ASSESSMENT OF ENVIRONMENTAL PRESSURES AND STATE IN RELATION TO THREE DANISH OFFSHORE WIND FARMS

Scientific Report from DCE – Danish Centre for Environment and Energy No. 576 2023

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Data sheet

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Abstract: This report is a catalogue prepared for the Danish Energy Agency with focus on describing the ecological conditions and pressure factors in the waters in and around the three planned offshore wind farms: North Sea I, Kattegat and Kriegers Flak II. The catalogue is intended for use as inspiration in future tenders for the three farms where a "nature inclusive design" can be used to remedy the general environment and the state of nature in the area.

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Preface

The Danish Energy Agency (ENS) asked DCE, Aarhus University, to provide knowledge and assessments of the environmental state and importance of human pressures in three marine areas prior to upcoming government tenders for offshore wind farms (OWF) here. The assessments are provided for each of the planned farms in the North Sea (North Sea I), Kattegat (Kattegat) and the Baltic Sea (Kriegers Flak II).

The report is to serve as a catalogue, allowing ENS to select one or more site-specific pressures that affect the state of nature and the environment in the three areas. For those pressures, measures are expected to be suggested and implemented in a coming OWF project by the contracting party. The measures may include "nature inclusive design". The catalogue focus is not solely on the effects of OWFs, it also includes effects caused by other human activities. Suggestions of measures are not part of this work.

The current report is based on existing knowledge of activities, pressures and the state of the environment that is available in recent publications. A short description of national obligations in terms of relevant EU directives sets the frame.

This work cannot be considered an environmental impact assessment.

Sammenfatning

Dette katalog er udarbejdet for Energistyrelsen med fokus på at beskrive den økologiske tilstand og betydningen af presfaktorer i farvandet i og omkring de tre planlagte havvindmølleparker: Nordsøen I, Kattegat og Kriegers Flak II. Kataloget skal bruges som inspiration for kommende udbud, hvor "nature inclusive design" kan komme på tale for at afbøde for udvalgte negative presfaktorer på havmiljøet, inklusive effekter af havvindmølleparker, til gavn for den generelle miljø- og naturtilstand i de berørte marine områder.

Kataloget tager udgangspunkt i tilgængelig viden, herunder national og internationale tilstandsvurderinger udarbejdet i relation til havstrategidirektivet, regionale konventioner (OSPAR og HELCOM) samt viden om havfugle og havpattedyr, hvor Danmark har en forpligtigelse i henhold til habitat- og fuglebeskyttelsesdirektiverne. Data fra projekter, det nationale overvågningsprogram NOVANA samt international litteratur er også anvendt. Tilstanden for de tre områder bedømmes overordnet som moderat eller dårlig i henhold til havstrategidirektivet for de fleste af direktivets "deskriptorer". Havpattedyr optræder desuden i habitatdirektivets bilag, og her opnår havpattedyr som gruppe ikke "god bevaringstilstand" i den nationale danske vurdering på grund af dårlig tilstand for en eller flere arter i hver region. Kataloget beskriver også de væsentligste menneskelige aktiviteter, som genererer pres på natur- og miljøtilstanden. Her indgår offshore vind som den primære i presfaktoren "renewable energy". Samlet vurderes "renewable energy" at være en væsentlig presfaktor, som potentielt kan påvirke næsten alle de deskriptorer, som indgår i rapporten.

Det skal pointeres, at rapporten ikke udgør en egentlig miljøtilstandsvurdering for de tre berørte havområder. Dertil er usikkerheder ved de anvendte data for tilstand samt viden om betydningen af presfaktorer for overfladisk. Fremadrettet vil det derfor være nødvendigt at indsamle områdespecifikke data.

Summary

This catalogue has been prepared for the Danish Energy Agency with focus on describing the ecological conditions and pressure factors in the waters in and around the three planned wind farms: North Sea I, Kattegat and Kriegers Flak II. The catalogue is to be used as inspiration for future tenders of OWFs, where "nature inclusive design" might be used as an instrument to mitigate selected pressures for the benefit of the general environmental state. The pressures also include the effects generated by the OWFs themselves.

The catalogue is based on available knowledge, including national and international assessments prepared in relation to the Marine Strategy Framework Directive as well as knowledge about seabirds and marine mammals where Denmark has an obligation under the Habitats and Bird Protection directives. Data from projects, the national monitoring programme NOVANA and international literature have also been used. The condition of the three farms areas and surrounding waters is assessed as moderate or poor according to the Marine Strategy Framework Directive for most of the directive's descriptors. Marine mammals are also listed under the Habitats Directive, where marine mammal species as a whole fail to achieve "favourable conservation status" in Danish national assessments because of bad status of one or more species in each region.

The catalogue also describes the most important human activities generating pressures on the natural and environmental conditions. Here, off-shore wind is included as one of the primary pressure factors in the pressure factor "renewable energy". Overall, renewable energy is a significant pressure factor that can potentially affect almost all the descriptors included in the report.

It should be emphasised that this report is not an actual environmental impact assessment of the state of the environment in the three affected sea areas as the uncertainties of the data used to assess the environmental state, as well as knowledge of the importance of pressure factors, are not sufficiently area specific and detailed. Going forward, it will therefore be necessary to collect area-specific data on both status and pressures.

1 Introduction

1.1 Background

As part of the upcoming government tenders for offshore wind farms (OWFs), it has been decided by the Danish parliament that requirements shall be formulated for one or more future concession winners to implement measures to improve the state of nature and environment in Danish marine areas. The measures shall also provide practical experience with nature-inclusive design in a Danish context for use in the future OWFs. The measures may counteract negative impacts of the farms themselves and may also be of benefit to the marine ecosystem in general.

The Danish Energy Agency has selected three coming OWFs areas as potential demonstration sites. The location of the three sites, North Sea I with three subareas (A1, A2, A3), Kattegat and Kriegers Flak II with two subareas, Nord and Syd, can be seen in figure 1.1.

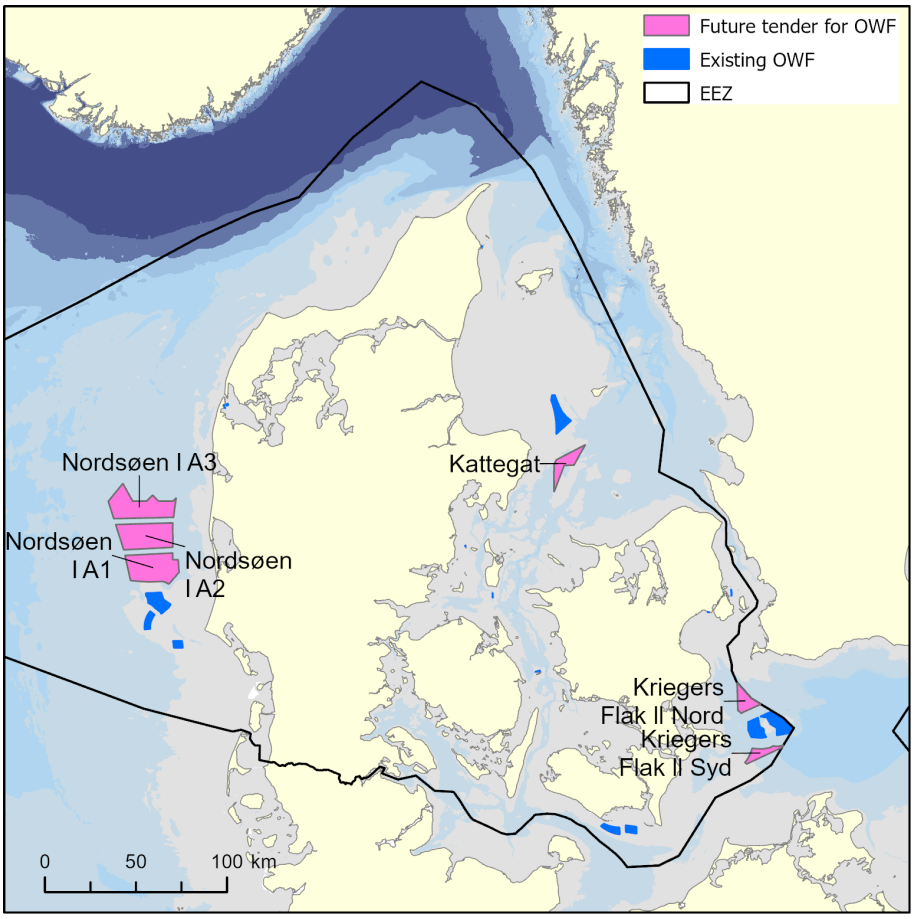

Figure 1.1. Location of the three OWF areas, North Sea I and its three subareas, Kattegat and Kriegers Flak II with the two subareas Nord og syd.

The Danish Energy Agency will identify one or more pressure factors relevant for the sea basin for each of the coming wind farms. The concession winner is subsequently obliged to contribute positively to mitigate the pressures via various nature and environmental promotion initiatives, e.g. in the form of nature-inclusive design.

1.2 Aim of this project

To select relevant ecosystem topics and pressures for the foreseen tenders, The Danish Energy Agency commissioned DCE – the Danish National Centre for Energy and Environment, Aarhus University, to provide a catalogue of environmental pressures and describe the state of the marine areas within the selected three areas for the future development of OWFs. The catalogue was to be based on already published data.

2 Method and data

This catalogue is based on extraction of knowledge about different existing assessments of the state of the marine ecosystems, human activities and the pressures caused by those activities. The assessments used have different purposes. Some were undertaken to fulfil national and regional sea convention (OSPAR and HELCOM) obligations according to the Marine Strategy Framework Directive (MSFD) at different geographical scales and in different periods, while others were made to fulfil obligations of the Habitats Directive or the Bird Directive.

The catalogue presented in this report represents aggregated information from the available national and regional sea convention assessments with a level of detail judged to be sufficient for the Energy Agency's coming work on forming the tenders. The aggregation was made across several MSFD assessments with different geographical scales, and it represent different years in different assessment systems, some of which are still under development. Human activities and their related pressures were selected according to their relevance for the overall aim. The selection of human activities and pressures was largely based on recent assessments under OSPAR (QSR2023) and HELCOM (HOLAS3). The aggregation and selections were based on DCE's long-term scientific knowledge gained from conducting monitoring and assessments of ecosystem components in Danish marine waters and scientific work related to pressure-state relationships.

It is important to note that there is not a strict 1:1 relationship between the national assessment and the assessments of the regional conventions HELCOM and OSPAR. The regional assessments are much more up-to-date regarding internationally agreed thresholds for good environmental status compared to the national MSFD assessment from 2019. On the other hand, local conditions might disqualify regional indicators and thresholds in the national assessment. The following text shortly describes the data sources used:

The assessments used in this work were:

- The national MSFD report from 2019*: Danmarks Havstrategi II Første del – God Miljøtilstand, Basisanalyse, Miljømål (Miljø- og Fødevareministeriet (2019))*. The report focuses on Danish waters and operates with two zones: a North Sea area including the Kattegat and a Baltic area including the Belt Sea. A large part of the assessment was made based on expert judgement. A new version of the assessment will be available in 2024.
- The OSPAR QSR reports from 2023 covering the North Sea area and the Kattegat regions as part of the OSPAR region II. The data used for assessment of the different descriptors were based on the thematic assessments available here: [All Thematic Assessments - OSPAR-OAP (Prod) (https://oap.ospar.org/en/ospar-assessments/quality-status-reports/qsr-2023/thematic-assessments/).](https://oap.ospar.org/en/ospar-assessments/quality-status-reports/qsr-2023/thematic-assessments/)
- The assessment of environmental status for the descriptors D1/D6 (pelagic habitat) and D4 (food webs) is partly based on recently published MSFD assessments by Tougaard et al. (2023) and Jakobsen et al. (2023).
- The HELCOM HOLAS3 reports from 2023 (HELCOM 2023a and b, covering the Baltic Sea and the Kattegat regions and targeting the MSFD. The

2023a report describes the state of biodiversity, and the 2023b report describes pressures and impacts. The information gathered from the HOLAS3 assessment covers the period 2016-2021 and was, to a large extent, made in sub-basins like the Kattegat area, the Belt Sea area, The Sound and the Arkona Sea. The HOLAS3 assessments used in this catalogue for each descriptor are thus based on the findings on status reported here: Findings – State of the Baltic Sea – Third HELCOM holistic assessment (HELCOM 2023c).

- The bird assessment in this report is based on various sources, primarily reports of previous investigations related to wind farm development in the three areas and, if available, surveys conducted under the NOVANA monitoring programme.
- As for the state of marine mammals, data from the NOVANA monitoring gathered by Hansen and Høgslund (2023) were used. Regarding cetacean abundance and distribution, data from SCANS and mini-SCANS surveys (Gilles et al. 2023) were used, for porpoise abundance in the Baltic Proper, data from the SAMBAH project (Amundin et al. 2022) were applied.
- As for bats, the report's assessment of the present status and relevant activities and pressures for the three projected offshore wind turbine areas is an expert assessment based on national monitoring data (Kjær et al. 2021), non-systematic but reliable observations and identification of bats as well as international and national research studies on bat ecology and wind turbines.

3 Obligations in relation to relevant EU directives and conventions

Habitats Directive

The EU Habitats Directive lists all cetacean species under Annexes II and IV and grey seal and harbour seal under Annexes II and V. All bat species are listed in Annex IV. Three bat species occurring in Denmark are also listed in Annex II.

Annex II requires the designation of special areas of conservation (Natura 2000 sites) with appropriate conservation objectives and measures to avoid significant disturbance of concerned species and secure their "favourable conservation status". Any project that is likely to have a significant effect on a Natura 2000 site is subject to assessment under Article 6 of the Habitats Directive to ensure that it does not have any significant impact on the integrity of the site as a habitat for the species that the N2000 area is designated for. This also includes projects outside the Natura 2000 boundaries.

Annex IV requires regimes of strict protection for listed species anywhere in the species distribution area. This includes prohibition of deliberate disturbance, particularly during breeding and migration, deterioration of important habitats, e.g. breeding and resting sites as well as foraging sites significant for the ecological functionality of breeding sites. Deliberate killing of Annex IV species is prohibited, and the Member States must monitor and ensure that incidental killings, e.g. collisions with wind turbines, do not impair the conservation status of the species.

Annex V lists species whose taking in the wild and exploitation may be subject to management measures to secure their favourable conservation status.

For all species under annexes II, IV and V, "favourable conservation status" in terms of abundance, range, distribution, habitat and future perspectives should be maintained or achieved.

For the Danish and Swedish bat populations, official species-specific national assessments of their conservation status in relevant biogeographical regions based on monitoring data are found in Fredshavn et al. (2019) and Naturvårdsverket (2020). For assessment of bats in, e.g., Finland and Estonia, see https://nature-art17.eionet.europa.eu/article17/.

Birds Directive

The Birds Directive provides a legal framework for the protection of birds, including their nests, eggs and habitats. Contrary to the Habitats Directive, the Birds Directive operates with a species-specific approach. The directive covers designation of protected areas, habitats for wild birds, species protection and hunting regulations. It has five annexes, which are briefly described in the following:

Annex 1: 194 bird species and sub-species are particularly threatened. Member States must designate Special Protection Areas (SPAs) for their survival and all migratory bird species.

Annex 2: 82 bird species can be hunted. However, the hunting periods are limited, and hunting is forbidden when birds are in their most vulnerable stages, which is during their return migration to nesting areas, reproduction and the raising of their chicks.

Annex 3: Overall, activities that directly threaten birds, such as their deliberate killing, capture or trade, or the destruction of their nests, are banned. With certain restrictions, Member States can allow some of these activities for 26 species listed in this Annex.

Annex 4: The directive provides for the sustainable management of hunting, but Member States must forbid all forms of non-selective and large-scale killing of birds, especially by the methods listed in this Annex.

In addition, the directive promotes research to underpin the protection, management and use of all bird species covered by the directive (Annex 5).

Marine Strategy Framework Directive (MSFD) operates with 11 different descriptors, each having one to several different indicators. The Danish assessment is conducted in two biogeographical sub-regions, the Baltic and the Greater North Sea. The border between the two regions is located between the Kattegat and the Belt Sea. A summary of the latest assessment of ecological status of Danish marine area can be found in appendix 1 (Miljøministeriet 2019). A new updated assessment is in preparation, including more specific targets for the indicators. As an example, with relevance for the establishment of OWFs, it has recently been decided at EU level that the indicator "seabed loss (NO)" for descriptor 6, seabed integrity, should not exceed 2% for each broad scale habitat type.

The OSPAR and HELCOM Conventions have, as far as possible, adopted the goals and methodology of the MFSD at regional sea scale. Both conventions have recently published reports presenting the state and pressures for the period 2016-2021; for some indicators (e.g. non-indigenous species in QSR2023,) the assessment period was 2015-2020.

4 Assessing human activities, pressures and environmental state in Danish waters

Human activities can cause pressures on ecosystem components. Often several activities can generate the same pressure, and given the fact that the activities are conducted at the same waters they will add to the effect, referred to as the cumulative effect. A matrix linking human activities to pressures in the Baltic region can be found on HELCOM's homepage: https://helcom.fi/action-areas/maritime-spatial-planning/human-activities-and-pressures/

4.1 General assessments of the environmental status of marine waters

Assessment of the environmental status of Danish marine as well as European waters is done according to the 11 marine environmental descriptors (D1 to D11) for which the Marine Strategy Framework Directive (MSFD) as a minimum requires assessment of Good Ecological Status (GES). In the same way, the conservation status of protected habitats or species is determined according to the Habitats Directive and the Birds Directive. In most cases, the assessments for each descriptor are based on a thorough assessment recently accomplished as part of the QSR2023 and HOLAS3. If no prior assessments are available, we provide an expert-based judgement. For some of the indicators, a GES indicator has not yet been developed. For these, we have assigned an expert-based judgement of GES based on the provided information of status.

The MSFD operates with 11 descriptors, of which eight are related to pressures, two to state and one "seabed integrity", to both pressure and state (table 4.1).

Table 4.1. Pressure and state descriptors used to assess the environmental status according to the Marine Strategy Framework Directive.

Pressure Descriptors	Environmental state descriptor
Descriptor 2: Non-indigenous species	Descriptor 1: Marine biodiversity
Descriptor 3: Commercial fish and shellfish	Descriptor 4: Food webs
Descriptor 5: Eutrophication	Descriptor 6: Seabed integrity
Descriptor 6: Seabed integrity	
Descriptor 7: Hydrographical conditions	
Descriptor 8: Contaminants	
Descriptor 9: Contaminants in seafood	
Descriptor 10: Marine litter	
Descriptor 11: Energy, including underwater noise	

A more detailed description of the 11 descriptors can be found in box 1.

Box 1 Descriptors used in the Marine Strategy Framework Directive (from: Descriptors under the Marine Strategy Framework Directive (europa.eu)).

Descriptor 1: Marine biodiversity

Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions

Under the Marine Directive, marine biodiversity covers all marine species of birds, mammals, reptiles, fish, and cephalopods found in EU waters. To be in good environmental status, the species' long-term viability should be ensured. This means looking at the species' mortality rates and abundance, as well as their distribution and several other demographic criteria, such as body size and age.

Marine biodiversity also covers all types of habitats, both pelagic and benthic. Pelagic habitats, such as habitats in the water column, need to be in a condition where their structure and functions allow species to thrive. For benthic habitats (habitats on the seabed), Member States need to look at the extent of loss and damage to the seabed. This is done under Descriptor 6.

The Birds and Habitats Directives, and the recent Commission proposal for a nature restoration law all contribute to achieving good environmental status for marine biodiversity. They aim to protect and restore several marine habitats, such as seagrass beds or sediment bottoms, that deliver significant benefits, including for climate change mitigation. They also aim to protect and restore the habitats of iconic marine species such as dolphins and porpoises, sharks and seabirds.

Descriptor 2: Non-indigenous species

Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems

Non-indigenous species are species that expanded their typical geographical distribution. They become 'invasive' when they can threaten marine biodiversity.

In their marine strategies, Member States primarily must ensure that no new non-indigenous species are introduced into their marine waters through human activity. They could also look at the abundance and spatial distribution of established non-indigenous species, as well as at the proportion of species group or habitats affected by non-indigenous species.

In EU waters, non-indigenous species are mainly introduced and spread through shipping and aquaculture. Climate change also allows sub-tropical species to settle in, for example the Mediterranean Sea.

Descriptor 3: Commercial fish and shellfish

Populations of all commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock

Fisheries management is an exclusive competence of the EU and is regulated by the Common Fisheries Policy. Overfishing and unsustainable fishing practices can lead to the progressive depletion and eventual collapse of stocks. It can also lead to seabed

damage and bycatch of unwanted or sensitive species. More coherence is needed between the Common Fisheries Policy and EU environmental legislation, notably with achieving good environmental status under the Marine Directive. Fisheries have a wide impact on marine ecosystems, including on its biological diversity, food webs and sea-floor integrity.

The Biodiversity Strategy for 2030 calls to reduce fishing pressure to sustainable levels. This includes reducing damage to the seabed and by-catch of sensitive species. In 2023, the Commission put forward an Action Plan to protect and restore marine ecosystems for sustainable and resilient fisheries.

Descriptor 4: Food webs

All elements of the marine food webs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity

Food webs are networks of feeding interactions between animals and their food (or predators and prey). This descriptor looks at the functional aspects of marine food webs. In particular, it looks at the diversity and balance between different groups of species and the characteristics of these. It is closely linked to Descriptors 1 and 6 as marine food webs can only be in a good state if marine species and habitats are healthy and in a good condition.

Descriptor 5: Eutrophication

Human-induced eutrophication is minimised, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algae blooms and oxygen deficiency in bottom waters

Eutrophication is a process driven by the enrichment of water by nutrients, usually from agriculture or urban discharges. Dissolved nitrogen and phosphorous are the main inorganic nutrients in the water column responsible for the eutrophication of marine waters. In their marine strategies, EU Member States need to look at the levels of nutrient concentrations, the levels of chlorophyll concentrations, the spatial extent and duration of harmful algal blooms, the transparency of the water column, and the levels of dissolved oxygen in the water. The Zero pollution action plan aims to reduce nutrient losses by 50% by 2030, thereby limiting the occurrence of eutrophication.

Descriptor 6: Seabed integrity

Sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected

The seabed provides the foundation of a healthy marine environment. Home to millions of marine species and habitats, it generates food and oxygen in our seas and ocean and contributes to regulating the climate. Protecting the seabed is therefore essential to meeting the EU's Biodiversity, Zero Pollution, Climate Adaptation and Food Security objectives.

Many human activities affect the quality of the seabed, particularly through physical disturbance and pollution. The most harmful are bottom-trawl commercial fishing, which has led to a significant loss of sensitive seabed habitats, and eutrophication, which causes long-lasting widespread damage to seabed habitats. Other potentially harmful activities and pressures include marine mining of sand and gravel, chemical

and plastic waste, renewable energy operations, land claim, port operations, and the laying of submarine cables and pipelines.

Threshold values were agreed in 2023. For a seabed habitat to be considered in good environmental status, no more than 25% should be adversely affected by human pressures, including no more than 2% that should be irreversibly lost. See the recommendation on the threshold values and the corresponding press item.

The Action Plan to protect and restore marine ecosystems for sustainable and resilient fisheries commits to setting these threshold values and sets out a vision for a gradual transition to more sustainable fisheries including to reduce damage on the seabed.

Descriptor 7: Hydrographical conditions

Permanent alteration of hydrographical conditions does not adversely affect marine ecosystems

Hydrographical conditions typically refer to the physical parameters of seawater: temperature, salinity, depth, currents, waves, and turbidity. They play a crucial role in the dynamics of marine ecosystems and can be altered by human activities, especially in coastal areas. Human activities such as coastal infrastructural development, dredging, sand extraction and desalination can impact on the physical properties of marine waters. They can therefore alter hydrographical conditions. In the marine strategies EU Member States should consider the spatial extent and distribution of hydrographical changes to the seabed and the water column, as well as the spatial extent of the impacts on seabed habitats.

Descriptor 8: Contaminants

Concentrations of contaminants are at levels not giving rise to pollution effects

Pollution from contaminants ends up in the sea. Contaminants are toxic and persistent chemical substances that degrade the marine environment and can cause serious damage. They mainly come from agricultural pesticides, paint coating on ships, pharmaceutical, industry and urban waste, including heavy metals. Implementing the measures under the various EU and global laws have led to a reduction of concentrations of these pollutants.

However these substances are very persistent and are therefore still present in the marine environment. In their marine strategies, Member States need ensure that the concentrations of contaminants do not exceed certain threshold values and, where appropriate, look at health of species and the condition of habitats. They also must address significant pollution events, such as oil spills.

Descriptor 9: Contaminants in seafood

Contaminants in fish and other seafood for human consumption do not exceed levels established by Union legislation or other relevant standards

Pollutants in the sea ultimately contaminate seafood intended for human consumption. It is therefore important for both environmental and human health reasons to ensure that the levels of contaminants in the marine environment remain low and within safe limits. In their marine strategies Member States need to ensure that the level of contaminants in edible tissues of seafood does not exceed certain levels.

Descriptor 10: Marine litter

Properties and quantities of marine litter do not cause harm to the coastal and marine environment

Every year millions of tonnes of litter end up in the oceans creating environmental, economic and health problems. This is caused by several reasons, including poor waste and wastewater management, lack of infrastructure and public awareness about the consequences of their actions.

The solution is to tackle the problem at source. In their marine strategies, EU Member States need to consider the composition, amount and spatial distribution of litter and microlitter on the coastline, in the water column, and on the seabed. They may also look at the amount of litter ingested by marine animals as well as the number of species that are adversely affected by litter, such as due to entanglement or mortality.

Threshold values need to be set through EU cooperation. In 2020 experts agreed that the amount of litter on the coastline should not exceed 20 items for every 100 metres of coastline. Other threshold values are being developed as required by the 'GES' Decision. See the recommendation on the threshold values and the corresponding press item.

The Zero pollution action plan aims to improve water quality by reducing waste, plastic litter at sea (by 50%) and microplastics released into the environment (by 30%). Most of the proposed Actions in the Strategy for Plastics are directly or indirectly related to marine litter, including the Directive on Single Use Plastics and fishing gear. The Port Reception Facilities Directive, address marine litter from ships, including from fishing vessels.

Descriptor 11: Energy, including underwater noise

Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment

Energy use, such as heating and electricity systems, artificial lighting, noise, electromagnetic radiations, radio waves or vibrations, can also be a pressure on the marine environment. So far, policy development and marine strategies have largely focused their efforts on underwater noise. The effects are complex and not yet fully understood. Underwater noise due to human activities at sea can harm marine biodiversity, leading for example to hearing impairment and behavioural disturbances. The 'GES' Decision requires Member States to look at the spatial distribution, temporal extent, and levels of anthropogenic impulsive (for example from oil and gas exploration and extraction) and continuous (such as from shipping) underwater noise.

In 2022, recommendations on the threshold values for underwater noise were agreed. These specify that no more than 20% of a given marine area, can be exposed to continuous underwater noise over a year. Similarly, no more than 20% of a marine habitat can be exposed to impulsive noise over a given day, and no more than 10% over a year.

Figure 4.1 illustrates the assessment system for the MSFD descriptor "Seabed integrity". The threshold values between good and moderate have just been agreed as assessment criteria at EU level. To assess the 11 MSFD descriptors, individual indicators of ecological status are applied.

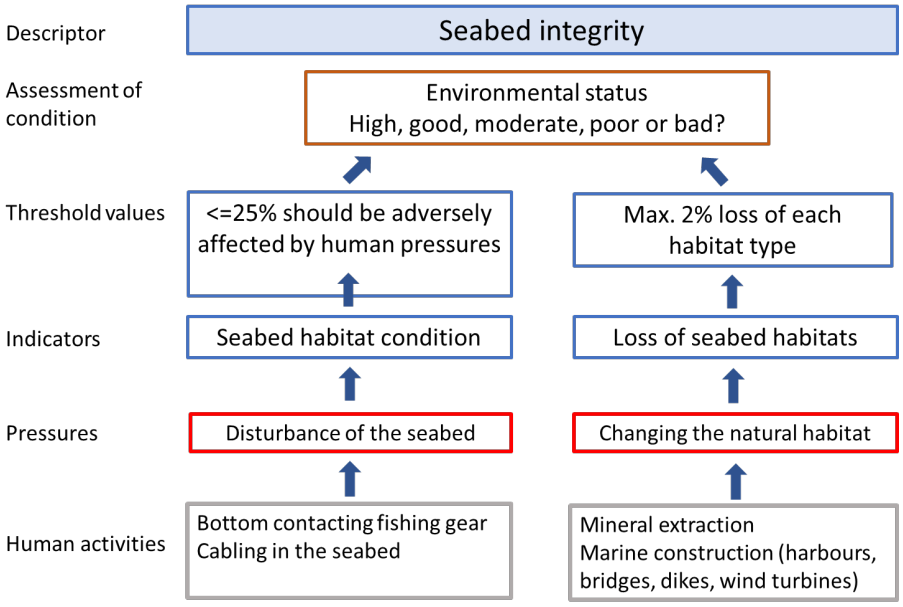

Figure 4.1. An example of assessment of the environmental status of the MFSD descriptor "Seabed integrity", including examples of potential pressures and human activities causing the pressures.

The goal is to obtain high or good environmental state in marine areas. Setting the threshold value between good and moderate state (the GES value) for all indicators is still in progress. Examples of the work on underwater noise are available in the guidance from the EU expert group (Sigray et al. 2021, TG-Noise 2022a, b) and Tougaard et al. (2023).

4.2 Assessment of offshore wind farm effects

Hydrography

A recent model shows that the associated wind wakes in the North Sea provoke large-scale changes in annual primary production with local changes of up to ±10%, not only at the offshore wind farm clusters but also distributed over a wider region. The model also projects an increase in sediment carbon in deeper areas of the southern North Sea due to reduced current velocities and decreased dissolved oxygen inside an area with already low oxygen concentrations (Daewel et al. 2022)

Model work is ongoing at DCE to clarify the magnitude and range of mixing of pelagic water masses by turbines. Increased mixing may stimulate pelagic production.

Benthic habitats and biodiversity

Installation of turbines and scour protection introduce hard substrate where soft bottom is often prevailing. This changes the benthic biota from soft bottom communities to hard bottom communities. Additional effects on commu-

nity structure may occur due to the changing food web due to new hard bottom communities. This food web effect is still not well described; however, a study is ongoing at Anholt windfarm.

Non-indigenous species

Introduction of numerous new hard substrates such as turbines and scour protection in wind farms spread over large regional areas dominated by fine sediments may act as a steppingstone for non-indigenous species. In this case, natural habitat barriers are broken down. Introduction of non-indigenous species in marine areas is recognized as a non-reversable effect.

Birds

Wind farms have the potential to negatively impact birds at both individual and population level. Negative effects may be a result of direct mortality from collision, displacement or barrier effects (Fox & Petersen 2019).

The population dynamics of bird species are affected unequally by the construction of offshore turbines. Obviously, bird flight behaviour will affect the risk of collision mortality because species that fly at rotor sweep heights are more vulnerable than those that fly low over the sea. Some species, such as divers, show strong responses to man-made objects and therefore avoid wind turbines, which leads to habitat loss. In contrast, other species, such as some gulls and cormorants, may be attracted to offshore wind farms as they offer new feeding opportunities, but this attraction may increase the risk of collision. Body size, aerodynamics and maneuverability will also affect the likelihood of collision with wind turbines (Drewitt & Langston 2006). In addition, long-lived species with low reproductive turnover, such as divers and some raptors, are far more vulnerable to even very small increases in adult mortality compared to short-lived small passerines, which are able to produce large numbers of offspring (Desholm 2009). Only little is known about the real number of collisions between birds and offshore wind turbines and, hence, the potential impacts at the population level. This knowledge gap is primarily a consequence of the unfeasibility of carcass searches offshore and limitations to the acquisition of collision data. Up to now, collision risk models are therefore the only possibility to obtain estimates of collision rates.

Recent studies have shown that negative effects from wind farms in the Baltic Sea and the North Sea on populations of nocturnal migrants are unlikely (Welcker & Vilela 2019), and Tjørnløv et al. (2023) found that seabirds will only be exposed to a very low risk of collision in offshore wind farms during daylight hours. Skov et al. (2017) showed that migrating raptor species displayed a significant attraction behaviour towards an offshore wind farm, which potentially increased their risk of collision. In contrast, Jakobsen et al. (2019) revealed a barrier effect of an offshore wind farm, influencing the migration of raptors by forcing many of the birds to use other and potentially more risky alternative sea crossings. Although this avoidance behaviour reduced the collision risk, the barrier effect may potentially affect the survival and fitness of populations.

The presence of offshore wind farms in the marine environment may impact the distribution of resting and/or migrating birds. While some bird species seem to be unaffected by the wind farms, others respond with either attraction or displacement (Fox & Petersen 2019). Marine bird species have been ranked

according to their vulnerability to displacement from offshore wind farms (Garthe & Hüppop 2004, Furness et al. 2013). Species of divers (*Gavia* sp.) and some species of diving ducks have been reported to be highly prone to displacement from offshore wind farms. Displacement of red-throated diver, common scoter and long-tailed duck has been demonstrated (Mendel et al. 2019, Petersen et al. 2011, 2013, 2014). Gradually reduced density effects for red-throated diver out to 16 km from the wind farm sites have been reported. The reason for the documented displacement of red-throated diver, common scoter and long-tailed duck is unknown. Displacement may be caused by the visual appearance of the turbines or, alternatively, by the light conditions in the wind farms at night. Changes in light use in the wind farms may be a potential way to mitigate displacement. An investigation of the role of light conditions in existing wind farms may elucidate this issue and could provide important information for the future designation of OWF areas in the Danish marine area.

Likewise, study of the impact on bird flight behaviour around existing wind farms would be useful. Are terrestrial birds attracted to the wind farms, particularly at night, when the turbines are illuminated? The use of advanced 3D radar systems in existing wind farms could inform the future process on this issue, including the role of nocturnal light in the wind farms.

The fly-way level impact on bird species from displacement is a challenging issue, and this challenge is best addressed by developing geographically explicit agent-based models. Such a development would also be able to address the issue of cumulative impacts, another challenging task.

Displacement effect is only documented for some species. Likewise, potential habituation over time has only been investigated for a few species and wind farm sites (Petersen et al. 2013, 2014).

The impact of offshore wind turbines on birds ultimately depends on the placement and how they overlap with bird habitats and migratory pathways. Therefore, it is important to consider these aspects throughout the lifecycle of the individual species when assessing the impact of offshore wind farms and identifying which species may be affected by a specific wind farm or when planning offshore wind energy development on a larger scale.

Marine mammals

A range of activities related to the construction of offshore wind farms can impact marine mammals. The greatest detrimental effect is probably the establishment of foundations for turbines, which causes loud impulsive noise (Madsen et al. 2006, Tougaard et al. 2009, Bailey et al. 2010). At distances close to the source, these sounds may cause permanent or temporary hearing loss, while at greater distances animals are disturbed and potentially displaced, leading to temporary habitat loss and impact of time budgets.

Other activities, such as dredging, transportation of materials and equipment, are also likely to cause disturbance and noise, although at much lower sound pressures than ramming of foundations. It is thus probable that marine mammals will leave the area during construction and suffer temporary habitat loss. Previous constructions of wind farms have shown displacement of marine mammals during construction (e.g. Tougaard et al. 2006, Carstensen et al.

2006, Brandt et al. 2009; Russell et al. 2016). Marine mammals will be particularly vulnerable to disturbances during key periods of the year, namely breeding and nursing periods (summer and autumn for porpoises and white-beaked dolphins). Seals breed and nurse at their land haul-outs, which are not near any of the proposed wind farm areas.

During operation of wind farms, the occurrence of porpoises has mostly returned to baseline levels from before the construction phase or to higher levels (Tougaard et al. 2006, Scheidat et al. 2011). In one wind farm, at Nysted, Denmark, porpoise activity did not return to baseline levels even after 10 years (Teilmann and Carstensen 2012), but it is unclear whether this is due to unusually high activity during the brief baseline period. During operation of the wind farms at Nysted and Rødsand, seals were neither attracted nor repelled by turbines (McConnell et al. 2011). On the other hand, Russell et al. (2014) found that individual seals can specialise in foraging around turbine foundations and spend a considerable amount of their time at sea inside the wind farms. Noise from operating wind turbines is low compared to noise from, e.g., shipping, but cumulative contributions from many turbines may be considerable (Tougaard et al. 2020).

Bats

Offshore and onshore wind turbines may impact bats negatively at individual and population levels due to increased mortality rates. The impact of wind turbines on bat populations probably depends on the placement and how they overlap with the migratory routes and foraging habitats of the bats. Impacts on bats are only expected in the operational period.

Bats are not usually regarded as marine species and as such the state of marine ecosystems may have little significance for their population status (e.g. Altringham 2011, Voigt & Kingston 2015). However, bats migrate seasonally between summer and w inter habitats, and some bat populations regularly migrate across marine waters (Ahlén 1997, Lagerveld et al. 2023, Kruszynski et al. 2020, Seebens-Hoyer et al. 2021). Furthermore, many species may forage regularly over marine waters (Ahlén et al. 2009). Onshore wind turbines may cause significantly increased mortality rates with negative impact on bat populations (e.g. Voigt & Kingston 2015, EUROBATS 2019). Increased development of wind farms is likely to enhance the impact on the conservation status of many bat species. Mortality estimates for offshore wind turbines do not exist as carcass searches offshore are unfeasible. There is no reason to expect that the cumulative effects of offshore wind turbines should not have similar effects on the exposed populations.

The life history traits and ecology of all bat species make them highly vulnerable to increased mortality and environmental changes (e.g. Altringham 2011, Voigt & Kingston 2015). Compared to similar-sized mammals, bats have a long-life expectancy (>40 years for some species), a long pre-reproduction period and a low reproductive rate. Adult females usually give birth to only one young per year, and not all adult females breed every year. Consequently, to maintain a favourable population status, the anthropogenic mortality must be low, and the recovery of bat populations will be slow and uncertain if they have been depleted.

Although the numerical mortality of bats at individual wind turbines is often low, modelling based on conservative mortality rates at wind turbines shows

that the cumulative effect of all wind turbines in species migration corridors and distribution ranges may threaten their conservation status (e.g. Rydell et al 2011, Freidenberg & Frick 2021).

The main conflict between bat conservation and offshore wind farms is probably related to long-distance migrating bat species (Hütterer et al. 2005, Ahlén et al. 2009), e.g. *Nyctalus noctula*, *N. leisleri*, *Pipistrellus nathusii* and *Vespertilio murinus*), but more regionally migrating species may cross inner Danish marine areas. The regionally migrating species may include *Pipistrellus pygmaeus*, *P. pipistrellus*, *Eptesicus serotinus*, *E. nilssonii*, *Myotis dasycneme*, *M. daubentonii*, *M. brandtii/mystacinus* and *Barbastella barbastellus*. These species may also forage over marine areas and during migration (Ahlen et al. 2009, Voigt et al. 2012). Bats are assumed to migrate out at sea from peninsulas, headlands and other projections on the coastline, but landfall of bats might be more disperse (Ahlen 1997).

There is a huge knowledge gap on bat population sizes, flyway-populations, migration routes and catchment areas for specific wind farms. It is well described that bats explore onshore wind turbines, either to forage on the insects around the turbines or to use the turbines as potential roost sites, thereby increasing the mortality risk compared to animal species that just pass by wind turbines (Voigt & Kingston 2015). This behaviour must also be assumed around offshore wind turbines. It might even be assumed that the tendency will be stronger when bats are flying in the vicinity of wind turbines in extremely open habitats near offshore wind farms. Roosting bats have been observed on offshore wind turbines (*Pipistrellus pygmaeus*, *P. nathusii* and probably *Nyctalus leisleri*) (Ahlén et al 2009).

A migrating individual is likely only to be recorded once at a detector, e.g. when migrating over marine waters. In contrast, an individual in a foraging habitat, e.g. onshore, is likely to be recorded several times over a period. Hence, the number of recordings of bats per time unit in migration corridors and foraging habitats cannot be compared 1:1, and the number of recordings per time unit does not reflect the number of bats that are present in an area or migrate past. Although there might be relatively few records of bats per night on offshore sites, it may be a significant proportions of the population that are exposed to offshore wind turbines in their migration corridors.

4.3 Selection of human activities

In our evaluation of the regional and national assessments as well as the literature, we identified the overall activities generating pressures in marine areas (table 4.2). In the selection of activities, we focused on activities and pressures relevant for offshore areas, thereby excluding activities such as dredging and recreational activities as these mostly take place near the shore.

Table 4.2. Selection of human activities relevant for offshore marine areas and assessment of their importance following a four-level assessment scale. For each descriptor, we have ranked a selection of relevant human activities with documented effects on the pressures affecting the descriptors. The ranking includes four levels: 0 – not relevant/no data; 1 – no effect; 2 – some/moderate effect; 3 – potentially large effect. The level of importance for each activity is based on recently published reports (see chapter 2) and expert-based judgements.

* For bats, the assessment is an expert judgment that is not based on EQR or similar indexes.

¤ For marine mammals and underwater noise the assessment of renewable energy pertains to the construction phase, whereas the effect level during operation is assessed to be "some/moderate effect.

^ For birds the collision risk is expected to be higher during the operational phase than during the construction phase.

Directive	Descriptors	Relevant activities								
		Aggregates extraction	Agriculture	Aquaculture	Fisheries	Oil and gas	Renewable energy (OWF)	Shipping	Recreational activities	Waste water
MSFD	D1 Biodiversity - fish	2	2	2	3	2	2	1	2	2
MSFD	D1 Biodiversity - marine mammals	0	2	2	3	2	3¤	3	3	2
MSFD	D1 Biodiversity – pelagic habitats	2	3	2	2	2	3	2	2	3
MSFD	D2 Non-indigenous species	0	0	3	1	2	3	3	2	0
MSFD	D3 Commercial fish and shellfish	2	2	2	3	2	3	2	2	2
MSFD	D4 Food webs/D1 Biodiversity - ecosystems	3	2	2	3	2	3	2	2	2
MSFD	D5 Eutrophication	2	3	2	2	1	2	2	1	3
MSFD	D6 Seabed integrity/D1 Biodiversity - benthic habitats	3	3	2	3	2	3	2	2	3
MSFD	D7 Hydrographical changes	2	0	0	0	0	2	2	0	0
MSFD	D8 Contaminants (in sediments)	3	3	2	3	3	2	3	2	3
MSFD	D9 Contaminants in seafood (in biota)	3	3	2	3	3	2	3	2	3
MSFD	D10 Marine litter	0	0	3	3	2	0	3	3	2
MSFD	D11 Energy, including underwater noise	2	0	1	2	3	3¤	2	2	0
BD	Birds - migratory	0	0	0	0	0	2^	0	0	0
BD	Birds - resting	1	2	0	3	0	2	1	3	0
HD	Bats	0	0	0	0	0	3*	0	0	0

Activity effect level
0 - not relevant/no data
1 - no effect
2 - some/moderate effect
3 - potentially large effect

5 State and pressure for the OWF areas

In relation to the Marine Strategy Framework Directive, several assessments are done using different geographical scales, in some cases even including subareas. The assessments also represent different assessment periods in a still ongoing process of developing indicators and their thresholds between environmental status classes.

In this chapter, we present different assessments of the environmental status relevant for the North Sea area, the Kattegat and the Baltic Sea areas. We also present an aggregated assessment based on the existing assessments and DCE expert knowledge from the national work with NOVANA data. In the aggregation, we have weighted new data information higher than old data and data relevant for Danish areas higher than more general information on the regional seas; finally data from subregions relevant for the planned OWF parks are weighted higher than regional or national data.

The selected set of human activities relevant for offshore waters in general (figure 4.2) is evaluated according to the local conditions prevailing in each of the three park areas. The adjustment of relevance for the three areas is shown in table 5.1. The underlying specific pressures can be found in the activity pressure matrices presented in the previous chapter.

Table 5.1. Relevant activities for the three OWF areas and their surrounding waters. 1 = high relevance, 0 =no or minor relevance. The determination of relevance is based on recently published reports (see chapter 2) and expert-based judgements.

Area / activity	Aggregates extraction	Agriculture	Aquaculture	Fisheries	Oil and gas	Renewable energy (OWF)	Shipping	Recreational activities	Waste water
North Sea I	1	1	0	1	1	1	1	0	1
Kattegat II	1	1	1	1	0	1	1	1	1
Kriegers Flak II	1	1	1	1	0	1	1	1	1

Relevance
0 - no relevance
1 - relevance

Finally, for each of the three areas, we briefly highlight the activities that we find most relevant in connection with the location of the specific wind farms and the adjacent waters.

5.1 North Sea I area and adjacent waters

The assessments of the environmental state of the North Sea area are listed in table 5.2 All state descriptors and most pressure descriptors are in poor or moderate state.

Information on the impact of the important human activities on the descriptors from the regional assessments is also presented in table 5.1. The effects of most activities are known.

Although several activities are rated as having a large or some effect on the descriptors, the activity may not be relevant within the specific area around the North Sea I wind farm area. The following highlights the important activities relevant for the farm area and the adjacent waters.

Aggregate extraction: There are several existing, potential or investigation areas for sand and gravel extraction in the vicinity of the North Sea I sites. Information is available at https://miljoegis.mim.dk/cbkort?profile=miljoegis-raastofferhavet.

Dredging, which is also included in this activity, is not relevant. Dredging near harbours may reintroduce buried pollutants, thereby affecting descriptors D8 and D9. Except for these two descriptors, we find consideration of the rating of effects relevant.

Agriculture, **wastewater**: The effects of these activities relate to different eutrophication processes and the distribution and accumulation of toxic substances. Large-scale effects are most likely to occur near shore, close to point sources and rivers.

Aquaculture: Not an activity in the Danish North Sea.

Fishery: Fishery is a highly relevant activity. Bottom-contacting gear affects the seabed and thereby its benthic habitats and associated communities. Exploitation of fish stocks and the resulting impact of benthic communities affect the food web. Disturbance, by-catch and competition for resources by birds and mammals are also effects of fishery.

Oil and gas exploitation: Takes place in the western part of the Danish North Sea. We find this activity less relevant to include as an important pressure in our assessment due to the distance between the planned farm area and the exploitation areas and due to the already existing pipelines from the sea to the shore. Seismic surveys in connection with oil and gas extraction activities are a significant source of impulsive noise in the North Sea.

Renewable energy: Highly relevant since the farm itself constitutes an important activity that affects several descriptors with potential large effects on seabed integrity (loss), benthic habitats (biodiversity) and the food web. New constructions might promote the introduction of non-indigenous species and the effect of this might be non-reversable in natural habitats. Hydroacoustic surveys prior to the planning and construction of OWFs and construction of the infrastructure are one of the most significant sources of impulsive noise in the North Sea. Underwater noise from turbines in operation is a local source of continuous noise.

The North Sea I area is not considered a pressure for migratory birds. Previous studies related to the Horns Rev III wind farm found rather low densities of migrating birds in the area (Jensen 2014). The diurnal migration is dominated by passerines, pigeons and sea ducks, whereas raptors occur in low numbers. Dislocation from feeding grounds is relevant for a number of species like red-throated diver, Northern gannet, kittiwake, little gull, terns, razorbill and common guillemot. Two species, red-throated diver and little gull, are designated as Appendix 1 species under the EU Birds Directive. Red-throated diver is furthermore on the designation list for the recently enlarged "Southern Danish North Sea" Birds Directive area. The area of interest for wind farm development partially overlaps with the Birds Directive area. The shallow southeastern parts can potentially have concentrations of common scoter. Little gull is only temporarily present in the area, with marked fluctuations in numbers.

It is likely that marine mammals use the North Sea I area extensively. Harbour porpoises have not been tagged in the vicinity of the area, but aerial surveys during summer indicate that the density of porpoises is high relative to their general distribution in the North Sea (Gilles et al. 2023). For both harbour seals and grey seals, the area is within travelling distance from important haul-out sites in the western Limfjord and the Wadden Sea.

Bats migrate regularly across the southern parts of the North Sea (Lagerveld et al. 2023, Seebens-Hoyer et al. 2021). Observations of bats on ships and oil rigs also suggest that bats may cross the northern parts of the North Sea between southern Norway, Denmark and the British Isles (Petersen et al. 2014, J. van der Kooij, pers. comm. 31/08/2023). However, there is significant absence of systematic data on the potential migration of bats across the North Sea west of Jutland and thus on the potential impact of the future development of OWF in the area. The bat species recorded on infrastructures and ships in the North Sea comprise primarily long-distance migratory species such as *Pipistrellus nathusii*, *Vespertilio murinus* and *Nyctalus noctula*. In the southern North Sea, *Nyctalus noctula* occasionally forage 18 km from the coast (Lagerveld & Mostert 2023). There is no information on regular occurrence of foraging bats in the projected OWF area North Sea I.

Shipping: Shipping generates underwater noise that disturbs marine mammals and birds

Recreational activity: Not relevant offshore.

Table 5.2. Assessments of the environmental state of different descriptors according to the MSFD, the Habitats Directive (HD) in relation to marine N2000 areas and the Birds Directive (BD) for the OWF area North Sea I. For each descriptor, we have ranked a selection of relevant human activities with documented effects on the pressures affecting the descriptors. The ranking includes four levels: 0 – not relevant/no data; 1 – no effect; 2 – some/moderate effect; 3 – potentially large effect The level of importance for each activity is based on recently published reports (see chapter 2) and expert-based judgements. The "overall" column (assessment) is a DCE-weighted assessment. B=Bad, P=Poor, M=Moderate, G=Good, H=High.
* For bats, the assessment is an expert judgment that is not based on EQR or similar indexes.
¤ For marine mammals and underwater noise the assessment of renewable energy pertains to the construction phase, whereas the effect level during operation is assessed to be "some/moderate effect.
^ For birds the collision risk is expected to be higher during the operational phase than during the construction phase.

Directive	Descriptors	Assessments						Relevant activities								
		HD N2000	BD 2019	DK MSFD (2019)	QSR 2023	HOLA SIII	Overall assessment	Aggregates extraction	Agriculture	Aquaculture	Fisheries	Oil and gas	Renewable energy (OWF)	Shipping	Recreational activities	Waste water
MSFD	D1 Biodiversity - fish	-	-	P	P	-	P	2	2	0	3	2	2	1	0	2
MSFD	D1 Biodiversity - marine mammals	U	-	M	G	P	M	0	2	0	3	2	3¤	3	0	2
MSFD	D1 Biodiversity – pelagic habitats	-	-	M?	P	-	P	2	3	0	2	2	3	2	0	3
MSFD	D2 Non-indigenous species	-	-	P	M	-	M	0	0	0	1	2	3	3	0	0
MSFD	D3 Commercial fish and shellfish	-	-	P?	B	-	B	2	2	0	3	2	3	2	0	2
MSFD	D4 Food webs/D1 Biodiversity - ecosystems	-	-	M?	M?	-	M	3	2	0	3	2	3	2	0	2
MSFD	D5 Eutrophication	-	-	G	M	-	M	2	3	0	2	1	2	2	0	3
MSFD	D6 Seabed integrity/D1 Biodiversity - benthic habitats	-	-	P	B	-	B	3	3	0	3	2	3	2	0	3
MSFD	D7 Hydrographical changes	-	-	P	?	-	P?	2	0	0	0	0	2	2	0	0
MSFD	D8 Contaminants (in sediments)	-	-	?	G	-	G	3	3	0	3	3	2	3	0	3
MSFD	D9 Contaminants in seafood (in biota)	-	-	M?	P	-	P	3	3	0	3	3	2	3	0	3
MSFD	D10 Marine litter	-	-	P	P	-	P	0	0	0	3	2	0	3	0	2
MSFD	D11 Energy, including underwater noise	-	-	P	P	-	P	2	0	0	2	3	3¤	2	0	0
BD	Birds - migratory	-		-	-	-	?	0	0	0	0	0	2^	0	0	0
BD	Birds - resting	-	-	-	-	-	?	1	2	0	3	0	2	1	0	0
HD	Bats	-	-	-	-	-	G*	0	0	0	0	0	2	0	0	0

Activity effect level
0 - not relevant/no data
1 - no effect
2 - some/moderate effect
3 - potentially large effect

5.2 Kattegat windfarm and adjacent waters

The assessments of the environmental state of the Kattegat area are listed in table 5.3 Most state and pressure descriptors are in poor or moderate state. The descriptor Seabed integrity is evaluated as being in bad state.

Information on the impact of important human activities on the descriptors from the regional assessments is also presented in table 5.3. The effects of most activities are known.

Although several activities are rated as having a large or some effect on the descriptors, the activity may not be relevant within the specific area around the Kattegat (II) wind farm area. The following highlights the important activities relevant for the farm area and the adjacent waters.

Aggregate extraction: There are some existing extraction sites in the area around the planned farm area. Larger potential sand and gravel extraction areas also occur in the area. Information is available at https://miljoegis.mim.dk/cbkort?profile=miljoegis-raastofferhavet. Dredging, which is also included in this activity, is not relevant. Dredging near harbours may reintroduce buried pollutants affecting descriptors D8 and D9. Except for those two descriptors, we find consideration of the rating of effects relevant.

Agriculture, **wastewater**: The effects relate to different eutrophication processes and the distribution and accumulation of toxic substances.

Aquaculture: Aquaculture with fish is not an activity in the offshore area of Kattegat. Some test farms of mussels and seaweed exist or will be established in the near future in the surrounding area.

Fishery: Fishery is a highly relevant activity. Bottom-contacting gear affects the seabed and thereby its benthic habitats and associated communities. Exploitation of fish stocks and the resulting impact of benthic communities affect the food web. Disturbance, by-catch and competition for resources by birds and mammals are also effects of fishery.

Oil and gas exploitation: Not a relevant activity for Kattegat.

Renewable energy: Highly relevant as the wind farms themselves constitute an important activity that affects several descriptors with potential large effects on seabed integrity (loss), benthic habitats (biodiversity) and the food web. New constructions might promote the introduction of non-indigenous species, and the effect of this might be non-reversable in natural habitats. Mammals may be affected during the construction phase, and potentially during operation as well, by noise. The area is expected to have moderate importance for migrating birds. For species or individuals flying at levels of collision risk, this may pose a threat. Displacement from feeding grounds may occur for razorbill and common guillemot and, to a lesser degree, for diver species. Northern gannets and kittiwakes may also occur in high numbers. Divers are present in the area, primarily red-throated diver and, in less numbers, black-throated diver.

The inner Danish waters generally have high densities of harbour porpoises, and the Kattegat windfarm area is within travelling distance of the important seal haul-outs at Anholt, Hesselø and Bosserne.

Bats have been recorded incidentally on the Danish islands in the Kattegat in the late summer-autumn period (e.g. *Vespertilio murinus* and *Nyctalus noctule)*, which indicates migration across the Kattegat. There is no systematic data on the intensity of the migration. Wind farms off the coast of Djursland could potentially have negative effects on the sub-populations migrating across the southern Kattegat.

Shipping: Shipping generates underwater noise that disturbs marine mammals. Shipping corridors may displace marine mammals from certain areas.

Recreational activity: Not relevant offshore.

Table 5.3. Assessments of the environmental state of different descriptors according to the MSFD, the Habitats Directive (HD) in relation to marine N2000 areas and the Birds Directive (BD) for the OWF area Kattegat. For each descriptor, we have ranked a selection of relevant human activities with documented effects on the pressures affecting the descriptors. The ranking includes four levels: 0 – not relevant/no data; 1 – no effect; 2 – some/moderate effect; 3 – potentially large effect. The level of importance for each activity is based on recently published reports (see chapter 2) and expert-based judgements. The "overall" column (assessment) is a DCE-weighted assessment. B=Bad, P=Poor, M=Moderate, G=Good H=High.
*For bats, the assessment is an expert judgment that is not based on EQR or similar indexes.
¤ For marine mammals and underwater noise the assessment of renewable energy pertains to the construction phase, whereas the effect level during operation is assessed to be "some/moderate effect.
^ For birds the collision risk is expected to be higher during the operational phase than during the construction phase.

Directive	Descriptors	Assessments						Relevant activities								
		HD N2000	BD 2019	DK MSFD (2019)	QSR 2023	HOLA SIII	Overall assessment	Aggregates extraction	Agriculture	Aquaculture	Fisheries	Oil and gas	Renewable energy (OWF)	Shipping	Recreational activities	Waste water
MSFD	D1 Biodiversity – fish	-	-	P	P	P	P	2	2	2	3	0	2	1	2	2
MSFD	D1 Biodiversity - marine mammals	U	-	M	G	B	M	0	2	2	3	0	3¤	3	3	2
MSFD	D1 Biodiversity – pelagic habitats	-	-	M?	P	M	M	2	3	2	2	0	3	2	2	3
MSFD	D2 Non-indigenous species	-	-	P	M	B	P	0	0	3	1	0	3	3	2	0
MSFD	D3 Commercial fish and shellfish	-	-	P?	B	P	P	2	2	2	3	0	3	2	2	2
MSFD	D4 Food webs/D1 Biodiversity - ecosystems	-	-	M?	M?	P?	P	3	2	2	3	0	3	2	2	2
MSFD	D5 Eutrophication	-	-	G	P	M	M	2	3	2	2	0	2	2	1	3
MSFD	D6 Seabed integrity/D1 Biodiversity - benthic habitats	-	-	P	B	M	B	3	3	2	3	0	3	2	2	3
MSFD	D7 Hydrographical changes	-	-	P	?	?	P?	2	0	0	0	0	2	2	0	0
MSFD	D8 Contaminants (in sediments)	-	-	?	?	P	P	3	3	2	3	0	2	3	2	3
MSFD	D9 Contaminants in seafood (in biota)	-	-	M?	P	P	P	3	3	2	3	0	2	3	2	3
MSFD	D10 Marine litter	-	-	P		P?	P	0	0	3	3	0	0	3	3	2
MSFD	D11 Energy, including underwater noise	-	-	P	M?	B	P	2	0	1	2	0	3¤	2	2	0
BD	Birds - migratory	-	-	-	-	-	?	0	0	0	0	0	2^	0	0	0
BD	Birds - resting	-	-	-	-	-	?	1	2	0	3	0	2	1	3	0
HD	Bats	-	-	-	-	-	M*	0	0	0	0	0	3	0	0	0

Activity effect level
0 - not relevant/no data
1 - no effect
2 - some/moderate effect
3 - potentially large effect

5.3 Kriegers Flak and adjacent waters

Table 5.4 presents the assessments of the environmental state of the western Baltic. All state descriptors and most pressure descriptors are in poor or moderate state.

Information on the impact of important human activities on the descriptors from the regional assessments is also presented in table 5.4. The effects of most activities are known.

Although several activities are rated as having a large or some effect on the descriptors, the activity may not be relevant within the specific area around the two planned Kriegers Flak II wind farms. The following highlights the important activities relevant for the farm area and the adjacent waters.

Aggregate extraction: Extraction of sand and gravel has taken place at Kriegers Flak, and reservation has been made for new extraction according to information available at https://miljoegis.mim.dk/cbkort?profile=miljoegis-raastofferhavet.

Dredging, which is also included in this activity, is not relevant. Dredging near harbours may reintroduce buried pollutants affecting descriptors D8 and D9. Except for those two descriptors, we find consideration of the rating of effects relevant.

Agriculture, **wastewater**: The effects relate to different eutrophication processes and the distribution and accumulation of toxic substances. Large-scale effects in terms of regular events of anoxic water masses occur at deeper water east of the shallow Kriegers Flak (Iltsvind i den danske farvande i oktober - november 2019 (au.dk)

Aquaculture: There are no commercial activity in the adjacent waters around Kriegers Flak. However, test cultures of line mussels and seaweed are to be established in the existing OWF area.

Fishery: Fishery is a highly relevant activity although it seems decreasing in the area, likely due to lack of exploitable resources. Bottom-contacting gear affects the seabed and thereby the benthic habitats and associated communities. Exploitation of fish stocks affects benthic communities and the food web. Disturbance, by-catch and competition for resources by birds and mammals are also effects of fishery.

Oil and gas exploitation: Not relevant for the western Baltic Sea.

Renewable energy: Highly relevant as the farm itself constitutes an important activity that affects several descriptors with potential large effects on seabed integrity (loss), benthic habitats (biodiversity) and the food web. New constructions may promote introduction of non-indigenous species, and the effect of this will be non-reversable in natural habitats. Mammals are disturbed during the construction phase, and perhaps during operation as well, by noise. The western Baltic Sea is situated on the annual migration route of many Scandinavian and NW-Russian bird populations. About half a billion individuals of more than 200 species are estimated to cross the western Baltic Sea during autumn migration, and around half of these also cross the area in spring (BSH 2021). Most of the birds are passerines such as warblers, thrushes,

and finches, many of which migrate during night (BSH 2021). Some of the bird populations are of international conservation interest, e.g. some raptors and common crane that have been identified as focal species in the area (Skov et al. 2015). The Kriegers Flak area is known to have concentrations of migrating and resting long-tailed ducks, which is the dominant duck species in the area. This species feed at water depths of up to ca. 25 metres. Red-throated diver and black-throated diver occur in the area in moderate numbers, mainly on passage during the spring and autumn migration.

Harbour porpoises, harbour seals and grey seals are known to use the Kriegers Flak area (Dietz et al. 2015).

There is significant migration of bats across the western Baltic Sea and eastern Denmark (Ahlén 1997, Ahlén et al. 2009, Rydell et al. 2014, Seebens-Hoyer et al. 2021). These bats may represent a significant proportion of the breeding populations in Sweden and Finland (Kruszynski et al. 2020). Species like *Nyctalus noctula*, *N. leisleri*, *Pipistrellus nathusii, P. pygmaeus*, V*espertilio murinus*, *Myotis dasycneme* and *M. daubentonii* have been recorded in significant numbers (Ahlén et al. 2009, Seebens-Hoyer et al. 2021). *Pipistrellus pipistrellus*, *Plecotus 33uratus, Myotis nattereri, M. brandtii/mystacinus* and *Barbastella barbastellus* may also migrate or forage over the Baltic Sea (Ahlén 1997, Ahlen et al. 2009).

Shipping: Shipping generates underwater noise, which is disturbing to marine mammals. Shipping corridors may displace marine mammals from certain areas.

Recreational activity: Not relevant offshore.

Table 5.4. Assessments of the environmental state of different descriptors according to the MSFD, the Habitats Directive (HD) in relation to marine N2000-areas and the Birds Directive (BD) for the OWF area Kriegers Flak. For each descriptor, we have ranked a selection of relevant human activities with documented effects on the pressures affecting the descriptors. The ranking includes four levels: 0 – not relevant/no data; 1 – no effect; 2 – some/moderate effect; 3 – potentially large effect. The level of importance for each activity is based on recently published reports (see chapter 2) and expert-based judgements. The "overall" column (assessment) is a DCE-weighted assessment. B=Bad, P=Poor, M= Moderate, G=Good H=High.

*For bats the assessment is an expert judgment that is not based on EQR or similar indexes.

¤ For marine mammals and underwater noise the assessment of renewable energy pertains to the construction phase, whereas the effect level during operation is assessed to be "some/moderate effect.

^ For birds the collision risk is expected to be higher during the operational phase than during the construction phase.

		Assessments						Relevant activities								
Directive	Descriptors	HD N2000	BD 2019	DK MSFD (2019)	QSR 2023	HOLA SIII	Overall assessment	Aggregates extraction	Agriculture	Aquaculture	Fisheries	Oil and gas	Renewable energy (OWF)	Shipping	Recreational activities	Waste water
MSFD	D1 Biodiversity - fish	-	-	P	-	P	P	2	2	2	3	0	2	1	2	2
MSFD	D1 Biodiversity - marine mammals	U	-	B?	-	P	P	0	2	2	3	0	3	3	3	2
MSFD	D1 Biodiversity – pelagic habitats	-	-	M?	-	M	M	2	3	2	2	0	3¤	2	2	3
MSFD	D2 Non-indigenous species	-	-	P	-	B	P	0	0	3	1	0	3	3	2	0
MSFD	D3 Commercial fish and shellfish	-	-	P?	-	P	P	2	2	2	3	0	3	2	2	2
MSFD	D4 Food webs/D1 Biodiversity - ecosystems	-	-	M?	-	P?	P?	3	2	2	3	0	3	2	2	2
MSFD	D5 Eutrophication	-	-	P	-	P	P	2	3	2	2	0	2	2	1	3
MSFD	D6 Seabed integrity/D1 Biodiversity - benthic habitats	-	-	P	-	P	P	3	3	2	3	0	3	2	2	3
MSFD	D7 Hydrographical changes	-	-	P	-	?	P?	2	0	0	0	0	2	2	0	0
MSFD	D8 Contaminants (in sediments)	-	-	M?	-	B	B	3	3	2	3	0	2	3	2	3
MSFD	D9 Contaminants in seafood (in biota)	-	-	M?	-	P	P	3	3	2	3	0	2	3	2	3
MSFD	D10 Marine litter	-	-	P	-	P?	P?	0	0	3	3	0	0	3	3	2
MSFD	D11 Energy, including underwater noise	-	-	P?	-	B	B	2	0	1	2	0	3¤	2	2	0
BD	Birds - migratory	-	-	-	-	-	-	0	0	0	0	0	2^	0	0	0
BD	Birds - resting	-	-	-	-	-	-	1	2	0	3	0	2	1	3	0
HD	Bats	-	-	-	-	-	P*	0	0	0	0	0	3	0	0	0

Activity effect level
0 - not relevant/no data
1 - no effect
2 - some/moderate effect
3 - potentially large effect

6 Discussion and summary

In this report, we evaluated the environmental status in three selected areas (North Sea I, Kattegat and Kriegers Flak II) where OWFs are expected to be established. Our assessment of environmental status was based on several relevant descriptors, involving 11 MSFD descriptors, supplemented with descriptors for bats and birds reported under the Habitats and Birds directives, respectively. Our evaluations are based on published assessments made available through regional sea conventions (OSPAR and HELCOM from 2023), the most recent Danish MSFD assessment (from 2019), assessments undertaken within the frameworks of the Habitats Directive (marine mammals and bats) and the Birds Directive (marine birds) as well as knowledge gained via the Danish national monitoring programme NOVANA and other surveys and research on these animal groups.

In addition to the assessments, we evaluated the importance of eight human activities, including renewable energy, where OWF is a major component. The human activities exert pressures on the environmental status in various ways, and for each activity, we assessed its importance for one or several of the MSFD descriptors using the available information.

Based on the selected descriptors, we overall found that the environmental status in all three OWF areas fell within the categories of poor to moderate, with a few exceptions of good status. Comparing the three areas, we found support for an overall slightly better environmental status in the North Sea area. For the bird descriptors, we did not elaborate a status assessment as such an assessment depends significantly on the selected bird species, rendering a general assessment across all birds meaningless. For bats, the assessment provided represents the most sensitive and exposed species to wind turbine mortality.

Although our status assessments are generally based on published reports, they are associated with great uncertainty. For some of the descriptors, a GES indicator has not yet been developed, and we consequently had to convert available assessments into the existing GES categories. Also, often no local data or assessments were available, and we therefore had to apply an assessment developed for a much larger geographical area. Given this uncertainty, it is important to emphasise the fact that the assessments made in this report cannot be used as an environmental assessment in future projects evaluating the impact of OWF establishment. Thorough area-specific assessments using recognised monitoring and reporting schemes are required for this purpose.

The importance of human activities was evaluated based on OSPAR and HELCOM reports as well as recent MSFD documentation. In addition, we used our scientific expertise on activities in the few cases where assessments were not available. If we could not find documentation of the importance of an activity, and if we had no prior knowledge of its importance, we used the assessment "no or unknown effect" as compared to situations where we did have some data at our availability but assessed that there were no effects. To evaluate differences in the importance of activities in the three areas (North Sea, Kattegat and Kriegers Flak), we made an overall decision about the relevance of the individual activity in the given area. As an example, recreational

activity was assumed to be negligible in the North Sea area (due to long distance from land) and oil and gas production activities to be absent in the areas of Kattegat and Kriegers Flak. A more detailed analysis of the importance of a given activity for a given descriptor is a highly comprehensive task. The management of natural resources tends to focus on controlling single stressors to achieve broad management goals such as biodiversity conservation and sustainable resource use.

In reality, multiple stressors operate simultaneously, generating cumulative impacts (Halpern & Fujita 2013). It is thus possible that the same level of a given activity (e.g. renewable energy) has a greater importance for/exerts a greater pressure on a given descriptor (e.g. D1 Fish diversity) in the Kattegat region compared to the North Sea. The reason for this is that the importance of a given pressure depends on the extent of multiple pressures in a given area (Halpern & Fujita 2013). Consequently, the current assessment of the importance of an activity should be taken as a preliminary rough assessment, which ideally should be supported by a more detailed analysis, optimally involving new data and allowing a direct comparison between the selected areas of interest.

Regardless of these reservations, our rough assessment of the importance of human activities highlighted that many of the eight chosen activities are likely to have a significant importance for/impact on several of the environmental descriptors. Also, renewable energy, including OWF, appeared as one of the most relevant and potentially most important activities by exerting multiple negative effects on several of the described environmental indicators.

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8 Annexes

Environmental status for the North Sea area and the Baltic Sea area assessed in 2019 according to the 11 descriptors in the Marine Strategy Framework Directive.

Descriptor		North Sea	Baltic Sea
D1	Biodiversity (marine mammals)	Good environmental status for marine mammals corresponds to favourable conservation status under the Habitats Directive. Good environmental status has been achieved for harbour seal. Grey seal populations are increasing but did not achieve good status in 2013. The population of harbour porpoises in the North Sea is stable. Knowledge about bycatch is limited, especially for seals, but by-catch for harbour porpoise is deemed to be less than 1% of the population.	Good environmental status for marine mammals corresponds to favourable conservation status under the Habitats Directive. Good environmental status has been achieved for harbour seal. Grey seal populations are increasing but did not achieve good status in 2013. The population of harbour porpoise in the Danish Straits is stable, whereas the population in the Baltic Sea is seriously endangered. Knowledge about by-catch is limited, especially for seals, but by-catch for harbour porpoise in the Danish Straits population is deemed to be less than 1% of the population.
D1	Biodiversity (fish that are not exploited commercially)	The status for fish that are not exploited commercially has been assessed based on 14 selected species. In relation to fish mortality, a little less than1/4 of the examined populations have good status. In relation to population density, just under half of the examined populations have good status.	Only one species on the list of the 14 species, starry ray (*Amblyraja radiata*), exists in the Baltic Sea (the western part). It is caught in trawl fishing but is only rarely landed, and the historical trends in catches are therefore unknown. The status for coastal fish (flounder and eelpout) is assessed as not good.
D1	Biodiversity (pelagic habitats)	Overall, the phytoplankton biomass declined steadily in the North Sea, Kattegat, the Danish Straits and in the Baltic Sea from 1978 to 2016 – although most significantly in the Baltic Sea. There is a slight increase after 2012 in both regions. There is not enough data on zooplankton to assess the development.	
D2	Non-indigenous species	New non-indigenous species are still being registered in both the North Sea and the Baltic Sea. It is not likely that a drop in new introductions of non-indigenous species can be achieved before international interventions such as the United Nations Ballast Water Management Convention start to have an effect. In general, there is insufficient data, but it is likely that good environmental status has not been achieved in the Baltic Sea or the North Sea.	
D3	Commercially exploited fish stocks	The environmental status for commercially exploited fish stocks is generally considered not good. The assessment was carried out for 22 selected stocks of fish, crustaceans and shellfish. Ten stocks have good status, but the status for eight of the stocks is not good.	The environmental status for commercially exploited fish stocks is generally not considered good. The assessment was carried out for six selected stocks of fish, crustaceans and shellfish in the Baltic Sea. Two stocks have good status, but the status for three of the stocks is not good.

Descriptor		North Sea	Baltic Sea
D4	Marine food webs	Marine food webs are assessed on the basis of organisms that represent different levels in the food web, i.e. plankton, fish, birds and marine mammals. Species diversity for plankton was calculated, where possible. Trends for the biomass of plankton, fish, birds and mammals have been presented. The general picture for several of the indicators assessed is a slight increase in biomass in recent years. For birds, the picture is more mixed. Phytoplankton biomass decreased steadily from 1978-2012, after which there was a slight increase. Despite assessments of the individual sub-components in the food web, it is not possible to assess whether the food web as a whole will have good environmental status in 2020.	
D5	Eutrophication	With regard to eutrophication, the status is good in the open Danish marine areas located far from the coast in the North Sea, including the Skagerrak. However, good status has not yet been achieved in the open marine areas closer to the coast, and none of the coastal areas have met their targets.	For eutrophication, the status is generally not good in the Danish marine areas in the Baltic Sea, including the Danish Straits and Kattegat. However, there are positive signs as good environmental status has been achieved in Kattegat for total nitrogen, chlorophyll *a* and water transparency; in the Great Belt for total nitrogen and total phosphorus and in the Sound for water transparency. Targets have been met in two coastal areas in the Baltic Sea.
D6	Seabed integrity/ D1 Biodiversity – benthic habitats	The seabed in Denmark is intensively utilised, with disturbance rates of around 85% in the North Sea and 67% in the Baltic Sea. Total losses are about 1% for the North Sea and the Baltic Sea, respectively, but for some habitat types, losses are high. Data from stone reefs and the soft seabed in open waters shows that light penetration in the sea has improved, and this optimises the conditions for benthic species. No threshold values for good status have yet been set, but on the basis of the above statistics, it is likely that the seabed status is not good in terms of disturbance or in terms of losses for some habitat types.	
D7	Alteration of hydrographical conditions	Permanent alteration of hydrographical conditions has been identified in both the water column and on the seabed. The adverse effects of these changes are assessed to be insignificant. The greatest impact per habitat type occurs on infralittoral mixed sediments, infralittoral rocks and biogenic reefs.	Permanent alteration of hydrographical conditions has been identifed in both the water column and on the seabed. The adverse effects of these changes are assessed to be insignificant. The greatest impact per habitat type occurs on infralittoral mixed sediments.
D8	Contaminants (concentrations and species health)	Outside territorial waters, there is generally good environmental status for the substances PFOS and Benzo(a)pyrene. Good environmental status has not been achieved for either mercury or the group of brominated flame retardants. Moreover, the content of both these substances in fish has increased over recent years. There are higher levels of TBT in several places, in particular around shipping lanes and in ports and harbours in the Baltic Sea and Kattegat. Levels of deformed young eelpout have increased, which indicates an environmental impact.	
D8	Contaminants (acute pollution events)	Good environmental status cannot be assessed for acute pollution events in the North Sea as there are large annual variations over the period for oil and chemicals spills from oil and gas installations. Therefore, it is not possible to derive a trend over the years.	Generally, there is a decrease in both the numbers and volumes of registered illegal oil spills from ships in the Baltic region. Several of the assessed sub-basins comply with the threshold values set. Therefore, it is likely that good environmental status will partly be achieved in 2020 in the Baltic region.

D9	Contaminants in fish and other seafood for human consumption.	There is good status regarding concentrations of the heavy metals lead, cadmium, mercury as well as benzo(a)pyrene in fish and other seafood for human consumption. There are, however, too high concentrations of dioxins and PCB in mackerel, cod liver and salmon. Because of excessive concentrations, there is a ban on selling specific fish of a certain size caught in the Baltic Sea.	
D10	Marine litter	Basically, litter should not be found in nature, and therefore it is assessed that there is currently too much litter in the marine environment. Primarily because of currents, marine litter is a particular problem on beaches along the west coast of Jutland, and plastic is the dominant litter type. The highest levels in 2015 were on Skagen beach. During 2012-2016, 95% of fulmar (bird) had plastic in their stomach, while microparticles were found in 20-30% of the fish stomachs examined.	
D11	Underwater noise	A 2015 analysis shows that noisy activities with impulse sound occurred in the North Sea and the northern part of Kattegat. The sound level is high enough to have a harmful effect. The majority of Danish marine areas were affected by impulse noise for less than 10 days. Continuous low-frequency sound has not been surveyed in the North Sea.	The level of continuous low-frequency sound is highest around the major shipping routes. Several of the major shipping routes overlap with habitats for Danish harbour porpoise populations and cod spawning areas. It is uncertain whether this noise has a significantly adverse effect on stocks. Impulse sound has not been surveyed in the Baltic Sea.

ASSESSMENT OF ENVIRONMENTAL PRESSURES AND STATE IN RELATION TO THREE DANISH OFFSHORE WIND FARMS

This report is a catalogue prepared for the Danish Energy Agency with focus on describing the ecological conditions and pressure factors in the waters in and around the three planned offshore wind farms: North Sea I, Kattegat and Kriegers Flak II. The catalogue is intended for use as inspiration in future tenders for the three farms where a "nature inclusive design" can be used to remedy the general environment and the state of nature in the area.

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