collected over the last 20 years in connection with SCANS, SAMBAH, NOVANA and satellite marking of harbour porpoises. The report forms a robust basis for the description of the existing conditions for harbour porpoises in and near the development area.

As the existing basis for describing the occurrence of harbour porpoises in and near the development area is very detailed, it has been assessed that the existing studies on occurrence of harbour porpoises in and near the development area are sufficient to describe the existing conditions for harbour porpoises.

The description of the occurrence of harbour seals and gray seals in and near the development area for Triton Wind Farm is based, among other things, on results / knowledge collected in connection with the preparation of the EIA report for Kriegers Flak Offshore Wind Farm. Here seals were equipped with GPS transmitters to investigate their use and occurrence in and near the development area for Kriegers Flak, as well as the seals' nearby resting and foraging areas (Dietz, et al., 2015). Kriegers Flak is located in the western part of the Baltic Sea approx. 20 km west of the development area for Triton Wind Farm.

A total of 10 harbour seals were equipped with GPS transmitters at the haul-out at Måkläppen, Falsterbo, Sweden, which is located approximately 50 km northwest of the development area for Triton Wind Farm (the nearest seal colony to the development area). The GPS transmitters were put on five one-year-old, three juvenile, and two adult harbour seals in the fall of 2012. The seals were tracked until the summer of 2013 (for the longest transmitting tag). Data from 11 gray seals equipped with the same type of GPS transmitters were also included in the data base for Kriegers Flak. The GPS transmitters were installed on eight one-year-old, and three juvenile gray seals in the period 2009-2012, and the seals were followed until the spring of 2013. Six of the gray seals were equipped with GPS transmitters at the haul-out at Måkläppen, five at the haul-out at Rødsand and one at Åland Islands, Finland.

The GPS transmitter registers and stores information about the seals' position and diving depth, thus providing a detailed picture of the seals' behavior, as well as where and when they have been at a specific location (Dietz, et al., 2015). The use of this type of GPS data provides the most solid and detailed basis for assessing the seals' use of a specific area. As the haul-out at Måkläppen is located approx. 50 km from the development area for Triton Offshore Wind Farm, and as the haul-out is an important area for both harbour seals and gray seals, the results of these tagging studies are relevant to describe both harbour seal and gray seal use of the area in and near the pre-investigation area for Triton Offshore Wind Farm as well as the nearby resting and foraging areas. The estimated used of the development area by seals will therefore be based mainly on knowledge gathered in connection with the preparation of the EIA report for Kriegers Flak Wind Farm. No new analyzes of GPS data have been performed, but data from aerial and ship surveys in 2018-2019 in the German part of the Southern Baltic Proper just south of the Triton Wind Farm development area was used to corroborate the findings (IBL Umweltplanung et al., 2020)(IBL Umveltplanung, 2020).

As the existing basis for describing the occurrence of harbour seals and grey seal in and near the development area is very detailed, it has been assessed that the existing studies on occurrence of the two seal species in and near the development area are sufficient to describe the existing conditions for harbour seals and grey seals.

3.1.1 Passive acoustic monitoring

Underwater passive acoustic monitoring with fixed hydrophones in automated click-detectors such as C-PODs and F-PODs has become an important standard method for detecting the small-scale distribution and relative abundance of odontocetes in the wild (Gordon & Tyack, 2002; Evans & Hammnd, 2004). Since harbour porpoises emit echolocation clicks almost continuously (Linnenschmidt, et al., 2012; Wisniewska, et al., 2016), passive acoustic data is a very suitable source for evaluating temporal variations in harbour porpoise presence as an indicator for the habitat use. However, the detection range of the different PODs are limited (approx. 300 meters - 400 meters) and the data is not suitable for calculating absolute densities.

In July 2021 ten F-PODs were placed in and near the development area for Triton offshore wind farm, with four FPODs inside the development area and six in the area around the development area (se Figure 4.11).

3.2 Assessment criteria

According to the EIA criteria the aim of an impact assessment is to estimate direct or indirect impacts at population level as well as cumulative effects with other developments (e.g., other planned or present nearby offshore windfarms) in relation to the number of impact criteria. An impact assessment at population level is often difficult since many factors, whether their effect on the animals is positive or negative, are unknown. Accordingly, an overview of significant as well as assumed factors affecting marine mammals is given.

For the impact assessment, the chosen method is based on the criteria of the EIA directive. In the following the underlying assessment criteria are explained:

- Degree of disturbance /sensitivity
- Geographic
- Likelihood of occurrence
- Persistence

A combination of these criteria according to table A.1, A.2 and A.3 in the Appendix section leads to a given magnitude of impact within the categories "major, moderate, minor or negligible/neutral/no effect/positive". A description of these categories with examples of dominating effects is given in Table 3.1.

Table 3.1: Category terminology for impact assessment (the terminology is used where legislation does not give quantifiable environmental goals or criteria).

Magnitude of impact	The following effects are dominant.
Negligible negative/ Neutral/ no impact/positive	Positive or small impacts, that are spatially restricted, uncomplicated, short-term or without long-term effects and without any irreversible effects.
Minor negative impacts	Impacts of some extent and complexity, a certain degree of persistence on top of the short-term effects, and with some likelihood to occur, but most probably without irreversible effects.
Moderate negative impact	Impacts with either a relatively large extent or long-term effects (e.g., lasting for the entire life span of the wind farm), occurring occasionally or with a relatively high probability, and which may cause local irreversible effects, e.g., loss of preservation worthy elements (nature, culture, etc.). Impacts that may necessitate mitigation measures.
Major negative impact	Impacts with a large extent and/or long-term effects, frequently occurring and with a high probability, and with the possibility of causing significant irreversible impacts. Impacts are classified as serious, thus changes in the project or the application of mitigation measures should be considered in order to minimize the impact amplitude.

3.3 Impact criteria

In the following the four different impact criteria used in this background report are described. They are related to the relevant marine mammal species in the development area and the potential impacts cause by the establishment of an offshore wind farm.

3.3.1 Degree of disturbance/Sensitivity

The criteria used for the impact assessment in this report is described in the following. The evaluation follows either measurements according to the studies performed or is based on expert judgments with reference to the knowledge of previous studies on offshore wind farm projects or on relevant adjacent populations. The potential pressures on marine mammals due to the construction, operation and decommissioning of an offshore wind farm can be summarized as three main impacts: injury, behavioural response, and changes to their habitat – habitat change. The same applies to offshore and near shore cable laying. The criteria determining the degree of disturbance/sensitivity regarding these impacts are described in Table 3.2.

Table 3.2: Definition of the parameter 'degree of disturbance' for different impacts.

Impact	Ranking of degree of disturbance	Explanation of ranking
Injury	general remarks	Risk of a permanent or temporary hearing threshold shift (PTS/TTS)
	High	For the risk of PTS, the degree of disturbance is generally ranked as 'high'
	Medium	For the risk of TTS, the degree of disturbance is generally ranked as 'medium', as the impact is reversible, however for species with a conservation status 'critically endangered' TTS is ranked as 'high'.
Behavioural response	general remarks	Dependent on the sensitivity of species, conservation status, behavioural responses to project related pressures may vary widely ranging from small changes in activity level of the animal to total avoidance behaviour. Marine mammals are believed to be more sensitive to behavioural responses in the season where the calves and pubs are born.
	High	High sensitivity of the species to anthropogenic disturbances, total avoidance of the relevant impact area.
	Medium	Moderate sensitivity to anthropogenic disturbances, partial avoidance of the relevant impact area.
	Low	Low sensitivity to anthropogenic disturbances, little or no avoidance of the relevant impact area.
Habitat change	general remarks	Habitat changes may result in direct loss of habitat. The impact level also depends on the flexibility of the species and conservation status.
	High	Species is affected by severe loss of food resources and direct loss of habitat; species shows low flexibility in food choice and depends on the site.
	Medium	Species is fairly flexible in the choice of food; prey is not restricted to particular area.
	Low	Species is flexible, low numbers of individuals are affected.

3.3.2 Geographic

The central aspects for assessing the geographic impact for a species are: the conservation status of the affected species, the importance of the affected area for the species (abundance, function), and the spatial extent of the affected area. The assessment is an expert judgement based on a mixture of the criteria laid out in Table 3.3, i.e., not all criteria attributed to a particular importance ranking need to be fulfilled.

Table 3.3: Definition of the parameter 'geographic'.

Ranking of geographical extent	General remark / Explanation of ranking
General remarks	Range of impacts related to the project area. Conservation status: harbour porpoise (EU Habitats Directive Annex II, IV) ranked as superior to harbour and grey seal (Annex II, V) Abundance and function: Density of species, presence of calves and breeding sites in relation to other areas inhabited by the biogeographical population
International	Impact area widely exceeding the project area; above-average densities of species that are protected by international legislation; important ecological function for the species (breeding, migration etc.)
National or regional	Impact area exceeding the project area; average densities of species that are protected by international legislation; average ecological function for the species
Local	Impact area limited to the project area and immediate surroundings; average or below-average densities of species that are protected by international legislation; average or below-average ecological function for the species
Not important	Impact area limited to the project area or a fraction of it; below-average densities of species protected by international legislation; below-average ecological function for the species

3.3.3 Likelihood of occurrence

This criterion mainly defines the likelihood that an impact will affect marine mammals at population level. For impacts where little is known of the long-term effects it can also define the likelihood of actual occurrence (see Table 3.4).

An impact at population level can be judged in different ways. A rough estimate can be obtained by looking at the percentage of the population affected. A 1 % criterion is often applied to indicate a high level of impact (e.g. ASCOBANS 2000, 2002). Given that the relevant porpoise population consists of about 42,000 animals for the Belt Sea population (Sveegaard et al. 2018), the 1 % criterion is reached if 420 animals are affected. The very low population estimate of the Baltic harbour porpoise population (500 individuals, (Carlén, et al., 2018) would, on the other hand led to a 1% criterion of only 5 animals.

Table 3.4: Definition of the parameter 'likelihood of occurrence'.

Ranking of likelihood of occurrence	General remark / Explanation of ranking
General remark	Considered as relevant biogeographical population estimates are 42,000 harbour porpoises in the Belt Sea and 500 harbour porpoises in the Baltic Proper population
High	The occurrence of the impact is very likely; more than 1 % of the biogeographical reference population is affected
Medium	The occurrence of the impact is likely; more than 0,3 % of the biogeographical reference population is affected
Low	The occurrence of the impact is unlikely; less than 0,3 % of the biogeographical reference population is affected

3.3.4 Persistence

The persistence of the impact gives a temporal scale of how long the pressure is present. There are three categories defined: permanent, temporary and short-term (see Table 3.5).

Table 3.5: Definition of the parameter "persistence.

Ranking of persistence	General remark / Explanation of ranking
General remarks	Impacts related to the operation of the wind farm are mainly permanent. During construction, most pressures are short-term. Impacts lasting the whole construction phase are considered as temporary.
Permanent	impact lasts for more than 5 years
Temporary	impact lasts for a period of 1 to 5 years
Short-term	impact lasts for a period of less than one year

3.4 Worst case assumptions

Since the turbine size and the layout of the Triton wind farm depends on a number of factors such as environmental conditions like ground texture and technical factors, or wake loss and wind climates, the final layout has not yet been determined. Therefore, underwater noise levels considered in this report are based on a worst-case assumption, of the following criteria:

- Installation of a monopile with a diameter of 14 meter (for more details see section 5.3 in the Underwater noise Technical report).
- Underwater noise modelling has been conducted for four positions in the development area for Triton offshore wind farm. The positions are chosen as worst case positions where the largest underwater noise propagation is expected (based on physical environmental parameters). Thus, for other positions in the development area, the impact ranges of underwater noise from pile driving is expected to be smaller or in the worst case, the same.
- The modelling was conducted for March which is a worst-case month regarding sound propagation (highest sound propagation). Thus, for pile driving in other months, the impact ranges of underwater noise from pile driving is expected to be smaller or in the worst case, the same.
- Realistic worst case installation procedure in relation to the needed hammer energy and number of strikes required to complete piling. In the underwater noise modelling the use of soft start procedure and efficient noise abatement system[2] is included in this case a big bubble curtain (BBC).
- Location of foundation in relation to nearby Natura 2000 areas that have been designated for marine mammals.

The impact of the different scenarios on the different marine mammal populations is assessed based on these listed criteria.

3.5 0-alternative

For an impact assessment to be applicable a common base for comparison is necessary. The impact assessment must be compared with the 0-alternative, which is defined as the situation where the wind farm is not established. The 0-alternative entails:

- A wind farm will not be built in the development area.
- Environmental impact as a result of the project will not occur.

[2] With the suggested monopile size and pin pile size, piling without mitigation measures is unrealistic because of the impacted area, thus it is a construction requirement, that a realistic suitable mitigation measure will be applied.

- The wind farm will not contribute to the urgent need for a large-scale expansion of renewable electricity production in Sweden.
- The wind farm will not contribute to reduce the climate change by production of renewable and therefore not contribute to maintain the existing environment for marine mammals.
- Current activities in the development area related to fishing and trawling activities will continue. Unintentional by-catch from fishing plays an especially significant role for harbour porpoises and is considered to be the primary cause of human induced mortality of harbour porpoises (ASCOBANS, 2012). Gillnets are thought to be responsible for most bycatches, but porpoises are also occasionally taken in trawls (ASCOBANS, 2012). The wind farm will not contribute to reduce by-catch of harbour porpoise by fishing.
- Underwater noise level in the area continues as it is at present.

4 Existing conditions

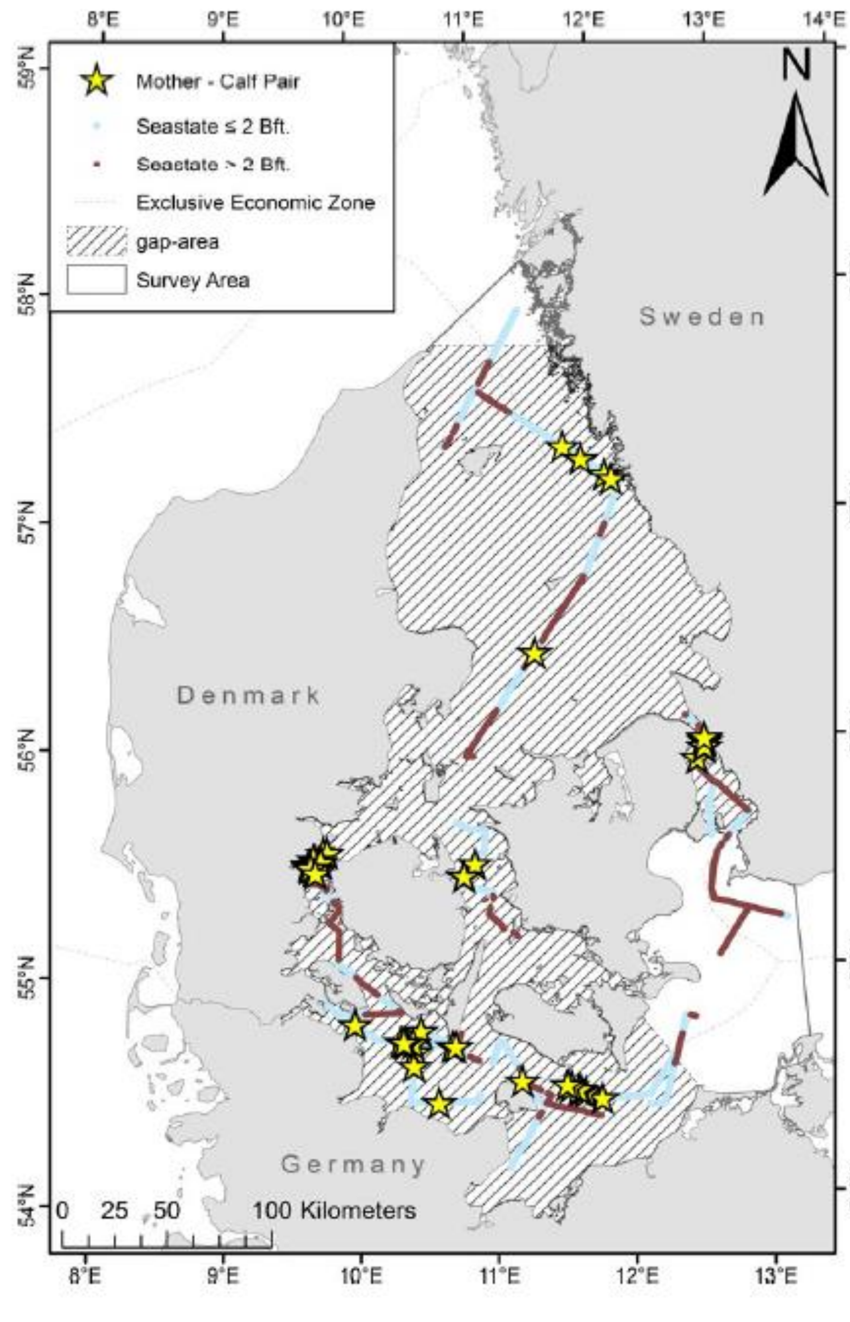
This chapter contains background information on the three resident marine mammal species, harbour seals, grey seals, and harbour porpoises.

4.1 Biology of harbour porpoises

Harbour porpoises (*Phocoena phocoena*) are Europe's smallest toothed whales. At an average weight of 60 kg females can reach a length of about 160 cm. Males are smaller than females with an average length of 145 cm and weighing about 50 kg (Børge & Tolley, 2009). With an average lifetime of 8-10 years and a maximum of 20 years, their lifespan is short compared to other toothed whales. Harbour porpoises reach their sexual maturity at an age of 3-4 years. At the age of 5 (males) and 7 years (females) the animals are fully grown. After a 10.5 month pregnancy females give birth to one calf every or every other year. The breeding season varies regionally, but in most areas calving takes place from late May to August (Børge & Tolley, 2009) and the mating season for porpoises in Kattegat/Øresund in July to mid-August (Carlström & Carlén, 2016).

Porpoises are sensitive to impact, especially during the summer when they give birth to their calves (May-June) and mate (July-mid-August). Lactating females with calves are sensitive to impact as disruption of nursing behaviour can have consequences for the calf's survival. Over the couse of the nursing period calves transition to a more juvenile diet (Smith & Read, 1992), which will likely reduce the sensitivity to disruption somewhat in older calves. Species specific breeding grounds in Swedish waters are unknown. Some breeding "hotspots" in the northern part of Øresund and in the most western part of the Southern Baltic Sea are assumed on the basis of calf sightings (Loos, et al., 2010; Viquerat, et al., 2013) (Figure 4.1). The areas where mother-calf pairs have been regularly sighted is more than 100 km away from the development area for the Triton offshore wind farm and the development area is therefore not considered to be an important area to harbour porpoises during the breeding season.

Figure 4.1: Observation of mother-calf pairs during the mini-SCANs ship survey conducted in in July in 2012 (Viquerat, et al., 2013).



4.1.1 Feeding ecology and foraging behaviour

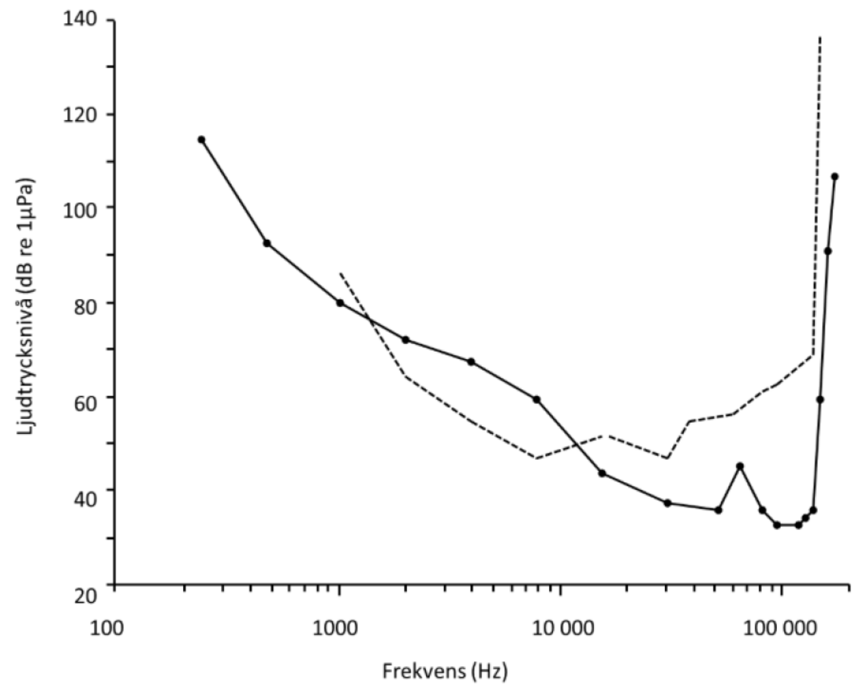
Harbour porpoises are known to feed on a relatively broad spectrum of prey. They mainly feed on small and medium sized pelagic fish as well as on demersal and benthic fish species (Santos & Pierce, 2003) Major prey species such as sandeel, gobies, cod and herring have been shown to be important prey in the North Sea and in the Baltic Sea (Gilles, et al., 2008; Sveegaard, et al., 2011). Prey composition can vary regionally and seasonally and interannual differences have also been demonstrated (Gilles, et al., 2008). The combination of a harbour porpoise' relatively small size and the fact that it lives in temperate waters implies that it has a relatively high energy consumption (Kastelein, et al., 1997; Lockyer, et al., 2003), and studies show that harbour porpoises forage both during the day and night, where they can hunt up to 550 small fish per hour (Wisniewska, et al., 2016). Due to their high energy consumption, it has been suggested that the presence of harbour porpoises is related to the density of their prey, which is supported by a study on harbour porpoise in Øresund (Sveegaard, et al., 2012). Sveegaard et al. (2012) showed that the density of harbour porpoises in Øresund was low in the winter months (November-March). This coincided with a low availability of prey in the area, whereas the density of harbour porpoises was high in the summer months (April-October), where prey availability in the area was high.

4.1.2 Echolocation and hearing

Hearing is an important sensory modality for harbour porpoises, as they, like other toothed whales, actively use sound to navigate and find prey. Harbour porpoises use echolocation, where they emit high-frequency sounds (peak frequency of 130 kHz) and listens for reflected echoes (Møhl & Andersen, 1973; Miller, 2010; Wisniewska, et al., 2016; Villadsgaard, et al., 2007). The use of echolocation to find prey enables harbour porpoises to forage both at day and night (Akamatsu, et al., 2005; Wisniewska, et al., 2016).

Several studies have tested the hearing ability of harbour porpoises, and all studies show that harbour porpoises have a keen hearing and can hear sounds over a wide frequency spectrum (Andersen, 1970; Kastelein, et al., 2002; Kastelein, et al., 2010). Mammals, including harbour porpoises, do not hear equally well at all frequencies. As shown in Figure 4.2, harbour porpoises hear well in the frequency range 10-140 kHz, but are most sensitive in the frequency range from 90-140 kHz, with a hearing threshold of approx. 40-60 dB re 1 µPa (Kastelein, et al., 2002). This coincides with the frequency range at which the main energy in their echolocation signals is found (Møhl & Andersen, 1973; Villadsgaard, et al., 2007). Harbour porpoises also hear sounds at frequencies below 10 kHz, but with decreasing sensitivity toward to the lower frequencies. Above 140 kHz there is a sharp drop in sensitivity toward higher frequencies (Figure 4.2).

Figure 4.2: Audiogram for harbour porpoises modified after Kastelein et al. (2010) (solid line) and Andersen (1970) (dotted line). The frequency range with best sensitive is between 10-140 kHz (Tougaard & Michaelsen, 2018).



4.1.3 Abundance and distribution of harbour porpoises

There are three subpopulations of harbour porpoises in Swedish waters - the North Sea population which is primarily found from the central Kattegat to Skagerrak, the Belt Sea population which is found from the central Kattegat to the south-western Baltic Sea just east of Bornholm, and the Baltic Sea population in the Baltic Proper (Figure 4.3). The three populations are not separated by geographical barriers and there is some degree of overlap in the distribution between the three populations.

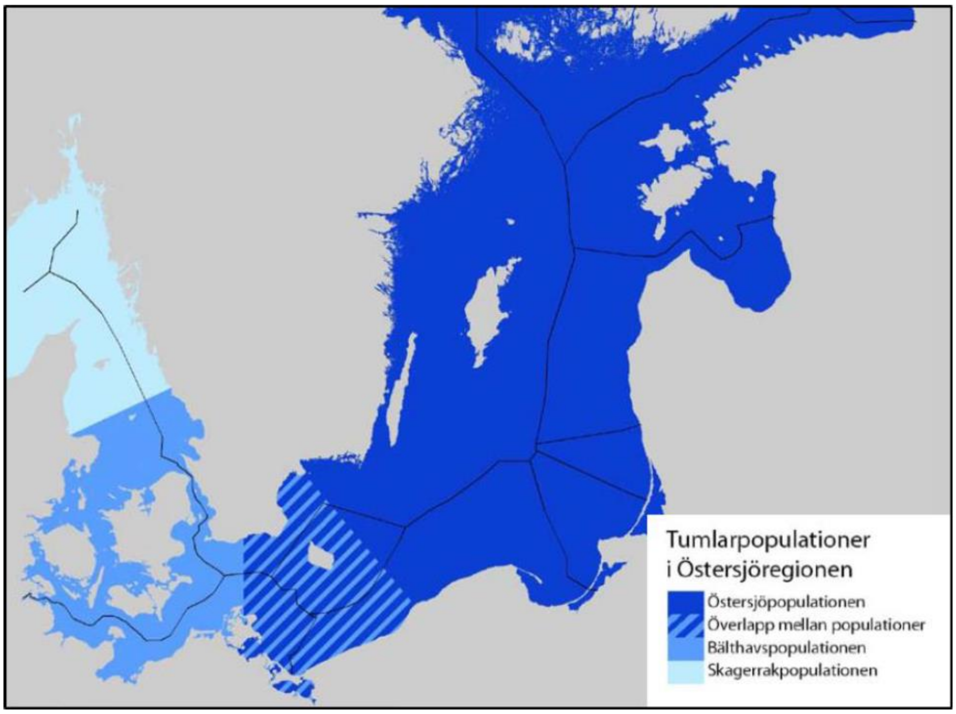


Figure 4.3: Harbour porpoise populations in Swedish waters (Carlström & Carlén, 2016).

The development area for Triton offshore wind farm is located in a transition area that is used by used by porpoises from both the Belt Sea population and the Baltic Propper population (Carlström & Carlén, 2016; Sveegaard, et al., 2018).

4.1.3.1 *Belt Sea population*

Studies of the occurrence and distribution of harbour porpoises in the European part of the Atlantic (including the harbour porpoise populations in the Kattegat, the Belt Sea, the Sound and the western part of the Baltic Sea) have been carried out in connection with the international project SCANS. In 1994, 2005, 2012 and in 2016, both aircraft and ship-counts of harbour porpoises were conducted covering varying degrees of the Belt and western Baltic Seas (Hammond, et al., 2002; Hammond, et al., 2013; Hammond, et al., 2017; Viquerat, et al., 2013). In connection with SCANS, the absolute population size of the Belt Sea population was estimated (Figure 4.4).

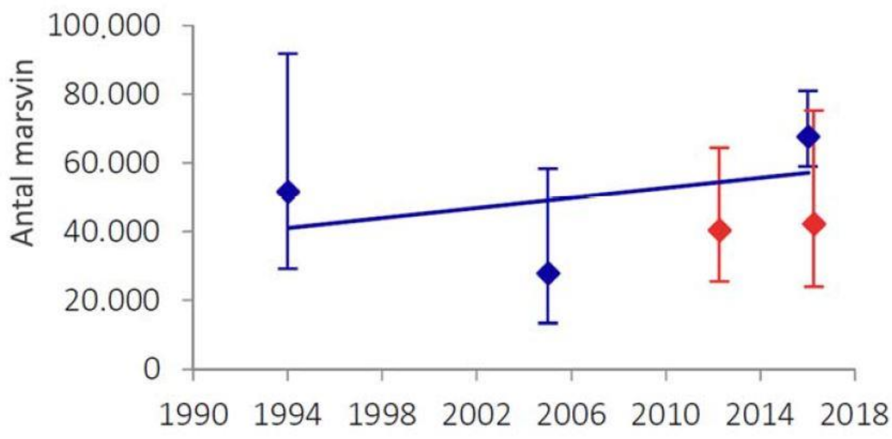


Figure 4.4: Absolute population estimates of harbour porpoises for the area covering the Skagerrak, Kattegat, Belt Sea and Western Baltic Sea based on the four SCANS surveys, SCANS I (1994), SCANS II (2005), miniSCANS (2012) and SCANS III (2016). The red dots (2012 and 2016) show the number of harbour porpoises exclusively for the Belt Sea population, whereas the blue dots include the entire counted area, and the size of the area varies from survey to survey (Sveegaard, et al., 2018).

Between 2012 and 2016 no significant difference in population size was observed, suggesting that the population is not in decline. The Belt Sea population was estimated to be just over 42,000 harbour porpoises (Sveegaard, et al., 2018), and it is assessed by the IUCN as being "not endangered" (IUCN, 2020).

Data from SCANS II in 2005 estimates the summer density of harbour porpoises as approx. 0.1-0.2 individuals / km^2 in and near the development area for Triton Wind Farm (Figure 4.5). The latest SCANS III survey from 2016 estimates 1.04 individuals / km^2. However, this is an overall density estimate for the entire Belt Sea population in the inner Danish waters and will be an overestimate of harbour porpoises in and near the development area for the Triton Wind farm.

Figure 4.5: Estimated harbour porpoise densities based on flight and ship observations from SCANS II carried out in the summer of 2005 (Hammond, 2006).

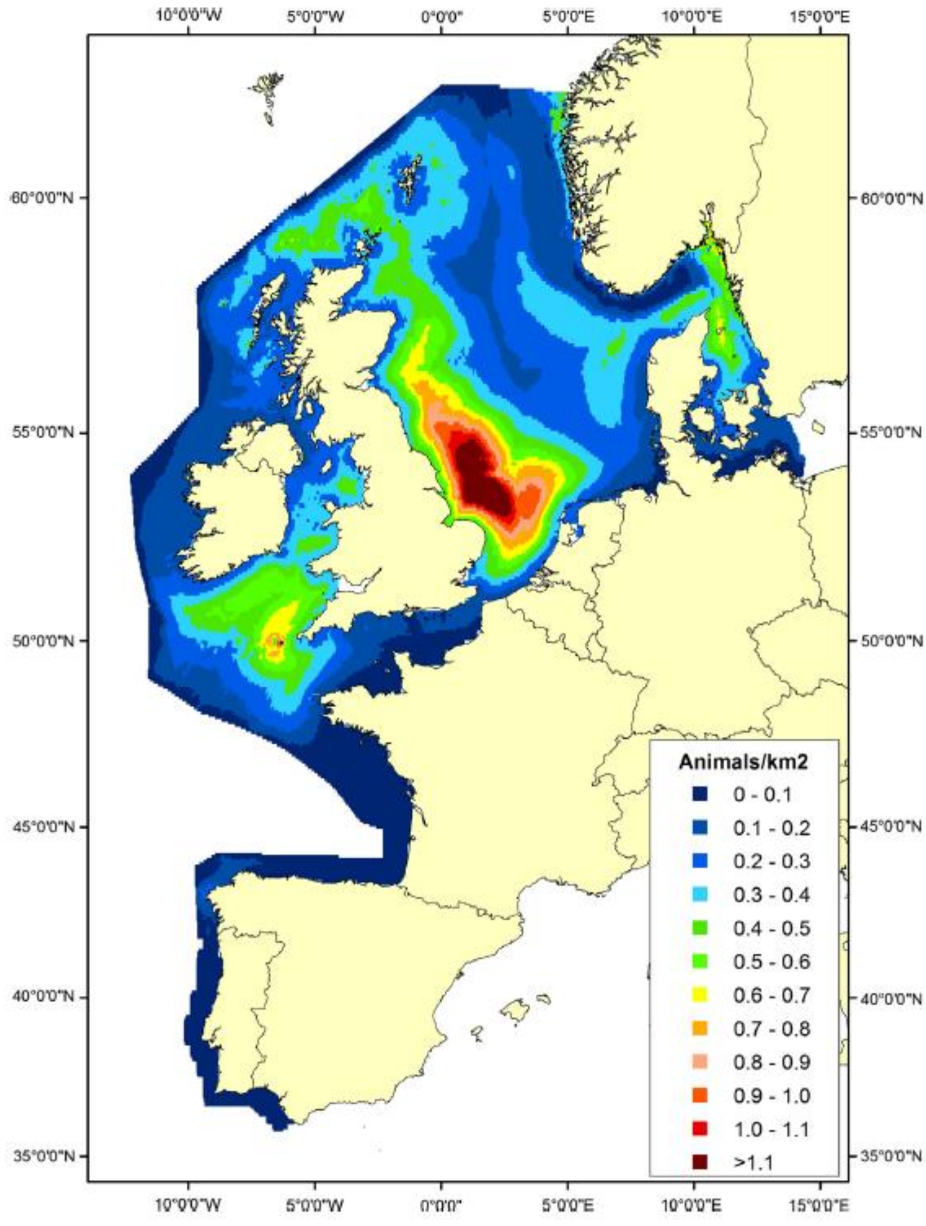
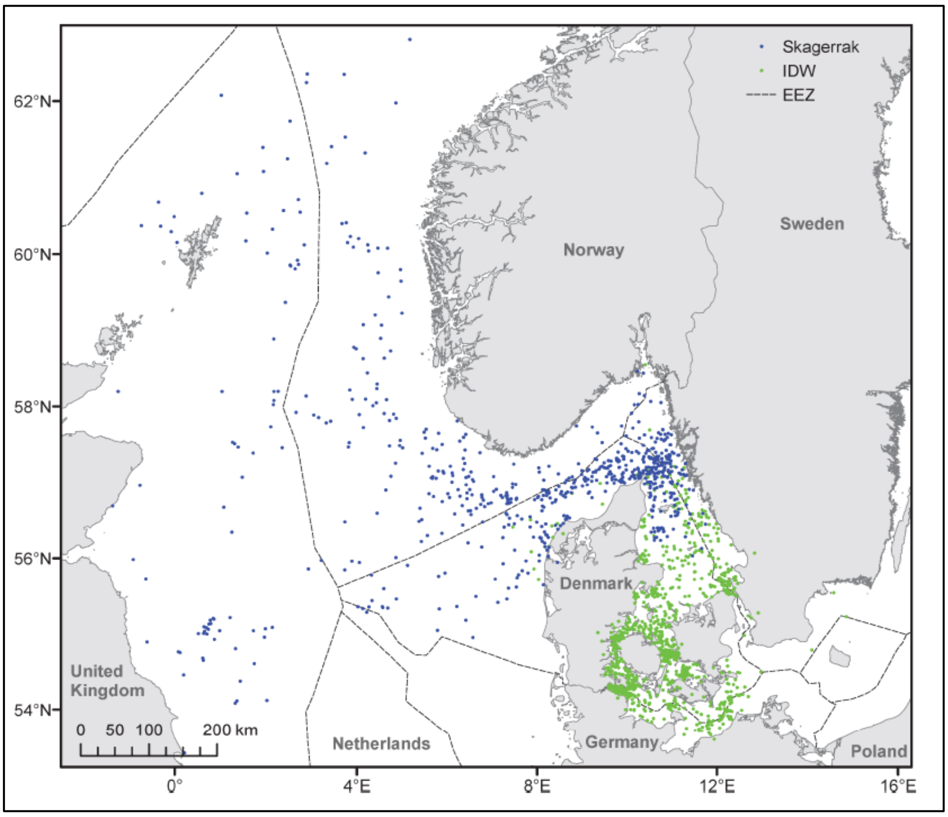


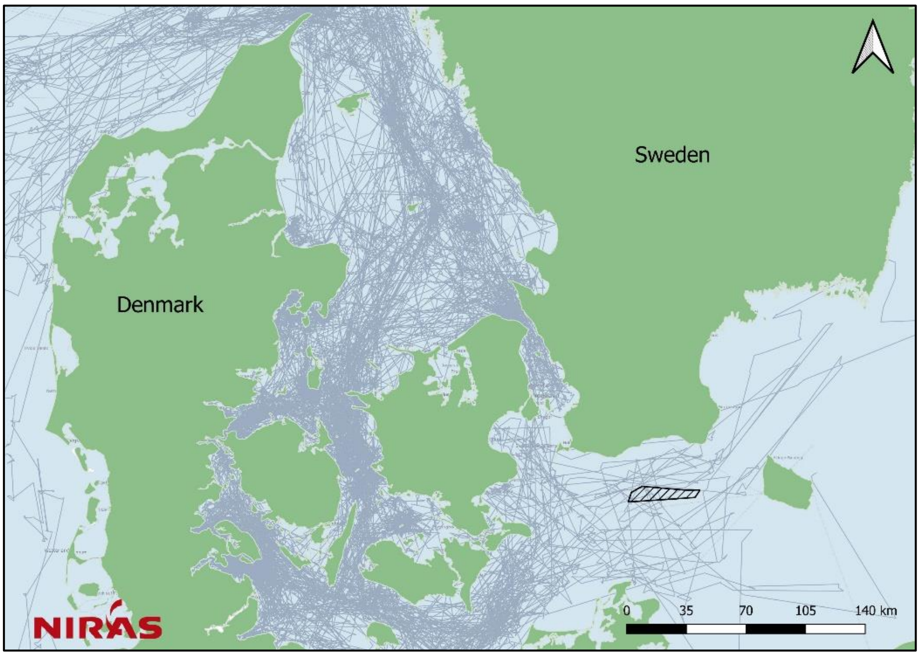
Fig. 8. Predicted density surface for harbour porpoise in 2005

In the period from 1997 to 2016, 125 harbour porpoises were tagged with satellite transmitters in Danish waters in connection with various projects (Teilmann, et al., 2008; Edrén, et al., 2010; Sveegaard, 2011; Sveegaard, et al., 2015; Sveegaard, et al., 2018). These taggings have provided a solid insight into the distribution of harbour porpoises on a local scale over time as well as providing insight into movements of individuals over larger areas. The satellite transmitters are attached to harbour porpoises that have inadvertently been caught in pound nets, and individuals have been traced for up to 500 days (Sveegaard, et al., 2018). All porpoises caught in the period 1997-2015 were caught in Danish waters within the management boundary and the transition area for the Belt Sea population (Kattegat, Belt

Sea and the western part of the Baltic Sea) (Sveegaard, et al., 2015). Figure 4.6 shows the occurrence and distribution of 99 harbour porpoises, equipped with satellite transmitters during the period 1997-2013. As can be seen from the figure, the porpoises use large parts of the inner Danish waters, and few moves into the Baltic Proper (Sveegaard, 2011; Dietz, et al., 2015).

Figure 4.6: The upper figure shows the occurrence and distribution of satellite-tagged harbour porpoises in Danish waters. 26 harbour porpoises were tagged at Skagen (blue dots) and most likely belong to the North Sea population, while the 38 individuals that were tagged in the inner Danish waters (green) and most likely belong to the Belt Sea population. Each point represents a position for every 4 days (Sveegaard, et al., 2011). The lower figure shows the migration routes of the 99 harbour porpoises (grey line). The figure has been modified after (Dietz, et al., 2015), and telemetry data has been collected by DCE, Aarhus University. The development area for Triton Wind Farm is marked as a striated area. ©SDFE





Using data from 125 harbour porpoises tagged with satellite transmitters in the period 1997-2016, Sveegaard et al. (2018) modeled the distribution of harbour porpoises in the Belt Sea management area. The data is separated into two 10-year periods (1997-2006 and 2007-2016), then further divided into summer and winter periods (Figure 4.7). The distribution of the satellite-tagged harbour porpoises is shown as relative densities (Kernel Density Estimation).

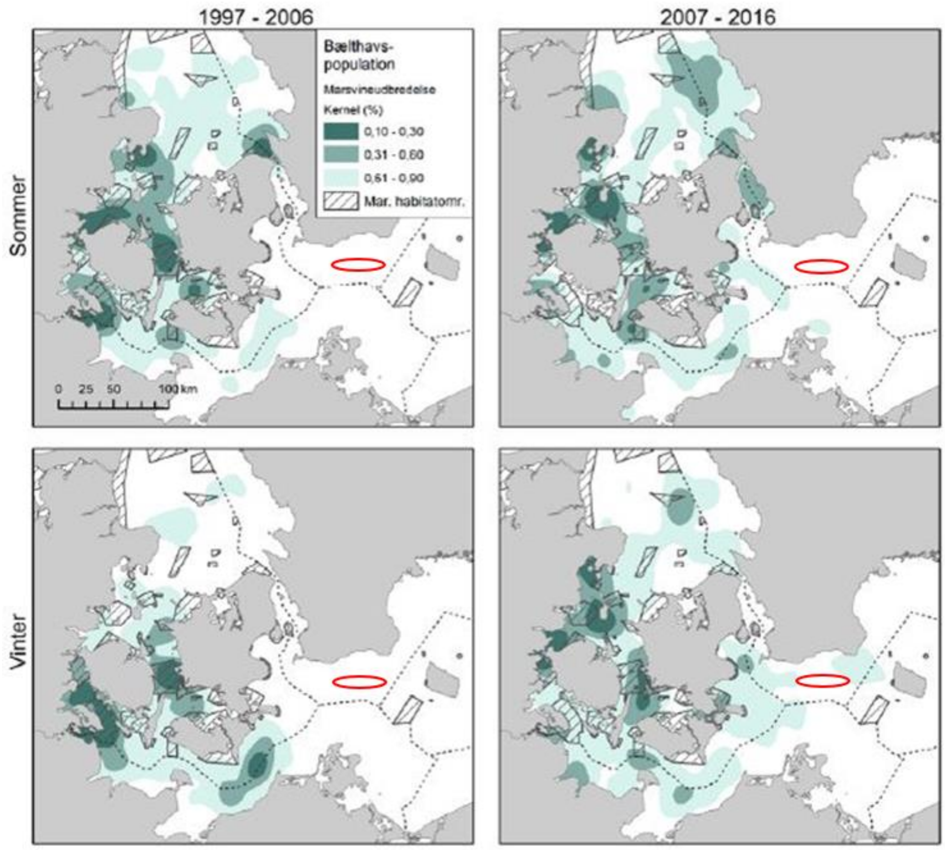


Figure 4.7: Distribution of satellite-tagged harbour porpoises in the Belt Management area modeled as Kernel densities. Kernel density modeling indicates the smallest possible area with the most possible positions. The kernel categories are divided into three densities: 1) High density (contains 30% of all positions from harbour porpoises in the smallest possible area), 2) Medium density (31-60%), and 3) Low density (61-90%) (Sveegaard, et al., 2018). The red circle indicated the position of Triton offshore wind farm.

The result of the modeling shows that harbour porpoises use some areas more than others, and that there is clear seasonal variation in the occurrence of harbour porpoises in some areas. Seasonal variations in the occurrence of harbour porpoises may be related to the use of some areas in connection with the breeding season (Teilmann, et al., 2008), or it may be associated with the availability of prey (Sveegaard, et al., 2012; Sveegaard, 2011). The findings have been further corroborated for the south-western Baltic Sea in a study that compared data from tagged individuals with the passive acoustic monitoring data from 36 SAMBAH stations in the same area (Mikkelsen, et al., 2016). Mikkelsen et al. (2016) correlated the distribution with environmental factors and found that habitat suitability also likely decreased towards the eastern part of the area. Overall, the modeling of the distribution of harbour porpoises in the Belt Sea for the two 10-year periods shows that the porpoises are concentrated in the waters around Funen (the Little Belt, the Great Belt, the South Funen Archipelago and the Småland waters). In addition, the modeling shows that large parts of the Øresund north of the bridge are relatively important for harbour porpoises in the summer (Figure 4.7), which is probably due to the availability of prey (Sveegaard, et al., 2012).

The development area for Triton Offshore Wind Farm is not a core area for harbour porpoises belonging to the Belt Sea population, and likely has a relatively low habitat suitability for harbour porpoises (Mikkelsen, et al., 2016). Harbour porpoise detections are also generally low in the area compared to other areas of the Belt Sea, housing the same population of harbour porpoises (Mikkelsen, et al., 2016; Sveegaard, et al., 2015).

4.1.3.2 *Baltic Proper porpoise population*

Prior to the early 20th century, harbour porpoises were widespread throughout the Baltic Sea, but during the last approx. 50 years the number of individuals has been drastically declining. Until recently only limited data was available regarding the distribution and status of the Baltic Sea population of harbour porpoises (Skora, et al., 1988; Koschinski, 2002; Andersen, et al., 2001). However, in 2011-2013 the international SAMBAH project was carried out to investigate the population size and prevalence of the Baltic Sea population (SAMBAH, 2016). The project was a collaboration between all countries bordering the Baltic Sea except for Russia. During the study period 2011-2013, passive acoustic monitoring was undertaken in large parts of the Baltic Sea with over 300 CPODs deployed (SAMBAH, 2016, Carlén et al. 2018). CPODs can detect harbour porpoise echolocation sounds within a radius of up to 300 meters (Dietz, et al., 2015; SAMBAH, 2016). Based on the recorded acoustic data, the size and distribution of the Baltic Sea harbour porpoise population was estimated to be approx. 500 individuals (95% confidence interval 80-1100 harbour porpoises), which is in stark contrast to the Belt Sea harbour porpoise population, estimated to be over 42,000 individuals. The population of harbour porpoises in the Baltic Sea is the smallest harbour porpoise population in the world (ASCOBANS, 2002) and has been declared "critically endangered" by the IUCN and the Swedish ArtdataBanken Redlist 2020 (https://artfakta.se/naturvard/taxon/phocoena-phocoena-baltic-population--232475).

In addition to providing a population estimate of the Baltic Sea harbour porpoise population, the SAMBAH project also provided important information about the distribution of harbour porpoises in the Baltic Sea, including the investigation area for the Triton Wind Farm. One of the 304 stations that were deployed during the SAMBAH project were located inside the development area for the Triton Wind Farm and another were located just south of the development area (see Figure 4.8).

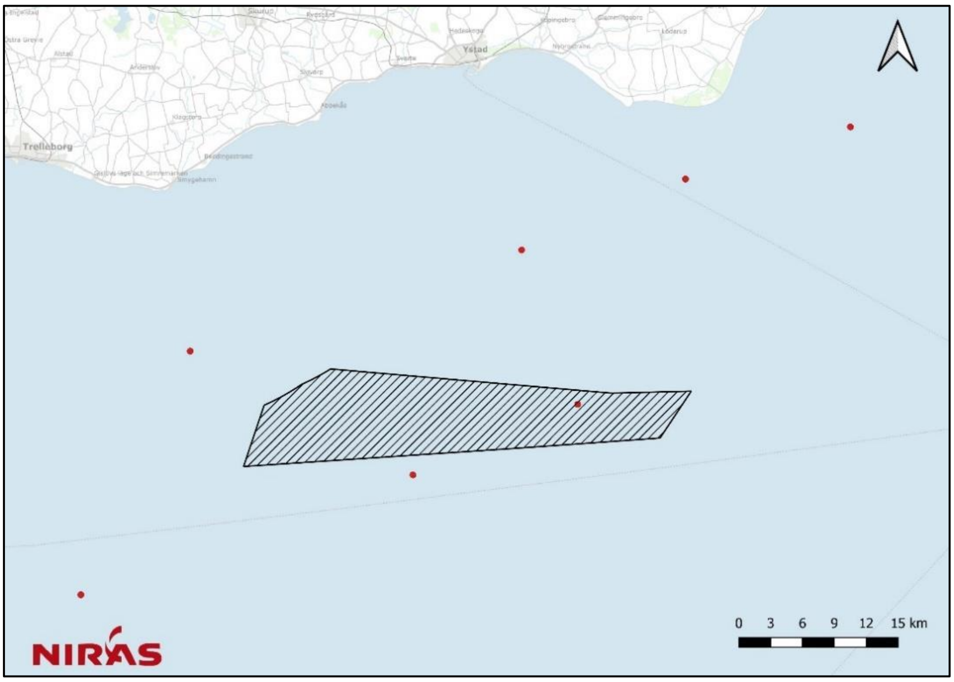


Figure 4.8: Location of SAMBAH CPOD stations (red dots) in the vicinity of the Triton Wind Farm (black shaded). The figure is modified after Dietz et al. (2015). The red dots indicate the location of the SAMBAH CPOD stations ©SDFE

Based on CPOD detections "porpoise positive minutes per day" have been calculated, and from this the probability of the presence of porpoises is estimated. As shown in Figure 4.9, the probability of harbour porpoises presence in and near the entire development area is relatively high during summer, and somewhat lower during winter, but the figure also shows that porpoise detections per day are very low at the two CPOD stations located inside the Triton Wind Farm development area during both summer and winter (Figure 4.9).

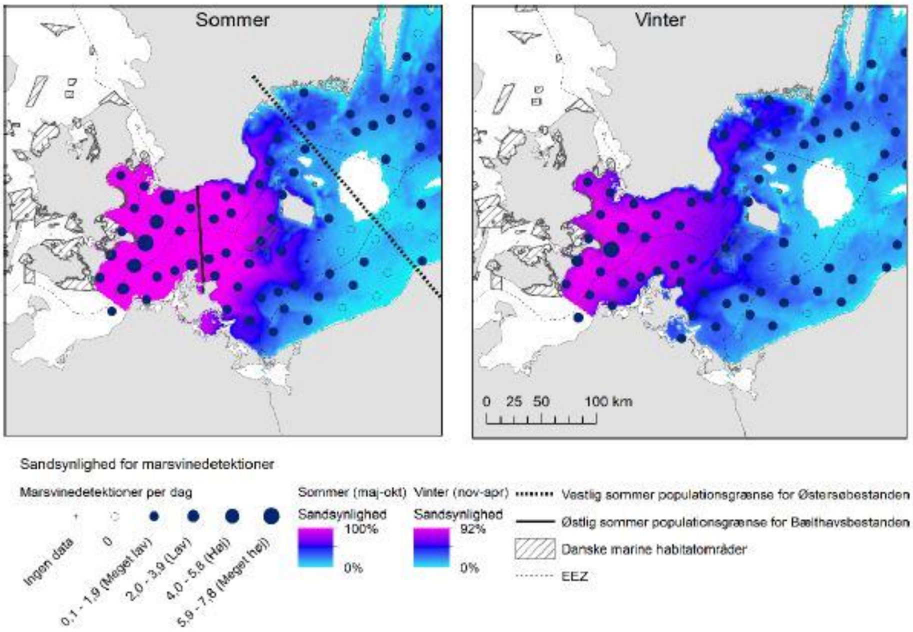


Figure 4.9: Harbour porpoise detection probability divided into summer period (May-October) and winter period (November-April). Light blue indicates a low probability, and purple indicates a high probability of harbour porpoise detection. The black circles show the positions of CPODs deployed in connection with SAMBAH, and the size of the circle indicates the number of harbour porpoise detections. The dotted line indicates a likely western population boundary during summer for the Baltic Sea harbour porpoises. The black solid line indicates the eastern management boundary for the Belt Sea harbour porpoise population during summer. The area between the boundaries is not considered important for either of the two populations (Sveegaard, et al., 2018).

Figure 4.10 shows separate average porpoise positive minutes per month east and west of the Eastern Summer Population Boundary for the Belt Sea Population. As can be seen from the monthly detections of harbour porpoises in the area near Zealand (west of the summer population limit for the Belt Sea population), there is a strong seasonal variation of porpoises in the area, with few porpoises from December to May and far more porpoises in the summer (shown with a dark turquoise line in the figure), where the area is used exclusively by individuals from the Belt Sea population.

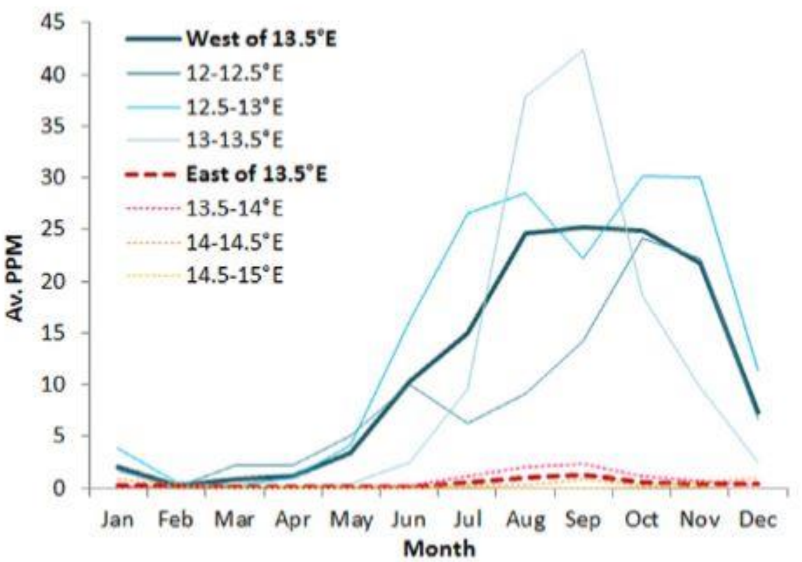


Figure 4.10: Seasonal variation in harbour porpoise detection in the western and eastern part of the Baltic Sea. By far the largest occurrence of harbour porpoises in the western part of the Baltic Sea is during summer, when only harbour porpoises from the stable Belt Sea population use the area. During winter, there is a very low detection rate overall. There may be single individuals from the critically endangered Baltic Sea population, but it will most likely be harbour porpoises from the Belt Sea population in the Triton Wind Farm development area (Sveegaard, et al., 2015).

From July 12th to September 8th, 2021, ten F-PODs were deployed inside the Triton Wind Farm investigation area as part of this project (Figure 4.11). F-POD data was converted to C-POD equivalent numbers, to allow for comparison with previous investigations. Table 4-1 summarizes the mean detection positive minutes per day (dpm/d), as well as for the entire deployment period for the ten F-POD stations. The data supports the observations by SAMBAH, that there are harbour porpoises present during the summer and early fall months in the area, though at relatively low detection rates. The findings are further corroborated by CPOD data from the German part of the Western Baltic Sea (Kadet Trench, waters around Rügen, and the Pomeranian Bay; Gallus, et al., 2015; IBL Umweltplanung et al., 2020). These data suggests that harbour porpoises from the Belt Sea population migrate through the Kadet Trench in spring/summer and return to Danish waters during late fall (Gallus, et al., 2015).

Table 4-1 The mean detection positive minutes per day (dpm/m) at each F-POD recording station in the Triton Wind Farm investigation area, converted to C-POD equivalent numbers. A mean dpm/d for the entire recording period July 12th to September 8th is also reported.

Mean DPM/D (C-POD equivalent)										
	Triton F-POD station ID									
	6293	**6077**	**6076**	**6294**	**6073**	**6075**	**6078**	**6079**	**6295**	**6450**
2021										
Jul.	10	25	5	14	13	3	7	4	4	4
Aug.	18	39	26	41	58	18	17	17	29	20
Sep.	12	35	25	22	39	11	21	22	25	11
Mean Entire period	14	34	19	29	40	12	14	13	21	13

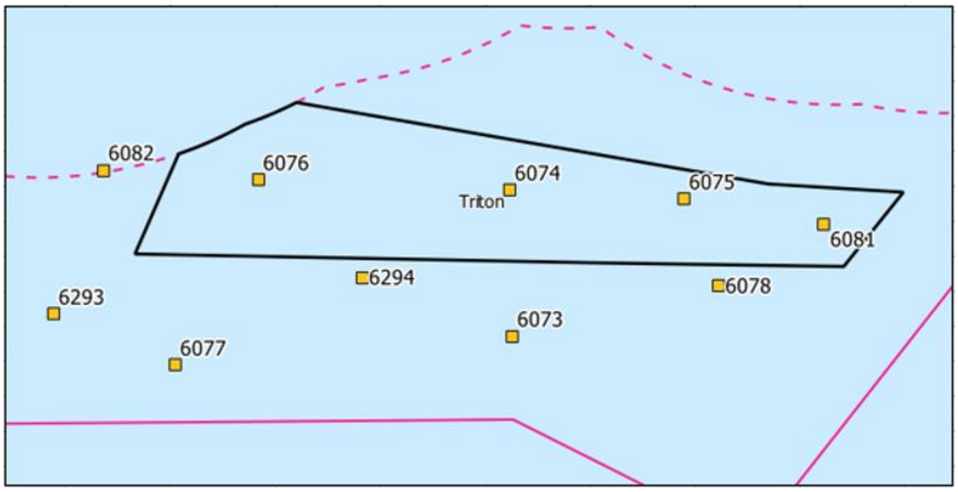


Figure 4.11: F-POD deployment positions inside the Triton Wind Farm investigation area.

Based on SAMBAH data, the density of harbour porpoises in large parts of the Baltic Sea (except for the deep parts of the Baltic Sea, where it has not been possible to deploy CPODs) was estimated. Results are shown in Figure 4.11.

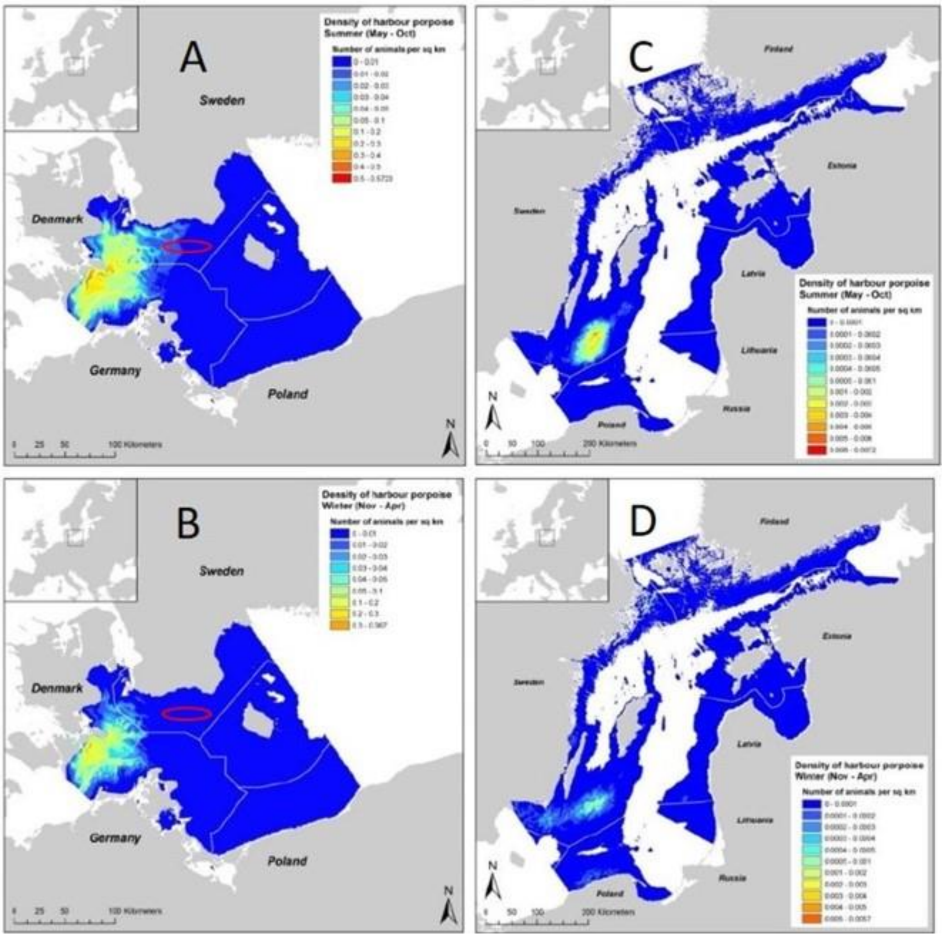


Figure 4.12: Estimated density of harbour porpoises (expressed as number of individuals per km^2) for the south-western (A - summer, B - winter) and north-eastern (C - summer, B-winter) part of the Baltic Sea, respectively. The development area for Triton Wind Farm is located in the Proper. Since the number of harbour porpoises in the south-western part of the Baltic Sea is significantly greater than the number of harbour porpoises in the north-eastern part, the contour colors for sub-figures A and B have a different scale than sub-figures C and D. Modified from (SAMBAH, 2016).

The figure shows a very clear division of the Belt Sea and Baltic Sea harbour porpoise populations during summer (Figure 4.11, A and B). This division coincides with calving and mating periods for harbour porpoises and further supports that crossbreeding between the Baltic Sea and Belt Sea populations does not occur. The Baltic Sea porpoise population seem to congregate around the shallow Midsjö banks south of Öland and Gotland in Swedish waters, with relatively low likelihood of porpoise detections outside this core area. During the winter months, the distribution of the Baltic Sea population is much more diffuse (Figure 4.11, D). It is unknown how far west the Baltic harbour porpoises move, as harbour porpoises from the Baltic Sea population have never been tagged with satellite transmitters (unlike porpoises from the Belt Sea population) (Sveegaard, et al., 2018). It therefore cannot be completely ruled out that a few individuals of the Baltic Proper population may occasionally be found in or near the development area for Triton Offshore Wind Farm during winter. In the summer and early fall months, however, the SAMBAH data indicates that the development area is used exclusively by individuals from the much larger Belt Sea population (Sveegaard, et al., 2018)(Figure 4.10). Therefore, although the Baltic Proper population may occur in the development area during the winter months, it will still primarily be individuals from the Belt Sea population who use the area in and around Triton Offshore Wind Farm. Furthermore, the occurrence of harbour porpoises in the development area is relatively limited during the winter months. The estimated densities in and around the development area of the Triton Offshore Wind

Farm are generally low based on the SAMBAH data. The highest density of harbour porpoises is observed in the summer, and based on SAMBAH data (from 2011-2013), the density of harbour porpoises in and near the development area is 0.02-0.1 individuals / km^2 in this period, while it is between 0.01–0.05 individuals / km^2 in during winter. As mentioned above this density estimate will primarily relate to the Belt Sea porpoises in and near the development area for Triton offshore wind farm.

A similar trend has been observed in the German part of the Southern Baltic Proper close to the German/ Swedish EEZ border just south of the Triton Offshore Wind Farm development area (IBL Umweltplanung et al., 2020). Through a concerted effort of aerial surveys, ship surveys and passive acoustic monitoring using CPODs it was found that the area generally has a low harbour porpoise occurrence. Relatively low densities were observed during summer (0.007-0.009 individuals / km^2), lower densities during spring (0.002 individuals / km^2) and fall months (0.003 individuals / km^2), and no harbour porpoises were detected during winter (IBL Umweltplanung et al., 2020). The ship and aerial surveys also observed very few individuals during the two-year study period (March 2016 to February 2018). During the entire period, a total of 13 harbour porpoises were observed, which including a single calf which was observed during an aerial survey in July 2016.

A recent study published in 2021 has compared passive acoustic monitoring data from 12 stations that were utilized both in the SAMBAH project (2011–2013) and as a part of the Swedish National Monitoring Program (2017–2020) to determine trends in porpoise detection rates. The stations were located in the core breeding area for the Baltic Proper population. The data showed that there was a 29% increase in mean daily harbour porpoise detection rate during May–October (over the breeding season) between the two study periods. This may be indicative of the beginnings of population recovery, or simply an indication that the decline has stalled (Owen, et al., 2021). It is unknown what may have driven an increase in detection rates over time. Of the threats classified as "high" for the Baltic Proper harbor porpoises, a reduction in bycatch risk is most likely to be the most significant factor as it would directly influence mortality rate of the population (Owen, et al., 2021; ICES, 2020) (see section 6.2). Between 2009 and 2018, gillnet fishing has been reduced by 45% over the entire Baltic Sea (ICES, 2020), which may have simultaneously lowered the risk of bycatch (Owen, et al., 2021).

4.1.3.3 *Importance of the development area for Triton for harbour porpoises*

Based on SAMBAH data (from 2011-2013), which directly covers the development area for Triton Offshore Wind Farm, the density of harbour porpoises in and near the development area is estimated to be 0.02-0.1 individuals / km^2 in the summer, while it is estimated to be between 0.01 - 0.05 individuals / km^2 in the winter. Based on SCANS II carried out in 2005, the density of harbour porpoises close to the Triton Wind Farm in the summer is estimated to be 0.1-0.2 individuals / km^2, which corresponds well with the estimated density based on SAMBAH data. The later estimates of harbour porpoise densities SCANS III (2016) come with overall porpoise densities for the entire Belt Sea population of 1.04 individuals / km^2 respectively in the entire range of the Belt Sea population, which is significantly higher than the densities of both SAMBAH and SCANS II. As harbour porpoises are very unevenly distributed in coastal waters, the overall densities for the entire Belt Sea population in inner Danish waters will significantly overestimate harbour porpoise densities in the development area for Triton Offshore Wind Farm. Finally, the very low estimates in the German part of the Arcona Basin were obtained during a period where wind farm construction activities were underway close to the investigation area. These densities may therefore underestimate the densities, as harbour porpoises may have been somewhat displaced from the area. Therefore, a density interval based on SAMBAH and SCANS II has been used in the assessment for the Belt Sea population of porpoises, which for the summer is 0.02-0.2 individuals / km^2, while the winter density interval is 0.01-0.1 individuals / km^2, which is approx. half of what it is in summer.

It is at present not possible to differentiate between porpoises from the Baltic Proper population and the Belt Sea population based on neither acoustics nor visual cues. It is therefore not possible to distinguish between the two populations in the collected SAMBAH data set. However as the Belt Sea population (42.000) is far more numerous than the Baltic Proper population (500), the relationship between the two populations ((500/42.000)*100=1.19 %) is used to estimate the how large a proportion of the potentially impacted harbour porpoises belongs to the Baltic Proper population. The various studies carried out to determine the occurrence of harbour porpoises in the Baltic Proper (partly via satellite tagging of harbour porpoises, aircraft and ship surveys (SCANS studies) and via passive acoustic monitoring (SAMBAH)) show that though harbour porpoises are occurring in the development area for the Triton Offshore Wind Farm, it is not a primary habitat for either the Belt Sea population or the Baltic Sea population (Carlström & Carlén, 2016) and have a relatively low habitat suitability for harbour porpoises in generel (Mikkelsen, et al., 2016).

Though one calf has been observed in the Arcona Basin in summer it was observed far from the development area and does not suggest that this is a general calving ground for the Belt Sea population. The Baltic Proper harbour porpoise population is not found in the development area during summer. The area is therefore not a calving ground for this population. The very low level of observations during winter, also suggests that it is not an important wintering area for neither the Belt Sea nor the Baltic Proper harbour porpoise populations.

That the development area is not important for harbour porpoises is further supported by the lack of harbour porpoise eDNA in the 20 test samples conducted in August 2021.

Based on the latest studies of the occurrence of harbour porpoises, it is estimated that the development area (and the immediate area) for Triton Offshore Wind Farm has a low significance for harbour porpoises (both porpoises from the Belt Sea population and porpoises form the Baltic Proper population).

4.2 Biology of harbour seal

Harbour seals (*Phoca vitulina*) are found from the east Atlantic to the north Pacific and are the most widely distributed seal species in the world (Reeves, et al., 2002). Harbour seals occur in a wide variety of marine habitat types along the coasts of the northern hemisphere (Burns, 2009). They are especially found in areas with undisturbed resting/breeding sites on sandbanks, reefs, islets, and islands (DCE, 2019).

Males can grow to a body length of 150-170 cm and weigh up to 100 kg, and females can reach a body length of 130-155 cm and weigh up to 80 kg (Reijnders, 1992). With a maximum life expectancy of 35 years, females become sexually mature at an age of 6-7 years. Sexual maturity of males occurs a little later at an age between 7-9 years. Depending on population and region, moulting takes place within 2-3 months from midsummer to early autumn (Burns, 2009). The main breeding season in Kattegat and the Belt Sea is from the end of May to the end of June (Olsen, et al., 2010). After a gestation period of 10-11 months, including 2.5 months of embryonic diapause, females give birth to a single pup (rarely twins) (Burns, 2009). Unlike grey seal pups, harbour seal pubs lose their embryonic fur (lanugo) during parturition, which enables them to follow their mother into the water shortly after birth, though pups are nursed on land for four weeks. Mating takes place after the nursing period, primarily in July-August and though actual mating sites are unknown, mating is thought to occur in the water relatively close to haul-outs (Søgaard, et al., 2015). In August adult seals moult which requires longer periods on land, as the skin must be dry for this process (Burns, 2009; Søgaard, et al., 2015). Moulting and weaning take place on haul-out areas on sandbanks and inshore coastal areas. During these periods, harbour seals spend more time resting on land than during the rest of the year. Harbour seals are therefore more sensitive to disturbances in the period from June to September.

4.2.1 Feeding ecology and foraging behaviour

Harbour seals are opportunistic in prey selection and various studies have shown that prey varies with season and location (Härkönen, 1987; Olsen & Bjørge, 1995; Andersen, et al., 2007). Harbour seals exhibit a high degree of site fidelity and will often remain relatively close to haul-out sites (Dietz, et al., 2013; Olsen, et al., 2014). They usually feed rather close to their haul-outs as well (Dietz, et al., 2013). Many harbour seal subpopulations reside in areas with relatively shallow water and are not deep divers. However, studies from Svalbard, North America and Greenland have reported dive depths on excess of 450 m (450 – 631) during foraging trips (Rosing-Asvid, et al., 2020; Kolb & Norris, 1982; Frost, et al., 2001).

Seals equipped with satellite transmitters at haul-out sites at Rødsand, in the Southern part of the Baltic Sea, remained within a radius of 50 km from the resting site (McConnell, et al., 2012). Despite this, individual harbour seals can travel over long distance, and in a study from 2013, satellite-tagged harbor seals from Anholt in Kattegat moved over distances of up to 249 km from the haul-out sites, where they were equipped with satellite transmitters (Dietz, et al., 2013).

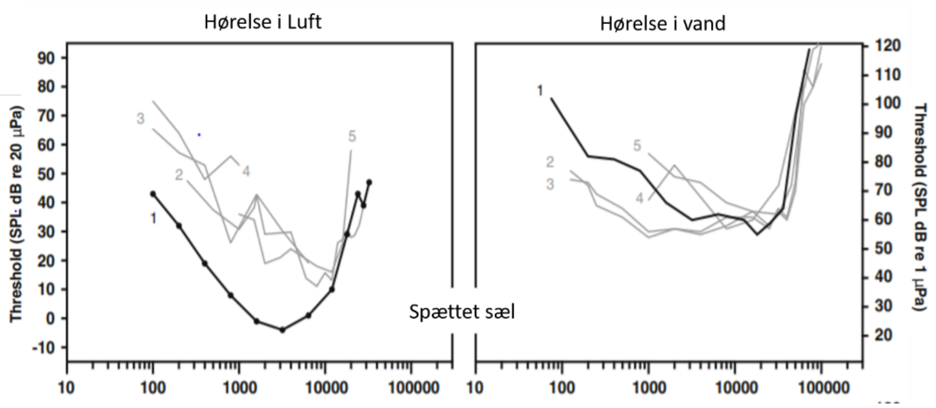
As mentioned, harbour seals are opportunistic in prey selection, but often their food choices are dominated by a few species of fish, and there can be great variation in which fish, depending on which area the seal lives. A study analyzed the seals' prey (based on for example stomach contents) in an area that covers the Southwestern Baltic Sea region, including a region relevant to the harbour seals that are expected to use the development area for Triton offshore wind farm (Scharff-Olsen et al., 2019). 20 prey species were identified in 42 sample. Small sandeel (*Ammodytes tobianus*), black goby (*Gobius niger*), and Atlantic cod (*Gadus morhua*) were found in the highest quantities, comprising 43%, 15%, and 12%, respectively, of the estimated number of prey items (Scharff-Olsen et al., 2019).

4.2.2 Senses

Seals have a good vision both above and in water. The seal's large eyes show that vision is important for orienting and locating prey (Hanke, et al., 2006; Hanke & Dehnhardt, 2009). However, seals can find and catch prey in the dark or in turbid water (which can often occur in coastal areas) based on their tactile sense. Seals have specialized sensory cells in their vibrissae, and can detect very small movements in the water (hydrodynamic traces e.g. the movements of their prey) with great precision, even several minutes after the prey has passed (Dehnhardt, 1998; Hanke, et al., 2010; Dehnhardt, et al., 2001). As seals are adapted to life both in water and on land, their hearing ability, like their vision, has adapted to function in both air and water (Møhl, 1968; Reichmuth, et al., 2013). Seals produce a wide variety of communication calls both in air and in water, e.g., in connection with mating behavior and defense of territory (Bjørgesæter, 2004). It is believed that the hearing of seals in air functions in the same way as in terrestrial mammals. How the seal ear functions in water are not completely clear, but the seals' outer ear canal closes when they dive (Møhl, 1967), and it is believed that they hear through ”bone conduction” in water (Hemilä, et al., 2006; Kastelein, et al., 2008).

A number of studies have been performed on hearing ability in harbor seals in water (primarily behavioral studies) (Kastak & Schusterman, 1998; Møhl, 1968; Terhune, 1988; Reichmuth, et al., 2013; Kastelein, et al., 2008) and in water (Reichmuth, et al., 2013; Kastak & Schusterman, 1998; Møhl, 1968). Figure 4.12 summarizes the results for the different studies, both in air (left) and in water (right).

Figure 4.12: Audiogram of harbour seals in air (left) and in water (right). Modified after (Reichmuth, et al., 2013).



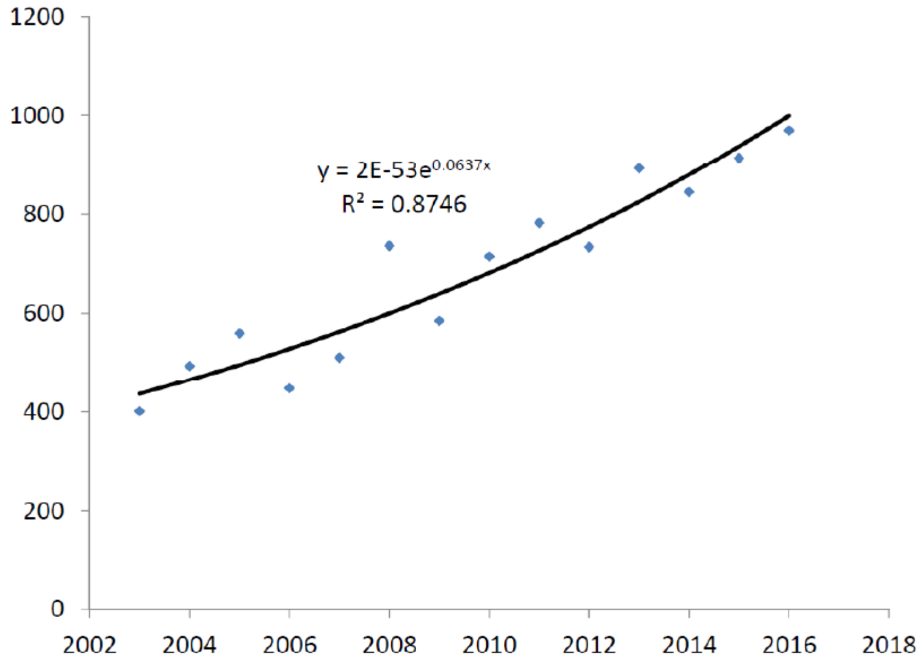
Based on the various studies of the harbor seal's hearing ability in water, the results show that the seals hear well in the frequency range from a few hundred Hz up to 50 kHz. Above water, the harbor seal also hears well from a few hundred Hz up to 20-30 kHz.

4.2.3 Abundance and distribution of harbour seals

According to HELCOM, harbour seals in Swedish waters are divided into four subpopulation/management units: Limfjord, Kattegat (including the Northern part of the Great Belt assessment unit), Southern Baltic Sea (i.e. Bornholm Basin, Arkona Basin, Bay of Meklenburg, Kiel Bay, The Sound and the Southern part of the Great Belt assessment units) and the Kalmarsund (HELCOM, 2018b).

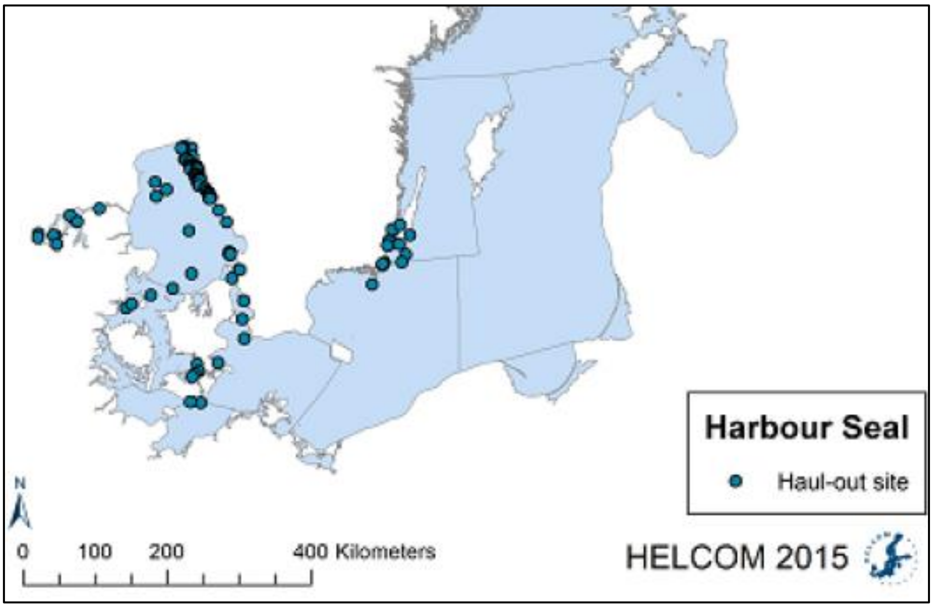
The development area for Triton is used by harbour seals belonging to the Southern Baltic Sea subpopulation. The Southern Baltic Sea subpopulation is connected to the Kattegat subpopulations (HELCOM, 2018b). The Southern Baltic Sea subpopulation experienced a mass mortality caused by an Phocine Distemper Virus (PDV) epidemic in 2002. Since the mass mortality the subpopulation in Southern Baltic Sea has increased and in the time period 2003-2016 the annual growth rate has been estimated to be approximately 6.6 %. The latest count of the subpopulation is about 900 seals in 2016 (HELCOM, 2018b) (Figure 4.13).

Figure 4.13: The annual growth rate of counted harbour seals belonging to the Southern Baltic subpopulation (HELCOM, 2018b).



Haul-out sites of the harbour seals in Swedish and Danish waters are shown in Figure 4.14.

Figure 4.14: Haul-out sites of harbour seals in Swedish and Danish water. Modified from (HELCOM, 2018a).



4.2.3.1 *Importance of the development area for Triton offshore wind farm for harbour seals*

There are no haul-out sites in the Triton development area. The nearest haul-out site is located in the Natura 2000 area SE0430095, Falsterbohalvön, appointed for both harbour seals and grey seals. Harbour seals at the haul-out sites have been counted in 2015-2018 by several yearly flight observations conducted by DCE, Aarhus University. Based on the flight observations the number of harbour seals at the resting ground vary between no sighting to up to 200 seals. It is especially in the summer period that high numbers of both harbour seals and grey seals are counted at the Måkläppen (DCE, 2020).

In connection with the preparation of the EIA for Kriegers Flak offshore wind farm in Danish waters, located approximately 17 km west of the Triton offshore wind farm development area, seals were equipped with GSM transmitters (Dietz, et al., 2015). A total of 10 harbour seals were equipped with satellite transmitters at the haul-out site at Måkläppen in the time period 2012-2013. Figure 4.15 shows the swimming track from the 10 harbour seals and their estimated home range covering the whole year.

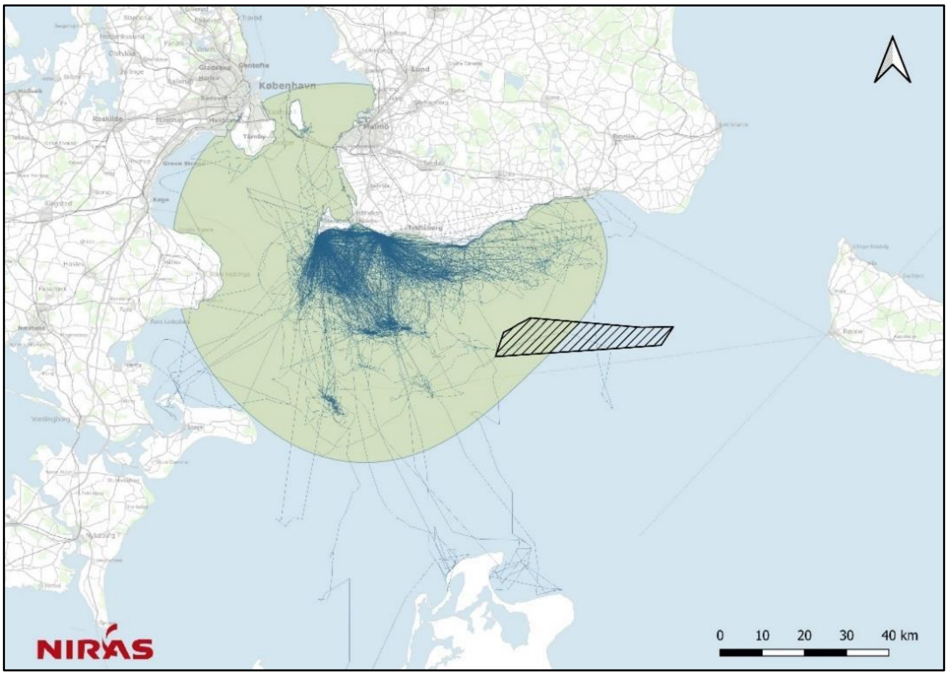


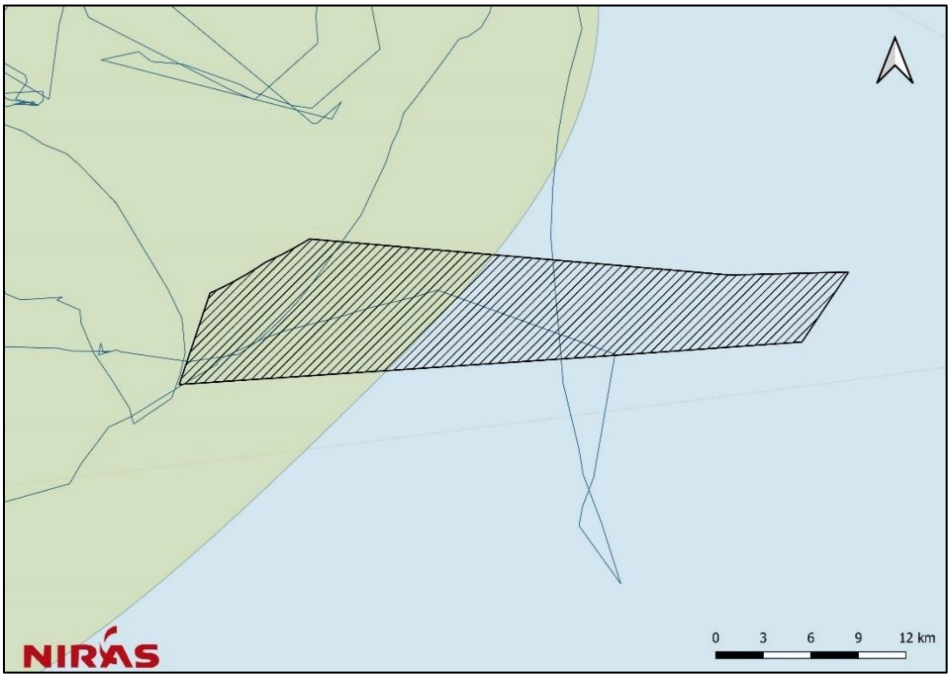
Figure 4.15: Swimming tracks (blue lines) from ten harbour seals equipped with GPS-transmitters at Måkläppen, Sweden in connection with preparation of the EIA for Kriegers Flak OWF in Danish waters. The green area is the estimated harbour seal 95% kernel homes range based in the swimming tracks. Black shaded area is the Triton Offshore Wind Farm. Modified after Dietz et al. (2015). GPS data is collected by DCE, Aarhus University. ©SDFE

The development area for Triton offshore wind farm is partly overlapping with the home range for the harbour seals that use the haul-out site at Måkläppen, meaning that the western part of the offshore wind farm will be located in an area that the seals use for foraging and migration, however it is primarily the shallower water north of Triton towards the coast of Skåne and the area west of the development area for Triton that is used by the harbour seals at Måkläppen (Figure 4.15).

The overall 95% kernel home range of the harbour seals was estimated to be 5.234 km^2 of which the western part of the development area for Triton offshore wind farm that overlaps with the home range (approximately 200 km^2) constitutes only 3.9 %.

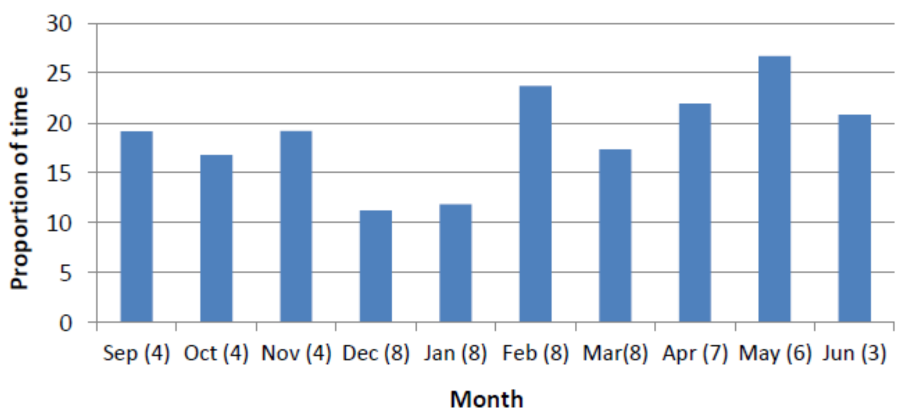
The GPS data showed that one of the harbour seals entered the development area for Triton offshore wind farm (Figure 4.16).

Figure 4.16: Swimming tracks from the harbour seal that entered the Triton offshore wind farm area. The harbour seal were equipped with GPS-transmitters at Måkläppen, Sweden in connection with preparation of the EIA for Kriegers Flak OWF in Danish waters. The green area is the estimated harbour seal 95% kernel homes range based on the swimming tracks from ten harbour seals. GPS data is collected by DCE, Aarhus University. ©SDFE



The harbour seals in the area moult their fur in July to September with the peak season in August. During this period, the seals spend a lot of time hauled out, whereas harbour seals spent less time hauled out during December and January (Dietz, et al., 2015) (se Figure 4.17).

Figure 4.17: The mean percentage of time spent hauled out of the 10 tagged harbour seals. Numbers in parentheses indicate that number of individuals available for each monthly mean (Dietz, et al., 2015).



Based on the analyses, the western subarea of the Triton offshore wind farm is partly located in an area of high importance to the ten harbour seals (especially in the winter), while the remaining part of the western subarea and the eastern subarea is located in an area of low importance for the harbour seals (Dietz, et al., 2015).

In the preliminary site investigation for the potential German offshore wind farm in area O-1.3, located approximately 15 km south of the development area for Triton, data from marine mammal ship-based and flight-based surveys conducted in connection with the environmental monitoring in the "Westlich Adlergrund" OWF cluster, were analyzed. The surveys were conducted in the period 2016-2018. A total of 20 digital aerial surveys and 24 ship-based surveys were completed form March 2016 to February 2018 (IBL Umweltplanung et al., 2020).

Over the course of the two-year survey of the "Westlich Adlergrund" cluster, a total of one Grey seal and twelve unidentified pinnipeds were detected during twenty digital aerial surveys. By means of ship-based transect surveys, seven Grey seals, one Harbour seal and one unidentified pinniped were sighted. The animals were sighted throughout the year. The sightings mainly occurred in the south of the survey areas near coasts and shallow water areas (IBL Umweltplanung et al., 2020).

Only two harbour seals were observed inside the wind farm area and given the low sample size (10 tagged animals), it must be concluded that encountering harbour seals from Falsterbo in the wind farm area is very likely. Only very few harbour seals were observed during the German monitoring program and it is assessed that the area south of the development area for Triton offshore wind farm is not important for harbour seals

It is therefore expected that harbour seals use the development area, especially in winter, and that the area is regularly used, but the area is not regarded as a particular important feeding area for harbour seals. The area is therefore assessed to be of low to medium importance for harbour seals belonging to the Southern Baltic subpopulation.

4.3 Biology of grey seal

The grey seal (*Halichoerus grypus*) is found along the eastern and western coasts of the North Atlantic Ocean. Like the harbor seal, the grey seal is depended on coastal waters, where there is plenty of food and undisturbed haul-out sites (Galatius, 2017). It is a large seal of the family Phocidae ('true seals').

In the Baltic, grey seals grow to an average length of 1.7–2.1 meters and a mass of 100–180 kg for females and > 300 kg for males. They can reach an age of 25 (males) – 35 (females) years (HELCOM, 2013). Females reach sexual maturity at 3-5 years, males around 6 years, attaining a 'socially mature' status some years later (Hall & Thompson, 2009). The breeding season varies between populations and for the North Sea grey seals it is usually autumn and winter while the Baltic population gives birth in February and March (Härkönen, et al., 2007). Pupping in the Baltic Sea takes place mostly on drift ice although in some areas seals also give birth on land. Pups are born with a dense, creamy white fur (laguna), that is not waterproof. They moult the laguna after 2-4 weeks and it is replaced with a shorter adult-like fur. The pup is nursed for an average of 18 days, rapidly gaining weight from approximately 10 to 50 kg. After the pup is weaned it stays some weeks at the rookery until it has fully moulted, living off its blubber reserves, and eventually goes to sea to feed on its own (Hall & Thompson 2009). Thus, the pup must remain on land for several weeks until it has finished nursing, developed its adult fur, and it is considered a period where the pup is particularly vulnerable to disturbance.

Grey seals moult on ice and haul-out sites from April-June and spend much time on land at the haul-out sites in that period (HELCOM, 2013). However, studies of both harbor seals and grey seals have shown that grey seals spend significantly less time at the haul-out sites compared to harbor seals in general (Dietz, et al., 2013).

4.3.1 Feeding ecology and foraging behaviour

Like harbour seals, grey seals are opportunistic feeders. Grey seals are able to eat larger prey items compared to harbor seals due to their larger size, but also because grey seals bring their prey to the water surface, where they tear it into smaller pieces with the help of their mitts. Grey seals migrate (and forage) over significantly greater distances compared to harbor seals. Like harbour seals, many grey seals live in areas with relatively shallow water, and are therefore not deep divers, but dive depths of over 400 meters have been recorded (Boehme, et al., 2012).

As mentioned, grey seals are opportunistic feeders, but often their food choices are dominated by a few fish species, and there can be great variation in which fish are included in the diet depending on which area the seal lives in. A study analyzed the seals' prey (based on for example stomach contents) in an area that covers the Baltic Sea, including a region in the Southwestern Baltic Sea and Gotland covering the waters around the development area for Triton (Scharff-Olsen et al., 2019). Overall, a clear correlation was found between prey selection and fish found in the specific areas. In the southwestern Baltic Sea, 11 fish species were identified in 39 samples, 24% of these were identified as black goby (*Gobius niger*), 18% as round goby (*Neogobius melanostomus*), 16% as Atlantic cod (*Gadus morhua*), and 12% as plaice (*Pleuronectes platessa*). In the 41 collected samples at Gotland, nine fish species were identified, with the most dominant being herring (*Clupea harengus*), sprat (*Sprattus sprattus*) and cod accounted for approximately 33 %, 31 % and 25 % of the diet, respectively (Scharff-Olsen et al., 2019).

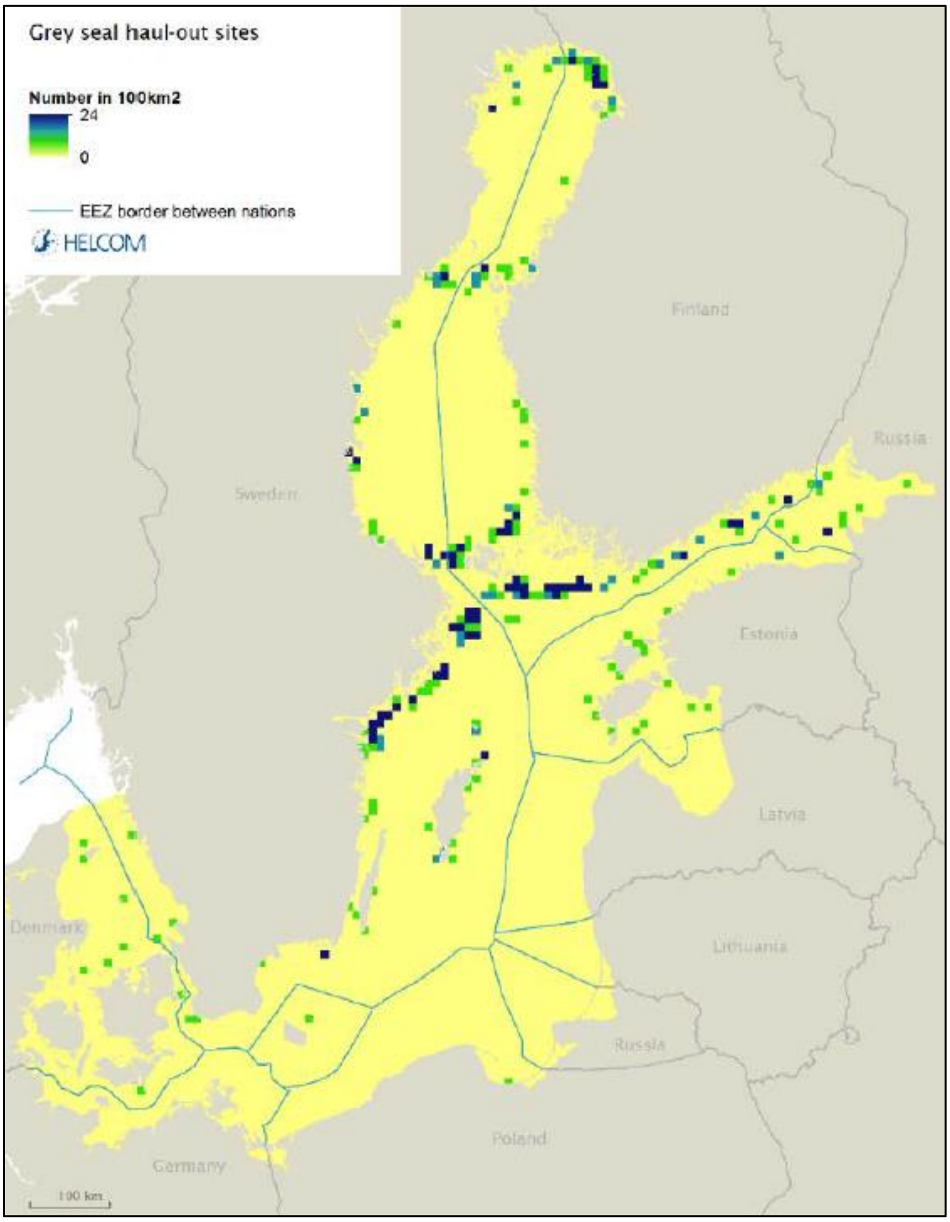
4.3.2 Senses

There is limited information about the grey seals' senses. However, as there is a great anatomical resemblance between grey seals and harbour seals, and the two species are taxonomically close (Arnason, et al., 1995; Mouchaty, et al., 1995), is it assessed that their senses are comparable (Dietz, et al., 2015). Studies of grey seals' hearing in air show that their hearing in air is best between 3-20 kHz, which is comparable to harbor seals (Ruser, et al., 2014). Unlike the underwater hearing of harbour seals, the underwater hearing of grey seals has only been investigated in a single study (Ridgway & Joyce, 1975). This study was conducted using auditory evoked potentials, which are not directly comparable to the psychophysical data obtained from harbour seals. The hearing threshold of harbour seals are generally recommended to be used as a conservative estimate of the hearing threshold for those Phocids (earless seals), where the hearing has not been as thoroughly investigated (Southall, et al., 2019).

4.3.3 Abundance and distribution of grey seals

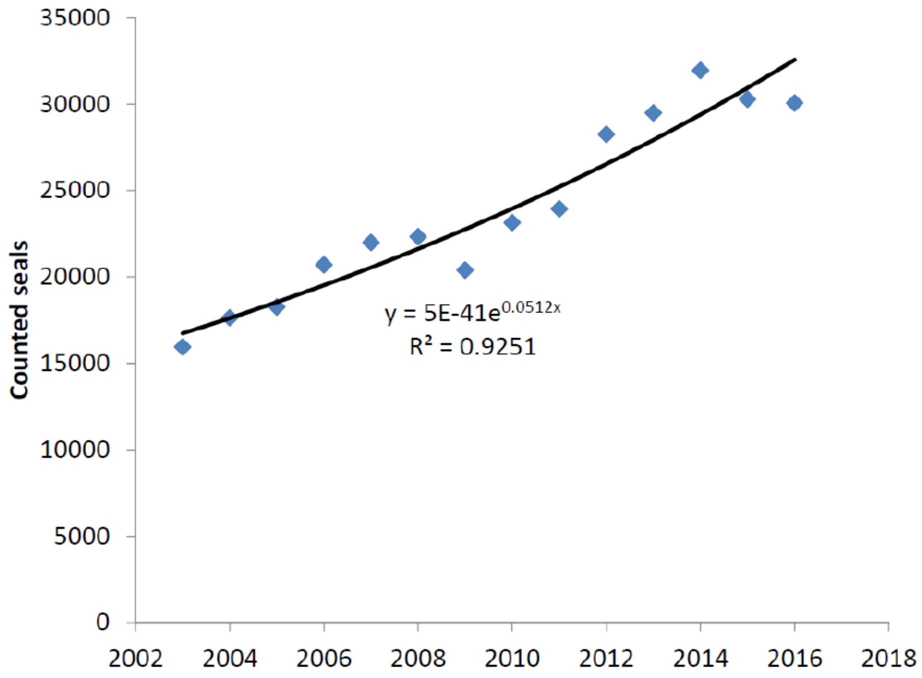
Grey seals are found on both sides of the North-Atlantic in temperate and sub-Arctic waters. Grey seals in Swedish waters belong to two subspecies, the Baltic grey seal (*Halichoerus grypus grypus*) and the North Sea grey seal (*Halichoerus grypus atlantica*) (HELCOM, 2018b; Olsen, et al., 2016). Grey seal haul-out sites in the Baltic Sea are shown in Figure 4.18.

Figure 4.18: Grey seal haul-out sites in the Baltic Sea and Kattegat. The map includes all currently known haul-out sites, but seals were historically known to use haul-out sites Southwest of Samsø and around Fyn in Southwestern Baltic (HELCOM, 2018a).



Grey seals in and near the development area for Triton offshore wind farm belong to the Baltic Sea population. The annual population growth rate during the period 2003-2016 was 5.3%. Earlier data from the Swedish monitoring programme indicate that the grey seal population was growing at a rate of about 8% per year from the early 1990s in the Baltic Sea (Stenman et al. 2005; Hårding et al. 2007). Although the growth rate is well below the threshold value for good status (7%) according to HELCOM, the population growth rate seems to level off, which indicates that the population is approaching the carrying capacity (HELCOM, 2018b). More than 30,000 animals have been counted since 2014 (se Figure 4.19).

Figure 4.19: The annual growth rate of counted Baltic grey seals (HELCOM, 2018b)



Grey seals migrate over large distances compared to harbour seals, and the presence of grey seals in an area does not mean, in the same way as for harbour seals, that the individual has strong site fidelity (McConnell, et al., 2012; Galatius, 2017). This is supported by the study where both grey and harbour seals were tagged with GSM at Måkläppen in Southern Sweden. Figure 4.20 shows the swim tracks from both harbour and grey seals. It is evident that grey seals forage and travel in the entire Baltic Sea, whereas harbour seals stay in relatively close proximity to the haul-out site (Figure 4.20).

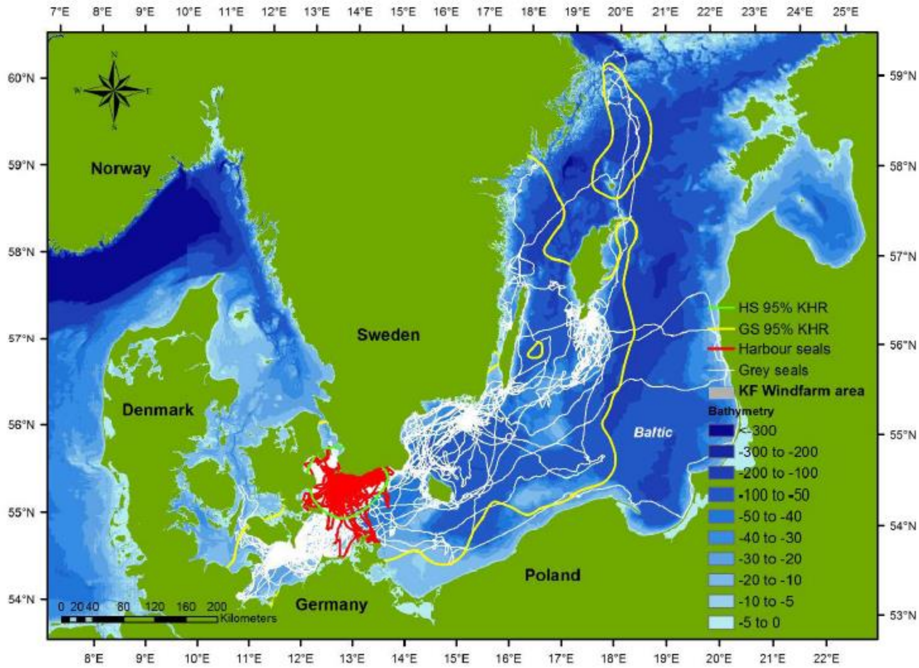


Figure 4.20: Movements of grey seals (white) and harbour seals tagged with GSM transmitters at Måkläppen in Southern Sweden. Grey seals travel extensively in the Baltic whereas harbour seals are more sedentary (HELCOM, 2018a).

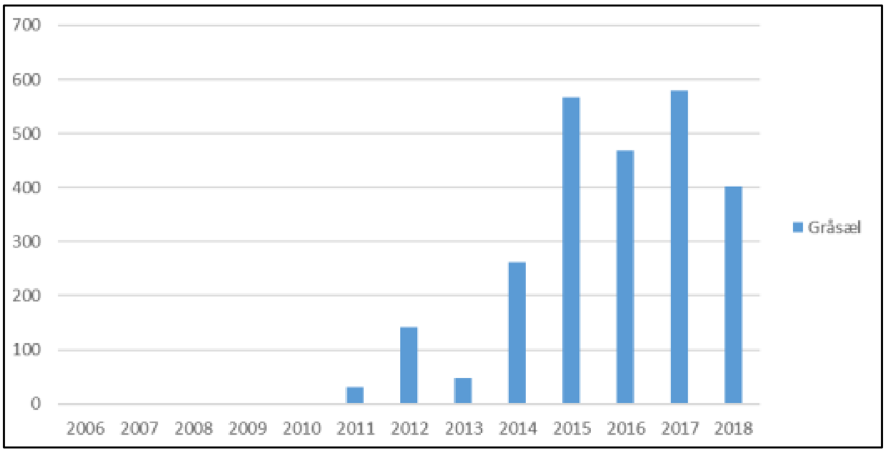
A tagged female from Rødsand in the Danish Baltic was observed with a pup in Estonia and observed back at Rødsand a month later. This indicates seasonal migrations that are closely related to the requirements for feeding and site fidelity for a breeding area, where grey seals travel up to 380 km from the tagging site (Dietz, et al., 2015). Typically, however, they feed more locally, foraging just offshore, and adopting a regular pattern of travelling between local feeding sites and preferred haul-outs (Oksanen, et al., 2014).

4.3.3.1 Importance of the development area for Triton offshore wind farm for grey seals

There are no grey seal haul-out sites in the Triton development area. The nearest haul-out site is located at Måkläppen in southwestern Skåne, which is also a breeding site (see Figure 4.18). The windfarm area is located approximately 50 km east of the haul-out site. The haul-out site is located in the Natura 2000 area SE0430095, Falsterbohalvön, appointed for both harbour seals and grey seals. Grey seals at the haul-out sites have been counted in 2015-2018 by several yearly flight observations conducted by DCE, Aarhus University. Based on the flight observations the number of grey seals at the resting ground vary between no sighting to up more than 1000 grey seals. It is especially in the summer period that high number of both harbour seals and grey seals are counted at Måkläppen (DCE, 2020).

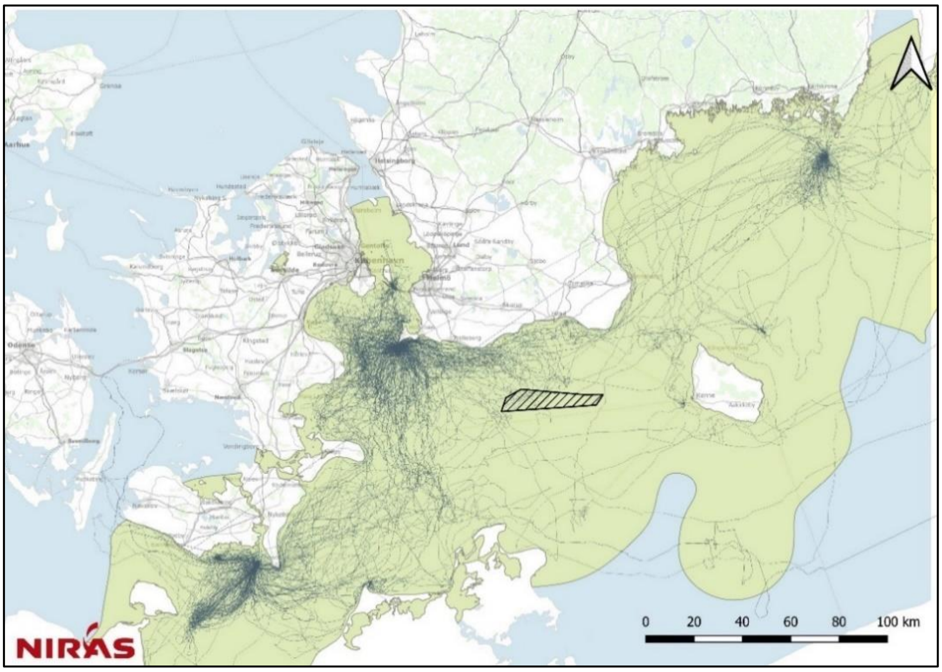
Another relatively nearby important grey seal haul-out site is located 70 km east of the development area close to the Danish island Christiansø (Bornholm) inside the Natura 2000 site 189, Ertholmene. The occurrence of grey seals in the Natura 2000 area is part of the total population in the Baltic Sea. The grey seals returned to Christiansø in 2010 and is the largest Danish colony of grey seals. In 2018, 403 grey seals were counted at Christiansø. As shown below in Figure 4.21, the number of animals has varied in recent years, which is probably due to the fact that grey seals are only counted once during the moulting season (Miljøstyrelsen, 2020).

Figure 4.21: Yearly counting of grey seals at the haul-out site at Christiansø in the period 2006-2018 based on the Danish national monitoring program (NOVANA) (Miljøstyrelsen, 2020).



In connection with the preparation of the EIA for Kriegers Flak offshore wind farm in Danish waters, located approximately 17 km west of the Triton offshore wind farm development area, data from GSM transmitters re-analysed (Dietz, et al., 2015). In total, data from 11 grey seals were included, of which six were tagged at the haul-out site at Måkläppen, Falsterbo, Sweden, and five at the haul-out site at Rødsand and one at Åland island, Sweden. Figure 4.22 shows the swimming track from the 11 grey seals and their estimated home range covering the whole year home range.

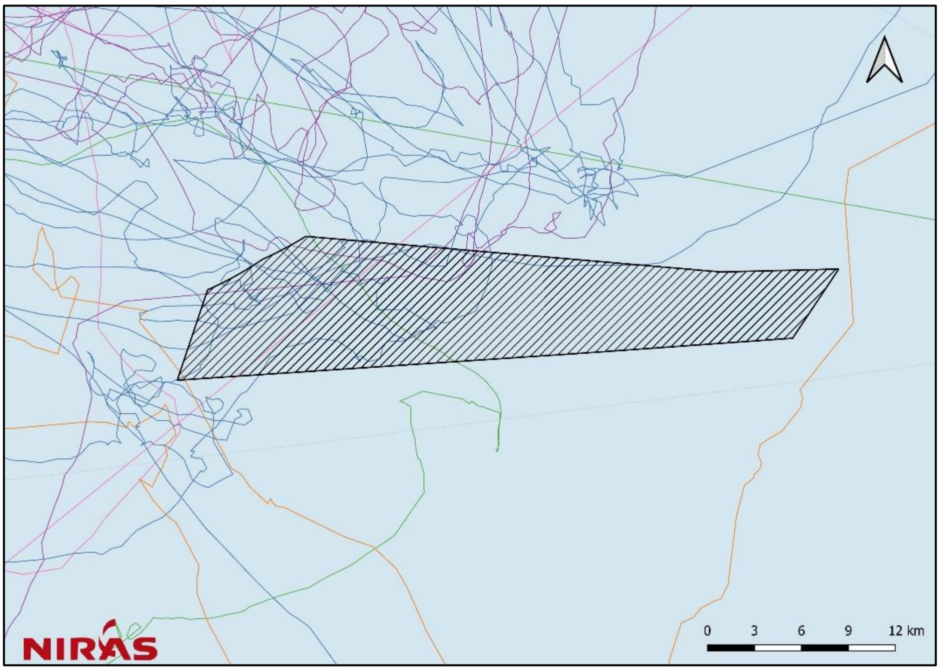
Figure 4.22: Swimming tracks from 11 grey seals (grey lines) equipped with GSM-transmitters in connection with preparation of the EIA for Kriegers Flak OWF in Danish waters. The yellow area is the estimated grey seal 95% kernel homes range based in the swimming tracks. The black shaded area is the development area or Triton Offshore Wind Farm. Modified after Dietz et al. (2015). GPS data is collected by DCE, Aarhus University. ©SDFE



As shown in Figure 4.22, the development area for Triton offshore wind farm is located inside the grey seal home range, which means, that the offshore wind farm will be in an area that is used by grey seals. The overall 95% kernel home range of grey seals was estimated to be 70.727 km^2 of which the development area constitutes 0.7 % for the 11 grey seals.

The GPS data showed that four of the grey seals entered the development area for Triton offshore wind farm (Figure 4.23).

Figure 4.23: Swimming tracks from the five grey seals that entered the Triton offshore wind farm area. GSM data is collected by DCE, Aarhus University. ©SDFE



Baltic grey seals moult their fur in May and June. During this period, the seals spend a lot of time hauled out. During the present studies, grey seals spent considerably less time hauled than harbour seals. The shortest time spent at haul-outs was during October (Dietz, et al., 2015) (se Figure 4.24).

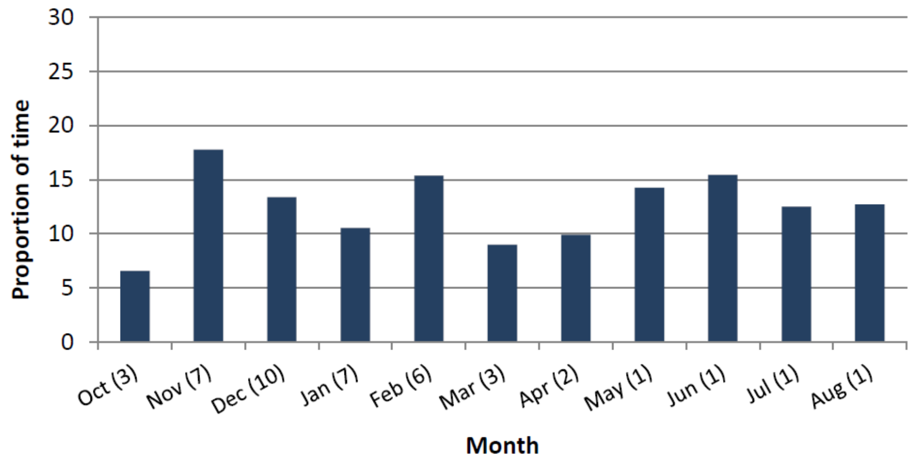


Figure 4.24: The mean percentage of time spent hauled out of the 11 tagged grey seals. Numbers in parentheses indicate that number of individuals available for each monthly mean (Dietz, et al., 2015).

Based on the analyses, both subareas of the Triton offshore wind farm are partly located in an area of medium to high importance for the 11 grey seals (especially in the winter and summer) (Dietz, et al., 2015).

In the preliminary site investigation for the potential German offshore wind farm area O-1.3, located approximately 15 km south of the development area for Triton, data from marine mammal ship-based and flight-based surveys conducted in connection with the environmental monitoring in the "Westlich Adlergrund" OWF cluster, were analyzed. Over the course of the two-year survey (from March 2016 to February 2018) of the "Westlich Adlergrund" cluster, a total of one grey seal and twelve unidentified pinnipeds were detected during twenty digital aerial surveys. By means of ship-based transect surveys, seven grey seals, one Harbour seal and one unidentified pinniped were sighted. The animals were sighted throughout the year. The sightings mainly occurred in the south of the survey areas near coasts and shallow water areas. Due to the low number of sightings, no reliable assertion can be made on the spatial distribution of pinnipeds in the survey area (IBL Umweltplanung et al., 2020).

Only four grey seals were observed inside the wind farm area and given the low sample size (11 tagged animals), it is assessed that encountering grey seals in the wind farm area is very likely. Only very few grey seals were observed during the German monitoring program and it is assessed that area south of the development area for Triton offshore wind farm is not important for grey seals

It is therefore expected that grey seals use the development area, especially in winter and summer, and that the area is regularly used by grey seals, but the area is not regarded as a particular important feeding area for grey seals. The area is therefore assessed to be of low to medium importance for grey seals belonging to the Baltic subpopulation.

5 Conservation

In this chapter the conservation status and the protection of the three marine mammal species, harbour porpoises, harbour seals and grey seals is described. Furthermore, a description of existing pressures for the three species are discussed.

5.1 Protection of marine mammals

Since marine mammals are one of the most important top-predators in the marine environment they are listed in different conventions aiming to protect populations and their living environment. In table Table 5.1 a list of the international conventions and protection conditions for harbour porpoises, harbour seals and grey seals are provided.

Table 5.1: International conventions and protection status of the marine mammal species occurring in the development area for Triton offshore wind farm area.

Protection	Baltic Proper harbour porpoise (*Phocoena phocoena*)	Harbour seal (*Phoca vitulina*)	Grey seal (*Halichoerus grypus*)
IUCN red list	Baltic Proper population: Critically endangered (CR) Belt Sea population: Least concern (LC)	Least concern (LC)	Least concern (LC)
The Swedish red list	Baltic Proper population: Critically endangered (CR) Belt Sea population: Least concern (LC)	-	Least concern (LC)
CITES (Washington Convention)	Annex II, IV	-	-
EU's Habitat directiv (92/43/EEC)	Annex II, IV	Annex II, V	Annex II, V
Bern Convention	Annex II	Annex III	Annex III
Bonn Convention	Annex II	Annex II	Annex II
HELCOM (Helsinki Convention)	Included	Included	Included
OSPAR (Oslo og Paris Convention)	Included	Included	Included

5.1.1 Harbour porpoise protection and conservation status

In European waters, harbour porpoises are listed in annex II and IV of the Habitats Directive (European Commission, 1992) (see chapter 12 for an assessment after the Habitats Directive), annex II of the Bern Convention, annex II of the Bonn Convention and annex II of the Washington Convention (CITES). Furthermore, the harbour porpoise is covered by the terms of the Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (ASCOBANS), a regional agreement under the Bonn Convention and HELCOM (The Helsinki Commission; protection of the marine environment of the Baltic Sea).

The ASCOBANS agreement states that member states are obligated to "*Work towards ...(c) the effective regulation, to reduce the impact on the animals of activities which seriously affect their food resources, and (d) the prevention of other significant disturbance, especially of an acoustic nature*" (Annex to Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (ASCOBANS, 2021). Furthermore, as an extension of the ASCOBANS agreement, the member states have signed the "Recovery plan for porpoises in the Baltic Sea (Jastarnia plan)", (ASCOBANS, 2002), which highlights the highly threatened status of the Baltic Proper subpopulation. The aim of the recovery plan is to reestablish the porpoise population in the Baltic to min. 80% of its carrying capacity. The recommendations of the plan are focused on measures to reduce incidental bycatch in fisheries.

Harbour porpoises in Swedish waters are divided into three management sub populations. The Baltic Proper population, the Belt Sea population and the North Sea population. The porpoises that occur in and near the development area for Triton offshore wind farm belong to two subpopulations; the Belt Sea population and the Baltic Proper population (see section 4.1.3 for more details).

Based on the results from the SCANS project, a large-scale European ship and aerial survey to study the distribution and abundance of cetaceans in European Atlantic waters, conducted in 1994, 2005 and the 2016, the distribution, abundance and population size for the Belt Sea population was estimated. Only counts from 2012 and 2016 surveys isolated the Belt Sea population and can therefore be compared directly (Sveegaard, et al., 2015). There is no significant difference in the population estimate from 2012 and 2016, which is estimated to be just over 42,000 harbour porpoises.

According to the Swedish Red list from 2020 the Belt population is classified as of least concern (LC) (Artdatabanken, 2020) and the conservation status in the marine Atlantic region for the populations are generally considered to be favourable (Fredshavn, et al., 2019).

Based on the results from the SAMBAH project, a large-scale passive acoustic monitoring in the Baltic Sea aiming at investigating the distribution and abundance of the Baltic Proper subpopulation of harbour poises, the population size was estimated to consist of only approximately 500 individuals +- (SAMBAH). This makes the subpopulation the smallest in the world and it is declared critically endangered (Artdatabanken, 2020).

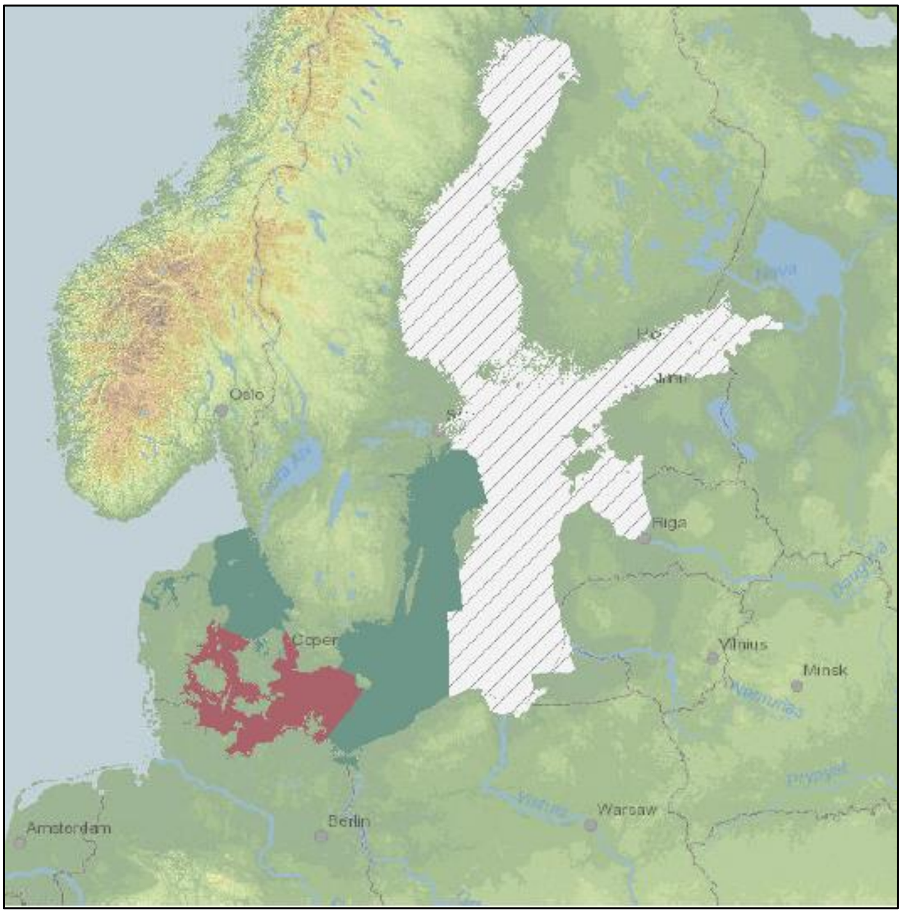
5.1.2 Harbour seals protection and conservation status

Harbour seals are protected under the EU Habitats Directive, the Convention for the Protection of Migratory Species (Bonn Convention) as well as protected under national legislation. The harbour seal is listed on the EU Habitats Directive annex II, which means that they should be protected by the designation of special areas of conservation. For seals, these areas are primarily placed in connection with important haul outs on land. See chapter 12 for an assessment after the EU Habitats Directive. According to the Swedish Red list from 2020 the harbour seal population in the Southern Baltic Sea is classified as of least concern (LC) (Artdatabanken, 2020).

According to the HELCOM core indicator evaluation of a population, a "good status" is achieved when: i) the abundance of seals in a management unit has attained a 'limit reference level' (LRL), of at least 10,000 individuals to ensure long-term viability and ii) the species-specific growth rate is achieved indicating that abundance is not affected by severe anthropogenic pressures (HELCOM, 2018b)

The HELCOM core indicator assessment on the state of the harbour seal (based on three components - distribution of haul-out sites, breeding sites and foraging areas) shows that the threshold for good status has not been achieved for harbour seals belonging to the Southern Baltic population (se Figure 5.1). In this context, the population of harbour seals in Kattegat and the Southern Baltic Sea are considered as one overall metapopulation, where the population estimates are summed in relation to evaluation after the HELCOM core indicator parameters. The estimate of the size of the metapopulation of harbour seals is above the LRL as the latest abundance estimate from 2016 for the harbour seals in Kattegat is approximately 16,800 seals. For the harbour seals in the Kattegat and Southern Baltic, good status has been achieved under the abundance criterion of the metapopulation. However, the population growth rate parameters for the Southern Baltic are below the criteria for good status. In the Southern Baltic, the average annual rate of increase during the assessment period 2003-2016 was 6.6%. Thus, this subpopulation does not achieve good status (HELCOM, 2018b).

Figure 5.1: Distribution of and status of harbour seal indicator, 2018 (HELCOM, 2021). Green is symbolising good environmental status is achieved and red is symbolising that good environmental status has failed.



5.1.3 Grey seals protection and conservation status

Grey seal is a protected species listed in Appendix II and Appendix V of the EU Habitats Directive and Appendix III of the Bern Convention. A limited number of grey seals are hunted under quotas in Finland (Finnish Ministry of Agriculture and Forestry, 2007) and Sweden (Havs- och vattenmyndigheten, 2012). The actual number of seals shot have always been far below the quota, the highest number shot in Sweden in any one year was 132 in 2008, in Finland it was 632 in 2009 (HELCOM, 2014). Denmark has opened small quotas to protect fisheries (Naturstyrelsen (2014).

Grey seals occur in the entire Baltic region. According to the Swedish Red list from 2020 the grey seal population in the Baltic Sea is classified as of least concern (LC) (Artdatabanken, 2020). According to the HELCOM core indicator evaluation the abundance and population growth rate for the grey seal population in the Baltic Sea exceed the threshold value, while greys seals in the southern Baltic has not achieved a good environmental status (se Figure 5.2).

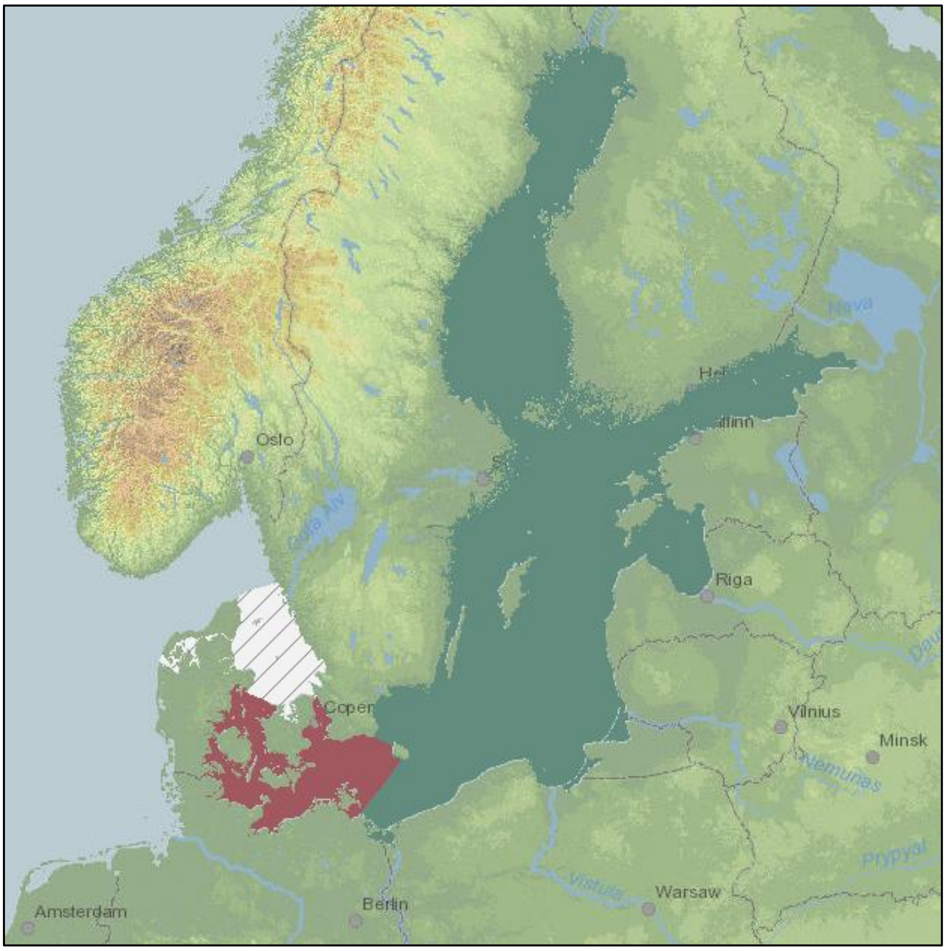


Figure 5.2: Distribution of and status of grey seal indicator, 2018 (HELCOM, 2021). Green is symbolising good environmental status is achieved and red is symbolising that good environmental status has failed.

Abundance is considerably above the LRL of 10,000. However, growth rate is below the threshold of 7%. As the population is suggested to approach the carrying capacity, grey seals will achieve good status if criteria for this scenario are used, i.e., no decrease greater than 10% during a 10-year period. Data remain inconclusive (i.e., longer time series are required for a full statistical evaluation of carrying capacity) though based on expert opinion good environmental status is assigned to the grey seals in the HELCOM assessment (HELCOM, 2018b). The population estimate for grey seals belonging to the Baltic Sea population is above approximately 30.000 individuals (HELCOM, 2018a).

5.2 Existing pressures harbour porpoise

Historically, there have been large catches of harbour porpoise in the Baltic region, with 2 000 individuals taken annually in Danish waters in the late 19th century and possibly larger catches in the Baltic Proper (HELCOM, 2013). Porpoises are threatened by a variety of anthropogenic activities and impacts. Unintentional by-catch from gillnet fishing plays an especially significant role for Harbour porpoises and is considered to be the primary cause of human induced mortality of Harbour porpoises (ASCOBANS, 2012). Gillnets are thought to be responsible for most bycatches, but porpoises are also occasionally taken in trawls (ASCOBANS, 2012). In addition, fishing has an indirect effect on harbour porpoises, since overfishing reduces their main food source (ASCOBANS, 2012).

Furthermore, harbour porpoises and other marine mammals in their distribution area, particularly in the Baltic Sea region, are still exposed to high levels of pollutants such as lipophilic compounds including polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane (DDT) and other organic substances as well as heavy metals (Bruhn, et al., 1999). Murphy, et al. (2010) found indications for a link between higher organochlorine concentrations and lower pregnancy rates in harbour porpoises. Porpoises in the Baltic Sea have been reported to have up to 254% higher mean levels of PCBs than samples from Kattegat and Skagerrak (Bruhn, et al., 1999; Berggren, et al., 1999). In later years, levels of PCBs in Baltic biota have declined, so the negative impacts of pollution may be reduced in the future. Little is known currently about the precise impact of pollutants on marine mammals. Potentially, they can attack the lymphatic system, the endocrine system (e.g. the thyroid gland) and enzymes, thereby permanently damaging the animals (Das, et al., 2006a. ; Das, et al., 2006b; Beineke, et al., 2007; Yap, et al., 2012). Mahfouz et al. (2014) discovered that the concentration of various metals in the liver and kidneys was elevated in stranded harbour porpoises who died of infectious diseases in comparison with animals that had died of injuries. Jepson et al. (2005) reached a similar conclusion after examining stranded Harbour porpoises in Great Britain. Animals that had died of infectious diseases showed increased PCB concentrations in their blubber.

Noise pollution from shipping, construction of OWFs and seismic surveys, is a further level of pollution that affects harbour porpoises in the Baltic Sea. For a more detailed description see section 6.2.2 and 6.2.7. In addition, eutrophication and an increase in water temperature due to climate change affect the organisms in the Baltic Sea. They are both phenomena that change phytoplankton production and thus fundamentally impact the food chains in marine systems (Andersson, et al., 2015; Andersen, et al., 2017). While the eutrophication level is stagnating or slightly declining, the effects of climate change are only beginning to be felt with increasing intensity. Although both processes generally increase the productivity of the marine system, increased phytoplankton production can also lead to toxic algal blooms or declining fish populations (Andersson, et al., 2015). On the other hand, the interrelationships are very complex, especially due to climate change and can be difficult to predict. Climate change is not only causing a rise in water temperature, but salinity is also increasing because of decreasing freshwater supply (Takolander, et al., 2017).

5.3 Existing pressures seals

The common seal populations were severely depleted by hunting, by-catch in fisheries, and later by diseases related to effects of pollution and the PDV virus. Other threats include habitat loss due to coastal development (HELCOM, 2013).

One of the main threats for seals is entanglement in fishing gear (by-catch), however it does not appear to pose a threat to the harbour seal and grey seal population or the population's recovery (Herrmann, 2013). Fisheries do also have an indirect effect on seals as fishing reduces their main food source (ASCOBANS, 2012).

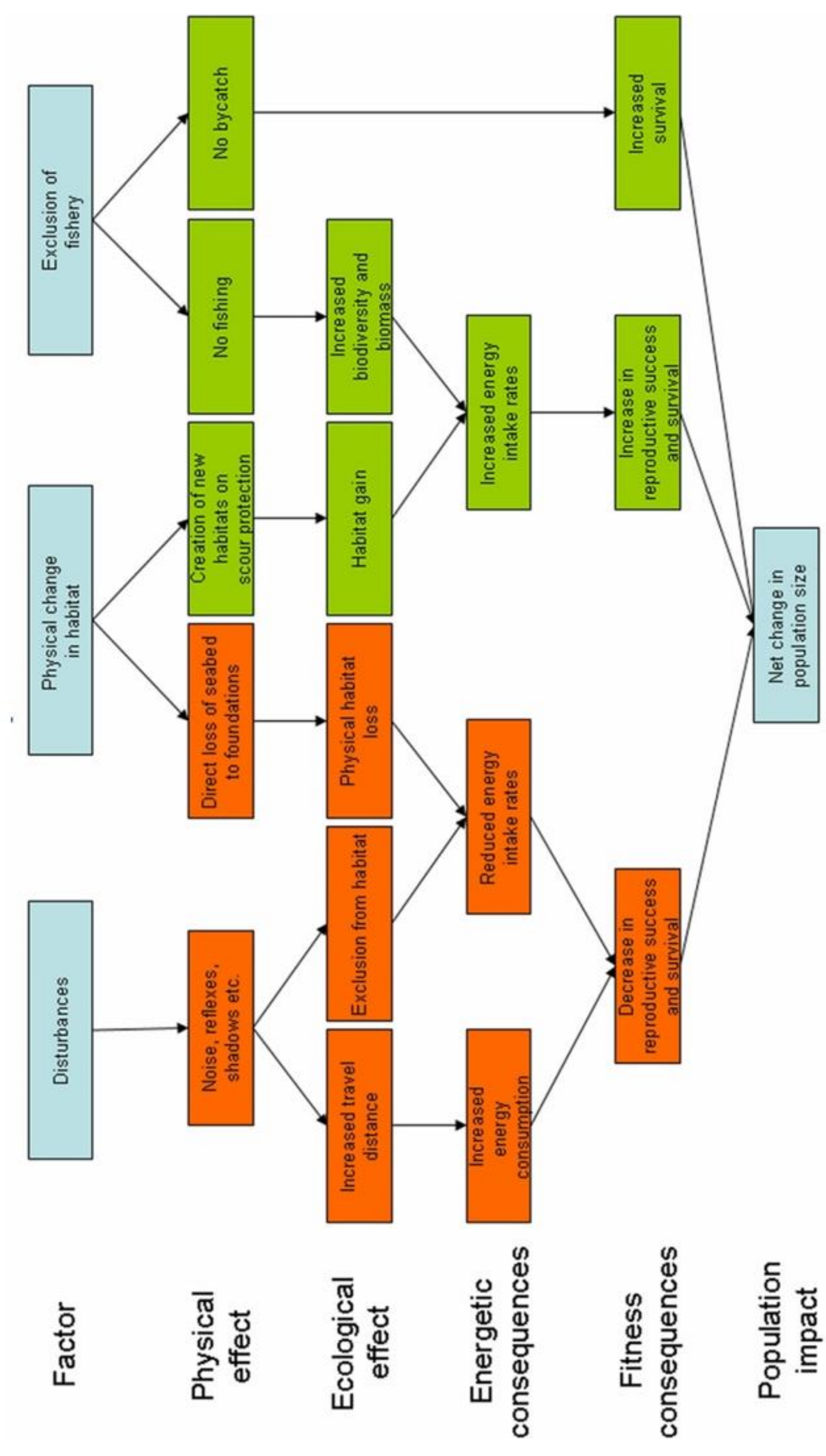
Furthermore, pinnipeds in their distribution area, particularly in the Baltic Sea, are still exposed to high levels of pollutants such as lipophilic compounds including polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane (DDT) and other organic substances as well as heavy metals (Sørmo, et al., 2005). Contaminants accumulate in these animals via their food chain. DDT and PCBs especially cause reproductive problems in the Baltic Sea, so that despite decreasing persecution of grey seals from the 1950s onwards, the population continued to decline and has only been recovering since the 1980s (Herrmann, 2013). Only little is currently known about the precise impact of pollutants on harbour seals. Potentially, they can attack the lymphatic system, the endocrine system (e.g. the thyroid gland) and enzymes, thereby permanently damaging the animals (Sørmo, et al., 2005). Negative effects of various heavy metals on the immune system have been shown in North Sea pinnipeds (Kakuschke, et al., 2009).

Noise pollution from shipping, construction of OWFs and seismic surveys, is a further level of pollution that affects Harbour porpoises in the Baltic Sea. For a more detailed description see section 6.2.2 and 6.2.7. In addition, eutrophication and an increase in water temperature due to climate change effect the organisms in the Baltic Sea. The effects on pinnipeds are identical to those for harbour porpoises (se section 5.2).

6 Potential impacts on marine mammals

Turbine (foundation) size as well as the wind farm layout (number of turbines) are important factors for the assessment of impact on marine mammals especially during the construction phase. The impact on marine mammals might be different depending on turbine size, number and position (e.g., distance to Natura 2000 areas appointed for marine mammals or important seal colonies). To give an overview, a description of activities considered to influence marine mammals in the wind farm area is given in Figure 6.1

Figure 6.1: Potential effects of offshore wind farms on marine mammals in the surrounding waters. Factors with negative effects are shown in red; factors with positive effects are shown in green. Disturbance is the dominant factor during construction, whereas all three factors could play a role during operation of the wind farm. (Tougaard & Teilmann 2007, after: Fox et al. 2004).



Both potential positive and negative effects related to the construction and operation of wind farms are represented. In this report the effects assumed to be most likely and most substantial are discussed. Thus, the focus is on the activities/pressures, that may cause a potential negative impact or a potential positive impact on marine mammals and therefore the following assessments are based on a worst case scenario for the activities/pressures that is related to the establishment of Triton offshore wind farm.

6.1 Potential impacts related to preliminary measures

During the construction phase before foundation installation, detailed seismic pre-investigation surveys are conducted to evaluate the seabed and minimize potential risks (e.g., detection of military remains, UXO unexploded ordnance and for localizing the optimal position of the foundation).

6.1.1 Removal of UXO

Presence of UXOs in the development area for Triton is not expected. However, if there (against expectations) are UXOs in the development area the first step is to avoid construction in that particular part of the area. If it is not possible to avoid the area, and the UXO have to be removed, a separated assessment will be conducted as explosions are considered as special cases not directly related to the wind farm. Furthermore, each UXO is a unique site specific situation that needs a site-specific underwater noise modelling and it therefore cannot be done in advance. Below is a general description of the potential impacts from the removal of UXOs

If UXO is found it can be necessary to remove it by explosion. Underwater explosions constitute the most intense anthropogenic noise point source in the oceans and have the potential to lead to severe injuries in marine mammals (Lewis, 1996; Richardson, et al., 1995). Because of the extremely high detonation velocity, the pattern of sound propagation is unique: After an initial shock wave, characterized by an extremely short signal rise time and a high overpressure, this primary pulse can be followed by a negative phase and a travelling sound pressure wave (Landsberg, 2000).

The initial shock wave decreases rapidly with distance from the source, as much of the energy form the explosion is lost due to heat loss or by pressure equalization at the sea surface. Depending on the intensity of the detonation, injuries directly caused by the shock wave are often lethal at very close ranges (Landsberg, 2000). Experiments on dead porpoises have shown that shock waves from explosions can cause massive bleeding, bone fractures and damage to ears, pharynx, intestines and lungs (Ketten, 2004). Measurements and subsequent modelling of detonation of unexploded ordnance in the southern North Sea have shown that the shock wave is strong enough to cause damage to the ears of harbour porpoises up to 500 meters from the site of the explosion (von Benda-Beckmann, et al., 2015). However, modelling of the shock wave at the specific site is necessary from case to case, to indicate exact critical distances.

The underwater detonation generates a broadband sound pressure wave that can lead to auditory threshold shift and behavioural avoidance responses in marine mammals at further distance from the explosion site (Lewis, 1996; Koschinski, 2011; Southall, et al., 2019). The sound pressure wave is directly related to the size of the explosive charge. The explosion of 1 kg TNT generates a sound pressure wave of approximately 270 dB re 1 µPa @1 meter (Rihardson, et al., 1995). Dos Santos et al. (2010) measured more than 170 dB re 1 µPa at a distance of 2 km from an explosion site, which is far above the avoidance threshold for porpoises in relation to underwater noise from pile-driving (Brandt, et al., 2018). Furthermore, underwater noise levels high enough to cause permanent threshold shift (PTS) in porpoises at several kilometers distance have been modelled in the southern North Sea (von Benda-Beckmann, et al., 2015). The German Bundesamt für Naturschutz (BfN) have recently examined the possible effects from the explosion of 42 naval mines within the Natura 2000 area Fehmernbelt (Wölfing, et al., 2020). It was shown that porpoises were present in the area during the detonations and that the noise levels in most of the area was above the German threshold for temporary threshold shift (TTS) (160 dB re 1μPa^{2}s SEL). Subsequent autopsies of 24 harbour porpoises, stranded in the following months, revealed tissue damage in 8 harbour porpoises, likely caused by high sound pressure level.

It is possible to and strongly recommended to make use of mitigation measures, whenever underwater detonations cannot be avoided to reduce sound energy emitted into the marine environment. A newly described mitigation measure is deflagration, where a small explosive charge is used to neutralize the UXO (NPL, 2020). In this way the explosive charge becomes significant smaller, which will result in a reduced emitted sound energy level. If it is not possible to avoid larger explosive charges the emitted sound energy level can be reduced by the application of bubble curtains (Nützel, 2008; Schmidtke, 2010; Koschinski, 2011).

As started above , each UXO is a unique site specific situation that needs a site-specific underwater noise modelling and it therefore cannot be done in advance.

6.1.2 Seismic pre-investigation surveys

Before construction works of the offshore wind farm (installation of foundations and cables) can take place, detailed information of the seabed is needed. Some of the seismic survey equipment (e.g. airguns, sparker, boomer and sub-bottom profilers) generate underwater noise levels that may cause avoidance responses, and temporary (TTS) and permanent (PTS) hearing threshold shifts in marine mammals. To assess the impact from the seismic pre-investigation survey a detailed underwater noise modelling has been conducted to estimate impact ranges (behavioural, TTS and PTS ranges). Underwater noise modelling was carried out for three equipment scenarios. The full setup (scenario 1) using an Innomar (Innomar SES-2000 Medium 100 parametric sub bottom profiler), a sparker (Geosource 200-400) and four mini airguns of the type MiniG. The scenario 2 omits the sparker, and the third setup only includes the Innomar system. Scenario 1 and 2 are expected to be used during the pre-investigation survey conducted in the Triton offshore wind farm area, where turbines will be installed. In the investigation corridor it will only be the Innomar system (scenario 3), that will be used. All three equipment scenarios may generate underwater noise levels that may cause avoidance responses, and temporary (TTS) and permanent (PTS) hearing threshold shifts in marine mammals For more details se the technical background report "Seismic Survey, Triton (NIRAS, 2021).

6.2 Potential pressures related to the construction

During the construction phase, the most important impact on marine mammals caused by the offshore wind farm is noise from building activities (e.g. pile driving) and ship traffic. Pile driving is assumed to have the most disturbing effect on marine mammals as it can potentially cause avoidance responses, temporary (TTS) and permanent (PTS) hearing threshold shift and in the worst-case acoustic trauma to non-auditory tissue (Madsen, et al., 2006). Furthermore, the underwater noise from pile driving of foundations will cause a temporary habitat loss as the marine mammals will be displaced from the construction area as well as from nearby noise-affected areas.

Sediment spill from the installation of foundations, pre-drilling of monopiles in hard substrates and installation of subsea cables (both inter-array cables and export cables) can potentially cause an impact if it impedes the marine mammals' ability to find prey or reduces the food resources in the area.

During the construction phase an increase in ship traffic within the project area is expected to occur.

6.2.1 Underwater noise

Underwater noise can affect marine mammals in many ways. Depending on the noise source underwater sound can travel very far and fast in water, about four times faster than in air due to the higher density of water. How noise affects marine mammals depends on different Properties of the noise source, e.g. the frequency content, intensity, duration and how fast the noise increase in intensity as well as the marine mammals hearing abilities. As noise spreads through the water, its acoustic energy decreases due to propagation losses. Thus, the scale of the effect largely depends on the animal's proximity to the noise source with increasing impact the closer the marine mammal is to the source. A marine mammal moving towards a noise source will, at some point, come within detection distance of the noise. Closer to the noise source, the noise can cause masking of the animal's communication and/or echolocation signals and behavioural responses, that can range from increase in swimming speed and breathing frequency to cessation of ongoing behavior or a fleeing/avoidance response (HELCOM, 2019; Kastelein, et al., 2013a; Dyndo, et al., 2015). Even closer to the noise source, it can cause temporary changes in the hearing sensitivity (TTS) and in very close proximity it can cause permanent changes in hearing sensitivity (PTS), and physical injury in non-auditory tissue (acoustic trauma) (HELCOM, 2019; Southall, et al., 2007; Richardson, et al., 1995).

The range of the different impacts is ideally defined by a species-specific threshold for each impact, creating species specific impact zones as shown in Figure 6.2.

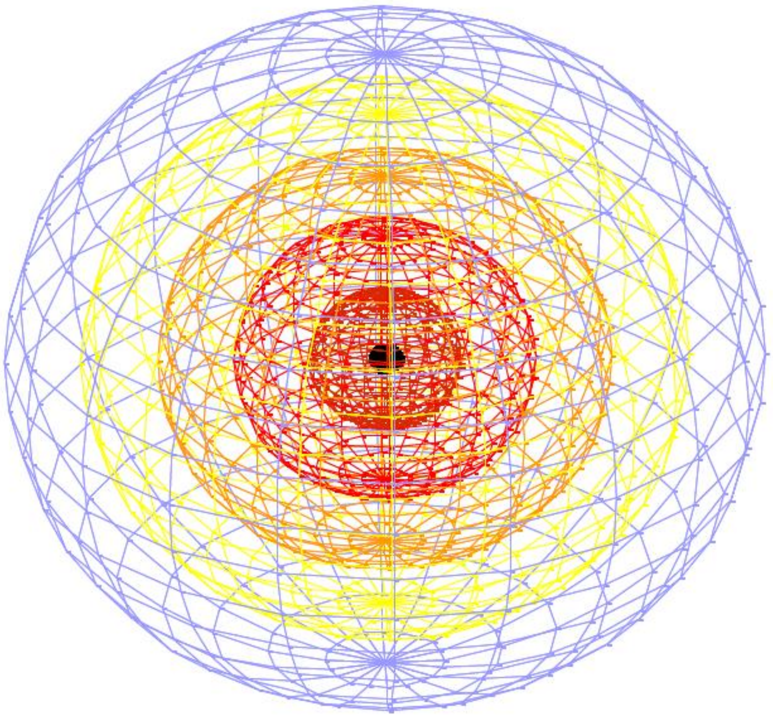


Figure 6.2: The different zones of impact generated by underwater noise. The noise point (black dot) is at the center of the sphere. As the distance to the noise source increases, the severity and number of different effects experienced by a marine mammal decreases. Injury and PTS (dark red sphere) only occur close to the sound source. TTS (red sphere) behavioural responses and stress (orange sphere) can also occur further away along with masking (yellow sphere). Furthest away from the noise source the marine mammal is just able to detect the noise (blue sphere) (HELCOM, 2019).

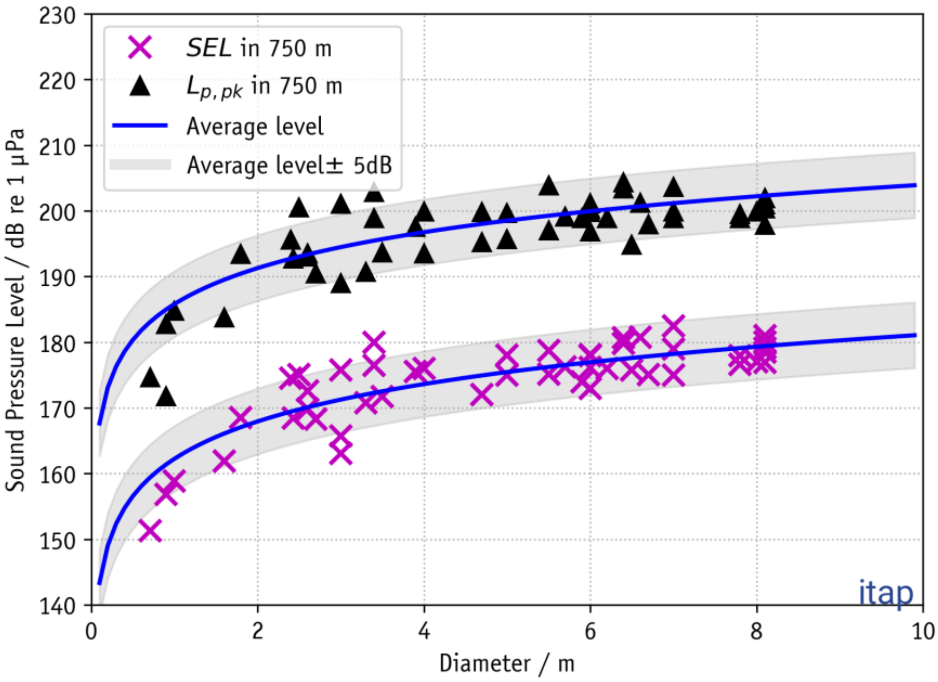
In reality the different impact zones are not sharply defined, and there can be a large overlap between the different impact zones, which complicates the decision-making process on species-specific thresholds. There are several, both external and internal variables, that affect the extent of the different zones (the thresholds), such as age, sex and the general physiological and behavioural states as well as the experience of the individual marine mammal (Popov, et al., 2011; Southall, et al., 2019; Buck & Tyack, 2000; Kastelein, et al., 2013a). Furthermore, behavioural responses like fleeing or avoidance can be hard to detect. It is difficult to define thresholds for behavioural responses, as changes in behaviour caused by underwater noise exposure might differ greatly among individuals. Studies have shown that changes in behaviour caused by underwater noise can vary significantly between species exposed to the same noise source (Richardson, et al., 1995). The existing background noise level is also an important factor for determining the extent of the zones of impact (HELCOM, 2019).

6.2.2 Pile driving noise

Noise from pile driving is the most disturbing effect on marine mammals during the installation of offshore wind farms (Madsen, et al., 2006) as the unmitigated pile driving noise can reach levels that at close distance can cause severe negative impact on marine mammals. Steel monopiles are one of the most common foundation designs in offshore wind farm construction due to their ease of installation in shallow to medium depths of water. The dominant method used to drive monopiles into the seabed is by hydraulic impact piling (hammering), which generate intense underwater noise levels, characterized as being of short duration and with a steep raise in energy level (Madsen, et al., 2006; Bellmann, et al., 2020)[3].

The intensity of the underwater noise from pile driving depends among other things on the diameter of the monopile. A larger diameter will cause a higher intensity of pile driving noise (Bellmann, et al., 2020).

Figure 6.3: Measured sound exposure level (SEL_{SS}, crosses) and peak pressure levels (L_{Peak}, triangles) in a distance of 750 m from monopiles with different diameter (Bellmann, et al., 2020).



A large number of noise measurements in German waters (measured in 750 meters from the installation site) have been conducted for unmitigated pile driving of monopiles with a diameter of up to 8.2 meter in diameter (Figure 6.3). Pile driving of a monopile with a diameter of 8.2 meters generates an unmitigated sound exposure level between 175-185 dB re 1 µPa^{2}s for a single pile strike (SEL_{SS}) at 750 meters from the pile driving site. This corresponds to a sound pressure level of 195-207 dB re 1 µPa. Installation of monopiles with a diameter of 14 meters, have not been conducted yet, however by extrapolating the curves in figure 7.3 to a 14 meter monopile (and back calculating from 750 meters to 1 meter), sound exposure levels of 229.7 dB re 1 µPa^{2}s at a distance of 1 meter from the pile driving site can be expected for an unmitigated pile driving signal.

The main part of the underwater noise energy from pile driving is below 10 kHz. A generalized spectrum of the underwater noise from pile driving is shown in Figure 6.4. The frequency content of the underwater noise is important when assessing the

[3] Depending on the substrate type in the development area it can be necessary with pre-drilling before the monopile can be installed in the seabed. In this case, it is expected that the underwater noise will be significantly reduced compared to pile driving without pre-drilling, especially the cumulative underwater noise (acoustic energy). It is however, expected that the installation period will be longer as there will be breaks in the piling activity while the pre-drilling is going on.

impact on the different species of marine mammals as they do not hear equally well at all frequencies.

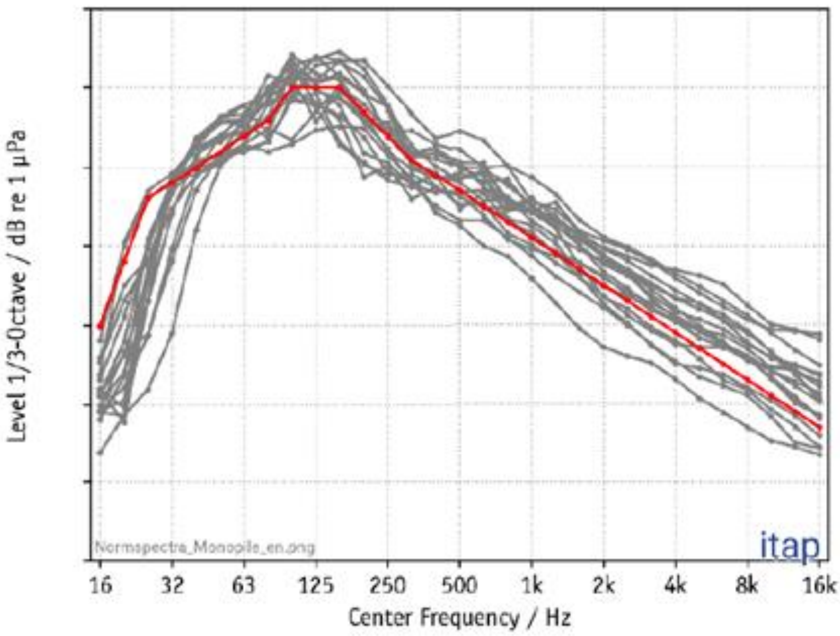


Figure 6.4: Pile driving frequency spectrum (grey lines) measured at 750 m for monopiles with diameters of minimum 6 m. The red line indicates the averaged spectrum (Bellmann, et al., 2020).

The main energy of pile driving noise is below a few kHz (Figure 6.4), where especially porpoises have a poor hearing (Figure 4.2). Because of the very high energy level of pile driving noise, there is still some energy at higher frequencies, where both seals and porpoises have a good hearing. This can potentially lead to negative impacts on the marine mammals near the pile driving site.

6.2.2.1 *Acoustic trauma*

Very loud, impulsive sound (e.g., a shock wave) is capable of inflicting direct tissue damage (acoustic trauma). There is limited information about blast injuries in marine mammals. However, Tougaard and Mikaelsen (2018) argued that a sound pressure level of 226 dB re 1 µPa may cause acoustic trauma in small marine mammals, based on blasting injuries on human divers, that have approximately the same lung volume as smaller marine mammals (lung volume is believed to be a major factor determining vulnerability). Such high acoustic pressures are only encountered in connection with underwater explosions, not relevant for the offshore wind farm, or perhaps very close to the monopile (<tens of meters) during pile driving. It is therefore not considered relevant in the assessment, as it is unlikely that any marine mammal will be this close at the onset of pile driving.

6.2.2.2 *Auditory Threshold shift (TTS and PTS)*

Pile driving noise exposure can result in a decrease in hearing sensitivity either permanent or temporary, termed threshold shift. If hearing returns to normal after a recovery time, the effect is a temporary threshold shift (TTS); otherwise, it is a permanent threshold shift (PTS). TTS is considered auditory fatigue, whereas PTS is considered injury (Southall, et al., 2007). Sound intensity, frequency, and duration of exposure are important factors for the degree and magnitude of hearing loss, as well as the length of the recovery time (Popov, et al., 2011). Recovery from small amounts of TTS is fast (minutes to hours) and complete, whereas large prolonged exposures to noise, where the ear is re-exposed to TTS inducing sound pressure levels before it has had time to recover from previous TTS, may result in a building TTS, that can result in permanent threshold shift (PTS) (Ketten, 2012).

TTS has been studied in both harbour porpoises and seals (see reviews from (Southall, et al., 2007; Southall, et al., 2019)). TTS is in general localised to frequencies around and immediately above the frequency range of the noise inducing the TTS. TTS induced by low frequency noise typically affects the hearing at lower frequencies (Kastelein, et al., 2013c). However, at higher noise levels TTS can also be measured several octaves beyond the center frequency of the noise (Kastelein, et al., 2015; Kastelein, et al., 2016)

Lucke et al. (2009), exposed harbour porpoises to impulsive airgun signals to study TTS. TTS of more than 6 dB was measured after a single exposure to a very intense signal of 200 dB (peak-peak) re 1 µPa or SEL of 164 dB re µPa^2s unweighted (broadband). In another study performed by Kastelein et al. (2015) a harbour porpoise was exposed to playbacks of pile driving sounds. During exposure sessions, the average received SEL of a single pulse (SEL_{ss}) was 146 dB re µPa^2s, unweighted. Within each exposure session, the animal was exposed to 2760 playbacks of pile driving strikes with an inter-pulse interval of 1.3 s, resulting in a total exposure duration of 60 min and a cumulative sound exposure level (SEL_{cum}) of 180 dB re µPa^2s unweighted. The maximum TTS found after 1 h exposure was 3.6 dB at 8 kHz, and the hearing recovered within 48 min after exposure (Kastelein, et al., 2015). Other studies with longer noise exposure at lower intensity levels in the low frequency range (1-4 kHz; Kastelein et al. 2012, Kastelein et al. 2013, Kastelein et al. 2014) have also resulted in significantly higher thresholds compared to the threshold of Lucke et al. (2009).

Two conclusions can be drawn from the TTS studies on harbour porpoise: 1) TTS can be induced in different ways: A single intense impulsive noise can be sufficient to induce TTS or repeated impulsive noise at a lower energy levels can induce a similar TTS. Thus TTS (and also PTS) is best described and estimated by the cumulated sound exposure level over time (SEL_{cum}). 2) Extrapolating between different impulsive noise sources (like e.g., airgun signals and pile driving signals) may not be appropriate because of the different TTS levels.

PTS in cetaceans has not been documented, however a very strong TTS of 44 dB was accidentally induced in the Yangtze finless porpoise (Popov, et al., 2011). PTS thresholds are estimated by extrapolation from TTS thresholds and a noise exposure that induces 40-50 dB of TTS will most likely induce PTS (Southall, et al., 2019).

TTS in a harbour seal exposed to longer duration noise was investigated twice (Kastak, et al., 2005; Kastelein, et al., 2012b). Kastak et al. (2005) were able to induce 6 dB TTS after 25 min exposure to 152 dB re 1 µPa using octave band noise centered at 2.5 kHz. Kastelein et al. (2012b) found that TTS of approximately 6 dB was induced after 60 min exposure to 136 dB re 1 µPa octave band noise centered around 4 kHz.

PTS was accidentally induced in a harbour seal by Kastak et al. (2008), where the seal was exposed to a 60 s tone at 4.1 kHz at a total SEL of 202 dB re. 1 µPa^2s. A second experiment produced a very strong TTS at 44 dB (considered to be very close to PTS), also by accident, by exposure to 60 minutes of 4 kHz octave band noise at a SEL of 199 dB re. 1 $\mu Pa^2 s$ (Kastelein, et al., 2013b).

As described above the underwater noise from pile driving can lead to TTS and PTS in the frequency range where the energy of the signal is located. PTS serves as a well-defined and precautionary criterion for injury in porpoises and seals. However, there is very limited knowledge on both the short-term and long-term consequences of TTS in marine mammals. Tougaard and Mikaelsen (2020) concluded that, the consequences for a porpoise suffering of a small elevation in hearing threshold at low frequencies, which recovers completely within a few hours at most (Popov, et al., 2011), are likely to be very low. TTS induced by pile driving noise occurs at very low frequencies, well outside the frequencies used for echolocation and communication (Kastelein, et al., 2015). Therefore, it is plausible that neither echolocation, nor communication between mother and calf will be affected by TTS induced by pile driving noise. The overall effect of inducing small amounts of TTS in porpoises because of pile driving will most likely not cause a reduction in long-term survival and reproduction of the animal, because of the short duration.

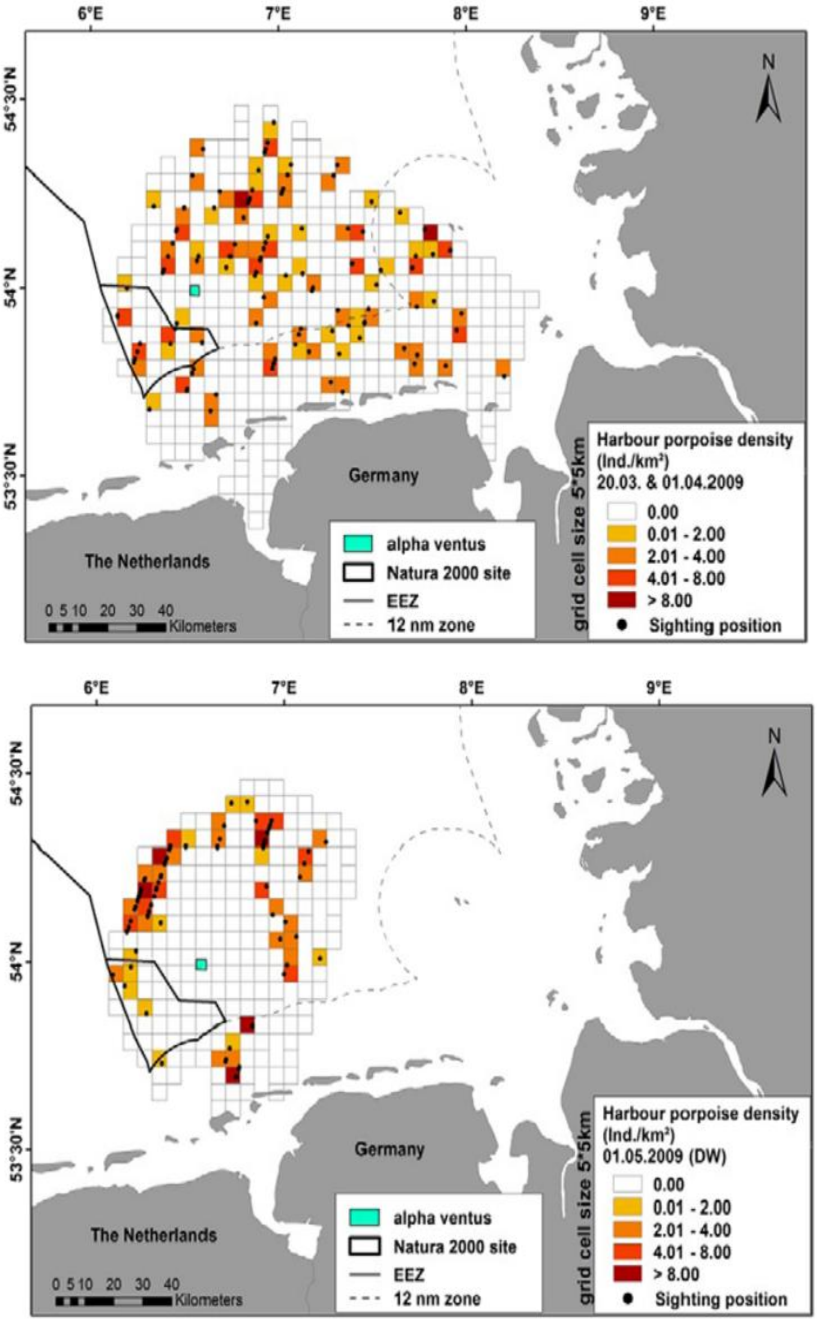
6.2.2.3 *Behavioural effect of pile driving noise*

Behavioural responses of marine mammals can vary significantly from small changes in behaviour e.g., increase in swimming speed or a short interruption in feeding behaviour (Dyndo, et al., 2015) to more severe behavioral changes like panic or fleeing responses. In worst-case situations a fleeing response can increase the risk of mortality due to bycatch in gill nets or separation of calves from mothers. Severe behavioural reaction could therefore have implications for the long-term survival and reproductive success of individual marine mammals. Furthermore, repeated pile driving noise in one area (where several offshore wind farms are installed) may cause long term effects if pile driving events are occurring frequently (Rose, et al., 2019). All individuals might not return to the area after being displaced by multiple piling events and are therefore deterred from a specific area. Multiple disturbances may reduce fitness, and consequently affect the population level over several years. However, drawing conclusions from non-lethal disturbance effects to population-level consequences remains challenging (Pirotta, et al., 2018). Although quantitative models are under development to provide a better understanding of the link between behavioural disturbance and effect on population level (King, et al., 2015; Nabe-Nielsen, et al., 2018) such models are uncertain, as they use either expert judgement, strongly simplified relationships and/or include informed assumptions (Pirotta, et al., 2018).

The Gescha 2 project analysed the "long term trends" of impact on harbour porpoise densities during and after the construction of eleven offshore wind farms and offshore convert platforms built in the German North Sea and adjacent Dutch waters in the period 2010-2016. The project did not find a negative impact on the porpoise activity in the area related to the installation of several adjacent offshore wind farms (Rose, et al., 2019).

The knowledge of avoidance reactions of harbour porpoises to pile driving noise during construction has increased during the last ten years. The studies cover both installations with unmitigated pile driving (Tougaard, et al., 2009; Brandt, et al., 2011; Dähne, et al., 2013) and installation where mitigation measures have been applied (e.g. the use of air bubble curtains) (Dähne, et al., 2017; Nehls & Bellmann, 2016; Rose, et al., 2019; Brandt, et al., 2018). A single illustrative example, from the German wind farm Alpha Ventus, is shown in Figure 6.5.

Figure 6.5: Porpoise observed from aerial survey before (top) and during (bottom) pile driving at the German offshore wind farm Alpha Ventus. The turquoise indicate the position of the pile driving position (Dähne, et al., 2013).



For unmitigated pile driving installations, the results showed displacement and/or disturbance of the behaviour of porpoises out to distances of 15-34 km from the piling site during pile driving (Tougaard, et al., 2009; Brandt, et al., 2011; Dähne, et al., 2013; Rose, et al., 2019). The duration of deterrence/disturbance appears to be in the range of some hours to at most a day after end of pile driving (Brandt et al. 2011, Dähne et al. 2013, Brandt et al. 2018). Based on the maximum reaction distances, the lowest sound level capable of disturbing porpoises has been estimated to be about 140 dB re. 1 μPa²s (SEl_{ss}), unweighted (Dähne, et al., 2013; Brandt, et al., 2018). The behavioural reaction of porpoises appears to be graduated with distance from the pile driving site, such that fewer animals respond and/or the response of the individual animals becomes less severe, the further from the pile driving site (e.g. Dähne et al. 2013). A study by Graham et al. 2019 studied the behavioural responses of harbour porpoises during the 10 months installation period of the Beatrice offshore wind farm in the North Sea in 2017 at 84 wind turbine locations using 2.2-meter steel piles. Each steel pile was hammered into the seabed. The passive acoustic monitoring of porpoises showed a 50% probability of response within 7.4 km at the first location piled, decreasing to 1.3 km by the final location. For the relationship with unweighted single-pulse SEL, there was a greater than or equal to 50% chance of porpoises responding in the 24-h period after piling to unweighted SEL of 144.3 dB re 1 μPa^2s at the first location piled, increasing to 150.0 dB re 1 μPa^2s by the 47^{th} location and 160.4 dB re 1 μPa^2s by the final location. This study shows there is a clear tendency for habituation in the behavioural responses of harbour porpoises (Graham, et al., 2019).

Application of mitigations measures cause a marked reduction in impact ranges compared to installation without mitigation measures. Pile driving using mitigations measure caused impact ranges of 10-15 km (Dähne et al 2017; Rose et al 2019), during installation of DanTysk Offshore wind farm in the German part of the North Sea. Pile driving was conducted both without mitigation measures and with the application of either a single big bubble curtain (BBC) or double big bubble curtains (DBBC) (Dähne, et al., 2017). With the DBBC the lower underwater noise level caused a reduction in habitat loss (disturbed area) by 75 % compared to pile driving without mitigation measures. For the installation of the offshore wind farm Trianel Windfarm Borkum Phase I, mitigated piling, also led to a reduction of the disturbed area by 90 % compared to non-mitigated piling (Nehls & Bellmann, 2016).

There are only a few studies addressing the avoidance behaviour and impact ranges of seals exposed to pile driving noise. During construction of offshore wind farms in The Wash, south-east England in 2012 harbour seals were equipped with satellite transmitters and the results showed that seal usage (abundance) was significantly reduced up to 25 km from the pile driving site during unmitigated pile driving and within 25 km of the centre of the wind farm, there was a 19 to 83% decrease in usage compared to during breaks in piling (Russell, et al., 2016). Based on the results Russell et al. (2016) suggested that the reaction distance for harbour seals to unabated pile driving was comparable to that of porpoises. On the other hand Blackwell et al. (2004) studied the reaction of ringed seals (*Pusa hispida*) to pile driving on an artificial island in the arctic and saw limited reactions to the noise.

6.2.2.4 Masking

Masking occurs when a sound or noise signal eliminates or reduces an animal’s ability to detect or identify other sounds such as communication signals, echolocation, predator and prey signals, and environmental signals. Masking depends on the spectral and temporal characteristics of signal and noise (Erbe, et al., 2019). Sound processing in the mammalian ear happens in a series of band-pass filters (Patterson, 1974) best described as one-third-octave band filters for marine mammals (Lemonds, et al., 2011). Masking of signals can therefore occur, if there is an overlap in frequency between the signal in question and the underwater noise (1/3 octave noise level).

Compensation mechanisms to overcome masking of communication signals have been described in several marine mammal species either increasing the amplitude of their signal or shifting the frequency of the signal (Holt, et al., 2009; Parks, et al., 2011). Masking can also be overcome by increasing the call duration or call rate making it more probable that a signal is detected or by waiting for the noise to cease (Brumm & Slabbekoorn, 2005).

Porpoises rely heavily on acoustic signals (echolocation) for all aspects of foraging, navigation, sexual displays and in communication between the mother and the calf (Clausen, et al., 2010). However, the emitted signals are in the ultrasonic frequency range between 129-145 kHz (Villadsgaard, et al., 2007; Møhl, 1968), well above the frequency of the main energy in the pile driving and it is therefore unlikely that pile driving noise would mask communication or echolocation in porpoises.

Underwater signals are particularly important in courtship and mating behaviour in seals (Van Parijs, 2003). The communication signals of seals are in the low-frequency range and masking from the pile driving noise may occur. However, harbour seals and grey seals are not known to vocalize outside the context of mating, and this takes place close to the haul-out sites. Thus, pile driving close to a seal haul out can mask the communication signals whereas pile driving occurring far offshore, appears unlikely to have any potential to interfere with communication during mating displays (Tougaard & Michaelsen, 2018).

Passive listening by both seals and porpoises could potentially be masked by pile driving noise. However, pile driving is an impulsive noise source and the duty cycle of a pile driving signal is relatively low, which leaves large gaps in between pulses, where signals can be detected. It is thus difficult to imagine a complete masking of passive listening by pile driving noise.

6.2.3 International guidelines and threshold values

Guidance or threshold values for regulating underwater noise during construction of offshore wind farms (pile driving) have been developed by several different countries and international organizations. However, setting threshold levels is not a simple task and there is not a standardised international guideline on how to assess impact of underwater noise on marine mammals nor on the thresholds that should be used. The efforts began in the late 1990s with seismic surveys and have in recent years been applied to impact pile driving. Early guidance contains no set thresholds but instead addresses more of the visual and technical methods for reducing the impact. In recent years, countries such as Denmark, Germany and the United States have proposed thresholds for impulsive sounds like pile driving noise and a short review of the different approaches is provided in the section below. For a more detailed review see e.g. Andersson et al. (2016) and the specific guidelines mentioned under the different sections.

6.2.3.1 Great Britain

In 2010, the British government published a document in co-operation with the Joint Nature Conservation Committee (JNCC) that presented a protocol for how to limit the potential effects of pile driving on marine mammals (JNCC, 2010).

The protocol did not provide threshold criteria for threshold shift (TTS and PTS) or avoidance behavior. It was rather designed to reduce the risk of injury on marine mammals in the immediate vicinity of the pile driving site. The protocol provided information about the role of Marine Mammal Observers (MMO), and the use of passive acoustic monitoring (PAM) during execution. Around the pile driving site a mitigation zone should be established, with at least a 500-meter radius from the sound source. It was within this area that PAM and MMOs should monitor the presence of marine mammals before pile driving began. In addition, recommendations for ramp-up and possible use of acoustic deterrent devices (ADDs) were discussed. At that time when the protocol was published knowledge on impact from underwater noise from pile driving was limited and the protocol was based on the underwater noise from seismic surveys. In the protocol it was argued that the noise levels from a seismic survey could be equal to those associated with pile driving, and that it was appropriate to adopt similar alleviation measures. However, this should be used with caution, as later studies have shown that there is a significant difference in the nature of the signals. Since the protocol was published our knowledge on impact from pile driving has increased significantly, and so has the size of the monopiles that are being installed. As discussed in section 6.2.2.2, the different signals from pile driving and airguns also result in different TTS inducing noise levels in marine mammals.

It is stated at the JNCC web page, that the guideline is due to be updated (JNCC, 2020).

A later report from JNCC published in (2020) regarding impact on five large Natura 2000 areas suggested that if underwater noise exceeding the threshold for behavioural avoidance responses was only occurring in or below 20% of the relevant[4] area of the Natura 2000 area during one installation episode, and an average of 10% of the relevant area of the Natura 2000 area over the entire installation period, the noise disturbance would not be significant.

is the five areas are very large Natura 2000 areas.. Applying this threshold on other and/or smaller Natura 2000 area might be a too conservative approach and should be used with caution, especially as the some of the Natura 2000 areas in the Southern Baltic Sea are not equally important all year round.

6.2.3.2 *USA*

In 2007 Southall and colleagues (Southall, et al., 2007) published the first scientific guidance regarding noise exposure criteria for marine mammals in relation to underwater noise from e.g., pile driving which founded the basis for the American guidelines (NMFS, 2016). They set acoustic threshold levels for exposure to impulsive anthropogenic noise levels above which marine mammals are expected to experience TTS or PTS.

As marine mammals have different hearing abilities and do not hear equally well at different frequencies, the authors argued, that it is essential to take the hearing abilities of the marine mammals into account when evaluating the impact of a particular sound by weighting the sound after the hearing ability of the marine mammal (called frequency weighting[5]). The hearing of marine mammals differs between species in terms of sensitivity and frequency range. To reflect this variable hearing ability Southall et al. (2007) divided marine mammals into functional groups based on their known or presumed (based on communication signals) hearing frequency range: low-frequency cetaceans, high-frequency cetacean and phocid carnivores (seals) and other carnivores and proposed M-weighted audiograms for each group.

At the time of completion of the first guidelines (2007), no experimental data was available on TTS in harbour porpoises or any other very high-frequency-cetacean

[4] The relevant area is defined as that part of the SAC that was designated on the basis of higher persistent densities for that season (JNCC, 2020)
[5] Frequency weighting consists of a band pass filter that de-emphasis those part of the signal that fall outside the range of best hearing of the marine mammal.

and TTS and PTS thresholds had to be extrapolated from data on TTS in bottlenose dolphins and beluga whales. The situation was the same for true seals (including harbour seals and grey seals) and estimated TTS and PTS thresholds for seals were based on data from bottlenose dolphins, beluga whales and California sea lions. However, since 2007 measurements from both harbour porpoises and harbour seals have become available and harbour porpoises are now one of the best-studied species when it comes to TTS (Southall, et al., 2019).

Based on the latest knowledge and a comprehensive review of the entire literature on TTS and PTS in marine mammals, an updated guidance on TTS and PTS thresholds have recently been provided in the US (NMFS, 2018; Southall, et al., 2019). In the updated recommendations all measurements of TTS in marine mammals are combined with available information on auditory sensitivity in marine mammals (audiograms) to create appropriate frequency weighting curves for the different functional groups. The TTS threshold (for impulsive signals) for very high-frequency cetaceans (including harbour porpoises) is 140 dB re 1 μPa^{2}s (SEL_{cum}) and the PTS threshold is 155 dB re 1 μPa^{2}s (SEL_{cum}). The TTS threshold for phocid carnivores in water (including harbour seals and grey seals) is 170 dB re 1 μPa^{2}s (SEL_{cum}) and the PTS threshold is 185 dB re 1 μPa^{2}s (SEL_{cum}).

The effect of applying frequency weighting is shown in Figure 6.6 were the energy content of a pile driving signal is shown both with and without weighting after the M-weighted audiogram for harbour porpoises.

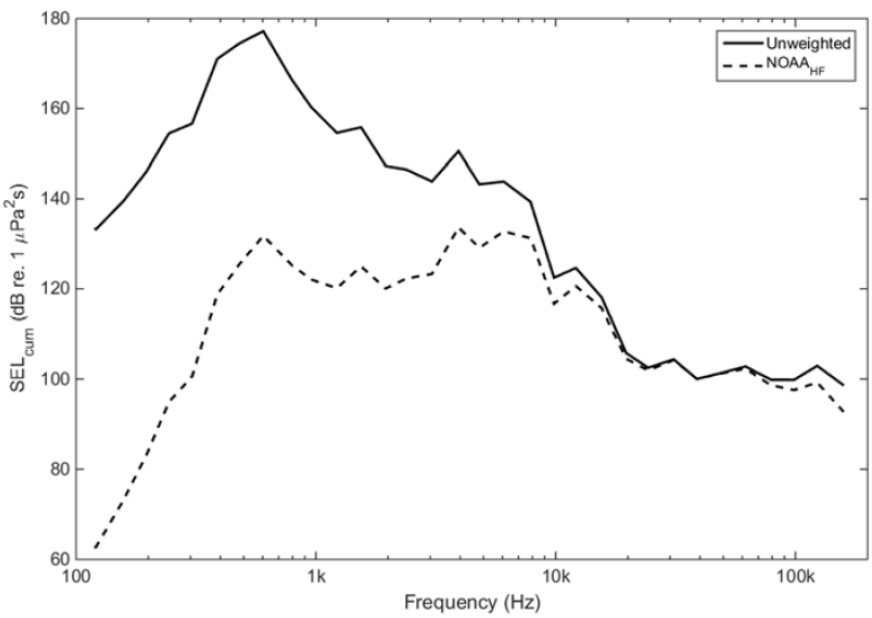


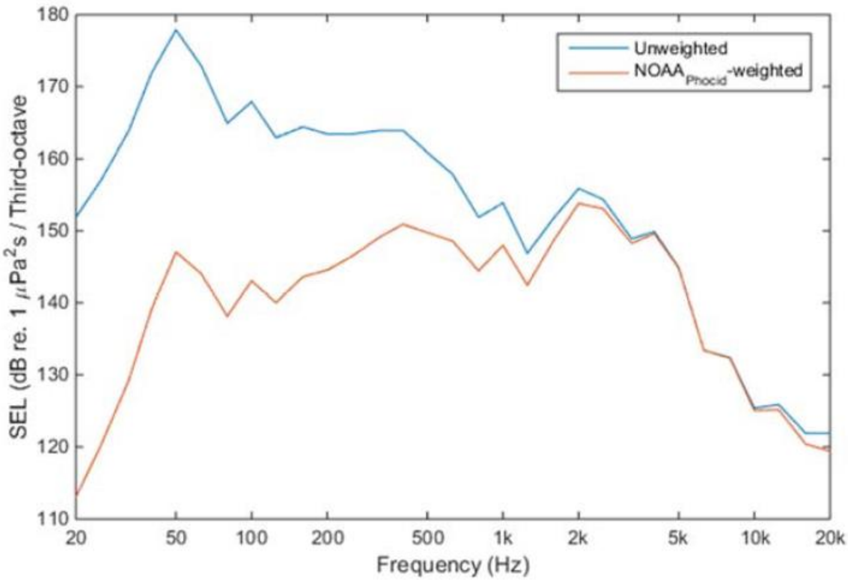
Figure 6.6: Third-octave spectrum of the stimulus used by Kastelein et al. (2015) in his playback studies on harbour porpoises, adjusted to a total SEL_{cum} of 180 dB re. 1 μPa^{2}s (solid line) and the same spectrum weighted with the $VHF_{cetacean}$ weighting function of National Marine Fisheries Service (2016) (Tougaard & Dähne, 2017).

There is a significant effect as harbour porpoises have poor hearing abilities at the lower frequencies where the main part of the energy is in a pile driving signal.

Even though seals have a more sensitive hearing at lower frequencies compared to harbour porpoises, frequency-weighting also has a significant effect on the underwater noise signals, when weighing after the hearing ability of seals. In Figure 6.7

an impulse sound from a low frequency airgun signal is shown unweighted (blue line) and weighted according to the audibility of seals (including harbour seals and grey seals) (orange line).

Figure 6.7: Third-octave spectrum of the loudest airgun pulse used by Reichmuth et al. (2016), both as unweighted (blue) and NOAAphocid-weighted (red) (Tougaard & Michaelsen, 2018).



6.2.3.3 *Denmark*

The Danish guidelines regarding impact pile driving were published in 2016 (Energistyrelsen, 2016). The guidelines build on recommendations from a technical report prepared by a research group in 2015 (Skjellerup et al., 2015) followed by a revision of the recommendations containing updates from the most current research at that time (Skjellerup & Touggard, 2016).

The recommendations stated the PTS (injury) to the marine mammals should be avoided and that appropriate measures (mitigation measures) should be taken to avoid exposure to noise above the PTS threshold. The guidelines do not address how these measures should be put into practice, but the guidelines stated that acoustic deterrence devises and a soft start procedure should be applied. When applying a soft start procedure, the first hammer strikes should be at the lowest possible energy level to allow marine animals to swim as far away as possible before hammer energy was gradually increased as installation progressed.

The technical report pointed out that the use of cumulated sound exposure level (SEL_{cum}) was now widely accepted as a measure for TTS, based on recent scientific knowledge and gave a TTS threshold from repeated pile driving pulses of $SEL_{(cum)}$ 175 dB re 1 μPa²s and a PTS of $SEL_{(cum)}$ 190 dB re 1 μPa²s, unweighted for harbour porpoises and $SEL_{(cum)}$ 176 dB re 1 μPa²s and a PTS of $SEL_{(cum)}$ 200 dB re 1 μPa²s, unweighted for harbour seals. The suggested thresholds for harbour porpoises were based on a precautionary interpretation of Kastelein et al. (2015), that exposed a harbour porpoise to a series of pile driving strikes.

Sounds that fall below the PTS and TTS thresholds can still lead to changes in the behaviour of single individuals. If enough individuals are affected, this can have negative consequences for the entire population. Skjellerup et al. (2015) discussed the thresholds for the management and conservation of entire populations but believed that knowledge (at the time) was too flawed concerning how direct, short-term changes in behaviour could be translated into effects on an entire population. Several studies have examined the behavioural response of harbour porpoises exposed to noise from pile driving and a behavioural threshold (avoidance response) for harbour porpoises of $SEL_{(ss)}$ 140 dB re 1 µPa²s, unweighted was suggested based on the study by Dähne et al. (2013).

Both TTS, PTS and behavioural thresholds recommended by the research group are all based on broadband signals and do not account for marine mammals not hearing equally well at all frequencies. The current Danish guidelines are from 2016, and at that time frequency weighting of thresholds where not included, as there was no consensus at the time on how frequency weighting should be performed. This has since changed, due to recent scientific studies and a thorough review by the National Marine Fisheries Service (NMFS) (2018) and Southall et al. (2019) about the hearing abilities of marine mammals (especially harbour porpoises). It is therefore recommended that thresholds for temporary and permanent hearing loss that include frequency weighting are applied in the future. The Danish guideline is currently under revision and it is expected that thresholds weighted after the hearing abilities of the marine mammal are applied in the future.

6.2.3.4 *Germany*

Germany's Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) has created guidelines for how to protect harbour porpoise from harmful effects during the construction of offshore wind farms in the German exclusive economic zone in the North Sea (BMUB, 2014). The German Federal Maritime and Hydrographic Agency (BSH) has established a threshold for acceptable noise levels. The underwater noise level must not exceed 160 dB re 1 µPa²s ($SEL_{single\ strike}$) or 190 dB re 1 µPa $SPL_{(peak\text{-}peak)}$, unweighted at 750 meters away from the piling site. The 160 dB re 1 µPa²s limit was based on the results found by Lucke et al. (2009), where TTS was induced in a harbour porpoise exposed to a single air gun pulse. Furthermore, the installation time most not exceed 3 hours. With the set guidelines, disturbances are expected within a radius of 8 kilometers around the source as the calculated noise levels are expected to decline from SEL 160 dB re 1 µPa²s (750 meters), unweighted to SEL 140 dB re 1 µPa²s (8 kilometers), unweighted, which are thresholds previously shown to have caused avoidance and flight in harbour porpoises (Dähne, et al., 2013). In areas where noise levels are above the 160 dB re 1 µPa²s threshold value, intrusive methods such as acoustic deterrent devices should be used to minimize the risk of injury to the animals (BHS, 2013).

The German guidelines focus on a single pile driving strike and do not include thresholds for the cumulated sound exposure level (SEL_{cum}), that is the appropriate measure to estimate TTS and PTS thresholds and should therefore be used with caution. Furthermore, the German guideline is based on the study by Lucke et al. 2009, that induced TTS in porpoises using airgun signals as a sounds source and not a pile driving signal. Since the German guideline was published significantly more knowledge about how pile driving noise affect both harbour porpoise and seals showing higher TTS thresholds compared to the threshold found by Lucke et al. (2009)

(see section 6.2.2.2 for more details), further supporting that the German TTS threshold should be used with causing.

6.2.3.5 Sweden

Sweden does not have established guidelines for impact pile driving, however in 2016 Andersson et al. published a review describing a framework for regulating underwater noise during pile driving with a focus on both marine mammals and important and relevant fish species in the Swedish waters. Andersson et al. (2016) suggested a threshold for TTS of 175 dB re 1 μPa²s (SEL_{cum}), unweighted and a threshold for PTS of 190 dB re 1 μPa²s (SEL_{cum}), unweighted. The suggested thresholds were based on the work by the Danish working group (see section 6.2.3.3) and were thus based on unweighted thresholds.

6.2.4 Applied threshold criteria for TTS, PTS and behaviour

6.2.4.1 TTS and PTS thresholds

There are different approaches in the different countries when it comes to estimating impacts from pile driving on marine mammals. Based on the newest scientific literature it is recommended that the cumulated sound exposure level and frequency weighting is used to estimate TTS and PTS (se section 6.2.2.2 and section 6.2.3). Therefore, auditory frequency weighting will be applied following the National Marine Fisheries Service (2018) and Southall et al. (2019). Table 6.1 shows the used thresholds for harbour porpoise and seals.

Table 6.1: Weighted thresholds for TTS and PTS for very high frequency hearing cetaceans (including harbour porpoises) and phocid seal. From National Marine Fisheries Service (2018) and Southall et al. (2019).

Species	Impact	Threshold
Harbour porpoise	PTS	155 dB re 1 μPa²s (SEL_{cum})
	TTS	140 dB re 1 μPa²s (SEL_{cum})
Seals	PTS	185 dB re 1 μPa²s (SEL_{cum})
	TTS	170 dB re 1 μPa²s (SEL_{cum})

6.2.4.2 Avoidance behavior threshold

In several of the international guidelines a behavioural threshold of 140 dB re 1 μPa²s (SEL for a single strike), unweighted is used for harbour porpoises (e.g. Germany and Denmark). The thresholds are based on empirical data from e.g. the study by Dähne et al. (2013) were harbour porpoise reaction distances were monitored during unmitigated pile driving in the North Sea. Based on the maximum reaction distances, the lowest sound level capable of disturbing porpoises was estimated to be about 140 dB re. 1 μPa²s, expressed as single pulse, unweighted sound exposure level. This threshold is applicable to pile driving noise without mitigation measures in general, however for piling with application of a noise abatement systems, it should be used with caution, as the different noise abatement system efficiencies generally increase with frequency, which means that the dampening effect will most likely be underestimated (Tougaard, et al., 2015; Tougaard & Dähne, 2017). In addition, there are several different noise abatement systems and often a combination of different systems is applied in praxis. The different systems do not dampen in the same way, thus a single threshold that is applicable to all the different mitigation solutions is questionable.

Tougaard et al. (2015) suggested another theoretical approach where the behavioural avoidance thresholds are related to the hearing abilities of harbour porpoise. A review of results from behavioural reactions to noise in wild porpoises was performed by Tougaard et al. (2015) and based on the review the authors proposes a generic response threshold of a sound pressure level 40-50 dB above the hearing threshold (audiogram) of the porpoise, which corresponds to about 100 dB re. 1 µPa VHF-weighted. The authors also suggested that in addition to frequency weighting, the sounds should also be averaged over an appropriate time window, approximating the auditory integration time of porpoise ears (Tougaard, et al., 2015), which is on the order of 0.125 s. This coincidentally is very close to the duration of pile driving pulses, which means that any adjustment for sound duration is of little importance for these types of sound. In the present report a behavioural threshold for harbour porpoises at 100 dB $SPL_{RMS\text{-}fast}$ VHF-weighted is therefore applied.

Tabel 6.2: Weighted thresholds for behavioural avoidance responses for harbour porpoises.

Species	Impact	Threshold
Harbour porpoise	Behavioural avoidance response	100 dB re 1 µPa ($SPL_{RMS\text{-}fast}$)

There is a general lack of quantitative information about reaction distances for both harbour seals and grey seals. However, seals are generally considered less reactive to noise than porpoises (Blackwell, et al., 2004; Mikkelsen, et al., 2017), and although some studies indicate that they react as far away from pile driving noise as porpoises do (Russell, et al., 2016) there are no indications that they are more responsive to noise than porpoises.

6.2.5 Underwater noise modelling

The underwater noise modelling used in this report builds on the recommendations of Skjellerup et al. (2015,2016) and the Danish ministry of Energy (Energistyrelsen, 2016), where the cumulated sound exposure level (SEL_{cum}) is modelled over the time period it is estimated to take to complete pile driving of one monopile (as it is assumed that one pile will be installed per day). The cumulated sound exposure level will be used to estimate the distances where TTS will occur.

In the calculations it is considered that a soft start procedure will be applied. At the onset of the piling process the piling strokes are conducted with low energy. The energy per stroke then increases gradually until the full energy per stroke is applied. With increasing amount of energy, the emitted noise increases as well, allowing the porpoises to move out of the construction site before the noise becomes physically dangerous to them. It is also included that the exposed animals will flee from the noise during piling at a speed of 1,5 m/s, which is a precautionary estimate for both seals and harbour porpoise (Tougaard & Michaelsen, 2018).

Underwater noise modelling has been conducted for one position in the eastern area and for two positions in the western. The positions are chosen as worst case positions where the largest underwater noise propagation is expected. The modelling was conducted for March which is a worst-case regarding sound propagation (highest sound propagation). For the two positions in the western area there are no significant difference in the calculated underwater noise propagation (se section 7 in Technical report for underwater sound propagation.

The worst-case installation scenario covers installation of monopiles with a diameter of 14 meter. The installation scenario is based on a realistic conservative installation procedure in relation to the needed hammer energy (source level), number of strikes and time required to complete piling and a realistic generalized soft start/ramp up phase (Table 6.3).

Table 6.3: Installation scenarios for installation of a monopile with a diameter of 14 meter.

	Scenario 1
Foundation	Monopile
Pile diameter	14 meters
Number of foundations	129
Hammer Energy (HE)	7.000 kJ
Source level	229.7 dB SEL@1m
Number of pile strikes	10,4000
Piling driving sequence (soft start/ramp up phase)	200 at 15 % max HE with 30 strikes/min 1400 at 20 % max HE with 60 strikes/min 500 at 40 % max HE with 50 strikes/min 500 at 60 % max HE with 50 strikes/min 1000 at 80 % max HE with 50 strikes/min 6800 at 100 % max HE with ~24 strikes/min
Installation time	~6 hours
Mitigation measure	Big Bubble Curtain (BBC)

As it is assumed that no PTS is allowed, the underwater noise modelling has been conducted with the application of mitigation measures, big bubble curtain (BBC) (for a description of different mitigation measure see section 14.2). It is important to emphasize that even though a specific noise mitigation system has been applied in the underwater noise modelling (showing that it is possible with the available mitigation solutions to provide significant mitigation of the underwater noise), installation will not be bound to the suggested mitigation system. The installation will occur in the future (in a few years) and at the moment the technological development regarding mitigation systems related to pile driving is moving at a fast pace. Therefore, other mitigation solutions and/or more efficient mitigation solutions might be available at the time of installation. If other types of mitigation solutions are applied, it should be sufficient to prevent surpassing the modelled impact distances.

6.2.6 Airborne noise

Pile driving does not only generate underwater noise, but also airborne noise. Harbour porpoises will not be affected by the airborne noise, as the stay in the water their entire life and only go to the surface to breathe. Seals on the other hand are adapted for a life in both water and on land (amphibious). It is especially at their resting and breeding grounds on land, seals can be disturbed by the airborne noise. Nysted offshore wind farm, built in 2002/2003, consist of 72 pc 2.3 MW turbines. The offshore wind farm is located approximately 4 km from an important seal colony for both harbour seals and grey seals. During both the construction and operational phases, the impacts on seals at the colony was monitored (Edrén, et al., 2010). There was a change in seal behavior during the construction phase when pile driving took place, as the number of seals resting at the seal banks was reduced to 20-60

% of the number before pile driving was initiated. However, the effect was short term, and seals returned to the sand banks shortly after pile driving was completed. They returned in the same numbers as before the wind farm was built (Edrén, et al., 2010).

6.2.7 Ship traffic, ship noise, and noise from drilling activities

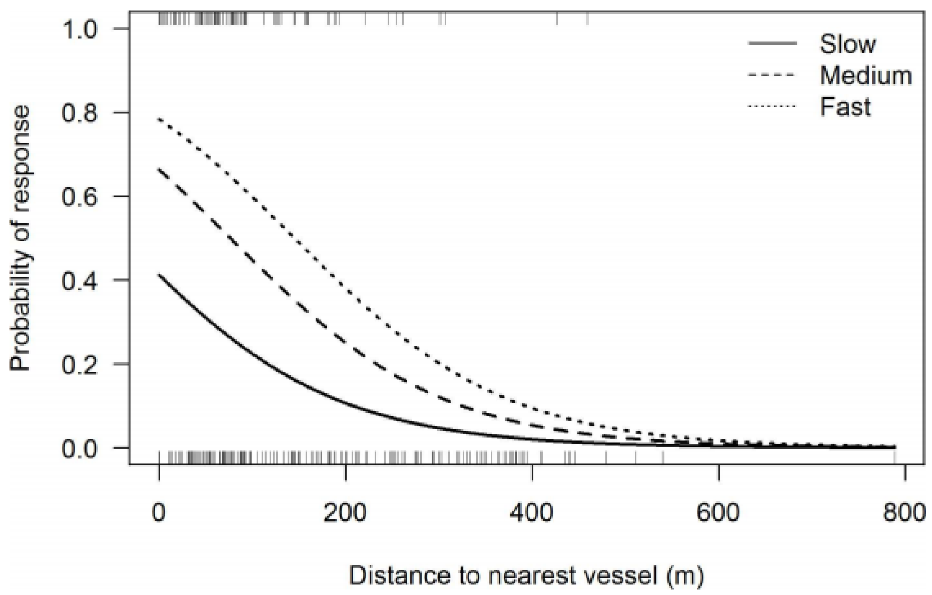
About 75 % of the anthropogenic underwater noise is caused by ships (ICES, 2005). Ship noise is suspected to have caused an increase in the ambient ocean noise level of about 12 dB during the latter part of the 20th century (Hildebrand, 2009). During construction, an increase in ship traffic is expected. Most of the underwater noise comes from the ship's propeller. The underwater noise has an uneven distribution in the water column and around the ship. As the propeller is positioned a few meters below the water surface, the emitted noise from the propeller will be reflected when it hits the underside of the water surface, resulting in a strong downward underwater noise pattern (Gassmann, et al., 2017). The propagation of the underwater noise in the surrounding water depends on the frequency content of the underwater noise, the surrounding environment (e.g. temperature, salinity and depth) and factors such as sailing speed, size of the ship, cargo etc. (Wisniewska, et al., 2016; Erbe, et al., 2019; Urick, 1983).

It is expected that both small and fast boats as well as larger, slower moving vessels will be used during the construction work. Underwater noise from smaller boats is measured to have a noise level of between 130-160 dB re 1 µPa@1meter (Erbe, 2013; Erbe, et al., 2016), while the underwater noise levels from larger vessels is measured to be up to 200 dB re 1 µPa@1 meter (Erbe & Farmer, 2000; Simard, et al., 2016; Gassmann, et al., 2017). Most of the underwater noise is generated by the motion of the ship's propeller causing cavitation (Ross, 1976), where "clouds" of gas bubbles formed behind the rotating propeller collapse. This generates broad-band underwater noise with energy at frequencies from a few Hz to 100 kHz (Ross, 1976). Studies show that the underwater noise levels increase when the ship is maneuvered, such as when the ship backs, or thrusters are used to hold the ship at a certain position (Thiele, 1988). In a recent Danish study, the underwater noise from several different types of ships was measured, and it was found that the frequency content was broadband from 0.025 to 160 kHz, which is in a frequency range where it can potentially have a negative effect on marine mammals (Hermannsen, et al., 2014). However, the main energy is at low frequencies (>1 kHz) (Erbe, et al., 2019), where especially porpoises have poor hearing (Figure 4.2).

The degree of negative impact caused by ship noise during the construction phase depends on the type and number of ships used but also on the baseline situation in the area, whether the area is dominated by heavy ship traffic or not. There is a risk that persistent ship noise can cause temporary threshold shift (TTS) in porpoises. A study by Kastelein and colleagues (2012a) found that porpoises exposed to prolonged low frequency noise centered at 4 kHz could develop TTS at energy levels between 166-190 dB re 1 µPa^{2}s. A similar study on harbour seals, showed that harbour seals exposed to a prolonged low frequency noise centered 4 kHz could develop TTS at energy levels between 151-190 dB re 1 µPa^{2}s (Kastelein, et al., 2012a).

There is limited knowledge about how marine mammals are affected by ship noise. The largest impact of ship noise, however, will be in the form of masking of the marine mammals' communication signals as well as potential behavioral changes e.g. changes in their foraging pattern (Richardson, et al., 1995). A recent study examined the relationship between ship noise and harbour porpoise hunting behaviour and found initial signs of short-term behavioural changes because of the ship noise (Wisniewska, et al., 2016). Dyndo et al. (2015) concluded that ship noise can lead to avoidance responses in harbour porpoise out to more than 1 km. Another study conducted on Black Sea harbour porpoise in the Istanbul Strait examined changes in behaviour caused by different types of ship traffic (cargos, speed boats, fishing boats and vessels, ferries and research boats). It was shown that the speed of the ship and distance to the porpoise have a significant effect on the probability of response of the porpoises (Bas, et al., 2017). The correlation between distance to the nearest ship and the probability of porpoises responding by changing their swimming direction is shown in Figure 6.8.

Figure 6.8: Probability of harbour porpoises showing a response on their swimming direction towards ships as a function of the distance to the nearest ship for a slow, medium and fast moving ship (Bas, et al., 2017).



The study shows that porpoise is more likely to change behaviour, if ships are within a 400 m radius of the porpoise. At any given ship speed there is little probability (<10%) of a behavioural reaction if the boat is more than 400 m away. As ship speed increases from slow (<3 knots) to fast (>9 knots), the probability of reaction to the ship 400 m away increases from about 10% to 40%. This study indicates that ships do disturb the animals at close range, but the study found no overall significant effect of the disturbance on the animals' cumulative (diel) behavioural budget (i.e. total amount of time spent on the different types of behaviour) (Bas, et al., 2017).

Furthermore, whether or not a whale exhibits behavioral responses in the vicinity of a ship depends not only on the underwater noise from the ship. A study of baleen whales shows that the direction of a ship is decisive for whether the whale reacts or not. If the ship has a direct course towards the whale, the whale is more likely to react than if the ship moves away from the whale (Richardson, et al., 1995). This has however not been studied in harbour porpoises yet.

In connection with the installation of the inter array cables as well as the foundations, it may be necessary to drill in the seabed in areas where the seabed consists of hard substrate. There are very few measurements of underwater noise from drilling activities (Erbe & McPherson, 2017; Kyhn, et al., 2011). Studies where underwater noise from geotechnical drilling activities have been measured, show that the noise is limited to the low-frequency range with source levels of between 142-145 dB re 1 µPa at 30-2000 Hz (Erbe & McPherson, 2017).

Measurements of underwater noise in connection with test drilling for oil in Greenlandic waters showed that the underwater noise is primarily in the low-frequency range below 1 kHz and with underwater noise levels that are comparable to underwater noise from a large tanker (Kyhn, et al., 2011).

As the knowledge on how ship noise affects marine mammals is limited, there is no consensus on how impact of ship noise should be quantified or assessed (Erbe, et al., 2019). The development area for the Wind Farm is located in an area with pronounced ship traffic and is located in close vicinity to the main ship routes in the southern Baltic Sea, thus it is expected that the area is relatively dominated by low-frequency ship noise (Figure 6.9), and that the marine mammals occurring in the area are adapted to a certain degree of ship noise.

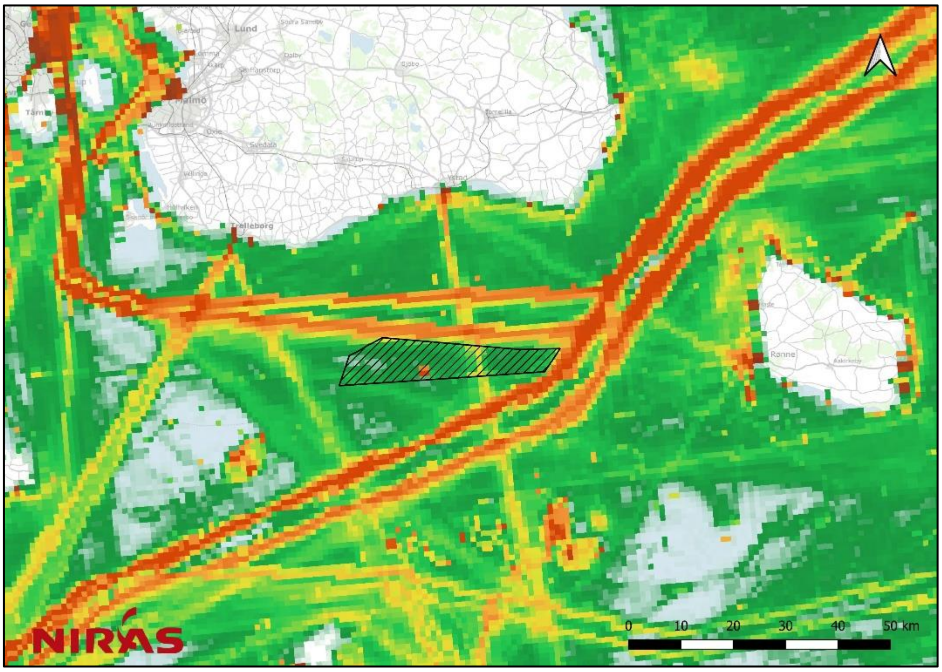


Figure 6.9: Ship density in and near the development area for Triton OWF measured as ship hours per month. Modified after EMODnet 2019.

Based on data from the BIAS-project, the underwater noise level measured in 2000 Hz band is assessed to be above 100 dB re 1uPa in main part of the development area for Triton offshore wind farm, especially in the wither period, where sound tend to travel further, compared to the summer period (https://underwater-noise.ices.dk/continuous/viewonmap).

6.2.8 Sedimentation and turbidity

During the construction phase, periods of increased amounts of suspended material in the water column (and subsequently increased sedimentation) will occur in connection with the installation of foundations, inter array cables, as well as the landfall cable. The increased amounts of suspended material in the water column can reduce the visibility in the water column. In addition, sediment spills can affect marine mammals indirectly by causing a negative impact on their prey.

6.2.8.1 *Harbour porpoises*

Harbour porpoises are adapted to life in the coastal waters, where visibility is often limited. Like other toothed whales, harbour porpoises use echolocation to navigate and the find prey. Echolocation is an active process, where the porpoise emits high-frequency sounds and listens for reflected echoes from e.g. prey or obstacles in the surroundings (Miller, 2010). Verfuß et al. (2009) tested the ability of porpoises to navigate and find prey after their eyes had been covered. Using of echolocation alone, porpoises could navigate and find prey with the same success rate as when they could use both their vision and the ability to echolocate. Echolocation activity (number of transmitted echolocation signals per unit time) remained the same, but the harbour porpoise reduced their swimming speed, when they could not use their vision. Other studies have shown that harbour porpoises forage both during day and night (Wisniewska, et al., 2016; Kyhn, et al., 2018), which supports the idea that the vision is not essential for harbour porpoises to find and catch prey.

It is therefore not expected that harbour porpoises will be directly affected by suspended sediment in the water column. However indirectly, harbour porpoises can be negatively affected by suspended sediment, as fish and benthic fauna potentially can be negatively affected by an increased amount of suspended sediment and subsequent sedimentation, which could lead to a reduction in the amount of prey in and around the construction area for Triton offshore wind farm, at least for a limited amount of time.

6.2.8.2 *Seals*

Both harbour seals and grey seals, are (like harbour porpoise) adapted to life in coastal waters, where they are often exposed to cloudy water due to suspended sediment in the water column after e.g., a storm. Unlike harbour porpoise, seals do not use echolocation to find and catch prey. Studies on harbour seals have shown that they use their vibrissae to find prey in water with low visibility (Dehnhardt, et al., 2001). These tactile sensory organs can - in addition to sensing the prey by direct contact - also detect prey at up to 40 meters by detecting the wake of a swimming fish in the water (Dehnhardt, et al., 2001). This sense together with their hearing ability makes it possible to find prey in water with low visibility where the use of vision is impeded. Grey seals, like harbour seals, have vibrissae, and it is expected that they also use these in water with low visibility to locate and catch prey. It is therefore not expected that seals are directly affected by suspended sediment. However, as mentioned for harbour porpoises, the seals can be indirectly affected by suspended sediment, as fish and benthic fauna can potentially be affected by the increased amount of suspended sediment and subsequent sedimentation.

6.3 Potential pressures related to the operation phase

During the operation phase of the wind farm, habitat changes and noise emissions could affect harbour porpoises and seals. Disturbance due to underwater noise during operation is known to affect marine mammals much less than during installation (Madsen, et al., 2006). In the operational phase, the underwater noise will be significantly less compared to the construction phase, as no pile driving will take place. Thus, the underwater noise in the operational phase will be limited to ship noise and operating noise from the moving wind turbines.

Underwater noise produced by ships during the operation phase will mainly be linked to maintenance and service. Since this includes crew transfer and transport of equipment, normally small vessels or motorboats will be used. It is expected that shipping activity will be less frequent compared to the activity during the construction phase. In addition, habitat changes will occur because of introduction of the foundations and scour protection (artificial reef effect).

6.3.1 Operational noise

Noise emissions which are associated with the operation of wind turbines can be aerodynamic noise and mechanical noise. The aerodynamic noise coming from the spinning rotor is broad-band and relatively unobtrusive. Moreover, the transmission of airborne sound into the water body is limited as the major part is reflected from the sea surface (Richardson, et al., 1995). Therefore, the aerodynamic noise of the wind turbines is not considered as relevant for marine mammals. Nevertheless, seals are able to hear the aerodynamic noise as they regularly raise their head and ears into the air when breathing or resting at the surface.

The mechanical noise that comes from the wind turbines in operation comes from the moving parts of the wind turbine (blades, gears, etc.). Movements from gears are the primary source of noise that is transmitted as vibrations down into the water column primarily through the submerged part of the tower and the foundation (Tougaard & Michaelsen, 2018). As shown in Figure 6.10 the main energy of the underwater noise from operating turbines is in the low frequency area and more specifically at individual frequencies (100 Hz) with associated harmonics at higher frequencies.

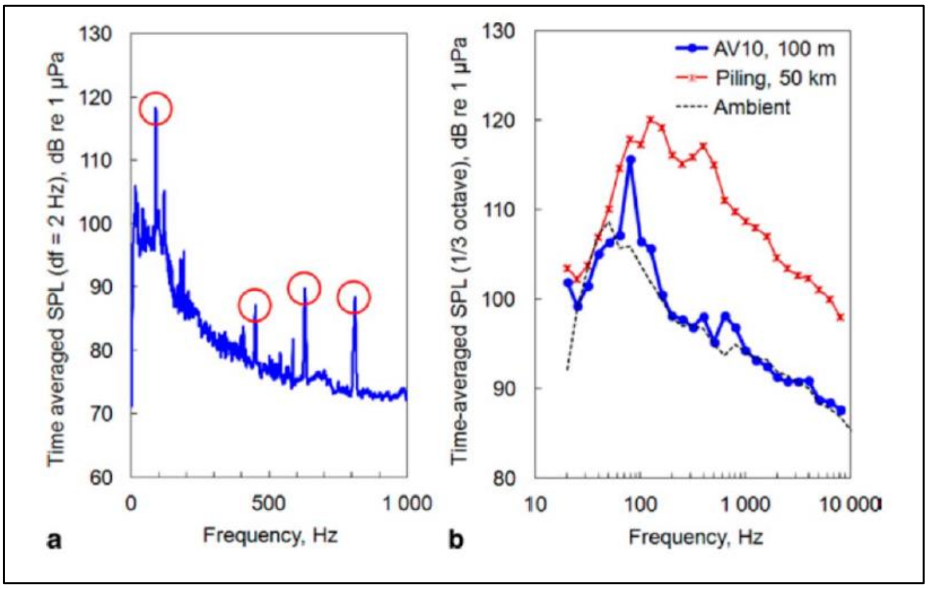


Figure 6.10: Operational noise measured 100 meters from a 5 MW turbine in Alpha Ventus OWF, driving at maximal capacity. A) Frequency content (spectral noise) divided in Hz bands. Red circles indicate the peak frequencies B) 1/3 octave spectrum of the same noise (blue) as shown in A), the background noise and underwater noise from pile driving of monopile measured 50 km form the pile driving site (Betke, 2014).

Several measurements of the underwater noise from wind turbines in operation have been conducted. Measurements of underwater noise from three smaller offshore wind farms; Middelgrunden (2 MW wind turbines), Vindeby (450 kW wind turbines) in Denmark and Bockstigen-Valar in Sweden showed underwater noise levels in the range between 109 and 127 dB re 1 µPa measured 14-20 meters from the foundations. Here the main energy of the underwater noise was in the frequency range below a few hundred Hz (Tougaard, et al., 2009). Similarly, Elmer et al. (2007) measured underwater noise from wind turbines in operation at two Danish wind farms; Horns Rev I (North Sea) and Nysted (Western Baltic Sea), with wind turbine sizes of 2-2.3 MW. When the wind turbines were operated at maximum capacity, underwater noise at 100 meters were measured to have a maximum sound pressure level of 120 dB re 1 µPa with main energy in the low frequency range centered at 125 Hz. The measured underwater noise at 100 meters corresponds to the harbour porpoise's hearing threshold in this frequency range. When the wind turbine is not operated at maximum capacity (at wind speeds below 12 m/s), the measured underwater noise will be significantly lower. Thus, numerous recordings of underwater noise from operating turbines exist and there is a tendency for the radiated noise to increase with increasing turbine size, despite the increase in size the underwater noise from operating turbines are at least 10-20 dB lower than ship noise in the same frequency range (Tougaard, et al., 2020).

Noise from several operating turbines can add up and result in an increased sound level compared to a single wind turbine. A recent study by Tougaard et al. (2020) modelled the cumulative underwater noise from several turbines in a wind farm area consisting of 81 wind turbines. The results show that cumulative noise levels could be elevated up to a few kilometers from a wind farm area under very low ambient noise conditions. In contrast, the results showed that the cumulative noise level from several operating turbines is well below ambient noise levels in areas with high ambient noise level from e.g., from shipping or high wind speed.

As shown in Figure 6.9 the development area for Triton offshore wind farm is located next to important shipping lanes in Southern Baltic, and the ambient noise within the area is dominated by ship noise from the nearby shipping lane. Thus, the development area for Triton offshore wind farm is located in an area with expected high ambient noise levels (dominated by ship noise) and the operation noise from the wind farm is therefore expected to be below the ambient noise level as in the modelled situation in Tougaard (2020).

Harbour porpoises have very poor hearing in the low frequency range where the operational turbine noise has most of its energy. At 125 Hz harbour porpoises have a hearing threshold of 126 dB re. 1 µPa was estimated (Kastelein, et al., 2017). This threshold is so high that the turbine noise is expected to be inaudible to porpoises, unless they are very close to the turbine, within 100 m (Tougaard, et al., 2009).

A recent study shows that porpoises may be attracted to offshore oil and gas platforms despite confirmed elevated underwater noise and are likely exploiting higher prey abundance in the vicinity of such structures. This is possibly due to increased prey availability created by the combined effect of the artificial reef formed by the underwater structure and the local protected area around all platforms where fishery is banned (Clausen, et al., 2021).

Sources of underwater noise associated with oil and gas platforms include production and processing equipment (e.g. pumps, generators, turbines), discharge of produced or cooling water, drilling rigs, stand-by vessels, vessels or helicopters used for transporting personnel and supplies and equipment associated with maintenance operations (Clausen, et al., 2021). As oil and gas operations continue around the clock, the noise level is expected to be continuously elevated around active platforms. Noise from oil and gas platforms is not identical to noise from operating offshore wind farm, however it is still comparable, as it is mainly in the low frequency range and of a continuous character.

Seals have better hearing capabilities within the frequency range of the operating sounds and will therefore probably be able to hear the operational noise at longer distance. However, as the ambient noise is expected to be relatively high within area because of shipping traffic, the ambient noise is expected to be the limiting factor in the low frequency range. Furthermore, seals seem to be more tolerant to underwater noise (Kastelein, 2011; Southall, et al., 2019). This finding is supported by a relatively recent study on seals at the German offshore wind farm Alpha ventus (Russell, et al., 2014). A tagged harbour seal foraged at the foundations of all 12 operating wind turbines, and it clearly preferred the foundation structures over other areas inside the wind farm (see Figure 6.12). Noise from wind farms could therefore potentially also serve at a kind of "dinner bell".

6.3.2 Ship noise – maintenance

In connection with the maintenance of the wind farm during the operational phase, there will be increased shipping activity in the area of the wind farm. This includes transport of crew to and from the wind farm as well as transport of equipment with smaller boats. It is expected that the normal established inspection will occur every 6 months and will be of 3 days duration for the individual wind turbines. In addition, unexpected operating errors etc. may occur, which do not require scheduled inspections and repairs. It is therefore expected that for each wind turbine there will be a need for service approx. 10 times a year (which includes both the annual scheduled inspection and unplanned visits). For a more detailed description of how ship noise and ship traffic potentially affect marine mammals, see 6.2.7

6.3.3 Habitat Changes/loss

The wind turbine foundations and erosion protection will cause a reduction in the naturally occurring habitats (soft bottom substrate) that will be replaced with introduced hard bottom substrates in the form of concrete, rock formations and steel. The changes in the habitat could lead to a change in the composition of the prey items in the development area around the foundations as soft bottom species will be replaced with species that live on hard bottom substrates.

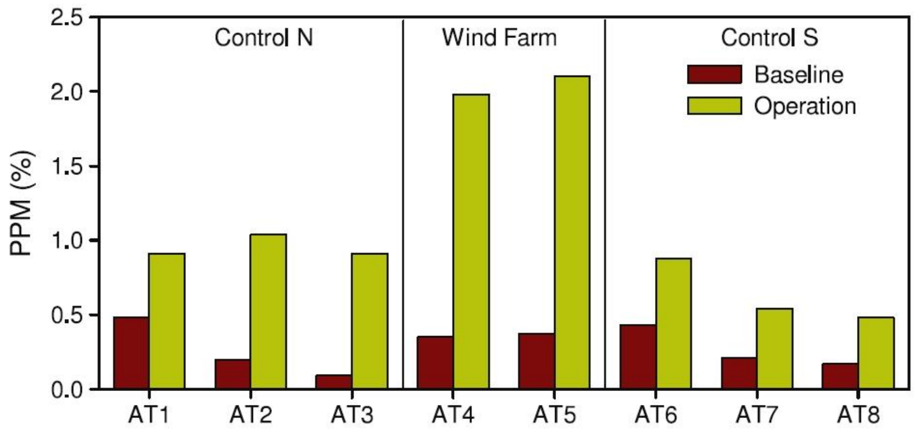
It is expected that the foundations and erosion protection will, after a period of time be able to function as so-called artificial reefs. The new hard bottom substrate at the wind turbine foundations will after some time be overgrown with algae and become a habitat for a fauna consisting of a large number of epibentic invertebrates (bottom-dwelling invertebrates) (Gutow, et al., 2014). This could attract fish, which in turn could mean increased feeding opportunities for the marine mammals and thus could potentially have a positive effect on the marine mammals as all three species of marine mammals are opportunistic feeders. Therefore, it is possible that the group of fish relying on soft bottom habitats could be reduced, but it is highly likely that this will be offset by the creation of a species community that relies on hard substrate (e.g. artificial reefs).

6.3.3.1 Harbour porpoises

Studies on the impact of an operating wind farm on harbour porpoises, has predominantly shown that harbour porpoises return in the same or higher numbers after the wind farm has been build compared to before. During construction there is generally a reduction in the presence of porpoise mainly due to underwater noises caused by pile driving. After construction, the numbers of harbour porpoises in and around the wind farm increase again. However, on the question of whether wind farms are preferred or avoided results are different and possibly site specific. 10 years after the construction of Nysted Offshore Wind Farm in the western part of the Baltic Sea, the harbour porpoise activity (density) was still below what it was before the wind farm was installed (Teilmann & Carstensen, 2012). The potential reasons for this are uncertain, and there is no direct relationship between the construction of the wind farm and the decline in the number of harbour porpoises in the area. One explanation is that the time period during which the baseline studies took place was too short (few months) to give a true picture of the harbour porpoise' activity in the area (Tougaard & Michaelsen, 2018). This explanation is supported by the later establishment of Rødsand 2 offshore wind farm next to Nysted offshore wind farm, where results from Rødsand 2 showed that there were generally more harbour porpoises in the reference area compared to the wind farm area, but that the ratio between the two areas was not affected by the construction of the wind farm, i.e. the relative presence of harbour porpoises within the wind farm area was not affected by the presence of the wind turbines (Teilmann, et al., 2012). The absence of effects in the harbour porpoise density in the area supports the notation that the baseline studies for Nysted offshore wind farm were not adequate to provide a complete and accurate picture of the situation (Tougaard & Michaelsen, 2018).A later study from a UK offshore wind farm found no significant displacement of harbour porpoises during operation. There was a significant reduction in relative harbor porpoise abundance both within and surrounding the Robin Rigg offshore wind farm during construction, but no significant difference was detected between the preconstruction and operational phases (Vallejo, et al., 2017).

A Dutch study showed that the harbour porpoise activity in the Egmond aan Zee wind farm in the Dutch part of the North Sea was higher after the wind farm was in operation, compared to before the farm was built (Scheidat, et al., 2011)(Figure 6.11). The activity level increased in the whole study area because of a general increase of porpoises in Dutch waters. However, the porpoise activity increased disproportionally showing a clear preference for the wind farm area (Scheidat, et al., 2011). The reasons for the preference are unclear and it could be attributed to a foraging area favored due to artificial reef effects, or it could also be caused by an absence of ship traffic in the wind farm (shelter effect), or a combination of both factors.

Figure 6.11: Activity of harbour porpoises within the OWF 'Egmond aan Zee' and two reference areas during baseline monitoring and operation of the wind farm (Scheidat, et al., 2011).



6.3.3.2 Seals

Like harbour porpoises, seals too could be affected by wind farms. Observational data from harbour seals at Horns Rev I offshore windfarm show, that harbour seals enter the wind farm and use the area and its surroundings with intensities as in other areas (Tougaard, et al., 2006). In another study harbour seals were tagged with high resolution GPS tags in the Netherlands and in Great Britain. Harbour seals tagged in Dutch waters entered the offshore wind farm alpha ventus and harbour seals tagged in British waters entered Sheringham Shoal. Some of the tagged seals moved and foraged at random patterns inside the wind farm area, while other seals showed a more structured and predictable foraging strategy. They visited one turbine and stayed around the foundation for a while and then went directly to another wind turbine foundation as shown in Figure 6.12. This results in a very structured movement pattern that demonstrates that foundations were searched systematically for food (Russell, et al., 2014).

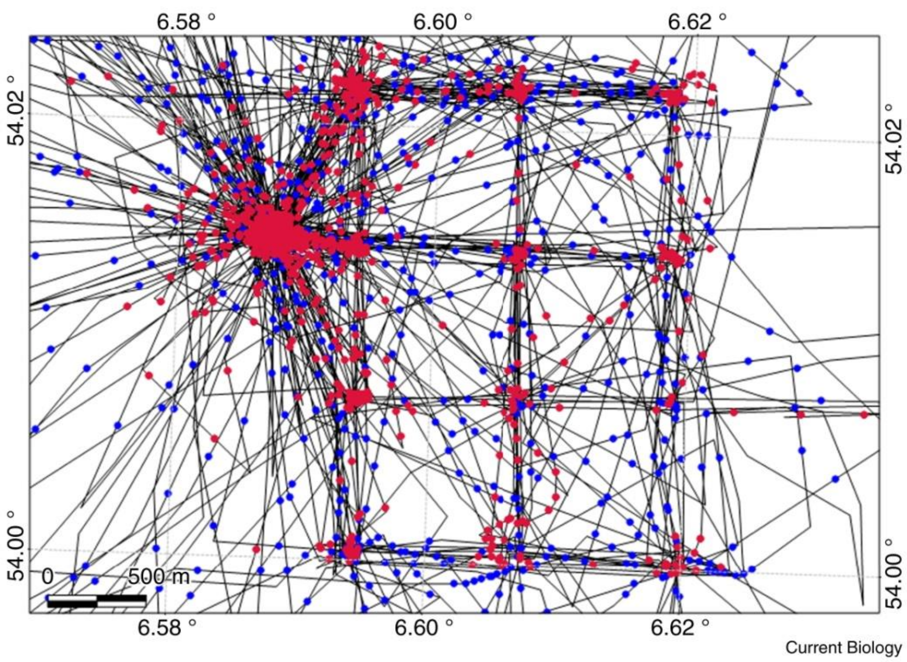


Figure 6.12: Tracks of a tagged harbour seal around the wind farm'alpha ventus' (12 turbines) and the research platform FINO 1 (left of alpha ventus). Points show locations at 30 minute intervals; red indicates greater foraging potential (Russell, et al., 2014).

As with the harbour seals, grey seals were also reported to follow anthropogenic structures such as underwater cables and forage along the cables (Russell, et al., 2014). It is, therefore expected that grey seals will react to wind farms in the same way as harbour seals.

That operating wind farms will not cause seals to avoid the area is further supported by GPS data from both harbor seals and grey seals in the western Baltic as both species enter the Swedish offshore wind farm Lillgrund in the Øresund and Nysted and Rødsand II offshore Wind Farms in the southwestern part of the Baltic Sea. For both areas, data shows that the seals swim into the wind farms while these are in operation (Dietz, et al., 2015; McConnell, et al., 2012).

6.3.4 Electromagnetic fields from high voltage cables

During the operation phase, an oscillating electromagnetic field will arise around the subsea cables (inter-array cables and export cables). The intensity of the field decreases rapidly with increasing distance from the cable (it decreases with the inverse square of the distance to the cable). The impact on whales and seals is therefore assumed to be small. However, whales like some other vertebrates seem to possess the ability to orientate with the help of magnetic fields. Magnetic anomalies might increase the likelihood of strandings (Kirschvink, 1990). But it is unclear how electromagnetic fields might contribute to strandings. Magnetic orientation is still not completely understood, and the underlying sensory systems are not known. If the magnetic senses in whales are similar to those in birds, whales could possibly possess a magnetic map and a magnetic compass. The magnetic map could help the whale to determine its position and the compass to determine its direction. Even just a few meters away from the cable the magnetic field is so reduced that it constitutes only a small part of the overall magnetic field, resulting in no more than a marginal magnetic anomaly (Tricas & Gill, 2011). Therefore, disorientation would only be a problem close to cables and reorientation would be possible as soon as whales leave these areas.

6.4 Potential pressures related to the decommission phase

During decommissioning of the offshore wind farm, impacts on marine mammals similar to those during construction are to be expected. These include underwater noise emissions due to the decommissioning work and the increasing ship traffic as well as increasing sedimentation and turbidity. Ship traffic is likely to be as frequent as during the construction phase. The removal of the wind turbine foundations leads to habitat changes by reversing the changes during construction, it is possible that part of the foundations may be left at the bottom in order not to destroy the artificial reefs. In general, the decommissioning of the wind turbines is expected to be less noisy than the pile driving during construction.

7 Impact assessment of the geophysical survey

Before construction work of the offshore wind farm (installation of foundations and cables) can take place, information of the seabed is needed. Several different types of equipment may be used during the seismic survey, including some types of equipment that generate high underwater noise levels in frequency ranges that partly overlaps with hearing ranges of marine mammals. Based on a screening of the different types of equipment, detailed noise emission calculations have been carried out for the seismic survey equipment (e.g. airguns, sparker, boomer and sub-bottom profilers), that can generate underwater noise levels that may cause avoidance response, temporary (TTS) or permanent (PTS) hearing threshold shifts in marine mammals (for more details see (NIRAS, 2021a)). To assess the impact from the seismic pre-investigation survey the underwater noise modelling has been conducted (behavioural, TTS and PTS ranges) based on a worst case situation, with different types of equipment operation at maximum source levels and without application of mitigation measures. The modelling has been carried out for three positions in the development area for Triton offshore wind farm (see Figure 7.1)

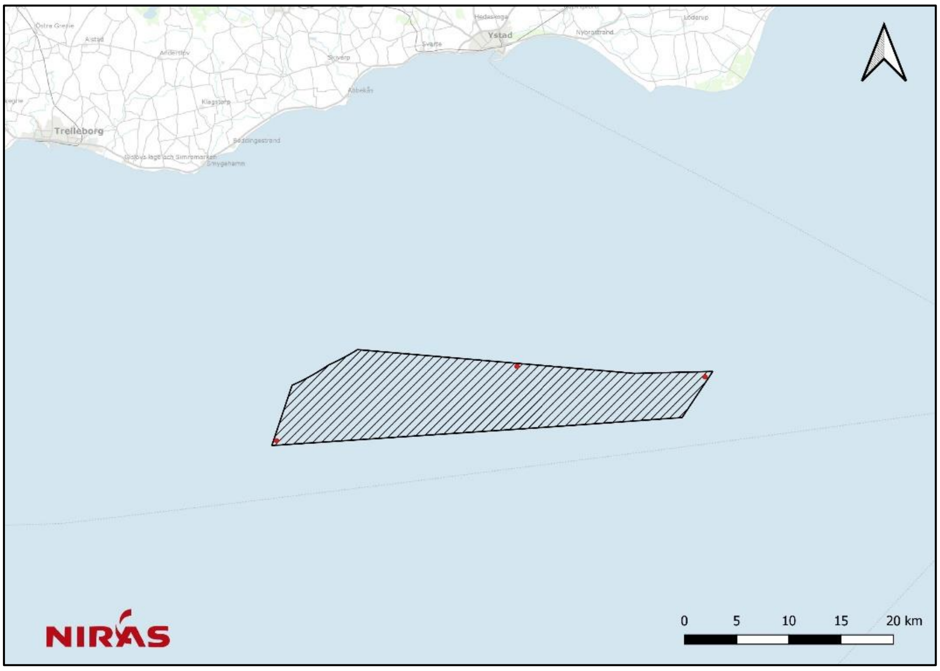


Figure 7.1: Overview over the selected source starting positions indicated by the red stars

Table 7-1: Threshold impact distances for the seismic survey activities split into equipment setup scenarios. The distances for PTS and TTS indicate, at which range of distances, in meters, from the survey vessel, a marine mammal must at least be at the onset of full survey activities in order to avoid each of the given impacts. Results represent worst case survey month of March and without application of mitigation measures.

Equipment scenario	Threshold distance [m]				
	Harbour porpoise			Seal	
	Avoidance Behavior	TTS	PTS	TTS	PTS
1: Sparker Airguns & Innomar (Wind farm area)	6550	1300-3000	425-1050	90-350	< 25
2: Airguns & Innomar (Wind farm area)	3400	1300-3000	425-1050	< 50	< 25
3: Innomar (Cable corridors)	3400	1300-3000	425-1050	< 50	< 25

7.1 Seismic survey in the development area for Triton offshore wind farm

As shown in table 8.1 Equipment scenario 1 will cause the longest impact distances and is considered a worst-case scenario. The assessment is based on this worst-case scenario.

As mentioned in section 4.1.3 the development area for Triton offshore wind farm is located in a transition zone for the Belt Sea and Baltic Proper harbour porpoise populations and the area is at the border of both populations range. The density in the area is low especially compared to the density west of the development area towards Danish waters, which are inhabited by the Belt Sea population of harbour porpoises. It is therefore expected that by far most of the porpoises in the development area for Triton offshore wind farm belong to the Belt Seas population (an assumption also supported by telemetry data from harbour porpoises tagged in the inner Danish waters se Figure 4.7), whereas a smaller fraction, during the winter months, can be from the critically endangered population from the Baltic Proper (approximately 1.19 % se section 4.1.3).

<u>Harbour porpoises - TTS/PTS</u>

Harbour porpoises found within 425-1050 meters from the survey vessel, may be at risk of developing PTS when the equipment is started assuming the equipment is operated at full exposure level without mitigation measure i.e. a soft-start procedures. If harbour porpoises are within 1300-3000 meters of the vessel at the onset of operation, they may be exposed to underwater noise levels high enough to cause TTS.

The risk of harbour porpoises being within the critical distance at equipment startup can be significantly reduced with the application of an appropriate startup procedure. This could include a slow increase in the emitted energy/and or the firing frequency of the equipment over a period of time (softs start/ramp up). This could give the harbour porpoises time to swim out to a safe distance before the equipment is operated at full power.

It is therefore recommended that any seismic survey includes a soft start with ramp up to full power over a sufficiently long period to allow animals time to leave the area. As an example, a 30-minute soft start would allow a marine mammal swimming at 1.5 m/s to reach a distance of 2.7 km before the equipment is operated at full power. Add to that the vessel speed of 4 knots (2.0 m/s), and the resulting distance between fleeing marine mammals and survey vessel will be over 5 km under the assumption that the animal is not fleeing in the same direction as the ship is sailing. It is assessed that a 30-minute soft start procedure would be sufficient to avoid PTS and TTS in harbour porpoises by allowing harbour porpoises in the potentially hazardous zone near the seismic survey vessel to swim away, before the seismic survey is running at full power. If there is a stop of more than 15 minutes in the seismic survey it is also recommended that the equipment is restarted with application of a soft start/ramp up procedure.

In the assessment it is assumed that a soft start procedure will be applied in operation of the seismic survey equipment (e.g. airguns, sparker, boomer and sub-bottom profilers), thus mitigation measures are considered to be a requirement for operation of this type of equipment.

The degree of disturbance of PTS and TTS are ranked as high/medium, however with the appropriate soft start/ramp up procedure, the geographic extent is limited and ranked as local and the likelihood of occurrence is also limited and is ranked as low. Because of the limited survey period, the persistence is ranked as short-term. Therefore with application of an appropriate soft start/ramp up procedure the impact of PTS and TTS is considered as negligible for porpoises belonging to both the Belt Sea population and harbour porpoises belonging to the critically endangered Baltic Proper population (and without consequences for the short-term and long-term status of the populations).

<u>Harbour porpoises - Behavioral response</u>
Harbour porpoises may exhibit avoidance behaviour within approximately 6550 meters of the survey vessel in the worst case scenario. This corresponds to an area of approximately 135 km^2 and can be estimated as the immediate habitat loss during the survey period, which is expected to last few weeks. Because of the limited impacted area, the geographical extent is considered local, and because of the limited survey period, the persistence is ranked as short-term.

Porpoises belonging to the Belt Sea population may occur in the development area all year round. The degree of disturbance is ranked as low/medium for harbour porpoises belonging to the Belt Sea because of the populations favorable conservation status. The impacted area is of limited size (local) and the duration of the disturbance (the survey) is very short-term (few weeks) leading to a short-term persistence. That in combination with the fact that the development area is not a suited habitat for harbour porpoises leads to an assessment of the combined impact, with application of appropriate soft start/ramp up procedure on the Belt Sea subpopulation of harbour porpoises as negligible/minor and without consequences for the short-term and long-term status of the population.

Porpoises from the critically endangered Baltic Proper subpopulation can be found in the impacted area, in the winter months. The degree of disturbance is ranked as high for the Baltic Proper population because of the populations unfavorable conservation status. However, as this population is estimated to be very small, the proportion of porpoises in the waters around Triton belonging to the Baltic Proper population is expected to be very low. Most of the harbour porpoises found in the development area for Triton offshore wind farm are expected to belong to the far more numerous Belt Sea subpopulation. This assumption is supported by the telemetry data from tagged harbour porpoises in the inner Danish waters (Belt Sea subpopulation; see Figure 4.7). If this is combined with the limited size of the impacted area and the short duration of the disturbance (few weeks), as well as the fact that the development area is not a suited habitat for harbour porpoises the combined impact, with application of appropriate soft start/ramp up procedure on the Baltic Proper subpopulation is assessed to be minor in the winter months and without consequences for the short-term and long-term status of the population. If the survey is conducted in the summer months, the impact on the Baltic Proper subpopulation is assessed as negligible, as they are not expected to occur in the area in the summer months (April to September).

It is recommended that the seismic survey is conducted with application of passive acoustic monitoring and marine mammal observers onboard the survey vessel, to make sure that there are no harbour porpoises in the nearfield of the survey vessel.

Harbour seals and grey seals - TTS/PTS
Seals are considered significantly less sensitive to underwater noise and have higher thresholds for TTS and PTS caused by underwater noise. The modelling results show that if seals are within 25 meters of the survey vessel when the equipment is operated at full capacity without soft-start procedures, they may be at risk of developing PTS. while seals within 90-350 meters of the vessel may be at risk of developing TTS. Furthermore seals, unlike harbour porpoises, can actively reduce the impact from underwater noise by sticking their head out of the water. It is still recommended that any seismic survey includes a soft start with ramp up to full power over a sufficiently long duration to give the seals time to leave the area impacted by underwater noise before the equipment is operated at full power.

The impact of PTS and TTS is overall assessed to be negligible (for both harbour seals and grey seals), where the degree of disturbance is ranked as high for PTS and medium for TTS, the geographic extent is not important (under the assumption, that an appropriate soft start procedure will be applied), and the likelihood of occurrence is ranked as low because of the very short impact ranges.

Harbour seals and grey seals – Behavior
There are no specific studies addressing how and at what distances seals react to underwater noise from geophysical surveys. There are a few studies addressing the avoidance behaviour and impact ranges of seals exposed to pile driving noise, showing reaction distances comparable to those of harbour porpoises. Therefore, as a precautionary approach, it has been assumed that seals react to underwater noise from geophysical surveys at the same distance as harbour porpoise (6550 meters). It is expected that both harbour seals and grey seals occur in the area regularly, however the area is not a particularly important area for either species. The degree of disturbance is ranked as low for grey and harbour seals, as it is expected that the seals will avoid the impacted area to some degree. The geographic extent is ranked as local, persistence as short-term (few weeks) and the likelihood of occurrence is ranked as low because of the relatively short impact ranges, the short duration, and as it is an area that is not important for harbour seals or grey seals. The overall impact of behavioural responses is therefore assessed as negligible for both species.

The combined impact on the harbour porpoises, harbour seals and grey seals is assessed as negligible to minor and without consequences for the short-term and long-term status of populations (Table 8.5). This assessment is under the assumption that an appropriate soft start/ramp up procedure is applied.

7.2 Seismic survey in the cable corridors

The corridors for the export cable(s) have not been decided yet and it is therefore not possible to conduct an impact assessment of the possible seismic surveys in the cable corridors. However, it is expected that the used setup during the seismic survey in the cable corridors will be setup number 3 shown in Table 7.1 using only an Innormar sub-bottom profiler. Based on the underwater noise modelling, the Innormar will cause underwater noise levels where behavioral avoidance responses for both harbour porpoises, harbour seals and grey seals are estimated to occur within approximately 3400 meters of the survey vessel in the worst-case scenario. This corresponds to a noise impacted area of approximately 36 km^2. The impact range for TTS and PTS is similar for equipment setup nr. 1. As suggested for the seismic survey in the development area for Triton offshore wind farm, it is recommended that any seismic survey includes a soft start with ramp up to full power over a sufficiently long duration to give the marine mammals time to leave the area before the equipment is operated at full power. This will significantly reduce the risk of both TTS and PTS. Assuming appropriate upstart procedures are put in place the impact caused by the underwater noise from the seismic survey in the potential cable corridors will be the same or smaller compared to the impact in the development area for Triton offshore wind farm. However, the positions of the export cable corridors are need before an impact assessment can be undertaken.

7.3 Conclusion of impact of seismic survey and suggested mitigation measures

For the seismic survey, the following mitigation measures should be included (following the Danish guidelines for seismic surveys (Energistyrelsen, 2018), to reduce the impact:

- The seismic survey should be started with a 30 minute soft start/ramp up to full power to ensure that porpoises and seals are not within the risk zone for TTS and PTS.
- Passive acoustic monitoring should be applied as well as observers should be onboard the survey vessel to ensure that no marine mammals are in close proximity of the survey vessel at the onset of the seismic survey.
- If the seismic survey is interrupted, the onset of the seismic survey should include a soft start procedure.

The combined impact on the harbour porpoises, harbour seals and grey seals is assessed to be negligible to minor and without consequences for the short-term and long-term status of populations (Table 7.1Table 8.5). This assessment is under the assumption that an appropriate soft start/ramp up procedure is applied.

Table 7.1 Impact on harbour porpoise and seals caused by seismic surveys (worst case setup)

Source of impact	Impact	Degree of disturbance	Geographic	Likelihood of occurrence	Persistence	Magnitude
Belt Sea porpoise						
Seismic survey	PTS	High	Not important	Low	Long-term	Negligible
	TTS	Medium	Not important	Low	Short-term	Negligible
	Behaviour	Low/Medium	Local	Low	Short-term	Negligible/Minor
Baltic Proper porpoise (only winter months)						
Seismic survey	PTS	High	Not important	Low	Long-term	Negligible
	TTS	High	Not important	Low	Short-term	Negligible
	Behaviour	High	Local	Low	Short-term	Minor
Seals						
Seismic survey	PTS	High	Not important	Low	Long-term	Negligible
	TTS	Medium	Not important	Low	Short-term	Negligible
	Behaviour	Low	Local	Low	Short-term	Negligible

8 Impact assessment of the Construction

This chapter describes the impact of different factors which are assumed to affect marine mammals during the wind farm construction. A summary of the impact assessment is listed in Table 8.10. Arguments with respect to the evaluation of the magnitude of the specific impacts are discussed in separate subchapters referring to the source impact.

8.1 Underwater noise

The main and most intense underwater noise during the construction of the wind farm will be underwater noise emitted during pile driving. The impact from noise on marine mammals will be most pronounced close to the installation site and will decrease with increasing distance to the installation site. Underwater noise originating from the increase in construction-related ship traffic as well as other activities in the construction area will be much weaker compared to pile driving but can also affect marine mammals.

8.1.1 Pile driving

Underwater noise from installation of foundations by pile driving could cause masking of the animals' communication and echolocation signals, behavioural avoidance responses, temporary and permanent threshold shifts (TTS and PTS), and in worst case tissue damage on non-auditory tissue. These potential impacts are described and assessed in section 8.1.1.1. In addition, the underwater noise can result in a temporary habitat loss. This is described and assessed in section 8.1.1.2.

8.1.1.1 *Temporary threshold shift (TTS) and behavioural avoidance responses*

The modelled impact ranges for TTS and behavioural responses for harbour porpoises are shown in Figure 8.1 for the western part of the development area and in Figure 8.2 for the Eastern part of the development area.

Figure 8.1: Modelled impact ranges for TTS in harbour porpoises (red line), behavioural avoidance responses harbour porpoises (green line) in the western part of the development area. The underwater noise modelling is based on a worst-case scenario with installation of a monopile with a diameter of 14 meter and with application of mitigation measure corresponding to big bubble curtain ©SDFE.

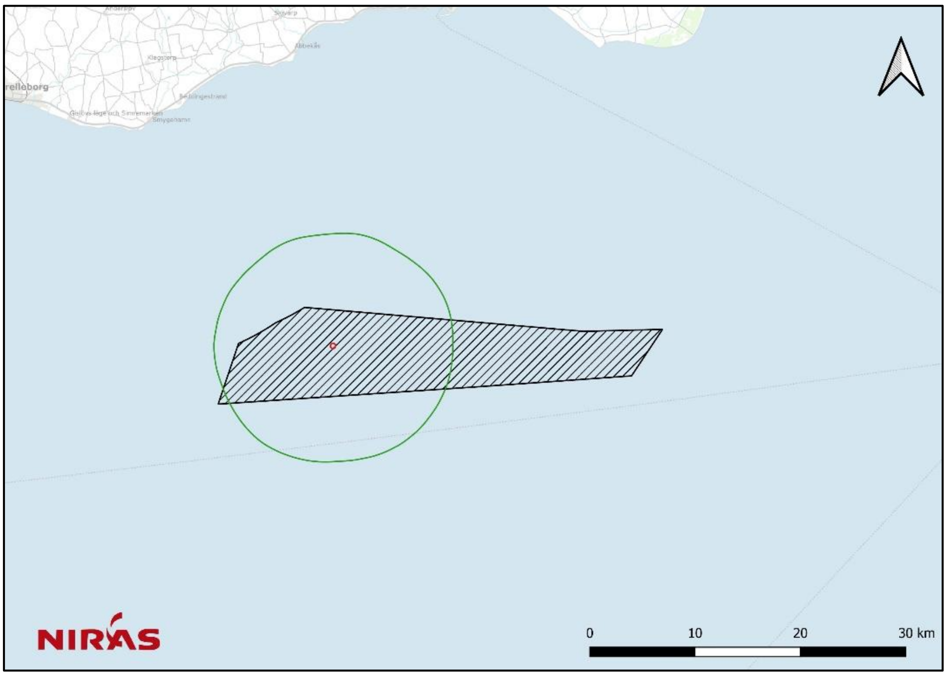
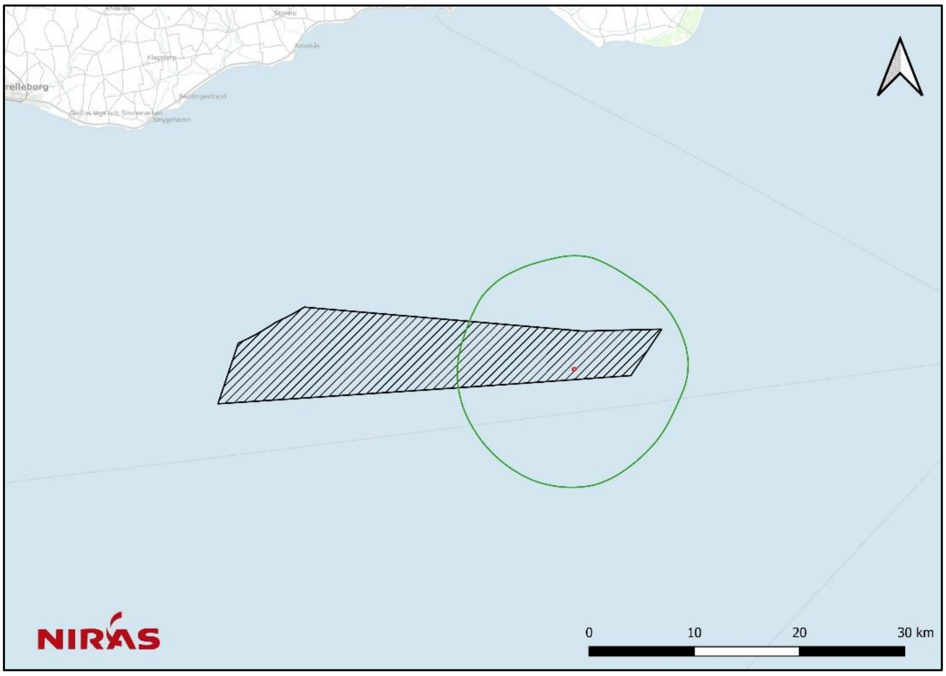


Figure 8.2: Modelled impact ranges for TTS in harbour porpoises (red line), behavioural avoidance responses harbour porpoises (green line) in the eastern part of the development area. The underwater noise modelling is based on a worst-case scenario with installation of a monopile with a diameter of 14 meter and with application of mitigation measure corresponding to big bubble curtain©SDFE.



In the calculations it is assumed that a soft start procedure will be applied, where the onset of the piling process is conducted with low energy. The energy per stroke then increases gradually until the full energy per stroke is applied. This approach allows the marine mammals to move out of the construction site before the noise becomes physically dangerous to them. It is also included in the modelling that the nearby marine mammals will flee from the underwater noise during piling at a pace of 1,5 m/s, which is a precautionary estimate for both seals and harbour porpoises.

In the underwater noise modelling it is assumed that no PTS is allowed and therefore the underwater noise modelling has been conducted with the application of mitigation measures, in this case a big bubble curtain (BBC).

Table 8.1 shows the result of the modelled underwater noise impact ranges and impact areas of pile driving of a monopile with a diameter of 14 meter (worst case scenario).

Table 8.1: Modelled impact ranges (km) and impacted areas (km^2) for PTS, TTS and behavioural avoidance responses for harbour porpoises and seals for a monopile with a diameter of 14 meter with application of a BBC mitigation system (worst case scenario).

Species	Impact	Threshold	location	Impact Distance	Impact Area (km^2)
Harbour porpoise	PTS	155 dB SEL_{C24}	Western	<25 m	-
			Eastern	<25 m	-
	TTS	140 dB SEL_{C24}	Western	300 m	<1 km^2
			Eastern	180 m	<1 km^2
	Behaviour	100 dB $SPL_{RMS-fast}$	Western	11.6 km	390 km^2
			Eastern	11.3 km	368 km^2
Seals	PTS	185 dB SEL_{C24}	Western	<25 m	-
			Eastern	<25 m	-
	TTS	170 dB SEL_{C24}	Western	825 m	2.13 km^2
			Eastern	225 m	<1km^2

As shown in Table 8.1, the impact range for TTS is very limited. Harbour porpoises may be exposed to noise levels high enough to induce temporary threshold shift (TTS) within approximately 300 meters of the pile driving site in the western part of the development area and 180 meters from the pile driving site in the eastern part of the development area. Behavioural avoidance responses of harbour porpoises may occur up to approximately 11.6 km from the pile driving site in the western part of the development area and 11.3 km from the pile driving site in the eastern part of the development area. The size of the corresponding impact areas will be less than 1 km^2 for TTS for both the western and the eastern part of the development area. For behavioural avoidance response the corresponding area will be 390 km^2 and 368 km^2 for the western and the eastern part of the development area, respectively. The impact areas are calculated based on the position causing the largest impacted area - a worst-case scenario.

The modelled impact areas are used in combination with the estimated density of harbour porpoise in and near the development area of Triton offshore wind farm to estimate the number of harbour porpoises that could potentially experience temporary hearing loss (TTS) or exhibit behavioural avoidance responses during pile driving of one monopile (Table 8.2). The estimate does not represent an exact number of harbour porpoises experiencing TTS or showing behavioural avoidance responses. Instead, the estimate represents an average that is associated with substantial uncertainty. There is a large natural variation in distribution of porpoises in the area and thus uncertainty in modelling the distribution. This uncertainty is further combined with variation in how responsive individual harbour porpoises are to underwater noise from pile driving. In general, the reaction appears to be graduated with distance from the pile driving site, such that fewer animals respond and/or the response of the individual animals becomes less severe, the further they are from the pile driving site. Furthermore, studies have shown, that there is a tendency for harbour porpoises to exhibit some degree of habituation to the underwater noise from pile driving over the course of the wind farm construction period (Graham, et al., 2019). The estimated numbers should thus not be taken as indications of the actual number of porpoises affected by pile driving, but instead as an indication of the scale of the impact on the local populations.

Table 8.2: Impact areas for behavioural responses and TTS for harbour porpoises and the estimated number of harbour porpoises that might risk behavioural responses and TTS for pile driving of a 14 meter monopile with application of a BBC mitigation system.

Site	Impact	Impacted area (km²)	Number of Belt Sea harbour porpoises		Number of Baltic Proper harbour porpoises
			Summer (0.02-0.2 individuals/km²)	Winter (0.01-0.1 individuals/km²)	Winter (1.19 % of harbour porpoises in the area)*
West	TTS	<1 km²	<1	<1	<<1
	Behaviour	390 km²	8-78	4-39	<1
East	TTS	<1 km²	<1	<1	<<1
	Behaviour	368 km²	8-74	4-37	<1

**It is not possible to differentiate between porpoises from the Baltic Proper population and the Belt Sea population. However as the Belt Sea population (42.000) is far more numerous than the Baltic Proper population (500), the relationship between the two populations ((500/42.000)*100=1.19 %) is used to estimate how many harbour porpoises from the Baltic Proper population are likely to be impacted.*

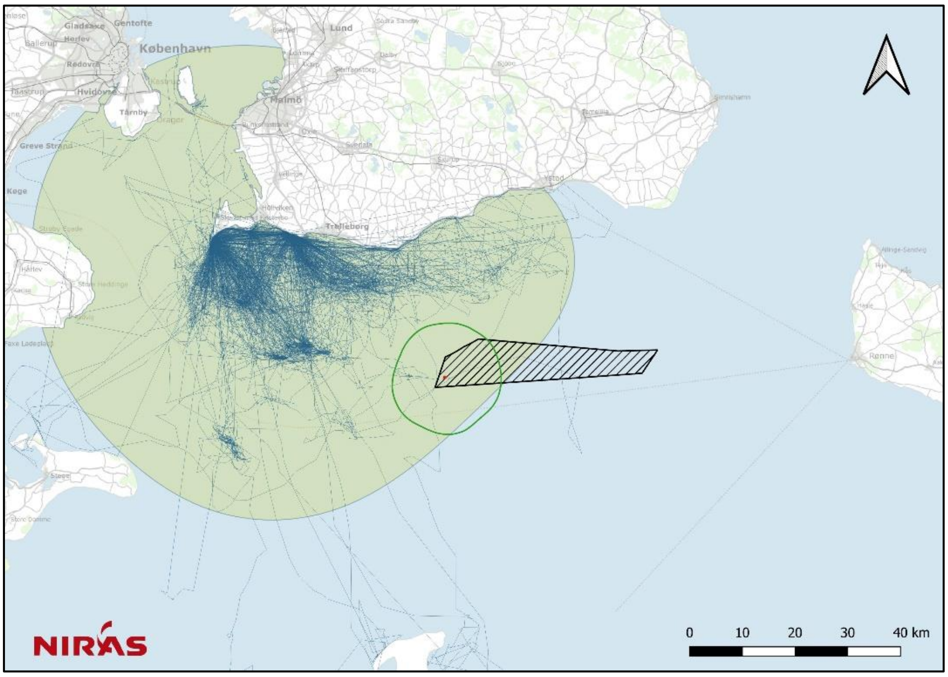
The area where the underwater noise level exceeds the threshold for TTS is very limited and less than one harbour porpoise may be exposed to TTS inducing noise levels during the installation of one monopile regardless of whether construction takes place in the summer or winter period. This estimate is for both Belt Sea population of harbour porpoises and the Baltic Proper population. Between 8-78 harbour porpoises from the Belt Sea population may experience underwater noise levels exceeding the threshold for behavioural responses within the western part of the development area in the summer. This number is considerably reduced to 4-39 harbour porpoises during the winter. For the eastern part of the development area, the numbers are very similar. 8-74 harbour porpoises from the Belt Sea may experience underwater noise levels exceeding the threshold for behavioural responses within the eastern part of the development area in the summer, whereas this has been reduced to 4-37 harbour porpoises during the winter (Table 8.2). In the winter porpoises from the Baltic Proper population can occur in the area and based on the relationship between the two populations, it is expected that 1,19 % of the harbour porpoises occuring in the area belongs to the Baltic Proper population. Based on this assumption less than one harbour porpoises from the Baltic Proper, might experience underwater noise levels above the behavioral avoidance threshold both in the western and eastern part of the development area (Table 8.2).

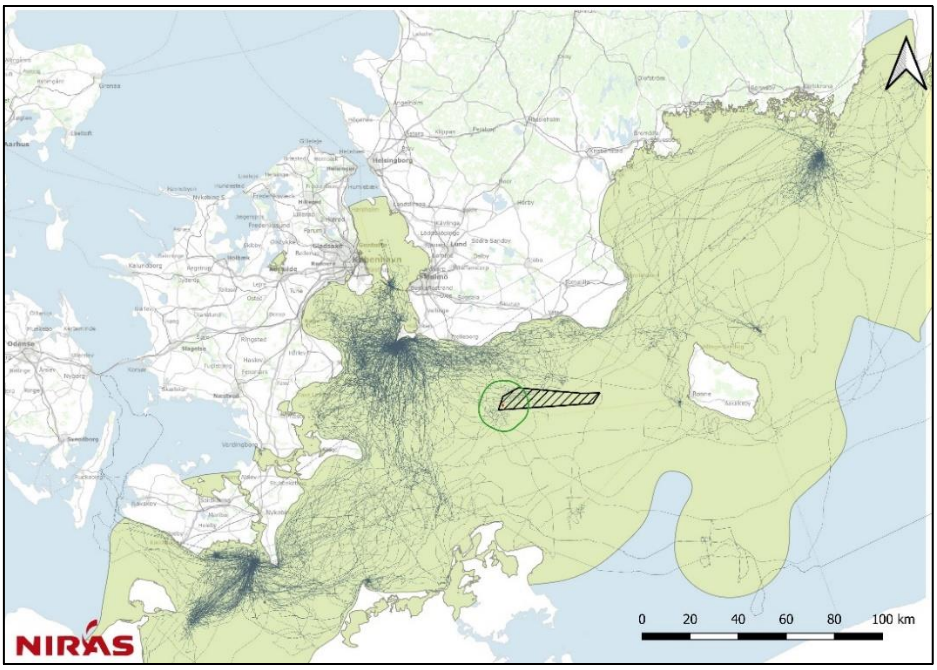
The TTS impact range for seals is also very limited and seals may risk temporary threshold shifts (TTS) within approximately 825 meters from the pile driving site in the western part of the development area and 225 meters from the pile driving site in the eastern part of the development area. The impacted areas are therefore negligible. There is a general lack of quantitative information about reaction distances for both harbour seals and grey seals. However, seals are generally considered less reactive to noise than porpoises (Blackwell, et al., 2004; Mikkelsen, et al., 2017), and although some studies indicate that they react as far away from pile driving noise as porpoises do (Russell, et al., 2016) there are no indications that they are more responsive to noise than porpoises. Thus, as a precautionary principle the behavioural avoidance impact range calculated for harbour porpoises is also used for seals.

As the density of harbour seals is not known in the development area, the numbers of seals that may exhibit behavioural responses cannot be calculated in the same way as for harbour porpoises. Instead, it is estimated how large a proportion of the seal kernel home range is temporary affected by underwater noise.

The nearest and most important seal colony is the colony at Måkläppen in Skåne, where harbour seals and grey seals have been tagged with satellite tags. The underwater noise impacted area during pile driving is within or overlapping with the area of the home range of both harbour seals and grey seals (Figure 8.3).

Figure 8.3:Overlap between the harbour seal (top) and grey seal (bottom) home range (based on satellite data from seals tagged at Måkläppen, Sweden) and the behavioural avoidance range. The underwater noise modelling is based on a worst-case scenario with installation of a monopile with a diameter of 14 meter and with application of mitigation measure corresponding to double big bubble curtain in combination with a hydrosound damper ©SDFE





It is assumed that the impacted area where the underwater noise level exceeds the threshold for behavioural avoidance responses is the same as for harbour porpoises (Table 8.3).

Table 8.3: Impact areas for behavioural responses in harbour seals and grey seals and the estimated overlap between the two seal species estimated home range and the impacted areas for pile driving of a 14 meter monopile with application of a BBC mitigation system.

Site	Species	Impacted area (km²) (worst case)	Home range size (km²)	% impacted area of the harbour seals summer home range
Triton	Harbour seal	390	5.234	7.5 %
	Grey seal		70.727	0.55%

In approximately 7.5 % of the harbour seals' home range the underwater noise will temporarily reach levels where behavioural avoidance responses may occur. For grey seals approximately 0.55 % of their home range will have underwater noise levels temporarily reaching levels where behavioural avoidance responses may occur (Table 8.3).

The potential impact of the pile driving noise on the two relevant harbour porpoise populations referring to the worst-case scenario is shown in Table 8.4. The total estimate of 42.000 individuals in the Belt Sea population and a total estimate of 500 individuals for the Baltic Proper population are considered as the relevant reference populations. The Baltic Proper porpoises are only expected to occur in the area during the winter season, whereas the Belt Sea population is expected to occur in the pre-investigation area all year round.

Table 8.4: Potential behavioural impact of pile driving on the two harbour populations in the development area for Triton offshore wind farm. The assessment is based on a worst-case scenario for pile driving of a 14 meter monopile with application of a BBC mitigation system.

Population	Population size	Number of impacted harbour porpoises		Percentage of affected porpoises within a population	
		Summer	Winter	Summer	Winter
Baltic Proper	500	-	<1	-	0.01-0.095%
Belt Sea	42.000	8-78	4-39	0.019-0.19 %	0.01-0.093%

The Belt Sea population of harbour porpoises may occur in the area all year round For the Belt Sea population it is far less than 1% of the biogeographical population that may exhibit behavioural avoidance responses, because of the very low density of harbour porpoises in and near the development area for Triton offshore wind farm. PTS will not occur, and the risk of TTS is extremely limited because of the very short impact ranges (300 meter) and therefore considered as being negligible.

In the winter period, harbour porpoises from both the Belt Sea population and the Baltic Proper population may occur in the area. The proportion of porpoises in the waters around Triton belonging to the Baltic Proper population is therefore expected to be very low. It is expected that most harbour porpoises in the Triton area belong to the Belt Sea population, which is also supported by satellite data from harbour porpoises tagged in inner Danish waters (see Figure 4.6). For the Baltic Proper population, it is estimated that up to 0.09% of harbour porpoise in the population will be exposed to underwater noise levels above the behavioural threshold.

It is estimated that the underwater noise level will exceed the threshold for behavioral avoidance responses within 7.5 % of the home range for harbor seal. For grey seals it is a significantly smaller proportion of their home range that is affected by underwater noise, only 0.55 %. For both harbor seals and grey seals, it is a very small part of their home range that is temporarily affected by underwater noise, resulting in a relatively small proportion of the biogeographic population of both the harbor seals and grey seals that are temporarily affected by underwater noise from pile driving. In general, seals are more tolerant of underwater noise and adapt faster than harbour porpoise.

8.1.1.1.1 Impact assessment of hearing impairment and behavioural avoidance responses

As mentioned in section 4.1.3 the development area for Triton offshore wind farm is located in a transition zone for the Belt Sea and Baltic Proper harbour porpoise populations and the area is at the border of both populations range. The density in the area is low especially compared to the density west of the development area towards the Danish waters, which are inhabited by the Belt Sea population of harbour porpoises. It is therefore expected that most of the porpoises in the development area for Triton offshore wind farm belong to the Belt Seas population, whereas a smaller number, during the winter months, may be from the critically endangered population from the Baltic Proper.

<u>Harbour porpoises - TTS/PTS</u>

The degree of disturbance of permeant threshold shift (PTS) is generally ranked as high, because PTS may have serious consequences for the affected individual. However, as the underwater noise from pile driving will be mitigated by application of e.g., a big bubble curtain or other types of mitigation systems with the same efficiency, underwater noise levels that can cause PTS will not occur and this effect is therefore assessed as negligible.

TTS can potentially lead to a small decrease in the individual’s fitness by for example causing a reduction in feeding or reproduction success. The degree of disturbance of temporary threshold shift (TTS), is therefore assessed as medium for harbour porpoises belonging to the Belt sea population but has high for harbour porpoises belonging to the Baltic Proper population, because of the populations’ conservation status. The persistence of the impact is generally considered to be short-term for TTS, as the risk of TTS only occurs during the actual pile driving. Hearing is expected to reach a normal level a few days after the pile driving is completed.

The distances where TTS may occur are very limited (300 m for harbour porpoises) and the geographical extent is therefore ranked as local and the risk (likelihood of occurrence) of TTS is ranked as negligible for harbour porpoises belonging to both the Belt Sea and the Baltic Proper population. The combined impact from TTS on both populations of harbour porpoises that may occur in the area (the Belt Sea and the Baltic Proper) is therefore assess as negligible.

<u>Harbour porpoises - Behavioral response</u>

Depending on the sensitivity of the species, behavioral responses caused by a project's activities can range widely from small changes in activity level to escape responses, where individuals completely avoid the area. The degree of disturbance is ranked as low/medium for harbour porpoises belonging to the Belt Sea population , as it is expected that the animals will partially avoid the impacted area. But it is ranked as high for the Baltic Proper population because of the unfavorable conservation status

Because of the behavioural impact ranges the geographic extent for harbour porpoises is ranked as regional/national for behavioral avoidance responses. For harbour porpoises the likelihood of occurrence is assessed as low for behavioral responses for the Belt Sea population, as less that than 0.3 % of the biogeographical population is estimated to be affected.

The persistence of behavioral avoidance responses is also considered to be short-term, as several studies indicate that harbour porpoises return to the area a few days after the installation has been completed.

As the absolute number of porpoises disturbed by the piling noise is very low and the disturbance itself is likely to be small (approximately six hours pr. installation) the impact of construction of Triton offshore wind farm on the Belt Seas population, which is considered to be in favorable conservation status, is assessed to be minor both during winter and summer periods (Table 8.5). The assessment is the same for both sub areas.

Porpoises from the critically endangered Baltic Proper population may be found in the impacted area, in the winter months. However, as this population is estimated to be very small, the proportion of porpoises in the waters around Triton potentially belonging to the Baltic Proper population is expected to be very low. Combining low probability of encountering a Baltic Proper harbour porpoise with the already very low number of porpoises disturbed by a single pile driving event during winter (<1 animal) and the short duration of the disturbance (approximately six hours pr. installation), as well as the development area being a low quality habitat for harbour porpoises (Mikkelsen, et al., 2016) the likelihood of occurrence is assessed as medium for behavioral responses for the critically endangered Baltic Proper population. Because of the behavioural impact ranges the geographic extent for harbour porpoises is ranked as regional/national for behavioral avoidance responses. The persistence of behavioral avoidance responses is also considered to be short-term, as several studies indicate that harbour porpoises return to the area a few days after the installation has been completed. The impact on the Baltic Proper population is assessed to be minor and without consequences for the short-term and long-term status of the population (Table 8.5). This assessment is under the assumption that an adequate noise mitigation system along with an appropriate soft start procedure is applied. The assessment is the same for both the western and the eastern part of the development area.

<u>Harbour seals and grey seals - TTS/PTS</u>
The degree of disturbance from permeant threshold shift (PTS) is generally ranked as high for seals. However, as the underwater noise from pile driving will be mitigated by application of e.g., a big bubble curtain or other types of mitigation systems with the same efficiency, underwater noise levels that can cause PTS will not occur. It is therefore assessed as negligible.

TTS can potentially lead to a small decrease in the individual's fitness by for example causing a reduction in feeding or reproduction success. The degree of disturbance from temporary threshold shift (TTS), is therefore assessed as medium for seals. The persistence of the impact is generally considered to be short-term for TTS for both seals and harbour porpoises, as the risk of TTS only occurs during the actual pile driving. Hearing is expected to reach a normal level at maximally a few days after the pile driving is completed. The ranges at which TTS may occur in seals are very limited (825 m) and the geographical extent is therefore ranked as local. The risk (likelihood of occurrence) of TTS is negligible for both grey and harbour seals.

The combined impact from TTS in both harbour seals and grey seals occurring in the area is assess as negligible.

Harbour seals and grey seals – Behavior
Depending on the sensitivity of the species, behavioral responses caused by a project's activities can range widely from small changes in activity level to escape responses, where individuals completely avoid the area. The degree of disturbance is ranked as medium in the worst case for grey and harbour seals, as it is expected that the seals will avoid the impacted area to some degree.

The geographic extent is ranked as regional/national for behavioral avoidance responses as the development area is located near an important seal colony at Måkläppen in Sweden, where both harbour seals and grey seal haul-out.

For seals, it has not been possible to estimate the percentage of the biogeographical population that is affected, but as it is a relatively small area of their home range that is temporarily affected, the likelihood of occurrence of behavioral avoidance responses is ranked as low.

The persistence of behavioral avoidance responses is also considered to be short-term for both seal species, as several studies indicate that both species of seal return to the area a few days after the installation has been completed.

Installation of two foundations sequentially
The assessment has been conducted under the assumption that one foundation will be installed per day. Another installation scenario is that two foundations are installed sequentially pr day, which will reduce the overall time period, where pile driving is taking place. If installation of two foundations is carried out sequentially, where installation of a second pile, located next to the first pile, is started as soon as the former is completed, the impact of underwater noise exposure is assessed to be in the same ratio compared to installing one foundation pr. day. If the pile driving sites are located adjacent to one another, the marine mammals being affected by the second pile installation, are assumed to have already left the impacted area. For behavior, the impact distance would not be affected by interference patterns, nor would it equate the sum of impact areas for both installations, rather it would shift from one location to the next. For PTS and TTS, the impact distances are assessed to increase no more than 10-20%, as the marine mammals are already far from both installation sites and will therefore be exposed to a minimal additional underwater noise from the installation of the second pile installation. It is however important that the second installation is not delayed significantly in time after the completion of the first, as this would allow for marine mammals to return to the area.

Thus, installation of two foundations (positioned next to each other) sequentially will not increase the impact ranges for behavioural avoidance responses and only cause a minor increase in the TTS and PTS impact ranges. Sequential installation will prolong (double) the daily time period where pile driving is taking place, however the total installation period will be cut in half.

The combined impact on harbour seals and grey seals is assessed to be minor and without consequences for the short-term and long-term status of populations (Table 8.5). This assessment is under the assumption that an adequate noise mitigation system along with an appropriate soft start procedure is applied.

Table 8.5 Impact on harbour porpoise and seals caused by pile driving of a monopile with a diameter of 14 meter and with application of a BBC mitigation system .

Source of impact	Impact	Degree of disturbance	Geographic	Likelihood of occurrence	Persistence	Magnitude
14 meter monopile with application of BBC						
Belt Sea porpoise						
Pile driving	PTS	High	Negligible	Low	Long-term	Negligible
	TTS	Medium	Local (negligible)	Low	Short-term	Negligible
	Behaviour	Low/Medium	Regional/National	Low	Short-term	Minor
Baltic Proper porpoise (only winter months)						
Pile driving	PTS	High	Negligible	Low	Long-term	Negligible
	TTS	High	Local (negligible)	Low	Short-term	Negligible
	Behaviour	High	Regional/National	Medium	Short-term	Minor
Seals						
Pile driving	PTS	High	Negligible	Negligible	Long-term	Negligible
	TTS	Medium	Local (negligible)	Low	Short-term	Negligible
	Behaviour	Low/Medium	Regional/National	Medium	Short-term	Minor

8.1.1.2 *Piledriving with application of HSD + DBBC*

In addition to underwater noise modelling with application of a mitigation system corresponding to a single big bubble curtain (BBC), underwater noise modelling assuming the application of a mitigation system corresponding to a double big bubble curtain combined with a hydro sound damper (DBBC+HSD) has been conducted for March, the worst-case scenario with respect to sound transmission. The modelled impact ranges for behavioural responses for harbour porpoises are shown in Figure 8.4 for the western part of the development area and in Figure 8.5 for the Eastern part of the development area.

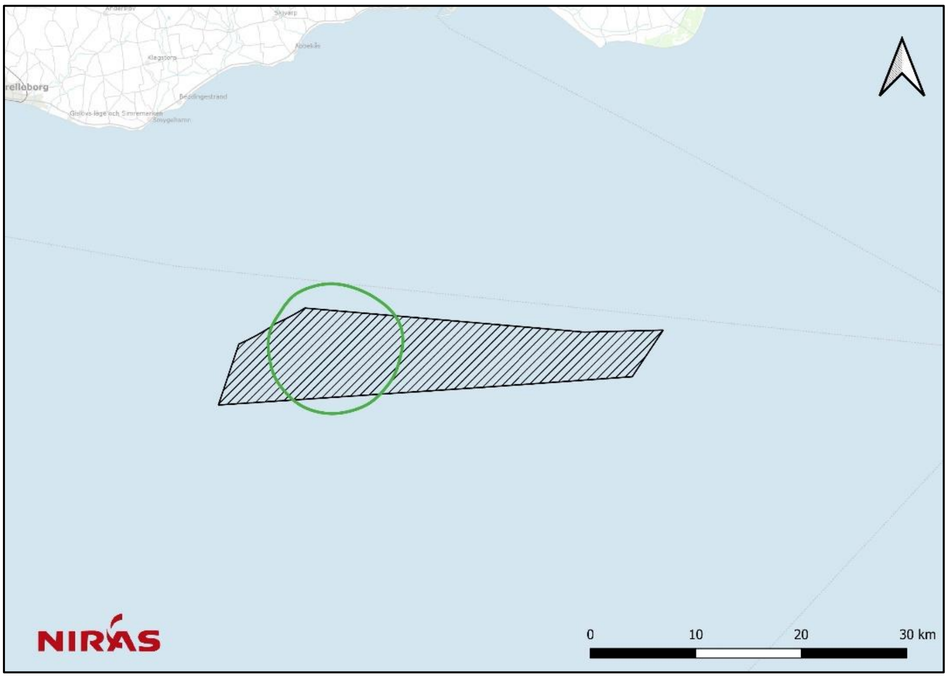


Figure 8.4: Modelled impact ranges for behavioural avoidance responses harbour porpoises (green line) in the western part of the development area. The underwater noise modelling is based on a worst-case scenario with installation of a monopile with a diameter of 14 meter and with application of mitigation measure corresponding to double big bubble curtain in combination with a hydrosound damper ©SDFE.

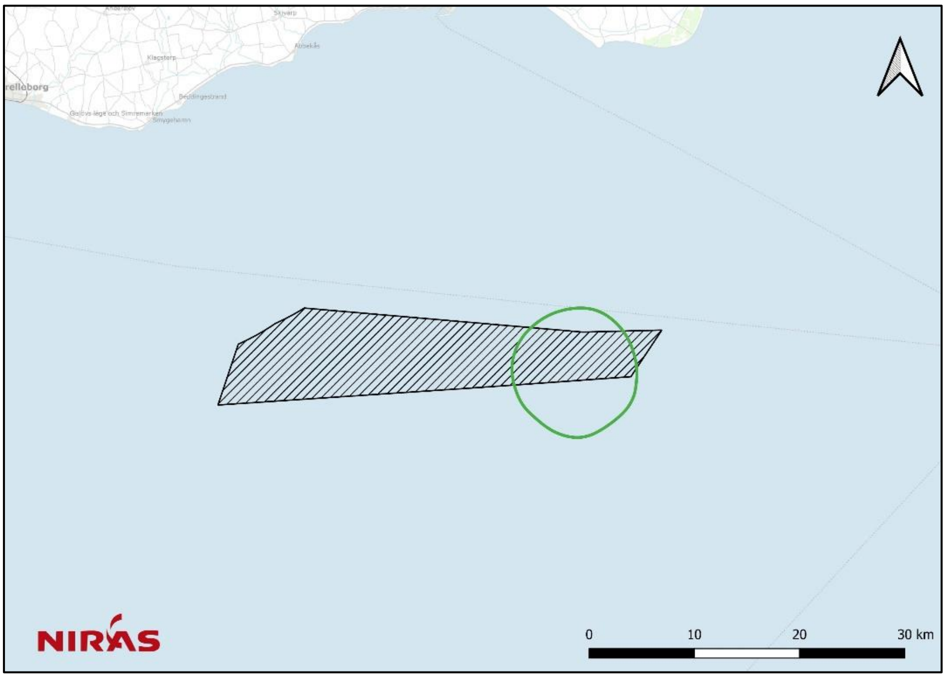


Figure 8.5: Modelled impact ranges f for behavioural avoidance responses harbour porpoises (green line) in the eastern part of the development area. The underwater noise modelling is based on a worst-case scenario with installation of a monopile with a diameter of 14 meter and with application of mitigation measure corresponding to double big bubble curtain in combination with a hydrosound damper ©SDFE.

Based on the underwater noise modelling no PTS (<25 meter) or TTS (<50 meter) will be elicited in any harbour porpoise. The behavioural impact ranges, impacted areas, and likely impact on the harbour porpoise populations are provided in table 8.6.

Table 8.6: Potential impact of pile driving on the two harbour populations in the development area for Triton offshore wind farm. The assessment is based on underwater noise modelling for pile driving of a 14 meter monopile with application of a DBBC + HSD in March (worst-case scenario).

Impact	Impact range	Impact area	Number of affected porpoises		Percentage of affected porpoises within a population	
			Baltic Proper	Belt Sea	Baltic Proper (500)	Belt Sea (42.000)
Behaviour	6,7 km	122 km^2	< 1	1-13	0.0029-0.029	0.0028-0.028

During winter installation of a monopile with a diameter of 14 meters with the application of a mitigation system with an efficiency corresponding to DBBC+HSD leads to a reduced behavioural impact area, as well as a reduced number of impacted harbour porpoises compared to installation of a 14-meter monopile applying BBC. The impact area is reduced to 122 km^2, reducing the affected number of harbour porpoises to 1-13 harbour porpoises from the Belt Sea population potentially experiencing underwater noise levels exceeding the threshold for behavioural responses in winter. For the Baltic Proper population the number of porpoises potentially affected is still less than 1 individual. For both harbour porpoise populations less than 0,3% of the biogeographical population may exhibit behavioural avoidance responses.

The TTS and PTS impact range for seals is very limited and seals may risk temporary threshold shifts (TTS) within <50 meters from the pile driving site and PTS within <25 meters from the pile driving site. The impacted areas for TTS and PTS are therefore negligible. As a precautionary principle the behavioural avoidance impact range calculated for harbour porpoises is also used for seals. The underwater noise impacted area during pile driving with application of DBBC+HSD is within or overlapping with the area of the home range of both harbour seals and grey seals (Figure 8.6).

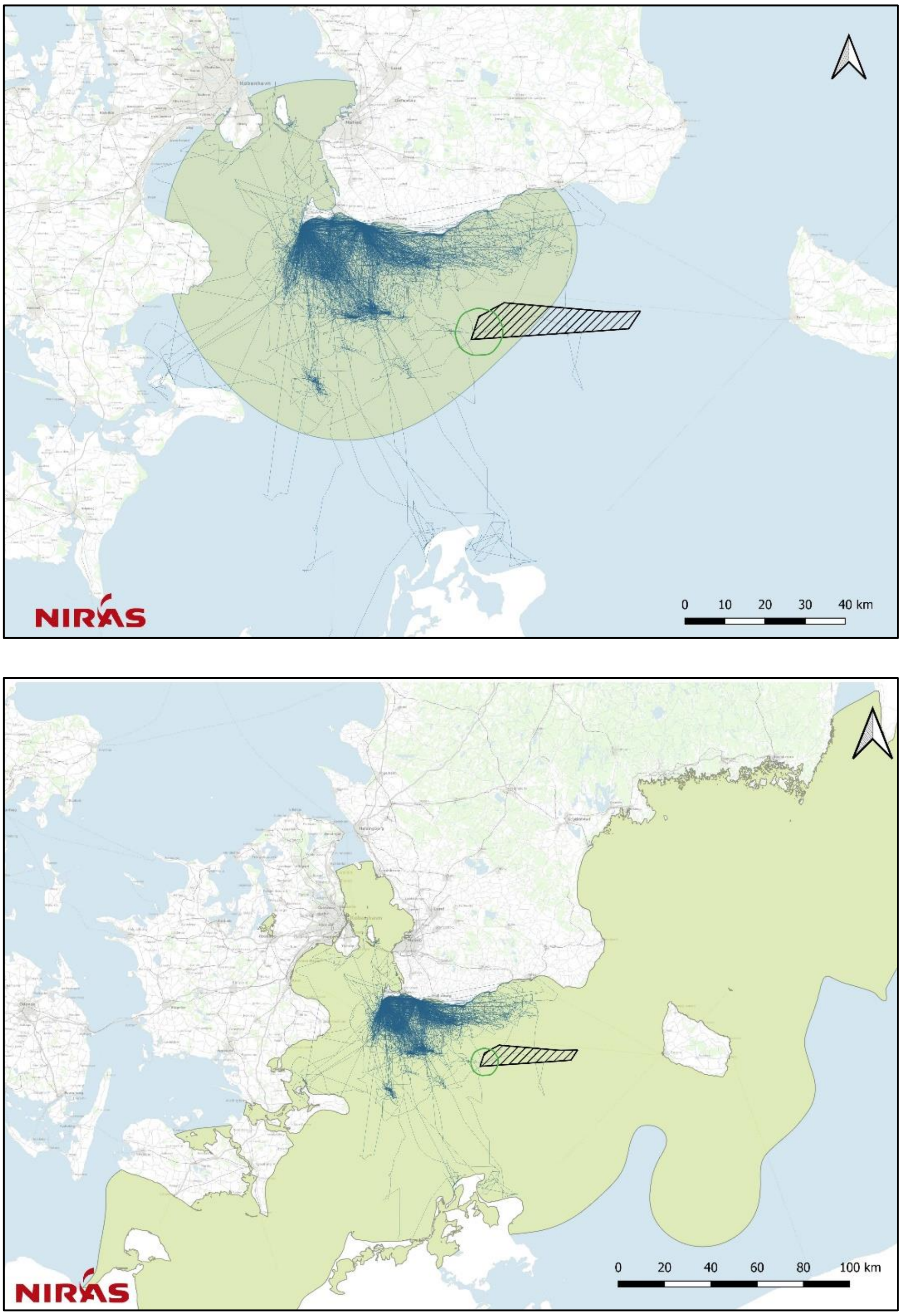


Figure 8.6: Overlap between the harbour seal (top) and grey seal (bottom) home range (based on satellite data from seals tagged at Måkläppen, Sweden) and the behavioural avoidance range. The underwater noise modelling is based on a worst-case scenario with installation of a monopile with a diameter of 14 meter and with application of mitigation measure corresponding to double big bubble curtain in combination with a hydro-sound damper ©SDFE

It is assumed that the impacted area where the underwater noise level exceeds the threshold for behavioural avoidance responses is the same as for harbour porpoises (Table 8.7).

Table 8.7: Impact areas for behavioural responses in harbour seals and grey seals and the estimated overlap between the two seal species estimated home range and the impacted area. The assessment is based on underwater noise modelling for pile driving of a 14 meter monopile with application of a DBBC + HSD in March (worst-case scenario).

Site	Species	Impacted area (km²) (worst case)	Home range size (km²)	% impacted area of the harbour seals summer home range
Triton	Harbour seal	122	5.234	2.3 %
	Grey seal		70.727	0.17 %

In approximately 2.3 % of the harbour seals' home range the underwater noise will temporarily reach levels where behavioural avoidance responses may occur. For grey seals approximately 0.17 % of their home range will have underwater noise levels temporarily reaching levels where behavioural avoidance responses may occur (Table 8.7).

The degree of disturbance is still ranked as low/medium for the Belt Sea harbour porpoise and as high for the Baltic Proper harbour porpoise population. The geographic extent is ranked as local for the Belt Sea harbour porpoise and as regional/national for the Baltic Proper harbour porpoise population. The likelihood of occurrence is assessed as low for behavioral responses, as far less than 0.3 % of the biogeographical populations, is estimated to be affected. Under these conditions, the impact on the two harbour porpoise populations by pile driving with application of a mitigation corresponding to DBBC+HSD is assessed to be minor (Table 8.7).

The degree of disturbance is still ranked as medium in the worst case for grey and harbour seals, as it is expected that the seals will avoid the impacted area to some degree. The geographic extent is ranked as regional for behavioral avoidance responses as the development area is located near an important seal colony at Måkläppen in Sweden, where both harbour seals and grey seal haul-out, however as it is a relatively small area of their home range that is temporarily affected, the likelihood of occurrence of behavioral avoidance responses is ranked as low. The persistence of behavioral avoidance responses is considered to be short-term for both seal species, as several studies indicate that both species of seal return to the area a few days after the installation has been completed. Under these conditions, the impact on the harbour seals and grey seals by pile driving with application of a mitigation corresponding to DBBC+HSD is assessed to be minor.

Table 8.8 Impact on harbour porpoise caused by pile driving of a 14-meter monopile with application of a DBBC+HSD mitigation system in March (the breeding and mating season for porpoises).

Impact	Degree of disturbance	Geographic	Likelihood of occurrence	Persistence	Magnitude
14 meter monopile with application of DBBC+HSD					
Belt Sea porpoise					
PTS	High	Negligible	Low	Long-term	Negligible
TTS	Medium	Negligible	Low	Short-term	Negligible
Behaviour	Low/Medium	Local	Low	Short-term	Minor
Baltic Proper porpoise (only winter months)					
PTS	High	Negligible	Low	Long-term	Negligible
TTS	Medium	Negligible	Low	Short-term	Negligible

Impact	Degree of disturbance	Geographic	Likelihood of occurrence	Persistence	Magnitude
Behaviour	High	Regional/National	Low	Short-term	Minor
Seals					
PTS	High	Negligible	Negligible	Long-term	Negligible
TTS	Medium	Local (negligible)	Negligible	Short-term	Negligible
Behaviour	Low/Medium	Regional/National	Medium	Short-term	Minor

Based on the underwater noise modelling, piledriving of a 14 meter monopile with application of a noise mitigation system corresponding to the efficiency of a BBC result in single strike sound exposure level of 120 dB re 1 µPa measured at 750 and a sound pressure level of 100 dB re 1µPa ($SPL_{RMS\text{-}fast,VHF}$) (behavioural threshold for harbour porpoises) at a distance of 11.6 km distance from the piledriving site. Whereas piledriving of a 14 meter monopile with application of a noise mitigation system corresponding to the efficiency of a DBBC+HSD result in single strike sound exposure level of 112 dB measured at 750 meters and a sound pressure level of 100 dB re 1µPa ($SPL_{RMS\text{-}fast,VHF}$) at a distance of 6.7 km (NIRAS, 2021b). Based on the underwater noise modelling, piledriving with application of a BBC is sufficient to only cause a minor impact on marine mammals. Therefore underwater noise from piledriving, must not exceed $SEL_{ss,750m} <$ 120 dB re 1µPa^{2}s measured at 750 meters distance or 100 dB re 1µPa ($SPL_{RMS\text{-}fast,VHF}$) at a distance of 11.6 km.

8.1.1.3 *Temporary habitat loss due to pile driving noise*

When the monopiles are installed in the seabed by pile driving, the marine mammals will be temporarily displaced from the area around the monopile as it is installed because of high underwater noise levels. The temporary avoidance of the installation site can cause marine mammals to use more energy, as they have to spend more time swimming away from the area and will have less time to feed. In addition, it can cause the animals to be displaced from important foraging areas, or prevent free migration between foraging areas, which can lead to less successful foraging.

Behavioral avoidance response thresholds do not necessarily indicate that marine mammals completely avoid the area where underwater noise exceeds the threshold for behavioral responses. Studies show that the response is more gradual, and the effect of the impact decreases with increasing distance to the construction site. There is also some degree of habituation to the underwater noise taking place (Graham, et al., 2019). It would therefore be too conservative to assume that all harbour porpoises and seals are displaced from the area. Here it is assumed that 60% of harbour porpoises are displaced from the area when the underwater noise exceeds the behavioral avoidance threshold following Pehlke et al. (2013). This would lead to 5-47 harbour porpoises being temporarily displaced during pile driving in the western part of the development area during the summer months and 3-24 harbour porpoises during the winter months. For the eastern part of the development area, it will lead to 5-45 harbour porpoises being temporarily displaced during pile driving and 3-23 harbour porpoises during the winter months.

Similar studies exist for seals (Russell, et al., 2016), and it is also more realistic to assume that up to 60-70% of the seals are displaced within the area where the underwater noise exceeds the threshold for behavioral avoidance responses. This would lead to approximately 5-6 % of the harbour seals home range becoming temporarily unavailable and a very small proportion of the grey seals home range.

For harbour porpoises, the development area for Triton offshore wind farm is ranked as being of low importance and for harbour seals and grey seals the development area is ranked as medium. Furthermore, both harbour porpoises and seals are opportunistic feeders, and their prey is not limited to a specific area. The degree of disturbance in relation to a temporary habitat loss is considered as low for both harbour porpoises belonging to the Belt Sea population and seals, but high for harbour porpoises belonging to the Baltic Proper population.

The affected area is limited to the development area and immediately adjacent areas, as it is expected that the displacement will be gradual within the area where the behavioral threshold is exceeded. The spatial extent of the impact is therefore considered to be local.

The likelihood of occurrence for temporary habitat loss is ranked as low for harbour porpoise of both biogeographical populations.

For seals, it is a relatively small area of their home range that is affected, and the probability of occurrence is therefore assessed to be low.

In theory installation of the foundations by pile driving will last approximately a little more than 4 months (of effective work) with approximately six hours of piledriving per day, under the assumption, that one foundation is installed pr. day without any pauses. If two foundations are installed pr. day the pile driving period will be reduced and last approximately half the time. However in praxis the total time for installation of one foundation will be longer and last approximately 2 days. The six hours pr day for one foundation and the 4 months for all foundations does only relate to time where piling occurring and not the other construction work related to foundation installation. The total installation time for the foundations will be longer than 4 months. Furthermore the installation period may be longer due to for example bad weather conditions, causing days where pile driving is not possible. Still, the duration of the temporary habitat loss is considered to be short-term, as both harbour porpoises and seals can return to the area after the foundation installation is complete.

The overall magnitude of impact due to temporary habitat loss during pile driving is assessed as minor for both harbour porpoises and seals (Table 8.6).

Table 8.6 Impact on harbour porpoises and seals caused by temporary habitat loss due to pile driving.

Impact	Degree of disturbance	Geographic	Likelihood of occurrence	Persistence	Magnitude
Harbour porpoise					
Temporary habitat loss	Low/High	Local	Low	Short-term	Negligible
Seals					
Temporary habitat loss	Low	Local	Low	Short-term	Negligible

8.1.2 Airborne noise

Since harbour porpoises are always in the water and only come to the surface to breathe, they will not be affected by the airborne noise from pile driving. Seals, on the other hand, can be affected by the airborne noise from pile driving, as they are adapted to an amphibious lifestyle, and hear well in both water and in air. It is especially at their haul-out sites that seals can be disturbed by airborne noise.

The degree of disturbance is considered as medium, as seals have a moderate sensitivity to man-made disturbance. The geographic extent is ranked as local and the likelihood of occurrence is ranked as negligible as the nearest haul-out site is located at Måkläppen, Sweden, located approximately 50 km from the development area for Triton offshore wind farm. The impact will be short-term, as it will only occur during the foundation installation period (pile driving).

The overall magnitude of impact on seals caused by airborne noise from pile driving is assessed as negligible (Table 8.7).

Table 8.7 Impact on seals caused by airborne noise from pile driving.

Impact	Degree of disturbance	Geographic	Likelihood of occurrence	Persistence	Magnitude
Seals					
Airborne noise	Medium	Local	Negligible	Short-term	Negligible

8.1.3 Ship traffic

The potential impacts from ship traffic on seals and harbour porpoises will most likely be masking of communication signals due to ship noise. Furthermore, potential behavioral changes in e.g., their foraging pattern in the immediate vicinity of the ships can occur. The behavioural impact is partly due to the ship noise. However, the direction and maneuverability of the ship likely also plays a role in the magnitude of the impact.

The degree of disturbance is ranked as medium in the worst-case as only a fraction of the marine mammals in the development area will be affected by the underwater noise from the increased ship traffic during the construction phase. This must also be seen in the light of the fact, that the development area is located adjacent to main shipping routes in the Southern Baltic Sea. The additional impact of construction related ship traffic will therefore be modest.

The geographic extent of the impact is considered as local as mainly a limited area around the current location of ships is affected. The likelihood of occurrence is ranked as low as only a small proportion of the mammal population will be affected. The persistence is considered as temporary because the increase in ship traffic will probably endure throughout the construction phase that last between 3-5 years.

The overall magnitude of impact on marine mammals caused by ship traffic is assessed as minor for both harbour porpoises and seals (Table 8.8).

Table 8.8 Impact on harbour porpoises and seals caused by ship traffic.

Impact	Degree of disturbance	Geographic	Likelihood of occurrence	Persistence	Magnitude
Harbour porpoise					

Impact	Degree of disturbance	Geographic	Likelihood of occurrence	Persistence	Magnitude
Ship traffic	Low/Medium	Local	Low	Temporary	Minor
Seals					
Ship traffic	Low/Medium	Local	Low	Temporary	Minor

8.2 Sedimentation and turbidity

Installation of the foundations will result in some degree of suspended sediment and a following sedimentation, especially if pre-drilling is used. The degree of disturbance is ranked as low as both harbour porpoises and seals can still hunt in turbid waters. The geographic extent of the effect is considered as local as it is mainly the area around the installation that is affected by sediment spill. In areas further away the suspended sediment is diluted by the currents and settlement of suspended sediments is marginal. The likelihood of occurrence is ranked as medium as some marine mammals will encounter waters that are at least slightly affected by these sediments. Most of the suspended sediment will settle within a short time, the persistence is therefore considered as short-term. It is expected that both seals and to a minor extent harbour porpoises use the development area for foraging, but the development area is not considered to be an important feeding area for marine mammals, so the indirect impact of sediments spill on marine mammals due to impact on their prey is also considered low.

The overall magnitude of impact on marine mammals caused by sedimentation and turbidity, both direct and indirect is assessed as negligible for both harbour porpoises and seals (Table 8.9).

Table 8.9 Impact on harbour porpoise and seals caused by sedimentation and turbidity.

Impact	Degree of disturbance	Geographic	Likelihood of occurrence	Persistence	Magnitude
Harbour porpoise and seals					
Sedimentation and turbidity	Low	Local	Medium	Short-term	Negligible

8.3 Total impact from construction

The assessment of potential impacts during construction of the wind farm is summarised in Table 8.10. The magnitude of impact on marine mammals is assessed to be minor in the worst-case during the construction phase, assuming appropriate mitigation measures are put in place.

Table 8.10: Total impact on marine mammals during construction.

Source of impact	Impact	Degree of disturbance	Geographic	Likelihood of occurrence	Persistence	Magnitude
Harbour porpoise						
Pile driving	PTS	High	Negligible	Low	Long-term	Negligible

Source of impact	Impact	Degree of disturb-ance	Geo-graphic	Likeli-hood of occur-rence	Persis-tence	Magni-tude
	TTS	Me-dium/High	Local (negligi-ble)	Low	Short-term	Negligi-ble
	Behaviour	Low/High	Re-gional/National	Low/Me-dium	Short-term	Minor
	Temporary habitat loss	Low/High	Local	Low	Short-term	Negligi-ble
Ship traffic	Behaviour	Low/Me-dium	Local	Low	Temporary	Minor
Sedimenta-tion and turbidity	Behaviour	Low	Local	Medium	Short-term	Negligi-ble
Seals						
Pile driving	PTS	High	Negligi-ble	Negligible	Long-term	Negligi-ble
	TTS	Medium	Local (negligi-ble)	Low	Short-term	Negligi-ble
	Behaviour	Low/me-dium	Re-gional/National	Medium	Short-term	Minor
	Temporary habitat loss	Low	Local	Low	Short-term	Negligi-ble
Airborne noise	Behaviour	Medium	Local	Low (Neg-ligible)	Short-term	Negligi-ble
Ship traffic	Behaviour	Low/Me-dium	Local	Low	Temporary	Minor
Sedimenta-tion and turbidity	Behaviour	Low	Local	Medium	Short-term	Negligi-ble

9 Impact assessment of the operating phase

The lifetime of the wind farm is expected to be around 35-40 years. This chapter describes the impact of different factors which are assumed to affect marine mammals during the wind farms operational phase. The overall impact assessment during the operational phase is listed in Table 9.5. Arguments relevant to the evaluation of the degree of disturbance are discussed in separate subchapters.

9.1 Operational noise

The operational noise of wind turbines can be transmitted into the water through the pile and the foundation. Compared to the construction noise, the level of operational noise will be much lower. However, it will be permanently present during the whole operating phase, except for brief periods without wind or during storms. It is expected that the turbines will begin generating power when wind speed at hub height is between 3 and 5 m/s and achieve their rated output at wind speeds above 12 m/s. It is assumed that they will shut down automatically when the average wind speed exceeds 25 - 30 m/s for extended periods.

The impact range of operational underwater noise is limited as previous assessments indicate (Tougaard & Michaelsen, 2018). In view of measured sound levels and analyses of frequency content the turbine noise can be heard by porpoises at maximum distances of around 100 m from the individual wind turbines. Because of their better hearing capability at low frequencies, seals will hear the noise at longer distances.

Harbour porpoises as well as seals have been observed in operating offshore wind farms in numbers comparable with those observed before construction (Tougaard, et al., 2006; Scheidat, et al., 2011). As the worst-case turbine type for Triton offshore wind farm (25 MW) is larger than the turbines in the above-mentioned studies, it cannot be excluded that the source level of the operational noise occasionally exceeds the harbour porpoise avoidance threshold. The corresponding impact radius is assumed to be 100 m in a precautionary worst case (see section 6.3.1 for more details). Based on this the total impact area of 129 turbines (total for both areas) would be ~4 km² within the wind farm. However, as the noise is stationary, not harmful and of a permanent character, the porpoises will probably become accustomed to it. A recent study show that porpoises may be attracted to offshore oil and gas platforms despite confirmed elevated underwater noise and are likely exploiting higher prey abundance in the vicinity of such structures . The same can be the situation in the wind farm, as foundation and scour protect generate artificial reefs, that is expected to provide higher prey abundance. Seals can hear the operational noise from wind turbines at longer distances, but studies have shown that some harbour seals actively seek out the turbines during foraging (Russell, et al., 2014). Therefore, for both harbour seals and grey seals no avoidance behavior is expected.

As only few harbour porpoises would show behavioural reactions in the worst case, the degree of disturbance is low. The effect is restricted to a fraction of the wind farm and therefore the geographic extent is considered local. The likelihood of occurrence at population level is low. The persistence is considered permanent as the turbine sounds will be present throughout the operating phase.

The overall magnitude of impact on marine mammals caused by operational noise is assessed as negligible (Table 9.1).

Table 9.1 Impact on harbour porpoise and seals caused by operational noise.

Impact	Degree of disturbance	Geographic	Likelihood of occur-rence	Persistence	Magnitude
Harbour porpoises and seals					
Operational noise	Low	Local	Low	Permanent	Negligible

9.2 Service and maintenance traffic

Linked to maintenance and service during the operation phase, underwater noise will mainly be caused by ships. This includes crew transfer and transport of equipment, mostly by small vessels or motorboats. It is expected that the shipping activity will be less frequent compared to the construction phase. It is expected that the normal servicing interval for the turbines will be approximately six months and last three days for each turbine. Unexpected operational defects can occur which require unplanned inspections and repairs.

The ships used during maintenance are usually small and the amount of traffic is limited. As the density of harbour porpoises in the area is expected to be of a low occurrence, and the development areas is not an important feeding area for seals, the degree of disturbance is rated as medium. The geographic extent of the impact is local, and the likelihood of occurrence is ranked as medium. The traffic from maintenance is not permanently present in the wind farm, so the persistence of the impact is assumed to be temporary.

The overall magnitude of impacts on marine mammals due to the maintenance of the wind farm is assessed as minor (Table 9.2).

Table 9.2 Impact on marine mammals due to the maintenance of the wind farm.

Impact	Degree of disturb-ance	Geographic	Likelihood of occur-rence	Persis-tence	Magnitude
Harbour porpoises and seals					
Mainte-nance	Medium	Local	Medium	Temporary	Minor

9.3 Habitat Changes

The introduction of hard-bottom substrates, in the form of foundations, will create changes to the habitat. It is expected that most of the development area will remain unaffected.

The hard-bottom substrate may on the other hand form the basis of artificial reef structures where sessile organisms can settle. Additionally, young fish are attracted by the shelter of the artificial reef structures. Furthermore, the exclusion or regulation and limitation of fishery would also support the enhancement of the young fish population (Gutow, et al., 2014). Taking both effects in to account the overall presence of prey items will probably increase, attracting opportunistic feeders like harbour porpoises, harbour seals and grey seals. It has been documented that harbour seals benefit from offshore wind farm as at least some individuals target specific pile structures during foraging (Russell, et al., 2014) (Figure 6.12).

Thus, the introduction of hard-bottom substrates may have a positive effect on marine mammals in the longer run as they may serve as artificial reefs that offer feeding opportunities, and potentially shelter from traffic noise compared to other locations (Scheidat, et al., 2011; Teilmann & Carstensen, 2012). The impact of habitat change is assessed as positive, however as this artificial reef effect is limited to the foundation and closely around it as well as that our knowledge on the effect is limited, the positive impact is assessed as being negligible positive (Table 9.3).

Table 9.3 Impact on marine mammals due to the habitat change.

Impact	Degree of disturbance	Geographic	Likelihood of occurrence	Persistence	Magnitude
Harbour porpoises and seals					
Habitat changes	Low	Local	Low	Permanent	Negligible Positive

9.4 Electromagnetic fields from high voltage cable

The submarine cables (inter array and export cables) are expected to be operated at voltage levels of between 66 and up to 220 kV or more for the export cable, The strength of electromagnetic fields decreases rapidly with the distance from the source. Therefore, it is assumed that the effect (if any) is localised at the cables and does not cover the entire wind farm, and the importance is therefore negligible. Only very few porpoises will be in the possibly affected area and it is not likely that an effect will occur. There is no evidence that seals use the magnetic field and so for pinnipeds assessments of possible effects are even more speculative. The likelihood of occurrence is low. However, the cables and the electromagnetic fields will remain during the entire operational phase and are therefore permanent. This results in a magnitude of impact that is ranked as negligible (Table 9.4).

Table 9.4 Impact on marine mammals due to electromagnetic fields from high voltage cables.

Impact	Degree of disturbance	Geographic	Likelihood of occurrence	Persistence	Magnitude
Harbour porpoises and seals					
EMF	Low	Local	Low	Permanent	Negligible

9.5 Total impact during operation phase

The assessment of potential impacts during operation of the wind farm is summarized in Table 9.5. The magnitude of impact on marine mammals is assessed to be negligible to minor for the potential effects.

Table 9.5: Total impact on marine mammals during the operation phase.

Source of impact	Impact	Degree of disturbance	Geographic	Likelihood of occurrence	Persistence	Magnitude
Harbour porpoise						
Operational noise	Behavioural response	Low	Local	Low	Permanent	Negligible
Service and maintenance traffic	Behavioural response	Low	Local	Low	Temporary	Minor
Habitat Changes	Changes in prey	Low	Local	Low	Permanent	Negligible Positive
EMF	Behavioural response	Low	Local	Low	Permanent	Negligible
Seals						
Operational noise	Behavioural response	Low	Local	Low	Permanent	Negligible
Service and maintenance traffic	Behavioural response	Low	Local	Low	Temporary	Minor
Habitat Changes	Behavioural response	Negligible	Local	Low	Permanent	Negligible
EMF	Behavioural response	Low	Local	Low	Permanent	Negligible

10 Impact assessment during the decommission phase

The method for decommissioning the wind farm will follow best practice and the legislation at that time. It is unknown at this stage how the wind farm may be decommissioned. This chapter describes the impact of different factors which are assumed to affect marine mammals during decommissioning. The impact assessment is listed in Table 10.4. Arguments relevant to the evaluation of the degree of disturbance are discussed in separate subchapters.

10.1 Underwater noise

During decommissioning of the offshore wind farm impacts on marine mammals are expected to be smaller than those of the construction phase of the wind farm. This includes underwater noise emission due to decommissioning work and increased ship traffic in the development area for the Triton offshore wind farm. As the decommissioning procedure is not known and there is limited experience from decommissioning of other offshore wind farms, the assessment of the impact on marine mammals caused by underwater noise during the decommissioning phase is difficult to predict. However, it is expected that the underwater noise will be less intense compared to the construction phase, as there will be no pile driving activities.

There will be no risk of permanent hearing damage but in the event of persistent noise in connection with the decommissioning work TTS-inducing noise levels may occur in the nearfield of the decommissioning position. The sensitivity to TTS is considered as medium for both seals and harbour porpoises. Behavioral responses can also occur, and the sensitivity of both harbour porpoises and seals is assessed to be medium, as it is not expected that the marine mammals completely avoid the noise-affected area. Due to the densities of harbour porpoise and the seals use of the development area, the geographic extent of the impact is assessed to be Regional/National and the likelihood of occurrence is ranked as medium for behavior and low for TTS. It is expected that the decommissioning work will have a duration that is comparable to the duration of the construction work and is thus assessed to be short-term.

Given the impact being short-term, the overall assessment of impacts on marine mammals caused by underwater noise from decommissioning of the offshore wind farm is assessed as negligible for TTS and minor for behavioural avoidance responses (Table 10.1).

Table 10.1 Impact on marine mammals from underwater noise during the decommissioning phase.

Impact	Degree of disturbance	Geographic	Likelihood of occurrence	Persistence	Magnitude
Harbour porpoises and seals					
TTS	Medium	Regional/National	Low	Short-term	Negligible
Behavioural response	Medium	Regional/National	Medium	Short-term	Minor

10.2 Habitat change/loss

It is expected that all or the main part of the scour protection of the foundations will not be removed during the decommissioning phase, and that the cables will either be removed or remain in the seabed. If the cables are removed, there will be a short-term increase in the amount of suspended sediment, which will be local in both temporal and geographical extent.

After decommissioning hard substrate will most likely remain, partly from foundations plus scour protection and possibly rock dumping on cables. They constitute structures resembling artificial reefs. Therefore, remaining hard structures are very unlikely to constitute habitat impairment for marine mammals. As described in section 9.3, especially seals will likely benefit from such artificial reefs around the foundations (Russell, et al., 2014).

It is assumed that the habitat changes remain constant. It is therefore assessed that the degree of disturbance for both harbour porpoise and seals is low and the geographic extent is not important, the likelihood of occurrence is assessed as low and the persistence is permanent. This all adds up to a positive but negligible impact (Table 10.2).

Table 10.2 Impact on marine mammals caused by habitat change/loss during the decommissioning phase.

Impact	Degree of disturbance	Geographic	Likelihood of occurrence	Persistence	Magnitude
Harbour porpoises and seals					
Habitat change	Low	Not important/negligible	Low	Permanent	Negligible Positive

10.3 Sedimentation and turbidity

It is assumed that the amount of sediment spilled during decommissioning of the wind farm will be comparable to the sediment spill during the construction phase. Therefore, the impact assessment is also the same (8.2). The degree of disturbance is considered as low, the geographical extent is local, the likelihood of occurrence is medium, and the persistence is short-term. The magnitude of impact is therefore negligible (Table 10.3).

Table 10.3 Impact on marine mammals caused by sedimentation and turbidity during the decommissioning phase.

Impact	Degree of disturbance	Geographic	Likelihood of occurrence	Persistence	Magnitude
Harbour porpoises and seals					
Sedimentation and turbidity	Low	Local	Medium	Short-term	Negligible

10.4 Total impact during the decommissioning phase

The assessment of potential impacts during the decommissioning phase of Triton offshore wind farm on marine mammals is summarized in Table 10.4. The magnitude of impact on marine mammals is assessed to be negligible to minor.

Table 10.4: Total impacts of the wind farm decommissioning on marine mammals.

Source of impact	Impact	Degree of disturbance	Geographic	Likelihood of occurrence	Persistence	Magnitude
Harbour porpoise (both Belt Sea and Baltic Proper)						
Decomissioning noise	TTS	Medium	Regional/National	Low	Short-term	Negligible
	Behavioural response	Medium	Regional/National	Medium	Short-term	Minor
Habitat change	Habitat loss	Low	Negligible	Low	Permanent	Negligible Positive
Sediment spill	Behavioural response	Low	Local	Medium	Short-term	Negligible
Seals						
Decomissioning noise	TTS	Medium	Regional/National	Low	Short-term	Negligible
	Behavioural response	Medium	Regional/National	Medium	Short-term	Minor
Habitat change	Habitat loss	Low	Negligible	Low	Permanent	Negligible
Sediment spill	Behavioural response	Low	Local	Medium	Short-term	Negligible

11 Impacts due to Emission and discharges

During cable laying, wind farm construction and decommissioning as well as from maintenance in the operation phase, some emissions from vessels and helicopters working in the wind farm area will be released into the atmosphere. These emissions are not considered to be markedly higher than emissions from the normal daily shipping traffic in the surrounding area. No effect of emissions and discharges on marine mammals is expected.

The risk of marine mammals being affected by other pollutants in terms of discharges e.g., oil or other chemicals is extremely low. As there is a minor risk of accidental discharges or spill from the turbines or vessels associated with the construction and decommissioning, it would be desirable to minimize potential environmental pollution by use of environmentally friendly oil and lubricants.

12 Natura 2000 and Annex 4 species assessment

This chapter describes and assesses the potential impacts of the project on the nearby relevant Natura 2000 areas, that have been designated for harbour porpoises, grey seals and/or harbour seals. Both Swedish, German and Danish Natura 2000 areas are included in the assessment. In addition, the potential impact from the project on relevant Annex IV species is assessed, which in this case is limited to harbour porpoises.

12.1 Natura 2000 sites

Natura 2000 is the term for a network of protected areas in the European Union, designed under the EC Habitats Directive (Council Directive 92 / 43 / EEC, u.d.) and the EC Birds Directive (Directive 2009/147/EC, u.d.) to secure and protect core breeding and resting sites for rare and threatened species, and some rare natural habitat types which are protected in their own right. It stretches across all EU countries, both on land and at sea. Under the Habitats Directive Special Areas of Conservation (SACs) and Sites of Community Importance (SCIs) are designed for species other than birds, and for habitats. Similarly, the Special Protection Areas (SPAs) are designed under the Birds Directive to protect bird species. Together, SPAs and SACs/SCIs make up the Natura 2000 network of protected areas, with the overarching aim of ensure the long-term survival of Europe's most valuable and threatened species and habitats.

EU Member States are required to propose sites to protect the habitat types listed in Annex I and the species listed in Annex II as SCI. If the SCI is accepted by the procedure described in the Habitats Directive (Council Directive 92/43/EEC), the area will be designed as SAC. Both harbour seals, grey seals and harbour porpoises (as well as all other species of cetacean) are listed on the Habitat Directive Annex II. The Habitats Directive Article 6 (paragraph 3) states:

"Any plan or project not directly connected with or necessary to the management of the site but likely to have a significant effect thereon, either individually or in combination with other plans or projects, shall be subject to appropriate assessment of its implications for the site in view of the site's conservation objectives. In the light of the conclusions of the assessment of the implications for the site and subject to the provisions of paragraph 4, the competent national authorities shall agree to the plan or project only after having ascertained that it will not adversely affect the integrity of the site concerned and, if appropriate, after having obtained the opinion of the general public."

An objective screening of the likely effects on a Natura 2000 site from a project must be carried out before a project can be approved by the Authorities. Cumulative impacts arising from co-occurrence of other planned projects or plans must also be assessed.

The Natura 2000 assessment in this report focuses only on marine mammals and is not a complete Natura 2000 assessment. Instead, it serves as an input for the full appropriate assessment carried out in a separates report. The Natura 2000 assessment starts with identification of relevant nearby Natura 2000 areas designed for any of the marine mammal species. There are several possible effects associated with the construction of an offshore windfarm (see section 6.1). Sediment suspension, pollutants and changes in habitat are not expected to have a significant impact on marine mammals as they are either very local effects (sediment plumes, pollutants), or can have a positive effect by creating an artificial reef. Marine mammals can, however, potentially be impacted by underwater noise from the installation of foundations at longer distances and underwater noise from the pre-investigation survey. In the operational phase the turbines generate low frequency underwater noise, however the effects are assessed as being local and thereby do not have a significant impact on the marine mammals.

For each Natura 2000 area, there is either a bevarandeplan (Swedish Natura 2000 areas) or a baseline analysis and a plan (Danish Natura 2000 areas) with overall objectives as well as specific objectives for the species and the habitat types the area has been designated for. An area can be designated as a Natura 2000 area because the area has an important function for the listed species. It could for example be a breeding area for seals or porpoises. In that case, this will be stated in the specific objectives for the individual Natura 2000 area. For some Natura 2000 areas designated for marine mammals, no specific objectives for the marine mammals have been described, however for all listed habitat types and species, the objectives are that they must achieve a long-term favorable conservation status.

Figure 12.1 provides a map showing nearby Natura 2000 areas to the development area for Triton Offshore Wind Farm appointed to protect harbour porpoises (top), harbour seals (middle) and grey seals (bottom).

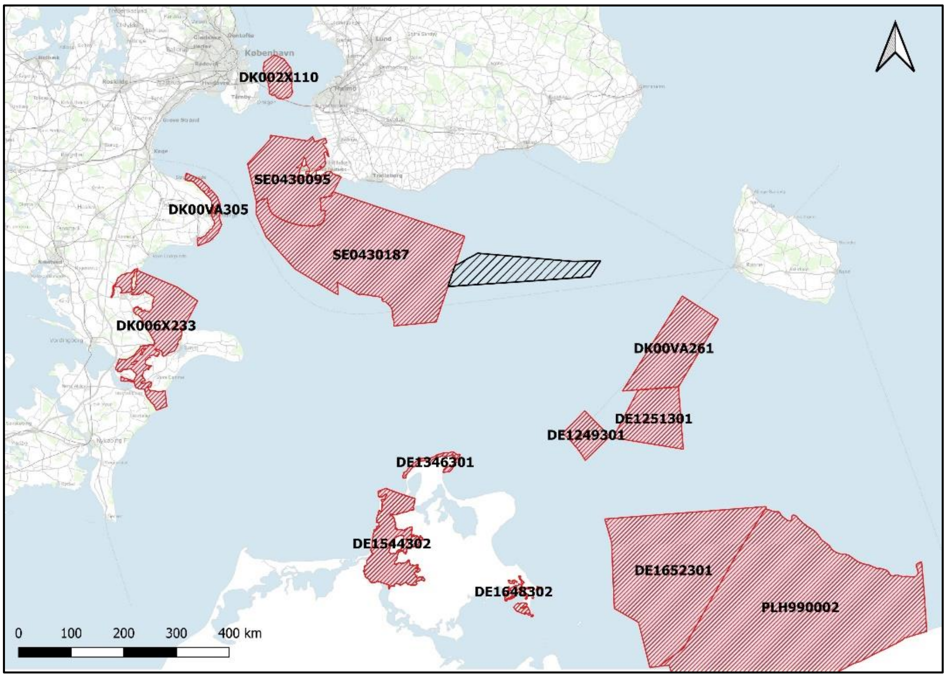
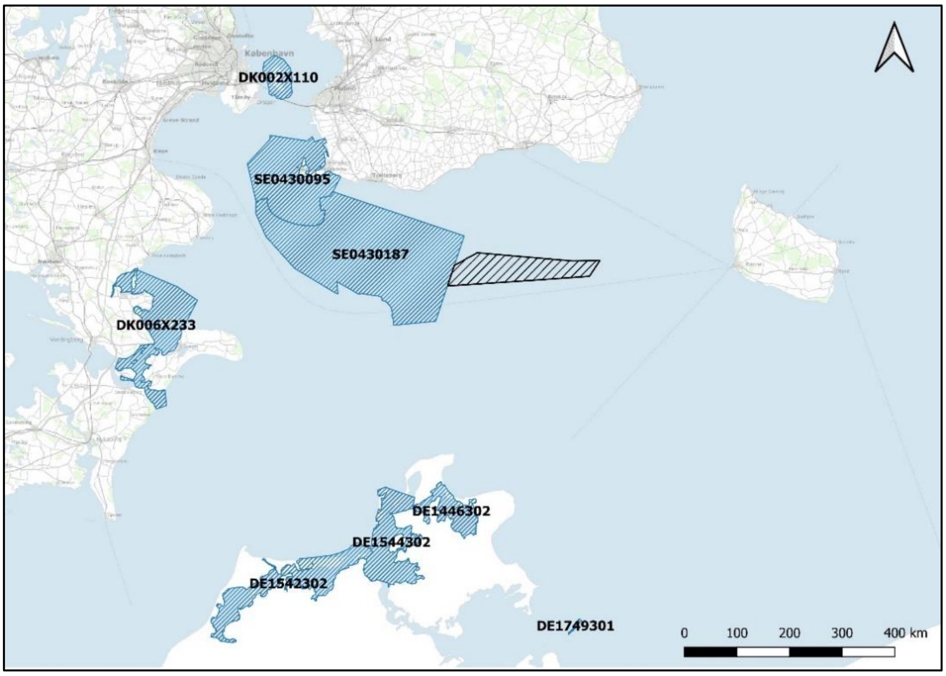
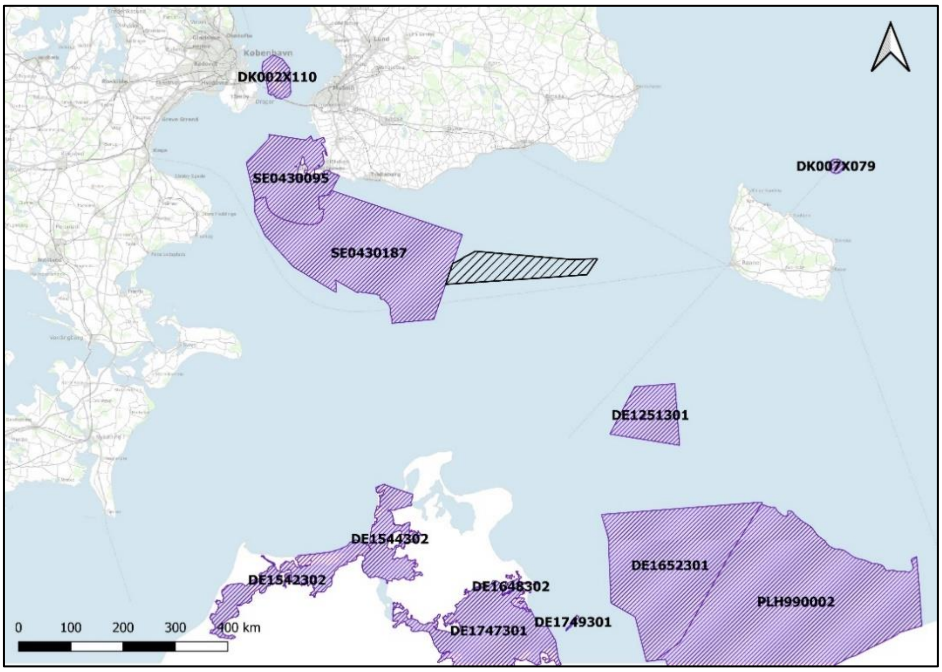


Figure 12.1: Natura 2000 areas in relatively close proximity to Triton Offshore Windfarm. Natura 2000 areas designed for harbour porpoises (red shaded) are shown in the top map, areas designed for harbour seals (blue shaded) are shown on the middle map and areas designed for grey seal (purple shaded) are shown in the bottom map. ©SDFE





There is one Natura 2000 area appointed for harbour porpoises close to the development areas for Triton Offshore Wind Farm, SE430187. Further away, there are both Swedish, Danish, German and a single Polish Natura 2000 areas designated for either porpoises, seals, or both. Table 12.1 lists the Natura 2000 areas that are within less than 100 km from the development area. Furthermore, the approximate distances to the Natura 2000 areas from the development area and the area for Triton Offshore Wind farm are provided.

Table 12.1: Natura 2000 areas designed for marine mammals and the approximately distance between the development area from Triton Offshore Wind Farm and the Natura 2000 areas. Areas that can be directly affected by underwater noise are marked in bold.

Natura 2000 area	Areal (km²)	Minimum distance between Triton and the N2000 area	Marine mammals species that the area has been designed for
SE0430187 -Sydvästskånes utsjövatten	**1151**	**0**	**Harbour porpoise, grey seal and harbour seal**
SE0430095 Falsterbohalvön	423	37	Harbour porpoise, grey seal and harbour seal
DK00VA261 Adler Grund og Rønne Banke	319	25	Harbour porpoise*
DK007X079 Ertholmene	13	70	Grey seal
DK002X110 Saltholm og omkringliggende hav	72	65	Harbour porpoise*, grey seal and harbour seal
DK00VA305 Stevns Rev	46	65	Harbour porpoise*
DK006X233 Havet og kysten mellem Præstø Fjord og Grønsund	319	70	Harbour porpoise and harbour seal
DE1251301 Adlergrund	234	30	Harbour porpoise, grey seal
DE1747301 Greifswalder Bodden, Teile des Strelasundes und Nordspitze Usedom	604	80	Grey seal
DE1749301 Greifswalder Oie	2	90	Grey seal and harbour seal
DE1648302 Küstenlandschaft Südostrügen	24	80	Harbour porpoise, grey seal
DE1446302 Nordrügensche Boddenlandschaft	111	55	Harbour seal
DE1652301 Pommersche Bucht mit Oderbank	1102	65	Harbour porpoise, grey seal
DE1542302 Recknitz-Ästuar und Halbinsel Zingst	279	75	Grey seal and harbour seal
DE1346301 Steilküste und Blockgründe Wittow	18	45	Harbour porpoise, grey seal
DE1249301 Westliche Rönnebank	86	35	Harbour porpoise
DE1544302 Westrügensche Boddenlandschaft mit Hiddensee	233	55	Harbour porpoise, grey seal and harbour seal
PLH990002 Ostoja na Zatoce Pomorskiej	2431	80	Harbour porpoise, grey seal

*Harbour porpoise have been suggested to be included in the designation for the area, however it awaits final approval.

There are one Swedish Natura 2000 area appointed for harbour porpoises harbour seals and grey seals close to the development areas: SE0430187 (Sydvästskånes utsjövatten) west of Trition. Further away, there are both Swedish, German Polish and Danish Natura 2000 areas designated for either porpoises, seals, or both, however as there will be no direct impact on the more distant Natura 2000 areas (se section 12.2) the following description focus on SE0430187 (Sydvästskånes utsjövatten).

SE0430187 Sydvästskånes utsjövatten

The western part of the development area for Triton offshore wind farm borders the Swedish Natura 2000 area "Sydvästskånes utsjövatten" - a 1151 km^2 100 % marine area. The area is designed for both harbour porpoise, harbour seals and grey seals.

The area was assigned as a Natura 2000 area in 2016, but there is no conservation plan (bevarande plan) for the area yet however for all listed habitat types and species, the objectives are that they must achieve a long-term favorable conservation status. The area is described as important spawning and adolescence grounds for several fish species and an important feeding ground for marine mammals (https://skyddadnatur.naturvardsverket.se/).

The area is particularly important in the period September to November according to Carlström and Carlén (2016). In the Summer period only porpoises from the Belt Sea population occur in the area, however in the winter period also individuals from the Baltic Proper subpopulation can occur in the area. There is no national monitoring in the Natura 2000 area.

According to the Swedish Red list from 2020 the Belt population is classified as of least concern (LC) (Artdatabanken, 2020) and the conservation status in the marine Atlantic region for the population is generally considered to be favourable (Fredshavn, et al., 2019). According to the Swedish Red list from 2020 the Baltic Proper population is classified as critically endangered (CR) (Artdatabanken, 2020) and the conservation status in the Baltic region for the population is considered to be unfavourable (Fredshavn, et al., 2019).

12.1.1 Natura 2000 impact assessment during the pre-investigation - geophysical survey

Before the construction of the offshore wind farm (installation of foundations and cables) can take place, information of the seabed is needed (geophysical survey) and some of the equipment used for such a survey generates underwater noise levels, that may cause avoidance responses, and temporary (TTS) and permanent (PTS) hearing threshold shifts in marine mammals. As described in chapter 8, underwater noise from the seismic survey is not expected to cause underwater noise levels that can cause TTS or PTS in neither harbour porpoises, harbour seals nor grey seals, if , the following mitigation measures is included (following the Danish guidelines for seismic surveys (Energistyrelsen, 2018):

- The seismic survey should be started with a 30 minute soft start/ramp up to full power to ensure that porpoises are not within the risk zone for TTS and PTS.
- Passive acoustic monitoring should be applied as well as observers should be onboard the survey vessel to ensure that no harbour porpoise are in close proximity of the survey vessel at the onset of the seismic survey.
- If the seismic survey is interrupted, the onset of the seismic survey should include a soft start procedure.

Underwater noise levels from the seismic survey can lead to impact ranges of up to 6.55 km for behavioural avoidance responses for both harbour porpoises and seals.. The underwater noise could potentially cause behavioral avoidance responses of marine mammals inside the nearest Natura 2000-area (Sydvästskånes utsjövatten), bordering the western part of the development area for Triton offshore wind farm. However, it is a small fraction of the Natura 2000 area in which the underwater noise levels are above the avoidance response threshold. In the worst-case scenario, when the survey is conducted at the border of the Natura 2000 area, approximately 68 km^2 of the Natura 2000 area may be impacted by the underwater noise, corresponding to less than 6% of the area being impacted by underwater noise levels above the avoidance response threshold.

12.1.1.1 *Harbour porpoises*

Porpoises belonging to the Belt Sea population may occur in the development area all year round. The degree of disturbance is ranked as low/medium for harbour porpoises belonging to the Belt Sea population because of its favorable conservation status. The impacted area is of very limited size (local) and duration of the disturbance (the survey) is very short-term (few weeks) leading to a short-term persistence. With application of the above mentioned mitigation measures, the total impact on individual level is assessed as limited and without risk of impact at population level. The combined impact on the Belt Sea subpopulation of harbour porpoises is therefore assessed as negligible/minor and without consequences for the short-term or long-term status of the population for harbour porpoises both inside and outside the Natura 2000 area.

Porpoises from the critically endangered Baltic Proper subpopulation can be found in the impacted area, in the winter months. The degree of disturbance is ranked as high for the Baltic Proper population because of the unfavorable conservation status. However, as this population is estimated to be very small and very scattered, the proportion of porpoises in the Natura 2000 area that belongs to the Baltic Proper population is expected to be very low. Most of the harbour porpoises found in the Natura 2000 area are expected to belong to the far more numerous Belt Sea subpopulation. This is supported by telemetry data from tagged harbour porpoises in the inner Danish water (Belt Sea subpopulation; see Figure 4.7). In combination with the very limited impacted area (68 km^2) and the short duration of the disturbance (few weeks), the overall impact on the Baltic Proper subpopulation is assessed to be minor in the winter months and without consequences for the short-term or long-term status of the population. If the survey is conducted in the summer months, the impact on the Baltic Proper subpopulation is assessed as negligible, as they are not expected to occur in the area in the summer months (April to September).

Due to the very limited area that is disturbed, the impact on porpoises in the nearby Natura2000 site Sydvästskånes Utsjövatten is assessed to be minor and without consequences for the integrity of the site. It is therefore assessed thatseismic surveys in the development area for Triton offshore wind farm, will not give rise to either short-term or long-term consequences for the conservation status of harbour porpoises from the Belt Sea population or porpoises from the Baltic Proper population within the area. It is assessed that underwater noise from geophysical surveys will not cause negative impacts on harbour porpoises (from the Belt Sea and the Baltic Proper populations) within or outside the Natura 2000 area SE0430187 Sydvästskånes utsjövatten, and thus not prevent favorable conservation status for harbour porpoises located outside or inside in this Natura 2000 site nor prevent fulfillment of the conservation objectives for harbour porpoises in the Natura 2000 site SE0430187.

12.1.1.2 *Harbour seals and grey seals*

There are no specific studies addressing how and at what distances seals react to underwater noise from geophysical surveys. There are a few studies addressing the avoidance behaviour and impact ranges of seals exposed to pile driving noise, showing reaction distances comparable to those of harbour porpoises. Therefore, as a precautionary approach, it has been assumed that seals react to underwater noise from geophysical surveys at the same distance as harbour porpoise which leads to only a very small fraction of the Natura 2000 area (less than 6%) being short-term (few weekd) impacted by underwater noise levels above avoidance response levels. It is expected that both harbour seals and grey seals occur in the area regularly. As described in chapter 8 the degree of disturbance is ranked as low for grey and harbour seals, as it is expected that the seals will avoid the very limited impacted area to some degree. The geographic extent is ranked as local, persistence as short-term (few weeks) and the likelihood of occurrence is ranked as low because of the relatively short impact ranges, short duration in combination with area not being an important area for harbour seals or grey seals. The impact of behavioural responses is overall assessed to be negligible (for both harbour seals and grey seals).

Due to the very limited area being disturbed, the impact on harbour seals and grey seals in the nearby Natura2000 site Sydvästskånes Utsjövatten is assessed to be negligible and without consequences for the integrity of the site. It is assessed that underwater noise from the geophysical survey will not cause negative impacts on harbour seals or grey seal within or outside the Natura 2000 area SE0430187 Sydvästskånes utsjövatten, and thus not prevent favorable conservation status for harbour seals or grey seals located outside or inside in this Natura 2000 site nor prevent fulfillment of the conservation objectives for harbour seals and grey seals in the Natura 2000 site SE0430187.

12.1.1.3 *Geophysical survey in possible cable corridors in Natura 2000 area*

The corridors for the export cable(s) have not been decided yet. The preliminary routes for the export cable(s) are located outside the Natura 2000 areas, but it is possible that the cable corridor passes close by the Natura 2000 Sydvästskånes Utsjövatten and/or Falsterbohalvön, both appointed to protect harbour porpoises, harbour seals and grey seals. As it has not been decided yet it is not possible to conduct a Natura 2000 impact assessment of the possible geophysical surveys in the cable corridors. However, it is expected that the used setup during the seismic survey in the cable corridors will be setup number 3 shown in Table 7.1 using only an Innomar subbottom profiler. Based on the underwater noise modelling, the Innomar will cause underwater noise levels where behavioral avoidance responses for both harbour porpoises, harbour seals and grey seals can occur at approximately 3400 meters from the vessel in the worst-case scenario, which corresponds to a noise impacted area of approximately 135 km^2. The impact range for TTS and PTS is similar for equipment setup nr. 1 (see Table 7.1). As suggested for the seismic survey in the development area for Triton offshore wind farm (see chapter 8), it is recommended that any seismic survey includes a soft start with ramp up to full power over a sufficiently long duration to give the marine mammals time to leave the underwater noise impacted area before the equipment is operated at full power. This will significantly reduce the risk of eliciting both TTS and PTS. Assuming appropriate start-up procedures are put in place the impact caused by the underwater noise from the seismic survey in the potential cable corridors will be similar or smaller than the impact in the development area for Triton offshore wind farm. However, the position of the export cable corridors is needed before a Natura 2000 impact assessment can be undertaken.

12.1.2 Natura 2000 impact assessment during the construction

As described in section 12.1, there is one Natura 2000 area close to the development area for Triton offshore wind farm, appointed to protect marine mammals. However, as the rest are located 25 km or more from the development area, they will not be directly impacted by the offshore wind farm. The construction of an offshore wind farm will have several impacts (see section 7.2), which could potentially affect the Natura 2000 areas and the marine mammals that the areas are appointed to protect. Suspended sediment and changes in habitats are not considered to have a significant impact on marine mammals, as the impacts are either of a very local character or may have a positive effect on the formation of artificial reefs, which could potentially lead to an increase in prey availability in that area. In contrast, marine mammals can potentially be affected by underwater noise from the installation of monopole foundations at a relatively large distance from the installation site and impacts into nearby Natura 2000 sites can therefore not be excluded in advance.

As the underwater noise from pile driving leads to impact ranges for behavioural avoidance responses out to 10.4 km, the underwater noise could potentially cause behavioral avoidance responses of marine mammals inside the nearest Natura 2000-area.

Duration of the deterrence/disturbance appears to be in the range of some hours to at most a day after end of pile driving (Brandt et al. 2011, Dähne et al. 2013, Brandt et al. 2018). The behavioural reaction of porpoises appears to be graduated with distance from the pile driving site, such that fewer animals respond and/or the response of the individual animals becomes less severe, the further away from the pile driving site (e.g. Dähne et al. 2013). A study by Graham et al. 2019 studied the behavioural responses of harbour porpoises during the 10 month installation period of the Beatrice offshore wind farm in the North Sea in 2017 at 84 wind turbine locations. The passive acoustic monitoring of porpoises showed a 50% probability of response within 7.4 km at the first location piled, decreasing to 1.3 km by the final location. This study shows there is a clear tendency for habituation in the behavioural responses of harbour porpoises (Graham, et al., 2019).

The overlap between the Natura 2000 areas and the underwater noise level where the threshold for behavioural avoidance response is exceeded has been calculated and is described in the following section.

The results from the underwater noise modeling show that there is only one Natura 2000 area, where the threshold for behavioral avoidance responses in harbour porpoises is exceeded. It is in the following one Swedish Natura 2000 area SE0430187 Sydvästskånes utsjövatten, appointed to protect harbour porpoise, grey seals and harbour seals.

12.1.2.1 Harbour porpoises

Table 12.2 shows the percentage of the relevant nearby Natura 2000 area impacted by pile driving noise. The impact was estimated as the proportion of the Natura 2000 area where underwater noise levels are expected to exceed the behavioural avoidance responses for harbour porpoises. Based on the SCANS survey and the SAMBAH survey the latest density estimate for harbour porpoises from the Belt Sea population in Southern Baltic Sea is between 0,02-0,2 animals/km^2 in the summer and 0,01-0,1 animals/km^2 in the winter (se section 4.2.3.1). In the winter porpoises from the Baltic Proper population can occur in the area and based on the relationship between the two populations, it is expected that 1,19 % of the harbour porpoises occuring in the area belongs to the Baltic Proper population (see Figure 4.11).

The assessment is conducted for a worst-case scenario and is based on the turbine position (according to the layout) where the largest overlap between the underwater noise propagation and the Natura 2000 area will occur. Figure 12.2 shows the overlap with the specific Natura 2000 area and the underwater noise (based on a worst-case scenario with installation of a monopile with a diameter of 14 m).

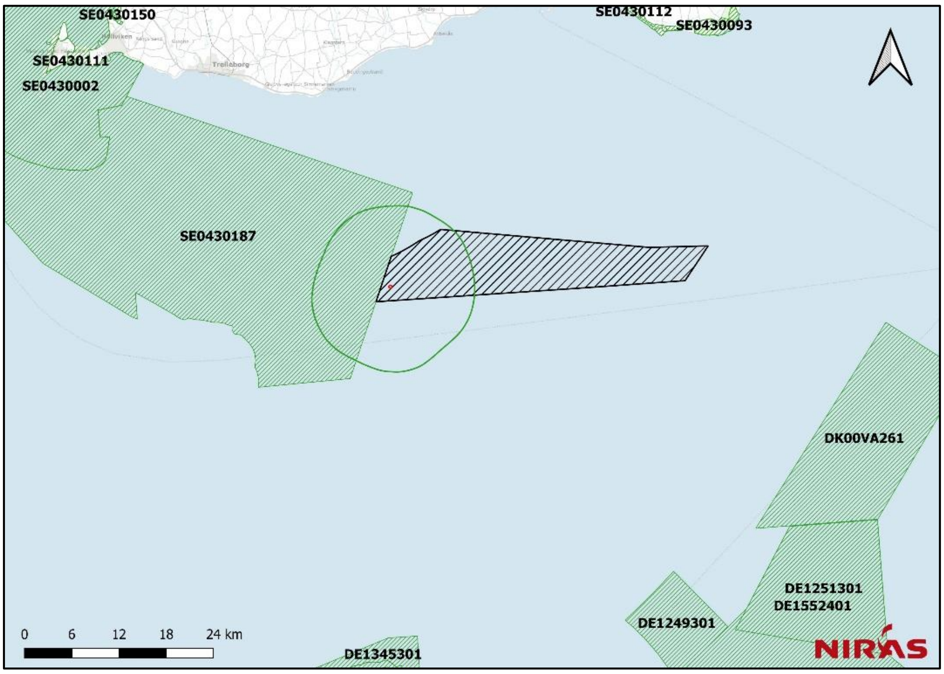


Figure 12.2: Maximum overlap with SE0430187 Sydvästskånes utsjövatten and the underwater noise from pile driving based on a worst-case scenario. TTS will not occur inside the Natura 2000 area. The underwater noise modelling is based on a worst-case scenario with installation of a monopile with a diameter of 14 meter and with application of mitigation measure corresponding to big bubble curtain ©SDFE

Thus, for installation of the vast majority of monopiles, the affected area will be smaller than what is presented in Table 12.2.

Table 12.2: Overlap between the underwater noise and the nearby Natura 2000 area and potentially impacted numbers of harbour porpoises based on densities from SCANS and SAMBAH. The overlap is based on a worst-case scenario with installation of monopiles with a diameter of 14 m and for the foundation closest to the Natura 2000 area.

Natura 2000-area	Size of Natura 2000 area	Overlap of harbour porpoise behaviour impact with Natura 2000 area	Overlap of harbour porpoise behaviour impact with Natura 2000 area	Number of potentially affected harbour porpoises Belt Sea (summer/winter)	Number of potentially affected harbour porpoises Baltic Proper (winter)
SE0430187 Sydvästskånes utsjövatten	1151 km^2	137 km^2	12%	3-28/2-14	<<1

In the Swedish Natura 2000 area Sydvästskånes utsjövatten, located west of the Triton offshore wind, the underwater noise will exceed the threshold for behavioral avoidance responses for harbour porpoises within an area of 137 km^2, which corresponds to 12 % of the area being temporarily affected by underwater noise levels from the pile driving of monopile foundations (see Table 12.2). This corresponds to between 3-28 harbour porpoises potentially experiencing underwater noise levels that exceed the threshold for behavioral avoidance responses during the summer, where only porpoises belonging to the Belt Sea subpopulation are expected to be in the area. In the winter between 2-14 harbour porpoises may be experiencing underwater noise levels that exceed the threshold for behavioral avoidance responses. In the winter harbour porpoises belonging to both the Belt Sea and endangered Baltic Propper population may occur in the area, however it is expected that by far most of the porpoises in the area belong to the significantly larger Belt Sea population.

As the absolute number of porpoises (both inside and outside the Natura 2000 area) disturbed by the piling noise is very low and the disturbance itself is likely to be short-term the impact of construction of Triton offshore wind farm on the Belt Seas population (that can occur in the area all year around), which is considered to be in favorable conservation status, is assessed to be minor. Porpoises from the critically endangered Baltic Proper population can be found in the impacted area, during the winter months. However, as this population is estimated to be very small and very scattered, the proportion of porpoises in the waters around Triton offshore wind farm belonging to the Baltic Proper population is expected to be very low. It is expected that far less than 1 porpoise from the Baltic Proper population may experience underwater noise levels above the behavioural response threshold. If this is combined with the already very low number of porpoises disturbed by a single pile driving event and the short duration of the disturbance, the impact on the Baltic Proper population is assessed to be minor and without consequences for the short-term and long-term status of the population.

Due to the very low absolute number of animals disturbed, the impact from construction of Triton offshore wind farm on porpoises in the nearby Natura2000 site Sydvästskånes Utsjövatten is assessed to be minor and without consequences for the integrity of the site. It is therefore assessed that the construction phase, will not give rise to either short-term or long-term consequences for the conservation status of harbour porpoises from neither the Belt Sea population nor Baltic Proper population within the area. It is assessed that underwater noise from pile driving of monopile foundations with application a soft start/ramp up procedure and application of a big bubble curtain or another equally efficient mitigation system will not cause negative impacts on harbour porpoises (both the Belt Sea and the Baltic Proper) within and outside the Natura 2000 area SE0430187 Sydvästskånes utsjövatten, and thus not prevent maintenance of favorable conservation status for the Belt Sea population of harbour porpoises or achievement of favorable conservation status for the Baltic Proper population of harbour porpoises nor prevent fulfillment of the conservation objectives for the Natura 2000 site SE0430187.

12.1.2.2 *Harbour seals and grey seals*

Table 12.3 shows the percentage of the relevant nearby Natura 2000 SE0430187 area impacted by pile driving noise. The impact is estimated as the proportion of the Natura 2000 area where underwater noise levels are expected to exceed the behavioural avoidance responses for seals (both harbour and grey seals), that as a precautionary principle is assumed to be the same for harbour porpoises. TTS in seals will only occur very close to the piledriving site (within 170 meter) and not inside the Natura 2000 area.

Table 12.3: Overlap between the underwater noise and the nearby Natura 2000 area and impact on harbour seal and grey seal. The overlap is based on a worst-case situation scenario with installation of monopiles with a diameter of 12 m.

Natura 2000-area	**Areal (km²)**	**Harbour seals and grey seals**	
		Overlap of seals behaviour impact with Natura 2000 area	Overlap of seal behaviour impact with Natura 2000 area
SE0430187 Sydvästskånes utsjövatten	1151 km^2	137 km^2	12 %

In the Natura 2000-area SE0430187, located adjacent to the western development area for the Triton offshore wind farm, the underwater noise from piledriving will exceed the behavioral avoidance threshold for seals within an area of 137 km^2, which corresponds to 12 % of the Natura 2000 being short-term affected by underwater noise.

The foraging pattern of harbour seals at Måkläppen (based on tracking data) shows, that the harbour seals primarily use the western part of the Natura 2000 area (see Figure 4.15) and to a smaller extent the eastern part of the Natura 2000 area, that will be temporally exposed to underwater noise from pile driving. Grey seal move over lager distances compared to harbour seals, however based on the tracking data from the eleven grey seals, the grey seals like the harbour seals primarily use the western part of the Natura 2000 area (see Figure 4.22) and to a smaller extent the eastern part of the Natura 2000 area, that will be temporally exposed to underwater noise from pile driving.

As the impacts on harbour seals and grey seals from pile driving will be short term and are expected to be fully reversible, it is assessed that the impact of construction of Triton offshore wind farm on harbour seals and grey seals in the Southern Baltic Sea (both populations are considered to be in favorable conservation status), is minor. The construction of Triton offshore wind farm will not cause negative impacts on harbour seals and grey seals no matter if the marine mammals are located outside or inside the nearby Natura 2000 sites, that have been appointed to protect them.

Construction of Triton offshore wind farm will therefore not prevent achievement of favorable conservation status for, harbour seals and grey seals in the Natura 2000 area SE0430187 nor prevent fulfillment of the conservation objectives for harbour porpoises, harbour seals and grey seals in the Natura 2000 site SE0430187.

12.1.2.3 *Piledriving with application of HSD + DBBC*

In addition to underwater noise modelling with application of a mitigation system corresponding to a single big bubble curtain (BBC), underwater noise modelling assuming the application of a mitigation system corresponding to a double big bubble curtain combined with a hydro sound damper (DBBC+HSD) has been conducted for March, the worst-case month with respect to sound transmission. Figure 12.3 shows the overlap with the specific Natura 2000 area and the underwater noise (based on a worst-case scenario with installation of a monopile with a diameter of 14 m).

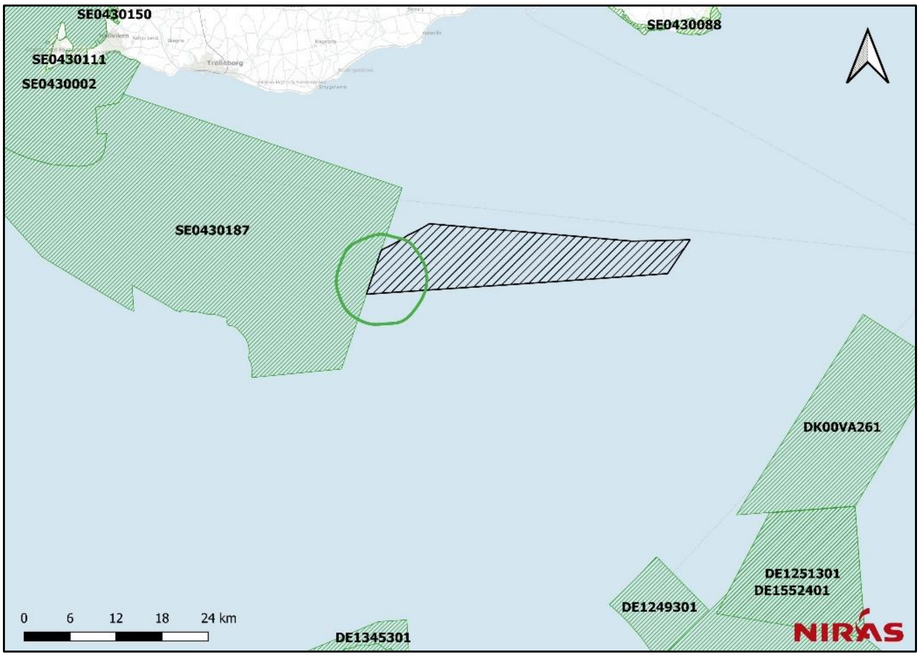


Figure 12.3: Maximum overlap with SE0430187 Sydvästskånes utsjövatten and the underwater noise from pile driving based on a worst-case scenario. TTS will not occur inside the Natura 2000 area. The underwater noise modelling is based on a worst-case scenario with installation of a monopile with a diameter of 14 meter and with application of mitigation measure corresponding to double big bubble curtain in combination with a hydro-sound damper ©SDFE.

The installation is shown for the position with the largest overlap with the Natura 2000 area. Thus, for installation of the vast majority of monopiles, the affected area will be smaller than what is presented in Table 12.2.

Table 12.2: Overlap between the underwater noise and the nearby Natura 2000 area and potentially impacted numbers of harbour porpoises based on densities from SCANS and SAMBAH. The overlap is based on a worst-case scenario with installation of monopiles with a diameter of 14 m and for the foundation nearest to the Natura 2000 area.

Natura 2000-area	Size of Natura 2000 area	Overlap of harbour porpoise behaviour impact with Natura 2000 area	Overlap of harbour porpoise behaviour impact with Natura 2000 area	Number of potentially affected harbour porpoises Belt Sea	Number of potentially affected harbour porpoises Baltic Proper
SE0430187 Sydvästskånes utsjövatten	1151 km^2	40 km^2	3.5%	<1-4	<<1

During winter installation of a monopile with a diameter of 14 meters with the application of a mitigation system with an efficiency corresponding to DBBC+HSD leads to a reduced behavioural impact area and thereby reduced impact on the nearby Natura 2000 area, as well as a reduced number of impacted harbour porpoises compared to installation of a 14-meter monopile applying BBC. The impact area (overlap between the Natura 2000 area and the area where the sound level is above the behavioural threshold) is reduced to 40 km^2, reducing the affected number of harbour porpoises to <1-4 harbour porpoises from the Belt Sea population potentially experiencing underwater noise levels exceeding the threshold for behavioural responses in winter. For the Baltic Proper population the number of porpoises potentially affected is still less than 1 individual.

Table 12.3 shows the percentage of the relevant nearby Natura 2000 SE0430187 area impacted by pile driving noise. The impact is estimated as the proportion of the Natura 2000 area where underwater noise levels are expected to exceed the behavioural avoidance responses for seals (both harbour and grey seals), that as a precautionary principle is assumed to be the same for harbour porpoises. TTS in seals will only occur very close to the piledriving site (<170 meter) and not inside the Natura 2000 area.

Table 12.5: Overlap between the underwater noise and the nearby Natura 2000 area and impact on harbour seal and grey seal. The overlap is based on a worst-case situation scenario with installation of monopiles with a diameter of 14 m.

Natura 2000-area	Areal (km^2)	Harbour seals and grey seals	
		Overlap of seals behaviour impact with Natura 2000 area	Overlap of seal behaviour impact with Natura 2000 area
SE0430187 Sydvästskånes utsjövatten	1151 km^2	40 km^2	3.5 %

In the Natura 2000-area SE0430187, the underwater noise from piledriving will exceed the behavioral avoidance threshold for seals within an area of 40 km^2, which corresponds to 3.5 % of the Natura 2000 being short-term affected by underwater noise.

Thus for both seals and harbour porpoise piledriving with application of mitigation corresponding to DBBC+HSD will caused reduced impacted range compared to piledriving with application of mitigation corresponding to BBC. As for piledriving with application of BBC, piledriving with application of DBBC+HSD will not cause negative impacts on harbour porpoises (both the Belt Sea and the Baltic Proper), harbour seals and grey seal within and outside the Natura 2000 area SE0430187 Sydvästskånes utsjövatten, and thus not prevent maintenance of favorable conservation status for the Belt Sea population of harbour porpoises, harbour seals and grey seals or achievement of favorable conservation status for the Baltic Proper population of harbour porpoises.

12.1.3 Natura 2000 impact assessment during the operation phase

In section 9.1 on impacts on marine mammals during the operational phase it is described that noise from the turbines in operation will only affect harbour porpoises in the immediate vicinity of the turbines (within 100 meters), and it is assessed to have a negligible impact on harbour porpoise. Because of their better hearing capability at low frequencies, seals will hear the noise at longer distances, However, seals seem to be more tolerant to underwater noise (Kastelein, 2011; Southall, et al., 2019). This finding is supported by a relatively recent study on seals at the German offshore wind farm Alpha ventus (Russell, et al., 2014). A tagged harbour seal foraged at the foundations of all 12 operating wind turbines, and it clearly preferred the foundation structures over other areas inside the wind farm (see Figure 6.12). Noise from wind farms could therefore potentially also serve as a kind of "dinner bell".

Electromagnetic fields from the operating offshore wind farm are considered to have negligible impact on harbour porpoises (se section 9.4). It is also assessed that underwater noise from ships and maintenance of the wind farm will have a minor impact on harbour porpoises and seals (se section 9.2). Introduction of hard bottom substrates (foundations and erosion protection) and thus the introduction of artificial reefs will potentially have a positive (albeit limited) impact on the marine mammals, as it may lead to introductions of more fish species associated with hard bottom substrates and thus increase the foraging opportunities for the marine mammals (see section 9.3).

As the impacts on harbour porpoises, grey seals and harbour seals in the operational phase will be very limited and will only affect harbour porpoise that may be in the immediate vicinity of the wind farm, it is assessed that the operation of Triton offshore wind farm will not cause negative impacts on harbour porpoises, harbour seals and grey seals no matter whether the marine mammals are located outside or inside the nearby Natura 2000 sites, that have been appointed to protect them.

Operation of Triton offshore wind farm will therefore not prevent achievement/maintenance of favorable conservation status for harbour porpoises, harbour seals and grey seals in the Natura 2000 areas SE0430187 nor prevent fulfillment of the conservation objectives for harbour porpoises, harbour seals and grey seals in the Natura 2000 area SE0430187.

12.1.4 Natura 2000 impact assessment during the decommissioning phase

As described in chapter 10, the decommissioning phase is expected to include more or less the same type of activities as the construction phase, but with the important exception, that no foundations will be installed in the seabed by pile driving. As impacts from the decommissioning phase are comparable to, or less than impacts from the construction phase, the impacts from sediment spillage, habitat loss, noise and disturbance to marine mammals are all ranked to cause a minor to negligible impact (see section 12.1.4 for more details). It is therefore assessed that the decommissioning of Triton offshore wind farm will not cause significant impact on the harbour porpoises, grey seals and harbour seals no matter whether the marine mammals are located outside or inside the nearby Natura 2000 sites, that have been appointed to protect them.

Overall, the decommissioning phase is not considered to cause any significant impact to harbour porpoises, harbor seals and grey seals in the nearby Natura 2000 sites, and the decommissioning phase of the offshore wind farms will therefore not prevent maintenance/achievement of favorable conservation status for harbour porpoises nor prevent fulfillment of conservation objectives for harbour porpoises, harbour seals and grey seals in the Natura 2000 area SE0430187.

12.2 Species protection

The harbour porpoise is a species protected by several international agreements and laws (see section 5.1.1). Since the harbour porpoise is listed in Annex IV of the Habitats Directive the species is subject to an assessment of strictly protected species in relation to Article 12 (1) of the Directive 92/43/EEC of the Council on the protection of species.

Article 12 (1) states that Member States shall take the requisite measures to establish a system of strict protection for the animal species listed in Annex IV in their natural range, prohibiting:

(a) all forms of deliberate capture or killing of specimens of these species in the wild;

(b) deliberate disturbance of these species, particularly during the period of breeding, rearing, hibernation and migration;

(c) deliberate destruction or taking of eggs from the wild;

(d) deterioration or destruction of breeding sites or resting places.

As harbour porpoises do not have definable breeding and resting sites the obligations under (c) and (d) are not applicable for the species.

An assessment according to Article 12 (1) of the Directive 92/43/EEC of the Council on the protection of species is conducted in the following section.

12.2.1 Assessment of Article 12 (1) (a) and (b)

As described in the previous chapters, the construction, operation and decommissioning of Triton offshore wind farm will not directly result in the death of harbour porpoises. The project will also not cause permanent hearing damage in harbour porpoises, that could potentially reduce the individual's fitness and thus increase the risk of the individual dying, as harbour porpoises depend on their hearing for foraging and navigation.

The underwater noise from pile driving during construction of the Triton offshore wind farm, will most likely lead to short-term disturbances of harbour porpoise behaviour at a range of up to 10.4 km (worst-case). Within shorter distances, it could lead to more severe evasive responses and total evasion of the area in the immediate vicinity of the pile driving site. It is expected that there will be a decrease in the occurrence of harbour porpoises in and near the development area for Triton offshore wind farm and that the effect will last a few days - to few weeks after pile driving of foundations has been completed. It is expected that the impact will be fully reversible and that harbour porpoises will return to the area soon after piling has ceased.

In the summer period only porpoises from the Belt Sea population occur in the area, however in the winter period individuals from the Baltic Proper subpopulation can also occur in the area.

The Belt Sea population is considered to be in favourable conservation status, whereas the Baltic Proper population is critically endangered and is in unfavourable conservation status (Fredshavn, et al., 2019). The development area is not an important feeding ground for harbour porpoises in general and has not been identified as an important breeding area for harbour porpoise. Furthermore, as mentioned in section 4.1.3 the development area for Triton offshore wind farm is located in a transition zone for the Belt Sea and Baltic Proper harbour porpoise populations and the area is at the border of both populations range. The density in the area is low especially compared to the density west of the development area towards the Danish straits inhabited by the Belt Sea population of harbour porpoises. It is therefore expected that most of the porpoises in the development area for Triton offshore wind farm belong to the Belt Seas population, whereas a smaller number, during the winter months, may be from the critically endangered population from the Baltic Proper population.

The impact on harbour porpoises from the project is assessed as minor (see section 8.1.1). Therefore, the Annex IV protection of harbour porpoises is maintained, as the project does not result in harbour porpoises being caught, killed, intentionally disturbed or having their breeding or resting areas damaged or destroyed. Triton offshore wind farm will therefore not affect the areas ecological functionality for harbour porpoises in general or affect the ecological functionality of habitats for the subpopulations of harbour porpoises in the area. It is therefore assessed that the Triton offshore wind farm will not give rise to either short-term or long-term consequences for the conservation status of either the Belt Sea population or the Baltic Proper population.

13 Cumulative effects

The assessment of cumulative effects is based on the impact assessment of the project in combination with other local or regional projects or plans, which may contribute to a cumulative environmental impact. When several planned projects within the same area affect the same environmental recipients at the same time, cumulative impacts will occur. For Triton offshore wind farm, cumulative impacts may arise if other wind farms or projects that cause the same type of impacts are constructed at the same time. The assessment is based on projects that have obtained a construction permit as well as project in the planning phase and simultaneous construction of the two sub-areas.

Cumulative effects on marine mammals are assumed to occur only during the construction phase, as impact during the operational phase is assessed as having a limited local impact on the marine mammals (se section 9.1) and therefore cumulative impacts in the operational phase are unlikely to occur.

The underwater noise from construction of Triton offshore wind farm (especially pile driving) can cause both spatial and temporal cumulative impacts with other projects if the construction phase of Triton offshore wind farm overlaps with the construction phase at an adjacent site.

Spatial cumulative impacts may occur when/if noisy construction works in Triton, especially pile driving, takes place simultaneously with comparable measures in adjacent projects. In this case the individual impact zones from the individual projects may add up and thereby constitute an even larger impact zone from which marine mammals cannot flee as quickly as from a single impact zone.

There are other planned offshore wind farms relatively close to the development area for Triton offshore wind farm. Table 13.1 lists nearby offshore wind farm projects that are either under construction, with a consent authorized or in the early planning phase.

Table 13-1: Projects considered for cumulative assessment.

Wind farm	Country	Total planned MW/number of turbines	Approximate distance to Triton	Consenting phase	Expected construction year
Sydkusten Vind	Sweden	500/25-33	10 km	Early planning	2025
Kriegers Flak II	Sweden	500-640/32-80	17 km	Consent Authorized	2026-2028
Kriegers Flak	Denmark	605/72	38 km	Partial Generation/Under construction	2019-2021
Bornholm	Denmark	90-100 MW/8	42 km	Early planning	2030
Bornholm I + II	Denmark	3 GW	16 km/19 km	Early planning	2030
O-1.3	Germany	200 MW	19 km	Early planning	2026
Arcadis Ost 1	Germany	257/27	27 km	Consent Authorized	2025
Baltic Eagle	Germany	476/52	27 km	Under construction	2025
Wikinger Süd	Germany	10/1	31 km	Under construction	2025

Offshore wind farms under construction will not overlap with the construction phase for Triton offshore wind farm, as it is expected that they are in operation when the construction of Triton offshore wind farm is initiated in 2028-2030. This applies to Sydkusten Vind, Kriegers Flak, Arcadis Ost 1, Baltic Eagle and Wikinger Süd. For Kriegers Flak II consent has already been authorized and, it is unlikely that the construction phase of Triton offshore wind farm and these two projects will overlap. The German O-1.3 offshore wind farm development area is in the early planning phase, however construction is planned to be conducted in 2026, why it is unlikely that the construction phase of Triton offshore wind farm and this project will overlap. The cumulative impacts are therefore expected to be negligible for these projects.

Approximately 16 and 19 km southeast of the Triton, Energinet is planning to construct Bornholm I and II offshore wind farms with a capacity of 3 GW. Bornholm I and II are in the early planning phase. It has not deemed likely that the construction of Bornholm I and II would overlap with the construction phase of Triton. If simultaneous pile driving occurs during construction in the project areas, cumulative impacts regarding behavioural responses would very likely occur as the distance between the project areas is approximately 16. The two zones of impact could add up to a large, connected impact area. The displacement from one site may also drive animals inside the impact area of the other site and increase the overall disturbance effect. It is not possible to make detailed predictions for the probability of cumulative impacts between simultaneous pile driving events at the project areas as the uncertainties are still too large as to whether cumulative impact will even arise as Bornholm I and II have not been given a final construction permit and it is still unclear when the wind farm will be realized.

14 Possible mitigation measures and monitoring

In the following different types of mitigation measures are described.

14.1 Avoidance of the sensitive periods (scheduling)

In the European guidance document on wind energy developments and EU nature legislation it is stated the scheduling involves avoiding or suspending construction activities (e.g., pile driving) during sensitive periods of the biological cycles of species (e.g., in breeding or feeding seasons). Scheduling is considered a very effective measure as it can prevent the disturbance of species from noise and other effects during these periods. However, it is also mentioned that seasonal restrictions could be hard to implement for some species with long sensitive periods. For example, the harbour porpoises in the North-Atlantic. They mate in July/August and give birth to their calves in May/June the following year. Thereafter, the calves are completely dependent on their mothers for milk for about 8-10 months. During this time, it is assumed that if mother and calf are separated, this can very easily lead to the calf's death. There are therefore no 'safe' periods for harbour porpoise (European Commission, 2020) in such cases noise abatement systems can often be preferred. Even though there are no safe periods, over the cause of the nursing period calves slowly transition to a more juvenile diet (Smith & Read, 1992), which will likely reduce the sensitivity to disruption somewhat in older calves. Therefore, it is assessed that the most sensitive period is when the females give birth and mating takes place. As the development area for Triton is not important in the breeding season (or in any other season) time restrictions to avoid the breeding season is not necessary and noise abatement systems can often be preferred.

14.1.1 Underwater noise abatement systems

As foundation structures become larger and more knowledge comes to light about marine mammal hearing, the more unlikely it is that the projects can comply with local regulation without source mitigation. The underwater noise modelling, that forms the basis for the assessment of impact of underwater noise in the present report, has therefore been conducted with application of big bubble curtains (an often-used approach in offshore wind farm construction). However, other types and mitigations systems are available. The following section provides a brief description of different Noise Abatement Systems (NAS) which in one way or another reduce the noise emission from pile driving events. Knowledge of the best achievable source mitigation, currently available, is also presented.

The most frequently applied technique uses bubble curtains. Air is pumped into a hose system positioned around the pile installation at the bottom of the sea (Figure 14.1). The hoses are perforated and air bubbles leak and rise toward the surface. This forms a curtain through the entire water column from seabed to sea surface. Due to the change in sound speed in the water-air-water bubble interface, a significant part of the outgoing noise is reflected backwards and kept near the pile, while the remaining noise energy going through the bubble curtain is greatly attenuated (Tsouvalas, 2020).

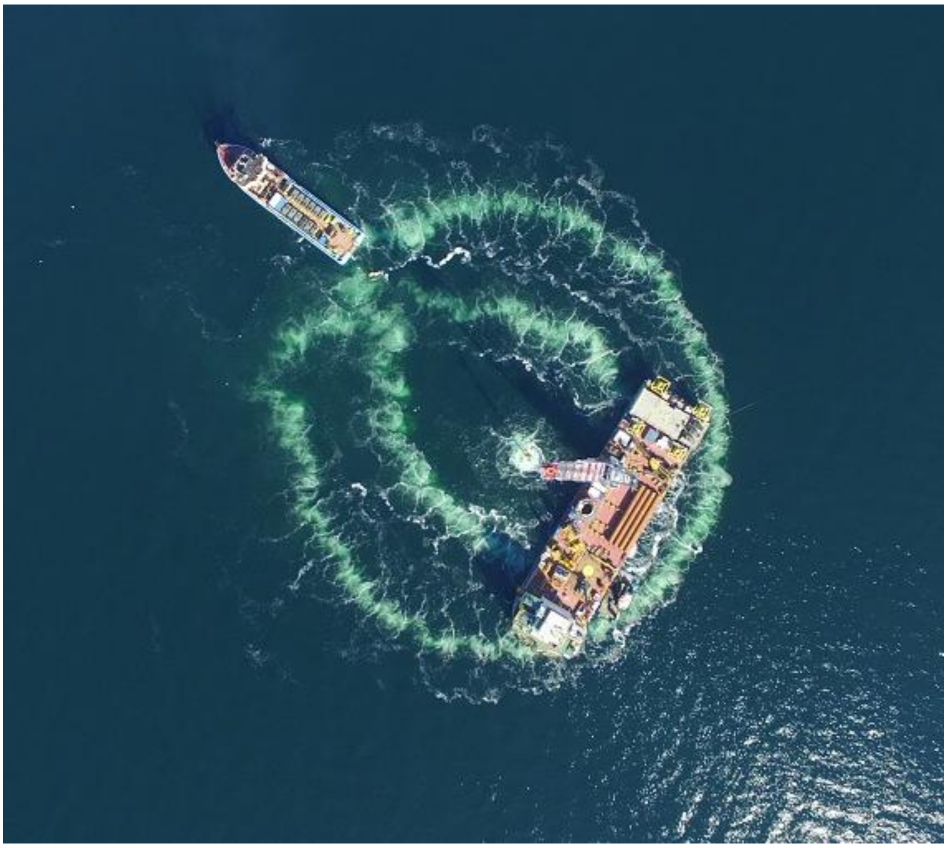


Figure 14.1: Example of active bubble curtain (double Big Bubble Curtain) deployed around the jack-up platform used for pile driving. Air bubbles are visible in the surface as the white ring. The ship in the front is used for deployment and retrievement of the hose system and contains the very large compressors needed to feed the bubble curtain with compressed air. Hydrotechnik Lübeck.

Part of the noise emission from pile driving occurs through the sediment, which is then reintroduced to the water column further from the pile. It is therefore important, that bubble curtains are not placed too close to the source, as this would reduce their effectiveness on the ground borne noise contribution. Big Bubble Curtains can mitigate some of this noise as it is partly reintroduced to the water column after a few metres. Big Bubble Curtains usually surround the construction site completely leaving no gaps where noise is emitted unhampered. Currents can cause a drift in bubbles, but this difficulty can be overcome if the Big Bubble Curtain is installed in an oval rather than a circle. This system was used for example in Borkum West II, where a noise reduction of on average 11 dB (unweighted broadband) was achieved with the best configuration. This project tested different configurations. The success depended on three parameters: size of holes in the hosepipe (determines bubble sizes), spacing of holes (determines density of bubble curtain) and the amount of air used (air pressure). The best configuration was found to be with relatively small holes, a small spacing and using a substantial air pressure (Diederichs, et al., 2014).

The effect of bubble curtains can be increased further if a second bubble curtain is installed even further from the installation, thereby forming a Double Big Bubble Curtain (DBBC). The effect is greatest if the distance between the systems is at least three times the water depth (Koschinski S et al., 2013)..

Another type of NAS are pile sleeves, which act as a physical wall around the pile. One such system is the Noise Mitigation Screen (IHC-NMS) where a double walled steel sleeve is positioned around the pile, thus using the impedance difference in the water-steel-air-steel-water interfaces to reduce the sound transmission. This system was used for example at the German wind farm Riffgat. Noise mitigation was assessed to be around 16-18 dB (Verfuß, 2014). Often, a pile sleeve NAS is applied in combination with a bubble curtain solution to increase the overall mitigation effect.

Another type of NAS is the Hydro Sound Damper (HSD), which is in many ways similar to the bubble curtain, however instead of using hoses with air, the curtain consists of fixed position air-filled balloons or foam-balls. The size, spacing and density of the foam balls or air-filled balloons then dictate the achievable noise mitigation. With the HSD system, it is possible to "tune" the NAS to work optimally at specific frequencies, thus allowing for project specific optimal solutions.

Cofferdams are a special type of pile sleeve. They also surround the pile, however in comparison to the IHC-NMS, the water in between the pile and the sleeve is extracted, so that the interface from pile to water becomes air-steel-water. These sleeves are estimated to reduce noise by around 20 dB, as demonstrated in Aarhus Bay (Verfuß, 2014). However, tests further offshore and in connection with the construction of wind farms have yet to be carried out (Verfuß, 2014). An inherent challenge with this solution is however that it can be difficult to keep the water out of the cofferdam.

For commercially available and proven NAS, a summary of achieved mitigation levels throughout completed installations is given in (Bellmann, 2020), as shown in Figure 14.2.

Figure 14.2: Achieved source mitigation levels on completed projects using different NAS (Bellmann, et al., 2020).

No.	Noise Abatement System resp. combination of Noise Abatement Systems (applied air volume for the (D)BBC; water depth)	Insertion loss ΔSEL [dB] (minimum / average / maximum)	Number of foundations
1	IHC-NMS (different designs) (water depth up to 40 m)	$13 \leq 15 \leq 17$ dB IHC-NMS8000 $15 \leq 16 \leq 17$ dB	> 450 > 65
2	HSD (water depth up to 40 m)	$10 \leq 11 \leq 12$ dB	> 340
3	optimized double BBC[*1] (> 0,5 m^3/(min m), water depth ~ 40 m)	15 – 16	1
4	combination IHC-NMS + optimized BBC (> 0,3 m^3/(min m), water depth < 25 m)	$17 \leq 19 \leq 23$	> 100
5	combination IHC-NMS + optimized BBC (> 0,4 m^3/(min m), water depth ~ 40 m)	17 – 18	> 10
6	combination IHC-NMS + optimized DBBC (> 0,5 m^3/(min m), water depth ~ 40 m)	$19 \leq 21 \leq 22$	> 65
7	combination HSD + optimized BBC (> 0,4 m^3/(min m), water depth ~ 30 m)	$15 \leq 16 \leq 20$	> 30
8	combination HSD + optimized DBBC (> 0,5 m^3/(min m), water depth ~ 40 m)	18 – 19	> 30
9	GABC skirt-piles[*2] (water depth bis ~ 40 m)	~ 2 – 3	< 20
10	GABC main-piles[*3] (water depth bis ~ 30 m)	< 7	< 10
11	„noise-optimized" pile-driving procedure (additional additive, primary noise mitigation measure; chapter 5.2.2)	~ 2 - 3 dB per halving of the blow energy	

It must, however, be noted that the reported broadband mitigation, ΔSEL is given for a flat frequency spectrum, to compare the efficiency of the different mitigation systems on different pile installations. That is, the source level mitigation achievable for a source with equal acoustic energy in all octave bands, also called pink noise. Pile driving spectra however, as described in section 6.2.2, are far from a flat octave band spectrum, and the effective noise mitigation achieved, in terms of sound level measured with and without the system in use at a specific installation, will therefore differ from the listed mitigation. In Figure 14.3, the broadband flat spectrum attenuation achieved with the different NAS, are instead given in 1/3 octave bands, thus showing the achieved mitigation per frequency band.

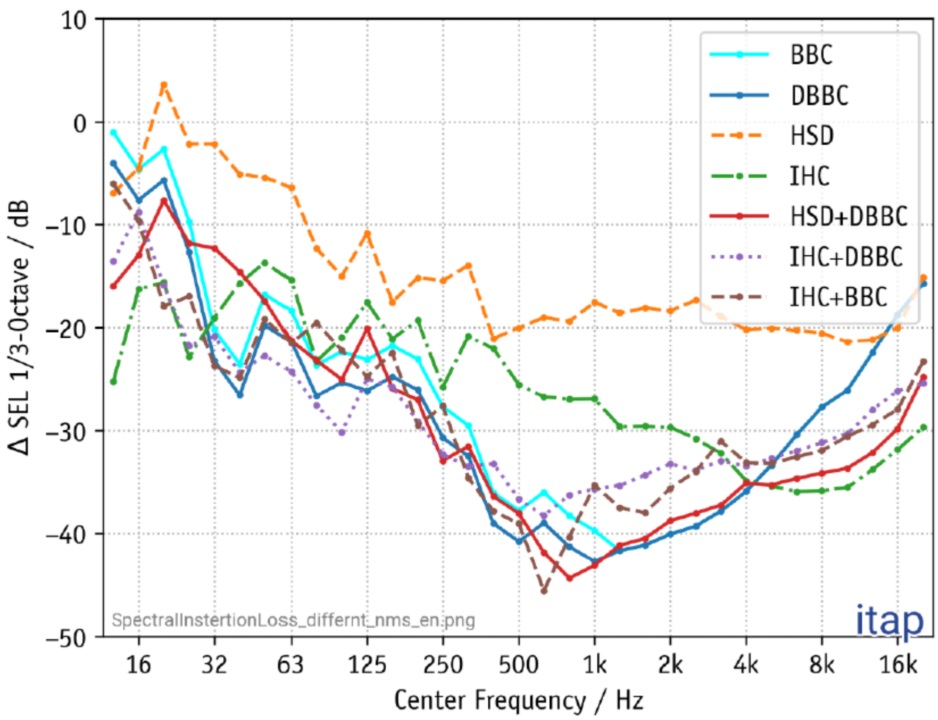


Figure 14.3: Frequency dependent noise reduction for Noise Mitigation solutions (Bellmann, et al., 2020).

Lastly, it is important to recognize, that development of new and improved noise mitigation systems is an ongoing process, and with every offshore wind farm installed, new knowledge and often also new solutions become available.

14.1.2 Adjustment of Piling Procedure

As an obvious adjustment the piling energy can be reduced. The less energy used for the hydraulic hammer the less noise is emitted. The application of a soft start procedure is therefore a good mitigation measure and has been applied in the underwater noise modelling. For a description of soft start/ramp up procedure see section 6.2.5 (Underwater noise modelling).

A certain amount of energy is however required especially in hard substrates and the entire piling procedure is prolonged. Therefore, a reduction in hammer-energy as a means to lowering the noise level leads to an increase in the time required for pile-driving and thus a prolonged period with piling noise (Nehls & Betke, 2011; Koschinski S et al., 2013).

Another adjustment can be impulse prolongation. The contact time between the hydraulic hammer and the pile is increased. In this way the energy is transferred over a longer time, which reduces the maximum emitted noise. At 30 m from the construction site this can reduce the noise level by 11 dB (Verfuß, 2014).

14.1.3 Surveillance of exclusion zones: visual and acoustic observations

The demarcation and surveillance of exclusion zones can reduce disturbance and displacement effects and avoid the acoustic impairment of marine mammals. Surveillance is a commonly implemented measure and involves marine-mammal observers being tasked to visually - and often also acoustically - monitor a zone around the noise source for at least 30 minutes (e.g., the British guidelines). This is to ensure, as far as possible, the absence of marine mammals (before beginning piling, UXO detonation, etc). This zone may be demarcated by a fixed distance from the source (e.g., 500 m). The exclusion zone is aimed at reducing close proximity noise exposure and protecting animals from direct physical harm. It is unlikely to be effective in mitigating behavioural responses over greater distances, since disturbance in more remote areas is still likely to occur (European Commission, 2020).

It is important to note that effectiveness may be limited by: (i) adverse weather conditions and darkness (both of which restrict visual observation); (ii) factors such as the limited propagation of vocalizations of some species such as the harbour porpoise (typically not more than around 200 m for this species); and (iii) the general absence of vocalizations in pinniped species of relevance to most offshore wind energy assessments.

14.1.4 Deterrence device

Pingers and seals scarers are regularly used as deterring devices before the soft start procedure is initiated. Pingers are designed specifically to scare harbour porpoises away from fishing nets and there are different devices on the market. Pingers scare harbour porpoise out to distances of 100-300 meters depending on the used type (Kindt-Larsen, et al., u.d.; Omeyer, et al., 2020). Seal scarers are more powerful underwater sound emitters and deter seals out to some hundred meters (Mikkelsen, et al., 2017b). They are even more effective in deterring harbour porpoises out to at least 1300 meters (Mikkelsen, et al., 2017a) and can cause behavioural responses as far away as 10-12 km (Dähne, et al., 2017), thereby causing a significant disturbance of porpoises in itself. Dahne et al. (2017) describe the use of an acoustic deterrent device to protect harbour porpoises from losing their hearing due to pile-driving noise. The authors noted strong reactions to the seal scarer and raised concerns that it may surpass the reactions to the pile-driving noise itself when operating with bubble curtains. This suggests that there are grounds for a re-evaluation of the specifications of such acoustic deterrent devices (European Commission, 2020). Acoustic deterrent devices do not reduce behavioural effects, but only reduce the direct physical effects. Seal scarers should therefore only be used to the extent it can aid in mitigating more serious effects, such as hearing loss (Tougaard & Mikaelsen, 2020). Alternatively, other deterrent devices with lower source levels and/or higher frequency signals with lower long-range propagation should be utilized, such that deterrence within a suitable safety zone can be assured, while long-range disturbance is minimized.

14.2 Monitoring during the construction

14.2.1 Monitoring to ensure the efficiency of mitigation measures

As mentioned in the description of the underwater noise modelling, mitigation measures such as bubble curtains (BBC) or similar mitigation measures systems (just as or more efficient system) will be used during pile driving as will a soft start/ramp up procedure. To ensure mitigation and to document the efficiency of the noise mitigation and that the requirements of the underwater noise modelling fulfilled, a passive acoustic monitoring system of stationary hydrophones is recommended, deployed in the vicinity of construction sites. The monitoring protocol could e.g., follow the Danish guideline for underwater noise – Installation of impact-driven piles (Energistyrelsen, 2016), where control measurements is suggested to be performed at a distance of 750 meters from the pile driving site as well as additional control measurements. The additional control measurements could for example be at 3 km and at a further distance, such as the predicted behavior impact distance.

14.2.2 Monitoring for detection and documentation of disturbance effects during pile driving

The effects of disturbance during construction can be assessed in two ways. Firstly, the degree of disturbance due to a single pile driving event can be detected. For this purpose harbour porpoise detectors (e.g. F-PODs) and additional hydrophones (to monitor the underwater noise from pile driving) are placed in the wind farm area as well as at defined distances in order to estimate zones of impact. By this means, avoidance behaviour during single pile driving events as well as between these events can be documented on a spatial scale. This method has been applied for example during pile driving in the German Bight (Rose, et al., 2019).

15 Applied mitigation measures

For the seismic survey, the following mitigation measures should be included (following the Danish guidelines for seismic surveys (Energistyrelsen, 2018), to reduce the impact on marine mammals:

- The seismic survey should be started with a 30 minute soft start/ramp up to full power to allow marine mammals in the potentially hazardous zone near the seismic survey vessel to swim away, before the seismic survey is running at full power, to ensure that porpoises and seals are not within the risk zone for TTS and PTS.
- Passive acoustic monitoring should be applied as well as observers should be onboard the survey vessel to ensure that no marine mammals are in close proximity of the survey vessel at the onset of the seismic survey.
- If the seismic survey is interrupted, the onset of the seismic survey should include a soft start procedure.

For pile driving, the following mitigation measures should be applied to reduce the impact on marine mammals:

- Prior to commencement of pile driving deterrence devises developed for harbour porpoises should be used in the required extent. Consultation with the relevant authority must take place (before the planned piling takes place) for decision on methods, scope and duration.
- Pile driving should be conducted with application of a soft start /ramp up procedure.
- Pile driving should be conducted with application of a noise abatement systems with an efficiency corresponding to the attenuation achieved by application of a Big Bubble Curtain (BBC) or more.

16 Potential uncertainties for assessment

The knowledge on the potential impacts on marine mammals from construction of offshore wind farms has increased significantly in recent years, but there are in certain parts some deficits in total knowledge on the long-term consequences of noise for marine mammals, especially at long-term population level. In situations where in-depth scientific knowledge is lacking, a worst-case approach is applied based on available scientific knowledge. Such an approach safeguards that no impact is underestimated or disregarded, and results in conservative impact assessments.

For some potential pressures, the impact is not clear. It is for example not clear how electromagnetic fields affect harbour porpoises and other toothed whales in general (if at all). Electroreception has been documented in one species of marine mammal, the Guiana dolphin (*Sotalia guianensis*), but this has yet to be found in any other marine mammal. It could have a negative effect on the species' sense of orientation if it uses electromagnetic fields as a guide, but the sensory basis for this orientation is still unclear and the effects are apparently even more complex. It can only be stated that no direct visible / detectable effect on toothed whales has been observed yet.

Only few studies have addressed the impact from ship traffic, and therefore there is still a lack of knowledge on how to assess the consequences of such activities.

Many effects are complex or site specific. For instance, the redistribution of porpoises in a wind park during operation is different from site to site. In Dutch waters an above-average usage of wind farms was demonstrated, whereas in another wind farm the local porpoise population increased only slowly after construction. This indicates that site specific factors are involved. Why and how porpoises behave differently at different sites remains speculative. Possibly, porpoises in an environment influenced by human activity accommodate faster and better to new impacts than animals at remote and more undisturbed locations, but this is only speculative at this point. Animal behavior and distribution likely depend on a great variety of factors which makes it hard to predict and assess a single one. Large agent-based models are being developed to aid in answering some of these questions, but there still quite a way to go.

17 Conclusion of the total impact

Impacts on marine mammals because of the construction of the Triton offshore wind farm will be of short-term or of temporary duration for the investigation, construction and decommissioning phase, while any impacts of the operational phase will be of permanent duration.

Underwater noise from seismic surveys and construction is considered by far the most important source of potential impacts on marine mammals.

For the seismic survey, the following mitigation measures should be included (to reduce the impact:

- The seismic survey should be started with a 30 minute soft start/ramp up to full power to ensure that porpoises and seals are not within the risk zone for TTS and PTS.
- Passive acoustic monitoring should be applied as well as observers should be onboard the survey vessel to ensure that no marine mammals are in close proximity of the survey vessel at the onset of the seismic survey.
- If the seismic survey is interrupted, the onset of the seismic survey should include a soft start procedure.

For pile driving, the following mitigation measures should be applied to reduce the impact on marine mammals:

- Prior to commencing with pile driving deterrence devises developed for harbour porpoises should be used in the required extent. Consultation with the relevant authority must take place (before the planned piling takes place) for decision on methods, scope and duration.
- Pile driving should be conducted with application of a soft start /ramp up procedure.
- Pile driving should be conducted with application of a noise abatement systems with an efficiency corresponding to the attenuation achieved by application of a Big Bubble Curtain (BBC) or more.

The combined impact on the harbour porpoises, harbour seals and grey seals is assessed to be negligible to minor and without consequences for the short-term and long-term status of populations. This assessment is under the assumption that an appropriate soft start/ramp up procedure is applied.

Underwater noise during the construction phase is considered by far the most important source of potential impacts on marine mammals. This applies in particular to underwater noise from pile driving, which if not mitigated could cause behavioural avoidance responses, temporary threshold shift (TTS), and permanent threshold shift (PTS) in marine mammals. In the worst-case scenario, underwater noise from efficient pile driving of one monopile will be present 6 hours per day for approximately four months if one pile is installed pr. day. However, the total period where foundation installation work takes place will be longer, as e.g. weather conditions can delay the construction work and it is expected that installation of one foundation will take 2 days leading to 260 days of foundation installation. The intense ship traffic associated with the construction activities may also contribute to the impact from underwater noise.

In this project noise propagation modelling of underwater noise from pile driving assumes that a noise abatement system is used, with an efficiency corresponding to the attenuation achieved by application of a big bubble curtain (BBC), and impact ranges were calculated including this. Application of BBC prevents PTS in both harbour porpoises and seals. Furthermore, the impact range for TTS is very limited for both harbour porpoise (~300 meter) and for seals (~825 meter) and is assessed to cause a negligible impact on both harbour porpoise and seals.

The development area for Triton offshore wind farm is located in a transition area, where harbour porpoises from both the Belt Sea subpopulation and the critically endangered Baltic Proper population may occur. However, the area is at the border of both populations range and the development area is not assess as being a suitable harbour porpoise habitat (supported by low porpoise densities), or a breeding ground for harbour porpoises. Porpoises from the Belt Sea population can occur in the area during all seasons, whereas few individuals from the Baltic Proper population are only potentially found in the area during the winter period. It should be noted that during the winter period, it is still expected that by far the majority of harbour porpoises in the area are expected to be from the Belt Sea population, as it is far more numerous.

In the worst-case scenario 4-39 harbour porpoises from the Belt Sea population and less than 1 harbour porpoises from the critically endangered Baltic Proper population may be exposed to underwater noise levels the exceed the threshold for behavioural avoidance responses during installation of one monopole during the winter period. It is expected that harbour porpoises will avoid the construction site during pile driving and that they will return a few days to a few weeks after the pile driving is completed.

Since calculated estimates show that less than one Baltic Proper harbour porpoise may experience underwater noise levels above the behavioral threshold during pile driving in winter months and that the development area is a low quality habitat for harbour porpoises overall, supports that time restrictions for pile driving in the winter months are unnecessary.

In addition to underwater noise modelling with application of a mitigation system corresponding to a single big bubble curtain (BBC), underwater noise modelling has also been undertaken assuming the application of a mitigation system corresponding to a double big bubble curtain combined with a hydro sound damper (DBBC+HSD). Modelling has been conducted for March a worst-case scenario with respect to sound transmission). The underwater noise modelling showed that no PTS or TTS will be elicited in any harbour porpoise. Noise levels exceeding the threshold for behavioural reactions may occur out to 6.7 km from the pile driving site in the worst-case scenario. Based on this worst-case scenario 1-13 harbour porpoises from the Belt Sea population and far less than 1 harbour porpoises from the critically endangered Baltic Proper population may be exposed to underwater noise levels that exceed the threshold for behavioural avoidance responses during installation of one monopole during the winter period. Based on the underwater noise modelling with application of a mitigation system corresponding to a DBBC+ HSD, the impact assessment of behavioural avoidance responses in harbour porpoises is still minor for the Belt Sea population and minor for the Baltic Proper population during the winter period.

The overall assessment of the impact of underwater noise from pile driving on harbour porpoise in relation to behavioural avoidance responses is assessed to be minor for both populations during the winter period and negligible for the Baltic Proper harbour porpoises during the summer, as they are not expected to be in the Southern part of the Baltic Sea in this period.

The impact of underwater noise from pile driving on harbour seals and grey seals is assessed as minor, as it is a limited area of the seals home range, in which the underwater noise exceeds the threshold for behavioural avoidance responses. In the worst-case scenario (piledriving with application of BBC) up to 7.5 % of the home range for harbour seals and 0.55 % of the home range for grey seals will be affected short-term. Seals are in general, considered to be more noise tolerant compared to harbour porpoises. The impact of underwater noise from pile driving with application of DBBC+HSD on harbour seals and grey seals is assessed as minor. In the worst-case scenario up to 2.3 % of the home range for harbour seals and 0.17 % of the home range for grey seals will be affected short-term.

The assessments of the potential impacts on marine mammals are based on a worst-case scenario in relation to the underwater noise propagation and specific thresholds for behavioral avoidances responses and temporary threshold shift. If the actual underwater noise propagation during the installation of foundations is reduced, due to e.g., smaller foundations, less hammer energy or fewer hammer blows, the impact on marine mammals will be correspondingly reduced.

Other construction-related impacts on marine mammals could potentially result from sediment spills and increased concentrations of suspended sediment, especially during the installation of foundations, inter-array and export cables. However, the effects on marine mammals due to suspended sediment is more indirect and is rated as negligible.

All potential impacts related to the operational phase of the wind farm are assessed as negligible to minor. This applies to underwater noise from the wind turbines in operation and maintenance traffic as well as to electromagnetic fields around the cables and permanent habitat changes by the introducing of hard bottom substrate at the wind turbine foundations. Underwater noise from the wind turbines in operation will only exceed the existing background noise level in close vicinity to each wind turbine. Regarding habitat changes the small direct habitat loss is accompanied by alterations that may lead to an improvement of the food resources for marine mammals (introduction of hard substrate, exclusion or regulation and limitation of fisheries).

Noise will occur in connection with the decommissioning work, although it is expected to be considerably less intensive compared to the construction phase, as there will be no pile driving activities. For other potential impacts during the decommissioning phase, it is expected that they will be smaller or equal to the impacts during the construction phase. The overall impact on marine mammals in the decommissioning phase is assessed to be minor.

The protection of harbour porpoises, harbour seals and grey seals is part of the conservation objectives for a large number of both Danish and Swedish marine Natura 2000 areas. During pile driving of foundations, one of the nearby Natura 2000 areas "SE0430187 Sydvästskånes utsjövatten" appointed to protect both harbour porpoises, harbour seals and grey seals will be affected by underwater noise levels that exceed the threshold for behavioural avoidance responses, however only in 12% of the Natura 2000 area. There will be no risk of temporary thresholds shift or permanent threshold shift inside the Natura 2000 area. It is therefore assessed that construction of Triton offshore wind farm will not harm or have any negative impact on the short-term and long-term conservation status of harbour porpoise (both the Belt Sea population or the Baltic Proper population), harbour seals and grey seals in SE0430187 Sydvästskånes utsjövatten nor prevent fulfillment of the conservation objectives for harbour porpoises, harbour seals and grey seals in the Natura 2000 area SE0430187.

Underwater noise from seismic surveys may cause behavioural avoidance responses, temporary threshold shift (TTS), and permanent threshold shift (PTS) in marine mammals. Under the assumption that an appropriate soft start/ramp up procedure is applied as a mitigation measure, the combined impact on the harbour porpoises, harbour seals and grey seal in the nearby Natura 2000 area. It is therefore assessed that seismic surveys will not harm or have any negative impact on the short-term and long-term conservation status of harbour porpoise (both the Belt Sea population or the Baltic Proper population), harbour seals and grey seals in SE0430187 Sydvästskånes utsjövatten nor prevent fulfillment of the conservation objectives for harbour porpoises, harbour seals and grey seals in the Natura 2000 area SE0430187.

With application of the above-mentioned mitigation measures, the impact from seismic survey, construction, operation and decommissioning of Triton offshore wind farm on individual level is assessed as limited and without risk of impact at population level. Construction, operation and decommissioning of Triton offshore wind farm do not give rise to either short-term nor long-term consequences for the conservation status of harbour porpoises and thereby do not prevent maintenance of favorable conservation status for the Belt Sea population of harbour porpoises, harbour seals and grey seals inside or outside the Natura 2000 area SE0430187 Sydvästskånes utsjövatten. Furthermore, the construction, operation and decommissioning of Triton offshore wind farm do not give rise to either short-term nor long-term consequences for the conservation status of harbour porpoises belonging to the Baltic Proper and thereby do not prevent achievement of favorable conservation status for the Baltic Proper population of harbour porpoises, inside or outside the Natura 2000 area SE0430187 Sydvästskånes utsjövatten.

Harbour porpoises are listed in Annex IV of the Habitats Directive and are therefore strictly protected wherever they occur. It is concluded that the Annex IV protection of harbour porpoises is maintained, as the project does not result in harbour porpoises being caught, killed, intentionally disturbed or having their breeding or resting areas damaged or destroyed. It is therefore assessed that the project will not affect the area's ecological functionality for harbour porpoises (both the Belt Sea population and the Baltic Proper population).

The assessments of the overall impact of the Triton offshore wind farm during its entire lifetime from construction to decommissioning on marine mammals are summarized in Table 17.1.

Table 17.1: Magnitude of impacts on marine mammals during construction, operation and decommissioning of Triton offshore wind farm.

Phase/source of impact	Under water noise	Habitat change	Sediment spill	EMF	Airborne noise	Persistance
Harbour porpoise						
Pre-investi-gation	Minor	-	-	-	-	Short-term
Construc-tion	Minor	-	Negligible	-	-	Short-term
Operation	Minor	Negligible Positive	-	Negli-gible	-	Permanent
Decommis-sion	Minor	Negligible Positive	Negligible	-	-	Short-term
Seals						
Construc-tion	Minor	-	Negligible		Negligible	Short-term
Operation	Minor	Negligible	-	Negli-gible	Negligible	Permanent
Decommis-sion	Minor	Negligible	Negligible	-	Negligible	Short-term

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Appendix 1: Impact matrix

Table A.18-1 Assessment of the degree of impact (high degree of disturbance)

Degree of disturbance	Geographic	Likelihood of occurrence	Persistence	Magnitude of impact
High	International interests	High (>75%)	Permanent (> 5 years)	Major
			Temporary (1-5 years)	Major
			Short-term (0-1 years)	Moderate
		Medium (25-75%)	Permanent (> 5 years)	Major
			Temporary (1-5 years)	Major
			Short-term (0-1 years)	Moderate
		Low (<25%)	Permanent (> 5 years)	Moderate
			Temporary (1-5 years)	Moderate
			Short-term (0-1 years)	Minor
	National or regional interests	High (>75%)	Permanent (> 5 years)	Major
			Temporary (1-5 years)	Moderate
			Short-term (0-1 years)	Moderate
		Medium (25-75%)	Permanent (> 5 years)	Moderate
			Temporary (1-5 years)	Moderate
			Short-term (0-1 years)	Minor
		Low (<25%)	Permanent (> 5 years)	Moderate
			Temporary (1-5 years)	Minor
			Short-term (0-1 years)	Minor
	Local interests (important for the area directly affected or for the immediate surroundings)	High (>75%)	Permanent (> 5 years)	Moderate
			Temporary (1-5 years)	Moderate
			Short-term (0-1 years)	Minor
		Medium (25-75%)	Permanent (> 5 years)	Moderate
			Temporary (1-5 years)	Minor
			Short-term (0-1 years)	Negligible/positive
		Low (<25%)	Permanent (> 5 years)	Minor
			Temporary (1-5 years)	Negligible/positive
			Short-term (0-1 years)	Negligible/positive
	Negligible/not important	High (>75%)	Permanent (> 5 years)	Negligible/positive
			Temporary (1-5 years)	Negligible/positive
			Short-term (0-1 years)	Negligible/positive
		Medium (25-75%)	Permanent (> 5 years)	Negligible/positive
			Temporary (1-5 years)	Negligible/positive
			Short-term (0-1 years)	Negligible/positive
		Low (<25%)	Permanent (> 5 years)	Negligible/positive
			Temporary (1-5 years)	Negligible/positive
			Short-term (0-1 years)	Negligible/positive

Table A.18-2 Assessment of the degree of impact (medium degree of disturbance)

Degree of disturbance	Geographic	Likelihood of occurrence	Persistence	Magnitude of impact
Medium	International interests	High (>75%)	Permanent (> 5 years)	Major
			Temporary (1-5 years)	Moderate
			Short-term (0-1 years)	Moderate
		Medium (25-75%)	Permanent (> 5 years)	Moderate
			Temporary (1-5 years)	Major
			Short-term (0-1 years)	Minor
		Low (<25%)	Permanent (> 5 years)	Moderate
			Temporary (1-5 years)	Minor
			Short-term (0-1 years)	Minor
	National or regional interests	High (>75%)	Permanent (> 5 years)	Moderate
			Temporary (1-5 years)	Moderate
			Short-term (0-1 years)	Minor
		Medium (25-75%)	Permanent (> 5 years)	Moderate
			Temporary (1-5 years)	Minor
			Short-term (0-1 years)	Minor
		Low (<25%)	Permanent (> 5 years)	Minor
			Temporary (1-5 years)	Minor
			Short-term (0-1 years)	Negligible/positive
	Local interests (important for the area directly affected or for the immediate surroundings)	High (>75%)	Permanent (> 5 years)	Moderate
			Temporary (1-5 years)	Minor
			Short-term (0-1 years)	Minor
		Medium (25-75%)	Permanent (> 5 years)	Moderate
			Temporary (1-5 years)	Minor
			Short-term (0-1 years)	Negligible/positive
		Low (<25%)	Permanent (> 5 years)	Minor
			Temporary (1-5 years)	Minor
			Short-term (0-1 years)	Negligible/positive
	Negligible/not important	High (>75%)	Permanent (> 5 years)	Negligible/positive
			Temporary (1-5 years)	Negligible/positive
			Short-term (0-1 years)	Negligible/positive
		Medium (25-75%)	Permanent (> 5 years)	Negligible/positive
			Temporary (1-5 years)	Negligible/positive
			Short-term (0-1 years)	Negligible/positive
		Low (<25%)	Permanent (> 5 years)	Negligible/positive
			Temporary (1-5 years)	Negligible/positive
			Short-term (0-1 years)	Negligible/positive

Table A.18-3 Assessment of the degree of impact (low degree of disturbance)

Degree of disturbance	Geographic	Likelihood of occurrence	Persistence	Magnitude of impact
Low	International interests	High (>75%)	Permanent (> 5 years)	Moderate
			Temporary (1-5 years)	Minor
			Short-term (0-1 years)	Minor
		Medium (25-75%)	Permanent (> 5 years)	Moderate
			Temporary (1-5 years)	Minor
			Short-term (0-1 years)	Negligible/positive
		Low (<25%)	Permanent (> 5 years)	Minor
			Temporary (1-5 years)	Minor
			Short-term (0-1 years)	Negligible/positive
	National or regional interests	High (>75%)	Permanent (> 5 years)	Moderate
			Temporary (1-5 years)	Minor
			Short-term (0-1 years)	Negligible/positive
		Medium (25-75%)	Permanent (> 5 years)	Minor
			Temporary (1-5 years)	Negligible/positive
			Short-term (0-1 years)	Negligible/positive
		Low (<25%)	Permanent (> 5 years)	Minor
			Temporary (1-5 years)	Negligible/positive
			Short-term (0-1 years)	Negligible/positive
	Local interests (important for the area directly affected or for the immediate surroundings)	High (>75%)	Permanent (> 5 years)	Minor
			Temporary (1-5 years)	Negligible/positive
			Short-term (0-1 years)	Negligible/positive
		Medium (25-75%)	Permanent (> 5 years)	Minor
			Temporary (1-5 years)	Negligible/positive
			Short-term (0-1 years)	Negligible/positive
		Low (<25%)	Permanent (> 5 years)	Minor
			Temporary (1-5 years)	Negligible/positive
			Short-term (0-1 years)	Negligible/positive
	Negligible/not important	High (>75%)	Permanent (> 5 years)	Negligible/positive
			Temporary (1-5 years)	Negligible/positive
			Short-term (0-1 years)	Negligible/positive
		Medium (25-75%)	Permanent (> 5 years)	Negligible/positive
			Temporary (1-5 years)	Negligible/positive
			Short-term (0-1 years)	Negligible/positive
		Low (<25%)	Permanent (> 5 years)	Negligible/positive
			Temporary (1-5 years)	Negligible/positive
			Short-term (0-1 years)	Negligible/positive