Exploring co-use of offshore wind farms by passive fisheries in Borssele wind farm, the Netherlands

Author(s): Neitzel, S.M.[1], Serraris, J.W.[2], Deetman, B.[3], Rozemeijer, M.J.C[1], Jurrius, L.H.[1], Taal, K.[3], de Graeff, P.[2], Afranewaa, N.[1]

Wageningen University & Research report: C032/24

WAGENINGEN UNIVERSITY & RESEARCH

Exploring co-use of offshore wind farms by passive fisheries in Borssele wind farm, the Netherlands

An experimental study on the technical, ecological, economic and safety considerations of fishing with handline, gill nets, pots and jigging machines

Author(s): Neitzel, S.M.[1], Serraris, J.W.[2], Deetman, B.[3], Rozemeijer, M.J.C[1], Jurrius, L.H.[1], Taal, K.[3], de Graeff, P.[2], Afranewaa, N.[1]

[1] Wageningen Marine Research

[2] Maritime Research Institute Netherlands (MARIN)

[3] Wageningen Economic Research

This research project was carried out by Wageningen Marine Research and subsidized by the Ministry of Agriculture, Nature and Food Quality for the purposes of Policy Support Research Theme
'E5 Visserij Monitoring' (project no. BO-43-119.01-054 & BO-43-119.01-055).

Wageningen Marine Research
IJmuiden, May 2024

Wageningen Marine Research report C032/24

Keywords: *passive fishing, small-scale fisheries, offshore wind farm, co-use*

Client: Ministry of Agriculture, Nature and Food Quality
Attn.: N.M. Visser
Bezuidenhoutseweg 73
2594AC Den Haag

BO-43-119.01-054 ADD Fase 2b - Praktijktesten passieve visserij - Jiggen en potten
BO-43-119.01-055 ADD Fase 2a - Praktijktesten passieve visserij - Handlijn en staandwant

This report can be downloaded for free from https://doi.org/10.18174/659099
Wageningen Marine Research provides no printed copies of reports

Wageningen Marine Research is ISO 9001:2015 certified.

Photo cover: Sophie Neitzel

KvK nr. 09098104,
WMR BTW nr. NL 8113.83.696.B16.
Code BIC/SWIFT address: RABONL2U
IBAN code: NL 73 RABO 0373599285

A_4_3_2 V32 (2021)

Contents

Acknowledgement

The authors would like to thank the Ministry of Agriculture, Nature and Food Quality (LNV) for making this project and fieldwork financially possible and for their input and cooperation throughout the process of testing the opportunities for fishing in wind farms. The field tests required a lot of coordination, communication and preparation between all parties involved. Therefore, the authors would also like to thank all persons involved that made this project successful. First of all, the fishers from the focus group that designed the project together with the researchers for their effort and guidance during very time consuming meetings. Also, the fishers that were out at sea together with a highly motivated field team performing heavy duty work in all weather circumstances imaginable, during weekends, holidays and at night if needed. Also, the authors would like to thank wind farm owner Ørsted, the Dutch Coastguard and Rijkswaterstaat for their cooperation during this project. We would also like to thank our colleagues from the Flanders Research Institute for Agriculture, Fisheries and Food (ILVO) in Belgium for borrowing their cuttlefish pots for this experiment and for sharing their knowledge from previous experiments. Finally, we would like to thank our reviewers of this report for their constructive feedback throughout the process.

Summary

This study commissioned by The Ministry of Agriculture, Nature, and Food Quality facilitated the initiation of passive fishing in wind farms, by experimenting with four fishing methods in offshore wind farm Borssele. Through a pilot experiment in offshore wind farm Borssele, the ecological parameters, economic considerations, (by)catch and safety requirements of applying various passive fishing methods in an offshore wind farm were explored. This report outlines the results, possibilities as well as challenges, and considers operational factors, safety measures, fishing gear specifications, economic feasibility, and ecological aspects.

The experimental set-up was developed collaboratively with a focus group of fishers and scientists. The gears to be tested were selected based on target species (*is the species present in the fishing area and is it expected to yield*?), gear-type (*is the gear legally allowed to be used, is the gear testable in the short term, and is there enough confidence from the fishers in this gear*?), planning (*are there enough available vessels and crew, do the gears overlap*?), available space within wind farm (*does the experimental plot allow for enough room for the gear to be applied?*) and seasonality (*to test the gears, do the target species match the chosen seasons, and are there enough days with calm weather circumstances in a particular season*?). It led to the selection of four gears: handline fishing, mechanical jigging, multi-species pots and gillnets. For each gear, multiple testing days were made in the period April to October 2023, in offshore wind farm Borssele, off the Dutch coast. Three fishing vessels were used: YE 152 (9.95 m in length) for gillnet and multi-species pot fishing, KG 7 (6.5 meter in length) for handline fishing and MDV 2 (30.51 meter in length) for jigging. During experimental fishing in the field, data on operations and safety, economics, ecology and catch were collected. The experiment had an explorative character. Not all gears were repeated in the similar approach, reducing replicates.

Catch

Each gear was deployed with a specific target species as a focus: handline on seabass, gillnet on sole, multi-species pots on cuttlefish, Atlantic squid, Atlantic cod, seabass and sole, jigging on Atlantic mackerel, horse mackerel and European squid. Target species were caught with gillnets (sole) and jigging machines (Atlantic mackerel), yet for handline, jigging for Atlantic squid and multi-species pots, it appeared more difficult to catch target species. For handline, although no seabass was caught, commercially valuable Atlantic mackerel was caught despite not being the species initially targeted. For multi-species pots, more brown crab and velvet swimming crabs than anticipated were caught as secondary target species, both having commercial value. Many factors have influenced catch-success during the experiments: weather circumstances, peak seasons of target species and therefore the right time of fishing, fishing gears and their settings and characteristics, soaking times and locations. Therefore, to limited data availability no conclusions could be drawn on the presence of the target species in the offshore wind farm based on this experimental study. In addition, CPUE (catch per unit effort) and LPUE (landings per unit effort) could not be determined, as this would give a non-representative overview of the catch potential.

Safety

A dominant focus of the study was whether passive fishing in wind farms can be carried out safely. Both the risks for the fishers as well as for the offshore wind farm were evaluated. Regarding the former, the already applicable national regulations for crew and vessels appear adequate to mitigate any risk. There is no necessity to prescribe additional measures beyond the present regulations of fishing vessels, crew and operations within the wind farm.

The risks of passive fishing activities for the wind farm were evaluated by a Task Risk Assessment together with the focus group. One identified considerable risk for the wind farm is the potential displacement of

gears, which might results in interaction between gears, wind turbines or in-field cables. To mitigate this risk, in the experimental set-up the gears were positioned with 200 meters leeward distance to the maintenance zone, resulting in a total distance in leeward direction to any infrastructure of 450 meters. Furthermore, qualitative and quantitative evaluations were performed to explore the risk of gear displacement. The quantitative analysis of string displacements shows 8% of the measurements exceed the mean + 1.std measurement deviation. However there is additional registration uncertainty in the measurements of the anchor positions, since the orientation of setting and hauling, either from North to South or vice versa, and thereby the definition of the first and second anchor is not always well registered. For following experiments it is advised to improve the accuracy of the anchor position measurements and registrations to reduce uncertainty from the measurements. Qualitative experiences of the skipper and researchers indicate that no notable drift of the gears has taken place, maximum in the order of meters to decameters. From these analysis it is concluded that the risk of displacement of gears moored by Bruce anchors is marginal. The findings spur the discussion of whether the 250-meter maintenance zone could be reduced to potentially improve catch rates, provided the appropriate risk assessment is applied. Other, lower classed risks were evaluated by a qualitative approach together with the focus group.

The vessels applied in the experiments are capable of operating up to significant wave height of 0.8 meter (KG 7), 1.0 meter (YE 152) and 1.5 meter (MDV 2). In offshore wind farms, the wave conditions regularly exceed these operational limits, especially for small vessels such as KG 7 and YE 152, even in summer. Evaluation of wave conditions in wind farm Borssele in 2023 in addition to long-term statistics showed that wave conditions in spring and summer 2023 were more severe than in average years, but the differences were not large. This was in-line with the experience of the fishers.

Birds and sea mammals
Another point of attention in the study was whether passive fishing in wind farms might have an effect on birds and marine mammals. Very few sea birds and sea mammals were seen in the offshore wind farm during experimental fishing. Only when crew threw unwanted catch (discards) overboard, birds seemed attracted to fishing activities, which happened in just two cases, both outside of the wind farm. Discarding was done both inside and outside of the wind farm, following fishing legislation. Sea mammals did not appear to be attracted to or influenced by the fishing activities. In none of the gears, birds or sea mammals were by-caught.

Economy
To investigate whether passive fishing in wind farms could be economically attractive for the fishers, an exploration of economic variables was included in the study. Compared to commercial fishing the number of gears deployed in this study was limited leaving little data availability on catches. A complete overview of what is required to fish successfully commercially cannot yet be given due to the novelty of the playing field and consequent limited practical experience. This study elaborates on the initial indications from economic data and discusses possible developments that could improve the economic feasibility of fishing in wind farms.

The economic feasibility of fishing in an offshore wind farm depends on various factors, such as required gear adaptations, sailing time, the amount of space available, lay-out of the wind farm, restrictions within the wind farm and how activities in wind farms can be combined with conventional practices outside the wind farm. The report presents an overview of the costs per year and per fishing trip of the vessels involved. Cost per fishing day vary from 900 euro (small scale fishing vessel, 2 crew members) to 6,000 euro (32-meter vessel, 5 crew members). If economically feasible, the revenue must meet these costs.

The project further explored the potential opportunity of converting shrimp cutters for passive fishing in a wind farm. Due to regulatory restrictions regarding nitrogen impacts, as well as declining catch rates in 2023, several Dutch shrimp fishers are looking for alternative ways to deploy their fishing vessel. As these types of vessels have more work and storage space on deck than smaller vessels, are navigable but stable enough in slightly more turbulent weather, they could be suitable to be used for passive fishing in offshore wind farms. The costs per fishing trip for these vessels vary between 2,123 and 2,774 euro.

Based on yield data of potential target species, a first indication is given of catch rates required to cover costs of fishing in wind farms.

Overall reflections

The study yielded the first pilot results for the four gears experimented with, but also revealed four overarching reflections on passive fishing in offshore wind farms. As the experiment had an explorative character, only a very limited number of gears per fishing trip compared to commercial fishers were deployed and few fishing trips per gear were done. Due to this the reflections below could be different than in case of commercial fishing.

1) *Passive fishing in offshore wind farms appears technologically feasible and safe.* Applicable gears are available. One should take into account the limited workability of small fishing vessels in offshore wind farm in the outlooks for passive fishing within wind farms, or look at alternative vessel-types (e.g. converted shrimp cutter). By providing a clear risk framework for all parties involved, and addressing key knowledge gaps, the government could create a more enabling environment for passive fishing in wind farms.

2) *Passive fishing in offshore wind farms differs significantly from current fishing practices and therefore calls for adapted or alternative frameworks*. Challenges encountered when applying the novelty of fishing in wind farms within the current regulatory frameworks include accessibility to offshore wind farms, vessel size and gear restrictions. Adjustments in both fisheries and policies are needed to align the sector's capabilities with the prevailing co-use ambitions. For instance, allowing multiple gears on board could allow for more realistic expansion of passive fishing into wind farms, and fishing closer to monopiles could increase catch potential for various gears, provided the appropriate risk assessment is applied.

3) *Passive fishing in offshore wind farms may complement, but not substitute current fisheries.* Dutch fisheries face pressure from many sources, such as international policy, sustainability and climate change, offshore wind development, and inevitably face a strong transition at sea. Despite initial discussions depicting fishing in wind farms as part of the transition of Dutch fisheries, the initial reflections from this study indicate that fishing solely in wind farms is unlikely to gain an optimistic business model. Fishing opportunities within these novel arenas seem challenged due to the type of gear that will likely be allowed and space constraints (allocated area in area passport guides and prohibited access to maintenance areas). In case fisheries within wind farms is desired, economic viability, gear allowance and innovation should be addressed.

4) *Communication between parties should be improved, simplified and standardised.* Both the quantitative and qualitative level of required communication between the parties concerned (including fishers, researchers, wind farm operator, government officials, Coast Guard) as experienced during the experiments, led to reluctance among fishers to fish in offshore wind farms. It is recommended to reduce, standardize and automatize these communications to ensure the motivation and attractiveness of enabling fishing in wind farms, both for the fishers themselves but also for other stakeholders.

This study investigated the possibilities as well as challenges of passive fishing in an offshore wind farm in the Netherlands. To explore this novel playing-field, it consisted of a limited trial setup in offshore wind farm Borssele II. Despite statistical evaluations being limited, which was further afflicted by unfavourable weather conditions, this study was able to gather first insights, prompt needed discussions and provide evaluations on the ecological, economic and safety considerations of passive fishing in wind farms. Not only regarding the four gears tested, but also in general. By taking the first steps through gaining practical experience, incorporating the engagement and collaboration across all stakeholders and uncovering crucial discussion points and suggestions, it provides a launch pad for further exploration of fishing opportunities in offshore wind farms.

1 Introduction

1.1 Background

1.1.1 History of wind energy

Over the past few decades, the Netherlands has been at the forefront of implementing wind energy in the North Sea, marking an important chapter in the nation's commitment to sustainable and renewable practices. As the Netherlands has to keep the balance between renewable energy goals and environmental sustainability, the history of Dutch wind farms in the North Sea unfolds as a very dynamic working field of innovation, collaboration, and a commitment to a greener future. The North Sea has therefore become an important place for the development of numerous wind farms, contributing significantly to the country's renewable energy portfolio.

As of 2024, the Dutch North Sea counts a total of 9 offshore wind farms (OWFs) with a total surface area of 954km^2 of the lots combined, with each of the wind farms comprising a multitude of wind turbines and delivering a total of 4.7 gigawatt (GW) (Table 1.1). These wind farms are important to the Netherlands' dedication to transitioning towards cleaner energy sources, aiming to reduce reliance on traditional fossil fuels.

Table 1.1 *– Dutch offshore wind farms currently in operation with their amount of wind turbines, output in megawatt (MW) and year they started operating. Source: Windparken op de Noordzee (rvo.nl).*

Name of wind farm	**Wind turbines (#)**	**Output per turbine**	**Total capacity**	**Year**
Hollandse Kust Noord	69	11	759	2023
Hollandse Kust Zuid	139	11	1529	2023
Borssele V	2	9.5	19	2021
Borssele I en II	94	8	752	2020
Borssele III en IV	77	9.5	731.5	2020
Gemini Windpark	150	4	600	2016
Luchterduinen	43	3	129	2015
Prinses Amaliawindpark	60	2	120	2008
Egmond aan Zee	36	3	108	2007
Total	**670**		**4738.5**	

1.1.2 Future of wind energy

In the near future, another two offshore wind farms will be put to operation in the wind energy areas of Hollandse Kust West and IJmuiden Ver. New wind energy areas are also allocated for future use: Nederwiek, Doordewind and Lagelander. Figure 1.1 gives an oversight of all current and future wind energy areas in the North Sea. It is expected that by 2030, the total capacity of offshore wind will be 21 GW with a total surface area of 2600km^2 [1]. Other countries and their parts of the North Sea follow this trend. For the Netherlands, this means that in 2030, 4.5% of the total area of the Dutch exclusive economic zone

[1] Hoeveel ruimte gebruikt wind op zee? - Wind op zee

(EEZ) will be used for offshore wind. This percentage includes only the area of the wind farms itself, without safety zones around the wind energy areas. The development of new wind energy areas will not stop after 2030. A case study by den Ouden et al. (2020) on the exploration of integrated infrastructure assumes that within the time frame of 2030-2050, a total of 38 to 72 GW of offshore wind energy will be needed by 2050. In terms of space, this means that between 7.5% to 13.4% of the Dutch Exclusive Economic Zone (EEZ) of the North Sea will be allocated to offshore wind.

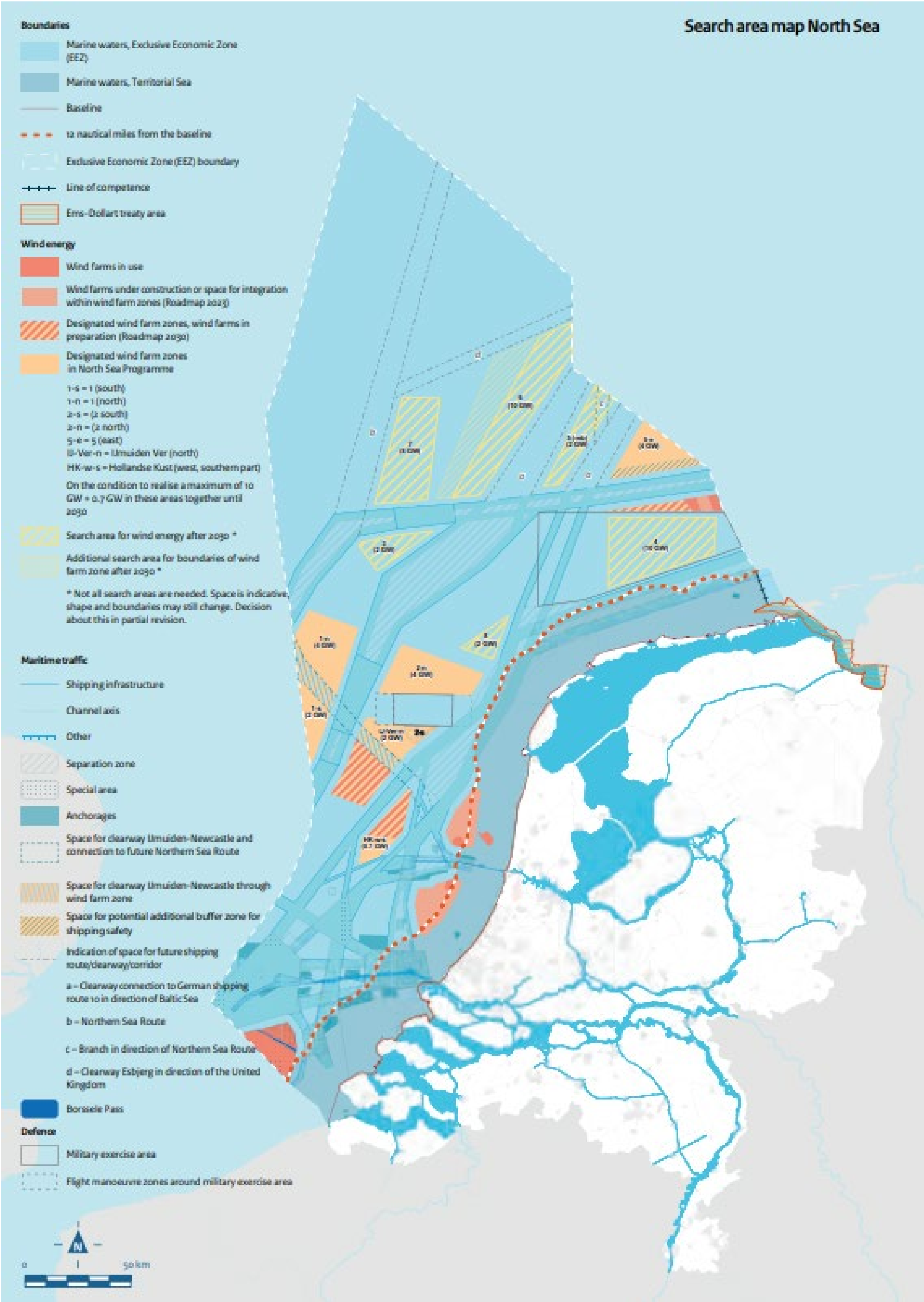


Figure 1.1 *– Dutch offshore wind energy areas in the North Sea (current and near future). Source: North Sea Programme 2022-2027 (North Sea Programme 2022-2027 - Noordzeeloket UK). Note: Map shows areas that are designated for wind energy, which may differ from the actual land take of wind farms in the area.*

1.1.3 Other North Sea stakeholders

The utilization of space in the Dutch EEZ in the North Sea is not solely driven by wind energy; there are various other activities competing for spatial allocation, such as shipping routes, oil and gas industry, defence training areas and nature reserves. Currently, nature reserves cover approximately 30% of the space in the Dutch EEZ of the North Sea and this percentage will continue to increase (*Windparken op de Noordzee (rvo.nl)*). In relation to fishing, 5% of these reserves are currently closed for bottom-trawling and the North Sea Agreement (2020) stipulates that by 2023, 13.7% of the North Sea within ecologically valuable areas bottom-trawling fishing will be banned. The recently presented plan by the European Commission states that from 2030 onwards, there will be a complete ban on bottom-trawling fishing in all nature reserves at sea, meaning the percentage will double from the in the North Sea Agreement originally decided 15% to 30%. However, the EU member states still need to translate that plan into national measures. Shipping routes and cables and pipelines also occupy space in the North Sea: approximately 6.2% to 13.4%. Although fishing is allowed in these areas, in practice, it may not always occur due to the risks of damage or collisions. All forms of utilization together leaves less and less space for fisheries in the future. The only current option for fishers who want to fish in offshore wind farms is to look for profitable non-bottom-trawling alternatives.

1.1.4 Change towards co-use

In a progressive move towards optimizing the utility of these wind farms, the Dutch government has actively embraced the concept of co-use. The implementation of policies facilitating co-use, such as passive fishing and mariculture, reflects a nuanced approach to maximize the benefits derived from these expansive offshore energy areas. One notable initiative in this direction is the introduction of the "handreiking gebiedspaspoort" (area passport guide) for wind farms Borssele, Hollandse Kust Zuid and Hollandse Kust Noord. This document delineates the preferred methods of co-use in various zones within the wind energy area (Figure 2.1). Apart from mariculture, sustainable energy generation and storage, and nature-enhancing projects, a specific area within wind farm Borssele has been designated for passive fishing. However, at present, passive fishing within wind farms is limited to experimental settings and specific conditions. The North Sea Agreement has determined that additional rules and regulations will be developed, if necessary, before allowing commercial passive fishing in offshore wind farms. The revision of these regulations aims to allocate usage rights and prevent overexploitation (North Sea Agreement, 2020, p. 20, agreement 4.20). The Ministry of Agriculture, Nature, and Food Quality is currently evaluating the need for additional regulations to establish safe, economically viable, and sustainable fishing within wind farms. This research project was commissioned by the Ministry for this purpose.

1.1.5 Passive fishing

Bottom trawling is the most commonly used fishing technique in Dutch fisheries. It is currently not allowed in existing wind farms, and the likelihood of it being permitted in future wind farms appears small. Passive fishing gears are generally not actively moved like beam trawls or trawl nets but remain in one place (in the water column or on the seabed) for a certain period (ranging from hours to days) before being retrieved. Examples of passive fishing gear include pots, handlines, jigs, and gillnets (van Marlen et al., 2011). In this study, jigs and handlines are considered as passive gears, although their actual application requires a more active approach compared to the other investigated gears. In contrast to active fishing methods (such as beam trawling), passive fishing methods can be applied more locally, and have limited contact with the seabed but need a large number of gear to be economically viable (e.g. pots or gillnets). Passive fishing in the North Sea is a seasonal fishery, mainly done from April to October.

Passive fishing gear could be suitable for use in wind farms where limited manoeuvring space is available due to structures as wind turbines, transformer stations and infield cables, provided there is sufficient free space to deploy the gear.

1.2 Scope of the research

1.2.1 Aim

The Ministry of Agriculture, Nature, and Food Quality is actively engaged in assessing the need for further regulations to establish safe, economically viable, and sustainable fishing practices within these wind farm areas. Ongoing and completed projects provide insights into the possibilities and limitations for fishers in wind farms, with a focus on safety, risk management, and operational aspects. In "Vissen voor de wind" (2016), an initial exploration was conducted regarding the possibilities and limitations for fishers in wind farms. The project "Win-Wind" (2019 - 2023) includes an exploration, partly in practice, of the operational aspects (safety and risk management) of navigating and working as a commercial fisher in wind farms. Prior to this present study, all knowledge concerning passive fishing in general, and specifically in relation to wind farms, was compiled during a desk study and published in 2023 (Neitzel et al. 2023a). While some completed and ongoing projects have already explored some of the possibilities of (passive) fishing in wind farms, these opportunities have been minimally investigated, and practical knowledge and experiences from the field are currently lacking. This study therefore builds upon the desk study by conducting actual field tests and exploring the practical aspects of passive fishing in wind farms. The first report of this study has already been delivered and goes into detail about the practical aspects of this study (Neitzel et al. 2023b). This report includes all data analyses and final conclusions as well.

1.2.2 Objectives

Despite considerable progress in prior research on passive fishing in wind farms, there remains a scarcity in practical experience regarding fishing activities in wind farms. Questions regarding legal considerations, safety protocols, economic feasibility, and ecological impacts associated with implementing (passive) fishing in wind farms remain unanswered. Moreover, there has been no specific evaluation of interest from the fishing sector, particularly identifying how many and which fishers would be willing and able to engage in fishing within wind farms in the future and using which gears. To address this gap, the present study collaboratively developed a research outline with a focus group of commercial fishers to explore suitable fishing methods for implementation within wind farms. This includes evaluating economic viability, ecological effects, and safety requirements to facilitate the initiation of passive fishing in wind farms. The overall project investigates additional possibilities of commercial passive fishing gears by considering operational factors, safety measures, fishing gear specifications, economic feasibility, and ecological aspects.

1.2.3 Research questions

For this study, six specific research questions were defined. When possible, the research questions will be quantitatively answered with a justification based on available and collected data. However, in some cases, there may not be sufficient data available or concrete statements cannot be made, and the answers to these research questions will be qualitatively described.

1. “What are possible problems that may arise during the testing of different gears, taking into account”:
    - Technical aspects of the fishing gears and vessels
    - Safety issues or potential risks
    - Distance from the coast
    - Weather conditions

2. "Is it possible to catch target species within Borssele I and II offshore wind farm using the following fishing gears”:
    - Handline (fishing gear code LHP)
    - Gillnet (fishing gear code GNS)
    - Multi-species pots (fishing gear code FPO)
    - Jigging (fishing gear code LHM)

3. “What are the catches per unit effort (CPUE) and landings per unit effort (LPUE) of the caught target species per fishing gear?”

4. “What is the composition and quantity of bycatch per fishing gear when considering”:
    - Non-target species (fish)
    - Birds
    - Marine mammals
    - Benthic species/crustaceans

5. “To what extent are birds attracted to fishing activities in offshore wind farms?”

6. “Is it economically feasible to fish commercially within Borssele I and II offshore wind farm when considering the four different fishing gears?”

1.2.4 Bookmark

Chapter 2 describes the materials and methods used in this study, as well as the research area, fishing gears and vessels. Chapter 3 gives the results on risks and nautical operations, whereas chapter 4 describes the results on the ecological and biological data. Chapter 5 gives the economical analysis. Chapter 6 goes into detail on the discussion and finally, chapter 7 is a concluding chapter with the main conclusions found during this study and chapter 8 gives the overall reflections.

2 Materials and methods

2.1 Research set-up

2.1.1 Fishers participation

The initial consultations with the fisheries sector took place during the previous desk study (Neitzel et al. 2023a) at the National Fisheries Knowledge Day (Nationale Kennisdag Visserij) on April 2, 2022. Further discussions within the previous project were structured through three physical meetings with interested fishers. The first session involved a workshop (IJmuiden, November 18, 2022), for which fishers could sign up if they were interested in contributing and/or participating in the research. The fisheries sector and Dutch POs (Producer Organizations) also played a role in recruiting fishers, and the workshop was announced through (social) media and Visserijnieuws, a weekly newspaper for fishers. Additionally, a separate working session on passive fishing occurred during a meeting of the Fisheries Innovation Network (Visserij Innovatie Netwerk) on December 20, 2022, where researchers were present to guide the session and expressed their interest. Potential participants could register for participation in the focus group after the session.

Following the first workshop in IJmuiden and the Fisheries Innovation Network working session, a focus group consisting of 9 interested and active fishers was formed. This focus group then further designed the field tests in Borssele. Two additional sessions were held with focus group participants on January 13, 2023, and March 17, 2023, where the setup of the field experiments was discussed in more detail and where preparations for the actual field work were made. During these sessions, additional information was gathered on the mentioned themes, and a joint action plan with criteria for fishing types, economy, ecology, policy, and safety was established.

The practical plan was subsequently shared during a presentation on the National Fisheries Knowledge Day on March 24, 2023, with a group of over 50 interested individuals from the fisheries sector, government, research institutes and universities.

An advisory group, consisting of fishers from both the active and passive fleet, consultants, advisors, representatives from the government and producer organizations, was also established, and was kept informed about ongoing matters related to passive fishing in wind farms and was consulted on specific issues or advice arising from the focus group meetings. A meeting with this advisory group took place online on June 24, 2023, and this group was further informed by e-mail.

2.1.2 Selection of fishing gears and next steps

From the focus group, several gears emerged as potentially suitable for fishing within wind farms. Gears such as handlines, jigs, trammel nets, small-scale flyshoot, traps, pots, longlines, and gillnets were mentioned. Regarding target species, commercially valuable species such as sole, turbot, brill, cod, seabass, European squid, and cuttlefish were highlighted. The focus group, in collaboration with scientists, proposed four gears for practical testing based on target species (is the species present in the fishing area and what does it potentially yield?), gear (is the gear allowed, available and testable in the short term, and is there enough confidence from the fishers in this gears?), planning (are there enough available vessels and crew, do the gears overlap in suitable application period?), and season (is there sufficient time to test the gears, do the target species match the chosen seasons, and are there enough days with calm weather circumstances in a particular season expected?). The selected gears based on the beforementioned questions were handline fishing, mechanical jigging, multi-species pots and gillnets.

It was then decided together with the fishers which materials were needed for each of the fishing gears. Some of the gears had never been used by the fishers themselves or in the North Sea, and some of the gears were innovative and needed previous testing and adjustments before going out at sea. This was the case for the jigging machines and multi-species pots. The upcoming paragraphs describe how the process was done and which steps were taken before the actual field experiments.

This project was carried out as 'research project commissioned by the state' and as such, permission to access to the offshore wind farm was granted based on article 2 sub 1 d of the BAS[2], instead of article 4 'experiments with passive fishing'. This meant that the conditions and restrictions under which the field experiments took place, were not bound to the limitations of article 4 of the BAS. For this reason, also gillnets and jigging could be tested in this project, although not mentioned in the list of gears listed in article 4. However, article 4 was used as a guideline when writing the action plan. The action plan was then agreed upon by Rijkswaterstaat and Ministry of Agriculture, Nature and Food Quality and this action plan, together with some conditions(which corresponds with article 4), mentioned in the letter granting access, dictated the rules to be followed in this project.

2.1.3 Research area

The operations took place in Borssele I and II offshore wind farm off the Dutch coast, 23 km (12.42nm) away from Westkapelle, during the period April to October 2023. This exploration of possibilities for passive fishing in wind farms focused on the Borssele wind farm, because it is the first operational wind farm in the 'new style', where the space between the wind turbines is available for (large-scale) co-use, including passive fishing. In older small wind farms in the 'old style,' the space between the wind turbines is too limited, and it was decided at a later stage to partially open it up for (integrated) passage and co-use (only recreative fishing with handlines). The area passport guide for Borssele specifies the forms of co-use allowed and where they can be applied in the area, including passive fishing. Regulation for this experiment was carried out through a 'letter of consent'. For short-term practical tests, the Borssele wind energy area was therefore seen as the most suitable.

Tested gears are hand line fishing, gillnets, multi-species pots and (mechanical) jigging: these are further described in Chapter 2.3. For handline fishing and jigging, the space in Borssele I offshore wind farm was also used (Figure 2.1). The positions of the fishing gear that were used for gillnet and multi-species pot fishing are shown on the bathymetry map of Borssele II offshore wind farm (Figure 2.6). During this experiment, no fishing activities were allowed in the area around the wind turbines where nature inclusive design (artificial reefs for conducting cod and lobster experiments by Ørsted) was applied (Figure 2.2). The maintenance zones around the wind turbines were taken into account in the planning of the deployment of fishing gears.

[2] Staatscourant 2021, 13511 | Overheid.nl > Officiële bekendmakingen (officielebekendmakingen.nl)

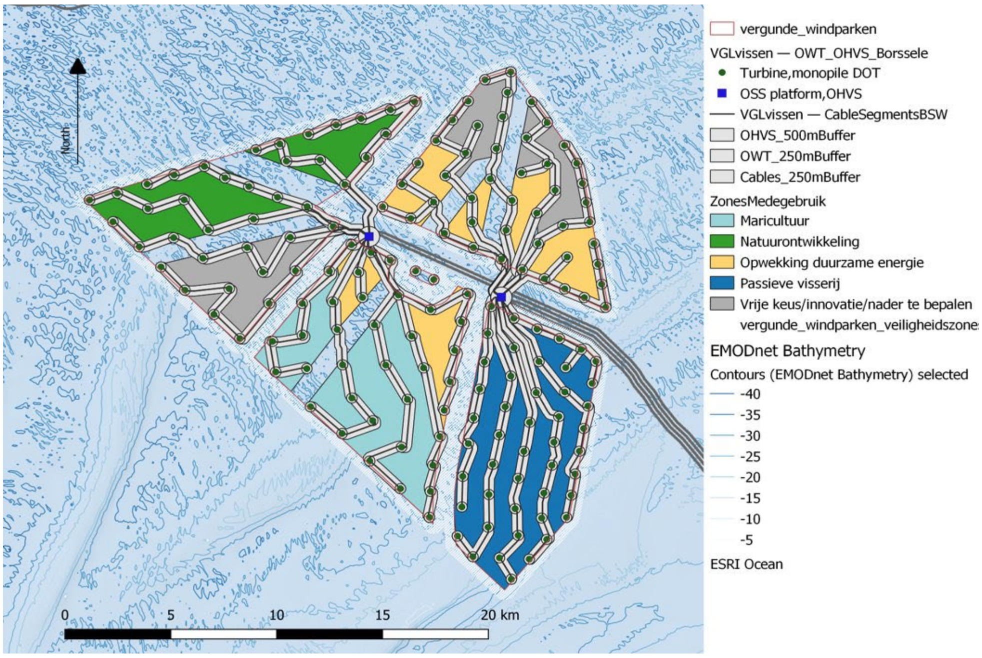


Figure 2.1 *– Spatial plan of Borssele offshore wind farm. For the gillnet and multi-species pot experiments the dark blue area in the South West of the wind farm was used, except for the fishery free zone (Figure 2.2). For handline and jigging experiments both plot I (grey area in the North) and II (dark blue area in the South West) were used except for the fishery free zone, as indicated in Figure 2.2. The exact locations used for gillnet and multi-species pots are shown in Figure 2.5 and 2.8, respectively.*

Figure 2.2 - *Areas in which the various gears have been tested. The green area is the area where no fishing activities were performed because nature inclusive design was applied by the wind farm operator.*

2.1.4 Time schedule

The timeline for this study as discussed with the focus group of fishers involved is shown in Figure 2.3. Dark yellow means it is anticipated peak season for that particular fishery and target species, light yellow means crew and scientists were stand-by for possible changes in schedule and for testing other gears that are less sensitive to season or species that are only available in a certain month. Throughout the project, the research team kept close contact (on a weekly and sometimes on daily basis) with both the focus group of fishers involved and with fishers outside of the project that target the same species. In that way, researchers could decide whether the planning would still match with peak seasons for particular species or if planning had to be adjusted.

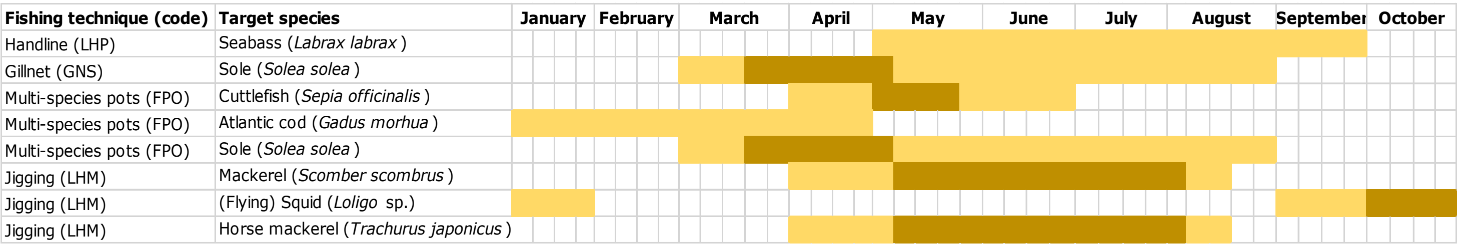


***Figure 2.3** – Schedule of field activities in Borssele offshore wind farm 2023.*

2.1.5 Handline fishing (LHP)

Handline fishing encompasses all forms of fishing where a rod and reel with a line, to which one or more hooks are attached (a maximum of three in coastal waters; however, there is no limit on the number of hooks outside coastal waters), are used. Handline fishing can be conducted passively (with the vessel anchored on the seabed or with an electric motor or dynamic positioning system (DP) keeping the vessel in the same position), drifting (no or little engine power and using the current to move in a certain direction), or trolling (using engine to move in the right direction). In the Netherlands, commercial handline fishing is mainly done anchored (for seabass) and drifting (for cod, pollack) near sandbanks or hard substrates like reefs or ship wrecks, where fish aggregate. For handline fishing where seabass is the target species, it is important that the vessel does not get too close to the areas where seabass are present, as they may be startled by the motor noise. The vessel is therefore anchored at an appropriate distance upstream using an anchor and anchor line. The intention is for the hooks to be carried towards the right spot by the tidal currents.

Fishing can be done with natural bait or artificial bait (lures). Examples of natural bait include Atlantic mackerel, horse mackerel, sardines, sandeels, smelt, lugworms, ragworms, razor clams, shrimp and crabs. Artificial baits include metal jigs, hardbaits (hard plastic or wooden artificial lures in the shape of a fish, often equipped with treble hooks), shads or softbaits (soft plastic lures in the shape of a fish or worm), or paternosters (a line equipped with 3 or more hooks with feathers, glitter, rubber, and/or beads stacked above each other). When having a fish on the line, the line is reeled in from the boat again.

For this experiment a small vessel (Chapter 2.2 for vessel details) was used with 3 crew on board fishing with handlines (rod and reel) to mainly target seabass and Atlantic mackerel (Figure 2.4). In this fishery, a line with a weighted jig or hook was sent to the bottom and baits used were artificial (lures) or natural (baitfish, pieces of fish, worms). This fishery was carried out both while drifting as well as anchored on the bottom using an anchor. A total of 10 fishing days were foreseen.

Gear specifications:

- Spinning rod and reel combinations with lengths of 240cm to 270cm and casting weights up to 80 grams
- Braided main lines 0.20mm thickness and up to 20kg strength
- Fluorocarbon leaders 0.60mm to 0.80mm thickness and up to 20kg strength
- Weighted jigheads of 40 to 60 grams with softbaits
- Metal jigs of 60 grams
- Single hooks baited with livebait such as crabs and worms
- Sabiki rigs for mackerel with 3 to 5 hooks per line
- Bruce anchor of 15kg when anchoring

Figure 2.4 *– Handline fishing in Borssele offshore wind farm. Photo: Wageningen Marine Research.*

2.1.6 Gillnet fishing (GNS)

A gillnet is a fishing gear consisting of an upper line with buoyancy and a weighted lower line with one (gillnet) or multiple walls (trammel net) of netting in between. The gillnet is anchored on the seabed on both sides and in between with anchors weighing about 8 to 10kg. The length of a gillnet is measured along the extended upper line and can vary from 200 meters per net (especially in cod fishing around wrecks) to 500 up to 10,000 meters per (combined) net in the flatfish fishery, particularly targeting sole. In general, commercial fishers fish with 10 to 25 km of gillnets per vessel. Fish are caught as they swim into the net and become entangled. There are variations in the type of net material used (mono- or multi-filament nylon), the height of the net, the use of 'ladders' or 'trammel walls', and mesh size. These factors determine the catch of target species and any (desired or undesired) bycatch. In the Netherlands, gillnets are used on small vessels, close to the coast, and mainly for targeting sole, mullet, and seabass. For sole, the nets are set in the direction of the current and remain in place for about 12 to 20 hours before being retrieved.

For this experiment, a small number of 4 gillnets (2 km in total) were deployed from one vessel (Chapter 2.2 for vessel details; Figure 2.5 for a photo of gillnet activities). Target species of this experiment was mainly sole. Each gillnet had a total length of 550 meters, from anchor to anchor. Anchoring was done by means of Bruce anchors, which are typical anchors used for passive fishing in sandy soils. The bruce anchors were applied and evaluated in previous experiments and are found suitable to use within offshore wind farms, minimizing the risk interaction with the wind farm infrastructures (Rozemeijer 2021 & 2022). Alternative positioning techniques for passive fishing gears are bundles of chains. These allow displacement of the gear and are therefore considered not preferred for positioning of the gear within a wind farm. The ropes from the anchors to the net were 25m on each side, leaving a total gillnet length of 500 meters per string. A string consisted of 10 net sections of 50 meters each. Other vessels could cross the area where the nets are located as the nets had a height of maximum 0.5 meters from the seafloor. Figure 2.6 shows the locations of the gillnets within Borssele II offshore wind farm. With the distribution over depth, information about areas with a lot of currents (the sandbank ridge) and little current (the valleys) were obtained and therefore catch could be compared over the two sediment types and depths. Before each trip, in consultation with lead scientist and skipper, it was decided which of the locations would be used to actually deploy the nets, taking into account weather circumstances and tides. A total of 14 days were foreseen. This means total number of fishing trips were less, as nets had to be deployed (1 day trip), left to fish (overnight) and be picked up the next day (1 day trip).

Gear specifications:

- 4 strings of gillnets (500m)
  - Consisting of 10 net sections of 50 meters each
  - 50cm height
  - 94mm mesh size
  - Blue coloured nylon netting

Different parts of gear in order per string:

- Front buoy (pick-up buoy)
- Line 3m from front buoy to dahn
- North dahn
- Line 6m from dahn to A1 buoy
- A1 Buoy
- Buoy line 105m (3* water depth); first 10m with lead line, forcing sinking
- Bruce anchor of 15kg
- Line 25 m from anchor to net sections
- 10 x 50m net sections, 50cm high with a 90mm mesh size
- Line 25m from net sections to anchor
- Bruce anchor 15kg
- Buoy line 105m (3* water depth); first 10m with lead line, forcing sinking
- A1 Buoy
- Line: 6m from A1 buoy to dahn
- South dahn
- Front buoy (pick-up buoy)

Total length 550m from anchor to anchor.

Figure 2.5 *– Gillnet fishing in Borssele offshore wind farm. Photo: Wageningen Marine Research.*

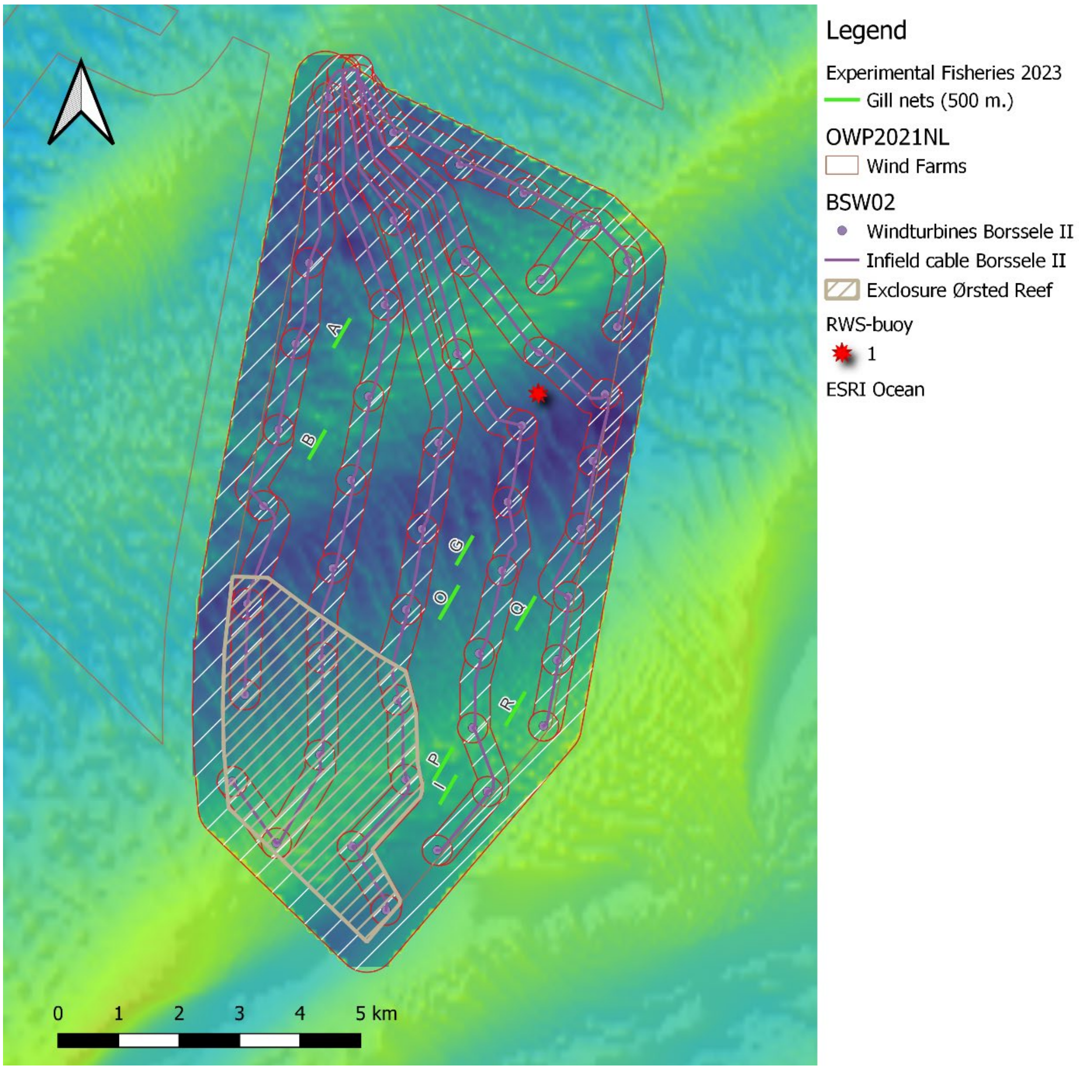


Figure 2.6 *- Bathymetry map of Borssele II offshore wind farm showing positions of gillnet strings in the experiment (green lines). Deployment of fishing gears was not allowed in the shaded areas as they were either maintenance or safety zones or in use by Ørsted (reef). Depth profile: dark blue: -40 m, green/yellow: -12 m.*

2.1.7 Multi-species pots (FPO)

In the pot fishery, creels, pots, traps, or cages are used, which are equipped with bait or other attractive materials (light, sound, milk bottles) to lure the target species into the gear. The design of this gear can vary and is mainly due to the many variations in size, netting, materials, entrances and mesh size of the gear. All these variants fall under the same gear code, and therefore, in this report, the all-encompassing term 'pots' is used. The basis of this fishing gear is a frame that is covered with a network (netting) and has one or more entrances. The pots are usually deployed in series, connected to each other on a rope, and set out in the sea. In other cases, they may be used as individual pots. For lobster fishing, typically 50-100 pots are used per string, while in brown crab fishing, 150-300 pots per string are used. Commercial fishers deploy at least 1,500-2,000 pots per vessel. A string of pots is anchored on both sides with anchors weighing about 8-18kg and marked with buoys or dahns. In the Netherlands this fishing gear is currently used for brown crab and lobster. Abroad, this gear is also used for different species of squid, cuttlefish and fish like Atlantic cod.

For this experiment three different pot types were used: cuttlefish pots (with two types of netting: fluorescent and normal netting) (Figure 2.7), fish pots and sole pots (Figure 2.8). These different pots were combined in one string (multi-species). Per string, 5 pots were attached with a distance of 40 meters apart, making each string from first to last pot 160m long. The order of the different pot types was always the same: sole pot – cuttlefish pot with fluorescent netting – fish pot – cuttlefish pot with non-fluorescent netting – sole pot. Each individual pot kept the same 'pot ID' (yellow label with a three-digit number) throughout the entire experiment.

Figure 2.7 *– Cuttlefish pot with fluorescent netting (left) and cuttlefish pot with original netting (right). Photo's: Wageningen Marine Research.*

Figure 2.8 *– Sole pot (left) and fish pot (right). Photo's: Wageningen Marine Research.*

Baits were chosen in consultation with the fishers: fatty fish like mackerel and horse mackerel create a big bait plume but can, depending on factors like water temperature and crabs, rot away or get eaten very quickly and therefore last from hours to a couple of days (short bait). Fish like dogfish or starry smoothhound give little bait plume but stay in the water for a long time from days to weeks (long bait). Therefore, a combination of short- and long baits were chosen for sole and fish pots. Literature study, experiences from sports fishers and experts on fish nutrition from Wageningen University and Wageningen Livestock Research were consulted and therefore it was decided that, for sole pots, ragworms were also added as these were seen as the most suitable sole bait. For fish pots, cuttlefish and/or squid was added to the combination of short- and long bait for the same reason. The total weight of the bait per pot was approximately 350 grams.

Before testing in the field, the sole pots were tested in the Wageningen Marine Research laboratory with wild caught sole from previous experiments to determine if the entrances of the pots made by the fishers were suitable for the species. On two separate days, the prototype sole pots were left in the basin in the laboratory overnight as sole are night feeders. The next morning, pots were checked and in both cases, sole were present inside the prototypes. For fish pots, this experiment could not be done as there were no basins big enough to actually test the prototypes, so therefore these prototypes were made from examples used abroad for Atlantic cod and seabass. Cuttlefish pots were borrowed from the Flanders Research Institute for Agriculture, Fisheries and Food (ILVO) and were previously tested in the field in Belgium. No bait was used in cuttlefish pots, except a single milk bottle in each of the pots. This milk bottle represents a female cuttlefish and therefore attracts males. Pots that were not previously used were left in the sea without bait for at least 2 months to get rid of any odour coming from the new netting, which could deter target species.

In total, nine multi-species pot strings were (re)deployed per trip, from one vessel (Chapter 2.2 for vessel details): 4 shallow strings (about 12 m) and 5 deep strings (between 30 and 35 m) (Figure 2.9). The locations were kept the same throughout the experiment. The strings had a length of 210 meters from anchor to anchor. As for gillnet fishing, anchoring was also done according to previous experiments and was therefore suitable to use within offshore wind farms, minimizing the risk of touching cables (Rozemeijer et al. 2021 & 2022). Other vessels could cross the area where the strings were located as the pots had a height of maximum 0.5 meters from the seafloor. Figure 2.10 shows the positions for the locations of the deployed strings within Borssele II offshore wind farm. Before each trip, in consultation with lead scientist and skipper, it was decided which of the suitable locations were going to be used to actually deploy the strings, taking into account weather circumstances and tides. A total of 16 days were foreseen.

Gear specifications:

- 5 pots per string of 4 different types in always the same order:
    1. Sole pot
    2. Cuttlefish pot with fluorescent netting
    3. Fish pot
    4. Cuttlefish pot with normal netting
    5. Sole pot
- Natural baits: mackerel, horse mackerel, cuttlefish, squid, dogfish, starry smoothhound and ragworms
- Artificial baits: milk bottle

Dimensions and mesh size of the different pots used:

Sole pots

- Length: 60cm
- Width: 35cm
- Height: 32.5cm
- Entrance (1 entrance): 32cm in length, 4cm in height
- Mesh size: 30mm

Cuttlefish pots

- Diameter: 85cm
- Height: 30cm
- Entrance (4 entrances): 25cm x 15cm
- Mesh size: 7cm outer netting, 5cm inner netting

Fish pots

- Length: 130cm
- Width: 65cm
- Height: 78cm
- Entrance (2 entrances): 21cm
- Mesh size: 4cm

Different parts of gear in order per string:

- Front buoy (pick-up buoy)
- Line 3m from front buoy to dahn
- North dahn
- Line 6m from dahn to A1 buoy
- A1 Buoy
- Buoy line 105m (3* water depth); first 10m with lead line, forcing sinking
- Bruce anchor of 15kg
- Line 25 m from anchor to net sections
- 5 pots 40m apart
- Line 25m from net sections to anchor
- Bruce anchor 15kg
- Buoy line 105m (3* water depth); first 10m with lead line, forcing sinking
- A1 Buoy
- Line: 6m from A1 buoy to dahn
- South dahn
- Front buoy (pick-up buoy)

Total length 210m from anchor to anchor.

Figure 2.9 *– Pot fishing in Borssele offshore wind farm. Photo: Wageningen Marine Research.*

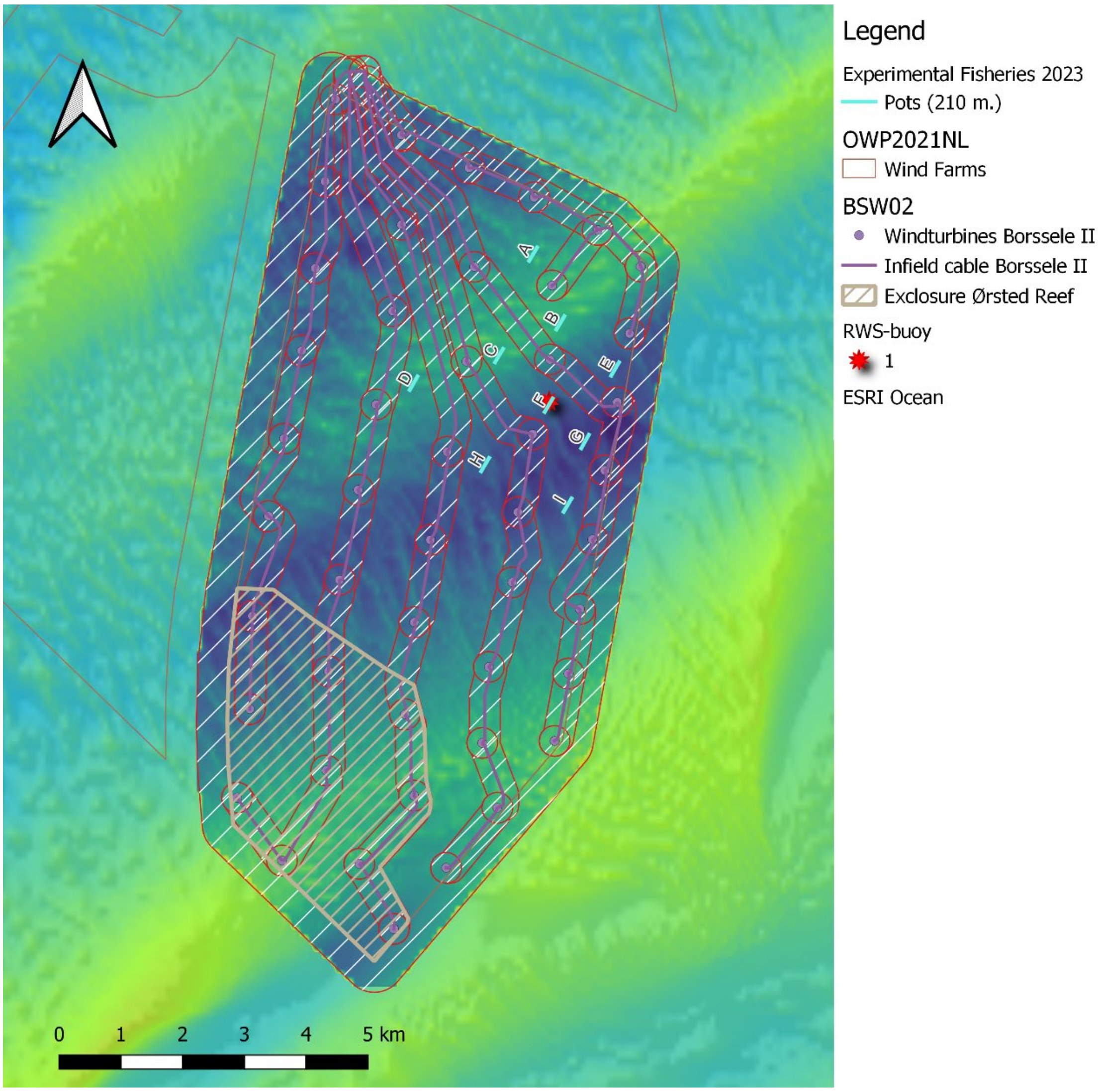


Figure 2.10 *- Bathymetry map of Borssele II offshore wind farm showing positions of multi-species pot strings in the experiment (blue lines). Deployment of fishing gears was not allowed in the shaded areas as they were either maintenance or safety zones or in use by Ørsted (reef). Depth profile: dark blue: -40 m, green/yellow: -12 m.*

2.1.8 (Mechanical) jigging (LHM)

The basic principle of mechanical jigging is to lower one or more lines with a multitude of hooks equipped with artificial bait or feathers into the sea using a so-called jigging machine on board. The jigging machine then automatically moves the hooks up and down and can be adjusted in various ways. For example, the distance to the bottom, the speed, and the range of a jig movement can be adapted to conditions and target species. Similar to handline fishing, there are many variations possible in jig fishing: the number of lines and hooks per line, hook type, jig type, hook size, line thickness, material of the lines, and weights. The hooks can be jigs (for example, for squid), covered with feathers (for example, for mackerel), or rubber, the so-called rubber macs (for cod, haddock, and pollack). Jigs or feathered hooks fall under the category of artificial bait; natural bait is not used in this type of fishing. Jig fishing is often done drifting.

For this experiment 4-5 jigging machines (Figure 2.12) were used on the vessel (Chapter 2.2 for vessel details) to fish for mackerel, horse mackerel or European squid. With this gear, lines with many hooks were sent to the bottom and are immediately reeled in again when fishing for European squid, or make movements up and down in the case of (horse) mackerel. This movement imitates a school of small baitfish or prey that attracts the fish. Figure 2.1 and Figure 2.2 shows no designated areas for this gear as this way of fishing required a flexible approach, depending on weather circumstances and tides, but taking into account ongoing traffic, objects such as buoys and wind turbines (including their maintenance zones), other fishing gears present, and other ongoing experiments. In addition, schools of target species can move very quickly. For this experiment the space between maintenance zones for both Borssele I and II (Figure 2.1) was used. A total of 10 fishing days were foreseen and divided into two separate trips: one for mackerel and one for squid as some specifications like hooks and movement of the fishing gears were different. Normally in commercial jig fishing for squid, fishing practices are done at night using lights on the vessel. In this study, crew only fished for squid during the day as entrance to the wind farm was only allowed between sunrise and sunset.

Gear specifications (see also Figure 2.11):

- 5 mechanical jigging machines (Oilwind)
- Monofilament main line 3mm thickness
- Mackerel hooks type 'super shrimp' approximately 15 per line, 0.9-1.2mm thickness
- Squid jigs: 23 per line, in 10 different colours, of which one with a light
- Weight on the end of the line (3kg)

Figure 2.11 *– Jigs used for mackerel (left) and squid (right) in the field tests for (mechanical) jigging.*

During both expeditions, different settings of the mechanical jigging machines were used as it was a first trial. Settings included: hauling speed, distance to the bottom, distance of a single jigging movement, time intervals (stops) and automatic hauling when a catch was detected.

***Figure 2.12** – Jig fishing in Borssele offshore wind farm. Photo: Wageningen Marine Research.*

2.2 Fishing vessels

This section describes the vessels used for the experiments. From the participating fishers in the focus group, vessels were chosen together with the fishers based on the following criteria: availability for testing, most suitable for performing the field experiments and licenses for specific gears to be tested. All vessels chosen comply with regulations for fishing vessels, additional regulations for fishing in Borssele wind farm zone and additional regulations for the experiments. These regulations include:

- The captain and vessel are in the possession of a fishing permit for the applied passive fishing methods.
- The maximum length over all (Loa) of the vessels is 45m
- Vessels up to 24m comply with the *Vissersvaartuigenbesluit 1989*, where applicable;
- Vessels above 24m comply with the *Vissersvaartuigenbesluit 2002*. These vessels have been issued with *Certificaat van deugdelijkheid*;
- Vessels have an active Automatic Identification System (AIS);
- Vessels have a VHF radio, standby at channel 16
- Vessels have an insurance for fishing in the wind farm with a minimum coverage of 500 million euros.
- Access to the wind farm is only admitted during daytime.

2.2.1 KG 7 'Flying Dutchman'

The field experiments for handline fishing were done onboard KG 7 'Flying Dutchman', small fishing vessel (6.50 m, Figure 2.13). The crew consisted of 3 persons: 1 scientific personnel (project leader) and 2 crew members (including skipper).

The main port of departure for the experiments was Roompot Marina in the village of Kamperland, with a distance of 24 miles to the wind farm.

Operational limits of the vessel for the undertaken passive fishing activities in the Borssele II wind farm are:

- Maximum sea state (Beaufort): depending on the environmental direction[3].
- Maximum significant wave height (Hs_max) = 0.6-0.8m, depending on the wave period (Tp).

Figure 2.13 *– KG 7 'Flying Dutchman' with MMSI number 244615352. This vessel was used for handline fishing.*

2.2.2 YE 152 'Meru'

The field experiments for both gillnet fishing and multi-species pots fishing were done onboard YE 152 'Meru' with MMSI number 244727000, a small fishing vessel (9.95 m, Figure 2.14). The crew consisted of 3 to 4 persons: 1 or 2 scientific personnel (1 project leader and research assistant) and 2 crew members (including skipper).

The main port of departure for the experiments was Neeltje Jans, with a distance of 23 miles to the wind farm.

Operational limits of the vessel for the undertaken passive fishing activities in the Borssele II wind farm are:

- Maximum sea state (Beaufort): depending on the environmental direction.
- Forecasted maximum significant wave height (Hs_max) = 0.8-0.9m, depending on the wave period (Tp).
- Maximum significant wave height (Hs_max) = 1.0m, depending on the wave period (Tp).

[3] Environmental direction of wind means the direction the wind comes from

Figure 2.14 *– YE 152 'Meru' (formerly SCH 87) with MMSI number 244727000. Equipment on the lower (stern) deck was adjusted to equipment specific for the type of fishing: gillnets or pots. This vessel was used for multi-species pots and gillnet fishing.*

2.2.3 MDV 2 'Metanoia'

The field experiments for jigging were done onboard MDV 2 'Metanoia' with MMSI number 244373000, a large fishing vessel (30.15 m, Figure 2.15). The crew on board consisted of 5 to 9 persons: 2 scientific personnel (1 project leader and 1 research assistant) and 5 to 7 crew members (including skipper).

The main port of departure for the experiments was Vlissingen, with a distance of 25 miles to the wind farm.

Operational limits of the vessel for the undertaken passive fishing activities in the Borssele II wind farm are:

- Maximum sea state (Beaufort): depending on the environmental direction.
- Maximum significant wave height (Hs_max) = 1.5m, for this project, depending on the wave period (Tp).

Figure 2.15 *– MDV 2 'Metanoia' with MMSI number 244373000. This vessel was used for jigging.*

2.3 Procedures used in this experiment

2.3.1 Roles and responsibilities during the field tests

Risk Assessment Method Statement and action plan
Prior to the field experiments, an action plan together with a Risk Assessment Method Statement (RAMS) was delivered and agreed upon with the Ministry of Agriculture, Nature and Food Quality, Rijkswaterstaat, the wind farm operator Ørsted and the researchers involved. This document describes all the procedures in case of emergency, contains a risk assessment and mitigation measures, describes the roles and responsibilities of personnel involved including their contact information and holds detailed information about the field experiments such as the names and numbers of the vessels involved, data collection and procedures in the field, characteristics of the fishing gears and test locations with their coordinates within the offshore wind farm. Also, previously to the field experiments, field protocols for each of the experiments (per fishing gear) were delivered and aligned with the skippers and crew and also shared with the Ministry and Rijkswaterstaat. Prior to the field trips, safety measures and protocols were explained to participating crew.

GO/NO-GO decision
Weather was a crucial factor for being able to sail out. The skipper stayed in close contact with the project leader to coordinate when sailing was possible. The project leader was responsible for a well in advance communication of plans to Rijkswaterstaat, Ørsted, and the Coast Guard (under a specific reference number given by the Coast Guard). For this purpose, an email was sent each day before sailing out with the plans, coordinates of the fishing gears to be deployed, the number of people on board, and the team's location in the wind farm. To ensure the safety of personnel and equipment, work at the site could only be carried out during daylight and under 'good weather conditions.' The ultimate decision on whether the work could be safely performed considering the weather conditions was done in close consultation between the project leader and the skipper.

Reporting procedure on a day at sea
When going out at sea, the parties involved had to be informed. Therefore, initially, 5 calls were made:

1. Call to the Coast Guard when leaving the harbour, informing them that the activities under reference number NSA1765 were starting. If necessary, the project leader would specify the vessel and its name and the number of crew on board.
2. Call to Ørsted MHCC when leaving the harbour, mentioning that research activities were foreseen that day inside of the wind farm.
3. Call to Ørsted MHCC when approaching the wind farm. During this call it was mentioned that testing would take place and information about the vessel was also provided. Then the project leader would ask if entering the wind farm was safe, where the wind farm operator would give its green light.
4. Call to Ørsted MHCC again when leaving the wind farm. The project leader informed them that the work on site was completed and that the vessel had left the wind farm. If fishing gears were left behind in the wind farm, the specific coordinates of the gears were sent to Ørsted immediately after finishing the work on site.
5. Upon entering the harbour, a call to the Coast Guard had to be made once more to report the completion of activities under reference number NSA1765.

The project leader of the day handled all communication with the mentioned parties to prevent confusion and miscommunication and always clearly stated his or her identity.

Crew on board
On each day of operation, a crew of 3 to 6 participated in the research activities in the field, consisting of:

- The skipper, in charge of manoeuvring the vessel, controlling safety and good practices onboard according to the Risk Assessment Method Statement.
- The deck crew assisting the skipper in dedicated tasks.
- The lead scientist or project leader in charge of scientific part of the expedition.
- The scientist crew doing the measurements of animals caught and registration of birds and sea mammals during hauling and deploying the gear.

In the case of 3 crew members present (for example when handline fishing), the lead scientist was also in charge of the measurements and registrations. Furthermore, a Designated Person Ashore (DPA) was informed about the field tests and acted as an extra safety measure in case of emergency.

2.4 Data acquisition

During each day at sea, different types of information were collected:

1. Operational data (vessel activity, working times, gear aspects, anchor positions, sailing time, operational and safety aspects)
2. Environmental data (weather circumstances, depths, locations)
3. Ecological data (birds and sea mammals)
4. Biological data (catch data such as length frequencies and weights of the species)
5. Economic data (e.g. investments, costs of vessels involved and fuel use)

2.4.1 Collection of operational and environmental data

The vessel's sailing trajectories, towards and inside the wind farm, were retrieved from the vessels AIS signal. The following information was accurately recorded during hauling or setting:

- The GPS locations of the anchors of each string (gillnet and pots) or start/end of fishing activity (handline and jigging).
- The time of hauling or setting.
- The depth (beginning or end), as a magnitude
- Weather conditions (wind direction, wind speed, wave height).

Also, any odd observations were recorded, such as:

- Damage to markers or nets.
- Unusual conditions: visibility, blooms, indications of fish on the fishfinder or echosounder.
- Traffic in the waterway, movements of vessels.
- Safety risks or the visibility of markers.

To document the process and any peculiarities, photos and videos were taken during the trips.

2.4.2 Collection of ecological and biological data

2.4.2.1 Biological (catch) data

The frequencies of lengths for each species caught per gear were recorded. For each net or pot, the catch was kept and recorded separately. For handline and jigging, the total catch of a fishing operation (consisting of a certain amount of hours) was recorded. In instances where there were an excess of small fish from the same species in the sample, researchers followed a standardized sub-sampling procedure. The benthic species and other fractions in the sample were weighed, and subsequently, all the data were entered into the Wageningen Marine Research program Billie. This included information from both the trawl list, which the project leader filled in together with the skipper, and other registered data. Trawl list data included dates and trip numbers, as well as positions of the gears, crew on board, relevant observations, sightings of birds and sea mammals and setting and hauling times. Data were thoroughly checked following standardized procedures of Wageningen Marine Research before importing the data into the database, called FRISBE. Subsequently, the data were extracted for compilation and analysis.

In summary, the following biological data was recorded:

- Fish: quantities and individual lengths. Lengths were rounded 'to the cm below'.
- Weights per fish species per size category; undersized and marketable size.
- Quantities and, where possible, carapace length, and width (cm) of lobsters, velvet swimming crabs, Norway lobster, and Brown crabs.
- Quantities, lengths, and gender of elasmobranchs.
- Quantities of other species, such as benthos (starfish, hermit crabs, shellfish).

The biological and catch data are described in Chapter 4. Appendix 3 describes all species per gear caught, including their minimum sizes (MCRS[4]) and species type: target species, landable or non-landable. In this report, English names are used for species. Scientific names can be found in Appendix 3 as well.

2.4.2.2 Bycatch

In this study, we distinguish between different types of bycatch and whether the bycatch is directly captured by the fishing gear itself or if unwanted species are indirectly attracted by the vessel, the caught fish, or the fishing gear.

The following categories of bycatch can be identified based on if the bycatch must be discarded or kept onboard in accordance with the Fisheries Legislation (Source: RVO Aanlandplicht (rvo.nl)):

These fish must be discarded:

- undersized fish of species not subject to a catch limit but subject to a minimum conservation reference size;
- species subject to a catch ban;
- fish that have been eaten by predators.

These fish may be discarded:

- fish for which there is no catch limit or catch prohibition, and no minimum conservation reference size;
- sizable fish for which there is no catch limit or catch prohibition, but a minimum conservation reference size;
- species subject to an exception to the catch ban, if this exception applies to you;
- species subject to an exception based on high survival, if this exception is applicable;
- species subject to a de minimis exemption, if this exemption is applicable.

All other fish except for when there is a deminimus exemption, should be kept onboard according to the landing obligation, which says that all catches of species regulated through catch limits should be landed and counted against the fishers' quotas.

Another type of unwanted catch is the bycatch of marine mammals or birds by fishing gear. An example of this is diving birds or marine mammals getting entangled in gillnets suspended in the water column or getting hooked after ingesting the bait on the hook.

Additionally, there is a category that does not fall under bycatch but poses a risk to certain species indirectly caused by fishing activities. The discarding of unwanted bycatch and fish waste attracts birds, exposing them to the risk of colliding with the blades of wind turbines. This risk also exists during the

[4] The minimum conservation reference size (MCRS) is the size of a living marine aquatic species, taking into account maturity, as established by Union law, below which restrictions or incentives apply that aim to avoid capture through fishing activity.

processing of marketable fish at sea. The extent to which this risk is realistic for Dutch fisheries depends heavily on factors such as the applied gears, types of bait used, target species caught, the number and type of discards, location, and the density of birds at that time. Therefore, this study examines observations of birds in relation to each of the four gears used.

2.4.2.3 Ecological data

For ecological data, an estimation of the number of birds per category (seagulls, cormorants, gannets, songbirds, others) was made. Each category is scored on 5 levels: <5, 5-10, 10-50, 50-100, or >100 birds. Also, sightings of sea mammals such as harbour porpoises and seals were recorded on each of the trips.

2.4.3 Collection of economic data

The economic feasibility of fishing in an offshore wind farm depends on various factors, such as the type of vessel used, gear adaptations, sailing time, the amount of space available, lay-out of the wind farm, restrictions within the wind farm and how activities in wind farms can be combined with conventional practices outside the wind farm. Compared to commercial fishing the number of fishing trips and gears deployed in this study was limited leaving little data availability on catches.
This study elaborates on the initial indications from economic data and discusses possible developments that could improve the economic feasibility of fishing in wind farms. Therefore, we look beyond the data collected during the experiments.

Firstly, the following data on the specific costs for each vessel used in this study are provided:

- Investments costs (to calculate depreciation),
- Costs fishing gear used and its deployment,
- The number of sea and fishing hours per year,
- Costs of crew and their deployment,
- The commercial catch (kg and costs),
- Costs of repair of fishing gear on shore,
- Consumption figures and costs of fuel/energy,
- Other costs incurred to assess the profitability of the fishing activity, etc.

These collected data from the fishers involved were used to calculate the costs of the fishing vessel per year and per fishing trip.

Second, the cost structure of two other types of vessels potentially suitable for fishing in a wind farm are described. The potential opportunity of converting shrimp cutters for passive fishing in a wind farm is explored. Due to regulatory restrictions regarding nitrogen impacts, as well as declining catch rates in 2023, several Dutch shrimp fishers are looking for alternative ways to deploy their fishing vessel. As these types of vessels have more work and storage space on deck than smaller vessels, are navigable but stable enough in slightly more turbulent weather, they could potentially be applied for fishing in an offshore wind farm. The costs per year and per fishing trip of two types of vessels were calculated based on publicly available data.

Based on yield data of potential target species, a first indication is given of catch rates required to cover costs of fishing in wind farms.

3 Risks and nautical operations

Until recently, any nautical activity within the boundaries of an offshore wind farm other than for maintenance and operations of the wind farm itself was prohibited. As legislation allows experimental passive fishing activities within specific conditions, the intended operational activities and the associated risks were identified and assessed before the start of the operations, and validated after completion. This section describes the risk evaluation method, identified risks qualification and quantification.

3.1 Risks

3.1.1 Approach

The risks of passive fishing activities in offshore wind farms were evaluated using established risk assessment methods:

- Prior to the experiment the risk was evaluated using a Task Risk Assessment (TRA) (Appendix 1). The risks associated with passive fishing in the wind farm were evaluated in consultation with the fishers. The resulting Risk Assessment Form was included in the action plan.
- After the experiments the risks were re-evaluated with the focus group and the TRA table was updated.

3.1.2 Risk evaluation

Cramer et al. (2011), Rasenberg et al. (2015), Röckmann et al. (2015), Steenbergen et al. (2022) and Verhaeghe & Polet (2012) explored possibilities for passive fishing in wind farms. These studies emphasized that there are risks associated with passive fishing in wind farms (as there are risks associated with any activity), but do not provide a detailed overview or quantification.

Anecdotical experiences from the fishing sector indicate that displacement of deployed gear secured with anchors is very small, but displacement of gear positioned with chain mooring lines is considerable. Therefore, to reduce offsets of gears, anchors are applied to moor the fishing gears. Anecdotical loss of complete gear is considered to mainly occur due to oversailing of passive gear by active fishing vessels. Because active fishing is not allowed within the wind farm, the probability of loss of complete gears is small. The risk of interaction of passing vessels with dahns is mitigated by the designated passages. Passing vessels are only allowed to cross the wind farms through these corridors. Only vessels active in the wind farm for maintenance purposes risk to interact with the dahns. Visibility of the gear is therefore important. Crew transfer and maintenance vessels can however utilise the 500-meter wide 'corridors' over the infield cables between the turbines. Because fishing in this area is prohibited there will be no fishing gear present.

In the maritime industry, the Task Risk Assessment (TRA) method is applied to achieve an objective assessment of risks. This method is described by IMO (2018). The North Sea Farm Foundation (2020) and Van der Want (2021) provide an application using this method for various forms of co-use in wind farms. This also includes fishing activities but did not focus on specific methods of passive fishing.

The risk of damage to wind turbines by vessel collisions is detailed in Van Rooij (2020) and Presencia (2016). Van Rooij (2020) shows that the damage to the turbine from a collision by vessels up to 1500 Gross Tonnage is nil. The vessels for the present passive fishing experiments are all well below this value. As a result, the risk of collision between a fishing vessel and wind turbine is primarily with the fishers and not with the wind farm operator. A wind turbine will not experience significant damage because of collision.

MARIN carried out safety assessments regarding co-use within wind farms (Van der Want, 2021; Schipper & Nap 2023). These studies focused on large-scale installations, such as solar panels, mussel and seaweed cultivation. Specific risk analysis regarding passive fishing gear within a wind farm is not available in the literature. Furthermore, MARIN carried out a safety assessment for passages within wind farms on behalf of Rijkswaterstaat (Huisman & Kolderhof 2021). Although this study mainly focused on passage and not on the co-use of wind farms, the qualitative analysis gives a good impression of expectations. The risk of a vessel colliding with a wind turbine or co-use installation is considered low in the study when *good seamanship*[5] is applied. Good information provision and communication are seen as essential for the safe use of the available space.

Based on literature and consultations, the following global risk assessment is derived:

- The risk of damage to a wind turbine as a result of passive fishing with vessels up to 46m is nil.
- The risks of damage to the wind farm by the vessels and crew are limited by the applicable laws and regulations for vessels and crew.
- The risks of damage to the wind farm due to the use of equipment are limited. Experiments carried out in the Win-Wind project (Rozemeijer et al., 2022) show that the risk of damage to the in-field cables is marginal when using Bruce anchors.

3.1.3 Vessels and crew

Because fishing is regulated by both national and international legislation, an overview of the relevant regulations is given. Following the existing regulations, a distinction is made between crew requirements for vessels below and above 12 meters length, technical requirements for vessels below and above 24 meters length and operational requirements. The following overview is distilled from existing regulations and relevant for the present activities:

Crew requirements

- Vessel length up to 12 meters: Maritime Medical Examination + STCW Basic Safety Certificate module Fishery safety
- Vessel length above 12 meters: Relevant Navigation license and medical fitness in accordance with the Seafarers Act + STCW BST.

Vessel technical requirements

- Up to 24 meters: *Vissersvaartuigenbesluit* 1989, where applicable. Since not all vessels under 24 meters can comply with the decision due to their construction, there is a construction in which IL&T applies tailor-made solutions.
- From 24 meters: *Vissersvaartuigenbesluit* 2002. These vessels are in the possession of *Certificaat van deugdelijkheid*.

Operational requirements applicable for the experiments with passive fishing in the Borssele wind energy area

[5] Whether the ship's officer in question acts in accordance with the care he should exercise as a good seaman towards the persons on board, the ship, the cargo, the environment or shipping traffic (Disciplinary Board for Shipping)

- Fishing permit (sea fishing implementation regulations) on which the fishing gear and fishing vessel to be used are registered with the Nederlands Register Vissersvaartuigen (NRV);
- An offset of 250 meters is maintained from the wind turbines, including any object;
- An offset of 250 meters is maintained on either side of the infield cables, including any object;
- An offset of 500 meters from a transformer station is maintained;
- The fishing vessel used for passive fishing experiments may only be in the safety zones between sunrise and sunset;
- The fishing vessel to be deployed has a maximum length overall of forty-five meters;
- The vessel has an Automatic Identification System in operation (AIS Class A);
- The vessel has a marine radio system on board, which communicates on channel 16;
- The Working Conditions Act and Working Hours Act is applicable to employers / employees, partnerships and passengers;
- The Prevention of Pollution from Ships Act and the International Regulations for the Prevention of Collisions at Sea continue to apply within the wind farm.

The applicable regulations for crew and vessels are adequate for passive fishing in offshore wind farms. There is no necessity for prescribing additional measures. The parties involved are however free to do so in the context of their occupational health and safety responsibility.

3.1.4 Fishing gear

The risks per type passive fishing activity are identified by means of the Risk Assessment. This analysis is carried out with the focus group prior to and after the experiments and consists of:

1. Identification / inventory of the threats
2. Risk analysis: estimate chance x effect per threat
3. Risk management: mitigating measures

In Step 1, all possible threats associated with the passive fishing activities in offshore wind farms are identified. In Step 2, the probability and effect of each threat are normalized: probability on a scale from A to E, effect on a scale from 1 to 5. Clarification and interpretation of these scales is given in Appendix 1. Probability and effect are finally combined into a risk index on a scale from 1 to 25. The score of each risk can be carried out through a qualitative or quantitative approach. The qualitative approach consists of consultation with stakeholders. The quantitative approach consists of analyses based on static data.

In the Risk Assessment Form given in Appendix 1 risks are classed in the following main categories:

- Gear/ anchoring: these are risks associated with deployment of gears i.e. gillnets and pot strings.
- Operations: these are risks related to vessel activities in the wind farm and applicable to all four undertaken types of passive fishing.
- SIMOPS: Simultaneous Operations. These are risks for other vessels performing activities in the wind park, mainly CTVs, due to the presence of fishing gear and/ or vessels.

The major deemed threats for the wind farm is the displacement of gears. This risk is evaluated by the quantitative approach based on the position registrations of the gears and described in Section 3.2. Other threats are evaluated by the qualitative approach with the focus group. Finally, in Step 3 risk mitigation measures are defined. Including the mitigation measures in the risk matrix from Step 2, gives and overview of the relevant and less relevant operational risks of passive fishing within offshore wind farms.

3.1.5 Results

The Risk Assessment Form derived with the focus group upon completion of the experiments is given in Appendix 1. As initial risk, prior to applying the mitigation measures, the risk table shows the highest risk index of 8 in case a fisher has to retrieve a gear that has drifted into a maintenance zone. The risk of damage to a monopile or in-field cable is classed to be 6. The major deemed threats for the wind farm is damage of the in-field cables by the anchors. In case an anchor is dropped on an unburied cable the effect could be significant (4). However the probability that an anchor is released on top of an in-field cable is mitigated by the maintenance zones, where anchoring is prohibited and which are aligned with the infield cables. This probability is thereby very small (A). The probability that an anchor interferes with an in-field cable due to displacement of the gear is evaluated by the quantitative approach based on the position registrations of the gears and described in Section 3.2. This analysis does show the probability of gear displacement is likely (C). However the effect is small (2) due to the use of small scale Bruce anchors to anchor the gear.

Mitigation measures in place are: the in-field cables are generally buried, the maintenance zones around the cables and the use of small Bruce anchors to anchor the gears. As an additional mitigation measure, to reduce this risk the gears are positioned such that there is approx. 200m margin towards the North East – the dominant leeward direction – before the gear enters a maintenance zone. All together the mitigation measure reduces the risks associated with retrieval of the gear to 5, which can be interpreted as low risk.

As fishing activities can and will also take place around the wind farm the risk of drifting vessels and displacement of fishing gear from fishing vessels in the vicinity of a wind farm equals the identified risk of activities within the perimeter of the wind farm.

3.2 Net and pot string positions

The risk of drift of gears is described in this section. Drift of gears is evaluated qualitative by the observations of the skipper and onboard researchers during the experiments as well as quantitative from the registered anchor positions. The displacement of the gears is taken into account in the risk evaluation. In the evaluation of the experiments the skipper and researchers indicate that no notable drift of the gears has taken place, maximum in the order of meters to decameters. During the experiments the skipper did sail towards the theoretical positions of the gears on the onboard nautical charts. The dahns were found in close proximity of these locations with no notable displacements. This indicates nil or marginal displacement of gears.

For the quantitative analysis the measured positions of the anchors during setting and hauling are analysed to derive the displacement of the gears. The onboard GPS position is registered at the moments of setting (T1) and hauling (T2) of the first (A1) and second (A2) anchor of each string. These positions are registered in the daily field reports. However, these registrations do include the following uncertainties:

- Uncertainty in GPS registration, which is in the order of meters.
- Operational uncertainties. This is the difference between the vessel position at the sea surface and the actual position of the anchor on the seabed. Due to current, drift and attachment of the net the drop trajectory of the anchor will not be straight vertical and the actual position of the anchor on the seabed will differ from the position of the vessel at which the GPS location is registered. The operational uncertainty is considered to be order of decameters up to a hectometer.
- Registration uncertainty. The position of the first anchor (A1) and second anchor (A2) are registered at setting (T1) and hauling (T2). The first anchor (A1) is defined as the anchor deployed first. As such, depending on the orientation of setting or hauling, the first anchor could either be the Northern or the Southern anchor. When the anchor is set in one direction and hauled in the

other direction anchor 1 during setting (A1T1) is not the same as anchor 1 during hauling (A1T2). The operational direction of setting and hauling is not always well registered in the daily field reports. The direction of setting and hauling is calculated and added in post-processing by analysis of the bearing of the gears at setting and hauling. When the bearing during setting and hauling deviates the registrations of anchors A1 and A2 at T1 are swapped in the analysis. Since the registrations of A1 and A2 do include the abovementioned uncertainties there is a chance that the analysis and correction are applied inappropriate. This results in a registration uncertainty equal to the string length (210m for the pot-strings).

The GPS uncertainty and operational uncertainty are uncertainties in position and together result in measurement deviations. The registration uncertainty adds additional uncertainty in time, between setting and hauling. Summarizing, the measurements at the moment of hauling (T2) include 1) the actual displacement of the gear – if any; 2) the measurement deviation and 3) the registration uncertainty.

3.2.1 String length

For the displacement analysis the anchor positions measured during the 15 pot-string trips are used. The measurements from the gillnet trips are too few for statistical analysis and have not been taken into account. From the pot-string trips in principle 135 anchor registrations (15 trips x 9 strings) are available for the analysis (Figure 3.1). These registrations are first subjected to the following quality control:

- Quality control is performed on the GPS registrations. Registrations with errors in the hand written field report are removed from the dataset. Errors include: no GPS positioned registered at all or GPS registrations outside Borssele wind farm. For example the registrations made during Trip 4 were incorrect. These registrations are shaded dark grey and denoted Not Available (N/A) in Table 3.1.
- Sensibility check is performed on the remaining registrations. This check consists of:
  - Calculation of the distance between the first and second anchor (A1 and A2). The actual line length between the two anchors is 210m. Measured distances below 50m and above 500m are not trustworthy and therefore rejected. This range is subjective, but can be justified by the measured distances shown in Figure 3.1, which are mostly between 150m and 350m with some outliers.
  - Calculation of the bearing i.e. earth fixed orientation. The nets are positioned with the tide in the direction 30° North or 210° South. Calculated bearing outside the ranges [-15°,75°] and [165°,255°] are rejected, based on the consideration of errors in the registrations.

  In case either the distance or the bearing is outside the sensibility range the registration is rejected. These registrations are shaded light grey in Table 3.2

The quality and sensibility check leave 109 registrations for the uncertainty analysis (n = 109). The derived measured distances between the first and second anchor and the bearing are presented in the tables below for the considered 15 pot-trips and all 9 strings (A to I).

***Table 3.1** – Derived measured distance (m) between first and second anchor of each pot string calculated based on GPS registrations. Colours indicate: dark grey=erroneous registration; light grey=non sensible registration; colour scale: green=low, red=high.*

	String								
Trip	A	B	C	D	E	F	G	H	I
1	299	*1012*	281	288	N/A	236	198	318	312
2	292	250	266	226	294	221	N/A	284	285
3	332	256	273	311	267	259	235	*647*	276
4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5	302	270	256	282	299	283	262	281	289
6	*273*	274	267	274	295	*676*	*991*	280	243
7	304	254	323	300	306	215	239	*12760*	288
8	292	256	241	282	307	281	148	275	N/A
9	259	231	289	315	440	*2067*	273	*2131*	284
10	287	252	273	287	*9532*	162	224	290	189
11	90	289	273	273	*786*	297	277	292	N/A
12	234	248	233	261	223	292	258	*1021*	N/A
13	261	245	263	N/A	214	N/A	*36533*	285	N/A
14	284	235	262	284	299	307	266	286	5
15	383	253	271	290	241	302	248	284	285

***Table 3.2** – Bearing (°) of each pot string calculated based on GPS registrations. Colours indicate: dark grey=erroneous registration; light grey=non-sensible registration.*

	String								
Trip	A	B	C	D	E	F	G	H	I
1	210	*101*	210	215	N/A	234	206	221	212
2	210	217	208	29	214	50	N/A	214	223
3	29	30	34	36	31	230	204	*17*	17
4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5	218	215	208	208	213	224	213	216	214
6	*165*	209	210	215	219	*248*	*189*	214	35
7	36	37	38	32	11	22	27	*179*	38
8	215	216	204	215	221	219	205	223	N/A
9	204	214	37	37	196	*4*	34	*5*	33
10	211	206	208	211	*181*	215	211	212	32
11	226	212	212	211	*252*	222	208	214	N/A
12	33	219	32	24	228	219	214	*262*	N/A
13	31	27	34	N/A	26	N/A	*0*	36	N/A
14	199	204	209	204	42	41	40	213	43
15	37	28	25	35	36	34	32	32	36

To quantify the gear displacement, first the measurement deviation is evaluated. The measured length of the gear is the distance between the first (A1) and second anchor (A2) at the moment of setting (different anchors, same time: A1T1 and A2T1). The measurement deviations are evaluated as the difference between the measured length and the actual length of the gear at the moment of setting (T1). The measurement uncertainty is equal to two times the standard deviation of the measurement deviations.

This is the expanded uncertainty for a confidence level of 95% (U95). The measurement deviation is calculated as follows:

$\delta L = L_{meas}(A1T1, A2T1) - L_{act}$

in which:

δL : Mean measurement deviation [m]

$L_{meas}(A1T1, A2T1)$: Mean measured distance between first and second anchor during setting ie mean measured string length [m]

L_{act} : Actual length of the gears (210m for pot strings, 550m for gillnets) [m]

The derived measured distances are presented in the distribution plot below (Figure 3.1). The grey shaded area indicates the registrations included in the analysis, between 50m and 500m. The analysis results in a mean measured string length of 270m and U95 of 82m. This results in a mean measurement deviation of δL = 60 (U95=82, n=109) m.

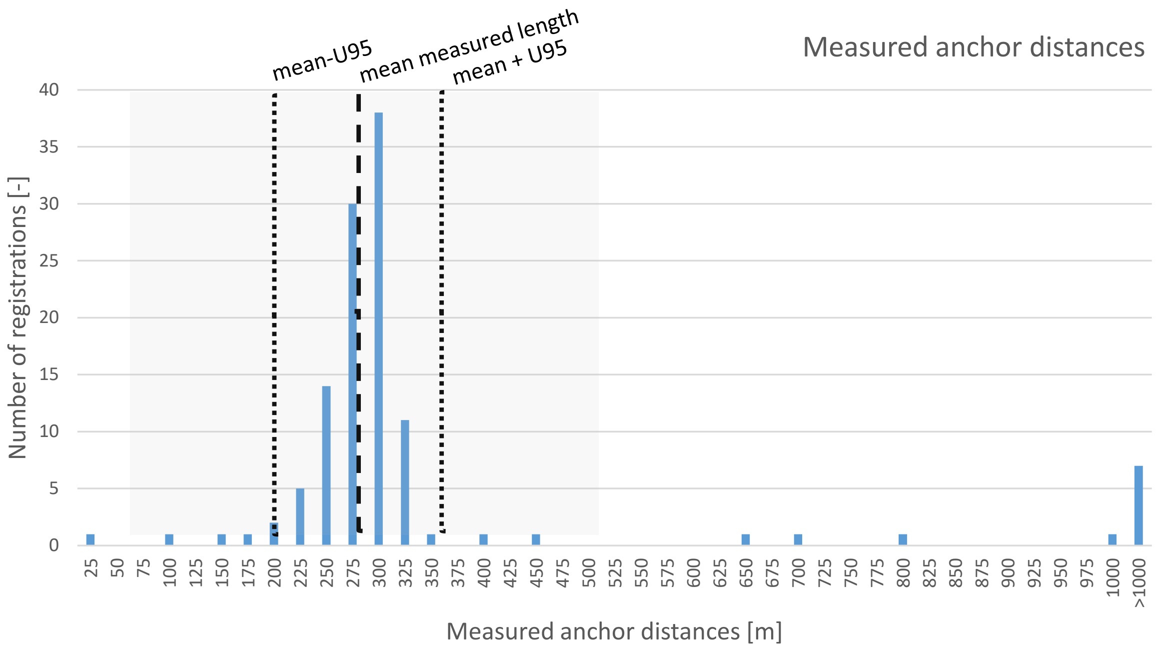


Figure 3.1 *– Measured distances between first and second anchor (A1 and A2) during setting (T1).*

3.2.2 String displacement

The measured string displacements are the displacements of the first anchor (A1) and second anchor (A2) between the moment of setting and hauling, denoted xA1(t) and xA2(t). In the analysis of the string displacements first the same quality control and sensibility checks as applied in the string length analysis are performed. Out of the maximum 135 pot-string registrations the quality and sensibility check leave 87 displacements for each anchor, resulting in a total of 174 measured displacements. The anchor displacements are evaluated as follows:

xA1(t) = A1T2 − A1T1
xA2(t) = A2T2 − A2T1
x(t) [xA1(t), xA2(t)]
δx(t) = x(t) − δL

xA1(t) : Measured displacement of anchor 1 as function of time [m]
xA2(t) : Measured displacement of anchor 2 as function of time [m]
x(t) : Measured displacement of anchors 1 and 2 as function of time [m]
δx(t) : Evaluated displacement of gears as function of time [m]

The measured displacements (x(t)) are presented in the distribution plot below (Figure 3.2). Also the mean (60m) and mean+U95 (142m) measurement deviation are indicated in this figure.

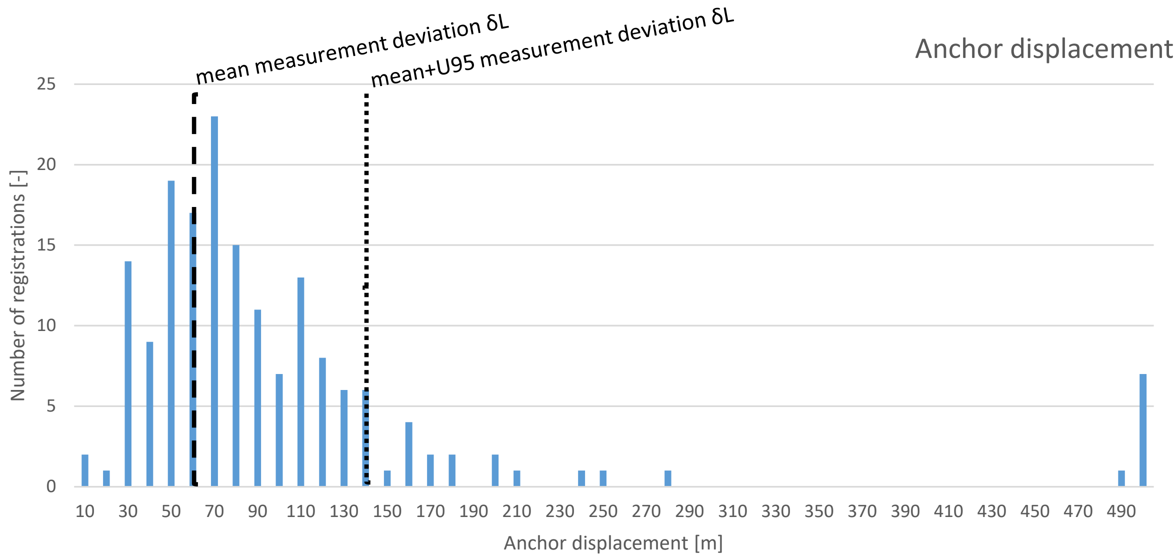


Figure 3.2 *– Measured anchor displacements of anchor 1 (A1) and anchor 2 (A2) between setting (T1) and hauling (T2).*

The results presented in the Figure 3.2 show that most of the measured displacements are within the range of the measurement deviation (mean+U95). The evaluated displacements beyond this range are 13%, which is 8% more than statistically acceptable based on the U95 confidence level. It is considered that these are a result of the registration uncertainty, since the skipper and researches indicate that these displacement have not actually been observed during the experiments. For following experiments it is advised to improve the accuracy of the anchor position measurements and registrations to reduce uncertainty from the measurements. Qualitative experiences of the skipper and researchers indicate that no notable drift of the gears has taken place, maximum in the order of meters to decameters. From quantitative and qualitative evaluation it is concluded that the risk of displacement of gears moored by Bruce anchors is marginal.

Finally the displacements are correlated to the intermediate weather conditions and soaking time to evaluate the effect of weather and time on the displacements. Figure 3.3 shows the measured anchor displacements as function of the maximum intermediate wave height Hs_max between setting and hauling Figure 3.4 shows the dependency of soaking time (ΔT = T2-T1). The results presented in these figures show no clear correlation between displacement and soaking time or displacement and maximum intermediate wave height. Also for more severe intermediate wave heights and long soaking time the measured displacements remain mainly within the measurement deviation. Figure 3.5 shows the relation between soaking time and the maximum intermediate wave height. These results demonstrate that longer soaking time occurs when intermediate wave heights are more severe. During the intervals of severe wave heights the strings couldn't be retrieved within few days after setting.

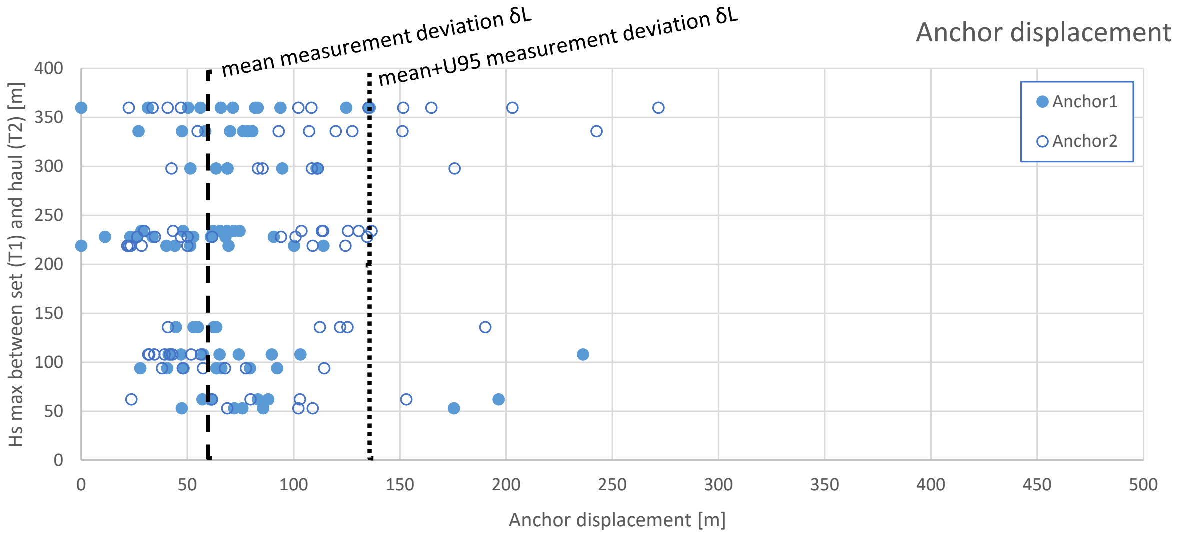


Figure 3.3 *– String offset as function of maximum wave height Hs between setting and hauling.*

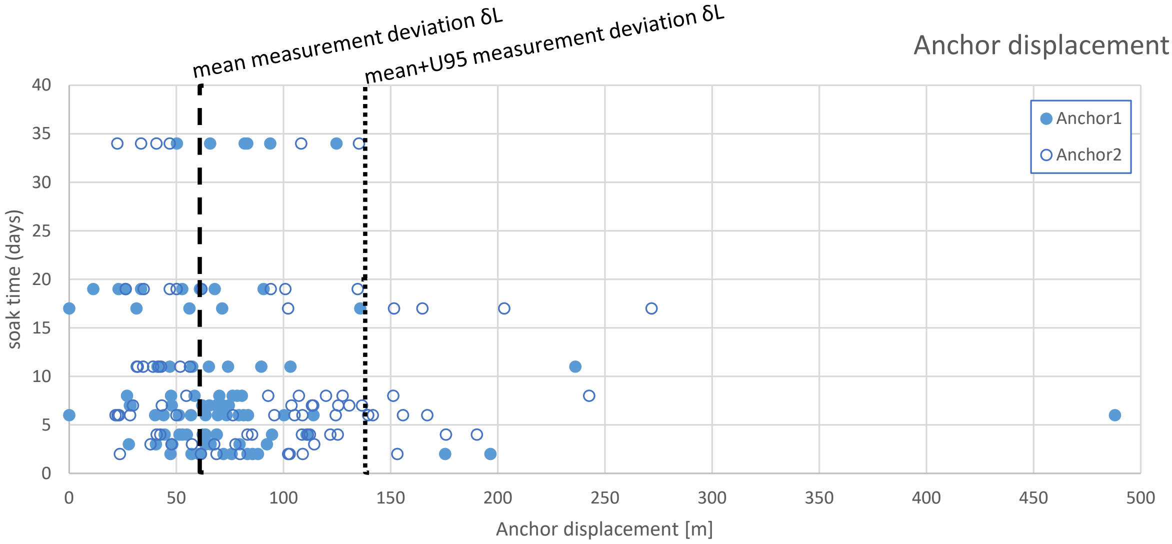


Figure 3.4 *– String offset as function of soaking time.*

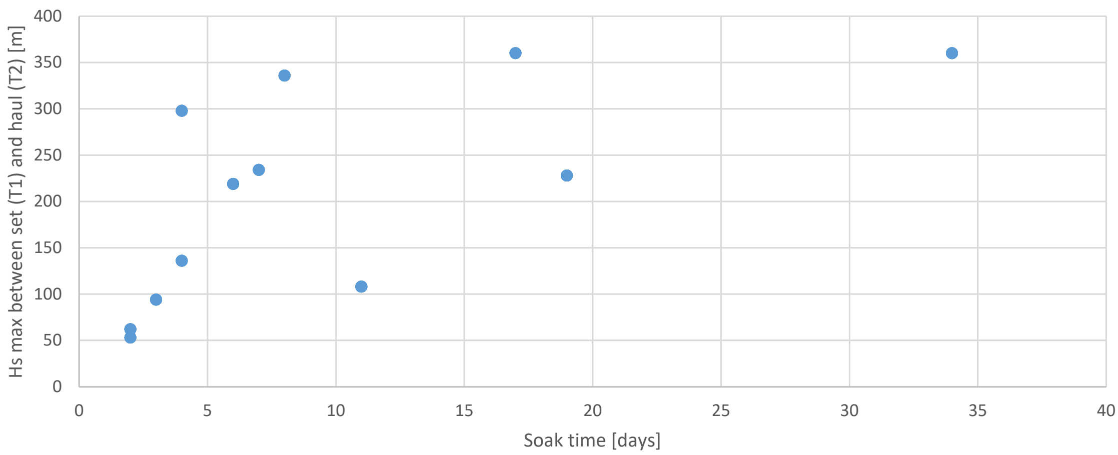


Figure 3.5 *– Soaking time as a function of wave height Hs between setting and hauling.*

3.3 Nautical operations

3.3.1 Experiences

Most field trips were undertaken as foreseen in the action plan and did not require additional communication with Rijkswaterstaat, the coast guard or the wind farm operator. General operational observations of the field trips are listed below. During some of the field experiments unanticipated events did take place. These are described in Appendix 5.

- The maintenance zones around the turbines and in-field cables are not available onboard in the nautical charts. It is recommended to make the maintenance zones available onboard in the nautical charts to reduce incidental entering of the maintenance zones.
- Prior to the start of the experiments a total of 5 phone calls for each trip were foreseen: calls to both the coast guard and wind farm operator at 4 moments during the trip: departure from port, arrival at wind farm, departure from wind farm and arrival at port. Notification of activities within the safety zone at the coast guard is mandatory for SAR operations in case of calamities. Notification to the WFO is not mandatory, but the WFO would like to be informed about activities within the wind farm and facilitates to pass these activities through to the coast guard. These phone calls were experienced as considerable administrative load by the fishers. During the first days of the experiments of this project the coast guard and wind farm operator indicated to reduce the number of calls: calls to the coast guard are not necessary, since they receive a list with vessels that will undertake activities in the wind farm through the wind farm operator; only calls to the wind farm operator upon arrival at and departure from the wind farm were required. The reduced number of 2 phone calls is workable for the fishers participating in the experiments.
- Sailing time from coast to wind farm and vice versa with a small vessel (Lpp<12m) takes approximately 3 hours, resulting in a total of 6 hours sailing time per workday. The time required to empty and replace pot strings in the wind park is approximately 3/4 hours, resulting in approximately 7 hours to replace all 9 strings. The time to haul and deploy a gill net is approximately 1½ hour, resulting in approximately 6 hours to haul and deploy all 4 gillnets. Together sailing time and working time in the wind park result in 12-13 hour working days. Increasing the number of nets or strings would result in even longer working days.
- Specific unanticipated events, which have required additional communication with Rijkswaterstaat and the wind farm operator, are described in Appendix 5.

3.3.2 Sailing trajectories

The Figures 3.6 to 3.10 reflect the sailed tracks of the fishing vessels MDV 2, YE 152 and KG 7 in the months of June until September within wind farm Borssele. These tracks have been created using AIS data from the respective vessels and provide a geographical image of the total operational activities by this group of fishing vessels during the experiments per month. The vessel tracks do not show individual vessels in order to visualise the overview of activities during the respective month. Using different colours for each vessel separately would have made the image less readable.

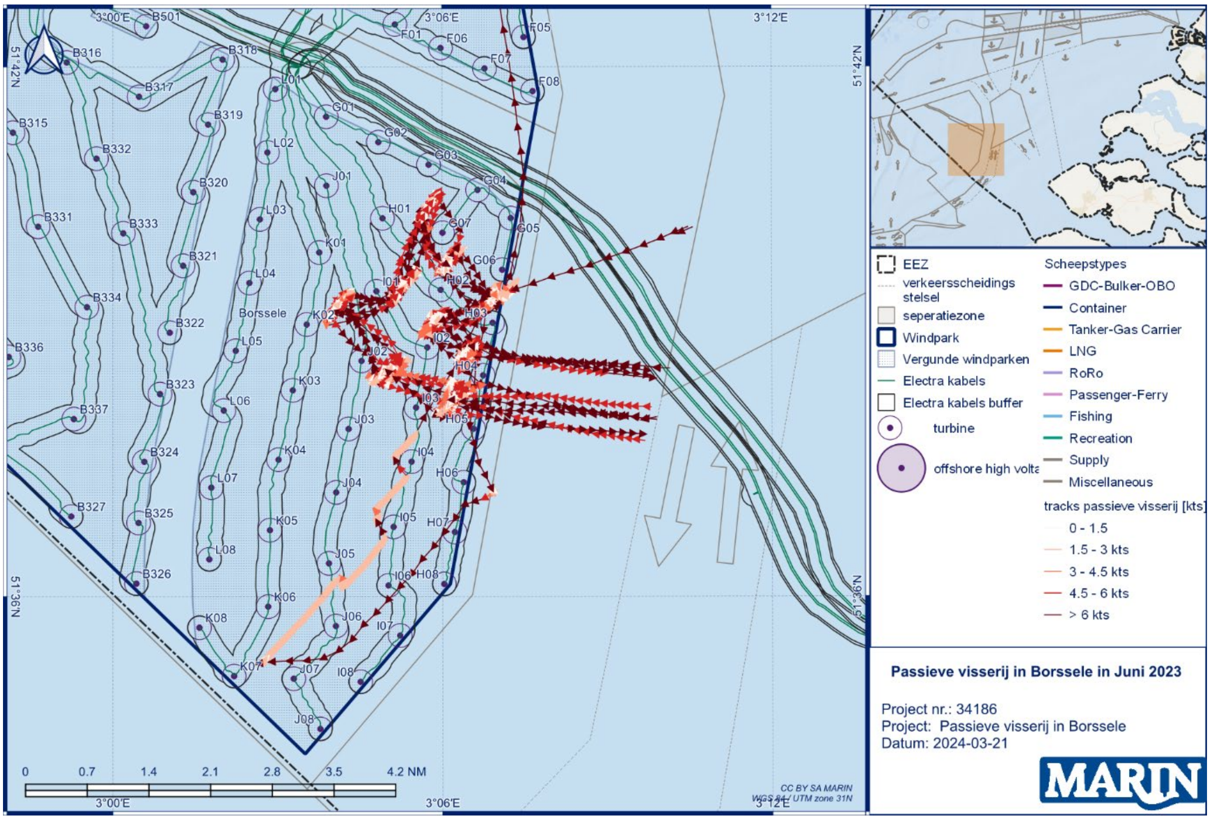


Figure 3.6 *– Passive fishing trajectories in Borssele offshore wind farm, June 2023.*

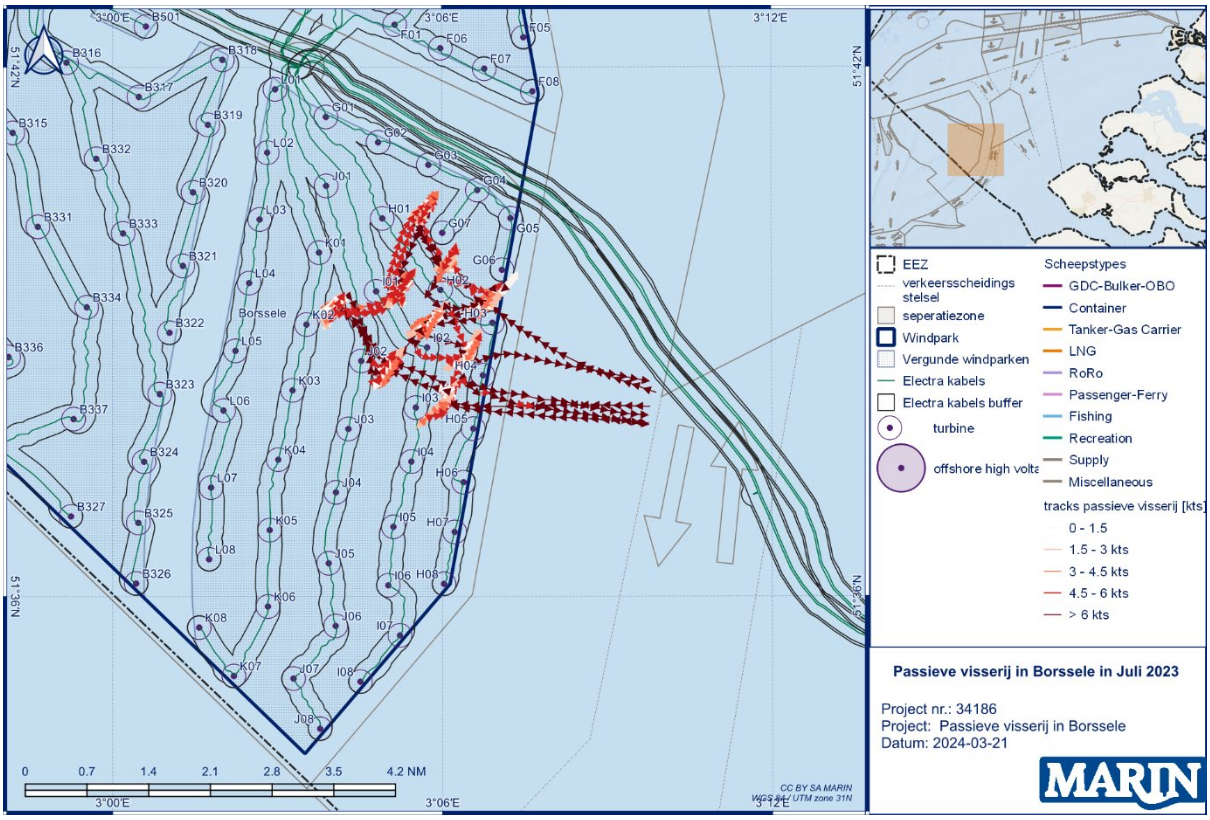


Figure 3.7 *– Passive fishing trajectories in Borssele offshore wind farm, July 2023.*

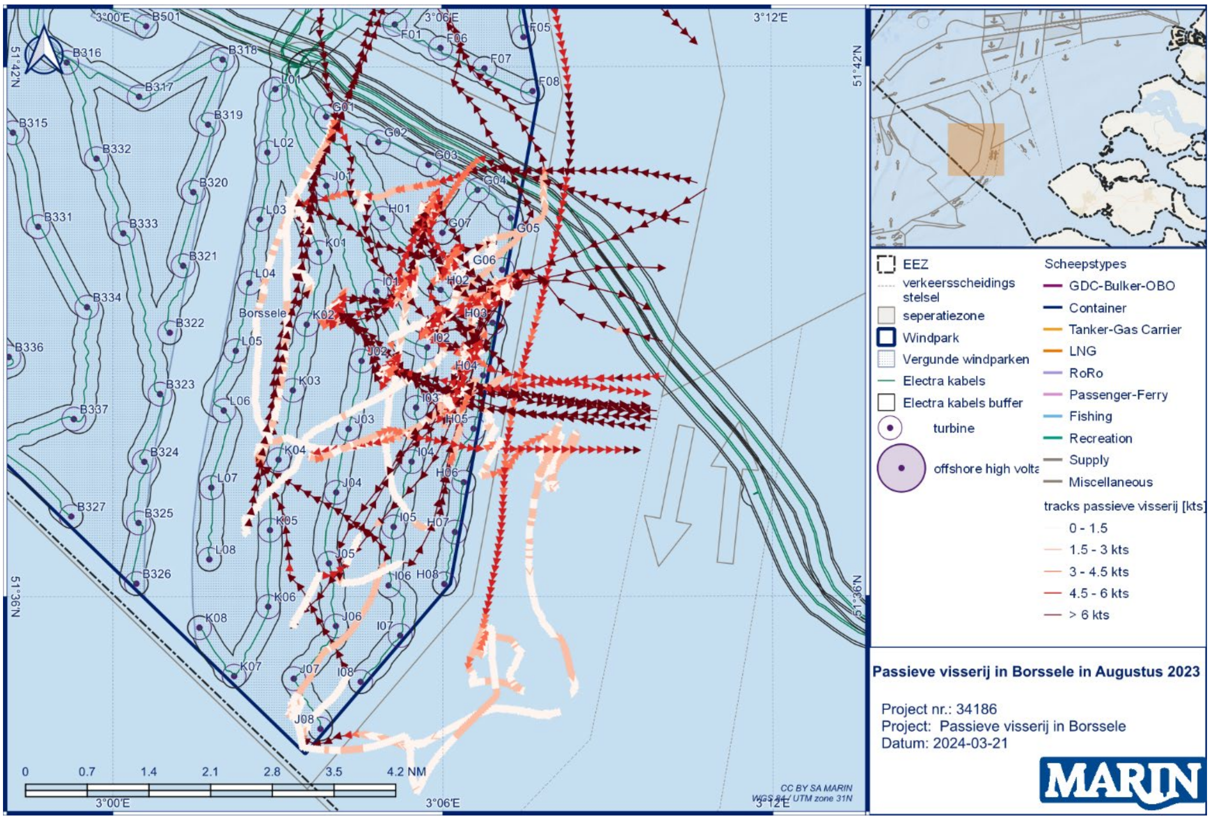


Figure 3.8 *– Passive fishing trajectories in Borssele offshore wind farm, August 2023.*

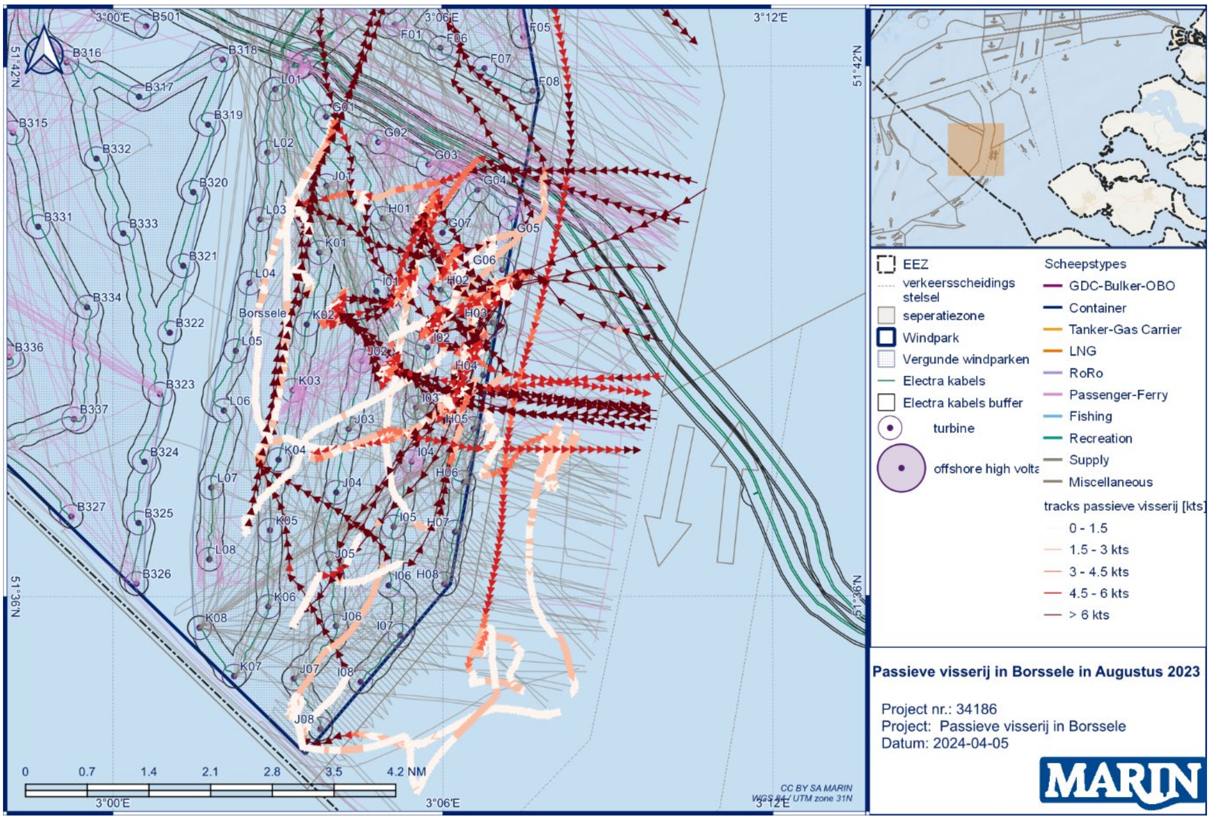


Figure 3.9 *– Passive fishing and working vessel trajectories in Borssele offshore wind farm, August 2023.*

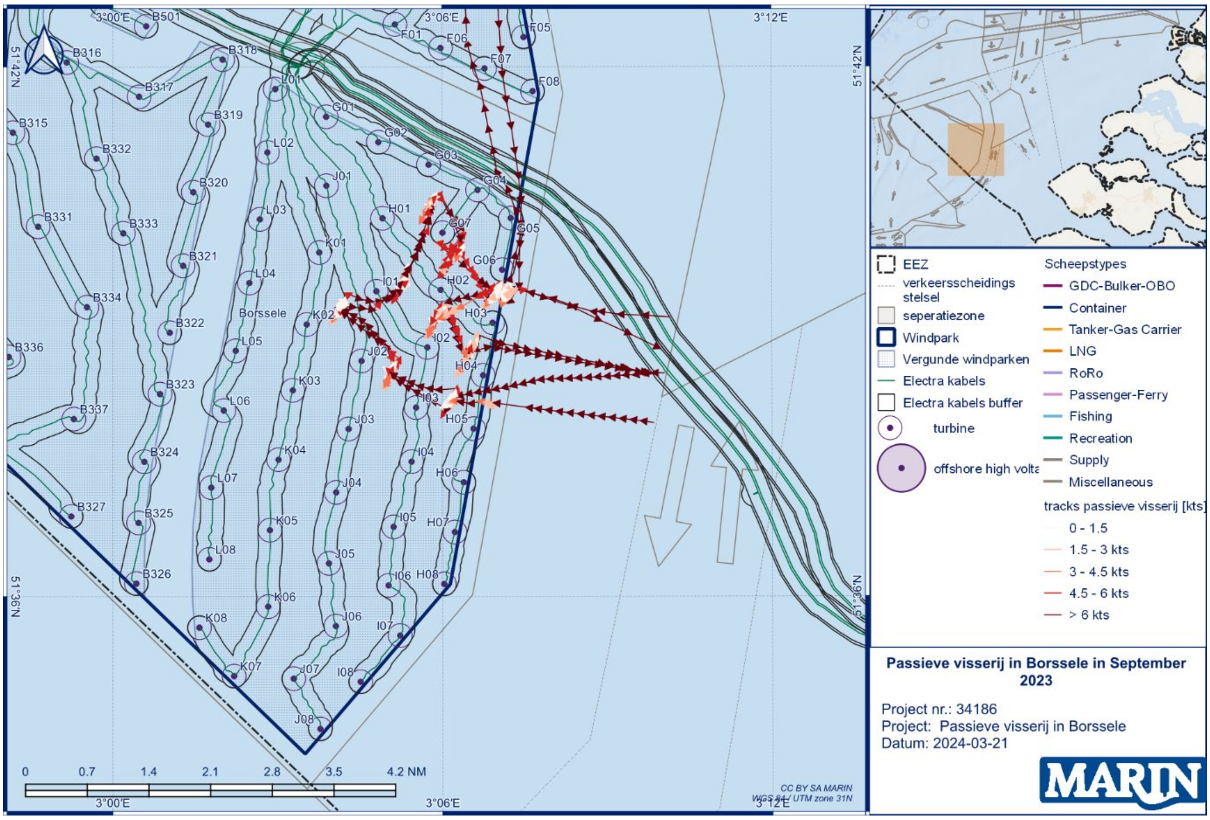


Figure 3.10 *– Passive fishing trajectories in Borssele offshore wind farm, September 2023.*

The images are high-level but provide sufficient detail regarding the positioning of the vessels related to the safety and maintenance zones of the wind farm and the individual turbines. The vessel tracks are limited to the activities within the wind farm as arrival and departure courses are not relevant to this report.

The images are prepared for the months June till September and show the actual trajectories of the fishing vessel activities withing the wind farm during that month. The trajectories are coloured to highlight the speed of the vessels. A dark red colour indicate a speed over 6 knots. The lighter the colour of the track, the slower the speed of the respective vessel, which is an indication of the activities while handling the fishing gear.

The month of August has been supplemented with tracks of working vessels inside the wind farm, represented by the grey lines. This image only highlights the interaction and difference in operational size between the two types of operations. No conclusions can be made from this but the image shows the significant amount of working vessel activity in conjunction with the fishing activities. Although there was no interference reported during the experiments, simultaneous operations are taking place.**Fout! Verwijzingsbron niet gevonden.**

3.4 Weather conditions and operability

The possibility to operate safely within the wind farm, hence the feasibility of passive fishing within the wind farm from an operational point of view, does depend on vessel, captain and weather. The present section addresses weather conditions in Borssele II, operational decision making and operability.

The primary factor for decision making to sail out or not is the wave height, followed by wave period, wind direction, tide and other factors. The focus of the present section is therefore on the wave height. Wave height within the wind farm are used for the decision making. This is the most exposed location, where wave height are generally higher than near the coast. This is also the location where the most restricting operations on deck are performed.

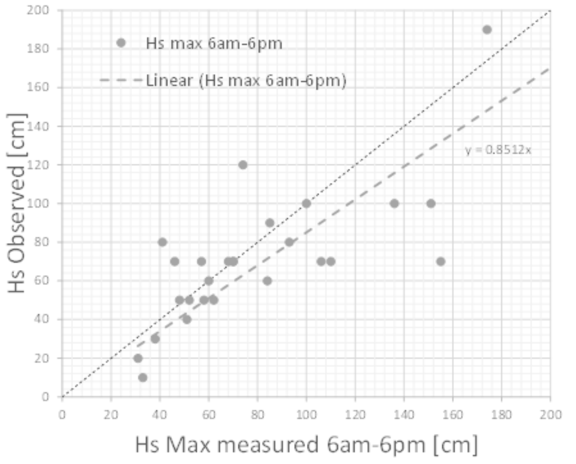
The evaluation of the weather conditions in Borssele II in 2023 is made based on measured conditions at station Borssele Alpha (Platform). These weather conditions are obtained from https://waterinfo.rws.nl and are the actual weather conditions measured in the wind park. For 2023 Borssele Alpha (Platform) provides measured wave height, periods and tide; wave direction and wind direction are not available. Since wave height is the dominant factor for operational decision making the weather analysis focusses on this parameter.

3.4.1 Wave height

Wave conditions are obtained from the following sources (see also Appendix 2):

- "Observed" wave conditions are the conditions reported in the field reports. These are based on the weather "forecast" and personal observations of the captain within the wind farm. On each trip typically a single condition is registered, two in the case of strongly varying conditions during the day.
- "Forecast" wave conditions are obtained prior to the voyages from available weather prediction reports, such as StormGeo and Windfinder. These sources predict the weather conditions few days ahead, based on which the decision is taken to sail out or not. The forecast wave conditions as listed on the daily field reports are adopted.
- "Measured" wave conditions in Borssele during the period of the experiments (2023) are obtained from https://waterinfo.rws.nl. This source provides the measured local weather conditions at station Borssele Alpha (Platform).
- "Hindcast" weather conditions are long term statistical conditions from prediction models. These weather conditions are available in the tender packages of the wind farms: for Borssele in RVO/ Deltares (2015), for HKZ in HKWFZ (2017), for HKN in HK(N)WFZ (2019), and for HKW in HK(W)WFZ (2020). The hindcast data is applied for comparison with the measured wave conditions in Borssele in 2023 and for a comparison of the wave conditions amongst wind parks Borssele, HKZ, HKN and HKW.

A comparison of the observed and measured wave height on the days of the experiments is given in Figure 3.11 and Figure 3.12. From the wave measurements the average and maximum wave heights measured during daytime, between 6 am and 6pm, is taken.



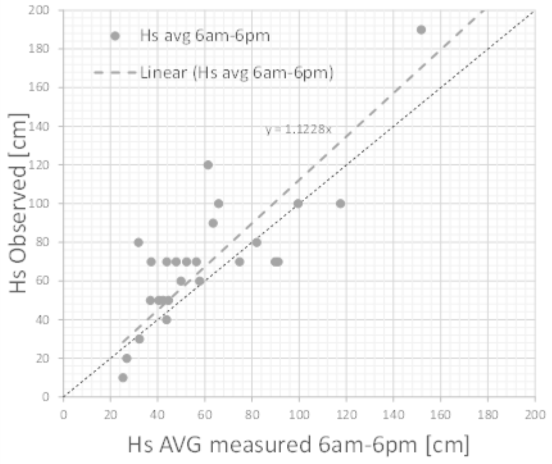
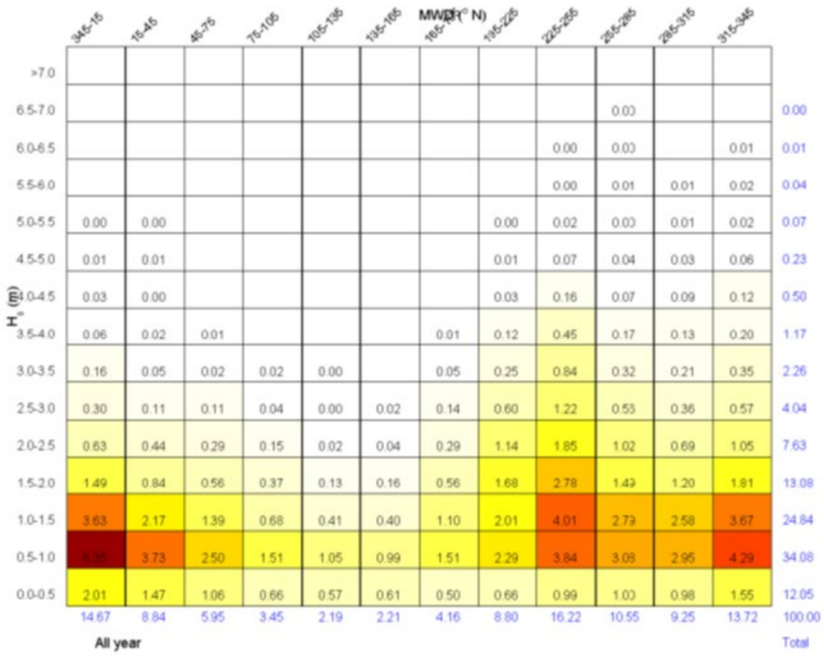


Figure 3.11 *- Observed wave height versus measured maximum wave height during daytime on sailing days.*

Figure 3.12 *- Observed wave height versus measured average wave height during daytime on sailing days.*

Figure 3.11 and Figure 3.12 show that the observed wave heights are in general in-line with the measured wave heights by the Borssele Alpha Platform. The observed wave heights are in general +10% higher than the average measured wave heights and -10% lower than the maximum measured wave heights. This is a validation of the measured wave heights by the observed wave heights and justifies the use of measured wave heights.

Figure 3.13 is adopted from Deltares (2015) and shows the Joint Occurrence Table (JOT) of wave height versus wave direction at Borssele II. This figure shows that 46% of the time the wave height is below Hs=<1.0m and 71% of time the wave height is below Hs=<1.5m. The figure furthermore shows the dominant wave directions are South-West (26% of time) and North to North-North-West (28% of time).
The JOT shows wide scatter of the wave direction, especially in the range up to Hs<=1.5m, which is the operational range of the small fishing vessels used in the experiments. The dominance of wave heights in the operational range of the fishing vessels, in combination with the wide scatter of wave directions demonstrates the uncertainty in operability of the fishing vessels.



H_s (m)	345-15	15-45	45-75	75-105	105-135	135-165	165-195	195-225	225-255	255-285	285-315	315-345	Total
>7.0													
6.5-7.0										0.00			0.00
6.0-6.5									0.00	0.00		0.01	0.01
5.5-6.0									0.00	0.01	0.01	0.02	0.04
5.0-5.5	0.00	0.00						0.00	0.02	0.00	0.01	0.02	0.07
4.5-5.0	0.01	0.01						0.01	0.07	0.04	0.03	0.06	0.23
4.0-4.5	0.03	0.00						0.03	0.16	0.07	0.09	0.12	0.50
3.5-4.0	0.06	0.02	0.01				0.01	0.12	0.45	0.17	0.13	0.20	1.17
3.0-3.5	0.16	0.05	0.02	0.02	0.00		0.05	0.25	0.84	0.32	0.21	0.35	2.26
2.5-3.0	0.30	0.11	0.11	0.04	0.00	0.02	0.14	0.60	1.22	0.53	0.36	0.57	4.04
2.0-2.5	0.63	0.44	0.29	0.15	0.02	0.04	0.29	1.14	1.85	1.02	0.69	1.05	7.63
1.5-2.0	1.49	0.84	0.56	0.37	0.13	0.16	0.56	1.68	2.78	1.49	1.20	1.81	13.08
1.0-1.5	3.63	2.17	1.39	0.68	0.41	0.40	1.10	2.01	4.01	2.73	2.58	3.67	24.84
0.5-1.0	6.35	3.73	2.50	1.51	1.05	0.99	1.51	2.29	3.84	3.08	2.95	4.29	34.08
0.0-0.5	2.01	1.47	1.06	0.66	0.57	0.61	0.50	0.66	0.99	1.00	0.98	1.55	12.05
All year	14.67	8.84	5.95	3.45	2.19	2.21	4.16	8.80	16.22	10.55	9.25	13.72	100.00

MWDR (° N)

Figure 3.13 *– Joint Occurrence Table of wave height versus wave direction at Borssele II from Deltares (2015).*

3.4.2 Operability

The decision whether to sail out or not (go/ no-go) is taken per trip by the skipper and depends on weather conditions, including: wave height, wave period (short wind waves or longer swell waves), wind velocity, wind direction, precipitation, visibility, temperature and experience. The members of the focus group indicate the following order in weather conditions to decide the sail out or not:

- The wave height is the dominant factor in the decision making. This factor dominates the vessel motions and the ability to safely work onboard of the vessel. The wave height is results from the wind velocity and direction, but wind velocity itself is not a decision making factor.
- Wave period. Short wave periods, as experienced in the Southern North Sea increase vessel motions of small to medium sized vessels, decrease motion comfort and are unfavourable. For KG 7 especially short waves from East are unfavourable due to limited motion comfort on the return voyage.
- Wind velocity and direction. These are the driving factors behind the wave height, wave period and wave direction, but by itself less a driving factor in the decision making.
- Tide is of limited influence on decision making. The workable period in the wind farm is dominant for the daily schedule. Since working is only allowed during day time departure is in the morning and arrival in the afternoon or evening. On average over all trips favourable and unfavourable tide is encountered. This results in average fuel consumption.

The significant wave height (Hm0) measured at Borssele Alpha Platform is shown in the figure below (Figure 3.14). The days on which experiments are conducted are visualized in this figure as well.

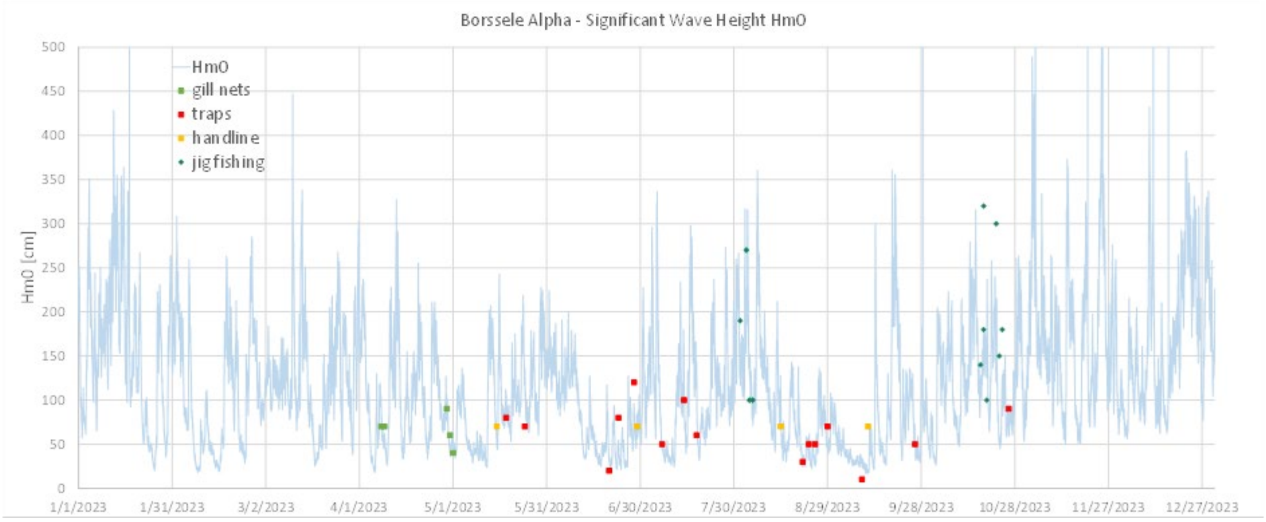


Figure 3.14 *- Significant wave height Borssele 2023 (measured).*

Indicative operational limits are:

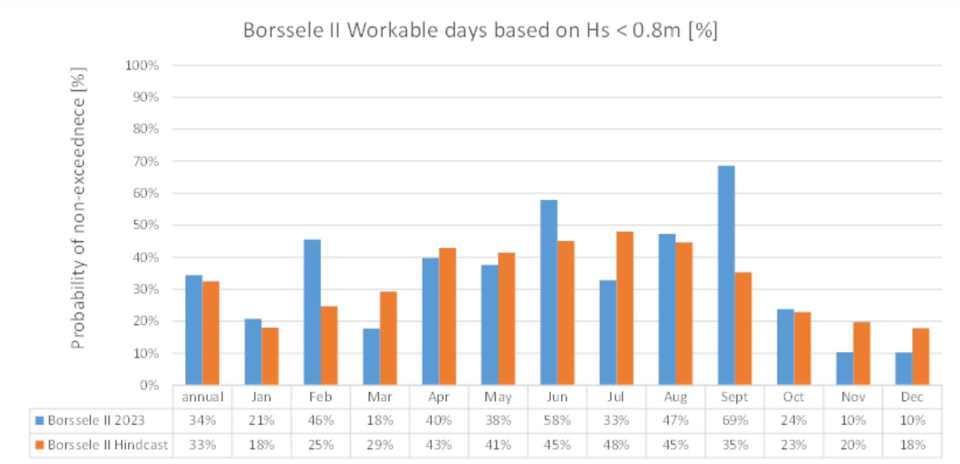
- Small vessels (Lpp=<12m), such as the YE 152 Hs=<1m
- Medium sized vessels (Lpp=<~30m), such as MDV 2 Hs=<1.5m in southern North Sea (short waves)

Indicative limits for decision making whether to sail out or not are somewhat lower than the operational limits of the vessel to have margin for unforeseen increase of the weather conditions. Indicative limits for decision making whether to sail out or not are:

- Small vessels (Lpp=<12m): KG 7 Hs<0.8m, YE 152 Hs=<0.9m
- Medium sized vessels (Lpp=<~30m), such as MDV 2 Hs=<1.5m in southern North Sea (short waves)

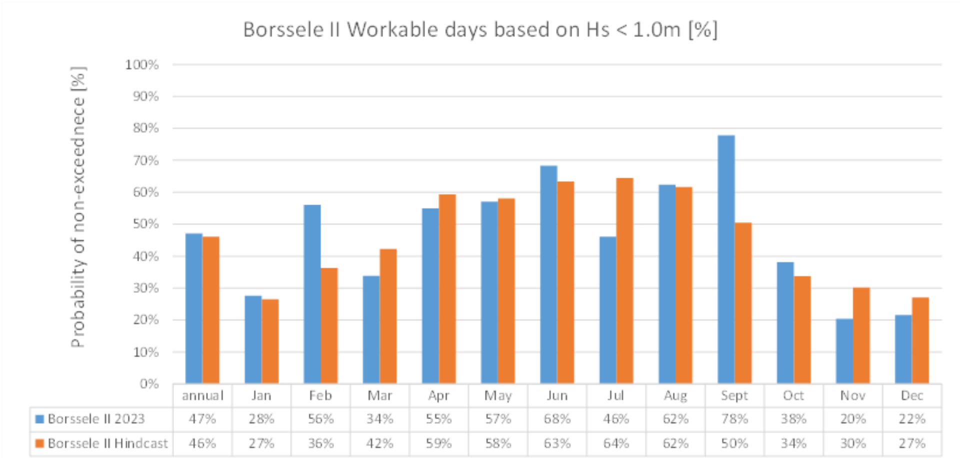
The limits mentioned above are indicative values, in accordance with the experiments. The decision whether to set sail out or not is weighed and taken per trip by the skipper and also depends also on precipitation, visibility, temperature and experience.

Operational limits of Hs=<0.8m, 1.0m and 1.5m are applied to determine the workable days (in %) in Borssele during the experiments of 2023 (measured weather data) and on average (Borssele hindcast data, RVO/ Deltares (2015)). The results of this evaluation are shown in the figures 3.15 to 3.17 below on an annual and monthly basis. Comparison between the workable days of 2023 with the long-term statistics shows less workable days during the spring and summer period (March till August) in 2023, especially in March and July. This is in-line with the experience of the fishers and project team that 2023 had less workable days due to bad weather compared to other years. The distribution of workable days in 2023 is also in-line with the wave height shown in Figure 3.14 which shows periods of high wave heights in spring and July and low wave height in September. However, the difference between 2023 and average years is not very large. One should take into account the limited workability of small fishing vessels in offshore wind farm in the outlooks for passive fishing within wind farms.



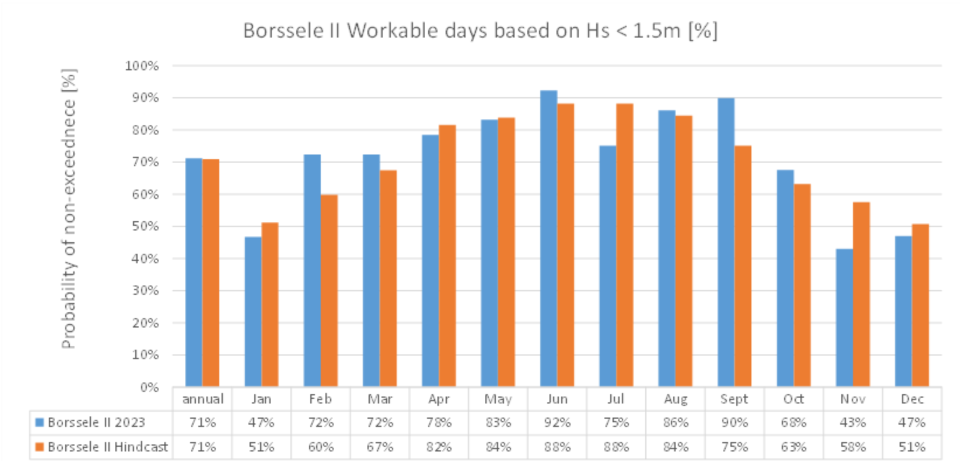
	annual	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Borssele II 2023	34%	21%	46%	18%	40%	38%	58%	33%	47%	69%	24%	10%	10%
Borssele II Hindcast	33%	18%	25%	29%	43%	41%	45%	48%	45%	35%	23%	20%	18%

Figure 3.15 *- Workable days based on wave height criteria Hs<0.80m in Borssele 2023 (blue) and average (orange).*



	annual	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Borssele II 2023	47%	28%	56%	34%	55%	57%	68%	46%	62%	78%	38%	20%	22%
Borssele II Hindcast	46%	27%	36%	42%	59%	58%	63%	64%	62%	50%	34%	30%	27%

Figure 3.16 *- Workable days based on wave height criteria Hs<1.0m in Borssele 2023 (blue) and average (orange).*



	annual	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Borssele II 2023	71%	47%	72%	72%	78%	83%	92%	75%	86%	90%	68%	43%	47%
Borssele II Hindcast	71%	51%	60%	67%	82%	84%	88%	88%	84%	75%	63%	58%	51%

Figure 3.17 *- Workable days based on wave height criteria Hs<1.5m in Borssele 2023 (blue) and average (orange).*

Note the decision to sail out is made in the days prior to the fishing trip based on the weather forecast. Since the forecast is approximately +10% higher than the average measured wave height, the operational limit are even lower than the limits reported above based on the measured and hindcast weather data. A forecast wave height of 0.9m, on the basis of which a decision is made to sail, in reality results in an average wave height of 0.8m.

Furthermore, the operability is reduced by the tide. Since working in the wind farm is only allowed during day time departure is in the morning and arrival in the afternoon or evening. Sailing with the tide reduces the nominal sailing time of 3 hours to approximately 2.5 hours, while sailing against the tide increases the sailing time to approximately 4 hours. The restriction to only be allowed to access the wind farm during daytime hampers the flexibility to select the ideal sailing times. For commercial fishing operations sailing against the tide is unfavourable because of higher fuel consumption and more working hours. Likely one only would like to sail out on mornings without current or current from the stern.

4 Ecological and biological data

4.1 Overview

From the field experiences it became clear that field trips performed were very sensitive to winds and waves. Therefore, this planning (and therefore also the people participating) was subject to constant changes and required continuous adaptations. The experiment had an explorative character. Not all gears were repeated in the similar approach, reducing replicates. In addition, unfavourable weather conditions reduced the number of possible expeditions per gear. All these aspects hampered statistical evaluations. For mechanical jigging for instance, not a constant approach was used in the set-up of the jigging machine as these had never been used before. The trial included many different settings of the machines and adjustments of the gears that were done in the actual fishing hours. Therefore, for none of the gears CPUE and LPUE were determined as these would give a non-representative overview of the catch potential. For gillnet and handline alike low replicates reduce statistical resolution and accuracy. The multi-species pots have more replicates but results were influenced by the long soaking time (due to unfavourable weather hampering the possibility of sailing out to retrieve the pots) which can lead to mortality of target species, reducing statistical resolution. The analysis should therefore be considered as a first inventory. Therefore, per gear type, a descriptive table is included with the fishing effort, the total catch per (sub)target species, as well as important factors such as gear adjustments, relevant observations, weather circumstances and bird and sea mammal sightings. Catch compositions in the upcoming chapters were all based on weights. In the few cases where no weights could be registered in the field, a length-weight relationship was used to estimate the weights.

The total amount of days in the field per month and per gear are shown in Table 4.1.

Table 4.1 *– Overview on the total days in the field per fishing gear and per month.*

	Handline	***Gillnet***	***Multi-species pot***	***Jigging***
April	0	4	0	0
May	0	1	2	0
June	1	0	5	0
July	0	0	3	0
August	2	0	4	4
September	1	0	2	0
October	0	0	1	6
Total	**4**	**5**	**17**	**10**

4.2 Handline fishing (LHP)

4.2.1 Fishing operations

A total of 10 fishing days were foreseen; 4 trips have been undertaken. This was due to unsuitable weather circumstances. Figure 2.1 shows no designated areas for this gear as this technique of fishing needed a flexible approach, depending on weather circumstances and tides, but taking into account ongoing traffic, deployed objects, other fishing gears present, or other ongoing experiments. For this experiment the blue and grey space between maintenance zones for both Borssele I and II (Figure 2.1) was used.

The first day, the vessel crew searched for suitable fishing spots inside both Borssele I and II offshore wind farm by sailing transects through the area. Suitable fishing spots include for example hard substrates, structures on the bottom, ship wrecks and sudden changes in depth. No hard substrates were found, but sudden changes of depths in the South of Borssele II offshore wind farm were seen as most suitable fishing spots. Therefore, fishing while drifting was done in the first two days.

Because catches were lacking and the drifting speed was quite high due to spring tide, it was decided together with the skipper and crew that it would be more favourable to fish anchored to the bottom. Because anchoring with this vessel and fishing gear was not originally included in the risk assessment method statement and action plan, the Rijkswaterstaat had to be consulted and anchoring was approved. See also Appendix 5, case 3). Passive fishing near a wreck is, however, allowed. The Cultural Heritage Agency (RCE) indicated that bottom-disturbing fishing is considered harmful to the wreckage. When anchoring is desired, the anchor could potentially cause damage to the wreck and therefore in that case, it is advisable to keep some distance from the wreck when anchoring. This distance was set at 100 meters, which is often also used in permits for other bottom-disturbing activities on the North Sea. Fishing closer to a wreck than 100 meters is also not favourable as the noise of the engine or dropping of the anchor might scare away the fish present near or in the wreck.

Fishing while anchored to the bottom was done in the last two days in the field. Anchoring was done near a wreck present inside the offshore wind farm, taking into account 100 meters from the wreck to prevent possible damage to the wreck by the anchor. The wreck is called “GO5” and has the coordinates: N51.39.450, E003.07.144. For anchoring, A bruce anchor of 15 kg was used as they were previously tested and are currently seen as most suitable for use in offshore wind farms due to low risk of damage to cables (Rozemeijer et al. 2021 & 2022). While fishing closer to the wreck, catches significantly improved. However, no seabass were caught during the field tests.

While sailing transects through the research area in the first days, indications of bigger fish like seabass and Atlantic cod were seen on the echosounder above the wreck but were gone by the time the decision had been made that fishing near the wreck was allowed. On other sites in the wind farm, no indications of fish were found on the echosounder except for some scattered schools of pelagic fish, probably mackerel and/or horse mackerel. To see if indications of fish and catches were different inside and outside the wind farm, two other suitable areas for seabass just outside of Borssele II were fished on the way back from testing inside the wind farm. On both occasions, several seabass were caught outside the wind farm using the same techniques and gears. Catches ranging from 20 to 60 kilos of seabass were realized on those occasions in a time frame of about two hours, indicating fish was present on reference locations at the time of testing, only not inside the wind farm on the locations where crew was allowed to fish. However, also in reference locations, catch can be highly variable and depending on factors such as tide, time of day, current and the amount of fish and baitfish present at that time.

Table 4.2 shows per trip: the fishing effort, the total catch per (sub)target species, as well as important factors such as gear adjustments, relevant observations, weather circumstances and bird and sea mammal sightings.

__Table 4.2__ - Fishing effort, the total catch per (sub)target species, as well as important factors such as gear adjustments, relevant observations, weather circumstances and bird and sea mammal sightings for all handline trips.

Date	Trip number	Fishing effort (hours)	Species	Total catch per species (kg)	Gear Adjustments	Important weather conditions and other external observations	Birds and sea mammal sightings
28/06/23	1	5.5	Atlantic mackerel	0	Spent a lot of time searching for indications on the echosounder and structures on the bottom. Used baits: crab, worms, pilks.	The area where can be fished seems sandy and flat, no structures or sightings of schools of fish on the echosounder. Found one ship wreck with indications of bigger fish (possibly seabass and/or Atlantic cod)	No
			Horse mackerel	0.4			
			Seabass	0			
14/8/23	2	4.5	Atlantic mackerel	13.3	Used baits: ragworms as and pilks and feathered hooks for mackerel	Fished on the wreckage and on sandy bottoms; most catch was realized nearby the wreckage (anchored). Drift fishing is going too fast, need heavy weights.	Sighting of two Harbour porpoise and one grey seal
			Horse mackerel	0.4			
			Seabass	0			
15/8/23	3	4.5	Atlantic mackerel	3	Used baits: pilks and feathered hooks for mackerel.	Fished on the wreckage (anchored).	No
			Horse mackerel	0.1			
			Seabass	0			
11/9/23	4	5	Atlantic mackerel	23.7	Used baits: pilks and feathered hooks for mackerel.	Fished on the wreckage (anchored).	One seagull on the water, about 50 meters distance from the vessel. One grey seal.
			Horse mackerel	0			
			Seabass	0			

The following species were caught in Borssele II offshore wind farm using handline: Atlantic mackerel, horse mackerel (both sub target species) tub gurnard, whiting, , lesser weever and bib (bycatch) (Appendix 3). Atlantic mackerel and horse mackerel were considered sub-target species, as they can be valuable and abundant in some seasons. None of the prime target species, seabass or Atlantic cod, were caught inside the offshore wind farm. Table 4.2 also shows that catch was highly variable over time and between days.

The catch composition per trip and overall (combined over all trips) are shown in Figure 4.1.

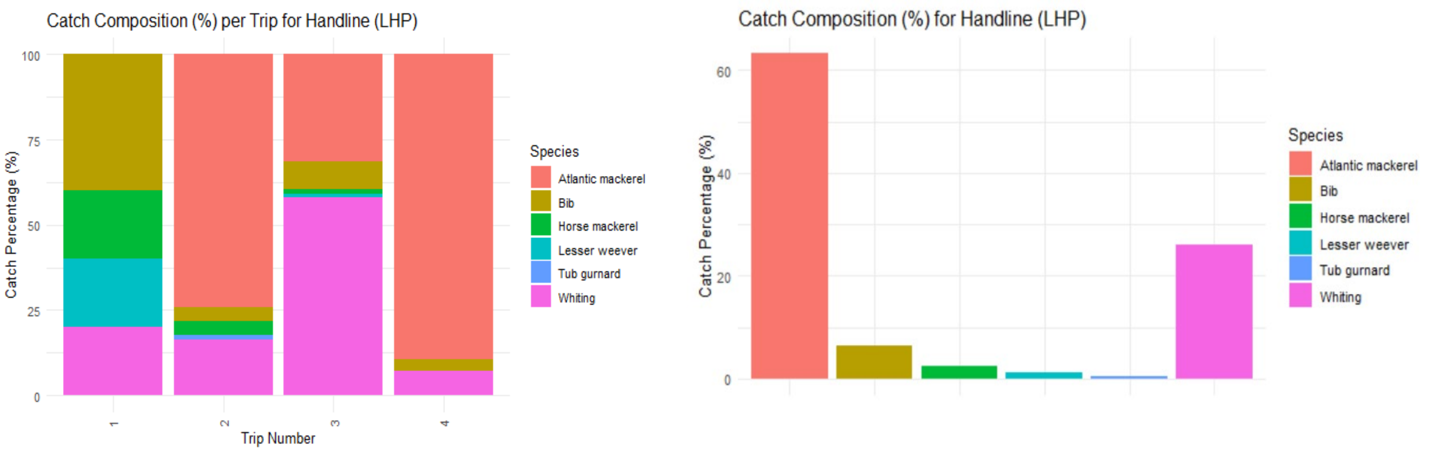


__Figure 4.1__ – Catch composition per trip (left) and overall (right) based on weights for all species caught during handline fishing in the offshore wind farm.

From the species caught, only Atlantic mackerel and horse mackerel, and in some cases also whiting and tub gurnard, can be commercially interesting. Bib was considered by-catch and non-landable and was therefore discarded when caught. Figure 4.2 shows the overall catch distribution for the main three (sub)target species for the landable catch (>MCRS) or non-landable catch (<MCRS). It shows that for Atlantic mackerel, more than half of the total catch was above minimum size and therefore landable. For horse mackerel, all catch was above minimum size and therefore landable.

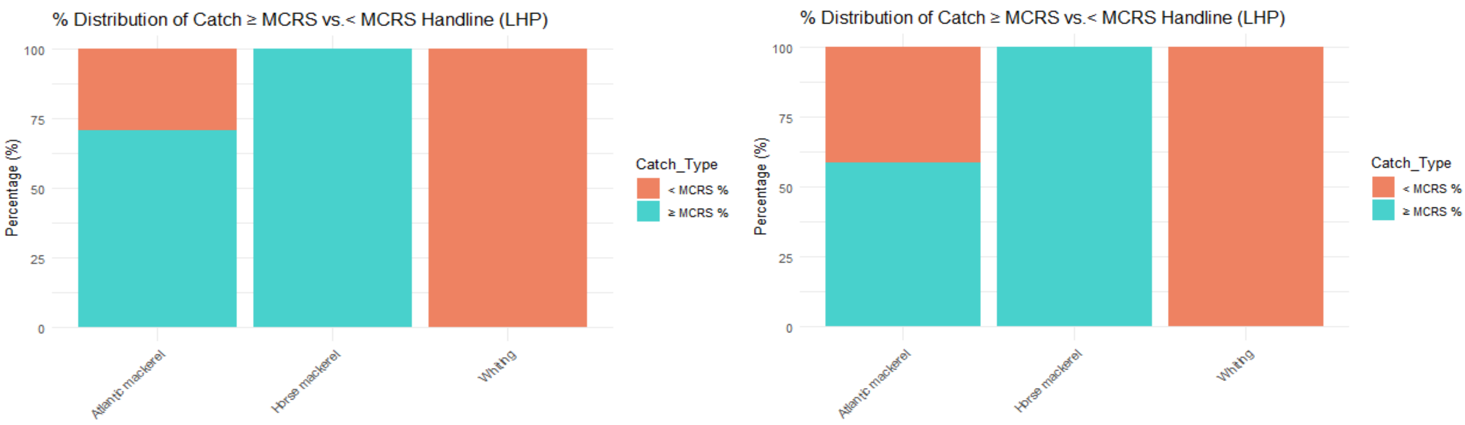


Figure 4.2 *– Catch distribution for (sub)target species in categories of landable (>MCRS) or non-landable (<MCRS) based on weights (left) and on numbers (right).*

Figure 4.3 shows the length frequency distribution for (sub)target species caught during all the trips combined. The red dotted lines represent the minimum sizes for the species shown.

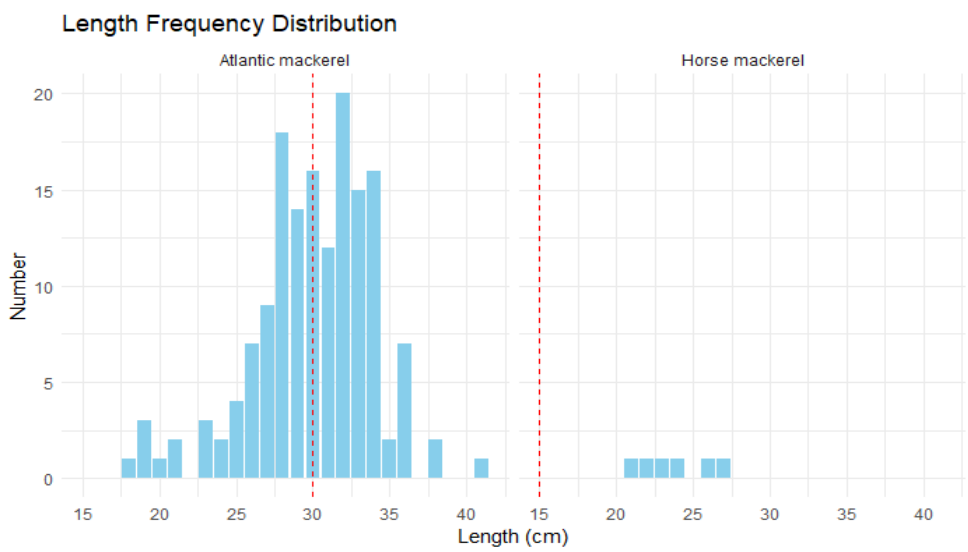


Figure 4.3 *– Length frequency distribution for most caught species in all handline trips combined.*

Length frequencies of all species caught are shown in Appendix 4.

No benthic species were caught when fishing with handlines.

4.2.2 Birds and sea mammals

During one day in the field, a seagull was seen next to the vessel. During 2 out of 4 days in the field, sea mammals were observed: on one day two harbour porpoises were seen passing by in the offshore wind farm. On two days, one grey seal was seen in the offshore wind farm. In all cases, the observations were not related to fishing activity or discarding bycatch.

4.3 Gillnet fishing (GNS)

4.3.1 Fishing operations

A total of 16 fishing days were foreseen and 5 days have been undertaken from which the researchers obtained biological data from 3 days (trips) mainly due to unsuitable weather circumstances and switching fishing gears on the same vessel. Four days were realized in April, one in May (Table 4.3). For this experiment the blue space between maintenance zones for Borssele II (Figure 2.1) was used, see exact locations in Figure 2.6. The first day of setting gillnets, crew decided to go ahead with operations as the visibility and circumstances were favourable close to shore. However, when setting the nets inside the wind farm, crew noticed a change in visibility due to the algal bloom that happens every year in spring. When hauling the next day, many net sections were damaged. This was probably due to the fact that algae got stuck in the net, making the nets much heavier and therefore more vulnerable to the strong current at that time (spring tide). Crew noticed that nets were therefore too heavy to keep their straight position on the seabed, whereby the nets closed against the bottom and were worn out by the action of the tide and currents against the seabed. It was then decided to only go ahead with future expeditions when algal bloom was over. The next trip was performed when the water was clear again. The gears were not severely damaged as during the first trip, and probably kept a more straight position on the seabed. Since circumstances were favourable, the nets were immediately set again after hauling and were hauled the next day. After this last day, the crew had to switch the gears on the vessel from gillnets to multi-species pots since it was peak season for target species for that fishery as well and it wasn't allowed to test two gears simultaneously. Therefore, all other days that were foreseen were not realized.

4.3.2 Catch composition

Table 4.3 shows per trip: the fishing effort, the total catch per (sub)target species, as well as important factors such as gear adjustments, relevant observations, weather circumstances and bird and sea mammal sightings.

Table 4.3 *- Fishing effort, the total catch per (sub)target species, as well as important factors such as gear adjustments, relevant observations, weather circumstances and bird and sea mammal sightings for all gillnet trips.*

Date	Trip number	Fishing effort (hours)	Species	Total catch per species (kg)	Gear Adjustments	Important weather conditions and other external observations	Birds and sea mammal sightings
8/4/2023	1		Dab	2.3	4 nets deployed/hauled	Algal bloom in the water; the combination with spring tide caused damaged nets. Lots of squid eggs attached to gears.	No
			Plaice	0.2			
			Sole	1.4			
			Seabass	0.4			
30/4/2023	2		Atlantic mackerel	0.3	4 nets deployed/hauled	Nets fished well; no more algal bloom and catch improved. Decided to set again after hauling. Very little damage. Lots of squid eggs attached to gears.	No
			Dab	34.3			
			Horse mackerel	0.5			
			Lesser spotted dogfish	7.7			
			Plaice	3.3			
			Sole	21.9			
			Starry smoothhound	8.2			
1/5/2023	3		Atlantic mackerel	0.6	4 nets deployed/hauled	Nets fished well; very little damage. Lots of squid eggs attached to gears.	2 seagulls
			Atlantic cod	2			
			Dab	22.8			
			Horse mackerel	3.4			
			Lesser spotted dogfish	1.5			
			Plaice	2.7			
			Sole	13.1			
			Starry smoothhound	7			

To keep the overview as many different species were caught, the most important species in weight are described in this chapter (Figure 4.4). All species caught can be found in Appendix 3. The species caught in Borssele II offshore wind farm using gillnet that are potentially commercially interesting were (in order from highest to lowest catch in weight): dab, sole, starry smoothhound, lesser spotted dogfish, plaice, horse mackerel, Atlantic cod, Atlantic mackerel and seabass. Also brill, tub gurnard, whiting, sea scorpion, flounder, common dragonet, herring, common cuttlefish and European squid were caught but in such low numbers that they are not shown in Table 4.3. Table 4.3 also shows that catch in both weight and in number of species was highly variable over time and between days.

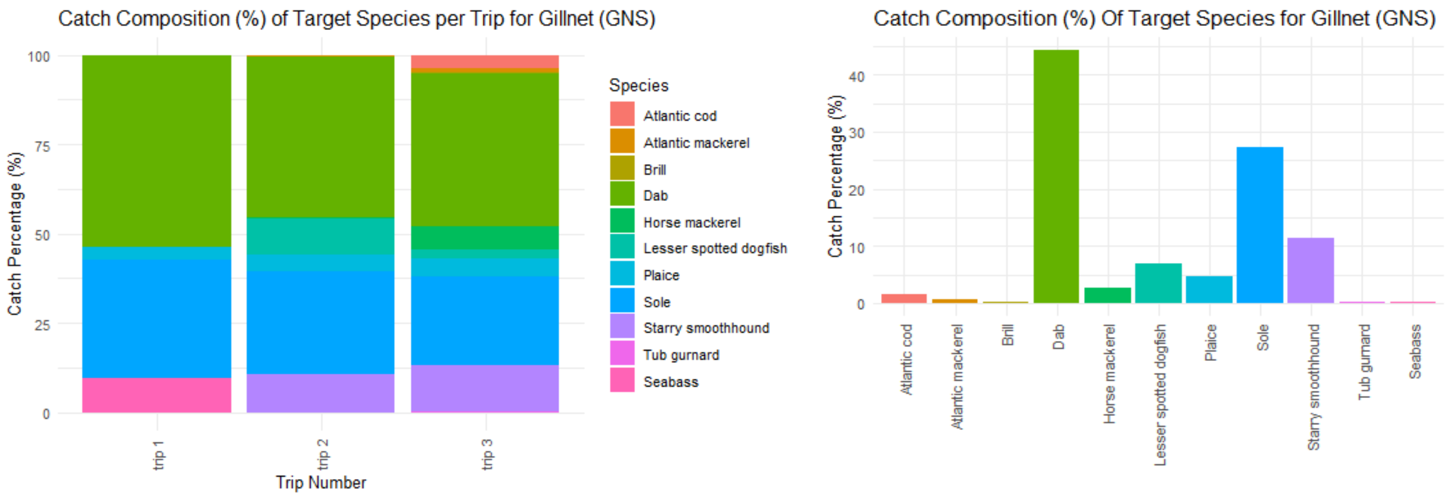


Figure 4.4 *– Catch composition per trip (left) and overall (right) based on weights for all species caught during gillnet fishing in the offshore wind farm.*

From the species caught, only dab, sole, plaice, seabass, Atlantic cod, and in some cases Atlantic mackerel, brill, tub gurnard and horse mackerel, can be commercially interesting. In this experiment, lesser spotted dogfish and starry smoothhound were considered by-catch and non-landable and were therefore discarded when caught. Figure 4.5 shows the overall catch distribution for (sub)target species for the landable catch (>MCRS) or non-landable catch (<MCRS).

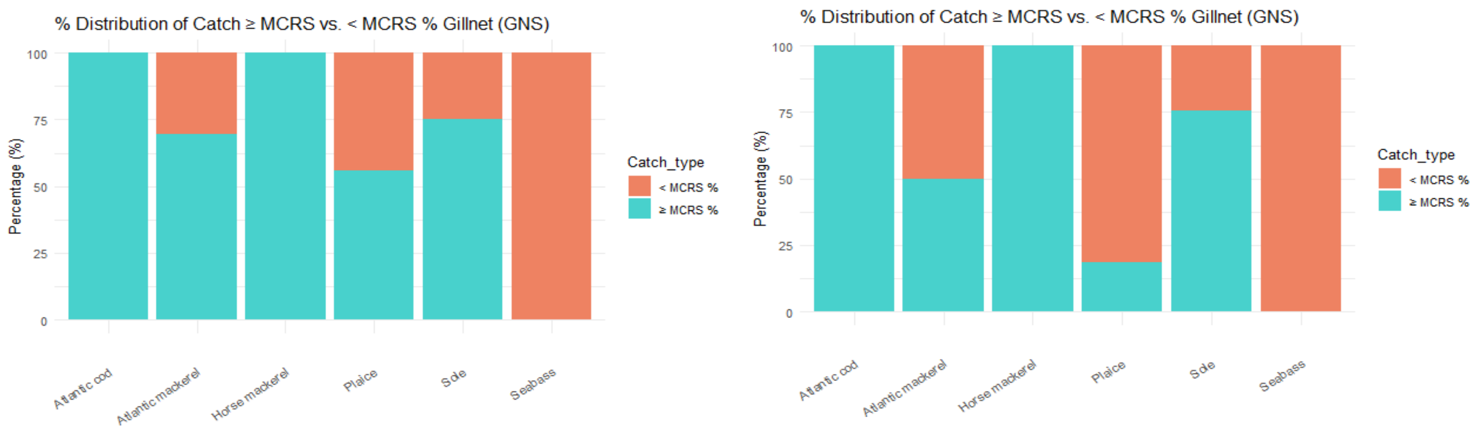


Figure 4.5 *– Catch distribution for (sub)target species in categories of landable (>MCRS) or non-landable (<MCRS) based on weights (left) and on numbers (right).*

It shows that for Atlantic mackerel, plaice and sole, more than half of the total catch was above minimum size and therefore landable. For horse mackerel and Atlantic cod, all catch was above minimum size and therefore landable. One seabass was caught which was below minimum size. Dab is not shown in this figure as it has no minimum size.

Figure 4.6 shows the length frequency distribution for (sub)target species dab and sole caught during all the trips combined, as these two species were caught in high numbers. The red dotted lines represent the minimum sizes for the species shown. For dab, no red dotted line is shown in this figure as it has no minimum size.

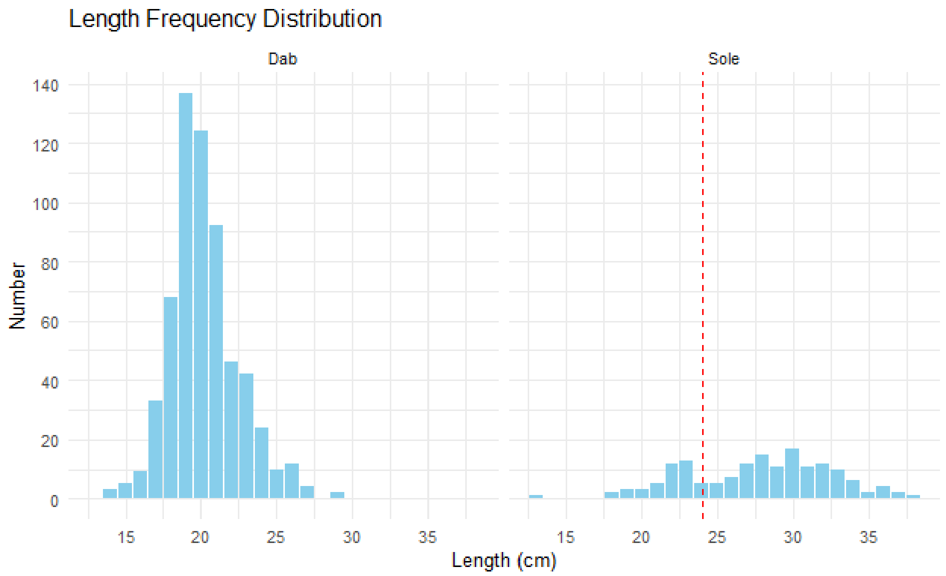


Figure 4.6 *– Length frequency distribution for the most caught species in all gillnet trips combined.*

Length frequencies of all species caught are shown in Appendix 4.

The benthic species caught consisted mostly of low numbers of bottom dwelling crustacean species. In decreasing weight: brown crab, common swimming crab, great spider crab, helmet crab, long-legged spider crab, spinous spider crab, starfish and velvet swimming crab. Brown crab is for this fishing gear not seen as a target species because they are such entangled in the gillnet that they have to be crushed in order to clean the gillnet.

4.3.3 Birds and sea mammals

During two out of three trips no birds or sea mammals were observed. On the last trip, two seagulls were seen inside of the offshore wind farm. These observations were not related to the fishing activities. However, while stripping the fish on the return of the third trip outside of the offshore wind farm, some seagulls came to the discarded fish waste.

4.4 Multi-species pots (FPO)

4.4.1 Fishing operations

A total of 16 fishing days were foreseen; 17 fishing days have been undertaken. The additional trip was made to haul 3 strings from the seabed using a small dredge, of which dahns became loose in a storm (see also Chapter 3 and Appendix 5, case 4). For this experiment the blue space between maintenance zones for Borssele II (Figure 2.1) was used, see exact locations in Figure 2.10. Strings did remain in the field during the course of the experiments (May to October, see Table 4.4**Fout! Verwijzingsbron niet gevonden.**) and were rebaited and redeployed directly after emptying the pots. Days in between deploying and hauling (soaking time) varied from 2 to 34 days, due to weather circumstances. Crew noticed that when pots were left on the seabed for a long time (>4 days), baits were completely gone and part of the catch became bait for other species and got eaten as well. Especially for squid and cuttlefish this became a problem as ideally, gears must be hauled every 1-3 days to maintain a good quality of the catch. When pots were left in the field longer, target species got eaten and died. This could also be due to the high presence of velvet swimming crabs and brown crabs. Furthermore, from April to July, lots of cuttlefish and European squid eggs were released on the gears, indicating that those species were present at that time. The main target species of the pots are listed in Chapter 2. However, although in some cases target species were not caught, other commercially interesting species were caught and are therefore also described in the next paragraphs.

Table 4.4 *– Fishing effort, the total catch of brown crab and velvet swimming crab, as well as important factors such as gear adjustments, relevant observations, weather circumstances and bird and sea mammal sightings for all multi-species pot trips.*

Date	**Fishing effort (hours)**	**Species: brown crab or velvet swimming crab**	**Sole Pot Total catch per species (kg)**	**Cuttlefish pot with fluorescent mesh Total catch per species (kg)**	**Cuttlefish pot with normal mesh Total catch per species (kg)**	**Fish Pot Total catch per species (kg)**	**Gear Adjustments**	**Important weather conditions and other external observations**	**Seabirds and sea mammal sightings**
18/05/2023							First time deploying all 9 strings; left out 8 fish pots (did not fit on deck)		No
24/05/2023	Average over all strings 6.2 days, ranging from 6.0 to 7.0.	Brown crab	13.50	6.60	5.60	3.3	A measurement buoy was placed nearby and had caught one of the dahn lines (see also Appendix 5)	Wind force 3-4 Bft, wave height 0.7m.	No
		Velvet swimming crab	1.85	1.10	0	3.3			
12/06/2023	Average over all strings 19.4 days, ranging from 19.0 to 20.0.	Brown crab	28.43	18.69	6.81	6.91	Starting to see some egg deposits from squids and cuttlefish on the pots.	Wind force 1-2 Bft, very good working conditions	One sea gull
		Velvet swimming crab	0.075	0.16	0.07	0.33			
17/06/2023	Average over all strings 3.9 days, ranging from 3.8 to 4.0.	Brown crab	7.43	5.64	7.13	6.49		Wind force 3-4 Bft, good working conditions in the beginning, later on more waves (bumpy)	8 sea gulls and one grey seal
		Velvet swimming crab	0.195	0.26	0.15	0.35			
20/06/2023	Average over all strings 3.1 days, ranging from 3.0 to 3.1	Brown crab	10.47	4.90	5.60	6.82		Wind force 4 Bft	No
		Velvet swimming crab	0.135	0.04	0.21	0.84			

23/06/2023	Average over all strings 2.5 days, ranging from 2.0 to 3.0	Brown crab	21.64	11.83	8.96	10.30	Living tanks for crabs were installed – due to no continuous flow we experienced some mortality.	Good visibility and moderate wind (1 -2 Bft), low waves (0.5-0.8m)	No
		Velvet swimming crab	0.78	1.01	0.13	0.69			
28/06/2023	Average over all strings 6.1 days, ranging from 6.0 to 7.0	Brown crab	28.86	25.04	16.99	15.45	Living tanks for crabs were installed with continuous flow – better survival.	Reasonable visibility, cloudy. Strong winds (Bft 5) and high waves (0.8-1.2m). This weather seems to be the limit to be able to sail safely.	No
		Velvet swimming crab	0.43	0.62	0.95	1.01			
7/07/2023	Average over all strings 9.1 days, ranging from 8.0 to 9.0	Brown crab	26.98	28.75	22.34	16.32	Many soft crabs; these are crabs that have just shed their shell.	Weather conditions good, good visibility, 4 Bft, swell 0.4-0.5m.	About 5 to 10 seagulls during discarding the fish outside of the wind farm.
		Velvet swimming crab	0.41	0.94	0.65	1.89			
14/07/2023	Average over all strings 7.7 days, ranging 7.0 from to 8.0	Brown crab	18.35	13.42	10.23	12.08	The pots are becoming very heavy due to fouling; from a safety point of view, this is not convenient. Decided to install a high pressure hose to clean the pots.	Rough sea, big swell (+/- 1m). Wind force 4 Bft.	4 seagulls
		Velvet swimming crab	0.76	0.61	0.97	3.04			
18/07/2023	Average over all strings 4.6 days, ranging 4.0 from to 5.0	Brown crab	12.79	9.37	11.17	6.74	The snap hook of string S9 (location G) had come loose, causing a dahn and two blisters to disappear. The ring of two fish pots had been shot open, repaired with tie-wraps.	Good sea, decreasing swell 0.8-0.4m. Good visibility. Wind force 3 Bft.	10 seagulls
		Velvet swimming crab	0.79	1.75	0.80	2.80			
21/08/2023	Average over all strings 34.0 days,	Brown crab	7.83	2.29	2.42	0.71	First trip in a long time.	Good weather conditions: good	No

	ranging 34.0 from to 34.0	Velvet swimming crab	1.90	0.90	0.75	3.69	String I not found, markings came loose due to rough weather. Has to be retrieved next trip.	visibility, waves 0.1 to 0.3m. Wind force 2 to 3 Bft.	
23/08/2023	Average over all strings 3.0 days, ranging from 2.9 to 3.0	Brown crab	0.12	3.77	0.71	3.25	Where necessary, new dahns and harp closures on the buoys to reduce / slow down wear. Retrieved string I.	Weather conditions good, good visibility, swell 0.4-0.5m, Wind force 0-2 Bft.	No
		Velvet swimming crab	3.40	1.71	0.92	1.82			
25/08/2023	Average over all strings 3.0 days, ranging from 2.9 to 3.0	Brown crab	4.53	1.51	1.44	1.33		Good weather conditions, fog in the morning, 0 - 1 Bft, swell 0.4-0.5m.	No
		Velvet swimming crab	1.74	1.47	0.93	1.23			
29/08/2023	Average over all strings 4.9 days, ranging from 4.0 to 5.0	Brown crab	12.30	6.92	5.89	1.83		Weather conditions reasonable. Swell 0.5 - 0.7m, wind force 4 Bft. A number of whirlwinds were seen in the offshore wind farm.	No
		Velvet swimming crab	2.86	2.18	0.89	2.08			
09/09/2023	Average over all strings 11.1 days, ranging from 11.0 to 11.8	Brown crab	20.52	5.35	6.09	1.72		Weather conditions good: 30 degrees, swell 0.1m, good visibility. Wind force 2 - 4 Bft. Regional heat wave.	No
		Velvet swimming crab	2.40	0.98	0.53	3.02			
26/09/2023	Average over all strings 17 days, ranging from 16.9 to 17.3	Brown crab	15.03	4.54	5.33	0	Got 6 out of 9 strings that were not placed back because of the end of the project: 3 strings (A, B, H) are missing the markers so they have to be removed in an additional trip.	Weather conditions reasonable: swell 0.5m, good visibility.	No
		Velvet swimming crab	1.18	1.77	0.27	0			

26/10/2023	Not applicable.		0	0	0	0	Extra trip (day 17) had to be made to haul out the remaining three strings. The catch has not been measured because the pots have not fished correctly; two buckets of North Sea crabs in the remaining pots, but the pots were buried under the sand.	Weather conditions not very good, swell 0.8-0.9m, good visibility.	No

4.4.2 Sole pots

Catch composition

The catch composition in numbers and weight per trip for sole pots is given in Figure 4.7 (in weight and numbers respectively). No individuals of the primary target species, sole, was caught during the experiment. The most dominant species was brown crab in the beginning of the season (around 80% in numbers and weight) and velvet swimming crab increasing in numbers with the season to ~60% towards the end of the experiment. The maximum total catch of brown crab in a single trip was 29 kg on 29-6-2023 after 6.1 days soaking time. The catch decreased to 16.4 kg per trip in September.

In weight, velvet swimming crab had its peak on 23-08-2023: 3.4 kg after 3 days soaking time. Leaving out the first haul out, the velvet swimming crab started low in the beginning of the season with 0.08 kg per trip and ended with catches > 1 kg per trip towards end of August and September.

Dab and common cuttlefish were caught in the beginning of the experiment (1 and 1.2 kg respectively and once more cuttlefish 0.2 kg). Common cuttlefish was also encountered as the cuttlebones: these are common cuttlefish that had been eaten while inside the pot. Also an Atlantic mackerel was caught (0.2 kg).

Non-target species caught during the pot experiments were five-bearded rockling, bull-rout, snake pipefish, tompot blenny, sea-horse, blue-leg swimming crab, common swimming crab, viviparous blenny, spinous spider crab and starfish in the beginning of the experiment (Appendix 4). Towards the end of the experiment the amount of species caught reduced.

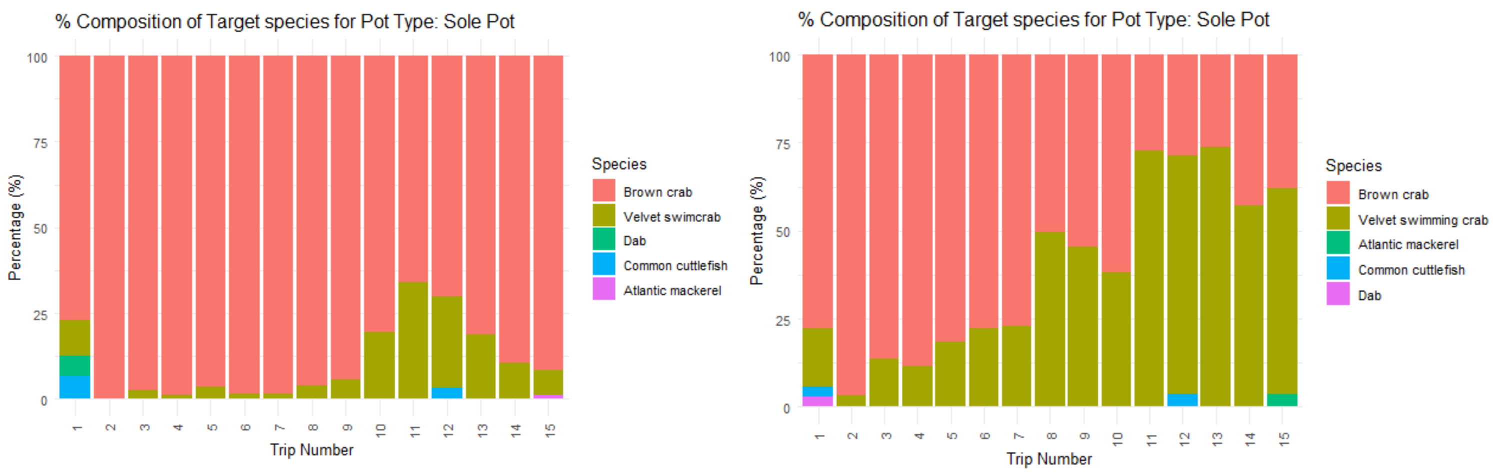


Figure 4.7 *– Catch composition per trip for commercially interesting species caught during sole pot fishing in the offshore wind farm (left panel composition distribution based on numbers, right panel composition distribution based on weight).*

4.4.3 Cuttlefish pot with fluorescent mesh

Catch composition

The catch composition per trip for the cuttlefish pot with fluorescent mesh is given in Figure 4.8 (in weight and numbers respectively). The most dominant species was brown crab in the beginning of the season (around 85% in numbers) and velvet swimming crab increasing with the season (to around 80% in numbers) towards the end of the experiment. The highest total catch of brown crab per trip was realized on 07/07/2023 after 9.1 days soaking time: 29 kg. The least total catch of brown crab was 4.5 kg on 25/08/2023 after 3 days soaking time. The highest total catch of velvet swimming crab was caught on 29/08/2023 after 4.9 days soaking time, and the least total catch was 0.04 kg on 20/06/2023 after 3.1 days soaking time. For common cuttlefish, 59 individuals were caught, spread over all the trips with total catch weights ranging from 0.25 kg per trip to 6.3 kg per trip. Common cuttlefish were also encountered as cuttlebones, especially after long(er) soaking times. No European squid was caught.

Other commercially interesting species that were caught were plaice and striped red mullet: both were caught in low quantities. A total of 0.06 kg of plaice and 0.02 kg of striped red mullet was caught in the experiment.

From the non-target species, the most encountered species in numbers was bib. Other non-target species encountered were great spider crab, blue-leg swimming crab, common swimming crab, bull-rout, common hermit crab and starfish (Appendix 4).

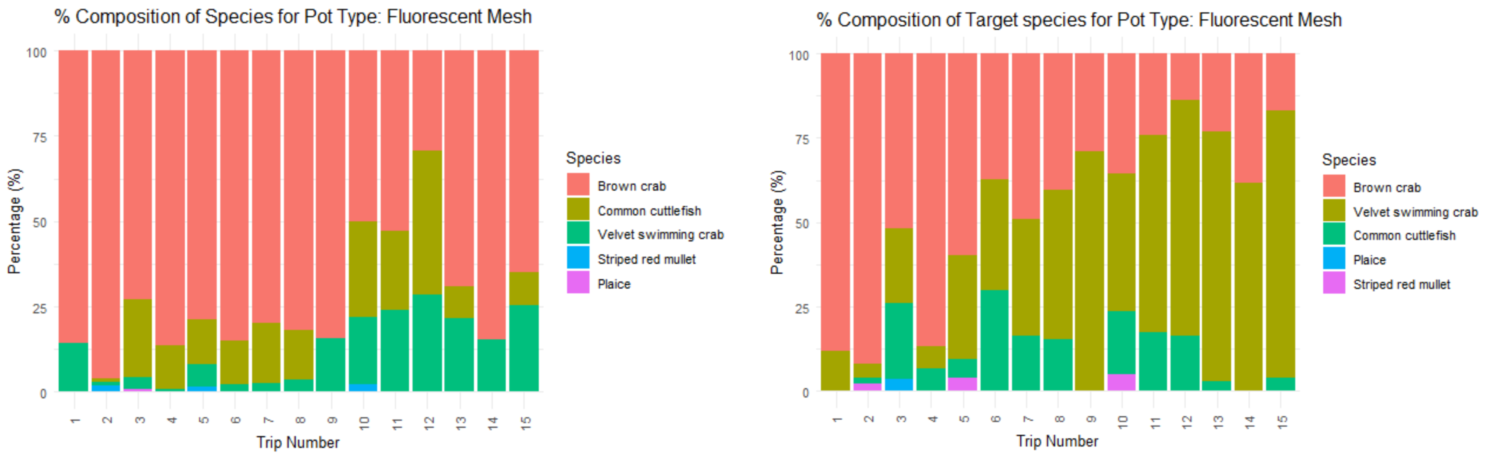


Figure 4.8 *– Catch composition per trip for commercially interesting species caught during cuttlefish with fluorescent mesh pot fishing in the offshore wind farm (left panel composition distribution based on numbers, right panel composition distribution based on weight).*

4.4.4 Cuttlefish pot with normal mesh

Catch composition

The catch composition per trip for the cuttlefish pot with normal mesh is shown in Figure 4.9 (in weight and numbers respectively). The most dominant species was brown crab in the beginning and end of the season (around 60-70% in numbers) and velvet swimming crab increasing in the middle of the season to around 65% (in numbers). The highest total catch of brown crab was caught on 07/07/2023 after 9.1 days soaking time: 22 kg (Table 4.4). The least total catch was 0.1 kg on 25/08/2023 after 3 days soaking time. The highest total catch of velvet swimming crab was caught on 23/08/2023 after 3 days soaking time. The least total catch was 0.04 kg on 20/06/2023 after 3.1 days soaking time. For common cuttlefish, 36 specimens were caught, spread over all the trips ranging from 0.2 kg per trip to 2 kg per trip. Common cuttlefish was also encountered as cuttlebones. No European squid was caught.

Other commercially interesting species were caught in low quantities. In total, 1.8 kg of plaice, 0.2 kg of dab, 0.2 kg of whiting and 0.04 kg of herring was caught during the whole experiment.

Non-target species encountered were bib, butterfish, herring, blue-leg swim crab, bull-rout, common swimming crab and starfish (Appendix 4).

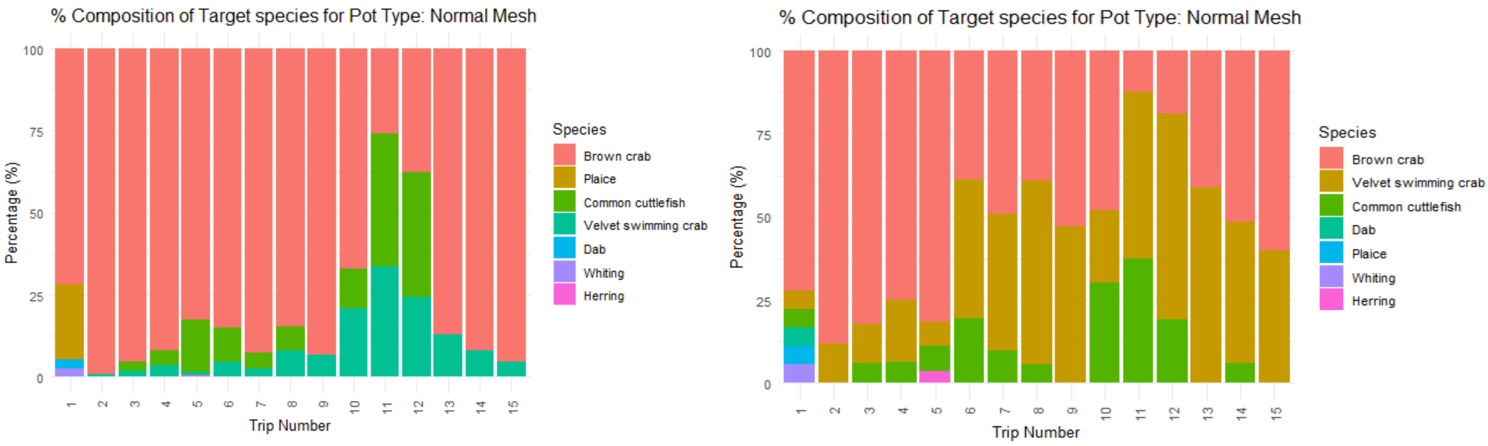


Figure 4.9 *– Catch composition per trip for commercially interesting species caught during cuttlefish with normal mesh pot fishing in the offshore wind farm (left panel composition distribution based on numbers, right panel composition distribution based on weight).*

4.4.5 Fish pot

Catch composition
The catch composition per trip for fish pots is given in Figure 4.10 (in weight and numbers respectively). Most dominant species the first trip was European squid. After this trip brown crab was caught in the beginning and end of the season (around 70% in numbers) and velvet swimming crab towards the end of the season to around 80% (in numbers). The highest total catch of brown crab was caught on 07/07/2023 after 9.1 days soaking time: 16.3 kg (Table 4.4). The least total catch was 7.8 kg on 21/08/2023 after 34 days soaking time. The highest total catch of velvet swimming crab (3.7 kg) was caught 21/08/2023 after 34 days soaking time. The least total catch was 0.2 kg on 12/06/2023 after 2 days soaking time. For common cuttlefish, 36 individuals were caught, spread over all the trips ranging from 0.2 kg per trip to 2 kg per trip. No primary target species, Atlantic cod or seabass was caught during the experiment.

Other commercially interesting species were caught in low quantities. In weight, between 0.2 to 2.6 kg of common cuttlefish were caught per trip, 0.1 kg of dab, 0.04 kg of whiting, 0.1 kg of horse mackerel and 0.03 kg of striped red mullet.

Bycatch of non-target species consisted of bib, butterfish, herring, four-bearded rockling, five-bearded rockling, spinous spider crab, long legged spider crab, arch-fronted swimming crab, great spider crab, blue-leg swimming crab, common jellyfish, bull-rout, common swimming crab, Norway lobster and starfish (Appendix 4).

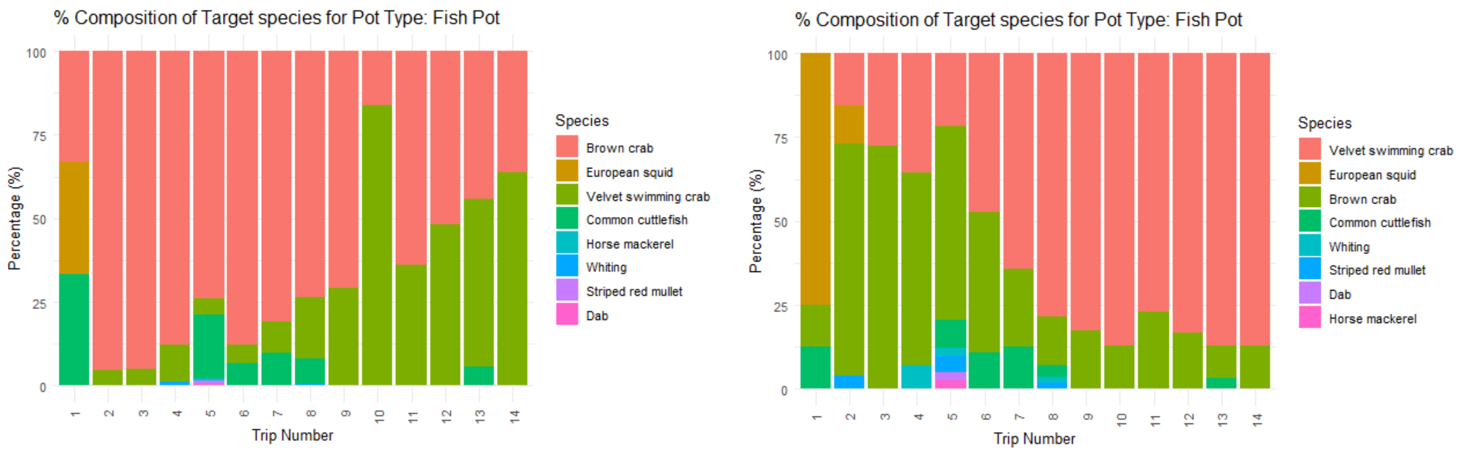


Figure 4.10 *– Catch composition per trip for commercially interesting species caught during fish pot fishing in the offshore wind farm (left panel composition distribution based on numbers, right panel composition distribution based on weight).*

4.4.6 Width and length composition of the catch

The width and length composition of brown crab are given in Figure 4.11 and for other commercially interesting species in Figure 4.12. Most brown crab were above minimum landing size of 13 cm and therefore landable. The maximum carapace width was 21 cm. Atlantic mackerel, plaice and whiting were all non-landable, as they were below MCRS (except one whiting). Herring was at MCRS length and horse mackerel was above MCRS.

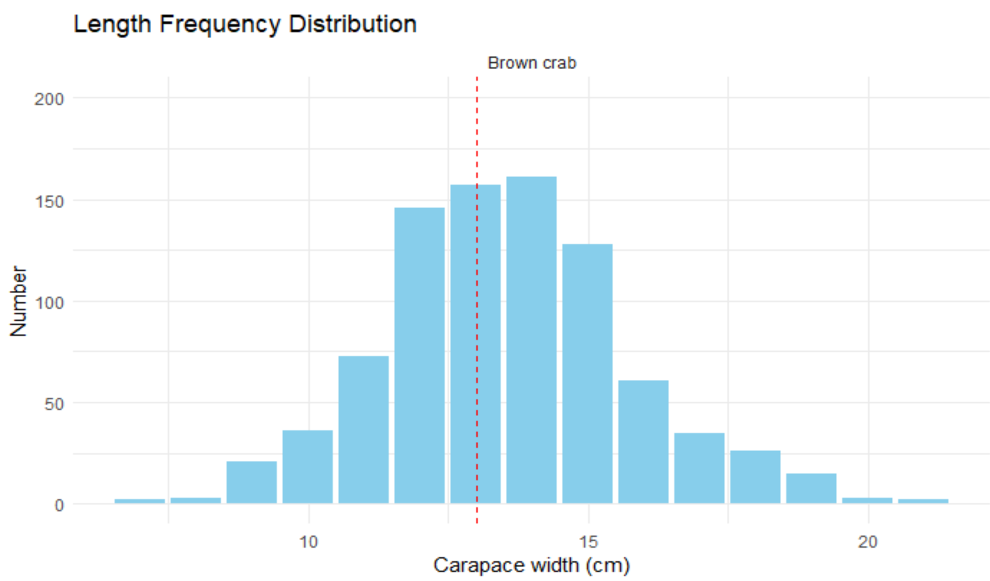


Figure 4.11 *– Length frequency of brown crab caught throughout the experiment. Dashed lines the minimum conservation reference size (MCRS) for the individual species. The length is measured as carapace width of brown crab.*

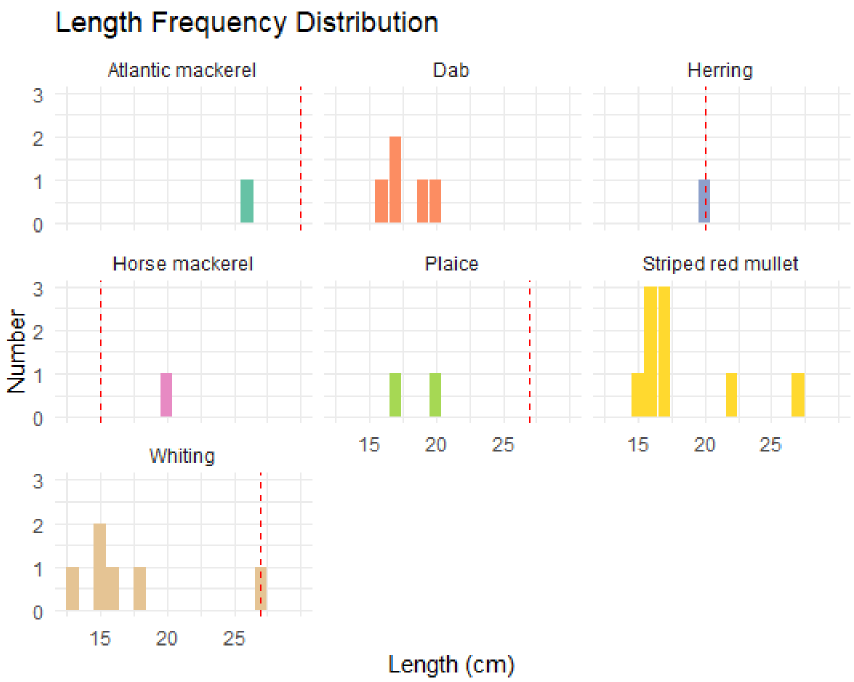


Figure 4.12 *– Length frequency of other commercially interesting species caught throughout the experiment. Dashed lines the minimum conservation reference size (MCRS) for the individual species. Dab and striped red mulled do not have a MCRS.*

4.4.7 Birds and sea mammals

During the days at sea while pot fishing, few birds or sea mammals were seen inside the wind farm. On 4 out of 17 days during pot fishing, seagulls were seen inside the wind farm, resulting in a total of 23 individual seagulls over the entire pot fishing experiment. The sightings were for all cases not related to the fishing activities. On one occasion, 5 to 10 seagulls were seen following the vessel while discarding fish outside of the wind farm. No other species of birds were seen during the pot fishing experiment. On one day in the wind farm, one grey seal was spotted by the crew. This sighting was not related to the fishing activity.

4.5 (Mechanical) jigging (LHM)

4.5.1 Fishing operations

A total of 10 fishing days were foreseen; all 10 days have been undertaken. This technique of fishing needed a flexible approach, depending on weather circumstances and tides, but taking into account ongoing traffic, deployed objects, other fishing gears present, or other ongoing experiments. Therefore, for this experiment, the blue and grey space between maintenance zones for both Borssele I and II (Figure 2.1) was used. Also, when fishing for European squid, reference grounds outside of the wind farm (in the English channel) have been used to see if the fishing gears would catch European squid on proven fishing grounds.

The first day of the field tests, the crew searched for indications of fish (schools of mackerel) on the echosounder inside both Borssele I and II offshore wind farm by sailing transects through the area. Once found, the gears were prepared and fishing operations started. The first day was mainly used to get to know the many different settings of the jigging machines and to try different types of hooks and settings in the field. After that, the storm picked up and adjustments to the gears and settings were made from the harbour of Vlissingen. When the conditions were improving the day after, crew went back to the wind farm where schools of mackerel were actively searched. As mackerel are known to be fast swimmers, they were hard to find and keep up with. A total of 4 days were used to fish for mackerel (June), all inside the wind farm. The other 6 days were spent fishing for European squid (October). Two days of the squid fishery were done inside the wind farm, the other four days were done in the English channel on fishing grounds where the fleet fishing for squid had the best results at that time. This was done to test the gear on proven fishing grounds, as all other aspects of the gear such as safety and operational characteristics were already tested thoroughly inside the wind farm. On fishing days in the English channel, crew tried different settings of the jigging machines and fished night and day to see if results were different under several circumstances. In addition, each day of the fishing operation outside the wind farm, reference hauls were performed using otter trawl (gear code OTB) to estimate how much European squid was present in the area, therefore giving an indication about the chances of actually catching European squid. When preparing reference hauls, the crew made sure jigging machines were immobilized. On these hauls, trawling time was standardized and the total catch of European squid was weighed. Also, about ten kilos of European squid was measured for their lengths and weights. From the gear specifications (width of the net opening, hauling speed and trawled distance) researchers could calculate how much European squid would be present per hectare.

4.5.2 Atlantic mackerel jigging

Table 4.5 *- Fishing effort, the total catch per (sub)target species, as well as important factors such as gear adjustments, relevant observations, weather circumstances and bird and sea mammal sightings for all Atlantic mackerel jigging trips.*

Date	Trip number	Fishing effort (hours)	Target species	Total catch of Atlantic mackerel (kg)	Gear Adjustments	Important weather conditions and other external observations	Birds and sea mammal sightings
1/8/23	1	5	Atlantic mackerel	34.5	Spent a lot of time trying the different programs of the machine, fishing on different depths and speeds. 5 jigging machines but one got stuck underneath the vessel, took out 1, continued with 4.	Sightings of mackerel on the echosounder, fish seem to be clustered in larger schools. Hard to keep up with the schools, catch comes in small batches.	No
3/8/23	2	5	Atlantic mackerel	0.3	Trial with inshore mackerel hooks; not strong enough so after testing switched back to super shad hooks. 4 jigging machines.	Schools seem very much scattered after the storm, only few individuals visible on echosounder. Very poor visibility.	No
4/8/23	3	15	Atlantic mackerel	9.6	1 jigging machine keeps giving error. 3 jigging machines.	Very poor visibility. When the sun is out, catch seem to improve but schools are still scattered.	No
5/8/23	4	5	Atlantic mackerel	10.9	3 jigging machines.	Small schools of mackerel are seen near the bottom, while in previous days they were still higher up in the water column.	No
19/10/23	5	5	Atlantic mackerel	5.5	4 jigging machines.	Very little to no sightings of mackerel on the echosounder.	No

The species caught in Borssele II offshore wind farm when jigging are Atlantic mackerel and whiting (Appendix 3 and Figure 4.13). Atlantic mackerel was considered a target species, while whiting was considered (sub)target species that may be commercially interesting when reaching minimum size. Table 4.5 also shows that catch was highly variable over time and between days.

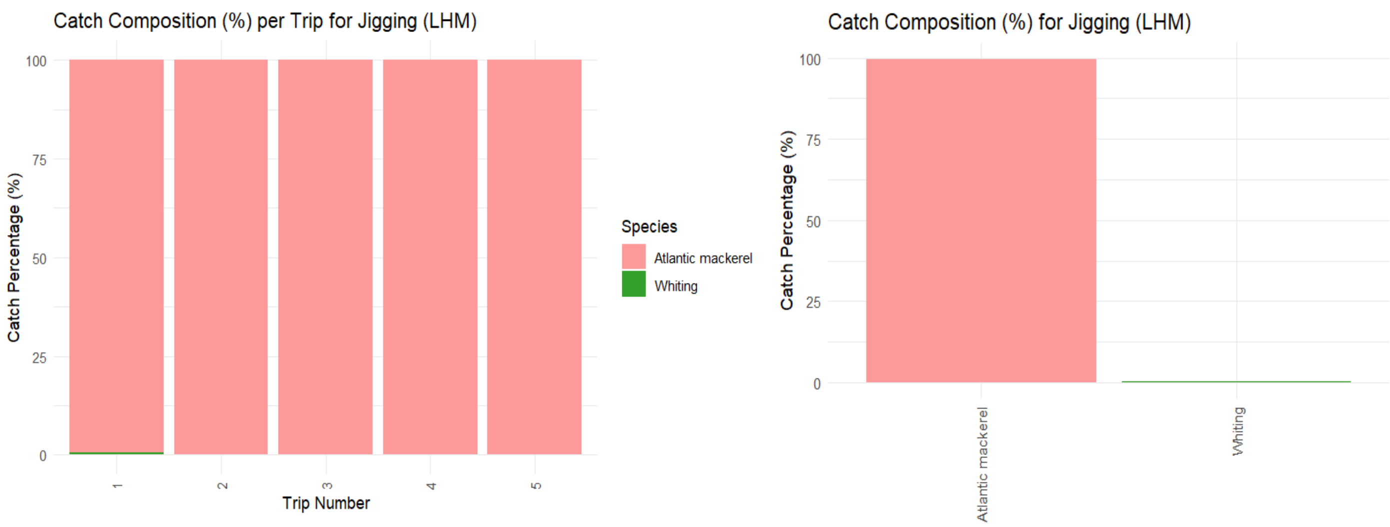


Figure 4.13 *– Catch composition per trip (left) and overall (right) for all species caught during handline fishing in the offshore wind farm.*

Figure 4.14 shows the overall catch distribution for (sub)target species for the landable catch (>MCRS) or non-landable catch (<MCRS).

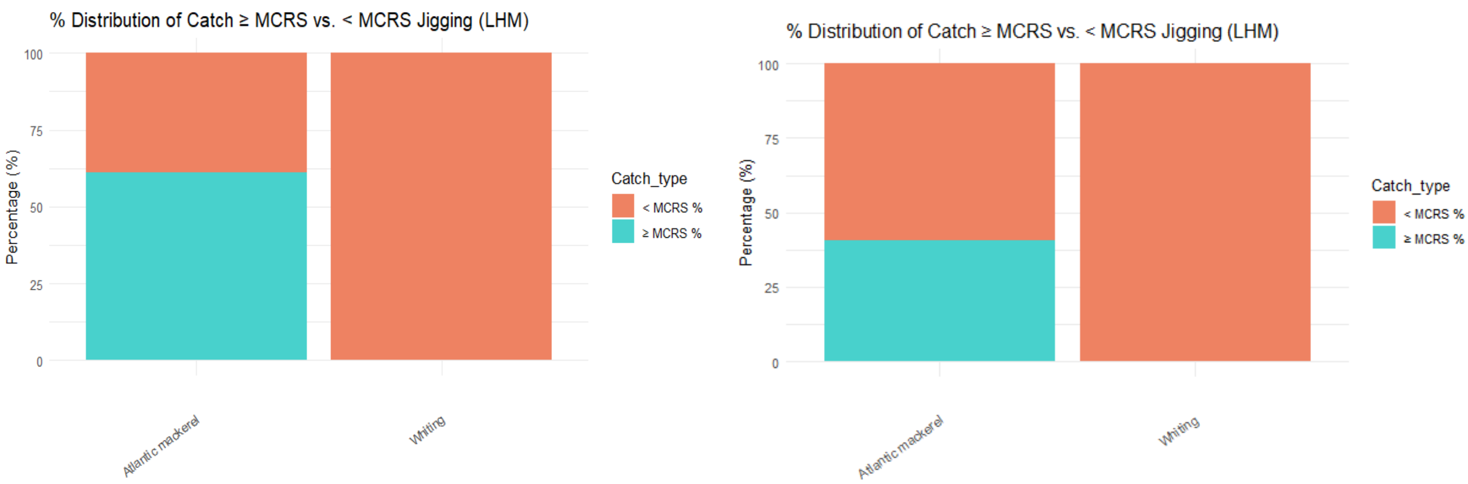


Figure 4.14 *– Catch distribution for (sub)target species in categories of landable (>MCRS) or non-landable (<MCRS) based on weights (left) and on numbers (right).*

It shows that for Atlantic mackerel, more than half of the total catch was above minimum size and therefore landable (in weight). For whiting, all catch was below minimum size and therefore non-landable.

Figure 4.15 shows the length frequency distribution for (sub)target species Atlantic mackerel and whiting caught during all the trips combined. The red dotted lines represent the minimum sizes for the species shown.

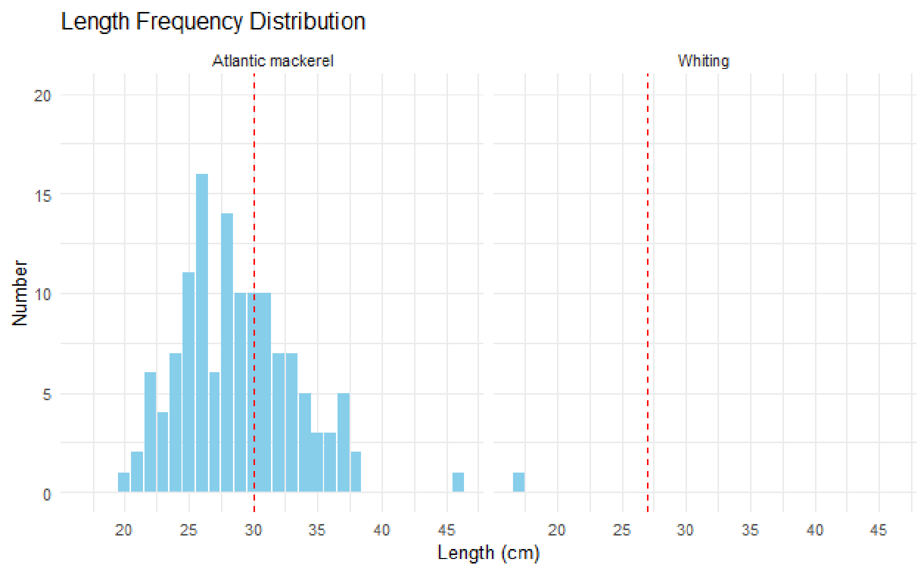


Figure 4.15 *– Length frequency distribution for both caught species in all Atlantic mackerel jigging trips combined.*

4.5.3 European squid fishing

When fishing with jigging machines for European squid, no species were caught (Table 4.6).

Table 4.6 *– Fishing effort, the total catch per (sub)target species, as well as important factors such as gear adjustments, relevant observations, weather circumstances and bird and sea mammal sightings for all European squid jigging trips.*

Date	Trip number	Fishing effort (hours)	Target species	Total catch of European squid (kg)	Gear Adjustments	Important weather conditions and other external observations	Birds and sea mammal sightings
17/10/23	1	6	European squid	0	4 jigging machines		No
18/10/23	2	2.5	European squid	0	4 jigging machines	Tested outside of the offshore wind farm	No
19/10/23	3	5	European squid	0	2 jigging machines	2 lines got stuck, continued with 2 jigging machines	No
22/10/23	4	6.15	European squid	0	2 jigging machines		No
23/10/23	5	5.25	European squid	0	2 jigging machines		No
24/10/23	6	2	European squid	0	2 jigging machines	Caught one European squid but it fell off the hook	No

No benthic species were caught when jigging for either Atlantic mackerel or European squid.

4.5.4 Reference hauls with otter trawl

As described in Chapter 4.5.1, reference hauls outside of the offshore wind farm were done using otter trawl to make an estimation on how much European squid would be present in areas where most catch of the commercial fleet was realized at that moment. Table 4.7 shows per reference haul the fishing effort, the total catch of European squid, the amount of European squid in the subsample used for length-frequency distributions, the variables used to calculate the density of European squid per hectare, as well as important factors such as weather circumstances and other external factors.

Table 4.7 *– Variables for reference hauls using otter trawl for European squid.*

Date	Reference haul number	Total catch of squid (kg)	Subsample of squid (kg)	Density of squid (kg per hectare)	Fishing effort (hours)	Net opening (m)	Speed (knots)	Weather conditions and other external factors
18/10/23	1	71	8.8	3.1	1	50	2.5	Net was tangled, did not fish well
18/10/23	2	79	10	1.7	1	83	3	
22/10/23	3	216	10.2	1.6	2	79	4.5	
22/10/23	4	41	10	0.6	1	85	4.2	
23/10/23	5	321	10	2.3	2.5	88	3.5	
24/10/23	6	210	10	0.9	3.5	90	4.0	

Table 4.7 shows that at the time of testing the jigging machines, density of European squid per hectare was quite low (ranging from 0.6 to 3.1kg per hectare). Therefore, the probability of catching European squid with jigging machines was also very low.

Figure 4.16 shows the length frequency distribution for European squid caught with otter trawl during the reference hauls combined.

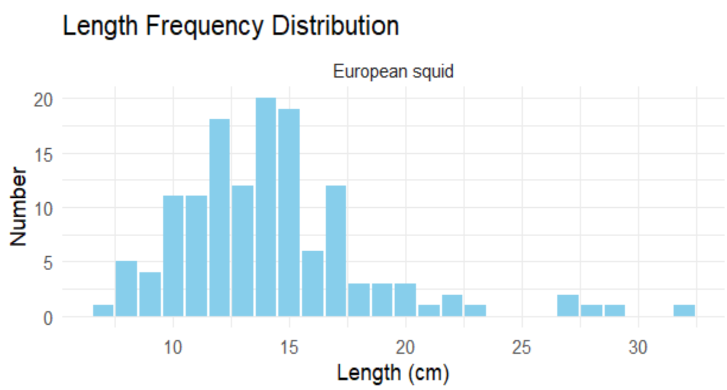


Figure 4.16 *– Length frequency distribution of European squid caught during reference hauls.*

From this figure it becomes clear that the European squid caught were small in size and very few bigger squid were caught.

4.5.5 Birds and sea mammals

During the days at sea using jigging machines, no birds or sea mammals were seen inside or outside the wind farm. During the reference hauls using otter trawl, between 50 to 100 gannets and seagulls were following the vessel, foraging on the catch that escaped from the net or was sticking out of the net when hauling.

5 Economy

The economic feasibility of fishing in an offshore wind farm depends on various factors, such as gear adaptations, sailing time, and the possibility to combine the activities in the wind farm with conventional practices outside. A complete overview of what is required to fish successfully commercially in a wind farm cannot yet be given due to the novelty of the playing field and consequent limited practical experience. This chapter elaborates on the initial indications from economic data and discusses possible developments that could improve the economic feasibility of fishing in wind farms. Thereby, we look further than the data collected during the experiments done in this study. Firstly, data on the specific costs for each vessel used in this study are provided. Second, the cost structure of two other types of vessels potentially suitable for fishing in a wind farm are described. Based on yield data of possible target species, catch rates required to cover costs of fishing in wind farms with these two vessel types are indicated.

5.1 General

5.1.1 Handline fishing KG 7

The handline fishing operation was conducted with a relatively small vessel, the KG 7 (Section 2.2.1). The vessel owners fish mainly with handline for seabass. During the project, it seemed that weather conditions play an important role in the conduct of fishing activities. As prescribed in Chapter 4.2, 10 fishing days were planned, but only 4 were undertaken. This resulted in little information on potential catches, sizes of the fish caught and market prices for the landed fresh fish. As there were almost no catches, no estimates of revenues were made. Research information is available about some of the costs incurred to complete the four trips made.

To complete the costs of fishing with the KG 7, estimates of investments in the vessel and engine, and in shore-based accessories such as transport equipment and a storage box, were made to calculate depreciation and interest on investments (see Table 5.1). The total investment for this specific fishing activity (handline) is estimated at over 135,000 euro. The vessel and engine will cost around 100,000 euro, a storage place for fishing gear, spare parts for the vessel and other materials is estimated at 10,000 euro and means of transport (a car or a van with capabilities to transport all supplies for fishing and also for transporting the crew to port and back home) is estimated at around 25,000 euro. Licenses, permits and fishing rights have been seen here as a pro memory investment.

Table 5.1 *– Vessel KG 7: Estimated investment and depreciation costs in first 5 years. Source: WEcR[6] and personal communication Strating.*

	Total investment	**Years**	**Depreciation costs per year**
Company assets:			
Vessel and engine	€ 100,000	20	€ 5,000
Cool boxes	€ 500	5	€ 100
Storage place/shed	€ 10,000	20	€ 500
Means of transport	€ 25,000	8	€ 3,125
Licenses	PM	PM	PM
Total costs and depreciation costs	**€ 135,500**		**€ 8,725**

Capital costs are calculated at a minimum of 2,466 euro a year, considering an interest rate of 3.5%, calculated on the average invested capital, licenses excluded (Table 5.2).

Table 5.2 *– Vessel KG 7: Capital costs in first 5 years. Source: WEcR and personal communication Strating.*

	Average invested capital	**Average capital costs per year**
Capital costs*	€ 70,464	€ 2,466

*3.5% on average invested capital (based on STECF's Annual Economic Report on the EU Fishing Fleet (2024) – Market Advisory Council (marketac.eu))

In Table 5.3 the number of trips during the project is given as well as fuel consumption and fuel costs per trip. A trip took on average around 11 hours of sailing, in and out of port. Per trip, the KG 7 covered a total of about 70 miles, requiring about 140 liters of fuel. The actual fuel (petrol) costs were 220 euro per trip.

Table 5.3 *– Vessel KG 7: Effort and fuel-consumption, costs and price per trip. Source: WEcR and personal communication Strating.*

trips to Borssele	4
Per trip, average	
Number of hours	11
Fuel consumption (ltr)	140
Fuel costs (in euro)	€ 220
Fuel price (in euro)*	€ 1.57

*Fuel price is Petrol

Table 5.4 shows the fixed costs per year and the variable costs per fishing trip. At a minimum, income from fishing should cover these costs. The calculations in the tables are based on consultation with the participating fisher and data from WEcR.

6 agrimatie.nl/SectorResultaat.aspx?subpubID=2232&sectorID=2860

Table 5.4 *– Vessel KG 7: Total fixed costs and variable costs per trip. Source: WEcR and personal communication Strating.*

Fixed costs	**Total per year**
Harbour	€ 1,000
Bait	€ 2,500
Fishing gear	€ 1,000
Instruments	€ 500
Assurance	€ 500
Maintenance	€ 2,000
Depreciation and capital	€11,191
Total fixed costs per year	**€ 18,691**
Variable costs	**Per trip**
Crew (2)	€ 380
Provisions	€ 20
Fuel	€ 220
Total variable costs per trip	**€ 620**

To cover the costs mentioned in Table 5.4, the minimum income per trip is given for various number of trips, and the resulting needed landings of fish (at different price levels) are given in Table 5.5.

Seasonal handline fishing in the North Sea is very weather dependent and fishers experience that on average about 50 trips can be made, while 80 trips per year can be considered the maximum for small vessels like vessel KG 7 (VIRIS, LNV and personal communication Strating). Making 50 trips a year, around 66 kg of fish (seabass) is needed at a market price of around 15 euro per kg to reach a value of landings of 994 euro per trip. The total cost and the total revenue per year and per vessel will both be about 50,000 euro (break-even). At 80 trips, the costs are about 850 euro per trip (854 euro) and break-even revenue will be reached when catching 56 kg per trip. The total cost and the total revenue per year and per vessel both will be about 68,000 euro (break-even).

With 50 trips a year, costs for wages and provisions (40%), depreciation and capital (23%) and fuel (22%) make up the bulk of costs (85%).

Average landings per fishing trip in the last few years are estimated at around 50 kg of seabass (personal communication Strating). Landings per fishing trip can vary enormously. Sometimes catches are up to 100 kg of seabass on one trip, while on other trips catches can be very low (near zero).

The two crew members spend more time per year than only the 50 or 80 trips of on average 11 hours a trip. Preparing fishing activities, like fixing gear and loading the vessel with supplies and after the fishing trip unloading the vessel, bunkering fuel, repairing and replacing parts and cleaning of the vessel are also activities done by the crew. Payment per fishing trip includes payment for this work.

Table 5.5 *– KG 7: Average volume of landings (kg) per trip needed to reach break-even for value of landings for a given number of trips and price of the target species. Source: WEcR and personal communication Strating.*

		Price per kg fish (seabass)					
		€ 10.00	€ 12.00	€ 14.00	€ 15.00	€ 16.00	€ 18.00
Number of trips	Value of landings						
5	€ 4,358	**436**	**363**	**311**	**291**	**272**	**242**
10	€ 2,489	**249**	**207**	**178**	**166**	**156**	**138**
15	€ 1,866	**187**	**156**	**133**	**124**	**117**	**104**
20	€ 1,555	**155**	**130**	**111**	**104**	**97**	**86**
25	€ 1,368	**137**	**114**	**98**	**91**	**85**	**76**
30	€ 1,243	**124**	**104**	**89**	**83**	**78**	**69**
35	€ 1,154	**115**	**96**	**82**	**77**	**72**	**64**
40	€ 1,087	**109**	**91**	**78**	**72**	**68**	**60**
45	€ 1,035	**104**	**86**	**74**	**69**	**65**	**58**
50	€ 994	**99**	**83**	**71**	**66**	**62**	**55**
55	€ 960	**96**	**80**	**69**	**64**	**60**	**53**
60	€ 932	**93**	**78**	**67**	**62**	**58**	**52**
65	€ 908	**91**	**76**	**65**	**61**	**57**	**50**
70	€ 887	**89**	**74**	**63**	**59**	**55**	**49**
75	€ 869	**87**	**72**	**62**	**58**	**54**	**48**
80	€ 854	**85**	**71**	**61**	**57**	**53**	**47**
85	€ 840	**84**	**70**	**60**	**56**	**52**	**47**
90	€ 828	**83**	**69**	**59**	**55**	**52**	**46**
95	€ 817	**82**	**68**	**58**	**54**	**51**	**45**
100	€ 807	**81**	**67**	**58**	**54**	**50**	**45**

5.1.2 Gillnet fishing YE 152

The gillnet fishing operation was also conducted with a relatively small vessel, the YE 152 (section 2.2.2). During the project, it appeared that weather conditions play an important role in the conduct of fishing activities. As prescribed in Chapter 4.3, a total of 16 fishing trips were foreseen and only 5 trips have been undertaken, including 3 trips with catches, due to unsuitable weather circumstances and switching fishing gears on the same vessel. This resulted in little information on potential catches, sizes of the fish caught and market prices for the landed fresh fish. As there were almost no catches, no estimates of revenues were made. Research information is only available about some of the costs incurred to complete the five trips made.

To complete the costs of fishing with the YE 152, estimates of investments in the vessel and engine, and in shore-based accessories such as transport equipment and a storage box, were made to calculate depreciation and interest on investments (see Table 5.6). The total amount of (initial) investment for this specific fishing activity (gillnet) is estimated at more than 244,000 euro. The vessel and engine will cost around 200,000 euro, a storage place for fishing gear, spare parts for the vessel and other materials is estimated at 10,000 euro and means of transport (a car or a van with capabilities to transport all supplies for fishing and also for transporting the crew to port and back home) is estimated at around 25,000 euro. Licenses, permits and fishing rights have been seen here as a pro memory investment. Total investment to start this fishing activity with a vessel like YE 152 amount at least 244,400 euro which shows a yearly depreciation of around 15,500 euro.

***Table 5.6 –** Vessel YE 152: Estimated investment and depreciation costs in first 5 years. Source: WEcR and personal communication Zoeteweij.*

	Total investment	**Years**	**Depreciation costs per year**
Company assets			
Vessel and engine, including refit	€ 200,000	20	€ 10,000
Haul machine	€ 5,000	5	€ 1,000
Gear and other	€ 3,900	5	€ 780
Cool boxes	€ 500	5	€ 100
Storage place/shed	€ 10,000	20	€ 500
Means of transport	€ 25,000	8	€ 3,125
Licenses and permits	PM	PM	PM
Total investment and depreciation costs	**€ 244,400**		**€ 15,505**

Capital costs are calculated at almost 4,400 euro a year, considering an interest rate of 3.5%, calculated on the average invested capital, licenses and permits excluded (Table 5.7).

***Table 5.7** – Vessel YE 152: Capital costs in first 5 years Source: WEcR and personal communication Zoeteweij.*

	Average invested capital	**Average capital costs per year**
Capital costs*	€ 125,537	€ 4,394

*3.5% on average invested capital (based on Economic Report Fisheries 2024)

In Table 5.8, an overview of the number of trips, effort at sea and average fuel consumption per trip is given. The trips took an average of 11 hours of sailing, in and out of port. Per trip, the YE 152 covered a total of about 70 miles which required about 110 litres of fuel. The actual fuel (diesel) costs were 88 euro per trip.

***Table 5.8** – Vessel YE 152: Effort and fuel-consumption, costs and price per trip. Source: WEcR and personal communication Zoeteweij*

Trips to Borssele	5
Per trip, average:	
Number of hours sailing	11
Fuel* consumption (ltr)	110
Fuel costs (in euro)	€ 88.00
Fuel price (in euro)	€ 0.80

*Fuel is Diesel

Table 5.9 shows the estimated fixed costs per year and the variable costs per trip. At a minimum, income from fishing should cover these costs. The calculations in the tables are based on consultation with the participating fisher and data from WEcR.

Table 5.9 *– Vessel YE 152: Fixed costs and variable costs. Source: WEcR and personal communication Zoeteweij.*

Fixed costs:	**Total per year**
Harbour	€ 1,000
Other	€ 5,000
Fishing gear	€ 20,000
Instruments	€ 1,000
Assurance	€ 1,000
Maintenance	€ 4,000
Depreciation and capital	€ 19,899
Total fixed costs per year	**€ 51,899**
Variable costs:	**Per trip**
Crew (2)	€ 570
Provisions	€ 30
Fuel	€ 88
Total variable costs per trip	**€ 688**

Table 5.10 shows the average volume of fish in kg, per trip, which is needed to reach a break-even situation given different numbers of fishing trips achieved and fish prices. For example, making 50 trips a year, 115 kg of fish (sole) per trip is needed at a market price of around 15 euro per kg to reach a value of landings of 1,726 euro which gives a break-even result.

Table 5.10 *– Vessel YE 152: Average volume of landings (kg) per trip needed to reach break-even for value of landings. Source: WEcR and personal communication Zoeteweij.*

		Price per kg fish (sole)							
		€ 10.00	€ 12.00	€ 14.00	€ 15.00	€ 16.00	€ 18.00	€ 20.00	€ 22.00
Number of trips	Value of landings								
5	€ 11,068	**1,107**	**922**	**791**	**738**	**692**	**615**	**553**	**503**
10	€ 5,878	**588**	**490**	**420**	**392**	**367**	**327**	**294**	**267**
15	€ 4,148	**415**	**346**	**296**	**277**	**259**	**230**	**207**	**189**
20	€ 3,283	**328**	**274**	**234**	**219**	**205**	**182**	**164**	**149**
25	€ 2,764	**276**	**230**	**197**	**184**	**173**	**154**	**138**	**126**
30	€ 2,418	**242**	**201**	**173**	**161**	**151**	**134**	**121**	**110**
35	€ 2,171	**217**	**181**	**155**	**145**	**136**	**121**	**109**	**99**
40	€ 1,985	**199**	**165**	**142**	**132**	**124**	**110**	**99**	**90**
45	€ 1,841	**184**	**153**	**132**	**123**	**115**	**102**	**92**	**84**
50	€ 1,726	**173**	**144**	**123**	**115**	**108**	**96**	**86**	**78**
55	€ 1,632	**163**	**136**	**117**	**109**	**102**	**91**	**82**	**74**
60	€ 1,553	**155**	**129**	**111**	**104**	**97**	**86**	**78**	**71**
65	€ 1,486	**149**	**124**	**106**	**99**	**93**	**83**	**74**	**68**
70	€ 1,429	**143**	**119**	**102**	**95**	**89**	**79**	**71**	**65**
75	€ 1,380	**138**	**115**	**99**	**92**	**86**	**77**	**69**	**63**
80	€ 1,337	**134**	**111**	**95**	**89**	**84**	**74**	**67**	**61**
85	€ 1,299	**130**	**108**	**93**	**87**	**81**	**72**	**65**	**59**
90	€ 1,265	**126**	**105**	**90**	**84**	**79**	**70**	**63**	**57**
95	€ 1,234	**123**	**103**	**88**	**82**	**77**	**69**	**62**	**56**
100	€ 1,207	**121**	**101**	**86**	**80**	**75**	**67**	**60**	**55**

Seasonal gillnet fishing in the North Sea is very weather dependent and fishers experience that about 100 trips per year can be made as a maximum (inside or outside a wind farm). A fisher can deploy 10 to max 25 km gillnets per fishing trip. Landings per fishing trip vary a lot. Sometimes more than 100 kg of sole is caught on one trip, depending also on the number of nets set, while on other trips catches can be very low (near zero or a few kilogrammes). Total costs per year and per vessel will be around 120,000 euro at the maximum of 100 trips per year. With this number of trips, costs for wages and provisions (48%), depreciation and capital (17%) and fishing gear (17%) make up the bulk of costs (82%).

Wages per crew member have been fixed here at 190 euro per trip on average. In this case, gill net fishing for sole with 3 crew members and making 100 trips per year (as a maximum), a crew member can earn around 19.000 euro per year. Crew members spend more time per year than only the 100 trips of on average 11 hours per trip. Preparing fishing activities, like fixing gear and loading the vessel with supplies and after the fishing trip unloading the vessel, bunkering fuel, repairing and replacing parts and cleaning the vessel are also activities done by the crew. Payment per fishing trips includes payment for this work. Extra salary is needed to meet a modal income.

5.1.3 Multi-species pots YE 152

The field experiments for both gillnet fishing and multi-species pots fishing were done onboard YE 152. 16 trips were foreseen; 17 trips were undertaken. An additional trip was made to haul 3 strings from the seabed using a small dredge, of which dahns became loose in a storm (par.4.4.1). As earnings were very low, no estimates of the value of landings were made. The costs of the vessel, YE 152, are described in 5.2.2. Cuttlefish pots were borrowed from the Flanders Research Institute for Agriculture, Fisheries and Food. Sole pots were made by the fishers themselves. Only the fish pot was an existing pot. Average costs of these fishing pots could not be determined.

5.1.4 (Mechanical) jigging MDV 2

The field experiments for jigging were done onboard MDV 2, a large vessel (30.15 m) compared to the other vessels involved in this project (Section 2.2.3). A total of 10 fishing days were foreseen; all 10 days have been undertaken. As there were almost no earnings, no estimates of value of landings were made. Limited data is available about costs incurred to complete the 10 days made.

Estimates of investments in vessel and engine, fishing gear and in shore-based accessories such as transport equipment and a storage box, were made to calculate depreciation and interest on investments (see Table 5.11). The total amount of (initial) investment for this specific fishing activity (jigging) with this vessel is estimated at almost 5 million Euro, based on the actual depreciation costs of the vessel involved. The vessel and engine cost around 4.8 million Euro. In contrast to the depreciation period of 20 years applied to the vessels KG 7 and YE 152, a depreciation period of 15 years has been applied for the MDV 2. This is due to current requirements from financial institutions that facilitate financing of new fishing vessel constructions like MDV 2.

A storage place for fishing gear, spare parts for the vessel and other materials is estimated at 40,000 euro and means of transport (a car or a van with capabilities to transport all supplies for fishing and also for transporting the crew to port and back home) is estimated at around 25,000 euro. Licenses, permits and fishing rights have been seen here as a pro memory investment. Depreciation on investments is around 335,800 euro per year.

Table 5.11 *– Vessel MDV 2: Estimated investment and depreciation costs in first 5 years. Source: WEcR and personal communication Kramer.*

	Investment	**Years**	**Depreciation costs**
	Total		Per year
Company assets:			
Vessel and engine, complete	€ 4,800,000	15	€ 320,000
Jiggers	€ 53,501	5	€ 10,700
Storage place/shed	€ 40,000	20	€ 2,000
Means of transport	€ 25,000	8	€ 3,125
Licenses and permits	PM	PM	PM
Total (depreciation) costs assets	**€ 4,918,501**		**€ 335,825**

Capital costs are calculated at 86,500 euro a year, considering an interest rate of 3.5%, calculated on the average invested capital, licenses and permits excluded (Table 5.12).

Table 5.12 *– Vessel MDV 2: Capital costs in first 5 years. Source: WEcR and personal communication Kramer.*

	Average invested capital	**Average capital costs per year**
Capital costs*	€ 2,472,501	€ 86,538

*3.5% on average invested capital (based on Economic Report Fisheries 2024)

In this project 10 days at sea have been undertaken. In Table 5.13 an overview of the effort at sea and average fuel consumption per day at sea is given. The days at sea took 24 hours. A total of around 70 miles were covered which required about 1,750 litres of fuel per day. The actual fuel (diesel) costs were around 1,400 euro per day at sea.

Table 5.13 *– Vessel MDV 2 – Effort and fuel-consumption, costs and price per trip. Source: WEcR and personal communication Kramer.*

Days at sea	10
Per day at sea, average:	
Number of hours	24
Fuel consumption (ltr)	1,750
Fuel costs (in euro)	€ 1,400
Fuel price (in euro) *)	€ 0.80

*Fuel is Diesel

Table 5.14 shows the estimated fixed costs per year and the variable costs per day at sea. At a minimum, income from fishing should cover these costs. The calculations in the tables are based on consultation with the participating fisher and data from WEcR.

Table 5.14 *– Vessel MDV 2 – Total fixed costs and variable costs per day at sea. Source: WEcR and personal communication Kramer.*

Fixed costs:	**Total per year**
Harbour	€ 20,000
Other	€ 40,000
Fishing gear (other than Jig)	€ 5,000
Instruments	€ 6,000
Assurance	€ 25,000
Maintenance	€ 80,000
Depreciation and capital	€ 422,363
Total fixed costs per year	**€ 598,363**
Variable costs:	Per trip
Crew (5)	€ 1,500
Provisions	€ 50
Fuel	€ 1,400
Total variable costs per trip	**€ 2,950**

In Table 5.15 the costs per day at sea are based on 200 trips per year. At an average price for mackerel of 2.50 euro per kg and an average landing volume of 2,400 kg per day, assuming 200 days at sea per year, the value of landings will be enough to cover the costs. The total costs per day at sea (200 days per year) are estimated at about 6,000 euro. Landings per day at sea and per trip can vary a lot during the year and in the season. In practice it is very unlikely a vessel as the MDV 2 fishes year-round on one single species like mackerel. The given amount of mackerel per fishing day is an indication for the required catch per day. This type of vessel can only be explored if it's used year-round. Jig fishing on mackerel is seasonal. During the rest of the year, similar yields per trip will have to be obtained with other gears.

Costs for wages and provisions (25%), depreciation and capital (36%) and fuel (23%) make up the bulk of the costs (84%).

Table 5.15 *– Vessel MDV 2: Average volume of landings (kg) per trip needed to reach break-even for value of landings. Source: WEcR and personal communication Kramer.*

		Price per kg fish (mackerel)						
		€ 2.00	€ 2.25	€ 2.50	€ 2.75	€ 3.00	€ 3.25	€ 3.50
Days at sea	Value of landings							
200	€ 5,942	**2,971**	**2,641**	**2,377**	**2,161**	**1,981**	**1,828**	**1,698**

Wages for the total crew are fixed at around 1,500 euro per day at sea. As there are five crew members, wages per crew member are 300 euro per day at sea. Considering the feasibility of 200 days at sea per year, wages will be around 60,000 euro per crew member per year. To have a complete overview over working hours, also in this case the time that crew spends with fishing activities (say 200 days on average and 24 hours a day), they also spend time on shore to prepare for going out fishing (producing nets, repair the nets, loading the vessel with supplies etc.). And after a fishing trip, the crew spend time finishing their fishery activity (including handling and storing the fish). They unload and load the vessel (the catch, the nets and other accessories), bunker fuel, repair, maintain or replace instruments, clean the vessel etc. and prepare it for fishing again next time. This labor of crew is not extra paid since there are no direct revenues related to this labor.

5.2 Opportunities for part of the current Dutch fleet?

The vessels used in this experimental study were initially selected based on their availability, fishers' interest and suitability for applying certain gears. However, no standard is yet present for the optimal vessel suitable for fishing operations in wind farms. The possibility of converting current Dutch vessels into suitable vessels for fishing in wind farms is explored, in coordination with the focus group. After first shortly elaborating the current Dutch fleet (size, target species), the current costs and revenues of two types of vessels that could potentially be applied for fishing in an offshore wind farm are explored. This is based on publicly available data.

5.2.1 Current Dutch fleet

The number of vessels is shown in Table 5.16. Shellfish fishery and culture are not included. In 2022 the total number of active vessels was 499. 46% of the active fleet were small-scale fisheries vessels, 52%were cutters and 2% were pelagic trawlers.

Table 5.16 *– Dutch sea fishery fleet, number of active vessels. Source: Agrimatie Visserij, WEcR and Viris, LNV.*

Year	**2022**	**2023***
Number of vessels:		
Pelagic	8	8
Cutter	261	210
Small scale	230	231
Total	499	449

*Provisional figures

Total amount of landed fish and shrimp in 2022 was 274 million kg. The pelagic fleet landed 225 million kg of fish and the cutter fleet 48 million kg. The small-scale fleet landed just 1 million kg (see Table 5.17). Beside volume of landings, also the value of landings is shown in that table. The landings of the small-scale fleet in 2022 were around 0,4% of total value of landings (Agrimatie.nl). The pelagic fleet landed more than 80% of total volume of landings of the Dutch fleet. Those 8 vessels are not suitable for co-use of offshore wind farms.

Table 5.17 *– Dutch sea fishery fleet, landings of fish and shrimp in 2022. Source: Agrimatie Visserij, WEcR and Viris, LNV.*

Year	**2022**	**2022**
	Volume of landings (mln kg)	Value landings (mln euro)
Pelagic	225	104
Cutter	48	247
Small scale	1	6
Total	**274**	**357**

The most important fish landed by Dutch cutters are flatfish species like sole, plaice and turbot. Coastal fishing cutters target mainly shrimp and a specific part of the cutter fleet targets squid and mullet. In Table 5.18 an overview is given of the most important species landed, the value of those landings and the prices of the fish in 2022.

Table 5.18 *– Dutch cutterfleet 2022 landings, value and prices. Source: Agrimatie Visserij, WEcR and Viris, LNV.*

	Volume of landings (kg)	**Value of landings (euro)**	**Price (euro/kg)**
Species			
Shrimp	16,091,796	€ 80,348,091	€ 4.99
Plaice	11,176,046	€ 31,881,005	€ 2.85
Sole	4,247,214	€ 65,088,319	€ 15.32
Squid	1,578,946	€ 13,694,753	€ 8.67
Mackerel	1,016,547	€ 2,025,997	€ 1.99
Crab	263,098	€ 776,053	€ 2.95
Seabass	75,309	€ 962,723	€ 12.78
Other	13,367,522	€ 51,474,447	€ 3.85
Total	**47,741,169**	**€ 245,288,665**	**€ 5.14**

Most of the vessels belonging to the small-scale fisheries, have a size between 7 and 12 meters, and are active in seasons when fish is locally there in coastal areas. Only if weather conditions are good for safe fishing, these vessels go out at sea. Total value of landings of this fleet in 2022 reached 5,5 million euro. This is 2,3% compared to value of landings of the cutter fleet. In Table 5.19, a specification is given of the most important species landed by these vessels and the revenues as well as average prices for fish. Seabass is with 36% of the total revenues, the most important species for the small-scale fishing fleet.

Table 5.19 *– Small scale fishing fleet, active vessels, 2022. Source: Agrimatie Visserij, WEcR and Viris, LNV.*

	Landings (kg)	**Revenues (euro)**	**Price (euro/kg)**
Seabass	151,766	€ 2,026,025	€ 13.35
Sole	47,263	€ 740,219	€ 15.66
Mullet	73,894	€ 323,164	€ 4.37
Shrimp	41,915	€ 196,817	€ 4.70
Other	824,133	€ 2,267,029	€ 2.75
Total	**1,138,970**	**€ 5,553,253**	**€ 4.88**

Note: Shellfish is excluded

5.2.2 Criteria for fishing in an offshore wind farm

Most Dutch active fishing vessels are cutters. Most cutters meet the maximum size criterion of 45 meters to enter an offshore wind farm. However, most cutters fish with bottom trawls. As only passive gear is allowed in offshore wind farms, they would have to be converted to passive gear. The active small-scale fishing fleet could also fish in an offshore wind farm, predetermined the vessel can safely navigate to and from the wind farm and operate in a wind farm under the then prevailing weather conditions.

Compared to active gear, fishing with passive gear generally entail lower costs, but also lower revenues. In general, the catches per fishing day are lower while costs to sustain fishing activities (active use of nets) is lower. Nonetheless, sailing back and forth to the wind farm could take a lot of time and relatively large amounts of fuel, compared to catches and fishing time available.

In any case, all fishers have financial investments such as vessel (maintenance), licenses, fishing quotas, (multiple), fishing gear, and land-based assets (storage box and (transporter)van; these must be covered by revenues.

Lastly, the way the current fleet fishes differ from potential fishing in an offshore wind farm in their spatial behavior. In a wind farm more consideration must be given to turbines, cables, presence of maintenance vessels and agreements on where gear is placed. In general fishing vessels depend on good weather conditions to fish, especially smaller sized vessels.

5.2.3 Possible suitable Dutch vessels and costs

To explore the possibilities of enabling passive fishing in wind farms by the current fleet, the shrimp fishery is elaborated on. Due to regulatory restrictions regarding nitrogen impacts, as well as declining catch rates in 2023, several Dutch shrimp fishers are looking for alternative ways to deploy their fishing vessel. As these types of vessels have more work and storage space on deck than smaller vessels, are navigable but stable enough in slightly more turbulent weather, they could be suitable to be used for passive fishing in offshore wind farms.

The Dutch shrimp fleet can be divided into two types of vessels:

- length over all of less than 20 meters and an average engine power of 231 hp and
- length over all of less than 24 meters with an average engine power of 300 hp

An average cost structure of these two vessel types in the Dutch shrimp fleet was calculated, which can provide an indication of the required revenues to cover at least the cost per fishing day, including the labor of the crew and the (on board) vessel owner. It is a rough initial estimate of costs, as no costs have been calculated for vessel and gear modifications. The current costs of both vessels are the basis for calculating the cost per fishing day.

Type 1 vessel
The average characteristics of the Type 1 vessel are shown in Table 5.20. On average, this vessel spends 92 days at sea per year. The rest of the time is spent on gear and vessel maintenance and other work ashore. Usually, a day at sea results in a day of work ashore. The average gas oil consumption is 280 liters per day at sea.

Table 5.20 *- Characteristics of shrimp vessel with engine capacity of 231 hp and Loa of <20 meters, year 2021. Source: BedrijvenInformatieNet, WEcR.*

	Per year	**Per day at sea**
Engine power (hp)	231	
Age of engine (years)	16	
Hull capacity (GT)	36	
Age of hull (years)	63	
Number of days at sea	92	
Average crew	2	
Litres of gas oil	25.752	280

The costs per year and per day at sea of this type of vessel are in Table 5.21. Sailing and fishing with this vessel with two adult crew members costs 2,122 euro per fishing day. These costs should be covered by revenues from catches. When the costs and revenues are at break-even point, no surplus is left. Sailing and fishing with this vessel costs a bit more than 2,122 euro per fishing day.

Table 5.21 *- Costs per year and per day at sea of Vessel 1, year 2021. Source: BedrijvenInformatieNet, WEcR.*

Costs	**Per year**	**Per day at sea**
Gas oil	€ 12.540	€ 136
Lubricating oil	€ 267	€ 3
Deck requirements	€ 3.058	€ 33
Navigation + fish detection	€ 4.409	€ 48
Hull maintenance	€ 18.771	€ 204
Engine maintenance	€ 10.014	€ 109
Insurance	€ 5.285	€ 57
Gear maintenance	€ 2.410	€ 26
Ice & cooling	€ 857	€ 9
Provisions	€ 1.282	€ 14
Travel allowance crew	€ 4.051	€ 44
Social benefits	€ 5.156	€ 56
General	€ 16.201	€ 176
Producer organisation levy	€ 612	€ 7
Auction rights	€ 893	€ 10
Sorting and unloading	€ 2.093	€ 23
Cargo	€ 36	€ 0
Conserving fish/materials	€ 5.800	€ 63
Salt and plastic bags	€ 503	€ 5
Sub total costs	*€ 94.238*	*€ 1.024*
Share crew + skipper	€ 91.338	€ 993
Depreciation hull + engine	€ 8.536	€ 93
Interest	€ 1.088	€ 12
Total costs	**€195.200**	**€ 2.122**
Share adult crew member	€ 45.669	€ 496

Type 2 vessel

The average characteristics of this type of vessel are shown in Table 5.22. On average, the vessel spends 123 days at sea per year. The rest of the time is spent on gear and vessel maintenance and other work ashore. The average gas oil consumption is 519 liters per day at sea.

Table 5.22 *- Characteristics of shrimp vessel with engine capacity of 300 hp and Loa of <24 meters, year 2021. Source: BedrijvenInformatieNet, WEcR.*

	Per year	**Per day at sea**
Engine power (hp)	300	
Age of engine (years)	11	
Hull capacity (GT)	67	
Age of hull (years)	42	
Number of days at sea	123	
Average crew	3	
Litres of gas oil	63.802	519

The costs per year and per day at sea of this type of vessel are shown in Table 5.23. The costs and revenues for this vessel are at break-even point. Everything and everyone are paid, but no extra surplus is left. Sailing and fishing with this vessel with three adult crew members costs 2,771 euro per fishing day.

Table 5.23 *- Costs and revenues per year and per day at sea of Vessel 2 , year 2021. Source: BedrijvenInformatieNet (BIN) WEcR.*

Costs	**Per year**	**Per day at sea**
Gas oil	€ 30.591	€ 249
Lubricating oil	€ 839	€ 7
Deck requirements	€ 5.698	€ 46
Navigation + fish detection	€ 4.930	€ 40
Hull maintenance	€ 28.407	€ 231
Engine maintenance	€ 9.201	€ 75
Insurance	€ 9.764	€ 79
Gear maintenance	€ 9.714	€ 79
Ice & cooling	€ 1.496	€ 12
Provisions	€ 1.944	€ 16
Travel allowance crew	€ 3.121	€ 25
Social benefits	€ 8.294	€ 67
Wages for small maintenance	€ 1.391	€ 11
General	€ 20.460	€ 166
Producer organisation levy	€ 1.708	€ 14
Auction rights	€ 1.151	€ 9
Sorting and unloading	€ 3.117	€ 25
Cargo	€ 562	€ 5
Conserving fish/materials	€ 7.908	€ 64
Salt and plastic bags	€ 229	€ 2
Subtotal costs	**€ 150.525**	**€ 1.224**
Share crew + skipper	€ 153.237	€ 1.246
Depreciation hull + engine	€ 33.314	€ 271
Interest	€ 3.723	€ 30
Total costs	**€ 340.799**	**€ 2.771**
Part adult crew	€ 51.079	€ 415

These two types of fishing vessels were discussed with the focus group. The presented costs for these two vessels will differ if they fish in a wind farm depending on the selected gear and species caught. In discussion with the focus group, however, it was confirmed that the presented costs were recognizable and give a very good overview of what the value of landings per vessel should be.

5.2.4 Required revenue to cover the costs

The catches per day at sea in Table 5.24 give an idea of magnitude of catches needed to cover the costs for both vessels presented above. These costs are related to the costs of the two shrimp vessels, which were around 2,100 and 2,800 respectively per day at sea. As for the target species and price levels of 2022, to meet these costs, the following catches per fishing day must be realized. The catch per day at sea for vessel 1 should be around either 166 kg of seabass, 139 kg of sole, 245 kg of squid, 1,067 kg of mackerel or 720 kg of Brown crab.

Table 5.24 *Catches required (in kg per day at sea) to cover the costs. Prices are at the level of 2022. Source: BedrijvenInformatieNet (BIN) WEcR.*

	Price per kg	**Vessel 1 (kg per day at sea)**	**Vessel 2 (kg per day at sea)**
Seabass	€ 12.78	166	217
Sole	€ 15.32	139	181
Squid	€ 8.67	245	320
Atlantic Mackerel	€ 1.99	1,067	1,394
Brown Crab	€ 2.95	720	940

6 Discussion

6.1 Environmental factors

From communication with the fisheries sector, commercial fleet and from experiences in the field, it became clear that the 2023 season was different compared to other years in terms of peak seasons of the target species. The peak season started later than it normally does, making the initial timeline for these field experiments perhaps not optimal. Evaluation of wave conditions in Borssele 2023 and long term statistics show indeed more severe wave conditions in the spring and summer of 2023 than in average years, which is in-line with the experience of the fishers. However, the difference between 2023 and average years is not very large. During the experimental tests in the field, bad weather hampered testing in certain (peak) seasons and caused longer soaking times than preferred, resulting in catches being eaten or testing during the wrong seasons. One should take into account the limited workability of small fishing vessels in offshore wind farm in the outlooks for passive fishing within wind farms.

6.2 Operational and safety

Experimental fishing activities currently require consultation and coordination with the wind farm operator who takes a great deal of responsibility for the activities within the wind farm area. The government is, however, the competent authority regarding the implementation of the Water Act (recently included under Environment and Planning Act) and thus the authority for the safety zone for the offshore wind farms and the permits for co-use. Because commercial fishing is currently not allowed within the wind farms, it is important to regulate such activities in the future so that all parties involved have a clear framework.

The following knowledge gaps are identified and need to be addressed:

- Anchoring of gears, co-use structures and vessels, in areas for co-use, outside the maintenance zones of the wind turbines and cables, need to be clarified and regulated.
- In case of loss of gear, fishers are responsible for locating and retrieving gear. During the present experiments loss of dahns did occur and the gear was retrieved from the seabed with a dredge anchor, see Appendix 5. In these cases, the missing strings had not moved and remained at the installed location. However, it is imaginable that a string could move from the passive fishing zone and end up within the 250m maintenance zone around the in-field cables and wind turbines. It is advisable to use a risk assessment to determine how and by who the search should be conducted in such a case and how the equipment shall be recovered. In order to be able to act adequately in such a case, it is advisable to carry out this evaluation prior to further rollout of passive fishing within the wind farm and to include actions in the action plan.
- Re-evaluation of the 250 meters maintenance zone. From the undertaken risk analysis on passive fishing in offshore wind farms this distance seems excessive. Furthermore, it limits the business case of the fishers. Fishers ideally would like to fish directly next to the turbine. It is recommended to perform further risk assessment for reduction of the maintenance zone.

6.3 Catch and bycatch

6.3.1 Handline fishing

The experimental field testing with handlines in offshore wind farm Borssele gave a first impression about the species that can be caught, although data is very limited for this study. No target species, seabass or Atlantic cod, were caught. Bycatch consisted mainly of Atlantic mackerel, horse mackerel and whiting. Catch seemed to improve when fishing closer to a wreckage rather than a sandy bottom, regardless of depth, as hard substrates often provide shelter and opportunities to forage. Nevertheless, catches didn't meet commercial volumes. Fish can either be locally growing and procuring or been attracted for e.g. shelter (Mavraki et al., 2020, 2021, DeGraer et al., 2020, Berges et al., 2024)). Field tests in previous studies involving fishing with handlines for tagging of Atlantic cod in Borssele II offshore wind farm and Belwind (Belgium) show that both seabass and Atlantic cod were present inside both wind farms, but only on hard substrates like (artificial) reefs and next to the wind turbines (van der Knaap et al. 2021; Berges et al. 2024). Those areas could not be fished in this experiment. Also, reference catches by both the research crew and commercial fishers outside of the offshore wind farm show that seabass was present at the time of testing.

6.3.2 Gillnet fishing

During the experimental field tests with gillnets, the primary target species, sole, was caught but catch highly dependent on different factors. For example, when algal blooms were present, sole could escape more easily from the meshes of the net and when hauling, sole were falling out of the net. This was not the case when algal blooms had disappeared. In the other two trips, sole catches per km gillnet were equal or even higher than catches per km gillnet of commercial fishers outside of the offshore wind farm. The total catch was too low to cover costs. However, one must take into account only three trips were made and the amount and composition of the catch could be due to many factors. More repetition of trips in the peak season for sole would produce more reliable data on catch potential and bycatch composition.

In general, the bycatch of various forms of gillnet fishing includes undersized target species, other fish species, elasmobranchs, birds, local fish species, crustaceans, and marine mammals (Shester & Micheli, 2011; Lewison et al., 2014; Petetta et al., 2020). Van Marlen et al. (2011) observed primarily bycatch of undersized fish and benthos in gillnet fishing in the North Sea. In this experiment two species of elasmobranchs were caught: starry smoothhound and lesser spotted dogfish. In general, much of the starry smoothhound landed is caught as bycatch in trawl and gillnet fisheries and is used for human consumption. Although many fishers will discard starry smoothhounds depending on market demand, they can also be sold as bait for pot fisheries, particularly whelk fisheries (ICES,2017, Small, 2021a), and potentially as long term bait for brown crab (personal communication S. Tijsen). Starry smoothhound is known for having a winter - summer migration from the English Channel to the Southern North Sea (Brevé et al., 2016). The starting point of the migration is when the water temperature is above 13^{0}C and the starry smoothhound arrives at the Borssele II region between April and June (Brevé et al., 2016) and can be in the same period as when fishers are using gillnets to target sole. Therefore in some months and only in the Southern regions of the North Sea, bycatch rates of starry smoothhound might be higher.
The lesser-spotted dogfish is an abundant species occurring on a range of substrates (from mud to rock) on the European continental shelves, from coastal waters to the upper continental slope, but is most abundant on the shelf. Its distribution ranges from Norway and the British Isles to the Mediterranean Sea and Northwest Africa. ICES currently consider 4 stock units for this species, one of them the North Sea ecoregion. In this region population is rising in the past few years (ICES, 2023c). When caught, they are often returned to the sea because of their low market value but those that are landed are utilised as bait

for pot fisheries, particularly for whelk (Small, 2021b) and as long term bait for in brown crab pots (personal communication S. Tijsen).

What the effect of gillnets is on bottom disruption and especially the reef-forming organisms is unknown. On the one hand, the effect is estimated to be low (Rijnsdorp et al., 2006, Bos et al., 2021). On the other hand, in accordance with Shester & Micheli (2011), reef-forming structures might be damaged, although oyster and mussel beds are generally stronger structures than the kelp and coral habitats studied by Shester & Micheli (2011) and the North Sea consists mainly of sandy bottoms. As an illustration, Bos & Suykerbuyk (unpublished) observed that gillnets hardly damaged oyster reefs in the Dutch coast, as the boat was pulled along the gill nets instead of the net towards the boat.

6.3.3 Multi-species pots

General observations
The inventory approach gave a clear view on potential of bycatch. Catch on primary target species was scarce but were abundant for commercially interesting species brown crab and velvet swimming crab. The cuttlefish pots caught cuttlefish but not in large amounts, and the fish pots caught some European squid. Fish pots however caught low amounts fish like Atlantic mackerel and no primary target species like Atlantic cod or seabass.

Environmental impacts
In general pots are considered to have low impact and to be fuel efficient fishing gears (Suuronen et al., 2012). The pots catch larger specimens (for common cuttlefish, Richardson, 2018) and have little bycatch and discards (Shester & Micheli, 2011, Rozemeijer et al., 2021, 2023a,b). Especially larger species of concern like protected elasmobranchs are caught less than in other gears (Petetta et al., 2020) and discards are more likely to survive because they are less damaged. The bottom damage is much less than with trawl nets (Shester & Micheli, 2011, Richardson et al., 2018). The lack of having to do demersal trawling over and in the bottom but instead using fixed positions results in low fuel costs during fishing and reduced carbon footprint (Suuronen et al., 2012).

Temporal aspects
Brown crab and velvet swim crab demonstrated a seasonal pattern in most cases. Brown crab decreasing along summer, alike Steenbergen et al. (2012) and Öndes et al. (2019) and velvet swimming crab catches rising during summer. The velvet swimming crab catches increasing during the season could either be due to their natural seasonal cycle or due to the reduction of numbers of brown crab and thereby predation in the pots. Rozemeijer et al. (2021, 2023a,b) postulated that the reduction in velvet swimming crabs during prolonged soaking time was caused by predation by brown crab. Henderson (in ICES 2005) found no seasonal pattern for velvet swimming crab for the Shetlands. That could be a temperature aspect as well. Henderson also did not encounter a seasonal pattern for brown crab. The seawater temperature at the Shetlands ranges from ~8°C to 13°C, less different than the Dutch North Sea (~5°C to 20°C). Fahy et al. (2008) mentioned that the CPUE in the Outer Hebrides was highest in October, three times higher than in the period January / June. In Ireland a peak July was observed declining sharply. Wilhelm (1995) showed a summer - winter rhythm with low CPUE in January February and the higher CPUE in August and September in the South of France. Alike brown crab the peak in catchment seems depending of local circumstances.

Bycatch
Both sole pots and fish pots caught a high diversity on species as bycatch. Both types of cuttlefish pots caught less species than the other pot types. Alike Meintzer et al. (2018) and Rozemeijer et al. (2021, 2023a,b) the bycatch is low in numbers and rarely damaged and suitable to be returned to the sea (Olson, 2014).

Sole pots
The sole pots caught no primary target species. Potentially different causes were either the fact of newly developed pots or not deployed in the appropriate season. The sole pot catch effectivity in the open sea has not been tested before, although they showed in a laboratory environment that sole could be caught. In this laboratory environment however, sole and pot are in a closed, small basin resulting in a density which was much higher than in the North Sea. The second option could be that the sole season had already passed before deploying the pots at sea. The gill nets had been deployed just for deploying the pots and the last gill net hauls caught already low amounts of sole.

No specific sole pots are known in literature as they were specifically designed for this study. In Lyme Bay (South England and Canal area) crab and lobster pots caught less than 1% of the total landings of sole by nets, demersal otter trawls, beam trawls and dredges (Desender & Santos, 2023). In the north-western Adriatic Sea small and large Trapula pots with a single oval entrance caught at least 40 times less sole than gill nets (Petetta et al., 2020). This gives an indication pots might not be the best gear to catch sole. However, personal experience of the collaborating fisher from the focus group was that sole was caught during crab pot fishing, sometimes several individuals per pot, especially when shark meat was used as bait (personal communication S. Tijsen). This gear requires further testing before it can be concluded if the gear might be suitable for catching sole as target species. Further testing must include factors that determine whether target species can be caught such as: the design of the pot and its characteristics, the baits used, the diet and feeding behaviour of the target species, right season and time of deployment and suitable fishing grounds.

Cuttlefish pots with fluorescent mesh and normal mesh
The common cuttlefish pots were described in ICES 2023b (De Vlasselaer & Opstal). In the English Channel, two designs of pots are often used: 1. either a rectangular/square cuttlefish pot that usually has a steel frame and nylon net and are sometimes baited with live females to attract males, or 2. a smaller round pot, also known as a 'French style' pot (Richardson et al., 2018). Both pots have a 'feathered' entrance, designed to enable cuttlefish to enter but not escape, and a door for emptying and baiting. The pot entrances used in this study had a conical net, therefore reducing escapes from the pot.

Cuttlefish pots are used across many seas: the Atlantic Ocean and English Channel (UK and France, Richardson et al., 2018), Portugal (Pereira et al., 2019), Mediterranean like Spain and Italian Adriatic sea (Belcari et al., 2002, Melli et al., 2014, Petetta et al., 2020), Morocco, Mauritania, Senegal and Gambia (FAO CECAF 2007). Cuttlefish pots can be used for certain seasons during cuttlefish migration (spring and early summer months) (Belcari et al., 2002, Richardson et al., 2018).

Mostly brown crab and velvet swim crab were caught during the experiment. De Vlasselaer & Opstal (ICES 2023b) described the fluorescent pots caught a tenfold more than normal mesh cuttlefish pots. In this experiment both cuttlefish pots caught alike quantities of common cuttlefish. Most common cuttlefish were damaged by predation. When catching common cuttlefish, soaking time should be reduced to a maximum of 1 to 3 days to prevent damage to the catch. In this experiment this was not possible due to unfavourable weather circumstances that prevented crew from hauling the gear.

Fish pots
Several types of fish pots exist (Hedgärde et al., 2016, Meintzer et al., 2018). These could be floating pots or standing on the seabed. Pots can have a separate fish holding chambers and entrances could be fixed conical mesh funnels or large slits, oval, round or rectangular. There can be up to four entrances per pot and entrances can also have (metal) retention devices reducing the exit of fish (Königson et al., 2015, 2022, Hedgärde et al., 2016, Meintzer et al., 2018). Factors that influence the catch in pots are the design and type of pot (especially the entrance type and amount), the direction of the entrance towards the currents, sea current conditions, depth (an aspect of local circumstances), soaking time and the number of fish present in the pots (Königson et al., 2015, 2022, Hedgärde et al., 2016, Meintzer et al., 2018). In

this study, the fish pots used appeared to be large for the vessel. The pots had large dimensions and were heavy, and therefore were hard to handle in the limited space available.

The comparison of pots with other gear types showed that the pot fishery generated lower daily catches than the gillnet and longline fisheries at comparable fishing efforts. However, in general the quality of the caught fish is higher for pots as compared to gill nets (Olsen, 2014, Meintzer et al., 2018, Nguyen & Morris, 2022). In addition, the depredation by seals is much less (Suuronen et al., 2012, Königson et al., 2022).

Königson et al. (2022) investigated multi species pots for European lobster, brown crab and Atlantic cod. The study showed that European lobster, brown crab and Atlantic cod could be caught in the same gear when the gear is properly designed. The relative CPUE of European lobster and Atlantic cod was highest in larger pots with two chambers and three entrances. Only on a few occasions, pots were subjected to seal damage. Seal damage was more common in pots with a relatively high numbers of Atlantic cod. Since brown crabs and velvet crabs were caught in this experiment Borssele 2023 in sometimes high amounts, it might be interesting to look into the possibilities for designing new pot types suitable for fishing in offshore wind farms on small vessels in the North Sea, for the primary target species. As for sole pots, further testing must include factors that determine whether target species can be caught such as: the design of the pot and its characteristics, the baits used, the diet and feeding behaviour of the target species, right season and time of deployment and suitable fishing grounds. Also, scaling up the number of pots, and placing the strings perpendicular to the currents could increase the bait plume and thereby catch (Rozemeijer et al., 2023a,b).

6.3.4 (Mechanical) jigging

For mechanical jigging experiments, only Atlantic mackerel and very few whiting were caught in Borssele II offshore wind farm. Schools were found using an echosounder/multi beam. The principle of jigging is that the hooks with artificial bait (jigs) imitate a school of bait fish which keeps the school of predators (in this case, Atlantic mackerel or European squid) nearby. Therefore it is advisable to have several machines operating simultaneously (Van Marlen et al., 2011). At the beginning of the experiment, early in the season, schools of mackerel were more abundant and visibility of the water was higher than after the summer storms. Schools seemed scattered and visibility got less, possibly leading to decreasing catches as Atlantic mackerel are sight-predators. This fishery requires a flexible approach and therefore the vessel must follow schools of target species. However, in offshore wind farms this seemed difficult as fishing was not allowed in many areas inside the offshore wind farm because of infield cables, turbines and their maintenance zones. Jigging is a type of fishing where there is no bottom impact, minimizing the risk of touching infield cables. Therefore it would be interesting to look into the possibilities of reducing maintenance zones or allowing gears such as jigging which has no bottom impact and require a more flexible approach, for fishing closer to turbines and infield cables.

No European squid was caught in Borssele offshore wind farm using jigging machines. Reference hauls on European squid were performed in the English Channel, both jigging and with otter trawl. For jigging, only one European squid was caught in the English channel but fell off the jig before hauling on board. Fishing with otter trawl showed that the density of the European squid at the time of testing was low. Mechanical jigging in combination with attraction by light at night is a practice that is often done and which will have a very low by catch (Hastie et al., 2009). However, these practices are often done under different circumstances: higher density of squid, smaller vessels and higher visibility of the water compared to the North Sea, and therefore realizing higher catches. The English Channel only had few occasions of sufficiently high densities to allow jigging (Wilson, 1985). Previous studies also show that insufficient light penetration during high turbidity can be a major issue for the catch success (Wilson, 1985, Hastie et al., 2009).

6.4 Ecology

6.4.1 Birds

Birds may be attracted to wind farms as wind turbines provide opportunities for resting and drying, especially for cormorants (Leopold et al., 2013). Other diving birds such as auks, guillemots, divers, and gannets, to some extent, avoid the wind farm. Various species of seagulls can be found in wind farms, but they are not necessarily attracted to or deterred by them. However, seagull species are known to follow fishing vessels when fish waste and discards are thrown overboard (Röckmann et al., 2015). Vessels that discard little to nothing pose less danger, as birds are less attracted. Gannets, cormorants, and (petrel) storm petrels may also follow vessels for the same reason. Also when retrieving the nets, birds can be attracted by the quantities of fish directly at the surface (Bærum et al., 2019). However, in all types of gears tested within Borssele offshore wind farm during this experiment, the gear was immediately brought alongside the boat (and for gillnet and pots over the net / trap roller), ensuring that the catch and discards are not left at the surface but brought on board immediately. However, gillnet fishing may still be a risk to diving birds such as grebes, guillemots, divers, and diving ducks because they actively search for food underwater and can become entangled in the net (Röckmann et al., 2015). Nevertheless, the most common form of gillnet fishing in the Netherlands is gillnetting for sole, with net heights of no more than half a meter from the seabed, at greater depths, reducing the risk of bird bycatch (Klinge, 2008).

The explanation of article 5 of the BAS states the following: "throwing caught fish or residual waste from cleaned fish overboard can also cause hinder because of the attractive effect on birds". Very few birds were seen during the experimental days at sea. Out of all 36 days at sea, bycatch was discarded on 32 days (only on days where gear and catch was hauled). The amount of discarded bycatch, however, was limited in terms of number and weight (as shown in Chapter 4 per gear). For handline fishing and jigging, no benthic species were caught and discarded, and only a few individuals of undersized target species were discarded per trip. For gillnet fishing, benthic species were not discarded as they were crushed while hauling the nets. During gillnet trips, only fish species were discarded in low numbers. For pot fishing, very little amounts were discarded as most benthic species were landed (brown crab) and fish species were caught in very small numbers. In only two occasions, one while pot fishing and one while gillnet fishing, birds were attracted to the fishing activities. On both occasions this was due to the discarding of bycatch of fish, benthos and residual waste, and both occasions were just outside of the wind farm. Discarding was done on each day in the wind farm where gears were hauled, both inside and outside of the wind farm, as discarding only outside of the wind farm is not possible under current fishing legislation. This is mainly due to the fact that in some cases fish, as also described in chapter 2, must be thrown overboard immediately. Due to hygiene requirements, discards and fish waste must be kept well separated from the catch for food safety reasons. The space on board was very limited for the two smaller vessels and it was therefore standard fishing practice to immediately throw all fish waste overboard.

No birds were caught in any of the tested gears. These observations indicate that the risk of (passive) fishing activities attracting birds seems small. Also, volumes of discarded bycatch from passive fishing gears in general are very low compared to conventional beam trawlers (Garthe et al. 1996). However, this study was only done within a specific time frame (April to October) in a single year. The occurrence of species varies by season, and birds may appear more or less in the vicinity of a wind farm during certain seasons. Therefore, attraction of birds to fishing activities and the possibility of birds being caught in the gears might also vary throughout the different seasons.

6.4.2 Sea mammals

Various species of marine mammals inhabit the North Sea, with porpoises, grey seals, and common seals being the most common. Seals have a diverse diet and are found throughout the North Sea. Telemetry research indicates that seals do not actively avoid wind farm, but the majority do not enter them. However, there are exceptions, and research shows that certain individuals swim through wind farms (Russel et al., 2014; Röckmann et al., 2015). As seals might be present inside the offshore wind farm, they may be susceptible for being caught in fishing gears. Previous studies for gillnet fisheries show no bycatch of seals in gillnets off the West and Southwest coast of Ireland and suggest the risk of bycatch in gillnet fisheries is low (Cosgrove et al. 2016). Unlike harbour porpoises, seals are able to swim backwards, preventing them from getting entangled. As proof often heads of caught fish are found in nets while the body is eaten (Neitzel et a., 2023a). In other gillnet fisheries targeting crawfish and monkfish using other net types and mesh sizes, bycatch of grey seals and harbour porpoises were observed. Authors state that catches, depth of gear deployment and larger mesh size were significantly positively correlated with seal bycatch. In none of the field experiments in Borssele offshore wind farm and in none of the fishing gears tested, seals were caught or directly attracted to fishing activities. On three days in the field one grey seal was seen inside the offshore wind farm.

Common dolphins are known to be widespread in the North Sea. Literature provides various examples: in some cases, porpoises avoid wind farms (Tougaard et al., 2006a; Blew et al., 2006), while in other cases, there is no difference between areas outside the wind farms and the wind farms themselves (Blew et al., 2006; Tougaard et al., 2006a; Polanen Petel, 2012), or porpoises may even use wind farms (Scheidat et al., 2009; Lindeboom et al., 2011). However, these are observations based on short-term monitoring programs. Bycatch of marine mammals in passive fishing gear is recognized as a problem worldwide (Read et al., 2006; Reeves et al., 2013), particularly leading to declining population sizes for small cetaceans (Brownell et al., 2019). Couperus (2018a,b, 2019, 2020) recorded bycatch of marine mammals during a limited number of trips under the Data Collection Framework (DCF). During these trips, he observed bycatch of marine mammals and several birds. Additionally, it has been demonstrated that harbour porpoises can be caught incidentally in passive fishing gear in the North Sea. Scheidat et al. (2018) calculated an average bycatch of 0.0006 harbour porpoises per kilometer of gillnet. During the days at sea, no dolphins were observed either inside or outside the offshore wind farm. On one occasion, two harbour porpoises were seen cruising along inside the offshore wind farm. This sighting was not related to fishing activities. No literature is available on bycatch of seals, harbour porpoises or dolphins for handline fishing, jigging or pot fishing. During the field tests in Borssele, no sea mammals were caught in any of the tested gears.

6.4.3 Ecological status and passive fishing

As the current ecological status of the North Sea is considered low and damaged, the policy intention is to restore, maintain and strengthen the North Sea ecosystem. In addition it is the ambition that increases of usage and associated impacts do not hamper this improvement of the North Sea ecosystem. This ambition will be executed along five approaches as described in the marine strategy of the North Sea Programme 2022-2027 (Programma Noordzee 2022-2027 - Noordzeeloket). In this paragraph, the potential effects of passive fishing in offshore wind farms, thereby building upon initial experiences from field tests at Borssele, will be reflected against these five policy intentions.

1. **Reducing pollution and disturbance**

The pollution by the fishing vessel fishing in an offshore wind farm will be no different from the pollution by the same vessel fishing on another location outside of the offshore wind farm, as the activities will remain identical in case regulation allows so. Fishing activities are known to both potentially disturbing and attracting to various animals such as birds and sea mammals. The extent of disturbance however is due to many factors such as gears used and the duration of the fishing activity. In the field experiments, low to no disturbance and attraction of birds and sea mammals was experienced, both in Borssele II 2023 (this study) nor in PAWP (Rozemeijer et al., 2023). This counts for all gear types used. It is currently prohibited to fish in the offshore wind farms at night, so no attraction or disturbance of species like bats or migratory birds was measured. The experiment covered only one year with a limited number of trips per gear type, and therefore only a first indication on attraction and disturbance can be given.

2. **Protected areas and habitat types**

In offshore wind farms, bottom-trawl fisheries activities are currently prohibited. The potential extent of bottom disturbance by passive fishing activities are minor. Firstly, because the actual bottom impact (footprint) of passive fishing gear (anchors, pots, lines and gillnets) is relatively small. Secondly, these gears are stationary and do not actively 'plough' through the seafloor. Finally, the space between the nets and anchors of the pots is spread over a larger area to maintain the highest yield, resulting in a relatively low 'surface contact/area' ratio. The Dutch North Sea includes several protected areas, including Natura 2000 areas like Doggersbank, Klaverbank and Friese Front. Since offshore wind farms are not and will not be placed in protected areas, potential impacts anticipated from passive fisheries in offshore wind farms in Natura 2000 areas are non-existent.

3. **Protected species**

Species of birds, marine mammals and bats are protected through the Act of Nature Conservation and may not be deliberately killed or disturbed. As mentioned in the previous paragraphs, it is very unlikely bats will be disturbed as fishing activities in offshore wind farms are currently prohibited during nighttime. Moreover, the experiments have shown an absent to low disturbance and attraction to both birds and sea mammals. However, the limited number of test days and therefore indicative results of this study, from which no firm conclusions can be drawn, needs to be emphasized again.

4. **Integral nature enhancement**

In the discourse towards rapid upscaling of offshore wind energy generation, the focus on how to make these areas as 'nature-inclusive' or even 'nature-enhancing' as possible grows simultaneously. This also includes a focus on the potential 'artificial reef effects' of these areas, in which hard substrates act as attracting areas for various ranges of species to settle and forage, thereby increasing biodiversity. This for example includes brown crab, Atlantic cod and European lobster. Nature enhancement and fisheries enhancement can potentially go hand in hand in this case (Rozemeijer et al., 2016, Rozemeijer & van de Wolfshaar, 2019, DeGraer et al., 2020, Neitzel et al. 2023a). This however, will have to stay within carrying capacity of this novel environment, which asks for more research to support this potential valuable synergy between nature and fisheries enhancement.

5. **Sustainable use**

A larger emphasis of passive fisheries could contribute to a more sustainable food availability. Passive gears are considered to have low impact and to be fuel efficient (Suuronen et al., 2012). Furthermore, passive fisheries are usually small-scale and localized activities compared to active trawling. Therefore, fishing at maximum sustainable yield on selected populations of high valuable species can also be managed rather easily. These factors contribute to the motivation of exploring different forms of both existing passive fisheries as innovative gears as a sustainable form of fishing in the food- and nature transition on the North Sea.

6.5 Economy

Currently, most Dutch fishers fish with active gears throughout the year on different fishing grounds. The presence of wind farms on part of these grounds limits the alternatives for those fishers who must reschedule their fishing operations. The active gears used by these fishers are currently not allowed in wind farms so they need to find other fishing grounds and perhaps other fishing activities.

Also, fishing in an offshore wind farm is limited to fishing with passive gear, during daytime, in a specific part of the wind farm and under good weather conditions. It is also a seasonal fishing practice. This limits the options for achieving the revenue needed to cover the costs of a fishing trip. Opportunities to increase revenue per fishing trip should therefore be explored.

The option of passive fishing in a wind farm should be considered as an addition to fishing activities in other parts of the sea. Fishing in a wind farm is part of the total fishing strategy of a fisher during the year, depending on the seasons and depending on the catchability of species in that part a wind farm where fishing is allowed.

Depending on the feasible number of fishing trips or days at sea per year, the average costs and landings per trip or per day at sea, a fisher can partly, make a living fishing in a wind farm. This study gives a first insight in the costs of a fishing trip with different types of vessels and the catches needed to cover these costs. The experiments have not resulted in enough data on landings to test whether fishing in an offshore wind farm can be economically viable.

The vessels used in the current experimental study were initially selected based on their availability, fishers' interest and suitability for applying certain gears. However, no standard is yet present for the optimal vessel suitable for fishing operations in wind farms. Interestingly, a specially designed, so-called multi-purpose, vessel is developed (only on paper): Project Octopus[7]. Although this vessel is not yet up and running, it could provide possibilities for fishing in wind farms.

[7] Octopus (projectoctopus.nl)

7 Conclusions

"What are possible problems that may arise during the testing of different gears, taking into account the technical aspects of the fishing gears and vessels, safety issues or potential risks, distance from the coast and weather conditions?"

Both the risks for the fishers as well as the offshore wind farm were evaluated. Regarding risks associated with passive fishing within offshore wind farms, the already applicable regulations for crew and vessels appear adequate. There is no necessity to prescribe additional measures beyond the present regulations of fishing vessels, crew and operations within the wind farm.

Furthermore, the risks of passive fishing activities for the wind farm were evaluated by a Task Risk Assessment together with the focus group. One identified considerable risk for the wind farm is the potential displacement of gears, which might result in interaction between gears, turbines or in-field cables. To mitigate this risk, in the experimental set-up the gears were positioned with 200 meters leeward distance to the maintenance zone, resulting in a total distance in leeward direction to any infrastructure of 450 meters. Furthermore, qualitative and quantitative evaluations were performed to explore the risk of displacement and interaction. The analysis found the risk of interaction between the gears and the wind farm structures to be low, with derived displacements fairly smaller than the 250-meter maintenance zone. The findings spur exploration of whether the 250-meter maintenance zone could be reduced, provided the appropriate risk assessment is applied. Other, lower classed risks were evaluated by a qualitative approach together with the focus group.

Comparison between the workable days of 2023 with the long-term statistics shows less workable days during the spring and summer period (March till August) in 2023, especially in March and July. This is in-line with the experience of the fishers and project team that 2023 had less workable days due to bad weather compared to other years. However, the difference between 2023 and average years is not very large. One should take into account the limited workability of small fishing vessels in offshore wind farm in the outlooks for passive fishing within offshore wind farms.

The vessels applied in the experiments are capable of operating up to significant wave height of 0.8 meter (KG 7), 1.0 meter (YE 152) and 1.5 meter (MDV 2). In offshore wind farms, the wave conditions regularly exceed these operational limits, especially for small vessels such as KG 7 and YE 152, even in summer. Evaluation of wave conditions in wind farm Borssele in 2023 in addition to long-term statistics showed that wave conditions in spring and summer 2023 were more severe than in average years, but the differences were not large. This was in-line with the experience of the fishers.

The sailing time from the harbour to the offshore wind farms is time-consuming: up to 3 to 3.5 hours one way, depending on currents. Consequently, the total sailing time is 6 to 7 hours in a day. All in all, this is a relatively substantial amount of time per day compared to the time actually spent fishing in a wind farm and limits the potential earnings per fishing day. Fishing with a vessel and gear that can be deployed outside the wind farm or a vessel that is suitable for staying overnight outside the wind farm limits the number of times sailing back and forth and as a result the sailing time per fishing hour.

The limitation to only access the wind farm during day time limits the possibilities of passive fishing in wind farms. Since access to the wind farm is not allowed during night time fishers sail back to shore on a daily basis and the workable time in the wind farm is limited particularly from late autumn to early spring. Furthermore this limitation forces the fishers to sail out towards the wind farm in the morning and sail back to shore in the afternoon or evening, regardless of the tide. Sailing against the tide is unfavourable because of an increase in sailing time and fuel consumption and as a consequence, higher costs. It is recommended to allow passive fishing in wind farms during night time in order to increase workability and reduce fuel consumption and costs.

"Is it possible to catch target species within Borssele I and II offshore wind farm using handline, gillnet, multi-species pots and jigging and what is the composition and quantity of bycatch per fishing gear when considering non-target species (fish), birds, marine mammals, and benthic species/crustaceans?"

The results show that is it possible to catch target species with gillnets (sole) and jigging machines (Atlantic mackerel). For handline, jigging for Atlantic squid and multi-species pots, it was more difficult to catch target species. For handline, no seabass was caught, only some Atlantic mackerel which can be commercially valuable, but were not seen as prime target species. During jigging for Atlantic squid, no Atlantic squid were caught. For multi-species pots, no target species were caught, except small amounts of common cuttlefish and Atlantic squid. However, substantial amounts of brown crab and velvet swimming crabs were caught as a secondary target species that has commercial value. Other bycatch consisted of non-target species, either non-landable or undersized fish species or non-landable benthic species. No birds or sea mammals were bycaught during this experiment. From this study, it becomes clear that many factors have influence on catch: weather circumstances, peak seasons of target species and therefore the right time of fishing, fishing gears and their settings and characteristics, soaking times and differences between locations within an offshore wind farm.

"What are the catches per unit effort (CPUE) and landings per unit effort (LPUE) of the caught target species per fishing gear?"

The experiment had an explorative character. Not all gears were repeated in the similar approach, reducing replicates. In addition, unfavourable weather conditions reduced the number of possible expeditions per gear. All these aspects hampered statistical evaluations. For mechanical jigging, not a constant approach was used in the set-up of the jigging machine as this had never been used before by the fisher involved. The trial included many different settings of the machines and adjustments of the gears that were done in the actual fishing hours. For gillnet and handline alike low replicates reduce statistical resolution and accuracy. The multi species pots have more replicates but results were influenced by the long soaking time (due to unfavourable weather) which can lead to mortality of target species, reducing statistical resolution. Therefore, for none of the gears CPUE and LPUE were determined as these would give a non-representative overview of the catch potential.

"To what extent are birds attracted to fishing activities?"

Very few sea birds and sea mammals were seen in the offshore wind farm during experimental fishing. In only two cases, bird seemed attracted to fishing activities; this was when crew threw unwanted catch (discards) overboard outside the offshore wind farm. This could demonstrate a potential risk mitigation measurement: discarding outside of the offshore wind farm. However, very little birds were seen inside the offshore wind farm and while discarding inside the wind farm, no birds were attracted throughout the entire experiment. In none of the sea mammal sightings, the individuals were attracted or influenced by the fishing activities. In none of the gears, birds or sea mammals were bycaught.

"Is it economically feasible to fish commercially within Borssele I and II offshore wind farm when considering the four different fishing gears?"

A complete overview of what is required to fish successfully commercially cannot yet be given due to the novelty of the playing field and consequent limited practical experience. An overview of the costs per year and per fishing trip of the vessels involved were presented. Cost per fishing day vary from 900 euro (small scale fishing vessel, 2 crew members) to 6,000 euro (32-meter vessel, 5 crew members). If economically feasible, the revenue must meet these costs.

The potential opportunity of converting shrimp cutters for passive fishing in a wind farm is explored. As these types of vessels have more work and storage space on deck than smaller vessels, are navigable but stable enough in slightly more turbulent weather, they could potentially be applied for fishing in an offshore wind farm. The costs were 2,123 and 2,774 euro respectively per fishing day. Examples of catches needed for the various target species are presented.

8 Overall reflections on passive fishing in offshore wind farms

This research is conducted under the ambition of the North Sea Agreement to enable co-use of offshore wind farms and passive fisheries. The study yielded the first pilot results, which were both limited and collected in the context of an entirely new playing field, and therefore novelty and unexpectedness. Nonetheless, it revealed several overarching aspects to consider in order to unlock the full potential of passive fishing in offshore wind farms.

The research has contributed to the pursuit of ecological responsible, economically viable as well as safe co-use of offshore wind farms and passive fisheries. Besides these requirements, however, a key enabling factor when conducting research on passive fishing in offshore wind farms is the actual interest, ability and motivation of fishers. Therefore, from the very start, the project was carried out in cooperation and collaboration with a focus group of commercial fishers that indicated willingness, ability and interest to engage in these activities. Their inputs during the project (developmental, experimental and reporting phase) are an important part of the project results. This chapter thus considers both acquired experimental output as well as focus group reflections.

This chapter presents four reflections on passive fishing in offshore wind farms.

1) Passive fishing in offshore wind farms appears technologically feasible and safe.
2) Passive fishing in offshore wind farms differs significantly from current practices and calls for alternative frameworks.
3) Passive fishing in offshore wind farms may complement, but not substitute current fisheries.
4) Communication between parties should be improved, simplified and standardised.

1) Passive fisheries in offshore wind farms appears technological feasible and safe

In this study, various fishing gears were examined that are usually not applied this far out at sea, revealing their respective strengths, weaknesses, challenges, and opportunities within these novel locations. Applicable gears are readily available, yet their successful application is dependent on mostly uncontrollable conditions (distance, weather and safety requirements). For instance, algal blooms damaged gill nets, and pots were covered in sand when leaving them too long on the seabed, reducing their effectiveness. Implementing these passive techniques in remote sea locations necessitates further experimentation and adaptation to optimize their effectiveness, especially for the innovative and newly designed gears tested in this study.

Although there is room for further technological advancement, the pilot study showed that passive fishing activities in offshore wind farms pose little risk to the offshore wind farm and to the fishers themselves. The pilot emphasizes the importance of wave height as a primary factor for determining operational readiness and decision-making related to sailing within the wind farm. Though weather conditions might pose hazards to small vessels operating offshore, adequate planning and working guidelines mitigate these risks. This project has paved the way for such a framework, which should be finetuned in the future roll-out of passive fishing in offshore wind farms, similar to other co-use operations.

By providing a clear framework for all parties involved, the government can create a more enabling environment for passive fishing in offshore wind farms. Currently, experimental fishing activities require coordination with the wind farm operator, who holds significant responsibility for activities within the wind farm area. The government needs to address key knowledge gaps such as clarifying regulations for anchoring gears and vessels in co-use areas outside maintenance zones. Within the present framework anchoring of gears and vessels is allowed within the wind farm in area's for passive fishing outside the maintenance zone. Additionally, protocols for locating and retrieving lost gear need to be established through risk assessments to ensure effective response and equipment recovery. The 250-meter maintenance zone around turbines and cables should be re-evaluated to optimize fishing opportunities while maintaining safety and operational integrity, which could benefit from further risk assessments for potential reduction.

2) **Ambitions vis-à-vis possibilities: Passive fishing in offshore wind farms differs significantly from current practices and calls for alternative frameworks**

Adjustments in fishing operations as well as policy are needed to align the co-use ambitions with the current capabilities of the fishery sector. However, certain mismatches between co-use aspirations, the current policy framework, and characterisation of the current passive fishing sector were found. Challenges for example involve offshore wind farms accessibility, vessel optimalisation and gear application (spatial deployment, combinations of gears).

Passive fishing further out at sea

The current Dutch passive fishery comprises mainly in coastal areas, with relatively small vessels. This makes the passive fishing sector radically different from the fisheries currently operating around offshore wind farms areas, which mainly consist of larger vessels fishing with gear that is not allowed in a wind farm yet. The latter are better equipped to withstand (unexpected) weather conditions and offer more space for on-board safety measures. It would make them more suitable for fishing in wind farms considering that most of the wind farms are too far away from the coast for small vessels. Vessels up to 45 meters are allowed in offshore wind farms. It is recommended to further explore the possibilities for passive fishing in offshore wind farms, but in doing so, consider the possibilities of using vessels with a length of 20 to 24 meters.

Accessibility of wind farm

The sailing time from the harbour to the offshore wind farms is time-consuming for small-scale vessels: up to 3 to 3.5 hours one way, depending on currents. Consequently, the total sailing time can be 6 to 7 hours in a day. All in all, this is a relatively substantial amount of time per day compared to the time actually spent fishing in a wind farm. Access limitations to the wind farm only during daylight limit flexibility in choosing optimal sailing times. Sailing with the tide shortens the nominal 3-hour sailing time to about 2.5 hours, while sailing against it extends the time to around 4 hours. For commercial fishing, sailing against the tide is unfavourable due to increased fuel consumption and longer working hours. Being present in an offshore wind farm during the night is not allowed, yet could offer enhanced opportunities. Overnight stays just outside a wind farm would reduce navigation time and increase available fishing time. Larger vessels are required to withstand weather changes and sufficient facilities on board for living and resting. Another possibility would be allowing continuing fishing during the night. According to fishers from the focus group, fishing at night does not increase safety risks. This possibility should therefore be further explored, especially to deploy fishing technics where the catches at night are good or even better.

Available space in wind farm

Future prospects in economic terms (promising revenue model) was a major point of discussion among fishers. Fishers raised concerns regarding harvest rates, partially resulted from their expectations of spill-over effects. Fishing closer to the monopiles may increase catch potential, mainly for handline and pot fisheries. Fishers indicate that fishing closer to monopiles can be safely executed, both for offshore wind farm structures and other users. As maintenance zones are not based on international legislation, but national regulation implemented by Rijkswaterstaat, it would be advisable to reopen the discussion on the extent, flexibility and regulation of these zones. For example, communication of maintenance practices per turbine may allow fishers to avoid these areas at those times, thereby limiting overlap in activities and reducing risks and hindrance.

Furthermore, a challenging balancing act was found between optimal gear-use and provided space within the co-use area designated to passive fisheries. The co-use compartments appeared to provide significant sub-optimal conditions for the tested gears types. On many occasions, the limited area available necessitated shorter lines to be used, and therefore a longer sail back and forth to haul than usual. This consumed a lot of time. Especially for gillnet, the limited available space in combination with limited catches, caused demotivation among fishers. Ideally, lines should be longer to reduce hauling time and to increase their catch potential (placed parallel to the current for gillnet, perpendicular to the current for pots). Therefore, it is highly recommended that when allocating areas for offshore wind areas in the future in which passive fisheries is aimed for as co-use activity, inclusion of technical catch considerations are taken into account in order to exploit the full potential and increase opportunities for passive fisheries. This can be done in consultation together with the industry or researchers.

*Plannability of fishing trip*s
To recoup the sailing time to the wind farm, there should be a high probability of good fishing. Currently, catches in wind farms are, as in other fishing areas, very variable. If one could increase the predictability of catching, fishing in a wind farm will be more profitable. Catches could be enhanced by the use of fish aggregating devices (FADs) or fishing closer to hard substrates such as wrecks, monopiles or artificial reefs.

Combination of gears on board
Currently, due to legislation, it is not possible to have multiple gears on board to be deployed. Several considerations can be raised as to why it is desirable to allow this to accommodate the future roll-out of passive fishing in wind farms. First, it would enable fishers to combine operations on one vessel, to minimize sailing to and from the farm, ideally on a larger and more weather-resistant vessel. Sailing towards an offshore wind farm for 6 hours for setting out gears may feel cumbersome, whereas having a combination of gears on-board such time could be much better utilized. In addition, combining gears would facilitate on-the-spot decision-making on which type of fishery to apply that day (depending on season, weather conditions, available target species, etcetera), likely improving the economic output of the executions.

3) **Passive fishing in offshore wind farms may *complement*, but not *substitute*, current fishing activities**

Dutch fisheries face pressure from many sources, such as international policy, sustainability and climate change, and inevitably face a strong transition at sea. The rapid increase in offshore wind farms also decreases the available space for fishing. The usually seasonal and economically uncertain (partly due to high fuel prices) passive fishing sector has also only shrunk in recent years.

Based on the initial findings from this pilot study, opening up wind farms to passive fishing, however, will unlikely satisfy the desire for compensation for lost fishing grounds. Moreover, the type of fishery that may initially gain access to the park (passive fishing) is very different from the fishery that first had access to the area (namely bottom trawling). Fishing solely in wind farms is unlikely to gain an optimistic business model, mainly due to restrictions in gear use and fishing period, limited fishing space (for example due to monopiles and cables and the fact that only a part of the wind farm is designated for fisheries), the aforementioned sailing times and catch uncertainties. Therefore it seems unrealistic to create a stand-alone business from passive fishing in offshore wind farms. Following the experiences and findings from this study, allowing passive fishing in wind farms should therefore not be regarded as a replacement or substitute for current fishing at sea. In case realizing fisheries within wind farms is desired, economic viability, gear allowance and innovation should be addressed.

This is not to say that the wind farm should be closed to (passive) fishing. It could still provide an addition to the current fishery, albeit seasonally or occasionally, especially when flexibility and experience increase. For example, fishers express that potentially opportunities for passive fishing in offshore wind farms could be further enhanced by creating hard substrates to attract target species, fishing closer to monopiles, or potential future multi-gear vessels could employ passive fishing to complement their conventional fishing techniques. In that sense, a space for development and exploring should be maintained.

4) Communication across parties should be improved, simplified and standardized

The project required communication between all parties (project team, fishers, Ministry of Agriculture, Nature and Food Quality, Coast Guard, Rijkswaterstaat, wind farm operator). The project team further arranged the mail exchange necessary for entrance to the park, including three mails per fishing day (appointment, go-no go, positions). In case such communication levels are retained when moving towards commercial fishing in offshore wind farms, it involves a great deal of work for fishers, adding to the already existing obligations and reports for NVWA. Furthermore, the amount of communication required to enter, attend, and leave the offshore wind farm also seemed to give fishers a sense of 'being controlled'. All in all, the quantitative and qualitative level of communication in the current framework led to reluctance among fishers to fish in offshore wind farms.

In these first pilot experiences, sufficient and continuous communication was a major point of focus. However, the degree of communication duties, as decided in the experimental set-up, proved to be beyond measure. Safe execution could also be done with fewer moments of communication. Both the offshore wind farm operator and the Coast Guard raised the desire to reduce the obligatory moments of communication. The communication between the offshore wind farm operator, the Coast Guard and the Department of Public Works needs to be further aligned to increase communication efficiency, minimize risk for miscommunications and reduce loss of fishing time. To safeguard the willingness of fishers to fish in offshore wind farms, as well as to reduce the administrative burden for all other parties and reduce the risk for miscommunications, it would be recommended to 1) reduce levels of required communication, but above all 2) standardize and automatize the required communications between parties. For fishers, for example, two manual communications per fishing trip appears acceptable.

Quality Assurance

Wageningen Marine Research utilises an ISO 9001:2015 certified quality management system. The organisation has been certified since 27 February 2001. The certification was issued by DNV.

References

Bærum KM, Anker-Nilssen T, Christensen-Dalsgaard S, Fangel K, Williams T, Vølstad JH (2019). Spatial and temporal variations in seabird bycatch: Incidental bycatch in the Norwegian coastal gillnet fishery. PLoS ONE 14(3): e0212786. https://doi.org/10.1371/journal.pone.0212786

Belcari, Paola & Sartor, Paolo & Sánchez, Pilar & Demestre, M. & Tsangridis, Alexis & Leontarakis, Panos & Lefkaditou, Evgenia & Papaconstantinou, Constantinos. (2002). Exploitation patterns of the cuttlefish, Sepia officinalis (Cephalopoda, Sepiidae), in the Mediterranean Sea. Bulletin of Marine Science. 71. 187-196.

Bergès, B.J.P., I. van der Knaap, O.A. van Keeken, J. Reubens, H.V. Winter (2024).Strong site fidelity, residency, and local behaviour of Atlantic cod (Gadus morhua) at two types of artificial reefs in an offshore wind farm. Royal Society Open Science submitted

Blew J, Diederichs A, Grünkorn T, Hoffmann M & Nehls G. (2006). Investigations of the bird collision risk and the responses of harbour porpoises in the offshore wind farms at Horns Rev, North Sea and Nysted, Baltic Sea, in Denmark. Status report 2005 to the Environmental Group. Hamburg, BioConsult SH.

Bos OG, Coolen JWP, van der Wal JT (2019). Biogene riffen in de Noordzee: actuele en potentiële verspreiding van rifvormende schelpdieren en wormen. Wageningen marine research rapport C058/19. https://doi.org/10.18174/494566

Brevé, N.W.P., Winter, H.V., Van Overzee, H.M.J., Farrell, E.D. and Walker, P.A. (2016), Seasonal migration of the starry smooth-hound shark Mustelus asterias as revealed from tag-recapture data of an angler-led tagging programme. J Fish Biol, 89: 1158-1177. https://doi.org/10.1111/jfb.12994

Brownell, R. L. Jr., Reeves, R. R., Read, A. J., Smith, B. D., Thomas, P. O., Ralls, K., et al. (2019). Bycatch in gillnet fisheries threatens critically endangered small cetaceans and other aquatic megafauna. Endang. Species Res. 40, 285–296. doi: 10.3354/esr00994

Cosgrove, R., Gosch, M., Reid, D.G., Sheridan, M., Chopin, N., Jessopp, M., Cronin, M.A. (2016) Seal bycatch in gillnet and entangling net fisheries in Irish waters. Fisheries Research 183: 192-199. DOI:10.1016/j.fishres.2016.06.007

Couperus, A.S. (2018a). Annual Report on the Implementation of Council Regulation (Ec) No 812/2004 2016. CVO report 18.008. https://edepot.wur.nl/450585

Couperus, A. S. (2018b). Annual report on the implementation of Council Regulation (EC) No 812/2004 2017. (CVO report; No. 18.019). Centre for Fishery Research (CVO). https://doi.org/10.18174/464120

Couperus, A. S. (2019). Annual report on the implementation of Council Regulation (EC) No 812/2004 2018. (CVO report; No. 19.021). Centre for Fishery Research (CVO). https://doi.org/10.18174/509868

Couperus, A. S. (2020). Report on incidental bycatches in Dutch pelagic fishery – 2019. (CVO report; = No.20.029). Stichting Wageningen Research, Centre for Fisheries Research (CVO). https://doi.org/10.18174/536967

Cramer R., Korving A., van der Tuin E. (2015). Project Vissen voor de Wind, Eindrapport. Ursa Major Services BV/CPO Nederlandse Vissersbond U.A.. Europees Visserijfonds 4600010913291.

Degraer S., Carey D.A., Coolen J.W.P., Hutchison Z.L., Kerckhof F., Rumes B., Vanaverbeke J. (2020). Offshore wind farm artificial reefs affect ecosystem structure and functioning: a synthesis. Oceanography 33(4):48–57, https://doi.org/10.5670/oceanog.2020.405.

Deltares, Site Studies Wind Farm Zone Borssele; Metocean study for the Borssele Wind Farm Zone Site II. January 2015.

Den Ouden B., Kerkhoven J., Warnaars J., Terwel R., Coenen M., Verboon T., Tiihonen T., Koot A. (2020). Klimaatneutrale energiescenario's 2050. Scenariostudie ten behoeve van de integrale infrastructuurverkenning 2030-2050.

Desender, M., Santos, A.R. (2023). Common sole (Solea solea) in Lyme bay. Cefas report p.44

Fahy Edward, Jim Carroll, Aisling Smith, Sinead Murphy, Sarah Clarke (2008). Ireland's velvet crab (Necora Puber (L.)) pot fishery. Proceedings of the Royal Irish Academy 108B: 157-175.

FAO CECAF (2007). FAO CECAF Scientific Sub- Committee. CECAF Scientific advice 2007. Cuttlefish - Morocco, Mauritania Senegal and Gambia. FIRMS Reports. In: Fisheries and Resources Monitoring System (FIRMS) [online]. Rome. Updated . [Cited 7 April 2024]. https://firms.fao.org/firms/resource/13485/en

Garthe, S., Camphuysen, K.C.J. & Furness, R.W. (1996). Amounts of discards by commercial fisheries and their significance as food for seabirds in the North Sea. Marine ecology progress series 136, 1- 11

Hastie Lee, Graham Pierce, Cristina Pita, Mafalda Viana, Jennifer Smith, Sansanee Wangvoralak (2009) Squid Fishing in UK Waters. School of Biological Sciences. University of Aberdeen

Hedgärde, M., Berg, C. W., Kindt-Larsen, L., Lunneryd, S. G., & Königson, S. (2016). Explaining the catch efficiency of different cod pots using underwater video to observe cod entry and exit behaviour. The Journal of Ocean Technology, 11: 67-90.

Huisman H. & Koldenhof Y. (2021) FSA Routing Baltic. MARIN, 32091-1-MO-rev0.2.

Humborstad Odd-Børre, Anne Christine Utne-Palm, Michael Breen, Svein Løkkeborg, Artificial light in baited pots substantially increases the catch of cod (Gadus morhua) by attracting active bait, krill (Thysanoessa inermis). ICES Journal of Marine Science, Volume 75, Issue 6, November-December 2018, Pages 2257–2264. https://doi.org/10.1093/icesjms/fsy099

ICES (2005). Report of the study group on the biology and life history of crabs (SGCRAB), 9–11 May 2005, Galway, Ireland. ICES CM 2005/G:10. Available at http://www.ices.dk/sites/pub/CM%20Doccuments/2005/G/SGCRAB05.pdf

ICES (2017). Report of the Working Group on Elasmobranchs (2017), 31 May-7 June 2017, Lisbon, Portugal. ICES CM 2017/ACOM:16. 1018 pp.

ICES (2023a). Working Group on the Biology and Life History of Crabs (WGCRAB; outputs from 2020–2022 meetings). ICES Scientific Reports. 5:110. 123 pp. https://doi.org/10.17895/ices.pub.24720936

ICES (2023b). ICES-FAO Working Group on Fishing Technology and Fish Behaviour (WGFTFB). ICES Scientific Reports. 5:83. 317 pp. https://doi.org/10.17895/ices.pub.24080889

ICES (2023c). Lesser spotted dogfish (Scyliorhinus canicula) in Subarea 4 and divisions 3.a and 7.d (North Sea, Skagerrak and Kattegat, eastern English Channel). ICES Advice: Recurrent Advice. Report. https://doi.org/10.17895/ices.advice.21858426.v1

International Maritime Organisation (IMO) (2018) Revised guidelines for formal safety assessment (FSA) for use in the IMO rule-making process. IMO, MSC-MEPC.2/Circ.12/Rev.2.

Klinge, M. (2008) Ecologische inpasbaarheid staand want visserij kustwateren (exclusief Noordzeekustzone) 4 Onderzoek naar bijvangst watervogels en zeezoogdieren. DDT12441/rijm3/026.

Königson S. J. , Fredriksson R. E., Lunneryd S.-G., Strömberg P., Bergström U. M. 2015. Cod pots in a Baltic fishery: are they efficient and what affects their efficiency? ICES Journal of Marine Science, 72: 1545–1554.

Königson Sara, Naddafi Rahmat, Lunneryd Sven-Gunnar, Bryhn Andreas C., Macleod Kelly, Ljungberg Peter (2022). Effects of fishery and environmental factors on a novel multispecies pot targeting European lobster (Homarus gammarus), Atlantic cod (Gadus morhua) and edible crab (Cancer pagurus). Frontiers in Marine Science 9: 1-16 DOI=10.3389/fmars.2022.985431

Leopold M., Van Bemmelen R., Zuur A. (2012). Responses of Local Birds to the Offshore Wind Farms PAWP and OWEZ off the Dutch mainland coast. IMARES Report C151/12

Lewison R.L., Crowder, L.B., Wallace, B.P., Moore, J.E., Cox, T., Zydelis, R., McDonald, S., DiMatteo, A., Dunn, D.C., Kot, C.Y., Bjorkland, R., Kelez, S., Soykan, C., Stewart, K.R., Sims, M., Boustany, A., Read, A.J., Halpin, P., Nichols, W.J., Safina, C. (2014). Global patterns of marine mammal, seabird, and sea turtle bycatch reveal taxa-specific and cumulative megafauna hotspots.

Proceedings of the National Academy of Sciences of the United States of America. 111. 10.1073/pnas.1318960111.

Lindeboom H.J., Kouwenhoven H.J., Bergman M.J.N., Bouma S., Brasseur S., Daan R., Fijn R.C., de Haan D., Dirksen S., van Hal R., Hille Ris Lambers R., ter Hofstede R., Krijgsveld K.L., Leopold M., Scheidat M. (2011). Short-term ecological effects of an offshore wind farm in the Dutch coastal zone; a compilation doi:10.1088/1748-9326/6/3/035101

Marlen B., van., Vandenberghe C., van Craeynest C., Korving A., Cramer, R., Reker, E., 2011. VIP project Passieve Visserij Ontwikkeling. IMARES (is nu Wageningen Marine Research) Rapportnummer C117/11. 86 blz. https://edepot.wur.nl/356076

Mavraki N., Degraer S., Moens T., Vanaverbeke J. (2020). Functional differences in trophic structure of offshore wind farm communities: A stable isotope study. Marine Environmental Research 157: 104868. ISSN 0141-1136.

Mavraki N., Degraer S., Vanaverbeke, J. (2021). Offshore wind farms and the attraction–production hypothesis: insights from a combination of stomach content and stable isotope analyses. Hydrobiologia 848: 1639–1657. https://doi.org/10.1007/s10750-021-04553-6

Meintzer P, Walsh P, Favaro B (2018) Comparing catch efficiency of five models of pot for use in a Newfoundland and Labrador cod fishery. PLOS ONE 13(6): e0199702.

Melli V, Riginella E, Nalon M, Mazzoldi C (2014) From Trap to Nursery. Mitigating the Impact of an Artisanal Fishery on Cuttlefish Offspring. PLoS ONE 9(2): e90542. doi:10.1371/journal.pone.0090542

Metocean Study; Hollandse Kust Wind Farm Zone; version September 2017. Project. ID RVO.nl: WOZ1600017; September 2017.

Metocean Study; Hollandse Kust (noord) Wind Farm Zone; version October 2019. Project. ID ROV.nl: WOZ2180106; September 2019.

Metocean Study; Hollandse Kust (west) Wind Farm Zone; version December 2020. Project. ID RVO: WOZ2180106; December 2020

Neitzel S.M., Jurrius L.H., Deetman B., Serraris J-J., Taal K., Rozemeijer M.J.C., de Graeff, P. (2023a). Stand van zaken kleinschalige, passieve visserij in windparken op zee: Een bundeling van bestaande kennis en een verkenning naar de mogelijkheden voor kleinschalige, passieve visserij in windparken. Wageningen Marine Research rapport, no. C055/23, Wageningen Marine Research, IJmuiden. https://doi.org/10.18174/637589

Neitzel, S.M., Serraris, J.W., de Graeff, P., Deetman, B., Taal, K. (2023b). Field report passive fishing in offshore wind farm Borssele. https://doi.org/10.18174/642358

Nguyen Khanh Q., Corey J. Morris, 2022. Fishing for Atlantic cod (Gadus morhua) with pots and gillnets: A catch comparison study along the southeast coast of Labrador. Aquaculture and Fisheries 7: 433-440, https://doi.org/10.1016/j.aaf.2021.05.006.

North Sea Farm Foundation (NSF) (2020) Multi-use Procedure Risk Register. NSF, Revision01.Olsen, Leonore (2014). Baited pots as an alternative fishing gear in the Norwegian fishery for Atlantic cod (Gadus morhua). Master thesis Agriculture and fishery disciplines. The Arctic University of Norway. FSK-3961

Petetta A, Vasapollo C, Virgili M, Bargione G, Lucchetti A. (2020). Pots vs trammel nets: a catch comparison study in a Mediterranean small-scale fishery. PeerJ. Jul 17;8:e9287. doi: 10.7717/peerj.9287.

Pereira Fábio, Paulo Vasconcelos, Ana Moreno, Miguel B. Gaspar (2019). Catches of Sepia officinalis in the small-scale cuttlefish trap fishery off the Algarve coast (southern Portugal). Fisheries Research 214: 117-125. https://doi.org/10.1016/j.fishres.2019.01.022

Polanen Petel, T. van, Geelhoed S., Meesters E. (2012). Harbour porpoise occurrence in relation to the Prinses Amalia windpark Report / IMARES C177/10.

Presencia C.E. (2016) Risk analysis of maintenance ship collisions with offshore windturbines. International Journal of Sustainable Energy 37:6, 576-596, Taylor & Francis.

Rasenberg M., Smith S., Turenhout M., Taal, K. (2015) Vissen in windparken: inventarisatie van de (on)mogelijkheden. Imares & LEI, Rapport C030/15.

Read, A. J., Drinker, P., and Northridge, S. (2006). Bycatch of marine mammals in US and global fisheries. Conserv. Biol. 20, 163–169. doi: 10.1111/j.1523-1739.2006.00338.x

Reeves, R. R., McClellan, K., and Werner, T. B. (2013). Marine mammal bycatch in gillnet and other entangling net fisheries, 1990 to 2011. Endang. Species Res. 20, 71–97. doi: 10.3354/esr00481

Richardson H., S. Durrance, R. Mitchell (2018). Management recommendations for English non-quota fisheries: Common cuttlefish. MRAG Ltd report. Blue Marine Foundation Final Report (rev 1.1) 19th September 2018

Rijnsdorp, A.D., Hiddink, J.G., van Denderen, P.D., Hintzen, N.T., Eigaard, O.R., Valanko, S., Bastardie, F., Bolam, S.G., Boulcott, P., Egekvist, J., Garcia, C., van Hoey, G., Jonsson, P., Laffargue, P., Nielsen, J.R., Piet, G.J., Sköld, M., van Kooten, T., 2020. Different bottom trawl fisheries have a differential impact on the status of the North Sea seafloor habitats. ICES Journal of Marine Science 77(5), 1772-1786. [fsaa050]. https://doi.org/10.1093/icesjms/fsaa050

Röckmann C., van der Lelij AC., van Duren L., Steenbergen J. (2015). VisRisc – risicoschatting medegebruik visserij in windparken. IMARES (is nu Wageningen Marine Research) rapportnummer C138/15 https://library.wur.nl/WebQuery/wurpubs/fulltext/360260.

Rozemeijer M.J.C., D. Slijkerman, O.G. Bos, C. Röckmann, A.J. Paijmans, P. Kamermans (2016). Bouwen met Noordzee-natuur; Uitwerking Gebiedsagenda Noordzee 2050. Wageningen Marine Research Wageningen UR (University & Research centre), Wageningen Marine Research rapport C024/17. 48 blz.

Rozemeijer M.J.C., van de Wolfshaar K.E. (2019). Desktop study on autecology and productivity of European lobster (Homarus gammarus, L) in offshore wind farms. Wageningen Marine Research report C109/18. KB-30: Resource Use Efficiency (project no. KB-30-002-011).

Rozemeijer M.J.C, Chun C., Cramer R., A. Korving, Meeldijk C. (2021). Assessing the stability and mobilisation of crab-pot-strings anchored with Bruce anchors under different marine conditions. With information of catchment of brown crab (Cancer pagurus), European lobster (Homarus iocons) and other species. Wageningen Marine Research report C107/21 https://doi.org/10.18174/560823

Rozemeijer M.J.C, R. Cramer, B. Deetman, A. Korving (2022). An overview and conclusion concerning the use of Bruce anchors to anchor crab-pot-strings in Prinses Amalia Offshore Windpark. Wageningen Marine Research Report C051/22. https://doi.org/10.18174/576750

Rozemeijer M.J.C, C. Chen, van der Wal J.T. (2023a). Passive fisheries on brown crab, velvet swimming crab and European lobster in Prinses Amalia Wind Park in the North Sea, Netherlands. Establishing a form of co-use fisheries in an Offshore Wind Farm by the project Win-Wind. Wageningen Marine Research report C078/23.

Rozemeijer M.J.C, Chen C., van der Wal J-T. (2023b). Experimental pot fishing on brown crab and European lobster in offshore wind farm Borssele II. The first passive fishing as a form of multi-use in an offshore wind farm in the Netherlands. WUR Wageningen Marine Research Report C052/23.

Russell D.J.F., Brasseur S.M.J.M., Thompson D., Hastie G.D., Janik V.M., Aarts G., McClintock B.T., Matthiopoulos J., Moss S.E.W., McConnell B. (2014). Marine mammals trace anthropogenic structures at sea. Current Biology, 24, R638-R639.

Scheidat, M., Couperus, B., Siemensma, M. (2018) Electronic monitoring of incidental bycatch of harbour porpoise (Phocoena phocoena) in the Dutch bottom set gillnet fishery (September 2013 to March 2017).

Scheidat M., Aarts G., Bakker A., Brasseur S., Carstensen J., van Leeuwen P.W., Leopold M., van Polanen Petel T., Reijnders P., Teilmann J., Tougaard J., Verdaat H. (2009). Assessment of the Effects of the Offshore Wind Farm Egmond aan Zee (OWEZ) for Harbour Porpoise (comparison T0 and T1). IMARES Texel

Shester G.G., F. Micheli (2011). Conservation challenges for small-scale fisheries: bycatch and habitat impacts of traps and gillnets. Biol. Conserv., 144 pp. 1673-1681, 10.1016/j.biocon.2011.02.023

Schipper M. & Nap A. (2023) Maritieme risico's omtrent medegebruik windparken op zee. MARIN 34486 1-MO-rev1.0.

Small Jamie (2021a). Starry Smooth-hound (Mustelus asterias). IFCA profile Version 1.2 19/05/2021.

Small Jamie (2021b). Lesser spotted dogfish (Scyliorhinus canicula). IFCA Profile 1.2 Version 16-03-2021.

Steenbergen J., Neitzel S.M., Molenaar P. (2020) Visserij in windparken. Een verkenning van de mogelijkheden. Wageningen Marine Research (WMR), BO43-23.03-002.

Suuronen Petri, Francis Chopin, Christopher Glass, Svein Løkkeborg, Yoshiki Matsushita, Dante Queirolo, Dominic Rihan (2012). Low impact and fuel efficient fishing—Looking beyond the horizon. Fisheries Research 119–120: 135-146. https://doi.org/10.1016/j.fishres.2011.12.009.

Tougaard J., Carstensen J., Bech, N.I., Teilmann J. (2006a). Final report on the effect of Nysted Offshore Wind Farm on harbour porpoises. Annual report to EnergiE2. Roskilde, Denmark, NERI. Alverson DL, Larkin P. Fisheries science and management; Century 21. In: Proceedings of the World Fisheries Congress, Athens, Greece, 1992; 3-8.

van der Knaap, I., Slabbekoorn, H., Winter, H.V., Moens, T., Reubens, J. (2021). Evaluating receiver contributions to acoustic positional telemetry: a case study on Atlantic cod around wind turbines in the North Sea. Anim Biotelemetry 9, 14. https://doi.org/10.1186/s40317-021-00238-y

van der Want G.J. (2021) Risk Mitigation Multi-Use Offshore Wind Farms. MARIN, 32934-1-MO-rev.2.

van Rooij J.H.A. (2020) Investigation of ship impact against wind turbine foundations in the Dutch part of the North Sea. HVR engineering, 081.R030.M006.

Verhaeghe D. & Polet H. (2012) Eindrapport "Studie en demonstratie van geselecteerde passieve visserijmethodes in de Noordzee en de Keltische Zee". Instituut voor Landbouw- en Visserijonderzoek (ILVO), TECH/2012/02.

Wilhelm, G. 1995 Contribution a l'etude de l'etrille Necora puber dans le Mor-Braz: donnees halieutiques, biologiques et pathologiques. Unpublished PhD Thesis, University of Rennes, France.

Wilson A. T. (1985). A study of squid and it's potentials in UK waters. Sea Fish Industry Authority Industrial Development Unit. Internal report no. 1235.

Justification

Report C032/24
Project Number: 4318100426

The scientific quality of this report has been peer reviewed by two colleague scientists and a member of the Management Team of Wageningen Marine Research

Approved: Wouter Suykerbuyk
Reviewer 1 (Wageningen Marine Research), researcher

Signature: DocuSigned by:
Wouter Suykerbuyk
0E83DC63EEA147C...

Date: 27 May 2024

Approved: Hans van Oostenbrugge
Reviewer 2 (Wageningen Economic Research), researcher

Signature: DocuSigned by:
D71337419F12427...

Date: 27 May 2024

Approved: Dr. A.M. Mouissie
Business Manager Projects

Signature: DocuSigned by:
291E7A4CA7DB419...

Date: 27 May 2024

Appendix 1 – Task Risk Assessment

				A	B	C	D	E
		Gevolg beoordeling (Impact)		frequentie / Kans (Probability of occurrence)				
				On waarschijnlijk	Nauwelijks	Af en toe	Regelmatig	Vaak
Qualitative description		Mensen	milieu en economie	A. Nauwelijks (< 1/20 jaar)	B. Nauwelijks (1 x per 20 jaar - 1 x per 5 jaar)	C. af en toe 1 x per 5 - 1 x per 2 jaar	D. regelmatig 1 x per 2 jaar - 5 keer per jaar	E. Vaak 5-50 keer perjaar
Rank		Defenitie		A	B	C	D	E
5	Catastrofaal	meer dan 10 doden of vermisten	Grote impact	5	10	12.5	15	20
4	Ernstig	meer dan 10 ernstig gewonden minder dan 10 doden of vermisten	significate impact	4	8	10	12	16
3	Matig	geen doden minder dan 10 ernstig gewonden	Lokale verstoring	3	6	7.5	9	12
2	Gering	overwegend licht gewonden	kort durend effect	2	4	5	6	8
1	Verwaarloos baar	geen slachtoffers	geen effect	1	2	2.5	3	4

Table A4.1 -Description of categories of probability, severity and risk

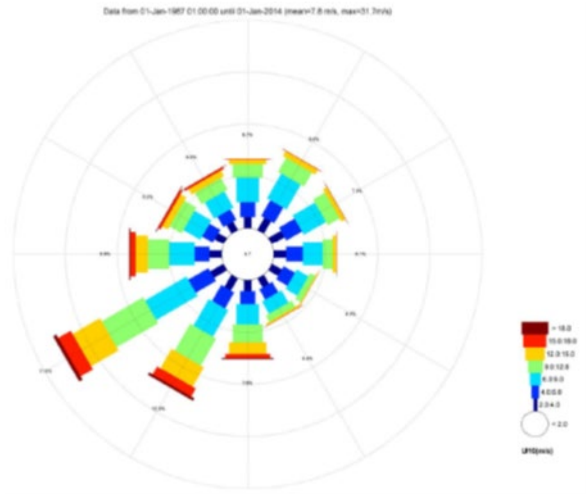
PROBABILITY OF OCCURRENCE	SEVERITY	RISK
A May never occur	**1** Negligible	Low = No immediate action required, proceed with care
B May occur	**2** Moderate	
C Might occur	**3** Serious	Medium = Review & implement preventative measures
D May occur infrequently	**4** Major	
E Will probably occur	**5** Catastrophic	High = Unacceptable. Find alternative method

Table A4.2 - Detailing categories of severity to concrete measurable criteria			
SEVERITY	HUMAN	ENVIRONMENT	MATERIALS / EQUIPMENT
NEGLIGIBLE	No or minor injury.	No or insignificant clean up naturally dispersed	No or insignificant damage to equipment or materials
MODERATE	One lost time accident, with no loss of part of the body, or prolonged disability	Clean up requires less than 1day	Damage to equipment or materials with lost time of less than 1 day production damage < 1 Mln
SERIOUS	Multiple lost time accidents. One injury with loss of part of body, or with permanent disability	Clean up requires approx 1 week	Significant damage to local area or essential equipment stops the work for 1 day 1Mln < damage < 15 Mln
MAJOR	One fatal injury. Several victims with loss of part of the body, or with permanent disability	Clean up requires approx 1 month	Significant damage to local area or essential equipment which stops the work until a later date 15Mln < damage < 100 Mln
CATASTROPHIC	Several fatal injuries	Clean up requires more than 1 month	Extensive damage to local area or essential equipment which stops the work totally for multiple days damage > 100 Mln

			Initial risk				Residual risk			
Aspect / Activity	Possible hazards	Possible consequences	Probability	Effect	Risk	Mitigating measures	Probability	Effect	Risk	Responsible person
			A - E	1 - 5			A - E	1 - 5		
GEAR / ANCHORING	Currents/waves(storm) cause gear to move and anchors to drag	Cable damage	A	4	4	Use non-seize anchor Place gear outside maintenance zone, Back-off cable to pull anchor backwards from cable Test anchors with dahns in various conditions (outside OWF) to determine holding capacity Insurance of the captain of the vessel	A	4	4	Captain of fishing vessel (FV) & HSSE manager
GEAR / ANCHORING	Storm conditions forecasted (high waves, strong currents)	Collision of strings with monopile or cable	B	3	6	Field tests have shown critical conditions. Strings are not in colliding course with monopiles.	A	3	3	Captain of FV
GEAR / ANCHORING	Blocked boat landing due to string position	No access to boat landing leading to possible delays for maintenance. Entanglement of CTV	B	2	4	Place gear outside maintenance & manoeuvring zone Selected specific and uniform positions which prevents blocking. In case of emergency, fast response time (max 1 day) to remove fish string	A	2	2	Captain of FV
GEAR / ANCHORING	Anchor is released on top of the cable	Cable damage	A	4	4	Never release gear in maintance zones.	A	4	4	Captain of FV
GEAR / ANCHORING	Currents/waves(/storm) cause dahn to disconnect	Fisserman is obliged to retrieve net by drag anchor.	D	1	3	Fishing gear remains in position when dahns are lost. Proper anchoring of fishing gear with leeward/ NE approx 200m margin to maintenance zone.	D	1	3	
GEAR / ANCHORING	Currents/waves(/storm) cause gear to move and get lost in windpark	Fisserman is obliged to retrieve net. This might be conflicting with restricted areas/ maintenance zones.	C	2	5	Fishing gear remains in position when dahns are lost. Proper anchoring of fishing gear with leeward/ NE approx 200m margin to maintenance zone.	C	2	5	
GEAR / ANCHORING	Currents/waves(/storm) cause gear to move and entangle with monopile	Fissherman is obliged to retrieve net. Risk of entanglement by divers during inpsections and operations.	C	2	5	Proper anchoring of fishing gear with leeward/ NE approx 200m margin to maintenance zone.	C	2	5	
GEAR / ANCHORING	Currents/waves(/storm) cause gear to move and entangle with unburried infield cable	Fisserman is obliged to retrieve net. This might be conflicting with restricted areas/ maintenance zones. Use of drag anchor for recovering might damage cable.	B	4	8	Proper anchoring of fishing gear with leeward/ NE approx 200m margin to maintenance zone.	C	2	5	
GEAR / ANCHORING	Anchor lost when retrieving strings (obliged to report)	removal and associated costs	C	2	5	Back-off cable to pull anchor from cable Pull back gear at end range Bft 6 Cable and ropes maintenace	B	2	4	Captain of FV
GEAR / ANCHORING	Anchor does not hold due deployment on scour/anchor design	Strings are moving incl. anchors	C	2	5	Test effectiveness of non-seize anchor Use non-seize anchor Place strings outside safety zone	B	2	4	Captain of FV / Project team /researchers
GEAR / ANCHORING	location determination of strings/nets	Loss of accuracy	C	1	2.5	1. DGPS positioning / (GPS back up) determination of strings to determine as is position. 2. Weather limitation < *sign wave height ?ms* 3. calculation of the placement of cages (calculation sum in operations plan) 4. prior storm conditions based on the field test results removal of cages or strengthen the cage with additional weight (validated data 2.5knots /1.3 meters per second current with 7btft, cages stable)	B	1	2	Captain of FV
OPERATIONS	Deploying strings/nets/lines with unfavourable tide	Vessel entering maintenance zone	D	1	3		D	1	3	Captain of FV
OPERATIONS	Navigational error	Collision of fishing vessel with monopile	C	2	5	Keep a proper lookout / seamanship AIS / Radar / GPS / Up-to-date nautical charts	B	2	4	Captain of FV
OPERATIONS	Communication equipment failure	No communication possible in case of an emergency	C	2	5	Operations are communicated to OWF and Coastguard 5 day ahead, at port departure and at entry en departure of OWF. Multiple means of commincation on board. PLB / EPIRB for emergency notification. OWF MOC keeps a 24/7 monitoring of the area	B	1	2	Captain of FV
OPERATIONS	Electrical failure	Effect on propulsion / navigational and communication equipment failure	C	2	5	Proper vessel maintenance Redundancy equiment Back-up battery system for critical equipment	B	2	4	Captain of FV
OPERATIONS	Propulsion failure	Loss of stability due to an unfavourable course	C	2	5	Deploy anchor or floating anchor Vessel maintenance Planning of operations in appropriate weather window	B	2	4	Captain of FV
OPERATIONS	Propulsion failure	Collision of fishing vessel with monopile	C	2	5	Deploy anchor or floating anchor Vessel maintenence Planning of operations in appropriate weather window	B	2	4	Captain of FV
OPERATIONS	Anchoring in the park to keep position during line fishing	Damage cables	A	4	4	Use of small anchors. Deploy anchor outside the maintenence area's of cables and windturbines.	A	4	4	Captain of FV
OPERATIONS	Anchoring in the park because of emergency situation	Damage cables	A	4	4		A	4	4	Eneco design, Captain of FV
SIMOPS	Ship (passage/CTV) collides with fisheries equipment, entanglement of strings in propeller	Vessels drag equipment around/damage to vessel	B	3	6	Dahns are attached in such way that ropes go straight down and cannot get entangled Designated and known locations	A	3	3	Captain of FV & HSSE manager
SIMOPS	Buoys and subsurface ropes present	Entanglement by CTVs leading to damage and operational delay	B	3	6	Standardization of positioning of strings and buoys (*specific side of WTG?*). No floating lines. Safety zone defined for critical part CTW landing zone. Fixed positions of buoys known up forehand by CTV captain. Dahns with flags, reflection tapes and lights regular report during working operations about buoy locations. Final reporting after each working day. During fishing activities fishing vessel has VHF listening watch insurance to be determined who will pay for damages to CTV in case rope will caught the props.	A	2	2	Captain of FV, CTV captains
SIMOPS	Buoys and subsurface ropes present	Entanglement by recreational vessels resulting in vessel stuck at location	A	1	1	Selected area is excluded recreational vessels. Fixed positions of buoys known up forehand by captain of recreational vessel. Dahns with flags, reflection tapes and lights. Presence of buoys and subsurface ropes regularly by VHF channel coast guard	A	1	1	Captain of FV, Coastguard, Captain of recreational vessel
SIMOPS	SIMOPS CTV	Campaign delayed by presence of fishing strings	D	2	6	SIMOPS with CTV to be addressed (to determine what the interaction will be)	A	3	3	Risk manager
SIMOPS	Third party campaigns (jack up intervention)	Campaign delayed by presence of fishing strings	C	3	7.5	SIMOPS to be addressed	D	1	3	OWF O&M manager & fishermen
OTHER	Theft/ sabotage of cages/nets	Loss of capital and scientific data	B	1	2	Commitment of fishermen community it is only possible with dedicated fishing gear to haul the fishing strings. Field surveillance during daylight by CTV's	A	1	1	Fishermen

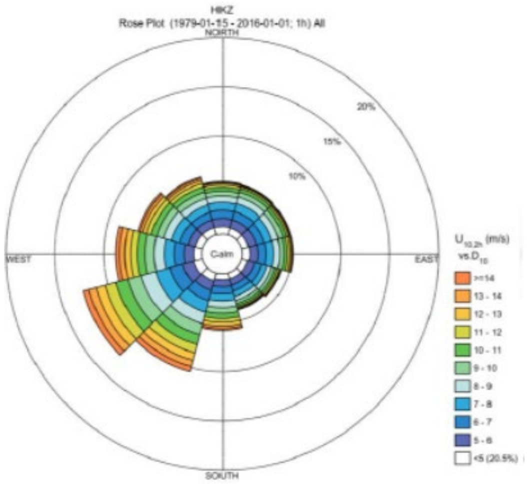
Appendix 2 – Wind, wave and current plots

Figure A2.1 *- Annual wind rose plots from metocean reports of Borssele II, HKZ, HKN and HKW.*



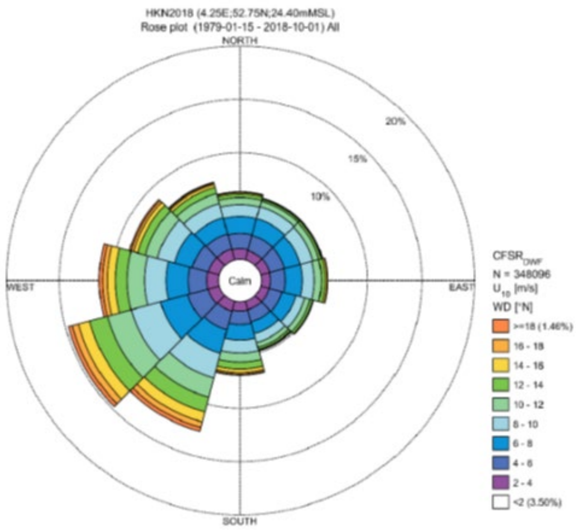
Borssele

Average annual wind rose at Borssele II at 10mMSL (source: Deltares (2015), Figure 3.17)



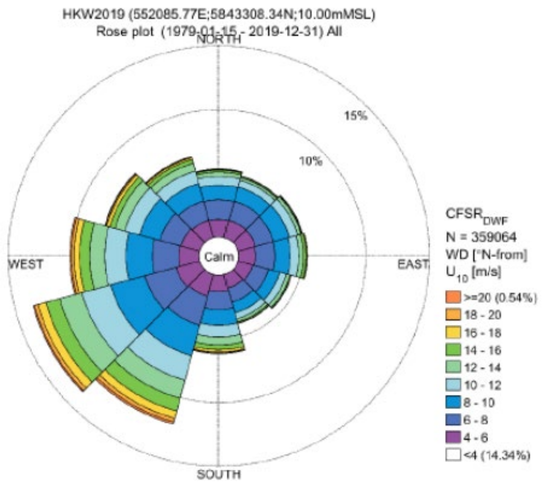
HKZ

Average annual wind rose at HKZ at 10mMSL (source: Metocean Study; HKWFZ (2017), Figure 9.2)



HKN

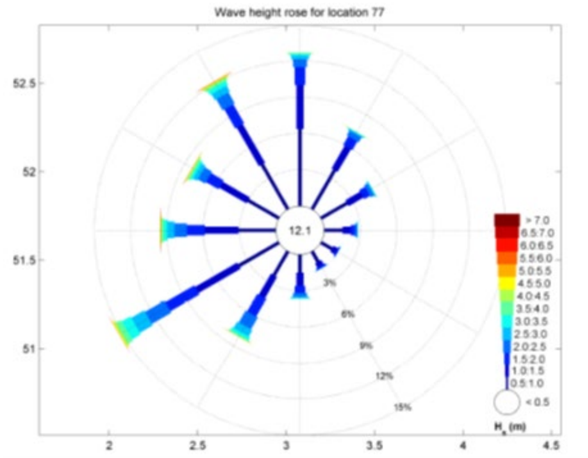
Average annual wind rose at HKN2018 at 10mMSL (source: Metocean Study; HK(N)WFZ (2019), Figure 8.2)



HKW

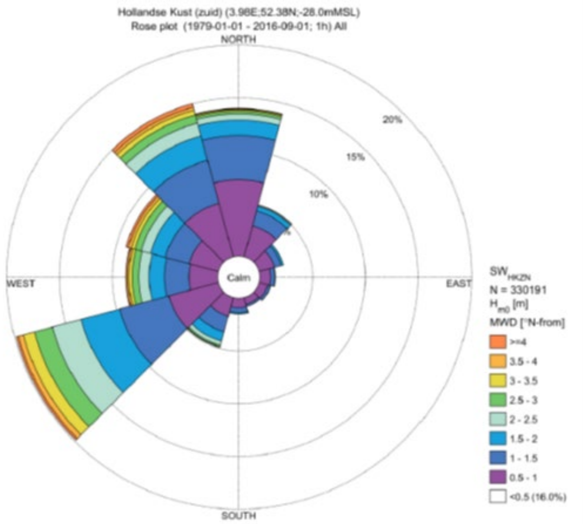
Average annual wind rose at HKW2019 at 10mMSL (source: Metocean Study; HK(W)WFZ (2020), Figure 8.2)

***Figure A2.2** - Annual wave rose plots from metocean reports of Borssele II, HKZ, HKN and HKW.*



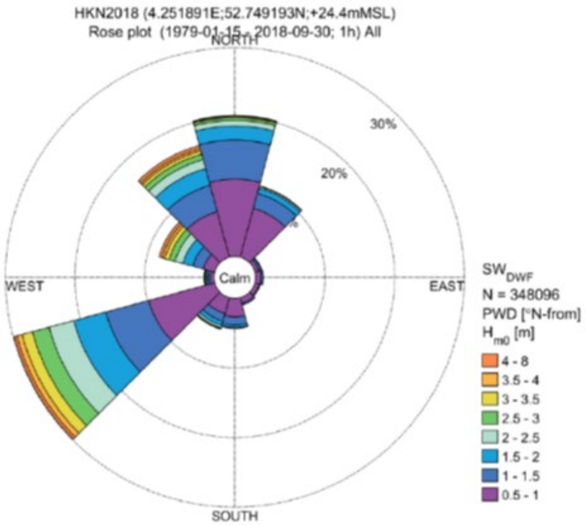
Borssele

Annual wave rose at Borssele II (source: Deltares, 2015, Figure 4.5)



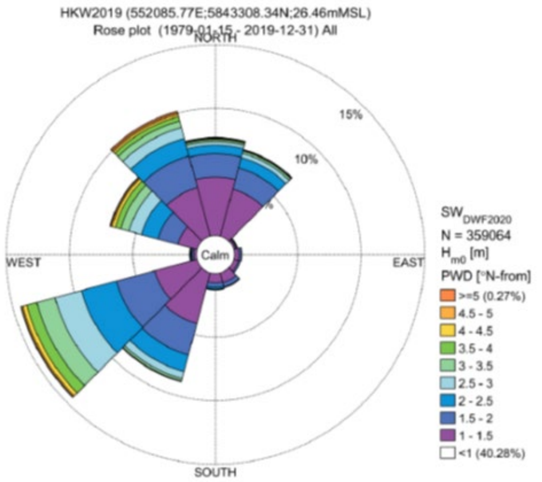
HKZ

Wave rose at HKZ for the period from 1980-01-01 to 2016-09-01 (source: Metocean Study; HKWFZ (2017), Figure 9.48)



HKN

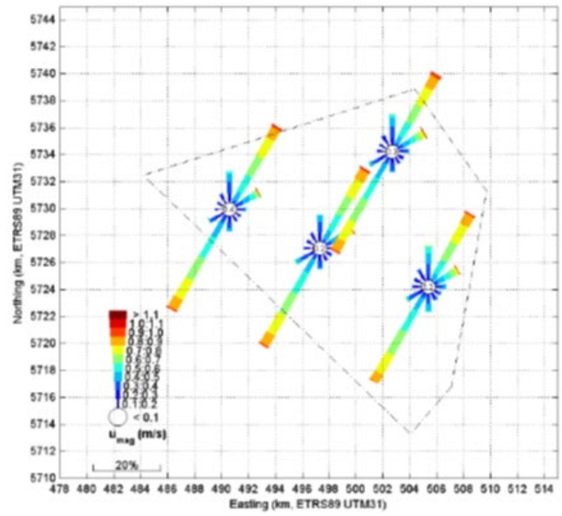
Wave rose at HKN for the period from 1979-01-15 to 2018-09-30 (source: Metocean Study; HK(N)WFZ (2019), Figure 8.54)



HKW

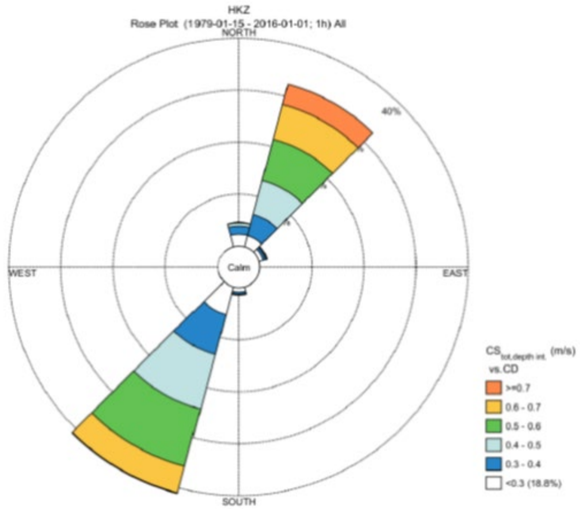
Wave rose at HKW for the period from 1979-01-15 to 2019-12-31 (source: Metocean Study; HK(W)WFZ (2020), Figure 8.50)

__Figure A2.3__ - Annual current rose plots from metocean reports of Borssele II, HKZ, HKN and HKW.



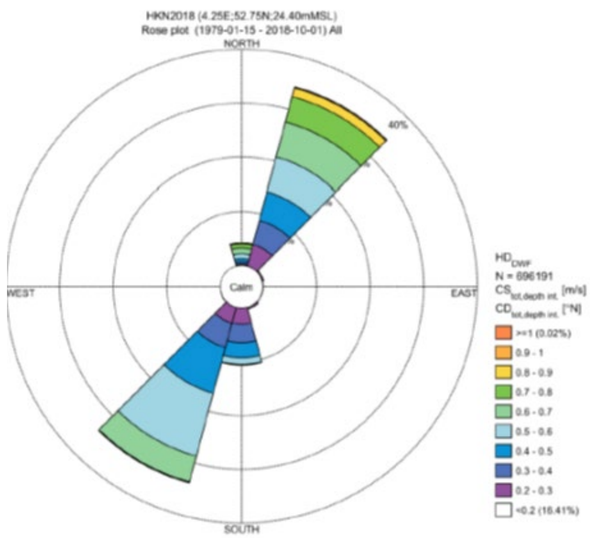
Borssele

Annual current roses in the BWFZ (source: Deltares, 2015, Figure 6.2)



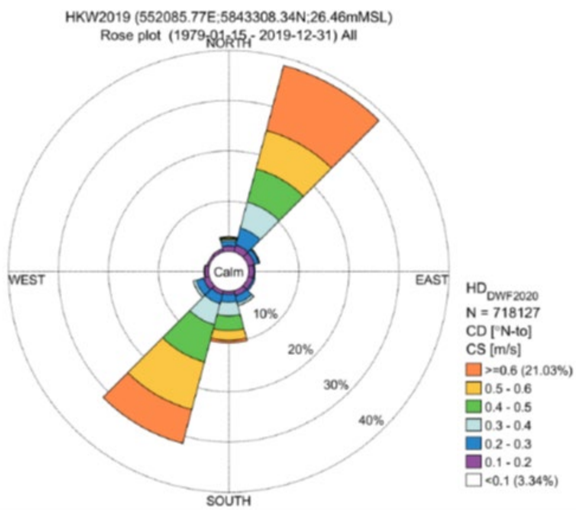
HKZ

Depth-integrated current roses (going to) at HKZ: total current (source: Metocean Study; HKWFZ (2017), Figure 8.39)



HKN

Depth-integrated current roses (going to) at HKN2018: total current (source: Metocean Study; HK(N)WFZ (2019), Figure 8.41)



HKW

Depth-averaged current roses (going to) at HKW2019: total current (source: Metocean Study; HK(W)WFZ (2020), Figure 8.37)

Appendix 3 – Species lists per gear

Table A3.1 *– Species caught while handline fishing in Borssele offshore wind farm.*

Handline (LHP)				
Scientific name	**English Name**	**Dutch Name**	**Minimum landing size (cm)**	**Species type**
Scomber scombrus	Atlantic mackerel	Makreel	30	Target species
Echiichthys vipera	Lesser weever	Kleine pieterman	N.A.	Non-landable
Trisopterus luscus	Bib	Steenbolk	N.A.	Non-landable
Merlangius merlangus	Whiting	Wijting	27	Landable
Trachurus trachurus	Horse mackerel	Horsmakreel	15	Landable
Chelidonichthys lucerna	Tub gurnard	Rode poon	N.A.	Landable

Table A3.2 *- Species caught while gillnetting in Borssele offshore wind farm.*

Gillnet (GNS)				
Scientific name	**English Name**	**Dutch Name**	**Minimum landing size (cm)**	**Species type**
Hyas araneus	Great spider crab	Gewone spinkrab	N.A.	Non-landable
Asterias rubens	Starfish	Zeester	N.A.	Non-landable
Necora puber	Velvet swimming crab	Fluwelen zwemkrab	6.5	Landable
Liocarcinus holsatus	Common swimming crab	Gewone zwemkrab	N.A.	Non-landable
Cancer pagurus	Brown crab	Noordzeekrab	13	Landable
Scomber scombrus	Atlantic mackerel	Makreel	30	Landable
Pleuronectes platessa	Plaice	Schol	27	Landable
Limanda limanda	Dab	Schar	N.A.	Landable
Mustelus mustelus	Starry smoothhound	Gladde haai	N.A.	Landable
Solea solea	Sole	Tong	24	Target species
Scyliorhinus canicula	Lesser spotted dogfish	Hondshaai	N.A.	Landable
Sepia officinalis	Common cuttlefish	Zeekat	N.A.	Landable
Taurulus bubalis	Sea scorpion	Groene zeedonderpad	N.A.	Non-landable
Platichthys flesus	Flounder	Bot	20	Landable
Merlangius merlangus	Whiting	Wijting	27	Landable
Trachurus trachurus	Horse mackerel	Horsmakreel	15	Landable
Chelidonichthys lucerna	Tub gurnard	Rode poon	N.A.	Landable
Maja squinado	Spinous spider crab	Maja	N.A.	Non-landable
Corystes cassivelaunus	Helmet crab	Helmkrab	N.A.	Non-landable
Scophthalmus rhombus	Brill	Griet	N.A.	Landable
Loligo vulgaris	European squid	Gewone pijlinktvis	N.A.	Landable
Gadus morhua	Atlantic cod	Kabeljauw	35	Landable
Clupea harengus	Herring	Haring	20	Landable
Macropodia rostrata	Long-legged spider crab	Hooiwagenkrab	N.A.	Non-landable
Dicentrarchus labrax	Seabass	Zeebaars	42	Landable

Callionymus lyra	Common dragonet	Pitvis	N.A.	Non-landable

Table A3.3 *- Species caught while fishing with pots in Borssele offshore wind farm.*

Pots (FPO)				
Scientific name	**English Name**	**Dutch Name**	**Minimum landing size (cm)**	**Species type**
Entelurus aequoreus	Snake pipefish	Adderzeenaald	N.A.	Non-landable
Cancer pagurus	Brown crab	Noordzeekrab	13	Landable
Liocarcinus holsatus	Common swimming crab	Gewone zwemkrab	N.A.	Non-landable
Necora puber	Velvet swimming crab	Fluwelen zwemkrab	N.A.	Landable
Asterias rubens	Starfish	Zeester	N.A.	Non-landable
Limanda limanda	Dab	Schar	N.A.	Landable
Trisopterus luscus	Bib	Steenbolk	N.A.	Non-landable
Sepia officinalis	Common cuttlefish	Zeekat	N.A.	Target species
Pagurus bernhardus	Bernhard's hermit crab	Gewone heremietkreeft	N.A.	Non-landable
Myoxocephalus scorpius	Bullrout	Gewone zeedonderpad	N.A.	Non-landable
Pleuronectes platessa	Plaice	Schol	27	Landable
Loligo vulgaris	European squid	Gewone pijlinktvis	N.A.	Target species
Liocarcinus depurator	Blue-leg swimming crab	Blauwpootzwemkrab	N.A.	Non-landable
Merlangius merlangus	Whiting	Wijting	27	Landable
Mullus surmuletus	Striped red mullet	Mul	N.A.	Landable
Aurelia aurita	Common jellyfish	Oorkwal	N.A.	Non-landable
Pholis gunnellus	Butterfish	Botervis	N.A.	Non-landable
Clupea harengus	Herring	Haring	20	Landable
Hyas araneus	Great spider crab	Gewone spinkrab	N.A.	Non-landable
Trachurus trachurus	Horse mackerel	Horsmakreel	15	Landable
Nephrops norvegicus	Norway lobster	Noorse kreeft	2.5	Landable
Maja squinado	Spinous spider crab	Maja	N.A.	Non-landable
Parablennius gattorugine	Tompot blenny	Gehoornde slijmvis	N.A.	Non-landable
Macropodia rostrata	Long-legged spider crab	Hooiwagenkrab	N.A.	Non-landable
Ciliata mustela	Five-bearded rockling	Vijfdradige meun	N.A.	Non-landable
Hippocampus guttulatus	Short-snouted seahorse	Kortsnuitzeepaardje	N.A.	Non-landable
Zoarces viviparus	Viviparous blenny	Puitaal	N.A.	Non-landable
Enchelyopus cimbrius	Four-bearded rockling	Vierdradige meun	N.A.	Non-landable
Scomber scombrus	Atlantic mackerel	Makreel	30	Landable
Liocarcinus navigator	Arch-fronted swimming crab	Gewimperde zwemkrab	N.A.	Non-landable

Table A3.4 *- Species caught while jigging in Borssele offshore wind farm.*

Jigging (LHM)				
Scientific name	**English Name**	**Dutch Name**	**Minimum landing size (cm)**	**Species type**
Scomber scombrus	Atlantic mackerel	Makreel	30	Target species
Merlangius merlangus	Whiting	Wijting	27	Landable
Loligo vulgaris	European squid	Gewone pijlinktvis	N.A.	Target species

Appendix 4 - Additional data on catches

A1.1 Handline fishing (LHP)

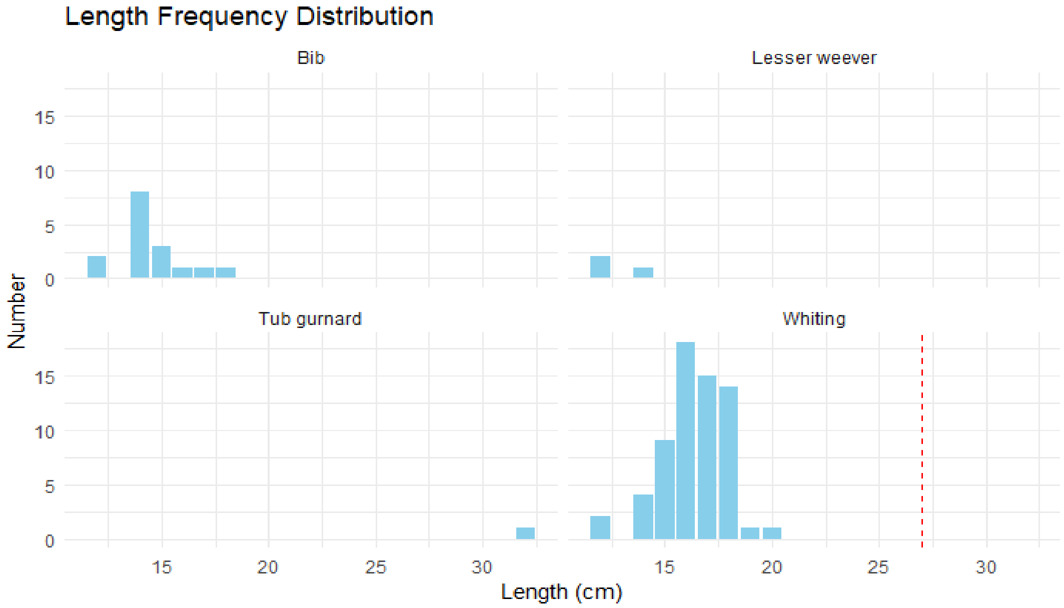


Figure A1.1 *– Length frequencies of other species caught while handline fishing.*

A1.2 Gillnet fishing (GNS)

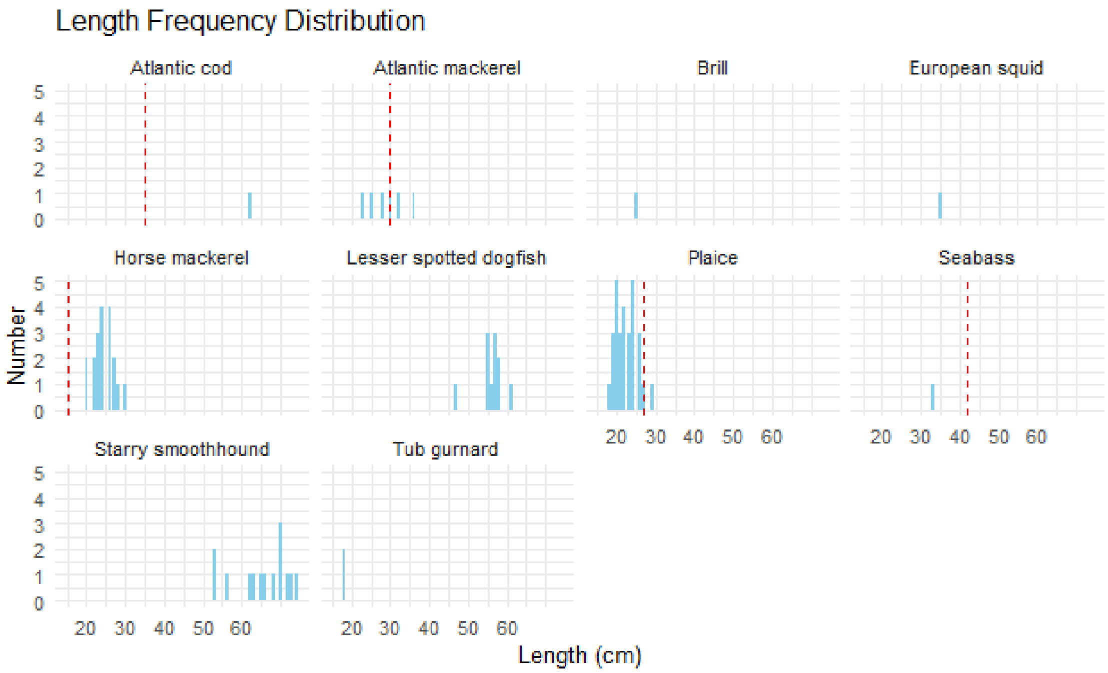


Figure A1.2 *– Length frequencies of other species caught while gillnet fishing.*

A1.3 Multi-species pots (FPO)

Sole pot

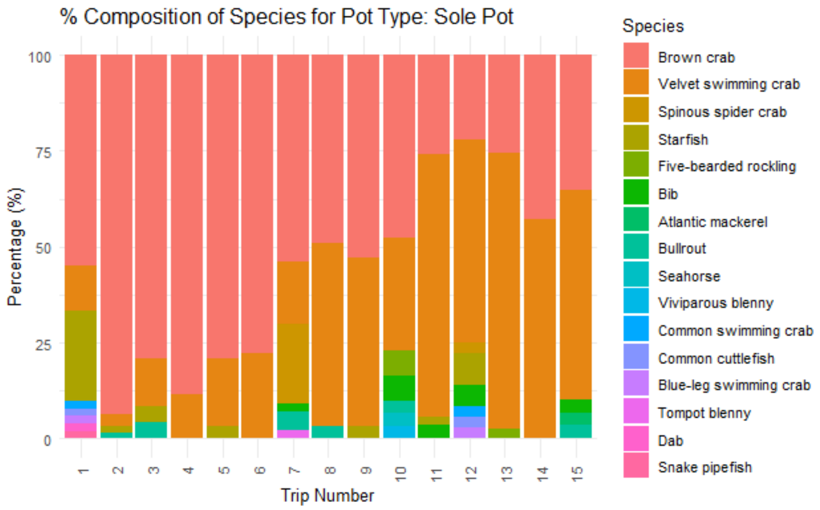


Figure A1.3 *– Catch composition per trip based on weights for all species caught during sole pot fishing in the offshore wind farm.*

Cuttlefish pot with fluorescent mesh

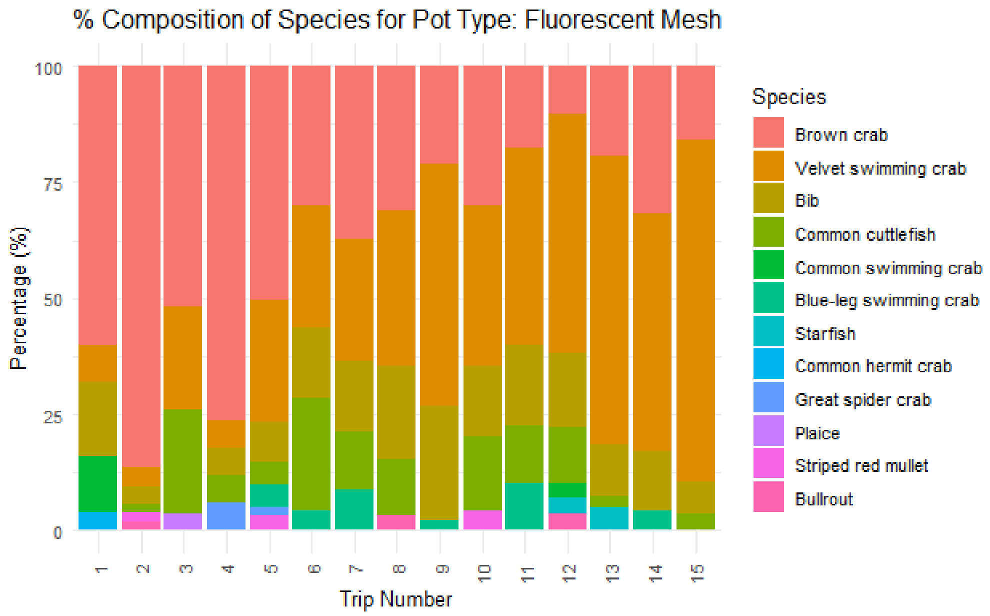


Figure A1.4 *– Catch composition per trip based on weights for all species caught during cuttlefish pot with fluorescent mesh pot fishing in the offshore wind farm.*

Cuttlefish pot with normal mesh

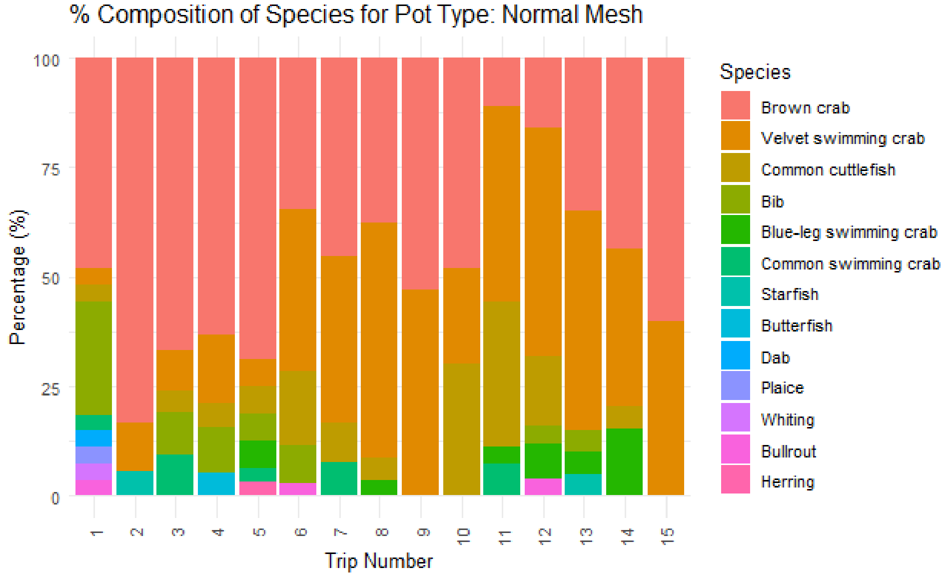


Figure A1.5 *– Catch composition per trip based on weights for all species caught during cuttlefish pot with normal mesh pot fishing in the offshore wind farm.*

Fish pot

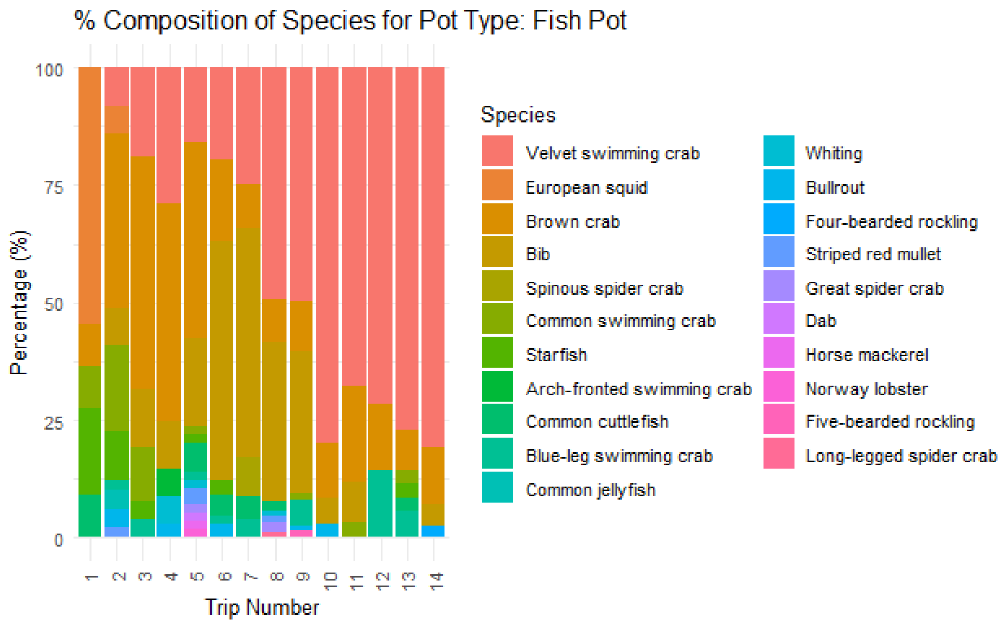


Figure A1.6 *– Catch composition per trip based on weights for all species caught during fish pot fishing in the offshore wind farm.*

A1.4 Mechanical jigging (LHM)

No additional figures.

Appendix 5 – Unanticipated events

A total of 35 field trips have been undertaken into Borssele II wind farm from April till October 2023 for the experimental passive fishing project ‘Passive fishing in Borssele’. The activities consisted of: 5x gill net fishing with YE 152, 17x pot fishing with YE 152, 4x handline with KG 7 and 10x jig fishing with MDV 2. Prior to the experiments the anticipated operational procedures are described in the Plan van Aanpak and confirmed by Ministry of Agriculture, Nature and Food Quality and Rijkswaterstaat. The Plan van Aanpak is also shared voluntarily with the wind farm operator ie. Ørsted. Most field experiments were undertaken as foreseen in the Plan van Aanpak and did not require additional communication with Rijkswaterstaat, the coast guard or the wind farm operator. During some of the field experiments unanticipated events did take place. These are described in the present document. The cases were resolved during the experiments but did require unanticipated additional communication. This additional communication was acceptable for the project team in light of the experiments but should be avoided for fishers in daily operations.

The intention of the present case description is to 1) create awareness for unanticipated events and 2) were possible, avoid the additional communication for future activities within the wind farm. The lessons learned from these cases could be taken into account in the framework for further passive fishing activities in wind farms.

The following unanticipated events were experienced:

1) Discovery of unidentified moored object (03-08-2023)
2) Entanglement of a dahn line with Rijkswaterstaat wave buoy (24-05-2023; Pots)
3) Anchoring (29-06-2023; handline)
4) Loss of dahns and missing string I (21-08-2023; Pots)
5) Unidentified vessel report to the Coast Guard by Ørsted (11-09-2023; Handline)
6) Contact by Coast Guard about fishing activity (17-10-2023; Jigging with MDV 2)

1) Discovery of unidentified moored object (03-08-2023)

A moored empty red oil canister was discovered during field tests with MDV 2 'Metanoia' by the project team within the wind park. This oil canister is not part of our fishing gear. The project team informed the Dutch coastguard about the unidentified object. The coastguard inspected the object and concluded it has drifted into the wind farm.

Figure A5.1: 03/08/2023 unidentified moored object

From this case follows:

- There can be unidentified objects within the wind park, not all objects within the wind farm can be associated to the experiments.
- Fishers can provide additional monitoring within the wind farm and report unidentified activities. In case of reporting feedback is appreciated.

2) Entanglement of a dahn line with Rijkswaterstaat wave buoy (24-05-2023; Pots)

On 23-05-2023, Ørsted reported entanglement of fishing gear with a Rijkswaterstaat wave buoy. One of the lines of string F appeared to be entangled with the wave buoy. The presence of this wave buoy was not known to the project team and was not noticed during the deployment of the gears. The line has been disconnected from the buoy. The positions of the string have been adjusted to prevent future entanglement.

Figure A5.2: 24/05/2023 line of string F entwined with Rijkswaterstaat wave buoy

3) Anchoring (29-06-2023; handline)

Handline fishing and jigging are usually carried out drifting. This approach was foreseen in the Plan van Aanpak. However, during the first fishing trip for handline fishing with the KG 7 on 29-06-2023, it turned out that drift fishing in the wind farm is difficult due to the geometry/orientation of plots for passive fishing between the maintenance zones and the current direction. This is depending on the strength and direction of the tide, wave height, wind force and wind direction. The project team requested Rijkswaterstaat to allow anchoring with the same type of anchor (Bruce anchor) as used to anchor the strings, within the area for passive fishing. The proposed anchoring location is near the GO5 wreck, due to favourable catch expectations near objects. Rijkswaterstaat has agreed to this adapted approach and granted permission to anchor within the area for passive fishing, taking into account a distance of 100 meters from the wreck to prevent damage to this potential cultural heritage.

From this case follows:

- Permission for anchoring within the passive fishing zone was in this case granted by Rijkswaterstaat, with the same type of anchor as used for anchoring the strings, the so-called

Bruce anchor. General permission regarding the use of anchors for future handline activities needs to be clarified.

4) Loss of string markings (dahns and buoys)

- **String I without markings (21-08-2023; Pots)**

The wind farm was not visited in the period between 18-07-2023 and 21-08-2023 due to bad weather and the holiday period. During this period the 9 pot strings have remained in the wind farm. Upon return on 21-08-2023, 6 dahns were found to have been thrown loose by storms in July and August (6-8Bft, Hs up to 3.5m), including both dahns of string I. As a result, this string could not be recovered. This was reported to Rijkswaterstaat and Ørsted on 22-08-2023. The project team recommended, after discussing the case with experienced fishers, dredging with light dredge anchors to recover the string without the markings. The dredge anchor is of a similar size to the Bruce anchors used to anchor the nets. Anchoring and dredges were not included in the action plan (Plan van Aanpak). Following the advice of the project team, Rijkswaterstaat granted permission to dredge up the string without markings. On 29-08-2023 the string was recovered within 2 attempts. The string was still at the installed location in the wind farm and had not been moved.

Figure A5.3: 29/08/2023 light dredge anchor used for recovery of string without markings

- **String A, B and H without markings (26-09-2023; Pots)**

The wind farm was not visited in the period between 09-09-2023 and 26-09-2023 (intended last expedition) due to bad weather. Upon return on 26-09-2023, it appeared 3 strings had lost both dahns due to the storm and continued rough weather in September (up to 6-8Bft, Hs up to 3.5m).

During the expedition on 26-09-2023 the 6 accessible strings were removed from the wind farm. The 3 strings (string A, B and H) without markings remained in the wind farm, waiting for suitable weather to dredge the strings. On 26-10-2023 the 3 remaining strings were dredged from the seabed; two strings in just one attempt, the other string in 3 attempts. The strings were still at the installed location in the wind farm and had not been moved.

From these cases follows:

- There is a substantial risk of loss of dahns during storm periods. On the one side this might be prevented by improving the connection between the dahn and line or by the use of floats, on the other side the failing connection might act as a quick release system, reducing the load on the anchor to zero and avoiding movement of the string on the seabed.
- The use of a light dredge anchor for the recovery of missing gear, within the passive fishing zone, is proven effective and does not lead to a significant risk for the wind farm and was in this case permitted.

Further considerations

In this case, the missing strings had not moved and remained at the installed location. However, it is imaginable that a string could move from the passive fishing zone and end up within the 250m maintenance zone around the in-field cables and wind turbines. It is advisable to use a risk assessment to determine how and by who the search should be conducted in such a case and how the equipment may be recovered. In order to be able to act adequately in such a case, it is advisable to carry out this evaluation prior to further rollout of passive fishing within the wind farm and to include actions in the action plan (Plan van Aanpak).

5) Unidentified vessel report to the Coast Guard by Ørsted (11-09-2023; Handline)

On September 11 the Ørsted MHCC reported a fishing vessel between wind turbines H03 and H04 without permission to the Coast Guard. Ørsted warns that passive fishing within the wind farm is prohibited and the fishing gear also poses a danger to fast-moving vessels that are active within the park, especially when it is dark. A photo of the vessel was taken from a wind turbine, but the name of the vessel could not be detected.

The Coast Guard confirmed the situation and did an investigation, indicating that research into passive fishing had already been announced. The Coast Guard contacted the vessel on VHF Channel 16 about their activities and it quickly became clear that the activities were known and permitted. The KG 7 was identified on the photo taken from the wind turbine.

The next day there was contact between the Coast Guard, Ørsted and the project team, indicating that the activities had been properly reported and carried out as agreed. It seems that a mistake had been made in internal communication at Ørsted. The Coast Guard emphasized Ørsted first to verify such situations internally before reporting them to the authorities.

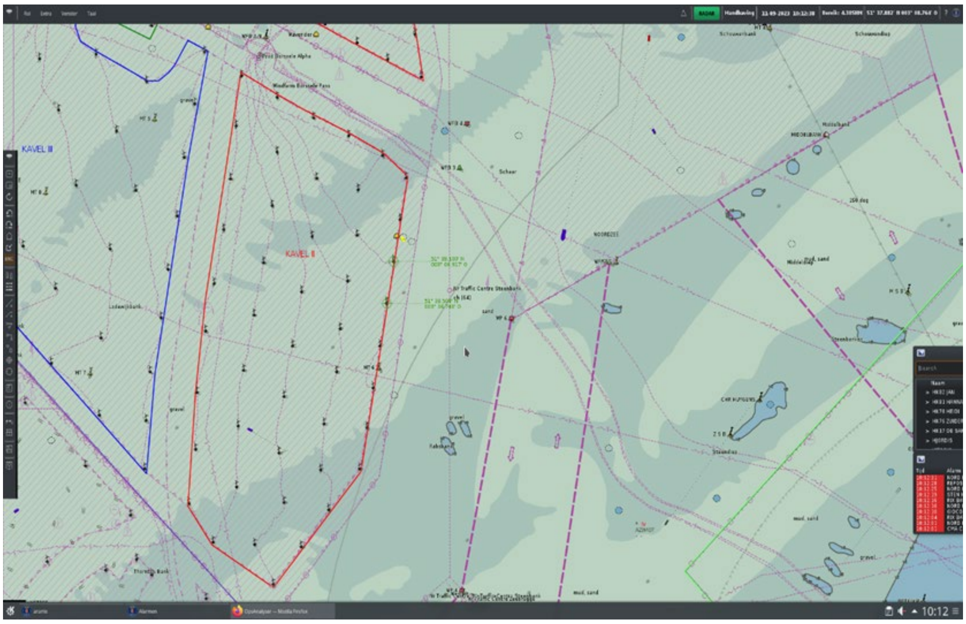


Figure A5.4: 11/09/2023 identification of the vessel

6) Contact by Coast Guard about fishing activity (17-10-2023; Jigging)

Prior to the start of the experiments a total of 8 phone calls for each trip were foreseen: calls to both the coast guard and wind farm operator at 4 moments during the trip: departure from port, arrival at wind farm, departure from wind farm and arrival at port. Notification of activities within the safety zone at the coast guard is mandatory for SAR operations in case of calamities. Notification to the wind farm operator is not mandatory, but the wind farm operator would like to be informed about activities within the wind farm and facilitates to pass these activities through to the coast guard. These phone calls were experienced as considerable administrative load for the fishers. During the first days of the experiments of this project the coast guard and wind farm operator indicated to reduce the number of calls: calls to the coast guard are not necessary, since they receive a list with vessels that will undertake activities in the wind farm through the wind farm operator; only calls to the wind farm operator upon arrival at and departure from the wind farm were required. The reduced number of 2 phone calls is workable for the fishers.

On 17-10-2023 the Coast Guard contacted MDV 2 'Metanoia' on VHF Channel 16 to explain their fishing activities in the wind farm. Following the initial fishing experiments, it was discussed and agreed that activities did not have to be reported by the fishing vessel to the Coast Guard. Reporting to the wind farm operator is sufficient, the wind farm operator informs the Coast Guard. The Coast Guard confirms again that this is agreed and the call on VHF channel 16 to MDV 2 was unnecessary.

Wageningen Marine Research
T +31 (0)317 48 7000
E: marine-research@wur.nl
www.wur.eu/marine-research

Visitors' address
- Ankerpark 27 1781 AG Den Helder
- Korringaweg 7, 4401 NT Yerseke
- Haringkade 1, 1976 CP IJmuiden