Coexistence of offshore wind power with commercial fishing, aquaculture and nature conservation

A synthesis of knowledge about preconditions and measures

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Coexistence of offshore wind power with commercial fishing, aquaculture and nature conservation

A synthesis of knowledge about preconditions and measures

This report was prepared by the Swedish Agency for Marine and Water Management and the Swedish Energy Agency.
These agencies are responsible for the content and conclusions of the report.

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Preface

A safe and secure energy supply is the basis for any well-functioning modern society. Russia's war of aggression against Ukraine has clearly demonstrated the vulnerability of the European fossil-based energy system. The major challenges we face involve accelerating the transition to fossil-free electricity supply and meeting the growing demand for electricity in the future. Given the many major industrial and electrification initiatives planned from north to south in our country, all signs point to a substantial increase in electricity demand by 2045. Offshore wind power will play an important role in both the energy transition and the ongoing electrification process.

At the same time, marine ecosystem services are threatened by climate change and other human pressures such as eutrophication, hazardous substances, increased transport, some recreational activities and, in many cases, excessive exploitation through fishing. According to the in-depth evaluation of the milestone targets which the Swedish Environmental Objectives Council reported to the Government in 2023, the Environmental Quality objective *A Balanced Marine Environment, Flourishing Coastal Areas and Archipelagos* will not be achieved by 2030.

Offshore wind power also has an impact on our marine areas and may come in conflict with other societal needs. The solution is coexistence between the different legitimate interests. The conflicts of interest we now see emerging between offshore electricity generation and other industries and interests need to be balanced and resolved. This report highlights the need for the development and operation of offshore wind power to be well planned, taking into account ecological, economic and social needs. It also highlights the relevance and need for cooperation, adaptability and responsiveness.

We also point out that there are synergies which can be achieved between offshore wind power and other interests, if coordinated planning takes place. Co-location with aquaculture, for example, could lead to improved security of supply of both electricity and marine food. We are convinced that coexistence between different interests can not only strengthen Sweden in a variety of ways, but also strengthen the valuable marine ecosystem services.

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Summary

In February 2022, the Swedish Agency for Marine and Water Management (hereinafter SwAM) and the Swedish Energy Agency (hereinafter Energy Agency) were tasked by the Government of Sweden with compiling a knowledge synthesis of the possibilities and preconditions for coexistence of offshore wind power with commercial fishing, aquaculture and nature conservation. The agencies have interpreted the assignment as referring to coexistence in the same location, highlighting in particular the importance of and prerequisites for adapting the different activities. This final report is based on a review of literature and projects, an analysis of navigational safety conditions, exchanges of experiences with other countries and dialogue with Swedish authorities and stakeholders.

Offshore wind power

The increasing demand for electricity is increasing interest in developing new offshore wind power. As a result, wind power's claims on marine space have also increased, which could lead to conflicts with existing uses. The impacts of offshore wind power and the conditions for coexistence differ between the construction, operation and decommissioning phases, and are dependent on factors such as the choice of technology and type of installation. The rapid technological development that characterises offshore wind power creates both opportunities and challenges for coexistence, and there are currently several uncertainties that remain to be resolved.

The regulatory framework applicable to the establishment of offshore wind power is extensive and complex, particularly in terms of regulating its environmental impacts. At the same time, there are no regulations explicitly aimed at coexistence with other activities. Both in Sweden and other countries, there is limited experience in testing co-location of activities in offshore wind farms.

For offshore wind power, the lack of predictability in the permitting process is an important challenge both for the state and the developer in terms of enabling coexistence while promoting new electricity generation. The planning and establishment system for offshore wind power that is currently in place in Sweden is limited in its ability to steer the expansion of offshore wind power in terms of the cumulative effects on the environment and other activities. More broadly, the system is ill-suited to promote coexistence at a more strategic level. This report presents arguments for a revised establishment system with stronger state steering and control of where offshore wind power may be located. The arguments highlight factors such as the potential for improved steering based on benefits for the electricity system, for better coexistence with other uses and assessment of cumulative effects, as well as for greater control over the pace of establishment and knowledge gathering.

Coexistence between offshore wind power and commercial fishing

The potential for coexistence between offshore wind power and commercial fishing differs depending on the fishing method, the type of wind park and the environmental conditions in the area. Coexistence with fishing with active gear is largely untested and is considered difficult or very difficult, mainly due to the associated safety risks. The current knowledge of opportunities and obstacles is largely based on experiences from older installations. The conditions for coexistence in future wind farms are judged to be better, although opinions vary.

To date, the vast majority of countries have not planned for offshore wind in the most valuable fishing areas. This may be about to change in some countries, as governments are beginning to realise that conflict-free areas are not sufficient to meet offshore electricity generation targets. In Sweden, where there are wind power projects in some of the country's most valuable fishing grounds, two recent draft permits have proposed measures requiring the development of coexistence solutions. Coexistence is one of the fundamental objectives of Swedish marine spatial planning, and it is primarily within the framework of marine spatial planning that trade-offs between competing activities should be made.

Where the coexistence of wind power and fishing is deemed possible, guidance on conditions may be relevant in terms of both the design of the wind park and the fishing activities. The focus should be on the safety and efficiency of both activities. The guidance may be of a general nature in marine spatial planning, and more detailed for the permit granting process. In the latter case, such guidance should contribute to uniform permit granting processes for future wind power projects. In the future, it may be necessary for the state to impose specific requirements regarding coexistence in certain areas. There is a need to investigate what opportunities the Swedish state has to impose such requirements within the existing wind power establishment system.

This report also highlights the need for a robust, quantitative analysis of navigational risks related to fishing within wind parks in Swedish waters. Opportunities and obstacles to insurance of fishing activities in wind parks also need further analysis, taking fishermen, fishing boats and wind park developers into account. Cooperation between the sectors is crucial for the development of mutually beneficial coexistence solutions, which is why continued support for dialogue between fisheries and wind power is important.

Coexistence between offshore wind power and aquaculture

Offshore aquaculture is a new and growing activity. Although the industry is still in its infancy, there is a growing awareness of its commercial potential. Coexistence with offshore wind power can provide an opportunity for aquaculture to establish itself offshore and could lead to more efficient utilisation of wind power areas. At present, there is a very small number of combined aquaculture and wind power installations, all of which are at a research stage. There are currently no active facilities or license requests for offshore aquaculture in Swedish waters. Coexistence is currently hampered by a number of challenges relating primarily to the technology, operation and safety of combined installations, as well as to regulations, finances and insurance.

The coexistence of aquaculture and offshore wind power can benefit from explicitly identifying sites for multi-use during the planning process, as recently introduced by the Netherlands. This may be the case in Sweden in the future, based on the ambition in the 2021 Aquaculture Action Plan to identify suitable areas for offshore aquaculture. Future marine spatial plans could provide guidance on coexistence in such sites. Ultimately, it may also be necessary to develop criteria for the assessment of combined installations, possibly taking into account both environmental risks and benefits.

Continued support for the development of solutions of combined aquaculture and wind power installations is needed. Private actors play the most important role, but there is also scope for the state to support this development.

Coexistence between offshore wind power and nature conservation

The coexistence of wind power with nature conservation is strongly regulated in environmental legislation and concerns the assessment of permissibility in relation to conservation objectives. All countries, including Sweden, have extensive experience of environmental permitting of wind power. However, there are still significant knowledge gaps in knowledge about the impact of wind power on the marine environment, ranging from local impact on individual species to impact on populations at the sea basin level. The effects are often site-specific, which makes it more difficult to draw general conclusions about where and how coexistence may be possible.

In most other countries, the state has steered offshore wind power away from protected areas and areas with particularly valuable species and habitats through marine spatial planning. Permit decisions are usually preceded by a site-specific assessment of whether the effects of wind power are within or above acceptable thresholds. There are currently no fixed threshold values for most effects, and decisions are instead based on the estimated impact on the conservation status of species and habitats. Clear assessment criteria for both effects and mitigation measures facilitate a uniform assessment of wind power and create predictability for both the permit review bodies and developers.

For the establishment of offshore wind power in protected areas, the permitting process is even more complex and time-consuming, which increases the unpredictability and investment risks for the wind developer. To accelerate the development of offshore wind power, it may be necessary to divert wind power from protected areas or areas with protected species and habitats in the maritime spatial planning process. At a strategic level, it is also important to address future heightened marine protected area targets in the European Union Biodiversity Strategy.

The coexistence of offshore wind power and nature conservation is hampered by a lack of knowledge about the environmental effects of wind power. Knowledge acquisition programmes are important in order to gradually develop robust assessment criteria for assessing wind power projects and develop conditions for construction and operation. It is important that the state collaborates with the wind power industry and academia to develop such a programme, taking inspiration from the experience of other European countries.

Nature-inclusive design in or adjacent to wind power foundations is driven by the wind developers themselves based on the ambition for offshore wind parks to have a net positive contribution to the environment. The way in which the designs should be assessed and their actual environmental effects need to be clarified in order to assess whether they can help to make coexistence between offshore wind power and nature conservation more feasible.

Content

1 Content and preparation of the assignment

This introductory chapter summarises the background to and the agencies' interpretation of the assignment and presents the definition of coexistence used in the assignment. The method used in the assignment is described in section 1.1.

The Swedish Agency for Marine and Water Management (hereinafter SwAM) and the Swedish Energy Agency (hereinafter Energy Agency) were tasked by the Government of Sweden with compiling a knowledge synthesis of conditions and possible measures for future coexistence of offshore wind power with commercial fishing, aquaculture and nature conservation in areas intended for wind power establishment. The agencies have interpreted the scope of the assignment as primarily concerning co-location, in the sense of coexistence of two or more interests in the same geographical location. The purpose of the delimitation is to approach the subject in a clearer way and highlight the opportunities and obstacles that exist with having multiple interests in the same place. The report therefore does not delve deeply into the possibilities for relocation of interests to another place, where possible.

Definition of coexistence used in this assignment: The ability of one or more interests to share marine space while avoiding significant harm to any of these interests.

Adaptations that may enable coexistence include restrictions to operations, technical solutions, and the positioning of fixed installations in such a way that other interests do not suffer significant harm. Successful coexistence requires good planning and consideration of ecological, economic and social needs, and can create synergies at the site.

The development of renewable energy is an important part of the work to achieve the climate and energy targets set by the Swedish Parliament. The expansion of offshore wind power can make a major contribution to the development of fossil-free energy within the Swedish energy system. The possibilities for generating 90 TWh annually from offshore wind power are being investigated in an ongoing assignment on new areas for energy production in the marine spatial plans (MSPs) (M2022/00276; Figure 1). The MSPs adopted by the Government in February 2022 estimate that a further 20–30 TWh are realisable (M2019/02217).

Promoting collaborative solutions is an important element in enabling additional areas for offshore energy production in the MSPs. This is done by resolving the conflicts that may constitute obstacles to offshore energy. Such conflicts include, in no particular order, commercial fishing, nature conservation, defence, cultural values, shipping, recreation and outdoor activities. This knowledge synthesis can inform future planning and permitting processes for offshore wind power.

The coexistence of offshore wind power and nature conservation differs from its coexistence with commercial fishing and aquaculture. Nature conservation has a number of statutory requirements that need to be met in order to be considered sufficient. For commercial fishing and aquaculture, the issue instead lies in balancing the priorities of different industries. Compensatory measures also differ between these different interests. This report discusses the possibilities for financial compensation for lost fishing opportunities, but not ecological compensation for lost natural values.

In particular, the assignment includes wind park design, adaptation of fishing activities, and measures to minimise damage to or promote biodiversity and ecosystem services. Specific

attention is paid to wind power technology development and type of wind power installations, which include fixed-bottom and floating foundations, larger turbines spaced at greater distances, and the potential benefits of nature-based solutions. Experiences from other countries were gathered and compiled. In the course of the assignment, SwAM and the Energy Agency have had a dialogue with the Swedish Environmental Protection Agency, the Swedish Board of Agriculture, the Swedish Transport Agency, and the county administrative boards, in line with the mandate of the respective authorities. The assignment includes previous studies on the impact of wind parks on marine protected areas, in particular Natura 2000 sites, as well as on Natura 2000 habitats. In addition to a review of the literature and projects on coexistence, reviews of the legal and maritime safety conditions for coexistence were commissioned as part of the assignment. Previous studies carried out under the knowledge project Vindval and international examples were included in the analysis. Exchanges were held with sector representatives from Sweden in the implementation of the project. .

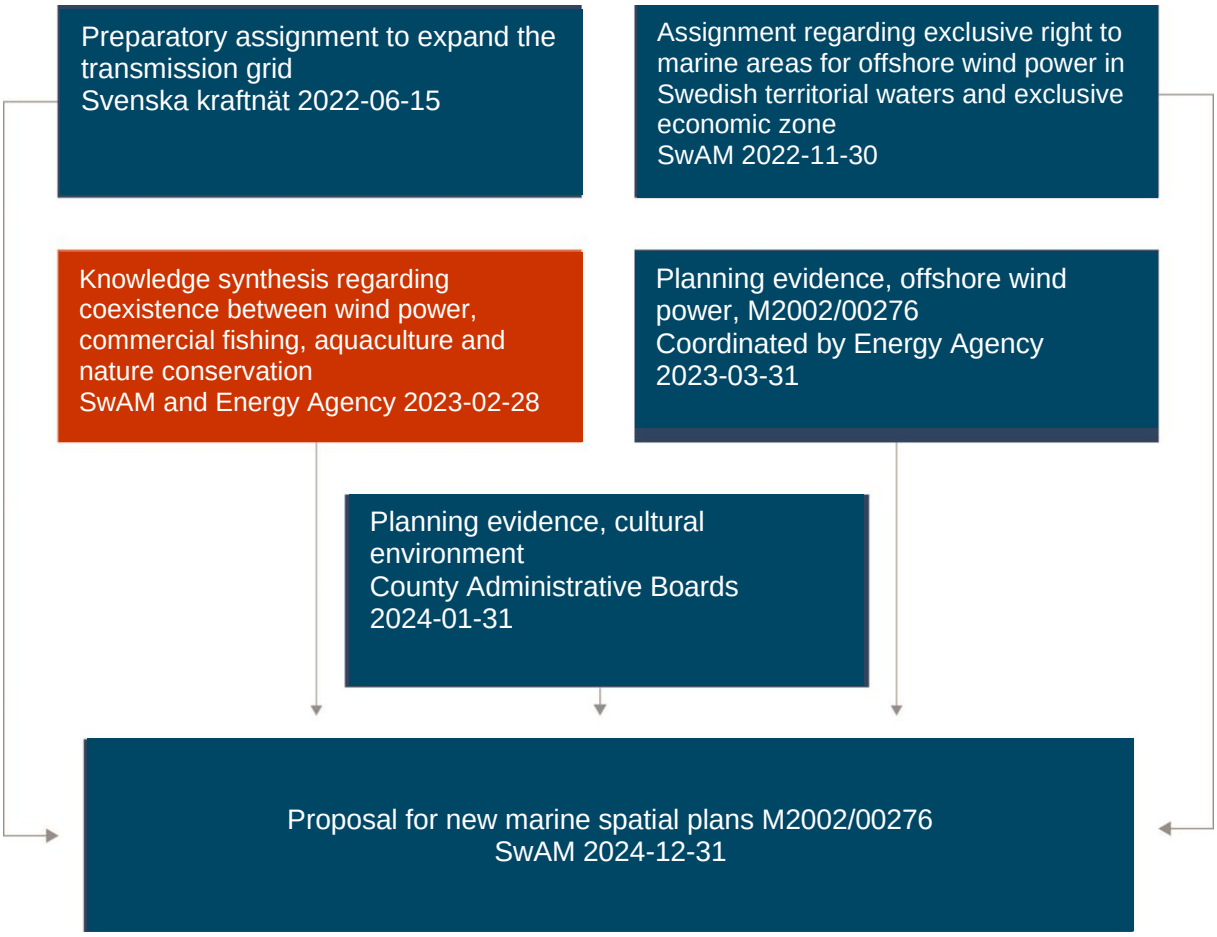

Figure 1 – The relationship between this assignment, in orange, and other government assignments related to the expansion of offshore wind power in Sweden, in blue. The assignment was preceded by an investigation into the expansion of the transmission grid in the territorial sea, which was finalised by Svenska kraftnät in June 2022, and an investigation into issues regarding exclusivity in the construction of offshore wind power, which SwAM reported on 30 November 2022. The assignment ran in parallel with and contributed to the assignment to identify areas for an additional 90 TWh of annual production. The assignment is coordinated by the Energy Agency and will be finalised on 31 March 2023. By the end of January 2024, the county administrative boards will report to the Government on their assignment regarding planning documents for cultural environmental values, carried out in collaboration with the Swedish National Heritage Board. All five of these assignments form the basis for the SwAM assignment to update the marine spatial plans, which is to be finalised by 31 December 2024.

1.1 Method

The assignment was carried out in three steps: 1. identification of knowledge gaps; 2. acquisition of new knowledge; and 3. collation and analysis of the new knowledge. The work was conducted jointly by SwAM and the Energy Agency.

1.1.1 Identification of knowledge gaps

The knowledge gaps that needed to be addressed were identified jointly by SwAM and the Energy Agency, and involved gathering input from stakeholders and an external outlook. The four dialogue authorities also provided their views on what the assignment should encompass. SwAM and the Energy Agency held a joint meeting in May 2022 to present the assignment and gather information from representatives of the wind power industry, commercial fishing, aquaculture and nature conservation. In the work to identify knowledge gaps, SwAM and the Energy Agency also participated in the Swedish Board of Agriculture's EU-funded dialogue forum with wind developers and commercial fishing producer organisations. The main knowledge gaps identified included the current status regarding coexistence and multi-use of marine areas in Sweden and abroad, national and international legal perspectives, and risks associated with fishing in offshore wind parks.

1.1.2 Acquisition of new knowledge

To cover the knowledge gaps, three studies were commissioned: a literature review conducted by the Swedish University of Agricultural Sciences (SLU), an analysis of the current legal framework conducted by the Swedish Institute for the Marine Environment (HMI), and an assessment of maritime safety of fishing vessels in offshore wind parks conducted by SSPA. In connection with the meeting with the stakeholder organisations in May 2022, SwAM and the Energy Agency also asked for input from each organisation, (see the questionnaire in Annex 1). In addition to the commissioned studies, the decision was also made to gather information from public authorities in other European countries that are more advanced in their development of offshore wind power. Knowledge exchanges took place with Marine Scotland (Scotland, video meeting), the Federal Maritime and Hydrographic Agency (BSH, Germany, study visit) and the Danish Maritime Authority (Søfartsstyrelsen), the Danish Energy Agency (Energistyrelsen) and the Ministry of Food, Agriculture and Fisheries (Ministeriet for Fødevarer, Landbrug og Fiskeri, Denmark, study visit). Within the assignment, dialogue was also conducted with the Norwegian Water Resources and Energy Directorate (Noregs vassdrags- og energidirektorat, NVE, Norway, visit) as part of the Directorate's cooperation with the Energy Agency.

During the knowledge compilation, the Swedish Board of Agriculture launched a dialogue forum for commercial fishing and wind power representatives to meet and discuss issues pertaining to coexistence. SwAM and the Energy Agency participated in the dialogue forum, both to acquire knowledge for this assignment and to contribute expert knowledge in their respective areas. Together with the information received from stakeholders following the stakeholder meeting in May 2022, inputs from the dialogue forum formed the basis for assessing how the organisations involved view the possibilities for coexistence.

1.1.3 Collation and analysis of new knowledge

The knowledge collected and generated in the studies and collected from dialogues with stakeholders and other authorities nationally and internationally was used to compile the current best knowledge. It was also used to analyse both the main obstacles and possible measures for

the coexistence of offshore wind power with commercial fishing, aquaculture and nature conservation.

2 Offshore wind power

This chapter starts with an overview of the development and importance of offshore wind power (section 2.1). It then continues with a description of regulations regarding protection of the marine environment and coexistence with other activities (section 2.2), and concludes with a presentation of wind power technology (section 2.3).

2.1 The development of offshore wind power

The construction of offshore wind power in Sweden began in the early 2000s. Despite this early start, development never gained traction, and fixed offshore installations are relatively rare in Swedish waters. Developers have instead focused on developing wind power on land, where the costs and risks have been lower. Some countries have a greater experience of fixed offshore installations, and thus also have more mature legislation on the matter. In the latest follow-up of the Swedish Maritime Strategy, the indicator *"sea-based energy production"* shows that the installed capacity of offshore wind power remained largely unchanged during the period 2014–2021 (SwAM, 2023, pp. 55–58). Interest in expanding offshore wind power in Swedish waters remained low until around 2021, when the number of applications increased. At the time of writing, three offshore wind parks have been granted permission to start construction, but none of these have set a start date as yet. A further seven projects have submitted permit applications, and another 35 have begun consultations (County Administrative Board, 2023). Although many of the projects overlap, according to the Swedish transmission system operator Svenska kraftnät, there are currently over 90 TWh annual production in permit applications. Several of these projects relate to or overlap with interests such as nature conservation or commercial fishing, or both. In the Swedish marine spatial plans, there are no areas designated for co-location of aquaculture and wind power, but one project has signed a letter of intent to investigate the possibilities for combined aquaculture and offshore wind power (OX2, 2022).

Offshore wind power is in a growth phase. It is difficult to accurately estimate the revenues from the electricity generated by an offshore wind power plant, as the parks have long-term Power Purchase Agreements (PPAs) that are not publicly available. Based on a qualified estimate, the selling price of the electricity from the current offshore wind power in Sweden lies within the range SEK 153–229 million. A more modern wind park with planned annual production of 5 TWh can generate an estimated SEK 3–3.7 billion annually.

At present, there are older offshore wind power plants in very limited areas in southern Sweden. Today, Sweden's largest offshore wind park is Lillgrund in the Sound, which was built in 2007. The wind park consists of 48 turbines with a hub height of 68.5 metres and a rotor diameter of 93 metres, giving a total height of 115 metres. The distance between the turbines at the site is approximately 300 metres (County Administrative Board, 2023). Today's offshore wind power has different spatial requirements than earlier parks, which poses a different kind of challenge for coexistence with other interests. The wind power currently being planned in Swedish waters can have a total height of over 300 metres, with turbines spaced at distances of up to 2 kilometres or more. It is now also possible to build offshore wind power at much greater depths than before. With the trend towards greater distances between turbines, areas are opening up within the wind parks. However, the total spatial demand is increasing, even though the footprint per turbine is still small. Much of the knowledge that exists regarding opportunities for coexistence is based on older wind park designs, where the parks are much more crowded and difficult to navigate, with more concentrated impact on the site.

The number of offshore wind projects has increased worldwide, with a large number of projects in Europe in particular. The renewable energy and climate neutrality targets of the European Union (EU) are one reason for the large number of projects, with the latest REpowerEU target being 45 per cent renewable energy in the EU by 2030 (European Commission, 2023). At the same time, Sweden's target is to have a 100 per cent renewable electricity system by 2040, and an electricity demand that is expected to increase significantly by 2045 (Swedish Energy Agency, 2023). Offshore wind power has the potential to be an important part of the future electricity system based on the three pillars of the Swedish energy policy: security of supply, competitiveness and sustainability. However, clear, predictable and legally certain legislation is needed for such development to materialise (SwAM, 2022c).

2.2 Legal requirements for coexistence with offshore wind power

In order to establish offshore wind power, a number of permits are needed from several different permitting authorities, depending on the design and the planned location of the park. Some of these permits will be briefly described here. The guiding principle is that establishment at sea and in other water bodies in Sweden often takes place outside of cadastral properties. Thus, there is no relationship with any property owner or ownership of the area. The permits regulate the conditions for permissibility and operations and thus the possibilities for coexistence.

In order to obtain a permit to survey the seabed prior to an application for the construction of offshore wind power, a permit is required under the Continental Shelf Act (1966:314). The Continental Shelf Act, in turn, refers to parts of the Environmental Code and the provisions on Natura 2000 permits. There is nothing preventing multiple developers from applying for and receiving survey permits for the same area at the same time. A given permit does not imply an exclusive right of use or disposal over the area in such a way that the holder can steer other activities in the licensed area.

Different regulations apply depending on where in Swedish waters a developer wants to apply to build offshore wind power. Within the territorial sea, which is part of Sweden, the Environmental Code is applied. The developer therefore needs a permit for environmentally hazardous activities (Chapter 9 of the Environmental Code) and water activities (Chapter 11 of the Environmental Code). Such permits are issued by the Land and Environment Court. In Sweden, the territory of coastal municipalities extends to the outer limit of the territorial sea. Hence, for installations in the territorial sea, a favourable opinion issued by the affected municipalities is also required under Chapter 16, Section 4 of the Environmental Code. Wind power that is planned in or risks affecting a Natura 2000 site also requires a permit under Chapter 7, Section 28a of the Environmental Code. Projects may also be affected by the provisions in Sections 4 and 4a of the Species Protection Ordinance, unless an exemption is granted under Section 14 of the same. In addition to these permits, separate permits are also required to route cables from the park to a connection point on the shore.

Within Sweden's exclusive economic zone, a developer needs a permit from the Government pursuant to Section 5 of the Act (1992:1140) on Sweden's Exclusive Economic Zone (SEZ) instead of permits for environmentally hazardous and water activities from the Land and Environment Court. In this Act, Section 6 governs which parts of the Environmental Code apply, namely Chapters 2–4, Chapter 5, Sections 3–5 and 18 as well as the relevant provisions of Chapter 6 of the Environmental Code. Chapter 6 of the SEZ Act regulates the environmental impact assessment. The provisions of Chapter 7 of the Environmental Code on Natura 2000 are also applicable in the Swedish exclusive economic zone, pursuant to Chapter 7, Section 32 of the

Environmental Code. In its judgment in Case C-6/04, the European Court of Justice clarified that Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora (Habitats Directive) is to be given effect in the exclusive economic zone of a Member State. The rules on species protection thus also need to be taken into account in the exclusive economic zone, even if the Species Protection Ordinance is not directly applicable according to the formulations of the authorisations in Chapter 8, Section 1 of the Environmental Code. Instead, the permitting authority may apply the general rules of consideration in Chapter 2 of the Environmental Code to give effect to the provisions of the Species Protection Ordinance. The interpretation can therefore be made that EU law specifies how the rules of consideration are to be applied in a license review process. This means, for example, that the strict species protection that exists for certain designated species, such as porpoises, as laid down in the Habitats Directive, applies in the entire marine area, including the exclusive economic zone.

The brief explanation above shows that the regulatory framework applicable to the licensing of offshore wind power can affect the possibility of coexistence in several ways. There are also other regulatory frameworks that apply. For example, it is possible for the Government or a designated authority to prescribe a safety zone of no more than 500 metres from an installation in Sweden's exclusive economic zone (Section 7 of the SEZ Act). Such a safety zone would affect shipping and fishing. The SEZ Act also states that fishing is regulated under the Fisheries Act.

Other rules that may affect coexistence are the basic provisions concerning the management of land and water areas in the Environmental Code. Chapter 3 sets out basic provisions, whereas Chapter 4 contains special provisions concerning areas of national interest. Chapter 3 contains provisions specifying which public interests are to be given special consideration when balancing different uses of land or water in order to achieve good management. A starting point for the application of the provisions is: "When assessing the most appropriate use of an area, the possibility of simultaneously exploiting an area for different activities should always be explored. The starting point for the assessment should be the overall objective of promoting sustainable development, as set out in Chapter 1, Section 1, first paragraph of the [Environmental] Code." (Proposition 1997/98:45 Part 2 p. 30). The possibility of coexistence thus appears to be a fundamental starting point. If coexistence is excluded because of incompatible interests, preference shall be given to such use that entails general good management pursuant to Chapter 3, Section 1 of the Environmental Code.

2.2.1 Designated national interests

If a particular area has been declared to be of national interest by several designated national authorities pursuant to Chapter 3 of the Environmental Code, i.e. there are several national interest claims and these are found to be incompatible, Chapter 3, Section 10 is applied and priority shall be given "to the purpose or purposes that are most likely to promote sustainable management of land, water and the physical environment in general. If the area, or part of the area, is needed for a total defence installation, priority shall be given to defence interest. Decisions taken pursuant to the first paragraph must not be contrary to the provisions of Chapter 4." (Proposition 1997/98:45 Part 2 p. 34). The defence interest and areas referred to in Chapter 4, including Natura 2000 sites, therefore take precedence. Chapter 3, Section 10 of the Environmental Code is thus a rule that can indirectly hinder coexistence between designated national interests, but only when it has been established that coexistence is not feasible.

When balancing different interests, the guiding principle is always coexistence, as described above. The designation of an area as being of national interest does not guarantee that the site will be used for the designated activity, such as wind power. What it means is that the area must

be protected from other types of use that “may significantly impede” access to or use of the area for the designated use. Fishing or aquaculture should therefore be allowed in an area of national interest for energy generation as long as this does not constitute a significant impediment to the national interest.

“The expression 'may significantly impede', as used in several paragraphs in the chapter, does not include minor effects. It refers solely to measures which may have a lasting negative impact on the interest in question or which may temporarily have a very large negative impact on it are referred to.” Proposition 1997/98:45 Part 2 p. 30).

2.2.2 Areas not designated as being of national interest

If the area is not of national interest but by its nature is deemed suitable for certain uses, it must be protected “as far as possible” against measures that “may significantly impede” that use. Thus, the suitability of the area in itself has a protective effect with regard to other uses.

“The expression ‘as far as possible’, used in several paragraphs of the chapter, implies that the balance to be struck between the protected interest and opposing interests shall include consideration of the practical and economic consequences of the protection provided by the paragraph. In the first instance, the intention is to provide scope for socio-economic considerations on a case-by-case basis, e.g. with regard to regional or employment policy interests. The impact on the individual interests concerned must also be taken into account. However, the expression also implies that economic considerations alone may not jeopardise the values that the provision is intended to protect, unless an overall assessment in accordance with Section 1 shows that this promotes good management from a general perspective.” (Proposition 1997/98:45 Part 2 p. 30).

The limits of what constitutes a “significant impediment” and the application of "as far as possible" in practice are relevant to examine further to deepen the analysis of the conditions for coexistence in existing law. Within the framework of this assignment, SwAM has not had the opportunity to conduct a fuller analysis.

It is reasonable to conclude that Chapter 3 of the Environmental Code provides a basis for promoting coexistence in the permitting process and that such processes constitute a starting point for coexistence. The manner in which the permitting authorities have implemented and applied the provisions in that chapter can therefore also provide guidance on how to apply the rules on coexistence.

Finally, the conditions set by the permitting authorities in the above-mentioned permits could also promote coexistence. However, challenges exist because the permit granting process only examines the activity applied for, not any potential future activity. Thus, all the above-mentioned rules can be applied in such a way that they affect coexistence positively or negatively.

2.3 Technical solutions

Offshore wind power currently employs two types of foundations, either fixed-bottom or floating. The most common types of fixed-bottom foundations are gravity-based foundations, monopiles and jacket foundations. Monopiles and jacket foundations can be anchored in place with suction anchors, or by piling or drilling into the seabed. Fixed-bottom foundations have a very small footprint in the water column. Including all cabling in the wind park, the impact on the seabed is about 1-2 per cent of the total surface area of an average offshore wind park (Isaeus, Beltrán,

Stensland, Öhman, & Andersson-Li, 2022, p. 29). This means that, despite the large spatial claims of offshore wind power, the actual footprint in terms of affected seabed is limited. The type of foundation used is determined by the characteristics of the site. At present, fixed-bottom foundations are used in depths up to about 70 metres, but experiments are ongoing at greater depths.

Floating foundations are a new technology that is currently in place in Scottish and Norwegian waters, among other locations. The depth should be at least about 50 metres in order for floating foundations to be used instead of fixed-bottom foundations. A common feature of all floating foundations is that they are anchored to the seabed with lines. The most common type of anchorage involves catenary mooring, which needs mooring lines that are several times longer than the distance between the turbine and the seabed in order to be effective. The power cable then needs to be even longer to avoid straining. This means that floating wind power generally has a much larger footprint in the water column than fixed-bottom wind power. However, the footprint on the seabed is similar. Floating wind power will also need a larger safety distance due to the anchorages. At present, floating foundations with taut lines, referred to as tension leg platforms, are also being researched. These have a smaller footprint in the water column (SSPA, 2022). However, no such anchorages are currently in operation.

Within wind parks, a network of power cables runs between each turbine, coming together at one or more substations. From the substations, another cable, larger than those within the park, then runs to the shore and connects to the grid. Additional offshore structures may be needed to collect electricity from multiple installations. There are different methods for routing the cables from each turbine, depending on the type of foundation. In most cases, the cables cannot be buried directly adjacent to the foundations, and instead lie on the seabed some distance before they are buried. Depending on the site, the cables can either be buried or covered. In some cases, it can be difficult to bury the cables properly, for example at joints, which can reduce their protection. Since a wind park usually has a large number of turbines, there will be a large number of cables buried within the park. If a wind developer plans to produce hydrogen on the same site, the hydrogen will have to be transported from the park either by ship or by pipeline. Pipelines are not buried under the seabed, thus becoming another obstacle for fishing (SSPA, 2022).

Offshore wind power is still more expensive than onshore wind power, meaning that larger areas are needed to have an economically viable project. The farther from shore the project is, the more expensive it will be. If a project is far from shore and has new technologies, costs will further increase. The result of these costs is that the farther from shore and the deeper the water, the larger the project’s surface area needs to be for the project to be economically viable. To some extent, this increase in costs is offset by more stable and stronger winds further out at sea. In the first part of the assignment to find new energy areas at sea, M2022/00276, the Energy Agency defined 500 MW as the minimum capacity for offshore wind parks with fixed-bottom foundations and 1 GW for parks with floating foundations. However, discussions with industry representatives have shown that projects smaller than this may be possible closer to land.

The impacts of offshore wind power can be divided according to its three main parts, the construction phase, the operational phase and the decommissioning phase. The impacts associated with the construction phase depend on the technology used at the site. In the operational phase, turbines with fixed-bottom foundations generally have a kind of impact that differs from that of turbines with floating foundations. During the decommissioning phase, environmental impacts may occur when the foundations are removed and the seabed is restored. A wind park may also lead to an increase in ship traffic in the area during the construction phase, when ships install the foundations. Even during the operational phase of a wind park, a large

number of vessels are required for servicing and maintenance. Some of this ship traffic can be replaced by helicopters, which also causes a disturbance in the area.

Impacts during the construction phase depend on the type of foundation used. One type of impact is sediment dispersion, whereby the seabed is disturbed, causing sediment to be suspended and transported by currents. Sediment dispersion can affect marine life at the site. The foundation that stirs up the most sediment is pile-driven monopiles. Some sediment dispersion may also occur when cables are buried under the seabed. Underwater noise during construction can distress, hinder communication between, or harm marine life. Pile driving for foundations is one example of when very high underwater noise occurs (Isaeus, Beltrán, Stensland, Öhman, & Andersson-Li, 2022). Different mitigation measures can be put in place during the construction phase to reduce the dispersion of underwater noise, such as bubble curtains (Bergström, et al., 2022, p. 70).

During the operational phase, wind power affects the local hydrography to a limited extent. Wind turbines also emit underwater noise in the same way as ship traffic during the operational phase. There is a magnetic field around the internal cable network and the connection to land. The magnetic field is stronger around the connection to land, as the cable has greater capacity. The magnetic field has been shown to have a negligible effect on marine life (Bergström, et al., 2022, pp. 9, 45, 55).

During the decommissioning phase, wind turbines and foundations are dismantled and the seabed environment is restored. However, some parts of the installation may be left in place, such as parts of foundations or cables. The impact of the decommissioning phase depends in part on the type of foundation and the methods used. The impacts during the decommissioning phase can be described as similar to the construction phase, but on a smaller scale (Isaeus, Beltrán, Stensland, Öhman, & Andersson-Li, 2022, P. 36; Bergström, et al., 2022, p. 46).

3 Offshore wind power and commercial fishing

The chapter begins with an overview of Swedish commercial fishing (section 3.1) and how they are regulated (section 3.2). It then reviews the issues related to coexistence with offshore wind power from a broader perspective (section 3.3) and closes with a discussion of the preconditions and measures for coexistence (section 3.4).

3.1 Commercial fishing in Sweden

Commercial fishing involves the catching and selling of fish, shellfish and molluscs. Swedish commercial fishing is carried out in both international and domestic waters. Foreign fishing fleets also operate in Swedish waters, particularly fleets from neighbouring countries. The number of vessels in the Swedish fishing fleet has shown a downward trend in recent decades, standing at 1,020 vessels at the end of 2021, (SwAM, 2022a), of which about 20 per cent were counted as inactive (SwAM 2022b). Approximately 85 per cent of the fishing fleet consists of vessels under 12 metres using gear such as trawls, cages, traps and nets. At the same time, the largest landing volumes and highest landing values are in the fleet segment with vessels longer than 24 metres that fish with active gear. Many of these vessels fish pelagically.

The total landings from commercial fishing in 2021 amounted to just over 153,000 tonnes in live weight, down from around 220,000 tonnes in 2017. The landings from the Baltic Sea and the Sound account for approximately 60 per cent of the total, while the remaining 40 per cent originate in the North Sea and the Skagerrak and Kattegatt. The value of landings in 2021 was approximately SEK 767 million, a decrease of just over eight per cent compared to the year before (SwAM, 2022a). Three quarters of the catches were landed abroad, of which just over 84 per cent consisted of fodder fish, i.e. fish used to produce feed for other bred species. In demersal fisheries, species such as Norway lobster, northern shrimp, cod and vendace are highly valued. In the pelagic segment, species such as herring, sprat and lesser sand eel account for most of the catches. In 2021, these species accounted for about 92 per cent of the total landed weight of the Swedish fleet.

Pelagic commercial fishing in the sea targets species that live in the open water. Most often, these are species that swim in schools and are caught using large pelagic trawls drawn in the water column. Demersal commercial fishing targets species that live on or close to the seabed, such as Norway lobster, northern shrimp, cod and saithe. The demersal fleet consists of small and medium-sized vessels with active gear such as trawls and passive gear such as nets, cages, traps and fyke nets. Trawl fishing requires not only healthy fish stocks, but also large areas of sea free of obstacles. Trawls can last for several hours and extend over several kilometres. In addition, demersal trawls are limited to areas with soft bottom without major obstacles, and often follow depth curves. Pelagic trawls follow shoals of fish, which tend to have unpredictable movement patterns.

The landings from freshwater commercial fishing have varied between 1,300 and 1,700 tonnes per year over the past decade, with species such as zander, vendace, signal crayfish, salmon and pike being particularly important. In contrast to commercial fishing in the sea, the landings from freshwater commercial fishing have increased by about 30 per cent and the total sales value by about 40 per cent since 2010. The lakes Vänern, Vättern, Hjälmaren and Mälaren account for most of the landings. The freshwater fishing fleet consists of small and medium-sized vessels that mainly fish with passive gear such as nets and crayfish cages (SwAM and Swedish Board of Agriculture, 2021).

3.2 The regulation of commercial fishing

In the sea, fish move freely across national borders to varying degrees. EU fisheries legislation, the Common Fisheries Policy (CFP), regulates the management of shared commercial stocks. Under articles 2(1) and 3(1)(d) of the Treaty on the Functioning of the European Union, the Union has exclusive competence to legislate and adopt legally binding acts in the field of the conservation of marine biological resources under the CFP. In marine areas, Member States may take decisions only after authorisation by the EU or to implement Union acts. In other fisheries matters, the Union and the Member States have shared competences under article 4(2)(d) and (e) of the Treaty. With the exception of certain species, the regulation of freshwater fishing is an area which essentially lacks EU legislation and in which Member States may, under certain conditions, introduce national legislation.

Regulation (EU) No 1380/2013 of the European Parliament and of the Council of 11 December 2013 on the Common Fisheries Policy (basic regulation) lays down provisions relative to the objectives of the CFP and how to achieve them. The CFP shall, among other things, ensure that common fishery resources in the sea are managed in a sustainable manner and that management is carried out in a manner consistent with the objectives of achieving economic, social and employment benefits and contributing to food security. The CFP shall apply the precautionary and ecosystem approaches to fisheries management and ensure that harvested species are restored and preserved above levels ensuring maximum sustainable yield.

Fish stock conservation measures adopted by Member States within the scope of national discretion must be consistent with the objectives of article 2 of the basic regulation and at least as strict as measures under Union law. There is also the possibility for Member States to introduce non-discriminatory measures for the conservation and management of fish stocks and to maintain or improve the conservation status of marine ecosystems in the territorial sea. For example, the EU regulatory framework allows Member States to introduce national fisheries regulations to minimise the impact of fishing on marine ecosystems in accordance with the Marine Strategy Framework Directive, the Habitats Directive and the Birds Directive, or to take decisions on fishing-free areas, the protection of spawning and breeding areas and technical regulations. Many species that are important for Swedish fishing are regulated nationally by the Fisheries Act (1993:787), the Ordinance (1994:1716) on Fishing, Aquaculture and the Fishing Industry, and SwAM's regulations.

EU Council Regulation (EC) No 1224/2009 of 20 November 2009 establishing a Community control system for ensuring compliance with the rules of the CFP regulates fisheries control, which is a prerequisite for achieving the objectives of the CFP. Member States have an obligation to verify that fishing is carried out in accordance with current EU law and have the possibility to strengthen and supplement these provisions at the national level. In Sweden, this is done through SwAM's regulations.

Fisheries management must be based on scientific evidence on the status of the resources in different waters, as well as on levels of harvesting. Management decisions are informed, among other things, by catch data from logbooks, data from controls at sea and at landing sites, as well as other information on commercially exploited species obtained, for example, from sampling on board and by research vessels (SwAM and Swedish Board of Agriculture, 2021).

3.3 Opportunities and obstacles

All new offshore installations restrict fishing activities. The extent to which a wind power installation restricts fishing depends on a combination of the characteristics of the area, the design of the park, existing regulations, and the willingness to fish within the park. For fisheries, the risk of being excluded from fishing areas is a major concern. For offshore wind power, the risk of collision[1] with wind turbines and otherwise unintended damage to foundations and cables is seen as the major problem of coexistence. There are a number of possible adaptations to promote coexistence, but these often entail high costs for both fisheries and wind power developers.

In and around wind parks with fixed-bottom foundations, each turbine creates a new navigation barrier. These barriers constitute an increased risk during both fishing and sailing, especially in extreme weather conditions (SPFPO, 2022), or in the event of failure in the fishing vessel's equipment or human error. The risks can result in damage to equipment, turbines, cables, fishing vessels or, in the worst case, loss of life.

According to commercial fishing producer organisations, the possibilities for coexistence differ between the different types of fishing. Pelagic fishing follows the shoals in the water column and can therefore have an unpredictable movement pattern. A pelagic trawler's gear, including trawl and cables, can reach lengths of up to 1.5 km and weigh up to 300–400 tonnes. Under such conditions, navigation in wind parks is difficult or impossible and involves a high risk (SPFPO, 2022; SFPO, 2022; HKPO, 2022).

In the case of bottom trawling or other fishing with gear that has contact with the seabed, there is a risk of the gear becoming entangled with an underwater cable, which could cause damage to cables, gear, vessels and persons. Such situations can occur if the cable was not buried from the beginning, if the seabed has shifted, or if the fishing or other activities have affected the seabed in a way that caused cables to be exposed. Depending on the nature of the seabed, it may be difficult or impossible to bury cables to a depth that prevents damage. If cables are covered with stones or other material instead of being buried, a new underwater obstacle is created that hinders bottom trawling. The burial of cables carries with it an additional cost for the cable owner, and the deeper the cable is buried, the higher the cost and the larger the impact on the seabed environment. Even for fishing with passive gear, there is a risk of the gear detaching, getting caught on the foundation and causing damage.

In parks with floating turbines, opportunities for coexistence are generally more limited than in parks with fixed-bottom turbines. The increased footprint of anchorages and cables that are not visible in the water column poses a greater risk to both installations and fishers. All types of foundations have the inherent risk of fishing gear possibly becoming entangled and causing damage, either to the foundations or the gear, which entails a risk and a cost for both parties. Monopile foundations have a smoother surface compared to other foundation types, and are therefore deemed to have a lower risk of fishing gear entanglement.

Damage to a turbine or cable may disrupt or even interrupt the electricity supply from the park. In addition to the impact for society, this may have significant financial implications for all parties involved. The high costs associated with damage to cables or other equipment have so far resulted in difficulties or very high costs for getting insurance coverage for such damages (HMI,

[1] The term "allision" is sometimes used to describe collision between a moving object and a static object. In the same context, "collision" is used for collisions between two moving objects. In this report, we use collision for both cases.

2023; Bundesamt für Seeschifffahrt und Hydrographie, 2022; Marine Scotland, Dialogue, 2022). This constitutes an important challenge to coexistence between offshore wind power and commercial fishing.

Germany (Bundesamt für Seeschifffahrt und Hydrographie, 2022) and the USA, among others, have highlighted the difficulties of conducting some marine environmental monitoring in offshore wind areas (Hare, et al., 2022). This concerns, in particular, fisheries surveys or other surveys at certain locations at sea. If access to these locations is hindered by, for example, a new wind park, there is a risk that previous data series will be interrupted and thus lose their value. At the same time, wind parks create new opportunities for continuous monitoring of the marine environment, for example by means of equipping turbines or other fixed installations with measurement devices both above and below the water surface.

Offshore wind power can also have an indirect impact on commercial fishing through effects on fishery resources. Although the greatest effects are associated with the relatively short-term construction phase, there are still knowledge gaps and thus concerns in the fishing industry about the long-term effects of the operational phase, which may last for up to three or four decades. The enhanced protection introduced and the reef effect that may occur around each turbine foundation may, under certain circumstances, benefit marine life (see section 5.2). Whether this can be favourable for fishing depends on which species are benefited, how dispersed the effect is, and how fishing is regulated in the areas that remain open to fishing.

3.4 Conditions and measures for coexistence

3.4.1 Adaptation of wind parks

The measure used so far by many countries to reduce conflicts between commercial fishing and offshore wind power has been to strive towards locating wind parks in areas with little or no fishing. Separating the two activities spatially regarded as entailing the least risks in order to ensure that both are carried out as safely and efficiently as possible (SSPA, 2022, p. 1). This concerns in particular fishing with active gear, which is more mobile and needs larger areas than fishing with passive gear (SLU, 2022, p. 14). A related measure is to provide guidance or set conditions during the planning and license review of offshore wind power concerning the establishment of wind power in spawning and nursery areas for commercially relevant species (SSNC, 2022; SPFPO, 2022). This applies in particular to the risks associated with underwater noise and sedimentation during the construction phase.

Coexistence can be facilitated by defining the layout of the wind park with care in consultation with the fishers concerned, such that turbines are positioned in such a way as to allow fishing and navigation in between (SSPA, 2022, pp. 1, 2; European MSP Platform, 2021b). The distance between wind turbines is often seen as the main parameter affecting coexistence. When defining the layout of the wind park, one needs to ensure that there is enough space for fishing gear to be operated at a safe distance from the park's fixed installations (SLU, 2022, p. 14; Pol & Ford, 2020). With larger wind turbines, the distances between turbines are generally also greater (SSPA, 2022, p. 1), which is why modern parks are considered to offer better opportunities for coexistence with commercial fishing than older parks where turbines are positioned closer together. At the same time, wind park design needs to take into account the efficiency and profitability of the park.

Wind parks with fixed-bottom turbines require shorter safety distances between fishing vessels and wind turbines than parks with floating turbines. This is because it is more difficult to know

exactly where the mooring lines are located and because of the more serious consequences arising from gear getting caught in a mooring line. The position of a floating turbine can also change due to weather and water levels. The qualitative navigation risk analysis carried out within the framework of this assignment suggests that the distances between turbines in parks with fixed-bottom foundations should not be less than 1,000 m for fishing with active gear to be possible. In parks with floating turbines, the distance should be greater than 1,000 m. The exceptions are parks with so-called tension-leg platforms, where the distances could be similar to those for fixed-bottom turbines. However, these are not precise figures, and more exact values need to be determined for each individual park based on the local conditions and the fishing taking place in the area (SSPA, 2022, pp. 71, 74).

In addition to the distance between turbines, there are some general design choices that are preferable. These primarily involve positioning the turbines in straight rows and avoiding pointed corners at the edges of the park. However, irregular positioning of the turbines may be preferred if they are located over top of existing obstacles that bottom trawlers already avoid. For fishing that follows depth curves, such as shrimp trawling, turbines should preferably be positioned along a depth curve in order to facilitate coexistence (SSPA, 2022, pp. 70, 72). The most suitable design choices should be based on the type of fishing in an area and the type of foundation planned in the park (SSPA, 2022, p. 2).

The choice and design of foundations is usually made by the wind park developer based on a variety of technical, economic and environmental parameters and taking into account the conditions of the wind park area. However, the foundations themselves also have an impact on the possibility of coexistence between offshore wind power and commercial fishing. Protruding elements of the foundation may cause holes in the hull if there is a collision, and should be avoided. Foundations should instead have a smooth surface. Adding fenders to the wind turbines may also be considered as a means of avoiding serious consequences in the event of a collision. The number of parts and attachment points should also be minimised in order to reduce the likelihood of fishing gear becoming entrapped (SSPA, 2022, pp. 60, 76).

The foundations, structures and erosion protection of offshore wind turbines can lead to reef effects (Bergström, et al., 2022). Wind power developers have begun to investigate whether adaptations in the design of these different elements can benefit marine life in general, and some commercial species in particular (Vattenfall, 2022). However, as with other nature-inclusive designs, there is currently no scientific evidence of the effects on the species that the designs intend to benefit or of the effects on fishing (see also section 5.3.5).

In order to enable fishing with bottom gear, in particular bottom trawling, it is important to bury the cables within and from the wind park at a depth of 1–2 m (SSPA, 2022, p. 60). In order to reduce the overall spatial claim, cables should be gathered in cable corridors by coordinating and co-locating cables and pipes for different purposes (European MSP Platform, 2021a; SSPA, 2022, p. 2). This is already happening in Germany, where corridors for pipes and cables in Germany's exclusive economic zone are identified in the marine spatial planning process. However, there may be a need to introduce protective measures along the cable corridors, for example by prohibiting anchorage within a certain distance (European MSP Platform, 2021a). If bottom trawling is to be allowed in wind parks, further cable protection measures may need to be developed, which could require targeted investments in both technology improvements and innovation (Bocci, et al., 2019). In Denmark, according to the Decree on the protection of marine cables and underwater pipelines (Bekendtgørelse om beskyttelse af søkabler og undersøiske rørledninger, Kabelbekendtgørelsen, BEK No 939 af 27/11/1992), fishing with gear with seabed contact within 200 m of underwater cables is prohibited. In practice, this has meant that bottom

trawl fishing could not be carried out within existing wind parks. With increasing spatial claims from wind power and thus a greater risk of displacement from key fishing areas, the Danish State has recently launched an assessment of alternative solutions for the protection of pipelines in the context of a broader study of coexistence possibilities (Soefartsstyrelsen, 2023).

With navigation safety as one of the main prerequisites for fishing in wind parks, the navigational risk analysis carried out for this assignment proposed the establishment of a centralised monitoring and safety service for offshore wind parks. The overall purpose of the service would be to monitor fishing vessels and inform about prevailing weather, wind and current conditions within and near wind parks. The service could also coordinate emergency response operations (SSPA, 2022, pp. 70, 72–73). It may also be advisable to develop cable monitoring systems. If alerts can be sent in real time when a cable has been exposed or its protection damaged, such alerts could reduce the risks to fishing vessels in the area (Kafas, 2017). Sites with cables that have been repaired could also be labelled as sensitive on a map shared with fishermen (SSPA, 2022, p. 75). Monitoring, together with further research, is considered the basis for an adaptive approach to safety of fishing in wind parks (SSPA, 2022, p. 2).

Adapting the timing of construction work to that of fishing in or in the vicinity of the wind park area is an additional aspect of relevance for coexistence (SSPA, 2022, p. 2). For safety reasons, all activities unrelated to the construction of the wind park are generally prohibited in the wind park area during the entire construction phase. At the same time, several fisheries are seasonal. In order to reduce disturbances to fishing, it may be important that construction avoids periods that are critical for fish reproduction or that are important for fisheries in a given area (European MSP Platform, 2021b).

3.4.2 Adaptation of fishing activities

The fishing gear used is something that significantly affects the conditions for coexistence with offshore wind power. Fishing with passive gear has greater potential for coexistence than fishing with active gear (Kafas, 2017; SSNC, 2022). The type of fishing with the greatest potential is fishing with cage, hook and gillnet (IVL, 2022; SFPO, 2022). Passive gear generally poses a lesser risk to wind turbines, although it may pose a limited risk to the fisherman if it gets stuck in the foundations (SSPA, 2022, pp. 61, 66). Active gear poses greater risks to turbines, gear and fishing vessels due to its size and weight as well as the very large forces used to handle it (SSPA, 2022, p. 61). It is important that the trawlers are equipped with sensors that indicates the position of the trawl in real time in order to reduce the risk of the gear colliding with wind turbines (SSPA, 2022, p. 71). In Sweden, most trawlers are equipped with such systems.

Generally speaking, smaller gear and gear with less contact with the seabed is better suited for coexistence (European MSP Platform, 2021c), but this affects the efficiency of fishing. In practice, however, the possibility of changing gear is very limited, or impossible, for most fishermen and vessels. Vessels and gear are usually adapted for a particular fishery, and switching to other fishing is usually very difficult due to fishing licensing, not to mention very costly. The few experiences from other countries show that a greater number of fishermen choose to stop fishing or, when possible, fish in other areas, rather than switching to other types of fishing (Gray, Stromberg, & Rodmell, 2016; Soefartsstyrelsen, 2023). The literature also highlights the possibility for fishing to focus on the specific species suitable for fishing in the wind park (SLU, 2022, p. 20). However, such adaptation may involve major changes in gear, vessels and fishing activities, which is very difficult, assuming it is even possible. It may also have an impact on the economy of fishing, which may constitute a further obstacle to adaptation.

The conditions for coexistence between offshore wind power and commercial fishing is considered to be improved by better understanding of safety concerns and potential damage to wind park structures (Schupp & Buck, 2017). Based on actual experience from such studies, gear can be developed that minimise risks, such as the risk of damage to cables (European MSP Platform, 2021a). Further innovation of fishing gear suitable for wind parks is considered necessary (Van Hoey, et al., 2021). Various initiatives are already underway to support the innovation and development of adaptations of vessels and gear for fishing in wind parks, including the International Council for the Exploration of the Seas (ICES), the Baltic Sea Advisory Council (BSAC) and a few national and international projects (Kafas, 2017).

Where commercial fishing is not considered compatible with offshore wind power, there may sometimes be opportunities to fish in other areas. However, fishing is usually carried out where the fish resource is present, and changed access to the fish resource often constitutes the biggest obstacle to movement. When moving, however, the effects on fishing and the marine environment need to be clear (Depellegrin, et al., 2021) in order to regulate fishing in the best possible way. Within the framework of license review processes, most states, including Sweden, have so far found that the impact of wind power on fishing is not so high that it is considered an impediment to wind park construction. The assessment is partly based on assumptions that it should be possible to adapt fishing or carry it out elsewhere, while the area in which the wind park can be established is limited. However, this may change as wind parks become more common (Malafry & Öhman, 2022), which is why research into displacement effects is becoming more important.

To reduce the risks associated with fishing in wind parks, it may be appropriate to impose restrictions on when fishing may take place in the wind park (European MSP Platform, 2021b). For example, fishing in the wind park could be allowed only under specific conditions in terms of visibility, wind and current, but also for vessels with, for example, a maximum length, speed and with a certain type of gear. Limits regarding under which conditions fishing should not take place should be based on different types of fishing and size of vessels. These limits and other guidance could be developed in consultation between local fishermen and the wind park operator ((SSPA, 2022, p. 70). In the UK, for example, the *Kingfisher Information Service – Offshore Renewable & Cable Awareness* (KIS-ORCA) project has developed a bulletin system that reminds fishermen to be particularly cautious when fishing near the various wind park structures and their associated cables, as there is a risk of damage to the cables and nets (SSPA, 2022, p. 12). With the increasing spatial demands of offshore wind power and the need for coexistence solutions, there is a need to further develop monitoring systems and guidelines for fishing in wind parks (HMI, 2023). The use of industry standards can help increase preparedness, minimise technical failures of vessels and potentially also lack of skills (SSPA, 2022, pp. 68, 69).

3.4.3 Regulations and insurance issues

In Sweden, there are currently no explicit rules that either contribute to or prevent coexistence between offshore wind power and commercial fishing (HMI, 2023). At present, it is the circumstances of the individual case that determine whether the permitting authority determines that national interests can coexist in an area or not. This applies in cases when there are multiple national interest claims for an area, such as the national interest of commercial fishing and the national interest of energy production. If the national interest claims are incompatible, the national interest claim that promotes sustainable management in the most appropriate way is given priority in accordance with Chapter 3, Section 10 of the Environmental Code. For overlapping interests that are not claims of national interest, coexistence must be investigated. Otherwise, the interest that "provides good management from a general perspective" takes precedence under

Chapter 3, Section 1 of the Environmental Code. This balancing of competing interests is often difficult to assess, and there is currently no specific guidance on the balance between offshore wind and commercial fishing.

To promote coexistence, there may therefore be a need to review and supplement the existing regulatory framework (Malafry & Öhman, 2022), and to develop guidance on balancing offshore wind with other interests. There may also be a requirement for a coexistence plan for fishing in order for the wind developer to be granted a permit (HMI, 2023). In Denmark, for example, wind power developers are required to have initiated a dialogue with affected fishermen in order for a permit to be granted. Similarly, in its draft decisions on the permits for the Kattegatt Syd and Galatea-Galene wind parks, the Halland County Administrative Board proposed conditions for the developer to "maintain a dialogue with the commercial fishing producer organisations and [...] work with them to establish and maintain a cooperation plan with a view to enabling commercial demersal fishing in the wind park" (Halland County Administrative Board, 2023; Halland County Administrative Board, 2022). Neither Denmark's requirements nor the County Administrative Board's proposed conditions specify the content of the coexistence plan. However, permits could include measures to ensure coexistence between the wind park and fishing (Schupp & Buck, 2017; SFPO, 2022), as well as conditions for regular evaluation and auditing (European MSP Platform, 2021b). It is important that such measures are developed jointly to benefit both activities and to strengthen cooperation between the sectors (SSPA, 2022, pp. 14–15).

At a more general policy level, the relevance of creating a policy for fishing in wind parks is also highlighted. As several authorities often have the issue of fishing in wind parks on their agenda, it is important to have clarity regarding the roles of the different authorities, including whether any authority should be convening or guiding the coexistence issue (SSPA, 2022, p. 1; European MSP Platform, 2021b; HMI, 2023). If there is a political aim to promote multi-use at sea, this can also stimulate innovation and development of, for example, fishing methods and wind park design (Kafas, 2017). The European Commission also recommends that Member States introduce specific regulatory frameworks for multi-use at sea. Such a regulatory framework needs to identify and remove obstacles to coexistence (European Commission, 2022b).

Since the conditions for coexistence change over time, it is important to have regular monitoring in the form of control programmes or the like. Requirements for control programmes are often laid down by law, for example in Sweden they are found in Sections 19–20 of the Environmental Code. When fishing in a wind park, it is important that the control programme focuses on direct effects on fishing activities, as well as on impacts on fishing resources that indirectly affect fishing activities. In order to identify the effects of the wind park, it is important that data are collected both before and after the wind park has been established (Bergström, et al., 2013; FLOWW, 2014). In the draft decisions for the wind parks Kattegatt Syd and Galatea-Galene, the Halland County Administrative Board does not specify any parameters for verifying the condition of creating a cooperation plan with commercial fishing. (Halland County Administration Board, 2022; Halland County Administration Board, 2023). However, such parameters may be developed at a later stage when the wind power operator develops the control programme.

An important prerequisite for coexistence is the existence of insurance for both fishermen and wind power operators that covers the risks arising from fishing in the wind park. Today, there is a great need for the development of such insurance, which is partly due to the difficulty of estimating safety risks in a robust way that makes it possible to set appropriate premium levels (European MSP Platform, 2021a; Van Hoey, et al., 2021). Even in cases where the state authorises fishing in wind parks, it has nevertheless proven to be problematic for fishing vessels from an insurance perspective. The elevated risk of fishing within the wind park may also result in

excessive insurance premiums for the wind park operator as well, reducing incentives for coexistence. There is a need for further studies on liability and insurance for damage to cables and collision with fixed and moving objects in the wind park. It is also important that insurance policies cover the loss of fishing gear and controlled retrieval of lost gear in cases where fishermen need to cut and release fishing gear for safety reasons (SSPA, 2022, pp. 75–76). In a broader perspective, there is a need to develop insurance models adapted to multi-use of marine areas, which most are not considered to be today (HMI, 2023).

3.4.4 Communication and collaboration

In Sweden, a wind developer must currently consult on the location, scope, design, possible environmental effects and the design and content of the environmental impact assessment as part of a delimitation consultation in accordance with Chapter 6, Section 29 of the Environmental Code. However, to promote coexistence between fishing and offshore wind power, it is an important measure to establish a consultation group much earlier, preferably as early as the process of physical planning of the coast and sea (SSPA, 2022, pp. 1–2; FLOWW, 2014). An early dialogue both generally and locally supports the wind park localisation process (European MSP Platform, 2021b; Stelzenmüller, Gimpel, Letschert, Kraan, & Döring, 2020). This can make it possible to optimise, for example, the extent of the park, and the distance between and location of the turbines (SSPA, 2022, pp. 1, 74).

Early dialogue then also needs to be followed up by continuous consultations. For example, key issues can be discussed in special working groups that meet regularly. However, it is important that it is clear what kind of influence is possible and in which of the various planning stages (Van Hoey, et al., 2021).

The UK government funds forums that aim to enable and facilitate discussions about coexistence. The groups also aim to share practical experiences and to promote networking between different actors at sea. For example, they have published a guide on when and how communication between actors should take place, and what responsibilities they have in the process (FLOWW, 2014). In Sweden, the Swedish Board of Agriculture, supported by SwAM and the Energy Agency, initiated a project in the spring of 2022 aimed at laying the foundations for a dialogue platform between the commercial fishing industry and the wind power industry. The project has focused on strengthening mutual understanding of both activities and stimulating a solution-oriented dialogue. Experience so far suggests that dialogue requires a long-term commitment, that disagreements exist not only between but also within sectors, and that the state or another third party has a role to play as convening mediator.

In countries such as the Netherlands, participatory forums, also known as *Communities of Practice*, were created to encourage and facilitate cooperation and multi-use. Such forums can give stakeholders the opportunity to create informal and self-organised groups around a particular area of interest. Through these groups, joint activities and discussions can be conducted. They can also share knowledge and experience with each other. Finally, the group can also create opportunities to find partners and resources, and to get help from each other (Oelen, 2022; Steins, Veraart, Klostermann, & Poelman, 2021).

It is important to invite a diverse and representative group to the consultation meetings, in particular involving representatives from different parts of the fisheries sector (Van Hoey, et al., 2021). All actors need to be heard and included in the planning (Fiskekommunerna, 2022), ensuring that weaker sectors have an influence (European MSP Platform, 2021b). It may also be

relevant to invite an independent party if difficulties arise in the communication between the different interests (Fiskekommunerna, 2022).

A prerequisite for building constructive relationships and common values is that the participating actors are engaged. For this to be possible, they must have the resources and capabilities and be willing to listen, learn and adapt (SLU, 2022, p. 48). This can ultimately save time and resources by preventing delays, protests, complaints and lawsuits (Bennun, et al., 2021). Engaged local actors can also promote local acceptance by sharing results and existing knowledge (Bocci, et al., 2019).

Integration and coordination between sectors and across organisational levels are important prerequisites to increasing opportunities for coexistence. The organisational levels can range from the local level to the European level (Bocci, et al., 2019). At the local or national level, this may involve discussing technical solutions in the planning process to find opportunities for increased synergies. Examples include access to vessels, harbour facilities, emergency systems, monitoring systems or technical personnel (SSPA, 2022, pp. 1-2). It may also involve mapping the existence and value of small-scale commercial fishing activities, as was the case in the Scottish collaborative project *Scot Map*. The mapping made an important contribution to the marine spatial planning of Scottish waters (Kafas, McLay, Chimienti, & Gubbins, 2014). In another example from a floating wind project in Ireland, a partnership has been signed between the largest fisheries organisation, the main regional shipping company and a wind park. The aim is for the wind park to have no negative impact on fishing or the marine environment. The wind power project will also use local infrastructure and local industries (McKenna, 2022). In other cases, it may be a matter of co-management (European MSP Platform, 2021b). However, there is a need to develop joint research between wind power and other activities on how synergies can be increased (IVL, 2022). By supporting small-scale pilot projects, coexistence and its benefits can also be marketed to wind developers (Kafas, 2017; Bocci, et al., 2019).

At the international level, it is important that exchanges take place between countries. This enables common denominators to be discovered, management methods streamlined and knowledge shared (Bocci, et al., 2019; Schupp & Buck, 2017). For example, knowledge of existing practices can be shared to increase understanding of risks and risk mitigation measures (Stelzenmüller, Gimpel, Letschert, Kraan, & Döring, 2020). It is particularly important that countries share their plans for offshore wind power or other offshore activities in order to highlight potential cumulative adverse effects on the environment and other activities, namely commercial fishing (SSPA, 2022, p. 73).

A further condition for the coexistence of commercial fishing and offshore wind power to be possible is the increased availability of information, research data and knowledge (European MSP Platform, 2021b). Making data available to all stakeholders can help promote effective and transparent strategic planning (Bocci, et al., 2019; Nordic Energy Research, 2021). There needs to be open and clear communication between the sectors regarding added value, state of knowledge and safety (Schupp & Buck, 2017). One example is that fisheries need to be provided with updated maps of the seabed, as it changes through the construction and operation of wind parks (SSPA, 2022, p. 73). It is also possible that stakeholders, together with experts, design training programmes for everyone who fishes in Swedish waters on various aspects of fishing in wind parks (SSPA, 2022, p. 75).

The UK project KIS-ORCA aims to provide accurate and up-to-date information to fishermen free of charge. Through the project, an information system has been developed to be able to easily communicate, for example, the location of cables and wires or details of lost equipment or fishing

gear. It also provides information on appropriate approaches to fishing (SSPA, 2022, pp. 12–13; Seafish, n.d.). There are also examples of the development of guidance and licensing manuals aimed at preventing and minimising conflicts between commercial fishing and the wind industry (SSPA, 2022, p. 2). Such guidance may be based on results from small-scale pilot projects (Kafas, 2017). A pioneer in this regard is Scotland, where Marine Scotland has produced guidance documents and studies (SSPA, 2022, p. 2).

To ensure that data collection and monitoring are carried out in an appropriate manner, it may be useful to create a research and innovation programme at the national or EU level (Stelzenmüller, Gimpel, Letschert, Kraan, & Döring, 2020). Several countries have established national responsibility for data sharing, including Denmark, Belgium, Scotland and Norway (SLU, 2022, p. 49).

3.4.5 Compensation

Where the development of offshore wind parks has resulted in a loss of income or increased expenditure for fishing, compensation has in some cases been paid to the fishermen affected. For example, in Denmark, where cable protection regulations effectively exclude all fishing using gear with seabed contact from wind parks, monetary compensation to the fishermen affected has so far been the most common measure for managing the conflict with wind power. In connection with the establishment of the Lillgrund wind park in the Sound, compensation was also paid to fishermen whose income was affected. In the UK, the use of a *Fisheries Management and Mitigation Strategy* (FMMS) has become a standard part of the permitting process. The strategy includes financial compensation to fishermen affected by the construction and maintenance of a wind park and its infrastructure (Nimmo, MacNab, & Huntington, 2022).

The compensation is paid to offset the loss of income and is typically calculated based on catch and income history. It is designed through joint agreements between the actors concerned, usually without direct involvement of the state and in most cases at an early stage of the planning or permitting process (European MSP Platform, 2021b).

Other forms of financial compensation have been developed where it has not proved possible to compensate for reduced fishing opportunities. One example is financial compensation for loss of fishing time for participation in consultations on the establishment of a wind park (Van Hoey, et al., 2021). Another type of compensation may involve allowing fishermen to share in income from the wind sector, for example by hiring fishing vessels for surveys or as patrol ships during the construction phase. One measure proposed in the UK to support this synergy is the funding of training for alternative supply (FLOWW, 2014). An additional example is financial support for fishing fleet innovation (Stelzenmüller, Gimpel, Letschert, Kraan, & Döring, 2020). This has been used in France, where for two decades collective annual compensation for a wind park is paid to the national fisheries organisation to finance development projects. In the UK as well, funds have been set up to finance projects relevant to the fisheries sector, such as research vessels (Van Hoey, et al., 2021).

In the UK, the FLOWW (*Fishing Liaison with Offshore Wind and Wet Renewables*) group established by The Crown Estate has developed guidelines for fishing in wind parks. These include guidance on compensation for disturbances and loss of income for fishing during the installation and operation of the wind park (FLOWW, 2014). These could include measures to improve fish stocks, fishing vessels and fishing profit margins. The guidelines provide for the establishment of a fund for the development of the fishing communities concerned in connection with the construction of the wind park.

4 Offshore wind power and aquaculture

The chapter begins with an overview of Swedish aquaculture (section 4.1) and how it is regulated (section 4.2). It then reviews the issues related to coexistence with offshore wind power from a broader perspective (section 4.3) and closes with a discussion of the measures that can enable coexistence (section 4.4).

4.1 Aquaculture in Sweden

Aquaculture is a collective name for the breeding and farming of aquatic animals or plants, such as fish, crustaceans, mussels, oysters, sea squirts and algae. The dominant form of aquaculture in Sweden today is the breeding of fish in open cages located in lakes and to some extent along the coasts. Along the coast, there is also the cultivation of mussels and other low trophic species, especially in the North Sea. Aquaculture is also carried out in ponds and in various types of land-based facilities. A basic prerequisite for aquaculture, regardless of type and species, is access to an area with good water quality. Protected water areas close to support infrastructure on land are also important, not least to keep costs down.

The product of aquaculture is mainly used for human consumption, with rainbow trout, blue mussels and char making up the largest share of production by weight. Aquaculture is also carried out with the aim of releasing fish for fishing or further rearing, compensating for the absence of natural recruitment or strengthening wild stocks, and producing health products and animal feed, industrial products, fuel or cosmetics. Some species are also produced for their beneficial environmental properties, such as mussels that absorb nutrients by filtering water.

Aquaculture food fish production in 2021 amounted to 11,900 tonnes in estimated full live weight, of which rainbow trout accounted for just over 87 per cent, followed by char with about 11 per cent (Swedish Board of Agriculture, 2022). Fish production for restocking was estimated at almost 900 tonnes, while the production of mussels amounted to almost 3,500 tonnes. About 94 per cent of rainbow trout production and all char production were grown in fresh water. Production in the sea accounted for the remaining rainbow trout production as well as the entire harvest of mussels, oysters, sea squirts and algae. In 2021, there were 105 aquaculture businesses in Sweden, employing around 530 people at 150 sites.

Many aquaculture systems are currently monocultures, but the production of organisms from different trophic levels in the same establishment is under development. Open system aquaculture accounts for the largest share of food fish production. These systems typically consist of open, floating net pens in lakes, reservoirs or marine areas where natural water currents manage the water exchange in the pen. The production of organisms that do not require feeding, known as extractive aquaculture, is also carried out in open systems. There the organisms live, for example, attached to lines and nets floating on the surface or hanging in the water column, or in cages or pens on the bottom.

In semi-closed and closed systems, the fish are confined in an outer enclosure with no direct contact with the surrounding aquatic environment, reducing the risk of escape. The water is pumped into the installation and discharged through specific drains, allowing for treatment of the water, reducing the risk of parasite and pathogen infestation, and providing better control of the aquaculture environment. At present, the technology is mainly at the research and innovation stage.

There are also other forms of aquaculture conducted in land-based facilities, such as recirculation systems, aquaponics and biofloc. These forms are not relevant to the issue of coexistence with offshore wind power.

4.2 Legal conditions for the regulation of aquaculture

Within the Swedish territorial sea, all forms of aquaculture are subject to the requirements of the Environmental Code. The number of provisions to be complied with varies with the type of installation, the consumption of feed and the species being cultivated. Different authorities have different responsibilities in relation to aquaculture activities. The Act (1992:1140) on Sweden's Exclusive Economic Zone applies to aquaculture activities in the Sweden's exclusive economic zone.

SwAM has national responsibility for providing guidance on supervision with regard to the provisions of the Environmental Code and for drafting regulations for restocking and certain transfer of fish and shellfish. Permits for aquaculture, restocking or transfer of fish, crustaceans and molluscs are required under fisheries legislation and are issued by the relevant county administrative boards. Depending on its size and feed use, a fish farm may be subject to the provisions of the Environmental Assessment Regulation and constitute either a B or C activity, i.e. an environmentally hazardous activity. In such cases, a permit is required under environmental legislation. This is granted by either the municipality or the county administrative board, in most cases after drawing up an environmental impact assessment. If the activity is also assessed in accordance with Chapter 11 of the Environmental Code, i.e. as a water activity, the assessment is carried out by the Land and Environment Court. Commercial production of alien species requires measures to eliminate the risk of escape and the spread of infection. The cultivation of algae is not covered by the same exemption in Chapter 11, Section 11, point 2 of the Environmental Code as the construction of systems for the cultivation of fish, mussels or crayfish, and is therefore a water activity subject to permitting or notification under the Environmental Code. Even in cases where a system does not require a permit, the supervisory authority may order the developer to apply for a permit. Depending on the area utilised, the production of algae or sea squirts requires an environmental impact assessment. The application is assessed by the Land and Environment Court and usually takes several years, which may have hampered the development of the industry.

During operation, aquaculture establishments are regularly inspected, inter alia to ensure compliance with environmental, animal and disease protection regulations as well as food quality regulations. Since 2014, the Swedish Board of Agriculture has been responsible for the public disease protection and monitoring of Swedish aquaculture. In accordance with Swedish and EU legislation, the aim is to detect infectious diseases and minimise the risk of introducing and spreading infections. Animal welfare inspections aim to ensure that aquaculture animals are treated well and are not subjected to unnecessary suffering, for example when they are killed. Aquaculture products are also checked for the presence of hazardous substances such as pharmaceutical residues, biotoxins and environmental toxins.

4.3 Opportunities and obstacles

Fixed-bottom offshore wind power has stable foundations that can potentially be used to anchor different types of aquaculture. In aquaculture, this is seen as an opportunity for establishment in areas further offshore, which would otherwise be too costly for the vast majority of aquaculture forms. In addition, offshore wind parks offer an environment that is relatively protected from other

uses that may conflict with aquaculture (IVL, 2022), such as shipping and fishing. However, this means that the multi-use area will be inaccessible to these uses. Offshore wind power's large distance from the coast also results in less exposure to pollution from land-based sources. There are also hopes that co-management of both activities can reduce costs, for example in terms of servicing and maintenance.

However, combined aquaculture and wind power installations are still largely at an experimental stage, and thus lack maturity in legislation and permitting processes. Moreover, there are significant gaps in the knowledge of building, operating and decommissioning combined installations.

Establishing aquaculture together with offshore wind power involves uncertainty for the wind developer, given the risks involved in such a project. Co-locating wind power and aquaculture also means that the wind developer may have to sacrifice efficiency to provide a good solution for aquaculture. Aquaculture cannot be applied to offshore wind power that is already in operation; the activities must be adapted to each other at the planning stage (SLU, 2022, pp. 25–32; HMI, 2023). To date, the wind sector has not been in favour of sharing space with aquaculture, partly because of the constraints this imposes on the design and positioning of wind power plants.

The literature highlights a few environmental risks associated with combined aquaculture and wind parks. One such risk is that the aquaculture will be contaminated by pollutants from the wind power installations. However, the exact nature and quantities of these pollutants have not been specifically investigated. Another risk is that the aquaculture will attract seabirds, which could contaminate the aquaculture if there is a collision with the wind power installation (SLU, 2022, pp. 25–32).

There is also a risk that damaged aquaculture equipment could cause damage to the wind park, depending on the type of aquaculture taking place at the site. This means that an aquaculture operator needs to have adequate insurance to cover potential costs (HMI, 2023). As wind power is further offshore, installations also need to be designed for conditions other than coastal aquaculture. The cost of taking out such insurance, combined with a high deductible, is one reason why aquaculture in marine environments is not yet commercially viable.

The legal situation is also unclear in terms of what happens when a combined aquaculture and wind park reaches the end of its technical lifespan and has to be decommissioned. While the aquaculture might still be economically viable, it is unclear whether the structures to which they are anchored can remain, as they are potentially subject to dismantling requirements in the permitting conditions of the wind park (HMI, 2023).

4.4 Conditions and measures for coexistence

There are currently relatively few aquaculture installations in marine waters, most of which are located in coastal areas. Despite great interest in the integration of aquaculture in wind parks at the academic, industrial and political levels, there are currently no commercial combined installations. The few that exist are pilot installations intended to investigate technical, operational and commercial conditions. All these pilot installations are for the cultivation of extractive species such as mussels, oysters and algae. Despite relatively little empirical knowledge, the literature contains several arguments about conditions or measures for coexistence between marine aquaculture and offshore wind power. The reasoning is partly based on results from ongoing and completed research and development projects, and can be divided into four main themes: localisation, economics, governance and forms of operation.

4.4.1 Localisation

For aquaculture to co-exist with offshore wind power, there need to be areas where both activities can be co-located and operate simultaneously. In an increasing number of countries – including all EU Member States – the issue of localisation is addressed in marine spatial planning. However, most marine spatial plans rarely have areas specifically designated for co-located activities, instead indicating either one or more prioritised uses, or no prioritisation at all (referred to as general use) within each area. In cases where the marine spatial plan does not indicate co-location specifically, the possibility of coexistence is addressed in later processes, usually during permit assessment of individual projects (Schupp & Buck, 2017; Van Hoey, et al., 2021; Benassai, Mariani, Stenberg, & Christoffersen, 2014).

To facilitate future co-location of aquaculture in offshore wind parks, the literature highlights the need to designate areas specifically for combined installations in marine spatial planning. In other words, the marine spatial planning needs to indicate areas where both aquaculture and offshore wind power are priority uses (Bocci, et al., 2019; EU, 2021). The planning of such areas needs to take into account the conditions for both activities. For example, in addition to wind and depth conditions, which are important conditions for offshore wind power, aspects such as pollution levels, risk of spreading alien species, and nutrient salt levels, which are important for aquaculture, need to be taken into account (Banach, van den Burg, & van der Fels-Klerx, 2020).

The planning of areas for combined aquaculture and wind parks also needs to take into account effects on coexistence with other uses. In such installations, it tends to be more difficult to conduct any other activity involving spending time in or passing through the wind park, such as fishing, sailing or research (Bocci, et al., 2019). The potential impact on navigational safety may also differ between combined and conventional installations, and would therefore need to be investigated separately (SSPA, 2022, p. 34).

In the Netherlands, a new system for granting permits for offshore wind power has been introduced in recent years. This system takes into account the potential for coexistence with different uses, including aquaculture. Wind power projects that show greater potential are favoured in the permitting process. The process starts with an assessment of the conditions for different types of activities within the planning of the proposed wind park. The area is divided into different coexistence sub-areas – such as commercial fishing, aquaculture, other energy production and environmental restoration – within which different projects may be carried out. The different sub-areas of the area, with their respective conditions, are described in what is referred to as an area passport (from the Dutch term *gebiedspaspoort*) that stakeholders can use to develop their project idea (Van Hoey, et al., 2021).

4.4.2 Economics

Profitability is a fundamental prerequisite for the establishment of aquaculture to be built in wind parks. The development of offshore aquaculture has hitherto been hampered by the high cost of the installations, which have to withstand greater stresses than equivalent installations in protected areas in coastal waters. Greater distances from the coast also entail higher transport costs in connection with monitoring and maintenance (Van Hoey, et al., 2021).

The literature and several projects argue that costs of offshore aquaculture can be reduced through the combined use of parts of the wind park and the combination of certain monitoring and maintenance functions (Buck, et al., 2018; Christie, Smyth, Barnes, & Elliott, 2014; EU, 2021; Van Hoey, et al., 2021). At the same time, the profitability of aquaculture is affected by a number of

other market and management factors unrelated to location. Coexistence with offshore wind power has very little or no impact on such factors. Furthermore, there is a concern in the wind power industry that combined aquaculture and wind parks will result in increased costs for the wind park developer (Braga, 2020).

In light of this, both the literature and several research and development projects highlight the need to develop and test solutions for the construction and operation of combined installations that are economically viable for both aquaculture and wind power (SLU, 2022, p. 28). This needs to be done in connection with the development of solutions in terms of design, safety, maintenance, etc. that has been going on in recent years (see 4.4.4 Forms of operation) (SSPA, 2022, p. 34).

4.4.3 Governance

The basic premise of governance is that the regulatory framework and management should not hinder coexistence between aquaculture and offshore wind power. Beyond this minimum level, there are different degrees of measures that facilitate or even promote coexistence.

In most countries, including Sweden, there are no legislative texts that specifically address the coexistence of aquaculture and offshore wind power (HMI, 2023; SLU, 2022, p. 28). At the same time, the regulatory framework on offshore safety may, in practice, impose certain obstacles to the establishment of aquaculture within wind parks, for example if such installations are deemed to pose an unacceptably high risk to navigation, emergency response, etc. (HMI, 2023). Environmental legislation may also impose certain limitations if the environmental impact of aquaculture is deemed incompatible with the environmental conditions and objectives of the planned area. While some environmental aspects can be addressed within the context of marine spatial planning, the more specific aspects must often be assessed in the context of the permit assessment of each individual project (HMI, 2023).

Experience of testing combined aquaculture and wind parks is currently very limited (SLU, 2022, p. 26). Permit granting processes only concentrate on the activities that the permit concerns (HMI, 2023). In the case of offshore wind power, the permit granting process has so far only covered the wind park itself and no other activities with which the wind park may coexist. In other countries, the existing aquaculture testing facilities in wind parks have been built in already existing wind parks, and have thus undergone separate assessment. In the Netherlands, there is a requirement for a separate assessment of all proposed activities before a permit is granted. This also applies after the introduction of the area passport system, which integrates multi-use offshore wind parks into planning (SLU, 2022, pp. 30–31).

In order to facilitate combined installations, the literature proposes that permit granting be adapted so that combined installations are assessed as a single activity. It also proposes for the process to be conducted by a single authority and for uniform guidance to be drawn up for both developers and permitting bodies. These are, incidentally, two wishes that several maritime industries in Sweden have long voiced, with the aim of promoting the blue economy. The permit granting process also needs to deal with the dismantling of the combined installation. Under maritime law, installations must be removed when they are no longer in use. However, the regulatory framework is unclear when it comes to combined installations in which different parts are decommissioned at different times. For example, there may be a need to clarify how the dismantling of a combined aquaculture and wind park should be handled if the wind turbines reach their maximum lifespan before the aquaculture installation does.

A further measure to promote coexistence is to reward or even require multi-use in the construction of a wind park, on the grounds that it makes more efficient use of marine space (Buck & Langan, 2017; Bocci, et al., 2019; EU, 2021). Several countries have introduced or are investigating the possibility of introducing an assessment system that rewards coexistence solutions when granting permits for offshore wind power. This means that assessments of applications for the construction of wind parks take into account the benefits and risks associated with aquaculture and not just the wind park itself. Both benefits such as food production or nutrient uptake when cultivating low trophic species, and risks such as escape or the spread of alien species or diseases need to be taken into account.

4.4.4 Forms of operation

As the number of aquaculture installations within or adjacent to offshore parks is very low, there is very little experience and knowledge about safe and efficient ways of building, operating and decommissioning combined installations (SLU, 2022, p. 26). Both the literature and experts have pointed to development on these fronts as an important prerequisite for coexistence to be possible, which has given rise to several research and development projects in recent years (Schupp & Buck, 2017; European MSP Platform, 2021).

The importance of developing standards for combined installations has been highlighted by some authors and experts (Buck & Langan, 2017; Christie, Smyth, Barnes, & Elliott, 2014). At the same time, others argue that the introduction of standards could potentially hamper the development of different solutions needed today (Van den Burg, Röckmann, Banach, & Van Hoof, 2020). Areas in which regulations and procedures may become relevant in the future include not only structural aspects, but also maritime safety, monitoring, control and certification of aquaculture products, etc. (SLU, 2022, p. 28). With regard to maritime safety and emergencies, developments in insurance for combined operations are also highlighted as an important prerequisite (HMI, 2023).

In order for development on these different fronts to take place, both literature and policy documents emphasise the need to continue to support research and development efforts (European MSP Platform, 2021). Such support is currently provided by both public funding bodies and private companies, especially wind power companies (Buck & Langan, 2017). In Sweden, the first agreement between a wind power company and two seaweed farming companies was signed in autumn 2022 for the development of a combined installation in a planned wind park in Kattegatt (SVT Nyheter Halland, 2022). Similar agreements exist in other countries, and in Germany, Belgium and the Netherlands there are small pilot installations whose purpose is to test different solutions for future farms on a larger scale (SLU, 2022, pp. 30–32). One possible measure to facilitate the implementation of pilot projects is to simplify the permit granting process for test installations up to a certain size (Bocci, et al., 2019).

5 Offshore wind power and nature conservation

The chapter begins with an overall description of the legal conditions for offshore wind power in relation to protection of the marine environment (section 5.1). This is followed by a summary of the known environmental effects of offshore wind power (section 5.2) and a description of the conditions for coexistence with a focus on localisation (section 5.3.1), protection of species and habitats (section 5.3.2), mitigation measures (section 5.3.3), Natura 2000 habitats (section 5.3.4), and nature-based solutions (section 5.3.5).

5.1 Legal conditions for the protection of the marine environment

Under its jurisdiction, Sweden has various rights and obligations to act in the zones identified in the UN Convention on the Law of the Sea. The provisions of the Convention on the Law of the Sea have been incorporated into the Swedish Maritime Territory and Zones Act (2017:1271) and the Act (1992:1140) on Sweden's Exclusive Economic Zone. The Environmental Code is fully applied in the territorial sea in the same way as for activities on land. Thus, the establishment of offshore wind power in the territorial sea requires permits for environmentally hazardous activities and for water activities under Chapters 9 and 11 of the Environmental Code. A more detailed description of the rights applicable in the different marine areas of the territorial sea and Sweden's exclusive economic zone can be found in the SwAM report on exclusivity in the construction of offshore wind power (SwAM, 2022c).

Throughout the territorial sea, the Marine Environment Ordinance (2010:1341) applies, which implements the EU Marine Environment Directive in national law. In the part of the territorial sea that lies within a nautical mile from the baseline, the provisions on water management also apply as set out in, inter alia, the Water Management Ordinance (2004:66), which implements the EU Water Framework Directive in Sweden. In this context, the environmental quality standards and their significance are presented as an overview only. There are differences between marine environmental standards and environmental quality standards for water, in terms of both legal effect and management in general. Although wind parks are rarely constructed in the area within one nautical mile of the baseline, the provisions of the Water Management Ordinance apply to the routing of electrical grid cables through the coastal zone to land. An activity may not result in deterioration of the status of the environment or jeopardise attainment of the correct status according to the environmental quality standards established. This requirement is particularly stringent with regard to environmental quality standards for water through the introduction of Chapter 5, Section 4 of the Environmental Code, but the standards under the Marine Environment Ordinance are also applicable in the context of the permitting of offshore wind power.

According to the Marine Environment Ordinance, good environmental status in the sea shall be achieved and maintained. The definition of good environmental status is established in SwAM's regulations HVMFS 2012:18. The regulations also set the environmental quality standards with indicators (marine environmental standards) that are to be followed to achieve good environmental status. The regulations are relevant for, inter alia, site selection or the formulation of permit conditions. The applicant also needs to describe in the environmental impact assessment how the project relates to the marine environmental standards. The marine environmental standards, insofar as they are not limit value standards, constitute what are known as other standards under Chapter 5, Section 2, first paragraph, point 4 of the Environmental Code and therefore do not have the same status as standards for water or limit value standards.

If there is a risk of impact on the environment in a Natura 2000 site, the activity requires a special permit under Chapter 7, Section 28a of the Environmental Code, which is assessed by the County Administrative Board. In order to obtain a Natura 2000 permit, the activity must not damage a protected habitat or cause the species intended to be protected to be subjected to a disturbance that significantly impedes their conservation. Exactly what this means can be difficult to determine, as the level of knowledge about potential impact is lacking in certain areas. There is also a possibility for exemptions, for example linked to overriding public interest. A species protection exemption may also be required in cases where the activity causes disturbances covered by Sections 4 and 4a of the Species Protection Ordinance.

Additional permits are necessary for cable routing, maritime safety, connection to electricity grids, etc. Application review under the various regulations is handled by several different authorities and may run in parallel. If the activity is assessed in any part of the Land and Environment Court, the Natura 2000 permit must also be processed there pursuant to Chapter 7, Section 29b of the Environmental Code. The latter does not apply in the exclusive economic zone, as there, the Government assesses the permit for the park.

In the exclusive economic zone, the coastal state has jurisdiction in accordance with the rights and obligations conferred on it under the Convention on the Law of the Sea, such as exclusive rights to exploit natural resources as well as obligations to preserve them. The establishment of wind power in an exclusive economic zone requires a permit from the Government under Section 5 of the Act (1992:1140) on Sweden’s Exclusive Economic Zone. The permit may be subject to conditions related to factors such as environmental protection or navigation safety. The Halland County Administrative Board recently submitted a proposal for a decision to the Government on two wind parks, containing conditions on coexistence with fishing (Halland County Administrative Board, 2023; Halland County Administrative Board, 2022). The Government, which authorises permits for wind power projects in the exclusive economic zone, has, at the time of writing, not made a decision on these cases or on what conditions will apply (see section 3.4.3).

The basic provisions of Chapters 2–4, and Chapter 5, Sections 3–5 and 18 of the Environmental Code and the provisions of Chapter 6 shall also apply, including requirements for an environmental impact assessment, which also applies to applications in the territorial sea. The criteria for achieving or maintaining good environmental status, according to the Marine Environment Ordinance and its environmental quality standards in SwAM's regulations (HVMFS 2012:18), are generally applied and taken into account in the environmental impact assessments. The Natura 2000 provisions are applicable in the exclusive economic zone pursuant to Chapter 7, Section 32 of the Environmental Code, and it is the County Administrative Board that grants the permits. Provisions on species protection are not applied directly in the exclusive economic zone, but concretely define the requirements that need to be imposed through the application of the rules of consideration in Chapter 2 of the Environmental Code.

Permits under the Continental Shelf Act (1966:314) are required for studies of the project area prior to construction and for routing cables on or in the seabed. The permits are issued by the Government. Chapter 2 of the Environmental Code and the Natura 2000 provisions are applied in the assessment and a Natura 2000 permit may be required as early as the study stage.

5.2 Synthesis of the environmental effects of offshore wind power

The main positive environmental effect of offshore wind power arises from it replacing fossil fuel-based electricity generation, thereby reducing human climate impact. Because wind parks often limit what other activities can take place in and around them, they can have an indirect protective

effect that can benefit marine ecosystems and biodiversity. However, the potential for this is highly dependent on local conditions and must be assessed on a case-by-case basis. Depending on the conservation values and how these are affected by wind power, a wind park adjacent to a protected area could also potentially serve as an actual extension of the protected area (SLU, 2022, pp. 34–37; SSNC, 2022).

If fishing or other forms of marine resource exploitation are not allowed in wind parks, this could lead to indirect protection effects, depending on the size and location of the area. Species in the area can then recover, especially if fishing is prohibited for lengthy periods. This could also potentially lead to spill-over effects if eggs, larvae and adult fish leave the area (SLU, 2022, pp. 37–39; SSNC, 2022). A recent review of the effects of fishing-free zones in Swedish waters concluded that the proportion of larger and older fish was generally higher in these areas, and thus also the population's reproductive potential and the establishment of ecosystem functions through top-down control of the food web (Bergström, et al., 2022). At the same time, the authors point out that the location and size of the areas in relation to the species being protected, as well as the presence of predators, are important factors behind the effects of the areas. Since the location of wind parks is not guided by environmental protection objectives, wind parks are less likely to have the same protective effect as fishing-free areas.

Fixed-bottom wind turbines can result in an artificial reef effect throughout the water column. This can then attract other species by, for example, mussels growing on the introduced hard structure. The erosion protection on the bottom can also lead to new habitats for marine species. This means a new habitat could be created if the wind turbine is installed on a soft bottom. With this, there is a potential to benefit several different species, as well as to restore some environments that no longer have their hard bottom (SLU, 2022, pp. 39–43). The reef effect mainly benefits demersal species, but the effects on pelagic species that move in the free water mass have not been mapped. It is possible that the accumulation of species at wind turbine foundations will lead to greater predation by e.g. birds and marine mammals, but the effect is still insufficiently documented.

When constructing a wind park, it is possible to integrate so-called nature-inclusive design in certain situations. This means that, in addition to the artificial reef effect, the developer also positions customised objects or adapts the erosion protection based on the kind of species that need to be supported in the area. These objects can then potentially serve as a way to strengthen habitats (SLU, 2022, pp. 43–47; SSNC, 2022; Vattenfall, 2022). However, nature-inclusive designs are a relatively new concept and there is currently no scientific evidence of their actual environmental effects (see section 5.3.5).

Despite its various positive effects, the establishment of an offshore wind park always involves an intervention in the environment and a certain impact on marine ecosystems. The degree of impact depends largely on the conditions in the area. In addition, there are currently uncertainties regarding the impact of wind power on different environments, which is why it is often difficult to say in advance whether a wind park is compatible with the management and conservation objectives set for an area. Both the impact of the construction and operation of wind turbines and increased ship traffic in the area can negatively affect the environment and result in conservation objectives being unattainable. The artificial reef effect that may occur at the turbine foundations may also be incompatible with the conservation objectives if these relate to the protection of specific seabed environments. The reef effect is also considered to affect the connectivity of the marine environment, especially if several wind parks are built within the dispersal range of the various species (SLU, 2022, p. 40). This could affect networks of protected areas, but whether

the impact is positive or negative depends on the conservation values and objectives of the network, as well as which species are positively or negatively affected.

Fish can be affected during both the construction and the operational phase. The strong impulsive sounds generated during the construction phase, particularly during pile driving, can stress and harm fish, and also affect communication. If the wind power installation requires drilling, the resulting changed conditions in the water may also adversely affect fish. Fish may also be affected by sound during the operational phase. The underwater noise generated during the survey and construction phase is considered to be the most problematic for marine mammals. Seismic surveys of the seabed during the survey phase affect sound-sensitive species such as porpoises. Pile driving and blasting during construction could lead to harm and displacement of sound-sensitive marine mammals. The duration of the displacement effect has been seen to vary between areas and depends on various factors including other pressure factors, availability of food, alternative areas and population status. If wind power is built in an area that was not previously heavily trafficked, the increased traffic from maintenance vessels may affect marine mammals.

Apart from marine mammals, birds are the most at risk of being adversely affected by offshore wind power. The main conflicts between offshore wind power and birds are displacement effects and collision risk. Unlike marine species, birds are not expected to be significantly affected during the construction phase. It is mainly during the operational phase that the impact occurs. Impacts can mainly be categorised into the following three types:

- Collision mortality – birds that do not avoid flying through the park are at risk of being hit by the rotor blades or colliding with the wind turbine.
- Habitat loss, referred to as displacement – birds may partly or completely avoid being near or in wind park areas.
- Barrier effects – the wind park can form a barrier between areas so that birds are forced to detour or are prevented from, for example, moving between foraging sites or reaching wintering areas.

The risk of collision is highest for birds migrating over the open sea, such as cranes and birds of prey, but in weather conditions with poor visibility there may also be an increased risk of collision for birds migrating at night. Seabird species, on the other hand, are relatively large and have a predominantly low risk of collision, as they exhibit clear avoidance behaviour in relation to wind turbines during active migration. They also usually fly close to the sea surface, below the lowest tip of the rotor blades. For birds that choose to fly through a wind park, there is a risk of being killed by collision with the rotor blades, and to a lesser extent with the towers. The ability of birds to avoid rotor blades at the last moment depends on several factors, such as flight speed, wind conditions and visibility. Recent studies suggest that some species previously considered to be at high risk of collision are probably not as vulnerable as previous studies suggest (Isaeus, Beltrán, Stensland, Öhman, & Andersson-Li, 2022). However, there is some concern about the so-called lighthouse effect, which means that birds are attracted to wind power's aviation obstruction lighting in certain weather conditions and get killed in large numbers (BirdLife Sverige, 2022).

The sensitivity of different seabird species to wind parks is relatively well studied, but it can be difficult to draw any firm conclusions about it. The studies conducted so far have been carried out in wind parks with considerably closer spacing between the wind turbines than what is being built today and which will mainly be built in the coming five to ten years. Studies of displacement effects carried out so far indicate that greater distances between each wind turbine within a wind park may mean a lower degree of displacement. It is also unclear how displacement may affect

individual survival, and ultimately what impact this may have on populations (Isaeus, Beltrán, Stensland, Öhman, & Andersson-Li, 2022).

The detour around a wind park may result in some additional energy consumption, but this is likely to be small in most cases if compared to the entire migration route. However, multiple wind parks can have cumulative effects on long-distance migrating birds, particularly where wind parks span distances of perhaps several kilometres. There is also a lack of knowledge about the extent to which cumulative effects play a role, and it is therefore unclear how relevant the barrier effect is.

Recent research shows that bats often move offshore, especially during migration periods in spring and autumn, and may be subject to similar effects from offshore wind as birds. Land-based studies have shown that bats can collide with wind turbines, and it can be assumed that the same applies to offshore wind power. However, this is not as well studied. Another risk, in addition to bat migration, is that bats forage near wind turbines, which can increase the risk of collisions. The risks associated with this for offshore wind power are still relatively unstudied (Lagerveld, et al., 2020).

5.3 Conditions and measures for coexistence

5.3.1 Localisation

In Sweden, the Environmental Code's rules of consideration describe the basic conditions that need to be fulfilled in all permit granting (Malafry & Öhman, 2022). The following principles are important when it comes to assessing offshore wind power, regardless of where in the sea the wind turbines and cables are located.

- Knowledge requirement, Chapter 2, Section 2 of the Environmental Code: The knowledge requirement means that the person who pursues an activity or takes a measure must have sufficient knowledge of how human health and the environment are affected and can be protected.
- Precautionary principle, Chapter 2, Section 3 of the Environmental Code: Even if there is a risk of negative impact on human health and the environment, the developer must take measures to prevent damage and detriment. Furthermore, in the case of commercial activities, the best possible technology must be used to prevent damage and detriment. The technology must be industrially feasible to use in the sector in question, both technically and economically.
- Localisation principle, Chapter 2, Section 6 of the Environmental Code: The localisation principle means that a site for an activity must be chosen in such a way as to make it possible to achieve its purpose with a minimum of damage or detriment to human health and the environment. The choice of location is of great importance for the environmental effects and disturbances that arise when an activity is carried out.
- Principle of reasonableness, Chapter 2, Section 7 of the Environmental Code: The principle of reasonableness means that the rules of consideration shall be applied after the cost-benefit relationship has been determined. The requirements imposed must be environmentally justified without being economically unreasonable to implement.

It is the applicant who must demonstrate that the activity complies with these principles and that the environmental effects of the activity are acceptable. The general rules of consideration must permeate all permit granting, and the principle of choosing the right location is particularly

important when it comes to natural values and species protection. This applies both inside and outside of protected areas. Similar provisions also exist in other countries.

The location of the wind park is the most important measure of consideration in terms of impact on species that are highly dependent on specific areas and that are sensitive to the types of impact that occur during the long-lasting operational phase. In such cases, it is particularly important to avoid important foraging and reproduction areas. For birds, the impact on wintering and breeding areas is of particular importance, while for migrating birds it may also be reasonable to avoid important migration routes (Isaeus, Beltrán, Stensland, Öhman, & Andersson-Li, 2022).

A prerequisite for the assessment is that alternative locations have been investigated. In most European countries, an overall assessment is carried out as part of marine spatial planning (Kyriazi, Maes, & Degraer, 2016), and when areas are then auctioned off, the location is usually predetermined. This process assesses, among other things, whether wind power is compatible with the nature conservation regulations for the site, including area protection and species protection. This type of assessment is often done at a relatively general level, and in most cases needs to be supplemented with detailed studies for each individual project. However, in many countries marine spatial planning is an important measure to signal at a strategic level and early in the wind power development process where coexistence with nature conservation is appropriate. Most European countries have strongly governing marine spatial planning, which means that wind power may not be built outside the areas designated for energy production in the marine spatial plan. In these cases, marine spatial planning has played a crucial role in either separating wind power from nature conservation, or identifying the basic conditions that need to be met in areas where coexistence is deemed possible.

In Sweden, marine spatial planning has not had the same opportunities. On the one hand, the marine spatial plans designate energy production areas within or directly adjacent to Natura 2000 sites, and on the other hand, the guiding nature of the plans means that wind park developers have been able to apply for permits in protected areas or areas with protected species or habitats on their own initiative. Alternative locations are part of the data included in a wind power project's environmental impact assessment prior to a permit application. Thus, whether coexistence between wind power and nature conservation is ultimately possible has so far only been assessed on a case-by-case basis in Sweden.

5.3.2 Protection of marine areas and species

Most countries with constructed offshore wind power do not have a general ban on the construction of wind parks in or directly adjacent to marine protected areas (SLU, 2022, p. 37), although most have regulations restricting physical exploitation through, inter alia, the construction of installations. With the exception of a few protected areas whose regulations completely prohibit fixed installations at sea, this also applies to Sweden. One example of such an area is Kosterhavet National Park, where, pursuant to Chapter A, Sections 1 and 8 of the Swedish Environmental Protection Agency’s regulations for Kosterhavet National Park (NFS 2009:7), the construction of installations and cables and wires in land and water is prohibited. There are several national forms of area protection in Sweden, such as national parks and nature reserves. In this chapter, the report focuses on marine Natura 2000 sites and the possibility of coexistence in relation to them. This is because Natura 2000 sites are the protection that currently exists in the Swedish exclusive economic zone, where most wind power projects are currently being developed.

The possibility of coexistence between wind power and a protected marine area depends on whether there is a risk that the wind power activities will have an excessively negative impact on the conservation values, i.e. the species and environments that are to be protected (Christie, Smyth, Barnes, & Elliott, 2014; Thurstan, Yates, & O'Leary, 2018). Germany's Offshore Wind Law generally prohibits wind parks in protected areas. However, there is already one wind park in, and several others in close proximity to, the Sylter Aussenriff Natura 2000 site in the North Sea, and the state is now investigating the possibility of building within the German part of the Dogger Bank, directly adjacent to a Natura 2000 site. This is considered to allow for some degree of coexistence if the impact on conservation values is deemed acceptable (Bundesamt für Seeschiffahrt und Hydrographie, u.d.; Bundesministerium der Justiz och Bundesamt für Justiz, 2016).

In the absence of legal obstacles, a pre-condition for coexistence between offshore wind power and marine Natura 2000 site protection is that the developer demonstrates that the planned activity's impact on the conservation values does not constitute unauthorised damage or detriment to the species or habitats to be protected in the area. The conditions for conservation are generally set out in a conservation plan for each protected site. The assessment is made on a case-by-case basis following the definition of favourable conservation status applicable to the site. The conditions for coexistence are specific to each site, and permissibility needs to be assessed in each individual case. However, there are a few general conditions and possible measures that can be mentioned.

Like other EU member states, Sweden requires a so-called Natura 2000 permit for the construction of an offshore wind park that may affect a Natura 2000 site. The requirements for permissibility under Chapter 7, Section 28a of the Environmental Code are that a permit may only be granted if the activity or measure, alone or together with other ongoing or planned activities or measures, can neither damage the habitat or habitats of the site intended to be protected, nor cause the single or multiple species intended to be protected to be subjected to a disturbance that may significantly impede the conservation of the species of the site.

In addition, there are the Environmental Code's rules of consideration, which specify the basic conditions that need to be met in all permit assessment of offshore wind power, regardless of where in the sea the wind turbines and cables are located (Malafry & Öhman, 2022). It is the responsibility of the applicant to produce the necessary data showing the environmental effects of the proposed activity.

The assessment of permissibility is complex and takes into account, inter alia, the conservation status of the protected species or habitats, sensitivity to stressors from the proposed activity, conservation objectives for the site, etc. (Christie, Smyth, Barnes, & Elliott, 2014; Thurstan, Yates, & O'Leary, 2018). In the context of the permit granting process, the permit is often combined with mitigation measures that the applicant must follow in order to be able to use the permit (see section 5.3.3).

In addition to the protection of marine areas, EU environmental legislation also obliges Member States to protect a number of species deemed to be particularly endangered and thus in need of protection. The obligation covers the entire spatial distribution of the species, which is why the issue of coexistence between offshore wind power and the protection of these species also arises outside protected areas. Species protection is usually included in the assessment of suitable location, but in some cases special species protection exemptions may also be needed before an activity can be allowed.

When constructing offshore wind parks in areas that may adversely affect protected areas or species, it is particularly important to carefully monitor the environmental effects of the wind park, especially on the protected species and habitats (Kyriazi, Maes, & Degraer, 2016). Monitoring is an important prerequisite not only for adapting the activities of the park in question, but also as a basis for further development of future parks in line with nature protection and conservation objectives (Isaeus, Beltrán, Stensland, Öhman, & Andersson-Li, 2022). In Germany, for example, new monitoring data has shown greater effects of wind power on loons (*Gavia spp.*) than previously known. The state has therefore amended the maritime plan with a temporary reservation area, where all installations are paused until more knowledge has been gathered. Results from the ongoing investigation may affect the location and design of wind parks in areas that are particularly important for the species.

In discussions and literature on the interaction of offshore wind power with nature conservation, the potential of wind power as an indirect protection measure is highlighted (European MSP Platform, 2021c; Nordic Energy Research, 2021). The issue is disputed because the potential is based on assumptions that certain other activities are excluded from the wind park area, while the wind park also has a certain environmental impact. A prerequisite for a wind park to have an environmental protection function is that activities that previously harmed the environment are stopped with the construction of the wind park. An oft-cited example is the exclusion of bottom trawling, which can allow affected seabed environments to recover (Bennun, et al., 2021; Bergström, Sköld, Wennhage, & Wikström, 2016; Van Hoey, et al., 2021). However, an important prerequisite in such cases is that the environmentally harmful activity and associated environmental impact are not just moved to another area.

In cases where the ambition is instead to use the wider range of hard man-made underwater substrates offered by wind turbines, it is important to choose areas and species that are deemed to benefit from the so-called artificial reef effect (Bergström, et al., 2022). For example, it may be appropriate to expand the range of hard seabed substrates in areas where original hard seabed environments have been damaged, but not in areas that initially consist exclusively of soft seabed environments, especially if they are protected. The potential risks associated with the promotion of alien species also need to be considered, which is closely linked to the degree of change that wind turbine foundations cause to the seabed environments in the wind park area. Important measures to minimise such risks include the careful mapping of underwater ecosystems in the area concerned, as well as the study of connectivity with neighbouring areas (Boero, et al., 2016; Henry, et al., 2018; Glarou, Zrust, & Svendsen, 2020).

5.3.3 Mitigation measures

The permit granting process often identifies mitigation measures (also known as effect abatement measures) that the applicant must comply with in order to obtain the permit. This is an important mechanism for coexistence by ensuring that the environmental impact of the planned wind power activity does not exceed the limit values set based on conservation objectives for species or habitats to be protected. Mitigation measures could also enable the establishment of wind power in areas that are currently denied an environmental permit or are not considered suitable due to feared risks to the environment.

Table 1 compiles mitigation measures that may be relevant to the construction, operation and decommissioning of offshore wind power. The compilation is based on a review of literature and experiences in various North Sea countries within the OSPAR Group on the development of offshore renewable energy, ICG-ORED (*Intersessional Correspondence Group – Offshore Renewable Energy Development*). The mitigation measures are generally unique to each project

and are determined based on both the characteristics of the project and the environmental conditions in the project area (SLU, 2022, pp. 33–34).

Phase	Type of measure	Description and objectives	Mitigation
Research and project design	Localisation	Location and burial of cables in a way that avoids impact on sensitive seabed environments or species	Avoidance Reduction
Research and project design	Localisation and design	Design of the wind park, such as the positioning of individual turbines in a way that avoids damage to seabed environments, barriers to species movement or habitat fragmentation	Avoidance
Research and project design	Design	Selection of materials and equipment with the least possible impact on the environment, such as foundations that do not require pile driving or drilling, or turbines with greater clearance between rotor blades and water surface	Avoidance Reduction
Research and project design	Scheduling	Carrying out investigations outside sensitive periods for protected species, such as reproduction, foraging and migration periods	Avoidance Reduction
Construction and maintenance	Scheduling	Carrying out construction and maintenance work outside sensitive periods for protected species, such as reproduction, foraging and migration periods	Reduction
Construction and maintenance	Operational management and control	Emission controls to prevent or reduce various emissions or loads during construction or maintenance work, such as sound-absorbing mitigation measures when pile driving foundations	Avoidance Reduction
Construction and maintenance	Restoration	Restoration of seabed environments after completion of construction and maintenance work, e.g. burial of cables	Restoration
Construction and operation	Operational management and control	Regulation of aviation obstruction lighting or other lighting in areas where photosensitive species are found	Reduction
Construction and operation	Operational management and control	Use of acoustic harassment devices in connection with work causing noise at a level that may be harmful to species requiring protection	Reduction
Construction and operation	Operational management and control	Control of pollutant discharge into water and air which may be harmful to the environment	Avoidance Reduction
Construction and operation	Operational management and control	Regulation of boat traffic in connection with construction, servicing and maintenance in order to reduce the impact on species susceptible to noise or other human influences	Reduction
Operation	Operational management and control	Changes to wind turbines or other parts of the wind park in order to reduce the risk of collision for birds and bats, e.g. colour of rotor blades and stop control	Reduction
Operation and decommissioning	Operational management and control	Shutdown in case of unforeseen high environmental effects in order to implement mitigation or restoration measures	Reduction Restoration

Phase	Type of measure	Description and objectives	Mitigation
Decommissioning	Scheduling	Adaptation of the time of dismantling or upgrading (*repowering*) to sensitive periods for protected species present in the area, such as reproduction, foraging or migration periods	Avoidance Reduction
Decommissioning	Restoration	Restoration of seabed environments in connection with dismantling	Restoration

Table 1 – Mitigation measures applied to the establishment of offshore wind power, based on a compilation made for the OSPAR Group on the Development of Offshore Renewable Energy, ICG-ORED. Mitigation includes the following four types of measures according to the mitigation hierarchy: avoidance, reduction, restoration and acceptance, including compensation.

The construction of offshore wind parks is often subject to conditions regarding protection against highly impulsive underwater noise. Mitigation measures such as bubble curtains, acoustic harassment devices and soft start-up when pile driving wind turbines are well proven, although the effect on sound-sensitive species varies between areas, species and populations, and therefore cannot always be accurately assessed. Measures to protect against sediment dispersal during pile driving, drilling or excavation, and measures to protect seabed environments in need of protection are also commonly used.

In the case of birds and bats, experience from onshore wind parks has started to be applied to offshore parks. Different methods and technical solutions to protect birds from collisions are being developed. Shutting down wind turbines during critical migration periods is likely to reduce bird mortality. The Örnkoll project in Näsudden on eastern Gotland is evaluating a new protection system for eagles in Sweden. The system is already in use in the USA. Using artificial intelligence, the system can identify different bird species that are at risk of collision and then switch off the wind turbines. Initial results show a good ability to identify eagles from other species categories (Ottvall, 2021). A study in Norway has shown painting one of the rotor blades black to be effective in reducing the risk of collisions by birds. Mortality at painted wind turbines was reduced by 70 per cent compared to adjacent unpainted wind turbines (May, Nygård, Åström, Hamre, & Stokke, 2020).

In southern Sweden, operational regulation is a common mitigation measure for bats. This is especially true in areas with many protected bat species. From mid-July to mid-September, the turbines are allowed to be shut down when the wind speeds are less than 6 metres per second and the temperature is above 14 degrees Celsius. This is when there is the greatest risk of bats being killed by wind power. The Vindval research programme is conducting an evaluation study on how well this works until the end of 2023. The aim is, among other things, to develop knowledge that can facilitate decisions on when to use operational regulation, how it should be designed and how control programmes should be designed. The study may be relevant for the design of conditions for certain coastal wind parks in the future.

5.3.4 Natura 2000 habitat

This assignment includes a compilation of experiences regarding the impact of wind parks on Natura 2000 habitats, also known as natural habitats. Nine of the marine habitats classified under the Habitats Directive (Table 2) are found in Swedish waters, of which sandbanks (1110), reefs (1170) and to a lesser extent bubble structures (1180) are the most common in the offshore areas that are most relevant for wind power establishment. The more coastal habitats are relevant when it comes to routing of cables to land.

EU code	Description
1110	sandbanks
1130	estuaries
1140	exposed mudflats and sandflats
1150	lagoons
1160	shallow inlets and bays
1170	reefs
1180	bubble structures
1650	narrow Baltic Sea inlets
8330	sea caves

Table 2 – Marine habitats in Swedish waters, according to the Habitats Directive. The proposed nature restoration regulation puts forward new habitats in seven groups: 1) seagrass beds, 2) macroalgal forests, 3) shellfish beds, 4) maerl beds, 5) sponge, coral and coralline algae beds, 6) hydrothermal vents, and 7) soft sediments (European Commission, 2022c).

Natural habitats provide the basis for several protected habitats and species, and EU Member States have an obligation to ensure their long-term conservation status. The impact on listed habitat types is therefore an important aspect in the permitting of offshore wind power. The state of knowledge about the presence and status of most marine habitats in Swedish waters is poor (Swedish EPA and SwAM, 2020). The most recent overall assessment shows that, despite a favourable geographical distribution, the total coverage is unsatisfactory for several habitat types, including vegetated sandbanks and reefs. The quality is unsatisfactory or poor for all habitat types, mainly due to poor water quality and physical disturbance.

According to the latest synthesis of the effects of wind power on marine life, physical disturbance is the most significant stressor that wind power exerts on marine habitats (Bergström, et al., 2022; de Jong, et al., 2020). Disturbance occurs mainly as a result of the covering and destruction of natural habitats by turbine foundations, associated erosion barriers and cables on the seabed. During the construction and probably also the decommissioning phase, disturbance can also be caused by increased sediment dispersal associated with various interventions on the seabed (Bergström, et al., 2022).

In view of the obligation to protect listed habitats, minimising disturbance as much as possible is an important prerequisite for coexistence (Wikström, et al., 2020). The proportion of potentially destroyed seabed environments in modern wind parks is usually estimated to be a few per mille of the total area of the park. However, in some cases, the fragmentation of natural habitats that can occur when new artificial structures are established may be a greater problem than the total area of degraded seabed environments. The acceptability of this level of impact is assessed on a case-by-case basis, usually in the context of project-specific environmental impact assessments. In Germany, for example, the state applies a guideline of no more than 1 per cent loss of protected habitats in wind park areas. However, the latest strategic environmental assessment of the offshore wind area development plan (in German, *Flächenentwicklungsplan*) concluded that there was insufficient knowledge to estimate the proportion of marine habitat affected. The assessment was then postponed until the project-specific assessment (Bundesamt für Seeschifffahrt und Hydrographie, 2022). In a similar environmental assessment ahead of the Fourth Offshore Wind Leasing Round in England, The Crown Estate investigated the effects on seabed environments resulting from establishment in the English part of the Dogger Bank. In terms of surface area, damage to sandbanks was estimated at 2.6 per mille of the distribution of this habitat type in the protected area, which was deemed unacceptable given the restoration

targets for that particular habitat type. In order not to compromise England's renewable energy targets, the area was retained for wind energy development, but with a series of measures to minimise damage to the seabed, including the exclusion of gravity and caisson foundations and the limitation of erosion protection. Furthermore, decisions on the exact location of the turbines and the design solutions were deferred to future project-specific assessments (The Crown Estate, 2022).

These examples illustrate the difficulty of determining the conditions for construction in areas with listed habitats in the overall planning process, and thus for coexistence between offshore wind and nature conservation. In the absence of detailed data on seabed conditions, an assessment of permissibility can only be made after project-specific studies have been carried out.

5.3.5 Nature-based solutions

In recent years, the issue of the environmental impact of offshore wind power has gradually shifted from focusing solely on minimising negative effects to also exploring and promoting possible positive effects (Hermans, Bos, & Prusina, 2020; Glarou, Zrust, & Svendsen, 2020). Concepts such as nature-inclusive design or nature-based solutions have become more common, and in countries like the Netherlands, wind parks have begun to be required to demonstrate how new wind parks can benefit the marine ecosystem, nature protection and restoration (Hermans, Bos, & Prusina, 2020). In other European countries, such as Germany, Denmark or Norway, there are ongoing discussions about introducing criteria in the permit granting process regarding the positive contribution of wind parks to the environment. Similar criteria do not exist in Sweden, and there are no mechanisms to reward environmental or societal benefits in the current permit granting process.

However, experience and results from nature-inclusive designs are still very limited. The few pilot installations that exist today have not been in place for more than five years, and in most cases follow-up and analysis of results in the environment are ongoing. Existing pilot installations are located in the North Sea, and the relevance of the results for areas with different environmental conditions may be limited, such as the brackish water environments that characterise large parts of Sweden's seas. It is therefore important that such designs are adapted and tested in different environments to optimise their environmental benefits (Hermans, Bos, & Prusina, 2020).

A few technical and ecological risks associated with nature-inclusive designs have been identified in the literature (Ashley, Austen, Rodwell, & Mangi, 2018; Hermans, Bos, & Prusina, 2020). The literature review conducted within the framework of this assignment also summarised a number of possible risk mitigation measures, as shown in Table 3.

The risk of structural damage can be minimised through modular design, so that parts of the nature-inclusive supplementary structure can be easily removed if necessary. This also allows the design to be adapted with sufficient margin to avoid damage in the event of unforeseen loads, such as extensive growth. The growth could also limit the ecological function of the design, which may require the nature-inclusive structure to be designed in a way that minimises colonisation by plant species. It is important that the design of the nature-inclusive structure is integrated into the wind park design at an early stage to ensure that it is properly dimensioned and built (Hermans, Bos, & Prusina, 2020).

Technical risks	Ecological risks
1. Structural damage to wind turbines	1. Inter-species competition so that species intended to be protected are at a disadvantage
2. Structural damage to the nature-inclusive structure, with subsequent risk of causing damage to wind turbines	2. The species intended to be protected is in fact primarily limited by factors other than lack of structure (e.g. food limitation)
3. Growth such that the nature-inclusive structure no longer fulfils its intended function, or so that there is additional strain on the structure	3. Lack of ecological effect due to poor design or unforeseen environmental conditions
4. Shifts or redistributions in the nature-inclusive structure due to weather conditions, changes in the bottom substrate or deficient equipment	4. Absence of the species intended to be protected so that the nature-inclusive structure has no function
5. Unforeseen costs	5. Colonisation with unwanted alien species

Table 3 – Compilation of technical and ecological risks linked to nature-inclusive designs.

Measures to reduce ecological risks include initially testing the selected design based on relevant ecological assessment parameters and then optimising it. The likelihood of benefiting the desired species can be increased by synchronising the installation with key ecological processes, such as the colonisation period. This requires good knowledge of the local ecosystem and site-specific conditions in terms of both biotic and abiotic conditions. The physical and chemical properties of the surface coating should also be carefully selected in order to optimise the colonisation surfaces for the desired species (Hermans, Bos, & Prusina, 2020).

6 Conclusions and prospects

This last chapter discusses the significance of the synthesis results in chapters 2 to 5 for the future expansion of offshore wind power in Sweden and opportunities for coexistence with commercial fishing, aquaculture and nature conservation. The chapter addresses the assignment directive's requirement to evaluate the relevance of the results to Sweden and to discuss the relevance for marine spatial planning and permitting.

The chapter is divided by sector – commercial fishing, aquaculture and nature conservation. The conclusions concern aspects of relevance to planning, permitting, and support functions such as research and development, collaboration, guidance and guidelines. The analysis is forward-looking with a focus on the roles of the state, although the roles of private actors are also highlighted where relevant. A fundamental principle of the analysis is that better governance and guidance is needed to promote coexistence. At the same time, private actors should have the freedom needed to drive the continued development of solutions for coexistence.

With regard to the importance of marine spatial planning, the analysis is based on the current planning system, despite its limitations in terms of managing coexistence. The chapter therefore ends with a brief reflection on the possibilities that could be created by a new spatial allocation system of the type existing in most other countries and recently referred to by SwAM in the final report of the assignment on exclusivity for the construction of offshore wind parks (SwAM, 2022c).

6.1 Commercial fishing

The synthesis shows that coexistence between offshore wind power and fishing with active gear is difficult or very difficult. The reason is the high safety and economic risks associated with the operation of fishing vessels with relatively large and heavy gear through the limited space between wind turbines. Since most countries do not allow fishing with active gear in wind parks, the empirical knowledge of different solutions is extremely limited. The views of the commercial fishing industry and the wind power industry on the possibilities for coexistence vary, but fishing with passive gear is considered to have the best prerequisites for coexistence. While some representatives believe that coexistence is possible by adapting the respective activities, others believe that the risks and thus the costs remain too high for coexistence to be possible despite adaptations.

Thus far, most European countries have chosen to plan wind power areas outside the most valuable areas for commercial fishing. With few exceptions, fishing is heavily restricted in and around offshore wind parks, mainly for safety reasons. Even in countries such as the UK and Denmark, which do not formally prohibit commercial fishing in wind parks, the state has steered the establishment of offshore wind power away from the main fishing areas in its marine spatial planning. However, exchanges with other countries' planning authorities within the framework of this synthesis showed that this possibility is disappearing to some extent due to the countries' increasing commitment to electricity generation from offshore wind power. In line with the need for more offshore wind power areas, several countries have begun to realise the importance of developing coexistence solutions in the near future.

When it comes to the most valuable types of fishing for Sweden – bottom trawling for shellfish and fish, and pelagic trawling for small pelagic species – there is currently very little experience of coexistence with wind power in practice. For pelagic trawling, there are no reported experiences,

and for bottom trawling and passive gear fishing, which represents a small proportion of the total in Sweden, the few experiences that exist suggest that fishing is decreasing in scope. In Scotland, for example, the current marine spatial planning process has limited assumptions about fishing in wind parks compared to the previous marine spatial planning cycle. The reason is the realisation that fishermen are refraining from fishing in wind parks to a greater extent than previously thought.

In Sweden, there may also be areas where coexistence between offshore wind power and commercial fishing is difficult or impossible. Such an assessment should first be made in the context of state marine spatial planning, based on an analysis of factors such as the type of fisheries and wind parks as well as the respective societal benefits and costs in different areas. Chapters 2 and 3 describe the coexistence possibilities for different types of fisheries and wind parks in a comprehensive manner. Within the context of marine spatial planning, the local conditions need to be taken into account – for example, the conditions for trawling for crayfish within a wind park with fixed-bottom turbines in Skagerrak and Kattegatt differ from the conditions for pelagic trawling in a floating wind park in the central Baltic Sea. Ultimately, there will need to be a trade-off between the interests that use the same area as part of the wind park permit granting process.

This knowledge synthesis is based on literature and experience from recent years, and is largely based on wind parks that are generally smaller and denser than those currently being planned in most countries, including Sweden. Future offshore wind parks will be larger and have higher-positioned turbines at greater distances, affecting the conditions for coexistence with commercial fishing. The importance of technological development for coexistence has been expressed by representatives from the commercial fishing and wind power industries in the dialogue conducted within the framework of this assignment. Among other things, they underscored the value of continued dialogue to develop coexistence solutions, which also indicates how important industry input into marine spatial planning is for coexistence opportunities. Early involvement of the commercial fishing industry, before the layout of a wind park has been finalised, is also crucial for coexistence work to be possible.

In order to promote coexistence in areas where coexistence between wind power and fishing is deemed possible, a national guide with conditions for fishing within and near wind parks may be required. Such a guide should include the design of the park, such as distance between turbines, passage corridors, burial of cables and cable corridors, as well as fishing activities, including vessel size, size and type of gear, etc. The ambition should be for both activities to be conducted in a safe and efficient manner. The guide would need to take into account the different fisheries carried out in different Swedish marine areas — for example, a distinction should be made between conditions for coexistence with bottom trawling for shellfish in Skagerrak and Kattegatt and conditions for coexistence with vendace fishing in the Gulf of Bothnia.

The guidance provided in the marine spatial plans can be of a general nature, in line with other guidance provided in the marine spatial plans. In addition, it may be relevant to have more detailed guidance to support the permitting processes, including criteria for assessing coexistence solutions. The criteria should preferably be developed in dialogue with the industries, and must take into account guidelines on navigation safety and emergency situations (see below).

Where offshore wind power and commercial fishing are considered capable of coexisting, it may be necessary for the state to impose requirements on the industries to develop coexistence solutions. An example of this can be seen in Denmark, where there is a statutory minimum level

that negotiations with the fishermen concerned must have been initiated in order for the Danish Energy Agency to grant a permit for an offshore wind park. Similar conditions were recently laid down in the proposal for a decision on permitting the Kattegatt Syd wind park drawn up by the Halland County Administrative Board for the Government. These conditions included the wind power company being required to engage in dialogue with the commercial fishing producer organisations with the aim to establish and maintain a joint plan to enable demersal commercial fishing in the area. It is doubtful whether the state should impose additional conditions for coexistence, for example regarding the distance between wind turbines, cable corridors or the burial of cables, by means of criteria for the designation of areas and the granting of permits for offshore wind power. The literature review and exchanges with other countries carried out in the context of this synthesis have shown that no country has so far required such conditions. The responsibility for developing coexistence solutions has instead been placed on the relevant developers based on the site-specific conditions.

During this assignment, navigation safety came up as the main risk associated with fishing within or near wind parks. At the same time, the specific navigation risks for fishing vessels are rarely investigated during the construction of wind parks. However, detailed risk assessments are carried out for shipping as part of the offshore wind park permitting process, and should be applicable to fishing vessels as well. Moreover, industry guidelines and standards are much more developed for cargo ships than for fishing vessels. The development of a robust, quantitative assessment of navigation risks for commercial fishing in wind parks specifically for Swedish conditions emerged as an important aspect of this assignment. The assessment should take into account different fishing vessels in the fishing fleets active in Swedish waters, weather, wind and environmental conditions, type of parks, etc. and include emergency response. The results, in combination with other existing guidelines, can form the basis for national guidelines for fishing activities in wind parks. Comparisons can be made with guidelines from the UK (Maritime & Coastguard Agency, 2022; Maritime & Coastguard Agency, 2021).

Other important risks are the business economic risks arising from the safety risks. Fear of the economic consequences of an accident has been one of the main reasons behind the low interest in commercial fishing within wind parks in the UK. Contact with stakeholders in the context of this assignment has shown that the wind power industry generally considers such risks to be too high. For example, in Denmark, negotiations between wind parks and fishermen have usually resulted in the latter being compensated for their lost income rather than choosing to risk large economic losses. Fishing companies generally do not have the same financial resources as wind power developers, and the risks are therefore greater. There are also questions about insurance for fishing vessels operating in wind parks. A closer examination of insurance for risks associated with commercial fishing in wind parks may be warranted to promote coexistence. The insurance issue is probably best addressed by the private sector, but there may be a need for the state to regulate the minimum level of insurance for fishing vessels, gear and crew. If so, this should be done at the EU level, as commercial fishing takes place across national borders.

Finally, it is important to highlight a conclusion that permeates most parts of the coexistence issue, namely the importance of dialogue and collaboration between the wind power industry and the commercial fishing industry. The basic assumption is that concrete solutions can only be developed by the partners concerned because the solutions are specific to the activities and the area in which the wind power is to be established. However, the synthesis shows that the dialogue between the industries has often been unsatisfactory, as several stakeholders in Sweden have also testified. It is therefore important to continue to support the industries in developing forms of dialogue that lead to mutual learning and respect, as well as the

development of joint solutions. It may be relevant to learn from the experiences of countries such as the UK and Denmark that have developed such dialogues. In Sweden, the cooperation that exists between the fishing industry, authorities and research within the framework of the agencies' joint strategy for fishing and aquaculture, and the dialogue platform initiated by the Swedish Board of Agriculture in parallel with this assignment, provide a suitable foundation on which to build the future dialogue within and between the industries.

6.2 Aquaculture

The establishment of aquaculture in offshore wind parks is currently very rare. Today, there are only a few experimental installations, mainly for the cultivation of low trophic species such as mussels, oysters and algae. At the same time, the literature review and contacts with the industries indicate that the interest in combining aquaculture and offshore wind power is high in the aquaculture industry. Combined installations are seen as an opportunity for aquaculture to establish itself in offshore areas and as a way to utilise marine areas more efficiently through multi-use. For coexistence to develop, continued support for research and development of sustainable solutions adapted to the conditions and technology choices in the various wind power areas is needed in the coming years.

Several countries have identified suitable areas for offshore aquaculture in their marine spatial planning. According to several actors in the industry, the next step in promoting coexistence with offshore wind power is to plan specifically for coexistence by identifying multi-use areas in marine spatial planning. The Netherlands' area passport is an interesting model to draw inspiration from. However, the Swedish State has limited ability to apply a similar scheme under the current system for establishing offshore wind power, where the initiative lies almost exclusively with the wind developer.

In Sweden, the national marine spatial planning has so far not designated areas for aquaculture within the marine spatial planning areas. The main reason has been the lack of a basis in the form of, among other things, national interest claims or private claims. In order for marine spatial planning to identify suitable areas, the suitability of the marine areas for aquaculture needs to be analysed based on various environmental and socio-economic criteria. Dialogue with the industry is important in this process, as is experience from other countries that are more advanced in planning offshore aquaculture. This is in line with the Action Plan for the Development of Swedish Aquaculture adopted by SwAM and the Swedish Board of Agriculture in 2021 as part of the Joint Strategy for Fisheries and Aquaculture.

Where suitable areas for aquaculture coincide with suitable areas for offshore wind power, marine spatial planning can provide guidance on coexistence. However, the current state of knowledge is too poor to provide such guidance. Nevertheless, it is likely that experiences from other European countries in which pilot installations exist or the state has begun to reward multi-use will become available and can be used as a foundation within a few years. In the long run, the development of processes and assessment criteria for the testing of combined wind and aquaculture installations may be envisaged. In addition to environmental risks, they could also take into account potential environmental and societal benefits, such as the uptake of nutrient salts, food production or the creation of new habitats. Such a step needs to be preceded by a review of existing legislation underpinning the permitting of water activities. Guidance on the application of the new assessment criteria may need to be developed to ensure that this is done in a consistent manner.

As more countries begin to impose requirements or reward multi-use of offshore wind parks, wind parks will have greater incentives to develop coexistence solutions in conjunction with other uses,

including aquaculture. It is therefore likely that private companies will play an increasing role in the development of such solutions, through self-funded research and development programmes. In order to continue building a basic knowledge base on multi-use in this early development phase that all countries are in today, there may be a need for continued state support for publicly funded programmes. Support for the development of combined wind and aquaculture installations could possibly be part of a larger effort to address the coexistence of offshore wind power with other activities, such as commercial fishing and nature conservation.

6.3 Nature conservation

The coexistence between offshore wind power and nature conservation differs from the coexistence with commercial fishing or aquaculture in that nature conservation is not an activity whose environmental impact needs to be regulated or whose permissibility needs to be assessed. Nature conservation instead encompasses the conservation objectives that underpin the environmental regulation of aquaculture, commercial fishing and wind power. The extensive environmental legislation at the national and EU level is central to wind power permitting processes in all countries. This means that there is considerably more empirical data on opportunities and obstacles to coexistence with nature conservation compared to coexistence with commercial fishing or aquaculture. However, there are still gaps in knowledge about the impact of offshore wind energy on marine species and habitats. The lack of knowledge and the fact that most environmental impacts are site-specific make it difficult to draw general conclusions about the conditions and measures for coexistence between offshore wind power and nature conservation.

The assumption that offshore wind power may be difficult to reconcile with the protection of species and habitats has led most countries to avoid designating areas for wind power development within or directly adjacent to marine protected areas in their marine spatial planning. Although some countries have begun to review this principle in recent years due to increased demand for offshore electricity generation, there are few exceptions. The consequence is that there are currently only a very small number of small wind parks in marine protected areas. Experience from countries where co-location of offshore wind power with protected areas is possible, including Sweden, shows that the permitting processes are more complex and lengthier. This is due to the greater rigour in assessing thresholds for acceptable harm to protected species and habitats.

The greater complexity of the permit granting process for offshore wind power in protected areas often means greater unpredictability for the developer. Co-location is therefore usually not preferable for a faster deployment of offshore wind power, which is a policy objective in many countries, including Sweden. In most countries, the state has so far used their marine spatial planning to steer offshore wind power away from areas where there is a risk of an unacceptably high impact to natural values. This has been a way to not only ensure the protection of natural values, but also create the conditions for a smoother establishment of wind power in specially designated areas. Having that opportunity early in the process can be particularly valuable for future ambitions to increase the marine area protection target to 30 per cent, of which 10 per cent strict protection, proposed for 2030 under the EU Biodiversity Strategy. The areas of strict protection should be free from all local human influences, which can be interpreted as meaning that coexistence with offshore wind power will not be possible (European Commission, 2022a). In the case of the other 20 per cent protected areas, these shall be either formally protected areas or so-called other effective area-based conservation measures (*OECMs*). These OECMs are areas that, although not marine protected areas, still contribute to the protection of valuable

natural habitats and species. Examples that are sometimes mentioned as possible OECMs in international documents are areas with fishing regulations, such as fishing-free areas, areas with wrecks protected due to cultural historical values, and wind parks. However, the work to identify marine OECMs in Swedish seas has not yet progressed so far that it can be said that this could also be relevant in Sweden.

In Sweden, there are no possibilities for the indicative state marine spatial planning to control the establishment of wind power in the same way as in countries with a strongly guiding planning system. In addition, the existing marine spatial plans contain energy production areas on or directly adjacent to Natura 2000 sites. Though, the marine spatial plan can provide guidance on mitigation measures that should be taken into account in subsequent permitting procedures, based on an assessment of the possible effects of wind power on protected species and habitats. However, the impact assessment of the marine spatial plans is of a strategic nature and is therefore not suitable for a detailed assessment of environmental impacts and thus of the actual potential for coexistence. Such an assessment is carried out in the context of the permitting process, but the lack of national assessment criteria and thresholds have made it difficult to assess the effects of wind power on protected species and habitats. Uniform assessment criteria for both environmental effects and mitigation measures contribute to greater clarity and predictability for both permitting authorities and developers by setting the frameworks that the wind park must adhere to in order to coexist with nature conservation.

The lack of assessment criteria and thresholds affects most other countries with offshore wind power, and is something that will gradually be resolved with better knowledge of the marine environment and the actual impact of wind parks. It is therefore important to develop a national programme for the acquisition of knowledge on the impact of offshore wind power on marine ecosystems that complements existing environmental monitoring programmes. The programme should be developed and implemented in collaboration with the wind power industry, and focus on the species and habitats that are most likely to be negatively affected by offshore wind power. The programme should also include regularly updated synthesis reports of the effects of offshore wind power on marine life, including results from studies from around the world.

The growing interest in environment-enhancing or -inclusive designs also makes it necessary to follow up on the actual environmental effects they may cause as soon as possible. Going forward, an assessment of the potential environmental and societal benefits associated with such designs may become crucial for the granting of offshore wind power permits. With respect to the issue of coexistence with nature conservation, developments indicate a shift in focus from merely reducing negative environmental effects to being able to demonstrate positive effects. Wind power developers are leading this development, and it is important that the state strengthens its ability to assess and set requirements that increase the benefits to society. Such a development is also necessary if any future wind parks are to be identified as areas with OECMs.

6.4 The offshore wind establishment system

The current Swedish system for establishing offshore wind power is what is known as an open-door system, which is based on the initiative of market participants, usually wind power companies, to apply for a permit for a wind power project in Sweden’s territorial sea and exclusive economic zone. A developer gets to choose the area in which they wish to apply, even outside the areas designated for energy production in the marine spatial plans. The marine spatial plans guide the permitting process, and it is only in the context of the project-specific permit granting process that a decision on permissibility is made. Despite the strengths linked to the high degree

of freedom granted to private actors and the transparency of the permitting process, there are a number of weaknesses that affect factors such as the ability to steer and promote coexistence (SwAM, 2022c):

- There is little or no predictability, neither for the applicant nor the state, regarding the possibility of actually being able to build in a chosen area;
- It is difficult to resolve conflicts of competing activities, as consultations between the stakeholders only concern each specific project development area, while the consequences of the interaction between offshore wind power and other activities may extend beyond such an area. Consultation on each individual project site is thus a weak mechanism for highlighting more complex or extensive conflicts between competing activities, and thus also for resolving the coexistence issue, especially on a larger scale;
- Cumulative effects from several individual projects are more difficult to manage within an individual assessment than within the marine spatial plans, as assessments are made separately and often with incomplete information on other projects in the same sea basin. This applies both to the effects on the environment as well as other interests, which makes it difficult to assess the possibility of coexistence both in individual areas and on a larger scale.

The new establishment system proposed by SwAM (SwAM, 2022c) looks at the systems that exist in the rest of Europe. The system is judged to open up opportunities for coexistence between offshore wind power and commercial fishing, aquaculture and nature conservation by:

- At an early stage, directing the establishment of offshore wind power to places where it is the most beneficial for the electricity system and has the greatest potential for coexistence with other interests;
- Steering the establishment of offshore wind power based on a collective assessment of the effects of all projects in a sea basin (cumulative effects), which enables better planning of the conditions for coexistence on a larger scale. This is important within, for example, the permit granting process to be able to take into account the need for passage corridors for fishing vessels, conditions for the relocation of fishing activities or the possibility of alternative fishing areas. Meeting such needs is difficult, if not impossible, if decisions are only made for each individual wind park, which is largely what is happening today;
- Steering the pace of offshore wind power establishment to make it in line with the need for renewable electricity generation, with an aim to better monitor and control the long-term and cumulative effects on the environment and other activities;
- Requiring wind developers to develop coexistence solutions for not only commercial fishing, aquaculture and nature-enhancing designs, but also for other interests not addressed in this assignment. This may involve, for example, the development of coexistence or sustainability criteria for the granting of permits or the division of the wind power area into different coexistence compartments, as the Netherlands have done with their area passport;
- Centralising and streamlining all area survey and data collection, thus improving the state of knowledge of offshore wind establishment areas;
- Setting more precise requirements for studies and precautions for a particular area based on a deeper knowledge of protected nature.

The last two points presuppose that the establishment system also includes initial investigations of the project-specific area by the state, similar to countries such as the United Kingdom, Germany or Denmark. A transition to a new establishment system entails extensive changes to the regulatory framework and must be preceded by an investigation of the consequences for the wind power projects currently under development in Swedish waters.

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Annex 1

2022-04-26

Governmental assignment on coexistence – order for written input from stakeholders

The Government has mandated the Swedish Agency for Marine and Water Management and the Swedish Energy Agency to compile knowledge of the prerequisites and measures for coexistence between offshore wind power and commercial fishing, aquaculture and nature conservation, respectively, in areas relevant for the establishment of offshore wind parks (N2022/00515 Assignment to compile a knowledge synthesis of conditions and possible measures for coexistence in areas with future wind park establishment). The synthesis is based on experiences in Sweden and other countries.

SwAM and the Energy Agency are keen to capitalise on the extensive knowledge that exists in the Swedish wind power, commercial fishing, aquaculture and nature conservation industries, and therefore welcome input from industry representatives on the issue of coexistence. The contributions of the industries form an important basis for the knowledge synthesis that the agencies will submit to the Government at the end of February 2023.

SwAM and the Energy Agency would like to ask industry organisations in Swedish wind power, Swedish commercial fishing and aquaculture and Swedish nature conservation to submit a written report on the issues presented below. The industry organisations are free to decide on the form and scope of the report. Please submit the written report to Gonçalo Carneiro, goncalo.carneiro@havochvatten.se, and Jonas Bjärnstedt, jonas.bjarnstedt@energimyndigheten.se, with a copy to the SwAM Registrar, havochvatten@havochvatten.se, by 31 October 2022.

Questions:

- Wind power industry organisations: What are the main opportunities and obstacles for coexistence with commercial fishing, aquaculture and nature conservation?
- CF/AC/NP: What are the main opportunities and obstacles to coexistence between offshore wind and commercial fishing/aquaculture/nature conservation?
- Which areas in the Swedish sea do you think have the best and worst conditions for coexistence?
- Wind power industry organisations: Do you have experience from other countries in measures that have been shown to promote coexistence and synergies with commercial fishing, aquaculture or nature conservation?
- CF/AC/NP: Do you have experience from other countries in measures that have been shown to promote coexistence and synergies with offshore wind power?
- What measures do you think are needed to improve the conditions for coexistence in Sweden?
- What role can your organisation play in developing and implementing these measures?

Coexistence of offshore wind power with commercial fishing, aquaculture and nature conservation

A synthesis of knowledge about preconditions and measures

Sweden, like many other countries, is facing a major transition in its energy systems, with renewable electricity generation in general and offshore wind power in particular at the centre of this transition. The extensive expansion of offshore wind power that has begun brings not only benefits, but also risks to the environment and other uses of our seas.

The Swedish Government has commissioned the Swedish Agency for Marine and Water Management and the Swedish Energy Agency to compile knowledge about opportunities and conditions for coexistence between offshore wind power and commercial fishing, aquaculture and nature conservation. The aim of the assignment is to highlight the risks as well as the opportunities for synergy that can arise in marine areas with wind power establishment. This report summarises the state of knowledge at the beginning of 2023 and constitutes the agencies' joint final report of the assignment to the Swedish Government.