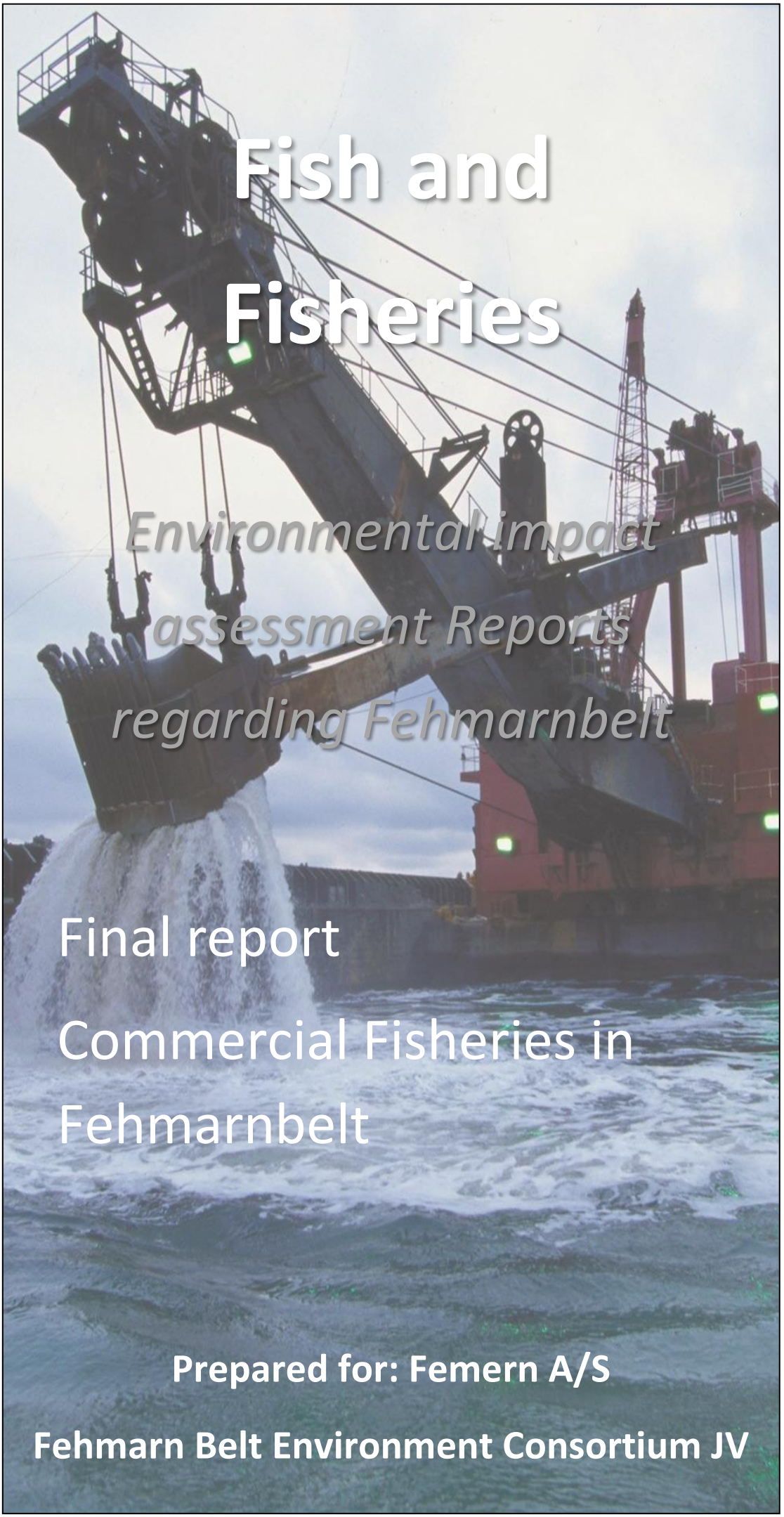

Fish and Fisheries

Environmental impact assessment Reports regarding Fehmarnbelt

E4TR0042

Volume II

Final report

Commercial Fisheries in Fehmarnbelt

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0. Summary

The following document describes the “Environmental Impact Statement” (EIS) of the Danish and German commercial fisheries due to the potential impacts from the proposed Fehmarnbelt Fixed Link between Denmark and Germany. These include impacts due to construction activities, the establishment and presence of physical structures and landfills, and operation of the fixed link which can potentially impact the undertaking of the commercial fisheries or the fish species that make up their “resources”. The assessments are based on information from the technical design of the fixed link solutions, modelled impacts of relevant pressures and available information on potential cumulative and transboundary pressures that can potentially arise.

Denmark and Germany are, more or less, the only two countries that undertake commercial fishing in Fehmarnbelt and its regional area. The primary components to these fisheries are the different gear; trawls used in deeper waters (>10 m) with soft bottoms, gill nets used in all types of seabed habitats, pound nets placed near the coastline and Danish seine nets typically used in deeper open waters. Landings in the Western Baltic, which includes Fehmarnbelt, in most recent years (1998-2008) have annually amounted to approximately 18,000 tons with a value of 14.7 million euro in the Danish fisheries and 10,600 tons with a value of 10.5 million euro in the German fisheries. In the fishery statistical area ICES 38G1 that contains the majority of Fehmarnbelt and the proposed Fehmarnbelt Fixed Link, Denmark undertakes a comparatively greater amount of fishing than Germany.

The primary catch and most important subcomponents to the commercial species in Fehmarnbelt over the last decade have been sprat by weight and cod by value. However, there are a number of other important species to the commercial fisheries such as herring, flatfish species (flounder, dab, plaice, turbot, brill and sole), whiting, horse mackerel, European eel, garfish, salmon and sea trout, which are at times the prominent fish targeted or are an important supplement to the overall landings.

Impact assessment methodology
The level of importance for each component to the commercial fisheries (trawl, gill nets, pound nets and Danish seine nets) were determined by evaluating how important or specific Fehmarnbelt was to the individual fisheries.

The methodology used to determine the loss or impairment due todifferent pressures (footprints, increases in suspended sediment, noise etc.) to the commercial fisheries was based on a stepwise process including elements such as identifying the environmental indicators (component and subcomponents), defining sensitivity and threshold values of the environmental indicators to pressures, and quantifying the magnitude of pressures which was often the fishing area lost or impaired by a pressure based on exceedance of threshold values and modelled scenarios of specific pressures (suspended sediment etc.) overlapping fishery areas. Exceedance of threshold values are considered as a loss or impairment of function and the magnitude of pressure are expressed as the percentage of reduction in the area. In general, the assessment follows a precautionary principle, and low values triggering responses have been chosen to describe the sensitivity thresholds.

The classification of loss of area is always considered to be a very high magnitude of pressure. The grading of the severity of loss is determined by the importance of the fishery component (see 3.1).The classification of the degree of impairment has been rated according to a set of criteria based on a series of arguments derived from the variation (SD) of the landings for each fishery component (trawl, gill nets, pound nets and seine nets) in Fehmarnbelt. Depending on the duration (temporary or permanent) of the pressure the specific criteria are defined by factors related to the standard deviation. The severity of impairment to each component by each pressure was then determined by combining the degree of impairment with the

level of importance of the specific components for the fishery in Fehmarnbelt. Finally the project impact summarises the accumulated impacts from all pressures.

In principle, all components and subcomponents have been assessed for the identified pressures in the areas of investigation. The smallest spatial unit that comprehensive commercial fisheries data from Fehmarmbelt were available was an ICES rectangle (30 x 30 nautical miles). This was therefore the primary unit of measurement used in the baseline report and was also the unit of measurement used in this assessment. ICES rectangle 38G1 was chosen to represent Fehmarnbelt and a slightly broader area (determined by the assessment of impacts to fish) was chosen to represent the fisheries in the Fehmarnbelt region. In cases where assessment is based on results from the assessment of impacts to fish (commercial species) the areas of investigation are defined according to other guidelines and include the near area (500 m zone), the local areas (10 km zone) and EEZ-zones in German and Danish territories.

The pressures used for the assessment to the commercial fisheries and their resources (commercial fish) were sea bed reclamation and structures, sediment spills, noise and vibration, hydrographical regimes and other pressures potentially causing avoidance responses and loss of fish habitats. For each of these specific pressures the construction and operation phases have been treated separately when relevant. Since the magnitude of pressure derived from light, electromagnetic fields and contaminents were insignificant for each of the proposed solutions the impact assessments of these pressures have been treated more generally.

Impact assessment results

An assessment summary of the impacts on the Danish and German commercial fisheries during construction, operation and due to structures/footprints from the immersed tunnel and cable-stayed bridge fixed link projects for Fehmarnbelt and the Fehmarnbelt region are given for the fishery components in the respective sections for Denmark (Table 0.1) and Germany (
Table 0.2).

Denmark

Table 0.1: Project impact on specific components in Danish commercial fisheries from the construction, operation and structures (footprints) of the immersed tunnel and cable-stayed bridge solution.

Severity of impairment/loss Denmark	**Immersed Tunnel**			**Cable-stayed Bridge**		
	Construction	Operation	Structures/ footprints	Construction	Operation	Structures/ footprints
Fehmarnbelt (ICES 38G1)						
Trawl	Minor	Minor	Medium	Minor	Minor	Medium
Gill nets	Minor	Minor	Medium	Minor	Minor	Medium
Pound nets	Minor	Minor	Very high	Minor	Minor	Very high
Danish seine nets	Minor	Minor	Minor	Minor	Minor	Minor
Fehmarnbelt Region						
Trawl	Minor	Minor		Minor	Minor	Medium
Gill nets	Minor	Minor		Minor	Minor	
Pound nets	Minor	Minor		Minor	Minor	
Danish seine nets	Minor	Minor		Minor	Minor	

Tunnel solution

Trawl
There were no impacts on the Danish trawl fishery in Fehmarnbelt and its region that exceeded "Minor" during construction activities or the operation of the tunnel. The loss of fishing area due to reclamation of areas/footprints was "Medium" according to the importance of this fishery. Trawl hauls in Fehmarnbelt are primarily undertaken through the central deeper (>10 m) parts of Fehmarnbelt and uneven sea floor topography or exposed boulders and stones created by the protective material placed across the tunnel trench could cause snagging of trawl lines and damage to bottom trawls. This will lead to considerable affects to the trawl fisheries ultimately depending on whether trawling activities over the tunnel trench will eventually return without the potential for gear damage. There were no aggregating impacts causing changes in the project impairment in Fehmarnbelt and the Fehmarnbelt region.

Furthermore, if there are permanent restrictions to trawling over the trench to avoid removing stones or disturbing the protective cover to the immersed tunnel then this will also have a considerable impact to the trawl fisheries. In general, impairments or stoppage of a trawl haul would make it necessary to undertake time consuming operations such as lifting and resetting trawl gear, which in a worst case scenario would mean that trawling through Fehmarnbelt will be impacted and the added cost to the fisheries will reduce the net value of their landings.

Gill nets
Results indicated that the severity of loss to the Danish gill net fisheries by losing or having an impairment of 84 ha of their fishing grounds (57 ha from tunnel trench and 27 ha from the construction area (22 ha permanent and 5 short-term) was Medium according to the importance of this fishery. The Danish gill net areas lost to this impact are in general, not gill net fishing areas that have a high intensity of the fisheries. Furthermore, the potential mobility of this fishery to other nearby gill net fishing areas and the very small total loss of gill net fishing area (0.12 % of the gill net fishing area in Fehmarnbelt) supports a low impact to the gill net fisheries. There were no impairments on the Danish gill net fishery in Fehmarnbelt and its region that exceeded "Minor" during construction activities or the operation of the tunnel.

Added structures along the seabed from the protective material used to fill the trench does not hinder or disturb the undertaking of using gill nets and this new habitat may function like an artificial reef which could benefit the gill net fisheries as stony heterogeneous habitats can attract fish to the local area.

Pound nets
The severity of the impact of reclamation areas and footprints from the tunnel solution on the Danish pound net fisheries was "Very high" according to its importance. This impact was primarily in the area of reclamation along the southern coastline of Lolland where more than 331 ha of the pound net fishing areas were lost (Figure 0.1). This will have some severe consequences to a few pound net fishermen who have their fishing areas in and adjacent to the area of reclamation. This impact is only considered to be significant on a local scale but not regionally. The other impacts (increased suspended sediment, sedimentation, noise and changes in hydrographical characteristics) on the pound nets fishery in Fehmarnbelt and its region were only considered minor during construction and operation activities. However, the sediment plumes with the highest suspended sediment concentrations were greatest along the coastal areas of Lolland, and thus may also have an impact to pound net fisheries when sediment plumes are most intense, as these conditions could create an avoidance response by some important commercial species in a few local areas.

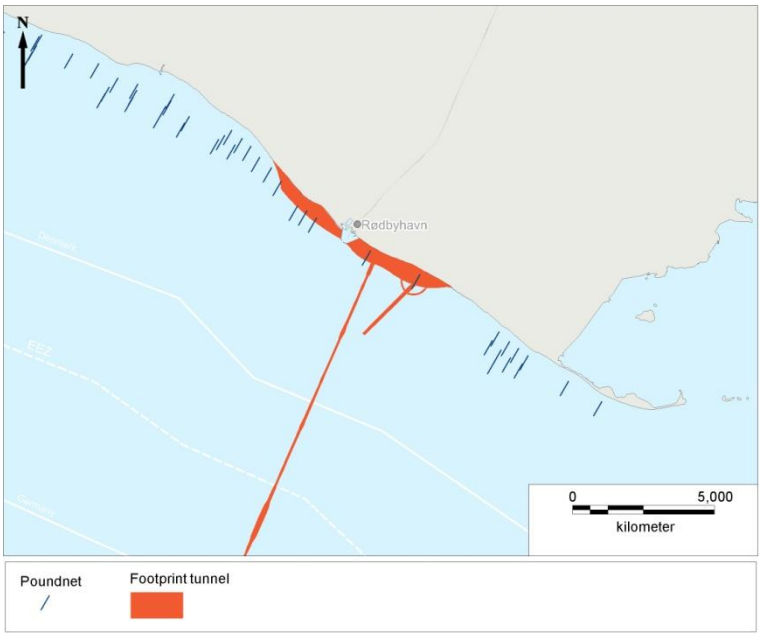


Figure 0.1: Reclamation areas from the tunnel solution and pound net fishing areas.

Danish seine nets

Impacts from the tunnel solution on the Danish seine net fishery in Fehmarnbelt and its region are minor or insignificant during construction activities, the operation of the tunnel or due to reclamation of areas/footprints. The seine net fisheries is undertaken in the deeper central parts of Fehmarnbelt where impacts from sediment plumes, noise and hydrographical changes have least affects.

Commercial species

In general, the impacts from the tunnel pressures such as sediment spills, noise and vibrations and hydrographical changes that cause commercial fish species to flee from or avoid an area used by the fisheries in Fehmarnbelt was only minor or insignificant in all cases. Of the pressures affecting the commercial species it is anticipated that sediment spills are probably the pressure that has the most impact. During tunnel construction excess suspended sediment during the first two years will at times be considerable in small, local areas. This will primarily impact the fisheries by causing the most sensitive fish species (cod, herring, sprat, whiting, horse mackerel, salmon, sea trout and garfish) to either flee from or avoid impacted areas that overlap with the different fisheries. Although the severity of this impact to commercial fisheries was considered minor in all cases, on a local scale, this pressure could possibly have a considerable impact, particularly to the pound net fisheries which are along the shore where suspended sediment plumes will be greatest, and because this fishery is stationary and cannot move to alternative areas.

Bridge solution

Trawl

During the construction phase of the bridge solution there will only be minor impacts to the Danish trawl fishery in Fehmarnbelt and its region. The loss of trawl area due to shipping lanes during operation will give a “Medium” impact on the trawl fisheries in Fehmarnbelt in accordance with its importance. Thisimpact is associated with the direct loss of area to these fisheries due to fishery restrictions in shipping lanes, and impairment to the continual undertaking of trawl fisheries due to structures. Previous investigations of the behaviour of trawling near a bridge fixed link (the Great Belt Bridge) indicated that trawl hauls stopped at a distance of approximately three kilometers to the bridge, which more or less equals the 2.7 kilometre “no

fishing zone" in association with shipping lanes (FeBEC, 2011b). Figure 0.2 illustrates a potentially similar zone across Fehmarnbelt in association with the establishment of a bridge solution. Trawl hauls in Fehmarnbelt are primarily undertaken through the central deeper (>10 m) parts of Fehmarnbelt and it is probably here that the two main pylons and the shipping lanes will be established. The project impacts to the trawl fisheries are based on assumptions that a bridge will have similar passing lanes and closed fishing areas as the nearby Great Belt Bridge. However, because this is an assumption and assessment based on a worst case scenario, the full significance of these impacts to the trawl fisheries will first be determined by the exact regulations for fishing (trawling) under bridge sections, and the exact placement of shipping lanes, and whether the physical structures and seabed morphology along alternative trawling routes will allow the undertaking of trawling without major disturbances or problems.

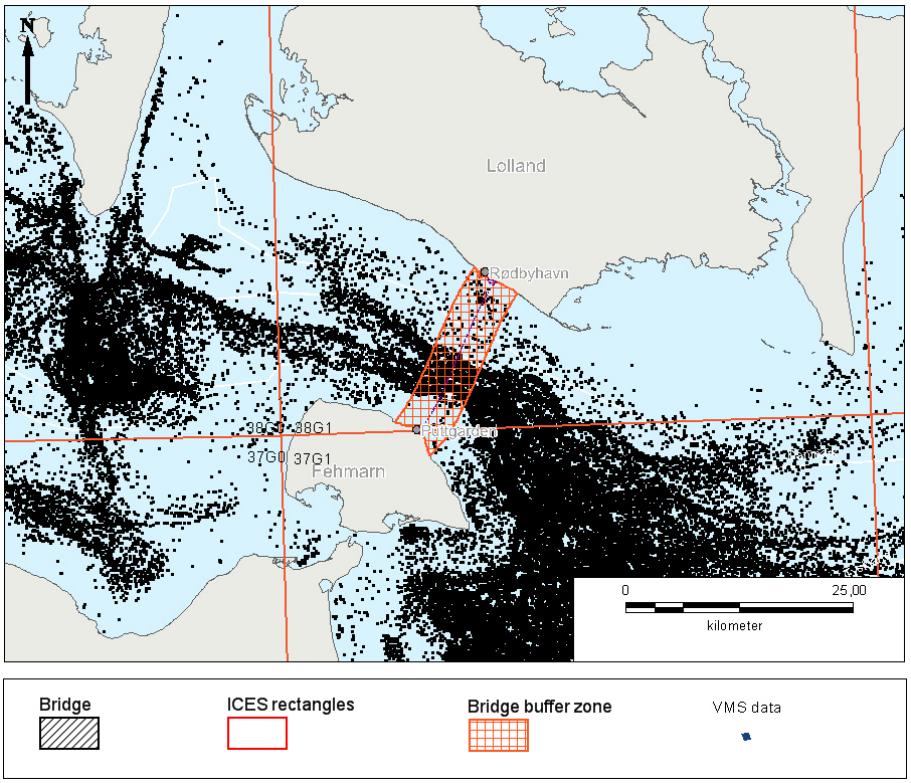


Figure 0.2: Potential "limited fishing zone" across Fehmarnbelt in association with the establishment of a bridge solution.

The trawl fisheries are, however, mobile and there are alternative trawling areas both to the east and west of Fehmarnbelt, which would relieve some of the direct impact from impairments to these fisheries from a bridge solution. In these instances there may be some potential impacts due to increasing the number and fishing pressure of trawlers in other fishing areas, however the consequences of this is not considered to be significant.

Gill nets

There were no impairments on the Danish gill net fishery in Fehmarnbelt and its region that exceeded "Minor" during construction activities and the operation of the bridge. The loss of fishing area due to reclamation of areas/footprints was "Medium" according to the importance of this fishery. Results indicated that the Danish gill net fisheries will only lose two ha of their fishing grounds to area use by bridge pylons, piers and embankments. The small amount of gill net fishing areas (<0.1 % of the gill net fishing area) lost to bridge structures is not considered to be of great importance in relation to the low intensity of the gill net fisheries in these areas. Furthermore, the potential mobility of this fishery to other nearby gill net fishing areas in Fehmarnbelt supports the low significance of the loss of this area to the gill net fisheries.

There are no Danish gill net fishing areas in the deeper parts of Fehmarnbelt where the bridge transect is planned and thus this fishery is not affected by restrictions to the fisheries due to shipping lanes under the bridge fixed link solution.

Added structures from piers, pylons and scouring protective material at their base will also create new habitats (reef effects) which could eventually benefit the gill net fisheries as these habitats have been known to attract fish to the local area. This benefit is, however, dependent on the fishing regulations that are implemented, and whether it will be allowed to fish near or under the bridge by gill net fishermen.

Pound nets
Approximately 32 ha of the pound net fishing area (0.5 % of the total pound net fishing area) were lost due to a bridge solution. This was primarily due to the build up of the bridge embankment landfill and the bridge piers and pylons and their foundations within the coastal area of Lolland. This impact leads to a very high severity of loss in accordance with the importance of the pound net fishery and is significant to a few pound net fishermen who have their fishing gear in the area of impact because of the high sensitivity of this fishery to any loss or impairments. Pound net fisheries are not very mobile and a loss of area cannot be compensated for by fishermen moving their fisheries to another area. However, significant impacts to the pound net fisheries are only considered to be local and not regional as the number of fishermen affected in this fishery is primarily limited to a few fishermen with their pound nets within or adjacent the area of impact.

Danish seine nets
In all, 1375 ha or 8.1 % of the seine net fishing area in Fehmarnbelt was impacted by the structures and footprints from the establishment of the bridge solution. This impact was considered to be minor in accordance with the minor importance of this fishery in Fehmarnbelt. Seine net fishing requires a considerably large area to undertake their fisheries as this fishery set their nets and retrieve them over a broad area. Thus closed and loss of fishing areas due to shipping lanes and bridge structures extending across their fishing areas and creating a barrier, will affect the undertaking of this fishery in Fehmarnbelt. However, because of the mobility of this fishery, its low importance in Fehmarnbelt and the potential for this fishery to relocate their efforts to other areas, the impact and the overall significance of the loss to this fishery is considered low.

Commercial species
The impacts on the commercial species and thus indirectly on the fisheries from sediment spills, noise and vibrations and hydrographical changes due the bridge solution was only minor or insignificant in all cases. The size of the fishing areas affected by the pressures and thus the the commercial species within these areas were typically small and pressures were only short-term. The pressure of most concern from the bridge solution that could potentially affect the commercial species is the barrier effect caused by bridge structures and/or the noise and vibration of the traffic on the bridge. This could cause disturbances to some migrating commercial species such as eel, cod, herring and sprat as well salmon and sea trout or affect the distribution of some important species. However, observations from other construction based impacts, for example the Sound “Øresund” Bridge, suggest that barriers to migration are of low intensity and do not extend impacts into other areas, and thus impacts to migrating species are only expected to be minor or insignificant.

Germany

Table 0.2: Project impact on specific components in German commercial fisheries from the construction, operation and structures of a tunnel solution and a bridge solution.

Severity of impairment/loss Germany	Immersed Tunnel			Cable-stayed Bridge		
	Construction	Operation	Structures	Construction	Operation	Structures
Fehmarnbelt (ICES 38G1)						
Trawl	Minor	Minor	Medium	Minor	Minor	Medium
Gill nets	Minor	Minor	Medium	Minor	Minor	Medium
Pound nets	Minor	Minor	Very high	Minor	Minor	Very high
Fehmarnbelt Region						
Trawl	Minor	Minor		Minor	Minor	Medium
Gill nets	Minor	Minor		Minor	Minor	
Pound nets	Minor	Minor		Minor	Minor	

Tunnel solution

Trawl
There were no impacts on the German trawl fishery in Fehmarnbelt and its region that exceeded “Minor” during construction activities and the operation of the tunnel. The loss of approximately 93 ha fishing area due to reclamation of areas/footprints was considered “Medium” according to the importance of this fishery. This is based on the assumption that the trawl fisheries over the tunnel trench cannot be undertaken without the potential for gear damage or if there are restrictions to the undertaking of trawl fisheries over the trench after the construction period.

There were no aggregating impacts causing changes in the project impairment in Fehmarnbelt and the Fehmarnbelt region.

Gill nets
The German gill net fisheries experienced an impact on approximately 47 ha or 0.5 % of their fishing grounds in Fehmarnbelt and its region due to reclamation of areas/footprints and the tunnel trench. This impact was considered to “Medum” according to the medium importance of the gill net fisheries.There were no impacts on the German gill net fishery in Fehmarnbelt and its region that exceeded “Minor” during construction activities and the operation of the tunnel.

The ability of this fishery to utilise other nearby gill net fishing areas and the very small total loss of area supports the generally low impact of these pressures. Furthermore, the added structure in the tunnel trench along the seabed might eventually add to benefit this fishery as stony heterogeneous habitats can attract fish to the local area.

Pound nets
In contrast to the considerably large impact to the Danish pound net fisheries on Lolland, the German pound net fisheries will only be disturbed by a relatively small reclamation area (7 ha) along the tunnel trench that is near the shore. The severity of this loss is considered very high mainly because of the very high importance and sensitivity of the pound net fisheries to any

form of disturbances. Overall however, this impact was significant locally but insignificant regionally as it will only affect a very little part of this fishery along the German coast.

Commercial species
The impacts from the tunnel pressures such as sediment spills, noise and vibrations and hydrographical changes that cause commercial fish species to flee from or avoid an area used by the fisheries was only minor or insignificant in all cases. The sediment spills along the deeper German coastline of Fehmarn were considerably less than those along the Danish coastline. Impacts from the other pressures were all low and not considered to have any significant affect on the abundance or distribution of the commercial species that would have any significant affect on the commercial fisheries.

Bridge solution

Trawl
During the construction phase there were almost no impacts on the German trawl fishery in Fehmarnbelt and its region. During the operation of the bridge it is anticipated that the loss of German trawl area due to shipping lanes will have a medium impact on the trawl fisheries in Fehmarnbelt by the loss of fishing area and the barrier effect the bridge will have on undertaking continual trawl hauls through Fehmarnbelt. The full extent of this impact however can first be determined when specifications of the restrictions to the fisheries are defined and the full extent of the closed areas for shipping lanes is determined. As mentioned, the trawl fisheries are mobile and there are alternative trawling areas both to the east and west of Fehmarnbelt which would offer alternative fishing areas and relieve some of the direct impact from losses to these fisheries from a bridge solution.

Gill nets
There were no impacts on the German gill net fishery in Fehmarnbelt and its region that exceeded “Minor” during construction activities or the operation of the bridge. The primary impact to the German gill net fisheries was a loss of 18 ha or approximately 0.2 % of the gill net fishing area in Fehmarnbelt due to bridge pylons, piers and embankments, which was assessed as “Medium” according to the importance of this fishery. Overall, the small area loss suggests this loss/impairment is not of great importance. Furthermore, there are other nearby gill net fishing areas in Fehmarnbelt where the mobile German gill net fisheries can also be undertaken. Added bridge structures will also create new habitats (reef effects) which have been known to attract fish to the local areas and, depending on the fishery regulations, may have a positive impact on the gill net fishery after bridge completion.

The German gill net fishing areas are primarily located along the coastal area of Fehmarn and thus these fisheries would not be affected by restrictions to the fisheries due to shipping lanes established under the bridge fixed link solution.

Pound nets
Impacts on the pound nets fishery in Fehmarnbelt and its region did not exceed “Minor” during bridge construction or operation activities. A total of 29 ha of German pound net fishing area (1.3 % of the total pound net fishing area), was lost due to bridge embankments and the bridge structures that are close to the coastal area of Fehmarn near Puttgarden. The loss of this fishing area was assessed as “Very high” according to the importance of the pound net fishery, and because of the limited mobility of this fishery a loss of area cannot be compensated for by moving to other areas. This very high impact, however, was only on a local scale and the impact of loss will typically only affect a small number of fishermen, thus overall the impact will be limited and considered to be low for the entire German pound net fishery in Fehmarnbelt.

There were no aggregating impacts causing changes in the project impairment.

Commercial species

The impacts on the commercial species from sediment spills, noise and vibrations and hydrographical changes due the bridge solution were only considered to be minor. Impacted areas are only small in size and except for the bridge structures are only temporary or short-term. The pressure of most concern to impacting the commercial species from the bridge solution is the barrier effect caused by bridge structures and/or the noise and vibration of the traffic on the bridge. However, information from other bridge fixed links for example the Sound "Øresund" Bridge suggest that any barriers to migration are of only low intensity and thus impacts to migrating species are expected to be minor or insignificant.

1. Introduction

1.1 Background

Soon after the opening of the Fehmarnsund Bridge and the Puttgarden-Rødby ferry route in 1963 – the so-called "Vogelfluglinie", or "Flying Bird Line" – there began thoughts on how the road and rail traffic between Scandinavia, Germany and the rest of Europe could be made more efficient. During and after the planning and construction of the Øresund Fixed Link from 1991-2000, the establishment of a Fehmarnbelt Fixed Link became more feasible. This instigated a series of investigations including a feasibility study on the environmental effects of a fixed link across the Fehmarnbelt.

In the years 2005 and 2006, an environmental consultation process was carried out, in which government agencies, interested associations and the public commented on the environmental aspects already examined.

In September of 2008, the Ministers of Transport of Denmark and Germany signed a state treaty on the Fehmarnbelt Fixed Link. In March of 2009, the Danish Parliament "Folketinget" approved a planning law for the planning of a coast-to-coast fixed link. In Germany, the law ratifying the state treaty was accepted by the Bundestag in June of 2009. The Bundesrat passed it in July of 2009, where after the law took effect on the 24 of July, 2009.

According to legislation in Denmark, Germany and international law, a State Treaty on the establishment of a fixed Link between the islands of Lolland and Fehmarn implies that an environmental impact assessment (EIA) must be conducted. The purpose of the EIA is to identify, describe and assess the environmental impacts of the project at an early stage where corrections and adjustment to design and the work processes are still possible. The results of the EIA will be part of the applicant's approval material.

The Danish planning law enables comprehensive preliminary investigations of, among other issues, the environment. As part of the environmental investigations a consortium FeBEC JV, lead by Orbicon A/S and partners IFAÖ (Germany) and Fiskeøkologisk Laboratorium (Denmark), have made a number of baseline surveys on fish and the fisheries for Femern A/S, who is responsible for the planning, environmental investigations and assessments, as well as the design of the approximately 19-kilometre long coast-to-coast connection across the Fehmarnbelt, planned as a combined four-lane motorway and a double-track electrically run railway system between Denmark and Germany.

Impacts to the fisheries
Establishment of a fixed link across Fehmarnbelt has the potential to negatively affect the fisheries by creating disturbances or restrictions that make it difficult or impossible to perform fishing with different gear and by affecting the abundance, distribution and migration of commercial fish species and their stocks and hence the resource yield in the region. For example, trawlers undertake long continuous hauls without breaks when they fish and placement of a fixed link in an area with important trawl routes could have a negative effect on the fishermens ability to trawl over large distances. Also, if there are obstacles or restrictions along a trawl route it might be necessary to retrieve the gear when approaching or crossing these obstacles. Similarly, fishing with seine nets requires a relatively large area without obstructions which would potentiallly make it difficult to continue these fisheries in sections of Fehmarnbelt with a fixed link. Passive gear such as gill/trammel nets are less affected by obstructions, however this type of fishery are often undertaken by smaller vessels that travel less distances from their basis harbours and use more specific local areas for their fisheries. This makes this fishery vulnerable to local disturbances or loss of specific fishing areas and potential displacement to other areas which might increase operating expenses. Similarly, the pound net fisheries are

limited to suitable areas along the coast and individual fishermen are often restricted to setting their gear within a limted area. This makes this fishery highly vulnerable to all pressures that have an impact in these fishing areas.

All types of fisheries are dependent on the presence and abundance of the commercial species of interest. Thus, all pressure affecting the presence and abundance of commercial species, for example by triggering avoidance responses away from an area or in a worst case scenario causing death or considerable reduction in the stocks, have a considerable impact on the fisheries.

Baseline information
Gathering baseline commercial fisheries statistics in Fehmarnbelt and its region (FeBEC, 2011b) is the first phase of identifying and documenting key elements in the commercial fisheries. This information is used together with impact scenarios to form the foundation for assessing the severity of anticipated impacts from the construction, structures and/or operation of the Fehmarnbelt Fixed Link in this EIA report.

Furthermore, an assessment of the impact to the fisheries not only includes what affects the undertaking of the fisheries but what has an impact on the commercial fish species that make up the resource. Thus, information on the sensitivity to pressures of commercial species and impacts to the commercial fish communities will also be included in this EIA to assess the impacts on fishery resources.

Baseline information, impact scenarios and assessments will also be used to identify sensitive areas and commercial fishery activities that can lead to suggestions for monitoring initiatives during the construction or operational phases.

Two fixed link solutions to be assessed
After preliminary rounds of comparing technical, economical and environmental aspects of a number of tunnel and bridge solutions, two main alternatives, an immersed tunnel alternative and a cable-stayed bridge alternative, have been identified and chosen as the main fixed link alternatives.

The environmental impact assessment of the main alternatives on the commercial fisheries is carried out in two steps. First, the impacts on the commercial fisheries from the preferred tunnel and bridge alternatives are assessed separately. Also included in this step is an assessment of a zero-solution, which is an impact assessment of existing pressures under the assumption that a fixed link will not be built. Secondly, the impacts of the tunnel and bridge alternatives are compared while considering the totality of all EIA components.

1.2 Overview of the commercial fisheries in Fehmarnbælt and region

Denmark and Germany are the only countries that undertake commercial fisheries in Fehmarnbelt (represented primarily by ICES statistical rectangles 38G1 and 37G1 in this report) and are by far the dominant countries that undertake their fisheries in its regional area (represented by ICES statistical rectangles ICES 37G0, 38G0, 37G2 and 38G2) (Figure 1.1).

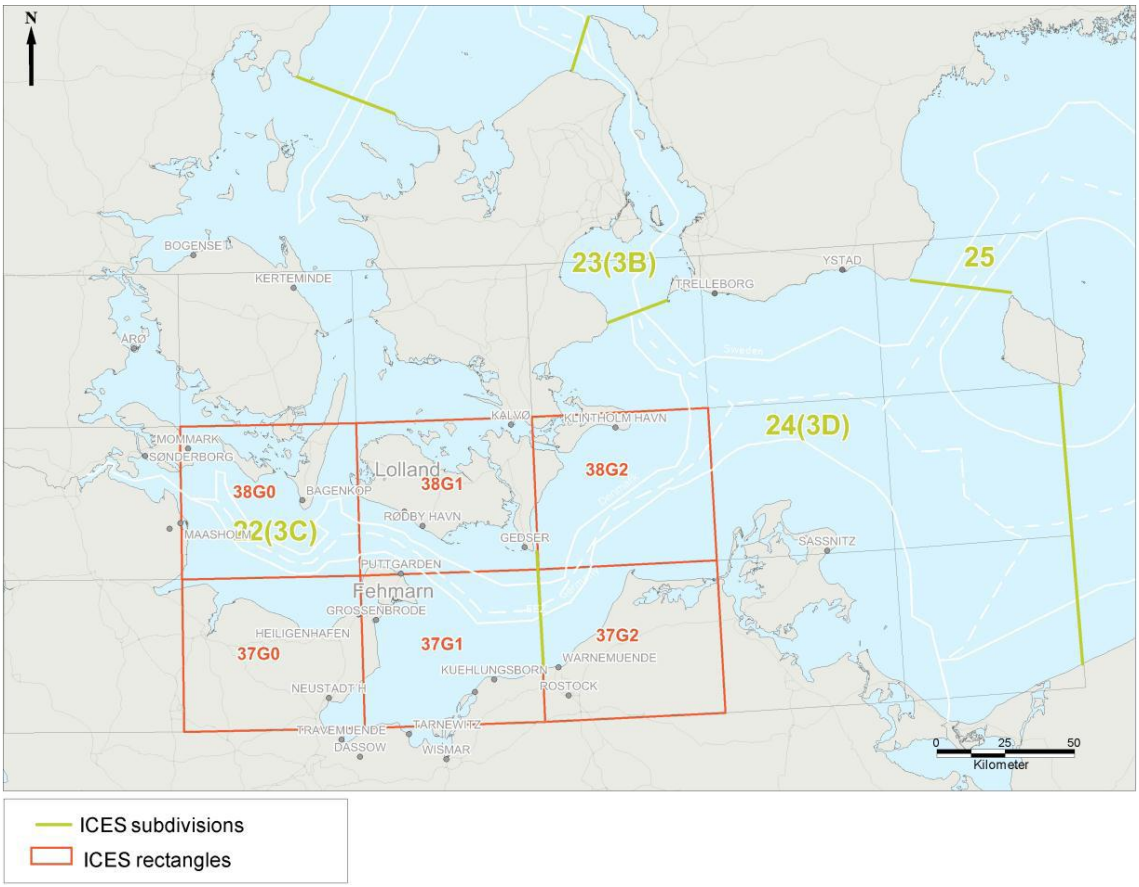


Figure 1.1: Map of the Western Baltic Sea including the outlines of ICES subdivisions (SD) 22, 23 and 24 and the statistical ICES rectangles including Fehmarnbelt (38G1) and the regional area (ICES 37G1, 37G0, 38G0, 37G2 and 38G2) of Fehmarnbelt.

The Danish and German commercial fisheries in Fehmarnbelt and region are represented by trawlers (both demersal or “bottom” and pelagic or “midwater”), gill/trammel net fishermen, Danish seine net fishermen and pound net fishermen and their associated fisheries with pound nets, fyke nets and occasionally gill nets along or near the coast.

In Fehmarnbelt and its western Baltic regional areas, Denmark has annually landed approximately 18,000 tons with a value of 14.7 million euro from 1998 to 2008. Over the same 11 year period, Germany has annually landed approximately 10,600 tons with a value of 10.5 million euro.

In the fisheries statistical area that contains the majority of Fehmarnbelt (ICES 38G1) and the proposed Fehmarnbelt Fixed Link, Denmark undertakes a comparatively greater amount of fishing than Germany. In contrast, Germany undertakes a comparatively greater amount of their fisheries in the statistical area (ICES 37G1) that contains the far eastern part of Fehmarnbelt.

In Fehmarnbelt (ICES 38G1), Denmark has annually landed an average of approximately 1,800 tons for a value of 1.25 million euro a year from 1998-2008. Over the same period, Germany has annually landed an average of approximately 259 tons for a value of 284,000 euro a year.

Table 1.1: The total landings (tons) and value (euro) of the Danish and German commercial fisheries in Fehmarnbelt (ICES 38G1) and the adjacent ICES rectangle to the east (37G1) from 1998-2008.

Denmark - landings (tons) and value (1,000 euro)

ICES Rectangles	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Landings (tons)											
37G1	2,826	1,174	1,806	2,701	863	491	1,043	658	3,574	2,495	1,739
38G1	1,551	1,260	1,540	2,859	1,121	975	671	1,702	4,160	2,071	2,092
Value (1,000 euro)											
37G1	938	615	1,629	1,147	561	299	705	401	1,139	1,364	730
38G1	1,187	1,489	2,076	1,838	1,096	618	707	875	2,031	1,087	781

Germany - landings (tons) and value (1,000 euro)

ICES Rectangles	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Landings (tons)											
37G1	4,364	6,068	5,889	4,560	6,314	5,502	4,662	4,796	6,591	5,355	5,339
38G1	241	453	260	156	85	188	93	181	885	178	127
Value (1,000 euro)											
37G1	4,761	6,809	6,531	5,697	5,336	4,027	3,816	4,794	5,480	5,550	4,538
38G1	319	655	392	240	158	236	122	110	478	218	197

The primary catch in Fehmarnbelt (38G1) over the last decade (1998-2008) has been sprat by weight and cod by value. During this period Denmark landed an annual average of 429 tons of cod (833,000 euro in value) and slightly less than 1,000 tons of sprat (149,000 euro in value). During the same period, Germany landed an annual average of 146 tons of cod (219,000 euro in value) and an average of 21 tons of sprat (8,000 euro in value), all of which have been landed in the last three years. Other important commercial species landed from Fehmarnbelt near the fixed link are herring, several flatfish species (flounder, dab, plaice and turbot) and occasionally whiting.

The general seasonal pattern of landings from the commercial fisheries in Fehmarnbelt show both the Danish and German fisheries are primarily undertaken in the colder months of the year (October to March). This is illustrated for the Danish fisheries in Figure 1.2. Total landings are most abundant during the winter months, predominately January-March where cod and sprat often dominate the landings. During the summer months the lower landings are primarily represented by gill/trammel net fishermen targeting both cod and valuable flatfish species (plaice, turbot, brill and in more recent years sole) which become more abundant to the fisheries as the water becomes warmer. The seasonal pattern for the landings of the most abundant but less valuable flatfish species (flounder and dab) show they are predominantly caught in the winter months. This pattern follows the landings of cod as these species are typically landed as a bycatch of the fisheries targeting cod.

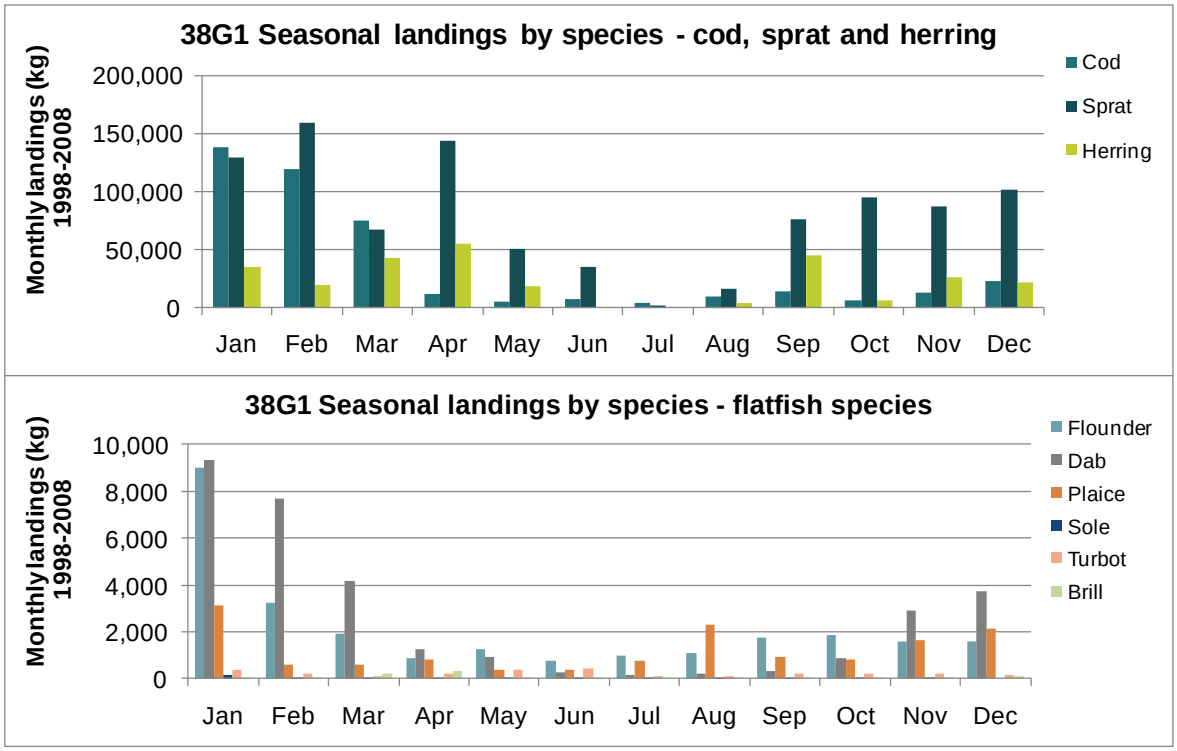


Figure 1.2: Monthly landings by Danish fishermen (1998-2008) for the most important commercial species (cod, sprat and herring) and flatfish species (flounder, dab, plaice, sole, turbot and brill) in ICES rectangle 38G1 in the near field of Fehmarnbelt.

Trawling
In Fehmarnbelt (primarily ICES 38G1), landings in the Danish and German fisheries have been dominated by trawlers (both midwater and demersal).

The average annual number of Danish trawlers registering landings from ICES 38G1 over an 11 year period (1998-2008) varied between 27-91 vessels. Over the same period the average annual number of German trawlers registering landings from ICES 38G1 varied between 7-21 vessels.

The average annual landings (1998-2008) in Fehmarnbelt (ICES 38G1) by Danish trawlers from 1998-2008 was 1,670 tons (554-3,980 tons) with an average annual value of 954,000 euro (426,000-1,678,000 euro). Similarly, during the same period (1998-2008) the average annual landings from ICES 38G1 by German trawlers was 209 tons (26-872 tons) with an average annual value of 196,000 euro (40,000-461,000 euro).

Sprat by weight and cod by value have been the most dominant species caught by Danish trawlers in Fehmarnbelt from 1998-2008. During this time the average annual landings of sprat have been 959 tons at an average annual value of 148,000 euro. The Danish annually landed an average of 320 tons cod at an average annual value of 621,000 euro from 1998-2008. In the German trawl fisheries from 1998-2008, cod have been the most dominant species landed by both weight (annual average of 100 tons) and value (annual average of 227,000 euro).

Distribution of trawl fisheries
The distribution of the trawl fisheries in Fehmarnbelt, represented by VMS data and supported by interviews, suggests that trawling by both Denmark and Germany is undertaken throughout the middle of Fehmarnbelt and along a broader belt both towards the west and the east and southeast from Fehmarnbelt into other more regional areas (Figure 1.3).

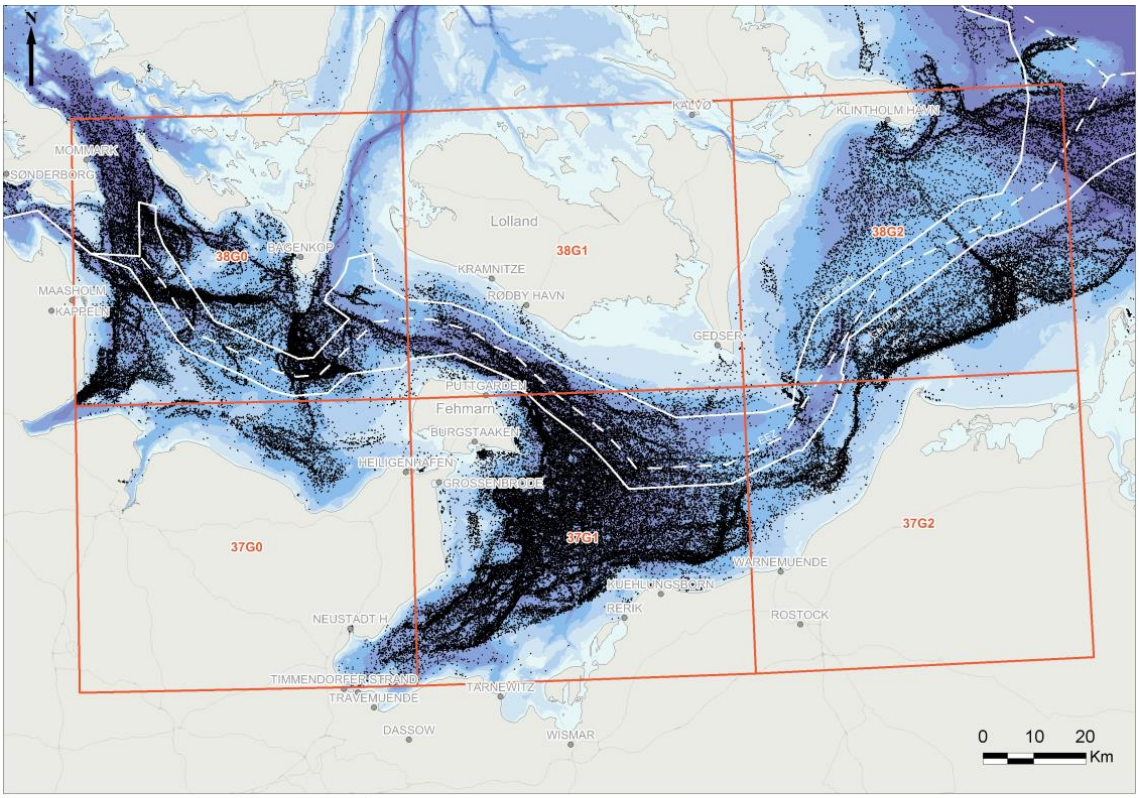


Figure 1.3: The overall distribution of the German and Danish trawl fisheries in Fehmarnbelt and the regional area of the Western Baltic as derived from VMS data from 2005-2008.

Gill/trammel net fishing

The gill/trammel net fisheries in Fehmarnbelt and near region are the second most important fisheries with respect to landings and value of landings after trawling.

The official landings of the gill/trammel net fisheries in Fehmarnbelt are represented by the landings registered in ICES 38G1 for the sake of having a well defined area in assessing impacts to these fisheries. However, a number of important gill/trammel net fishing grounds are adjacent ICES 38G1, thus in the event that impacts extend into these areas, the gill/trammel net statistics in other ICES rectangles will also be included to assess the impact quantitatively as best as possible.

The number of Danish gill/trammel net vessels registering landings in ICES 38G1 over an 11 year period (1998-2008), varied between 10-24 vessels. Over the same period the number of German gill/trammel net vessels registering landings from ICES 38G1 varied between 1-4 vessels. These numbers are, however, most likely underestimated for the net fisheries along the coast near Fehmarnbelt as official statistics in the ICES rectangles do not include small fishing vessels (less than 10 m before 2005 and less than 8 m as of 2005) which typically fish with gill/trammel nets. Thus, to supplement the estimate of the numbers of gill/trammel net vessels fishing in or near Fehmarnbelt, the average number of small (<8 m) vessels from the Danish and German harbours located in and near Fehmarnbelt are also presented. In the Danish and German harbours located in and near Fehmarnbelt there are an average number of 34 Danish vessels and 64 German vessels, respectively (2004-2008).

Furthermore, there are also a number of gill netting vessels that fish immediately to the west or southeast of Fehmarnbelt, which register their catches within other adjacent ICES rectangles (ICES 38G0, 37G0 and 37G1).

The average annual landings by Danish gill/trammel net fishing vessels in Fehmarnbelt (ICES 38G1) from 1998-2008 was 94 tons (43-183 tons). The average annual value of these landings was 180,000 euro (81,000-327,000 euro). Similarly, during the same period (1998-2008) the average annual landings from ICES 38G1 by German gill/trammel net fishing vessels was 41 tons (4-95 tons) with an average annual value of 62,000 euro (7,000-148,000 euro).

The most dominant species caught by gill/trammel nets in Fehmarnbelt from 1998-2008 have been cod by both weight and value and supplemented with a variety of different flatfish species (plaice, turbot, flounder and dab). In the Danish gill/trammel net fisheries from 1998-2008 the landings of cod have annually averaged 64 tons (31-107 tons) at an average annual value of 123,000 euro (60,000-211,000 euro). The German gill/trammel net fisheries have annually landed 39 tons (3.6-92 tons) of cod at an average value of 95,000 euro (6,100-282,000 euro) from 1998-2008.

The overall distribution of the Danish and German gill/trammel net fisheries is shown in Figure 1.4. The Danish fishing grounds are primarily along the southern coast of Lolland and in an area along the western part of Fehmarnbelt that stretches from the coast of southwest Lolland to an area of high fishing intensity immediately to the west of Fehmarn Island. Cod and several valuable flatfish species (plaice, turbot, brill and occasionally sole) are targeted in this area. The German gill/trammel net fishermen undertake their fisheries primarily in and near Fehmarnbelt along much of the coast of Fehmarn, and especially along the northeastern coast of Fehmarn where intensity of the gill/trammel net fisheries is high, and the target species is primarily cod.

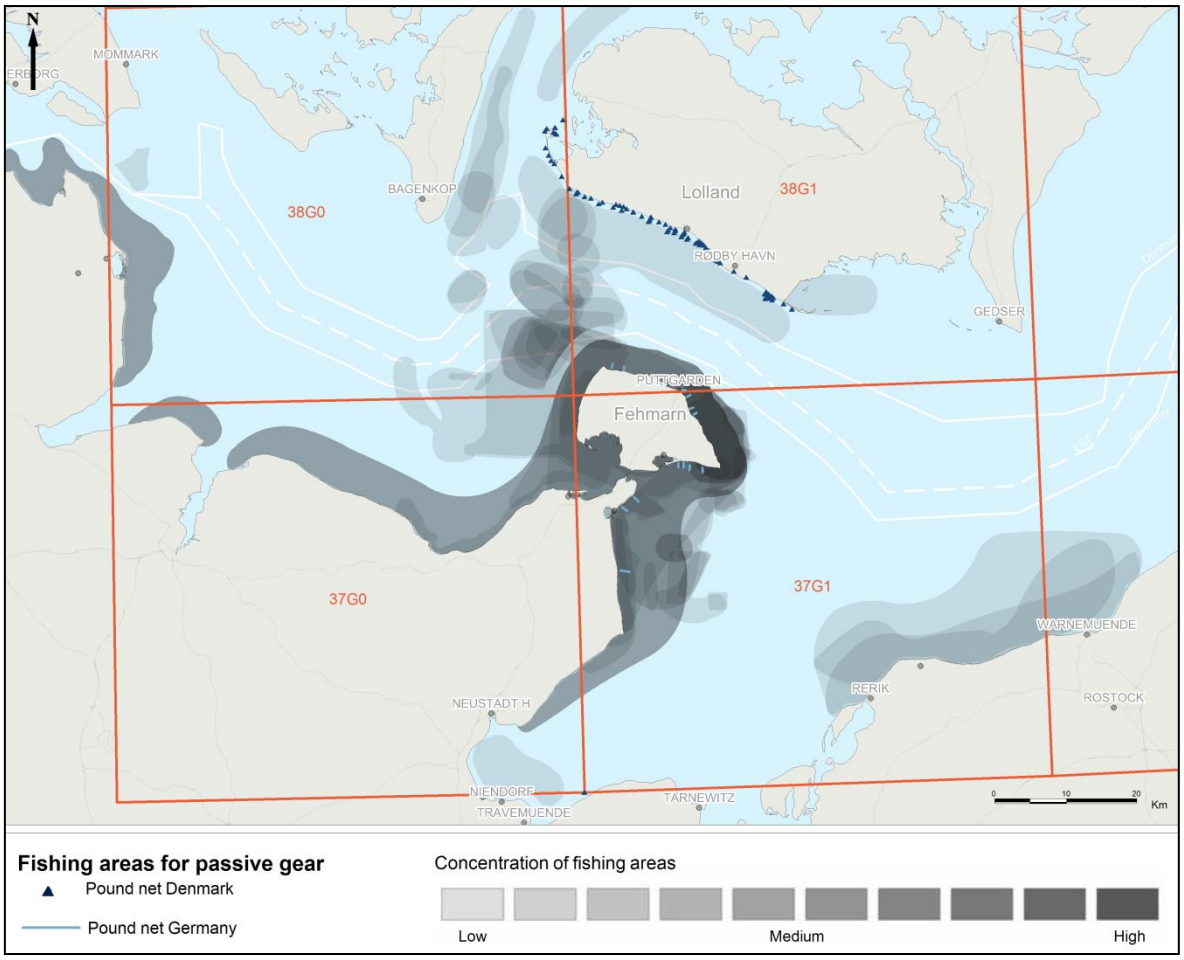


Figure 1.4: The distribution of the Danish and German gill/trammel net fisheries as derived from interviews with Danish and German fishermen. Danish pound net locations are shown by black triangles along the southern coast of Lolland. German pound nets are shown by blue lines along the coastline of Fehmarn and the immediate mainland to the east. The shaded fishing area in Rødsand Lagoon on the southeast coast of Lolland represents an area where a considerable amount of eel and shrimp fisheries are periodically undertaken with special fyke nets.

Seine nets

Only Danish seine netting vessels from the Danish fisheries have registered landings in Fehmarnbelt (ICES 38G1) from 1998-2008.

During this time the number of seine netting vessels registering their fisheries in Fehmarnbelt have varied between 1-18 vessels annually and have generally been declining, from a peak of 18 in 2001 to only three in 2007 and one in 2008, respectively.

The average annual landings from ICES 38G1 by Danish seiners from 1998-2008 was 45 tons (5-125 tons) with an average annual value of 82,000 euro (10,000-232,000 euro).

In the most recent years (2004-2008), between one to six Danish seine netting vessels have annually landed a total of 25 tons (5-46 tons) from fishing in Fehmarnbelt (ICES 38G1). The low number of vessels and landings in 2007 (4.8 tons) and 2008 (12 tons) suggests that in general, there has been a large decline in the seine net fishing being undertaken in Fehmarnbelt.

The most dominant species caught by Danish seine netters are cod by weight and value, and supplemented by a number of different flatfish species such as dab, flounder and plaice. The average annual landings of cod from 1998-2008 was 38 tons (4-103 tons) with an average

annual value of 74,000 euro (8,900-200,000 euro). Over the same period flatfish have on average made up two tons (0.1-6.1 tons) of the landings and 1,700 euro (50-7,200 euro) in value.

The distribution of the seine netting vessels fishing in Fehmarnbelt from 2005-2008 indicated that the central deeper parts of Fehmarnbelt are where the fishing is being undertaken. However, this is only periodic and the vast majority of the seine net fisheries in the Western Baltic are primarily undertaken in the regional areas to the east of Fehmarnbelt.

Pound nets
The Danish and German pound net fisheries in Fehmarnbelt are represented by 82 Danish pound nets positions along the entire southern coast of Lolland and 13 German pound nets located along the coastline of Fehmarn and the immediate mainland to the east (Figure 1.4). The Danish pound net enterprises also use other gear on occasion, and according to interviews have used more than 300 fyke nets and gill nets in coastal fisheries in nearby areas.

The annual landings in the Danish pound net and associated coastal fisheries were between 94-323 tons with a value of 221,000-569,000 euro from 2000-2009. The most important species economically is cod and European eel, which made up between 53-91% (117,000-518,000 euro) of the value of the overall landings over the last decade (2000-2009). Garfish (6.4-39 tons and 6,600-22,500 euro), diverse flatfish (flounder, dab, plaice and turbot) and more periodically the Baltic prawn (1-6 tons or 700-18,000 euro from 2000-2005) can also have periodic importance to these fisheries.

Limited landing data of the German pound net fisheries indicated an estimated average of 2,649 European eel (2,350 euro in value) was landed each year in 3-5 active pound nets over an 11 year period (1998-2008).

Seasonally, the Danish and German pound net fisheries are typically undertaken from September-November when migrating silver eel are targeted. Some Danish pound net fisheries, however, also undertake their fisheries in the spring and continue into the summer and target garfish, herring, cod, lumpsuckers (male and female) and eventually flatfish. Similarly, the fisheries after Baltic prawns are undertaken from April-August.

Other commercial fisheries (shellfish)
There are no consistent commercial shellfish fisheries undertaken in the Fehmarnbelt and region (Western Baltic) according to members the Danish Fishermen's Association that represent the Danish fisheries in the Western Baltic, as well as sources in the Danish Directorate of Fisheries. There are some sporadic logbook reporting's of oyster and blue mussel landings from the fisheries in the Western Baltic, however, the amounts are generally very small and not consistent for any particular area of the Western Baltic from year to year. Except for 2002, where 81 tons of blue mussels were landed from ICES 38G0 to the west of Fehmarnbelt, logbook data over an 11 year period (1998-2008) showed that oysters and blue mussels were only occasionally landed in small amounts (60-300 kg) primarily from ICES 38G0.

1.3 Importance of fishery components

It has been determined that the complexity of the components for the fisheries, according to assessment methods and criteria standards, has warranted a scaling of four levels (see 3.1.4)

The importance of the components representing the different fisheries in Fehmarnbelt according to gear types are determined by their importance and value to the fisheries in the local and regional areas of Fehmarnbelt as described in Table 1.2.

Table 1.2: Description of the criteria used to determine the importance (Very high, High, Medium and Minor) of the primary fisheries (Trawl, Gill/trammel nets, Pound nets and Danish seine nets) in Fehmarnbelt and regional area.

Importance	Criteria for assessment of the importance of the fisheries in Fehmarnbelt and its region	Component (Gear)
Very high	Fehmarnbelt is specific for the undertaking of the fisheries and is of high importance and value	Pound nets
High	Fehmarnbelt is the primary area for the undertaking of the fisheries and/or this area is of regional importance and value	
Medium	Fehmarnbelt is an area used for the undertaking of the fisheries and is of some local and regional importance and value	Trawling, Gill/trammel nets
Minor	Fehmarnbelt is an area only seldom or not used for the undertaking of the fisheries, or is of little local or regional importance and value	Danish Seine nets

Further justification for the classification of the specific “importance” levels for the commercial fishery components are given in the following:

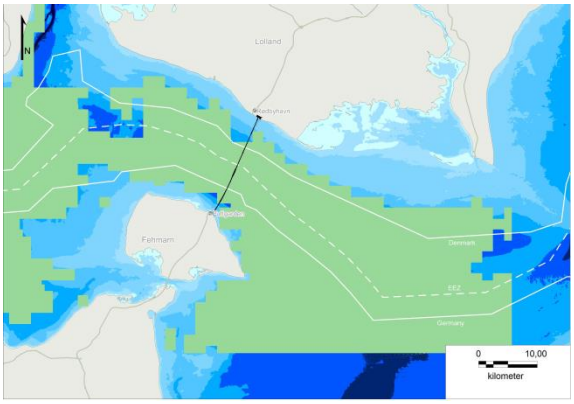
Trawl - Both mid-water and bottom trawling is consistently undertaken annually in the deeper (>10 m), central parts of Fehmarnbelt as well as in the deeper parts of the greater regional area. This fishery has some importance for trawlers from local, regional and distant harbours making Fehmarnbelt and its region of medium importance and value to these fisheries.

Gill/trammel nets - The gill/trammel net fishery is consistently undertaken annually along both the Danish and German coastal areas of Fehmarnbelt and in a belt across the western area of Fehmarnbelt and in an area west of Fehmarn. Fehmarnbelt and its regional area is of medium importance and value for net fishermen from many local harbours as this fishery is generally undertaken by smaller vessels which often undertake their fisheries closer to their basis harbours.

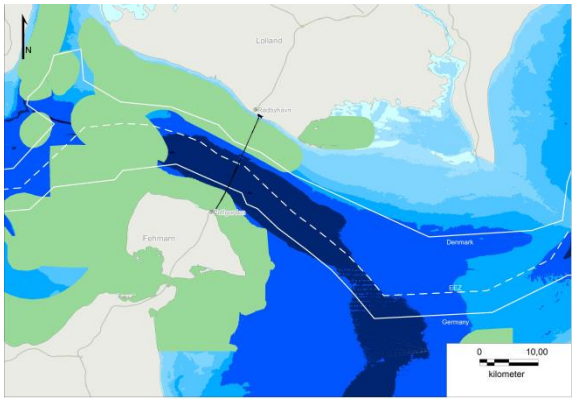
Seine nets - The seine net fishery (Danish seines) is only occasionally (not on an annual basis) undertaken in Fehmarnbelt and its regional area, and only with a low effort. The majority of the seine net fisheries are undertaken to the east of Fehmarnbelt and thus Fehmarnbelt is only of minor importance to this fishery.

Pound nets - The pound net fisheries in Fehmarnbelt and nearby areas are consistently undertaken annually all along the entire southern and southwestern coast of Lolland and in some areas along the coast of Fehmarn. This fishery is undertaken with stationary gear and the success of this fishery is highly dependent on the local environmental conditions of Fehmarnbelt, thus the importance of Fehmarnbelt for this fishery is very high.

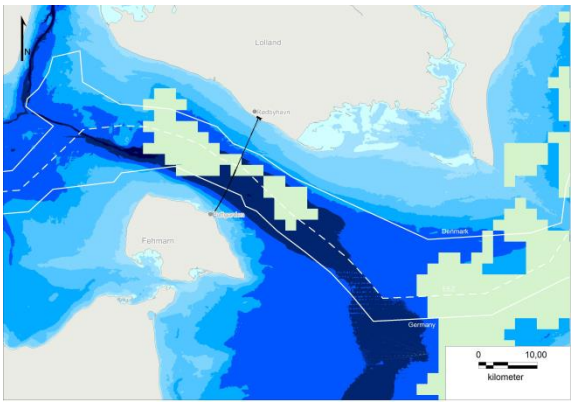
The distribution of the German and Danish fishery components (trawl, gill nets, pound nets and Danish seine nets (Denmark only)) in Fehmarnbelt and its regional area are depicted on maps according to their importance in Figure 1.5.



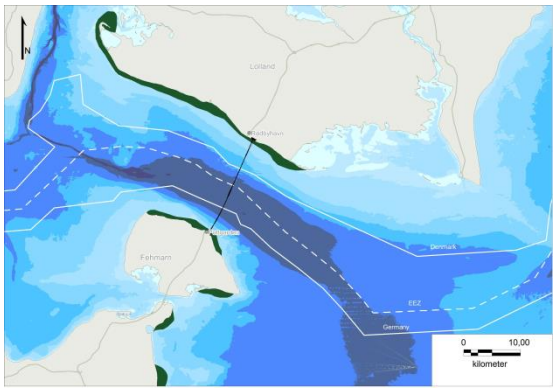
Areas of potential importance for the trawl fisheries in Fehmarnbelt and nearby areas



Areas of potential importance for the gill nets fisheries in Fehmarnbelt and nearby areas



Areas of Importance for the seine net fisheries in Fehmarnbelt and nearby areas



Areas of Importance for the pound net fisheries in Fehmarnbelt and nearby areas

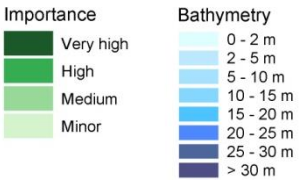


Figure 1.5: Maps showing the areas of importance for the Danish and German fishery components (trawl, gill nets, Danish seine nets (Denmark only) and pound nets) in Fehmarnbelt and nearby areas. Importance grading was done according to criteria summarised in Table 3.1.

Commercial species (fishery resource)

Because impacts to the fisheries are often a result of pressures affecting the commercial fish species that make up their resources, the affects on these sub components to the fisheries are used to determine the impact to the fisheries. The most important fish species that are the primary resources to the fisheries in Fehmarnbelt and its region are given in Table 1.3.

Table 1.3: A list of the most important commercial fish species that represent the main resources and thus the associated sub components to the fisheries in Fehmarnbelt and its regional area.

Associated sub-components (commercial species) to the fisheries
Atlantic cod
Sprat
Herring
Flounder
Dab
Plaice

Turbot
Brill
Sole
Whiting
Horse Mackerel
European eel
Salmon
Sea trout
Garfish

Further justification for including these fish species as associated sub components to the fisheries in Fehmarnbelt and its regional area is given in the following section.

Cod
Cod is consistently caught (>1000 tons annually, 1998-2008) in the commercial fisheries in Fehmarnbelt along with several other areas of the Western Baltic, and is an important component to the catch in all the major commercial fisheries (trawl, gill/trammel nets and pound nets). Cod is also consistently the most valuable commercial species in the fisheries in Fehmarnbelt (representing approx. 800,000 euro annually 1998-2008).

Sprat/Herring
Sprat and herring annually make up the largest catches of commercial species in Fehmarnbelt (1000 tons and 300 tons respectively, 1998-2008) and region and represent the second and third largest income from the commercial fisheries in Fehmarnbelt.

Dab/flounder/plaice
These flatfish species make up a considerable amount of the catches (landings and value) in the commercial fisheries of Fehmarnbelt and region. Dab and flounder are primarily caught as bycatch in the trawl fisheries, and plaice are both targeted and caught as bycatch in the gill/trammel net fisheries. These species are an important economic supplement to the commercial fisheries.

Turbot/Brill/Sole
These valuable flatfish species are an important sub component to the commercial fisheries in Fehmarnbelt, particularly the gill/trammel net fisheries which specifically target these species when abundant.

Eel
The European eel (primarily migrating silver eel) are a very important sub component to the commercial pound net fisheries in Fehmarnbelt primarily during the later part of the year (autumn). A decrease in the abundance or change in the distribution of this species could have serious consequences to the the pound net fisheries as a whole.

Whiting/Horse mackerel
These species are occasionally caught in large amounts in the commercial fisheries in Fehmarnbelt (>150 tons in some years). Whiting has been caught more consistently in the most recent years (>50 tons annually, 2005-2008).

Salmon/Sea trout
These species are only caught occasionally and are not a targeted species of the commercial fisheries in Fehmarnbelt.

Garfish
Garfish are an important supplement to some of the commercial pound net fisheries in Fehmarnbelt.

1.4 Area of investigation

The pressures and impacts of the Fehmarnbelt fixed link project on the commercial fisheries will be assessed on different spatial scales according to the official statistical area that includes most of Fehmarnbelt (ICES 38G1) and the Fehmarnbelt regional area (Figure 1.6).

These can be described as the:

- The ICES fishery statistical zone (ICES 38G1) which for the purpose of this assessment is considered to represent Fehmarnbelt
- Regional scale (an area of the Western Baltic considered to be within the regional area of Fehmarnbelt)

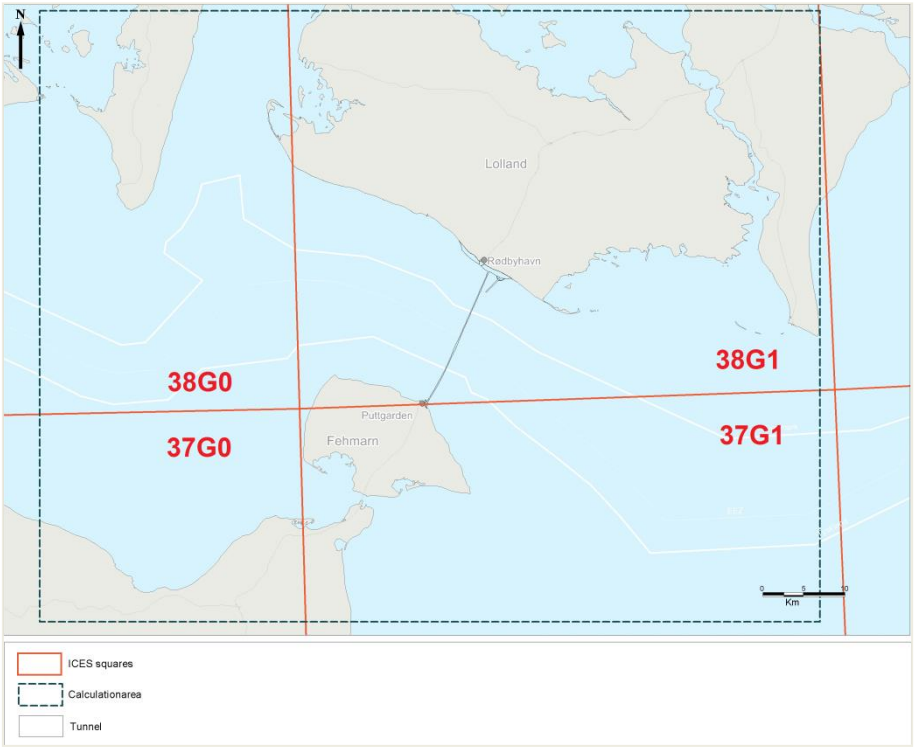


Figure 1.6: The area of investigation and assessment for the Danish and German fisheries in Fehmarnbelt (ICES 38G1) and the Fehmarnbelt regional area which includes the area within the dotted line (----). The immersed tunnel alignment and reclamation areas of the tunnel alternative are depicted across Fehmarnbælt.

Commercial fish species

The pressures and impacts of the Fehmarnbelt fixed link project on the resources to the fisheries (commercial species) include the near zone (500 m zone) for each of the described solutions and the local zone (10 km zone exclusive the 500 m zone) in German and Danish territories. In the German territory the two zones are further subdivided into the national Exclusive Economic Zones (EEZ) (Table 1.4).

Table 1.4: Description of the near and local zones addressed with respect to impacts on commercial fish species due to the Fehmarnbælt Fixed Link in the EIS on Fish Communities (FeBEC 2012). The names refer to the abbreviations presented in this report and described in greater detail in the EIS on Fish Communities.

Zone	Territory	Description of area	Name
Near zone	DE-national	+/- 500 m around the project Tunnel based on IMT-E-ME August 2011 Bridge based on Var2-BE-E October 2010	DE 500 m Nat.

	DE-EEZ	Do	DE 500 m EEZ
	DK	Do	DK 500 m
Local zone	DE-national	+/- 10 km from the alignment (excl. near zone). Alignment IMT-E-ME August 2011.	DE 10 km Nat.
	DE-EEZ	Do	DE 10 km EEZ
	DK	Do	DK 10 km

In addition to these zones Rødsand Lagoon was assessed with respect to impacts from sediment spill since the modelled excess concentrations of suspended sediment in the lagoon from the construction of both the tunnel and bridge solution are the highest expected in the Fehmarnbelt area. Furthermore, impacts from modelled changes in the hydrographical regime on the reproduction volume of cod in the Arkona Basin have been included in the assessment.

Figure 1.7 shows the respective zones and Rødsand Lagoon that have been addressed in the assessment on fish communities which include the fish species that represent the resources to the commercial fisheries (FeBEC 2012).

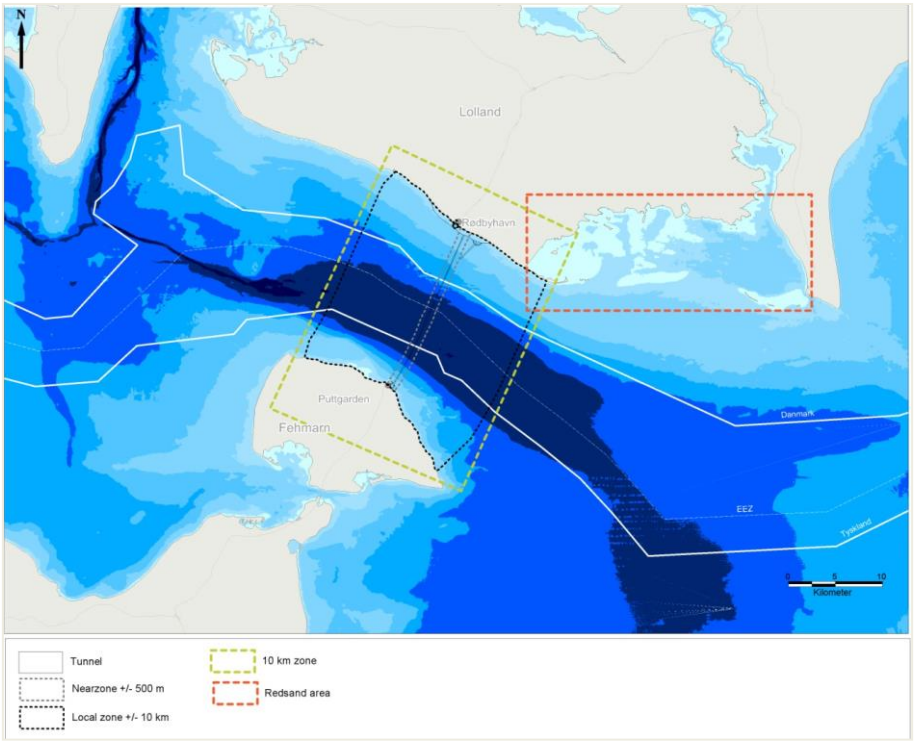


Figure 1.7: Areas of investigation addressed in the impact assessment of the fish communities (FeBEC 2012) in relation to the the proposed solutions of the Fehmarnbelt link.

In general, the boundaries of the areas refer to direct, on-site effects alone. However, the classification of the severity of impairment includes the rating of the importance of the specific fish community components, which are classified according to their regional and transboundary significance. This means that regional and transboundary impacts implicit are assessed although not quantitatively.

2. Technical project description

2.1 The Immersed Tunnel

The alignment for the immersed tunnel passes east of Puttgarden, crosses the Fehmarnbelt in a soft curve and reaches Lolland east of Rødbyhavn as shown in Figure 2.1 along with near-by NATURA 2000 sites.

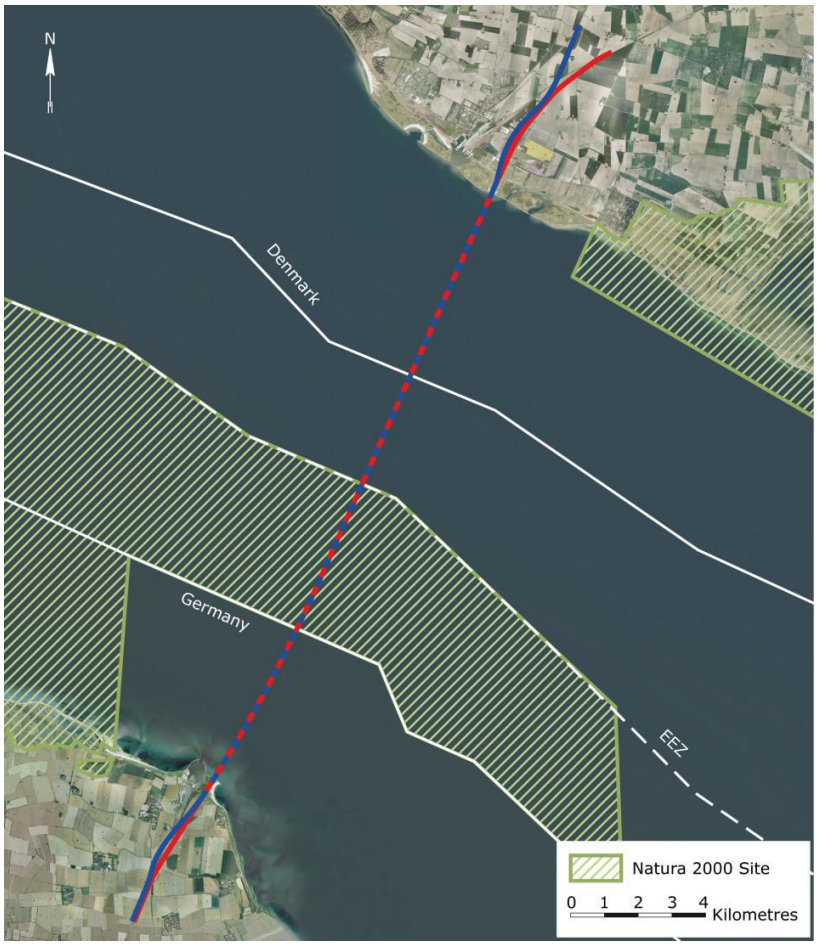


Figure 2.1: Conceptual design of tunnel alignment. © Femern A/S

2.1.1 Tunnel trench

The immersed tunnel is constructed by placing tunnel elements in a trench dredged in the seabed. The proposed methodology for trench dredging comprises mechanical dredging using Backhoe Dredgers (BHD) up to 25 meters and Grab Dredgers (GD) in deeper waters. A Trailing Suction Hopper Dredger (TSHD) will be used to rip the clay before dredging with GD. The material will be loaded into barges and transported to the near-shore reclamation areas where the soil will be unloaded from the barges by small BHDs. A volume of approx. 14,5 mio m^3 sediment is handled.

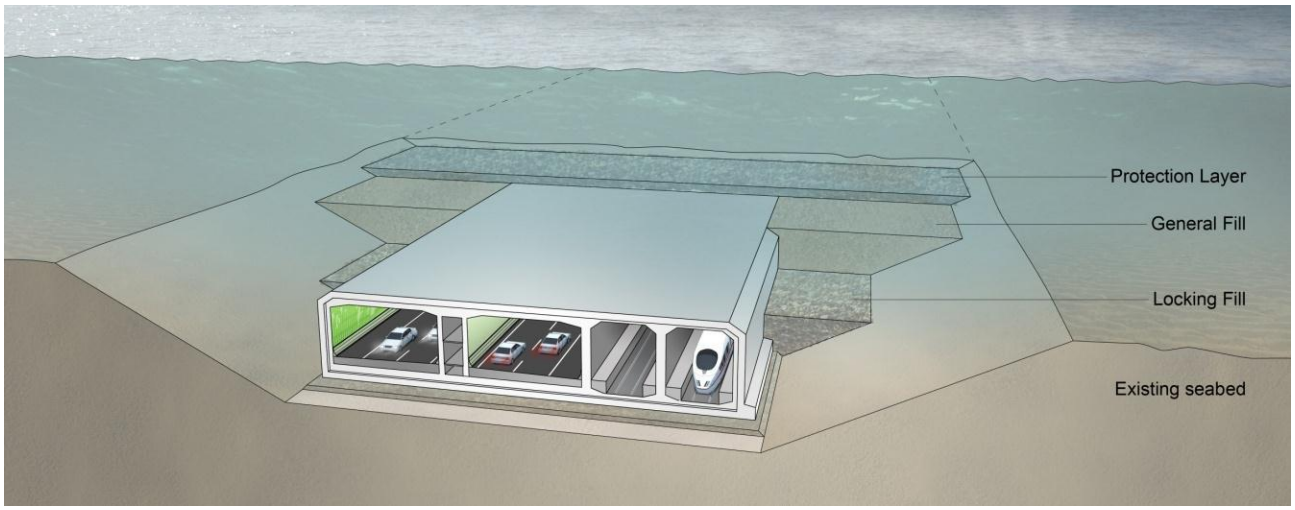


Figure 2.2: Cross section of dredged trench with tunnel element and backfilling. © Femern A/S

A bedding layer of gravel forms the foundation for the elements. The element is initially kept in place by placing locking fill followed by general fill, while on top there is a stone layer protecting against damage from grounded ships or dragging anchors. The protection layer and the top of the structure are below the existing seabed level except near the shore. At these locations, the seabed is locally raised to incorporate the protection layer over a distance of approximately 250 m from the proposed coastline. Here the protection layer is thinner and made from concrete and a rock layer.

2.1.2 Tunnel elements

There are two types of tunnel elements: standard elements and special elements. There are 79 standard elements. Each standard element is approximately 217 m long, 42 meters wide and 9 meters tall. Special elements are located approximately every 1.8 km providing additional space for technical installations and maintenance access. There are 10 special elements. Each special element is approximately 46 m long, 45 meters wide and 13 meters tall.

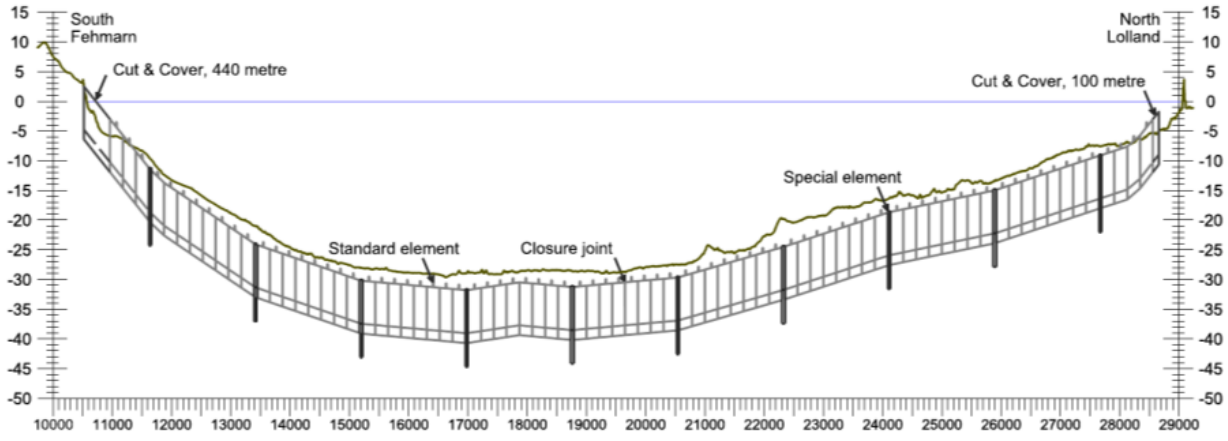


Figure 2.3: Vertical tunnel alignment showing depth below sea level. © Femern A/S

The cut and cover tunnel section beyond the light screens is approximately 440 m long on Lolland and 100 m long on Fehmarn. The foundation, walls, and roof are constructed from cast in-situ reinforced concrete.

2.1.3 Tunnel drainage

The tunnel drainage system will remove rainwater and water used for cleaning the tunnel. Rainwater entering the tunnel will be limited by drainage systems on the approach ramps. Fire fighting water can be collected and contained by the system for subsequent handling. A series of pumping stations and sump tanks will transport the water from the tunnel to the portals where it will be treated as required by environmental regulations before being discharged into the Fehmarnbelt.

2.1.4 Reclamation areas

Reclamation areas are planned along both the German and Danish coastlines to accommodate the dredged material from the excavation of the tunnel trench. The size of the reclamation area on the German coastline has been minimized. Two larger reclamations are planned on the Danish coastline. Before the reclamation takes place, containment dikes are to be constructed some 600m out from the coastline.

The landfall of the immersed tunnel passes through the shoreline reclamation areas on both the Danish and German sides.

Fehmarn
The proposed reclamation at the Fehmarn coast does not extend towards north beyond the existing ferry harbour at Puttgarden. The extent of the Fehmarn reclamation is shown in Figure 2.4. The reclamation area is designed as an extension of the existing terrain with the natural hill turning into a plateau behind a coastal protection dike 3.5 m high. The shape of the dike is designed to accommodate a new beach close to the settlement of Marienleuchte.

Figure 2.4: Reclamation area at Fehmarn. © Femern A/S

The reclaimed land behind the dike will be landscaped to create an enclosed pasture and grassland habitat. New public paths will be provided through this area leading to a vantage point at the top of the hill, offering views towards the coastline and the sea.

The Fehmarn tunnel portal is located behind the existing coastline. The portal building on Fehmarn houses a limited number of facilities associated with essential equipment for operation and maintenance of the tunnel and is situated below ground level west of the tunnel.

A new dual carriageway is to be constructed on Fehmarn for approximately 3.5 km south of the tunnel portal. This new highway rises out of the tunnel and passes onto an embankment next to the existing harbour railway. The remainder of the route of the highway is approximately at level. A new electrified twin track railway is to be constructed on Fehmarn for approximately 3.5 km south of the tunnel portal. A lay-by is provided on both sides of the proposed highway for use by German customs officials.

Lolland
There are two reclamation areas on Lolland, located either side of the existing harbour. The reclamation areas extend approximately 3.7 km east and 3.4 km west of the harbour and project approximately 500 m beyond the existing coastline into the Fehmarnbelt. The proposed reclamation areas at the Lolland coast do not extend beyond the existing ferry harbour at Rødbyhavn.

The sea dike along the existing coastline will be retained or reconstructed, if temporarily removed. A new dike to a level of +3 m protects the reclamation areas against the sea. To the eastern end of the reclamation, this dike rises as a till cliff to a level of +7 m. Two new beaches will be established within the reclamations. There will also be a lagoon with two openings towards Fehmarnbelt, and revetments at the openings. In its final form the reclamation area will appear as three types of landscapes: recreation area, wetland, and grassland - each with different natural features and use.

The Lolland tunnel portal is located within the reclamation area and contained within protective dikes. The main control centre for the operation and maintenance of the Fehmarnbelt Fixed Link tunnel is housed in a building located over the Danish portal. The areas at the top of the perimeter wall, and above the portal building itself, are covered with large stones as part of the landscape design. A path is provided on the sea-side of the proposed dike to serve as recreation access within the reclamation area.

A new dual carriageway is to be constructed on Lolland for approximately 4.5 km north of the tunnel portal. This new motorway rises out of the tunnel and passes onto an embankment. The remainder of the route of the motorway is approximately at level. A new electrified twin track railway is to be constructed on Lolland for approximately 4.5 km north of the tunnel portal. A lay-by is provided in each direction off the landside highway on the approach to the tunnel for use by Danish customs officials.

Figure 2.5: A facility for motorway toll collection will be provided on the Danish landside. © Femern A/S

2.1.5 Marine construction works

The temporary works comprises the construction of two temporary work harbours, the dredging of the portal area and the construction of the containment dikes. For the harbor on Lolland an access channel is also provided. These harbours will be integrated into the planned reclamation areas and upon completion of the tunnel construction works, they will be dismantled/removed and backfilled.

2.1.6 Production site

The current design envisages the tunnel element production site to be located in the Lolland east area in Denmark. The figure below shows one production facility consisting of two production lines. For the construction of the standard tunnel elements for the Fehmarn tunnel four facilities with in total eight production lines are anticipated.

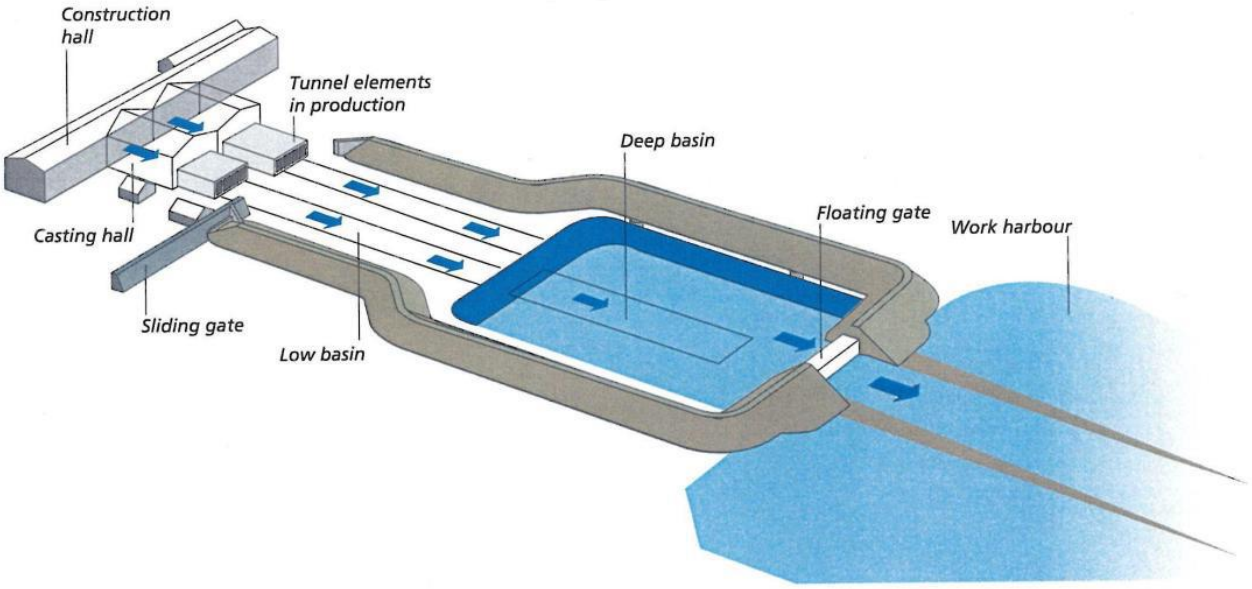


Figure 2.6: Production facility with two production lines. © Femern A/S

In the construction hall, which is located behind the casting and curing hall, the reinforcement is handled and put together to a complete reinforcement cage for one tunnel segment. The casting of the concrete for the segments is taking place at a fixed location in the casting and curing hall. After the concrete of the segments is cast and hardened enough the formwork is taken down and the segment is pushed forward to make space for the next segment to be cast. This process continues until one complete tunnel element is cast. After that, the tunnel element is pushed into the launching basin. The launching basin consists of an upper basin, which is located at ground level and a deep basin where the tunnel elements can float. In the upper basin the marine outfitting for the subsequent towing and immersion of the element takes place. When the element is outfitted, the sliding gate and floating gate are closed and sea water is pumped into the launching basin until the elements are floating. When the elements are floating they are transferred from the low basin to the deep basin. Finally the water level is lowered to normal sea level, the floating gate opened and the element towed to sea. The proposed lay-out of the production site is shown in 6.7.

Dredging of approx. 4 mio. m^3 soil is required to create sufficient depth for temporary harbours, access channels and production site basins.

Figure 2.7: Proposed lay-out of the production site on Lolland. © Femern A/S

2.2 Cable-stayed Bridge

The main bridge is a twin cable stayed bridge with three pylons and two main spans of 724 m each. The superstructure of the cable stayed bridge consists of a double deck girder with the dual carriageway road traffic running on the upper deck and the dual track railway traffic running on the lower deck. The pylons have a height of 272 m above sea level and are V-shaped in transverse direction. The main bridge girders are made up of 20 m long sections with a weight of 500 to 600 t. The standard approach bridge girders are 200 m long and their weight is estimated to ~ 8,000 t.

Caissons provide the foundation for the pylons and piers of the bridge. Caissons are prefabricated placed 4 m below the seabed. If necessary, soils are improved with 15 m long bored concrete piles. The caissons in their final positions end 4 m above sea level. Prefabricated pier shafts are placed on top of the approach bridge caissons. The pylons are cast in situ on top of the pylon caissons Pier Protection Works are prefabricated and installed around the pylons and around two piers on both sides of the pylons. These works protrudes above the water surface. The main bridge is connected to the coasts by two approach bridges. The southern approach bridge is 5,748 m long and consists of 29 spans and 28 piers. The northern approach bridge is 9,412 m long and has 47 spans and 46 piers.

Figure 2.8: Cable Stayed Bridge. © Femern A/S

2.2.1 Land works

A peninsula is constructed both at Fehmarn and at Lolland to use the shallow waters east of the ferry harbours breakwater to shorten the Fixed Link Bridge between its abutments. The peninsulas consist partly of a quarry run bund and partly of dredged material and are protected towards the sea by revetments of armor stones.

Fehmarn
The peninsula on Fehmarn is approximately 580m long, measured from the coastline. The gallery structure on Fehmarn is 320 m long and enables a separation of the road and railway alignments. A 400 m long ramp viaduct bridge connects the road from the end of the gallery section to the motorway embankment. The embankments for the motorway are 490 m long. The motorway passes over the existing railway tracks to Puttgarden Harbour on a bridge. The profile of the railway and motorway then descend to the existing terrain surface.

Lolland
The peninsula on Lolland is approximately 480m long, measured from the coastline. The gallery structure on Lolland is 320 m long. The existing railway tracks to Rødbyhavn will be decommissioned, so no overpass will be required. The viaduct bridge for the road is 400m long; the embankments for the motorway are 465 m long and for railway 680 m long. The profile of the railway and motorway descend to the natural terrain surface.

Figure 2.9: Approach bridge. © Femern A/S

2.2.2 Drainage on main and approach bridges

On the approach bridges the roadway deck is furnished with gullies leading the drain water down to combined oil separators and sand traps located inside the pier head before discharge into the sea. On the main bridge the roadway deck is furnished with gullies with sand traps. The drain water passes an oil separator before it is discharged into the sea through the railway deck.

2.2.3 Marine construction work

The marine works comprises soil improvement with bored concrete piles, excavation for and the placing of backfill around caissons, grouting as well as scour protection. The marine works also include the placing of crushed stone filling below and inside the Pier Protection Works at the main bridge.

Soil improvement will be required for the foundations for the main bridge and for most of the foundations for the Fehmarn approach bridge. A steel pile or reinforcement cage could be placed in the bored holes and thereafter filled with concrete.

The dredging works are one of the most important construction operations with respect to the environment, due to the spill of fine sediments. It is recommended that a grab hopper dredger with a hydraulic grab be employed to excavate for the caissons both for practical reasons and because such a dredger minimises the sediment spill. If the dredged soil cannot be backfilled, it must be relocated or disposed of.

2.2.4 Production sites

The temporary works comprises the construction of two temporary work harbours with access channels. A work yard will be established in the immediate vicinity of the harbours, with facili-

ties such as concrete mixing plant, stockpile of materials, storage of equipment, preassembly areas, work shops, offices and labour camps.

The proposed lay-out of the production site is shown in Figure 2.10.

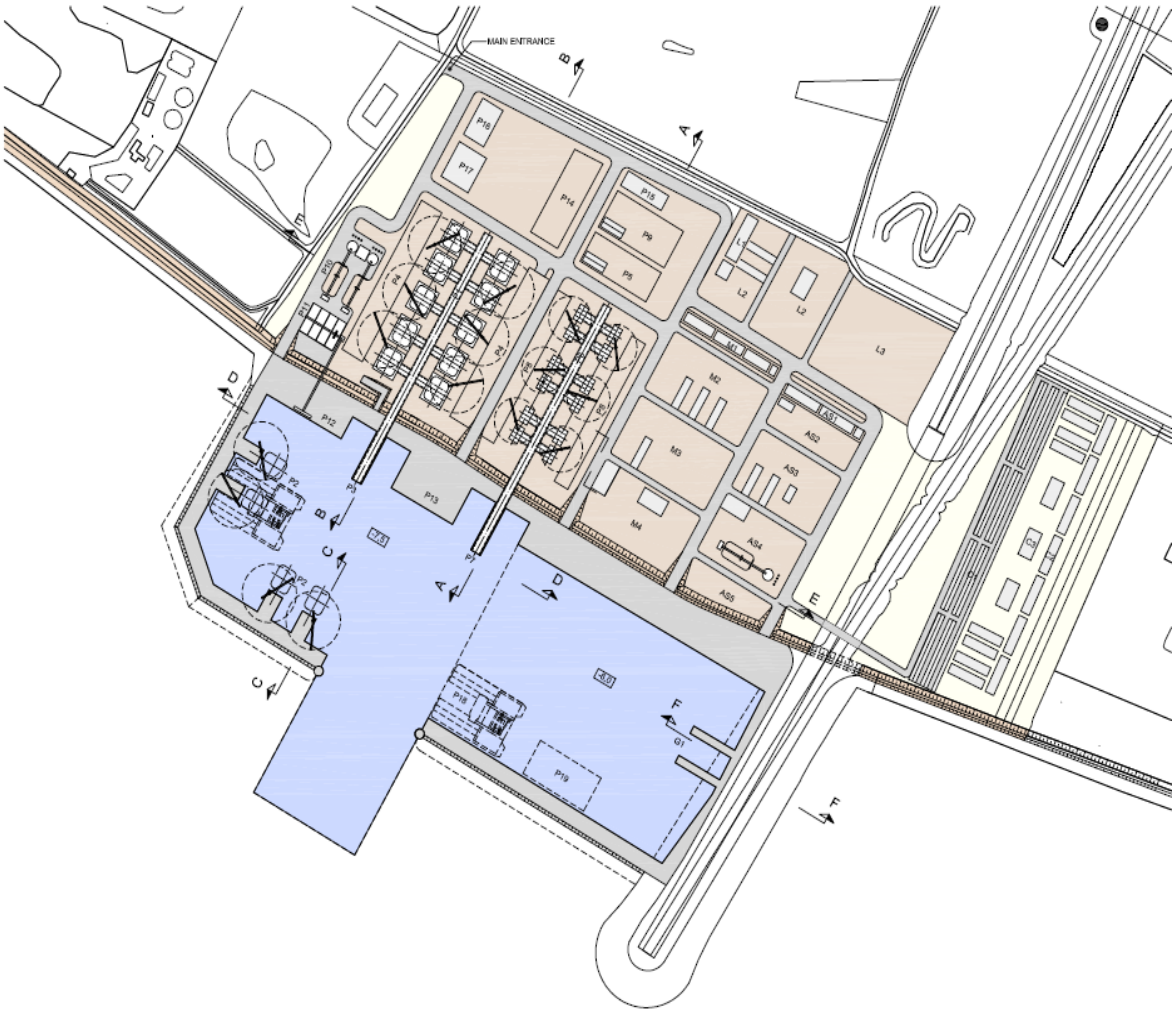


Figure 2.10: Proposed lay-out of the production site. © Femern A/S

3. Data and Methods

3.1 The Assessment Methodology

To ensure a uniform and transparent basis for the EIA, a general impact assessment methodology for the assessment of predictable impacts of the Fixed Link Project on the environmental factors (see box 3.1) has been prepared. The methodology is defined by the impact forecast methods described in the scoping report (Femern and LBV-SH-Lübeck 2010, section 6.4.2). In order to give more guidance and thereby support comparability, the forecast method has been further specified.

As the impact assessments cover a wide range of environs (terrestrial and marine) and environmental factors, the general methodology is further specified and in some cases modified for the assessment of the individual environmental factors (e.g. the optimal analyses for migrating birds and relatively stationary marine bottom fauna are not identical). These necessary modifications are explained in Section 3.1.2. The specification of methods and tools used in the present report are given in the following sections of Chapter 3.

3.1.1 Overview of terminology

To assist reading the background report as documentation for the German UVS/LPB and the Danish VVM, the Danish and German terms are given in the columns to the right.

Term	*Explanation*	*Term DK*	*Term DE*
Environmental factors	The environmental factors are defined in the EU EIA Directive (EU 1985) and comprise: Human beings, Fauna and flora, Soil, Water, Air, Climate, Landscape, Material assets and cultural heritage. In the sections below only the term environmental factor is used; covering all levels (factors, sub-factors, etc.; see below). The relevant level depends on the analysis.	Miljøforhold/-faktor	Schutzgut
Sub-factors	As the Fixed Link Project covers both terrestrial and marine sections, each environmental factor has been divided into three sub-factor: Marine areas, Lolland and Fehmarn (e.g. Marine waters, Water on Lolland, and Water on Fehmarn)	Sub-faktor	Teil-Schutzgut
Components and sub-components	To assess the impacts on the sub-factors, a number of components and sub-components are identified. Examples of components are e.g. Surface waters on Fehmarn, Groundwater on Fehmarn; both belonging to the sub-factor Water on Fehmarn. The sub-components are the specific indicators selected as best suitable for assessing the impacts of the Project. They may represent different characteristics of the environmental system; from specific species to biological communities or specific themes (e.g. trawl fishery, marine tourism).	Component/sub-komponent	Komponente
Construction phase	The period when the Project is constructed; including permanent and provisional structures. The construction is planned for 6½ years.	Anlægsfase	Bauphase
Structures	Constructions that are either a permanent elements of the Project (e.g. bridge pillar for bridge alternative and land reclamation at Lolland for tunnel alternative), or provisional structures such as work harbours and the tunnel trench.	Anlæg	Anlage

Operation phase	The period from end of construction phase until decommissioning.	Driftsfase	Betriebsphase
Permanent	Pressure and impacts lasting for the life time of the Project (until decommissioning).	Permanent	Permanent
Provisional (temporary)	Pressure and impacts predicted to be recovered within the life time of the project. The recovery time is assessed as precise as possible and is in addition related to Project phases.	Midlertidig	Temporär
Pressures	A pressure is understood as all influences deriving from the Fixed Link Project; both influences deriving from Project activities and influences originating from interactions between the environmental factors. The type of the pressure describes its relation to construction, structures or operation.	Belastning	Wirkfaktoren
Magnitude of pressure	The magnitude of pressure is described by the intensity, duration and range of the pressure. Different methods may be used to arrive at the magnitude; dependent on the type of pressure and the environmental factor to be assessed.	Belastningsstørrelse	Wirkintensität
Footprint	The footprint of the Project comprises the areas occupied by structures. It comprises two types of footprint; the permanent footprint deriving from permanent confiscation of areas to structures, land reclamation etc., and provisional footprint which are areas recovered after decommissioning of provisional structures. The recovery may be due to natural processes or Project aided re-establishment of the area.	Arealinddragelse	Flächeninanspruchnahme
Assessment criteria and Grading	Assessment criteria are applied to grade the components of the assessment schemes. Grading is done according to a four grade scale: very high, high, medium, minor or a two grade scale: special, general. In some cases grading is not doable. Grading of magnitude of pressure and sensitivity is method dependent. Grading of importance and impairment is as far as possible done for all factors.	Vurderingskriterier og graduering	Bewertungskriterien und Einstufung
Importance	The importance is defined as the functional values to the natural environment and the landscape.	Betydning	Bedeutung
Sensitivity	The sensitivity describes the environmental factors capability to resist a pressure. Dependent on the subject assessed, the description of the sensitivity may involve intolerance, recovery and importance.	Følsomhed/ Sårbarhed	Empfindlichkeit
Impacts	The impacts of the Project are the effects on the environmental factors. Impacts are divided into Loss and Impairment.	Virkninger	Auswirkung
Loss	Loss of environmental factors is caused by permanent and provisional loss of area due to the footprint of the Project; meaning that loss may be permanent or provisional. The degree of loss is described by the intensity, the duration and if feasible, the range.	Tab af areal	Flächenverlust
Severity of loss	Severity of loss expresses the consequences of occupation of land (seabed). It is analysed by combining magnitude of the Project's footprint with importance of the environmental factor lost due to the footprint.	Omfang af tab	Schwere der Auswirkungen bei Flächenverlust
Impairment	An impairment is a change in the function of an environmental factor.	Forringelse	Funktionsbeeinträchtigung

Degree of impairment	The degree of impairments is assessed by combining magnitude of pressure and sensitivity. Different methods may be used to arrive at the degree. The degree of impairment is described by the intensity, the duration and if feasible, the range.	Omfang/grad af forringelser	Schwere der Funktionsbeeinträchtigung
Severity of impairment	Severity of impairment expresses the consequences of the Project taking the importance of the environmental factor into consideration; i.e. by combining the degree impairment with importance.	Virkningens væsentlighed	Erheblichkeit
Significance	The significance is the concluding evaluation of the impacts from the Project on the environmental factors and the ecosystem. It is an expert judgment based on the results of all analyses.		

It should be noted that in the sections below only the term environmental factor is used; covering all levels of the receptors of the pressures of the Project (factors, sub-factors, component, sub-components). The relevant level depends on the analysis and will be explained in the following methodology sections (section 3.2.3 and onwards).

3.1.2 The Impact Assessment Scheme

The overall goal of the assessment is to arrive at the severity of impact where impact is divided into two parts; loss and impairment (see explanation above). As stated in the scoping report, the path to arrive at the severity is different for loss and impairments. For assessment of the *severity of loss* the footprint of the project (the areas occupied) and the *importance* of the environmental factors are taken into consideration. On the other hand, the assessment of severity of impairment comprises two steps; first the *degree of impairment* considering the magnitude of pressure and the sensitivity. Subsequently the severity is assessed by combining the degree of impairment and the importance of the environmental factor. The assessment schemes are shown in Figure 3.1 – Figure 3.3. More details on the concepts and steps of the schemes are given below. As mentioned above, modification are required for some environmental factors and the exact assessment process and the tools applied vary dependent on both the type of pressure and the environmental factor analysed. As far as possible the impacts are assessed quantitatively; accompanied by a qualitative argumentation.

3.1.3 Assessment Tools

For the impact assessment the assessment matrices described in the scoping report have been key tools. Two sets of matrices are defined; one for the assessment of loss and one for assessment of impairment.

The matrices applied for assessments of severity of loss and degree of impairment are given in the scoping report (Table 6.4 and Table 6.5) and are shown below in Table 3.1 and Table 3.2, respectively.

Table 3.1: The matrix used for assessment of the severity of loss. The magnitude of pressure = the footprint of the Project is always considered to be very high.

Magnitude of the predicted pressure (footprint)	**Importance of the environmental factors**			
	Very high	High	Medium	Minor
Very High	**Very High**	**High**	**Medium**	**Minor**

The approach and thus the tools applied for assessment of the degree of impairment varies with the environmental factor and the pressure. For each assessment the most optimal state-

of-the-art tools have been applied, involving e.g. deterministic and statistical models as well as GIS based analyses. In cases where direct analysis of causal-relationship is not feasible, the matrix based approach has been applied using one of the matrices in Table 3.2 (Table 6.5 of the scoping report) combining the grades of magnitude of pressure and grades of sensitivity. This method gives a direct grading of the degree of impairment. Using other tools to arrive at the degree of impairment, the results are subsequently graded using the impairment criteria. The specific tools applied are described in the following sections of Chapter 3.

Table 3.2: The matrices used for the matrix based assessment of the degree of impairment with two and four grade scaling, respectively

Magnitude of the predicted pressure	**Sensitivity of the environmental factors**			
	Very high	High	Medium	Minor
Very high	**General loss of function, must be substantiated for specific instances**			
High	**Very High**	**High**	**High**	**Medium**
Medium	**High**	**High**	**Medium**	**Low**
Low	**Medium**	**Medium**	**Low**	**Low**

Magnitude of the predicted pressure	**Sensitivity of the environmental factors**	
	Special	General
Very high	**General loss of function, must be substantiated for specific instances**	
High	**Very High**	**High**
Medium	**High**	**Medium**
Low	**Medium**	**Low**

To reach severity of impairment one additional matrix has been prepared, as this was not included in the scoping report. This matrix is shown in Table 3.3.

Table 3.3: The matrix used for assessment of the severity of impairment

Degree of impairment	**Importance of the environmental factors**			
	Very high	High	Medium	Minor
Very High	**Very High**	**High**	**Medium**	**Minor**
High	**High**	**High**	**Medium**	**Minor**
Medium	**Medium**	**Medium**	**Medium**	**Minor**
Low	**Minor**	**Minor**	**Minor**	**Negligible**

Degree of impairment	**Importance of the environmental factors**	
	Special	General
Very high	**Very High**	**Medium**

High	**High**	**Medium**
Medium	**Medium**	**Medium**
Low	**Minor**	**Minor**

3.1.4 Assessment Criteria and Grading

For the environmental assessment two sets of key criteria have been defined: Importance criteria and the Impairment criteria. The importance criteria is applied for grading the importance of an environmental factor, and the impairment criteria form the basis for grading of the impairments caused by the project. The criteria have been discussed with the authorities during the preparation of the EIA.

The impairment criteria integrate pressure, sensitivity and effect. For the impact assessment using the matrix approach, individual criteria are furthermore defined for pressures and sensitivity. The criteria were defined as part of the impact analyses (severity of loss and degree of impairment). Specific assessment criteria are developed for land and marine areas and for each environmental factor. The specific criteria applied in the present impact assessment are described in the following sections of Chapter 3 and as part of the description of the impact assessment.

The purpose of the assessment criteria is to grade according to the defined grading scales. The defined grading scales have four (very; high, Medium; minor) or two (special; general) grades. Grading of magnitude of pressure and sensitivity is method dependent, while grading of importance and impairment is as far as possible done for all factors.

3.1.5 Identifying and quantifying the pressures from the Project

The pressures deriving from the Project are comprehensively analysed in the scoping report; including determination of the pressures which are important to the individual environmental sub-factors (Femern and LBV SH Lübeck 2010, chapter 4 and 7). For the assessments the magnitude of the pressures is estimated.

The magnitudes of the pressures are characterised by their type, intensity, duration and range. The *type* distinguishes between pressures induced during construction, pressures from the physical structures (footprints) and pressures during operation. The pressures during construction and from provisional structures have varying duration while pressures from staying physical structure (e.g. bridge piers) and from the operation phase are permanent. Distinctions are also made between direct and indirect pressures where direct pressures are those imposed directly by the Project activities on the environmental factors while the indirect pressures are the consequences of those impacts on other environmental factors and thus express the interactions between the environmental factors.

The *intensity* evaluates the force of the pressure and is as far as possible estimated quantitatively. The *duration* determines the time span of the pressure. It is stated as relevant for the given pressure and environmental factor. Some pressures (like footprint) are permanent and do not have a finite duration. Some pressures occur in events of different duration. The *range* of the pressure defines the spatial extent. Outside of the range, the pressure is regarded as non-existing or negligible.

The magnitude of pressure is described by pressure indicators. The indicators are based on the modes of action on the environmental factor in order to achieve most optimal descriptions of pressure for the individual factors; e.g. mm deposited sediment within a certain period. As far as possible the magnitude is worked out quantitatively. The method of quantification de-

pends on the pressure (spill from dredging, noise, vibration, etc.) and on the environmental factor to be assessed (calling for different aggregations of intensity, duration and range).

3.1.6 Importance of the Environmental Factors

The importance of the environmental factor is assessed for each environmental sub-factor. Some sub-factors are assessed as one unity, but in most cases the importance assessment has been broken down into components and/or sub-components to conduct a proper environmental impact assessment. Considerations about standing stocks and spatial distribution are important for some sub-factors such as birds and are in these cases incorporate in the assessment.

The assessment is based on *importance criteria* defined by the functional value of the environmental sub-factor and the legal status given by EU directives, national laws, etc. the criteria applied for the environmental sub-factor(s) treated in the present report are given in a later section.

The importance criteria are grading the importance into two or four grades (see section 3.2.4). The two grade scale is used when the four grade scale is not applicable. In a few cases such as climate, grading does not make sense. As far as possible the spatial distribution of the importance classes is shown on maps.

3.1.7 Sensitivity

The optimal way to describe the sensitivity to a certain pressure varies between the environmental factors. To assess the sensitivity more issues may be taken into consideration such as the intolerance to the pressure and the capability to recover after impairment or a provisional loss. When deterministic models are used to assess the impairments, the sensitivity is an integrated functionality of the model.

3.1.8 Severity of loss

Severity of loss is assessed by combining information on magnitude of footprint, i.e. the areas occupied by the Project with the importance of the environmental factor (Figure 3.1). Loss of area is always considered to be a very high magnitude of pressure and therefore the grading of the severity of loss is determined by the importance (see Table 3.1). The loss is estimated as hectares of lost area. As far as possible the spatial distribution of the importance classes is shown on maps.

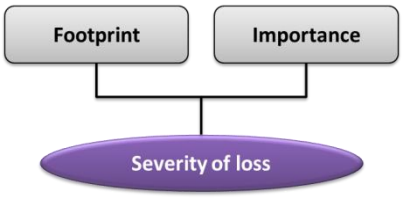


Figure 3.1: The assessment scheme for severity of loss

3.1.9 Degree of impairment

The degree of impairment is assessed based on the magnitude of pressure (involving intensity, duration and range) and the sensitivity of the given environmental factor (Figure 3.2). In worst case, the impairment may be so intensive that the function of the environmental factor is lost. It is then considered as loss like loss due to structures, etc.

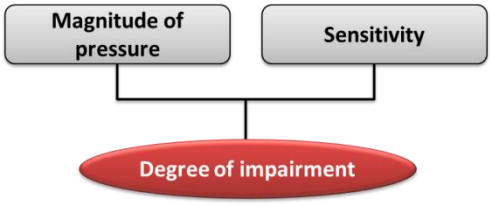


Figure 3.2: The assessment scheme for degree of impairment

As far as possible the degree is worked out quantitatively. As mentioned earlier the method of quantification depends on the environmental factor and the pressure to be assessed, and of the state-of-the-art tools available for the assessment.

No matter how the analyses of the impairment are conducted, the goal is to grade the degree of impairment using one of the defined grading scales (two or four grades). Deviations occur when it is not possible to grade the degree of impairment. The spatial distribution of the different grades of the degree of impairment is shown on maps.

3.1.10 Severity of Impairment

Severity of impairment is assessed from the grading's of degree of impairment and of importance of the environmental factor (Figure 3.3) using the matrix in Table 3.3. If it is not possible to grade degree of impairment and/or importance an assessment is given based on expert judgment.

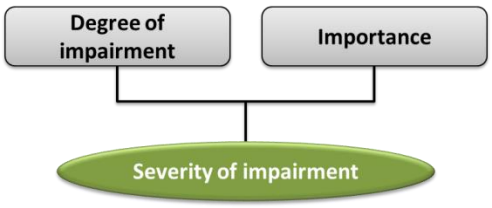


Figure 3.3: The assessment scheme for severity of impairment

In the UVS and the VVM, the results of the assessment of severity of impairment support the significance assessment. The UVS and VVM do not present the results as such.

3.1.11 Range of impacts

Besides illustrating the impacts on maps, the extent of the marine impacts is assessed by quantifying the areas impacted in predefined zones. The zones are shown in Figure 3.4. If relevant the area of transboundary impacts are also estimated.

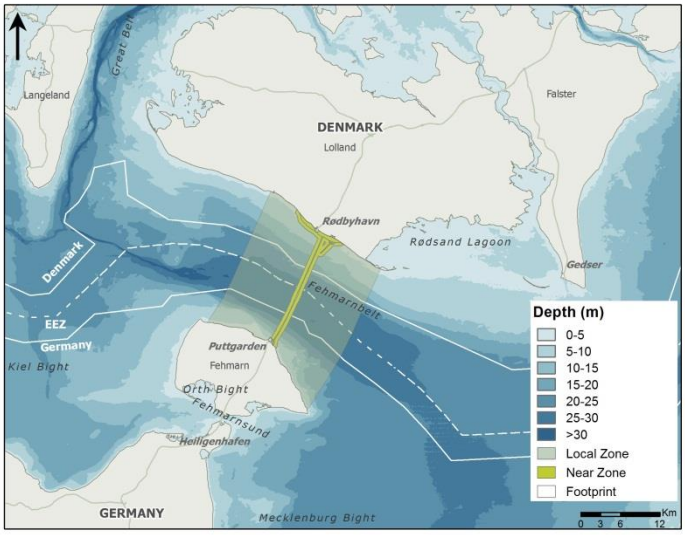


Figure 3.4: The assessment zones applied for description of the spatial distribution of the impacts. The near zone illustrated is valid for the tunnel alternative. It comprises the footprint and a surrounding 500 m band. The local zone is identical for the two alternatives. The eastern and western borders are approximately 10 km from the centre of the alignment.

3.1.12 Duration of impacts

Duration of impacts (provisional loss and impairments) is assessed based on recovery time (restitution time). The recovery time is given as precise as possible; stating the expected time frame from conclusion of the pressure until pre-project conditions is restored. The recovery is also related to the phases of the project using Table 3.4 as a framework.

Table 3.4: Framework applied to relate recovery of environmental factors to the consecutive phases of the Project

Impact recovered within:	In wording
Construction phase+	recovered within 2 year after end of construction
Operation phase A	recovered within 10 years after end of construction
Operation phase B	recovered within 24 years after end of construction
Operation phase C	recovery takes longer or is permanent

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

3.1.13 Significance

The impact assessment is finalised with an overall assessment stating the significance of the predicted impacts. This assessment of significance is based on expert judgement. The reasoning for the conclusion on the significance is explained. Aspects such as degree and severity of impairment/severity of loss, recovery time and the importance of the environmental factor are taken into consideration.

3.1.14 Comparison of environmental impacts from project alternatives

Femern A/S will prepare a final recommendation of the project alternative, which from a technical, financial and environmental point of view can meet the goal of a Fehmarnbelt Fixed Link from Denmark to Germany. As an important input to the background for this recommendation, the consortia have been requested to compare the two alternatives, immersed tunnel and cable-stayed bridge, with the aim to identify the alternative having the least environmental impacts on the environment. The bored tunnel alternative is discussed in a separate report. In order to make the comparison as uniform as possible the ranking is done using a ranking system comprising the ranks: 0 meaning that it is not possible to rank the alternatives, + meaning that the alternative compared to the other alternative has a minor environmental advantage and ++ meaning that the alternative has a noticeable advantage. The ranking is made for the environmental factor or sub-factor included in the individual report (e.g. for the marine area: hydrography, benthic fauna, birds, etc.). To support the overall assessment similar analyses are sometimes made for individual pressures or components/subcomponents. It should be noticed that the ranking addresses only the differences/similarities between the two alternatives and not the degree of impacts.

3.1.15 Cumulative impacts

The aim of the assessment of cumulative impacts is to evaluate the extent of the environmental impact of the project in terms of intensity and geographic extent compared with the other projects in the area and the vulnerability of the area. The assessment of the cumulative conditions does not only take into account existing conditions, but also land use and activities associated with existing utilized and unutilized permits or approved plans for projects in the pipe.

When more projects within the same region affect the same environmental conditions at the same time, they are defined to have cumulative impacts. A project is relevant to include, if the project meets one or more of the following requirements:

- The project and its impacts are within the same geographical area as the fixed link
- The project affects some of the same or related environmental conditions as the fixed link
- The project results in new environmental impacts during the period from the environmental baseline studies for the fixed link were completed, which thus not is included in the baseline description
- The project has permanent impacts in its operation phase interfering with impacts from the fixed link

Based on the criteria above the following projects at sea are considered relevant to include in the assessment of cumulative impacts on different environmental conditions. All of them are offshore wind farms:

Project	Placement	Phase	Possible interactions
Arkona-Becken Südost	North East of Rügen	Construction	Sediment spill, habitat displacement, collision risk, barrier effect
EnBW Windpark Baltic 2	South East of Kriegers Flak	Construction	Sediment spill, habitat displacement, collision risk, barrier effect
Wikinger	North East of Rügen	Construction	Sediment spill, habitat displacement, collision risk, barrier effect
Rødsand II	Off Lolland's southern coast	Operation	Coastal morphology, collision risk, barrier risk
Kriegers Flak II	Kriegers Flak	Construction	Sediment spill, habitat displacement, collision risk, barrier effect

GEOFReE	Lübeck bay	Construction	Sediment spill, habitat displacement, collision risk, barrier effect

Rødsand II is included, as this project went into operation while the baseline investigations for the Fixed Link were conducted, for which reason in principle a cumulative impact cannot be excluded.

3.1.16 Impacts related to climate change

The following themes are addressed in the EIA for the fixed link across Fehmarnbelt:

- Assessment of the project impact on the climate, defined with the emission of greenhouse gasses (GHG) during construction and operation
- Assessment of expected climate change impact on the project
- Assessment of the expected climate changes impact on the baseline conditions
- Assessment of cumulative effect between expected climate changes and possible project impacts on the environment
- Assessment of climate change impacts on nature which have to be compensated and on the compensated nature.

Changes in the global climate can be driven by natural variability and as a response to anthropogenic forcing. The most important anthropogenic force is proposed to be the emission of greenhouse gases, and hence an increasing of the concentration of greenhouse gases in the atmosphere.

Even though the lack of regulations on this issue has made the process of incorporating the climate change into the EIA difficult, Femern A/S has defined the following framework for assessment of importance of climate change to the environmental assessments made:

- The importance of climate change is considered in relation to possible impacts caused by the permanent physical structures and by the operation of the fixed link..

- The assessment of project related impacts on the marine hydrodynamics, including the water flow through the Fehmarnbelt and thus the water exchange of the Baltic Sea, is based on numerical model simulations, for baseline and the project case, combined with general model results for the Baltic Sea and climate change.

- Possible consequences of climate change for water birds are analysed through climatic niche models. A large-scale statistical modelling approach is applied using available data on the climatic and environmental factors determining the non-breeding distributions at sea of the relevant waterbirds in Northern European waters.

- The possible implications of climate change for marine benthic flora and fauna, fish, marine mammals, terrestrial and freshwater flora and fauna, coastal morphology and surface and ground water are addressed in a more qualitative manner based on literature and the outcome of the hydrodynamic and ecological modelling.

- Concerning human beings, soil (apart from coastal morphology), air, landscape, material assets and the cultural heritage, the implications of climate changes for the

project related impacts are considered less relevant and are therefore not specifically addressed in the EIA.

The specific issues have been addressed in the relevant background reports.

3.1.17 How to handle mitigation and compensation issues

A significant part of the purpose of an EIA is to optimize the environmental aspects of the project applied for, within the legal, technical and economic framework. The optimization occurs even before the environmental assessment has been finalized and the project, which forms the basis for the present environmental assessment, is improved environmentally compared to the original design. The environmental impacts, which are assessed in the final environmental assessment, are therefore the residual environmental impacts that have already been substantially reduced.

Similarly, a statement of the compensation measures that will be needed to compensate for the loss and degradation of nature that cannot be averted shall be prepared. Compensating measures shall not be described in the impact assessment of the individual components and are therefore not treated in the background reports, but will be clarified in the Danish EIA and the German LBP (Landschaftspflegerischer Begleitplan), respectively.

In the background reports, the most important remediation measures which are included in the final project and are of relevance to the assessed subject are mentioned. In addition additional proposals that are simple to implement are presented.

3.2 Assessment criteria specifically related to the commercial fisheries

To comply with the procedures of the EIA methodology, the environmental component concerning the commercial fisheries was divided into different sub-components representing the primary fisheries according to gear types. These sub-components comprise the foundation from which assessment will be undertaken based on the extent of the baseline data.

The assessment methodology is assessing against a set of criteria. These criteria are both qualitative and quantitative in nature.

3.2.1 Magnitude of pressure

As mentioned the magnitude of a pressure or the predicted effect of a specific impact is determined by the degree of intensity, duration and range of a specific pressure. The pressures affecting the commercial fisheries are quantified by indicating the temporary or permanent reduction in fishery area. The magnitude of pressures affecting the resource to the fisheries (commercial species) is quantified by using the sensitivity of specific fish species or fish groups (benthic or pelagic, gadoid or clupied) to a pressure and the area coverage by pressures that exceed threshold levels triggering avoidance response.

Calculation of the magnitude of pressure for the fishery components
The magnitude of pressure is calculated by overlapping the spatial coverage or area of occurrence of a pressure with the fishing areas of the different fishery components represented by the primary types of gear (trawl, gill/trammel nets, seine nets and pound nets). The maps representing the fishing areas of the fishery components correspond to the distribution outlined in the importance maps (Figure 1.5).

The area of occurrence (fishing areas) and the intensity of the fisheries for the fishery components are derived differently as described below.

Trawl and Seine net fisheries
The fishing areas or fishing grounds for the Danish and German trawling and Danish seine net fisheries are derived from the VMS (Vessel Monitoring System) plot points from 2005-2008. Under assumptions of specific vessel speed while fishing the distribution and number of these points are used to indicate the location and intensity of vessels actively fishing as a proxy for the distribution and intensity of these fisheries (FeBEC, 2011b).

Gill/trammel net fisheries
The distribution of the Danish and German gill/trammel net fishing grounds are derived from marking fishing grounds in Fehmarnbelt and its region according to data from interviewing fishermen and representatives of fishery organisations.

Pound net fisheries
The positions of Danish and German pound nets were obtained from fishery authorities in the respective countries and by interviewing the fishermen undertaking these fisheries. In general, there is a potential for fishing with pound nets along the entire coastal area of southern Lolland and Fehmarn and thus the entire area represents the potential area for this fishery that can be impacted. Because the minimum distance between pound nets to avoid competitive fishing or “shadowing effects” is 665 meters, the absolute number of pound fishing locations is limited.

Magnitude of pressures for commercial species
When pressures don’t affect fishery components (gear) directly yet indirectly affect fishery resources (commercial species) because of their differing sensitivity thresholds, then the area representing the magnitude of the pressures for each gear component will be used to represent the magnitude of the pressure on the affected commercial species according to their occurrence in the respective fishery.

3.2.2 Sensitivity

The sensitivity of the fishery components (gear types) to a pressure is dependent on the components distribution, mobility in relation to the pressure, and the potential of the fishery component to use alternative areas.

Loss of fishing areas or the ability to undertake fisheries due to footprints, i.e. areas occupied by project reclamation areas, structures or regulations forbidding commercial fisheries are always considered to be of the highest magnitude.

The sensitivity of the commercial fish species to a pressure (i.e. sediment spillage or increased noise levels) is dependent on species specific dose-response relationships that often trigger an avoidance response, or in worst case scenarios mortality due to extreme pressure situations. The knowledge of the sensitivity of commercial species to some pressures has been extracted from scientific literature (FeBEC 2012). Because this varied from source to source and was not always known or well documented, the sensitivity levels used for this assessment followed a conservative approach and were based on the lowest literature values found and conclusions from the information available (FeBEC 2012).

3.2.3 Assessment criteria

The criteria for assessing the Degree of Impairment for the different fishery components (trawl, gill net, pound net and seine net) was based on the variation (Standard Deviation) in the official landings of the fisheries for each component (trawl, gill nets, pound nets and seine nets) in Fehmarnbelt (ICES 38G1). For the fishery sub-components (commercial species) the criteria is based on the level of the variation of survey statistics for cod, sprat and herring recruitment in the Fehmarnbælt area (FeBEC, 2012).

The Standard Deviation (SD) is the average deviation from the mean of a series of observations (in this case the Standard Deviation of the landings in Fehmarnbelt by each gear component from 1998-2008). SD is calculated as the square root of the mean square deviation;

$$\Sigma (xi - x)^2 / (n-1)$$

Under the assumption that the observations are normally distributed, ±1 SD includes approx. 68% of the observations and ±2 SD includes approx. 95% of all observations.

Because variation (SD) in the landings will be biased due to quota regulations on some commercial species, the SD deviation of the landings was also calculated for these species separately and the most conservative SD was chosen to represent the criteria guidelines (Table 3.5).

Table 3.5: Criteria based on the SD of the landings over a 10 year perid for the individual fishery components.

Fishery components	**Criteria (SD)**	Danish fisheries			German fisheries		
	% of the mean	All Landings SD	Quota regulated species	Mean landings (kg) over 10 yrs	All Landings SD	Quota regulated species	Mean landings (kg) over 10 yrs
Trawl	**50**	53,9	55,1	1,668,946	55.5	51.1	209,056
Gill nets	**40**	46,0	40,0	93,641	43.1	42.0	40,736
Pound nets	**25**	26,2	-	155,813	33.1	-	1,117
Seine nets	**60**	65,9	66,2	44,768	-	-	-

The criteria are defined on the basis of the variation as SD in % of the mean. For example, for trawl, the variation of the annual landings over an 11 year period has been found to be approximately ± 50% of the mean (Table 3.5).

Because temporary impairments that are present during the construction phase can potentially last up to several years, the SD of the mean used to determine the Degree of Impairment for temporary impacts was lowered by a factor that matched criteria levels for three years (FeBEC 2012). For permanent impacts the SD variation of the mean was lowered by a factor that matched impacts for more than 8 years.

From the definitions described above the foundation for for setting the criteria for “temporary” and “permanent” impacts are presented in the following table:

Table 3.6: The foundation for establishing the criteria used to obtain the Degree of impairment when assessing temporary and permanent impairments.

Temporary	Degree of impairment	Permanent	Degree of impairment
A reduction equal to or more than 1 SD	Very High	A reduction equal to or more than 1/2 SD	Very High
A reduction between 1/2 – 1 SD	High	A reduction between 1/4 – 1/2 SD	High
A reduction between 1/4 – 1/2 SD	Medium	A reduction between 1/8 – 1/4 SD	Medium
A reduction less than 1/4 SD	Low	A reduction less than 1/8 SD	Minor

Results from the analysis of SD from variations in the landings for each fishery sub-component (trawl, gill nets, pound nets and Danish seine nets) is given in the criteria table below.

Table 3.7: Criteria for determining the Degree of Impairment for assessment of the sub-components (trawl, gill nets, pound nets and seine nets) to the fisheries. Data based on the Standard Deviation (SD) of the official landing statistics of the fisheries in Fehmarnbelt for each gear sub-component from 1998-2008.

Component	Sub-component	Reduction %		Magnitude of impact
		Temporary	Permanent	
Fisheries	Trawl - DK and G	> 50	> 25	Very high
		< 50	< 25	High
		< 25	< 12	Medium
		< 12	< 6	Minor

Component	Sub-component	Reduction %		Magnitude of impact
		Temporary	Permanent	
Fisheries	Gill/trammel nets - DK and G	> 40	> 20	Very high
		< 40	< 20	High
		< 20	< 10	Medium
		< 10	< 5	Minor

Component	Sub-component	Reduction %		Magnitude of impact
		Temporary	Permanent	
Fisheries	Pound nets - DK and G	> 25	> 12	Very high
		< 25	< 12	High
		< 12	< 6	Medium
		< 6	< 3	Minor

Component	Sub-component	Reduction %		Magnitude of impact
		Temporary	Permanent	
Fisheries	Danish seine nets - DK	> 60	> 30	Very high
		< 60	< 30	High
		< 30	< 15	Medium
		< 15	< 7	Minor

3.2.4 Degree of impairment (loss or impairment)

The statistical ICES rectangle ICES 38G1, which contains the majority of Fehmarnbelt within which the construction works and transects of the fixed link are planned, will outline the area for determining the degree of impairment or reduction of the fisheries in Fehmarnbelt. The Fehmarnbelt regional area is represented by an area of the western Baltic that has been chosen as the standard area for the region (see Figure 1.6). The pound net fishing area along the entire southern coast of Lolland will be used to determine the degree of impairment of the Danish pound net fisheries. Similarly, the pound net fishing area along the coast of Fehmarn will be used to determine the degree of impairment of the German pound net fisheries.

The intensity of fishing effort to determine degree of impact for the different fishery sub-components is calculated differently for the different sub-components as described below:

Trawl and Seine net fisheries

The fishing effort or intensity (I) within the fishing grounds for the trawl and seine net fisheries are determined by using the number of VMS plot points indicating vessels actively fishing (FeBEC, 2011b) as a proxy for effort.

To determine the degree of impact for these fisheries the VMS plot points, used as a proxy for effort or intensity (I) within an area of impact, are extrapolated and summed within a ha and the ratio of plot points within the impact area compared to the total number of plot points within the ICES rectangle (38G1) and Fehmarnbelt region represented the potential reduction in the fisheries (ratio (%) of impact) due to the respective pressure.

Gill/trammel net fisheries
The fishing effort or intensity within the gill/trammel net fishing grounds is determined by the area of use by Danish and German fishermen according to data from interviews. More specifically, fishing intensity is derived from outlining fishing areas from each interview on a common map with increasing areal overlap of their fishing grounds used as a proxy for fishing intensity.

To determine the degree of impact of a pressure on the gill/trammel net fisheries, the impact area covered by the pressure and its associated fishing intensity compared to the total fishing area and intensity representing the gill net fisheries within Fehmarnbelt (ICES 38G1) and the Fehmarnbelt regional area to calculate a ratio (%) of impact or reduction in the fisheries.

Pound net fishery
The degree of impact to the pound net fisheries was determined by overlapping the area of the specific pressure with the fishing areas of this fishery. The spatial extent of the pound net fishing areas will include the potential location of pound net fishing areas along the Danish southern coast of Lolland and the German coast of Fehmarn. The Danish and German potential pound net fishing areas extended from 200-1,500 m from the coastline, according to the current and historical gear settings. The seine net fisheries are located in the deeper (>10 m) central parts of Fehmarnbelt.

3.2.5 Importance

The importance for the commercial fisheries sub-components were determined on the basis of a set of criteria and their justifications presented in Table 1.2. A list and justification of the important commercial fish species that make up the resources to the fisheries is given in section 1.3.

Map showing the areas of importance for the fishery sub-components (Trawl, Gill/trammel nets, Danish seine nets and Pound nets) are shown in Figure 1.5.

3.2.6 Severity and significance of impact (loss or impairment)

The severity of an impact to the commercial fisheries is the final step of the impact assessment and follows the guidelines outlined in Sections 3.1.8 through 3.1.10.

In short for the commercial fisheries there are two different severities to consider; severity of loss and severity of impairment. The severity of loss is assessed by associating the loss of the fishery with the importance of the fishery sub-components. Loss is most often associated with footprints or loss of area and the ability to undertake the fisheries or the loss of a resource (commercial species). The severity of impairment refers to something that is temporary.

The guidelines to arrive at an overall significance of an impact are outlined in 3.1.13.

3.2.7 Project impact

In order to give a full overview of the overall impact to a specific sub-component the Project Impact is calculated. The Project Impact summarises all the different impairments/loss which

are imposed on each specific fisheries sub-component. The figure below gives the example of the different impairments/loss which potential affect the trawl fishery.

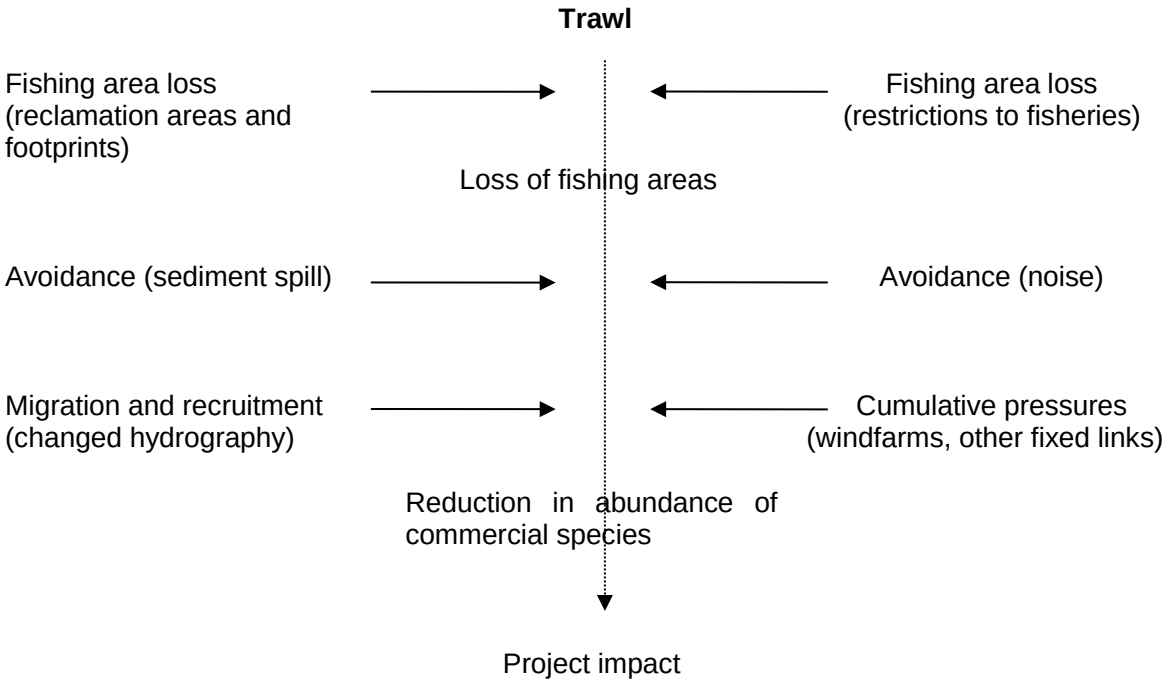


Figure 3.5: Flow chart giving an overview of the potential impairments/loss to the trawl fishery from a project.

The Project Impact is calculated for the tunnel and bridge fixed link solutions, respectively.

4. Assessment of Zero-alternative

4.1 Hydrographical regime

Hydrographical changes will generally affect the fisheries indirectly by potentially influencing the migration and distribution of the commercial species (resource to the fisheries). Thus the assessment of the impact to the commercial fisheries will primarily rely on results of the environmental impact to fish due to changes in the hydrographical regime in the zero-alternative (FeBEC 2012).

The Baltic Sea is one of the World's largest brackish water areas and several marine fish species have adapted to the low salinity and are an important resource to the commercial fisheries in the western Baltic and Fehmarnbelt region. According to the assessment on the impacts to fish, it was suggested that salinity is the hydrographical parameter that has the largest impact on fish communities. Changes in salinity primarily effect potential spawning areas and the survival of fish eggs and larvae. Thus impacts to the commercial fisheries due to this pressure are primarily due to the eventual recruitment to the fisheries.

Assessment
Results of the assessment of the zero-alternative on commercial fish suggest that the hydrographical regime has a "Minor" impact on the spawning of the important commercial species cod, sprat and flatfish species, and a "High impact on the survivial and drift of pelagic fish eggs and larvae, of which the influence on recruitment is not known.

4.2 Suspended sediment and sedimentation

In theory, the practical undertaking of the different forms of the primary fisheries (trawl, gill nets, seine nets or pound nets) is not affected by the amount of suspended material in the water environment or sedimentation on the seabed. Suspended material in the water phase, as well as sedimentation is a natural part of the environment in which fish live. Excess amounts of sediment can cause an avoidance response which effects the distribution of the different species depending on their species specific tolerance (FeBEC 2012).

The sensitivity of different commercial fish species to an increase in water turbidity is not only species specific but also depends on their life stage (larvae, juveniles, adults). Although pressures that impact the early life stages of fish potentially effect recruitment and thus the future resources to the fisheries, it is the impact on the late juvenile and adult fish stages (fish of minimum lengths in the fisheries) that are of greatest interest to the fisheries in this report as these represent the immediate resource that is available.

Natural sediment erosion and resuspension under some circumstances can exceed concentrations from dredging and other activities undertaken during the establishment of a fixed link.

For example, it is worth noting that the background concentrations measured in Fehmarnbelt in 2009-2010 are considerable higher than the modelled scenarios of the excess concentration of suspended sediment from the construction of the proposed link solutions (FeBEC 2012). For example, the back-ground suspended sediment level is estimated to be more than 5 times higher in the area around the measuring station then sediment spill from the construction of the main tunnel solution, which according to spill scenarios will cause the most sediment spill. These results suggest the natural background levels of suspended sediment in Fehmarnbelt potentially impact the distribution of commercial fish. This is particularly true in coastal waters where the concentration can vary significantly from day to day due to strong currents and waves induced by wind and tidal fluctuations. On a larger scale in Fehmarnbelt, the concentra tion of suspended and deposited material is affected by the inflow of waters from the Kattegat and the outflow of waters from the inner Baltic.

4.3 Noise and vibrations

In theory, the undertaking of the fisheries (trawl, gill nets, seine nets or pound nets) is not affected by noise in the water environment. However, loud noise can cause an avoidance response which effects the distribution of the different species depending on their species specific tolerance, and thus this response has the potential to affect the fisheries indirectly.

Typical sources of sound in the zero-alternative primarily include ship operations (ship traffic) which will emit noise and vibrations to its surroundings at varying intensity and duration. Considerably loud noise (high dB) in frequencies (Hz) that are within the hearing range of important commercial species can trigger avoidance responses which would reduce the abundance of fishery resources in fishing grounds.

Noise and vibrations emitted to the waters of Fehmarnbelt and its region are primarily due to the large number and intensity of ship traffic that pass through this area. This also includes the ferries that cross Fehmarnbelt from Rødbyhavn Denmark to Puttgarden Germany and the ships traffic near the main shipping routes, i.e. the T-route crossing the Fehmarnbelt from northwest to southeast.

The magnitude of the area with noise exceeding the threshold limit for avoidance behavoir was calculated from the registered traffic and the emitted noise from ships and ferries. The traffic was measured by Rambøll (2011) using AIS and radar registrations. Here they estimated the yearly traffic to 46.200 ships in the east-west T-route and 38.400 ferry departures between Rødby and Putgarden

A thorough description of the noise and vibrations in Fehmarnbelt and its region are described in detail in the assessment of fish (FeBEC 2012). Because these assessments also include commercial fish species, the assessment in this report will only summarize the relevant impacts and conclusions from the assessment of the impacts to commercial fish.

Underwater noise and vibrations in the zero-alternative are predominantly caused by the heavy traffic by the Rødby-Puttgarden ferries. The only potential significant impact is on the spawning and feeding migration of cod, whiting, herring and sprat. These species will be able to hear the noise from ships at any given time throughout the alignment, but noise level exceeds only the threshold for avoidance reactions in a very limited part of the area. In all this is estimated to have an effect on approximately 4 % of the migration of gadoids/clupeids and less than 1 % of the migration of other species (FeBEC 2012).

Furthermore, it is highly questionable whether affected fish would actually flee or just pass the alignment at a section or in an area with less noise.

4.4 Cumulative and transboundary pressures

Cumulative pressures
In general the stock size and structure of several commercial fish species are linked to naturally occurring annual variations which can generate a shift in species structure. This is particularly true of some species which have large fluctuations in recruitment. Food supply, temperature and salinity are known as important factors affecting variations.

Apart from natural variation, which might cause temporary changes in specific fish populations, no major changes are expected in the fish communities of Fehmarnbelt due to cumulative pressures in the zero-alternative. It is not know as to what extent the exploitation of fishing grounds might change or whether the fishing pressure on individual commercial species will remain at the same level. However, due the intent of management after sustainable fisheries objectives these parameters will probably remain at the same level, or decrease.

Within the next few decades an increase of marine traffic is expected. Fehmarnbelt is one of the main routes for international navigation in the Baltic Sea. This could lead to a greater disturbance to fishing vessels in Femharn Belt and an increase in noise emission and visual disturbance. Because the increase of ship traffic is considered to arise gradually, however, it is expected that fishing vessels, fish species and communities will habituate to these changes. In the zero-alternative no significant changes regarding the investigated fish species and communities are forseeable.

Transboundary pressures
In the case of the zero-alternative no transboundary effects are expected.

5. Assessment of impacts of main tunnel alternative

5.1 Seabed reclamation/footprints

The main tunnel alternative of the Fehmarnbelt-fixed-link will create a loss of fishing areas in Fehmarnbelt due to the reclamation of area and the establishment of structures such as a tunnel trench and access ramps.

The areas where reclamation land and seabed structures are placed will be permanently lost. However some areas will eventually be restored as the natural environment restores itself. In Rødbyhavn and Puttgarden, construction harbours will be established and a large area of reclamation will occur near Rødbyhavn. A loss of area is expected to occur along the tunnel transect where a trench will be dug to insert tunnel elements in the seabed. After tunnel completion the tunnel trench will be left to reestablish itself naturally. Furthermore, the construction based infrastructure will be scaled back and a permanent loss of area will occur within the coastal areas of Lolland and Fehmarn where construction facilities were established and where the tunnel access ramps will be built.

5.1.1 Environmental indicators

Because the location of the reclamation areas, construction facilities and access ramps are near the coast of Lolland and Fehmarn, most of the loss of fishing areas will be to the fisheries along the coast. This is primarily the pound net fisheries and the more coastal gill net fisheries. The pound net fisheries in Denmark extend along the entire coastline of southern Lolland and because of the very limited mobility of these fisheries some individual fishermen and their fisheries will undoubtedly be highly affected on a local scale.

The loss or hinderence to offshore fisheries due to the tunnel trench will potentially affect the undertaking of the trawl and seine net fisheries and depending on the final solution with regard to backfilling of the trench after construction or restrictions to the fisheries that want to trawl over the trench, this impact could be short or long term (permanent) and more or less extensive.

Table 5.1: An overview of the fishery sub-components (Trawl, Gill nets, Pound nets and Danish seine nets) that will be assessed in relation to seabed reclamation and footprints due to the establishment of the tunnel solution.

Component	Sub-components Primary gear
Fisheries	Trawl Gill/trammel nets Pound nets Danish seine nets

5.1.2 Sensitivity to pressure

The ability of the individual types of fisheries (trawl, gill nets, pound nets and seine nets) to move and fish in alternative areas is a key characteristic in determining their sensitivity to a permanent loss of fishing areas.

The Danish and German pound net fisheries are those that have the potential to be impacted the most due to loss of area. Fishermen are given licenses to set pound nets along specific sections of the coastline and are thus bound to set their gear within these areas i.e these fisheries are not very mobile. Pound nets in the Danish and German fisheries extend from 200 m to 1,500 m from the coastline. If some or all of this area is lost due to reclamation areas or other physical structures or loss of area then this will lead to a direct loss to their fisheries. Furthermore, the legal distance between pound nets has been set at 665 m to avoid a “shad-

owing effect" where one pound net effects the catchability of commercial species from an adjacent pound net. This also creates limitations of utilising or intensifying the pound net fisheries within an area that has been reduced in size.

Although the trawl, gill net and seine net fisheries are more mobil they still rely on the quality of the fishing areas that they utilize and are bound by the way these types are fisheries are performed. For example, it is well known that trawlers often take long hauls where they fish along specific tracks depending on the bottom topography, especially avoiding heterogeneous bottoms with stones and boulders which make fishing with bottom gear impossible or very difficult and full of risk of gear damage. As is observed from the distribution of the trawl fisheries in Fehmarnbelt, trawl hauls are taken through the central deeper parts of Fehmarnbelt (Figure 1.3). Uneven sea floor topography created by the tunnel trench can cause snagging of trawl lines and bottom trawls in pits. Furthermore, if there are exposed stones and small boulders created by the protective material placed across the tunnel trench, the extent of this preventing passage of bottom fishing gear will determine whether the trawl fishery can be undertaken or whether the impact or cost to the fisheries will be greater than the value of their landings. If there are hinderences or stoppage to their fisheries this would make it necessary to undertake difficult and time consuming operations such as lifting and resetting trawl gear which in a worst case scenario would mean that trawling through Fehmarnbelt will be impacted.

Fisheries with stationary gear, primarily gill nets, are generally carried out in areas with mixed bottoms, partly to minimize spatial conflicts with trawlers and because areas with structures such as stones and boulders on the bottom are often good fishing areas. Thus gill net fishermen would primarily be affected by loss or restricted access to fishing areas, especially if these areas are of importance to their fishery and have habitats that attract the commercial species that they target.

5.1.3 Pressure indicators

The loss of fishing areas will affect the different fisheries in different ways, however, in all cases the pressure indicator is determined by the temporal and spatial extent of the loss of fishing grounds.

The pound net fisheries within reclamation and footprint areas will lose their fishing grounds and not be able to compensate this loss by moving or utilising alternative fishing grounds. The loss to this fishery can be measured by the area lost and eventually the number of gear and fishermen that are impacted by this loss when assessing the severity.

Trawl, gill net and seine net fisheries will also lose a proportion of their fishing grounds in Fehmarnbelt and its region and this loss or percentage of loss in relation to the rest of Fehmarnbelt (38G1) and its region will be used to measure the degree of loss from this pressure.

Loss of important commercial fish habitats can have an indirect affect on the presence or abundance of the commercial species (fishery resources) and therefore an affect on the fisheries if large proportions of important habitats are lost.

5.1.4 Magnitude of pressure

The establishment of the main tunnel alternative in Fehmarnbelt will cause loss of commercial fishing areas due to reclamation areas, the tunnel trench and the access channel to construction facilities. The material used for protection of the tunnel elements along the tunnel trench are boulders and large stones which might be damaging to active gear such as trawls and seine nets. Thus, although it is anticipated that natural backfilling of sediment material to reestablish the seabed to its natural state will occur, this is estimated to take between 2–10 years on average (FEHY estimate). However, because the habitat within the tunnel trench along the seabed will be completely different from before and the potential problems for active-

ly trawling over the seabed are unknown, the transect of the tunnel is assessed as a permanent loss.

Similarly, anchoring blocks used to stabilize the construction vessels when lowering the tunnel elements might be left on the seabed. If this is the case then these structures might also represent permanent structures that might hinder the undertaking of some fisheries such as trawling and create a further loss of fishing areas in Fehmarnbelt. At present these are not assessed.

A summary of the tunnel structures and activities causing footprints is given in Table 5.2.

Table 5.2: A summary of the primary tunnel structures and reclamation areas causing footprints during the establishment of the tunnel alternative.

Primary tunnel structures and reclamation areas	Duration	Footprint area (ha)
Reclamation areas Lolland Access channel to construction facilities (working harbours)	Permanent	387.8
Tunnel trench	Permanent Backfilling will only include stones and boulders to stabilize the trench. Reestablishment of the original seabed is dependent on natural processes with an estimated duration of 2-10 years	196.3

5.1.5 Degree of impact (loss or impairment)

Denmark
A summary of the severity of loss to the Danish fisheries by footprints from the tunnel olution variant in Fehmarnbelt (ICES 38G1) and the Fehmarnbelt regional area is given in Table 5.3.

Table 5.3: The percentage of loss (%) and the degree of loss (ha) of the Danish fisheries (trawl, gill nets, pound nets and seine nets) due to tunnel reclamation areas and other footprints in comparison to the total fisheries in Fehmarnbelt (ICES 38G1) and the Fehmarnbelt regional area. * The amount of area planned to be restored after construction is finished.

Reduction of fishery sub-components, footprints (%-ha) TUNNEL - Denmark	**Fehmarnbelt (ICES 38G1) % (ha)**	**Fehmarnbelt region % (ha)**
Trawl		
Reclamation areas – Lolland		
Tunnel trench	0.31% (89)	0 %
Temp/perm construction area	0.01% (4)	0 %
Gill nets		
Reclamation areas – Lolland		
Tunnel trench	0.16% (57)	0 %
Temp/perm construction area	0.08% 27 (22/5*)	0 %
Danish seine nets		
Reclamation areas – Lolland		
Tunnel trench	0.26% (44)	0 %
Temp/perm construction area		
Pound nets	**Southern coast of Lolland (see Figure 1.5)**	
Reclamation areas – Lolland	5.51% (331)	
Tunnel trench	0.07% (4)	
Temp/perm construction area	0.28% 18 (11/7*)	

Overall 574 ha of the Danish fisheries in the Fehmarnbelt (ICES 38G1) and region are affected by tunnel reclamation areas, the tunnel trench and temporary constructions.

353 ha of the Danish pound net fishery, which is a fishery along the southern Lolland coastline with a very high importance, are lost to footprints. This is primarily due to the tunnel reclamation areas in the coastal area near Rødbyhavn which affects or creates a loss of 331 ha or approximately 5.5% of the pound net fisheries along the southern coast of Lolland. 22 ha of these are affected by the temp/perm constructions, 15 ha will eventually be permanent while 7 ha will be restored after tunnel construction is finished. Despite the restoration of 7 ha these will not help to restore the pound net fisheries in this area.

The Danish trawling fisheries in Fehmarnbelt, which is of medium importance, will lose approximately 93 ha or 0.2% of the area that is used for trawling due to the tunnel trench and temporary construction area. Because tunnel elements placed in the trench will be covered with a stony protection layer, and there is an anticipated time of 2-10 years before the seabed will reestablish itself naturally, these affects will therefore be considered long-term and lost to these fisheries. The 4 ha footprint from the construction area will be permanent.

84 ha or 0.3% of the Danish gill net fisheries in Fehmarnbelt, which are of medium importance, will be affected by the tunnel trench (57 ha) and temporary construction works (27 ha). 22 ha from the contructions area will be permanent while five will be restored after construction. Despite this restoration the 5 ha will be considered as lost in the assessment.

The Danish seine fisheries, of minor importance, will be affected by the tunnel trench in 44 ha or 0.3% of the seine net fishing area in Fehmarnbelt. This area is primarily in the middle of Fehmarnbelt.

Except for 1 ha of gill net fishing area, almost all of the Danish fishery area lost to footprints is within ICES 38G1 (Fehmarnbelt), and thus the regional area is not considered to be affected by footprints.

Germany
A summary of the severity/degree of loss to the German fisheries by reclamation areas and footprints from the tunnel solution variant in Fehmarnbelt (ICES 38G1) and the Fehmarnbelt regional area is given in Table 5.4.

In all, 147 ha (0.52%) of the German fisheries in Fehmarnbelt (ICES 38G1) will be affected by the tunnel trench and a small area of land reclamation to the east of the harbour on Fehmarn, which are the footprints from the tunnel variant that will affect the German fisheries.

7 ha or 0.3% of the German pound net fisheries along the coastal area of Fehmarn, which are of very high importance, will be affected by the tunnel trench and land reclamation.

The tunnel trench will also affect 93 ha or 0.4% of the German trawl fisheries in Fehmarnbelt, which are of medium importance.

Similarly, 47 ha of the German gill net fisheries of medium importance will be affected by the tunnel trench.

There has not been any German seine net fishing in Fehmarnbelt for more than ten years so this fishery is not represented in the assessment of German fisheries of Fehmarnbelt.

All of the German fisheries lost to footprints is within ICES 38G1 (Fehmarnbelt), and thus the regional area is not considered to be affected by footprints.

Table 5.4: The percentage of loss (%) and the degree of loss (ha) to the German fisheries (trawl, gill nets and pound nets) due to tunnel reclamation areas and other footprints in comparison to the total fisheries in Fehmarnbelt (ICES 38G1) and the Fehmarnbelt regional area.

Reduction of sub-components, footprints (%-ha) TUNNEL - Germany	**Fehmarnbelt (ICES 38G1) % (ha)**	**Fehmarnbelt region % (ha)**
Trawl		
Reclamation areas - Fehmarn		
Tunnel trench	0.38% (93)	0%
Temp/perm construction area		
Gill nets		
Reclamation areas - Fehmarn		
Tunnel trench	0.52% (47)	0.01% (1)
Temp/perm construction area		
Pound nets	**Fehmarn coastline and near mainland (see Figure 1.5)**	
Reclamation areas - Fehmarn		
Tunnel trench	0.30% (7)	
Temp/perm construction area		

The classification (minor, medium, high and very high) of the impact to the Danish and German fisheries from reclamation of area and other footprints from the tunnel solution as derived from the degree of impact together with assessment criteria is given in the following section.

Denmark

The classification of the impact to the Danish fisheries is very high in the pound net fisheries due to the reclamation of area along the southern coast of Lolland and medium (trawl and gill nets) and minor (seine nets) in the other primary fisheries where there was a loss of fishing area (Table 5.5)

Table 5.5: The severity of loss to the Danish fisheries due to tunnel footprints and reclamation areas. Results derived from analysis of the degree of impact and the importance level of the individual fisheries as described in the methods section.

Importance	Severity of loss			
	Very high	High	Medium	Minor
Very high	331 ha ‘’’ **Pound net fisheries** Permanent loss in reclamtion areas **22 ha** *** **15 ha** **Pound net fisheries** Long-term loss **7 ha** **Pound net fisheries** Short-term loss			0 ha
High	0 ha	0 ha	0 ha	0 ha
Medium	0 ha	0 ha	**177 ha** *** **93 ha** **Trawl fisheries** Long-term impairment-loss from tunnel trench ** **84 ha** **Gill net fisheries** **79 ha** Long-term Impairment-loss from tunnel trench and construction works **5 ha** Short term Impairment-loss from construction works	
Minor	0 ha	0 ha	0 ha	**44 ha** **Seine net fisheries** Long-term loss from tunnel trench and construction works

Germany
The classification of the impact to the German fisheries is very high locally for the pound net fishery and medium in the trawl and gill net fisheries where there is a loss of the fishing area (Table 5.6).

Table 5.6: The severity of loss to the German fisheries due to tunnel footprints and reclamation areas. Results derived from analysis of the degree of impact and the importance level of the individual fisheries as described in the method chapter.

Importance	Severity of loss			
	Very high	High	Medium	Minor
Very high	**7 ha** *** **7 ha** **Pound net fisheries** Long-term loss	0 ha		0 ha
High	0 ha	0 ha	0 ha	0 ha
Medium	0 ha	0 ha	**140 ha** *** **93 ha** **Trawl fisheries** Long-term Impairment-loss from tunnel trench ** **47 ha** **Gill net fisheries** Long-term Iimpairment-loss from tunnel trench	
Minor	0 ha	0 ha	0 ha	0 ha

5.1.6 Severity and significance

The severity and significance of the tunnel footprints on the Danish and German fisheries for each of the primary fishery types (trawl, gill nets, pound nets and Danish seine nets (Denmark only)) is given in the following sections:

Denmark
The severity of the tunnel footprints and reclamation areas to the Danish fisheries as derived from criteria leading to the degree of importance and the importance level of the individual fisheries is presented in Table 5.7.

Table 5.7: The classification of the impact (minor, medium, high, very high) to the Danish fisheries in Fehmarnbelt and its region due to the reclamation of areas/footprints from the establishment of the tunnel fixed link solution. See methods section for further explainations. The area of the pound net fishery is based on the southern coast of Lolland.

Severity of loss Footprints - Denmark	Fehmarnbelt (ICES 38G1)	Fehmarnbelt Region
Trawl		
Reclamation areas - Lolland	Medium	
Tunnel trench		
Temp/perm construction area		
Gill nets		
Reclamation areas - Lolland	Medium	
Tunnel trench		
Temp/perm construction area		
Danish seine nets		
Reclamation areas - Lolland	Minor	
Tunnel trench		
Temp/perm construction area		
Pound nets		
Reclamation areas - Lolland Tunnel trench Temp/perm construction area	Very high	

Trawl
Results showed that severity of impact to the Danish trawl fisheries by losing 93 ha of their fishing grounds due to the tunnel trench where the immersed tunnel will be placed under the seabed is medium.

For the assessment the fishing grounds lost due to the tunnel trench are considered permently lost, however, the full significance of the impact to the trawl fisheries will be determined by whether it will be possible to trawl over the trench without restrictions to the fisheries or without running the risk of damaging gear. Trawl hauls in Fehmarnbelt are primarily undertaken through the central deeper (>10 m) parts of Fehmarnbelt and uneven sea floor topography or exposed stones and small boulders created by the protective material placed across the tunnel trench could cause snagging of trawl lines and damage to bottom trawls.

Furthermore, if there are restrictions to the fisheries to trawl over the trench to avoid removing stones or disturbing the protective cover to the immersed tunnel then this will have a considerable impact to the trawl fisheries. In general, hinderences or stoppage of a trawl haul would make it necessary to undertake time consuming operations such as lifting and resetting trawl gear, which in a worst case scenario would mean that trawling through Fehmarnbelt will be impacted and the added cost to the fisheries will reduce the net value of their landings.

Gill nets
Results indicated that severity of impact to the Danish gill net fisheries by losing or having an impairment of 84 ha of their fishing grounds (57 ha from tunnel trench and 27 ha from the construction area (22 ha permanent and 5 short-term) is medium.

The Danish gill net areas lost to this impact are in general, not gill net fishing areas that have a high intensity of the fisheries. Furthermore, the potential mobility of this fishery to other nearby gill net fishing areas and the very small total loss of gill net fishing area (0.12% of the gill net fishing area in Fehmarnbelt) supports the low impact significance of the loss of this area to the gill net fisheries.

In addition, the added structure along the seabed from the protective material used to fill the trench does not hinder or disturb the undertaking of using gill nets and this new habitat may function like an artificial reef which could benefit the gill net fisheries as stony heterogeneous habitats can attract fish to the local area.

Pound nets

The severity of the impact of reclamation areas and footprints from the tunnel solution on the Danish pound net fisheries was “Very high” in the area of reclamation along the southern coastline of Lolland where more than 331 ha of their fishing areas were lost (see Table 5.5). A small loss of 22 ha in the construction area lead to a Very high severity of loss to this fishery in this area. A direct consequence of the loss of pound net fishing area was a loss of 6 pound nets and possible affects on other pound nets immediately to the east and west of the reclamation area (Figure 5.1).

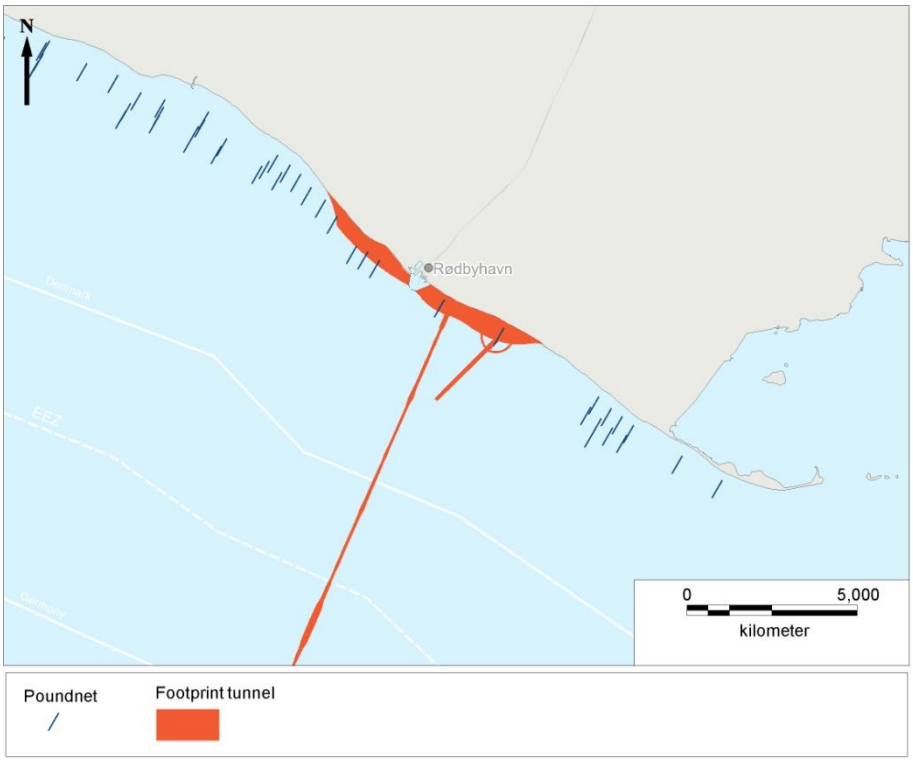


Figure 5.1: The location of the reclamation areas and footprints from the tunnel solution and their affects on the Danish pound net fisheries in Fehmarnbelt. Lines running perpendicular to the Lolland coast indicate the location of each pound net.

The significance of the very high severity of the impact to the pound net fisheries in the reclamation and construction areas is warranted. Although the pound net fisheries only contribute a small amount of landings and economy to the overall fisheries of Fehmarnbelt, this fishery is considered of high importance because of its high sensitivity on a local scale to even small loss or impairments to their fisheries and their importance to the individual fishermen with fishing rights in the areas of impact.

These fisheries are not very mobile and a loss of area cannot be compensated for by moving the fisheries to another area as fishermen only have permission to set pound nets in specific sections of the coastline and are thus restricted to fish within these areas. Furthermore, pound nets cannot be set close to each other because of a “shadowing effect” where one pound net affects the catchability of commercial species from an adjacent pound net. This creates limitations of utilising or intensifying the pound net fisheries within an area that has been reduced in size due to area loss from footprints.

Danish seine nets
In all, 44 ha or only 0.3% of the seine net fishing area is impacted by the structures and footprints from the establishment of the tunnel solution. Because of the minor degree of impact to these fisheries and the low importance of these fisheries in Fehmarnbelt, the severity of the impact to these fisheries from the reclamation areas and tunnel trench is insignificant.

Germany
The severity of the tunnel footprints and reclamation areas to the German fisheries as derived from the importance level of the individual fisheries is presented in Table 5.8.

Table 5.8: The severity classification (low, medium high and very high) of the impact to the German fisheries in Fehmarnbelt and its region due to the reclamation of areas/footprints from the establishment of the tunnel fixed link solution. The area of the pound net fishery is based on the northern and eastern coastal area of Fehmarn and the immediate mainland.

Severity of loss Footprints, Germany	Fehmarnbelt (ICES 38G1)	Fehmarnbelt Region
Trawl		
Reclamation areas - Fehmarn	Medium	
Tunnel trench		
Temp/perm construction area		
Gill nets		
Reclamation areas - Fehmarn	Medium	
Tunnel trench		
Temp/perm construction area		
Pound nets		
Reclamation areas - Lolland	Very high	
Tunnel trench		
Temp/perm construction area		

Trawl
The severity of impact to the German trawl fisheries by losing 93 ha of their fishing grounds due to the tunnel trench and associated footprint is medium.

Theseverity of impact to the trawl fishieries according to analysis could, however, be considerable if it is not possible to trawl over the trench without restrictions to the fisheries or without running the risk of damaging gear. This is because trawling in areas where stones and small boulders are exposed, such as those used as protective material placed across the tunnel trench, could cause damage to bottom trawls.

Furthermore, potential restrictions to undertaking trawling over the trench to avoid disturbing the protective cover on top of the immersed tunnel elements could have a considerable impact to the undertaking of trawl fisheries in this area. Restrictions to the trawl fisheries would make it necessary to undertake time consuming operations such as lifting and resetting trawl gear which could lead to added costs to the fisheries and a reduction in the net value of their landings.

Gill nets
Results indicated that severity of impact to the German gill net fisheries by losing 47 ha of their fishing grounds (all along the tunnel trench) is medium.

The German gill net areas lost by this impact make up 0.5% of the German gill net fisheries in Fehmarnbelt. The ability of this fishery to utilise other nearby gill net fishing areas and the very small total loss of gill net fishing area supports the low significance of the loss of this area to the gill net fisheries. Furthermore, the added structure along the seabed does not hinder or disturb the undertaking of this fishery and might add to benefit this fishery as stony heterogeneous habitats can attract fish to the local area.

Pound nets
The degree of impact to the German pound net fisheries due to reclamation areas and footprints from the tunnel solution ilosing 7 ha of the fishing area was very high locally.
In contrast to the considerably large impact to the Danish pound net fisheries on Lolland, the German pound net fisheries will only be disturbed by a relatively small reclamation area (7 ha) along the tunnel trench and land reclamation that is near the shore. Thus the impact to loss of area on the German pound net fisheries is only significant (very high) locally, and in a worst case scenario will only affect a very little section of this fishery as this fishery is not very mobile and a loss of any area for the individual fisherman cannot be compensated for by moving to another area.

5.2 Sediment spill

Sediment spill does not affect the practical undertaking of the fisheries directly but can affect the commercial fish species that make up the resource for the fisheries. Excess concentrations of suspended sediment and sedimentation can cause avoidance responses in commercial fish species which can affect their abundance and distribution in fishing areas that overlap with impact areas. Thus sediment spills and consequent increases in concentration of suspended material and sedimentation can have an indirect impact on the fisheries by reducing their availability of the commercial species targeted by the specific fishery.

5.2.1 Environmental indicators

Several of the most important commercial species making up the resource to the fisheries are potentially affected by an increase in the concentration of suspended sediment or an increase in sedimentation. High concentrations of suspended sediment and sedimentation are known to trigger avoidance responses in fish if their concentrations are high enough or if the pressure exists for a long period of time. The tolerance of commercial fish species to different concentrations of suspended sediment and sedimentation is species-specific and also appears to be associated with a pelagic or benthic lifestyle (FeBEC 2012).

The important commercial fish or sub component to the fisheries that are relevant to consider in relation to sediment spills due to the establishment of the tunnel variant is given in Table 5.5.

Table 5.5: The sub-components (gear types and commercial species) of the commercial fisheries selected for the assessment of existing pressures from suspended sediment for the evaluation of the tunnel alternative for the Fehmanbelt Fixed Link.

Component	Sub-components Fisheries - gear	Sub component Commercial species
Commercial Fisheries	Trawl Gill/trammel nets Pound nets Danish seine nets	Atlantic cod Whiting Herring Sprat Flatfish species Horse mackerel Salmon Sea trout Garfish Eel

5.2.2 Sensitivity to pressure

An increase in water turbidity in Fehmarnbelt associated with dredging, backfilling and general construction of the tunnel variant will cause fish sensitive to high water turbidity to avoid or move away from the areas where suspended sediment concentrations are high enough to trigger an avoidance response. Which commercial fish respond to these pressures depends highly on the species, as threshold levels triggering avoidance responses to high concentrateions of suspended sediment is species specific and often depends on their life stage (larvae, juveniles, adults) and habitat (pelagic or benthic).

Adult fish make up the majority of the fish targeted by the commercial fisheries and although extremely high concentrations of suspended sediment levels has the potential to cause lethal effects, the expected response and capability by most commercial species is to move away from the pressure source before severe effects are experienced.

Increased suspended and deposited sediment in fishing grounds will influence the commercial species in different ways. Commercial species that are pelagic (cod, sprat herring, whiting,

horse mackerel, salmon, sea trout and garfish) are not normally associated with any particular habitat and are not regularly exposed to conditions of sediment resuspension or high concentrations of suspended sediment due to turbulence along the bottom. Some of these commercial species like cod and the clupieds herring and sprat are generally more sensitive to the amount of suspended material in their environment (FeBEC 2012). In contrast benthic species are often associated with sediment and seabed material or specific benthic habitats and appear to have adapted a greater tolerance to changes in sediment concentrations as these species appear less likely to leave an area of increasing sediment concentrations until levels are considerably high (FeBEC 2012).

The overall net sedimentation due to the construction works of the the tunnel variant is generally considered below threshold values for the vast majority of fish present in Fehmarnbelt (FeBEC 2012). Thus direct impacts on the fisheries due to avoidance response by commercial fish caused by sedimentation are considered to be much less significant compared to the changes or impacts to their habitats. These impacts are generally associated with affects on fish eggs and larvae, and therefore the potential effect on the fisheries is primarily related to affects on eventual recruitment to the adult populations. This impact will therefore by dealt within the sections on the project impacts.

5.2.3 Pressure indicators

The pressure indicator to the commercial fisheries due to sediment spills is avoidance behaviour amongst commercially important fish species and thus the resource to the fisheries.

Thresholds of suspended sediment for triggering avoidance behaviour for the most important commercial species in Fehmarnbelt are given in Table 5.6. These thresholds were derived from sensitivity investigations of the environmental impacts to fish (FeBEC 2012). The threshold for avoidance behaviour for the predominately pelagic species (cod, sprat, herring, whiting, horse mackerel, salmon, sea trout and garfish) has been set at 10 mg/l of suspended sediment. The threshold level for triggering avoidance behaviour in the predominately benthic commercial species (flounder, dab, plaice, turbot, brill, sole and eel) has been set at 50 mg/l.

Table 5.6: Thresholds (mg/l of suspended sediment) for triggering avoidance behaviour for the most important pelagic and benthic commercial species in Fehmarnbelt.

Environmental indicators in the fisheries Commercial species	Sensitivity to pressure - Concentration of suspended sediment triggering an avoidance response
Pelagic species; Atlantic cod, Sprat, Herring, Whiting, Salmon, Sea trout, Garfish, Horse mackerel	≥10 mg/l
Benthic species; Flounder, Dab, Plaice, Turbot, Brill, Sole and European eel	≥50 mg/l

5.2.4 Magnitude of pressure

Periodic increases in the concentration of suspended material due to dredging the tunnel trench, backfilling, and from establishing the construction facility for the tunnel elements will cover a specific amount of area at different concentrations over time. This is dependent on the hydrographical conditions, the characteristics of the material and the dredging intensity.

The magnitude of the pressure is dependent on the level of suspended sediment that either causes commercial species to move away from or avoid an area where fisheries are being undertaken. Because threshold levels of when fish display avoidance responses are species-specific the magnitude of the pressures for commercial species differs according to levels of suspended material exceeding 10 mg/l for primarily pelagic species and levels of suspended material exceeding 50 mg/l for benthic species.

In general, an increased level of suspended material during the construction period of the tunnel is greatest during the first 1.5-2 years or more precisely from the end of 2014 to the spring of 2016. During this time the greatest amount of Danish and German fishing areas (ha) are affected as sediment plumes with high concentrations (>10 mg/l) generally extend along the entire length of the southern Lolland coast, into Rødsand Lagoon (Nysted Nor) to the east and Nakskov Fjord to the west (see Figure 5.2). On the German side of Fehmarnbelt sediment plumes with high concentrations (>10 mg/l) of suspended sediment are generally located in small areas along the northern and western coast of Fehmarn. Thus, the primary fisheries that this has an impact on are the more coastal pound net and gill net fisheries. On a temporal scale, sediment plumes with concentrations high enough to trigger avoidance responses (>10 mg/l – pelagic fish, and >50 mg/l – benthic fish) are generally present for less than 5-10% of the time during this period. After the spring of 2016, sediment plumes with concentrations above 10 mg/l and 50 mg/l from tunnel construction works affect only small isolated areas along the Lolland and Fehmarn coastline and with very little frequency.

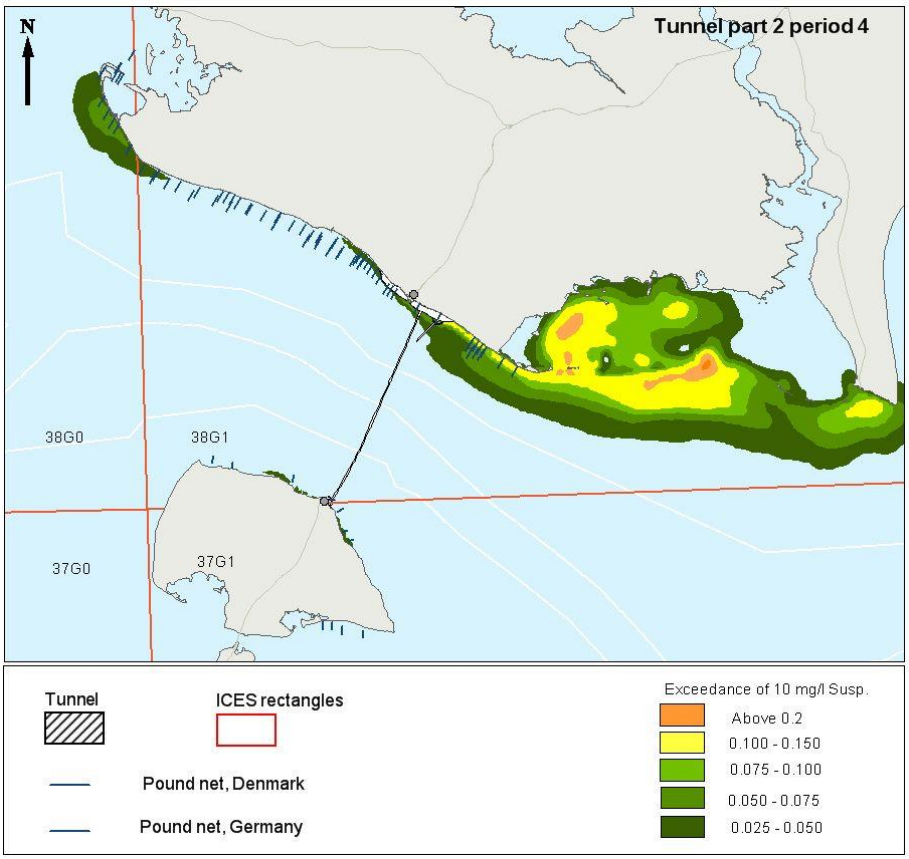


Figure 5.2: The simulated distribution of suspended sediment exceeding 10 mg/l during one of the most intensive periods (September-November, 2015) of sediment spillage in Fehmarnbelt and its region during the tunnel construction.

5.2.5 Assessment criteria

The assessment criteria used to classify the reduction of sub-components to the fisheries from increases in suspended sediment due to the establishement of a tunnel fixed link solution is outlined in section 3.2.3 and given in Table 3.7.

5.2.6 Degree of impairment

The estimated degree of impairment to the Danish and German fisheries due to suspended sediment that affects the commercial species in Fehmarnbelt and its region at suspended sed-

iment levels >10 mg/l and >50 mg/l during the course of the tunnel construction are given in the following sections for the individual fishery sub-components (trawl, gill nets, pound nets and seine nets).

Denmark

Trawl fishery - Denmark
Overall, the commercial species were affected very little by suspended sediment in areas of Fehmarnbelt and its region where trawling is undertaken. This is not surprising as the trawl fisheries are undertaken in the central deeper (>10 m) parts of Fehmarnbelt where sediment plumes according to computer simulations are not expected to extend to or last long during construction. The time period where most of the area for trawling was affected by increased suspended sediment was at the end of 2015 and the beginning of 2016. In the end of 2015, 171 hectares of trawling area in Fehmarnbelt and 249 ha in the entire Fehmarnbelt region were affected by suspended sediment with concentrations >10 mg/l. Similarly, in the early spring of 2016, 68 ha of the trawling area in Fehmarnbelt (100 ha, in the Fehmarnbelt region) were affected by suspended sediment >10 mg/l. This amounted to less than 0.3% of the area used for trawling in Fehmarnbelt (ICES 38G1) and far less than 0.1% of the area used for trawling in the Fehmarnbelt region. Thus if we assume the commercial species most sensitive to increased concentrations of suspended sediment are spread throughout the trawl fishing area than less than 0.3% of these species in Fehmarnbelt and 0.1% of these species in the Fehmarnbelt region would have been affected by an increase in suspended sediment.

At no other time before or after the periods with the greatest amount of increased suspended sediment in 2015 and 2016 were more than 32 ha of the trawling area affected by sediment plumes with concentrations great enough to cause an avoidance response by commercial species (Table 5.7).

Sediment plumes with concentrations more than 50 mg/l did not affect more than 1 ha over any of the measured time periods during the construction of the tunnel and thus species less sensitive to increased concentrations of suspended sediment in the trawling areas were almost not affected.

The degree of impairment to the trawl fisheries through the indirect impairment to their resource (commercial species) was minor during the construction of the tunnel in all cases (Table 5.7).

Table 5.7: The percentage (%) of trawl fishing area in Fehmarnbelt (ICES 38G1) and its region and the area (ha) affected by increased concentrations of suspended sediment above threshold levels triggering an avoidance response for sensitive commercial species (>10 mg/l) and less sensitive commercial species (>50 mg/l). The colour coding represents the degree of impairment which was minor in all cases according to guidelines outlined in method chapter.

Reduction of sub components, sediment spill (%-ha) Tunnel	Threshold	Commercial species	Year	Dec-Apr		May-Aug		Sep-Nov		Year	
				%	ha	%	ha	%	ha	%	ha
Trawl Fehmarnbelt (ICES 38G1)	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014					0.0	1.4	0.0	10.1
			2015	0.0	9.1	0.0	10.3	0.3	171.1	0.1	64.6
			2016	0.1	68.2	0.0	0.2	0.0	12.6	0.0	18.2
			2017	0.0	16.8	0.0	0.0	0.0	0.4	0.0	3.2
			2018	0.0	0.3	0.0	0.0	0.0	0.1	0.0	0.1
			2019	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014					0.0	0.0	0.0	0.2
			2015	0.0	0.1	0.0	0.2	0.0	0.0	0.0	0.1
			2016	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.1
			2017	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

			2018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			2019	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Reduction of sub compo-nents, sediment spill (%-ha) Tunnel	Threshold	Commercial species	Year	Dec-Apr		May-Aug		Sep-Nov		Year	
				%	ha	%	ha	%	ha	%	ha
Trawl Fehmarnbelt Region	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse macke-rel	2014					0.0	2.2	0.0	12.6
			2015	0.0	21.1	0.0	11.1	0.0	249.1	0.0	94.7
			2016	0.0	100.2	0.0	0.8	0.0	18.4	0.0	29.5
			2017	0.0	32.4	0.0	0.3	0.0	1.7	0.0	8.0
			2018	0.0	3.0	0.0	0.1	0.0	0.4	0.0	1.1
			2019	0.0	0.8	0.0	0.1	0.0	0.1	0.0	0.3
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014					0.0	0.0	0.0	0.2
			2015	0.0	0.3	0.0	0.2	0.0	0.0	0.0	0.2
			2016	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.2
			2017	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
			2018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			2019	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Gill net fishery - Denmark

The commercial species associated with the gill/trammel net fisheries were affected the most during the first two years of tunnel construction. The greatest affect was in the summer (May-Aug) and autumn (Sep-Nov) of 2015 when 1.4% (669 ha) and 1.9% (835 ha) of the gill net fishing area in Fehmarnbelt was affected by sediment plumes with concentrations high enough to trigger an avoidance response (>10 mg/l) by the most sensitive commercial species (cod, sprat, herring, whiting, horse mackerel, salmon, sea trout and most other pelagic species). The location of these plumes was primarily along the southeastern coastline of Lolland and in Rødsand Lagoon as well as the southwestern part of Lolland near Naksov Fjord (see Figure 5.3). An exceedance of 50 mg/l is estimated to cover approximately 0.2% (76 ha) and 0.24% (107 ha) of the gill net fishing areas and will thereby affect the commercial species that are less sensitive (>50 mg/l triggers an avoidance response) of increased suspended sediment concentrations. The distribution of these plumes are also primarily along the southeastern coast of Lolland and in Rødsand Lagoon as well as in the southwestern coastline of Lolland near Nakskov Fjord.

Suspended sediment concentrations also periodically exceeded 10 mg/l and 50 mg/l levels in the gill/trammel net fishing areas after the spring (Dec-Apr) of 2016 and over the following years (2016 -2019), however their area coverage was never greater than 0.6% (231 ha) of the gill net fishing areas in Fehmarnbelt (ICES 38G1) or 0.3% (279 ha) in the entire Fehmarnbelt region.

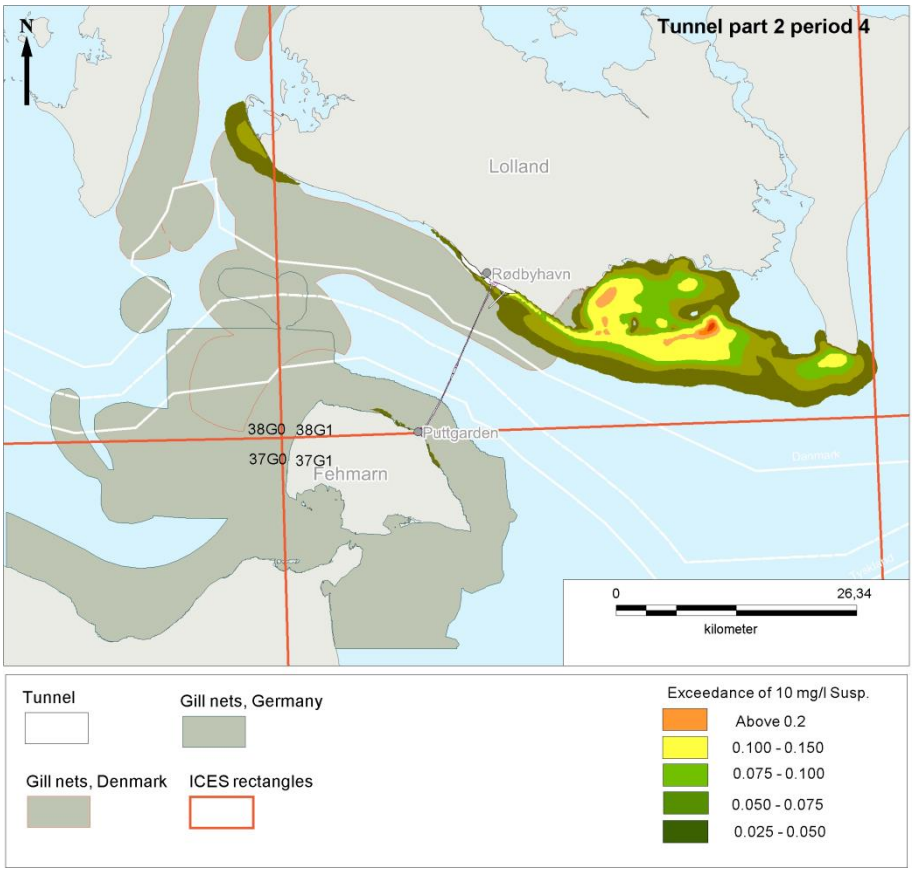


Figure 5.3: The simulated distribution of suspended sediment exceeding 10 mg/l in relation to the gill net fisheries of Fehmarnbelt during one of the most intensive periods (September-November, 2015) of sediment spillage during the tunnel construction.

The degree of impairment to the gill net fisheries through the indirect impairment to their resource (commercial species) was minor during the construction of the tunnel in all cases (Table 5.8).

Table 5.8: The percentage (%) of gill net fishing area in Fehmarnbelt (ICES 38G1) and its region and the area (ha) affected by increased concentrations of suspended sediment above threshold levels triggering an avoidance response for sensitive commercial species (>10 mg/l) and less sensitive commercial species (>50 mg/l). The colour coding represents the degree of impact which was minor in all cases according to guidelines outlined in the methods chapter.

Reduction of sub components, sediment spill (%-ha) Tunnel	Threshold	Commercial species	Year	Dec-Apr		May-Aug		Sep-Nov		Year	
				%	ha	%	ha	%	ha	%	ha
Gill nets Fehmarnbelt (ICES 38G1)	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014					0.1	42.9	0.5	228.3
			2015	0.6	285.5	1.4	689.8	1.9	834.8	1.4	619.0
			2016	1.5	655.2	0.2	78.8	0.4	170.5	0.6	262.0
			2017	0.5	212.0	0.0	6.4	0.1	34.4	0.2	69.4
			2018	0.1	42.2	0.0	0.5	0.0	9.7	0.1	30.4
			2019	0.2	96.4	0.0	0.5	0.0	3.2	0.1	24.9
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014					0.0	1.0	0.0	17.0
			2015	0.0	13.0	0.2	76.4	0.2	107.4	0.1	61.8
			2016	0.1	41.9	0.0	1.6	0.0	8.2	0.0	12.8
			2017	0.0	2.7	0.0	0.1	0.0	0.6	0.0	0.6
			2018	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.1
			2019	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.1

Reduction of sub components, sediment spill (%-ha) Tunnel	Threshold	Commercial species	Year	Dec-Apr		May-Aug		Sep-Nov		Year	
				%	ha	%	ha	%	ha	%	ha
Gill nets Fehmarnbelt Region	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014					0.0	43.0	0.2	266.2
			2015	0.3	312.6	0.6	743.4	0.8	948.6	0.6	713.9
			2016	0.7	772.1	0.1	131.3	0.2	216.8	0.3	316.6
			2017	0.2	253.1	0.0	15.2	0.0	35.5	0.1	76.5
			2018	0.0	50.2	0.0	2.0	0.0	9.7	0.0	34.1
			2019	0.1	104.6	0.0	4.1	0.0	3.2	0.0	27.2
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014					0.0	1.0	0.0	17.0
			2015	0.0	13.0	0.1	80.8	0.1	108.0	0.1	65.8
			2016	0.0	47.7	0.0	4.9	0.0	8.2	0.0	14.2
			2017	0.0	3.0	0.0	0.2	0.0	0.6	0.0	0.6
			2018	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.1
			2019	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.1

Pound net fishery – Denmark

The Danish commercial pound net fisheries are located along the entire southern coast of Lolland and because of the near shore distribution of suspended sediment plumes from tunnel construction works are possibly the fishery (in terms of area) that is most affected by this pressure. Over the first two years of tunnel construction when sediment plumes with concentrations greater than 10 mg/l and 50 mg/l were most prominent, from 3.4-5.0% (203 - 302 ha) and from 0.8-3.8% (46-225 ha) of the pound net fishing area in 2015 and 2016, respectively, was affected by sediment plumes with concentrations >10 mg/l, which trigger an avoidance response from the most sensitive fish species (Table 5.9) (see also Figure 5.2). Sediment plumes with concentrations higher than >50 mg/l covered approximately 0.1-0.8% (8-47 ha) of the pound net fishing area over the same period. The areas primarily affected by high concentrations of suspended sediment were those along the southeast and southwest coast of Lolland. In the years following 2016 sediment plumes from tunnel construction will increase the suspended sediment concentrations above levels where sensitive fish exhibit an avoidance response up to 1.2% (72 ha) of the pound net fishing area. Similarly, levels of suspended sediment which trigger avoidance responses by fish more tolerant to suspended sediment will cover up to 0.1% (6 ha) of the pound net fishing area. However, these events will occur only seldom and primarily be in isolated areas and only over short periods of time.

Table 5.9: The percentage (%) of pound net fishing area in Fehmarnbelt (ICES 38G1) and its region and the area (ha) affected by increased concentrations of suspended sediment above threshold levels triggering an avoidance response for sensitive commercial species (>10 mg/l) and less sensitive commercial species (>50 mg/l). The colour coding represents the degree of impact which was minor in all cases according to guidelines outlined in the methods chapter.

Reduction of sub components, sediment spill (%-ha) Tunnel	Threshold	Commercial species	Year	Dec-Apr		May-Aug		Sep-Nov		Year	
				%	ha	%	ha	%	ha	%	ha
Pound nets Fehmarnbelt Region	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014					0.3	20.5	2.0	118.3
			2015	3.7	224.8	5.0	302.3	3.4	203.2	4.4	265.3
			2016	3.8	225.4	2.1	125.5	0.8	46.1	2.1	124.0
			2017	1.2	71.9	0.7	40.2	0.1	6.9	0.5	32.2
			2018	0.4	23.8	0.3	18.1	0.1	5.5	0.4	24.5
			2019	1.1	63.6	0.4	25.7	0.0	1.3	0.4	24.0
	50 mg/l	Flounder, dab, plaice,	2014					0.0	0.1	0.1	3.8
			2015	0.1	7.6	0.8	46.6	0.1	7.8	0.4	26.4

		turbot, brill, sole and eel	2016	0.4	24.8	0.4	24.1	0.0	0.7	0.2	14.1
			2017	0.1	6.1	0.1	5.9	0.0	0.0	0.0	2.5
			2018	0.0	0.5	0.0	1.2	0.0	0.0	0.0	0.7
			2019	0.0	1.4	0.1	3.1	0.0	0.0	0.0	1.5

Seine net fishery – Denmark
The degree of impairment on the seine net fisheries due to suspended sediment from the construction of the tunnel is given in Table 5.10.

Overall, the seine net fisheries in Fehmarnbelt and region were affected very little by suspended sediment concentrations that affect the fishery resource by triggering avoidance responses away from fishing areas. This was exemplified by the degree of impairment being minor at all times during the construction of the tunnel.

The greatest amount of seine net fishing area in Fehmarnbelt (ICES 38G1) and its region affected by suspended sediment concentrations (>10 mg/l) that trigger an avoidance response by the most sensitive commercial species was in the autumn of 2015 and the winter/spring of 2016. During this time 35 ha (0.2% of the fishing area) in the autumn and 20.1 ha (0.1% of the fishing area) in the spring were affected by sediment plumes in Fehmarnbelt. Similarly, a total of 55 ha (0.13% of the fishing area) and 29.8 ha (0.07% of the fishing area) of the seine net fishing area in the region of Fehmarnbelt was affected by sediment plumes with concentrations >10 mg/l during the same time periods, respectively.

Sediment plumes with concentrations >50 mg/l only affected areas less than 1 ha (< 0.01% of the fishing area) in both Fehmarnbelt (ICES 38G1) and the Fehmarnbelt region throughout the tunnel construction period.

Table 5.10: The percentage (%) of Danish seine net fishing area in Fehmarnbelt (ICES 38G1) and its region and the area (ha) affected by increased concentrations of suspended sediment above threshold levels triggering an avoidance response for sensitive commercial species (>10 mg/l) and less sensitive commercial species (>50 mg/l). The colour coding represents the degree of impact which was minor in all cases according to guidelines outlined in the method chapter.

Reduction of sub components, sediment spill (%-ha) Tunnel	Threshold	Commercial species	Year	Dec-Apr		May-Aug		Sep-Nov		Year	
				%	ha	%	ha	%	ha	%	ha
Seine nets Fehmarnbelt (ICES 38G1)	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014					0.0	0.0	0.0	0.7
			2015	0.0	1.1	0.0	0.4	0.2	34.6	0.1	13.8
			2016	0.1	20.1	0.0	0.0	0.0	2.8	0.0	5.5
			2017	0.0	7.0	0.0	0.0	0.0	0.0	0.0	1.6
			2018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			2019	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014					0.0	0.0	0.0	0.0
			2015	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			2016	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.1
			2017	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			2018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			2019	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Reduction of sub components, sediment spill (%-ha) Tunnel	Threshold	Commercial species	Year	Dec-Apr		May-Aug		Sep-Nov		Year	
				%	ha	%	ha	%	ha	%	ha
Seine nets Fehmarnbelt Region	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014					0.0	0.0	0.0	0.8
			2015	0.0	1.3	0.0	3.5	0.1	55.0	0.1	21.8
			2016	0.1	29.8	0.0	0.0	0.0	4.0	0.0	8.3
			2017	0.0	8.8	0.0	0.0	0.0	0.1	0.0	2.1
			2018	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
			2019	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014					0.0	0.0	0.0	0.0
			2015	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			2016	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.1
			2017	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			2018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			2019	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Germany

Trawl fishery – Germany

The estimated affect of increased concentrations of suspended sediment that triggers avoidance responses in sensitive pelagic species (>10 mg/l suspended sediment) and less sensitive benthic species (>50 mg/l) appears to be very small in the German trawl fishing areas. A maximum of 30 ha (0.1% of fishing area) in Fehmarnbelt (ICES 38G1) and 69 ha (0.03% of fishing area) in the Fehmarnbelt region was affected in the autumn (Sep-Dec) of 2015. Hereafter, no more than 2 ha (<0.01% of fishing area) of the German trawl fishing areas in the Fehmarnbelt or 19 ha (0.01% of fishing area) of the German trawl fishing areas in the Fehmarnbelt region were affected by increased concentrations of suspended material.

This led to the degree of impairment to the German trawl fisheries from an increase in the suspended sediment and its effect on the fishery resource (commercial species) being minor in all cases throughout the construction of the tunnel (Table 5.11).

Table 5.11: The percentage (%) of trawl fishing area in Fehmarnbelt (ICES 38G1) and its region and the area (ha) affected by increased concentrations of suspended sediment above threshold levels triggering an avoidance response for sensitive commercial species (>10 mg/l) and less sensitive commercial species (>50 mg/l). The colour coding represents the degree of impairment which was minor in all cases according to guidelines outlined in the method chapter.

Reduction of sub components, sediment spill (%-ha) Tunnel	Threshold	Commercial species	Year	Dec-Apr		May-Aug		Sep-Nov		Year	
				%	ha	%	ha	%	ha	%	ha
Trawl Fehmarnbelt (ICES 38G1)	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014					0.0	0.0	0.0	0.1
			2015	0.0	2.7	0.0	0.7	0.1	29.7	0.0	9.1
			2016	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.5
			2017	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.4
			2018	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.1
			2019	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014					0.0	0.0	0.0	0.0
			2015	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			2016	0.0	0	0.0	0.0	0.0	0.0	0.0	0
			2017	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			2018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			2019	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Reduction of sub components, sediment spill (%-ha) Tunnel	Threshold	Commercial species	Year	Dec-Apr		May-Aug		Sep-Nov		Year	
				%	ha	%	ha	%	ha	%	ha
Trawl Fehmarnbelt Region	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014					0.0	0.0	0.0	0.1
			2015	0.0	8.6	0.0	0.7	0.1	69.0	0.1	23.3
			2016	0.0	18.9	0.0	0.0	0.0	0.7	0.0	6.4
			2017	0.0	12.2	0.0	0.0	0.0	0.0	0.0	4.2
			2018	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.7
			2019	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.1
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014					0.0	0.0	0.0	0.0
			2015	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.1
			2016	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
			2017	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
			2018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			2019	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Gill net fishery - Germany

The commercial species associated with the German gill/trammel net fisheries were primarily affected during winter and early spring months (December-April) with the highest degree of impairment during the first two years of tunnel construction.

The increased concentration of sediment (>10 mg/l and >50 mg/l) primarily affected areas along the northern and northeastern coast of Fehmarn. Up to 96 ha (1.0% of fishing area) and 82 ha (0.9% of fishng area) of the German gill net fishing area in Fehmarnbelt (ICES 38G1) was affected by increased suspended sediment concentrations (>10 mg/l) in the winter (Dec-April) and spring (March-May) of 2015, respectively. During the same period, 143 ha (0.25% of fishing area) and 105 ha (0.17% of fishing area) of the German gill net fisheries in the Fehmarnbelt region were affected by increased suspended sediment concentrations.

Sediment plumes with concentrations high enough (>50 mg/l) to trigger an avoidance response in the benthic fish that are more tolerant to increased suspended material covered approximately 16 ha and 14 ha (0.1% of fishing area) when they were most prominent in the winter and spring of 2015.

Overall, the degree of impairment to the German gill net fisheries through the indirect impairment to their resource (commercial species) was considered minor during the entire construction period of the tunnel (Table 5.12).

Table 5.12: The percentage (%) of gill net fishing area in Fehmarnbelt (ICES 38G1) and its region and the area (ha) affected by increased concentrations of suspended sediment above threshold levels triggering an avoidance response for sensitive commercial species (>10 mg/l) and less sensitive commercial species (>50 mg/l). The colour coding represents the degree of impact which was minor in all cases according to guidelines outlined in the methods chapter.

Reduction of sub components, sediment spill (%-ha) Tunnel	Threshold	Commercial species	Year	Dec-Apr		May-Aug		Sep-Nov		Year	
				%	ha	%	ha	%	ha	%	ha
Gill nets Fehmarnbelt (ICES 38G1)	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014					0.1	11.7	0.2	17.3
			2015	1.0	95.6	0.1	7.3	0.1	15.9	0.5	47.8
			2016	0.6	60.8	0.1	6.4	0.2	16.3	0.3	31.0
			2017	0.5	45.6	0.0	3.3	0.1	7.9	0.2	19.9
			2018	0.3	24.1	0.0	1.4	0.0	4.6	0.1	10.8
			2019	0.2	16.0	0.0	0.6	0.0	3.0	0.1	7.0
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014					0.0	1.3	0.0	2.7
			2015	0.2	14.2	0.0	0.1	0.0	2.9	0.1	7.0
			2016	0.1	10.4	0.0	0.1	0.0	3.1	0.1	5.1
			2017	0.1	6.9	0.0	0.1	0.0	1.5	0.0	2.8
			2018	0.0	3.2	0.0	0.0	0.0	0.9	0.0	1.4
			2019	0.0	1.9	0.0	0.0	0.0	0.5	0.0	0.8

Reduction of sub components, sediment spill (%-ha) Tunnel	Threshold	Commercial species	Year	Dec-Apr		May-Aug		Sep-Nov		Year	
				%	ha	%	ha	%	ha	%	ha
Gill nets Fehmarnbelt region	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014					0.0	17.7	0.0	28.0
			2015	0.2	142.7	0.0	13.9	0.1	30.1	0.1	75.8
			2016	0.2	93.6	0.0	11.8	0.1	29.4	0.1	49.4
			2017	0.1	73.8	0.0	6.5	0.0	13.3	0.0	30.8
			2018	0.1	32.1	0.0	3.0	0.0	6.3	0.0	14.4
			2019	0.0	19.3	0.0	1.6	0.0	3.8	0.0	8.5
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014					0.0	1.5	0.0	2.8
			2015	0.0	16.0	0.0	0.5	0.0	3.2	0.0	8.1
			2016	0.0	11.1	0.0	0.4	0.0	3.4	0.0	5.5
			2017	0.0	7.5	0.0	0.2	0.0	1.5	0.0	3.0
			2018	0.0	3.3	0.0	0.1	0.0	0.9	0.0	1.4
			2019	0.0	1.9	0.0	0.0	0.0	0.5	0.0	0.8

Pound net fishery - Germany

The German commercial pound net fisheries are located in specific areas along the coast of Fehmarn and the immediate mainland to the east of Fehmarn.

Sediment plumes with concentrations greater than 10 mg/l and 50 mg/l were most prominent along the northern and northwestern coast of Fehmarn during the first 2-3 years of tunnel construction. However, because the general distribution of increased suspended sediment from construction works is along the coastal areas of Fehmarn which is also where pound net fishing areas are also located there was a continual, yet small, affect of increased suspended sediment concentrations throughout most of the tunnel construction period.

Seasonally, the highest area coverage of the pound net fishery by suspended sediment plumes was primarily during the winter and spring periods of the year (December-May).
More specifically, from 2015-2017 increased concentrations of suspended sediment above 10 mg/l from tunnel construction activities affected between 11-67 ha (0.5 - 2.9% of the fishing area) of the German pound net fishing areas along the northern Fehmarn coast. During the same period approximately 0.4-12.2 ha (0.01 - 0.5% of the fishing area) of these pound net fishing areas were periodically covered by sediment plumes with suspended sediment concentrations (>50 mg/l) high enough to trigger avoidance responses by more tolerant benthic species.

Overall, the degree of impairment to the German pound net fisheries by increased concentrations of suspended material was estimated to be minor throughout the construction period of the tunnel (Table 5.13).

Table 5.13: The percentage (%) of pound net fishing area in Fehmarnbelt (ICES 38G1) and its region and the area (ha) affected by increased concentrations of suspended sediment above threshold levels triggering an avoidance response for sensitive commercial species (>10 mg/l) and less sensitive commercial species (>50 mg/l). The colour coding represents the degree of impact which was minor in all cases according to guidelines outlined in the methods chapter.

Reduction of sub components, sediment spill (%-ha) Tunnel	Threshold	Commercial species	Year	Dec-Apr		May-Aug		Sep-Nov		Year	
				%	ha	%	ha	%	ha	%	ha
Pound nets Fehmarnbelt Region	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014					0.7	16.3	0.9	21.5
			2015	2.9	67.1	0.5	12.4	0.9	21.1	1.7	39.6
			2016	2.0	45.0	0.5	10.7	1.0	22.4	1.2	27.6
			2017	1.5	33.7	0.3	5.8	0.4	10.4	0.7	15.8
			2018	0.8	17.6	0.1	2.7	0.2	5.4	0.4	8.6
			2019	0.5	12.2	0.1	1.3	0.1	3.4	0.2	5.7
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014					0.1	1.5	0.1	2.8
			2015	0.4	10.2	0.0	0.4	0.1	3.1	0.2	5.5
			2016	0.3	7.9	0.0	0.4	0.1	3.3	0.2	4.2
			2017	0.2	5.1	0.0	0.2	0.1	1.6	0.1	2.1
			2018	0.1	2.4	0.0	0.0	0.0	0.9	0.0	1.1
			2019	0.1	1.6	0.0	0.0	0.0	0.5	0.0	0.7

5.2.6.1 Classification of impact

The classification of the impact is according to guidelines outlined in the methodology section (section 3.1).

The classification of the impairment of sediment spills on commercial fish in the Danish and German fisheries (trawl, gill net, pound net and Danish seine net (Denmark only)) was “Minor” in all cases.

5.2.7 Severity and significance

The severity and significance of the suspended sedimentation from establishing the tunnel fixed link on the Danish and German fisheries is given in the following sections:

Denmark
The severity of impairment from sediment spills during establishment of the tunnel fixed link solution on the Danish fisheries is presented for each fishery component. The severity is derived from importance criteria leading to the degree of importance and the importance level of the individual fisheries.

Trawl
The severity of impact on both the most (avoidance response >10 mg/l) and less (avoidance response >50 mg/l) sensitive commercial species to suspended sediment in the trawl fisheries due to excess sediment was minor during the entire tunnel construction period (Table 5.14).

Table 5.14: The severity of impairment to the trawl fisheries due to sediment spills during the establishment of the tunnel fixed link soliution. Results derived from analysis of the degree of impairment and the importance level of the individual fisheries as described in the methods chapter.

Severity of impairment, sediment spill (%-ha) Tunnel	Threshold	Commercial species	Year	Dec-Apr	Mar-May	May-Aug	Sep-Nov	Year
Trawl Fehmarnbelt (ICES 38G1)	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014				Minor	Minor
			2015	Minor	Minor	Minor	Minor	Minor
			2016	Minor	Minor	Minor	Minor	Minor
			2017	Minor		Minor	Minor	Minor
			2018	Minor	Minor	Minor	Minor	Minor
			2019	Minor		Minor	Minor	Minor
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014				Minor	Minor
			2015	Minor	Minor	Minor	Minor	Minor
			2016	Minor	Minor	Minor	Minor	Minor
			2017	Minor		Minor	Minor	Minor
			2018	Minor	Minor	Minor	Minor	Minor
			2019	Minor		Minor	Minor	Minor

Severity of impairment, sediment spill (%-ha) Tunnel	Threshold	Commercial species	Year	Dec-Apr	Mar-May	May-Aug	Sep-Nov	Year
Trawl Fehmarnbelt Region	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014				Minor	Minor
			2015	Minor	Minor	Minor	Minor	Minor
			2016	Minor	Minor	Minor	Minor	Minor
			2017	Minor		Minor	Minor	Minor
			2018	Minor	Minor	Minor	Minor	Minor
			2019	Minor		Minor	Minor	Minor
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014				Minor	Minor
			2015	Minor	Minor	Minor	Minor	Minor
			2016	Minor	Minor	Minor	Minor	Minor
			2017	Minor		Minor	Minor	Minor
			2018	Minor	Minor	Minor	Minor	Minor
			2019	Minor		Minor	Minor	Minor

The greatest impairment was during the end of 2015 and the first part of 2016, where a maximum of 0.35% of the Danish trawl fishing area was affected. The significance of this to the trawl fisheries is also considered to be minor as this impairment affected the resource only on a local scale and the the ability of the trawl fisheries to utilise the other areas in the vast majority of the nonaffected trawling areas was considerable.

Gill nets
The severity of impact on all commercial species in the gill net fisheries due to excess sediment spillage was minor during the entire tunnel construction period (Table 5.15).

Table 5.15: The severity of impairment to the gill net fisheries due to sediment spills during the establishment of the tunnel fixed link solution. Results derived from analysis of the degree of impairment and the importance level of the individual fisheries as described in the methods chapter.

Severity of impairment, sediment spill (%-ha) Tunnel	Threshold	Commercial species	Year	Dec-Apr	Mar-May	May-Aug	Sep-Nov	Year
Gill nets Fehmarnbelt (ICES 38G1)	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014				Minor	Minor
			2015	Minor	Minor	Minor	Minor	Minor
			2016	Minor	Minor	Minor	Minor	Minor
			2017	Minor		Minor	Minor	Minor
			2018	Minor	Minor	Minor	Minor	Minor
			2019	Minor		Minor	Minor	Minor
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014				Minor	Minor
			2015	Minor	Minor	Minor	Minor	Minor
			2016	Minor	Minor	Minor	Minor	Minor
			2017	Minor		Minor	Minor	Minor
			2018	Minor	Minor	Minor	Minor	Minor
			2019	Minor		Minor	Minor	Minor

Severity of impairment, sediment spill (%-ha) Tunnel	Threshold	Commercial species	Year	Dec-Apr	Mar-May	May-Aug	Sep-Nov	Year
Gill nets Fehmarnbelt Region	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014				Minor	Minor
			2015	Minor	Minor	Minor	Minor	Minor
			2016	Minor	Minor	Minor	Minor	Minor
			2017	Minor		Minor	Minor	Minor
			2018	Minor	Minor	Minor	Minor	Minor
			2019	Minor		Minor	Minor	Minor
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014				Minor	Minor
			2015	Minor	Minor	Minor	Minor	Minor
			2016	Minor	Minor	Minor	Minor	Minor
			2017	Minor		Minor	Minor	Minor
			2018	Minor	Minor	Minor	Minor	Minor
			2019	Minor		Minor	Minor	Minor

During the worst period of sediment spillage in the gill net fishing areas from the summer of 2015 to the spring of 2016 an area between the size of 650-835 ha (1.4-1.9% of the gill net fishing area) was covered with suspended sediment that triggered an avoidance response of the most sensitive fish. These areas were primarily near the southern coast of Lolland where the gill net fisheries are undertaken with less intensity than in available areas in the western part of Fehmarnbelt. Although this impact could be considered significant on a local scale overall it is less significant due to the mobility of the gill net fisheries and the temporary status of the impact.

Pound nets

The severity of impairment of sediment spill from the tunnel construction works on the commercial species associated with the Danish pound net fisheries was minor in all cases (5.20).

Table 5.16: The severity of impairment to the pound net fisheries due to sediment spills during the establishment of the tunnel fixed link solution. Results derived from analysis of the degree of impairment and the importance level of the individual fisheries as described in the method chapter.

Severity of impairment, sediment spill (%-ha) Tunnel	Threshold	Commercial species	Year	Dec-Apr	Mar-May	May-Aug	Sep-Nov	Year
Pound nets Fehmarnbelt (ICES 38G1)	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014				Minor	Minor
			2015	Minor	Minor	Minor	Minor	Minor
			2016	Minor	Minor	Minor	Minor	Minor
			2017	Minor		Minor	Minor	Minor
			2018	Minor	Minor	Minor	Minor	Minor
			2019	Minor		Minor	Minor	Minor
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014				Minor	Minor
			2015	Minor	Minor	Minor	Minor	Minor
			2016	Minor	Minor	Minor	Minor	Minor
			2017	Minor		Minor	Minor	Minor
			2018	Minor	Minor	Minor	Minor	Minor
			2019	Minor		Minor	Minor	Minor

The pound net fisheries are along the entire southern coast of Lolland where spill scenarios indicated that the highest concentrations of sediment spillage and the most pronounced impairment from this pressure will be located (Figure 5.4). During 2015 and 2016 when sediment spills from the construction of the tunnel is greatest there will be an impairment of between 2-5% of the pound net fishing areas less than 5% of the time. Much of the impact is in the Rødsand Lagoon where the occasional use of fyke nets for catching eel or shrimp are the main fisheries. The significance of this impairment to the pound net fisheries could be quite significant on a local scale as this pressure could effect local pound net fisheries where sediment plumes are most prominent, as concentrations of suspended sediment above threshold levels could potentially reduce the abundance of the most sensitive commercial species considerably (in particularly cod, herring and garfish when migrating or in feeding areas).

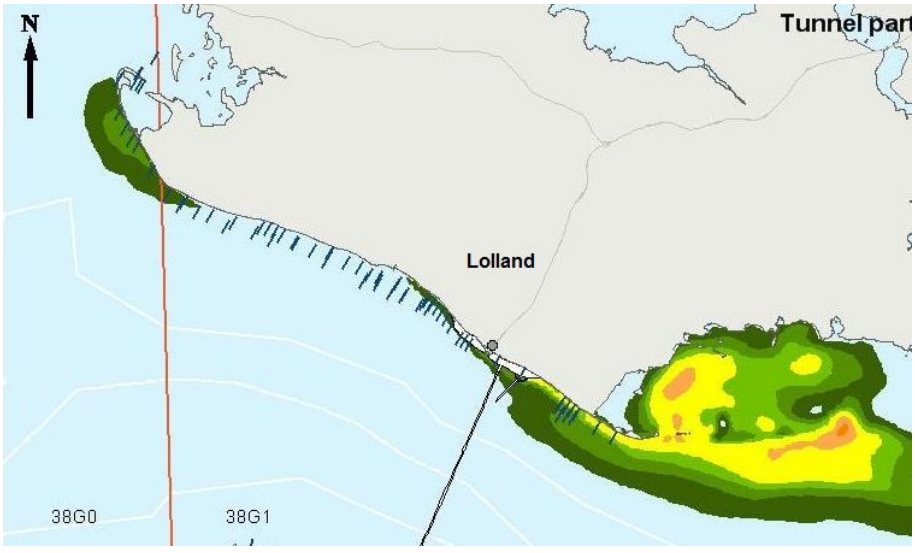


Figure 5.4: The simulated distribution of suspended sediment exceeding 10 mg/l in relation to the Danish pound net fisheries of Fehmarnbelt during one of the most intensive periods (September-November, 2015) of sediment spillage. Pound nets are represented by lines perpendicular to shore. The colour coding of the distribution is suspended sediment represent the amount of time in this period the concentration exceeded >10 mg/l; Dark green 2-5%, green 5-7.5%, light green 7.5-10%, yellow 10-15%, orange >20%.

Danish seine nets

The severity of impairment of sediment spill from the tunnel construction works on the resources (commercial species) to the seine net fisheries was insignificant at all times during the construction period of the tunnel fixed link solution (Table 5.17). This was both due to the location of the seine net fisheries being offshore where sediment plumes were less pronounced and the minor importance classification of the Danish seine net fisheries in Fehmarnbelt.

Table 5.17: The severity of impairment to the seine net fisheries due to sediment spills during the establishment of the tunnel fixed link solution. Results derived from analysis of the degree of impairment and the importance level of the individual fisheries as described in the method chapter.

Severity of impairment, sediment spill (%-ha) Tunnel	Threshold	Commercial species	Year	Dec-Apr	Mar-May	May-Aug	Sep-Nov	Year
Seine nets Fehmarnbelt (ICES 38G1)	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014				Insignif.	Insignif.
			2015	Insignif.	Insignif.	Insignif.	Insignif.	Insignif.
			2016	Insignif.	Insignif.	Insignif.	Insignif.	Insignif.
			2017	Insignif.		Insignif.	Insignif.	Insignif.
			2018	Insignif.	Insignif.	Insignif.	Insignif.	Insignif.
			2019	Insignif.		Insignif.	Insignif.	Insignif.
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014				Insignif.	Insignif.
			2015	Insignif.	Insignif.	Insignif.	Insignif.	Insignif.
			2016	Insignif.	Insignif.	Insignif.	Insignif.	Insignif.
			2017	Insignif.		Insignif.	Insignif.	Insignif.
			2018	Insignif.	Insignif.	Insignif.	Insignif.	Insignif.
			2019	Insignif.		Insignif.	Insignif.	Insignif.

Severity of impairment, sediment spill (%-ha) Tunnel	Threshold	Commercial species	Year	Dec-Apr	Mar-May	May-Aug	Sep-Nov	Year
Seine nets Fehmarnbelt Region	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014				Insignif.	Insignif.
			2015	Insignif.	Insignif.	Insignif.	Insignif.	Insignif.
			2016	Insignif.	Insignif.	Insignif.	Insignif.	Insignif.
			2017	Insignif.		Insignif.	Insignif.	Insignif.
			2018	Insignif.	Insignif.	Insignif.	Insignif.	Insignif.
			2019	Insignif.		Insignif.	Insignif.	Insignif.
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014				Insignif.	Insignif.
			2015	Insignif.	Insignif.	Insignif.	Insignif.	Insignif.
			2016	Insignif.	Insignif.	Insignif.	Insignif.	Insignif.
			2017	Insignif.		Insignif.	Insignif.	Insignif.
			2018	Insignif.	Insignif.	Insignif.	Insignif.	Insignif.
			2019	Insignif.		Insignif.	Insignif.	Insignif.

Germany

The severity of impact from sediment spills during establishment of the tunnel fixed link solution on the German fisheries as derived from criteria leading to the degree of importance and the importance level of the individual fisheries.

Trawl

The severity of impairment on both the most (avoidance response >10 mg/l) and less (avoidance response >50 mg/l) sensitive commercial species to suspended sediment in the German trawl fisheries due to excess sediment was minor during the entire tunnel construction period (Table 5.18).

Table 5.18: The severity of impairment to the trawl fisheries due to sediment spills during the establishment of the tunnel fixed link solution. Results derived from analysis of the degree of impairment and the importance level of the individual fisheries as described in the method chapter.

Severity of impairment, sediment spill (%-ha) Tunnel	Threshold	Commercial species	Year	Dec-Apr	Mar-May	May-Aug	Sep-Nov	Year
Trawl Fehmarnbelt (ICES 38G1)	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014				Minor	Minor
			2015	Minor	Minor	Minor	Minor	Minor
			2016	Minor	Minor	Minor	Minor	Minor
			2017	Minor		Minor	Minor	Minor
			2018	Minor	Minor	Minor	Minor	Minor
			2019	Minor		Minor	Minor	Minor
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014				Minor	Minor
			2015	Minor	Minor	Minor	Minor	Minor
			2016	Minor	Minor	Minor	Minor	Minor
			2017	Minor	Minor	Minor	Minor	Minor
			2018	Minor	Minor	Minor	Minor	Minor
			2019	Minor	Minor	Minor	Minor	Minor

Severity of impairment, sediment spill (%-ha) Tunnel	Threshold	Commercial species	Year	Dec-Apr	Mar-May	May-Aug	Sep-Nov	Year
Trawl Fehmarnbelt Region	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014				Minor	Minor
			2015	Minor	Minor	Minor	Minor	Minor
			2016	Minor	Minor	Minor	Minor	Minor
			2017	Minor		Minor	Minor	Minor
			2018	Minor	Minor	Minor	Minor	Minor
			2019	Minor		Minor	Minor	Minor
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014				Minor	Minor
			2015	Minor	Minor	Minor	Minor	Minor
			2016	Minor	Minor	Minor	Minor	Minor
			2017	Minor		Minor	Minor	Minor
			2018	Minor	Minor	Minor	Minor	Minor
			2019	Minor		Minor	Minor	Minor

The greatest period of impact from increased suspended sediment was during the first 1.5 years of construction (end of 2015 and beginning of 2016). During this time a maximum of 69 ha (0.02%) of the German trawl fishing area in the Fehmarnbelt region was affected. However, this impact affected the resource only locally and was not a significant impact to the trawl fisheries as a whole as this impairment only lasted over a few days (less than 5% of the time) and there were other nonaffected trawling areas available to the fisheries.

Gill nets

The severity of impairment to the German gill net fisheries due to sediment spills and an increase in suspended sediment was minor during the entire tunnel construction period (Table 5.19).

Table 5.19: The severity of impairment to the gill net fisheries due to sediment spills during the establishment of the tunnel fixed link soliution. Results derived from analysis of the degree of impairment and the importance level of the individual fisheries as described in the method chapter.

Severity of impairment, sediment spill (%-ha) Tunnel	Threshold	Commercial species	Year	Dec-Apr	Mar-May	May-Aug	Sep-Nov	Year
Gill nets Fehmarnbelt (ICES 38G1)	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014				Minor	Minor
			2015	Minor	Minor	Minor	Minor	Minor
			2016	Minor	Minor	Minor	Minor	Minor
			2017	Minor		Minor	Minor	Minor
			2018	Minor	Minor	Minor	Minor	Minor
			2019	Minor		Minor	Minor	Minor
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014				Minor	Minor
			2015	Minor	Minor	Minor	Minor	Minor
			2016	Minor	Minor	Minor	Minor	Minor
			2017	Minor		Minor	Minor	Minor
			2018	Minor	Minor	Minor	Minor	Minor
			2019	Minor		Minor	Minor	Minor

Severity of impairment, sediment spill (%-ha) Tunnel	Threshold	Commercial species	Year	Dec-Apr	Mar-May	May-Aug	Sep-Nov	Year
Gill nets Fehmarnbelt Region	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014				Minor	Minor
			2015	Minor	Minor	Minor	Minor	Minor
			2016	Minor	Minor	Minor	Minor	Minor
			2017	Minor		Minor	Minor	Minor
			2018	Minor	Minor	Minor	Minor	Minor
			2019	Minor		Minor	Minor	Minor
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014				Minor	Minor
			2015	Minor	Minor	Minor	Minor	Minor
			2016	Minor	Minor	Minor	Minor	Minor
			2017	Minor		Minor	Minor	Minor
			2018	Minor	Minor	Minor	Minor	Minor
			2019	Minor		Minor	Minor	Minor

Winter and early spring were characteristically the worst period of sediment spillage in the German gill net fishing areas from the tunnel construction. During this time the most sensitive commercial species (cod, sprat, herring, whiting, horse mackerel, salmon, sea trout and garfish) were affected in approximately 96 ha of Fehmarnbelt (143 ha in Fehmarnbelt region) from December-April in 2015 and 61 ha of Fehmarnbelt (94 ha in Fehmarnbelt region) from December-April in 2016.

These areas were primarily near the northern coast of Fehmarn. Although this impact leading to a reduction of some commercial species could be considered significant on a local scale, it is not considered very significant to the overall gill net fisheries in Fehmarnbelt due to the potential mobility of the gill net fishermen, availability of other gill net fishing areas and the temporary status of the impact.

Pound nets

The severity of impact of sediment spill from the tunnel construction works on the commercial species associated with the German pound net fisheries was minor in all cases (Table 5.20).

Table 5.20: The severity of impairment to the pound net fisheries due to sediment spills during the establishment of the tunnel fixed link solution. Results derived from analysis of the degree of impact and the importance level of the individual fisheries as described in the methods chapter.

Severity of impairment, sediment spill (%-ha) Tunnel	Threshold	Commercial species	Year	Dec-Apr	Mar-May	May-Aug	Sep-Nov	Year
Pound nets Fehmarnbelt (ICES 38G1)	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014				Medium	Medium
			2015	Minor	Minor	Minor	Minor	Minor
			2016	Minor	Minor	Minor	Minor	Minor
			2017	Minor		Minor	Minor	Minor
			2018	Minor	Minor	Minor	Minor	Minor
			2019	Minor		Minor	Minor	Minor
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014				Minor	Minor
			2015	Minor	Minor	Minor	Minor	Minor
			2016	Minor	Minor	Minor	Minor	Minor
			2017	Minor		Minor	Minor	Minor
			2018	Minor	Minor	Minor	Minor	Minor
			2019	Minor		Minor	Minor	Minor

Severity of impairment, sediment spill (%-ha) Tunnel	Threshold	Commercial species	Year	Dec-Apr	Mar-May	May-Aug	Sep-Nov	Year
Pound nets Fehmarnbelt Region	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014				Minor	Minor
			2015	Minor	Minor	Minor	Minor	Minor
			2016	Minor	Minor	Minor	Minor	Minor
			2017	Minor		Minor	Minor	Minor
			2018	Minor	Minor	Minor	Minor	Minor
			2019	Minor		Minor	Minor	Minor
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014				Minor	Minor
			2015	Minor	Minor	Minor	Minor	Minor
			2016	Minor	Minor	Minor	Minor	Minor
			2017	Minor		Minor	Minor	Minor
			2018	Minor	Minor	Minor	Minor	Minor
			2019	Minor		Minor	Minor	Minor

The German pound net fisheries are undertaken at various locations along the coast of Fehmarn (see Figure 1.4) where the highest concentrations of sediment spillage and the most pronounced impact from this pressure is located (Figure 5.5).

Sediment spillage from 2015 and 2016 when sediment spills were greatest amounted to an impact of between 11 and 68 ha or 0.5-2.9% of the pound net fishing areas less than 5% of the time (Table 5.13). Despite the limited impairment on the pound net fisheries overall, this impact could potentially have a very significant impact on some local pound net fisheries where sediment plumes are most prominent and exceed threshold levels that could potentially reduce the abundance of the most sensitive commercial species (particularly cod) considerably.

Figure 5.5: The simulated distribution of suspended sediment exceeding 10 mg/l (green areas) in relation to the German pound net fisheries of Fehmarnbelt during one of the most intensive periods (September-November, 2015) of sediment spillage. The amount of time in this period the concentration exceeded >10 mg/l was between 2-5%.

5.3 Noise and vibration

Noise and vibration is an indirect pressure on the fisheries due to the potential effect it may have on the commercial fish that are the resources to the fisheries.

The noise scenarios related to the construction of an immersed tunnel are primarily caused by ramming of steel sheets during construction of the harbour and fabrication area, dredging work and ships traffic associated with work at sea. During the operation of the tunnel low frequent noise (vibrations) from passing trains and heavy traffic could be a source of impairment.

A comprehensive assessment of the impact of noise and vibration on fish, including commercial fish species, due to the construction and operation of an immersed tunnel is presented in another report (FeBEC, 2011, in progress).

The following activities and sources of noise according to potential impacts to fish were assessed in their report:

- Dredging – tunnel and reclamation
- Dredging – harbour and approaches
- Harbour construction – sheet piles (Rødby construction facility)
- Construction vessels
- Ship traffic (including changes to ferry service)
- Tunnel traffic [tunnel operation phase]

Thus, results from the fish assessment that pertain to commercial fish species and thus the commercial fisheries will be summarised in the individual chapters of this report.

5.3.1 Environmental indicators

Several commercial fish species are potentially impacted by noise and vibrations generated from the establishment and operation of an immersed tunnel. Noise above threshold levels (dB) and within frequencies (Hz) that fish can hear have been shown to trigger avoidance responses and thus resident commercial fish species that may be in the vicinity of a noise source or migrating commercial species passing a source might be impacted.

The important commercial fish or sub component to the fisheries that are relevant to consider in relation to noise and vibrations due to the establishment of the tunnel variant is given in Table 5.21.

Table 5.21: The fisheries sub components (commercial species) that are of interest for the assessment of noise and vibrations from the tunnel construction and operation.

Component	Sub-components Fisheries - gear	Sub-component Commercial species
Commercial fisheries	Trawl Gill/trammel nets Pound nets Danish seine nets	Atlantic cod Whiting Herring Sprat Flatfish species Horse mackerel Salmon Sea trout Garfish Eel

5.3.2 Sensitivity to pressure

The impact of noise on the commercial fish species in Fehmarnbelt depends not only on the noise level but also on the species-specific sensitivity to the emitted noise. The hearing ability of fish is species specific and varies significantly with both sound level (dB) and frequency (Hz).

A summary of ways fish hear and the hearing capabilities of some relevant commercial species are described in the assessment of the impairment of noise on fish (FeBEC 2012) and summarised in the following chapter.

Fish have several organs sensing sound. The lateral line organ responds to very low frequencies of less than 200 Hz and serves primarily to perceive water movements relative to the fish's body (Sand, et al., 1986; Enger, et al., 1989). The inner ear senses primarily frequencies up to one kHz, as the otoliths and the associated sensory hair cells primarily react to particle displacement of the water (Bone, et al., 1995).

Fish with a close association between the swim bladder and the ear are sensitive to sound pressure, while those lacking gas filled cavities are only sensitive to particle motion (ICES, 2005). The gas-filled swim bladder is more compressible than water and acts as a "pressure fluctuation transducer" that transmits the sound-induced pressure fluctuation via the endolymph to the otoliths. There, deflections of the hair cells are eventually induced (Bone, et al., 1995).

Fish can be characterized as hearing generalists or hearing specialists (Fay, et al., 1999). Fish that are hearing generalists do not sense frequencies beyond one kHz and fish without swim bladders such as flatfish are practically deaf to frequencies above 250 Hz, while fish with a swim bladder yet no other specialisation can hear up to 500 Hz (Westerberg, 1993). Hearing specialists, like herring have specialisations for linking the swim bladder to the inner ear where they basically react to pressure fluctuations.

Gadoids (Atlantic cod, whiting)
Cod is a hearing "generalist" but it is known to detect sounds of at least 38 kHz, meaning it has ultrasonic hearing ability (Astrup, et al., 1993). If the cod are to detect the ultrasound, the sound pressure has to be very high (app. 200 dB). Cod have also been shown to react on infra sound below 20 Hz (Sand, et al., 1986).

Clupeids (relevant commercial species – herring and sprat)
All clupeids (herring-fish) that have been investigated are considered hearing specialists. They have a unique ear structure in which a pair of thin air-filled tubes project from the swim bladder and terminate in air chambers that are connected with the utricles of the inner ear. Herring can hear frequencies up to four kHz (Mann, et al., 2001).

Flatfish (flounder, plaice, dab, turbot, brill and sole)
Flatfish have poor hearing capabilities and can probably not hear at frequencies above 250 Hz. Flatfish might be sensitive to sounds with very low frequencies as plaice have been shown to react to infra sound (Karlsen, 1992).The swim bladder degenerates after the larval phase.

European eel
Jerkø et al. (1989) found that European eel *(Anguilla anguilla*) has an upper audible frequency limit of app. 300 Hz. The lowest threshold (95 dB re 1 µPa) was measured at 80 Hz. This in consistent with results by Hawkins & Johnstone (1978), who found, that the upper audible frequency limit in eel was 380 Hz. The lowest sound pressure threshold (95 dB re. 1 µPa) was measured at 180 Hz. Eel was recorded to have a similar avoidance response as salmon at 10 Hz (Sand, et al., 2000).

Salmonids
Salmonids are hearing generalists with relatively poor hearing abilities. They are sensitive to low frequency sound, and juvenile salmonids display strong avoidance reactions to near-by infrasound at ten Hz reacting on particle acceleration > 0.01 m/s^2 (Knudsen, et al., 1992; Knudsen, et al., 1994). On the other hand Ploskey and Johnson (2000) found that sound at 10-35 Hz did not elicit avoidance from juvenile salmon, even at 160 dB.

5.3.3 Pressure indicators

The pressure indicators to the fish species important to the commercial fisheries due to noise and/or vibration depends on the noise level and can be summarised for adult fish in the following five levels of response:

Noise detection
The noise level that a species would normally be capable of detecting. This is equal to the hearing threshold value for the fish species in question.

Avoidance level
The noise level at which the species would start to exhibit active avoidance behaviour, either swimming away from a noise source or avoiding getting closer to a noise source.

Temporary hearing damage level
A more extreme noise level that could cause temporary but reversible shift in the individual's hearing sensitivity.

Permanent hearing shift level
The noise level that would cause a permanent shift in the individual's hearing sensitivity.

Physical damage level
The noise level or pressure level that would result in considerable physical damage to the organism's auditory system, other organs or tissues.

Based on a review of the literature and on laboratory studies undertaken by Nedwell et al. (2007), the general threshold values for the specific effects of sound on fish and used as the criteria for assessment of impacts to fish including commercial fish species are given in Table 5.22 (FeBEC 2012).

Table 5.22: The criteria suggested for the effects of noise on fish according to Nedwell et al. (2007). The symbol dBht represents the dB above the species specific hearing threshold (ht).

Level in dBht(Species)	Effect
Less than 0	None
0 to 50	Mild reaction in minority of individuals, probably not sustained
50 to 90	Stronger reaction by majority of individuals, but habituation may limit effect
90 and above	Strong avoidance reaction by virtually all individuals
Above 110	Tolerance limit of sound; unbearably loud
Above 130	Possibility of traumatic hearing damage from a single sound event

On the basis of these criteria, noise sources within which auditory effects of noise will occur can be calculated. No construction works for the tunnel are planned that would create noise levels above 130 dBht levels where fish may suffer injury or permanent damage to their hearing, thus assessment was limited to threshold values associated with triggering avoidance behaviour. Threshold values triggering responses are calculated such that 50% of the fish will show avoidance response if the noise level is 70 dB over the threshold for fish hearing a

sound, and 100% of the fish will show an avoidance response if the noise level is 90dB over the threshold level for when fish can hear a sound (Table 5.23).

Table 5.23: The estimated threshold values used to determine avoidance response for fish species during the assessment of the impact of noise on fish (FeBEC 2012).

FEBEC - E4-TR-041	Theshold dB	50 % avoidance 70 dB $_{ht}$	100 % avoidance 90 dB $_{ht}$
Codfish species/Clupeids-herring and sprat	> 75 dB	> 145 dB	> 165 dB
Other	> 90 dB	> 160 dB	> 180 dB

5.3.4 Magnitude of pressure

The noise scenarios associated with the construction and operation of an immersed tunnel are mostly related to the establishment of the construction and harbour area on the coast of Lolland and Fehmarn, the dredging and back filling of the tunnel trench, the traffic of heavy vessels in connection with placement of the tunnel elements and the low frequency noise generated by trains and heavy vehicles in the tunnel tubes during operation.

No information was presently available for noise scenarios associated with the establishment of the construction areas or the construction work at sea, however, some assumptions were used to make the best estimate possible (FeBEC 2012).

Noise from dredgers used in creating the tunnel trench and landfill areas as well as tugs and barges that will transport material will be the main sources of noise offshore along the tunnel transect. All dredgers are modelled as Trailing Suction Hopper Dredgers with an SPL of 184 dB. That is a worst case assumption.

Near Lolland and Fehmarn noise and vibrations will come from ramming of steel sheets and concret piling in the construction areas. This could be rather severe as pile ramming is the traditional way of driving these installations into the ground and gives off a noise level of approximately 195 dB. Another form for establishing installations is by using vibratory hammers which produce slightly lower sound pressure levels approximately 15-20 dB below a traditional pile hammer (US Army Corps of Engineers, 2004).

The ramming on the coast of Lolland is planned to take place from the end of 2014 to the beginning of 2016.

Operation
Heavy vehicles and trains might produce significant low frequency noise or vibrations during tunnel operations, however there were no estimates for the magnitude of pressures during tunnel operations at this time. Vibrations attenuate very quickly in water and the range of vibrations is accordingly low.

A more thorough description of the sources of noise and vibrations during the construction and operational activities is given in the assessment of the impacts to fish (FeBEC 2012).

5.3.5 Assessment criteria

Assessment criteria used to classify the reduction of sub-component to commercial fish species are given in Table 5.24. These criteria are modified from the assessment of noise on fish (FeBEC 2012).

Table 5.24: The assessment criteria used to classify the reduction of commercial fish species. Criteria derived from the assessment of impacts to fish (FeBEC 2012). The criteria for temporary noise in these tables are taken from the temporary reduction over three years.

Environmental component	Environmental sub-component	Reduction %		Magnitude of impact
		Temporary noise construction	Permanent noise operation	
Cod, herring, silver eel, whiting,	Migration	> 40	> 10	Very high
		< 40	< 10	High
		< 20	< 5	Medium
		< 10	< 2	Minor

Environmental component	Environmental sub-component	Reduction %		Magnitude of impact
		Temporary noise construction	Permanent noise operation	
Flatfish, sprat	Overall	> 60	> 15	Very high
		< 60	< 15	High
		< 30	< 8	Medium
		< 15	< 4	Minor

5.3.6 Degree of impairment

The estimated impairment on commercial fish species from noise and vibrations during the tunnel construction and operation is derived from data of the assessment of fish. The results from the construction period are presented in Table 5.25.

Their results indicated that during construction approximately 5.5% of the migration of codfish (gadoids) and herring and sprat (clupeids) will be lost in the near zone (+/- 500 m to each side of the tunnel transect) due to noise, while 1.1% of the migration of other species will be lost.

Estimates from the affects of noise on some commercial species (cod, herring, sprat, whiting and flatfish species) from the construction activities of the tunnel indicate that no more than 13 ha or 1.2% of any specific area in the Fehmarnbelt were affected by noise levels above threshold levels that would create an avoidance response in areas where it is anticipated that the fish feed or migrate (Table 5.25). Most lost areas are close to the construction harbours (12 ha for gadoids and clupeids near Rødby and three ha near Puttgarden).

Table 5.25: Estimated impact from noise and vibrations on some commercial species during construction acitivities (% and ha). Data derived from the environmental assessment of noise on fish (FeBEC 2012). Area descriptions DE EEZ and DK EEZ represent the German and Danish economic zones of Fehmarnbelt and DE 500 m and DK 500 m represent the 500 m zones of the tunnel transect within the Danish (DK) and German (G) waters of Fehmarnbelt (see FeBEC 2012 for further details of area descriptions).

Reduction of environmental sub-components of noise and vibrations (%-ha) Tunnel - Construction	**DE 10 km Nat.**	**DE 10 km EEZ**	**DK 10 km**	**DE 500 m Nat.**	**DE 500 m EEZ**	**DK 500 m**
Cod						
Feeding (>5 m)	0.00 (0.0)	0.00 (0.0)	0.00 (0.0)	0.42 (2.0)	0.39 (1.9)	0.38 (3.4)
Migration (>5m)				5.49 (255)	5.49 (245)	5.49 (445)
Whiting						
Migration (>5 m)				5.49 (255)	5.49 (245)	5.49 (445)
Herring*						
Feeding (>5 m)	0.00 (0.0)	0.00 (0.0)	0.00 (0.0)	0.42 (2.0)	0.39 (1.9)	0.38 (3.4)
Migration (>5 m)				5.49 (255)	5.49 (245)	5.49 (445)
Sprat						
Feeding (>5 m)	0.00 (0.0)	0.00 (0.0)	0.00 (0.0)	0.42 (2.0)	0.39 (1.9)	0.38 (3.4)
Migration (>5 m)				5.49 (255)	5.49 (245)	5.49 (445)
Flatfish						
Feeding (>0 m)	0.00 (0.0)	0.00 (0.0)	0.00 (0.0)	0.01 (0.1)	0.02 (0.1)	0.01 (0.2)
Migration (>5 m)				1.14 (53)	1.14 (51)	1.14 (93)
Eel						
Feeding (<10 m)	0.00 (0.0)	0.00 (0.0)	0.00 (0.0)	0.54 (0.7)	0.02 (0.0)	0.26 (2.9)
Migration (>2 m)				1.14 (53)	1.14 (51)	1.14 (98)
Protected species* Salmonids						
Migration (>5 m)				1.14 (53)	1.14 (51)	1.14 (93)

Table 5.26: Estimated reduction of environmental sub-components caused by noise and vibrations during operation % and ha (m for migration). Data derived from the environmental assessment of noise on fish (FeBEC 2012). Area descriptions DE EEZ and DK EEZ represent the German and Danish economic zones of Fehmarnbelt and DE 500 m and DK 500 m represent the 500 m zones of the tunnel transect within the Danish (DK) and German (G) waters of Fehmarnbelt (see FeBEC 2012 for further details of area descriptions).

Reduction of environmental sub-components of noise and vibrations (%-ha/m) Tunnel - Operation	**DE 10 km Nat.**	**DE 10 km EEZ**	**DK 10 km**	**DE 500 m Nat.**	**DE 500 m EEZ**	**DK 500 m**
Cod						
Feeding (>5 m)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Migration (>5m)				0 (0)	0 (0)	0 (0)
Whiting						
Migration (>5 m)				0 (0)	0 (0)	0 (0)
Herring*						
Feeding (>5 m)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Migration (>5 m)				0 (0)	0 (0)	0 (0)
Sprat						
Feeding (>5 m)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Migration (>5 m)				0 (0)	0 (0)	0 (0)
Flatfish						
Feeding (>0 m)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Migration (>5 m)				0 (0)	0 (0)	0 (0)
Eel						
Feeding (<10 m)	0 (0)	0 (0)		0 (0)		0 (0)
Migration (>2 m)				0 (0)	0 (0)	0 (0)

Protected species* Salmonids						
Migration (>5 m)				0 (0)	0 (0)	0 (0)

5.3.6.1 Classification of impact

The classification of the degree of impairment from noise and vibrations during construction (Table 5.27) and operation (Table 5.28) of the tunnel fixed link was “Minor” in all cases. Results derived from the assessment of the impacts to fish (FeBEC 2012).

Table 5.27: Classification of the degree of impairment from noise and vibrations on some commercial fish species during construction of the tunnel fixed link. Data derived from the environmental assessment of impacts on fish FEBEC 2012. Area descriptions DE EEZ and DK EEZ represent the Danish and German economic zones of Fehmarnbelt and DE 500 m and DK 500 m represent the 500 m zones of the tunnel transect within the Danish (DK) and German (DE) waters of Fehmarnbelt (see FEBEC 2012 for further details of area descriptions).

Degree of impairment of Noise and vibration, Tunnel - Construction	DE 10 km Nat.	DE 10 km EEZ	DK 10 km	DE 500 m Nat.	DE 500 m EEZ	DK 500 m
Cod						
Feeding (>5 m)				Minor	Minor	Minor
Migration (>5m)				Minor	Minor	Minor
Whiting						
Migration (>5 m)				Minor	Minor	Minor
Herring*						
Feeding (>5 m)				Minor	Minor	Minor
Migration (>5 m)				Minor	Minor	Minor
Sprat						
Feeding (>5 m)				Minor	Minor	Minor
Migration (>5 m)				Minor	Minor	Minor
Flatfish						
Feeding (>0 m)				Minor	Minor	Minor
Migration (>5 m)				Minor	Minor	Minor
Eel						
Feeding (<10 m)				Minor		Minor
Migration (>2 m)				Minor	Minor	Minor
Protected species* Salmonids						
Migration (>5 m)				Minor	Minor	Minor

Table 5.28: Classification of the degree of impairment from noise and vibrations on some commercial fish species during operation of the tunnel fixed link. Data derived from the environmental assessment of impacts on fish FEBEC 2012. Area descriptions DE 500 m and DK 500 m represent the 500 m zones of the tunnel transect (including or excludint the EEZ – economic zone) within the German (DE) and Danish (DK) waters of Fehmarnbelt (see FEBEC 2012 for further details of area descriptions).

Degree of impairment of Noise and vibration, Tunnel - Operation	DE 10 km Nat.	DE 10 km EEZ	DK 10 km	DE 500 m Nat.	DE 500 m EEZ	DK 500 m
Cod						
Feeding (>5 m)				Minor	Minor	Minor
Migration (>5m)				Minor	Minor	Minor
Whiting						
Migration (>5 m)				Minor	Minor	Minor
Herring*						
Feeding (>5 m)				Minor	Minor	Minor
Migration (>5 m)				Minor	Minor	Minor
Sprat						
Feeding (>5 m)				Minor	Minor	Minor

Migration (>5 m)				Minor	Minor	Minor
Flatfish						
Feeding (>0 m)				Minor	Minor	Minor
Migration (>5 m)				Minor	Minor	Minor
Eel						
Feeding (<10 m)				Minor		Minor
Migration (>2 m)				Minor	Minor	Minor
Protected species* Salmonids						
Migration (>5 m)				Minor	Minor	Minor

5.3.7 Severity and significance

Results derived from the assessment of the impacts to fish indicated that the severity and significance of the impact from noise and vibrations on commercial fish species and thus the fisheries resources during construction and operation of the tunnel fixed link was either considered “Insignificant” or “Minor” in all case (Table 5.29 and Table 5.30). At no time were there more than 13 ha (<1%) of any area in the Fehmarnbelt affected by noise that would create the most sensitive fish to sound to avoid an area.

Heavy low frequency noise and vibrations from passing trains and heavy vehicles during tunnel operations might impact the migration of several fish species, if the level of sound is very high. However, the assessment of the impact of noise on fish including some commercial fish species suggested that the overall impact from tunnel construction and operation activities is less than the impact from the current existing heavy traffic of ferries, and the establishment of a tunnel would presumably reduce the current noise level in Fehmarnbelt.

Table 5.29: Estimated severity of noise and vibrations on some commercial fish species during construction – results derived from assessment of fish in Fehmarnbelt (FeBEC, 2011, in progress). Area descriptions DE 10 km and DK 10 km represent a 10 km zone on each side of the tunnel transect that extends across Fehmarnbelt from Lolland to Fehmarn, DE EEZ and DK EEZ represent the Danish and German economic zones of Fehmarnbelt, and DE 500 m and DK 500 m represent the 500 m zones of the tunnel transect within the Danish (DK) and German (DE) waters of Fehmarnbelt (see FEBEC 2012 for further details of area descriptions).

Severity of impairment/loss of noise and vibration, Tunnel - Construction	**DE 10 km Nat.**	**DE 10 km EEZ**	**DK 10 km**	**DE 500 m Nat.**	**DE 500 m EEZ**	**DK 500 m**
Cod						
Feeding (>5 m)				Minor	Minor	Minor
Migration (>5m)				Minor	Minor	Minor
Whiting						
Migration (>5 m)				Minor	Minor	Minor
Herring*						
Feeding (>5 m)				Insignif.	Insignif.	Insignif.
Migration (>5 m)				Minor	Minor	Minor
Sprat						
Feeding (>5 m)				Insignif.	Insignif.	Insignif.
Migration (>5 m)				Minor	Minor	Minor
Flatfish						
Feeding (>0 m)				Minor	Minor	Minor
Migration (>5 m)				Insignif.	Insignif.	Insignif.
Eel						
Feeding (<10 m)				Insignif.		Insignif.
Migration (>2 m)				Minor	Minor	Minor
Protected species* Salmonids				-		
Migration (>5 m)				Minor	Minor	Minor

Table 5.30: Estimated severity of noise and vibrations on some commercial fish species during operation – results derived from assessment of fish in Fehmarnbelt (FeBEC 2012). Area descriptions DE EEZ and DK EEZ represent the Danish and German economic zones of Fehmarnbelt, and DE 500 m and DK 500 m represent the 500 m zones of the tunnel transect within the Danish (DK) and German (DE) waters of Fehmarnbelt (see FEBEC 2012 for further details of area descriptions).

Severity of impairment/loss of noise and vibration, Tunnel - Operation	**DE 10 km Nat.**	**DE 10 km EEZ**	**DK 10 km**	**DE 500 m Nat.**	**GE 500 m EEZ**	**DK 500 m**
Cod						
Feeding (>5 m)				Minor	Minor	Minor
Migration (>5m)				Minor	Minor	Minor
Whiting						
Migration (>5 m)				Minor	Minor	Minor
Herring*						
Feeding (>5 m)				Insignif.	Insignif.	Insignif.
Migration (>5 m)				Minor	Minor	Minor
Sprat						
Feeding (>5 m)				Insignif.	Insignif.	Insignif.
Migration (>5 m)				Minor	Minor	Minor
Flatfish						
Feeding (>0 m)				Minor	Minor	Minor
Migration (>5 m)				Insignif.	Insignif.	Insignif.
Eel						
Feeding (<10 m)				Insignif.		Insignif.
Migration (>2 m)				Minor	Minor	Minor
Protected species* Salmonids						
Migration (>5 m)				Minor	Minor	Minor

5.4 Hydrographical changes

Hydrographical changes will generally affect the fisheries indirectly by potentially influencing the migration and distribution of the commercial species (resource to the fisheries). Thus the assessment of the impact to the fisheries will primarily rely on results of the environmental impact of potential changes to fish (FeBEC 2012) with focus on commercial species due to the establishment of a tunnel fixed link solution.

In some instances if hydrographical changes lead to an increase in the speed of water currents then this may have an impact on the ability of some passive gear fisheries (gill nets, pound nets and fyke nets etc.) to be able to undertake their fisheries in some local areas. If it is assumed that this potential impact could arise then this will dicussed qualitatively.

Fehmarnbelt is a part of the transition area between the Baltic Sea and the North Sea. It has a maximum depth of approximately 30 m and the depth in the adjacent areas Mecklenburg Bight and Kiel Bight are almost similar. The upper water layers consist of low saline water from the central Baltic Sea, which flows through the Belt Sea and Kattegat close to the surface. The bottom water layer consists of more saline water from the North Sea. The two water layers in Fehmarnbelt are strongly stratified in the summer months when wind conditions are often weak.

In general, the establishment of an immersed tunnel is only expected to impact the hydrodynamics of Fehmarnbelt in a minor way. However, the seabed reclamation area along the coast could cause permanent impact on the water flows that could potentially affect the gill net and pound net pound fisheries in nearby areas. Additionally, there could arise temporary effects to the hydrodynamics in the area during the construction period.

A more thorough description of the hydrographical characteristics of the waters around Fehmarnbelt is described in the assessment of the impacts to fish (FeBEC 2012).

5.4.1 Environmental indicators

The Baltic Sea is one of the World's largest brackish water areas and several marine fish species have adapted to the low salinity and are an important resource to the commercial fisheries in the Western Baltic and Fehmarnbelt region.

Hydrographical changes are natural occurring pressures for fish in the Baltic Sea, and marine species living in the Baltic are specially adapted to the brackish water conditions with events of oxygen depletion in the deeper water layers. Important commercial fish species that spawn in the Western Baltic are cod, herring, sprat, plaice, dab and flounder. The salinity, temperature and oxygen content are important parameters driven by hydrographical characteristics especially for species with pelagic eggs for e.g. fertilization success and egg buoyancy.

The activities during the construction such as dredging and excavation can affect the vertical mixing, water exchange and current pattern and thus the hydrography in Fehmarnbelt. This might affect the distribution and abundance of important commercial fish species on a local scale.

The important commercial fish or sub-components to the fisheries that are relevant to consider in relation to hydrographical changes due to the establishment of the tunnel variant is given in Table 5.31.

Table 5.31: The commercial fisheries sub-components (gear types and commercial species) selected for the assessment of existing pressures from hydrographical changes for the evaluation of the tunnel alternative for the Fehmanbelt Fixed Link.

Component	Sub-components Fisheries - gear	Sub-components Commercial species
Commercial fisheries	Trawl Gill/trammel nets Pound nets Danish seine nets	Atlantic cod Whiting Herring Sprat Flatfish species Horse mackerel Salmon Sea trout Garfish Eel

5.4.2 Sensitivity to pressure

The sensitivity of the commercial fish species to pressure from changes in the hydrographical regime differs between species as well as the different life stages. Fish living in the Baltic Sea are especially sensitive to changes in salinity, temperature and oxygen concentrations. Much of this sensitivity is in egg and larvae stages where changes could have an effect on their survival. This is because it is often essential that pelagic eggs are held buoyant by minimum salinities and also need to be transported to important nursery areas and avoid sinking to the bottom where oxygen levels are often low. These impacts would eventually have an effect on recruitment to the commercial fish stocks

For adult fish which are more mobile, changes in salinity, temperature and oxygen concentrations has an affect on their distribution and abundances which will have an affect on where and how many fish are available to the commercial fisheries in Fehmarnbelt and its region.

This may be especially true for the European eel which is one of the fundamental species in the pound net fisheries. The Danish sounds and belts are important passages for the eel between the Baltic Sea and the North Sea. This applies to the migration of silver eel back to spawning grounds in the Sargasso Sea and eventually the return of glass eel and elvers arriving from spawning grounds

The importance of Fehmarnbelt as a passageway for eel was studied prior to the assessment, as it is the only major alternative to Øresund as a migration route for silver eel from the entire hinterland of the Baltic Sea. Results indicated that the choice of migration route of European eel between Øresund and Fehmarnbelt was not dependant on imprinting during the juvenile stage. Thus, the final route may therefore depend on conditions of water currents and salinity in the Arkona Basin to the east of Fehmarnbelt (FeBEC, 2011).

For cod, which is the most important commercial species in Fehmarnbelt in terms of economy, flatfish species, and sprat which all have pelagic eggs, the greatest anticipated impact to these species from changes in hydrodynamic changes is the survival of their eggs, and transport of larvae and juveniles to nursery areas. Thus it is the affects on recruitment that are the primary impacts to the commercial species from hydrodynamic changes.

Both juveniles and adult herring are primarily pelagic and their distribution is affected by hydrographical features such as temperature, depth of the thermocline, mixing, frontal systems and the abundance and composition of the zooplankton on which they feed.

A more thorough description of the sensitivity of different fish species is given in the assessment on fish (FeBEC 2012).

5.4.3 Pressure indicators

As mentioned, changes in the hydrology of Fehmarnbelt due to the establishment of a tunnel solution will primarily have an affect on the commercial fisheries by potentially affecting recruitment to the commercial fish stocks. Recruitment success is dependent on spawning success and survival of eggs and larvae.

Marine fish species are affected by the natural hydrographical fluctuations and threshold values. These values regard primarily eggs and larvae as these life stages are most sensitive to changes in the hydrology. The overall pressure indicators selected for the impact assessment on fish and thus indirectly on the fisheries was the mortality of eggs and larvae and decrease in recruitment.

A more thorough description of these indicators is given in the assessment on fish (FeBEC 2012). Results pertaining to the commercial fisheries will be summarised accordingly in the following chapters.

5.4.4 Magnitude of pressure

The magnitude of pressure is determined as the difference between the background level and the duration and range of the hydrographical pressures exceeding the specific threshold value for the specific environmental indicators.

The natural hydrology conditions in the Baltic Sea vary greatly both between years and within a year. The impact from an immersed tunnel on the hydrology is very limited and the magnitude of pressure is very close to the fluctuations occurring in the zero-alternative.

Hydrographical pressures will mainly be caused by the structure of a fixed link. The pressure of the structure is permanent. However, the sensitivity will vary throughout the year, because eggs and larvae are particularly sensitive to hydrographical changes. Additionally, the present hydrographical conditions in the Baltic Sea are highly variable.

The blocking effect from reclamation areas and other parts of an immersed tunnel solution is estimated to be extremely low and the flow blocking is only 0.01 % (FEHY, 2011).

At the work harbour at Puttgarden and the immediate vicinity of the reclamation areas and the production facility access channel on the Lolland side, there will be local effects to currents. These effects are anticipated to be limited to only local areas. Thus the effects of changes in salinities and temperature in Fehmarnbelt are anticipated to be very local and limited. Furthermore, there are no indications of effects from a tunnel on concentration of local dissolved oxygen (FEHY, 2011).

The effects on local water quality and the Baltic Sea are assessed as non-existing due to the very limited permanent effects on the hydrography (FEHY, 2011).
The temporary work during the construction period and the production facility structures is not expected to add to the limited blocking effect seen in the permanent solution (FEHY, 2011).

In summary, the regional effects of a tunnel are assessed to be insignificant based on the modelling of local effects showing no blocking of flow. Furthermore, the local effects to water quality are assessed to be insignificant as a result of the local model of the hydrodynamic (FEHY, 2011).

Because the effects to hydrography and water quality are assessed to be insignificant, the effects of a tunnel solution to the fish communities of commercial species in Fehmarnbelt and adjacent areas are considered to be insignificant.

The magnitude of hydrographical pressures is insignificant compared to the current conditions. Regarding impacts to recruitment, the mortality of pelagic eggs is already high due to the low salinity which prevents eggs from staying buoyant in water layers with sufficient oxygen.

5.4.5 Assessment criteria

The assessment criteria used to classify the degree of impairment follows the general principles described in the methodology section (section 3.2.4).

5.4.6 Degree of impairment

The degree of impairment to fish communities including commercial fish species, due to effects by potential changes in the hydrographical regime were not fully assessed on a large scale because affects are very local and considered limited. This is due to only small physical changes in Fehmarnbelt, which includes the extension of land due to land reclamation along southern Lolland coast and some changes in the seabed structure in the tunnel trench. These affects were assessed in relation to potential impacts to the early fish stages (spawning, eggs and larvae drift) because these would be the most sensitive to changes in hydrography.

5.4.6.1 Analyses of impact

The assessment considered the reduction of environmental sub-components relative to background hydrographical conditions.

The effects on salinity and water temperature in the water column in Fehmarnbelt due to hydrographical changes will be very local and only of limited magnitude and these effects on the Baltic Sea are considered to be of insignificance (non-existant). Similarly, impairment to spawning, eggs and larvae are classified as only being minor.

5.4.6.2 Classification of impact

The assessment of fish and thus the commercial fish species has considered the magnitude of pressure and the reduction of environmental sub-components was relative to the background hydrographical conditions (FeBEC 2012). The results for spawning and egg-larve drift for cod, herring sprat and flatish was minor in all cases.

5.4.7 Severity and significance

The severity and significance of the impact to fish and thus the commercial fish species in all areas of Fehmarnbelt and it region due to changes in the hydrographical regime was either minor or insignificant in all cases (Table 5.32) (see the assessment of the impacts to fish (FeBEC 2012) for a more thorough description within the Fehmarnbelt).

Table 5.32: The severity of the impact to fish in all areas of Fehmarnbelt and its region. Data derived from the assessment on fish (FeBEC 2012).

Severity of impairment of Hydrographical regime, Tunnel - Structure	**DE 10 km**	**DK 10 km**	**DE EEZ**	**DK EEZ**	**DE 500 m**	**DK 500 m**	**Rødsand lagoon**
Cod							
Spawning (>20 m)	Minor	Minor	Minor	Minor	Minor	Minor	-
Egg-larvae drift (>10 m)	Minor	Minor	Minor	Minor	Minor	Minor	-
Herring*							
Spawning (mod)	Insignif.	Insignif.			Insignif.	Insignif.	Insignif.
Sprat							
Spawning (>10 m)	Minor	Minor	Minor	Minor	Minor	Minor	-
Egg-larvae drift (>10 m)	Minor	Minor	Minor	Minor	Minor	Minor	-
Flatfish							

Spawning (>15 m)	Minor	Minor	Minor	Minor	Minor	Minor	-
Egg-larvae drift (>10 m)	Minor	Minor	Minor	Minor	Minor	Minor	-

5.5 Other pressures (light, electromagnetic fields, contaminants etc.)

Other pressures that primarily will have an influence on the behaviour of commercial fish species and that are related to the tunnel scenario are mostly associated with the construction phase.

- *Artificial light*
  The construction work at sea implies additional artificial light from operating vessels, although this work presumably would be primarily in the daytime. The impact is considered negligible.

- *Spill of hazardous materials*
  Accidental spill of hazardous materials from the operating vessels might occur, but this assumed to only occur on a very small scale and it is not considered to have measurable impact on the commercial fish stocks.

- *Electromagnetic fields* (EMF)
  In the operational phase of the immersed tunnel solution the only potential pressure besides noise and vibration is electromagnetic fields (EMF) generated from the power supply cables for the electrified trains. The AC cables used for the electrified trains generate only a very weak EMF with a range of few metres. Taken into account, that the top of the tunnel is 3 m beneath the seabed the EMF would hardly be detectable on the seabed. Furthermore, the majority of migrating fish species have a pelagic migration (herring, sprat, whiting) or migrate near the surface well away from the potential EMF. Thus, EMF is not believed to have any impact on the distribution of fish and thus the resource to the commercial fisheries.

5.6 Cumulative and transboundary impacts

This section describes the probable and significant cumulative and impacts of the tunnel fixed link alternative in conjunction with other marine projects.

5.6.1 Cumulative impacts - projects and possible interactions

When other projects within the same region of the planned fixed link affect the same environmental conditions simultaneously, cumulative impacts can occur. For a project to be relevant to include in this assessment, it requires that the project:

- is within the same geographic area
- has some of the same impacts as the fixed link
- affects some of the same environmental conditions
- creates new environmental impacts during the period from the completion of environmental investigations to the operation of the fixed link.

The following projects at sea are considered relevant to include in the assessment of cumulative impacts with the fixed link tunnel alternative on different environmental conditions. All of the projects considered are offshore wind farms:

Projects relevant for the cumulative analysis in relation to the tunnel solution.

Project	Placement	Phase	Possible interactions
Arkona-Becken Südost	North East of Rügen	Construction	Sediment spill, habitat displacement, collision risk, barrier effect
EnBW Windpark Baltic 2	South East of Kriegers Flak	Construction	Sediment spill, habitat displacement, collision risk, barrier effect
Wikinger	North East of Rügen	Construction	Sediment spill, habitat displacement, collision risk, barrier effect
Rødsand II	Off Lolland's southern coast	Operation	Coastal morphology, collision risk, barrier risk
Kriegers Flak II	Kriegers Flak	Construction	Sediment spill, habitat displacement, collision risk, barrier effect
GEOFReE	Lübeck bay	Construction	Sediment spill, habitat displacement, collision risk, barrier effect

Rødsand II is also specifically included as this is a project that went into operation, while the Fehmarn conducted its environmental investigations, however because of its close proximity a cumulative effect in principle cannot be excluded.

Some projects are not selected for assessing potential cumulative impacts. This "non-selection" is based on whether a project was in operation, while the environmental investigations were carried out. In these cases their environmental impacts are included in the environmental baseline investigations, and are therefore included in the benchmark for the environmental assessment. Thus all their cumulative impacts are included in the environmental assessment of the fixed link.

Other reasons for not including projects and their potential impacts in a cumulative impact assessment include:

- A project has not yet been applied for. Impacts would be expected to occurr later than impacts from the fixed link.

- There are activities and changes over time, e.g. increase in shipping traffic, which is not of a project character. Thus, these are not considered as cumulative impacts. Instead, these changes would be included in the 0-alternative, if applicable.

- Potential consequences of climate change on the environmental assessment results in the long term are described in a separate chapter.

The following projects were considered and their reasons for not being included are given in the following table:

Project	Placement	Cause
Wind farm Baltic 1	The Baltic, Northeast of Darss	In operation
Wind farm Beta Baltic	Mecklenborg bay	Not applied for
Wind farm SKY 2000	East of Fehmarn	Not applied for
Wind farm "Vindeby"	North of Lolland	In operation - Distance
The Øresund bridge	The Sound	In operation
The Great Belt bridge	The Great Belt	In operation
Raw material extraction areas in German territorial waters	The southern Baltic	Not applied for, not of project character

5.6.2 Assessment and significance of cumulative and transboundary impacts

Cumulative impacts
Cumulative effects can occur both during the construction or operational phase of the tunnel fixed link alternative.

During the construction phase, the majority of the cumulative impacts to the fisheries are expected to be associated with changes in the distribution and density of the fishery resources (commercial fish species). If activities causing sediment spill during the construction phase of the tunnel such as dredging, or activities causing extreme noise situations overlap in time and space with similar events during the construction of other installations, then these impacts could instigate or further enhance avoidance responses in commercial fish and have a compounding impact on the distribution of commercial fish species and thus the fisheries.

Similarly, compounding effects of enhanced sediment concentrations or extreme noise might also create a barrier effect for migratory fish e.g. anadromous species (Atlantic salmon and sea trout) as well as cod, herring and sprat caused by overlapping zones of impact. If important migratory commercial species avoid areas of high impact and thus reach important fishing areas then this would have an effect on the fisheries.

In the tunnel fixed link solution, simulated suspended sediment and sedimentation rates beyond the tunnel alignment corridor are equal to naturally occurring rates (e.g. sediment rates during storms and high current flow). Depending on weather and current conditions, it is not likely that the impacts from suspended sediment from tunnel construction activities will overlap extensively with other projects also creating greater amounts of suspended sediment. It is therefore assumed that it would be possible for migrating commercial fish species to use sections of areas where suspended sediment in the water is low as migration routes, thus only minor barrier effects to migrating fish would be expected due to cumulative impacts of sediment spill during tunnel construction.

The environmental assessment indicates there is a possibility of cumulative impacts from sediment spill between the installation of the immersed tunnel and the offshore wind farm 'GEOF-

ReE', because sediment spill could overlap in time and space depending on when the project is constructed. This may indirectly impact fish and thus the commercial fisheries. However, based on experience from similar projects, it is estimated that the cumulative impacts from sediment spill will not be significant. Furthermore, cumulative impacts from 'GEOFReE' will not occur if the GEOFReE' wind farm project is not constructed at the same time as the tunnel fixed link.

There is also a possibility of cumulative effects from the tunnel reclamation areas and the Rødsand II offshore wind farm on the coastal morphology of Lolland in the operational phase. An environmental assessment of Rødsand II showed that this installation has an effect on erosion and deposition of material along the coast. A cumulative impact could occur from changes in local currents and sediment deposition due to the change in the coastal morphology from both extended land areas from the tunnel solution and change in hydrography from the windfarm foundations of Rødsand I and II on the south coast of Lolland. Impacts can be characterised as both leading to a slight increase of sedimentation in som areas and counteracting resuspension in other areas. It is assumed however that overall effects will be minor or insignificant both individually and collectively.

Cumulative impacts on the fisheries from seabed extraction and planned wind parks at Kriegers Flak and Rønne Banke in conjunction with the construction of the tunnel solution in Fehmarnbelt are not considered likely because of the distance to both Kriegers Flak and Rønne Bank extraction and windfarm sites and the Fehmarnbelt fixed link. Thus any impacts from these distant activities and installations would be considered insignificant or at worst of minor significance. Additionally, there are no fixed dates for the establishment of the wind farms, so it is possible that there will not be coinciding impacts in time and space between the projects.

No cumulative impacts are expected in relation to the operating offshore windparks “Nysted”/“Rødsand II” and the planed wind farms “Arkona-Becken Südost “, “EnBW Windpark Baltic 2”, “Wikinger“ and “Kriegers Flak II” (distances are too large for cumulative effects).

No significantly negative environmental effects on fish stocks are expected during the operational phase.

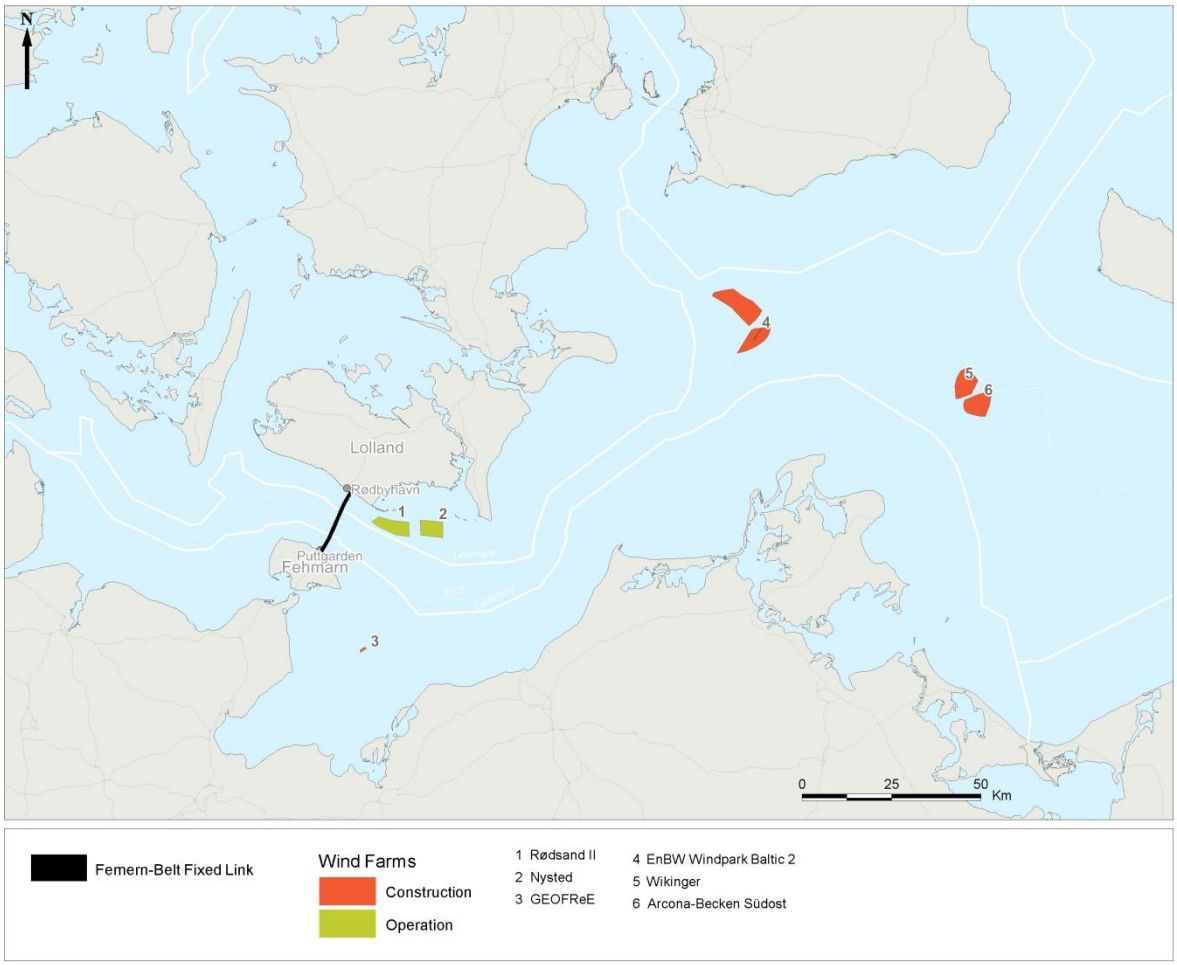


Figure 5.6: Overview of all projects in the Baltic Sea which can affect fish species and communities in the area of Fehmarnbelt by cumulative impacts.

Transboundary impacts

Concerns about transboundary impacts from development projects generating tensions and even conflicts between countries led to the forming of the Convention on Environmental Impact Assessment in a Transboundary Context also known as the Espoo Convention (Espoo Convention 1991). The Convention was adopted with the support of the United Nations Economic Commission for Europe (UNECE) and implemented in 1997 with the general aim of "ensuring environmentally sound and sustainable development in potentially transboundary projects" through open communication and if necessary international cooperation.

Denmark and Germany are the only 2 countries that have commercial fisheries in Fehmarnbelt and its region in the Western Baltic. An assessment of impacts due to the establishment of Fehmarnbelt Fixed Link tunnel solution directly relating to these fisheries has been undertaken in this report. However, a number of the commercial fish species present in Fehmarnbelt also migrate over large distances between spawning grounds, nursery areas and feeding grounds. During these migrations and residency periods, these commercial species will come to pass through or reside in national waters of other countries or in international waters and will be available to the respective fisheries of other countries.

Thus, it is recognised that the commercial fisheries in other countries could be indirectly impacted if shared commercial fish stocks are substantially impacted by the establishment of the Fehmarnbelt Fixed Link tunnel solution.

Assessments in relation to potential transboundary impacts to the commercial fisheries of other countries were assessed on the following migratory fish stocks in Fehmarnbelt listed together with the main countries that include these stocks in their commercial fisheries.

Commercial fish stocks	Primary areas of commercial fisheries	Main countries that undertake fisheries on these stocks
Cod (*Gadus morhua*)	Western Baltic	Denmark, Germany, Sweden, Poland, Estonia, Latvia, Finland and Lithuania*Den
Herring (Clupea harengus)	Western Baltic, Kattegat, Skagerrak and North Sea	Denmark, Sweden, Germany, Norway, Faroe Islands and Lithuania*
Sprat (Clupea sprattus)	Western Baltic	Denmark, Germany, Sweden, Poland and Finland
European eel (Anguilla anguilla)	Baltic Sea and Kattegat	Denmark, Sweden, Poland, Lithuania, Estonia, Latvia, Germany and Finland
Whiting (*Merlangius merlangus*)	Western Baltic	Denmark, Sweden and Norway

Results of the impact to the spawning, eggs and larvae, nursery area, feeding area and migration of the commercial fish stocks (cod, herring, sprat, European eel and whiting) that are recognised as transboundary stocks due to the construction, operation and structures for the tunnel fixed link solution are as follows:

Impacts from the construction, operation and structures of the tunnel project were low to medium on all commercial fish stocks that have extended geographical distributions. Impacts greater than “low or insignificant” were only registered in the near vicinity of the fixed link and can be considered insignificant in relation to potentially impacting any of the fish stocks other than on a local scale.

5.7 Project impact

5.7.1 Fishery sub-components

5.7.1.1 Denmark

The project impacts for each of the Danish fishery sub-components (trawl, gill nets, pound nets and Danish seine nets) are given in Table 5.33 and summarised in this section.

Table 5.33: The project impacts for the different sub-components of the Danish fisheries in the Fehmarnbelt (ICES 38G1) and the Fehmarnbelt Region in relation to pressures from the construction, operation and structures of the tunnel solution.

Fehmarnbelt (ICES 38G1) Tunnel	Reclamation areas/Footprints	Sediment spill	Noise and vibration	Hydrographical changes	Other pressures	Indirect pressures	Project impairment	Importance	Severity of impairment	Severity of loss
Trawl							Minor	Medium	Minor	Medium
Gill nets							Minor	Medium	Minor	Medium
Pound nets							Minor	Very high	Minor	Very high
Danish seine nets							Minor	Minor	Insignificant	Minor
Project severity									Minor	Very high

Fehmarnbelt Region - Tunnel	Reclamation areas/Footprints	Sediment spill	Noise and vibration	Hydrographical changes	Other pressures	Indirect pressures	Project impairment	Importance	Severity of impairment	Severity of loss
Trawl							Minor	Medium	Minor	
Gill nets							Minor	Medium	Minor	
Pound nets							Minor	Very high	Minor	
Danish seine nets							Minor	Minor	Insignificant	
Project severity									Minor	

Trawl
There were no impacts on the Danish trawl fishery in Fehmarnbelt and its region that exceeded “Minor” during construction activities or the operation of the tunnel. The loss of fishing area due to reclamation of areas/footprints was “Medium” according to the importance of this fishery. There might be considerable affects to the trawl fisheries from loss of fishing area due to the tunnel trench, depending on whether trawling activities over the tunnel trench will eventually continue without the potential for gear damage or added restrictions to the undertaking of the fisheries after the construction period and natural recovery of the seabed over time. There were no aggregating impacts causing changes in the project impairment thus the project severity for trawl is “Minor” in Fehmarnbelt and the Fehmarnbelt region.

Gill nets
Similar to the impact on trawls there were no impacts on the Danish gill net fishery in Fehmarnbelt and its region that exceeded “Minor” during construction activities or the operation of the tunnel. The small loss of fishing area due to reclamation of areas/footprints was “Medium” according to the importance of this fishery. There were no aggregating impacts causing changes in the project impairment thus the project severity for the gill net fisheries and their

associated sub-components (commercial fish species) is “Minor” in Fehmarnbelt and the Fehmarnbelt region.

Pound nets
There were no impacts on the pound nets fishery in Fehmarnbelt and its region that exceeded “Minor” during construction or operation activities, although sediment plumes were greatest along the coastal areas of Lolland and may have an impact during short time intervals that could have a considerable impact on the these fisheries.

There were no aggregating impacts causing changes in the project impairment. thus the project severity for the pound nets is “Minor”.

Danish seine nets
There were no impacts on the Danish seine net fishery in Fehmarnbelt and its region that exceeded “Minor” during construction activities, the operation of the tunnel or due to reclamation of areas/footprints. The seine net fisheries are more or less isolated in the deeper central parts of Fehmarnbelt where impacts from sediment plumes, noise and hydrographical changes have least affects. There were no aggregating impacts causing changes in the project impairment thus the project severity for the Danish seine nets is “Minor” or insignificant in Fehmarnbelt and the Fehmarnbelt region.

5.7.1.2 Germany

The project impacts for each of the German fishery sub-components (trawl, gill nets and pound nets) are given in Table 5.34 and summarised in this section.

Table 5.34: The project impacts for the different sub-components of the German fisheries in the Fehmarnbelt (ICES 38G1) and the Fehmarnbelt Region in relation to pressures from the construction, operation and structures of the tunnel solution.

Fehmarnbelt (ICES 38G1) Tunnel	**Reclamation areas/Footprints**	**Sediment spill**	**Noise and vibration**	**Hydrographical changes**	**Other pressures**	**Indirect pressures**	**Project impairment**	**Importance**	**Severity of impairment**	**Severity of loss**
Trawl							Minor	Medium	Minor	Medium
Gill nets							Minor	Medium	Minor	Medium
Pound nets							Minor	Very high	Minor	Very high
Project severity									Minor	Very high

Fehmarnbelt Region - Tunnel	**Reclamation areas/Footprints**	**Sediment spill**	**Noise and vibration**	**Hydrographical changes**	**Other pressures**	**Indirect pressures**	**Project impairment**	**Importance**	**Severity of impairment**	**Severity of loss**
Trawl							Minor	Medium	Minor	
Gill nets							Minor	Medium	Minor	
Pound nets							Minor	Very high	Minor	
Project severity									Minor	

Trawl

There were no impacts on the German trawl fishery in Fehmarnbelt and its region that exceeded “Minor” during construction activities and the operation of the tunnel. The loss of fishing area due to reclamation of areas/footprints was considered “Medium” according to the importance of this fishery. This is based on the assumption that the trawl fisheries over the tunnel trench cannot be undertaken without the potential for gear damage or if there come restrictions to the undertaking of trawl fisheries over the trench after the construction period.

There were no aggregating impacts causing changes in the project impairment thus the project severity for trawl is “Minor” in Fehmarnbelt and the Fehmarnbelt region.

Gill nets

There were no impacts on the German gill net fishery in Fehmarnbelt and its region that exceeded “Minor” during construction activities and the operation of the tunnel. The loss of fishing area due to reclamation of areas/footprints was considered “Medum” according to the medium importance of the gill net fisheries. There were no aggregating impacts causing changes in the project impairment thus the project severity for German gill nets is “Minor” in Fehmarnbelt and the Fehmarnbelt region.

Pound nets

There were no impacts on the German pound net fishery in Fehmarnbelt and its region that exceeded “Minor” during construction activities and operation of the tunnel. There were no aggregating impacts causing changes in the project impairment thus overall the project severity for pound nets is “Minor”.

6. Assessment of impacts of main bridge alternative

6.1 Seabed reclamation

During the establishment of the bridge variant in Fehmarnbelt areas of the seabed will be lost to bridge structures such as piers, pylons and ramp embankments as well as their associated protective scouring foundations. These physical structures will be spaced a set distances along a corridor that transverses Fehmarnbelt from Lolland to Fehmarn, thus a potential permanent loss of fishing area will occur along the entire bridge alignment.

6.1.1 Environmental indicators

The most important commercial fisheries in Fehmarnbelt that could be impacted by a bridge fixed link are trawling and Danish seine net fishing which are primarily undertaken in the central part of Fehmarnbelt, the gill net fisheries which are undertaken in areas near the southern Lolland and Fehmarn coast as well as in a belt that stretches across the western part of Fehmarnbelt, and pound net fisheries along both the southern coast of Lolland and the northern/northeastern coast of Fehmarn.

Furthermore, bridge structures could reduce the area of important fish habitats or change hydrographical characteristics in Fehmarnbelt and its region which could affect the abundance, distribution and migration routes of different commercial fish species and thus their availability to the fisheries.

The important commercial fish or sub component to the fisheries that are relevant to assess in relation to area reclamation and structures due to the establishment of the bridge alternative is given in Table 6.1.

Table 6.1: On overview of the fisheries components trawl, gill nets, pound nets and Danish seine nets that are selected for the assessment of impacts due to the establishment of bridge structures, reclamation areas and assumed restricted areas (Bridge shipping lanes).

Component	Sub-components Fisheries - gear
Commercial fisheries	Trawl Gill/trammel nets Pound nets Danish seine nets

6.1.2 Sensitivity to pressure

The sensitivity of the fisheries (trawl, gill nets, pound nets and seine nets) to the bridge footprints is different for each fishery and dependent on the extent of area loss, its location and limitations to undertaking fisheries which can arise due to restrictions of area use (shipping lanes).

The trawl and seine net fisheries in Fehmarnbelt are undertaken in the central deeper (>10 m) parts. Here, trawl hauls can stretch the length of Fehmarnbelt as hauls often last several hours and can be over many kilometres (15-30) in length. Bridge structures extending across trawl routes will affect the undertaking of this fishery as it creates a barrier that hinders or stops their progress. This would lead to an increase in time consuming operations as gear needs to lifted before and reset after passage of the bridge if trawlers want to continue. Similarly, seine net fishermen set their nets and retrieve them over a broad area and are also disturbed and affected by physical structures within their fishing grounds.

Furthermore, if there are restrictions to undertaking fisheries in shipping lanes or areas of traffic separation that extends from a bridge, such as is the case in the Great Belt Bridge, then the actual area lost to trawling or seine net fishing is much greater. This not only includes restrictions to trawling under the bridge but also restrictions to vessels crossing shipping lanes making it necessary to turn a trawling vessel away from a bridge several kilometres before the bridge. This appeared evident in a study of the trawling activities around the Great Belt Bridge. VMS data plots showing the distribution of the trawl fishery indicated trawlers almost never fished within three kilometers of each side of the bridge (Figure 6.1). Previous to the establishment of the Great Belt Bridge the deep channel that now runs under the bridge (deep blue in colour) was one of the most popular trawling routes for catching cod.

Figure 6.1: Trawl fishing activity around the The Great Belt Bridge in Denmark. Data derived from VMS data plots for vessels ≥15 m. (Source: FeBEC 2011b).

The gill/trammel net fisheries will be sensitive to the potential loss of fishing areas due to bridge structures, reclamation areas and areas forbidding the undertaking of fisheries (traffic separation lanes). This could have an impact on this fishery if lost areas contained habitats that attract commercial species or are areas where important commercial species were abundant. In contrast, added structures to the environment from bridge pylons, piers and protective scour material creates an artificial reef environment which can attract more fish than a less heterogeneous environments. These types of environments are often good fishing areas and are accessible to the gill net fisheries which are used to and capable of carrying out their fisheries in mixed heterogenous environments.

The trawl, gill net and seine net fisheries are all capable of moving their fisheries to alternative areas if available which may require longer fishing trips at a greater cost. Depending on the quality and distance of alternative fishing areas, this mobility is a key characteristic in these fisheries that help determine their sensitivity to temporary or permanent loss of fishing areas.

In contrast, the pound net fisheries which are stationary along the coast where fishermen are bound by the area in which they obtain permission to fish are very vulnerable to loss of fishing areas or impacts to the resources in their local area. Thus this fishery is very sensitive to impacts from piers, reclamation areas and loss of habitat within their fishing environment which

leads to a direct loss of fishing areas, where they are compounded by the fact that they have no possibility of utilising alternative fishing areas.

6.1.3 Pressure indicators

The temporary or permanent loss of fishing areas affects fisheries according to the location, extent and duration of the footprints due to the establishment of a bridge fixed link solution. In all cases the pressure indicator is determined by the temporal (temporary/permanent) and spatial extent of the area of fishing grounds lost to these pressures.

It is possible to measure the affects of reclamation areas and structures on the trawl and seine net fisheries by estimating the temporary and permanent loss of their fishing grounds in the more central parts of Fehmarnbelt due to the pylons, pillars and ship traffic corridors that will be established during the construction and operation of the bridge fixed link solution.

Similarly, the gill net and pound net fisheries will also temporarily and permanently lose a certain amount of area and thus a proportion of their fishing grounds in the more coastal areas of Fehmarnbelt.

6.1.4 Magnitude of pressure

A summary of the primary bridge structures and reclamation areas causing footprints during the establishment of the bridge alternative is given in Table 6.2

Permanent changes of the seabed will occur due to construction and structures from establishing the bridge fixed link solution. Permanent changes will occur from establishing pylon and pier foundations along a transect from Lolland to Fehmarn, as well as establishing ramp areas near both of these coasts, Rødbyhavn (Lolland) and Puttgarden (Fehmarn). Some area use comprising some of the construction work harbours will only be temporary and will be scaled back after construction.

Furthermore, the bridge itself and the narrow spaces between the pillars will create a barrier for undertaking some active fisheries such as trawling and seine netting and potential loss of some gill net fishing areas due to fishing restrictions. This will be compounded by the likely establishment of a traffic separation system under one or or more sections of the bridge. If passage lanes are similar to those of the Great Belt Bridge then there will be restrictions to undertake fisheries along a form for buffer zone up to 2.7 km from the bridge. In addition, it is prohibited to sail or fish across these lanes, which creates an even greater belt of area from which the practice of active fisheries such as trawling and seine net fishing will be strongly impaired.

Table 6.2: A summary of the primary bridge structures and reclamation areas causing footprints during the establishment of the bridge alternative.

Primary bridge structures causing footprints	Footprint area (ha)
Bridge – piers, pylons and reclamation/embankment areas	79.24 total *** 55.64
Working harbour and access channel	23.58
Bridge shipping lanes and associated area loss to fisheries	10,583 total

6.1.5 Assessment criteria

The assessment criteria used to classify the magnitude of the impact to the fisheries from seabed reclamation and footprints associated with the establishment of the bridge fixed link solution are given in section 3.2.3 (Table 3.7). In general, these pressures are estimated to be of permanent or long term character and are thus assessed as permanent impacts when using the criteria guidelines.

6.1.6 Degree of impairment

Denmark
A summary of the percentage of fishing area loss (%) and area loss (ha) of the Danish fisheries due to bridge footprints in comparison to the total fisheries in Fehmarnbelt and region is given in Table 6.3.

Table 6.3: The percentage of fishing area loss (%) and area loss (ha) to the fisheries (trawl, gill nets, seine nets and pound nets) due to bridge footprints in comparison to the total fisheries in Fehmarnbelt (ICES 38G1) and its region for trawl, gill nets and seine nets, and the southern coast of Lolland for pound nets.

Reduction of fishery sub-components, footprints (%-ha) Bridge - Denmark	**Fehmarnbelt (ICES 38G1) % (ha)**	**Fehmarnbelt region % (ha)**
Trawl		
Bridge - pylons, piers and embankment	0.05% (12)	
Bridge - shipping lanes and restricted areas	16.01% (5750)	0.26% (336)
Gill nets		
Bridge - pylons, piers and embankment	0.01% (2)	
Bridge - shipping lanes and restricted areas		
Danish seine nets		
Bridge - pylons, piers and embankment	0.04% (6)	
Bridge - shipping lanes and restricted areas	8.12% (1369)	
Pound nets	**Southern coast of Lolland (see Figure 1.5)**	
Bridge - pylons, piers and embankment	0.53% (32)	
Bridge - shipping lanes and restricted areas		

Overall 7,171 ha of the Danish fisheries in the Fehmarnbelt (ICES 38G1) including the pound net fishery area along the southern couast of Lolland are affected by bridge pylons, piers and embankments. The primary loss of area is due to the bridge shipping lanes (6,086 ha in all) where fishing is not allowed under the bridge and the non fishing zones.

32 ha or 0.5% of the Danish pound net fisheries, which is a fishery with a very high importance are affected by loss of area. This loss is due to the footprints of the bridge pylons and embankments along the Lolland coastal area.

The Danish trawling fisheries in Fehmarnbelt, which is of medium importance, will lose approximately 5,750 ha or 16.01% of the trawl fishing area in Fehmarnbelt (38G1) and an additional 336 ha in the Fehmarnbelt region to the anticipated footprint of the shipping lanes, and their limiting effect on the trawl fisheries near the bridge. Included in this area is the 12 ha lost due to the footprints of the piers pylons and embankments.

Only two ha or <0.1% of the Danish gill net fisheries in Fehmarnbelt, which are of medium importance, will be affected by the bridge pylon and pier footprint. This affect might increase if

there arises restrictions to gill net fisheries near the bridge structures when the bridge is in operation.

The Danish seine fisheries, of minor importance, will be affected by the bridge footprints in 1,375 ha or 8.2 % of its fishing area in Fehmarnbelt. This is mostly attributed to (1,369 ha) the anticipated establishment of the shipping lanes under the bridge and the restrictions to the fisheries that this will cause.

Germany
A summary of the degree of loss to the German fisheries by footprints from the bridge solution variant is given in Table 6.4.

Table 6.4: The percentage of fishing area loss (%) and area loss (ha) to the fisheries (trawl, gill nets and pound nets) due to bridge footprints in comparison to the total fisheries in Fehmarnbelt (ICES 38G1) and its region.

Reduction of fishery sub-components, footprints (%-ha) Bridge - Germany	**Fehmarnbelt (ICES 38G1) % (ha)**	**Fehmarnbelt region % (ha)**
Trawl		
Bridge - pylons, piers and embankment	0.07% (11)	
Bridge - shipping lanes and restricted areas	19.7% (3611)	
Gill nets		
Bridge - pylons, piers and embankment	0.25% (18)	0.03% (31)
Bridge - shipping lanes and restricted areas		
Pound nets	**Fehmarn coastline and near mainland (see Figure 1.5)**	
Bridge - pylons, piers and embankment	1.26% (29)	
Bridge - shipping lanes and restricted areas		

The footprints from the bridge solution wil have an affect on 3,669 ha of the German fishing areas in Fehmarnbelt (ICES 38G1) and along the Fehmarn coast and immediate part of the mainland for the pound net fishery. The majority of this affect, in relation to area, will be on the trawl fisheries.

29 ha or 1.3% of the German pound net fisheries along the coastal area of Fehmarn, which is a fishery of very high importance, will be affected by the physical structures of the bridge. This affect is mainly caused by the ramp area near the coast and pillars..

The bridge structures, embankments and restriction to fisheries, particularly shipping lanes, will affect in all 3,622 ha or approximately 19.7% of the German trawl fishing area in Fehmarnbelt. These fisheries are of medium importance. Affects to this fishery are primarily in the central part of Fehmarnbelt.

The structures from the bridge will affect 18 ha or 0.1% of the German gill net fisheries of medium importance.

No German seine net fishing has been undertaken in Fehmarnbelt for more than ten years and so this fishery is not represented in the German fisheries in Fehmarnbelt.

6.1.6.1 Classification of impact

The classification of the impact is according to guidelines outlined in the methodology section 3.1.

Denmark
The classification of the severity of loss of reclamation areas and structures on the Danish commercial fisheries (Table 6.5).

Table 6.5: The severity of loss to the Danish fisheries due to bridge footprints/reclamation areas and the establishment of shipping lanes. Results derived from analysis of the loss according to the importance level of the individual fisheries as described in the methodology section (section 3.1).

Importance	Severity of loss			
	Very high	High	Medium	Minor
Very high	**32 ha** *** **Pound net fisheries** Permanent loss due to pylons, piers and reclamation areas for embankments	0 ha		0 ha
High	0 ha	0 ha	0 ha	0 ha
Medium	0 ha		**6086 ha** *** **5750 ha - Fehmarnbelt** **336 ha - Fehmarnbelt region** **Trawl fisheries** Impairment-loss due to expected establishment of shipping lanes and their corridors and restrictions to the fisheries **14 ha** *** **12 ha** **Trawl fisheries** Permanent loss due to pylons, piers and reclamation areas ** **2 ha** **Gill net fisheries** Permanent loss due to pylons, piers and reclamation areas	
Minor	0 ha	0 ha		**1369 ha** *** **Seine net fisheries** Impairment-loss due to expected establishment of shipping lanes and their corridors and restrictions to the fisheries

Germany

The classification of the severity of loss of reclamation areas and structures on the German commercial fisheries due to the establishment of the bridge fixed link solution is given in Table 6.6.

Table 6.6: The severity of loss to the German fisheries due to bridge footprints/reclamation areas and the establishment of shipping lanes. Results derived from analysis of the importance level of the individual fisheries as described in the method chapter.

Importance	Severity of loss			
	Very high	High	Medium	Minor
Very high	**29 ha** *** **Pound net fisheries** Permanent loss due to pylons, pillars and reclamation areas for embankments	0 ha		0 ha
High	0 ha	0 ha	0 ha	0 ha
Medium	0 ha		**3611 ha** *** **Trawl fisheries** Impairment-loss due to expected establishment of shipping lanes and their corridors and restrictions to the fisheries **29 ha** *** **11 ha** **Trawl fisheries** Permanent loss due to pylons, pillars and reclamation areas **</** **18 ha** **Gill net fisheries** Permanent loss due to pylons, pillars and reclamation areas	0 ha
Minor	0 ha	0 ha	0 ha	0 ha

6.1.7 Severity and significance

The severity and significance of the bridge footprints on the Danish and German fisheries for each of the primary fishery types (trawl, gill nets, pound nets and Danish seine nets (Denmark only)) is given in the following chapters:

Denmark
The severity of the bridge footprints and reclamation areas to the Danish fisheries as derived from the severity of loss according to the importance level of the individual fisheries is presented in Table 6.7.

Table 6.7: Classification of the degree of impairment of reclamation areas and structures on the Danish commercial fisheries due to the establishment of the bridge fixed link solution. The area of the pound net fishery is based on the southern coast of Lolland.

Severity of loss **Footprints – Denmark - Bridge**	**Fehmarnbelt (ICES 38G1)**	**Fehmarnbelt Region**
Trawl		
Bridge - pylons, piers and embankment	Medium	Medium
Bridge - shipping lanes and restricted areas		
Gill nets		
Bridge - pylons, piers and embankment	Medium	
Bridge - shipping lanes and restricted areas		
Danish seine nets		
Bridge - pylons, piers and embankment	Minor	
Bridge - shipping lanes and restricted areas		
Pound nets		
Bridge - pylons, piers and embankment	Very high	
Bridge - shipping lanes and restricted areas		

Trawl
The severity of impact to the Danish trawl fisheries by losing fishing grounds amounting to 5750 ha in Fehmarnbelt and 336 ha in the Fehmarnbelt region due to the shipping lanes and anticipated restrictions to the fisheries was medium according to the medium importance of this fishery.

An area loss of 12 ha due to the establishment of bridge pillars and pylons across the trawling routes had a medium severity of impact according to criteria.

The significance of these impacts is associated with the direct loss of area to these fisheries due to fishery restrictions in shipping lanes under a bridge, and the hinderence or impairment to the continual undertaking of trawl fisheries when both shipping lanes restricting fisheries and physical structures such as pillars and pylons cross important trawling routes in Fehmarnbelt.

Trawl hauls in Fehmarnbelt are primarily undertaken through the central deeper (>10 m) parts of Fehmarnbelt and it is here that the two main pylons and the shipping lanes will be established. Thus, the full significance of these impacts to the trawl fisheries will be determined by exact regulations for trawling under other sections of the bridge than where shipping lanes are placed, and whether the physical structures and seabed morphology along alternative trawling routes will allow the undertaking of trawling without major disturbances or problems.

Furthermore, in the event that trawling under the bridge is stopped or impaired this creates operations such as lifting and resetting trawl gear, which means that trawling through Feh-

marnbelt will be impacted and the loss of good trawling routes and the added time consuming activities could potentially reduce the net value of the landings or the amount of landings for the trawl fisheries in Fehmarnbelt

The trawl fisheries are mobile and there are alternative trawling areas both to the east and west of Fehmarnbelt which would relieve some of the direct impact from impairments to these fisheries from a bridge solution, however potential of increasing the number of trawlers in other trawling areas and the stochastic characteristics of the distribution of commercial species and losing a fishing area where they may be at any one time will potentially lead to other indirect impacts and detrimental affects on the trawl fisheries in Fehmarnbelt and its region.

Gill nets
Results indicated that severity of impact to the Danish gill net fisheries by losing two ha of their fishing grounds to area use by bridge pylons, pillars and embankments was medium.

There are no Danish gill net fishing areas in the deeper parts of Fehmarnbelt where the bridge transect is planned and thus this fishery is not affected by restrictions to the fisheries due to shipping lanes under the bridge fixed link solution.

The small amount of gill net fishing areas (<0.1% of the gill net fishing area) lost to bridge structures is not considered to be of great importance in relation to the intensity of the fisheries in these areas. Furthermore, the potential mobility of this fishery to other nearby gill net fishing areas in Fehmarnbelt supports a low significance of the loss of this area to the gill net fisheries.

Added structures from pillars and pylons also create new habitats (reef effects) which could benefit the gill net fisheries as these habitats have been known to attract fish to the local area. This benefit is, however, dependent on the fishing regulations that are implemented with regard to fishing near or under the bridge by gill net fishermen.

Pound nets
A loss of 32 ha of pound net fishing area (0.5% of the total pound net fishing area) primarily due to the build up of the bridge embankment landfill and the bridge pillar and pylons and their foundations within the coastal area of Lolland lead to a very high severity of impact to the Danish pound net fishery in these areas.

The significance of the very high severity of loss to the pound net fisheries in the embankment areas is warranted as this fishery is considered of high importance and is highly sensitive to any loss or impairments to their fisheries. Pound net fisheries are not very mobile and a loss of area cannot be compensated for fishermen moving their fisheries to another area. In contrast, impacts to the pound net fisheries are very local and the fisheries and number of fishermen affected is primarily limited to a few fishermen with their pound nets within or adjacent the area of impact.

Danish seine nets
In all, 1375 ha or 8.1% of the seine net fishing area in Fehmarnbelt was impacted by the structures and footprints from the establishment of the bridge solution. The severity of loss was minor and the severity of the impact was considered low due to the minor importance of the Danish seine net fisheries in Fehmarnbelt.

Seine net fishing requires a considerably large area to undertake their fisheries as seine net fishermen set their nets and retrieve them over a broad area. Thus closed and loss of fishing areas due to shipping lanes and bridge structures extending across their fishing areas and creating a barrier, will affect the undertaking of this fishery in Fehmarnbelt.

However, because of the mobility of this fishery, its low importance, and the potential for this fishery to relocate their efforts to other areas in Fehmarnbelt, the low severity of impact and the overall significance of the loss of area can also be considered low.

The vast majority of the Danish fisheries lost to footprints is within ICES 38G1 (Fehmarnbelt), and thus the regional area is not considered to be affected by footprints.

Germany
The severity of the bridge footprints and reclamation areas to the German fisheries as derived from the degree of impairment and the importance level of the individual fisheries is presented in Table 6.8.

Table 6.8: Classification of the severity of loss of reclamation areas and structures on the German commercial fisheries due to the establishment of the bridge fixed link solution. The area of the pound net fishery is based on the northern and eastern coastal area of Fehmarn and the immediate mainland.

Severity of loss Footprints, Germany, bridge	Fehmarnbelt (ICES 38G1)	Fehmarnbelt Region
Trawl		
Bridge - pylons, piers and embankment	Medium	
Bridge - shipping lanes and restricted areas		
Gill nets		
Bridge - pylons, piers and embankment	Medium	
Bridge - shipping lanes and restricted areas		
Pound nets		
Bridge - pylons, piers and embankment	Very high	
Bridge - shipping lanes and restricted areas		

Trawl
The severity of impact to the German trawl fisheries due to an impact (loss) of 3611 ha of the German trawling grounds due to the shipping lanes, the permanent loss of 11 ha of trawling area due to pylons, pillars and embankments areas, and anticipated restrictions to the fisheries from establishing the bridge fixed link was medium according to the importance of this fishery.

Hinderances to the continuation of trawl fishing along important routes will potentially cause greater impacts than just the loss of area.

Like the impacts to the Danish trawl fisheries, the severity and significance of these impacts is associated with the direct loss of area to these fisheries and disturbance or stoppage of the continual undertaking of trawl hauls when areas restricting fisheries and physical structures create barriers across important trawling routes in Fehmarnbelt.

The final severity and significance of these impacts to the trawl fisheries will be determined by trawl regulations, the location of the shipping lanes, and whether the physical structures and alternative trawling routes will allow the undertaking of trawling without major disturbances or problems.

As mentioned the trawl fisheries are mobile and there are alternative trawling areas both to the east and west of Fehmarnbelt which would offer alternative fishing areas and relieve some of the direct impact from impairments to these fisheries from a bridge solution. Potential pitfalls to this are potentially increased steaming time in some instances and an increasing number of trawlers in other areas which could potentially lead to other indirect impacts and detrimental affects on the German trawl fisheries in Fehmarnbelt and its region.

Gill nets
The severity of impact to the German gill net fisheries was medium as 18 ha or approximately 0.2% of the gill net fishing area in Fehmarnbelt was lost to the establishment of bridge pylons, piers and embankments.

The significance of this loss/impairment is not considered to be of great as the lost areas do not appear to be of utilised as much as other areas, and there are other nearby gill net fishing areas in Fehmarnbelt where the German gill net fisheries can also be undertaken.

Furthermore, added bridge structures create new habitats (reef effects) which have been known to attract fish to the local areas and depending on the fishery regulations may have a positive impact on the gill net fishery after bridge completion.

The German gill net fishing areas are primarily located along the coastal area of Fehmarn and thus these fisheries would not be affected by restrictions to the fisheries due to shipping lanes established under the bridge fixed link solution.

Pound nets
A loss of 29 ha of German pound net fishing area (1.3% of the total pound net fishing area), primarily due to bridge embankments and the bridge structures that are close to the coastal area of Fehmarn, lead to a very high severity of impact to the German pound net fishery in this area.

This fishery is considered of high importance because pound net fisheries are not very mobile and a loss of area cannot be compensated for by moving the fisheries to other areas. The area lost, however, only affects a small part of the pound net fishery along the German coast-line of Fehmarnbelt and impacts to the pound net fisheries will typically only affect a small number of fishermen and thus the impact will be limited regionally.

6.2 Sediment spill

The establishment of the bridge solution will involve the undertaking of dredging and backfilling activities during the construction of work harbours and access channels near Rødby, Lolland and Puttgarden, Fehmarn and when establishing pylons and piers and their foundations along a transect that will cross the Fehmarnbelt.

Spilled sediment will consist of both coarse and fine sediment material where the largest material will quickly resettle near dredging sites while finer sediment may be carried away and produce plumes of suspended sediment depending on the hydrodynamic conditions.

Excess concentrations of suspended sediment and sedimentation may impact the commercial fisheries by causing commercial species to avoid or leave fishing areas where the concentration level of suspended sediments or sedimentation is greater than their threshold levels for avoidance behaviour. Furthermore, sediment spills from the bridge construction works might also affect the fisheries indirectly by changing or creating a loss of habitats important to commercial fish species.

6.2.1 Environmental indicators

Many important commercial species that represent the resource to the fisheries are potentially affected by an increase in the concentration of suspended sediment or an increase in sedimentation. If the concentration of suspended sediment or sedimentation are high enough or exist for a long period they can trigger avoidance responses in fish in important areas to the commercial fisheries. This will vary from species to species because of the differences in species-specific tolerance to different concentrations of suspended sediment and sedimentation. In general this appear to be associated with the fish have a predominantly pelagic or benthic lifestyle.

The important commercial fish or sub component to the fisheries that are of interest to assess in relation to sediment spills due to the establishment of the bridge variant is given in Table 6.5.

Table 6.5: The fisheries components and sub-components (commercial species) selected for the assessment of pressures from suspended sediment for the evaluation of the bridge alternative for the Fehmanbelt Fixed Link.

Component	Sub-components Fisheries – gear	Sub-component Commercial species
Commercial fisheries	Trawl Gill/trammel nets Pound nets Danish seine nets	Atlantic cod Whiting Herring Sprat Flatfish species Horse mackerel Salmon Sea trout Garfish Eel

6.2.2 Sensitivity to pressure

Sensitivity of different commercial fish species to an increase in water turbidity and sedimentation associated with activities such as dredging, landfilling etc. during the establishment of a bridge is species specific. However, the concentration of the material in sediment plumes is not necessarily the only critical factor causing fish avoidance. Exposure time and sediment

composition are also important factors effecting when fish react to these pressures (Newcombe and McDonald, 1991).

This has also been evident in studies of the tolerance of different fish species to different levels of suspended sediment. In these, pelagic species such as the clupeids herring and sprat as well as gadoids showed avoidance behaviour and signs of injury at suspended sediment levels much lower than benthic species such as flatfish (Table 6.6).

Table 6.6: Levels of suspended sediment that can trigger avoidance response or injury to some pelagic and benthic commercial species (table modified from data in FEBEC 2012.

Species	Life stage	Threshold concentration	Effect	Reference
Herring	Adult	19 mg/l fine sediment (+/- 5 mg) and 35 mg/l coarse sediment (+/- 5 mg)	Avoidance behaviour	Wildish, et al., 1977
	Adult	3-5 mg/l (type)	Avoidance behaviour	Appelberg et al. 2005
Cod	Adult	550 mg/l (1d-10d exposure	No significant mortality but moderate gill lesions that might be reversible	Humborstad et al. 2006
	Adult	3-5 mg/l (type)	Avoidance behaviour	Appelberg et al. 2005
Salmon and Sea trout	Adult	1-49 g/l, exposure 4 d	Lethal effects	Newcombe and MacDonald 1991 in: Keller et al. 2006
	Adult	100 mg/l, exposure 1 h	Salmon exhibit evasive behaviour 100 mg/l, exposure 1 h	Newcombe and MacDonald 1991 in: Keller et al. 2006
Flatfish	Adult	3000 mg/l	No mortality among plaice during 14 days exposure	Newton in Keller et al. 2006

In general, it was suggested that species associated with the pelagic environment are less tolerant to high amounts of suspended sediment and sedimentation than fish more associated with the benthic environment (FeBEC 2012). This suggests that less concentrations of suspended sediment will trigger an avoidance response in the pelagic commercial species of interest in this assessment (herring, sprat, cod, whiting, horse mackerel) than the benthic commercial species (flatfish species and European eel).

6.2.3 Pressure indicators

After examining the available literature on the affects of suspended sediment on different fish species it was shown that there was a wide range of threshold values that triggered an avoidance response or injury (FeBEC 2012). These are very different depending on the species, life stage and pelagic or benthic life style in question. Because the fish of interest to the commercial fisheries are generally adults their main response to high suspended sediment concentrations is to avoid or flee the area of impact. Avoidance response is thus the operational tool or indicator used to assess the impact of high suspended sediment on commercial fish species.

Thresholds of suspended sediment for triggering avoidance behaviour for the most important commercial species in Fehmarnbelt are given in Table 6.7.

The threshold for avoidance behaviour for the predominately pelagic species (cod, sprat, herring, whiting, horse mackerel, salmon, sea trout and garfish) has been set at 10 mg/l of suspended sediment. The threshold level for triggering avoidance behaviour in the predominately benthic commercial species (flounder, dab, plaice, turbot, brill, sole and eel) has been set at 50 mg/l.

Table 6.7: Thresholds (mg/l of suspended sediment) for triggering avoidance behaviour for the most important pelagic and benthic commercial species in Fehmarnbelt.

Environmental indicators in the fisheries Commercial species	Sensitivity to pressure - Threshold concentration of suspended sediment triggering an avoidance response
Pelagic species; Atlantic cod, Sprat, Herring, Whiting, Salmon, Sea trout, Garfish, Horse mackerel	≥10 mg/l
Benthic species; Flounder, Dab, Plaice, Turbot, Brill, Sole and European eel	≥50 mg/l

6.2.4 Magnitude of pressure

The pressure on the commercial fish species and thus the fisheries caused by sediment spill from the construction of the bridge solution is assessed according to spill scenarios established by FEHY. The dredging is planned to last three years and an estimate of 11 mill m^3 is estimated to be spilled. After three years no more sediment spillage associated with the bridge is expected. The impact assessment regarding sediment spill is therefore only related to the construction phase.

Simulations show that the concentration of suspended sediment will vary during the construction period depending on the location of the dredging operations and the current and wave conditions. In the coastal waters of primarily Lolland but also Fehmarn waves will slow the spilled material from settling and create a resuspension from the seabed. Excess concentrations from the construction of the bridge will therefore be higher in the shallow waters where sediment will be transported along the coastline before settling.

In the bridge solution, excess concentrations of suspended sediment and sedimentation and the time frame where this is present are generally much less than for the tunnel solution.

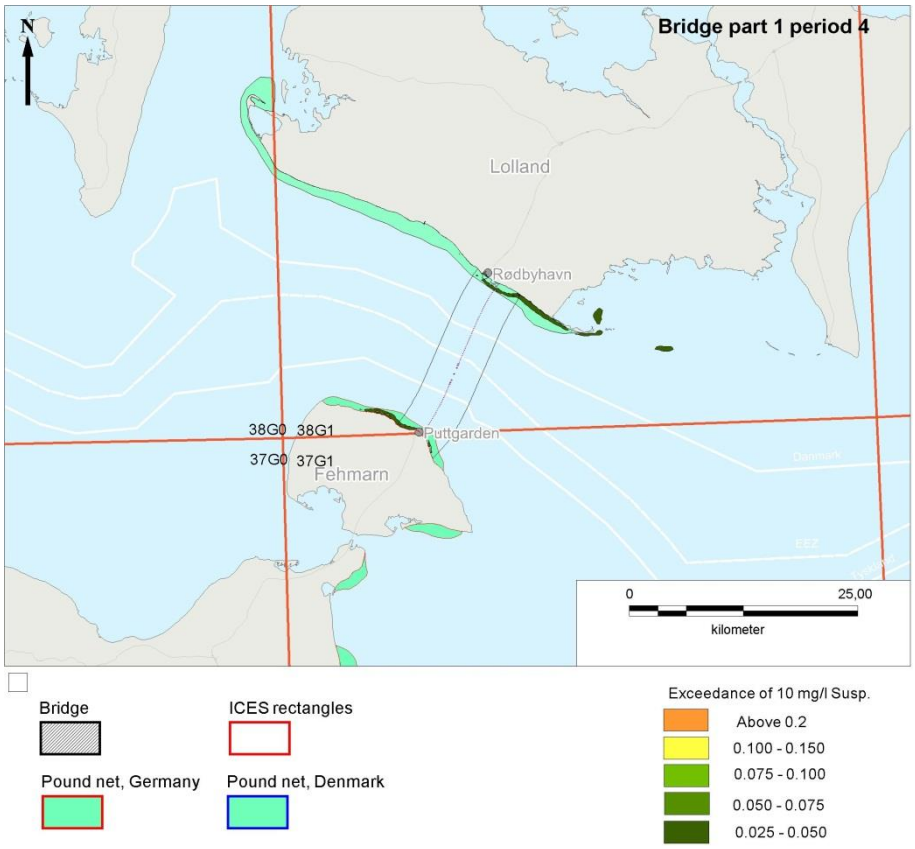


Figure 6.2: The simulated distribution of suspended sediment exceeding 10 mg/l in Fehmarnbelt from September to November 2014 due to the construction of the bridge fixed link. The distribution represents a period when sediment spills were highest.

The degree of sedimentation of excess sediment during bridge construction suggest that over the construction period sediment deposition will happen in a thin layer over large areas, which for all practical reason are considered insignificant (FEHY, 2011e). Thus the potential impact on the commercial species from sedimentation is considered to be insignificant.

6.2.5 Assessment criteria

The assessment criteria used to classify the magnitude of the impact to the fisheries from increases in suspended sediment due to the establishment of the bridge fixed link solution are given in section 3.2.3 (Table 3.7).

6.2.6 Degree of impairment

It is estimated that increased suspended sediment from construction of the bridge variant of the Fehmarnbelt fixed link affects the resources (commercial species) to the fisheries such that suspended sediment levels >10 mg/l or >50 mg/l will trigger an avoidance response in some commercial species.

The degree of impact is the amount of fishing area of the individual fishery sub-components (trawl, gill nets, pound nets and seine nets) that is affected by the coverage of suspended sediment in relation to the amount of fishing area available in Fehmarnbelt and its region.

Increases in suspended sediment from the construction works of the bridge Fehmarnbelt fixed link solution will affect areas of the fisheries over a three year period (2014-2016).

Denmark

Trawl fishery - Denmark

Overall, the commercial species in areas where Danish trawl fishing is undertaken were affected very little by increased suspended sediment due to construction of the bridge fixed link solution. This is generally because most of the sediment plumes from dredging and construction works was located in the shallow areas. In contrast, the trawl fisheries are undertaken in the deeper (>10 m) central parts of Fehmarnbelt (38G1) and its region.

A maximum of three ha (0.01% of the trawl fishing area in Fehmarnbelt) or six ha (0.003% of the trawl fishery in the Fehmarnbelt Region) was affected by sediment plumes >10 mg/l at any one time during construction. The maximum area of coverage by sediment plumes > 50 mg/l at any one time was 0.5 ha or less (<<0.01% of the trawl fishing area in Fehmarnbelt and region).

Thus if we assume the commercial species most sensitive to increased concentrations of suspended sediment are spread throughout the trawl fishing area than it can be assumed that less than 0.01% of these species in Fehmarnbelt and 0.003% of these species in the Fehmarnbelt region would have been affected by an increase in suspended sediment.

The degree of impairment to the trawl fisheries through the indirect impairment to their resource (commercial species) was minor in all cases (Table 6.8).

Table 6.8: The percentage (%) of trawl fishing area in Fehmarnbelt (ICES 38G1) and its region and the area (ha) affected by increased concentrations of suspended sediment above threshold levels triggering an avoidance response for sensitive commercial species (>10 mg/l) and less sensitive commercial species (>50 mg/l). The colour coding represents the degree of impairment which was minor in all cases according to guidelines outlined in the methodology chapter.

Reduction of sub components, sediment spill (%-ha) Bridge	Threshold	Commercial species	Year	Dec-Apr		May-Aug		Sep-Nov		Year	
				%	ha	%	ha	%	ha	%	ha
Trawl Fehmarnbelt (ICES 38G1)	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014	0.00	0.17	0.01	0.88	0.01	2.91	0.00	1.09
			2015	0.00	0.42	0.00	1.23	0.00	0.06	0.00	0.57
			2016	0.00	0.16	0.00	1.23	0.00	0.04	0.00	0.48
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014			0.00	0.01	0.00	0.01	0.00	0.01
			2015			0.00	0.03			0.00	0.01
			2016			0.00	0.03			0.00	0.01

Reduction of sub components, sediment spill (%-ha) Bridge	Threshold	Commercial species	Year	Dec-Apr		May-Aug		Sep-Nov		Year	
				%	ha	%	ha	%	ha	%	ha
Trawl Fehmarnbelt Region	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014	0.00	2.01	0.00	0.97	0.00	6.47	0.00	3.24
			2015	0.00	3.95	0.00	1.43	0.00	0.76	0.00	1.76
			2016	0.00	1.19	0.00	1.34	0.00	0.40	0.00	0.95
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014	0.00	0.05	0.00	0.01	0.00	0.02	0.00	0.03
			2015	0.00	0.00	0.00	0.03			0.00	0.01
			2016	0.00		0.00	0.03			0.00	0.01

Gill net fishery - Denmark

During the entire period of bridge construction there was no time or location in Fehmarnbelt or its region where the degree of impairment due to suspended sediment levels that were greater than “Minor” (Table 6.9).

The commercial species associated with the Danish gill net fisheries were affected the most by increased suspended sediment from the bridge construction works during the summer and autumn periods.

For suspended sediment concentrations >10 mg/l the greatest affect was in the autumn of 2014 (Sep-Nov) where approximately 52 ha or 0.11% of the fishing area in Fehmarnbelt (38G1) was affected. Following this, there was a moderate coverage of the gill net fishing areas of Fehmarnbelt during the summer and autumn of 2015 and 2016. At these times from 25-37 ha (0.05-0.08% of the gill net fishing area in Fehmarnbelt) were affected by suspended sediment concentrations >10 mg/l. The location of these affects was either in coastal areas on the far western part of southern Lolland or along the eastern coast of southern Lolland and in Rødsand Lagoon.

The maximum area of coverage by sediment plumes > 50 mg/l at any time was 1.2 ha or less than <0.01% of the gill net fisheries in Fehmarnbelt and region.

Table 6.9: The percentage (%) of gill net fishing area in Fehmarnbelt (ICES 38G1) and its region and the area (ha) affected by increased concentrations of suspended sediment above threshold levels triggering an avoidance response for sensitive commercial s species (>10 mg/l) and less sensitive commercial species (>50 mg/l). The colour coding represents the degree of impairment which was minor in all cases according to guidelines outlined in the methodology chapter.

Reduction of sub components, sediment spill (%-ha) Bridge	Threshold	Commercial species	Year	Dec-Apr		May-Aug		Sep-Nov		Year	
				%	ha	%	ha	%	ha	%	ha
Gill nets Fehmarnbelt (ICES 38G1)	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014	0.0	6.8	0.0	0.1	0.1	52.1	0.0	18.3
			2015	0.0	12.4	0.1	37.0	0.1	26.8	0.0	22.4
			2016	0.0	4.6	0.1	36.5	0.1	25.0	0.0	20.0
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014	0.0	0.0		0.0	0.0	1.2	0.0	0.3
			2015	0.0	0.1	0.0	1.0	0.0	0.6	0.0	0.5
			2016	0.0	0.0	0.0	1.0	0.0	0.6	0.0	0.5

Reduction of sub components, sediment spill (%-ha) Bridge	Threshold	Commercial species	Year	Dec-Apr		May-Aug		Sep-Nov		Year	
				%	ha	%	ha	%	ha	%	ha
Gill nets Fehmarnbelt Region	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014	0.0	6.8	0.0	0.1	0.0	52.1	0.0	19.9
			2015	0.0	16.2	0.0	37.4	0.0	26.8	0.0	22.6
			2016	0.0	4.7	0.0	36.9	0.0	25.0	0.0	20.1
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014	0.0	0.0			0.0	1.2	0.0	0.3
			2015	0.0	0.1	0.0	1.0	0.0	0.6	0.0	0.5
			2016	0.0	0.0	0.0	1.0	0.0	0.6	0.0	0.5

Pound net fishery – Denmark

The near shore distribution of suspended sediment plumes from bridge construction works will generally affect the near shore pound net fisheries more than other more predominantly off-shore and mobile fisheries (trawl, gill nets and seine nets) (Table 6.10).

Over the three years of bridge construction where increases of suspended sediment occurs, sediment plumes with concentrations greater than 10 mg/l affected up to a maximum of 38.4 ha (0.64% of the pound net fishing area) in September-November of 2014 and around 0.1-21.9 ha or 0.01-0.36% of the pound net fishing area at different time periods from 2015-2016. The primary areas of this impact were along the coast of southern Lolland and often near Nakskov Fjord to the far southwest and in Rødsand Lagoon to the far eastern part of southern Lolland.

Very high concentrations of suspended sediment (>50 mg/L) only affected 1.4 ha (0.02% of the Danish pound net fishing area) during the autumn of 2014 and summer 2015.

Table 6.10: The percentage (%) of pound net fishing area in Fehmarnbelt (ICES 38G1) and its region and the area (ha) affected by increased concentrations of suspended sediment above threshold levels triggering an avoidance response for sensitive commercial species (>10 mg/l) and less sensitive commercial species (>50 mg/l). The color coding represents the degree of impact which was minor in all cases according to guidelines outlined in the methodology section.

Reduction of sub compo-nents, sediment spill (%-ha) Bridge	Threshold	Commercial species	Year	Dec-Apr		May-Aug		Sep-Nov		Year	
				%	ha	%	ha	%	ha	%	ha
Pound nets Fehmarnbelt Region	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014	0.3	16.6	0.0	2.3	0.6	38.4	0.4	21.7
			2015	0.3	15.0	0.4	21.9	0.0	0.1	0.2	9.3
			2016	0.1	4.1	0.3	19.7	0.0	0.0	0.1	7.7
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014	0.0	0.6			0.0	1.4	0.0	0.6
			2015	0.0	0.1	0.0	1.4			0.0	0.5
			2016			0.0	1.1			0.0	0.4

Seine net fishery – Denmark

Due the near shore proximity of the sediment plumes from the bridge fixed link construction works the affects on the seine fisheries was at a minimum. During the autumn (Sep-Nov) of 2014, three ha of the Danish seine net fishing area in Fehmarnbelt region was affected by an increase in suspended sediment levels >10 mg/l. The degree of impairment on the seine net fisheries due to suspended sediment from the construction of the bridge was minor at all times Table 6.11.

Table 6.11: The percentage (%) of Danish seine net fishing area in Fehmarnbelt (ICES 38G1) and its region and the area (ha) affected by increased concentrations of suspended sediment above threshold levels triggering an avoidance response for sensitive commercial species (>10 mg/l) and less sensitive commercial species (>50 mg/l). The colour coding represents the degree of impairment which was minor in all cases according to guidelines outlined in the methodology chapter.

Reduction of sub compo-nents, sediment spill (%-ha) Bridge	Threshold	Commercial species	Year	Dec-Apr		May-Aug		Sep-Nov		Year	
				%	ha	%	ha	%	ha	%	ha
Seine nets Fehmarnbelt (ICES 38G1)	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014			0.0	0.1	0.0	2.1	0.0	0.5
			2015	0.0	0.1						
			2016								

	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014			0.0	0.0	0.0	0.0	0.0	0.0
			2015								
			2016								

Reduction of sub components, sediment spill (%-ha) Bridge	Threshold	Commercial species	Year	Dec-Apr		May-Aug		Sep-Nov		Year	
				%	ha	%	ha	%	ha	%	ha
Seine nets Fehmarnbelt Region	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014			0.0	0.1	0.0	3.0	0.0	0.7
			2015	0.0	0.1					0.0	0.0
			2016								
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014			0.0	0.0	0.0	0.0	0.0	0.0
			2015								
			2016								

Germany

Trawl fishery – Germany

The German trawl fishery was affected very little by increased concentrations of suspended sediment due to the construction works of the bridge fixed link solution in Fehmarnbelt.

No more than 4.2 ha (<0.01% of the German trawl fishing area in Fehmarnbelt region) or 2.5 ha (0.01% of the German trawl fishing area in Fehmarnbelt (38G1)) was affected by an increase in the suspended sediment >10 mg/l plumes from the bridge construction works.

The degree of impairment to the German trawl fisheries in Fehmarnbelt and its region was minor in all cases (Table 6.12).

Table 6.12: The percentage (%) of trawl fishing area in Fehmarnbelt (ICES 38G1) and its region and the area (ha) affected by increased concentrations of suspended sediment above threshold levels triggering an avoidance response for sensitive commercial species (>10 mg/l) and less sensitive commercial species (>50 mg/l). The colour coding represents the degree of impairment which was minor in all cases according to guidelines outlined in methodology chapter.

Reduction of sub components, sediment spill (%-ha) Bridge	Threshold	Commercial species	Year	Dec-Apr		May-Aug		Sep-Nov		Year	
				%	ha	%	ha	%	ha	%	ha
Trawl Fehmarnbelt (ICES 38G1)	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014	0.0	0.2	0.0	1.0	0.0	2.5	0.0	1.0
			2015	0.0	0.4	0.0	0.1	0.0	0.0	0.0	0.2
			2016	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014			0.0	0.02	0.0	0.1	0.0	0.01
			2015			0.0	0.01			0.0	0.0
			2016			0.0	0.01			0.0	0.0

Reduction of sub components, sediment spill (%-ha) Bridge	Threshold	Commercial species	Year	Dec-Apr		May-Aug		Sep-Nov		Year	
				%	ha	%	ha	%	ha	%	ha
Trawl Fehmarnbelt Region	10 mg/l	Cod, sprat, herring, whiting, salmon,	2014	0.0	1.3	0.0	1.0	0.0	4.2	0.0	1.8
			2015	0.0	2.4	0.0	0.1	0.0	0.1	0.0	1.0

		sea trout and horse mackerel	2016	0.0	0.6	0.0	0.1	0.0	0.1	0.0	0.2
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014			0.0	0.0	0.0	0.0	0.0	0.0
			2015	0.0	0.0	0.0	0.0			0.0	0.0
			2016			0.0	0.0			0.0	0.0

Gill net fishery - Germany

The commercial species associated with the German gill/trammel net fisheries were primarily affected by increases in the suspended sediment due to the bridge construction during winter and early spring months (December-April) with the highest affect on the fisheries in the first two years.

The increased concentration of sediment (>10 mg/l and >50 mg/l) affected near shore areas along the northern and northeastern coast of Fehmarn.

Up to 22 ha (0.2% of fishing area) and 32 ha (0.3% of fishng area) of the German gill net fishing area in Fehmarnbelt (ICES 38G1) was affected by increased suspended sediment concentrations (>10 mg/l) in the winter and spring (Dec-April) of 2014 and 2015, respectively.

During the same time period, 32 ha (0.06% of fishing area) and 45 ha (0.08% of fishing area) of the German gill net fisheries in the Fehmarnbelt region were affected by increased suspended sediment concentrations >10 mg/l.

Sediment plumes with concentrations high enough (>50 mg/l) to trigger an avoidance response in the benthic fish that are more tolerant to increased suspended material never covered more than 4.3 ha (Dec-Apr of 2015) of the gill net fishing area during the bridge construction period.

Overall, the degree of impairment to the German gill net fisheries through the indirect impairment to their resource (commercial species) was considered minor during the entire bridge construction period (Table 6.13

Table 6.13: The percentage (%) of gill net fishing area in Fehmarnbelt (ICES 38G1) and its region and the area (ha) affected by increased concentrations of suspended sediment above threshold levels triggering an avoidance response for sensitive commercial species (>10 mg/l) and less sensitive commercial species (>50 mg/l). The colour coding represents the degree of impairment which was minor in all cases according to guidelines outlined in the method chapter.

Reduction of sub components, sediment spill (%-ha) Bridge	**Threshold**	**Commercial species**	**Year**	**Dec-Apr**		**May-Aug**		**Sep-Nov**		**Year**	
				%	ha	%	ha	%	ha	%	ha
Gill nets Fehmarnbelt (ICES 38G1)	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014	0.2	22.4	0.0	1.0	0.2	16.2	0.2	14.8
			2015	0.3	32.0	0.0	1.8	0.1	6.1	0.1	13.7
			2016	0.2	18.3	0.0	1.1	0.0	4.8	0.1	8.8
	50 mg/l	Flounder, dabm plaice, turbot, brill, sole and eel	2014	0.0	2.3	0.0	0.0	0.0	2.4	0.0	1.90
			2015	0.0	4.2	0.0	0.0	0.0	1.3	0.0	1.8
			2016	0.0	2.3	0.0	0.0	0.0	1.0	0.0	1.1

Reduction of sub components, sediment spill (%-ha)	**Threshold**	**Commercial species**	**Year**	**Dec-Apr**		**May-Aug**		**Sep-Nov**		**Year**	
				%	ha	%	ha	%	ha	%	ha

Bridge											
Gill nets Fehmarnbelt Region	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014	0.1	32.3	0.0	2.3	0.0	25.3	0.0	23.2
			2015	0.1	44.8	0.0	3.9	0.0	9.0	0.0	18.7
			2016	0.0	22.7	0.0	2.5	0.0	6.6	0.0	11.2
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014	0.0	2.8	0.0	0.1	0.0	2.7	0.0	2.1
			2015	0.0	4.3	0.0	0.1	0.0	1.3	0.0	1.9
			2016	0.0	2.3	0.0	0.0	0.0	1.0	0.0	1.1

Pound net fishery - Germany

The general distribution of increased suspended sediment from bridge construction works is along the coastal areas of Fehmarn which is also the location of the German pound net fisheries.

Seasonally, the sediment plumes with concentrations greater than 10 mg/l and 50 mg/l were most prominent during the winter and early spring (Dec-Apr) during the first two years (2014-2015) of bridge construction. However, at no time was the degree of impairment from the increase in suspended sediment greater than “Minor”.

Increased concentrations of suspended sediment above 10 mg/l affected between 2-25 ha (0.09–1.1% of the total fishing area) of the German pound net fishing area along the Fehmarn coast during the construction of the bridge. Suspended sediment concentrations >50 mg/l affected from 0-3 ha (0-0.1% of the total fishing area) of the German pound net fisheries during the three year construction period.

Overall, the degree of impairment to the German pound net fisheries by increased concentrations of suspended material was “Minor” throughout the construction period of the bridge fixed link solution (Table 6.14).

Table 6.14: The percentage (%) of German pound net fishing area in the Fehmarnbelt region and the area (ha) affected by increased concentrations of suspended sediment above threshold levels triggering an avoidance response for sensitive commercial species (>10 mg/l) and less sensitive commercial species (>50 mg/l). The colour coding represents the degree of impairment which was minor in all cases according to guidelines outlined in method chapter.

Reduction of sub components, sediment spill (%-ha) Bridge	Threshold	Commercial species	Year	Dec-Apr		May-Aug		Sep-Nov		Year	
				%	ha	%	ha	%	ha	%	ha
Pound nets Fehmarnbelt Region	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014	0.8	17.7	0.1	1.7	1.0	22.1	0.7	15.8
			2015	1.1	25.1	0.1	3.2	0.3	7.1	0.5	10.9
			2016	0.6	13.6	0.1	2.0	0.2	5.5	0.3	7.3
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014	0.1	1.5	0.0	0.0	0.1	2.7	0.1	1.7
			2015	0.1	3.0	0.0	0.1	0.1	1.3	0.1	1.3
			2016	0.1	1.8	0.0	0.0	0.0	1.0	0.0	0.9

6.2.6.1 Classification of impact

Results from the analysis of the degree of impairment showed that the classification of the impact from excess suspended sediment was “Minor” for all the fisheries (trawl, gill nets, pound nets and Danish seine nets) in Fehmarnbelt (38G1) and the Fehmarnbelt region during the entire construction period of the bridge fixed link solution.

6.2.7 Severity and significance

The severity and significance of the suspended sedimentation from establishing the bridge fixed link on the Danish and German fisheries is given in the following sections:

Denmark
The severity of impairment from sediment spills during establishment of the bridge fixed link solution on the Danish fisheries as derived from criteria leading to the degree of importance and the importance level of the individual fisheries is presented for each fishery component.

Trawl
The severity of impairment on both the most (avoidance response >10mg/l) and less (avoidance response >50 mg/l) sensitive commercial species to suspended sediment in the trawl fisheries due to excess sediment was "Minor" during the entire bridge construction period (Table 6.15).

Table 6.15: The severity of impairment to the trawl fisheries due to sediment spills during the establishment of the bridge fixed link solution. Results derived from analysis of the degree of impairment and the importance level of the individual fisheries as described in the method chapter.

Severity of impairment, sediment spill (%-ha) Bridge	Threshold	Commercial species	Year	Dec-Apr	May-Aug	Sep-Nov	Year
Trawl Fehmarnbelt (ICES 38G1)	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014	Minor	Minor	Minor	Minor
			2015	Minor	Minor	Minor	Minor
			2016	Minor	Minor	Minor	Minor
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014		Minor	Minor	Minor
			2015		Minor		Minor
			2016		Minor		Minor

Severity of impairment, sediment spill (%-ha) Bridge	Threshold	Commercial species	Year	Dec-Apr	May-Aug	Sep-Nov	Year
Trawl Fehmarnbelt Region	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014	Minor	Minor	Minor	Minor
			2015	Minor	Minor	Minor	Minor
			2016	Minor	Minor	Minor	Minor
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014	Minor	Minor	Minor	Minor
			2015	Minor	Minor		Minor
			2016		Minor		Minor

No more than approximately three ha of the trawl fishing areas in Fehmarnbelt (38G1) or seven ha in the Fehmarnbelt region were affected by increases in suspended sediment >10 mg/ during any one period. Thus, the impacts of suspended sediment from the bridge construction works are not considered to have any significance on the trawl fisheries during the establishment of a bridge fixed link.

Gill nets
The severity of impairment on commercial species in the gill net fisheries due to excess sediment spillage was minor during the entire bridge construction period (Table 6.16).

The period with the greatest amount of impairment from sediment spillage in the gill net fishing areas was during the summer (May-Aug) and autumn (Sep-Nov) periods from 2014-2016.

During these periods between 25-52 ha were affected by suspended sediment >10 mg/l. This, however only amounted to coverage of between 0.05-0.1% of the total gill net fishing area in Fehmarnbelt (39G1) and thus this impact is not considered to be significant to the gill net fisheries, other than on a very local scale and for a very short time in the immediate vicinity of dredging.

Table 6.16: The severity of impairment to the gill net fisheries due to sediment spills during the establishment of the bridge fixed link solution. Results derived from analysis of the degree of impairment and the importance level of the individual fisheries as described in the methodology chapter.

Severity of impairment, sediment spill (%-ha) Bridge	Threshold	Commercial species	Year	Dec-Apr	May-Aug	Sep-Nov	Year
Gill nets Fehmarnbelt (ICES 38G1)	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014	Minor	Minor	Minor	Minor
			2015	Minor	Minor	Minor	Minor
			2016	Minor	Minor	Minor	Minor
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014	Minor		Minor	Minor
			2015	Minor	Minor	Minor	Minor
			2016	Minor	Minor	Minor	Minor

Severity of impairment, sediment spill (%-ha) Bridge	Threshold	Commercial species	Year	Dec-Apr	May-Aug	Sep-Nov	Year
Gill nets Fehmarnbelt Region	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014	Minor	Minor	Minor	Minor
			2015	Minor	Minor	Minor	Minor
			2016	Minor	Minor	Minor	Minor
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014	Minor		Minor	Minor
			2015	Minor	Minor	Minor	Minor
			2016	Minor	Minor	Minor	Minor

Pound nets

The severity of impairment of sediment spill from the bridge construction works on the commercial species associated with the Danish pound net fisheries was minor in all cases (Table 6.17).

Suspended sediment from bridge constructions impacts the coastal areas the most where the pound net fisheries are also distributed. However, sediment plumes from the bridge construction would only cover an area of approximately 38 ha (0,4% of the fishing area) with concentrations >10 mg/l in the autumn of 2014 and less than ten ha thereafter. The coverage of area by sediment plumes with concentrations >50 mg/l will only amount to 1.4 ha or less for the entire bridge construction period.

Table 6.17: The severity of impairment to the pound net fisheries due to sediment spills during the establishment of the bridge fixed link soliution. Results derived from analysis of the degree of impairment and the importance level of the individual fisheries as described in the methodology chapter.

Severity of impairment, sediment spill (%-ha) Bridge	Threshold	Commercial species	Year	Dec-Apr	May-Aug	Sep-Nov	Year
Pound nets Fehmarnbelt (ICES 38G1)	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014	Minor	Minor	Minor	Minor
			2015	Minor	Minor	Minor	Minor
			2016	Minor	Minor	Minor	Minor
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014	Minor	Minor	Minor	Minor
			2015	Minor	Minor		Minor
			2016		Minor		Minor

Severity of impairment, sediment spill (%-ha) Bridge	Threshold	Commercial species	Year	Dec-Apr	May-Aug	Sep-Nov	Year
Pound nets Fehmarnbelt Region	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014	Minor	Minor	Minor	Minor
			2015	Minor	Minor	Minor	Minor
			2016	Minor	Minor	Minor	Minor
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014	Minor		Minor	Minor
			2015	Minor	Minor		Minor
			2016		Minor		Minor

Danish seine nets

The severity of impairment of sediment spill from the bridge construction works on the commercial species associated with the Danish seine net fisheries was insignificant during the few times that sediment plumes >10 mg/l affected the seine net fishing areas (Table 6.18).

Table 6.18: The severity of impairment to the Danish seine net fisheries due to sediment spills during the establishment of the bridge fixed link solution. Results derived from analysis of the degree of impairment and the importance level of the individual fisheries as described in the method chapter.

Severity of impairment, sediment spill (%-ha) Bridge	Threshold	Commercial species	Year	Dec-Apr	May-Aug	Sep-Nov	Year
Seine nets Fehmarnbelt (ICES 38G1)	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014		Insignif.	Insignif.	Insignif.
			2015	Insignif.			
			2016				
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014		Insignif.	Insignif.	Insignif.
			2015				
			2016				
Severity of impairment, sediment spill (%-ha) Bridge	**Threshold**	**Commercial species**	**Year**	**Dec-Apr**	**May-Aug**	**Sep-Nov**	**Year**
Seine nets Fehmarnbelt Region	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014		Insignif.	Insignif.	Insignif.
			2015	Insignif.			Insignif.
			2016				
	50 mg/l	Flounder, dab,	2014		Insignif.	Insignif.	Insignif.

		plaice, turbot, brill, sole and eel	2015				
			2016				

Germany

Trawl
The severity of impairment on the commercial species to suspended sediment in the trawl fisheries due to excess sediment was considered minor during the entire bridge construction period (Table 6.19).

At most 4.2 ha of the German trawl fishing area in the Fehmarnbelt region is estimated to be affected by an increase in the suspended sediment (>10 mg/l) due to plumes from the bridge construction works. Thus an increase in suspended sediment from the constructions works on the the German trawl fisheries is so little that this pressure will not have any significant impact.

Table 6.19: The severity of impairment to the trawl fisheries due to sediment spills during the establishment of the bridge fixed link solution. Results derived from analysis of the degree of impairment and the importance level of the individual fisheries as described in the method chapter.

Severity of impairment, sediment spill (%-ha) Bridge	Threshold	Commercial species	Year	Dec-Apr	May-Aug	Sep-Nov	Year
Trawl Fehmarnbelt (ICES 38G1)	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014	Minor	Minor	Minor	Minor
			2015	Minor	Minor	Minor	Minor
			2016	Minor	Minor	Minor	Minor
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014		Minor	Minor	Minor
			2015		Minor		Minor
			2016		Minor		Minor

Severity of impairment, sediment spill (%-ha) Bridge	Threshold	Commercial species	Year	Dec-Apr	May-Aug	Sep-Nov	Year
Trawl Fehmarnbelt Region	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014	Minor	Minor	Minor	Minor
			2015	Minor	Minor	Minor	Minor
			2016	Minor	Minor	Minor	Minor
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014		Minor	Minor	Minor
			2015	Minor	Minor		Minor
			2016		Minor		Minor

Gill nets
The severity of impairment on commercial species in the German gill net fisheries due to excess sediment spillage was minor during the entire bridge construction period (Table 6.20).

The period with the greatest amount of impairment from sediment spillage in the gill net fishing areas in Fehmarnbelt was estimated to be in the winter and early spring (Dec-Apr) of 2014 and 2015, where only between 25-45 ha in the Fehmarnbelt region would be affected by suspended sediment >10 mg/l. This is less than 0.1% of the total gill net fishing area and thus an increase in the suspended sediment from the bridge construction is not considered to have an impact of any significance to the German gill net fisheries.

Table 6.20: The severity of impairment to the gill net fisheries due to sediment spills during the establishment of the bridge fixed link solution. Results derived from analysis of the degree of impairment and the importance level of the individual fisheries as described in the methodology chapter.

Severity of impairment, sediment spill (%-ha) Bridge	Threshold	Commercial species	Year	Dec-Apr	May-Aug	Sep-Nov	Year
Gill nets Fehmarnbelt (ICES 38G1)	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014	Minor	Minor	Minor	Minor
			2015	Minor	Minor	Minor	Minor
			2016	Minor	Minor	Minor	Minor
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014	Minor	Minor	Minor	Minor
			2015	Minor	Minor	Minor	Minor
			2016	Minor	Minor	Minor	Minor

Severity of impairment, sediment spill (%-ha) Bridge	Threshold	Commercial species	Year	Dec-Apr	May-Aug	Sep-Nov	Year
Gill nets Fehmarnbelt Region	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014	Minor	Minor	Minor	Minor
			2015	Minor	Minor	Minor	Minor
			2016	Minor	Minor	Minor	Minor
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014	Minor	Minor	Minor	Minor
			2015	Minor	Minor	Minor	Minor
			2016	Minor	Minor	Minor	Minor

Pound nets

The severity of impairment of sediment spill from the bridge construction works on the commercial species associated with the German pound net fisheries was “Minor” in all cases (Table 6.21).

Although suspended sediment from bridge constructions primarily impacts the coastal areas where the pound net fisheries are also distributed, it was estimated that the impact from the bridge construction would only affect small areas (25 ha at most) for short periods of time and thus the main impacts from this pressure are only in very local areas and only for short periods of time.

Table 6.21: The severity of impairment to the pound net fisheries due to sediment spills during the establishment of the bridge fixed link solution. Results derived from analysis of the degree of impairment and the importance level of the individual fisheries as described in the methodology chapter.

Severity of impairment, sediment spill (%-ha) Bridge	Threshold	Commercial species	Year	Dec-Apr	May-Aug	Sep-Nov	Year
Pound nets Fehmarnbelt (ICES 38G1)	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014	Minor	Minor	Minor	Minor
			2015	Minor	Minor	Minor	Minor
			2016	Minor	Minor	Minor	Minor
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014	Minor	Minor	Minor	Minor
			2015	Minor	Minor	Minor	Minor
			2016	Minor	Minor	Minor	Minor

Severity of impairment,	Threshold	Commercial species	Year	Dec-Apr	May-Aug	Sep-Nov	Year

sediment spill (%-ha) Bridge							
Pound nets Fehmarnbelt Region	10 mg/l	Cod, sprat, herring, whiting, salmon, sea trout and horse mackerel	2014	Minor	Minor	Minor	Minor
			2015	Minor	Minor	Minor	Minor
			2016	Minor	Minor	Minor	Minor
	50 mg/l	Flounder, dab, plaice, turbot, brill, sole and eel	2014	Minor	Minor	Minor	Minor
			2015	Minor	Minor	Minor	Minor
			2016	Minor	Minor	Minor	Minor

6.3 Noise and vibration

Excess noise from the establishment of a Fehmarnbelt fixed link does not directly affect the undertaking of fisheries but affects the commercial species that make up the resource of the commercial fisheries. The assessment of the impact of noise on the fisheries is therefore based on affects noise will have on the commercial fish species.

A comprehensive assessment of the impacts of a bridge variant of a fixed link on fish including commercial species has already been undertaken (FeBEC 2012), thus the foundation for the assessment of the impact of noise and vibrations from the construction and operation of the bridge fixed solution on commercial fish species is based on results from this assessment.

The noise scenarios related to the construction and operation of a bridge are primarily caused by dredging, drilling and backfilling in relation to the construction and placement of the pylons and piers and to the ship traffic associated with construction activities at sea. During the operation of the bridge low frequent noise (vibrations) from passing trains and heavy traffic could be a potential source of impact.

6.3.1 Environmental indicators

Several commercial fish species are potentially impacted by noise and vibrations generated from the establishment and operation of bridge fixed link solution. Noise above threshold levels (dB) and within frequencies (Hz) that fish can hear have been shown to trigger avoidance responses and thus resident commercial fish species that may be in the vicinity of a noise source or migrating commercial species passing a source might be impacted.

The important commercial fish or sub component to the fisheries that are relevant to consider in relation to noise and vibrations due to the establishment of the bridge variant is given in Table 6.22.

Table 6.22: The fisheries components and sub-components (commercial species) selected for the assessment of pressures from noise and vibrations for the evaluation of the bridge alternative for the Fehmarnbelt Fixed Link.

Component	Sub-components Fisheries - gear	Sub-components Commercial species
Commercial fisheries	Trawl Gill/trammel nets Pound nets Danish seine nets	Atlantic cod Whiting Herring Sprat Flatfish species Horse mackerel Salmon Sea trout Garfish Eel

6.3.2 Sensitivity to pressure

The sensitivity of the commercial fish species represented in the impact assessment of fish is given in section 5.3.2.

6.3.3 Pressure indicators

The pressure indicators used to assess the impact of commercial fish species to noise are described in section 5.3.3.

In summary, threshold values triggering responses are calculated such that 50% of the fish will show avoidance response if the noise level is 70 dB over the threshold for fish hearing a sound, and 100% of the fish will show an avoidance response if the noise level is 90dB over the threshold level for when fish can hear a sound (Table 6.23).

Table 6.23: The estimated threshold values used to determine avoidance response for fish species during the assessment of the impact of noise on fish (FeBEC 2012).

FEBEC - E4-TR-041	Theshold dB	50 % avoidance 70 dB $_{ht}$	100 % avoidance 90 dB $_{ht}$
Codfish species/Clupeids-herring and sprat	> 75 dB	> 145 dB	> 165 dB
Other	> 90 dB	> 160 dB	> 180 dB

6.3.4 Magnitude of pressure

Construction period
Currently, no information of noise scenarios associated with the contruction activities of the bridge variant at sea was available to the group assessing the impacts of fish. Furthermore, no information on dredger type or numbers has been provided. Thus, for the assesment of impacts to fish, the dredger specification and numbers used in the tunnel alternative will be used as a proxy for the bridge solution.

Limited information for the piling works at the harbours for the bridge option are available so the more detailed descriptions for the tunnel have also been used as a proxy for the production of noise from bridge construction. Thus for this assessment it is assumed, that the noise during the construction of the bridge is equal to the noise emitted in the tunnel scenario both during construction in the alignment and in the harbour areas.

Operation period
Heavy vehicles and trains might produce significant low frequency noise or vibrations during bridge operations where noise will be transmitted to the water through the bridge structures. At present, however there were no estimates for the magnitude of pressures during bridge operations.

A more thorough description of the construction and operational activites that will create noises and their timing is given in the assessment of the impacts to fish (FeBEC, 2012).

It is anticipated that during the operational fase of a bridge fixed link the heavy traffic of ferries will be gone and the emission of noises will decline accordingly.

6.3.5 Assessment criteria

Assessment criteria used to classify the degree of impairment to commercial fish species are given in the following table which are modified from the assessment of noise on fish (FeBEC 2012).

Table 6.24: The assessment criteria used to classify the degree of impairment to commercial fish species. Criteria derived from the assessment of impacts to fish (FeBEC 2012).

Environmental component	Environmental sub-component	Reduction %		Degree of impairment
		Temporary noise construction	Permanent noise operation	
Cod, herring, silver eel, whiting,	Migration	> 40	> 10	Very high
		< 40	< 10	High
		< 20	< 5	Medium
		< 10	< 2	Low

Environmental component	Environmental sub-component	Reduction %		Degree of impairment
		Temporary noise construction	Permanent noise Operation	
Flatfish, sprat	Overall	> 60	> 15	Very high
		< 60	< 15	High
		< 30	< 8	Medium
		< 15	< 4	Low

6.3.6 Degree of impairment

The estimated impact on commercial fish species from noise and vibrations during the bridge construction and operation is derived from data of the assessment of fish and presented in the following tables (

Table 6.25and Table 6.26).

Approximately 5.5 % of the migration of gadoids (cod, whiting) and clupeids (herring and sprat) are estimated to be lost due to noise in the near zone (+/- 500 m from the bridge transect), while 1.1 % of the migration of other species is estimated to be lost in the same area (

Table 6.25).

Estimates from the affects of noise on some commercial species (cod, herring, sprat, whiting and flatfish species) from the construction activities of the bridge indicate that no more than 3.5 ha or much less than <1% of any specific area in the Fehmarnbelt were affected by noise levels above threshold levels that would create an avoidance response in areas where it is anticipated that the fish feed or are resident. Most of the lost area is close to the construction harbours (12 ha for cod, whiting, herring and sprat near Rødby and 3 ha near Puttgarden) (

Table 6.25).

There is no sufficient data to estimate the impact from noise and vibrations during operation of the bridge.

Table 6.25: Estimated impact from noise and vibrations on some commercial species during bridge construction acitivities (% and ha). Data derived from the environmental assessment of noise on fish (FeBEC 2012). Area descriptions DE EEZ and DK EEZ represent the Danish and German economic zones of Fehmarnbelt and DE 500 m and DK 500 m represent the 500 m zones of the bridge transect within the Danish (DK) and German (DE) waters of Fehmarnbelt (see FEBEC 2012) for further details of area descriptions)

Reduction of environmental components due to noise and vibrations (%-ha/m) Construction - Bridge	**DE 10 km Nat.**	**DE 10 km EEZ**	**DK 10 km**	**DE 500 m Nat.**	**DE 500 m EEZ**	**DK 500 m**
Cod						
Feeding (>5 m)	0.00 (0.0)	0.00 (0.0)	0.00 (0.0)	0.45 (2.0)	0.40 (1.9)	0.43 (3.4)
Migration (>5m)				5.49 (255)	5.49 (245)	5.49 (445)
Whiting						
Migration (>5 m)				5.49 (255)	5.49 (245)	5.49 (445)
Herring*						
Feeding (>5 m)	0.00 (0.0)	0.00 (0.0)	0.00 (0.0)	0.45 (2.0)	0.40 (1.9)	0.43 (3.4)
Migration (>5 m)				5.49 (255)	5.49 (245)	5.49 (445)
Sprat						
Feeding (>5 m)	0.00 (0.0)	0.00 (0.0)	0.00 (0.0)	0.45 (2.0)	0.40 (1.9)	0.43 (3.4)
Migration (>5 m)				5.49 (255)	5.49 (245)	5.49 (445)
Flatfish						
Feeding (>0 m)	0.00 (0.0)	0.00 (0.0)	0.00 (0.0)	0.02 (0.1)	0.02 (0.1)	0.02 (0.2)
Migration (>5 m)				1.14 (53)	1.14 (51)	1.14 (93)
Eel						
Feeding (<10 m)	0.00 (0.0)	0.00 (0.0)	0.00 (0.0)	0.51 (0.7)	0.00 (0.0)	1.02 (2.9)
Migration (>2 m)				1.14 (53)	1.14 (51)	1.14 (98)
Protected species* Salmonids						
Migration (>5 m)				1.14 (53)	1.14 (51)	1.14 (93)

Table 6.26: Estimated reduction of some commercial species caused by noise and vibrations during operation of the bridge in % and ha (m for migration). Data derived from the environmental assessment of noise on fish (FeBEC 2012). Area descriptions DE EEZ and DK EEZ represent the Danish and German economic zones of Fehmarnbelt and DE 500 m and DK 500 m represent the 500 m zones of the bridge transect within the Danish (DK) and German (DE) waters of Fehmarnbelt (see FEBEC 2012) for further details of area descriptions)

Reduction of environmental components due to noise and vibrations (%-ha/m) Operation - Bridge	**DE 10 km Nat.**	**DE 10 km EEZ**	**DK 10 km**	**DE 500 m Nat.**	**DE 500 m EEZ**	**DK 500 m**
Cod						
Feeding (>5 m)				0.03 (0.1)	0.02 (0.1)	0.03 (0.3)
Migration (>5m)				0.40 (17)	0.27 (11)	0.40 (34)
Whiting						
Migration (>5 m)				0.40 (17)	0.27 (11)	0.40 (34)
Herring*						
Feeding (>5 m)				0.03 (0.1)	0.02 (0.1)	0.03 (0.3)
Migration (>5 m)				0.40 (17)	0.27 (11)	0.40 (34)
Sprat						
Feeding (>5 m)				0.03 (0.1)	0.02 (0.1)	0.03 (0.3)
Migration (>5 m)				0.40 (17)	0.27 (11)	0.40 (34)
Flatfish						
Feeding (>0 m)				0.03 (0.1)	0.02 (0.1)	0.03 (0.3)
Migration (>5 m)				0.40 (17)	0.27 (11)	0.40 (34)
Shallow water species						
Nursery (<10 m)				0.03 (0.1)		0.03 (0.3)
Feeding (<10 m)				0.03 (0.1)	0.02 (0.1)	0.03 (0.3)
Eel						
Feeding (<10 m)				0.03 (0.1)	0.02 (0.1)	0.03 (0.3)
Migration (>2 m)				0.40 (17)	0.27 (11)	0.40 (34)

6.3.6.1 Classification of impact

The classification of impact from noise and vibration according to the assessment criteria is given in Table 6.27 and

Table 6.28.

The classification of the degree of impairment from noise and vibrations during construction and operation of the bridge fixed link was “Minor” in all case.

Table 6.27: Classification of the degree of impairment from noise and vibrations on some commercial fish species during construction of the bridge fixed link. Data derived from the environmental assessment of impacts on fish (FeBEC 2012). Area descriptions DE EEZ and DK EEZ represent the Danish and German economic zones of Fehmarnbelt, and DE 500 m and DK 500 m represent the 500 m zones of the bridge transect within the Danish (DK) and German (DE) waters of Fehmarnbelt (see FEBEC 2012 for further details of area descriptions).

Degree of impairment due to Noise and vibration, Bridge - Construction	**DE 10 km Nat.**	**DE 10 km EEZ**	**DK 10 km**	**DE 500 m Nat.**	**DE 500 m EEZ**	**DK 500 m**
Cod						
Feeding (>5 m)				Minor	Minor	Minor
Migration (>5m)				Minor	Minor	Minor
Whiting						
Migration (>5 m)				Minor	Minor	Minor
Herring*						
Feeding (>5 m)				Minor	Minor	Minor
Migration (>5 m)				Minor	Minor	Minor
Sprat						
Feeding (>5 m)				Minor	Minor	Minor
Migration (>5 m)				Minor	Minor	Minor
Flatfish						
Feeding (>0 m)				Minor	Minor	Minor
Migration (>5 m)				Minor	Minor	Minor
Eel						
Feeding (<10 m)				Minor		Minor
Migration (>2 m)				Minor	Minor	Minor
Protected species* Salmonids						
Migration (>5 m)				Minor	Minor	Minor

Table 6.28: Classification of the degree of impairment from noise and vibrations on some commercial fish species during operation of the bridge fixed link. Data derived from the environmental assessment of impacts on fish (FeBEC 2012). Area descriptions DE EEZ and DK EEZ represent the Danish and German economic zones of Fehmarnbelt, and DE 500 m and DK 500 m represent the 500 m zones of the bridge transect within the Danish (DK) and German (DE) waters of Fehmarnbelt (see FEBEC 2012) for further details of area descriptions).

Degree of impairment due to Noise and vibration, Bridge - Operation	DE 10 km Nat.	DE 10 km EEZ	DK 10 km	DE 500 m Nat.	DE 500 m EEZ	DK 500 m
Cod						
Feeding (>5 m)				Minor	Minor	Minor
Migration (>5m)				Minor	Minor	Minor
Whiting						
Migration (>5 m)				Minor	Minor	Minor
Herring*						
Feeding (>5 m)				Minor	Minor	Minor
Migration (>5 m)				Minor	Minor	Minor
Sprat						
Feeding (>5 m)				Minor	Minor	Minor
Migration (>5 m)				Minor	Minor	Minor
Flatfish						
Feeding (>0 m)				Minor	Minor	Minor
Migration (>5 m)				Minor	Minor	Minor
Eel						
Feeding (<10 m)				Minor		Minor
Migration (>2 m)				Minor	Minor	Minor

6.3.7 Severity and significance

Results derived from the assessment of the impacts to fish on the the severity and significance of the impact from noise and vibrations on fish and thus the commercial fish species during construction of the bridge fixed link was either considered “Insignificant” or “Minor” in all case (

Table 6.29).

Although there is no data at present to make an assessment of the impact from the low frequency noise and vibrations from passing trains and heavy vehicles during bridge operations, it is estimated that affects from this pressure will be minimal and not have any severe or significant impact to commercial species and thus the fisheries.

Overall, the assessment of the impact of noise on fish including some commercial fish species suggested that impacts from bridge construction and operation activities is less than the impact from the current existing heavy traffic of ferries, and the establishment of a bridge fixed link solution would presumably reduce the current noise level in Fehmarnbelt.

Table 6.29: Estimated severity of noise and vibrations on some commercial fish species during bridge construction – results derived from assessment of fish in Fehmarnbelt (FeBEC 2012). Area descriptions DE EEZ and DK EEZ represent the Danish and German economic zones of Fehmarnbelt, and DE 500 m and DK 500 m represent the 500 m zones of the bridge transect within the Danish (DK) and German (DE) waters of Fehmarnbelt (see FEBEC 2012 for further details of area descriptions).

Severity of impairment/loss of noise and vibration, Bridge _Construction	DE 10 km Nat.	DE 10 km EEZ	DK 10 km	DE 500 m Nat.	DE 500 m EEZ	DK 500 m
Cod						
Feeding (>5 m)				Minor	Minor	Minor
Migration (>5m)				Minor	Minor	Minor
Whiting						
Migration (>5 m)				Minor	Minor	Minor
Herring*						
Feeding (>5 m)				Insignif.	Insignif.	Insignif.
Migration (>5 m)				Minor	Minor	Minor
Sprat						
Feeding (>5 m)				Insignif.	Insignif.	Insignif.
Migration (>5 m)				Minor	Minor	Minor
Flatfish						
Feeding (>0 m)				Minor	Minor	Minor
Migration (>5 m)				Insignif.	Insignif.	Insignif.
Eel						
Feeding (<10 m)				Insignif.		Insignif.
Migration (>2 m)				Minor	Minor	Minor
Protected species* Salmonids				-		
Migration (>5 m)				Minor	Minor	Minor

Table 6.30: Estimated severity of noise and vibrations on some commercial fish species during bridge operation – results derived from assessment of fish in Fehmarnbelt (FeBEC 2012). Area descriptions DE EEZ and DK EEZ represent the Danish and German economic zones of Fehmarnbelt, and DE 500 m and DK 500 m represent the 500 m zones of the bridge transect within the Danish (DK) and German (DE) waters of Fehmarnbelt (see FeBEC 2012) for further details of area descriptions).

Severity of impairment/loss of noise and vibration, Bridge - Operation	DE 10 km Nat.	DE 10 km EEZ	DK 10 km	DE 500 m Nat.	DE 500 m EEZ	DK 500 m
Cod						
Feeding (>5 m)				Minor	Minor	Minor
Migration (>5m)				Minor	Minor	Minor
Whiting						
Migration (>5 m)				Minor	Minor	Minor
Herring*						
Feeding (>5 m)				Insignif.	Insignif.	Insignif.
Migration (>5 m)				Minor	Minor	Minor
Sprat						
Feeding (>5 m)				Insignif.	Insignif.	Insignif.
Migration (>5 m)				Minor	Minor	Minor
Flatfish						
Feeding (>0 m)				Minor	Minor	Minor
Migration (>5 m)				Insignif.	Insignif.	Insignif.
Eel						
Feeding (<10 m)				Insignif.		Insignif.
Migration (>2 m)				Minor	Minor	Minor

6.4 Hydrographical changes

Hydrographical changes will generally affect the fisheries indirectly by potentially influencing the migration and distribution of the commercial species (resource to the fisheries).

Thus the assessment of the impact to the fisheries will primarily rely on results of the environmental impact of potential changes to fish which will also include commercial fish species due to the establishment of a bridge fixed link solution.

In some instances if hydrographical changes lead to an increase in the speed of water currents then this may have an impact on the ability of some passive gear fisheries (gill nets, pound nets and fyke nets etc.) to undertake their fisheries in some local areas. If it is assumed that this potential impact could arise then this will discussed qualitatively.

Fehmarnbelt is a part of the transition area between the Baltic Sea and the North Sea. It has a maximum depth of approximately 30 m and the depth in the adjacent areas Mecklenburg Bight and Kiel Bight are almost similar. The upper water layers consist of low saline water from the central Baltic Sea, which flows through the Belt Sea and Kattegat close to the surface. The bottom water layer consists of more saline water from the North Sea. The two water layers in Fehmarnbelt are strongly stratified in the summer months when wind conditions are often weak.

In general, the establishment of a bridge fixed link is only expected to impact the hydrodynamics of Fehmarnbelt in a minor local way. However, pylons and piers along the transect will cause some permanent impact on the water flows that could effect the gill net and pound net fisheries in nearby areas.

A more thorough description of the hydrographical characteristics of the waters around Fehmarnbelt is described in the assessment of the impacts to fish (FeBEC 2012).

6.4.1 Environmental indicators

The Baltic Sea is one of the World's largest brackish water areas and several marine fish species have adapted to the low salinity and are an important resource to the commercial fisheries in the Western Baltic and Fehmarnbelt region.

Hydrographical changes are natural occurring pressure for fish in the Baltic Sea and marine species living here are specially adapted to the brackish water conditions with events of oxygen depletion in the deeper water layers. Important commercial fish species such as cod, herring, sprat, plaice, dab and flounder spawn in the western Baltic. The salinity, temperature and oxygen content are important especially for species with pelagic eggs for e.g. the fertilization success and buoyancy.

The activities during the construction such as dredging and excavation can affect the vertical mixing, water exchange and current pattern and thus the hydrography in Fehmarnbelt. This might affect the distribution and abundance of important commercial fish species.

The important commercial fish or sub component to the fisheries that are relevant to consider in relation to hydrographical changes due to the establishment of the bridge variant is given in Table 6.31.

Table 6.31: The fisheries sub-components (gear types and commercial species) selected for the assessment of pressures from hydrographical changes for the evaluation of the bridge alternative for the Fehmarnbelt Fixed Link.

Component	Sub-components Fisheries - gear	Sub-components Commercial species
Commercial fisheries	Trawl Gill/trammel nets Pound nets Danish seine nets	Atlantic cod Whiting Herring Sprat Flatfish species Horse mackerel Salmon Sea trout Garfish Eel

6.4.2 Sensitivity to pressure

The background for the sensitivity to pressures are given in section 5.4.2 and more thoroughly in the impact assessment on fish due to hydrographical changes from a bridge fixed link solution (FeBEC 2012).

6.4.3 Pressure indicators

Changes in the hydrology of Fehmarnbelt due to the establishment of a bridge solution will not have a direct affect on the commercial fisheries but could potentially have an affect on recruitment of commercial species due to effects on spawning and survival of eggs and larvae and thus recruitment to the fish stocks.

Marine fish species are affected by the natural hydrographical fluctuations and threshold values. These values regard primarily eggs and larvae as these life stages are most sensitive to changes in the hydrology. The overall pressure indicators selected for the impact assessment on fish and thus indirectly on the fisheries was the mortality of eggs and larvae and decrease in recruitment.

A more thorough description of these indicators is given in the assessment on fish (FeBEC 2012) which is used in this section of assessment on the resource to the fisheries (commercial fish species).

6.4.4 Magnitude of pressure

In general, the magnitude of pressure for the assessment of changes in hydrographical parameters due to establishing the bridge fixed link are related to spawning success and fish egg/larvae survival. This is because changes in hydrographical characteristics in Fehmarnbelt will have the most impact on salinity, oxygen and possibly temperature levels. Impacts to these parameters are associated with the commercial fisheries in that they have a potential impact on recruitment to commercial fish stocks. However, because the assessment in this report is primarily related to impacts on the undertaking of commercial fisheries, loss of fishing grounds and more immediate impacts to the commercial species available to the current fisheries, only essential information from the assessment of hydrographical impacts to fish are given. Thus, only the essential information related to the commercial species are summarised and more thorough information of the magnitude of pressures is given in the assessment of the impacts on fish (FeBEC 2012).

The magnitude of pressure is determined on the basis of the duration and range of the hydrographical pressure in addition to the background level exceeding the specific threshold value for the specific environmental indicators.

The local area of Fehmarnbelt corresponding to a zone covering 10 km on each side of the alignment will be assessed for fish. However, if worst case scenario for hydrographical pressures is identified in an adjacent area this area will be assessed as well.

The results of the modelling of the "Bridge + Ferry" scenario performed by FEHY was chosen as the impact for the bridge variant is this is considered to be "worst case" scenario.

In general, the changes in hydrographical parameters, caused by a bridge, are limited compared to the temporal variability in the zero-alternative (Baseline situation). The structure of a bridge has an impact on the flow due to the extra resistance. The local effects to flow blocking are estimated to -0.42 to -0.50 %.

It was estimated that the bridge will have a general effect on salinity by creating a reduction from <0.03 psu and up to 0.08 psu less in the Arkona Basin. The local effect on the bottom salinity is primarily restricted to an area east of the bridge where a maximum decrease of 0.2 psu is estimated due to increased mixing at the piers and pylons.

At most, the oxygen concentration is estimated to decrease by approximately 0.09 mg/l. However, this may be countered by an estimated increase in oxygen content in the bottom water layer near the bridge piers due to increased turbulence. Thus, a local model of the bottom oxygen effect showed a minor increase in the concentration as a result of the increased mixing due to the structures. Isolated this can have a positive effect on the conditions in Fehmarnbelt.

The minor salinity and temperature changes will affect the water density and the vertical stratification. However, the impact of the density and stratification in the Baltic Sea was less than 0.01 kg/m^3 and 0.02 kg/m^3. The stratification in the Baltic Sea is in general 4 kg/m^3.

6.4.5 Assessment criteria

The assessment criteria used to classify the degree of impairment follows the general principles described in the methodology for impacts to fish (FeBEC 2012).

6.4.6 Degree of impairment

Changes in the hydrography from the bridge variant may impact the fish communites and the impairments of the important fish species will be assessed separately.

Results from FEHY indicated only small changes in temperature, salinity and oxygen. No significant changes are expected on fish communities including the commercial fish species.

The assessment considers the magnitude of pressure relative to the background hydrographical conditions.

6.4.6.1 Analyses of impact

The impact of hydrographical changes on commercial fish communities is difficult to assess due to the large natural fluctuations both between years and within a year, but because the changes in the hydrodynamics are small and considered limited, the impact on the commercial fish communities is also assessed to be limited.

6.4.6.2 Classification of impact

The classification of the degree of impairment on the spawning and egg-larve drift and thus the potential recruitment of some commercial fish species due to hydrographical changes was minor or insignificant in all cases and areas of Fehmarnbelt (Table 6.32).

Table 6.32: The classification of the degree of impairment on commercial fish species due to hydrographical changes. Area descriptions DE EEZ and DK EEZ represent the Danish and German economic zones of Fehmarnbelt, and DE 500 m and DK 500 m represent the 500 m zones of the bridge transect within the Danish (DK) and German (DE) waters of Fehmarnbelt (see FeBEC 2012 for further details of area descriptions).

Degree of impairment of Hydrographical regime, Bridge scenario	DE 10 km	DK 10 km	DE EEZ	DK EEZ	DE 500 m	DK 500 m	Rødsand Lagoon
Cod							
Spawning (>20 m)	Minor	Minor	Minor	Minor	Minor	Minor	-
Egg-larvae drift (>10 m)	Minor	Minor	Minor	Minor	Minor	Minor	-
Herring*							
Spawning (mod)	Insignif.	Insignif.			Insignif.	Insignif.	Insignif.
Sprat							
Spawning (>10 m)	Minor	Minor	Minor	Minor	Minor	Minor	-
Egg-larvae drift (>10 m)	Minor	Minor	Minor	Minor	Minor	Minor	-
Flatfish							
Spawning (>15 m)	Minor	Minor	Minor	Minor	Minor	Minor	-
Egg-larvae drift (>10 m)	Minor	Minor	Minor	Minor	Minor	Minor	-

6.4.7 Severity and significance

Tables of the severity of impairment due to the hydrographical regime in relation to construction and operation of a bridge are not included as it is only the bridge structures that are considered to have an impact on the hydrographical regime.

The severity of impairment on the spawning and egg-larvae drift and thus the potential recruitment of some commercial fish species due to hydrographical changes was “Minor” or “Insignificant” in all cases and areas of Fehmarnbelt (Table 6.33).

Table 6.33: The severity of impairment on the spawning and egg-larvae drift of commercial fish species due to changes in the hydrographical regime because of bridge structures. Area descriptions DE and DK 10 km represents the 10km zone on each side of the bridge transect, DE EEZ and DK EEZ represent the Danish and German economic zones of Fehmarnbelt, and DE 500 m and DK 500 m represent the 500 m zones of the bridge transect within the Danish (DK) and German (DE) waters of Fehmarnbelt (see FeBEC 2012 for further details of area descriptions).

Severity of impairment/loss of Hydrographical regime, Bridge structure	DE 10 km	DK 10 km	DE EEZ	DK EEZ	DE 500 m	DK 500 m	Rødsand Lagoon
Cod							
Spawning (>15 m)	Minor	Minor	Minor	Minor	Minor	Minor	-
Egg-larvae drift (>10 m)	Minor	Minor	Minor	Minor	Minor	Minor	-
Herring*							
Spawning (mod)	Insignif.	Insignif.			Insignif.	Insignif.	Insignif.
Sprat							
Spawning (>10 m)	Minor	Minor	Minor	Minor	Minor	Minor	-
Egg-larvae drift (>10 m)	Minor	Minor	Minor	Minor	Minor	Minor	-
Flatfish							
Spawning (>15 m)	Minor	Minor	Minor	Minor	Minor	Minor	-
Egg-larvae drift (>10 m)	Minor	Minor	Minor	Minor	Minor	Minor	-

6.5 Other pressures

Several other pressures to the commercial fisheries related to the bridge fixed link alternative are possible.

- *Artificial light*
  The construction work at sea implies additional artificial light from operating vessels, and this work is expected 24 hours a day during the entire construction phase. However, the impact is expected to negligible (FeBEC, 2011, in progress). The bridge is not planned to be lighted except for the pylons and this light is not expected to impact the fish fauna by creating an avoidance behaviour or change in migration routes.

- *Barrier effect*
  During construction and operational phase of the bridge solution a barrier effect could possibly occur for some commercial species of anadromous fish (Atlantic salmon and sea trout) and fish species with other kinds of biologically based migration-patterns (cod, herring, sprat). During construction high intensities of sediment plumes and noise might deter the migration of some of these species as they might avoid migrating through these areas or spend time migrating around these areas. However, construction based impacts that could create a barrier to migration are of low intensity and extension and thus impacts to migrating species are therefore only expected to be minor.

  During the operational phase of the bridge a barrier effect may also occur caused by the bridge piers and/or the noise and vibration of the traffic on the bridge blocking migration routes. However, results from an operational monitoring of the "Øresund Bridge" showed no negative impacts on the migratory behaviour of the spring spawning herring (Appelberg, et al., 2005). According to the authors the fluctuations of the spring spawning stock of herring was based on natural variations (by hydrography and climate-weather conditions) and thus impacts due to the bridge were not detected. Because of this, only minor if any transboundary effects on migrating fish species are expected during the operational phase of the bridge.

  A barrier effect might occur in the area around the bridge ramps which are along the coastal areas. The ramps are not planned to exceed beyond the present piers in the ferry harbours and a barrier effect from the ramps is not expected to impact the commercial fish fauna. However while the key migrating fish species cod, herring, silver eel, whiting and sprat are believed to prefer open waters when migrating through Fehmarnbelt, species such as silver eel are a very important fish species to the coastal pound net fisheries which are along the shore suggesting that eel also migrate within these areas. Thus local changes in the hydrographical characteristics could have an impact on local migration routes and thus the pound net fisheries in these areas.

- *Loss/change in habitats*
  Some of the commercial fish communities in Fehmarnbelt and adjacent areas depend on suitable habitats or habitats of preference. In the assessment to the impacts of fish only habitats with vegetation were assessed under scenarios where vegetation was affected and thus reduced in abundance.

  This impact primarily affects the shallow water fish communities which for the commercial fisheries potentially include herring and some flatfish. Flatfish are not associated with vegetation and herring is a migrant species that although are associated with vegetation when spawning will undoubtedly still seasonally be a part of the fisheries as the presence of vegetation does not change their migration through the Fehmarnbelt area.

- *Spill of hazardous materials*
  Accidental loss of debree from the operating vessels and spill of hazardous materials might occur, but this must be assumed only to occur in a small scale and it is not considered to have measurable impact on the fisheries.

- *Defrost liquids*
  In the operation of the bridge, liquids used to secure the road lanes during winter might pollute the surrounding waters, but with the present current regime this would probably dilute any pollutants very quickly and no impact on the fish fauna and consequently the fisheries is expected.

6.6 Cumulative and transboundary impacts

This section describes the potential and significant cumulative impacts of the bridge fixed link solution in conjunction with other marine projects.

6.6.1 Cumulative impacts - projects and possible interactions

If impacts from other projects within the same region of the planned fixed link affect the same environmental conditions simultaneously, cumulative impacts can occur. For a project to be relevant to include in this assessment, it requires that the project:

- is within the same geographic area
- has some of the same impacts as the fixed link
- affects some of the same environmental conditions
- creates new environmental impacts during the period from the completion of environmental investigations to the operation of the fixed link.

The following projects at sea are considered relevant to include in the assessment of cumulative impacts with the fixed link cable-stayed bridge alternative on different environmental conditions. All of the projects considered are offshore wind farms:

Projects relevant for the cumulative analysis in relation to the cable-stayed fixed link solution.

Project	Placement	Phase	Possible interactions
Arkona-Becken Südost	North East of Rügen	Construction	Sediment spill, habitat displacement, collision risk, barrier effect
EnBW Windpark Baltic 2	South East of Kriegers Flak	Construction	Sediment spill, habitat displacement, collision risk, barrier effect
Wikinger	North East of Rügen	Construction	Sediment spill, habitat displacement, collision risk, barrier effect
Rødsand II	Off Lolland's southern coast	Operation	Coastal morphology, collision risk, barrier risk
Kriegers Flak II	Kriegers Flak	Construction	Sediment spill, habitat displacement, collision risk, barrier effect
GEOFReE	Lübeck bay	Construction	Sediment spill, habitat displacement, collision risk, barrier effect

Rødsand II is also specifically included as this is a project that went into operation, while the Fehmarn conducted its environmental investigations, however because of its close proximity a cumulative effect in principle cannot be excluded.

Some projects are not selected for assessing potential cumulative impacts. This "non-selection" is based on whether a project was in operation, while the environmental investigations were carried out. In these cases their environmental impacts are included in the environmental baseline investigations, and are therefore included in the benchmark for the environmental assessment. Thus all their cumulative impacts are included in the environmental assessment of the fixed link.

Other reasons for not including projects and their potential impacts in a cumulative impact assessment include:

- A project has not yet been applied for. Impacts would be expected to occurr later than impacts from the fixed link.

- There are activities and changes over time, e.g. increase in shipping traffic, which is not of a project character. Thus, these are not considered as cumulative impacts. Instead, these changes would be included in the 0-alternative, if applicable.

- Potential consequences of climate change on the environmental assessment results in the long term are described in a separate chapter.

The following projects were considered and their reasons for not being included are given in the following table:

Project	Placement	Cause
Wind farm Baltic 1	The Baltic, Northeast of Darss	In operation
Wind farm Beta Baltic	Mecklenborg bay	Not applied for
Wind farm SKY 2000	East of Fehmarn	Not applied for
Wind farm "Vindeby"	North of Lolland	In operation - Distance
The Øresund bridge	The Sound	In operation
The Great Belt bridge	The Great Belt	In operation
Raw material extraction areas in German territorial waters	The southern Baltic	Not applied for, not of project character

6.6.2 Assessment and significance of cumulative impacts

Cumulative effects can occur both during the construction or operational phase of the cable-stayed fixed link alternative.

During the construction phase of the bridge the majority of the cumulative impacts are expected to occur in relation to excess suspended sediment and noise by ramming while establishing and constructing the bridge pillars and working harbors. During the most extreme situations and in the near vicinity of the bridge construction sites fish species are expected to exhibit avoidance behavior during these impacts which could effect the distribution of commercial fish species and thus the fisheries.

Overall, however, the duration of these impacts are short. According to simulations by FEHY (2010) the degree of the sediment spillage is small and in relatively low concentrations and does not extend very far or in a large area beyond the near zone of the bridge construction area. Noise impacts are primarily based on the frequency of the ramming that is required for each foundation of each bridge pillar. This impact is considered short but intensive and thus the natural behavior of many commercial fish species is a flight reaction or an avoidance reponse away from the area. However, because this impact will be short and impacting fish only in an area near the source, only a minor impairment by noise is expected and cumulative impacts with other potential sources are considered to be low or non existant.

There is also a possibility of cumulative effects from the cable-stayed tunnel reclamation areas and the Rødsand II offshore wind farm on the coastal morphology of Lolland in the operational phase. An environmental assessment of Rødsand II showed that this installation has an effect on erosion and deposition of material along the coast. A cumulative impact assessment indicated potential changes in local currents and sediment deposition due to the change in the coastal morphology from the bridge solution and change in hydrography from the windfarm foundation of Rødsand II on the south coast of Lolland. Impacts indicated that both installations would lead to a slight increase of sedimentation in some areas and counteracting resuspension in other areas. Results of the assessment indicated overall effects, however, will be minor or non-significant both individually and cumulatively.

A barrier effect to commercial fish species based upon the described impacts; sediment spill and noise extraction etc. is not expected.

Cumulative impacts on the fisheries from seabed extraction and planned wind parks at Kriegers Flak and Rønne Banke in conjunction with the construction of the cable-stayed solution in Fehmarnbelt are not considered likely because of the distance to both Kriegers Flak and Rønne Bank extraction, the windfarm sites and the Fehmarnbelt fixed link. Additionally, there are no fixed dates for the establishment of the wind farms, so it is possible that there will not be coinciding impacts in time and space between the projects.

No cumulative impacts are expected during the operation of offshore windparks "Nysted"/"Rødsand II" and the planned wind farms east of Rügen, "Arkona-Becken Südost ", "EnBW Windpark Baltic 2", "Wikinger" and "Kriegers Flak II" as distances are considered to be to great to create conditions for cumulative effects.

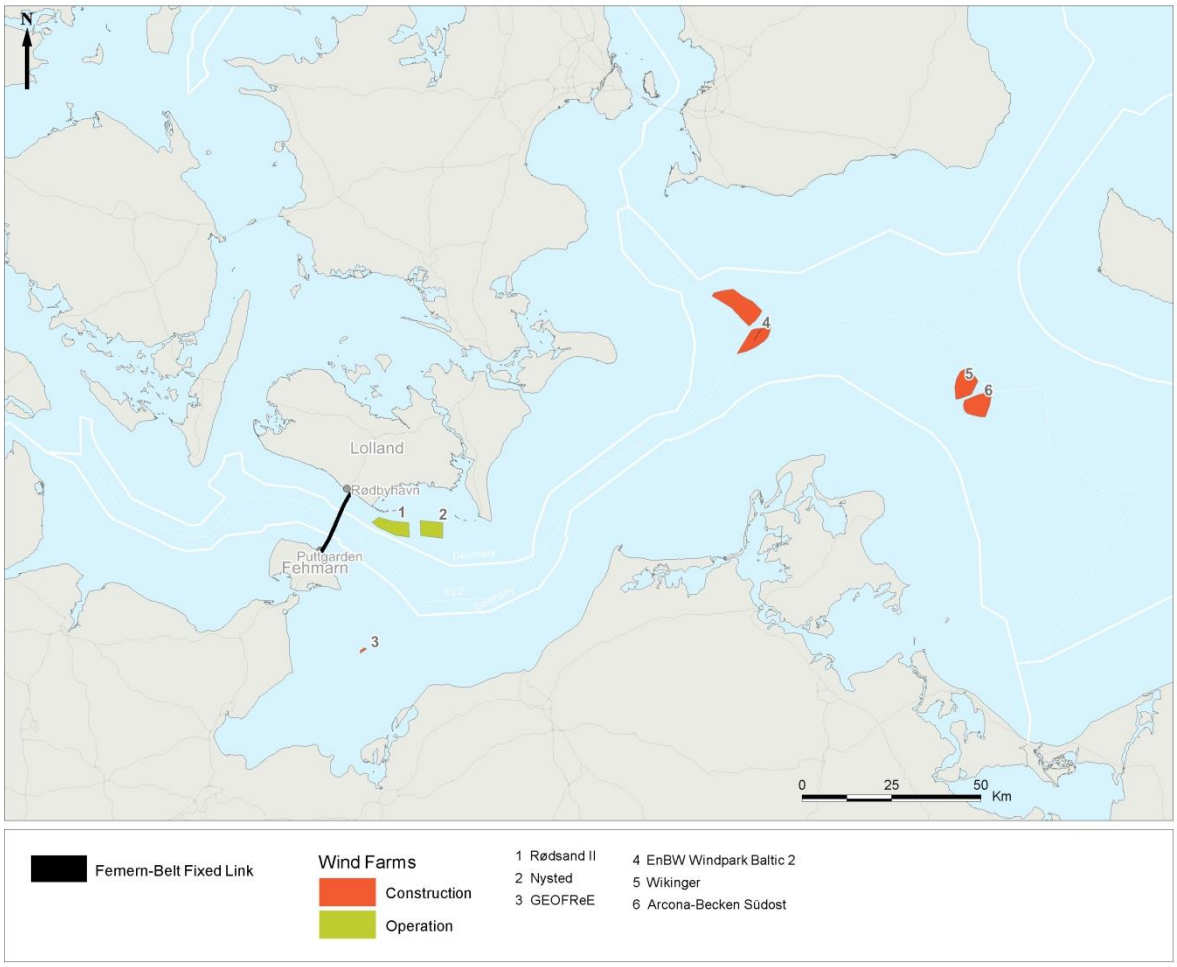


Figure 6.3: Overview of all projects in the Baltic Sea which might indirectly affect the commercial fisheries by affecting fish species and communities in the area of Fehmarnbelt by cumulative impacts.

Transboundary impacts

The possibility of transboundary impacts from development projects led to the forming of the Convention on Environmental Impact Assessment in a Transboundary Context also known as the Espoo Convention (Espoo Convention 1991). The Convention was adopted with the support of the United Nations Economic Commission for Europe (UNECE) and implemented in 1997 with the general aim of "ensuring environmentally sound and sustainable development in potentially transboundary projects" through open communication and if necessary international cooperation.

Denmark and Germany are the only 2 countries that have commercial fisheries in Fehmarnbelt and its region in the Western Baltic and an assessment of impacts due to the establishment of Fehmarnbelt Fixed Link bridge solution directly relating to these fisheries has been undertaken in this report. However, a number of the commercial fish species present in Fehmarnbelt migrate over large distances between spawning grounds, nursery areas and feeding grounds. During these migrations these species will pass through or reside in national waters of other countries or in international waters and will be available to the respective fisheries of other countries.

Thus, it is recognised that the commercial fisheries in other countries could be indirectly impacted if shared commercial fish stocks are substantially impacted by the establishment of the Fehmarnbelt Fixed Link bridge solution.

Assessments in relation to potential transboundary impacts to the commercial fisheries of other countries were assessed on the following migratory fish stocks in Fehmarnbelt listed together with the main countries that include these stocks in their commercial fisheries.

Commercial fish stocks	Primary areas of commercial fisheries	Main countries that undertake fisheries on these stocks
Cod (*Gadus morhua*)	Western Baltic	Denmark, Germany, Sweden, Poland, Estonia, Latvia, Finland and Lithuania*
Herring (Clupea harengus)	Western Baltic, Kattegat, Skagerrak and North Sea	Denmark, Sweden, Germany, Norway, Faroe Islands and Lithuania*
Sprat (Clupea sprattus)	Western Baltic	Denmark, Germany, Sweden, Poland and Finland
European eel (Anguilla anguilla)	Baltic Sea and Kattegat	Denmark, Sweden, Poland, Lithuania, Estonia, Latvia, Germany and Finland
Whiting (*Merlangius merlangus*)	Western Baltic	Denmark, Sweden and Norway

*Kun siden 2010

Results of the impact to the different life stages (spawning, eggs and larvae, juveniles and adults) and their important habitats (spawning area, nursery area, feeding area and migration) of the commercial fish stocks (cod, herring, sprat, European eel and whiting) that are recognised as transboundary stocks due to the construction, operation and structures of the bridge fixed link solution are as follows:

Impacts from the construction, operation and structures of the bridge project were low to medium on all commercial fish stocks that have extended geographical distributions. Impacts greater than “low or insignificant” were only registered in the near vicinity of the fixed link and can be considered insignificant in relation to potentially impacting any of the fish stocks other than on a local scale.

6.7 Project impact

6.7.1 Denmark

The project impacts for each of the Danish fishery sub-components (trawl, gill nets, pound nets and Danish seine nets) are given in Table 6.34 and summarised in this chapter.

Table 6.34: The project impacts for the different sub-components of the Danish fisheries in the Fehmarnbelt (ICES 38G1) and the Fehmarnbelt Region in relation to pressures from the construction, operation and structures/shipping lanes of the bridge solution.

Fehmarnbelt (ICES 38G1) Bridge	Reclamation areas/Footprints/ Shipping lanes	Sediment spill	Noise and vibration	Hydrographical changes	Other pressures	Indirect pressures	Project impairment	Importance	Severity of impairment	Severity of loss
Trawl							Minor	Medium	Minor	Medium
Gill nets							Minor	Medium	Minor	Medium
Pound nets							Minor	Very high	Minor	Very high
Danish seine nets							Minor	Minor	Minor	Minor
Project severity									Minor	Very high

Fehmarnbelt Region - Bridge	Reclamation areas/Footprints/ Shipping lanes	Sediment spill	Noise and vibration	Hydrographical changes	Other pressures	Indirect pressures	Project impairment	Importance	Severity of impairment	Severity of loss
Trawl							Minor	Medium	Minor	Medium
Gill nets							Minor	Medium	Minor	
Pound nets							Minor	Very high	Minor	
Danish seine nets							Minor	Minor	Minor	
Project severity									Minor	Medium

Trawl
During the construction phase there were no impacts on the Danish trawl fishery in Fehmarnbelt and its region that exceeded “Minor”. The loss of trawl area due to shipping lanes during operation will give a “Medium” impact on the trawl fisheries in Fehmarnbelt in accordance with it importance. The impact to the trawl fishery in the Fehmarnbelt due to the shipping lanes is considerable because of the amount of area lost to the trawl fisheries and the necessity to undertake time consuming operations such as lifting and resetting trawl gear which could lead to added costs to the fisheries and a reduction in the net value of their landings.

The project impairment and severity to the trawl fisheries is based on assumptions that a bridge will have similar passing lanes and area closure as the nearby Great Belt Bridge, thus an assessment of the project impairment and severity of the bridge project to the trawl fisheries may change if the passing lanes and restrictions to the fisheries in association with the establishment of a bridge fixed link are different. There were no aggregating impacts causing

changes in the project impairment thus the project severity for trawl is considerablein Fehmarnbelt.

Gill nets
There were no impacts on the Danish gill net fishery in Fehmarnbelt and its region that exceeded “Minor” during construction activities and the operation of the bridge. The loss of fishing area due to reclamation of areas/footprints was “Medium” according to the importance of this fishery. There were no aggregating impacts causing changes in the project impairment thus the project severity for the Danish gill nets is “Minor” in Fehmarnbelt and the Fehmarnbelt region.

Pound nets
Impacts on the pound nets fishery in Fehmarnbelt and its region did not exceed “Minor” during bridge construction or operation activities. The loss of pound net fishing area due to reclamation areas was very high on a local scale, however the impact of loss was only minor when considering the impact for the entire Fehmarnbelt Danish pound net fishery on the southern coast of Lolland. There were no aggregating impacts causing changes in the project impairment thus the project severity for the pound nets is “Minor” in the Fehmarnbelt region.

Danish seine nets
During the construction phase there were no impacts on the Danish seine net fishery in Fehmarnbelt and its region that exceeded “Minor”. During the operation of the bridge it is anticipated that the loss of seine net area due to shipping lanes will give a “Minor” impact on the trawl fisheries in Fehmarnbelt according to its importance. This impact is considerable on a local level but is only estimated to be “Minor” at the project level in relation to Femern Bælt and it region because of the low importance of the Siene net fishieries in Femern Belt. There were no aggregating impacts causing changes in the project impairment thus the project severity for the Danish seine net fishery of low importance is considered “Minor” in Fehmarnbelt and insignificant in the Fehmarnbelt region.

6.7.2 Germany

The project impacts for each of the German fishery sub-components (trawl, gill nets, pound nets and Danish seine nets) are given in Table 6.35 and summarised in this chapter.

Table 6.35: The project impacts for the different sub-components of the German fisheries in the Fehmarnbelt (ICES 38G1) and the Fehmarnbelt Region in relation to pressures from the construction, operation and structures/shipping lanes of the bridge solution.

Fehmarnbelt (ICES 38G1) Bridge	**Reclamation areas/Footprints Shipping lanes**	**Sediment spill**	**Noise and vibration**	**Hydrographical changes**	**Other pressures**	**Indirect pressures**	**Project impairment**	**Importance**	**Severity of impairment**	**Severity of loss**
Trawl							Minor	Medium	Minor	Medium
Gill nets							Minor	Medium	Minor	Medium
Pound nets							Minor	Very high	Minor	Very high
Project severity									Minor	Very high

Fehmarnbelt Region - Bridge	Reclamation areas/Footprints Shipping lanes	Sediment spill	Noise and vibration	Hydrographical changes	Other pressures	Indirect pressures	Project impairment	Importance	Severity of impairment	Severity of loss
Trawl							Minor	Medium	Minor	Medium
Gill nets							Minor	Medium	Minor	
Pound nets							Minor	Very high	Minor	
Project severity									Minor	Medium

Trawl
During the operation of the bridge it is anticipated that the loss of German trawl area due to shipping lanes will give a “Medium” impact on the trawl fisheries in Fehmarnbelt. During the construction phase there were no impacts on the German trawl fishery in Fehmarnbelt and its region that exceeded “Minor”. This impact is only estimated to be “Minor” in relation to the Fehmarnbelt Region.

Gill nets
There were no impacts on the German gill net fishery in Fehmarnbelt and its region that exceeded “Minor” during construction activities or the operation of the bridge. The loss of fishing area due to reclamation of areas/footprints was “Medium” according to the importance of this fishery. There were no aggregating impacts causing changes in the project impairment thus the project severity for the German gill nets is “Minor” in Fehmarnbelt and the Fehmarnbelt region.

Pound nets
Impacts on the pound nets fishery in Fehmarnbelt and its region did not exceed “Minor” during bridge construction or operation activities. There were no aggregating impacts causing changes in the project impairment thus the project severity for the German pound nets is “Minor” in the Fehmarnbelt region.

7. Assessment of climate change impact

7.1 Impact of predicted climate changes to commercial fish species in Fehmarnbelt

The assessment of climate change and the impacts to fish and thus indirectly to the fisheries is dealt with thoroughly in the document on the assessment of the environmental impacts to fish (FeBEC) and the fish baseline report (FeBEC 2011a). A summary of their results regarding the potential impacts to the most important commercial fish species, cod, sprat and herring will be presented in the following sections.

7.1.1 Cod

Atlantic cod is economically the most important commercial species to the fisheries in Fehmarnbelt and the Western Baltic. Climate-driven changes in environmental conditions may influence cod populations directly (e.g. growth, distribution) and indirectly (e.g. changes in food and predators) and the drastic decline in the eastern Baltic cod stock since 1980s has been related to a climate-driven reduction in their reproductive success in combination with increasing pressures from the fisheries (Köster, et al., 2003a).

In summary, climatic conditions in the past decade, as well as predicted climate changes are predominantly thought to be detrimental for Baltic cod recruitment strength and stock productivity, although some counteracting factors do exist. Determining the relative contribution of overfishing and climate variability in causing stock declines in the late 1980s is difficult (Eero, et al., in press; Lindegren, et al., 2010a). A healthy stock structure (Casini, et al., 2008; Ottersen, et al., 2006), sufficiently high stock size (Lindegren, et al., 2010b) and the implementation of an adaptive management system, taking climate change into account (Lindegren, et al., 2009; Lindegren, et al., 2010b), might help to reduce anticipated negative effects of climate change on Baltic cod stocks and promote a more sustainable commercial fishery targetting cod in a future with a changing climate.

7.1.2 Sprat

Baltic sprat is an ecologically important pelagic fish species (Rudstam et al., 1994; Kornilovs et al., 2001), being both a key prey species for top predators (e.g. cod and harbour porpoise) and predator on zooplankton and fish eggs (Arrhenius, et al., 1993; Bagge, et al., 1994; Köster, et al., 2003a). At present, sprat also represents the most abundant, commercially exploited fish species in the Baltic Sea (ICES, 2010b). During the previous two decades, the management of Baltic sprat has been challenged by large stock fluctuations mainly caused by highly variable recruitment success. These recruitment fluctuations appear to be driven by a number of interacting environmental drivers which appear to be subject to climate change. Baltic sprat represents an example of a species occurring at the northern boundary of the geographical distribution (Muus, et al., 1999) and is therefore especially vulnerable to cold temperatures. Sprat is adapted to marine environments but are tolerant of salinities down to approximately 5 ppt and can be present well into the the brackish Baltic Sea.

Baltic sprat stock productivity has been linked to large scale climate variability (North Atlantic Oscillation, NAO), suggesting that winter-time NAO is coupled to temperature conditions in the Baltic (MacKenzie, et al., 2004). Furthermore, temperature conditions have been shown to be positively correlated with recruitment strength. In recent years, more detailed, process-orientiated knowledge has been gained which forms the basis to explore the effects of potential changes in climate-driven, environmental forcing on different sprat life stages.

At present the available knowledge indicates predominantly positive effects of anticipated climate change on Baltic sprat stock dynamics and thus a positive potential for high exploitation levels for the commercial fisheries.

7.1.3 Herring

Herring is a key species in many temperate marine ecosystems (Blaxter, et al., 1982) and similar to sprat, it forms a major link between top-predators (e.g. seals, cod) and zooplankton production (Casini, et al., 2004). In the Baltic Sea a number of distinct herring populations exist (ICES, 2007a) that are of considerable economic importance to the fisheries by nine bordering countries that heavily exploit the herring stocks. According to their regional distribution, the stocks inhabit quite different local ecosystems, characterized by a large range in environmental conditions such as salinity, temperature and zooplankton communities (ICES, 2008). Stock dynamics have been different due to variable exploitation rates and stock productivity. The largest stock unit, the central Baltic herring stock, has shown a pronounced decline in spawning stock biomass since the late 1970s (Cardinale, et al., 2009). The decline in biomass is at least partly explained by a strong decrease in weight-at-age (ICES, 2009). Contrary to the development of the central Baltic herring stock, the stocks in the Gulf of Riga and the Bothnian Sea herring showed an increase in SSB levels in the 1980s. Climate forcing seems to influence stock components in variable extend and in combination with other factors.

The overall effect of projected climate change on Baltic herring stocks is difficult to determine. Most stocks will probably react differently; some might increase in stock production, abundance and fishing potential while others decrease. In general, the fate of the Baltic herring stocks seems closely linked to the stock dynamics of cod and sprat.

7.1.4 Interaction between cod, sprat and herring

The central Baltic Sea can be described as a relatively simple ecosystem in terms of biodiversity of the higher trophic levels, i.e. the fish stocks. There is only one dominating piscivour, i.e. cod and two important planktivours, i.e. herring and sprat. However, even this rather simple system gains complexity, as numerous interactions between the different life stages exist (Figure 7.1). Adult cod prey on adult sprat and juvenile herring, but are also cannibalistic (the degree is dependent on stock size and spatial overlap of age-classes). Adults of herring and sprat prey on cod eggs. Sprats are feeding on sprat eggs, i.e. are cannibalistic. Herring and sprat show food competition and adult sprat are able to exert top-down control on *Pseudocalanus acuspes*, the most important prey for cod larvae. In summary, the stock dynamics of all three species are closely linked and climate effects on one species will almost certainly also impact the other species in a scenario with changing environmental conditions due to climate change.

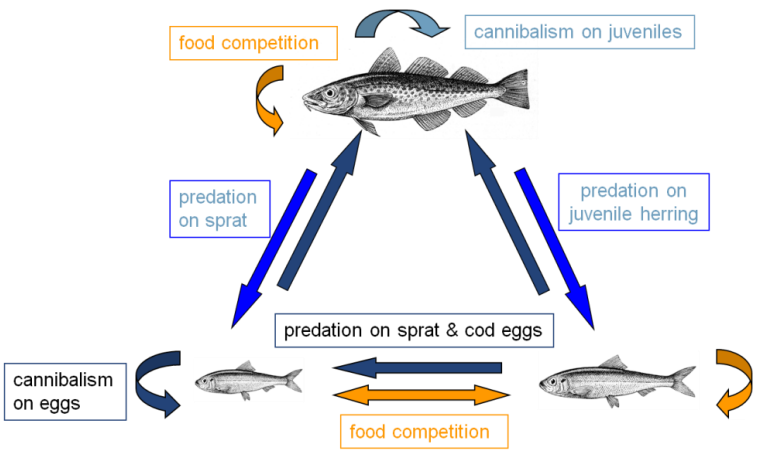


Figure 7.1. Simplified schematic diagram showing intra- and inter-specific relations between Baltic cod, herring and sprat. Figure adopted from Schnack (2003).

8. Comparison of bridge and tunnel main alternatives per component

The project impact of the tunnel and the bridge alternatives are compared for the Danish and German commercial fisheries in Table 8.1 and Table 8.2, respectively. Results are described in the following sections.

Denmark
The impact of the tunnel solution primarily affects the coastal pound net fisheries where there is a very high local impact due to the establishment of a reclamation area that would create a direct loss of some fishing areas to specific pound net fishermen. The footprint from the tunnel trench is assessed as a loss of area, however, it is unknown whether the footprint from the tunnel trench will also have an impact on the trawl or seine net fisheries by creating a permanent barrier or a belt of stone and boulder material that has the potential to damage gear or hinder the undertaking of these fisheries.

Similarly, the impact of the bridge structures would create the need for shipping lanes and lead to restrictions to undertaking fisheries in these areas. This will create a loss of fishing area in the deeper middle parts of Fehmarnbelt which, together with the piers and pylons would create a barrier primarily affecting the trawl fisheries of medium importance and the seine fisheries of low importance that have their fisheries in the central parts of Fehmarnbelt.

Although the tunnel solution will have a greater amount of sediment spillage over a longer time than the bridge solution during the construction period and potentially affect the distribution of the commercial species more severely, the severity of impact is minor in both cases suggesting the differences in this impact is not great enough to warrant a general difference in severity between the two solutions.

Table 8.1: Comparisons of the tunnel and bridge project impacts on the sub-components of the Danish commercial fisheries during construction and operation phases and is association with the respective structures.

Severity of impairment, Denmark	**Tunnel**			**Bridge**		
	Construction	Operation	Footprints/ Structures	Construction	Operation	Footprints/ Structures
Fehmarnbelt (ICES 38G1)						
Trawl	Minor	Minor	Medium	Minor	Minor	Medium
Gill nets	Minor	Minor	Medium	Minor	Minor	Medium
Pound nets	Minor	Minor	Very high	Minor	Minor	Very high
Danish seine nets	Minor	Minor	Minor	Minor	Minor	Minor
Fehmarnbelt Region						
Trawl	Minor	Minor		Minor	Minor	Medium
Gill nets	Minor	Minor		Minor	Minor	
Pound nets	Minor	Minor		Minor	Minor	
Danish seine nets	Minor	Minor		Minor	Minor	

Germany
The impact of the footprints from a bridge solution and anticipated shipping lanes that restrict the undertaking of primarily the trawl fisheries is estimated to have a medium impact to the German fisheries according to it importance. Furthermore, piers and pylons along the bridge transect will also create a barrier which primarily affects the trawl fisheries of medium importance by potentially causing time consuming breaks in trawl hauls.

The tunnel trench established from the tunnel solution will partially be covered with stones and boulders. This will be left to develop naturally. If the trench has exposed material that can cause impairments to the trawl fisheries or damage to gear, the tunnel solution could potentially create a permanent impact to the trawl fisheries.

Because land reclamation in the tunnel solution is primarily on the Danish side of Fehmarnbelt, this impact does not affect the German coastal or pound net fisheries as much it does the Danish coastal and pound net fisheries.

During the construction period, the tunnel solution will have a greater amount of sediment spillage over a longer period of time than a bridge solution. Although this impact from the tunnel solution will potentially affect the commercial species more severely, the severity of impact is minor in both cases suggesting the differences in this impact are not great enough to warrant a general difference in severity between the two solutions.

Table 8.2: Comparisons of the tunnel and bridge project impacts on the sub-components of the German commercial fisheries during construction and operation phases and is association with the respective structures.

Severity of impairment, Germany	**Tunnel**			**Bridge**		
	Construction	Operation	Footprints/ Structures	Construction	Operation	Footprints/ Structures
Fehmarnbelt (ICES 38G1)						
Trawl	Minor	Minor	Medium	Minor	Minor	Medium
Gill nets	Minor	Minor	Medium	Minor	Minor	Medium
Pound nets	Minor	Minor	Very high	Minor	Minor	Very high
Fehmarnbelt Region						
Trawl	Minor	Minor		Minor	Minor	Medium
Gill nets	Minor	Minor		Minor	Minor	
Pound nets	Minor	Minor		Minor	Minor	

The purpose of the comparison of tunnel and bridge is to find out which of the two alternatives are preferable in relation to the impacts on the fisheries in Fehmarnbelt. The comparison is based on the assessment results of the relevant pressures in terms of the affected areas and the severity of impacts. The main comparison of the relevant pressures on fisheries is shown in Table 8.3.

Table 8.3: Comparison of the main alternatives - tunnel and bridge. ++ = clear advantage, + = advantage.

Pressure	**Tunnel**	**Bridge**	**Preferred alternative**
Seabed reclamation	0	0	
Sediment spill	0	0	
Noise and vibration	0	0	
Indirect pressure	0	0	
Hydrological changes	0	0	
Summary			

9. Decommissioning

The immersed tunnel elements will not be removed from under the seabed after operation and therefore no impact from decommissioning of these structures are anticipated. The landbased entrance ramps to the tunnel may be removed but it is anticipated that this will only create a minor amount of sediment spill during a short period near the areas of activity.

The suspension bridge is planned to be decommissioned in year 2140 after 120 years of operation. In principle there is a decommissioning plan for all main structures of the bridge. For the marine environment all structures are planned to be removed except the pile inclusions structures which will be left beneath the seabed.

It is considered that the dismantling of the superstructures will take place at sea and eventually transported to the shore for further dismantling. The pillars and piers are all broken down on site and the pieces are transported to the shore. The pillar caissons are all transported to the shore after deballasting and re-floating. The pier caissons are also transported to the shore after removal of ballast material and scour protection.

Based on dismantling techniques as they are known today, any impairment or impacts to the commercial fisheries is expected to be related to extra ships traffic disturbing some fishing areas and activities producing noise at frequencies sensitive for fish. The degree of impairment is, however, considered only to be minor or negligible.

10. Mitigation

A mitigation plan is made to outline construction and operation related measures to reduce potential impacts from the individual fixed link alternatives. Specific mitigation actions related to the specific pressures from the construction of a tunnel or bridge alternative on the commercial fisheries could involve modifications of the design and structures of the links or to the construction strategy with respect to placement of deposition sites, temporary working access channels or working harbours, time schedules for dredging etc. Furthermore, the seasonality of the different fisheries and the distribution of their resources (commercial fish species) could call for mitigating time schedules concerning impacts disturbing specific fishing areas or the distribution of specific commercial species during the most intense fishing periods.

However, impact assessment results from the establishment of both link alternatives indicated that the degree of impairments to the commercial fisheries was “Minor” for all the commercial fisheries, except for pressures related to footprints and structures. Similarly, impacts on the commercial fish species were only as great as “Medium” in the near zone of alignments for noise and sediment spill, and were Minor or nonexistent for all other pressures.

The loss of area to commercial fisheries due to footprints/structures or safety zones prohibitting fisheries is a permanent impact that technically cannot be resolved or reduced through mitigation.

The potential loss of fishing areas along the entire bridge alignment will depend on the eventual rules regulating the fisheries close to the bridge structures and the ability to undertake fisheries near these structures. At present, these regulations and limitations are not known and thus suggestions for mitigation measures to reduce impacts are not possible.

Mitigation measures are not considered for either the bridge or the tunnel solution.

11. Inadequate data acquisition and knowledge gaps

11.1 Tunnel alternative

Tunnel trench
Regulations regarding the undertaking of fisheries across the tunnel trench are not available. This knowledge would allow for more specific impact assessments to the fisheries. At present, the assessment due to this impact has been based on the worst case scenario which is a loss of this area and the inability to undertake trawling or seine net fishing across the trench.

Noise and vibrations
Because no detailed information was available the noise scenarios for the construction of the harbours on Lolland and Fehmarn were derived from values obtained in literature rather than information on the specific machinery expected to be applied. Furthermore, the presence of dikes surrounding the working area complicates predictions of noise emmited to the waters outside the dikes from the planned pile ramming and steelsheet ramming activities.

The noise and vibration emmited during operation of the tunnel was predicted from measurements done during the establishment of the Øresund Tunnel. However, only sound frequencies higher than 50 Hz were measured efficiently as the low frequent vibrations measured on top of the tunnel were affected by the setup

11.2 Bridge alternative

Shipping lanes and restrictions to the fisheries
To fully assess the significance of the impacts to the fisheries due to security zones and the physical disturbance of piers and pylons along the bridge transect, it is necessary to have knowledge of the regulations for trawling under the different sections of the bridge, and whether the physical structures and sea bed morphology along alternative trawling routes will allow the undertaking of fisheries without major disturbances or problems.

Noise and vibration
The noise scenarios regarding the construction of the bridge were obtained from the predicted scenarios from the tunnel construction because no accurate information was available on the schedule and type of machinery related to the drilling, dredging, backfilling and ramming activities and on the ship traffic related to the construction activities. Furthermore, no detailed information was available on the construction of the harbours related to the construction activities.

12. References

Appelberg, M, Holmqvist, M and Lagenfelt, I. 2005. Øresundsforbindelsens inverkan paa fisk och fiske. Underlagsrapport 1992-2005. 2005, pp. 1-230.

Arrhenius, F and Hansson, S. 1993. Food consumption of larval, young and adult herring and sprat in the Baltic Sea. *Marine Ecology Progress Series.* 1993, Vol. 96, pp. "125-137".

Astrup, J and Møhl, B. 1993. Detection of intense ultrasound by the cod (Gadus morhua). *Journal of Experimanetal Biology.* 1993, Vol. 182, pp. 71-80.

Bagge, O; Thurow, F; Steffensen, E; Bay, J 1994. The Baltic cod. *DANA.* 1994, Vol. 10, pp. 1-28.

Beatrice. 2005. *Talisman Energy (UKJ), Limited.* Talisman House, Aberdeen : www.beatricewind.co.uk, 2005.

Belanger, AJ and Higgs, DH. 2004. Hearing and the round goby: Understanding the auditory system of the round goby (Neogobius melanostomus). *Journal of the Acoustical Society of America.* 2004, Vol. 117, 4.

Blaxter, JHS and Hunter, JR. 1982. *The biology of clupeoid fishes. .* New York : Academic Press, 1982.

Bone, Q and Marshall, NB, Blaxter, JHS. 1995. *Biology of fish.* Second edition. s.l. : Blackie Academic & Professional, 1995.

Brandt, E and Runge, K. 2002. *Kumulative und grenzüberschreitende Umweltwirkungen im Zusammenhang mit Offshore-Windparks. - Rechtsrahmen und Untersuchungsempfehlungen.* Baden-Baden : Nomos Verlagsgesellschaft, 2002. p. 166. Vols. Lünebürger Schriften zum Umwelt- und Energierecht 3.

Cardinale, M; Möllmann, C; Bartolino, V; Casini, M; Kornilovs, G; Raiid, T; Margonski, P; Grzyb, A; Raitaniemi, J; Gröhsler, T; Klinkman, J. 2009. Effect of environmental variability and spawner characteristics on the recruitment of Baltic herring Clupea harengus populations. *Marine Ecology Progress Series.* 2009, Vol. 388, pp. 221-234.

Casini, M; Cardinale, M and Arrhenius, F. 2004. Feeding preferences of herring (Clupea harengus) and sprat (Sprattus sprattus) in the southern Baltic Sea. *ICES Journal of Marine Science.* 2004, Vol. 61, pp. "1267-1277".

Casini, M; Lövgren, J; Hjelm, J; Cardinale, M; Molinero, J C; Kornilovs, G. 2008. Multi-level trophic cascades in a heavily exploited open marine ecosystem. *Proc. R. Soc. B.* 2008, Vol. 275, pp. 1793-1801.

COWI-Lahmeyer Joint Venture,. 1999. *Fehmarn Belt Feasibility Study. Coast to coast investigations. Investigations of Environmental Impact. Phase 2 Report.* 1999.

DMU. 2011. Den danske rødliste. *http://www2.dmu.dk/1_om_dmu/2_tvaer-funk/3_fdc_bio/projekter/redlist/gpdata2.asp?ID=12.* 2011.

Eero, M; MacKenzie, BR; Köster, FW; Gislason, H.. in press. Multi-decadal responses of a cod (Gadus morhua) population to human-induced trophic changes, exploitation and climate variability. *Ecological Applications.* in press.

Engell-Sørensen, K and Skyt, P H. 2002. *Evaluation of the Effect of Sediment Spill from Offshore Wind Farm Construction on Marine Fish.* s.l. : SEAS, 2002.

Enger, PS; Kalmijn, AD and Sand, O. 1989. Behavioural investigations on the function of the lateral line and inner ear in predation. [ed.] S Coombs, P Görner and H Münz. *The mechanosensory lateral line.* New York : Springer-Verlag, 1989, pp. 375-387.

Fay, RR and Popper, AN, [ed.]. 1999. *Comparative hearing: Fish and amphibians.* s.l. : Springer, 1999. p. 438.

FeBEC. 2011. *Baseline Fish Ecology.* s.l. : Prepared for Femern A/S, 2011. Doc. No. E4-TR-038.

FeBEC. 2011b. *Baseline Fisheries. s.l. : Prepared for Femern A/S, 2011.* 2011b. Doc. No. E4-TR-035.

FeBEC. 2012. *Environmental Impact Statement Fish Ecology.* s.l. : Prepared for Femern A/S. , 2012. Doc No. E4-TR-041.

FEHY. 2011. *Fehmanrbelt Fixed link EIA. Marine water Baseline, Volume II: Hydrography of the Fehmarnbelt area.* s.l. : Femern A/S, 2011. p. 173 pp. E1TR0057.

FEHY. 2011e. *Sediment Spill during construction of the Fehmarnbelt Fixed Link. .* s.l. : Draft report prepared by DHI/IOW Consortium in association with LICengineering, Bolding & Burchard and Risø DTU for Femern A/S., 2011e.

Fricke, R; Berghahn, R; Rechlin, O; Neudecker, T; Winkler, H M; Bast, H.-D.; Hahlbeck, E. 1998. Rote Liste gefährdeter Tiere Deutschlands. [ed.] M Binot, et al. s.l. : Schr.-R. f. Landschaftspfl. u. Natursch., 1998, pp. 60-64.

Fricke, R; Rechlin, O; Winkler, H M; Bast, H.-D.; Hahlbeck, E. 1996. *Rote Liste und Artenliste der Rundmäuler und Meeresfische des deutschen Meeres- und Küstenbereichs der Ostsee.* [ed.] T Merck. s.l. : Schr.-R. f. Landschaftspfl. u. Natursch., 1996. pp. 83-90. Vol. H. 48.

Hawkins, AD and Johnstone, ADF. 1978. The hearing of the Atlantic salmon (Salmo salar). *J. Fish. Biol.* 1978, Vol. 13, pp. 655-673.

Humborstad, O-B; Jørgensen, T and Grotmol, S. 2006. Exposure of cod Gadus morhua to resuspended sediment: an experimental study of bottom trawling. *Marine Ecology Progress Series.* 2006, Vol. 309, pp. 247-254.

ICES. 2005. Report of the ICES Advisory Committee on Fishery Management, Advisory Committee on the Marine Environment and Advisory Committee on Ecosystems. *ICES Advice.* 2005, Vols. 1-11, p. 418.

ICES. 2007a. Report of the ICES Advisory Committee on Fishery Management, Advisory Committee on Marine Environment and Advisory Committee on Ecosystems, 2007. *ICES Advice.* 2007a, Vols. Books 1-10(6), p. 310 pp.

ICES. 2008. Report on developing and testing environmentally-sensitive stock-recruitment relationships of Baltic herring and sprat stocks. *ICES CM .* 2008, 2008/BCC:05.ICES. 2009. Report of the Baltic Fisheries Assessment Working Group (WGBFAS) 22-28 April 2009 ICES Headquarters, Copenhagen. *ICES CM.* 2009, Vol. 2009/ACOM:07, p. 626 pp.

ICES. 2010b. Report of the Herring Assessment Working Group for the Area South of 62Â° N (HAWG), 15-23 March 2010, ICES Headquarters, Copenhagen, Denmark. 2010b.

ITAP. 2011. *Ambient noise measurements and modelling (noise maps).* 2011.

Jerkø, H; Turunen, I; Enger, PS; Sand, O. 1989. Hearing in the eel (Anguilla anguilla). *Journal of Comparative Physiology A.* 1989, Vol. 165, pp. 455-459.

Karlsen, HE. 1992. Infrasound sensitivity in the plaice (pleuronectes platessa). *J. Exp. Biol.* 1992, Vol. 171, pp. 173-187.

Keller, O; Lüdemann, K and Kafemann, R. 2006. Literature review of offshore wind farms with regard to fish fauna. *BfN-Skripten.* 2006, Vol. 186, pp. 47-130.

Klaustrup, M; Leonhard, S B and Skov, H. 2007. *EIA Report Fish. Rødsand 2 Offshore Wind Farm.* s.l. : DONG Energy, 2007.

Knudsen, FR, Enger, P and Sand, O. 1994. Avoidance responses to low frequency sound in downstream migrating Atlantic salmon smolt, Salmo salar. *Journal of Fish Biology.* 1994, Vol. 45, pp. 227-233.

Knudsen, FR, Enger, PS and Sand, O. 1992. Awareness reactions and avoidance responses to sound in juvenile Atlantic salmon, Salmo salar L. *Journal of Fish Biology.* 1992, Vol. 40, pp. 523-534.

Kornilovs, G, Sidrevics, L and Dippner, JW. 2001. Fish and zooplankton interaction in the Central Baltic Sea. 579−588. *ICES Journal of Marine Science.* 2001, Vol. 58, p. 579−588.

Köster, F W; Hinrichsen, H.-H.; Schnack, D; St. John, M A; MacKenzie, B R; Tomkiewicz, J; Møllmann, C; Kraus, G; Plikshs, M; Makarchouk, A; Aro, E. 2003a. Recruitment of Baltic cod and sprat stocks: identification of critical life stages and incorporation of environmental variability into stock-recruitment relationships. *Scient Marina.* 2003a, Vol. 67, pp. "129-154".

Lindegren, M; Diekmann, R and Möllmann, C. 2010b. Regime shifts, resilience and recovery of a cod stock. *Marine Ecology Progress Series.* 2010b, Vol. 402, pp. 239-53.

Lindegren, M; Möllmann, C; Nielsen, A; Brander, K; MacKenzie, BR; Stenseth, NC. 2010a. Ecological forecasting under climate change: the case of Baltic cod. *Proceedings of the Royal Society B.* 2010a, Vol. 277, pp. 2121-2130.

Lindegren, M; Möllmann, C; Nielsen, A; Stenseth, NC. 2009. Preventing the collapse of the Baltic cod stock through an ecosystem-based management approach. *Proceedings of the National Academy of Sciences of the United States of America.* 2009, Vol. 106, pp. 14722-14727.

MacKenzie, BR and Köster, FW. 2004. Fish production and climate: sprat in the Baltic Sea. *Ecology.* 2004, Vol. 85, 3, pp. 784-794.

Mann, DA; Higgs, DM; Tavolga, WN; Souza, MJ; Popper, AN. 2001. Ultra-sound detection by clupeiform fishes. *J. Acoust. Soc. Am.* 2001, Vol. 109, pp. 3048-3054.

MEMO. In progress. *Femern A/S - Developing the zero-alternative.* s.l. : Seacon, In progress.

Muus, BJ and Nielsen, JG. 1999. *Die Meeresfische Europas in Nordsee, Ostsee und Atlantik.* s.l. : Franck-Kosmos Verlag, Stuttgart, 1999.

Nedwell, JR; Turnpenny, AWH; Lovell, J; Parvin, SJ; Workman, RJAL Spinks; Howell, D.. 2007. *A validation of the dBht as a measure of the behavioural and auditory effects of underwater noise.* s.l. : Subacoustech Report No. 534R1231, 2007.

Newcombe, CP and Macdonald, DD. 1991. Effects of suspended sediments on the aquatic ecosystems. *North American Journal of Fisheries Management.* 1991, Vol. 11, pp. 72-82.

Ottersen, G, Hjermann, DØ and Stenseth, NC. 2006. Changes in spawning stock structure strengthen the link between climate and recruitment in a heavily fished cod (Gadus morhua) stock. *Fisheries Oceanography.* 2006, Vol. 15, pp. 230-243.

Ploskey, GR, Johnson, PN and Carlson, TJ. 2000. Evaluation of a low-frequency sound- pressure system for guiding juvenile salmon away from turbines at Bonneville Dam, Columbia River. *N Am J Fish Manage.* 2000, Vol. 20, pp. 951–967.

Rudstam, LG, Aneer, G and Hildén, M. 1994. Top-down control in the pelagic Baltic ecosystem. *Dana.* 1994, Vol. 10, p. 105−129.

Sand, O and Karlsen, HE. 1986. Detection of infrasound by the Atlantic cod. *J. Exp. Biol.* 1986, Vol. 125, pp. 197-204.

Sand, O; Enger, PS; Karlsen, HE; Knudsen, FR; Kvernstuen, T. 2000. Avoidance res-ponses to infrasound in downstream migrating European silver eels, Anguilla anguilla. *Environmental Biology of Fishes.* 2000, Vol. 47, pp. 327-336.

Schnack, D. 2003. Fische und Fischerei in Ost- und Nordsee. *Meer und Museum.* 2003, Vol. 17, pp. 96-103.

Suga, T; Akamatsu, T; Sawada, K; Hashimoto, H; Kawabe, R; Hiraishi, T; Yamamoto, K. 2005. Audiogram measurements based on the auditory brainstem response for juvenile Japanese sand lances Ammodytes personatus. *Fishery science.* 2005, Vol. 71, pp. 287-292.

Thomsen, F; Lüdemann, K; Kafemann, R; Piper, W. 2006. *Effects of offshore wind farm noise on marine mammals and fish.* s.l. : biola, Hamburg, Germany on behalf of COWRIE Ltd., 2006. p. 59 pp.

US Army Corps of Engineers. 2004. *Pile driving equipment.* 2004.

Westerberg, H. 1993. *Effekter av ljus och vibrationer paa fiskvandring i omraadet kring Øresundsbron.* s.l. : Fiskeriverket, Underlagsrapport, 1993.

Wildish, DJ; Akagi, H and Poole, NJ. 1977. Avoidance by Herring of Dissolved Components in Pulp Mill Effluents. *Bulletin of Environmental Contamination and Toxicology.* 1977, Vol. 18, 5

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