



# GUIDELINES FOR ENVIRONMENTAL IMPACT STUDIES ON MARINE BIODIVERSITY FOR OFFSHORE WINDFARM PROJECTS IN THE BALTIC SEA REGION





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## Guidelines for environmental impact studies on marine biodiversity for offshore windfarm projects in the Baltic Sea Region

### Disclaimer

The guidelines are produced in the frame of the LIFE+ Nature & Biodiversity project “Innovative approaches for marine biodiversity monitoring and assessment of conservation status of nature values in the Baltic Sea” (Project acronym -MARMONI). The content of this publication is the sole responsibility of the Baltic Environmental Forum and can in no way be taken to reflect the views of the European Union.



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## 1 Introduction

The number of development projects as well as sea uses is constantly rising in the Baltic Sea area. Besides intensification of traditional sea uses such as shipping and fishing, many other activities are emerging from rapid economic and technological development. The competition on the space in the sea is high and a variety of activities are striving for it, for example infrastructure development as pipelines and windfarms, various novel forms of aquaculture, mining of mineral resources and, often seen as barrier for development: nature conservation. Traditional maritime activities are well regulated by international conventions and instruments (e.g. IMO, MARPOL, London Convention) and national laws. For the emerging sea uses (Blue growth activities such as ocean energy including offshore wind farms), existing guidelines are not sufficient and have to be adjusted to these emerging uses, especially with regard to the cumulative impacts of the multitude of new uses. In many cases, the complexity of potential environmental impacts is not known because evidence based knowledge is not present in the region or anywhere else. In those cases, national requirements have to be interpreted in a more conservative and strict manner to apply the precautionary principle. At the same time, development pressure from a socio-economic perspective requires grounded decisions to satisfy development needs and minimize impacts on the environment.

In 1991, the world's first commercial offshore wind farm was installed in Vindeby, Denmark. The 11 turbines of the OWF with a 5 MW capacity are still successfully operating in the very Western part of the Baltic Sea, the Kattegat.

During the last decade, the production of electricity from wind power is a topical issue in the energy sector. The wind provides unlimited energy resources – the sun driven atmospheric movements have huge potential. Installation of wind turbines has been started on the mainland, but vast areas of oceans and seas are now assumed as even more attractive with much higher wind potential. The Baltic Sea is also well known for its windiness, which brings attention of potential investors and developers. At present, only a few projects have really led to installation of offshore wind farms in the Baltic Sea (the largest of which are the 90 turbine Nysted II wind farm in Denmark with capacity of 207 MW operating since 2010; Nysted I in Denmark with 72 turbines and capacity of 165.6 MW, launched in 2003; Lillgrund wind farm in Sweden with 48 turbines and a 110 MW capacity, which is operating since 2008), but there is a number of applications in the Baltic Sea Region (in Germany, Sweden and Finland) waiting for realisation.

The wind turbine technologies are quickly developing and could be fully competitive with energy production from fossil sources in the nearest future.

On the other hand, wind energy production has also its own problematic aspects. The wind velocity is not a steady factor, and energy production is not steady either. Thus, no country can base its energy production solely on the wind power. The wind energy production must be balanced with energy from other sources. Ecological concerns are evenly important. Seeming very sustainable (clean production from a renewable source), wind energy production areas occupy relatively large space, both in horizontal and vertical dimensions, and also have some impacts on biological communities, which often are not very well known.

Very comprehensive and high quality environmental impact studies must be performed before installation of any offshore wind farm to avoid negative impacts on the environment. A number of documents are already available providing more general or detailed guidance directions on how to perform such studies.

The aim of this report was to prepare a guidance document for the Baltic Sea Region, which would specifically target the impacts of offshore wind farms on biodiversity in the more Northern parts of the Baltic Sea (marine areas of Sweden, Finland, Estonia and Latvia). Nevertheless, the Guidelines do not provide a very detailed description of methodologies for environmental impact investigations – the exact methodologies have to be chosen depending on the conditions of the particular project area -, but rather outline the general requirements based on the state of the art knowledge – what is the objective of such study, which parameters have to be measured for different features of the marine ecosystem, when and how frequently the investigations have to be performed.

The knowledge included in the existing guidance documents, such as the German Standard "Investigation of the impacts of offshore wind turbines on the marine environment (StUK4)", the Baltic States' "Guidelines for the investigation of the impacts of offshore wind farms on the marine environment in the Baltic States" (2009), the Polish "Guide to the location determination and environmental impact forecasting procedures for offshore wind farms in Polish maritime areas", has been used to produce this report.

The MARMONI Guidelines aimed at serving as a supporting document for developers, consultants, marine experts and competent authorities dealing with the assessment of environmental impacts for development plans in the marine environment. Due to a very complex nature of the Baltic Sea environment and still limited practical experience, the level of detailness of the current document is kept at a general level. Therefore, the Guidelines mainly focus on the scope of the environmental impact or baseline studies for marine biodiversity providing the main principles and the list of compulsory topics, which are relevant for further assessment and decision making and accordingly shall be assessed within an EIA procedure.

On 21-22 May 2013 in Riga, the international seminar on "Environmental Impact Assessment of offshore wind farms and other large marine infrastructure" gathered more than 40 OWF experts from various organisations (state institutions, developers, scientists, non-governmental organisations) of the Baltic Sea and North Sea Regions. The outcomes of the seminar were largely used for the development of these Guidelines.

The Guidelines have been produced within the EU LIFE+ Nature & Biodiversity programme financed project "Innovative approaches for marine biodiversity monitoring and assessment of conservation status of nature values in the Baltic Sea" ([marmoni.balticseaportal.net](http://marmoni.balticseaportal.net)), which involved leading marine scientists from Sweden, Finland, Estonia and Latvia, whose up-to-date knowledge was highly essential for the preparation of the Guidelines.

## 2 Uniqueness of the Baltic Sea

The Baltic Sea is a very unique ecosystem having many characteristic features not found in the same amount or quality anywhere else in the world. These include a number of climatic, geomorphological and ecological factors and their various combinations.

### 2.1 Climate

The Baltic Sea is located in the northern hemisphere stretching in the north-south direction over 1400 km. The northernmost parts of the sea are experiencing almost arctic conditions while southern and south-eastern basins are influenced by mild conditions of the Gulf stream. Sea ice conditions have a very important role in shaping the whole ecosystem's functioning in the northern part of the sea, being more stochastic in the central part of the Baltic and more stable in the northern and north-eastern parts. As the Baltic Sea as a whole is considered to be more a cold-water ecosystem, the occasional rise in surface water temperatures induced by large scale climatic processes can cause changes in the habitat quality and induce instability to the shallow water communities.

### 2.2 Geomorphology

Location on the continental plate instead of filling the area between plates as most of the seas and oceans around Europe do causes the general shallowness of the Baltic Sea and relative tectonic stability. With some very limited basins deeper than 200 m, most of the seafloor has a depth of less than several tens of meters causing very peculiar hydrological regime characterized by stratification, stagnation and oxygen deficiency in deeper areas and a good mixing of full water column in other areas (e.g. Gulf of Riga). Diversity of the geological origin of the seafloor is particularly felt in shallow coastal sections of the central and northern parts of the Baltic Sea. Here on the scale of tens of kilometres the structure of the seafloor can change from crystalline bedrock to glacial moraine and then to sedimentary limestone. Wave and ice exposure conditions differ greatly in different parts of the sea also due to the complexity of the shoreline. Generally more complex shoreline is observed along the western coasts of the Baltic Proper and Gulf of Bothnia as well as northern coast of the Gulf of Finland culminating in the vast areas of Scandinavian archipelagos. Large scale hydrological processes shape the most of the simple morphology of coastline along the southern and eastern shores of the Baltic Proper and smaller basins as the Gulf of Riga.

### 2.3 The main ecological features

One of the main ecological features shaping the biological communities and functionality of the ecosystem is salinity. As in the Baltic Sea the salinity changes from almost oceanic conditions in the south western parts of the sea to practically freshwater conditions in the northernmost and easternmost parts, this stable salinity gradient influences the spread of species of typically marine and freshwater origin. So, along the gradient in each particular location we can count a certain amount of species of different ecological origin. This makes biological communities in the Baltic very unique. Lower salinity also has a strong influence on many typically marine species causing their different appearance (e.g. smaller size of species such as the blue mussel or Baltic herring) or ecologi-

cal function (e.g. shifting of habitat from littoral to sub-littoral for the bladder wrack) in the Baltic Sea compared to oceanic conditions of North Atlantic.

## 2.4 Vulnerability of the Baltic Sea ecosystem

The Baltic Sea is a unique marine ecosystem featured by presence of large variety of environmental gradients. Among those, most remarkable are the North–South and East–West salinity gradient, the North–South climate related gradients of water temperature and ice conditions and the East–West gradient of coastal habitats (changing from Scandinavian archipelago or skerry type coasts to exposed sandy beaches and limestone cliff coasts). All this contributes to several gradients in habitats and biodiversity as a whole. In addition to that, many different large–scale and local gradients of human impact exist by human introduced nutrient enrichment leading to eutrophication, pollution by toxic substances and oil products as well as mechanical disturbance by coastal defence and other construction.

The existing number of gradients results in uniqueness of the ecological features in almost all locations in the Baltic Sea. This means that it is not possible to find any location or area absolutely similar to another somewhere else. Destroying or changing the quality of a habitat in any particular location in the Baltic Sea may have a fatal result on the biological diversity of the whole sea area. Also, the processes of regional and global scale have a very important role in this, such as post glacial land uplift and global warming. These both processes have an especially strong influence on the sea level change. Currently, the global warming raises the sea level mainly due to the increase in seawater volume through heat absorption at the same time. Especially, the Northern part of the Baltic Sea is influenced by continuous land uplift lowering the sea level. These two processes have resulted in different rate of sea level change in different parts of the Baltic Sea contributing to the change in habitat quality for both pelagic and benthic species.

On a whole Baltic Sea scale, the biodiversity is most vulnerable in the central part – around the basin called Baltic Proper. According to the checklist of macroscopic species published by HELCOM, the lowest number of macroscopic species in the Baltic was observed in basins around the central part (Baltic Proper, Gulf of Riga, Archipelago Sea) (HELCOM 2012). This corresponds to the sea area where the salinity gradient is most unfavourable for both, marine and brackish water species. At the same time, this area is most favourable for development of wind parks having the best wind conditions. Analyses made on the data obtained from habitat modelling performed by EU funded BALANCE project show that the depth interval suitable for wind park development overlaps with most of the habitat diversity and existing nature conservation activities in the area.

An important aspect of modern ecology of the Baltic Sea is the high rate of colonization by non-native species. This process is both natural (due to relatively small geological age of the sea area) and artificial (induced by different human activities). As these processes are generally absolutely unpredictable, any new activity favouring these processes should be considered with extreme precaution.

All these features make the Baltic Sea very unique and vulnerable to different disturbances.

## 2.5 Biodiversity of the Baltic Sea

### 2.5.1 Habitats

Shallow marine areas (up to 20-30 m depth), where normally offshore wind farms are planned, are also the richest and most productive places from biodiversity point of view, especially in the Baltic Sea where the water is more turbid and thus the photic layer available to photosynthesising plants, algae and bacteria is narrower than in oceans (HELCOM, 2013).

Reef and sandbank habitats are most important Baltic Sea benthic habitats. Reefs are real oases of the Baltic Sea hosting a number of plant and invertebrate species, which attract fish, birds and mammals for feeding. Reefs also serve as spawning ground for many fish species.

Sandbanks are typically poorer in the number of species compared to reefs, but still host mussels, worms, crustaceans, which have to dig themselves into sediments, and, where area is sheltered, also seaweeds. Sandbanks provide fish spawning grounds and feeding and wintering areas for water birds (Ruskule, A. et al., 2009).

### 2.5.2 Fish

The total number of fish species in the Baltic Sea is not high due to low salinity of water or brackish water conditions. On the other side, the species composition is very unique because of the very same salinity – one can find typical marine species and typical freshwater species in the same area.

The shallow Baltic Sea has a very high fish productivity, although most of its stock is composed of just three key species: sprat, herring and cod.

### 2.5.3 Birds

The Baltic Sea is an internationally very important area for birds. The shallow sea with the diverse marine and coastal habitats (reefs, sandbanks, coastal lagoons) provides ideal residence, feeding and moulting habitats for various sea birds. The shallow offshore banks, which are of the highest interest for wind farm developers, harbour very large concentrations of sea ducks. About 20 different seabird species might use a certain offshore area during the course of a year: divers, grebes, sea ducks, diving ducks, mergansers, gulls, terns, and auks (Skov, H. et al., 2011). Some species occur only during the breeding season, some species rest during the migration periods, others stay over winter or moult during summer (Baltic Environmental Forum 2009).

Many bird species come from the Northern Eurasia to winter in the Baltic Sea. With the continuous climate change, it is expected that the Baltic Sea will have even a higher importance as wintering site in future (Lehikoinen, A. et al., 2013).

The Baltic Sea also marks a part of the Western Palaearctic flyway connecting Northern Eurasia (North Russia and Scandinavia) to Africa. About 200 bird species migrate across the Baltic Sea twice annually. Several hundred millions of terrestrial and water birds fly over the sea during spring and autumn migration time.

### 2.5.4 Marine mammals

Only four species of marine mammals can be found in the Baltic Sea: the grey seal, ringed seal, harbour seal and harbour porpoise. Two first of them inhabit mainly the Northern and two last mainly the Southern parts of the Baltic Sea.



While the grey seal and the harbour porpoise are highly migrating species, the ringed seal and the harbour seal prefer sedentary lifestyle.

### 3 The main principles of the EIA procedure

Potential negative impacts of offshore wind farm projects have to be investigated as part of the approval procedure through an Environmental Impact Assessment (EIA).

The EIA procedure in the European Union is being regulated by the Directive 2011/92/EU on the Assessment of the Effects of Certain Public and Private Projects on the Environment, which have been transposed into national EIA legislations and procedures of the EU Member States. EIA procedures may vary in their details but the practical stages in most systems are generally the following:

1. Project preparation and application to the Competent Authority – submission of the application for development consent to the Competent Authority.
2. Screening - The process by which the Competent Authority takes a decision on whether or not EIA is required. Public must be informed about the decision.
3. Scoping – The process of identifying the content and extent of the Environmental Information to be submitted to the Competent Authority under the EIA procedure. As result of scoping the EIA programme is prepared, which is subject for public consultation.
4. Environmental Studies – The surveys and investigations carried out by the Developer and the EIA Team in order to prepare the Environmental Impact Statement (EIS) for submission to the Competent Authority.
5. Preparation of Environmental Impact Statement (EIS). The draft EIS is a subject for consultation with Statutory Environmental Authorities, other interested parties and the public. Results of the consultation have to be considered when preparing the final EIS.
6. Decision by the Competent Authority and announcement of the decision (including the reasons for it and a description of the measures required to mitigate adverse environmental effects).
7. Post-decision monitoring if the project is granted consent (Baltic Environmental Forum, 2009).

**The current Guidelines provide help for designing the scope of environmental impact studies in relation to effects to marine biodiversity.**

### 4 General principles of environmental impact studies and monitoring

There are three distinct investigation & monitoring phases in each offshore wind farm project. Each of them has its own objective and often investigation parameters and details are different, although not necessarily.

## 4.1 Environmental impact (baseline) studies

The objective of the baseline study is to obtain a thorough status quo information with the help of field investigation in the project area and reference areas, which can be used as reference information to later judge about the changes in the quantity and quality of biological features (e.g. distribution of habitats, number of bird specimen). The widely accepted principle is to have at least two successive, complete seasonal cycles of investigation to avoid wrong conclusions from the studies due to annual variability of the data (Federal Maritime and Hydrographic Agency 2013). In the eastern part of the Baltic Sea, minor species diversity together with a low inter-annual variability in oceanographic parameters led to conclude that a one-year-investigation is sufficient for the baseline investigation for most conservation objects (Baltic Environmental Forum, 2009).

However, variability in meteorological conditions in winter seasons (especially ice conditions) is a major source of inter-annual variation in seabird and seal distribution within a certain area during winter and spring. For these conservation objects, therefore, a field survey in at least two successive years is recommended to obtain a reliable basis for the compliance monitoring during operation (Baltic Environmental Forum, 2009).

The baseline studies are the core of environmental impact studies for marine biodiversity.

An EIA for an offshore wind farm has to cover the following topics (Baltic Environmental Forum, 2009):

- The description of the status quo of the protection objectives (EIA, Habitats & Birds Directives, protection of species)
- Validation of the status quo
- Description of potential impacts/interactions
- Description of potential cumulative effects (with other offshore windfarms and other sea uses)
- Potential mitigation measures
- Monitoring concept (feed-back, compliance)

The EIA study shall cover various biotic components (seaweeds & algae, benthic invertebrates, fish, seabirds, marine mammals, migrating birds and bats, benthic and pelagic habitats) in relation to abiotic environmental components (hydrological, geological, climatic) and human caused pressures.

## 4.2 Construction monitoring

The objective of the construction monitoring is to evaluate impacts of pressures coming from construction works on biological and abiotic features of the surrounding marine environment. The monitoring is needed to ensure that maximum acceptable impact thresholds are not exceeded for certain protection objectives, i.e. sediment spills during seabed intervention works, noise emissions during pile driving of foundations, etc. (Baltic Environmental Forum, 2009).

The construction monitoring shall be carried out during the whole construction phase.

During the construction phase, investigations are very difficult to undertake within a project area because of safety reasons. Nevertheless, it is recommended to carry out monitoring of certain mobile species particularly susceptible to construction impacts (fish, mammals). The species to be monitored must be predefined during development of the EIA report. It is essential to understand that construction monitoring brings more knowledge on the response of certain species to various impacts, which are often not very clear. Accordingly, this will help in development of environmentally sounder construction techniques.

#### 4.3 Operation monitoring

The objective of the operation monitoring is to evaluate operational impacts of offshore wind farm on biological features after commissioning of wind turbines. A very important task of the operational monitoring is to demonstrate that the project stays within the predictions about potential environmental impacts drawn in the EIA report.

In this phase, the operational monitoring has to be performed for a period of 3 to 5 years, depending on specific conditions regarding the site/project and the features of conservation.

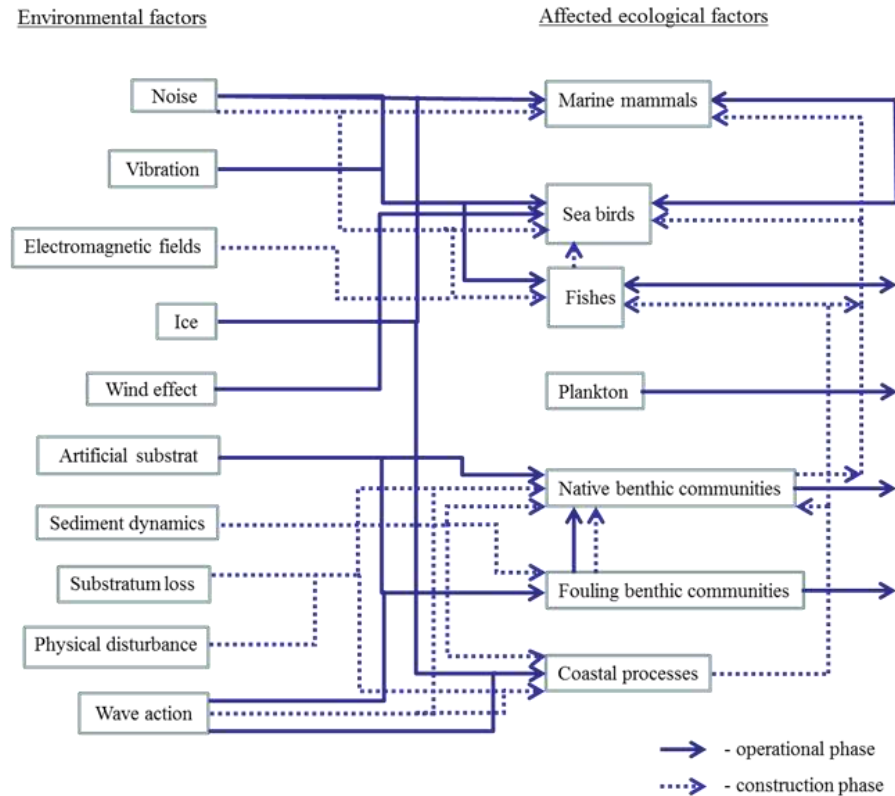
After the 5th year, the responsible authority shall determine in each individual case whether further monitoring is needed. In many cases, a longer period shall be considered, e.g. studies at Lillgrund proved that four years of bird monitoring were not sufficient to measure adaptation of birds to wind farm conditions.

### 5 Potential impacts of offshore wind farms

Currently, there are not many experiences from the Baltic Sea where the effects of established OWF could be documented and used to design EIA studies. Until now, all experience could be taken from e.g. North Sea installations and extrapolated to the conditions of the Baltic Sea by expert knowledge. In many cases, the actual impact can be somewhat different from the one predicted as the basic knowledge for describing relevant processes can be missing.

Offshore wind farms, while in operation, cover a large area of the sea and thereby include considerable part of marine habitats. The environmental impact on the marine ecosystem have been estimated to be positive (generally global) and negative (generally local) (Snyder & Kaiser, 2009). Some impacts are specific to offshore wind parks, but there are also a number of impacts that differ significantly between the construction and operation phases (see schematic illustration in Figure 1.).

All phases (construction, operation, decommissioning) may have a number of specific potentially adverse impacts and accordingly shall be taken into account when performing an EIA study. The overall impacts are reflected in Table 1.



**Figure 1: Diagram illustrating possible impact of different stressors related to the operation and construction of offshore wind park to different components of marine ecosystem (Redrawn from Hiscock *et al.* 2002).**

One of the largest impacts on the marine environment originating from offshore wind parks documented till now is the so called "reef effect" (Petersen & Malm, 2006) primarily caused by solid man-made structures founded on the seafloor (Maar *et al.* 2009, Punt *et al.* 2009). Offshore wind park turbines are functioning as artificial reefs, affecting local surrounding ecosystem (Wilhelmsson & Malm, 2008). Artificial structures may favour the settlement, reproduction, growth and change in biomass of native and fouling benthic species, which could influence the small and large scale processes in coastal and offshore systems (Wilhelmsson & Malm, 2008).

Blue mussels (*Mytilus edulis*) and barnacles (*Balanus improvisus*) dominate on hard bottom and also possible artificial substrate (Hiscock *et al.* 2002; Kautsky 1982; Maar *et al.* 2009; Westerbom *et al.* 2002; Wilhelmsson & Malm 2008) in the most part of the Baltic Sea. Both species are superior competitors in benthic communities due to a massive recruitment and rapid growth (Dürr & Wahl 2004). In areas previously lacking hard substrate, the mentioned two species introduced there by installations of artificial structures are able to significantly change the whole local dynamics of the ecosystem. Such a phenomenon is favourable for marine birds (especially sea ducks) and fishes (shelter against predators) – rich feeding areas for marine organisms (Hiscock *et al.* 2002; Leonhard *et al.* 2006; Roycroft *et al.* 2004; Snyder & Kaiser 2009) and more food to micro plankton (Leonhard & Pedersen 2006). It could have potential positive impacts also on marine mammals (Teilmann *et al.* 2006).

Till now, investigations show that from primary producers the artificial structures in the Baltic Sea are dominated by annual filamentous green algae in the sections close to sea surface (Nielsen 2006). The remaining part of the wind turbine is usually dominated by brown- and red algae (*Pilayella/Ectocarpus*, some species of *Ceramium* family) (Meißner & Sordyl 2006; Nielsen 2006). They have adaptation of poor light conditions in the cold and nutrient rich water (Leviton 2001). So far, relatively few macroalgae species have been identified to inhabit wind park installations, mainly because of poor light conditions (Leonhard *et al.* 2006). It has been also noted that occurrence of green algae is rare in those habitats (Meißner & Sordyl 2006).

Occurrence of reef effect in connection with installation of new hard substrate has high importance for the soft bottom communities. Construction of a wind park adds a hard substrate on soft bottoms, and it completely changes existing seabed habitats. Native benthic communities are partly or completely replaced by fouling benthic communities associated with hard bottom structures (Hiscock *et al.* 2002).

A study on possible effect of disturbance on hard bottom habitats by construction of gravitational foundations of offshore wind park was carried out in the North-East Baltic Sea, Neugrund Bank. It was concluded that in certain depth intervals the amount of disturbed seafloor causes significant, long term changes in benthic communities. While in shallower depths the disturbed communities recovered within one vegetation season, in deeper layers and intermediate depths the effect of disturbance was observed over several vegetation periods causing change in community structure and also favouring occurrence of new species previously not recorded in the native communities.

Physical disturbance, like installation of turbines and cables, affects sediment dynamics, also removal of sediments (substratum loss) (Leonhard *et al.* 2006; Meißner & Sordyl 2006; Nielsen 2006), as well as influences currents and waves. This situation affects benthic communities, fishes, sea birds and marine mammals (Poiwilleit *et al.* 2006; Reijnders *et al.* 2009). Habitat loss and hydrodynamic regime depends on the diameter, size and shape of the turbine and foundation type (Leonhard *et al.* 2006, Meißner & Sordyl 2006). By increasing turbine capacity, also diameters of monopoles increase. The result is a loss of substrate and changes in the water currents having a large impact on some species of fish (Leonhard *et al.* 2006).

Installation of cables could cause electromagnetic fields and heat emissions, which influence marine organisms (Meißner & Sordyl 2006), especially fish. It may influence the behaviour and migration of the fish fauna (Keller *et al.* 2006; Leonhard *et al.* 2006), because they use the Earth's magnetic fields for navigation. The cable could act as a barrier to the migration of fish (Keller *et al.* 2006; Leonhard *et al.* 2006) and also have scaring effect (Keller *et al.* 2006). Heat emission can change physicochemical conditions of sedimentary substrates leading to positive impact on reproduction of certain species, especially those adapted to warmer water (Meißner & Sordyl 2006). Until now, no impacts of electric or magnetic fields on benthic marine invertebrates have not been observed and reported so far (Meißner & Sordyl 2006).

Underwater noise and vibration doesn't affect marine invertebrates and attached fauna (Meißner & Sordyl 2006), but may have effects on fish and marine mammals. Pile driving and servicing vessels' activities are the main problems here (Brandt *et al.* 2011; Carstensen *et al.* 2006). Shallow areas are important

calving and nursing areas for harbour porpoises, and they are reported to avoid the wind park areas, partly or completely (Brandt *et al.* 2011; Carstensen *et al.* 2006; Keller *et al.* 2006, Teilmann *et al.* 2006). Turbine installation and servicing boats make loud noise that may cause injuries and deafness (Brandt *et al.* 2011; Keller *et al.* 2006, Snyder & Kaiser 2009). It has been observed that seals have returned to the construction sites after construction was completed.

Offshore areas are rich in large bird species, and these areas are breeding, roosting and deeding habitats. Offshore wind parks influence marine birds in several ways. Risk of collision is related to species, the number and behaviour of birds and the number of wind turbines (Hüppop *et al.* 2006). Collision risk is higher at sea than on land, because turbines are taller and rotor blades are longer (Derwitt & Langston 2006; Exo *et al.* 2003). Mostly, collision takes place at night, especially at moonless nights or in unfavourable weather conditions, like fog and rain (Exo *et al.* 2003). Offshore wind farms are considered to be artificial barriers on migration routes (Exo *et al.* 2003, Hüppop *et al.* 2006). During the construction phase, short-term breeding, deeding and roosting habitat may appear to be lost (Derwitt & Langston 2006; Exo *et al.* 2003).

Offshore wind parks will increase the collision risk for bats in flight and also cause destruction of habitats, commuting corridors, roosts and feeding areas (Rodrigues *et al.* 2006). Bats foraged over the sea in areas with an abundance of insects in the air and crustaceans in the surface water (Ahlén *et al.* 2009). Installation of wind turbines will probably have negative impacts on bat populations.

## 5.1 Specific impacts connected to construction phase

With the application of modern technologies and techniques, the construction phase can be as short as a year or even half a year depending on the size of the wind farm. This is the phase with most intensive impact on biodiversity due to large scale construction works and intensive traffic, due to high level of various disturbances and physical modification of habitats.

Construction works include digging, explosions, ploughing, and pile driving (Andersson 2011), which cause noise emissions and change seabed morphology and structure, as well as deteriorate water quality due to re-suspension of sediments.

Intensive traffic during construction may cause visual and audial disturbance of animals and their displacement from the site. Additionally, shipping is the source of emissions of pollutants, which adversely affect the physiological processes of organisms.

## 5.2 Specific impacts connected to operation phase

The operation phase takes place 20-25 years, which is the present lifespan of a typical wind farm. Although not as intensive as during the construction phase, impacts do persistently occur during all exploitation period.

The wind farm with its components (foundations, scour protections, piles) is to a certain extent changing various hydrological parameters, which could directly impact habitat distribution and quality: bottom type and sediments, local current regime, ice conditions, water turbidity and quality (Baltic Environmental Forum 2009). Changes in habitats may lead to changes in fish, bird and mammal populations due to changed living environment or disappearance of feeding grounds.

However, construction of an offshore wind farm also creates new hard substrate habitats that will be colonised by algae and animals new to the area thereby creating an artificial reef attracting fish, seals and porpoise (Danish Energy Agency *et al.* 2013, Bergström *et al.* 2013, Andersson 2011, Danish Energy Agency *et al.* 2006).

Each wind farm is serviced approximately twice during each operational year. Accordingly, disturbances (noise, emissions and visual effects) from service traffic could sum up as very significant taking into account the large number of turbines in an offshore wind farm (sometimes several hundreds) (Exo *et al.* 2003, Thomsen *et al.* 2006). Particularly, birds suffer from this activity, e.g. at the Lillgrund offshore windfarm the densities of ducks were lower on the main traffic lines to the windfarm.

Each offshore wind farm is connected to the electric grid. Cables laid on seabed generate electromagnetic field that can displace some fish species or change migration routes (Stryjecki *et al.* 2011, Danish Energy Agency, 2013). Cables also produce heat emissions, but there is no clear evidence of any impact from that.

Operating wind farms may cause avoidance response from many migrating and sea bird species, displacing them from traditional migration routes, feeding, wintering, nesting and moulting areas (Lebuss 2013, Petersen 2013, Exo *et al.* 2003).

Many terrestrial bird species and bats tend to cross the sea at low altitudes within the height span of the rotor blades and possess collision risk either with wind farm stationary constructions (towers, turbines), operating rotor blades or air turbulence (Baltic Environmental Forum 2009; Hötker *et al.* 2006; Exo *et al.* 2003). Nocturnal migrants have particular collision risk, which is increased because of attraction by artificial lights on the wind farm poles (Baltic Environmental Forum 2009).

The operational noise already merges with ambient noise (wind and wave sounds) in 1 km distance from the turbine, therefore its impact is rather uncertain (Andersson 2011).

### 5.3 Specific impacts connected to decommissioning phase

The decommissioning phase means removal of wind turbines and underlying structures (poles, basements) after the lifespan of a wind farm. The impacts are very similar to those of the construction phase. Another sustainable option is to upgrade the equipment and extend the wind farm's operational lifespan.

### 5.4 Known impacts of OWF on marine biodiversity in the Baltic Sea

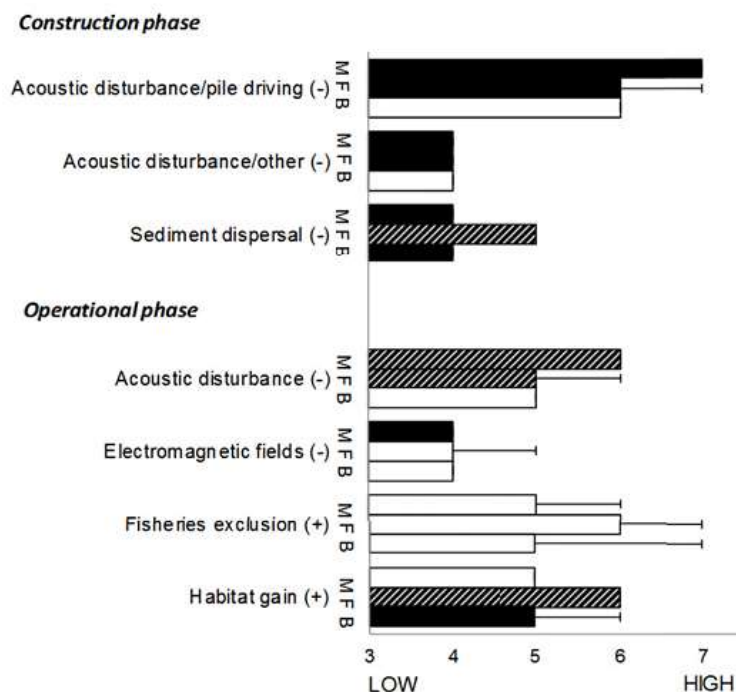
While general knowledge about the possible impacts on marine biodiversity in the Baltic Sea is very limited, a recent study by Bergström *et al.* (2014) made an attempt to score the probability of impacts on different organism groups based on literature studies. Specific criteria were used to score probability of impacts (Table 1). The study showed that so far most of the studies have been conducted on mobile species (fish, birds and mammals), while aspects of the impacts on sessile species have usually been ignored. In summary, for the construction phase, the available studies suggest that construction activities should not take place in important recruitment areas for marine mammals and fish, and that actions to reduce exposure to damaging noise levels should always be undertaken. For migrating species, this could potentially be solved by timing construc-

tion activities outside of biologically sensitive periods of the year. In the operation phase at the generalized level, the probability of negative impacts during the operational phase was rated low to moderate, whereas potential positive impact was rated low to high. The level of certainty was low to moderate, due to the high dependency on local conditions (variation within subareas). The result indicates a need for systematic studies across OWFs in different settings, in order to improve the scope for estimating outcomes under different environmental conditions (Figure 2).

**Table 1: Criteria for assessing the probability of impact on marine life from pressures associated with offshore wind farms**

Score	Spatial extent	Temporal extent	Sensitivity	Certainty
1 (low)	<100 m	During construction	Minor or no effects on the abundance and distribution of local species	Limited or no empirical documentation
2 (moderate)	<1000 m	Throughout operational phase	Effects on the abundance and distribution of local species, no effects on food web	Documentation available, but results of different studies may be contradictory
3 (high)	>1000 m	Permanent	Effects on the abundance and distribution of local species; effects on food web	Documentation available, relatively high agreement among studies

Note: The evaluation was made separately for each pressure (acoustic disturbance during construction, sediment dispersal during construction, habitat gain, fisheries exclusion, acoustic disturbance during operation, and electromagnetic fields). Spatial extent was defined as the expected dispersal of the pressure from its source, temporal extent as its expected duration. Sensitivity was assessed in relation separately for each ecosystem component (marine mammals, fish, and benthic species) and geographical area (Skagerrak–Kattegat, Baltic Proper, and Bothnian Sea). The level of certainty was assessed based on the level of documentation in peer-reviewed literature (Bergström et al 2014).



**Figure 2: Summary of the generalized impact assessment**

Note: Probable impacts on marine mammals (M), Fish (F) and Benthos (B) are shown from LOW to HIGH for the main pressures associated with OWF construction and operation. Bars show median scores for all subareas. Error bars show maximum score in any subarea. A minus (-) sign indicates negative impact, a plus (+) sign predominantly positive impact. Level of certainty in the assessment is indicated by the colour of each bar; black = high, striped = moderate, grey = low certainty, based on criteria shown in Table 1. (Redrawn from Bergström et al. 2014).



Table 2: Impacts of various stressors on organism groups in relation to offshore wind farm construction and operation

Factor	Overall impact	Pelagic communities	Benthos/benthic habitats	Fish	Birds	Mammals
<b>Noise</b>	Displacement			X		X
<b>Vibration</b>	Displacement					X
<b>Light</b>	Attraction				X	
<b>Electromagnetic fields</b>	Displacement or attraction		X	X		
<b>Traffic disturbance</b>	Displacement			X	X	X
<b>Emission of pollutants from ships</b>	Adverse effects on the physiological processes of organisms	X	X	X	X	X
<b>Seabed intervention</b>	Changed seabed morphology and structure Re-suspension of sediment/ deterioration of water quality	X	X	X		
<b>Blade rotation</b>	Collision Displacement				X	X (bats)
<b>Change in ice conditions</b>	Loss of breeding habitats					X (ringed & grey seal)
<b>Artificial structures</b>	Avoidance				X	
<b>Artificial substrate</b>	Development of new hard substrate habitats		X	X		

## 6 Requirements for the baseline study

The main aim of a baseline study is to obtain as complete as possible information on the original state of the environment prior to any development activities at the site. Additionally, the baseline study provides reference conditions for further monitoring of the state of the environment at the site and detecting impacts due to human activities. Offshore windfarms operate at least for 20 years, therefore a proper baseline information is extremely important.

The content of the baseline study is determined in the previous stage within an EIA process – the scoping. During a proper scoping, the developer together with experts determines a precise list of issues to be covered by the environmental impact study.

The baseline study usually is a combination of a **desk study** and **field sampling**. The desk study can use information available from various sources: data bases, scientific articles, reports and other publications. In most cases (e.g. the Baltic States with limited experience in offshore construction and comparatively few sources of biodiversity related information), this will not be sufficient for the specific site, therefore additional field work will be needed.

The acquisition of field data requires involving qualified/certified experts and using recognised/inter-calibrated investigation and monitoring methods to ensure credibility of the data.

During the study, special importance shall be paid on species and habitats protected according to the EU Habitats Directive and Birds Directive.

The marine environment is highly variable on a **temporal scale**, especially from season to season. Variations can be observed also from year to year. Accordingly, a widely accepted principle for a baseline study is to have two successive, complete seasonal cycles without any interruption covering seasonal variations [Federal Maritime and Hydrographic Agency, 2013]. For wintering seabirds it is important to have monitoring in two normal (not in a hard ice-winter) seasons in the base-line studies.

**A Holistic approach** shall be applied when assessing organism populations. It is important to assess whether building of the wind farm can affect just a part of a larger fish population (e.g. Baltic herring genetically/biologically is considered as one population) or a local population, which in case of possible negative effect would be much more vulnerable.

A very important issue - the **cumulative effect** of various impacts - is usually neglected by most of EIA processes. Even if a certain development project seems not posing threats to species and habitats on a local scale, the picture may look differently from a broader perspective. Combinations of impacts from many operating windfarms may sum up and lead to exceeding some critical thresholds for species populations. Particularly birds can suffer from the cumulative impacts. At present, the knowledge of assessing cumulative impacts is far from being sufficient. As many of species are highly migrating (birds, grey seals, harbour porpoises), it is highly advised to look at the Pan-Baltic scale, not only at the closest area with other development projects.

## 7 Provisional list of topics to be covered by EIA baseline study

When performing a baseline study for the impact assessment of offshore wind farms, a number of topics must compulsory be covered; other issues can be decided according to each specific case. The list includes basic components of marine biodiversity divided mainly by methodological principles. The main principle is that all possible components of biodiversity known to have a high possibility to be affected by either construction or operation of the OWF have to be evaluated. Under the specific conditions of the Baltic Sea only "background knowledge" is not sufficient at present moment to estimate all possible effects by a simple expert judgement. So, a complex sampling programme should be conducted, both, prior to the OWF project and during the operation to enable proper documentation of all possible effects.

### 7.1 Pelagic communities

The pelagic community is composed of organisms living in the water column above the seafloor and below the surface. Plankton (microscopic organisms that live in the water column and passively drift with sea currents) is probably the most significant group of the pelagic community. Planktonic organisms are closely connected to other components of the ecosystem: they are primary producers in the ecosystem and serve as food for many other organisms (e.g. fish, zoobenthos).

Plankton can be affected by the increased turbidity caused by disturbance of the seafloor during wind farm construction works and changed hydrological conditions after building. Accordingly, significant changes in plankton will lead to changes in the other components of the trophic chain.

The baseline study must cover the following components of the microscopic pelagic community:

- **Phytoplankton** – microscopic bacteria and plants.
- **Zooplankton** – microscopic animals.

Methodology for investigation of plankton is described in the HELCOM COMBINE monitoring manual available at <http://helcom.fi/action-areas/monitoring-and-assessment/manuals-and-guidelines/combine-manual> (HELCOM, 2015).

Among the described methods, remote sensing is still in development. Aerial phytoplankton surveys have been tested within the MARMONI project. It shall be noted that this cannot be the only method - parallel field sampling is necessary to validate the remote sensing data.

Plankton shows a substantial seasonal variation, therefore sampling needs to cover the entire growth season, which in parts of the Baltic Sea extends over the entire year.

**Table 3: Compulsory parameters in the baseline study of pelagic communities and related investigation methods**

	Parameters	Optional investigation methods
<b>Phytoplankton</b>	<ul style="list-style-type: none"> <li>• Species composition</li> <li>• Species distribution</li> </ul>	<ul style="list-style-type: none"> <li>• Manual sampling with plankton nets and samplers from ship/boat</li> </ul>
<b>Zooplankton</b>	<ul style="list-style-type: none"> <li>• Species abundance</li> <li>• Biomass</li> </ul>	<ul style="list-style-type: none"> <li>• Ship-of-opportunity sampling (unattended recording and sampling on ferries and other commercial ships with regular schedules)</li> <li>• Remote sensing</li> </ul>

## 7.2 Benthic communities

The benthic community is a group of organisms living in and on the bottom of the ocean floor. These organisms are known as benthos. Benthic habitats host a large variety of species, and destruction or modification by sea intervention works during offshore wind farm construction can lead to significant loss in overall biodiversity of the site.

When assessing the potential impacts of offshore wind farms on benthos and benthic habitats, attention must be paid on the diversity of benthic habitats as well as on presence of especially valuable habitats such as those habitat types protected according to the EU Habitats Directive (reefs and sandbanks which are slightly covered by seawater all the time). Benthic habitats can be classified according to the *Natura 2000* and *EUNIS* systems (by applying national/regional standards).

The baseline study must cover the following components of the benthic community:

- **Infauna** – benthic animals living within the bottom substrate.
- **Epifauna** – benthic animals living on the bottom substrate.
- **Phytobenthos** - plants belonging to the benthos.
- **Benthic habitats** - biological communities associated with the sea floor.

To distinguish natural fluctuations of the benthic community and construction effects of the wind farm, an analysis of long-term monitoring data must be made.

The benthic communities are very much dependent on the sea bottom sediments. Therefore, the results of the sedimentological and the benthological investigations must be combined in a single study. Results from geophysical and benthos surveys then are used to produce a habitat distribution map of the project area.

If possible, the benthos investigations must be carried out at the same time as the fish investigations, but mutual disturbance have to be avoided (Federal Maritime and Hydrographic Agency 2013)

**Table 4: Compulsory parameters in the baseline study of benthic communities and related investigation methods**

	Parameters	Optional investigation methods
<b>Infauna</b>	<ul style="list-style-type: none"> <li>Species' number and composition</li> <li>Species' abundance</li> <li>Biomass</li> </ul>	<ul style="list-style-type: none"> <li>Grab sampling</li> <li>Quantitative and qualitative sampling by scuba divers</li> <li>Statistical analyses (community analysis, spatial analysis)</li> </ul>
<b>Epifauna</b>		<ul style="list-style-type: none"> <li>Video survey</li> <li>Sampling by scuba divers</li> <li>Statistical analyses (community analysis, spatial analysis)</li> <li>Modelling</li> </ul>
<b>Phytobenthos</b>	<ul style="list-style-type: none"> <li>Species' number and composition</li> <li>Coverage</li> <li>Biomass</li> </ul>	<ul style="list-style-type: none"> <li>Video survey</li> <li>Quantitative and qualitative sampling by scuba divers</li> <li>Community analysis, spatial analysis, modelling</li> </ul>
<b>Benthic habitats</b>	<ul style="list-style-type: none"> <li>Distribution and main characteristics of habitats</li> </ul>	<ul style="list-style-type: none"> <li>Video survey</li> <li>Sampling by scuba divers</li> <li>Spatial modelling</li> </ul>

### 7.3 Fish

Fish are an important part of the marine ecosystem, because they are complexly related to other organisms. Different species occupy various habitats and have different roles in the trophic chain (from plankton eaters to top predators). Many species serve as food for birds, mammals, and humans. Accordingly, the changes in the populations of any fish species can cause changes in the populations of other marine organisms.

Investigations must cover two major groups of fish species in relation to habitats where they reside and feed, and one group in relation to fish development stage:

- **Demersal fish** species (e.g. cod, viviparous blenny, flounder) are directly associated with the sea bottom habitats. Accordingly, they might experience the largest impact due to destruction or modification of sea bottom during construction works.
- **Pelagic fish** are living mostly in water column and feeding on planktonic organisms (e.g. Baltic herring, sprat). Although the lifestyle of pelagic fish is not associated with solid ground, and some guidelines stress that no investigations are required during construction and operation of wind farms (Stryjecki, M. et al., 2011), the benthic habitats is important as a spawning ground for one of the most important commercial fish in the Baltic Sea – the herring.
- **Fish larvae** – the first stage of fish development after hatching.

Besides the biological parameters for fish populations, specific attention shall be paid on **recruitment** processes, which include fish migration to spawning sites, spawning, and early stages of living. Recruitment processes are most vulnerable and early life stages are the bottleneck for almost all fish populations.

Additionally to the sites/habitats important for recruitment processes, it is important to assess the distribution of habitats important for **feeding**.

**Methods** to be applied during investigations are similar for all biological parameters and should be chosen depending on local conditions.

**Table 5: Compulsory parameters in the baseline study of fish and related investigation methods**

Parameters		Optional investigation methods
<b>Demersal fish</b>	<ul style="list-style-type: none"> <li>• Observed species and abundance</li> <li>• Biomass</li> <li>• Dominance ratios</li> </ul>	<ul style="list-style-type: none"> <li>• Bottom-set gill net fishing</li> <li>• Otter trawl fishing</li> <li>• Stomach analyses of predatory fish (to identify small fish species that cannot be caught with gill nets)</li> </ul>
<b>Pelagic fish</b>		<ul style="list-style-type: none"> <li>• Hydro acoustics</li> <li>• Pelagic (mid-water) trawling</li> <li>• Vertical gillnets</li> </ul>
<b>Recruitment processes</b>	<ul style="list-style-type: none"> <li>• Spawning migration routes</li> <li>• Spawning grounds and related biological processes</li> <li>• Nursery areas and related biological processes</li> </ul>	<ul style="list-style-type: none"> <li>• Video tracking</li> <li>• Telemetry</li> <li>• For fish eggs: diving surveys, surveys using artificial spawning substrates</li> </ul>
	<ul style="list-style-type: none"> <li>• Fish larvae</li> </ul>	<ul style="list-style-type: none"> <li>• Manual sampling with plankton nets and samplers from ship/boat</li> </ul>

## 7.4 Birds

The composition of **sea bird** species and their numbers show a very high variety among seasons. Therefore investigations have to be done throughout the whole year (Baltic Environmental Forum, 2009).

The distribution and abundance of bird species have to be analysed taking into account the importance of the habitats in the project area and surrounding marine area as:

- Resting area
- Feeding area
- Moulting area

For relevant sea duck feeding areas, the harvestable food supply at the start of a wintering season must be documented for monitoring purposes (harvestable fraction of mussels and clams).

Twice a year - in spring and autumn, observations of **migratory birds** have to be carried out. Birds migrate up to an altitude of about 3000 m. Only about 5-10% of the birds fly below 100 m altitude during daytime. About 50% of all birds migrate at night. Hence, all methods which can be applied to investigate bird migration are highly selective [Baltic Environmental Forum, 2009].

Differently from the sea birds, migratory birds cover more bird taxa with a variety of different migration strategies, which must all be taken into account:

- Waterfowl (flapping; diurnal/nocturnal)
- Raptors/cranes (flapping/soaring; diurnal)
- Diurnal passerines (flapping)
- Nocturnal passerines (flapping)

**Table 6: Compulsory parameters in the baseline study of birds and related investigation methods**

	Parameters	Optional investigation methods
<b>Sea birds</b>	<ul style="list-style-type: none"> <li>• Distribution and abundance in the project area and vicinity</li> <li>• Numbers of all flying and swimming individuals</li> <li>• Age and sex distribution</li> </ul>	<ul style="list-style-type: none"> <li>• Ship transect surveys</li> <li>• Aerial transect surveys</li> <li>• Aerial photography</li> </ul>
<b>Migratory birds</b>	<ul style="list-style-type: none"> <li>• Flight direction and intensities at various altitude gradients (100 m steps) up to 1,000 m</li> </ul>	<ul style="list-style-type: none"> <li>• Radar surveys</li> <li>• Visual observations</li> </ul>

## 7.5 Marine mammals

All four marine mammal species of the Baltic Sea are top predators, and have an important role in controlling the food chain.

**Seals** usually cannot be investigated in relation to a given project area, except during the ice season. Sea ice is the crucial breeding habitat for the ringed seals. Also grey seals prefer drifting sea ice for breeding, but grey seal pups can survive also when born on land. Ringed seal breeding success depends, therefore, on presence of ice and ice structure. Ringed seals need pack ice and ice ridges with snow hummocks. Due to climate change influence they are highly endangered species in the Baltic Sea.

Investigation of impacts on **harbour porpoises** is relevant only in the southern parts of the Baltic Sea because in the northern parts they are very rare.

The potential impacts of offshore wind farms on marine mammals include noise emissions during construction and operation, change in ice conditions, traffic during construction and maintenance, seabed intervention works during construction and artificial reef effect [Baltic Environmental Forum, 2009].

As seals are very mobile animals whose feeding grounds can be very far from their preferred haul-out site, then it is still difficult to link importance of certain offshore areas to nearest haul out sites. Tagging and tracking seals with teleme-

try devices enable to obtain information on dive profiles and foraging trips, as well as oceanographic data.

For seals, it is important to gather information about the habitats, which are:

- Haul-out/moulting sites
- Breeding sites
- Feeding grounds

Breeding sites of the ringed seal shall have a special attention. Accordingly, ice conditions in the field and/or by remote sensing methods must be very carefully investigated, if the site appeared relevant for the ringed seal, and changes after installation of the wind farm assessed and modelled (Baltic Environmental Forum, 2009).

**Table 7: Compulsory parameters in the baseline study of mammals and related investigation methods**

	Parameters	Optional investigation methods
<b>Seals</b>	<ul style="list-style-type: none"> <li>• Habitat use</li> </ul>	<ul style="list-style-type: none"> <li>• Remote sensing: tagging and tracking seals with telemetry devices that enable to obtain information on dive profiles and foraging trips of marine mammals as well as oceanographic data</li> </ul>
	<ul style="list-style-type: none"> <li>• Abundance and distribution</li> </ul>	<ul style="list-style-type: none"> <li>• Aerial surveys during breeding and moulting season</li> <li>• Aerial photography</li> </ul>
<b>Harbour porpoise</b>	<ul style="list-style-type: none"> <li>• Species abundance and distribution</li> </ul>	<ul style="list-style-type: none"> <li>• Visual ship based surveys</li> <li>• Aerial digital surveys</li> </ul>
	<ul style="list-style-type: none"> <li>• Habitat use</li> </ul>	<ul style="list-style-type: none"> <li>• Stationary acoustic (click) detectors (POD)</li> <li>• Ship based and aerial surveys</li> </ul>

In the project "Testing new concepts for integrated environmental monitoring of the Baltic Sea" (BALSAM) all seal telemetry data from the whole Baltic Sea has been compiled into one database and distribution maps of seals were created, which are important background information for offshore wind farm projects.

## 7.6 Existing pressures

Performing a baseline study, it is important to remember that the site most probably is already exposed to certain human caused pressures. Therefore, information about the existing pressures must be gathered and impacts on species and habitats assessed.

- Noise
- Eutrophication
- Toxic substances



- Sea traffic
- Dredging and dumping

## 7.7 Abiotic variables

In parallel to biological parameters, a number of other factors exist that have to be registered during the baseline study. Most of non-biological parameters are closely related to biological ones (e.g. sediments determine the type of benthic habitats), or support the explanation of the obtained results (e.g. meteorological conditions during fish sampling).

The following non-biological parameters are most important to investigate during the baseline study:

- Seabed characteristics
  - Morphology
  - Bathymetry
  - Sediment type
  - Grain size distribution
  - Loss on ignition
- Physical-chemical characteristics of water layer
  - Salinity
  - Oxygen
  - Water turbidity
  - Temperature regime
- Hydrological characteristics
  - Current regime
  - Upwelling
  - Waves
- Ice conditions
  - Long term variation in regional ice coverage
  - Composition of ice types
  - Drift ice movements
- Meteorological conditions

**Table 8: Cross-references between biological and physical features**

Physical features	Pelagic communities	Benthos/benthic habitats	Fish	Birds	Mammals
<b>Seabed characteristics</b>		X	X		
<b>Physical-chemical characteristics of water layer</b>	X	X	X		
<b>Hydrological characteristics</b>	X	X	X		
<b>Ice conditions</b>	X	X		X	X
<b>Meteorological conditions</b>	X		X	X	X

## 8 Specific recommendations for organising OWF EIA and monitoring study

At present level of knowledge, a large number of issues can be solved and documented based on the experiences obtained from previous EIA studies and scientific research. The legal framework usually has strict requirements for evaluating and mitigating negative effects from construction projects. At the same time, a minimum set of requirements by the local legal system usually does not cover the full range of potential impacts: at current date we have a good knowledge on many of the general short-term effects on the marine system, however, we are far from fully understanding the ecological significance of the effects and only just beginning to consider the knowledge requirements for long-term changes. While most aspects associated with the interactions between OWF's and the surrounding environment have been included to a greater or lesser extent, no consistent development of the topic areas built on the evidence from previous studies in different countries has been achieved (Boehlert & Gill, 2010; Lindeboom *et al.* 2015).

We can observe a strong development of concepts for adequate coverage of topics and development of cost-effective approaches to the assessment of the effects caused by installation of windfarm projects. The case of the Baltic Sea, however, is a very good example of missing knowledge and experiences: the specific conditions of the Northern waters with its particular aspects of low salinity and winter ice call for additional studies and changes in monitoring strategy. Several suggestions of considering these new aspects in designing baseline or monitoring studies have been made, e.g. by Lindeboom *et al.* 2015 (Table 9). The MARMONI project team supports them strongly.

**Table 9: *In concreto* advice on major topics and issues in future monitoring programmes covering the environmental impacts from offshore wind parks (Lindeboom *et al.* 2015)**

Topic	Issue	Advice
<b>General</b>	Uncertainty in conclusions	Incorporate levels of confidence
<b>Sound during construction</b>	Depends on type and technique	Analyse species involved, costs; select sound compromise
<b>Sound during operation</b>	Effects on specific species is unknown	Research on different species (e.g. fish, cetaceans, invertebrates)
<b>Electromagnetic fields</b>	Largely unknown, possibly chronic effect	Research on specific groups (e.g. fish, cetaceans, crustaceans)
<b>Species and habitats</b>	Population demographics unknown	Study natural temporal and spatial variability
	Birds avoidance	Establish avoidance behaviour to develop mitigation strategies

Topic	Issue	Advice
	Bird collision unknown or only modelled	Collect factual data on species of specific concern
	Effect on bats in wind farms unknown	More research on presence and collision of bats
	Foundations as stepping stone	Determination of potentially invasive species
<b>Ecosystem and food webs</b>	Ecosystem and seascape scales	Include larger scales as just the OWP
	Attraction or production	Establish in situ production and potential fisheries benefit
	Underlying processes largely unknown	Include more functional (trait-based) assessment
	Elasmobranchs missing in the system	Investigate how OWPs can potentially contribute to recovery
	Cascading effects unknown	Develop new methodologies and analytical tools
	Long-term artificial reef effects unknown	Examine reproduction, growth and survival rates of local species
	Potential benefits of fish closure unknown	Study closure and displacement effects
<b>Multiple use of OWFs</b>	Can OWF's be used to produce proteins	Study possibilities to culture finfish and shellfish and macroalgae
<b>International cooperation</b>	Exchange of data hampered	Strive for an (open) exchange of knowledge, data and expertise
	National legislation determines monitoring	More use of science-based ecological criteria and studies of long-term ecosystem developments and regime shifts

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