SAEBY OFFSHORE WIND FARM

FISH
SAEBY OFFSHORE WIND FARM

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Abbreviations

AC Alternating Current
dB Decibel
DC Direct Current
DEA Danish Energy Agency
EIA Environmental Impact Assessment
Hz Hertz
ICES International Council For The Exploration Of The Sea
Km Kilometres
Km² Square kilometres
kV kilovolts
m Metres
MW Megawatt
PTS Permanent Threshold Shift
ROV Remotely operated vehicle
SEL Sound Exposure Level
T Tesla
TTS Temporary Threshold Shift
uPa Micro Pascal
1. **SUMMARY**

Sæby Offshore Wind Farm is located in Kattegat approximately 4 km off the coast east of Sæby. The area appointed for the wind farm is approximately 53 km², including a 6 km² cable corridor, where turbines cannot be installed. The water depth in the area varies between 7 and 17 m. A northern and a southern cable corridor, each 500 m wide, are identified for routing cables to the coast.

It is currently not decided what type of turbine type and size that will be used. One option is to set up many small turbines for example 67 units of 3 MW turbines. Alternatively, fewer and larger turbines for example 20 units of 10 MW turbines could be installed. The final setup will eventually be decided by the developer within the frame of the consent given by authorities.

The assessment of impacts from the Sæby Offshore Wind Farm is divided into three phases: construction, operation and decommissioning, each of which can comprise different impacts and magnitude of pressures.

Since the project is not yet fully developed the impact assessments are based on a "worst case" scenario – i.e. largest impact to the fish fauna. If these impacts are acceptable, it means that the project can be approved with respect to the fish regardless of the final project design.

The fish fauna in the area is described according to official fisheries statistics, literature and interviews with local fishermen.

Habitat mapping showed that the project area is dominated by sandy habitats which are perfect for flatfish. The areas lacked boulders and rocks and macroalgae was only detected at one of eight stations. The results from a fieldwork investigation carried out in 2013 shows that the typical infauna community in the project area is that of a typical Macoma community (from the shore to 8-10 m) - at larger depths (10 – 30 m) the benthic fauna is typified as a Venus community. As the names imply, the communities are named after the bivalves Macoma baltica and Venus striatula.

The impacts related to the construction phase are considered as the most crucial for fish species. The erection of the turbines, the establishment of the scour protections and jetting of cables are associated with significant pressures from sediment spill and noise.

The sensitivity of fish to suspended or settled particles varies highly between species and between their life stages. The sensitivity further depends on sediment composition, concentration and duration of exposure. In general, fish eggs and fish fry are more sensitive to increased concentrations of suspended sediment than juvenile and adult fish.

Based on the concentrations of suspended sediment during construction the duration of the impact and the sensitivity of the fish fauna impacts are evaluated to be insignificant. Any possible impacts would be limited to the close vicinity of the construction works. In general it is expected that fish temporarily will leave the areas during the construction activity. Food sources living in the seabed e.g. polychaetes will become exposed during cable jetting, and fish that are not sensitive to noise and higher turbidity are likely attracted to the construction site.

It is not known if construction will be carried out during spawning seasons for fish likely to be spawning in the area. However, if fish eggs or larvae are present in close to the intervention works they may perish due to high concentrations of suspended sediment. However, due to the relatively small area affected with sediment concentrations high enough to destroy fish eggs and larvae and the very limited time period with enhanced levels of suspended sediment the construction work is not estimated to have a significant impact on population levels.

The overall effects on fish from suspended sediment during construction are assessed to be small, regional and short-term. It is concluded that the overall impacts on fish and fish stocks from sediment spreading will be negligible.
There is a high diversity in hearing capabilities among fish, giving different hearing characteristics of the various species. Noise from shipping and pile driving is within the frequency range for most fish species. Some species respond to sound by fleeing while others are attracted by the sound and others again quickly become accustomed to new sources of noise. Difficulties in investigating responsiveness to noise in fish have consequences for deriving appropriate threshold values for behavioural reactions.

The highest noise levels during construction arise during pile driving of mono piles. There are in the literature several examples of pile driving resulting in the death of fish due to high levels of noise in the immediate vicinity of the pile driving activity. Acoustic modelling for the worst case scenarios (10 MW turbines) shows that according to the threshold values used damage to non-auditory tissue can happen within a maximum distance of 200 meter of the pile driving activity.

The effects of pile driving may be reduced by adopting certain mitigation measures. It is possible to reduce the level of noise transmitted through the water by using either air bubble curtains or cofferdams. Another possible mitigation could be to use ramp-up/slow start procedures, where the first hammer blows are at reduced energy. This would allow noise sensitive fish species to escape the immediate vicinity.

The noise during operation may have a masking effect, but it does not have any destructive effect on the hearing ability. The fact that fish are able to detect noise does not necessarily imply that the noise induces an avoidance reaction. It is estimated that sound waves from wind turbines are so constant and diffuse that fish are able to habituate to this. That some habituation takes place is supported by the experiences from other offshore wind farms where a high density of fish are registered around the turbine foundations. The effects on the fish fauna from noise during operation are assessed to be small, regional and long-termed. It is concluded that the overall impacts on fish and fish stocks will be negligible.

The issue of electromagnetic fields from the cables and whether they can create a barrier effect - preventing fish to pass over - was examined at Nysted Offshore Wind Farm /81/. The results from the survey show that the presence of the cables may have an effect on the behavioral pattern of some fish species. However, the possible effect is assessed to be very local. The fish communities were the same on both sides of the cable trace and identical to the community before establishment of the cable. This indicates that the presence of the power cable and the establishment of the cable trace have caused no significant spatial changes in the local fish fauna. No barrier effect could be identified /81/. Based on the low sensitivity of the fish to electromagnetism from cables the effects are assessed to be small, local and long-term. The overall impacts on fish and fish stocks from electromagnetism from cables are estimated to be minor.

Following the establishment of the wind turbines, areas of previously intact seabed will be occupied by wind turbine foundations including scour protections. In the worst case scenario (gravity based foundations) foundation including scour protections will occupy less than 0.5 % of the seabed of the project area. Areas previously consisting of e.g. sandy bottom will be replaced by foundations and scour protection. Species such as flounder (*Platichthys flesus*), sole (*Solea solea*), plaice (*Pleuronectes platessa*) etc. associated with sandy bottom will get their habitat reduced by the footprint by the turbines and scour protection. However, since the total area of introduced reef structure only takes up a very small portion to the total area, the effects will be minimal.

It is expected that the turbine foundations including scour protections will act as artificial reefs and that they will attract certain species of fish to find hiding places and food in hard bottom areas. Fish such as e.g. goldsinny wrasse (*Ctenolabrus rupestris*), corkwing wrasse (*Symphodus melops*), cod (*Gadus morhua*) and lump sucker (*Cyclopterus lumpus*) will especially profit from the new habitat. These fish are attracted to the boulders with their variety of habitats which creates a wealth of hiding places where e.g. small fish and fry can hide from predators. Fish are also attracted by the often larger food supply offered by heterogeneous structures such as boulder reefs.
Pelagic species are not expected to be affected by the physical presence of the turbines. Based on the relatively small resulting footprint from the turbines and scour protection, effects are assessed to be small, local and long-term (or permanent if scour protection is left on the seabed after decommissioning). The overall impacts on fish and fish stocks from the physical structures of the foundations and scour protection are estimated to be more positive than negative.

The decommissioning procedure is not defined yet, but the process will to a large extent include the same activities as during construction. However, the magnitude of noise and vibration is expected to be less intensive during decommissioning. According to the present decommissioning plan the scour protection will be left on site. Only negligible impacts from habitat changes are expected.

In conclusion, the construction, operation and decommissioning of the Sæby Offshore Wind Farm will involve a number of human activities and alterations of the existing environment, all of which may be associated with impacts on the fish fauna. However, all negative impacts are assessed to be minor or negligible both spatially and temporally. Thus, no significant negative impacts are expected. Contrarily, positive changes on diversity are expected due to the artificial reef effect.
2. INTRODUCTION

On 22 March 2012 a broad political majority of the Danish Parliament agreed to the establishment of 450 MW new near shore wind farms. Energinet.dk, with injunction from the Danish Energy Agency (DEA), is designated to carry out an Environmental Impact Assessment (EIA) and furthermore geophysical and met/ocean (wind, current and wave) investigations.

A total of 450 MW wind power is planned to be developed at six sites around Denmark. The six nearshore areas are selected as sites for wind farms of up to 200 MW each. The areas are shown in Figure 2-1.

Ramboll are preparing an environmental impact assessment (EIA) related to the construction, operation and dismantling phase of a potential wind farm at Sæby. To ease the task of writing the EIA report background reports are prepared for each discipline.

This present report evaluates potential impacts to the fish fauna at the construction site at Sæby and its surroundings.

Figure 2-1 Location of the six near shore wind farm areas.
3. PROJECT DESCRIPTION

This chapter describes elements of the project which is thought relevant for the assessment of potential impacts on the fish fauna. A full project description is given in a separate project description report /1/.

3.1 Location and wind farm layout

Sæby Offshore Wind Farm is located in Kattegat approximately 4 km off the coast east of Sæby. The area appointed for the wind farm is approximately 53 km², reduced however to approximately 47 km² by a cable corridor, where turbines cannot be installed. The water depth in the area varies between 7 and 17 m. A northern and a southern cable corridor, each 500 m wide, are identified for routing cables to the coast. Geophysical and metocean surveys are reported in /2//3/.

The wind farm will be able to deliver an output of up to 200 MW, equivalent to the electricity consumption of approximately 200,000 households and be ready to produce from 2020. How much of the project area that will be used for the construction of the wind turbines depends on an economic trade-off between costs of establishing a wind farm and revenue from electricity production. A wind farm of 200 MW has based on experience an area equivalent to approximately 2/3 of the project area. It is therefore not certain that the whole area will be used for wind turbines.

The final decision of wind farm size (the maximum power production), number and type of turbine depend on the concessionaire for the project. It is currently not decided which type and size of turbine type that will be used. One option is to set up many small turbines for example 67 units of 3 MW turbines. Alternatively fewer and larger turbines for example 20 units of 10 MW turbines could be installed. The final setup will eventually be decided by the developer, based on an optimisation of a number of parameters, within the frame of the consent given by authorities.

Plans for the wind farm construction have been developed by DTU Wind Energy, Wind farm layouts for Sæby, February 2014 /4/. Layout are presented for 3.0 MW and 10.0 MW turbine sizes for the purpose of Environmental Impact Assessment, but will eventually be decided by the developer, based on an optimisation of a number of parameters, within the frame of the consent given by authorities. Location and layouts are shown in Figure 3-1. Details on the layout can be found in the DTU layout report /4/.
3.2 **Construction**

The construction of the Sæby Offshore Wind Farm is scheduled to take place throughout the year. Construction activity is expected for 24 hours per day 7 days a week until construction is complete.

A safety zone of 500 m is expected to be established around the main construction sites in order to protect the project, personnel, and for the safety of third parties during the construction and commissioning phases of the wind farm. The safety zone may include the entire construction area or a rolling safety zone may be selected. The exact safety zone will be agreed with the Danish Maritime Authority prior to construction.

3.2.1 **Foundations**

The wind turbines will be supported by foundations fixed to the seabed. It is expected that the foundations will comprise one of the following options:

- Driven steel monopile
- Concrete gravity base
- Jacket foundations
- Suction buckets

![Figure 3-1 Sæby Offshore Wind Farm project area and wind farm layout.](image)
Installation of one turbine is roughly estimated to last 7 days and include the following steps:

- Seabed preparations/excavation and installation of gravel bed 5 days
- Installation of foundations, 1 day
- Installation of turbines 1 day

**Monopile foundations**

This solution comprises driving a hollow steel pile into the seabed. Scour protection is typically made by placing stone material around the foundation. The selection of the approach for the formation of scour will depend on the extent to which scour is expected to form – which again depends on the current and wave activity around the foundation and on the properties of the sea floor.

The installation of the monopile will involve either a jack-up vessel or floating vessel, equipped with a crane, a pile gripper and possibly pile tilting equipment. The expected time for driving each pile is between 4 and 6 hours, but this may extend significantly if the soil is hard or boulders are found. The pile installation involves driving the pile into the seabed using a hydraulic hammer. The hammer type and size, size of the pile and the soil properties influences the number of blows and time required to achieve the target penetration depth. The hammer typically delivers 30 to 50 blows per minute, dependent on size and type. On average the installation of a pile can be expected to require 4000 to 6000 hammer blows.

An illustration of a monopile foundation with scour protection and a photo of a jack-up installation vessel are presented in Figure 3-2.

![Figure 3-2  Monopile foundation with scour protection and jack-up installation vessel. Photo courtesy of Ramboll and Swire Blue Ocean.](image)

**Gravity base foundations**

Gravity base foundations are suitable for firm seabed conditions and are especially relevant in case of relatively large ice loads. Two basic types have been used;

- Open caisson gravity base foundation consists of a base plate with open ballast chambers and a central column onto which the wind turbine tower is bolted. After the structure is placed at the desired position the chambers are filled with ballast, typically heavy rock types, such as granite or olivine. The foundation type is suitable at water depths up to approximately 25 m, but not necessarily for the larger turbine types.
• The conical gravity base foundation is suitable for larger water depths – from 20 m to 50 m or more and for the larger turbine types.

The seabed will require preparation prior to the installation of the concrete gravity base. This is expected to be performed as described in the following sequence, depending on ground conditions:

• The top surface layer of the seabed is removed, using suitable dredging equipment, with the material loaded on a split-hopper barges for later disposal
• A gravel or stone bed is placed in the dredged hole to form a firm and level base
• The quantities for the seabed preparation depend on the soil conditions.

The approximate duration of each excavation is expected to be 2 days, with another 3 days for placement of the gravel/stone bed.

An illustration of an open caisson gravity base foundation and conical gravity base foundation is presented in Figure 3-3.

![Open caisson gravity base foundation and Conical gravity base foundation](image)

Figure 3-3  Open caisson gravity base foundation (left) and Conical gravity base foundation (right). Illustration courtesy of Ramboll.

The installation of the concrete gravity base will likely take place using a floating crane or crane barge with attendant tugs and support craft. The bases will either be floated or semi-floated (partially submerged supported by the crane) transported to site on a flat-top barge or a semi-submergible barge. The for-made structures will then be lowered onto the prepared stone bed and filled with ballast. Then the foundation pit is backfilled, and scour protection is installed.

**Jacket foundations**

A jacket foundation is a three or four-legged steel lattice structure. The jacket structure is typically supported by piles in each corner of the foundation. At the top of the jacket a transition piece is mounted, which connects the tops of the 3 or 4 legs of the jacket to the base of the turbine tower.
The installation of a jacket foundation and piles may be approached in several different ways and depends on, amongst others, whether 1) pre-installed piles, 2) skirt piles or 3) through-the-leg piles are used. An illustration of a jacket foundation and jacket structures on transport barge is presented in Figure 3-4.

Figure 3-4  Jacket foundation (left) and jacket structures on transport barge (right). Photo courtesy of Ramboll and RWE.

**Suction bucket foundations**
A suction bucket consists of an inverted bucket-like structure. During installation the bucket is placed at the desired position and the water trapped inside is pumped out. This creates a vacuum inside the bucket, which combined with the water pressure acting on the outside of the bucket forces the structure to penetrate into the seabed. When the target depth is achieved the bucket is sealed and the installation is largely complete.

### 3.2.2 Scour protection
Scour is the term used for the local removal of sediment around the base of a structures which arise in moving water. If the seabed is erodible and the current is high a scour hole forms around the structure.

Two different design approaches are typically applied:

- Installation of scour protection around the structure, typically by placing rocks around the foundation. This protects the seabed and prevents it from being further washed away and thus continues to support the foundation.
- Simply allow the scour hole to form, and to account for it in the design of the foundation by assuming a larger water depth and absence of the top layers of the seabed.

The scour protection typically consists below of a filter layer of stones followed by an armour layer of larger stones/rocks on the top. If scour protection is required the protection system normally consists of rock placement. The rocks will be graded and loaded onto a rock-dumping vessel and dumped either directly on the seabed from the barge using a grab or via a telescopic tube.

### 3.2.3 Cables and grid connection
Medium voltage inter-array cables will be connected to each of the wind turbines and for each row of 5-10 wind turbines depending on the size of the wind turbines. With the basis in 33 kV ca-
bles with a conductor cross-section area of 500 mm² Cu approximately 36 MW of wind turbines can be connected to each cable.

It is expected that the medium voltage submarine cables will run directly on shore as export cables, and that an offshore step-up transformer is not required. This solution requires that several cables are drawn between the wind farm and the shore. The distance between the export cables leading from the wind farm to shore should be no less than 50 meters and up to approximately 100 meters if space allows. The larger distance will reduce the risk of disconnecting the entire wind farm if all cables are damaged simultaneously by e.g. a dragging anchor.

All the submarine cables, both array and export cables will be buried to provide protection from fishing activity, dragging of anchors etc. Depending on the seabed condition the cable will be jetted, ploughed, installed in a pre-excavated trench or rock covered. A burial depth of approximately 1-1.5 meter must be expected. The final depth will vary depending on a more detailed seabed condition survey, incl. geophysical survey and the equipment selected.

**Cable burial by jetting**

Water jetting is a cable burial method in which a submersible device (usually a ROV) equipped with water jets fed by high power water pumps liquefy the sediment below the cable, allowing it to sink to a specified depth after which coarse sediments are re-deposited. Cable jetting can typically be used in seabed types such as silt, sand or peat.

The effectiveness of the cable protection depends not only on burial depth, but also on the amount of material that will be removed from the trench. The best protection is obtained if the trench is narrow and is filled with the original material immediately after the jetting operation. In some areas an open trench will be filled in a few days or weeks because of the natural current and tide induced transport of material. It is important to avoid a situation where the cable is jetted down to, typically, 1 m but is lying in a wide open trench without any protection because all material near the cable has been jetted away from the cable. The width of the seabed affected by the jetting operation will be approximately 0.7-1.2 meters depending on the size of cable and the jetting equipment used.

The rate of progress, of the jetting operation, is depending on the seabed encountered. Generally a progress of 500-2000 m/day can be expected.

**Cable burial by plough**

Another cable installation method is by direct burial of the cable into the seabed. The cable is guided into a self-closing furrow cut by a sea plough towed by a surface vessel. This method requires homogeneous and softer seabed conditions.

As a cable approaches the seabed, it is led through the plough, which inserts the cable into a narrow furrow. Different plough designs are available to suit various bottom conditions, e.g. the traditional plough-share is well suited for muddy substrates, whereas sandy sediments may require a plough equipped with water jets to cut a trench into which the cable is placed, thus reducing the needed mechanical power.

The pace of the ploughing operation is depending on the seabed encountered and the exact equipment used. Generally a progress of 100-2000 m/day can be expected.

**Vertical injector**

The vertical injector (jetting assisted plough) consists of a jetting head/sword with water nozzles on the leading edge. The cable is routed through the jetting head and thus the laying and protection is done in one operation. The method is well suited for deep installations in jet-able soils, where water depth is relatively shallow.

The method is very suitable for deep installations of cable near shipping lanes and in harbours as the cables can be buried very deep.
The width of the seabed affected by the vertical injector installation and the rate of progress can be expected to be the same as the general ploughing operation mentioned earlier, i.e. 1-2 m width, 100-2000 m/day progress.

**Pre-excavated trenches**
In case of hard seaboards such as stiff clay or compacted sand a trench can be made beforehand. With this method the cable is placed into the pre-prepared trench. After the cable has been installed the trench can be filled again with the excavated material, possibly with added stones or gravel or just left as is. In the latter case the optimum protection level is reached when the trench over time has filled itself.

The method with trenching by means of an excavator is suitable for shallow water installations (<18-20 m). The width of the trench in the seabed will be approximately 1-2 meters depending on the size of the grab on the excavator.

The pace of the trenching operation is depending on the seabed encountered. Generally a progress of 100-1000 m/day can be expected. The jetting operation that may follow the laying operation will be done in material that is already disturbed by the trenching and the rate of progress can be 2000-3000 m/day.

**Protection by rock cover**
Rock cover as protection method consists of covering the cable with mid-size regular rock forming a properly designed berm. This application is widely used for submarine pipelines. Depth, wave action, sea current, rock size, berm side slope and height are the most important variables to design appropriate cable protection with rock cover. Rock sizes normally utilized vary from 10 to 40 cm, depending on the application.

Typically an over-the-side rock dumping vessels will be used. The rock is pushed overboard at a steady pace. This rock dumping method is typically used in shallow water. For deeper water a telescopic fall-pipe may be used. The width of the rock cover can be expected to be 2-3 meters. The rate of progress of the operation will depend to great extent on the method used for covering the cables. 100-1000 meters/day may be expected.

### 3.3 Operation

Operation and maintenance of the offshore wind farm will continue 24 hours per day, 365 days per year, and access to site may be required at any time. Following the commissioning period of the wind farm, it is expected that the scheduled inspection and servicing interval for the turbines will be approximately 6 months. The harbour to be used during construction and maintenance has not yet been identified.

### 3.4 Decommissioning

The lifetime of the wind farm is expected to be around 25 years. It is expected that two years in advance of the expiry of the production time the developer shall submit a decommissioning plan. The method for decommissioning will follow best practice and the legislation at that time. It is unknown at this stage how the wind farm may be decommissioned; this will be agreed with the competent authorities before the work is being initiated. It is expected that an environmental impact assessment (EIA) will be required for the decommissioning of the wind farm.

The objectives of the decommissioning process are to minimise both the short and long term effects on the environment whilst making the sea safe for others to navigate. Based on current available technology, it is anticipated that the following level of decommissioning on the wind farm will be performed:

- Wind turbines will be removed completely
- Structures and substructures will be removed to at or just below the natural seabed level and below this left in situ
- Infield cables will either be removed (in the event they have become unburied) or to be left safely in situ, buried to below the natural seabed level or protected by rock-dump
• Export cables will be left safely in situ buried to below the natural sea-bed level or protected by rock-dump.
• Cable shore landing will either be safely removed or left in-situ, with particular respect to the natural sediment movement along the shore.
• Scour protection will be left in situ.
4. **BACKGROUND**

4.1 **Baseline methodology**

The description of the fish fauna in the project area and its surroundings are based on the official fisheries statistics and interviews with local fishermen. A dedicated field survey mapping habitat types and benthic flora and fauna in the project area is used to estimate the importance of the area for the fish fauna. The description is supported by various relevant literature.

4.2 **Impact assessment methodology**

The overall goal of the assessment is to describe the severity of impacts caused by the project. The assessment comprises two steps. The identification of potential impacts is based upon an assessment of the activities outlined in the technical project description in combination with a description of the baseline conditions.

4.2.1 **Criteria for categorising impacts on the environment**

Impacts are assessed separately for each of the environmental receptors/parameters according for the following constraints:

- Degree/scale
- Geographical extent
- Duration
- Sensitivity of the receptor/parameter
- Overall significance

For the project in question an impact is defined as the significance of an impact on the receptor/parameter prior to the application of mitigation measures.

The parameters applied to the assessment are detailed below. The assessments will be based on expert judgement, based on scientific knowledge and previous experience from similar projects and environments. This approach will contribute to achieving a reasonable degree of consensus in the assessments.

**Degree, extent and duration**

The assessment of the environmental impacts is based upon degree/scale, geographical extent and duration. Criteria for degree/scale, geographical extent and duration are presented in Table 4-1.

<table>
<thead>
<tr>
<th>Degree/scale of impact</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>None/insignificant</td>
<td>There will be no (or only insignificant) impact on the structure or function of the receptor.</td>
</tr>
<tr>
<td>Small</td>
<td>There will be a small impact on the structure or function of the receptor, but the underlying structure/function will be intact.</td>
</tr>
<tr>
<td>Medium</td>
<td>There will be some degree of impact on the structure or function of the receptor. There will be a partial loss of the structure/function of the receptor.</td>
</tr>
<tr>
<td>Large</td>
<td>The structure and function of the receptor will be affected to a large degree. There will be a complete loss of the structure/function of the receptor.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Geographical extent of impact</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local</td>
<td>Impact is restricted to the project area.</td>
</tr>
<tr>
<td>Regional</td>
<td>Impact is restricted to the project area and up to 20 km outside of the project area.</td>
</tr>
<tr>
<td>National</td>
<td>Impact is restricted to within Denmark.</td>
</tr>
<tr>
<td>Transboundary</td>
<td>Impact extends beyond Danish boundaries.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Duration of impact*</th>
<th>Description</th>
</tr>
</thead>
</table>
Short: Impact will occur during and immediately after the construction phase, but will stop once the impacting activity stops.

Medium: Impact will occur during the whole of the construction phase and up to three years after construction completion.

Long: Impact will occur during the whole of the construction phase and will continue over a prolonged period (> 3 years).

Permanent/irreversible: Impact will be permanent and irreversible

* Impacts that occur during the operations phase (i.e. low frequency noise) will be long

Sensitivity
The degree of sensitivity of the receptors that can potentially be affected by the project must be assessed. Different parameters are used to determine the degree of sensitivity including amongst others: tolerance to change, adaptability, rarity, diversity, value for other receptors, naturalness, fragility and whether the given receptor is present during a project activity. Criteria for sensitivity are described in Table 4-2.

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low:</td>
<td>A receptor that is not important for the functioning of the ecosystem or that is important, but tolerant to changes caused by project activities and that will quickly recover once activities cease.</td>
</tr>
<tr>
<td>Medium:</td>
<td>A receptor that is important for the functioning of the ecosystem, that is not tolerant to change, but can be restored to pre-impact status or will recover naturally over time.</td>
</tr>
<tr>
<td>High:</td>
<td>A receptor which is not resistant to impacts and which cannot be restored to the pre-impact status.</td>
</tr>
</tbody>
</table>

Overall significance
The overall significance of the impact is assessed on the basis of each criterion described above and the receptor’s sensitivity to impacts (see Table 4-3). The table is in accordance with the guidelines set by Energinet.dk for this project.

<table>
<thead>
<tr>
<th>Overall significance of impacts</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutral/no impact</td>
<td>No impacts compared to the status quo.</td>
</tr>
<tr>
<td>Negligible negative impact</td>
<td>Small impacts on a local scale and with low complexity that persist for a short-term or are without long-term effects and without any irreversible effects.</td>
</tr>
<tr>
<td>Minor negative impact</td>
<td>Impacts with a certain geographic extent or complexity, a certain degree of persistence aside from short-term effects, and a certain probability to occur, but in all likelihood will not cause irreversible effects.</td>
</tr>
<tr>
<td>Moderate negative impact</td>
<td>Impacts with either a relatively large geographic extent or long-term effects (e.g. throughout the lifespan of the wind farm), that occur occasionally or with a relatively high probability and which may cause some irreversible, but only localised effects e.g. impacts on elements worthy of preservation (culture, nature etc.).</td>
</tr>
<tr>
<td>Major negative impact</td>
<td>Impacts with a large geographic extent and/or long-term effects, frequently occurring and with a high probability, and with the potential of causing significant irreversible impacts.</td>
</tr>
<tr>
<td>Positive impacts</td>
<td>Positive impacts on one or more of the above mentioned.</td>
</tr>
</tbody>
</table>

4.2.2 Sources of impacts
Based on the experience gained from previous EIA studies of offshore wind farms in which potential project related impacts to the fish fauna have been anticipated are shown in Table 4-4.
Table 4-4  Anticipated potential project related impacts to the fish fauna.

<table>
<thead>
<tr>
<th>Impact</th>
<th>Construction phase</th>
<th>Operation Phase</th>
<th>Decommissioning phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sediment spreading and spill deposition</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Spreading of contaminants</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Noise and physical disturbance</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Electromagnetism from cables</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Habitat changes</td>
<td></td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>

4.3  Regulatory framework and legislation

EIA regulations for installations producing electricity at sea are defined in the Executive Order No. 68 of 26 January 2012 regarding assessment of environmental impact assessment (EIA) for projects for construction etc. of electricity production facilities at sea1.

The purpose of the regulations is to ensure that offshore electricity production facilities and related construction projects on land that are likely to significantly affect the environment only can be realized on the basis of an EIA report.

The purpose of the preparation of an EIA is to provide the best possible basis for both public debate and the final decision on the project. The EIA identified, described and assessed the direct and indirect effects on the environment, including effects on:

- People, fauna and flora
- Soil, water, air, climate and landscape
- Tangible assets and cultural heritage
- The interaction between these factors

The Danish Energy Agency (DEA) is the approval authority for planning and installation of electricity production facilities at sea and the coordinating authority for this project. The Danish Nature Agency is EIA the approval authority for the related onshore project.

4.4  Worst case scenario assumptions

As mentioned in Chapter 3, the project is not yet fully developed – e.g. the final choice of turbines, foundations and wind farm layout has not yet been decided. The impact assessments are therefore compiled on the basis of a “worst case” scenario with regard on the largest potential impact to the fish fauna. If these impacts are acceptable, it means that the project can be approved with respect to the fish regardless of the final project design.

Currently, the decommissioning approach has not been defined. The worst case scenario is considered to be a complete removal of all structures. The pressures during removal of foundations and cables are likely to include short-term increases in suspended sediment concentration and sediment deposition from the plume caused by foundation cutting or dredging and seabed disturbance caused by removal of cables and scour protection. The impacts during decommissioning are considered to be less than or comparable with those effects described during the construction phase.

Worst case scenarios related impacts to the fish fauna are assessed below for the following potential impacts:

- Sediment spreading and spill deposition
- Noise and physical disturbances
- Habitat changes

---

### 4.4.1 Sediment spreading and spill deposition
Several factors will have an influence on the amount of sediment spreading and spill deposition, including:

- Turbine type
- Foundation type
- Foundation installation
- Cable installation

The worst case scenarios in relation to sediment spreading and sediment spill deposition are presented in Table 4-5. The worst case scenarios have been used as input for the sediment spreading and sediment spill deposition modelling /5/.

**Table 4-5  Worst case scenarios for potential impacts on the fish fauna in relation to sediment spreading and spill deposition.**

<table>
<thead>
<tr>
<th>Impact</th>
<th>Consideration</th>
<th>Worst case scenario in relation to impact on fish fauna</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbine type</td>
<td>Total dredging volumes during installation of foundations and inter-array cables will be larger with 3 MW turbines than with 10 MW turbines. The 3 MW turbines are thus expected to cause higher spill volumes.</td>
<td>3 MW turbines will result in the highest spill volumes</td>
</tr>
<tr>
<td>Foundation type</td>
<td>The removal of topsoils and weaker soil layers will be more extensive for a gravity base foundation, than for other types, and it is thus expected that gravity base foundations will cause more sediment spill than other foundation concepts.</td>
<td>Gravity base foundation will result in the highest spill volumes</td>
</tr>
<tr>
<td>Foundation installation</td>
<td>The total spill volume and sedimentation will be unaffected by the number of dredgers working in parallel, but areas affected by more than one sediment plume will experience higher turbidity and sedimentation rates than other areas. Therefore, two dredgers are expected to cause larger impacts than one.</td>
<td>Two dredgers are expected to cause larger temporal impacts than one</td>
</tr>
<tr>
<td>Cable installation</td>
<td>Jetting of inter-array and export cables is expected to cause more spillage of fine sediments than trenching.</td>
<td>Jetting</td>
</tr>
</tbody>
</table>

### 4.4.2 Noise and physical disturbances
Several impacts in relation to the establishment of an offshore wind farm can cause habitat changes, including:

- Piling
- Turbine installation
- Cable installation
- Anchor handling

The worst case scenarios for potential impact on fish fauna relation to noise and physical disturbances are presented in Table 4-6.

**Table 4-6  Worst case scenarios for potential impacts on the fish fauna in relation to noise and physical disturbances.**

<table>
<thead>
<tr>
<th>Impact</th>
<th>Consideration</th>
<th>Worst case scenario in relation to impact on fish fauna</th>
</tr>
</thead>
<tbody>
<tr>
<td>Piling</td>
<td>Larger piles require larger pile drivers and hence the level of noise increases with the size of the turbine.</td>
<td>10 MW turbines will result in the highest noise levels.</td>
</tr>
<tr>
<td>Turbine installation</td>
<td>Although offshore contractors use varying construction techniques, the installation of the wind turbines will typically require one or more jack-up vessels. Jack-up vessels has the ability of lowering legs onto – and into - the seabed and lifts their hull out of the water and creates a stable work-</td>
<td>3 MW turbines will result in more jack-ups.</td>
</tr>
</tbody>
</table>
ing platform. Alternatively semi-jack-up vessels may be used (where the hull remains floating but is stabilized by posts or "spuds", lowered into the seabed), to ensure the stability required for the operation.

The bases of the legs, known as spud cans can cover an area of up to 575 m². The legs may penetrate 2 to 15 m into the seabed depending on seabed properties. The foot prints will be left to in-fill naturally.

Cable installation
Physical disturbance during installation of cables will depend on the final layout of the wind farm. The worst-case cable length is estimated for the 67 3MW wind turbines. In this scenario, the length of inter-array cables is estimated at 100,000 m, with export cables of a total length of 75,000 m. Depending on the seabed condition, cables will be jetted, ploughed, installed in a pre-excavated trench or rock-covered for protection. A burial depth of app. 1-1.5 m is expected, the final depth will be determined at a later stage of the project. Physical disturbance to the seabed is expected at a distance of 1-2 metres from the cable. Based on the total distance of inter-array and export cables, a total footprint has been estimated at 350,000 m² (0.35 km²).

Anchor handling
Disturbance of the seabed is expected associated with general anchoring of vessels and machinery. This disturbance is considered minor, and is not estimated in detail.

3 MW turbines will result in the longest cable route (inter-array)

4.4.3 Habitat changes
Several impacts in relation to the establishment of an offshore wind farm can cause habitat changes, including:

- Loss of seabed
- Introduction of hard substrate

The worst case scenarios for potential impact on fish fauna relation to habitat changes are presented in Table 4-7.

<table>
<thead>
<tr>
<th>Impact</th>
<th>Consideration</th>
<th>Worst case scenario in relation to impact on fish fauna</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss of seabed</td>
<td>Loss of seabed occurs when areas of seabed are subsequently covered by structures, scour protection etc. The loss of seabed area depends on the foundation type, number of foundations and extent of scour protection.</td>
<td>3 MW gravity base foundations as this combination will have the largest footprint</td>
</tr>
<tr>
<td>Introduction of hard substrate</td>
<td>Introduction of hard substrate occur in the areas where seabed is lost and hard substrate replace the previous seafloor substrate. This is a secondary aspect of establishing off-shore wind farms, as sub-surface sections of turbine towers and scour protections will introduce new types of sub-littoral structures and increase the heterogeneity. The area of hard substrate added to the offshore wind farm area (47 km²) will depend on the number of turbines, the type of foundations and the extent of scour protection. The introduced habitats will be suitable for colonisation by a variety of marine invertebrates and attached algae which will attract a number of fish species. In relation to establishment of scour protection the reef effect depends on the material used. Scour protections of rocks will induce a high reef effect whereas protections with sand-filled bags will have a low reef effect.</td>
<td>The worst case scenario depends on whether the new hard substrate the reef effect is viewed as being negative or positive for the fish fauna.</td>
</tr>
</tbody>
</table>
4.5 Alternatives
The EIA assessment is compiled on the "worst-case" scenario described in section 3.2 and will not be constrained to one exact definition of the project, but instead describe the boundaries and span of a project that incorporate the "most-likely" with a "worst-case" in mind. In this context the "worst-case approach" defines a "worst case alternative" (park layout, foundation type, turbine type and construction method) that would potentially cause the largest environmental impact. As such the "worst-case" approach envelopes a number of alternatives that may be considered mitigative to the potential environmental impacts of the "worst case alternative".

The so-called "0-alternative" defines the situation where the wind farm is not constructed. In this case, the energy, that the wind park would have produced, will have to be produced by other and alternative sustainable energy sources, in order to reach the political goals set out by the Danish government. Such sustainable energy could be produced by wind parks at other locations or from other sources of sustainable energy. Several sources for sustainable energy have experienced a significant development through the recent years. However, compared to the development within wind farms, they have not achieved the same degree of efficiency, which would make them less effective alternatives. Therefore, it is assessed that the only realistic alternative to sustainable energy production at a wind farm at Sæby would be an alternative location of the wind farm. The question of alternative location is dealt with in the set-up of this investigation, as six different wind park locations are investigated in parallel to the Sæby Offshore Wind Park.
5. BASELINE CONDITIONS

5.1 Habitat
The coastal zone and the shallow areas in general serve as nursery areas for a number of fish species, including commercially important flatfish species like sole, turbot and plaice. For these species, there is a direct link between the size of the nursery area and the size of the stock. This has the important implication that if the size of nursery area changed, it would also mean that the population size is changed.

The water depth in the project area varies between 7 and 17 m. A northern and a southern cable corridor, each 500 m wide, are identified for routing cables to the coast.

Geophysical investigations of the marine part of the project were carried out in 2013 /2/. Preliminary maps covering sediment types in the cable corridors and project area are presented in Figure 5-1 and Figure 5-2, respectively. The bathymetry is presented in Figure 5-3.

![Mapped sediments within the offshore cable corridors](image)
Figure 5-2  Preliminary substrate types within the project area /5/. 
Figure 5-3  Preliminary bathymetry of the project area. Depth in the project area varies between 7 and 17 m /5/.

A total of 8 stations were selected for biological survey - location of the stations is presented in Figure 5-4. Stations were selected based on results from a geophysical and geotechnical surveys, and based on the following areas of interest:

- Hard-bottom substrates, especially at shallow depths
- Areas of high density of gravel and rocks, especially reef areas
- Potential seagrass areas detected during geophysical investigation
- Sandy habitats.

The field survey was carried out at Sæby 26 March 2014. Each station was surveyed with an ROV (Remotely Operated Vehicle). As expected, none of the investigated areas was characterised as "Hard-bottom substrates, especially at shallow depths", "Areas of high density of gravel and
rocks, especially reef areas", or "Areas containing seagrass". All eight stations were characterised as sandy habitats. Selected snapshots from video recordings illustrating the habitat at each of the 8 stations and their location within the project area and the southern cable corridor are presented in Figure 5-4.

In general, visible flora and fauna was sparse/non-existent. The areas lacked boulders and rocks and macroalgae was only detected at one station, and only a few specimens. The epifauna consisted of mussels, hermit crab, sea snails, starfish, sea urchins and ascidians.

Figure 5-4  Selected snapshots from video recordings illustrating the habitat at each of the 8 stations and their location within the project area /6/.

5.2 Food resources – infauna
Fieldwork was carried out in December 2013 and covered 40 Van Veen sampling stations /6/. The stations were positioned uniformly in the project area.

In general, the area contains relatively low species diversity, with a total of 89 different infauna species. The taxa included polychaetes (38 species), bivalves (14 species), crustaceans (15 species), gastropods (11 species) and echinoderms and "other" included 4 species.

The result from the survey shows that the typical infauna community in the project area is that of a typical Macoma community (from the shore to 8-10 m) - at larger depths (10 – 30 m) the benthic fauna is typified as a Venus community. The communities are characterised by the dominant
species of especially polychaetes, bivalves, gastropods and echinoderms. As the names imply, the communities are named after the bivalves *Macoma baltica* and *Venus striatula*.

The most abundant species of polychaetes were - the bristle worm *Scoloplos armiger*, which is known to be an important source of food for many fish species, including flatfish. The survey showed that the area contain high numbers of bivalves including e.g. *Abra alba* and *Abra nitida* which are a preferred food source for many species of flatfish. The area also holds several species of crustaceans which are preferred food item by many fish species /7//8//9/ - see Appendix 1.

The largest biomass was found in the north-eastern part of the project area. The lowest biomasses were detected in the western part of the project area and in the cable corridor, see Figure 5-5.

![Figure 5-5](image)

**Figure 5-5** Biomass (g DW per 0.1 m$^2$) of infauna. Darker colours indicate a higher biomass and lighter colours a lower biomass. Purple dots indicate the sampling stations for infauna /6/.

### 5.3 Fish species

Habitat mapping (see section 5.1) showed that the project area is dominated by sand, which is especially preferred by flatfish /10/.

Based on the habitat types and the infauna communities the project area is able to support a variety of fish species. Coastal areas often functions as a nursery area for juvenile fish /18/ and so
it seems very likely that that the project area and its surroundings functions as a nursery area for juvenile fish, but also a population of adult fish species inside the area can be expected.

In the following sections 5.3.1 and 5.3.2 is a description of some of the most abundant and important non-commercial and commercial fish species to be expected inside and in the vicinity of the planned Sæby offshore wind farm area.

5.3.1 Non-commercial fish species
Inside the Sæby offshore wind farm area, with water depth ranging from 7 – 17 meters, it can be expected that there are a variety of non-commercial fish species that are resident and/or foraging in the area. Some of the most abundant species which is expected to occur in the area is:

- Viviparous eelpout (*Zoarces viviparous*)
- Black goby (*Gobius niger*)
- Sand goby (*Pomatoschistus minutus*)
- Shorthorn sculpin (*Myxocephalus Scorpius*)
- Armed bullhead (*Agonus cataphractus*)
- Greater weaver (*Trachinus draco*), that also belong to the group of more rare commercial fish species.

Furthermore fish species of the family Wrasse (*Labridae*), Pipefishes (*Syngnathidae*), and the Rock gunnel (*Pholis gunnellus*), Grey gurnand (*Eutrigla gurnardus*) may also be observed inside and/or in the vicinity to the Sæby Offshore Wind Farm area.

5.3.2 Commercial fish species
The official fisheries statistics, administered by The Danish AgiFish Agency is used to monitor the fishery activities in Danish waters. In Kattegat all fishing vessels ≥ 10 meters are required to report their catches (weight and species) and in which ICES square it was caught. This is done electronically in a so called “logbook”. Based on this information it is possible to get an overview of commercial species present within a given ICES square. Since the area of an ICES square is much larger than the project area it cannot be stated for sure that all reported species caught in the ICES square are also present within the project area. However, it can be used as an indication.

Figure 5-6 shows ICES square 43G0 from which logbook data has been acquired. Table 5-1 shows fish species caught within ICES square 43G0 and hence likely to be present in the project area. The information is based on logbook data from the last 10 years (2004-2013) from ICES square 43G0 which means that the table only represents commercial species above a certain size.
Figure 5-6  ICES square 43G0 from which log-book data has been acquired.

Table 5-1  Fish species likely to be present in the project area. The table is based on logbook data from ICES square 43G0 from the period 2004-2013 (registered catch weight in tonne).

<table>
<thead>
<tr>
<th>ICES 43G0 (weight in tonne)</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>Total</th>
<th>Yearly average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sprat (Sprattus sprattus)</td>
<td>1974</td>
<td>5846</td>
<td>3399</td>
<td>4114</td>
<td>2904</td>
<td>4222</td>
<td>3238</td>
<td>1521</td>
<td>3710</td>
<td>469</td>
<td>31396</td>
<td>3140</td>
</tr>
<tr>
<td>Herring (Clupea harengus)</td>
<td>0</td>
<td>0</td>
<td>95</td>
<td>833</td>
<td>180</td>
<td>681</td>
<td>188</td>
<td>316</td>
<td>166</td>
<td>0</td>
<td>2459</td>
<td>246</td>
</tr>
<tr>
<td>Sandeel (Ammodytes spp)</td>
<td>0</td>
<td>5</td>
<td>452</td>
<td>0</td>
<td>4</td>
<td>74</td>
<td>224</td>
<td>83</td>
<td>1</td>
<td>843</td>
<td>84</td>
<td></td>
</tr>
<tr>
<td>Norway lobster (Nephrops norvegicus)</td>
<td>56</td>
<td>44</td>
<td>40</td>
<td>53</td>
<td>53</td>
<td>71</td>
<td>60</td>
<td>60</td>
<td>122</td>
<td>140</td>
<td>697</td>
<td>70</td>
</tr>
<tr>
<td>Plaice (Pleuronectes platessa)</td>
<td>9</td>
<td>17</td>
<td>21</td>
<td>4</td>
<td>9</td>
<td>7</td>
<td>5</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>81</td>
<td>8</td>
</tr>
<tr>
<td>Sole (Solea solea)</td>
<td>6</td>
<td>10</td>
<td>11</td>
<td>6</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>6</td>
<td>3</td>
<td>61</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Edible crab (Cancer pagurus)</td>
<td>0</td>
<td>10</td>
<td>29</td>
<td>15</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>56</td>
<td>6</td>
</tr>
<tr>
<td>Cod (Gadus morhua)</td>
<td>10</td>
<td>6</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>38</td>
<td>4</td>
</tr>
<tr>
<td>Coldwater shrimp (Pandalus borealis)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>36</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>36</td>
<td>4</td>
</tr>
<tr>
<td>Atlantic horse mackerel (Trachurus trachurus)</td>
<td>35</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>35</td>
<td>4</td>
</tr>
<tr>
<td>Common whelk (Buccinum undatum)</td>
<td>0</td>
<td>0</td>
<td>28</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>28</td>
<td>3</td>
</tr>
<tr>
<td>Flounder (Platichthys flesus)</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>11</td>
<td>1</td>
</tr>
<tr>
<td>Dab (Limanda limanda)</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>11</td>
<td>1</td>
</tr>
<tr>
<td>Lumpshucker (Cyclopterus lumpus)</td>
<td>8</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>9</td>
<td>0.9</td>
</tr>
</tbody>
</table>
Below a short introduction to the most economic important species in the area which are Norway lobster, sprat, herring, sole, plaice and sandeel /11/.

5.3.3 Norway lobster (*Nephrops norvegicus*)

Norway Lobster lives in burrows on the seabed. They are limited to a muddy habitat and require sediment with a silt and clay content to excavate burrows. Their distribution therefore is determined by the availability of suitable habitat. Females mature at about 3 years. In the autumn they lay eggs which remain attached to the tail for 9 months. During this time the females rarely emerge from their burrows and therefore do not commonly appear in trawl catches. This habit has probably afforded their populations some resilience to fishing pressure. Egg hatching occurs in the spring, and females emerge in spring/summer to moult and mate.

Norway Lobster is a scavenger and predator that makes short foraging excursions mainly during periods of subdued light. The Norway Lobster mostly leaves they burrows in the evenings or in the mornings. They feed on active prey, including worms and fish which they capture with their chelipeds and walking legs, and food is conveyed to the mouth using the anterior walking legs, assisted by the maxillipeds.

Analysis of the fishery in the area shows that the Norway Lobster is not caught within the project area but at deeper depths and at more muddy habitats northeast of the project area /11/.

5.3.4 Sprat (*Sprattus sprattus*)

Sprat is a small-bodied pelagic schooling species that is most abundant in relatively shallow waters. It is an important food resource for many top predators. Sprat is mostly landed for industrial processing (often mixed with juvenile herring). Sprat is mostly found within the 50 m depth contour and is also common in inshore waters /14/.

Sprat is a multiple batch spawners, with females spawning repeatedly throughout the spawning season. Spawning is pelagic and eggs remain pelagic. The spawning ground are not as clearly defined as is the case for e.g. herring, but hydrography plays an important role as temperature and salinity is of great importance defining the spawning habitat. Sprat eggs are observed over most of the areas where sprat are found area, but defined areas with high concentrations of spawning individuals are known in the inner German Bight, the English Channel and southern North Sea, northeast of England, north and west of Scotland, and Skagerrak and Kattegat. Spawning occurs in both coastal and offshore waters, during spring and late summer, with peak spawning between May and June, depending on water temperature. There are no dedicated nursery grounds for sprat larvae as they largely staying with the adult population. Sprat larvae exhibit schooling behavior already from metamorphosis, and these schools are often found along the coasts /14/.

Sprat larvae feeds on plankton e.g. diatoms, copepods and crustacean larvae. After metamorphosis larger planktonic organisms are also eaten, including cladocerans, Oikopleura, bivalve larvae, mysids and euphausids /14/.

5.3.5 Herring (*Clupea harengus*)

Herring are demersal spawners, depositing their sticky eggs on coarse sand, gravel, shells and small stones, all the members of a shoal spawning over a relatively short time period. The fish congregate on traditional spawning grounds, many of which are on shoals and banks and in relatively shallow water, approximately 15-40 m deep. In the Skagerrak and Kattegat there are local spring and autumn-spawning populations.
The habitats of juveniles and adults are primarily pelagic, and many hydrographical features (e.g. temperature, depth of the thermocline, degree of mixing, proximity of frontal systems), as well as abundance and composition of the zooplankton on which they feed affect the distribution /15/.

It may take up to two weeks for the eggs to hatch, depending on sea temperature. After hatching, the pelagic larvae rise to surface waters where they are transported by the prevailing water currents towards the nursery grounds in the coastal waters. Observed shifts in the position of some spawning areas may be related to changes in the abundance and distribution of their planktonic food resources, which in turn are affected by hydrographical and environmental changes.

After spending their first few years in coastal nurseries, two-year-old herring move offshore into deeper waters, eventually joining the adult population in the feeding and spawning /15/.

The pelagic larvae feed on copepods and other small planktonic organisms - juvenile sandeel and fish eggs are also eaten. Larger herring are consuming predominantly copepods with small fish, worms and ctenophores as an aside.

Herring represent an important prey for many predators, including e.g. cod and other large gadoids, marine mammals and sea birds /15/.

According to information from the local fishermen – herring are spawning in the project area during spring – where the fishermen catch mature fish with eggs. However, whether the mature herring reported caught by the local fishermen is actually spawning in the area or are passing through cannot be stated for sure. Fishermen have not registered other mature fish in the area.

5.3.6 Sole (Solea vulgaris)

Sole lives buried in sandy or muddy bottoms. Juveniles spend their first year in shallow coastal waters. When they grow older they gradually disperse into deeper water /16/.

Sole tend to occupy shallow, sandy and sandy/muddy habitats. Spawning takes place in spring in coastal waters within the 30 m depth contour and is triggered by sea water temperature. The pelagic larvae hatch after about 7 to 8 days. After metamorphosis the post-larvae settle on the bottom about 3 weeks after hatching. Hence, the duration of the planktonic phase is very short, and settlement is usually close to the spawning area /16/.

The mechanism by which the metamorphosing larvae reach their nursery areas is not well established. It is speculated that they are transported passively but using bottom currents selectively. In autumn when temperatures fall, sole leave the shallow coastal areas and migrate to the warmer offshore grounds.

The pelagic larvae feed on copepod nauplii. Juveniles and adults feed on e.g. polychaete worms, and small echinoderms (e.g. brittlestars) /16/. Sole is most likely spawning in the project area according to a study mapping spawning and nursery area for commercial fish species /12/.

5.3.7 Sandeel (Ammodytidae)

"Sandeel" is a collective term for a number of species in the family Ammodytidae, which are fish characterised by a slim, eel-like body, which is somewhat laterally compressed. Sandeels are schooling fish which lives at a depth of 10–150 m on sandy bottoms. The sandeel is also known as the "sand badger", a name that reflects its biological peculiarities. This is because the sandeel stays on sandy bottoms with mean grain size of approximately 0.25 – 2 mm, wherein the weight ratio of silt/clay/fine sand (grain size <0.09 mm) is <10%, and with strong bottom currents, which share the characteristic of good oxygen conditions in the substrate. During the night and during winter when light conditions are bad the sandeel digs into the sand. When currents are strong the sandeel leaves the sand and forms large shoals /13/ /17/.

The sandeel spawns on the seabed, where its eggs attach themselves to grains of sand. However, they are easily torn loose and can therefore be found in the plankton. It appears that spawning takes place on the same sites as the sandeels occupy at other times of the year. Currents of-
ten cover the eggs with sand, but British aquarium experiments have shown that the eggs are still capable of developing to the hatching stage, with the result that they hatch as soon as the current uncovers them again. Eggs which have been buried under the sand have to withstand poor conditions such as reduced current flow and thus lower oxygen tension. Eggs of sandeel are adapted to such conditions, but the hatching is delayed when the oxygen tension is low. In the course of several months, therefore, larvae of all sizes can be found in the plankton until they reach a length of about 5 cm. At that point the larvae adopt an adult lifestyle and behaviour, and settle down in the sand. After the larvae have settled into the seabed they stay very much in the same place, i.e., for the rest of their lives they do not move to any great extent from where they originally settled down.

The diet consists mainly of zooplankton, small crustaceans and larvae where they form shoals during hunting. Sandeel is an important food resource for many fish species in the coastal ecosystem, i.e. for cod, saithe, haddock and flatfish species, particularly turbot and brill.

5.3.8 Plaice (Pleuronectes platessa)
The plaice live on sandy to clay bottom on very shallow water down to about 250 meters depth, but they are most common on 10 – 50 meters depth. Fry found in shallow water close to shore, while older individuals are to be found in deeper water.

Spawning takes place at the bottom of 30-200 meters. In Danish waters spawning take place from January to March. The female spawns up to 500,000 small eggs (1.5 mm) freely in the water after fertilization float in the water column. The pelagic eggs hatch after 1-2 weeks, the fry that at hatching measures 5-6 mm, are pelagic during a few weeks, until at length 14-20 mm, transformed into a ‘real’ flatfish, and seek to the bottom in shallow water. They live in shallow water until the first autumn, when they move into deeper water to overwinter. The growth is highly dependent on access to food and water temperature. In Danish waters the males mature 3-4 years old at a length of approximately 20-25 cm, females 5-6 years old at a length of 30-35 cm. Adult plaice feeds on various benthic invertebrates, mainly worms and small thin-shelled clams. Large individuals can also eat fish.

5.3.9 Spawning
As for spawning behaviour there are two main forms - demersal spawning and pelagic spawning, see Table 5-2. Demersal spawners lay their eggs on the bottom on sediment, algae or boulders – the preferred habitat for demersal spawners is species specific. Due to the often specific requirements for bottom conditions areas for demersal spawning are often well defined. Demersal spawners are especially sensitive to physical disturbance which has an effect on the seabed e.g. seabed intervention works or bottom trawling.

Pelagic spawners have free floating eggs that are fertilized in the water column. Spawning areas for pelagic spawners are often large and less well defined as they can move from year to year. Hydrographic conditions that are essential for the pelagic spawning have an important role regulating the boundaries of the spawning area. Pelagic spawning takes place mostly at depths of 20-100 m. Pelagic eggs and larvae are more or less passively carried around by ocean currents. Some are carried to nursery areas others stay in the water column. Larval growth and transport of larvae and eggs are regulated by a variety of environmental factors e.g. current, wind and temperature.

Except from flatfish most demersal fish spawn their eggs near or on vegetation and on hard substrates. Several species has developed parental care where one or both parents guard the eggs. This is for example the case for the lumpfsucker which arrive early in the year and spawn during the early spring in shallow water. Species such as sprat and herring spawn in the water column, but the fertilized eggs adhere to seabed substrate.
Table 5-2  Spawning period and pelagic/demersal spawning for relevant fish species.

<table>
<thead>
<tr>
<th>Species</th>
<th>Spawning period</th>
<th>Spawning</th>
<th>Pelagic</th>
<th>Demersal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>J</td>
<td>F</td>
<td>M</td>
<td>A</td>
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<tr>
<td>Sprat</td>
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<tr>
<td>Herring</td>
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<tr>
<td>Sandeel¹</td>
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<tr>
<td>Plaice</td>
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<tr>
<td>Sole</td>
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<tr>
<td>Cod</td>
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<tr>
<td>Atlantic horse mackerel</td>
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<tr>
<td>Flounder</td>
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<tr>
<td>Dab</td>
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<tr>
<td>Lumpsucker</td>
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<tr>
<td>Saithe</td>
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<tr>
<td>The European hake</td>
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<tr>
<td>Haddock</td>
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<tr>
<td>Greater weever</td>
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<tr>
<td>Lemon sole</td>
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<tr>
<td>Viviparous eelpout</td>
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<td></td>
<td></td>
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<tr>
<td>Black goby</td>
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<tr>
<td>Sand goby</td>
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<td></td>
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<td></td>
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<tr>
<td>Shorthorn sculpin</td>
<td></td>
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<tr>
<td>Armed bullhead</td>
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</tbody>
</table>

1:  *Ammodytes tobianus*

- : Overall spawning period.
- : Main spawning period.
6. IMPACT ASSESSMENT DURING CONSTRUCTION PHASE

This section addresses the conditions and factors that could potentially affect the fish fauna during the construction phase of Sæby Offshore Wind Farm. Potential impacts are assessed according to intensity, extent and duration. The overall significance of an impact is assessed based on the aforementioned criteria and the sensitivity of the fish fauna. Potential impacts on the fish fauna during the construction phase of Sæby Offshore Wind Farm can be caused by the following:

- Sediment spreading in the water column
- Sediment spill deposition
- Contaminants associated with sediment spill
- Noise and physical disturbance
- Impact on food resources

6.1 Sediment spreading in the water column

Potential pressures during construction arise from sediment spill due to seabed intervention prior to installation of the foundations and from intervention works due to cable installation (inter-array and export cables). Worst case scenarios have been estimated to be the 3 MW turbine on a gravity based foundations and if the cables are installed by jetting (see section 4.4.1). The sediment concentrations, sedimentation quantities and rates of spilled sediments during installation works have been modelled for this scenario /5/.

6.1.1 Dredging - foundations

Based on the worst case scenarios the results of the modelling showed that seabed preparation for installation of gravity based foundations will only result in minor increases in suspended sediment concentrations (= increased turbidity) and only for a short duration.

Figure 6-1 illustrates the frequency of the water column sediment concentrations in excess of 2, 5, 10 and 15 mg/l at any given location. As Figure 6-1 shows, the duration of all increased sediment concentrations are very limited in time. The model results show that sediment concentrations above 5 mg/l only can be found locally around some of the foundations for 1-10 hours. Concentrations above 10 and 15 mg/l are limited to the vicinity of a few foundations lasting only 1 and 6 hours, respectively (see Table 6-1).
Table 6-1  Frequency in which the modeled total suspended sediment concentrations are exceeded during dredging of foundations /5/.

<table>
<thead>
<tr>
<th>Total suspended sediment concentration (TSSC)</th>
<th>Maximum time exceeded</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 mg/l</td>
<td>The threshold is exceeded for approximately 3-20 hours inside the study area. Locally around foundations the threshold is exceeded for up to 60 hours. At a distance of 10 km north of the study area the threshold is exceeded for less than 10 hours and 2 km south of the study area the threshold is exceeded for less than 2-3 hours during.</td>
</tr>
<tr>
<td>5 mg/l</td>
<td>The threshold is exceeded locally around each foundation for 1-10 hours. At 5 km north of the study area the threshold is exceeded approximately 2 hours.</td>
</tr>
<tr>
<td>10-15 mg/l</td>
<td>Threshold exceeded locally around a few foundations for 1 - 6 hours and for less than 2 hours locally north of the study area.</td>
</tr>
</tbody>
</table>

Figure 6-1  Frequency of depth averaged suspended sediment concentrations in excess of 2, 5, 10 and 15 mg/l, during the dredging works. Hatched areas with black frames are NATURA 2000 areas /5/.

Figure 6-2 shows the maximum depth average total suspended sediment concentrations (TSSC) at any time during the entire dredging works. It is important to stress that the figure shows accumulated sediment spreading for the whole site. The sediment spreading at any time will be much less and concentrated to the vicinity of the ongoing intervention work. The sediment concentration will generally not exceed 20 mg/l inside the project area, but at a few foundations the concentration reaches 30 mg/l during the installation period. Outside the project area the sedi-
ment plume extents approximately 15 km north and 10 km south of the project area – but at low concentrations.
Figure 6-3  Frequency of depth averaged total suspended sediment concentrations (TSSC) in excess of 2, 5, 10 and 15 mg/l during the jetting of cables. Hatched areas with black frames are NATURA 2000 areas /5/.

Table 6-2  Frequency in which the modeled total suspended sediment concentrations are exceeded during cable jetting /5/.

<table>
<thead>
<tr>
<th>Total suspended sediment concentration (TSSC)</th>
<th>Maximum time exceeded</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 mg/l</td>
<td>Threshold exceeded for 10-100 hours inside the project area, with local exceptions at the seaward end of the southern cable corridor where the threshold is exceeded for up to 300 hours. Within a 10-12 km wide zone extending along the shoreline 15 km south to 20 km north of the project area the threshold is exceeded for 10-100 hours. Locally however, the threshold is exceeded for up to 200 hours in shallow water along the coast between the two cable corridors.</td>
</tr>
<tr>
<td>5 mg/l</td>
<td>Threshold exceeded for 5-60 hours inside the project area with local exceptions at the seaward end of the southern cable corridor where the threshold is exceeded for up to 200 hours. Within a 10 km wide zone extending along the shoreline 8 km south to 18 km north of the project area the threshold is exceeded for 10-60 hours. Locally however, the threshold is exceeded for up to 200 hours in shallow water along the coast between the two cable corridors, and for up to 100 hours another 3 km north of the northern cable corridor.</td>
</tr>
<tr>
<td>10-15 mg/l</td>
<td>Thresholds exceeded less than 30 hours inside the project area with local exceptions at the seaward end of the southern cable corridor where the threshold is exceeded for up to 100 hours. Outside the project area, the threshold is exceeded for 20-100 hours along the shore between the cable corridors and for 2-60 hours 12-13 km north of the project area. Within 6-7 km south of the project area the threshold is exceeded for 1-10 hours. Locally at the entrance to the port of Sæby the threshold will be exceeded for up to 200 hours.</td>
</tr>
</tbody>
</table>
Figure 6-4 shows the maximum suspended sediment concentrations at any time during the entire operation of jetting of cables.

Maximum increase in sediment concentrations of 10 to 60 mg/l are found inside the project area and up to 300 mg/l locally around some of the foundations and along the export cable corridor. Along the shore near the landfall of the cable corridors the concentrations reach more than 300 mg/l decreasing to 60 mg/l 3-4 km north of the northern and south of the southern cable corridor.

The sensitivity of fish to suspended particles varies highly between species and their life stages and depends on sediment composition, concentration and duration of exposure. High levels of suspended sediment for a short period of time may be less of a problem than a lower level that persists longer. Depending on the exposure the severity of impacts may go from behavioural effects, to sub lethal and lethal effects.

In general, fish eggs and fish fry are more sensitive to increased concentrations of suspended sediment than juvenile and adult fish species /19/. Normally, concentrations of suspended sediment that may be lethal to fish eggs and fish fry are expressed in mg/l, whereas the lethal concentration for juvenile and adult fish is expressed in g/l /19//21/.

High concentrations of suspended material may injure or kill adult and juvenile fish, e.g., if particles collect in their gills, reducing oxygen absorption, or if sharp-edged particles damage their gills /22/. However, there must be high concentrations of suspended material in the water column for fish to be injured or die. Literature reports lethal and sub-lethal concentrations in the magnitude of 580-225,000 mg/l and 650-13,000 mg/l, respectively /22//23//24//25//26/.
Pelagic fish are more sensitive to suspended sediment than demersal fish /22/. This is probably because the gills of pelagic fish are more susceptible to irritation and injury due to their faster swimming speed and larger gill area. Demersal fish are more adapted to occasional instances of increased concentrations of suspended material in their natural environment. Pelagic fish, therefore, will probably avoid suspended material to a greater extent than demersal fish /27/. Both laboratory and field investigations have showed that herring and smelt began to flee areas with fine-grained suspended sediment when the concentration reached approximately 10 mg/l and 20 mg/l, respectively /28/. Flatfish are especially tolerant to relatively high concentrations of suspended sediment. Studies of plaice with concentrations of 3,000 mg/l showed no increased lethality during a 14-day period /29/. Many species use their vision for feeding, and the feeding activity of herring fry is shown to be affected by concentrations of suspended matter of 20 mg/l /20/. Larvae of species like plaice, sole, turbot and cod sight their prey at a distance of only a few millimeters and can live a few days without food. Obviously, the more turbid the water is, the harder it is for the larvae to locate and catch their prey /30//31/. The most likely effects due to suspended material will be avoidance reactions or fish species fleeing an area during construction activities. These avoidance reactions are temporary and will have no long-term impact on fish and fish stocks. In general the pelagic is a more unspecific and wide spread habitat compared to many benthic habitats. Most pelagic fish species are usually not confined to a specific area, while many benthic species are resident and even tied to a specific area of a specific habitat. Fleeing may therefore constitute a greater barrier for benthic fish species. However, it seems also evident that many demersal fish in general are more tolerant towards suspended sediment. A fundamental difference between fish eggs/yolk sac larvae and juveniles/adults is the mobility, i.e. the capacity to swim. It is reasonable to presume that most fish capable of swimming moves away if conditions deteriorate, and therefore sediment spill probably seldom has direct lethal consequences among juveniles and adults. Laboratory experiments have been conducted to determine how suspended clay, a common source of turbidity in estuaries or due to spilling or dredging works, affected hatching success of six species of anadromous and estuarine fish. The result showed no deleterious effects at concentrations up to 500 mg silt/l, and a reduced hatching success in two of the species at a concentration of 1000 mg/l /32/. Pelagic fish eggs may also be affected if suspended matter adheres to eggs, causing them to sink to the bottom, where there is a risk of oxygen depletion /20/ and /33/. Studies have shown that cod eggs exposed to 5 mg/l suspended sediment was still able to float, while exposure to 100 mg/l of suspended solids increased mortality markedly /34/. Another study has shown that exposure to concentrations of suspended sediment at 300 and 500 mg/l for one day did not affect the development of herring eggs /35/. As it can be seen the sensitivity of fish to suspended particles varies highly between species and their life stages and depends on sediment composition, concentration and duration of exposure. Based on the text above, Table 6-3 present some very general threshold values. Which are difficult to apply as the duration of the suspended sediment concentration is a key factor for the effect. As mentioned above - high levels of suspended sediment for a short period of time may be less of a problem than a lower level that persists longer. So, the values presented shall not be seen as conclusive but more to show the range of impact values found in the literature.
Table 6-3  General threshold values (sensitivity) for fish of suspended sediment. The threshold values are based on the text and references mentioned above.

<table>
<thead>
<tr>
<th></th>
<th>Avoidance response</th>
<th>Lethal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pelagic species</td>
<td>10 mg/l</td>
<td>&gt;580 mg/l</td>
</tr>
<tr>
<td>Demersal species</td>
<td>50 mg/l</td>
<td>&gt;3000 mg/l</td>
</tr>
<tr>
<td>Eggs and larvae</td>
<td>-</td>
<td>&gt;5 mg/l, &lt;100 mg/l</td>
</tr>
</tbody>
</table>

Based on the concentrations of suspended sediment during the construction work, the duration of critical levels of suspended matter on the fish fauna are evaluated to be very limited. Any impacts would be limited to the very close vicinity of the construction works. In general it is expected that fish temporarily will leave the areas close to the construction activity. Food sources living in the seabed e.g. polychaetes will become exposed during cable trenching, and fish that are not affected by noise and higher turbidity might be attracted to the construction site /36//37//38/.

It has been assessed that the project area and the coastal area in its vicinity functions as a foraging and nursery areas for several fish species such as plaice, sole, flounder, dab, greater weaver and goby sp. The area is likely a spawning site for some fish species such as herring and sole. It is not currently known if intervention works will coincide with any spawning seasons. However, if there are eggs or larvae in close vicinity of the intervention works, they may perish. However, due to the relatively small area affected and the very short duration in which increased turbidity persist is not estimated to have a significant impact at the population level.

To put the sediment spreading from seabed intervention works in perspective, it can be mentioned that turbidity in coastal waters is often relatively high due to the low water depth and the mixing effect of waves and currents. In the open Øresund the naturally turbidity during stormy periods in the winter have been reported as high as 5-15 mg/l with local turbidity level up to 20-40 mg/l /39/. Furthermore, it can be noted that a concentration of 100-550 mg/l suspended material up to 50 m behind a bottom trawl has been reported /48/. Considering the fact that bottom trawling is carried out on a large scale every year, the released amount of sediment from seabed intervention works seems quite insignificant. Furthermore, sediment spreading due to seasonal and inter-annual changes, such as storm events is much greater than that caused by seabed intervention works /49/ /50//51//52//53/.

The overall effects on fish from increased turbidity during construction are assessed to be small, regional and short-term. The sensitivity of fish in relation to sediment spreading in the water column is assessed to be low. It is concluded that the overall impacts on fish and fish stocks from sediment spreading will be negligible.

6.2 Sediment spill deposition

The sediment released during seabed preparation will deposit on the seabed near the dredging and jetting activities. The material may deposit and get re-suspended several times before it deposits more permanently in a location where the waves and currents are not able to re-suspend it. The modelling of the spill deposit is based on the net deposition two weeks after dredging and jetting activities have been finalised. It is assumed that spilled material will have deposited in a relatively permanent location after two weeks.

Figure 6-5 shows the combined total deposition of spilled sediment from dredging and jetting. The figure shows that much of the spilled sediments will get deposited north of the project area and in the middle of the project area. The predicted sedimentation values are very small and will be expected to result in local seabed accretion in the order of only a few millimetres. Consequently, the pressure on the environment due to deposition of spilled sediments is expected to be minor.
The substrate of a preferred habitat can be highly altered by substrate removal or by sedimentation affecting particularly fish species that depend on certain bottom substrates for nursery, spawning and feeding. A study has found a strong selection for different grain size and sediment type among juveniles of four flatfish species. It was also found that none of the species selected sediments as granular and pebbles, which were too coarse to allow the flatfishes to bury themselves /44/.

Sediment spill deposit can also have an impact on bottom-laid eggs by covering the eggs – either destroying them or reducing egg respiration, leading to decreased survival and affecting embryonic development. A change in sediment composition can also negatively affect reproduction success /44/. Thus, various studies have shown that changes in sediment that serve as spawning grounds either prevent fish from spawning or cause them to lay their eggs in less adequate areas /47/.

If bottom laid eggs are present in the vicinity of the intervention works they may perish. However, due to the relatively small area affected is not estimated to have a significant impact on population level.

The overall effects on fish from sediment spill deposition during construction are assessed to be small, regional and short-term. The sensitivity of fish in relation to sediment spill deposit is assessed to be low. It is concluded that the overall impacts on fish and fish stocks from sediment spill deposition will be negligible.
6.3 Contaminants associated with sediment spill

During construction activities sediment will be spilled into the water column. If these sediments contain elevated levels of contaminants these may be dissolved and have a negative impact on the benthic flora and fauna.

Chemical analyses of the sediment in the marine part of the project area were carried out in 2011. Samples were analysed for metals (As, Cd, Co, Cr, Cu, Hg, Ni, Pb, V, Zn), PAHs (Anthracen, benz[a]anthracen, benz[ghi]perylene, benz[a]pyren, chrysen, fluoranthen, indeno[1,2,3-cd] pyren, pyren og phenanthren), organotin (TBT) and PCB (7 compounds; 28, 52, 101, 118, 138, 153 and 180) /45/.

Concentration of PAH, PCB and TBT were significantly lower than the lower thresholds presented in "klapbekendtgørelsens" lower action level, and the concentration of metals and TBT in sediments is thus characterised as "average background levels or insignificant concentrations with no expected negative impact on marine organisms" /46/.

6.4 Noise and physical disturbance

In connection with the construction of Sæby Offshore Wind Farm there will be an increased noise level and disturbance caused by increased traffic of various constructions and supporting vessels. It is in association with pile-driving that the greatest levels of noise are likely to arise (if monopiles are chosen as the preferred foundation). The extent to which such noise source levels would give rise to an impact upon fish is dependent upon a number of factors including the level of noise produced at the piling source, the frequencies at which the sound is produced, the rate at which sound attenuates (which will vary for different frequencies and environmental conditions), the varying sensitivities of different species and individuals to different volumes and frequencies of noise and the piling methods and thickness of piles utilised.

Noise associated with the piling activities can affect fish in several ways, including:

- Damage to non-auditory tissue
- Damage to auditory tissues (generally sensory hair cells of the ear)
- Hearing loss due to temporary threshold shift
- Masking of communication
- Behaviourally effects (e.g. avoidance)

Fish behaviour in response to noise is not well understood. Sound pressure levels that may deter some species, may attract others. There are relatively few studies that deal with noise-related impacts on fish, and moreover, the studies often show varying results. It is often difficult to extrapolate the results of specific studies or basic research to other conditions, mainly due to the different hearing systems for the species and differences in the physical properties of the sound stimuli.

There is a high diversity in hearing capabilities among fish, giving different hearing characteristics of the various species. Most species have hearing ranges from approximately 30 Hz to 1 kHz. Noise from shipping and pile driving exhibit most energy below 1 kHz and is within the frequency range for most fish species. Some species respond to sound by fleeing, others are to some extent attracted by the sound and some gets accustomed to new sources of noise /55/. For classification purposes, the terms hearing specialist and hearing generalist are commonly used. This classification is independent of the taxonomic grouping but is based entirely on a species hearing capability.

Hearing specialists have some means of mechanical coupling between the swim bladder and the inner ear. As a result of these additional features to the ears, hearing specialists have high sound pressure sensitivity and generally low hearing thresholds when compared to generalists. They can detect sounds to over 3 kHz with best sensitivity from about 300 to 1,000 Hz /54/.

In contrast, the majority of fishes are not known to have hearing specializations and only detect sounds up to 1,000 Hz, with best hearing generally from 100 - 400 Hz. They are classified hear-
ing generalists. These species hear primarily via the direct pathway (i.e. particle motion via the otoliths) with relative poor sensitivity /54/.

Difficulties in investigating responsiveness to noise in fish have consequences for deriving appropriate threshold values for behavioural reactions. For example, it has been proposed that sound pressure levels of 90 dB above the hearing threshold in fish lead to significant avoidance reactions, with mild behavioural reactions occurring at 70 dB above the hearing /57/. Based on these values zones where significant avoidance reactions to piling noise at North Hoyle wind farm were to be expected were calculated as 1.4 km (salmon), 5.5 km (cod) and 1.6 km (dab) /58/. However, the exact calculation of these dBht values (ht = hearing threshold) remains uncertain and support from experimental studies in peer-reviewed publications is lacking to date. Therefore, the ranges calculated might be viewed as only very provisional, needing much further evaluation. Thresholds for avoidance might be even much less than those described above. In the context of the effects of shipping noise on fish a threshold value of only 30 dB above hearing threshold for the induction of avoidance behaviour in fish has been proposed /56/. However, this was not based on experimental work.

Research on the effects of ship noise on fish, especially noise generated by ships using sonar systems, is summarised by ICES /59/. The authors noted that it is difficult to draw definite conclusions /55/. However, it is clear that fish can detect ship noise at long distances when the ambient levels from other sources are low but they are unlikely to react and move away unless the noise is relatively high, typically when the distance is a few hundred metres /56/.

A study of spawning herring was carried out in Norway to investigate the effects of repeated passage of a research vessel at a distance of 8 - 40 m, in 30 - 40 m water depth. At a peak value noise source level of around 145 dB re 1μPa 1Hz within the range 5 - 500 Hz, there was no detectable reaction amongst the spawning herring /60/.

The strongest noise during construction arises during pile driving of mono piles. There are in the literature several examples of pile driving resulting in the death of fish in the immediate vicinity of the pile driving activity. Typically, mortality is reported within a distance of about 0 to 50 meters from pile driving activity /55/. Fish further away will most likely move away from the sound source. It is estimated that, for example, flounder and cod will respond within a distance of 500 m and 2 km, respectively /63/.

A non-peer-reviewed study using sounds from 115-140 dB (re 1μPa, peak) on eggs and embryos reported normal survival or hatching, but few data were provided to evaluate the results /61/. Another study report damage on eggs of several marine species at up to 20 m from a source designed to mimic seismic airguns, but few data were given to ascertain the effects /62/.

In fish, physical damages to the hearing apparatus rarely lead to permanent changes in the detection threshold (permanent threshold shift, PTS), as the damaged sensory epithelium will regenerate in time /65/. However, hearing loss due to temporary threshold shift (TTS) does occur. The sound intensity is an important factor for the degree of hearing loss, as is the frequency, and the exposure duration.

Based on a review of recent literature regarding impact from noise on fish – various threshold criteria for effects are presented in Table 6-4. It is imperative that the criteria for effects on hearing and auditory tissues of fish consist of two metrics: peak sound pressure level and cumulative sound exposure level (SEL). If either of the recommended criteria levels is exceeded, then there is potentially an effect. The effect only applies to fish with swim bladders. The data on fish without swim bladders are insufficient to serve as a basis for recommendations. However, based on observations in the literature that fish without swim bladders (e.g. flatfish) may less likely be affected by sounds because they do not have an internal compliant air bubble that oscillates in response to acoustic pressure, it may tentatively be predicted that such species would less likely be affected than fish with swim bladders. When considering impacts to the auditory system, separate criteria are needed for hearing generalists and hearing specialists. However, it should also be recognised that the biology of individual fish species as well as the physiological state of individual fish may alter the nature and sequence of effects.
Table 6-4  Tentative criteria for effects on fish with a swim bladder from pile driving, based on /64/.

<table>
<thead>
<tr>
<th>Effect</th>
<th>Target</th>
<th>Peak</th>
<th>Cumulative SEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Damage to non-auditory tissue</td>
<td>All species</td>
<td>Not relevant</td>
<td>&gt;213 dB</td>
</tr>
<tr>
<td>Damage to auditory tissues - generally sensory hair cells of the ear. Also referred to as permanent threshold shift (PTS)</td>
<td>Hearing generalist</td>
<td>&gt;206 dB</td>
<td>&gt;189 dB</td>
</tr>
<tr>
<td></td>
<td>Hearing specialist</td>
<td>&gt;205 dB</td>
<td>&gt;185 dB</td>
</tr>
<tr>
<td>Hearing loss due to temporary threshold shift (TTS)</td>
<td>Hearing generalist</td>
<td>207 dB</td>
<td>185 dB</td>
</tr>
<tr>
<td></td>
<td>Hearing specialist</td>
<td>205 dB</td>
<td>183 dB</td>
</tr>
</tbody>
</table>

It should be noted that the effect from pile driving on fish and how impact criteria shall be defined is much debated. Based on the threshold values presented above modelling of the worst case scenario have been carried out /66/. The worst case results for the 10 MW turbines are presented in Table 6-5. The results presented are the worst cases – e.g. applies to hearing specialists and for the direction in which the longest impact distances have been calculated. More results are presented in Appendix 2.

Table 6-5  Result of the acoustic modeling carried out for piling of the 10 MW turbines at Sæby /66/.

<table>
<thead>
<tr>
<th>Effect</th>
<th>Cumulative SEL</th>
<th>Threshold distances (worst case)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Damage to non-auditory tissue</td>
<td>213 dB</td>
<td>200 meter</td>
</tr>
<tr>
<td>Damage to auditory tissues - generally sensory hair cells of the ear. Also referred to as permanent threshold shift (PTS)</td>
<td>185 dB</td>
<td>16.6 km</td>
</tr>
<tr>
<td>Hearing loss due to temporary threshold shift (TTS)</td>
<td>183 dB</td>
<td>17.8 km</td>
</tr>
</tbody>
</table>

Table 6-5 shows that according to the threshold values used damage to non-auditory tissue can happen within a maximum distance of 200 meter of the pile driving activity. Damage to the auditory tissues - generally sensory hair cells of the ear can happen within a distance of 16.6 km. However, physical damages to the hearing apparatus rarely lead to permanent changes in the detection threshold, as the damaged sensory epithelium will re-generate in time /65/. Masking of communication can happen within a distance of 17.8 km.

The available indications described above suggests that the noise generated by pile driving are at levels that could elicit behavioural responses for fish over a wide area from which fish could be displaced during piling activities. Fatalities or physical injury from piling is limited to a relatively small distance to the piling activities - making it more of an animal welfare issue than an ecological or population level effect.

The conclusion is that avoidance reactions from almost all fish species will occur in close proximity to the construction activities but that the fish population will return after the cessation of activities. Long-term effects are not envisioned. Installation of one turbine is roughly estimated to last 7 days in total. The expected time for driving each pile is between 4 and 6 hours implying that the fish has approximately 6 days rest between each piling activity.

The primary effect is likely to be that the fish leave the immediate area during the periods when construction activities and noise is most intense. However, it is expected that the fish will quickly return when construction work has ceased. Only in exceptional cases where there are fish in the immediate vicinity (<200 m) of the piling activity (if monopoles are selected), the fish could get physical damage and possibly die.

The effects on the fish fauna from noise and physical disturbance are assessed to be small, regional and short-term. It is concluded that the overall impacts will be moderate negative. However, by adopting certain more or less standard mitigation measures the effects of pile driving can be significantly reduced. It is possible to reduce the level of noise transmitted through the water.
by using either air bubble curtains or cofferdams. Bubble curtains have variable effectiveness, but can usually attenuate the sound by 0-20 dB. Some designs have achieved up to 30 dB attenuation. If dewatered, noise shields can be very effective at reducing the underwater noise, being equal or better to bubble curtains. Another possible mitigation could be to use ramp-up/slow start procedures, where the first hammer blows are at reduced impact energy. This would allow noise sensitive fish species to escape the immediate vicinity. By adopting mitigation measures the impact will be severely reduced and the overall impacts are assessed to be minor negative.

6.5 Impact on food resources

Many of the fish species within the project area feed on animals living in association with the seabed (benthos) such as polychaetes, bivalves and crustaceans - either exclusively or as part of the food source. This is for example true of most flatfish species including sole which is the economic most important flatfish species in the area. The economic important species sprat, herring and sandeel all mainly feed on zooplankton. In connection with the construction of the Sæby Offshore Wind Farm there will be increased turbidity and sedimentation during the various construction activities.

An impact assessment of how construction of the wind farm will affect the benthos fauna in the project areas is presented in /6/. The overall conclusion is that the impacts on the benthic flora and fauna are small, and in general local and short-termed with no significant overall impact. It is estimated that the habitat type and the associated benthic community is quite similar within the entire project area at Sæby indicating that most fish in generally will be able to swim to nearby foraging areas (within the project area or in its vicinity) during construction activities.

In general it is expected that fish temporarily will leave the areas in vicinity of the construction activity. Food sources in the seabed will become exposed during cable trenching, and fish that are not affected by noise and higher turbidity might be attracted to the construction site /36//37//38/.

The overall effects on fish from decrease in food resources during construction are assessed to be small, local and generally short or medium-term. The sensitivity of fish in relation to impact on food resources is assessed to be low. It is concluded that the overall impacts on fish and fish stocks from decrease in food resources will be negligible.

6.6 Overall impact

Table 6-6 shows the summary of estimated impact on fish during the construction phase. The criteria’s used are described in detail in section 4.2.1.

<table>
<thead>
<tr>
<th>Impact</th>
<th>Degree/scale</th>
<th>Geographic extent</th>
<th>Duration</th>
<th>Overall significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sediment spreading in the water column</td>
<td>Small</td>
<td>Regional</td>
<td>Short</td>
<td>Negligible</td>
</tr>
<tr>
<td>Sediment spill deposition</td>
<td>Small</td>
<td>Regional</td>
<td>Short</td>
<td>Negligible</td>
</tr>
<tr>
<td>Contaminants in the water column</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>No negative impact</td>
</tr>
<tr>
<td>Noise and physical disturbance</td>
<td>Small</td>
<td>Regional</td>
<td>Short</td>
<td>Moderate negative impact*</td>
</tr>
<tr>
<td>Impact on food resources</td>
<td>Small</td>
<td>Local</td>
<td>Short/medium</td>
<td>Negligible</td>
</tr>
</tbody>
</table>

*By adopting mitigation measures the impact will be severely reduced and the overall significance will be negligible.


7. IMPACT ASSESSMENT DURING OPERATION PHASE

This section addresses the conditions and factors that could potentially affect the fish fauna during the operation phase of Sæby Offshore Wind Farm. Potential impacts are assessed according to intensity, extent and duration. The overall significance of an impact is assessed based on the aforementioned criteria and the sensitivity of the fish fauna. Potential impacts on the fish fauna during the operation phase of Sæby Offshore Wind Farm can be caused by the following:

- Noise
- Electromagnetism
- Habitat changes

7.1 Noise

Noise and vibration generated from wind turbine gearboxes, turbines, generators and cables. In addition, the wings will generate aerodynamic noise during rotation. Noise and vibrations will be transmitted through the tower into the foundation, and from there through the sea floor and into the water. The noise of the turbines in operation varies with wind conditions, but the noise source is stationary and less time-varying compared to plant noise and traffic noise. This means that the noise from wind turbines is more predictable than noise from other human induced and moving noise sources.

The great majority of fish sounds are produced in a social context /40/ for example during aggression, defense, territorial advertisement, courtship and mating /41/. The noise during operation may decrease the effective range for sound communication of fish, but it does not have any destructive effect on the hearing ability. The fact that fish are able to detect noise does not necessarily imply that the noise induces an avoidance reaction.

Investigations dealing with the impact of wind farm induced operational noise specifically on fish were conducted at the Svante Wind Farm in Sweden. By means of ultrasonic telemetry and fishing, it was shown that European eels (Anguilla anguilla) passing a single (220 kW) wind turbine at a distance of 0.5 km did not substantially change their swimming behavior. When the rotor was stopped, the catch rates of cod and roach were significantly higher in the vicinity of the turbine (100 m) than at distances between 200 and 800 m. These findings indicate an attraction for fish, possibly due to the reef effect. By contrast, during operation, the catch rate decreased by a factor of 2 within 100 m from the windmill under otherwise similar conditions. This could be interpreted as a displacement effect. However, no investigations of the variation in fish density were performed prior to construction, so the differences may be attributable to other factors /42/ /43/.

The sound has a character and strength, which makes it likely that sound sensitive fish such as herring and cod, will be able to detect the turbine noise at a distance of up to a few hundred meters /67/. By contrast, the turbine noise could only be detected within short distances by flatfish, sculpins and other bottom-dwelling species with no or reduced swim bladders.

It is estimated, however, that sound waves from wind turbines are so constant and diffuse that fish are able to habituate to this /67/. That some habituation takes place is supported by the experiences from the offshore wind farms Rødsand and Horns Rev, where a high density of e.g. goldsinny wrasse, back goby and cod are registered around the turbine foundations. In terms of catches and the species observed no significant difference between wind farm areas and nearby reference areas were observed /77/. Experience from established offshore wind farms shows no effect of the noise on the fish fauna – fish species known to be associated with reefs or hard structures have been reported to gather around the foundations of the turbines.

The effects on the fish fauna from noise during operation are assessed to be small, regional and long-termed. The sensitivity of fish in relation to noise is assessed to be low. It is concluded that the overall impacts on fish and fish stocks will be negligible.
7.2 Electromagnetism from cables
Transportation of electric power from the wind farm through cables is associated with formation of electromagnetic fields (EMF) around the cables.

Electromagnetic fields emitted from the cables consist of two constituent fields: an electric field shielded by the cable coating and the seabed and a magnetic field detectable outside the cables. A secondary electrical field is induced in the surrounding water by the magnetic field. This secondary electrical field is detectable outside the cables /73/. The strength of the electrical field is measured in volts pr. meter (V/m) and the unit of measurement of the magnetic field is tesla (T).

The strength of the magnetic field is proportional to the amount of current running in the cable. The power production from the wind farm will display annual and diurnal variations in the current strength. The magnetic field will vary accordingly.

33 kV AC cables are expected to be chosen for the Sæby Offshore Wind Farm. Figure 7-1 shows the magnetic field for the 33 kV Sæby Offshore cable. The magnetic field level is highest closest to the cable and decrease with distance from the cable. The intensity of the magnetic field increases in rough proportion to the current flow in the cables, but is also influenced by the separation and burial depth of the cables. For the Sæby cable the level of the magnetic field is based on the expected average yearly production at the wind farm. The burial below the seabed is increasing the distance between the field source and the marine environment /68/.

![Figure 7-1 The magnetic field profile across the surface of the seabed for Sæby Wind Farm in comparison to the Horns Rev A and Rødsand 1 Offshore Wind Farms.]

Magnetic fields from AC cables can also induce electric currents. The polarity of the induced current would reverse at same frequency as that of AC magnetic field, potentially reducing the likelihood that the induced field from AC rotation would be detectable by organisms’ /68/.

It is generally known that the cartilaginous fish (sharks and rays) have electrorceptors that they use to perceive electromagnetic fields around the prey and to orient /69/. There is also evidence that some teleost fish (ray-finned fish) such as plaice /70/ and eel /71/ have the ability to use magnetic signals in their orientation. There is only a sparse literature that indicates that teleost
fish can sense magnetic fields, and there are almost no field studies of sensitivity in teleosts against the changes in magnetic fields, which can be experienced from cables of offshore wind farms.

That the effect of electromagnetic fields on teleost fish is likely to be minimal is confirmed in a report, which summarizes a number of studies of the effects of cables and in which it concludes that the electromagnetic fields around submarine cables from offshore wind farms do not have a significant effect on the marine environment /72/.

The issue of electromagnetic fields on fish was examined at Nysted Offshore Windfarm /77/ /81/. The results from the surveys and investigations carried out shows that the presence of the cable and/or the cable trace may have an effect on the behavioral pattern of some fish species. However, the possible effect is assessed to be very local and the possible barrier effect displays a temporary pattern depending on the power generated. The fish communities were the same on both sides of the cable trace and identical to the community present before establishment of the cable. This indicates that the presence of the power cable and the establishment of the cable trace have caused no significant spatial changes in the local fish fauna. The catch data by no means indicated that the cable trace constituted an absolute barrier for any species.

Finding the fish fauna to be unaffected by the cable trace with regards to species composition and community structure does however, not imply that the establishment of a cable surrounded by an electromagnetic field is without any impacts on fish at the regional or global level. It has been speculated if cumulative effects may exist due to the increasing number of power cables in the marine environment. One possible effect may be a changed pattern in the migration of species such as common eel /73/.

It can be concluded that the electromagnetic fields and induced electrical fields from power cables are detectable by a number of species and that many of these species may respond to the fields. However, threshold values are only available for a few species and the responds on individual and population level is accordingly uncertain /76/. Thus, the impact from electromagnetic fields is not assessed for the different key fish species but for the fish community at Sæby as one. Studies have shown that the electromagnetic fields decrease rapidly with distance from the cable. In addition the cable connecting the windmills with onshore station will be of relatively low voltage levels, i.e. 33 kV, compared to e.g. Nysted, Rødsand and Horns Rev wind farms. The resulting magnetic field is comparably lower. Thus, a potential negative impact will be limited to close vicinity of the cables.

It should however be noted that if both of the scheduled cables from the windfarm to land is realised then the stream outlet of Sæby Å to Kattegat will be “surrounded” by cables. This could hypothetically effect the migration of several anadromous fish species – fish that spawns in freshwater but completing part of its life cycle in the sea. Relevant species include lamprey, trout and salmon. Also catadromous species like eel could be affected. Eel migrate from fresh water into the sea to spawn. However, based on the current knowledge the effect from the electromagnetic fields is not assessed to create a barrier for migration.

Based on the low sensitivity of the fish to electromagnetism from cables the effects are assessed to be small and local lasting for as long as the cables are present and functioning. The overall impacts on fish and fish stocks from electromagnetism from cables are concluded to be negligible negative.

### 7.3 Habitat changes

Physical structures in relation to offshore projects can change the complexity and function of the habitats. The area of suitable habitats for spawning, nursery and feeding can be reduced. Furthermore, the transport of eggs and larvae and the migration can be affected by seabed reclamation due to barrier effect. On the other hand, physical structures which increase the habitat complexity tend to attract several fish species and can act as an artificial reef.

Following the establishment of the wind turbines, areas of previously intact seabed will be occupied by wind turbine foundations including scour protections. The size of the areas that will be
occupied depends on the selected foundation type. Of the four evaluated foundation types, gravity base foundation and 3 MW turbines define the worst case scenario. 67 gravity base foundations including scour protections will occupy a total of maximum 0.29 km² which correspond to less than 0.5 % of the marine part of the project area /1/.

Areas previously consisting of e.g. sandy bottom will be replaced by foundations and scour protection. Species such as flounder, sole, plaice associated with sandy soft bottom will get their habitat reduced by the footprint by the turbines. However, since the total area of introduced hard bottom structure only takes up a very small portion (0.5 %) of the total area, the effects will be minimal. On the other hand a so-called reef effect may have a positive effect on the fish fauna in the area. It is expected that benthic organisms will rapidly colonize the foundations scour protection partly through migration from the local area and by settling of larvae or spores. The nature and extent of this colonization depends on the locations of the foundation, including the depth and currents, as well and the material and structure of the foundation and scour protection, including its heterogeneity. The first to colonize the new structures will be filamentous algae and opportunistic invertebrates - typically barnacles and mussels. Over time, however, it is expected that there will be a more diverse fauna and flora.

It is expected that the artificial reef will attract certain species of fish to find hiding places and food in hard bottom areas /74/. Reef fish such as e.g. goldsinny wrasse, corkwing wrasse and lumpfish will especially profit from the new habitat. The fish are attracted to the boulders with their variety of habitats which creates a wealth of hiding places where e.g. small fish and fry can hide from predators. But also cod and whiting are attracted by the often larger food supply offered by heterogeneous structures such as boulder reefs /75/. Pelagic species are not expected to be affected by the physical presence of the turbines.

The results of a monitoring programme of benthic fish before and after the establishment of Lillgrund Wind Farm in Sweden could not demonstrate an effect on the fish fauna in general. However, a higher density of fish was observed around all turbine foundations /78/. A study of long-term effects on the fish community at Horns Rev 1 wind farm showed that the effects of the wind farm on the quantities of fish and diversity was negligible /79/. The baseline study of the fish community at Horns Rev 1 was carried out in September 2001 and in March 2002 and the effect studies were conducted seven years later in September 2009 and March 2010. The introduction of hard substrates and thus greater substrate complexity, resulted in minor changes in fish community structure and species composition in the area. The changes in the fish community after the establishment of the wind farm is primarily due to changes in the densities of the most commonly occurring fish, whiting (*Merlangius merlangus*) and dab (*Limanda limanda*) which reflected the general trend in the development of these fish stocks in the North Sea. The introduction of hard bottom substrate resulted in a higher species diversity close to each turbine foundation with a clear spatial (horizontal) division. Reef associated species as Goldsinny wrasse (*Ctenolabrus rupestris*), eelpout (*Zoarces viviparous*) and lumpfish (*Cyclopterus lumpus*) established itself on the new reef area /79/.

Given that the relatively small area occupied by the foundations compared to the total area of the entire wind farm area and in view of the relatively large distances between the turbines, it is estimated that any reef effect around turbine structures will be local and that it will not significantly alter the composition of fish in the area.

Based on the relatively small footprint left by the turbines and scour protection effects are assessed to be small, local and long-term (permanent if scour protection is left on the seabed after decommissioning). The sensitivity of fish in relation to habitat changes is assessed to be low. The overall impacts on fish and fish stocks from the physical structures of the foundations and scour protection are estimated to be positive.

### 7.4 Overall impact

Table 7-1 shows the summary of estimated impact on fish during the operation phase. The criteria used are described in detail in section 4.2.1.
Table 7-1  Summary of impacts on fish during the operation phase.

<table>
<thead>
<tr>
<th>Impact</th>
<th>Degree/scale</th>
<th>Geographic extent</th>
<th>Duration</th>
<th>Overall significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noise</td>
<td>Small</td>
<td>Regional</td>
<td>Long</td>
<td>Negligible negative impact</td>
</tr>
<tr>
<td>Electromagnetism</td>
<td>Small</td>
<td>Local</td>
<td>Long</td>
<td>Negligible negative impact</td>
</tr>
<tr>
<td>Habitat changes</td>
<td>Small</td>
<td>Local</td>
<td>Long/permanent</td>
<td>Negligible /Positive</td>
</tr>
</tbody>
</table>
8. IMPACT ASSESSMENT DURING DECOMMISSIONING

Prior to expiry of the production time a decommissioning for the wind farm plan should be prepared. Currently, the exact decommissioning approach has not been defined, and therefore this assessment of potential pressures uses a worst case consideration of complete removal of the structures.

The pressures during removal of foundations and cables are likely to include short-term increases in suspended sediment concentration and sediment deposition from the plume caused by foundation cutting or dredging and seabed disturbance caused by removal of cables and scour protection. Although there is no evidence on these potential effects, the effects during decommissioning are considered to be less than or comparable with those effects described during the construction phase, because the volumes of soil to be handled during decommissioning will be equal or smaller than during construction. This is because there will be no need for seabed preparation and there is a possibility that cables are left in situ with no consequential increase in suspended sediment concentration or changes to water quality.

During decommissioning both the turbine components and foundations will need to be removed. The effects during decommissioning are considered to be similar to those described during the construction phase. However, pile driving is not envisioned and hence the noise during decommissioning will be significantly lower than during construction.

The scour protection will most likely be left in situ and not be removed as part of the decommissioning. It will not be practically possible to remove all scour protection materials as major parts of it must be expected to have sunk into the seabed. Also it is expected that the scour protection will function as a natural stony reef. The removal of this stony reef is expected to be more damaging to the environment in the area than if left in situ. It is therefore considered most likely that the regulators at the time of decommissioning will accept or require the scour protection to be left on site.

8.1 Overall impact

Table 8-1 shows the summary of estimated impact on fish during the decommissioning phase. The criteria used are described in detail in section 4.2.1.

<table>
<thead>
<tr>
<th>Impact</th>
<th>Degree/scale</th>
<th>Geographic extent</th>
<th>Duration</th>
<th>Overall significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sediment spreading in the water column</td>
<td>Small</td>
<td>Local</td>
<td>Short</td>
<td>Negligible</td>
</tr>
<tr>
<td>Sediment spill deposition</td>
<td>Small</td>
<td>Local</td>
<td>Short</td>
<td>Negligible</td>
</tr>
<tr>
<td>Contaminants in the water column</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>No negative impact</td>
</tr>
<tr>
<td>Noise and physical disturbance</td>
<td>Small</td>
<td>Regional</td>
<td>Short</td>
<td>Negligible</td>
</tr>
<tr>
<td>Impact on food resources</td>
<td>Small</td>
<td>Local</td>
<td>Short/medium</td>
<td>Negligible</td>
</tr>
</tbody>
</table>
9. **CUMULATIVE IMPACTS**

The assessment of cumulative effects evaluates the extent of the environmental effects of the wind farm in terms of intensity and geographic extent compared with other projects in the area. The assessment of the cumulative conditions includes activities associated with existing utilised and un-utilised permits or approved plans for projects. When projects within the same region affect the same environmental conditions simultaneously, they are defined to have cumulative impacts. Cumulative effects can potentially occur on a local scale, such as within the wind farm area, and on a regional scale.

Two other projects in the area have been estimated to potentially cause cumulative impacts:

- Construction of six test offshore wind turbines at Frederikshavn
- Expansion of the Frederikshavn port (including deepening of the channel)

The cumulative effects could include:

- Larger footprint – potential changing sandy bottom to stony bottom
- More sediment spill

The additional wind turbines will lead to a higher overall footprint. The current habitat under each turbine will be replaced by turbine foundations and surrounding stone protection. For benthic fish species associated with sand and gravel (e.g. flatfish) this will have a negative effect, while stone reef associated species such e.g. goldsinny wrasse (*Ctenolabrus rupestris*), corkwing wrasse (*Symphodus melops*), cod (*Gadus morhua*) and lump sucker (*Cyclopterus lumpus*) will benefit from the new habitat. It is estimated however, that these turbine foundations and stone protection around its base would constitute such a small part of the area that it will not have a significant effect on the fish population.

Construction works - if the projects are carried out during the same period - could lead to a higher concentration of sediment spill in the water column and sedimentation.
10. HABITATS DIRECTIVE (NATURA 2000 SCREENING)

The "Natura 2000" network is the largest ecological network in the world, ensuring biodiversity by conserving natural habitats and wild fauna and flora in the territory of the EU. The network comprises special areas of conservation designated by EU States under the Habitats Directive on the conservation of natural habitats and of wild fauna and flora (92/43/EEC). Furthermore, Natura 2000 also includes special protection areas classified pursuant to the Wild Birds Directive (2009/147/EC).

According to Article 6 (3):

Any plan or project not directly connected with or necessary to the management of the site but likely to have a significant effect thereon, either individually or in combination with other plans or projects, shall be subject to appropriate assessment of its implications for the site in view of the site’s conservation objectives.

This chapter constitutes a Natura 2000 screening, to assess whether Sæby offshore wind farm causes a significant effect to the designated fish species in Natura 2000 sites within and near the project area.

This present Natura 2000 screening only concerns fish species, as this background report assess potential impacts to the fish fauna. Habitat types and habitat species (marine mammals and birds) are addressed and assessed in other background reports.

10.1.1 Description of the proposed project
The basis for this screening is the project description presented in Chapter 3.

Sæby offshore wind farm is not directly connected with, or necessary to, the management of Natura 2000 sites.

10.1.2 Identification of Natura 2000 sites potentially affected
Designated Natura 2000 sites in and near the project area are presented in Figure 10-1 and Table 10-1.
Table 10-1 Type of site, designated fish species and relevance for screening.

<table>
<thead>
<tr>
<th>Natura 2000 site</th>
<th>Special Area of Conservation (H)</th>
<th>Designated fish species (ID#)</th>
<th>Relevant for screening</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Special Protection Area (F)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ramsar site (R)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N4</td>
<td>Hirsholmene, havet vest herfor og Ellinge Å’s ud-løb</td>
<td>H4, F11, R8</td>
<td>The sea lamprey (<em>Petromyzon marinus</em>) (1095)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>The European brook lamprey (<em>Lampetra planeri</em>) (1096)*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>The landfall and cable route are within this site</td>
</tr>
<tr>
<td>N9</td>
<td>Strandenge på Læsø og havet syd herfor</td>
<td>H9, F10, R10</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>No</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Not designated for any fish species</td>
</tr>
<tr>
<td>N14</td>
<td>Ålborg Buft, Randers Fjord og Mariager Fjord</td>
<td>H14, F2</td>
<td>The sea lamprey (<em>Petromyzon marinus</em>) (1095)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>The European river lamprey (<em>Lampetra fluviatilis</em>) (1099)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>The twaite shad (<em>Alosa fallax</em>) (1103)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>No overlap with project area, but potential impacts are assessed</td>
</tr>
<tr>
<td>N20</td>
<td>Havet omkring</td>
<td>H176, F9, R9</td>
<td>The sea lamprey (<em>Petromyzon marinus</em>) (1095)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Yes</td>
</tr>
</tbody>
</table>

Figure 10-1 Natura 2000 sites.
Natura 2000 site | Special Area of Conservation (H) | Special Protection Area (F) | Ramsar site (R) | Designated fish species (ID#) | Relevant for screening
---|---|---|---|---|---
Nordre Rønner |  |  |  | marinus) (1095) | No overlap with project area, but potential impacts are assessed
N245 | Aalborg Bugt, østlige del | F112 | None | No | Not designated for any fish species

* The European brook lamprey lives its entire lifecycles in the streams. Hence, no impact from the wind farm is expected. No further impact assessments for this species are done.

10.1.3 Short description of the biology of the marine fish species listed in Table 10-1.

**Sea lamprey (Petromyzon marinus)**
Sea lamprey is anadromous - i.e. it spawns in freshwater but completing part of its life cycle in the sea. During fall or early spring the adult sea lamprey migrates from the sea into rivers where it spawns on rocky bottom in February to June - after spawning, the adults die. The young larvae, known as ammocoetes, spend several years in soft sediment before migrating to the sea as adults. It is thought that these fish spend three to four years in marine habitats before making the return trip to spawn. In the sea they lives as scavengers or it attaches itself to the sides or gills of fish (e.g. cod, mackerel or salmon), using its teeth to rasp away the skin and eat the flesh beneath. The larva stays in the river for 3-4 years after which they migrate to the sea where it lives as a scavenger. After 3-4 years they become mature and migrate up the streams /8/.

Occurrence sea lampreys are rare and in most of our streams, where it is registered, there are usually many years between records. It has been registered five times in Elling Å, five times in Sæby Å and spawning behavior has been observed in Voer Å twice /82/. Sea lampreys has not been observed in the coastal waters off Sæby, but the remains of a sea lamprey has been found in the belly of a cormorant on Hirsholmene, foraging in the shallow water of the Natura 2000 area /83/.

**The European river lamprey (Lampetra fluviatilis)**
The European river lamprey is found in coastal waters, estuaries and accessible rivers. The species is normally anadromous - i.e. spawning in freshwater but completing part of its life cycle in the sea. The European river lamprey lives and spawn similar to that of the sea lamprey. River lampreys migrate upstream from the sea to spawning grounds in autumn and winter. Spawning activity is greatest in the springtime and after spawning, the adults die. The young larvae, known as ammocoetes, spend several years in soft sediment before migrating to the sea as adults. It is thought that these fish spend one to three years in marine habitats before making the return trip to spawn /8/.

**The twaite shad (Alosa fallax)**
The twaite shad is anadromous - i.e. it spawns in freshwater but completing part of its life cycle in the sea. The twaite shad lives in shoals. The requirements of shads at sea are very poorly understood, but they appear to be mainly coastal and pelagic in habit. Twait shad have been reported from depths of 10–110 m, with a preference for water 10–20 m deep. At maturity, the adult twait shad stop feeding and gather in the estuaries of suitable rivers in early summer (April and May), moving upstream to spawn from mid-May to mid-July. The males usually move upstream first, but they are soon joined by the females. The spawning is a noisy affair, with much splashing and chasing near the surface above appropriate areas of clean gravel. Spawning takes place in flowing water over stones and gravel, among which the eggs sink. The eggs take about four to six days to hatch. The young fish then drop quickly downstream in the current to the quieter waters of the upper estuary where they start to feed and grow /86/.
The young fish feed mainly on invertebrates, especially estuarine zooplankton, but as they grow they take larger crustaceans of various types (for example, shrimps and mysids) and also small fish. Adults feed to an appreciable extent on other fish, especially the young of other members of the Clupeidae, such as sprat and herring /86/.

A suitable estuarine habitat is likely to be very important for twaite shad, both for passage of adults and as a nursery ground for juvenile /86/.

10.1.4 Identification and assessment of potential impacts
Potential impacts from construction, operation and decommissioning and assessments hereof in related to the fish species in general are described in Chapter 6, 7 and 0. Please refer to these chapters for a detailed description and a general assessment. The potential impacts in relation to the designated fish species are assessed below.

Construction phase
Potential impacts on the fish fauna during the construction phase of Sæby Offshore Wind Farm can be caused by the following:

- Sediment spreading in the water column
- Sediment spill deposition
- Contaminants associated with sediment spill
- Noise and physical disturbance
- Impact on food resources

Assessment:
None of the potential impacts during construction are assessed to have significant impacts on any of the three designated fish species in nearby Natura 2000 areas. All three species of fish are assessed to be most sensitive to human activity during their freshwater stage where poor water quality and degraded spawning habitat can have an impact on the species. The species are vulnerable to habitat modifications and the obstruction across their migratory routes, most importantly physical barriers to upstream migration. They are also affected by poor water quality in the larval habitat. Because they are widely distributed during the marine part of the life cycle there are no specific threats linked to habitat loss or modification within coastal waters.

Operation phase
Potential impacts on the fish fauna during the operation phase of Sæby Offshore Wind Farm can be caused by the following:

- Noise
- Electromagnetism
- Habitat changes

Assessment:
As for the construction phase.

Decommissioning phase
Potential impacts on the fish fauna during the decommissioning phase are likely to include short-term increases in suspended sediment concentration and sediment deposition from the plume caused by foundation cutting or dredging and seabed disturbance caused by removal of cables and scour protection. Although there is no evidence on these potential effects, the effects during decommissioning are considered to be less than or comparable with those effects described during the construction phase, because the volumes of soil to be handled during decommissioning will be equal or smaller than during construction.

Assessment:
As for the construction phase.
10.1.5 Cumulative impacts
None of the cumulative impacts described in Chapter 9 is assessed to have any significant impacts on the designated fish species.

10.1.6 Conclusion
Potential impacts to designated marine fish species have been assessed for impacts caused by the Sæby OWF during construction, operation and decommissioning. The sensitivity of all the designated fish species is mostly related to their freshwater stage where poor water quality and degraded spawning habitat can have an impact. Habitat modifications and the obstruction across their migratory routes, most importantly physical barriers to upstream migration would also be problematic. However, the Sæby OWF is not assessed to inflict any of the above mentioned impacts.

It is concluded, that there is no risk of significant effects to designated fish species in Natura 2000 sites in or near the project area.
11. MITIGATION MEASURES

As described in section 4.4, the present study adopts a "worst case approach" to park layouts as well as turbine and foundation types. Although the identified pressures and impacts during construction, operation and decommission are minor, they can be further reduced by design measures, for example by selecting larger turbines (i.e. 10 MW instead of 3MW). This will lead to fewer structures and lower impacts.

During construction, spill of dredged material and noise from pile driving are considered to give rise to the most severe impacts. Therefore, the mitigation is concentrated on:

- Equipment type for marine earth works (spill percentage)
- Dredging intensity (spill rate) and
- Dredging period (environmentally sensitive periods can be avoided)
- Noise from pile driving

11.1 Equipment type

It is proposed to apply equipment that causes as little sediment spill as possible. Backhoe or grab equipment usually gives rise to environmental friendly marine seabed intervention works.

11.2 Dredging intensity

The intensity in terms of m³/day determines the sediment concentration in the water column and sedimentation rates. Therefore, it is advisable to use small equipment or to stretch the earth works over a long period.

11.3 Dredging and jetting period

An important factor is to coordinate the dredging activities with seasons that are environmentally particular sensitive. For fish, this would be during the spawning season. The spawning period is however species specific (see section 5.3.9). Most spawning activity is expected to take place between February and June.

11.4 Pile driving

The effects of pile driving on fish may be reduced by adopting certain mitigation measures. It is possible to reduce the level of noise transmitted through the water by using either air bubble curtains or cofferdams.

Bubble curtains are commonly used to reduce acoustic energy emissions from high-amplitude sources. Bubble curtains can be generated by releasing air through multiple small holes drilled in a hose or manifold deployed on the seabed near the source. The resulting curtain of small air bubbles in the water provides significant attenuation for sound waves propagating through the curtain. The bubble curtain is often use as a mitigation choice for underwater pile driving and blasting activities at construction sites. Noise reduction with bubble curtains during pile driving is about 10 - 13 dB.

Dewatered cofferdam noise reduction systems have a removable cofferdam (large pile) in which, the water is pumped out, so pile driving of the monopile has limited direct contact with the cofferdam and thus the water. This type of noise reduction has been tested for offshore pile driving with noise reductions up to 22 dB.

Another way of noise reduction can be achieved by the use of unbalanced vibrators for pile driving. This will significantly reduce the underwater noise levels compared to using a hydraulic hammer, however this method is normally not considered feasible for large monopiles. Noise reduction during pile driving when using vibrators compared to impact driving is about 15 – 20 dB.

Another possible mitigation could be to use ramp-up/slow start procedures, where the first hammer blows are at reduced impact energy. This would allow noise sensitive fish species to move away from the immediate vicinity.
12. MONITORING

In order to increase the current but still limited knowledge about how an offshore wind farm affect the fish fauna and to confirm assessments made in this report various monitoring programme could be initiated, e.g.:

- A monitoring programme investigating effects of noise and vibrations on fish
- A monitoring programme investigating the long-term reef effects.

13. LACK OF INFORMATION AND UNCERTAINTIES

The establishment of offshore wind farms is relatively new and thus literature on e.g. long-term effects from noise and vibrations as well as electromagnetic fields is sparse. The areas with knowledge gaps noted in this report are:

- Effects of noise and vibrations on fish
- Sensitivity of fish to electromagnetic fields
- Long-term studies of reef effects

These knowledge gaps might result in inaccuracy of some parts of the assessment. However, the assessments are based on worst case scenarios, the newest knowledge within the area and expert knowledge. Thus, the knowledge gaps are expected to have a limited importance for the overall assessment of the impacts from Sæby Offshore Wind Farm on the fish fauna.

14. CONCLUSION

The overall assessment of the environmental effects during construction and operation and the quality of the data used are summarized in Table 14-1.

<table>
<thead>
<tr>
<th>Impact on fish</th>
<th>Overall significance</th>
<th>Basis for assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Construction phase</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sediment spreading in the water column</td>
<td>Negligible negative impact</td>
<td>2</td>
</tr>
<tr>
<td>Sediment spill deposition</td>
<td>Negligible negative impact</td>
<td>2</td>
</tr>
<tr>
<td>Contaminants in the water column</td>
<td>Neutral/no impact</td>
<td>2</td>
</tr>
<tr>
<td>Noise and physical disturbance</td>
<td>Moderate negative impact*</td>
<td>1</td>
</tr>
<tr>
<td>Impact on food resources</td>
<td>Negligible negative impact</td>
<td>2</td>
</tr>
<tr>
<td><strong>Operation phase</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Noise</td>
<td>Negligible negative impact</td>
<td>1</td>
</tr>
<tr>
<td>Electromagnetism</td>
<td>Negligible negative impact</td>
<td>1</td>
</tr>
<tr>
<td>Habitat changes</td>
<td>Negligible/Positive</td>
<td>2</td>
</tr>
<tr>
<td><strong>Decommissioning</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sediment spreading in the water column</td>
<td>Negligible negative impact</td>
<td>2</td>
</tr>
<tr>
<td>Sediment spill deposition</td>
<td>Negligible negative impact</td>
<td>2</td>
</tr>
<tr>
<td>Contaminants in the water column</td>
<td>Neutral/no impact</td>
<td>2</td>
</tr>
<tr>
<td>Noise and physical disturbance</td>
<td>Negligible negative impact</td>
<td>1</td>
</tr>
<tr>
<td>Impact on food resources</td>
<td>Negligible negative impact</td>
<td>2</td>
</tr>
</tbody>
</table>

*By adopting mitigation measures the impact will be severely reduced and the overall significance will be negligible
The quality and scope of data and documentation used in the assessment are evaluated using the following categories:

1. Limited (scattered data, some knowledge)
2. Sufficient (scattered data, field studies, documented knowledge)
3. Good (times series, field studies, well documented knowledge)
15. REFERENCER

/2/ Geo/ -, Geophysical survey, Sæby Offshore Wind Farm
/3/ Cowi, 2014. Metocean survey, Sæby Offshore Wind Farm
/14/ ICES-FishMap. Sprat
/15/ ICES-FishMap. Herring
/16/ ICES-FishMap. Sole
58


/45/ Ramboll. (2014). Kystnære havmøller; Sæby, Sejerø Bugt og Smålandsfarvandet. Sedi-
mentanalyse. Ref 1100011855.

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ning), samt tilhørende vejledning (VEJL 9702 af 20/10/2008).


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## APPENDIX 1
### ROUGH SCHEMATIC OVERVIEW OF THE FISH IN THE AREA OR ITS VICINITIES – BASED ON LOGBOOK DATA FOR ICES 43G0


<table>
<thead>
<tr>
<th>Species</th>
<th>Food preference</th>
<th>Preferred habitat</th>
<th>Spawning</th>
<th>Nursery areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atlantic horse mackerel</td>
<td>Juvenile: planktonic organisms such as Larger individuals: crustaceans and small fish</td>
<td>Coastal areas – 100 meter</td>
<td>Batch spawner Pelagic May-August In the North Sea Larvae floats with the current</td>
<td>Often under jellyfish</td>
</tr>
<tr>
<td>Cod</td>
<td>Crustaceans Polychaetes Bivalves Herring Caplin Sprat</td>
<td>Coast – 600 meter Mixed bottom</td>
<td>January-April 60-80 meters pelagic</td>
<td>Can be found in shallow waters</td>
</tr>
<tr>
<td>Dab</td>
<td>Crustaceans Polychaetes Brittle Star Sea urchin Bivalves</td>
<td>5-150 meter Sandy and soft bottom</td>
<td>April-August 20-40 meter Close to the bottom pelagic</td>
<td>6-70 meters</td>
</tr>
<tr>
<td>European hake</td>
<td>Juvenile: planktonic organisms such as Larger individuals: Fish (e.g. herring and sprat) and crustaceans</td>
<td>Fish fry in coastal waters Adults at deeper depths 70-300 meter</td>
<td>Hake spawn at 20 m depth in the Kattegat. It is a batch spawner. Eggs and larve are pelagic</td>
<td>Juveniles are usually located close to the coast</td>
</tr>
<tr>
<td>Plaice</td>
<td>Polychaetes Bivalves Crustaceans</td>
<td>Coast – 200 meter Sandy and mixed bottom</td>
<td>February-March 20-40 meter pelagic</td>
<td>Coastal areas</td>
</tr>
<tr>
<td>Flounder</td>
<td>Polychaetes Bivalves Amphipods Common shrimp Mud shrimp</td>
<td>Coast-100 meter</td>
<td>February-May 20-50 meter Pelagic</td>
<td>Coastal areas</td>
</tr>
<tr>
<td>Greater weever</td>
<td>Shrimp Polychaetes Fish (e.g. sandeel)</td>
<td>Coastal Muddy, sandy and gravelly bottoms</td>
<td>June-August Pelagic</td>
<td>Coastal areas</td>
</tr>
<tr>
<td>Haddock</td>
<td>Copepods Small fish (e.g. sandeel, gobies, sprat and herring)</td>
<td>Haddock has a demersal life style and shoals in colder waters at depths from 40-300 m, with a preference for depths between 75 and</td>
<td>February-June 100-150 meter Pelagic</td>
<td>Coastal areas</td>
</tr>
<tr>
<td>Species</td>
<td>Food preference</td>
<td>Preferred habitat</td>
<td>Spawning</td>
<td>Nursery areas</td>
</tr>
<tr>
<td>------------</td>
<td>------------------------</td>
<td>----------------------------</td>
<td>-------------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>Herring</td>
<td>Zooplankton, Fish larvae, Fish egg</td>
<td>0-200 meter Pelagic</td>
<td>March-May Pelagic</td>
<td>Coastal areas</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Eggs sinks to the bottom where they stick to rocks and macroalgae</td>
<td></td>
</tr>
<tr>
<td>Lemon sole</td>
<td>Polychaetes, Bivalves, Crustaceans</td>
<td>10-150 meter Hard or gravelly bottoms</td>
<td>May-September Pelagic 50-150 meter</td>
<td>Coastal areas</td>
</tr>
<tr>
<td>Lumpsucker</td>
<td>Zooplankton, Common shrimp, Small jellyfish</td>
<td>20-200 meter Hard bottom</td>
<td>February-May Shallow water Demersal Rocky bottom</td>
<td>Coastal areas</td>
</tr>
<tr>
<td>Saithe</td>
<td>Copepoda, Krill, Herring, Fish fry</td>
<td>Living in shoals in both offshore and inshore areas depending on size and age, and occurring in midwater, close to the bottom and even near the surface.</td>
<td>January-May Generally occurs along the edge of the continental shelf</td>
<td>Coastal areas</td>
</tr>
<tr>
<td>Sandeel</td>
<td>Zooplankton, Fish larvae, Fish egg</td>
<td>10-150 meter Smooth bottom of gravelly sand</td>
<td>November-June (dependent of subspecies) Demersal</td>
<td>The pelagic larvae seeks out the adult population</td>
</tr>
<tr>
<td>Sole</td>
<td>Crustaceans, Polychaetes, Bivalves, Fry</td>
<td>Coastal-150 meter Soft, muddy or sandy bottom</td>
<td>April-June 20-50 meter pelagic</td>
<td>Coastal</td>
</tr>
<tr>
<td>Sprat</td>
<td>Plankton, Fry</td>
<td>Pelagick in estuaries and coastal waters</td>
<td>May-June 10-20 Pelagic</td>
<td>Offshore</td>
</tr>
</tbody>
</table>
### APPENDIX 2
SUMMARY OF THE RESULTS OF THE ACOUSTIC MODELLING. DISTANCES FROM THE PILE DRIVING ACTIVITY TO THE APPLICABLE NOISE THRESHOLD LEVELS FOR FISH


<table>
<thead>
<tr>
<th>Effect</th>
<th>Threshold value (According to /64/)</th>
<th>Threshold distances</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Peak</td>
<td>SEL(Cumulative)</td>
</tr>
<tr>
<td>Damage to non-auditory tissue</td>
<td>-</td>
<td>213 dB</td>
</tr>
<tr>
<td>Damage to auditory tissues - generally sensory hair cells of the ear. Also referred to as permanent threshold shift (PTS)*</td>
<td>206 dB</td>
<td>185 dB</td>
</tr>
<tr>
<td>Hearing loss due to temporary threshold shift (TTS)</td>
<td>206 dB</td>
<td>183 dB</td>
</tr>
</tbody>
</table>

* Physical damages to the hearing apparatus rarely lead to permanent changes in the detection threshold, as the damaged sensory epithelium will re-generate in time /65/.