



Experimental gill net fishing for sole in two offshore wind farms in the Netherlands

Additional experimental trials on the technical, ecological, economic and safety considerations of fishing with gill nets in two offshore wind farms off the Dutch coast

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Wageningen Marine Research
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Summary

Background

This study, commissioned by the Ministry of Agriculture, Fisheries, Food Security, and Nature, aimed to further investigate passive fishing in two offshore wind farms in the Netherlands using gill nets. Through pilot studies in wind farms Borssele and Hollandse Kust Zuid, the ecological and economic factors, (by)catch, and safety requirements of fishing with gill nets in these environments were examined. This report presents the findings, opportunities, and challenges, while also addressing operational considerations, safety protocols, fishing gear specifications, economic viability, and ecological impacts. The experimental setup built upon the previous pilot study (Neitzel et al. 2024), with an extension to the Hollandse Kust Zuid wind farm. For each wind farm, multiple testing days were conducted between April and June 2024. Two fishing vessels participated in the sea trials: YE 152 (9.95 m in length) and WR 147 (18.80 m in length). During the field trials, data was collected on operations and safety, economics, ecology, and (by)catch.

Video observations

Video observations in both wind farms revealed that the seabeds consists of sandy sediments. The seabed of Hollandse Kust Zuid mainly consisted of loose, unconsolidated sand, whereas in Borssele large loose sand ripples alternated with stable sandy sediments. Only in the latter, reef building tube worms were observed. In both wind farms, fauna like brittle stars, starfish, sand eels and dragonets were observed on the seabed. On the hard substrate around the wind turbines, mussels, anemones, brown crabs, velvet crabs, starfish and pouting was observed. Video observations and analysis of anchor positions during setting and hauling of the nets showed that anchors and nets generally held their position. Displacement of the anchors during fishing was found to be minimal, as was also the case in the previous study of Neitzel et al. (2024). When hauling, anchors were generally pulled upright in the sediment before they were lifted to the surface. Only in wind farm Borssele, occasional anchors were observed to be moved through the big loose sand ripples upon hauling, possibly due to the lack of friction of these sediments. It is not clear how the drag of the anchors compares to the supposed high natural movement of the sea bed within the wind farm.

Safety, operational & nautical factors

The risks of passive fishing within wind farms is limited. The risk of damage to a wind turbine by a fishing vessel up to 46m is nil, where regulation for crew and vessel is adequate and therefore the risk of damage to the wind farm by vessel and crew is limited. The risk of damage by passive fishing equipment is limited, especially by the use of Bruce anchors to the in-field cables which is marginal. An investigation into gill net positions show that there is no or marginal displacement of the gears in both qualitative observations and quantitative measurements based on registered anchor positions.

During the experiments, nautical experience is gained regarding the communication processes with the wind farm operators, on the visibility of the maintenance zones on the nautical charts and the sailing time to wind farms in combination with working time. The operational aspects of passive fishing with gill nets are observed by a review of the wave conditions based on observed, forecasts, measured and hindcast weather conditions. The wave heights were evaluated and translated into operability based on a significant wave height limitation of 1 m.

Catch and bycatch

It is possible to catch sole (*Solea solea*) as target species using gill nets in both Borssele and Hollandse Kust Zuid offshore wind farms. Although a higher catch was realised in Hollandse Kust Zuid throughout the trips, sole is clearly present in Borssele and can be caught in areas where fishing is not hampered by bottom type or sharp objects, such as in Borssele I. For Borssele offshore wind farm, CPUE for sole ranged

from 0.3 to 2.6 kg/km/d while for Hollandse Kust Zuid, CPUE for sole ranged from 1.0 to 6.1 kg/km/d. LPUE for sole ranged from 0.3 to 2.4 kg/km/d in Borssele offshore wind farm and from 0.1 to 6.6 kg/km/d in Hollandse Kust Zuid offshore wind farm.

It is evident that many factors influenced the catch such as weather conditions, peak seasons of target species and therefore the right time of fishing, fishing gears and their characteristics, soaking times and differences between locations within an offshore wind farm. Catch in both wind farms consisted mainly of fish species of which dab, sole and plaice were caught in the highest amounts in terms of weight and numbers. Other fish species included bib, brill, bull-rout, dragonet, five-bearded rockling, flounder, horse mackerel, lesser spotted dogfish, lesser weever, greater weever, herring, pipefishes, Atlantic mackerel, seabass, solenette, starry smoothhound, striped red mullet, tub gurnard, turbot and whiting. Benthic species included mainly starfish, bottom-dwelling crustaceans and sea urchins. Some species were caught in higher amounts due to seasonality or location, such as starry smoothhound in summer months in Borssele offshore wind farm, and high amounts of dab and starfish on certain deeper locations in Hollandse Kust Zuid offshore wind farm.

Birds and marine mammals

Only a few individuals of sea birds and marine mammals were seen in both offshore wind farms during gill net fishing. On one occasion, five seagulls seemed attracted to fishing activities; this was when seagulls followed the fishing vessel when crew threw unwanted catch (discards) overboard inside the offshore wind farm. However, this was only the case in one individual situation out of 21 days at sea where a part of the catch was discarded, and very few birds were seen inside the offshore wind farm. For marine mammals, only grey seals, harbour seals and harbour porpoises were sighted and in none of the cases, the individuals were attracted or influenced by the fishing activities. In none of the gears, birds or marine mammals were caught.

Economy

The costs of fishing in a wind farm are higher due to the existing restrictions. Nets cannot be set freely, access is limited to daytime and areas outside maintenance zones and communication and planning is needed here and takes time. Most of the current gill net fishing takes place closer to the shore (1-12 NM) than where the wind farms are located, so fishing in the wind farm requires longer trips leading to higher fuel costs. Fishing for sole in a wind farm can be profitable at times when the (swimming) sole is abundant in the wind farm. Keeping these fishing grounds accessible can help fishers to keep their business profitable. For profitability, fewer restrictions on fishers would help, as would more surveying and monitoring to predict which fish might be caught in the wind farm.

Recommendations

Adjustments to both fishing operations and policies are necessary to align co-use ambitions with the current capabilities of the fisheries sector. Mismatches between co-use ambitions, the existing policy framework, and the characterization of the current passive fishing sector have been identified. Challenges that need to be addressed include offshore wind farm accessibility, vessel optimization, and gear application (such as spatial deployment and gear combinations). Therefore, it is strongly recommended that, when designating areas for future offshore wind farms intended for passive fisheries as a co-use activity, technical catch considerations be factored in to fully harness the potential and expand opportunities for passive fisheries. This should be done through consultation with industry professionals or researchers. Also, to make up for the rather long sailing time to the wind farm, there needs to be a high likelihood of successful fishing. At present, catches in wind farms, like in other fishing areas, are highly unpredictable. If the predictability of catches could be improved, fishing in a wind farm would become more profitable. Catches could be boosted by allowing fishing closer to monopiles or in areas over infield cables, enabling potential future multi-gear vessels to integrate passive fishing alongside their conventional methods and the possibility to enter the wind farm at night. Lastly, to alleviate the administrative burden on all parties and minimize the risk of miscommunication, it is therefore

recommended to reduce the frequency of required communication, and more importantly, standardize and automate the communications between parties.

1 Introduction

1.1 Aim and objectives

The Ministry of Agriculture, Fisheries, Food Security, and Nature is actively working to assess if fishing in offshore wind farms can be done safely and economically, ecologically and technically feasible to ensure safe and sustainable fishing practices within offshore wind farm areas under the current regulatory framework. Ongoing and completed projects provide valuable insights into the opportunities and challenges for fishers operating in wind farms, with particular attention to safety, risk management, and operational aspects. In the 2015 project *Vissen voor de wind*, an initial investigation was conducted into the possibilities and constraints for fishers within wind farms (Cramer et al. 2015). The *Win-Wind* project (2019-2023) explored, partly through practical implementation, the operational aspects, including safety and risk management, of commercial fishing within wind farms (Rozemeijer et al. 2023). Thereafter, a desk study compiling all existing knowledge on passive fishing, particularly in relation to wind farms, was published in 2023 (Neitzel et al. 2023a). While several completed and ongoing projects have touched on the potential of passive fishing in wind farms, these opportunities have been explored only superficially, and practical knowledge and field experiences remain limited. This study thus builds upon the desk study and earlier field trials, which involved various fishing gears and practical field tests, to further investigate the practical aspects of passive fishing in wind farms (Neitzel et al. 2024). Since data on gill net fishing was limited in prior research, the field trials were extended into the 2024 season and expanded to include another, newly built wind farm.

1.2 Research questions

For this study, six specific research questions were defined. Where possible, these questions will be answered quantitatively, with justifications based on already available data and data collected within the current project.

1. "Do anchors move from their position when holding the nets and if yes, does the anchor drag along the seafloor? And is this also the case when hauling the gill nets?"
2. "What are possible problems that may arise during the testing of gill net fishing, taking into account":
 - Technical aspects of the fishing gears and vessels
 - Safety issues or potential risks
 - Distance from the coast
 - Weather conditions
3. "Is it possible to catch the target species (*Solea solea*) within wind farms Borssele and Hollandse Kust Zuid offshore wind farm using gill nets (gear code GNS)?"
4. "What are the catches per unit effort (CPUE) and landings per unit effort (LPUE) of the target species (*Solea solea*)?"
5. "What is the composition and quantity of bycatch for gill net fisheries when considering":
 - Non-target species (fish)
 - Birds

- Marine mammals
 - Benthic species
6. "Are birds and marine mammals attracted to fishing activities inside the offshore wind farm and, if yes, which species and to what extent?"
 7. "Is it economically feasible to fish commercially with gill nets for sole within offshore wind farms Borssele and Hollandse Kust Zuid?"

1.3 Bookmark

Chapter 2 describes the materials and methods used in this study, as well as the research area, fishing gears and vessels used during field trials. Chapter 3 gives the results on the video surveys that were done, chapter 4 goes into detail about risks and nautical operations, whereas chapter 5 describes the results on the ecological and biological data. Chapter 6 gives the economic analysis. Chapter 7 goes into detail on the discussion and finally, chapter 8 is a concluding chapter with the main conclusions found during this study as well as 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 fishers interested in fishing in offshore wind farms. 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 where fishers could express their interest. Potential participants could register for participation in the focus group of fishers after the session.

Following these sessions, a focus group consisting of nine interested and active fishers was formed. This focus group then further designed the field tests in Borssele and thereafter also the additional trials in Borssele and Hollandse Kust Zuid. The advisory group which was previously established in 2023 was also maintained, 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.

2.1.2 Legal context

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 BAS¹², 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, gill nets 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 the Ministry of Agriculture, Fisheries, Food Security and Nature and this action plan, together with the conditions mentioned in the letter granting access, dictated the rules to be followed in this project.

2.1.3 Research area

The operations were conducted in two Dutch offshore wind farms: Borssele I and II, located 23 km (12.42 NM) off the coast of Westkapelle, and Hollandse Kust Zuid, near the port of IJmuiden. These field trials, similar to previous ones carried out in 2023, focused on newly constructed wind farms. These two wind farms are the first operational farms in the 'new style' meaning the wind farms were granted under the

¹ Staatscourant 2021, 13511 | Overheid.nl > Officiële bekendmakingen (officielebekendmakingen.nl)

² Staatscourant 2023, 29556 | Overheid.nl > Officiële bekendmakingen

law Wind energy at sea (*Wet windenergie op zee*)³. In these wind farms, the space between the wind turbines can be used by different forms of co-use, including passive fishing. In contrast, older, smaller wind farms built in the 'old style' such as Offshore Windpark Egmond aan Zee (OWEZ), Prinses Amalia Wind Park (PAWP), Luchterduinen and Gemini were granted under the water law (*Waterwet*)⁴ have limited space between turbines, and it was only later decided to allow partial co-use for activities like recreational fishing with handlines. An area passport guide is issued by the government after an offshore wind farm is operational and states the allowed forms of co-use and their designated locations within the areas, including passive fishing. These area passport guides were also delivered for Borssele and Hollandse Kust Zuid offshore wind farm. The regulations for these experiments were managed through a letter granting access as mentioned in the previous paragraph. As a result, Borssele (I and II) and Hollandse Kust Zuid offshore wind farms were deemed the most suitable for short-term practical tests.

2.1.3.1 Borssele I and II offshore wind farm

Figure 2.1 shows the map of Borssele I and II offshore wind farm. 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 positions of the fishing gear that were used during the experiment are shown on the bathymetry map of Borssele I and II offshore wind farm (Figure 2.3) and in more detail for Borssele I (Figure 2.4a) and Borssele II (Figure 2.4b). The maintenance zones around the wind turbines were taken into account in the planning of the deployment of fishing gears.

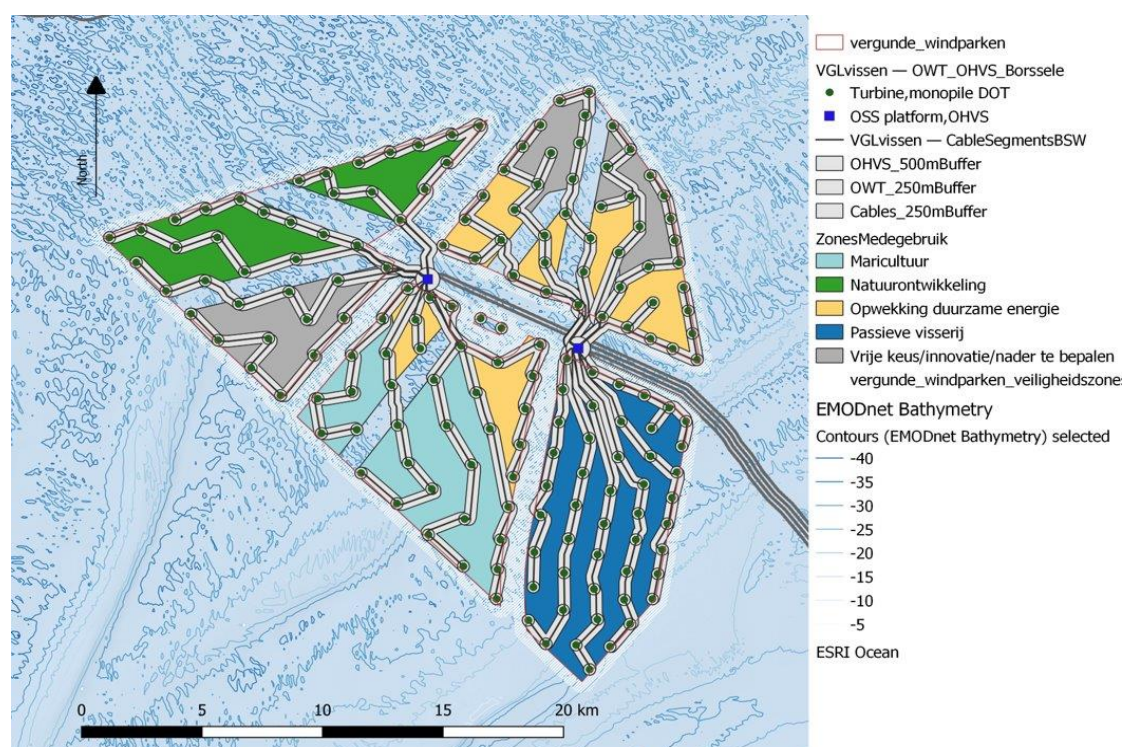


Figure 2.1 Spatial plan of Borssele offshore wind farm. For gill net experiments the dark blue area in the South West of the wind farm was used, except for the fishery free zone (Figure 2.2).

³ wetten.nl - Regeling - Wet windenergie op zee - BWBR0036752

⁴ wetten.nl - Regeling - Waterwet - BWBR0025458

Windenergiegebied Borssele



Figure 2.2 In the green area, no fishing activities were performed because nature inclusive design was applied by the wind farm operator.

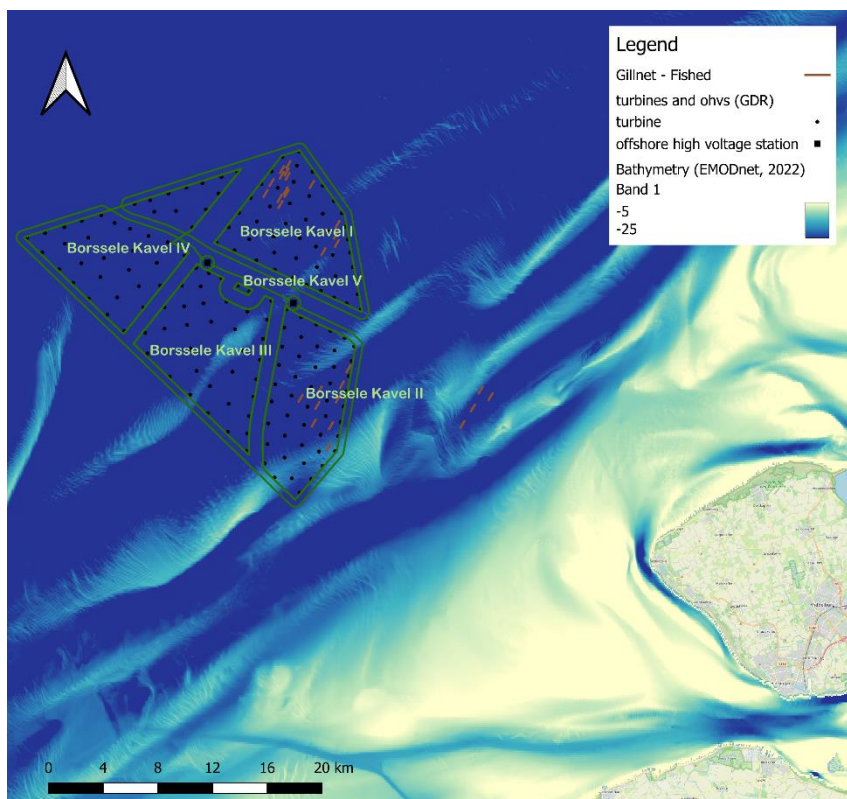


Figure 2.3 Map of Borssele offshore wind farm and its distance from the coast showing locations of gill net strings used in the experiment (brown lines). Note that the 4 lines outside the wind farm are reference locations (see chapter 4)

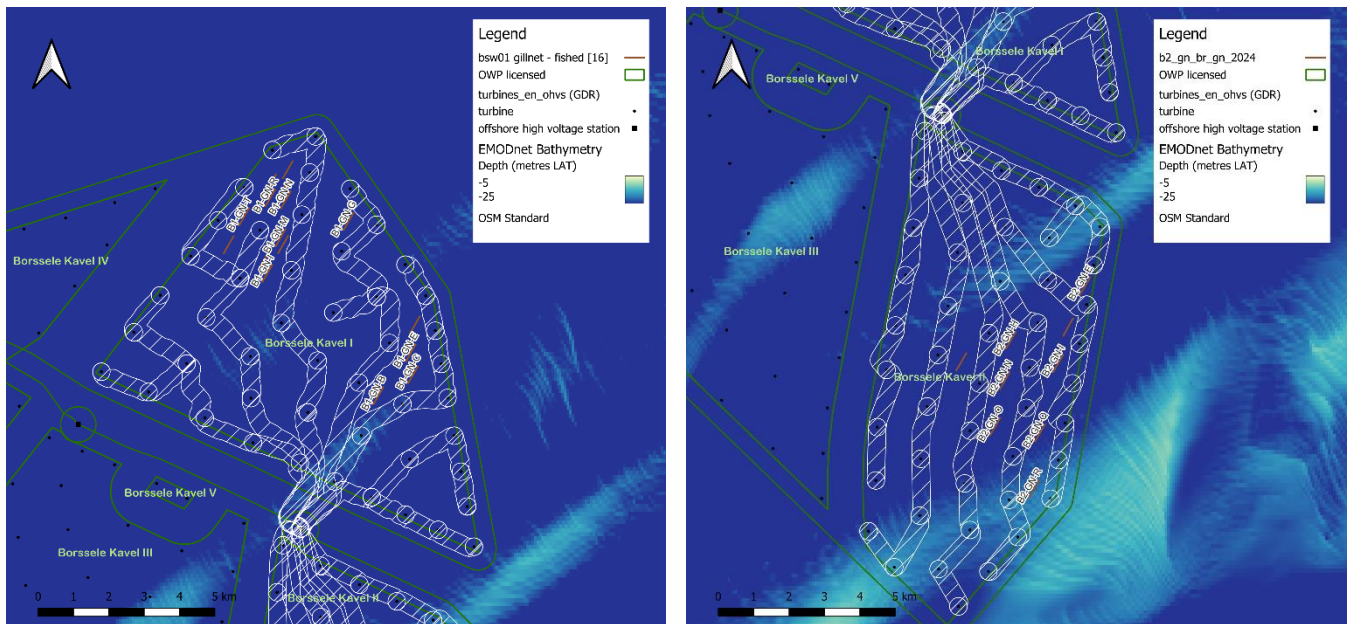


Figure 2.4a and 2.4b Detailed maps of fished locations (brown lines) in Borssele I (left) and Borssele II (right). Deployment of fishing gears was not allowed in the shaded areas as they were either maintenance or safety zones. Note that in the Southwestern part of Borssele II, a large area could not be used in this experiment because nature inclusive design was applied by the wind farm operator (Figure 2.2).

2.1.3.2 Hollandse Kust Zuid offshore wind farm

Hollandse Kust Zuid wind farm is made up of four sites and the Luchterduinen offshore wind farm (operational since 2015), see Figure 2.5. Sites I and II lie completely outside the 12 nautical mile-zone. The other two sites, III and IV, lie partially in a strip between 10 and 12 nautical miles from the coast of Zuid-Holland (Figure 2.6). The positions of the fishing gears that were used during the experiment are shown on the bathymetry map in Figure 2.7.



Figure 2.5 Map of Hollandse Kust Zuid offshore wind farm and the designated area for passive fishing from the area passport (blue). The gill net experiments were performed in the blue area.

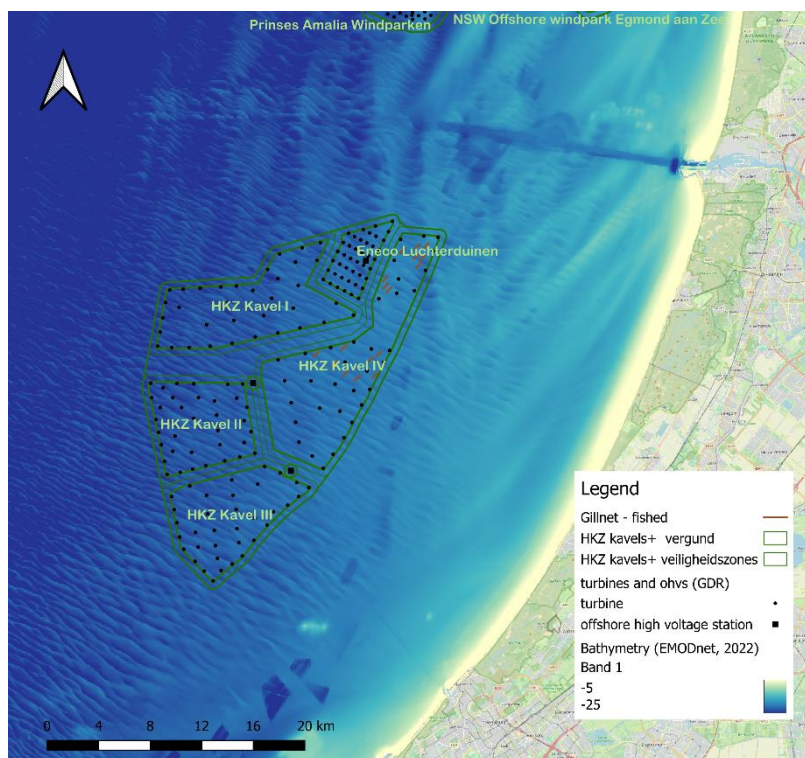


Figure 2.6 Map of Hollandse Kust Zuid offshore wind farm and its distance from the coast showing locations of gill net strings used in the experiment (brown lines).

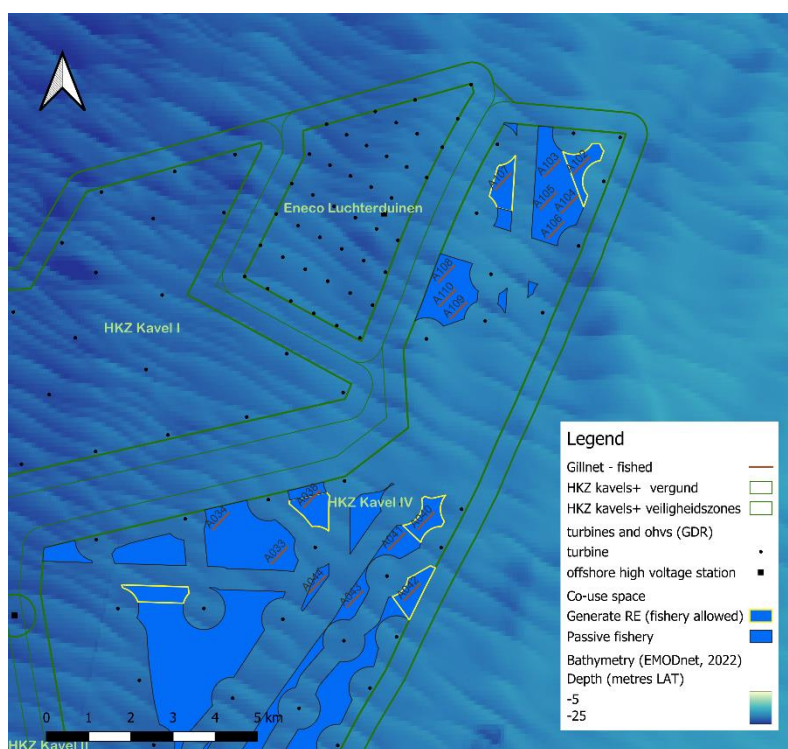


Figure 2.7 Detailed maps of fished locations (brown lines) in Hollandse Kust Zuid. Deployment of fishing gears was not allowed outside the bright blue areas as they were either maintenance or safety zones.

2.1.4 Time schedule

The timeline for this study was discussed with the focus group of fishers involved. It was agreed to conduct the study during the peak season for gill net fishing, specifically targeting sole (*S. solea*). Sole is a highly valuable target species caught mainly in the Dutch beam trawl fishery and gill net fishery. Since the research set-up was kept the same as in the previous trials of 2023 (Neitzel et. al 2024), sole was seen as the most suitable target species for this study as well. During peak season, which is typically starting in February and lasts until April or May, sometimes extending to June depending on environmental factors, sole migrate from their winter areas to their summer habitats, and can be caught while swimming in gill nets. To accommodate potential changes in the schedule and last-minute weather shifts, both crew and scientists were on standby. Throughout the project, the research team maintained regular communication weekly, and often daily, with both the focus group of participating fishers and other fishers targeting the same species. This close coordination allowed researchers to assess whether the schedule remained aligned with the anticipated peak season or if adjustments were needed due to unforeseen circumstances.

The total amount of days in the field per month and per wind farm are shown in Table 2.1. Catch data was collected on 11 out of 18 days in the field for Borssele and on 10 out of 17 days in the field for Hollandse Kust Zuid. On the last day in both wind farms, video footage was made inside the wind farm and no catch data was collected.

Table 2.1 Overview on the total days in the field per wind farm and per month.

	Borssele	Hollandse Kust Zuid
March	0	2
April	3	6
May	7	5
June	7	4
July	1	0
Total	18	17

2.1.5 Gill net fishing (GNS)

A gill net consists of an upper line with floats and a weighted lower line with one (gill net) or multiple walls (trammel net) of netting in between (Figure 2.8). The gill net, often consisting of multiple nets tight together into one string, is anchored on the seabed on both sides and in between with anchors weighing about 8 to 10 kg. The length of a gill net is measured along the extended upper line and can vary from 200 m per net (especially in cod fishing around wrecks) up to 10,000 m per (combined) net in the flatfish fishery, particularly targeting sole. In general, commercial fishers fish with 10 to 25 km of gill nets 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, gill nets are used on small vessels, close to the coast, and mainly catching sole, mullet, and seabass. When targeting sole, the nets are set in the direction of the current and remain in place for about 12 to 20 h before being retrieved.

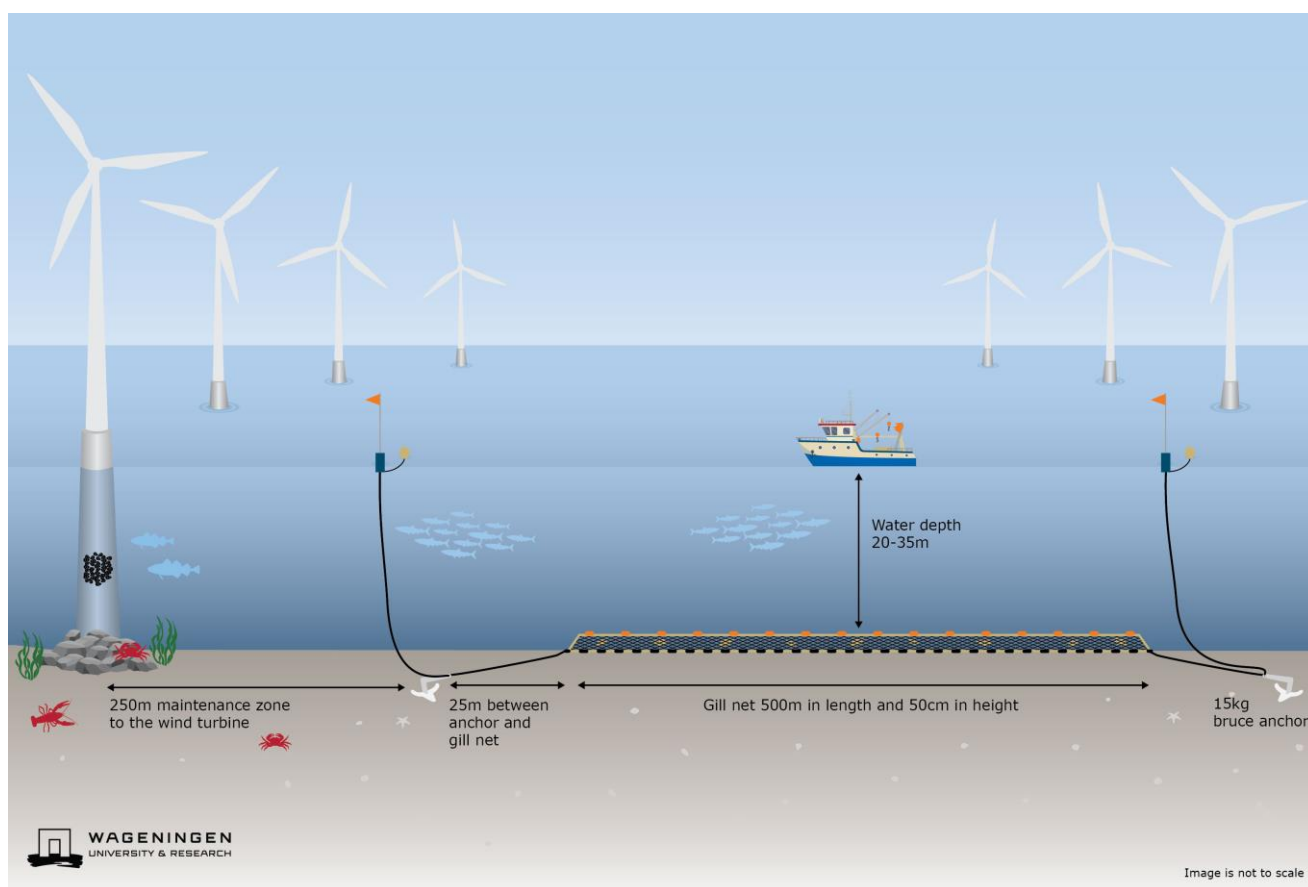


Figure 2.8 Gill net fishing in an offshore wind farm. Infographic: Wageningen University & Research.

For this experiment, 4 gill net strings, hereafter called gill nets were deployed from one vessel (Chapter 2.2 for vessel details, Figure 2.9 for gill net fishing in Hollandse Kust Zuid offshore wind farm during the field trials). Target species of this experiment was sole, but dab and other bycatch species were also seen as species that could be sold on the fish auction. Each gill net had a total length of 550 m, from anchor to anchor. The anchoring was done using Bruce anchors, which are commonly used for passive fishing on sandy sediments. These anchors were tested and found effective in previous studies, making them suitable for offshore wind farms, where they help reduce the risk of interfering with wind farm infrastructure (Rozemeijer, 2021 & 2022). Alternative anchoring methods, such as bundles of chains or other anchor types, allow for gear movement and are therefore not ideal for positioning gear within wind farms. The ropes connecting the anchors to the net were each 25 m long, resulting in a total gill net length of 500 m per string. Each string comprised 10 net sections, each 50 m long. Other vessels could pass through the area where the nets were located, as the nets were no higher than 0.5 m from the seafloor. The nets were placed as evenly as possible across different depths to gather data on areas with strong currents (sandbank ridge) and areas with weaker currents (valleys). Before each trip, the lead scientist and skipper would consult to decide on the specific location for deploying the nets, considering weather conditions and tides. A total of 14 days per offshore wind farm were foreseen, resulting in a total of 21 effective fishing days, 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 gill nets (500 m) per vessel / offshore wind farm
 - Consisting of 10 net sections of 50 m each
 - 50 cm height
 - 94 mm mesh size
 - Blue coloured nylon netting
 - Weighted lower line
 - Floating upper line

Different parts of gear in order per string:

- Front buoy (pick-up buoy)
- Line 3 m from front buoy to dahn
- North dahn
- Line 6 m from dahn to A1 buoy
- A1 Buoy
- Buoy line 105 m (3* water depth); first 10 m with lead line, forcing sinking
- Bruce anchor of 15 kg
- Line 25 m from anchor to net sections
- 10 x 50 m net sections, 50 cm high with a 94 mm mesh size
- Line 25 m from net sections to anchor
- Bruce anchor 15 kg
- Buoy line 105 m (3* water depth); first 10 m with lead line, forcing sinking
- A1 Buoy
- Line: 6 m from A1 buoy to dahn
- South dahn
- Front buoy (pick-up buoy)

Total length 550 m from anchor to anchor.



Figure 2.9 Gill net fishing in Hollandse Kust Zuid offshore wind farm during the field trials. Photo: Wageningen Marine Research.

2.2 Fishing vessels

This section outlines the vessels used for the experiments at sea. The vessels were selected based on input from participating fishers in the focus group and other nearby gill net fishers around the two chosen wind farms. The selection criteria included availability for testing, insurance coverage, suitability for the

field experiments, and licenses for the specific fishing gear to be tested. The two vessels chosen comply with all relevant regulations for fishing vessels, as well as additional rules specific to fishing in the Borssele⁵ and Hollandse Kust Zuid⁶ wind farms, and regulations for the experiments.

These requirements include:

- The captain and vessel must hold a fishing permit for the applied passive fishing methods (gill nets).
- The maximum overall length (Loa) of the vessels for offshore wind farm Borssele is 45 m, and for Hollandse Kust Zuid offshore wind farm 46 m.
- Vessels up to 24 m must comply with the *Vissersvaartuigenbesluit* 1989, where applicable.
- Vessels over 24 m must comply with the *Vissersvaartuigenbesluit* 2002 and have been issued a *Certificaat van deugdelijkheid*.
- Vessels are equipped with an active Automatic Identification System (AIS).
- Vessels have a VHF radio, with standby on channel 16.
- Vessels must have insurance for fishing within the wind farm, with a minimum coverage of 500 million euros.
- Access to the wind farm is permitted only during daylight hours.

2.2.1 YE 152 'Meru'

The field experiments in Borssele were done onboard YE 152 'Meru' with MMSI number 244727000, a small fishing vessel (9.95 m, Figure 2.10). The crew consisted of three to four persons: two scientific personnel (one project leader and one researcher) and two crew members (including skipper).

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

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

- Maximum sea state (Beaufort): depending on the environmental direction.
- Forecasted maximum significant wave height (H_{s_max}) = 0.8-0.9 m, depending on the wave period (T_p).
- Maximum significant wave height (H_{s_max}) = 1.0 m, depending on the wave period (T_p).



Figure 2.10 YE 152 'Meru' (formerly SCH 87) with MMSI number 244727000. Equipment on the lower (stern) deck was adjusted to equipment specific for gill net fishing.

⁵ stcrt-2021-13511.pdf

⁶ stcrt-2023-29556.pdf

2.2.2 WR 147 'Anna Lotte'

The operations for gill net fishing in Hollandse Kust Zuid offshore wind farm were conducted onboard WR 147 'Anna-Lotte' with MMSI number 244609000, a medium-sized fishing vessel (19 m, Figure 2.11). The crew consisted of three to four persons: one or two scientific personnel (one project leader and one researcher) and two crew members (including skipper).

The main port of departure for the experiments was IJmuiden, with a distance of 11 NM to the wind farm.

Operational limits of the vessel are:

- Maximum seastate: depending on the environmental direction.
- Forecasted maximum significant wave height (H_{s_max}) = 0.9-1.0 m, depending on the wave period (T_p).
- Maximum significant wave height (H_{s_max}) = 1.2 m, depending on the wave period (T_p).



Figure 2.11 WR 147 'Anna Lotte' with MMSI number 244609000.

2.3 Procedures used in this experiment

2.3.1 Roles and responsibilities during the field tests

Action plan and field protocols

Before the field experiments, an action plan was created and approved in collaboration with the Ministry of Agriculture, Fisheries, Food Security and Nature, Rijkswaterstaat, and the researchers involved. This document outlined emergency procedures, the roles and responsibilities of personnel (including their contact details), and provided detailed information on the field experiments, such as the names and numbers of the vessels involved, data collection methods, fishing gear characteristics, and test locations within the offshore wind farms, along with their coordinates. A field protocol was also prepared before the experiments and aligned with the skippers and crew. Before each field trip, safety measures and protocols were explained to the participating crew. A Risk Assessment Method Statement (RAMS), including mitigation measures, had been previously developed and discussed in prior studies, so it was no longer required for this study. All potential test locations were identified, and their coordinates were shared with both wind farm owners for safety and operational reasons.

GO/NO-GO decision

Weather conditions played a crucial role in determining whether the vessel could sail out. The skipper maintained close communication with the project leader to assess if the conditions allowed for the trip. The project leader was responsible for informing Rijkswaterstaat and the wind farm owners well in advance of the plans. An email was sent at least two days before the planned departure, including the coordinates of the fishing gear to be deployed, the number of people on board, and the locations to be fished within the wind farm. Unlike previous experiments, the Dutch Coast Guard was not directly notified by the project leader but was instead informed by the wind farm owners through their weekly vessel overview. Work was only carried out during daylight hours and under favourable weather conditions. The final decision to proceed was made jointly by the project leader and the skipper, taking weather conditions into account.

Reporting procedure on a day at sea

Once a GO was confirmed, the involved parties received a confirmation email detailing the final test locations and crew list.

On the day of the fieldwork, two calls were made:

- A call to Ørsted MHCC by phone and to Vattenfall MCC via tetra VHF when approaching the wind farm. This call included details about the deployment/hauling of the gear and vessel information.
- A call to Ørsted MHCC by phone and to Vattenfall MCC via tetra VHF when leaving the wind farm. The project leader informed them that the work had been completed, and the vessel had departed. If fishing gear had been left behind, the coordinates were immediately sent to the wind farm owner after the work was completed.

The field trip leader was responsible for all communication with the relevant parties to avoid confusion and ensure clear and consistent messaging, while the project leader handled the pre-trip email communications.

Crew on board

On each operational day, the crew (consisting of three to four people) was involved in the research activities. The crew included:

- The skipper: Responsible for manoeuvring the vessel, ensuring safety, and following the action plan and field protocol.
- The deck crew: Assisting the skipper with specific tasks.
- The lead scientist or project leader: In charge of the scientific aspects of the expedition.
- The scientist crew: Responsible for measuring caught animals and recording data on birds and marine mammals during gear deployment and hauling.

In cases where only 3 crew members were present, the lead scientist also handled the measurements and data recording.

2.4 Data collection

Data collection was aligned with the previous experiment (Neitzel et al. 2024) and kept the same for both wind farms. To ensure the same approach was carried out at the same time, in both wind farms and on the two participating vessels, the crew and skippers boarded together for the first trips so that they could discuss the protocol and fishing methods while fishing.

During this study, different types of data were collected:

1. Operational data (vessel activity, working times, gear aspects, anchor positions, sailing time, operational and safety aspects and unforeseen circumstances/cases)
2. Environmental data (weather conditions, depths, locations)

3. Ecological data (birds and marine mammal countings, possible attraction to fishing gears)
4. Biological data (catch data such as length frequencies and weights of the species caught)
5. Economic data (e.g. costs of one of the vessels involved and fuel use, fish auction data and public data of commercial fishers)

2.4.1 Video observations and anchoring

Additional to the anchor position data that are collected during each trip, video observations were performed in both wind farms, to look closer into the anchor behaviour at the seabed and the surroundings. On the days of video observations, crew attached three Go-Pro cameras on different positions of the net: one about 50 cm from the first anchor, one on the floating line of the gill net and one about 50 cm from the second anchor. The nets were deployed as normal and left on the seafloor for about 30 to 40 minutes before hauling again. This process was repeated several times to collect video footage from multiple scenarios in different locations inside the wind farm. In addition and while not part of the initial action plan, video footage was made in agreement with both wind farm owners using a sled with Go-Pro cameras attached to get a visual indication of the bathymetry and the species present on the seafloor. A rough estimate of the sediment type (mud vs. sand, consolidated vs. loose) was made from all footage based on the behaviour of the sediment (e.g. when anchors are dragged in and out it and after resuspension) and the visual appearance (e.g. microtopography). Video observations using a camera sled and ROV (Borssele only) were performed in Borssele wind farm on 18th and 23rd June 2024 and Hollandse Kust Zuid on 27th of June 2024. The sled and ROV were towed by the fishing vessel that was drifting on the current. Per day multiple surveys were performed (Appendix 2, Figure A2.1 and A2.2). Length of the drift was restricted by the course of the vessel (so the risk of collision with a wind turbine was avoided), and was in any case at least 5 minutes long. As the sled could not be used near turbines, video footage was made using a GoPro attached to a fishing rod to get a visual indication of the species present on and nearby wind turbines. These activities were not stated in the action plan but were added later on in this study and agreed upon by the wind farm owners as the vessel needed to cross the maintenance zone of 250m from the wind turbine. In Borssele, the additional ROV survey was done on the seabed as a steel slag was caught in the net (also see Chapter 5). As video efforts do only cover a small section of the wind farm that was fished within this study, observations are just indicative.

2.4.2 Collection of nautical, 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 gill net string.
- 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 buoys, dahns 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.

2.4.3 Collection of ecological and biological data

Catch

The lengths (total length, TL) of fish caught for each species were recorded. For each gill net string, the catch was kept and documented separately. When there was an excess of small fish from the same species, a standardized sub-sampling procedure was followed. Catch compositions in Chapter 5 were determined solely by weight. In instances where weights were not recorded in the field, estimates were derived using length-weight relationships.

Benthic species and other sample fractions were weighed, and all data were then entered into the Wageningen Marine Research survey database program, "Billie". This included information from both the trawl list, which the project leader and skipper filled out, as well as other registered data. The trawl list contained details such as dates, trip numbers, gear positions, crew on board, key observations, sightings of birds and marine mammals, and setting and hauling times. All data were carefully checked following Wageningen Marine Research's standardized procedures before being imported into the FRISBE database. Afterwards, the data were extracted for further compilation and analysis.

In summary, the following biological data was recorded:

- Fish: quantities and individual lengths. Lengths were rounded 'to the cm below'.
- Mass per fish species per size category; undersized (below MCRS) and marketable size (above MCRS), using a Marel PL2262 weighing scale.
- Quantities, lengths, and where possible gender of elasmobranchs.
- Quantities of other species, such as benthic species (starfish, crabs, lobsters, hermit crabs, shellfish).

The biological and catch data are described in Chapter 4. Appendix 1 describes all species caught per wind farm, including their minimum sizes (MCRS⁷). In this report, English names are used for species. Scientific names can be found in Appendix 1 as well.

Bycatch

In this study, we differentiate between various types of bycatch, noting whether the bycatch is directly caught by the fishing gear or if unwanted species are indirectly attracted to the vessel, the caught fish, or the fishing gear itself.

The following bycatch categories can be identified based on whether the bycatch must be discarded, may be discarded, or must be kept onboard⁸.

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 and are therefore damaged.

These fish may be discarded:

- fish for which there is no catch limit or catch prohibition, and no minimum conservation reference size;
- fish over the minimum size for which there is no catch limit or catch prohibition, but a minimum conservation reference size;
- species subject to an exemption to the catch prohibition, if this exemption is applicable;

⁷ 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.

⁸ Aanlandplicht | RVO.nl

- species subject to an exemption based on high survival, if this exemption is applicable;
- species subject to a de minimis exemption, if this exemption is applicable.

All other fish must be kept onboard in accordance with the landing obligation, meaning that all catches of species regulated by catch limits must be landed and counted against the fishers' quotas. All other discarded fish must be registered in the log books.

For catch compositions and length frequencies shown in Chapter 5, all trips were taken into account. This was also done for Borssele, since there was not much difference in compositions between the different areas in Borssele I and II and the two reference locations outside of the wind farm.

For dab, plaice and sole catch per unit of effort (CPUE) and landings per unit of effort (LPUE) were calculated by dividing the total catch per trip/day per species by the total length (km) of gill net used in that trip/day (Figure 5.6). Since the nets were in the water longer than when gill net fishing commercially (since setting and hauling could only be done during daylight), CPUE and LPUE based on total catch divided by the hours that the gill net was in the water (total soaking time) is not used in this analysis.

2.4.4 Birds and marine mammals

Another type of unwanted catch involves the bycatch of marine mammals or birds by fishing gear. For example, diving birds or marine mammals may become entangled in gill nets or lines suspended in the water column. Additionally, there is a category that is not considered bycatch but still poses a risk to certain species indirectly due to fishing activities. The discarding of unwanted bycatch and fish waste can attract birds, increasing the risk of collisions with wind turbine blades. This risk also exists during the processing of marketable fish at sea, when fish waste is thrown overboard. The likelihood of this risk in Dutch fisheries is influenced by various factors such as the types of gear used, target species, the number and types of discards, location, and bird density at the time (Tasker et al. 2000). Therefore, this study examines bird and marine mammal observations during gill net trials in both offshore wind farms.

Per trip, all birds seen inside the wind farm were counted and scored to category if necessary (seagulls, cormorants, gannets, songbirds, others). Also, sightings of marine mammals such as harbour porpoises and seals were recorded on each of the trips. For birds and marine mammals, it was also registered if animals were attracted to fishing activities or following vessels (for example behaviour other than just swimming by or foraging, like actively swimming behind the vessel, foraging on discards), and if this was the case during setting the nets, hauling or discarding unwanted catch when sailing out of the wind farm.

2.4.5 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 fishing with other gears and conventional practices outside the wind farm (Neitzel et al. 2024). Compared to commercial gill net fishing the number of fishing trips and gears deployed in this study was limited.

To calculate the costs per year and per day at sea, data from the previous pilot study (Neitzel et al. 2024) was updated. In this former study calculations were made for two types of vessels suitable for fishing in a wind farm. WR 147 'Anna Lotte', used in this study to fish in wind farm Hollandse Kust Zuid, is comparable with the type 1 vessel.

Based on price data of the target species sole and other fish, an indication is given of landing rates required to cover costs per day at sea of fishing in wind farm Hollandse Kust Zuid.

3 Video observations and anchoring

3.1 Borssele

Seabed

Video analysis showed that the seabed at the locations of the anchor tests and transects of the sled and ROV consists of coarse stable sediment with small ripples (few centimeter high, few decimeter apart) alternated with large sand ripples (several meters wide, several decimeter high, Figure 3.1). These large ripples turned out less stable than the small ripples: sediments were stirred up when the sled passed, resuspended sediments was deposited within seconds. These large ripples have a more gentle slope on one side and a steeper slope on the other side, the latter causing the sled to drop down several decimeters on the stable seabed. In the flat small ripple areas tube building worms, brittle stars, sea stars, common dragonets and brown crabs were observed. On the large loose ripples only sand eels were observed that escaped the sediments when the sled passed by. At the end of one sled survey a passing seal was recorded. During the ROV and sled video survey no steel slags or other sharp objects were observed.

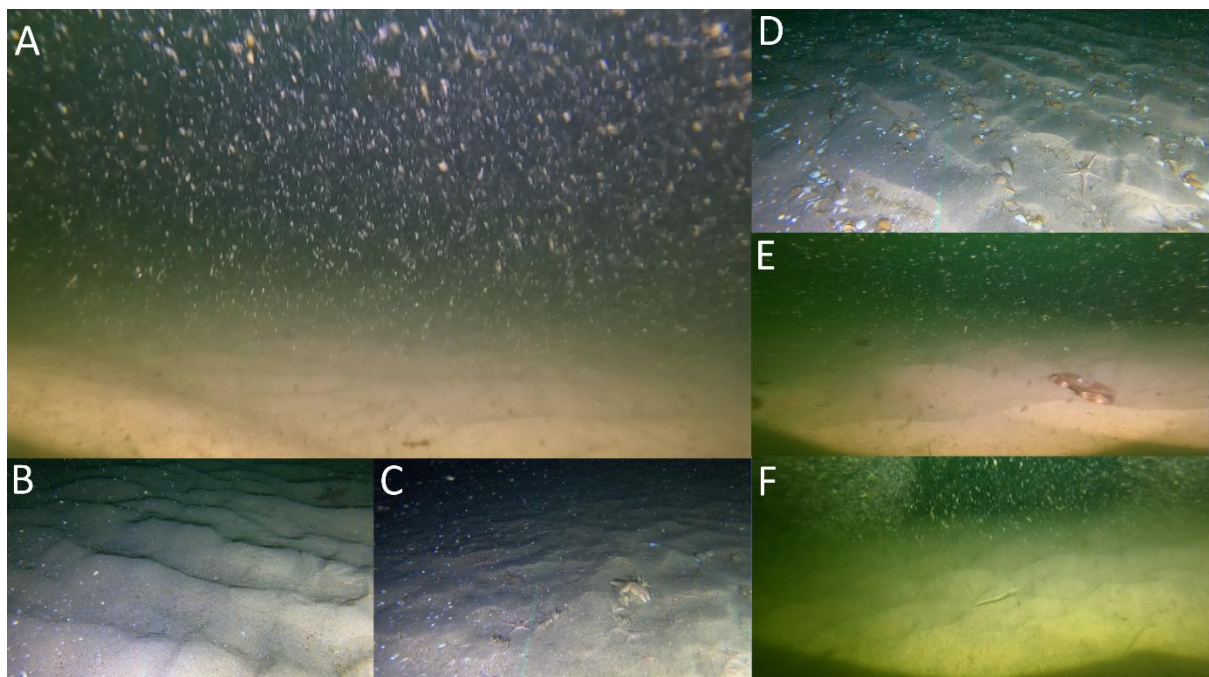


Figure 3.1 Stills of the sled and ROV underwater surveys in Borssele. A. Overview of the height differences of the seabed (left: the steep slope of the loose ripples, right: the more stable seabed). B,C,D. Close-ups of the sandy, stable seabed with shell fragments, tube building worms and sea and brittle stars. E. Brown crab on top of a big sand ripple. F. Sand eel escaping from the sediment.

Wind turbine

Around the wind turbines a higher biomass and number of (hard substrate related) species were observed compared to surrounding seabed (survey on 9 July 2024, Figure 3.2). The wind turbines were covered with anemones from the water line to the seabed. The scour protection (big rocks that lay several meters around the base of the wind turbines) was found to be covered with a moss like algae. On top of the scour protection clumps of mussels, starfish and anemones were found. In the cavities between the rocks brown crabs and velvet swimming crabs were observed. A shoal of pouting was observed swimming around the Wind turbine. Several meters away from the wind turbines the scour protection ends abrupt and from there a flat sandy seabed is observed with small (centimeter scale) sand ripples with broken shell material. On this, dragonets were observed, some sort of flatfish (unidentified) as well as a few velvet swimming crabs, all in low densities. Surveys ended approximately ten meter from the wind turbines.

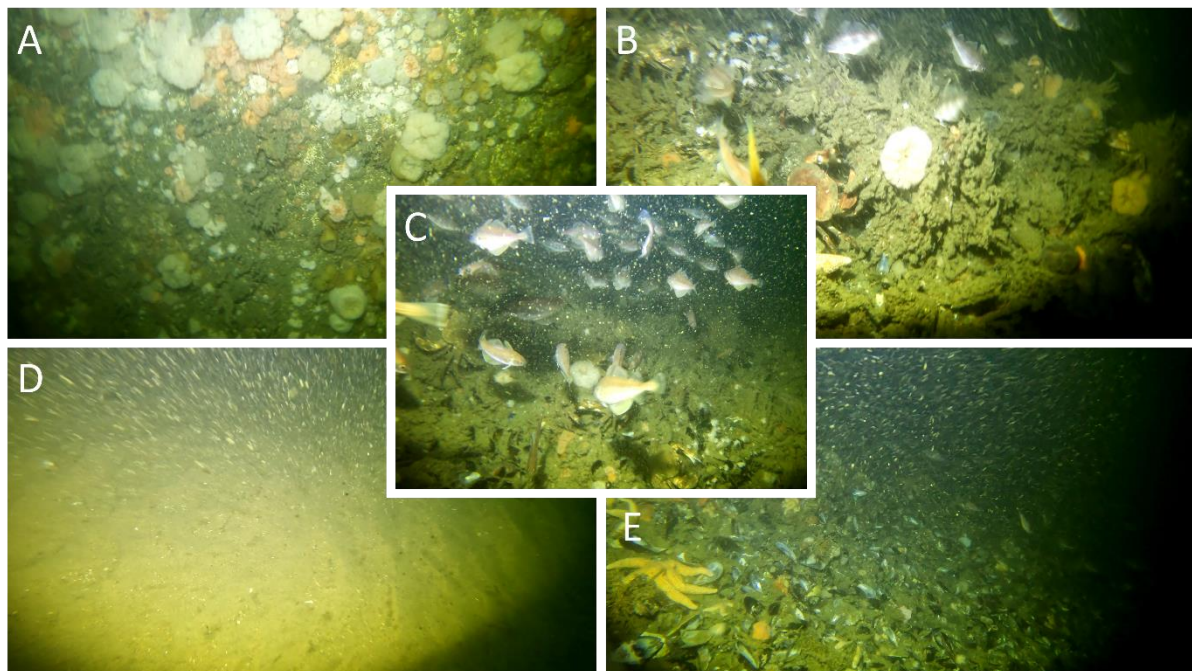


Figure 3.2 Stills of fishing rod underwater surveys around the wind turbines in Borssele. A. Anemones covering the wind turbine. B, C & E. Scour protection covered with moss, anemones, blue mussels, sea stars and presence of brown crab and pouting. D. Sand flat right next to the scour protection with low number and biomass of visually detectable species.

Anchor and net behaviour

Anchors reached the seabed 40 to 85 seconds after they were released in the water. In all cases they landed upright on top of the seabed without resuspension of the sediments or creating an impact crater. The first released anchor was pulled into the seabed (all three fins) within 30 seconds after landing and was then quite stable in position. Movement through the sediment was estimated to be a few centimeters to decimeters in the time frame of seven minutes and 30 seconds. Based on the anchor width of 41 cm and an estimated maximum drag of 25cm, the disturbed sea bed area is estimated to be maximum around 0.1m². During the first minutes after reaching the sea bed, both last released anchors were slowly and gradually pulled into the seabed with one of the lateral fins and hardly moved afterwards (max. 20 cm in total). Upon hauling of the nets the first released and hauled anchor was gradually pulled upright in the sediment over the course of 2 minutes, after which it came out and glided over the seabed for some seconds before it was lifted to the surface. Based on the fin width of 12 cm and an estimated maximum drag of 20cm, the disturbed sea bed area is estimated to be maximum around 0.02m². The last released anchors showed different behaviour upon hauling: one was gradually pulled upright and released the seabed without dragging through the sediment. The other wasn't pulled upright but was dragged flat into one of the unstable big ripples (all three fins of the anchor inside the sediment). Then it was steadily pulled through the ripple for about 3 to 4 m, and after reaching the steep slope of the ripple the anchor was

immediately released from the seabed, subsequently glided on top of the sediment for a few seconds, after which it was lifted to the surface. Based on the anchor width of 41 cm and an estimated maximum drag of 4m, the disturbed sea bed area is estimated to be maximum around 1.64m².

The camera facing the nets that was located on the lead line at the first anchor side recorded that the net was standing upright during deployment and some lateral movement (centimeter scale) of the net during deployment. The net lead line was not completely firm on the seabed as some parts were seen floating right above it. The footage confirmed the movements that were recorded at the first anchor: upon hauling no lateral movement of the net, but the net moved 3 to 4 m over the seabed in the direction of the line in the last phase of the hauling just before it was dragged to the surface.

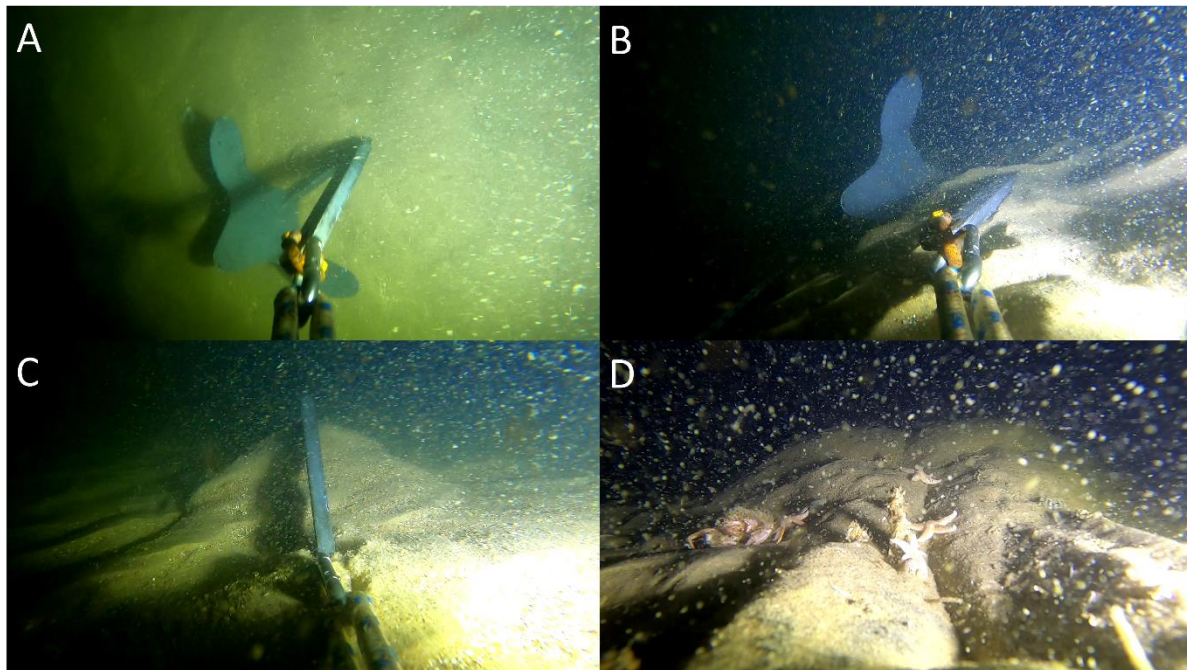


Figure 3.3 Stills of underwater surveys focused on anchor and net behaviour in Borssele. A. Anchor gently touching the seabed. B. Anchor secured in the seabed with 1 lateral fin. C. Anchor secured in the seabed with all fins. D. Anchor fully secured in the loose ripple sediment with benthic organisms on top.

3.2 Hollandse Kust Zuid

Seabed

Visibility was poor during all surveys. Video analysis showed that the seabed consists of coarse sediment with small ripples (up to decimeter high, few decimeter apart, Figure 3.4 and 3.5). The seabed seemed not consolidated and quite loose. Large topography with meter scale sand ripples (as seen in Borssele OWP) were absent along the observed trajectory. Shell fragments were found scattered over the seabed as were brittle stars. Dragonets, pouting, netted dog whelk, spin crab (*Maja spec.*) and brittle stars were observed on the footage of the net behaviour. Some of them very close to and on the netting and its lines.

Wind turbine

The wind turbines (survey on 27th of June 2024) were mainly covered with mussels from the water line to the seabed, alternated with some anemones. The scour protection around the wind turbines was covered with some kind of algae, suspended sediments, mussels, some anemones and lots of sea stars, ranging from small, centimeter size to big individuals of several centimeters in size. In the cavities between the rocks some brown crabs were observed. A shoal of pouting was observed swimming around the wind turbine. Several meters away from the wind turbines the scour protection ends abruptly and from there a flat sandy seabed is observed with small (cm to dm scale) sand ripples with broken shell material. On this,

brittle stars and some sort of flatfish (unidentified). Surveys ends approximately 10 m from the wind turbine.

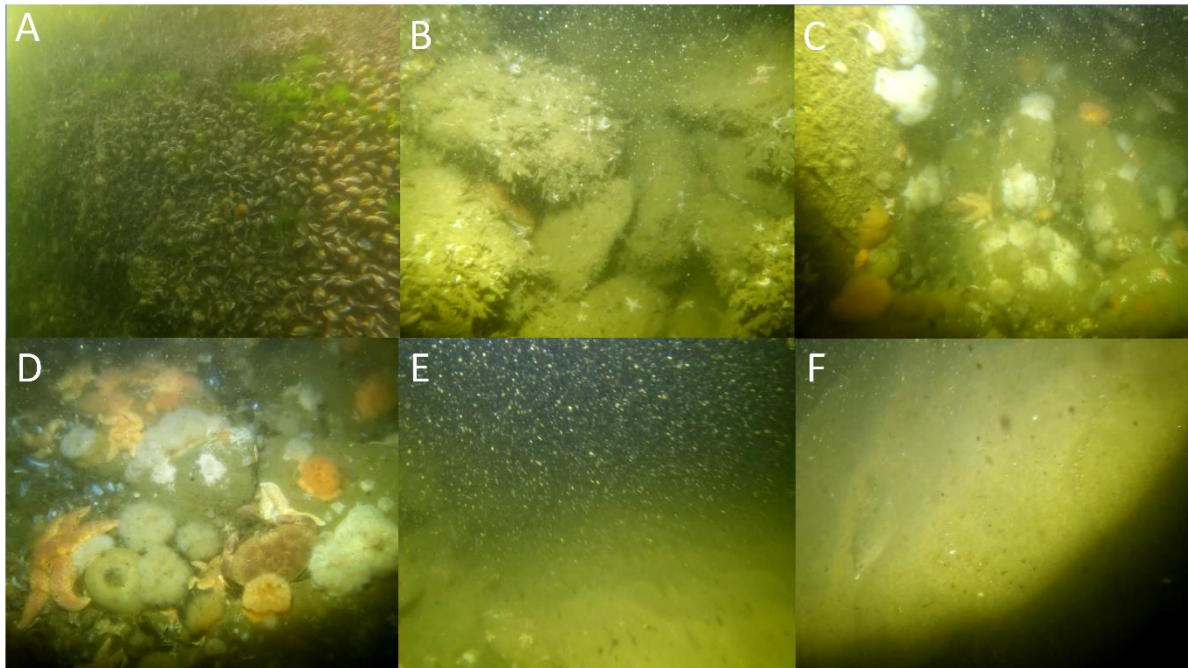


Figure 3.4 Stills of underwater surveys in Hollandse Kust Zuid. A. Mussels covering the wind turbine. B, C & D. Scour protection covered with moss, anemones, blue mussels, sea stars and presence of brown crab and pouting. E. End of scour protection (left) and start of flat sandy seabed (right). F. Sandy seabed next to the wind turbine with flat fish (left bottom corner).

Anchor and net behaviour

Anchors and net behaviour analysis at Hollandse Kust Zuid OWP is challenging due to the poor visibility of the water. Anchors reached the seabed 20 to 30 seconds after they were released in the water. It is not distinguishable if the landing was soft or hard as no resuspension or impact crater could be observed due to the poor visibility. One of the first released anchors was pulled into the seabed (all three fins) within 2 minutes after landing and was then quite stable in position (movement through the sediment few cm in the time frame of minutes). Upon hauling the anchor was pulled upright after it left the seabed without dragging through the sediment. Based on the anchor width of 41 cm and an estimated maximum drag of 25 cm, the disturbed sea bed area is estimated to be maximum around 0.1 m². The other first released anchor was anchored in the sediment with one of its lateral fins and was stable in position during deployment. Upon hauling all fins were pulled into the sediment securing the anchor in position. Some drag through the sediment is thought to be seen 10 seconds before the anchor was hauled to the surface, but this is highly uncertain due to the poor visibility. An estimation of the maximum drag cannot be made. The last released anchor was pulled into the seabed with one of its lateral fins and had a displacement of several centimeters during deployment. Upon hauling the anchor was pulled into the sediment and was slowly and steadily dragged through the sediment for 2 minutes / 1 meter in the direction of the bottom line, before it released from the seabed and was hauled to the surface. Based on the anchor width of 41 cm and the estimated maximum drag of 1 m, the disturbed sea bed area is estimated to be maximum around 0.4 m².

The camera facing the nets that was located on the lead line at the first anchor side recorded that the net was standing upright during deployment and some lateral movement (cm scale) of the net during deployment. The net lead line was firm on the seabed. Upon hauling no lateral movement of the net was recorded, but one of the two nets moved 2 to 3 m over the seabed in the direction of the line. The other net did not move during hauling.

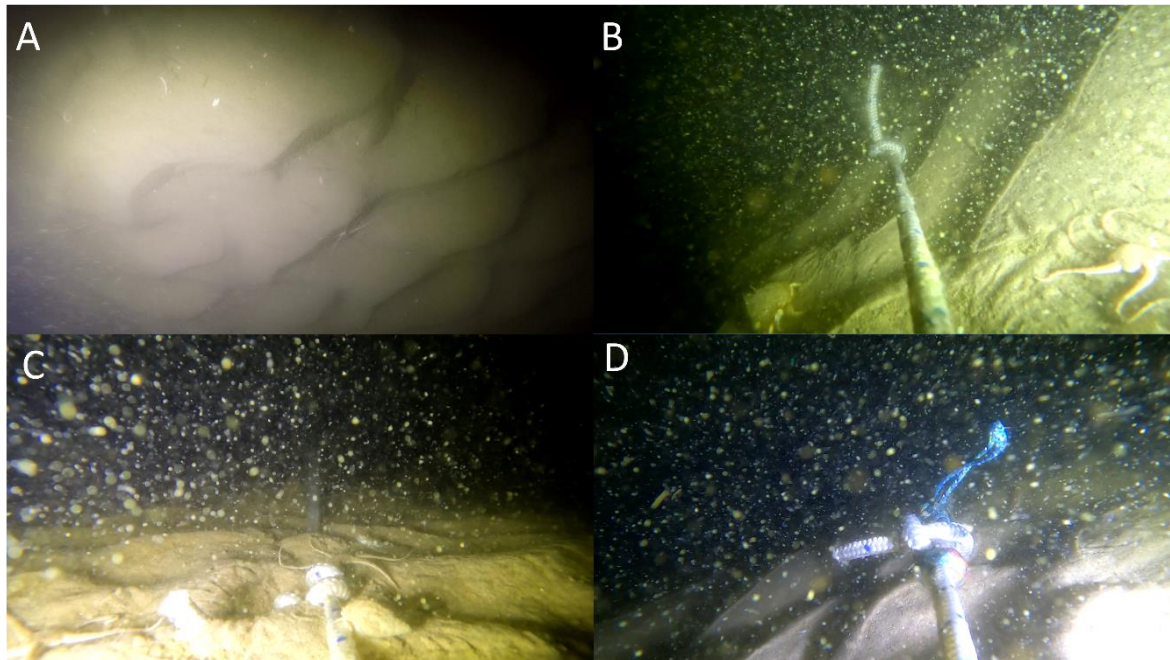


Figure 3.5 Stills of underwater surveys in Hollandse Kust Zuid. A. Seabed consists of loose sandy sediment with small ripples. B. Anchor secured in the seabed with 1 lateral fin, presence of brittle star and spider crab. C. Anchor secured in the seabed with all fins, presence of brittle stars and netted dog whelk. D. Very poor visibility, camera facing the start of the net.

4 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 chapter describes the risk evaluation method, identified risks qualification and quantification.

4.1 Risks

The risks of passive fishing by means of pot strings, handline fishing, gill net fishing and jigging, in offshore wind farms is evaluated in Neitzel et al. 2024. The vessels and fishing gear used for gill net fishing are similar as for passive fishing with pots strings. There are no notable variations in risks for the offshore wind farms between pot strings and gill nets. The risk assessment method and outcomes described in Neitzel et al. 2024 are applicable to gill net fishing as well.

Main conclusions adopted from Neitzel et al. 2024 about the risks of passive fishing in offshore wind farms are:

- The risk of damage to a wind turbine as a result of passive fishing with vessels up to 46 m 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 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.
- The risks of damage to the wind farm due to the use of passive fishing equipment are limited.
- The major deemed threats for the wind farm is the displacement of gears and damage by the anchor to the in-field cables. This risk is evaluated by the quantitative approach based on the position registrations of the gears. The results show that most of the measured displacements are within the range of the measurement deviation. This aligns with qualitative observations of the skipper and the onboard researchers, who indicate no notable drift of the gears takes place
- Furthermore experiments carried out in the Win-Wind project show that the risk of damage to the in-field cables is marginal when using Bruce anchors (Rozemeijer et al. 2022).
- 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 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.

The quantitative analysis of the displacement of the gear is repeated in Section 4.2 based on the position registrations from the present experiments.

4.2 Gill net positions

The risk of displacement of gill nets is described in this section. Displacement of the gill nets is evaluated qualitative by the observations of the fishers and researchers during the experiments as well as quantitative from the registered anchor positions. The displacement of the gill nets is taken into account in the risk

evaluation. In the evaluation of the experiments the skipper and researchers indicate that no notable displacement of gill nets has taken place. Maximal displacement is estimated to be meters to decametres. 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 gill nets. The onboard GPS location 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 decametres up to a hectometre.
- 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 gears, the first anchor could either be the Northern or 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 (T1) and hauling (T2). 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 incorrectly. This results in a registration uncertainty equal to the string length (550 m for the gill nets).

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. 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.

4.2.1 String length

For the displacement analysis the anchor positions measured during all gill net trips (10 in Hollandse Kust Zuid and 11 in Borssele) are used. From all gill net trips in principle 158 anchor registrations (21 trips x 2-4 strings x 2 anchors) are available for the analysis. 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 more than 1000 m away from the target location.
- Sensibility check is performed on the remaining registrations. When the distance between the first and second anchor (A1 and A2) at the moment of setting (T1) or hauling (T2) is more than 1000 m the registration is rejected based on the consideration of errors in the registrations. This range is subjective.

The quality and sensibility check leave 149 registrations for the uncertainty analysis (n = 149).

To quantify the gill net displacement, first the measurement deviation is evaluated. The measured length of the gill nets is the distance between the first (A1) and second anchor (A2) at the moment of setting (T1) or hauling (T2). The measurement deviations are evaluated as the difference between the measured length and the actual length of the gear at the moment of setting and hauling. 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:

$$\delta L = L_{\text{meas}} - L_{\text{act}}$$

in which:

δL : Mean measurement deviation [m]

L_{meas} : Measured distance between first and second anchor at the moment of setting and hauling [m]

L_{act} : Actual length of the gears (550 m for gill nets) [m]

The derived measured distances are presented in the distribution plot below (Figure 4.1). The analysis results in a mean measured distance of 551 m and U95 of 100 m. This results in a mean measurement deviation of $\delta L = 1$ (U95=100, n=149) m.

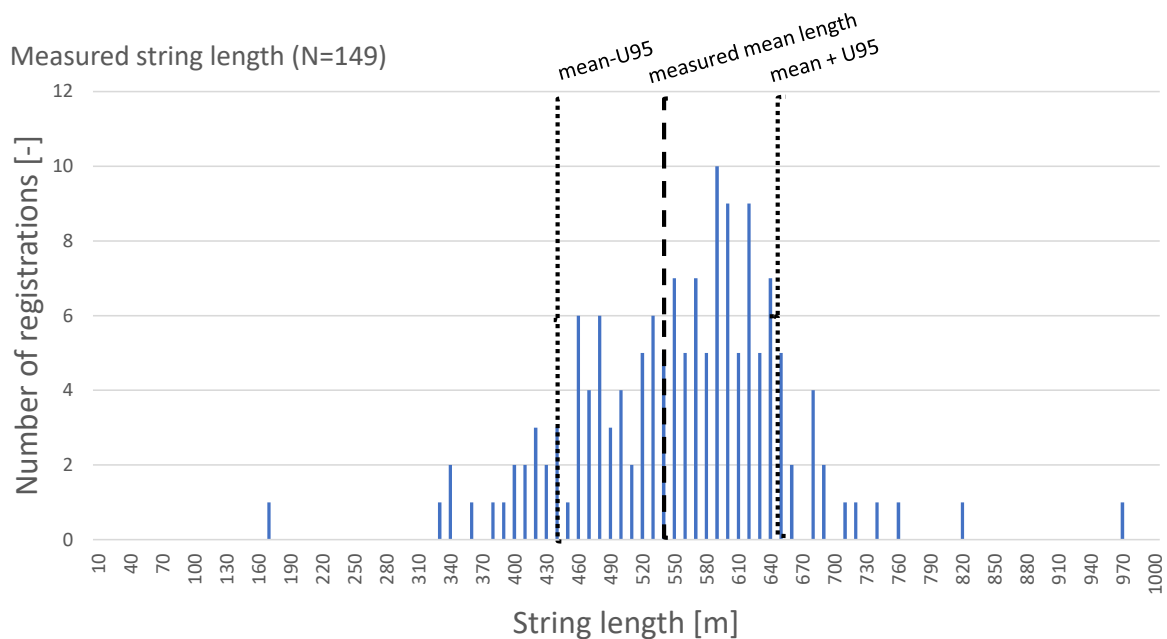


Figure 4.1 Calculated string lengths between first and second anchor (A1 and A2) during setting (T1) and hauling (T2).

4.2.2 Gill net displacement

The measured gill net displacements are the displacements of the first anchor (A1) and second anchor (A2) between the moment of setting and hauling, $x_{A1}(t)$ and $x_{A2}(t)$. In the analysis of the gill net displacements first the same quality control and sensibility checks as applied in the string length analysis are performed.

This results in a total of 149 measured displacements. Next, from the distance between the same anchor at the moment of setting (T1) and hauling (T2) the displacement of the gill nets during time is evaluated. This is considered as the actual gill net displacement.

The displacement is calculated as follows:

$$x_{A1}(t) = A1T2 - A1T1$$

$$x_{A2}(t) = A2T2 - A2T1$$

$$x(t) = [x_{A1}(t), x_{A2}(t)]$$

$$\delta x(t) = x(t) - \delta L$$

$x_{A1}(t)$: Measured displacement of anchor 1 as function of time [m]

$x_{A2}(t)$: Measured displacement of anchor 2 as function of time [m]

$x(t)$: Measured displacement of anchors 1 and 2 as function of time [m]

$\delta x(t)$: Evaluated displacement of gears as function of time [m]

The measured displacements ($x(t)$) are presented in the distribution plot below (Figure 4.2). Also the mean (1 m) and mean+U95 (101 m) measurement deviation are indicated in this Figure.

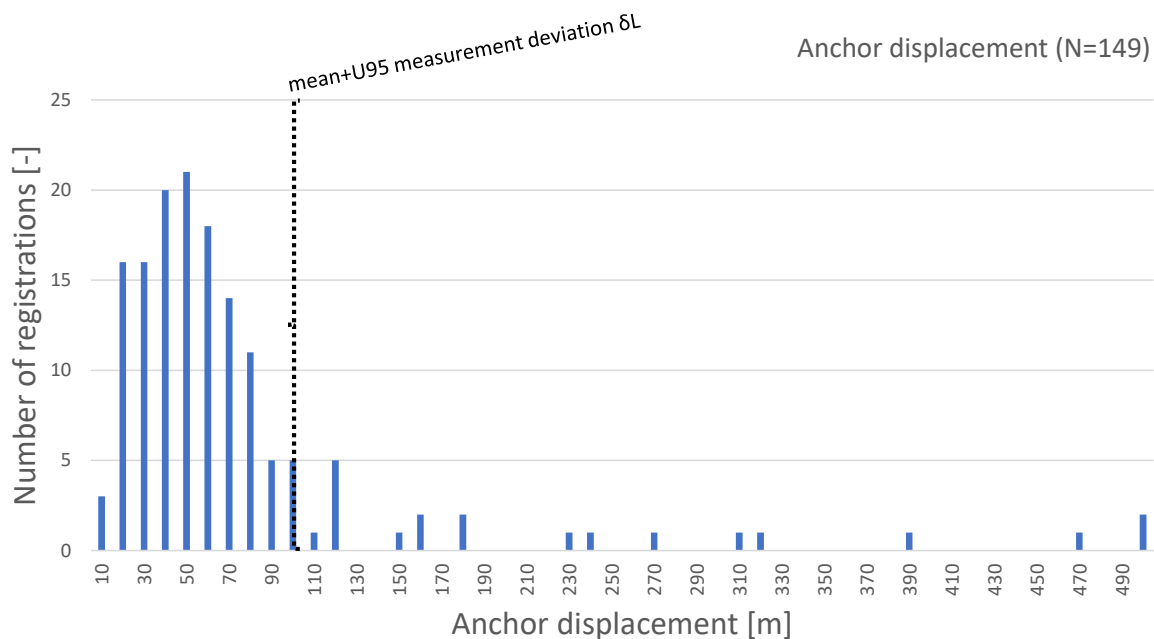


Figure 4.2 Measured anchor displacements of anchor 1 (A1) and anchor 2 (A2) between setting (T1) and hauling (T2).

The results presented in the Figure 4.2 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 researchers 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. From these analyses it is concluded that the risk of displacement of gill nets moored by Bruce anchors is marginal.

Absolute comparison of the gill net displacements with the displacements of cages reported in Neitzel et al. 2024 shows the derived gill net displacements are less than the derived displacements of the cages. Although Neitzel et al. 2024 does not show a clear trend between soak time, intermediate weather conditions and displacement of cages it is likely that soak time and intermediate weather condition are of influence on the displacement. The soak time of the gill nets is typically 1 day, while the soak time of the cages is few days up to a week. Gill nets are only set when the weather on two consecutive days is good and hauling is possible the following day. Between the setting and hauling of cages the weather can be worse.

4.3 Nautical operations

4.3.1 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 3.

- 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.
- The communication protocol as established by Neitzel et al. 2024 was adopted for the present experiments. This consists of 2 calls to the wind farm MCC, one for entering the wind farm and one at departure. In Borssele the calls were made by GSM, in Hollandse Kust Zuid by Tetra, installed onboard of the WR 147 by Vattenfall. The wind farm operator informs the coast guard of the presence of the fishing vessels. Communication about and confirmation for entering the wind farms went more smooth than during the experiments conducted in 2023 in Borssele. This is likely due to increased confidence and trust in the limited risk of the passive fishing operations.
- Sailing time from coast to wind farm and vice versa with a small vessel (Lpp<12 m) takes 2 (Hollandse Kust Zuid from IJmuiden) to 3 hours (Borssele from Neeltje Jans), resulting in a total of 4 to 6 h sailing time per workday. The time required to haul and set the gill nets in the wind farm for the experiments is approximately 1 to 1.5 h. Note that for the experiments all catch had to be counted and weighed. In normal fishing operations hauling and setting of gill nets can be faster. Together sailing time and working time in the wind farm result in 10-12 h working days.

4.3.2 Sailing trajectories

The Figures and maps in Appendix 4 reflect the sailed tracks of the fishing vessels YE 152 to Borssele and WR 147 to Hollandse Kust Zuid from April till July and other vessels in proximity and within the wind farms. These tracks have been created using AIS data from the respective vessels and provide a geographical image of the total operational activities by these 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.

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. One must take into account that it takes extra time and sailing trajectories within the wind farm for fishing vessels in comparison to CTVs, as maintenance zones around the wind turbines cannot be crossed. Maintenance zones around infield cables can be crossed.

The images have been supplemented with tracks of working vessels inside the wind farm, represented by the grey lines. This image only highlights the 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. Since there was no interference reported during the experiments, simultaneous operations are taking place.

4.4 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 and Hollandse Kust Zuid, 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 2024 is made based on measured conditions at measurements stations Borssele Alpha (Platform) and Hollandse Kust Zuid A (Platform). These weather conditions are obtained from <https://waterinfo.rws.nl> and are the actual weather conditions measured in the wind farms. The measurement stations provide 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.

4.4.1 Wave height

Wave conditions are obtained from the following sources:

- "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.
- "Measured" wave conditions in Borssele and Hollandse Kust Zuid during the period of the experiments (2024) are obtained from <https://waterinfo.rws.nl>. This source provides the measured local weather conditions at measurements station Borssele Alpha (Platform) and Hollandse Kust Zuid A (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 Hollandse Kust Zuid 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 farms Borssele, Hollandse Kust Zuid, HKN and HKW.

A comparison of the observed and measured wave height on the days of the experiments is given in Figure 4.3 and Figure 4.4. From the measured wave conditions the average and maximum wave heights measured during daytime, between 6 am and 6pm, is taken.

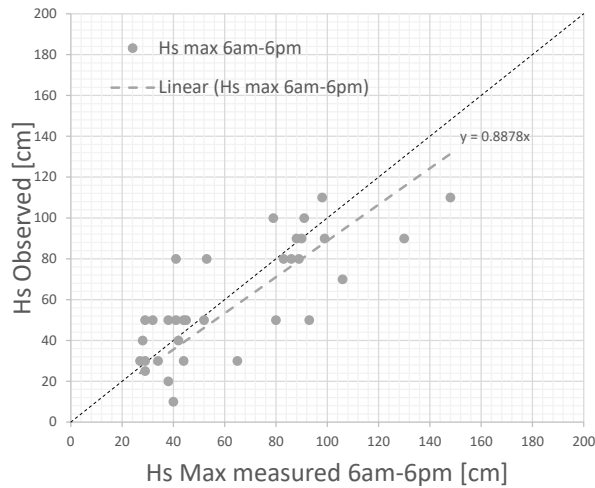


Figure 4.3 Observed wave height versus measured maximum wave height during daytime on sailing days.

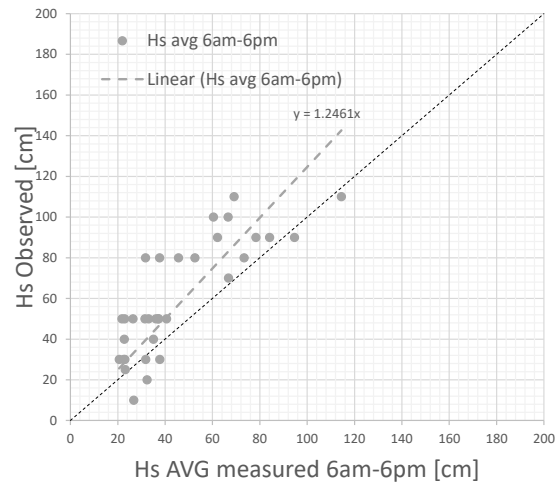


Figure 4.4 Observed wave height versus measured average wave height during daytime on sailing days.

Figure 4.3 and Figure 4.4 show that the observed wave heights are in general in-line with the measured wave heights. The observed wave heights are in general +25% higher than the average measured wave heights and -11% 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.

The significant wave height (H_{m0}) measured at Borssele Alpha Platform and Hollandse Kust Zuid A platform is shown in the Figures below (4.5a and 4.5b respectively). The days on which experiments are conducted are visualized in this Figure as well.

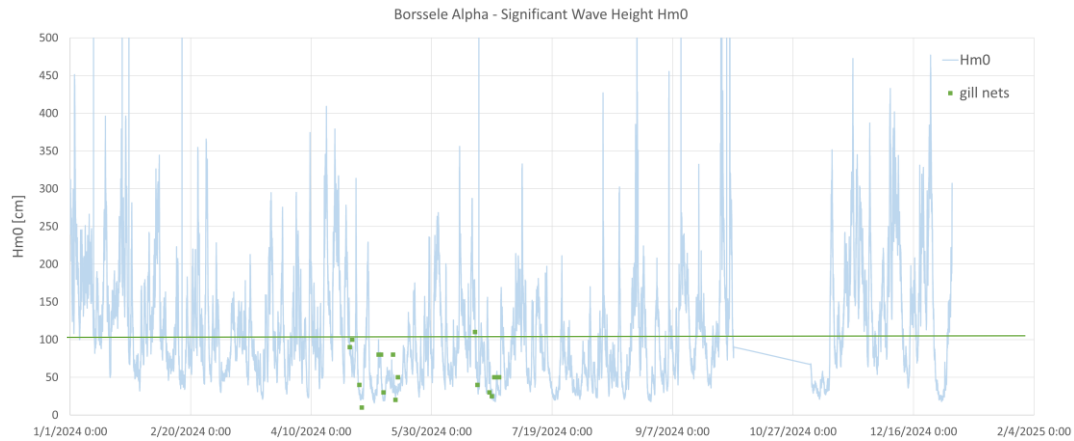


Figure 4.5a Significant wave height Borssele II024 (measured).

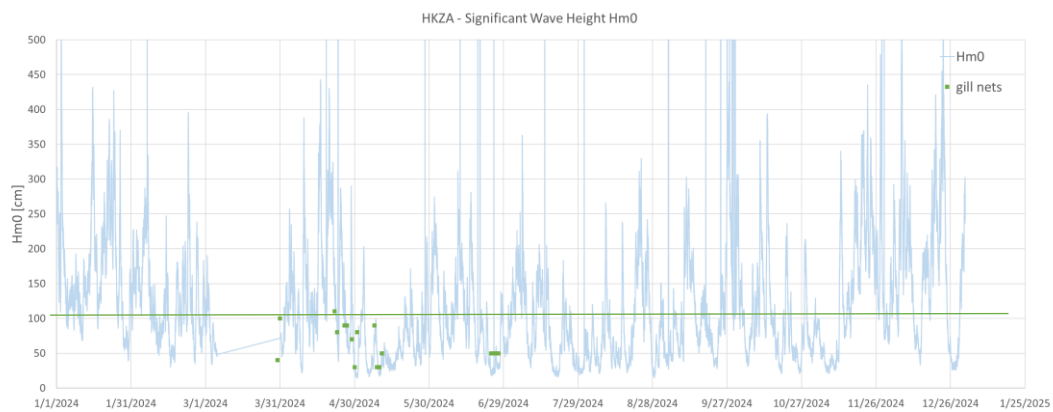


Figure 4.5b Significant wave height Hollandse Kust Zuid 2024 (measured).

4.4.2 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.

Indicative operational limits are:

- Small vessels ($L_{pp} < 12$ m), such as the YE 152 and WR 147, $H_s < 1$ m

The operational limit of $H_s < 1.0$ m is applied to determine the workable time (in %) in Borssele and Hollandse Kust Zuid during the experiments of 2024 (based on the measured weather data). In addition the workable time in an average year is derived from hindcast weather data. The results of this evaluation are shown in the Figures 4.6 to 4.8 below on an annual and monthly basis. Note that this comparison gives the time-based operability, but does not account for the duration of the operation, the so-called persistency. For example: when $H_s < 1.0$ m for half the day the time based workability yields 50%, while the captain might not sail out because of bad weather during the 2nd part of the day and the complete day is a non-sailing day (the persistency based workability is 0%). Also, non-workability during night time is not accounted for. Therefore the actual number of workable days are less than the workable time.

Comparison between the workable time of 2024 with the long-term hindcast statistics shows worse weather and less workable days in April, good weather and more workable days in May and better than average weather in summer.

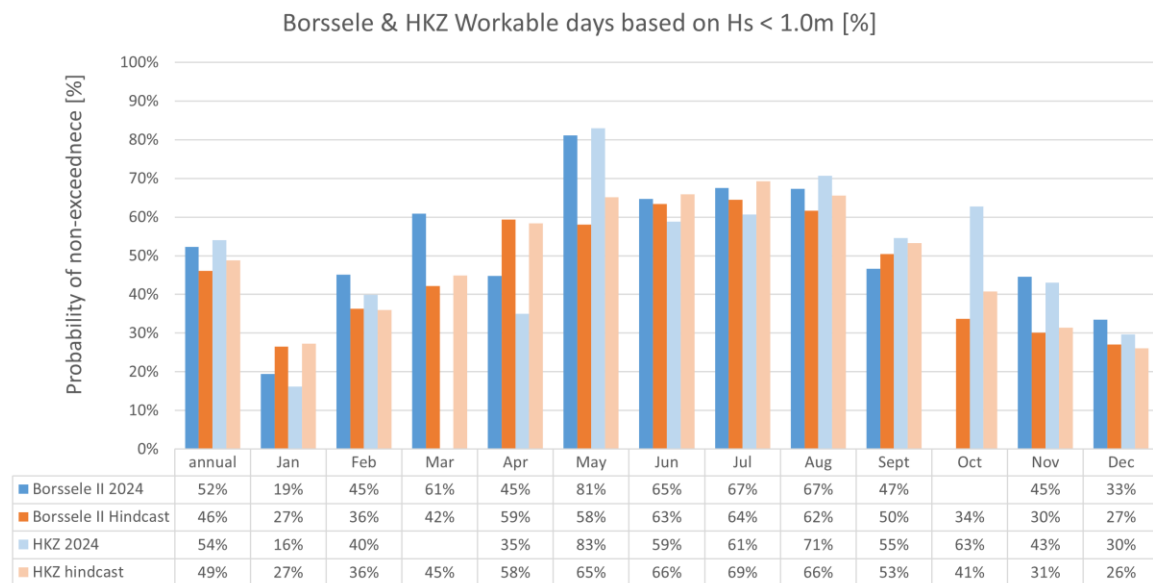


Figure 4.6 Workable time based on wave height criteria $H_s < 1.0\text{ m}$ in Borssele and Hollandse Kust Zuid 2024 (blue) and average (orange).

Finally, note the operability is reduced by the tide. Since working in the wind farm is only allowed during daytime departure is in the morning and arrival in the afternoon or evening. Sailing with the tide reduces the nominal sailing time by approximately 20%, while sailing against the tide increases the sailing time to by approximately 20%. 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. The restriction to only be allowed to access the wind farm during daytime hampers the flexibility to select the ideal sailing times.

5 Ecological and biological data

This chapter describes all results found in terms of gear adjustments, relevant observations, catch and bycatch amounts and compositions and sightings of birds and marine mammals from both offshore wind farms.

5.1 Overview

Based on field experiences, it became evident that field trips were, (as was also the case in the 2023 season) highly affected in terms of the number of attempts to go out during peak season by wind and wave conditions (Neitzel et al. 2023b). Consequently, the planning, and thus the participants involved, had to undergo frequent adjustments and continual adaptations. Descriptive tables are provided detailing fishing effort, total catches by target species, gear modifications, significant observations, weather conditions, and sightings of birds and marine mammals.

5.2 Borssele

5.2.1 Fishing operations

A total of 18 days were foreseen and 18 days have been undertaken from which the researchers obtained biological data from 11 days (trips). Three days were realised in April, seven in May, seven in June and one in July (Appendix 5, Table A5.1). For this experiment the blue space between maintenance zones for Borssele I and II (Figure 2.1) was used, and the exact locations are shown in Figure 2.4. As discussed with the focusgroup of fishers, the peak season for gill netting for sole is from February to April, sometimes extending to May or June depending on conditions. Therefore researchers and crew planned to have the most fishing effort in the first months of the year. However, on the first trip, crew noticed very bad visibility due to the algal bloom which typically happens during spring (see Figure 5.1). When hauling the next day, many net sections were damaged. This could be due to the fact that algae got stuck in the net, making the nets much heavier and therefore more vulnerable to the strong currents. Nets were probably 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.

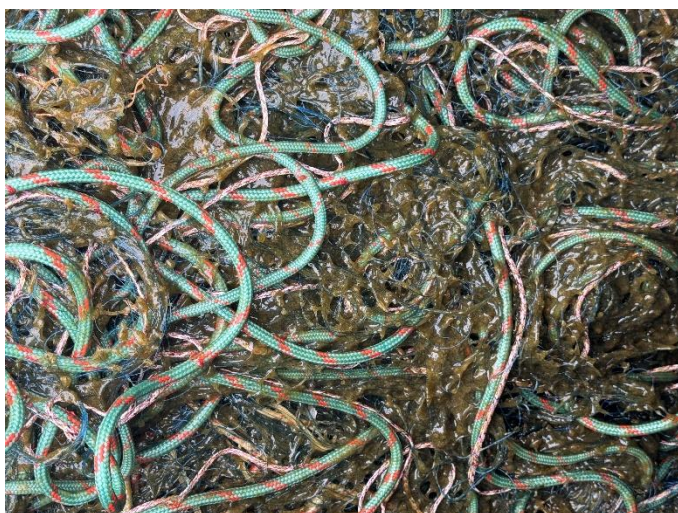


Figure 5.1 *Heavy nets due to algal bloom.*

However, the next trips, nets were still severely damaged, and one steel slag was caught in the net. In the 2023 experiment, another steel slag was caught in a pot string, so researchers consulted the wind farm owner, Rijkswaterstaat and the Ministry on how to proceed, and asked if steel slags were used as scour protection or during the construction phase of the wind farm. This was not the case, and it was discussed to first do video surveys on the seabed using ROV and sled with GoPro attached to look for any sharp objects. The first trial, the visibility was still too low due to ongoing algal bloom. On the same trip however, crew performed two reference hauls in addition to the video surveys, to determine whether the nets were also severely damaged outside of the wind farm. The locations for reference hauls were chosen based on being close to the wind farm, with similar depths and environmental conditions. This was repeated in another trip just outside of the wind farm and in both trips, none of the nets were damaged. Thereafter it was decided to expand the research locations to Borssele I in close consultation with Rijkswaterstaat, the wind farm owner and the Ministry for approval as these locations were not originally listed in the action plan. The remaining days, crew therefore fished in Borssele I instead of Borssele II, where nets were less damaged and often not damaged at all. During ROV and sled surveys once the algal bloom cleared, no (sharp) objects were found on the bottom. All important observations such as gear adjustments, communications, weather conditions and bird and marine mammal sightings, as well as trip specifics (date, fishing effort, total catch of marketable sole caught) are shown in Table A5.1 in Appendix 5.

5.2.2 Catch composition

The most important species in weight are described in this chapter. A list of all species caught in offshore wind farm Borssele can be found in Appendix 1 (Table A1.1). The species caught in Borssele offshore wind farm that are potentially commercially interesting were (in order from highest to lowest catch in weight): dab, sole and plaice.

Other species that could be landed as marketable fish included starry smoothhound, lesser spotted dogfish, horse mackerel, Atlantic mackerel, seabass, brill, turbot, tub gurnard, whiting, flounder and common cuttlefish but were only caught in lower quantities and therefore seen as possible marketable bycatch. Therefore, the length frequencies and CPUE/LPUE graphs in this chapter will focus on only the three beforementioned species. The catch composition for all fish species caught per trip is shown in Figure 5.2. Figure 5.2 also shows that catch of species was highly variable over time, location and between days.

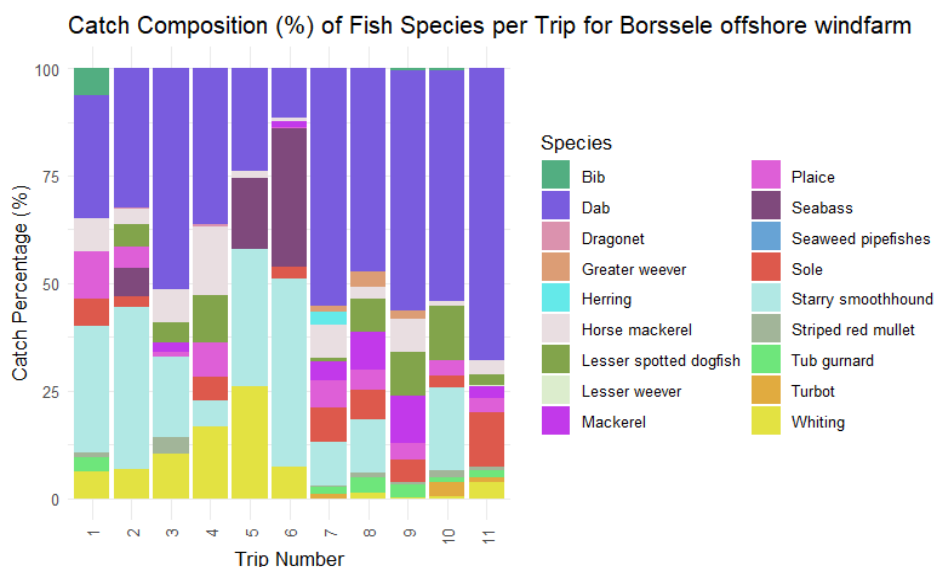


Figure 5.2 Relative, weight based catch composition per gill net fishing trip in offshore wind farm Borssele.

As can be seen in the Figure above, catch compositions highly varied over time and trip. Overall, dab and starry smoothhound dominated the total catch, followed by whiting, horse mackerel, seabass, plaice and sole, depending on the trip. The other species caught can be seen as incidental bycatch, of which some of the species have economic value and could be sold on the fish auction. For the two reference hauls (trip 5 and 6), the catch composition is different than for other trips. This is also the case for the trips made to Borssele I (trip 7 to 11).

Figure 5.3 shows the overall catch distribution for (sub)target species for the landable catch (>MCRS) or non-landable catch (<MCRS) for commercial species.

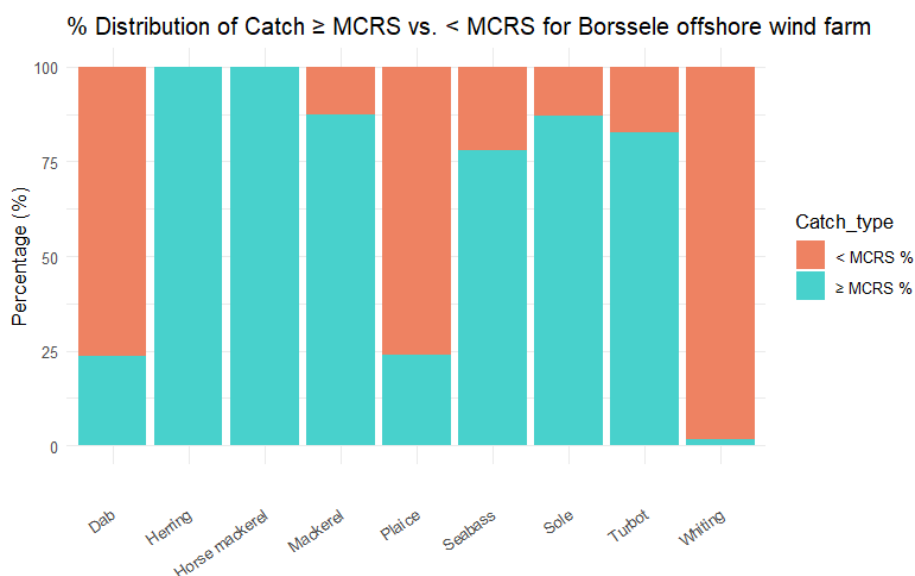


Figure 5.3 Weight based distribution over landable (>MCRS) and non-landable (<MCRS) for all marketable species caught in the gill net experiments.

Figure 5.3 shows that for sole, almost 88% of the total catch was above minimum size and therefore landable. For incidental bycatch such as herring, horse mackerel, mackerel, seabass and turbot, 74% or more was above minimum landing size. For dab, plaice and whiting catches were mainly below the

minimum landing size. Note that dab has no official MCRS, but in this study a minimum landing size of 23 cm was used, in agreement with the unofficial minimum landing size for dab to be sold on the fish auction.

Figure 5.4 shows the length frequency distribution for dab, sole and plaice caught during all the trips combined. The red dotted lines represent the minimum sizes (and for dab minimum size used on the fish auction) for the species shown. For dab and plaice, most of the fish caught were below minimum landing size while for sole, most fish were above minimum landing size.

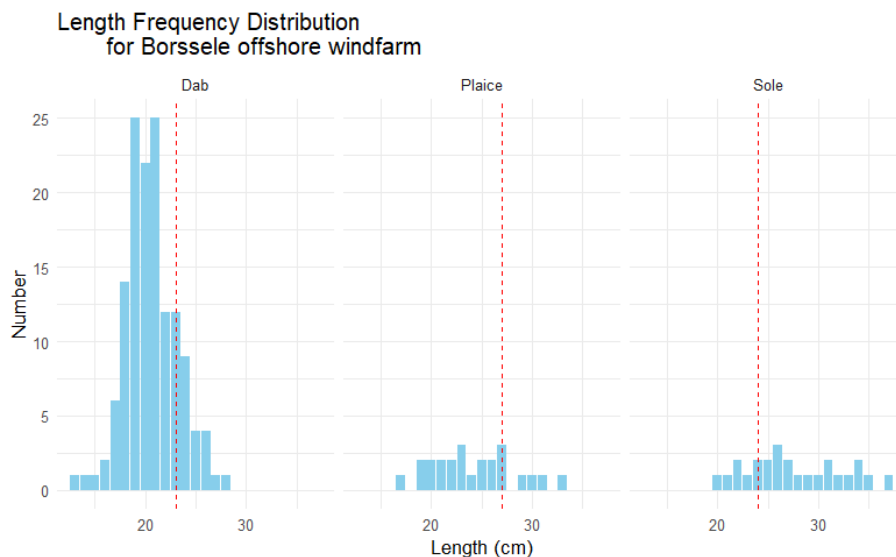


Figure 5.4 Length frequency distribution for dab, plaice and sole caught in gill net trips.

The benthic species caught consisted mostly of low numbers of bottom dwelling crustacean species and starfish (Figure 5.5). No weights could be determined from benthic species. Except for incidental bycatch of European squid and cuttlefish, none of the benthic species were seen as marketable. Brown crab is not seen as a target species in gill net fisheries but when caught, crab legs were collected as landable catch.

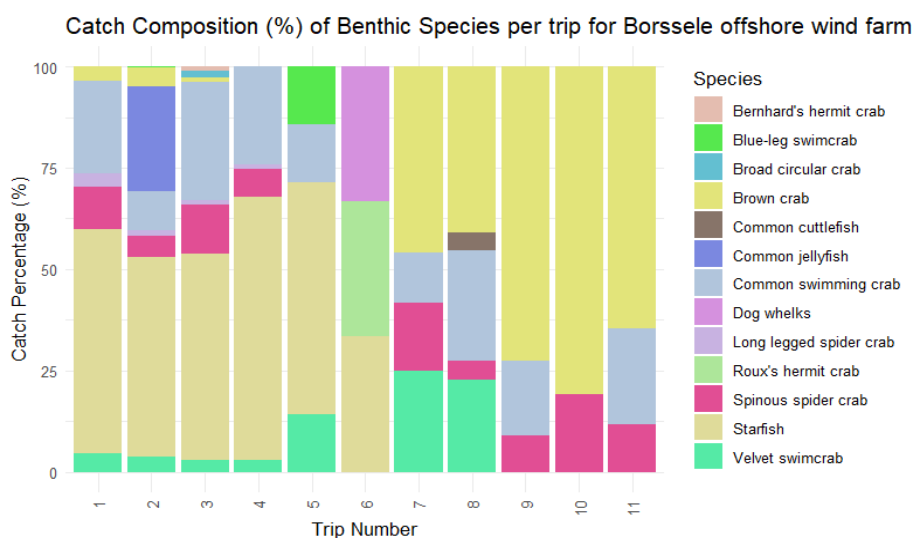


Figure 5.5 Catch composition for benthic species only based on numbers per trip.

Figure 5.6 shows the CPUE for dab, plaice and sole.

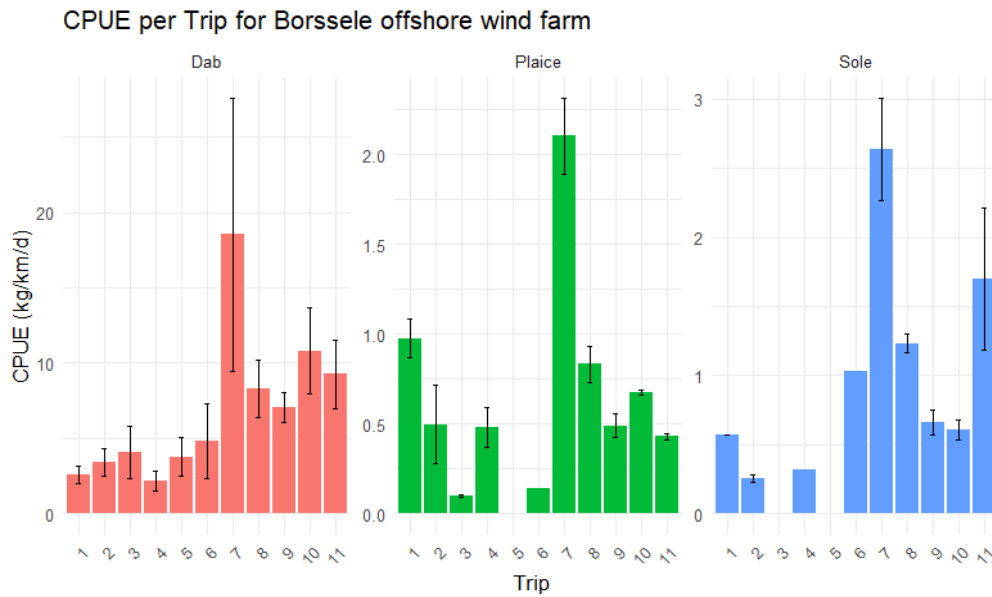


Figure 5.6 CPUE per trip expressed in kg/km/d realised during experimental gill net fisheries in wind farm Borssele for dab, plaice and sole.

Realised CPUE ranged for dab from 2.1 to 18.5 kg/km/d, for plaice from 0.1 to 2.1 kg and for sole from 0.3 to 2.6 kg/km/d.

Figure 5.7 shows the LPUE for dab, plaice and sole.

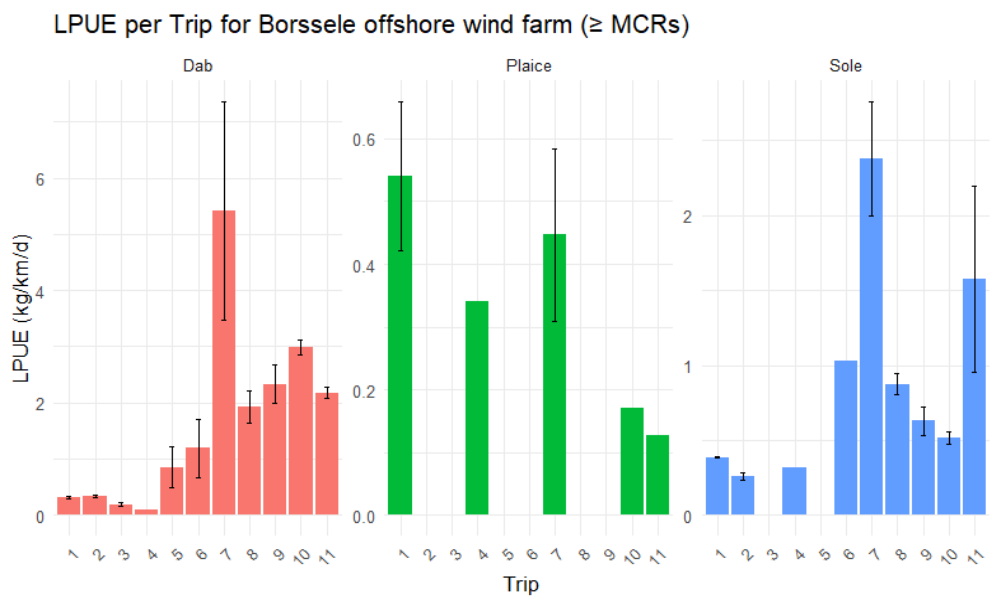


Figure 5.7 LPUE per trip expressed in kg/km/d realised during experimental gill net fisheries in wind farm Borssele for dab, plaice and sole.

Realised LPUE ranged for dab from 0.1 to 5.4 kg/km/d, for plaice from 0.1 to 0.5 kg and for sole from 0.3 to 2.4 kg/km/d.

CPUE (Table A6.1) and LPUE (Table A6.2) for all other commercial fish species caught can be found in Appendix 6.

It is important to mention that trips 1-4 were done in Borssele II with many broken nets. Trips 5 to 6 were done outside of the wind farm as reference hauls using 2 nets per trip only, and trip 7 to 11 were done in Borssele I with little to no damage to the nets. Although CPUE and LPUE calculations were done for all trips, catches differed among trips (and thus locations) due to the beforementioned factors.

5.2.3 Birds and marine mammals

During 8 out of 11 trips no birds or marine mammals were observed (Appendix 5). On one trip, about 15 seagulls were seen inside the wind farm (trip 2). On two trips, seals were seen of which one was a harbour seal (trip 8) and one a grey seal (trip 2). On one trip, two harbour porpoises were seen (trip 3). None of the sightings seemed related to our fishing activities (no active foraging from discards or swimming behind or next to the vessel) and no attraction or unusual behaviour (animals were seen swimming by from a distance) was observed. No birds or marine mammals were caught in the fishing gears.

5.3 Hollandse Kust Zuid

5.3.1 Fishing operations

A total of 18 days were foreseen and 17 days have been undertaken from which the researchers obtained biological data from 10 days (trips). The 18th day, crew went out with news reporters to make news articles and a video about the research for communication purposes. Of the days where data was collected, two days were realised in March, 6 days in April, five in May and four in June (Appendix 5, Table A5.2). For this experiment the blue space between maintenance zones for Hollandse Kust Zuid (Figure 2.5) was used, and the exact locations are shown in Figure 2.7. As described in the previous subchapter, the peak season for gill netting for sole is from February to April, sometimes extending to May or June depending on conditions and therefore researchers and crew planned to have the most fishing effort in the first months of the year. As was the case for Borssele, the algal bloom was also an issue encountered in Hollandse Kust Zuid wind farm. On the first trips, visibility was very poor and nets were heavy and slippery, causing catch to easily fall out of the net when hauling and probably to slip through the net more easily. However, no nets were severely damaged as was the case in Borssele. All important observations such as gear adjustments, communications, weather conditions and bird and marine mammal sightings, as well as trip specifics (date, fishing effort, total catch of marketable sole caught) are shown in Table A5.2 in Appendix 5.

5.3.2 Catch composition

As for Borssele, the most important species in weight are described in this chapter for Hollandse Kust Zuid. A list of all species caught in Hollandse Kust Zuid offshore wind farm can be found in Appendix 1 (Table A1.2). The species caught in Hollandse Kust Zuid offshore wind farm that are potentially commercially interesting were (in order from highest to lowest catch in weight): dab, sole and plaice. Other species that could be landed include starry smoothhound, lesser spotted dogfish, horse mackerel, Atlantic mackerel, seabass, turbot, tub gurnard, whiting and common cuttlefish, but were only caught in low quantities and therefore seen as possible marketable bycatch. Therefore, the length frequencies and CPUE/LPUE graphs in this chapter will focus on only the three beforementioned species. The catch composition for all fish species caught per trip is shown in Figure 5.8. Figure 5.8 also shows that catch of species was highly variable over time, location and between days, with dab dominating the total catch. Thereafter sole and plaice, which also have a relevant share of the total catch composition. The other

species caught can be seen as incidental bycatch, of which some of the species have economic value and could be sold on the fish auction.

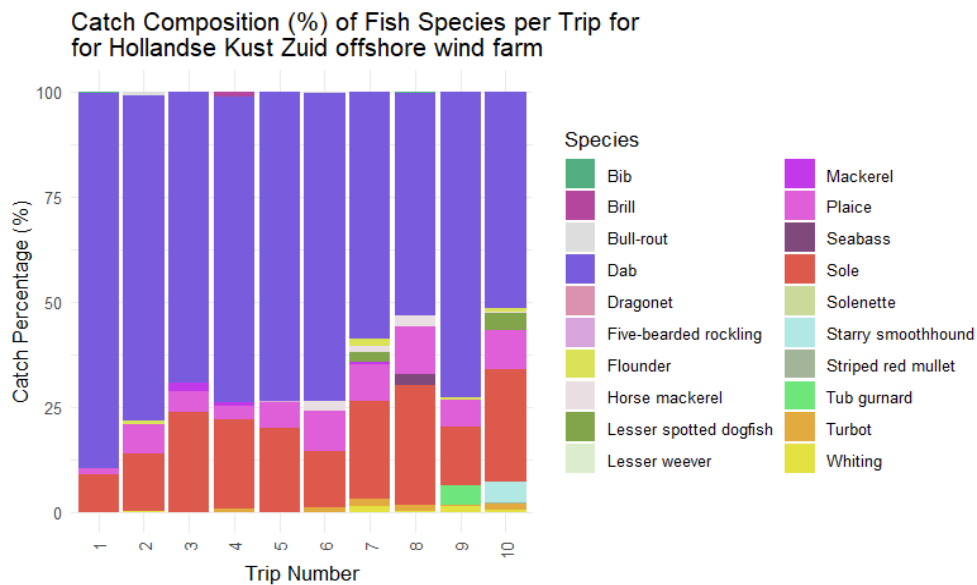


Figure 5.8 Relative, weight based catch composition per gill net fishing trip in offshore wind farm Hollandse Kust Zuid.

Figure 5.9 shows the overall catch distribution for (sub)target species for the landable catch (>MCRS) or non-landable catch (<MCRS) for commercial species.

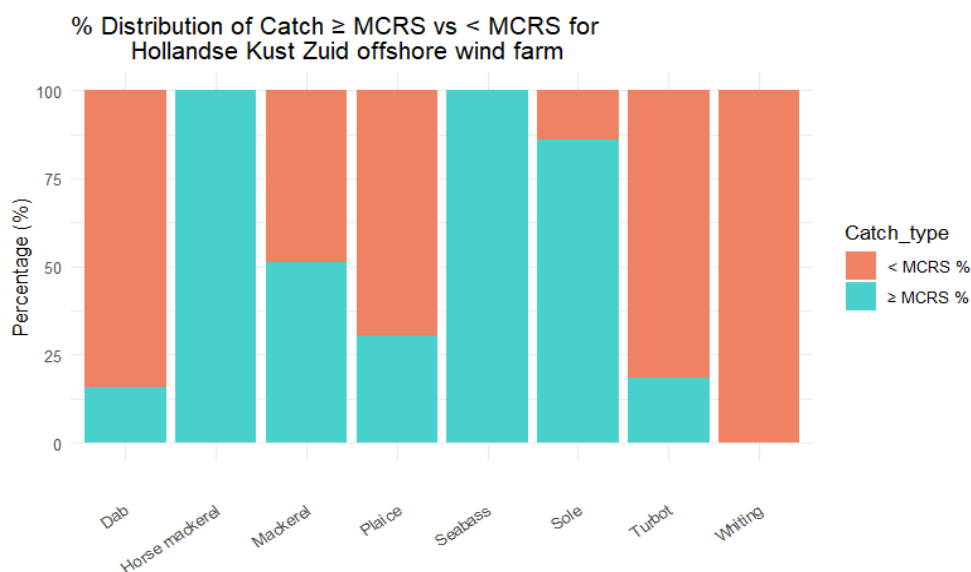


Figure 5.9 Weight based distribution over landable (>MCRS) and non-landable (<MCRS) for all marketable species caught in the gill net experiments.

Note that dab has no official MCRS, but in this study a minimum landing size of 23 cm was used, in agreement with the unofficial minimum landing size for dab to be sold on the fish auction. Figure 5.10 shows the length frequency distribution for dab, sole and plaice caught during all the trips combined. The red dotted lines represent the minimum sizes (and for dab minimum size used on the fish auction) for the species shown. For dab and plaice, most of the fish caught were below minimum landing size while for sole, most fish were above minimum landing size.

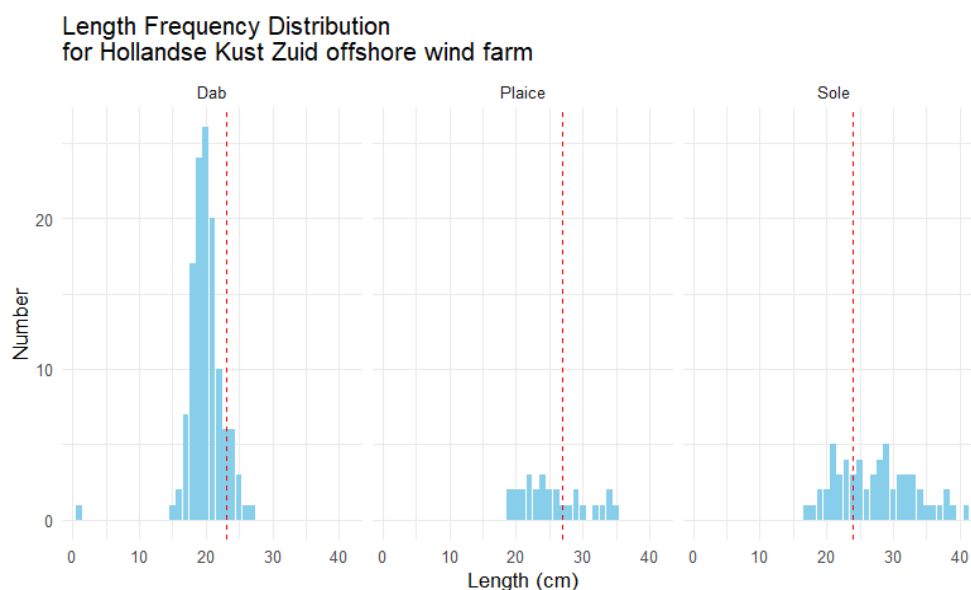


Figure 5.10 Length frequency distribution for dab, plaice and sole caught in gill net trips.

The benthic species caught consisted mostly of low numbers of bottom dwelling crustacean species and starfish (Figure 5.11). No weights could be determined from benthic species and except for incidental bycatch of European squid and cuttlefish, none of the benthic species were seen as marketable. Brown crab is not seen as a target species in gill net fisheries but when caught, crab legs were collected as landable catch.

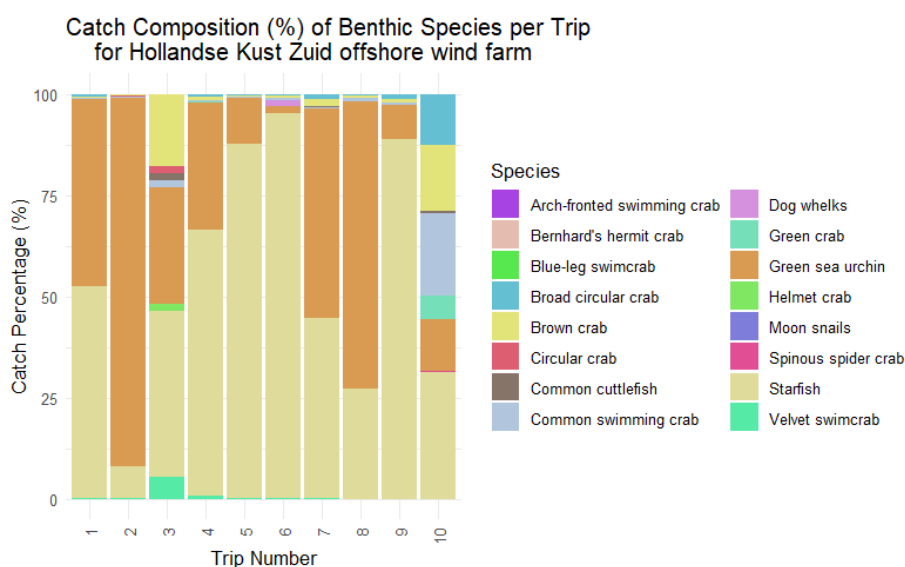


Figure 5.11 Relative catch composition for benthic species per trip based on counts.

Figure 5.12 shows the CPUE based on total catch (undersized and above MCRS).

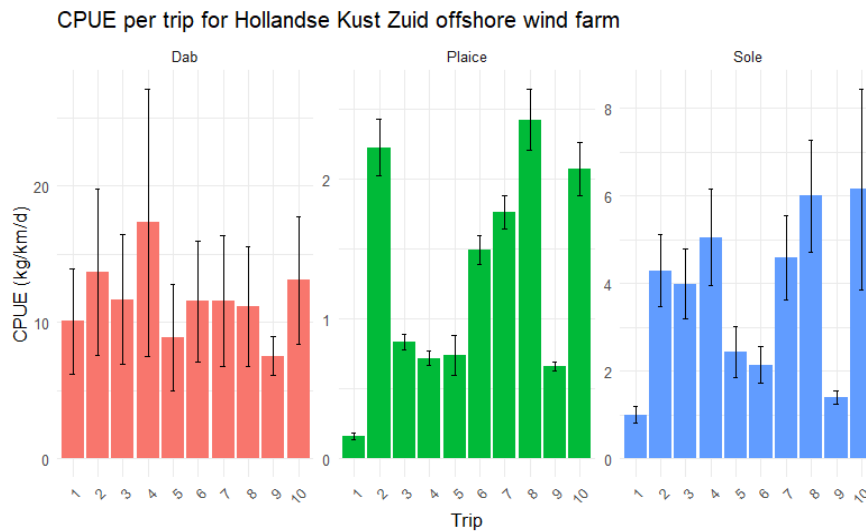


Figure 5.12 CPUE per trip expressed in kg/km/d realised during experimental gill net fisheries in wind farm Hollandse Kust Zuid for dab, plaice and sole.

Realised CPUE ranged for dab from 7.5 to 17.3 kg/km/d, for plaice from 0.2 to 2.4 kg and for sole from 1.0 to 6.1 kg/km/d.

Figure 5.13 shows the marketable share (landings) of the catch only (LPUE).

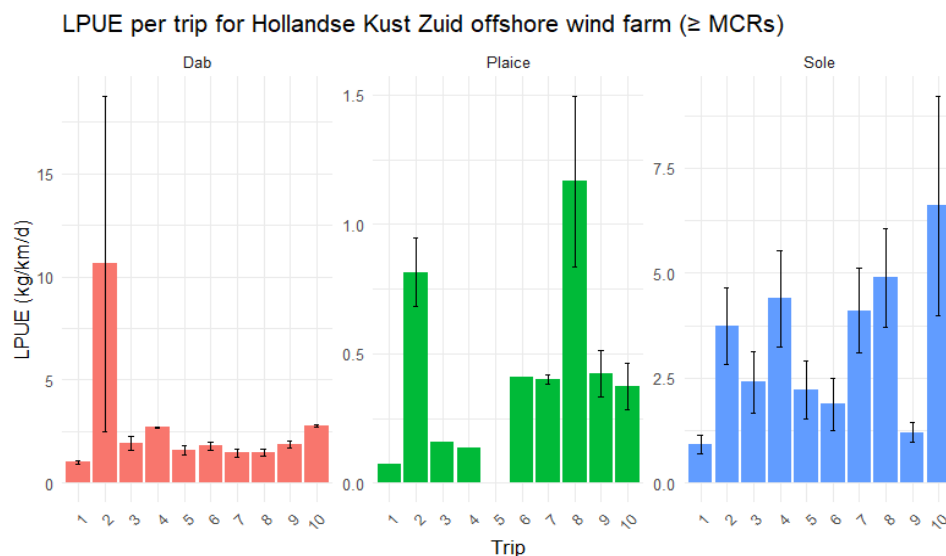


Figure 5.13 LPUE per trip expressed in kg/km/d realised during experimental gill net fisheries in wind farm Hollandse Kust Zuid for dab, plaice and sole.

Realised LPUE ranged for dab from 1.0 to 10.6 kg/km/d, for plaice from 0.1 to 1.2kg and for sole from 0.1 to 6.6 kg/km/d.

CPUE (Table A6.3) and LPUE (Table A6.4) for other commercial fish species can be found in Appendix 6.

5.3.3 Birds and marine mammals

During 2 out of 10 trips no birds or marine mammals were observed (Appendix 5). On four trips, seagulls were seen inside the wind farm ranging from 2 to 5 individuals per trip (trip 1, 6, 7 and 9). On six trips,

seals were seen of which two were harbour seals (trip 5 and 9) and four were grey seals (trip 1, 2, 4 and 8). On one trip (trip 9), four harbour porpoises were seen. Also, one songbird was sighted on one of the trips (trip 1). One of the sightings seemed related to fishing activities as five seagulls were seen following the fishing vessel after discarding some of the catch. None of the other sightings seemed related to our fishing activities (no active foraging from discards or swimming behind or next to the vessel) and no attraction or unusual behaviour (animals were seen swimming by from a distance) was observed.

6 Economy

6.1 Introduction

The economic feasibility of fishing in an offshore wind farm depends on various factors, such as gear adaptations needed to meet the limitations on gill net positioning, sailing time and access being limited to daytime (Neitzel et al. 2024).

Building on the previous study, the following was done for this study:

- In this experiment, per trip 4 gill nets (4 strings of 500 m, 2 km in total) were deployed from one vessel. Marketable landings of sole and other fish caught in the experiment in both wind farms were collected and, for the trips made in Hollandse Kust Zuid, scaled up to landings per 20 km net (total length of gill nets carried by a commercial vessel).
- Collected landing data of commercial gill net fishers for sole (2024).
- Updated the costs of a fishing vessel suitable for fishing in an offshore wind farm (comparable with WR 147 'Anna Lotte', used in this survey to fish in wind farm Hollandse Kust Zuid) and calculated the landings needed to cover the costs.

Based on landing data of the target species sole and other fish, an indication is given of catch rates (kg/km/d based on 20 km net) required to cover costs of fishing in wind farm Hollandse Kust Zuid. For wind farm Borssele catches from the first trips were lower due to damaged nets (5.2.1). The sole catches from trip 7 to 11 are presented to give an idea of the fishing opportunities in Borssele I. The landings from trip 1 to 3 from the 2023 survey (Neitzel et al. 2024) were presented as an extra to give an impression about the variety of the landings.

6.2 Borssele

Fishing with gill nets was done as described in chapter 2. For wind farm Borssele catches from the first four trips (5.2.1) were lower due to damaged nets. Trips 5 and 6 were done as reference hauls outside the wind farm. Trip 7 to 11 were done fishing in Borssele I. The sole catches from the last 5 trips are presented in Table 6.1 to give an idea of the fishing opportunities in Borssele offshore wind farm. On average, sole catches were 2 kg/2 km gill net/day. As it was later in the fishing season, landings were generally lower than expected during peak season.

Table 6.1 Sole landings (kg/2 km gill nets/day) in wind farm Borssele I (2024).

Trip ID	Date	Sole landings (kg/2 km/day)
7	18-6-2024	4.15
8	24-6-2024	1.74
9	25-6-2024	1.17
10	26-6-2024	0.93
11	27-6-2024	2.88

The landings from trip 1 to 3 from the survey 2023 (Neitzel et al. 2024) are presented in Table 6.2 to give an impression about the variety of the landings.

Table 6.2 Sole landings (kg/2 km gill nets/day) in wind farm Borssele (2023).

Trip ID	Date	Sole landings (kg/2 km/day)
1	9-4-2023	1.30
2	30-4-2023	20.00
3	1-5-2023	11.80

Due to differences in the presence and catchability of sole, landings from wind farm Borssele vary from 1 to 20 kg per 2 km gill nets per day.

6.3 Hollandse Kust Zuid

In wind farm Hollandse Kust Zuid 17 trips were undertaken (5.3.1). In 10 of these trips landings were registered. The landings of sole are given in Table 6.3. The landings of sole vary from 2 to 10 kg per 2 km gill nets per day.

Table 6.3 Sole landings per 2 km gill nets/day in wind farm Hollandse Kust Zuid (2024).

Trip ID	Date	Sole landings (kg/2 km/day)
1	31-3-2024	2.13
2	23-4-2024	4.29
3	27-4-2024	3.50
4	30-4-2024	6.31
5	1-5-2024	4.07
6	9-5-2024	3.22
7	10-5-2024	7.62
8	11-5-2024	8.59
9	25-6-2024	2.94
10	26-6-2024	9.97

A commercial fishing vessel as the WR 147 can carry up to 20 km of gill nets onboard (25 km per vessel is the maximum allowed). On average, 2.65 kg sole /km gill net /day was caught. When scaled up to the 20 km of gill nets this type of commercial vessel carries, this amounts to 53 kg sole/day on average (Table 6.4). If the landings of the trip with the lowest and the highest amount of sole were scaled up to 20 kilometers of gill nets, the landings would be respectively 21 and 100 kg/day. Besides sole, due to the fact that entering the wind farm only during daytime is allowed, dab was caught in relatively large quantities (Table 6.2). In commercial gill net fishing bycatch of dab is expected to be lower, since hauling is preferably done during of just after dusk when dab is less active than during the day. Prices for dab are in general far less than 1 euro/ kg. For determining the yield of the fishing trip, dab is also counted as 'other fish'. Other fish also includes plaice, mackerel, horse mackerel, turbot and sea bass, all caught in very small quantities, with an average total of almost 11 kg per 20 km gill nets.

Table 6.4 Average landings of fish from wind farm Hollandse Kust Zuid scaled up to 20 km gill nets. For sole and dab the lowest and highest landings are added (2024).

Species	kg fish/ 20 km/day	lowest	highest
Sole	52.6	21.3	99.7
Dab	41.3	23.6	122.0
Other fish	10.6		
Total	104.5		

6.4 Commercial gill net landings

Gill net fishing in the Netherlands is a small-scale fishery with vessels fishing mostly from the harbours of IJmuiden and Scheveningen. Almost all fish caught with gill nets is sold at the fish auctions in IJmuiden and Scheveningen. For 2024 the landings in euros and kg are presented in Table 6.5. In general seabass is caught with a different type of gill net and is therefore not included in the calculations for the gill net fishing for sole.

In total 57 tonnes of sole caught by gill nets were landed in IJmuiden and Scheveningen in 2024, generating 929k€. The overall average price of sole was €16.36/kg.

Table 6.5 Gill net landings sold at the fish auctions IJmuiden and Scheveningen (2024).

	IJmuiden			Scheveningen		
	landings (1,000 kg)	landings (1,000 euros)	Average price per kg	landings (1,000 kg)	landings (1,000 euros)	Average price per kg
Sole	41	€ 664	€ 16.40	16	€ 265	€ 16.36
Seabass	5	€ 67	€ 13.33	3	€ 38	€ 13.16
Other fish	17	€ 31	€ 1.84	7	€ 17	€ 2.36
Total	62	€ 762	€ 12.24	26	€ 319	

Source: Viris (RVO)

In 2024, eight of the vessels fishing with gill nets landed more than 1,500 kg of sole each. In total these vessels landed 37,350 kg of sole, generating 612k€ value of landings, representing 66% of the total gill net landings in kg and euros (Table 6.6). On average, the sole landings of these eight vessels were 76kEuro per vessel. The highest landing value was 113kEuro, the lowest 31kEuro. The eight vessels had some revenue from commercial valuable bycatches, but in general 95% of the value of the landings were from sole. In Table 6.5 the value of 'other fish' is 5% of the value of 'sole'. This corresponds to the catch composition of the eight vessels.

None of the Dutch vessels fish year-round with gill nets on sole. With a max value of 113k, other income is needed. Therefore, fishing with gill nets is combined with other fisheries (e.g. IJsselmeer fishery, shrimp fishery) or other work ashore.

Table 6.6 Gill net landings of sole for all the Dutch vessels, the eight vessels with more than 1,500 kg of sole and the average of these eight vessels (2024).

	1,000 kg	1,000 euros
Total landings all Dutch vessels	57	€ 929
Landings 8 vessels	37	€ 612
Average per vessel (8 vessels)	5	€ 76

Source: Viris (RVO)

In February/March, gill net sole catches can be very high in a short period of several weeks. At the end of the season (September/October), catches can be very low. Not only catches but also duration of fishing trips varies a lot. Some trips only last a few hours, and some trips last several days, as the vessel may spend one or more nights at sea. A comparison of catches per landing/fishing trip gives large differences partly due to the different duration of fishing trips. Data on the duration of commercial fishing trips is not available.

6.5 Costs and value of landings Hollandse Kust Zuid

A commercial fishing vessel like the WR 147 is suitable for fishing in wind farm Hollandse Kust Zuid. The vessel is large enough to store 20 km of gill nets and the landings. The designated area for passive fishing in Hollandse Kust Zuid is large enough to accommodate 20 km of nets. An example of what the landings are to cover the costs per trip is given in Table 6.8.

WR 147 'Anna Lotte', used in this study to fish in wind farm Hollandse Kust Zuid, is comparable with the type 1 vessel (Neitzel et al. 2024). In this study sailing and fishing with this type of vessel with two adult crew members was calculated at €2,122,- per trip, based on data 2021. For this new study, fuel prices were updated and some costs were indexed making the cost per trip about €2,264,- (Table 6.7).

Table 6.7 Costs per year and per day at sea of type 1 vessel, year 2022.

	Per year	Per day at sea
Costs:		
Gas oil	€ 20,064	€ 218
Lubricating oil	€ 427	€ 5
Deck requirements	€ 3,413	€ 37
Navigation + fish detection	€ 4,920	€ 53
Hull maintenance	€ 20,948	€ 228
Engine maintenance	€ 11,176	€ 121
Insurance	€ 5,898	€ 64
Gear maintenance	€ 2,690	€ 29
Ice + cooling	€ 956	€ 10
Provisions	€ 1,431	€ 16
Travel allowance crew	€ 4,521	€ 49
Social benefits	€ 5,754	€ 63
General	€ 18,080	€ 197
Producers organisation levy	€ 683	€ 7
Auction rights	€ 997	€ 11
Sorting and unloading	€ 2,336	€ 25
Cargo	€ 40	€ 0
Conserving fish/materials	€ 6,473	€ 70
Salt and plastic bags	€ 561	€ 6
Subtotal costs	€ 111,368	€ 1,211
Share crew + skipper	€ 87,338	€ 949
Depreciation hull + engine	€ 8,536	€ 93
Interest	€ 1,088	€ 12
Total costs	€ 208,330	€ 2,264
Share adult crew member	€ 43,669	€ 475

Source: *BedrijvenInformatieNet, WSER*

Not on all trips there are landings. In the first trip the nets are set. If the weather conditions and catches stay good every day hauling and setting the nets can be done. If the average price of the sole landed is €20 /kg, 140 kg per landing per daytrip is needed to cover the costs.

Table 6.8 *Costs and value of landing per fishing week (example).*

	Costs per trip	Activities per trip	sole landings (kg)	sole landings (€)	other fish 5% (€)	Total landings (€)
Monday	€ 2,264	setting	0	€ 0		€ 0
Tuesday	€ 2,264	hauling, setting	140	€ 2,800	€ 140	€ 2,940
Wednesday	€ 2,264	hauling, setting	140	€ 2,800	€ 140	€ 2,940
Thursday	€ 2,264	hauling, setting	140	€ 2,800	€ 140	€ 2,940
Friday	<u>€ 2,264</u>	hauling	<u>140</u>	<u>€ 2,800</u>	<u>€ 140</u>	<u>€ 2,940</u>
	€ 11,320		560	€ 11,200	€ 560	€ 11,760

This corresponds to a catch rate of 7 kg sole/km of gill net/day. In both surveys, this quantity was only caught once (in 2023). Fishers with years of experience in gill net fishing are expected to realize higher catches than in this survey. This survey was conducted with experienced fishers, but both fishers were not solely gill net fishers.

7 Discussion

7.1 Video observations and anchoring

Video observations in this study and analysis of anchor positions when setting and hauling nets to fish, anchors and nets were observed to hold position. Displacement of the anchors during fishing was found to be minimal. As expected, first anchors were fully pulled into the sediment by the hydrodynamic force on the net, while the last set anchors were only in the sediment with one of the lateral fins. Upon hauling, the anchors generally stayed in position inside the sediment, resulting in minimal drag through the sediment. The area of the sea bed that was disturbed by anchoring was estimated to be around 0.1 m² when anchors were not dragged through the sediment. When dragged, the area of the sea bed that was disturbed was estimated at 0.4 m² in Hollandse Kust Zuid and around 1.64m² in Borssele, the later probably as a consequence of the large loose sand ripples. Like the anchors, the nets were observed to hold position after setting in both the video surveys and when setting and hauling nets to fish within the wind farm. The effect of gill nets on bottom disruption, particularly on reef-forming organisms, remains unclear. Some studies consider the impact to be low (Rijnsdorp et al. 2006; Bos et al. 2021) while others suggest that reef-forming structures may be damaged, although oyster and mussel beds tend to be more resilient than the kelp and coral habitats (Shester & Micheli (2011)). Bos & Suykerbuyk (unpublished) observed that gill nets caused minimal damage to oyster reefs along the Dutch coast, as the boat was pulled along the gill nets rather than lateral dragging the net toward the boat. However, the North Sea is primarily composed of sandy bottoms, which was also the case in both offshore wind farms. The seabed of Hollandse Kust Zuid mainly consisted of loose, unconsolidated sand, whereas in Borssele large loose sand ripples alternated with a bit more stable sandy sediments. Only in the latter, reef building tube worms were observed. The movement of the nets and drag of the anchors are estimated of maximum 2 m² per 2 anchors in Borssele and maximum 0.5 m² in Hollandse Kust Zuid. The sea bed seems to be moved over time by the high local hydrodynamics, judging by the (large) sand ripples and the coarse and loose nature of the sediment. However, this cannot be confirmed from our video observations. It is therefore not clear how the drag of the anchors compares to the supposed high natural movement of the sea bed. No steel slags or any other sharp objects were observed during video observations. As video observations only covered a limited part of the fished wind farm, it is still unknown if the steel slags caught in the fishing gears (in pots in 2023 and in gill net in 2024) were an incident and what caused the damage to the nets.

In the direct surroundings of the wind turbines a higher biomass and number of species were observed compared to adjacent seabed of the safety zone and on the video transects outside of the safety zones. Most of the species found on and around the wind turbine are associated to hard-substrate for hold (e.g. anemones and mussels), shelter (e.g. crabs) or food (e.g. sea stars and crabs). Some fish were observed in the videos. Due to the limited area covered by the video observations, an estimate of the concentration and amount of the commercial interesting target species cannot be given other than that hard-substrate related species (i.e. Brown crab) seem to be more concentrated directly around the wind turbines.

7.2 Risks and nautical operations

Communication and coordination

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 project required, as was also the case in the previous study (Neitzel et al. 2024), communication between all parties involved (project team, fishers, Ministry of Agriculture, Fisheries, Food Security and Nature, Rijkswaterstaat and wind farm operator). The project team also managed the necessary email communication for accessing the park, which included three emails per fishing day (planning, go/no-go decision, and position updates). If such communication levels are maintained as offshore wind farms move towards commercial fishing, it could place a significant workload on fishers, adding to their existing obligations and reports for the NVWA.

Anchoring

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. Regulation is (nearly) available for each individual co-user of the wind farm, but a combination of tasks and/or the use of anchoring or other permanent structures is not available yet. For example, no combination of passive fishing techniques is allowed as well as a combination of passive fishery in combination with other types of multi-use.

Loss of gear

In case of gear loss, fishers are responsible for locating and retrieving gear. During the present experiments loss of dawns and a part of the gill net string did occur, and the gear was retrieved from the seabed with a dredge anchor, see Appendix 3. 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 250 m 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.

Maintenance zones

The results of this study show that the 250 m maintenance zones around wind turbines and infield cables can be reduced, since, from the undertaken risk analysis on passive fishing in offshore wind farms, this distance seems excessive from the fishing perspective. Fishing closer to the monopiles or over infield cables could enhance catch potential as longer gill nets could be deployed instead of only short strings which take a lot of time hauling, sailing to the next string, and re-deploying. Fishers suggest that sailing in maintenance zones from the wind turbines and fishing near the monopiles and over infield cables can be safely conducted. Since maintenance zones are determined by national regulations implemented by Rijkswaterstaat, rather than international law, it would be beneficial to revisit the discussion on the scope, flexibility, and regulation of these zones. For instance, sharing maintenance schedules for each turbine could allow fishers to avoid these areas during specific times, reducing overlap between activities and minimizing risks and disruptions.

Sailing times and access to the wind farm

The sailing time from the harbour to the offshore wind farms is time-consuming: 2-2.5 h to Hollandse Kust Zuid wind farm from IJmuiden) to 3-3.5 h (to Borssele wind farm from Neeltje Jans) one way. Consequently, the total sailing time is 4 to 7 h 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 sailing time by about 25%, while sailing against it extends the time by about 25%. 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 sailing 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 (partly) during the night. According to fishers from the focus group, fishing at night does not increase safety risks but could significantly enhance catch potential and could for some gears reduce unwanted bycatch, especially for species that are more active during the day which increases the chance of being caught in the gears.

7.3 Catch and bycatch

Environmental factors

During the experimental field tests the catch was highly influenced by various factors, as is also the case when fishing commercially. For instance, when algal blooms occurred, sole were expected to escape more easily through the net's meshes, and during hauling, sole were often seen falling out of the net as was also the case in the 2023 trial (Neitzel et al. 2024). However, this issue was not observed once the algal blooms had dissipated. Experience learns that, after algal bloom, catch of sole tends to increase again but bycatch is often dominated by higher amounts of dab. These cases were also confirmed when consulting fishers from the focus group and when talking to other commercial fishers in port. In most trips, the LPUE marketable sole was equal to or slightly higher than the LPUE realised by commercial fishers outside the offshore wind farm (information obtained by expert consultations with commercial fishers and from auction reports). Thus, there is no indication for a difference in sole fishing opportunities inside or outside the offshore wind farm when solely looking at the catch per km/d. It is however important to note that one can deploy less nets with shorter lengths of strings due to the limited space within an offshore wind farm, therefore limiting the possibilities.

Catch and bycatch

In general, bycatch in various forms of gill net 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). However, this is dependent on location and season. For example in this study, a larger amount of mackerel was caught later in the season, which is typically the case around June. Van Marlen et al. (2011) primarily observed bycatch of undersized fish and benthos in gill net fishing in the North Sea, which is in line with the findings of this study. In some areas, especially in deeper parts of the wind farm, higher amounts of dab and benthic species such as starfish were caught.

Elasmobranchs

Bycatch of starry smoothhound also showed a seasonal pattern. This species typically arrives around the end of April to June and can occur in very high numbers around the Southern Dutch coast up to Scheveningen, as they give birth to their pups in the Delta area around Neeltje Jans (Brevé et al. 2016). The starry smoothhound is often caught as bycatch in both trawl and gill net fisheries, and is sometimes used for human consumption. While many fishers discard starry smoothhounds depending on market demand, they can also be sold as bait for pot fisheries, particularly in whelk fisheries (ICES 2017; Small 2021a), and potentially as long-term bait for brown crab (S. Tijssen, pers comm.). In this study, starry smoothhounds were not landed. Starry smoothhounds are known for their winter-to-summer migration from the English Channel to the Southern North Sea (Brevé et al. 2016). The migration begins when water temperatures exceed 13°C, with the species arriving in the Borssele region between April and June (Brevé et al. 2016). This period may overlap with the time when fishers are using gill nets to target sole, meaning that in certain months, particularly in the southern regions of the North Sea, bycatch rates of starry smoothhounds could be higher.

Another elasmobranch that was abundant in the catch, especially for Borssele, was the lesser spotted dogfish. The lesser spotted dogfish is an abundant species found across a range of substrates, from mud to rock, on the European continental shelves, including coastal waters and the upper continental slope, though it is most common on the shelf, with its distribution reaching from Norway and the British Isles to the Mediterranean Sea and Northwest Africa (Rodriguez-Cabello et al. 2007). ICES currently recognizes four stock units for this species, including one for the North Sea ecoregion, where the population has been increasing in recent years (ICES, 2023c). Lesser spotted dogfish are often returned to the sea as was also

the case in this study, due to their low market value, but those that are landed can be used as bait for pot fisheries, particularly in whelk fisheries (Small, 2021b), and as long-term bait in brown crab pots (S. Tijssen, pers comm.).

Birds

Birds may be drawn to wind farms as wind turbines provide opportunities for resting and drying, particularly for cormorants (Leopold et al. 2012). Other diving birds, such as auks, guillemots, divers, and gannets, tend to avoid wind farms to some extent (Dierschke et al. 2016). Various species of seagulls can be found in wind farms, but they are not necessarily attracted to or repelled by them (Dierschke et al. 2016; Leopold and Verdaat 2018). Seagulls are known to follow fishing vessels to feed on fish waste and discards that are thrown overboard (Röckmann et al. 2015). Vessels that discard little or nothing present less of a risk to birds, as they are less likely to be attracted. Risks for birds include getting tangled in the fishing gear while trying to forage on fish stuck in the net or when discarding unwanted catch or fish remains. Gannets, cormorants, and storm petrels may also follow vessels for the same reason (Bærum et al. 2019). However, when commercially fishing with gill nets and also during the experiment at the Borssele offshore wind farm, the gear is immediately brought alongside the boat over the hauler, ensuring that catch was not left at the surface but instead brought onboard right away. Therefore, the risk of birds getting tangled in the gill nets is low. Despite this, literature shows that gill net fishing can still pose a risk to diving birds, such as grebes, guillemots, divers, and diving ducks, which actively search for food underwater and may become entangled in the nets (Röckmann et al. 2015). However, the most common form of gill net fishing in the Netherlands targets sole, with net heights of no more than half a meter from the seabed, reducing the risk of bird bycatch (Klinge, 2008). This was also seen in the results of this study, when no birds were caught in the gill nets.

During the experimental days at sea, very few birds were observed. Out of 21 sea days, bycatch was discarded on all days, but the amount of discarded bycatch was limited in both number and weight (as detailed in Chapter 4). Both fish and benthic species were discarded during gill net trips, of which discards consisted of guts and fish remains, unwanted fish species, undersized commercial fish species, and benthic species. Birds were only attracted to fishing activities on one occasion in Hollandse Kust Zuid offshore wind farm, where crew threw unwanted catch overboard which attracted 5 seagulls. Discarding occurred both inside and outside the wind farm where crew processed the fish and handled the fishing activities as is usually done when fishing commercially with gill nets. These observations suggest that the risk of gill net activities attracting birds is minimal. Additionally, the volume of discarded bycatch from passive fishing gears is generally low compared to conventional beam trawlers (Garthe et al. 1996), as was also the case for this study. However, this study was limited to a specific timeframe (April to October) in a single year. The occurrence of bird species varies by season, and birds may be more or less present in the vicinity of a wind farm at different times of the year. Therefore, bird attraction to fishing activities and the risk of bird bycatch in the gears may also vary across seasons and location.

Marine mammals

Seals have a diverse diet and can be found throughout the North Sea. Telemetry research suggests that seals do not actively avoid wind farms, but most do not enter them. However, there are exceptions, and studies have shown that certain individuals do swim through wind farms (Russel et al. 2014; Röckmann et al. 2015). Since seals may be present within offshore wind farms, they could be at risk of becoming entangled in fishing gear. Previous studies on gill net fisheries off the West and Southwest coasts of Ireland found no bycatch of seals, suggesting that the risk of bycatch in gill net fisheries is low (Cosgrove et al. 2016). Unlike harbour porpoises, seals are able to swim backwards, which helps prevent them from getting entangled. In other gill net fisheries targeting crawfish and monkfish, bycatch of grey seals and harbour porpoises was observed, with catches, depth of gear deployment, and larger mesh sizes being positively correlated with seal bycatch (Cosgrove et al. 2016). However, during this study in the two offshore wind farms, no seals were caught or directly attracted to fishing activities as the seals were seen swimming by or were seen hunting for fish, from a distance. None of the individuals reacted to setting or hauling the

nets, or were attracted by unwanted catch and fish remains when discarding. A total of 8 seals were sighted during the field trips at sea inside the offshore wind farms.

Harbour porpoises display various patterns of behaviour: in some cases, porpoises avoid wind farms (Tougaard et al. 2006a; Blew et al. 2006), while in other cases, no difference in abundance is found between areas inside and outside the wind farms (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 observations are based on short-term monitoring programs. Bycatch of marine mammals in passive fishing gear is a recognized global issue (Read et al. 2006; Reeves et al. 2013), particularly contributing to declining population sizes of small cetaceans (Brownell et al. 2019). However, (fixed or drifting) gill nets used in foreign fisheries differ in height, mesh size, materials and length from the gill nets that target sole in the North Sea. Couperus (2018a,b, 2019, 2020) recorded bird- and marine mammal bycatch during a limited number of trips under the Data Collection Framework (DCF). Harbour porpoises have also been shown to be incidentally caught in passive fishing gear in the North Sea, with Scheidat et al. (2018) reporting an average bycatch rate of 0.0006 harbour porpoises per km of gill net. During the sea days in this study, 6 harbour porpoises were observed cruising along inside the wind farm, but none of the sightings were related to fishing activities as the porpoises were seen swimming by, from a distance. None of the individuals reacted to setting or hauling the nets, or were attracted by unwanted catch and fish remains when discarding. During the field tests in both wind farms, no marine mammals were caught.

7.4 Economy

Gill net fishing further out at sea

The current Dutch gill net fishery mainly operates in coastal areas, with relatively small vessels. Gill net fishing in offshore wind farms, 10 nautical miles or more from the coast can best be done with vessels with a length of 20 to 24 m. These vessels can store 20-25 km of gill nets and are safer and able to sail out in different weather conditions.

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 multiple hours for setting out gears may feel cumbersome, whereas having a combination of gears on-board would allow better utilization of this time. 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 fishing activities. To fish profitably using passive fishing methods, such as gill nets, it is necessary to use the days at sea as efficiently as possible. More trips should result in landings to cover all costs per day at sea. In wind farm Hollandse Kust Zuid, for example, fish was landed in 10 out of 17 trips, so 7 trips did not result in a revenue. If a revenue could be realized in, say, 15 out of 17 trips then this will lead to an average reduction of 33% of the required revenue per fishing trip.

8 Conclusions

This follow-up research based on the previous study from Neitzel et al. 2024 has made significant progress in identifying the ecological, economic- and safety considerations of co-use of offshore wind farms and gill net fisheries. A crucial factor in researching passive fishing within offshore wind farms is the genuine interest, skills, and motivation of the fishers involved. Their input throughout the development, experimentation, and reporting stages has played a vital role in shaping the project's results. This chapter describes all key findings for every research question.

"Do anchors move from their position when holding the nets and if yes, does the anchor drag along the seafloor? And is this also the case when hauling the gill nets?"

Video surveys in this study and analysis of anchor positions when setting and hauling nets to fish, showed that anchors and nets hold position. Displacement of the anchors during fishing was found to be minimal. Following the design of the anchors, anchors are pulled into the sediment when they are under tension. The first released anchors will generally be fully pulled into the seabed by the hydrodynamic force on the set net. The last released anchors will experience less tension by the net and will thus only partly be pulled into seabed. When the nets are hauled the boat is pulled along the gill nets rather than that the net and anchors are dragged towards the boat. Anchors will thus generally be first pulled upright before they leave the seabed, like was observed in this study. However, we observed some dragging of the anchor during hauling through the large loose sand ripples in Borssele. From this it might be concluded that the sandy bottoms that are found in the North Sea and in both offshore wind farms generally provide sufficient friction to hold the nets and anchors during fishing and hauling. Only when sediments are more loose / less consolidated (like in the large sand ripples in Borssele) friction of the anchor is sufficient to hold the nets and anchors in position during fishing, but not when being hauled. This might result in some dragging through these loose sediments.

"What are possible problems that may arise during gill net fishing, 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.

The risks of passive fishing by means of pot strings, handline fishing and jigging, in offshore wind farms is evaluated in (Neitzel et al. 2024). The vessels and fishing gear used for gill net fishing are similar as for passive fishing with pots strings. There are no notable differences in risks for the offshore wind farms between pot strings and gill nets. The risk assessment method and outcomes described in (Neitzel et al. 2024) are applicable to gill net fishing as well. Qualitative and quantitative evaluations were performed to explore the risk of displacement of the gear. 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 m maintenance zone. The findings spur exploration of whether the 250 m 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.

The vessels applied in the experiments are capable of operating up to significant wave height of 1.0 m. In offshore wind farms, the wave conditions regularly exceed these operational limits, even in summer. One

should take into account the limited workability of small fishing vessels in offshore wind farms when considering the feasibility of passive fishing within these areas.

The sailing time from the harbour to the offshore wind farms is time-consuming: 2 h (Hollandse Kust Zuid from IJmuiden) to 3 h (Borssele from Neeltje Jans) on way. Consequently, the total sailing time is 4 to 6 h 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 daytime 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 the target species (*Solea solea*) within wind farms Borssele and Hollandse Kust Zuid offshore wind farm using gill nets (gear code GNS)?"

It is possible to catch sole using gill nets in both Borssele and Hollandse Kust Zuid offshore wind farms. Although a higher catch was realised in Hollandse Kust Zuid throughout the trips, sole is clearly present in Borssele and can be caught in areas where fishing is not hampered by bottom type or sharp objects, such as in Borssele I where fishing was not influenced by damage to the nets. It is evident that many factors influenced catch such as weather conditions, peak seasons of target species and therefore the right time of fishing, fishing gears and their 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 target species (*Solea solea*)?"

For Borssele offshore wind farm, CPUE for sole ranged from 0.3 to 2.6 kg/km/d while for Hollandse Kust Zuid, CPUE for sole ranged from 1.0 to 6.1 kg/km/d. LPUE for sole ranged from 0.3 to 2.4 kg/km/d in Borssele offshore wind farm and from 0.1 to 6.6 kg/km/d in Hollandse Kust Zuid offshore wind farm.

"What is the composition and quantity of bycatch for gill net fisheries when considering non-target species (fish), birds, marine mammals and benthic species?"

Catches in both wind farms consisted mainly of fish species of which dab, starry smoothhound, whiting, horse mackerel, seabass, sole and plaice were caught in the highest amounts in terms of weight. Other fish species included bib, brill, bull-rout, dragonet, five-bearded rockling, flounder, lesser spotted dogfish, lesser weever, greater weever, herring, pipefishes, Atlantic mackerel, solenette, striped red mullet, tub gurnard and turbot. Benthic species included mainly starfish, bottom-dwelling crustaceans and sea urchins. Some species were caught in higher amounts in part of the trips due to seasonality or location, such as starry smoothhound in summer months in Borssele offshore wind farm, and high amounts of dab and starfish on certain deeper locations in Hollandse Kust Zuid offshore wind farm. In none of the trips, birds or marine mammals were caught using gill nets.

"Are birds and marine mammals attracted to fishing activities inside the offshore wind farm and, if yes, which species and to what extent?"

Low amounts of sea birds and marine mammals were seen in both offshore wind farms during gill net fishing. On one occasion, five seagulls seemed attracted to fishing activities; this was when seagulls followed the fishing vessel when crew threw unwanted catch (discards) overboard inside the offshore wind farm. However, this was only the case in one individual situation out of 21 days at sea where a part of the catch was discarded, and very few birds were seen inside the offshore wind farm. For marine mammals, only grey seals, harbour seals and harbour porpoises were sighted and in none of the cases, the individuals were attracted or influenced by the fishing activities.

"Is it economically feasible to fish commercially with gill nets for sole within offshore wind farms Borssele and Hollandse Kust Zuid?"

The distance from a fishing port to the wind farms in this project is quite large. As a result, the costs for fishing activities are also higher than usual. Most fishing grounds of gill net fishers are normally closer to the Dutch coast.

To increase profitability the following steps help:

- Lifting of current restrictions in fishing activities in wind farms
 - o nets cannot be set freely (the length of the nets must be shortened due to cables and constructions in the fishing area);
 - o access is limited to daytime;
 - o it is not possible to have multiple gears on board.
- More surveying and monitoring to predict which fish might be caught. During the tests in this project, the catches and landings of sole varied greatly from day to day.

Sole was caught in the wind farms Borssele I and Hollandse Kust Zuid. Both wind farms can be attractive for commercial fisheries with gill nets. The expectation is that commercial fishers can increase their catches and landings per day at sea compared to the catches and landings during this project. The wind farm areas should be seen as part of the total fishing area for fishers. Commercial fishing with gill nets in wind farms give fishers an extra opportunity to fish seasonally. Fishing for sole in a wind farm can be profitable at times when the (swimming) sole is abundant in the wind farm.

9 Recommendations

Adjustments to both fishing operations and policies are necessary to align co-use ambitions with the current capabilities of the fisheries sector. Mismatches between co-use ambitions, the existing policy framework, and the characterization of the current passive fishing sector have been identified. Challenges that need to be addressed include offshore wind farm accessibility, vessel optimization, and gear application (such as spatial deployment and gear combinations). Therefore, it is strongly recommended that, when designating areas for future offshore wind farms intended for passive fisheries as a co-use activity, technical catch considerations be factored in to fully harness the potential and expand opportunities for passive fisheries. This should be done through consultation with industry professionals or researchers. Also, to make up for the rather long sailing time to the wind farm, there needs to be a high likelihood of successful fishing. At present, catches in wind farms, like in other fishing areas, are highly unpredictable. If the predictability of catches could be improved, fishing in a wind farm would become more profitable. Catches could be boosted by allowing fishing closer to monopiles or in areas over infield cables, enabling potential future multi-gear vessels to integrate passive fishing alongside their conventional methods and the possibility to enter the wind farm at night. Lastly, to alleviate the administrative burden on all parties and minimize the risk of miscommunication, it is therefore recommended to reduce the frequency of required communication, and more importantly, standardize and automate the communications between parties.

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.

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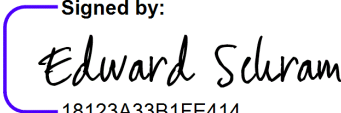
Justification

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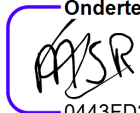
The scientific quality of this report has been peer reviewed by two colleague scientists and a member of the Management Team of Wageningen Marine Research

Approved: dr. ir. E. Schram
Researcher Wageningen Marine Research

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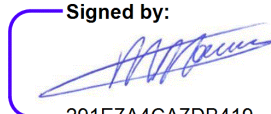
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Approved: Marc Robert
Researcher Wageningen Social and Economic Research

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Appendix 1 – Species list

Table A1.1 Species caught while fishing with gill nets in Borssele offshore wind farm. Please note that the MCRS for dab does not officially exist, but fish auctions use 23 cm as their minimum size for landing.

Scientific name	English name	Dutch name	Minimum size (MCRS)	landing
<i>Asterias rubens</i>	Common starfish	Gewone zeester		
<i>Atelecyclus undecimdentatus</i>		Ovaalronde krab		
<i>Aurelia aurita</i>	Common jellyfish	Oorkwal		
<i>Callionymus lyra</i>	Dragonet	Pitvis		
<i>Cancer pagurus</i>	Brown crab	Noordzeekrab		13
<i>Chelidonichthys lucerna</i>	Tub gurnard	Rode poon		
<i>Clupea harengus</i>	Herring	Haring		20
<i>Dicentrarchus labrax</i>	Seabass	Zeebaars		42
<i>Diogenes pugilator</i>	Roux's hermit crab	Kleine heremietkreeft		
<i>Echiichthys vipera</i>	Lesser weever	Kleine pieterman		
<i>Limanda limanda</i>	Dab	Schar		23*
<i>Liocarcinus depurator</i>	Blue-leg swimcrab	Blauwpootzwemkrab		
<i>Liocarcinus holsatus</i>	Common swimming crab	Gewone zwemkrab		
<i>Loligo vulgaris</i>	European squid	Gewone pijlinktvis		
<i>Macropodia rostrata</i>	Long legged spider crab	Hooiwagenkrab		
<i>Maja squinado</i>	Spinous spider crab	Maja sp.		
<i>Merlangius merlangus</i>	Whiting	Wijting		27
<i>Mullus surmuletus</i>	Striped red mullet	Mul		
<i>Mustelus</i>	Starry smoothhound	Gevlekte gladde haai		
<i>Nassarius</i>	Dog whelks	Fuikhoorns indet.		
<i>Necora puber</i>	Velvet swimcrab	Fluwelen zwemkrab		6.5
<i>Pagurus bernhardus</i>	Bernhard's hermit crab	Gewone heremietkreeft		
<i>Pleuronectes platessa</i>	Plaice	Schol		27
<i>Raja montagui</i>	Spotted ray	Gevlekte rog		55
<i>Scomber scombrus</i>	Mackerel	Makreel		30
<i>Scophthalmus maximus</i>	Turbot	Tarbot		27
<i>Scyliorhinus canicula</i>	Lesser spotted dogfish	Hondshaai		
<i>Sepia officinalis</i>	Common cuttlefish	Zeekat		
<i>Solea solea</i>	Sole	Tong		24
<i>Syngnathus</i>	Seaweed pipefishes	Zeenaalden indet.		
<i>Trachinus draco</i>	Greater weever	Grote pieterman		
<i>Trachurus trachurus</i>	Horse mackerel	Horsmakreel		15
<i>Trisopterus luscus</i>	Bib	Steenbolc		

Table A1.2 Species caught while fishing with gill nets in Hollandse Kust Zuid offshore wind farm. Please note that the MCRS for dab does not officially exist, but fish auctions use 23 cm as their minimum size for landing.

Scientific name	English name	Dutch name	Minimum landing size (MCRS)
<i>Asterias rubens</i>	Common starfish	Gewone zeester	
<i>Atelecyclus undecimdentatus</i>		Ovaalronde krab	
<i>Buglossidium luteum</i>	Solenette	Dwergtong	
<i>Callionymus lyra</i>	Dragonet	Pitvis	
<i>Cancer pagurus</i>	Brown crab	Noordzeekrab	13
<i>Carcinus maenas</i>	Green crab	Strandkrab	
<i>Chelidonichthys lucerna</i>	Tub gurnard	Rode poon	
<i>Ciliata mustela</i>	Five-bearded rockling	Vijfdradige meun	
<i>Corystes cassivelaunus</i>	Helmet crab	Helmkrab	
<i>Dicentrarchus labrax</i>	Seabass	Zeebaars	42
<i>Echiichthys vipera</i>	Lesser weever	Kleine pieterman	
<i>Entelurus aequoreus</i>	Snake pipefish	Adderzeenaald	
<i>Hippocampus hippocampus</i>	Short-snouted sea-horse	Kortsnuitzeepaardje	
<i>Limanda limanda</i>	Dab	Schar	23*
<i>Liocarcinus depurator</i>	Blue-leg swimcrab	Blauwpootzwemkrab	
<i>Liocarcinus holsatus</i>	Common swimming crab	Gewone zwemkrab	
<i>Liocarcinus navigator</i>	Arch-fronted swimming crab	Gewimperde zwemkrab	
<i>Maja squinado</i>	Spinous spider crab	Maja	
<i>Merlangius merlangus</i>	Whiting	Wijting	27
<i>Mullus surmuletus</i>	Striped red mullet	Mul	
<i>Mustelus</i>	Starry smoothhound	Gevlekte gladde haai	
<i>Myoxocephalus scorpius</i>	Bull-rout	Zeedonderpad	
<i>Nassarius</i>	Dog whelks	Fuikhoorns indet.	
<i>Natica</i>	Moon snails	Tepelhoorns indet.	
<i>Necora puber</i>	Velvet swimcrab	Fluwelen zwemkrab	6.5
<i>Pagurus bernhardus</i>	Bernhard's hermit crab	Gewone heremietkreeft	
<i>Platichthys flesus</i>	Flounder	Bot	20
<i>Pleuronectes platessa</i>	Plaice	Schol	27
<i>Psammechinus miliaris</i>	Green sea urchin	Zeeappel	
<i>Scomber scombrus</i>	Mackerel	Makreel	30
<i>Scophthalmus maximus</i>	Turbot	Tarbot	27
<i>Scophthalmus rhombus</i>	Brill	Griet	27
<i>Scyliorhinus canicula</i>	Lesser spotted dogfish	Hondshaai	
<i>Sepia officinalis</i>	Common cuttlefish	Zeekat	
<i>Solea solea</i>	Sole	Tong	24
<i>Trachurus trachurus</i>	Horse mackerel	Horsmakreel	15
<i>Trisopterus luscus</i>	Bib	Steenbolk	

Appendix 2 – Video observations

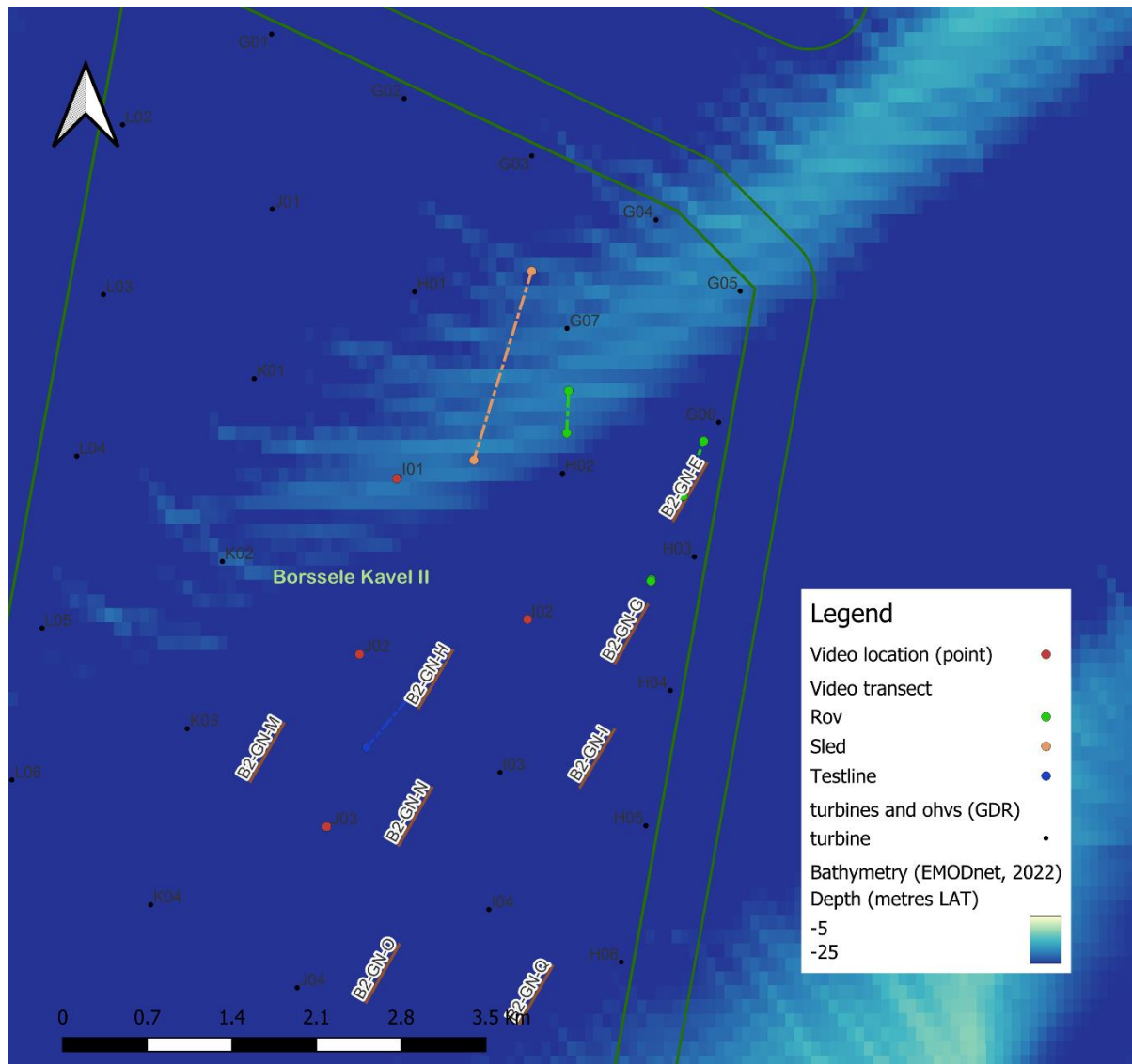


Figure A2.1 Video surveys Borssele

Colour legend:

green = rov transects

orange = sled transects

blue = anchor video test lines

red dots = video at wind turbines.

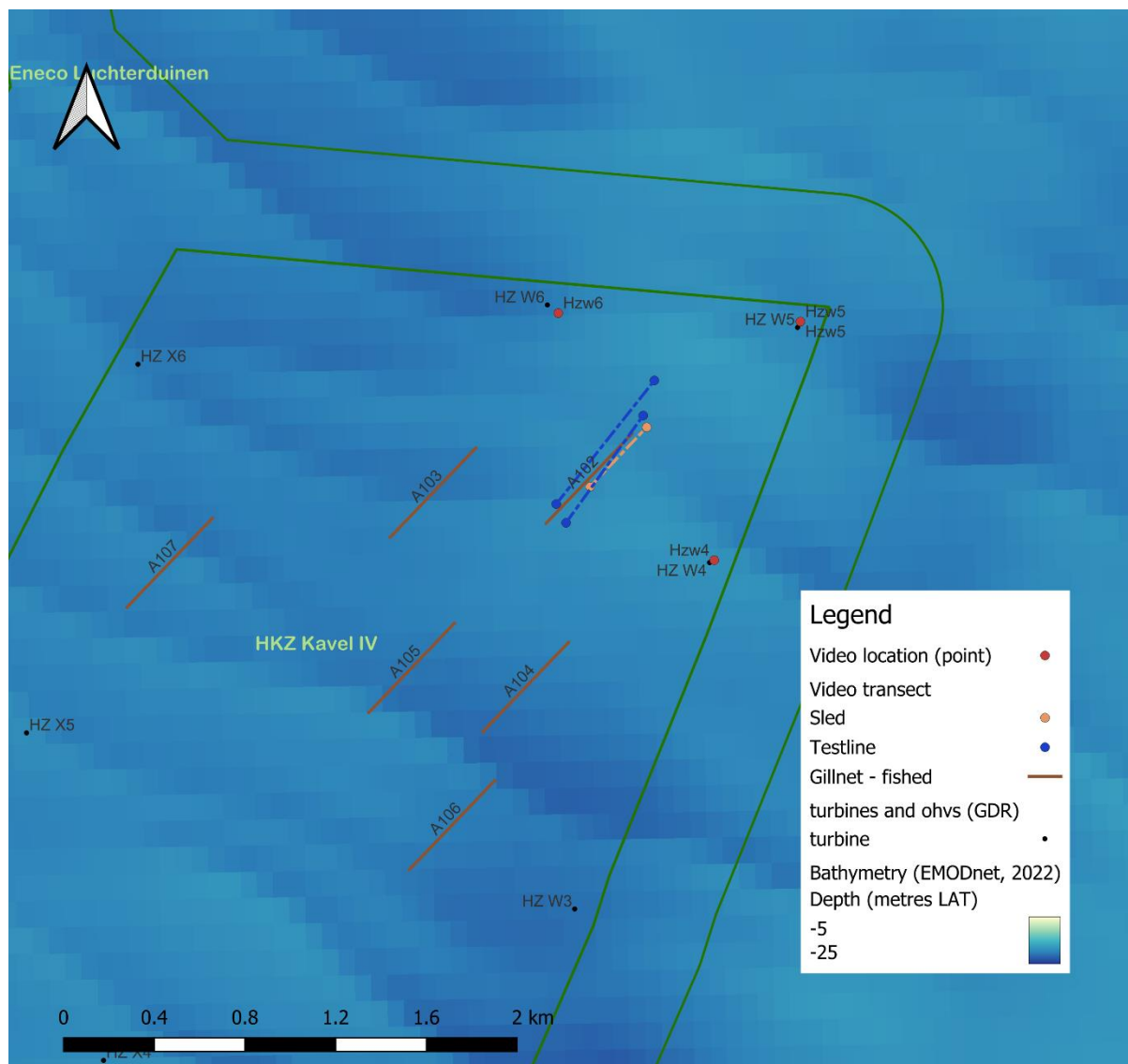


Figure A2.2 Videosurveys Hollandse Kust Zuid

Colour legend:

orange = sled transects

blue = anchor video test lines

red dots = video at wind turbines

Appendix 3 – Unanticipated events

Prior to the experiments the anticipated operational procedures are described in the action plan and confirmed by Ministry of Agriculture, Fisheries, Food Security and Nature and Rijkswaterstaat. The action plan is also shared voluntarily with the wind farm operators ie. Ørsted and Vattenfall. Most field experiments were undertaken as foreseen in the action plan 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) where 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) Net damage (Borssele II)
- 2) Steel slags (Borssele II)
- 3) Loss and recovery of gill net (Borssele; 09/10-05-2024)
- 4) Loss of anchor (Hollandse Kust Zuid; 30-04-2024)
- 5) Malfunctioning AIS (Borssele; 30-04-2024)
- 6) Dahns and life vests (several occasions)
- 7) Entanglement of net (Hollandse Kust Zuid; 01-05-2024)

1) Net damage (Borssele II)

During gill net fishing activities in Borssele II damage to the nets did occur on a regular basis. In most cases the damage was local and (parts of) the nets could be renewed. In some cases the damage was more significant and the nets could not be hauled, see Case 3. Damage of the nets could be caused by the dynamics of the bathymetry, steel slags (see Case 2) or other factors. Recovery and renewing of damaged nets does involve additional time and costs.

Hereupon the locations for the experiments were changed to Borssele I.

2) Steel slags (Borssele II)

A steel slag, see Figure 1, was caught in a net in Borssele II. The damage to the nets in Borssele II raises the suspicion that there are more steel slags on the seabed in Borssele II. Attempts were made to register steel slags by local video recordings. However no steel slags on the seabed were observed on the video recordings.



Figure A3.1 Steel slag

3) Loss and recovery of gill net (Borssele; 09/10-05-2024)

On 09-05-2024 the dahns of one of the gill nets in Borssele could not be found. The lost gill net was recovered on 10-05-2024 by dragging with a drag anchor, see



Figure A3.2 10/05/2024
light dredge anchor used for
recovery of gill nets without
markings.

Figure A3.. The dredge anchor is of a similar size to the Bruce anchors used to anchor the nets. The recovered net was cut through completely, potentially by the steel slags, see Case 2. In total retrieval of the net took about 4-5 hours and the net was considered total loss and had to be renewed.

4) Loss of anchor (Hollandse Kust Zuid; 30-04-2024)

One anchor got disconnected from the line during hauling and remains on the seabed on location N52.24.410 E004.12.588. It is deemed impossible to retrieve the anchor. Furthermore the risk of a lost Bruce anchor is nil: the anchor will sink into the soil and not move.

5) Malfunctioning AIS (Borssele; 30-04-2024)

Upon entrance of the wind farm YE 152 was called by the coast guard on VHF 16 because it's AIS was not active. The AIS appeared malfunctioning. Despite the malfunctioning AIS the fishing activities could be proceeded, because the coast guard was aware of the fishing experiments.

6) Dahns and life vests (several occasions)

Dahns get entangled with life vests on a regular basis. The use of dahns, onboard of small fishing vessels, in combination with life vests results in potential unsafe situations.

7) Entanglement of net (Hollandse Kust Zuid; 01-05-2024)

While hauling one gill net on 01-05-2024 the net was entangled with itself. The recovered net indicated that the southern, wave ward anchor had not hold well onto the seabed and had moved in leeward direction, leeward of the northern anchor. The net was entangled around the northern anchor and the southern dahn and anchor were retrieved approximately 250 m further northwards, within the maintenance zone of a turbine. No maintenance was ongoing and entrance of the maintenance zone did not result in any threat for the wind farm operations and/or the fishing vessel.

Appendix 4 - Sailing trajectories

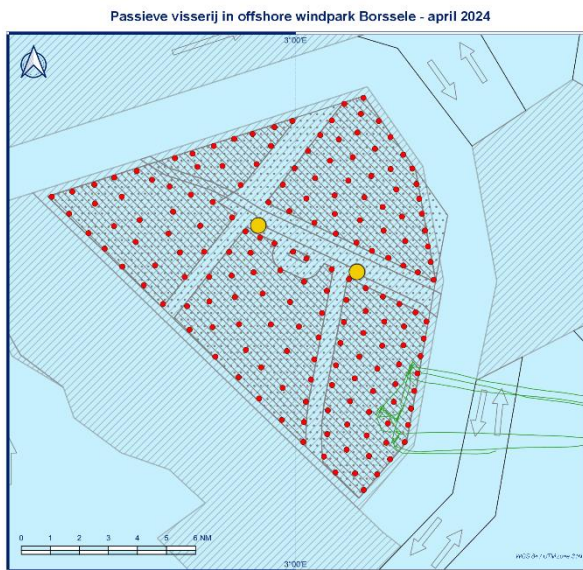


Figure A4.1 Passive fishing trajectories in Borssele offshore wind farm, April 2024.

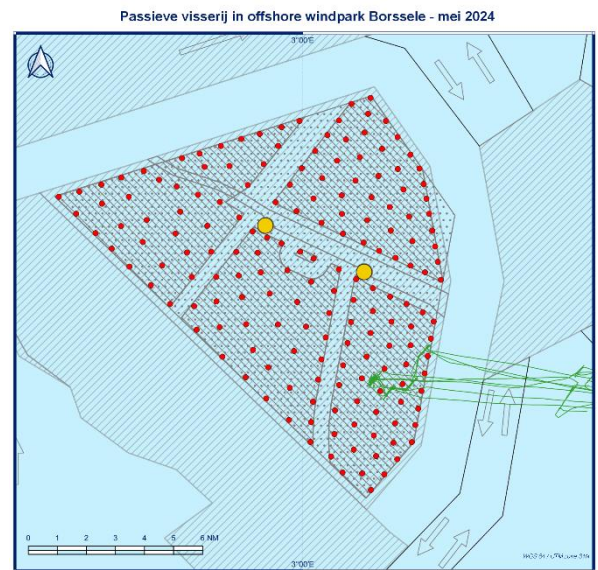


Figure A4.2 Passive fishing trajectories in Borssele offshore wind farm, May 2024.

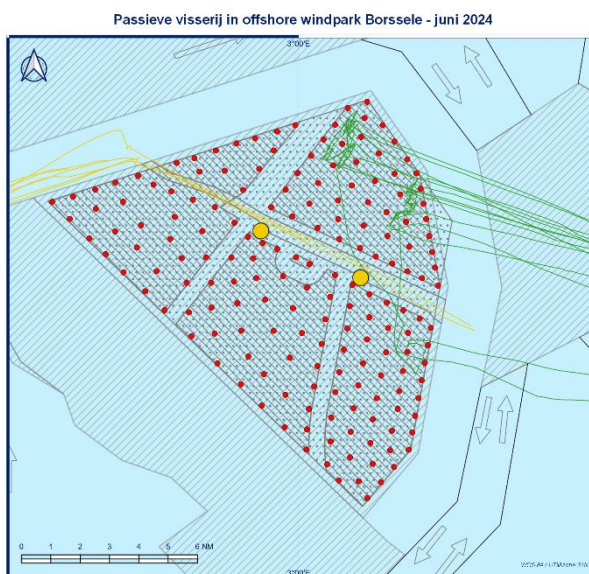


Figure A4.3 Passive fishing trajectories in Borssele offshore wind farm, June 2024.

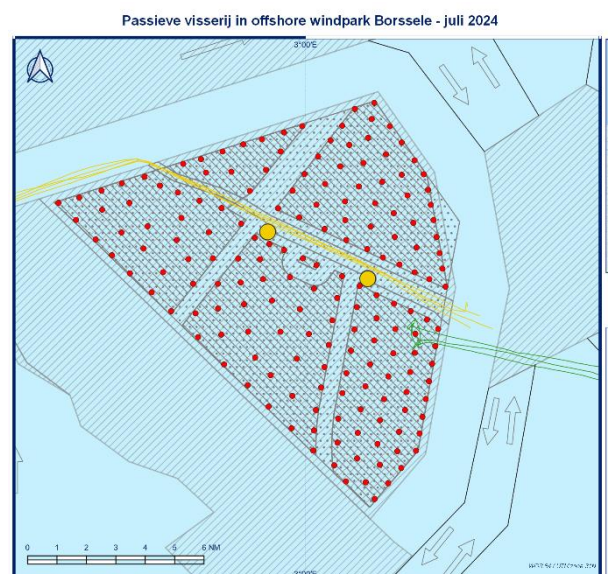
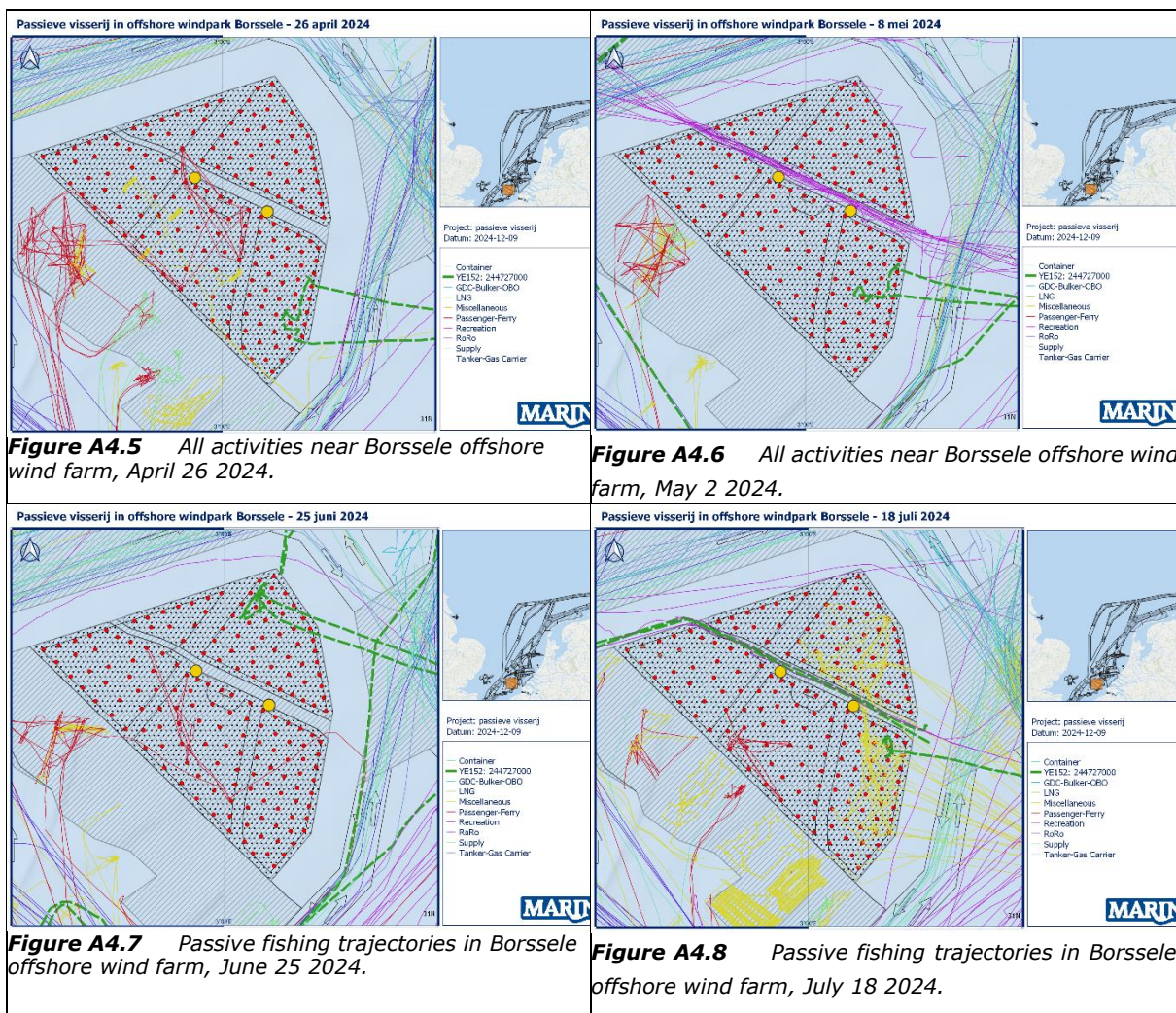


Figure A4.4 Passive fishing trajectories in Borssele offshore wind farm, July 2024.



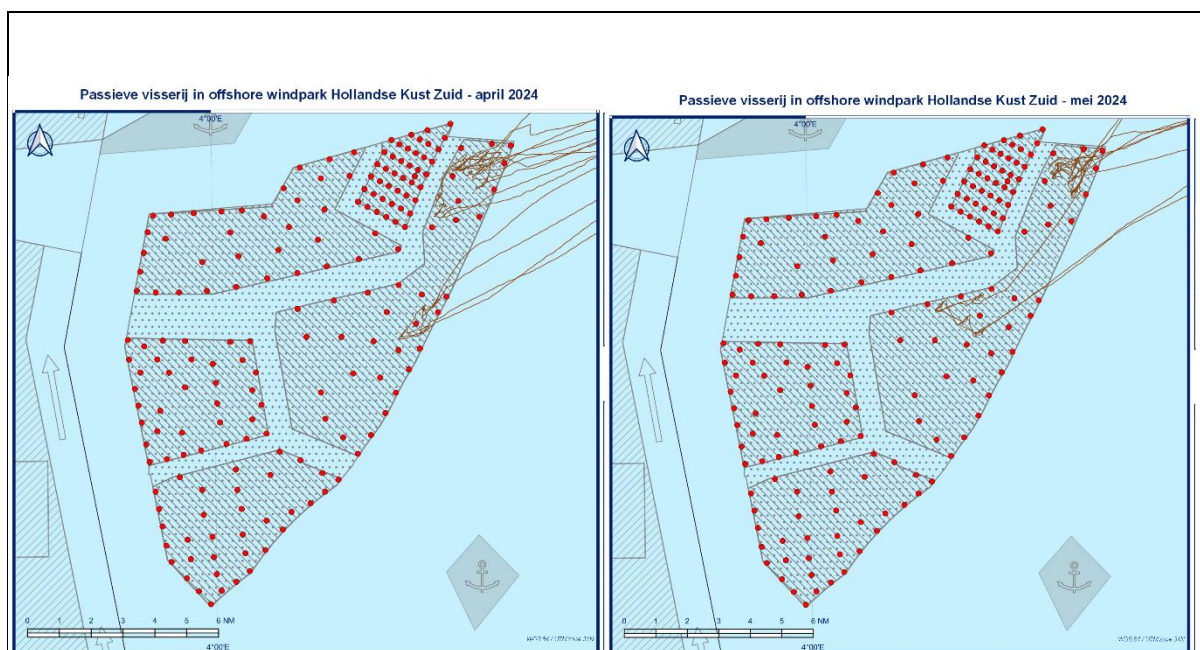


Figure A4.9 Passive fishing trajectories in Hollandse Kust Zuid offshore wind farm, April 2024.

Figure A4.10 Passive fishing trajectories in Hollandse Kust Zuid offshore wind farm, May 2024.

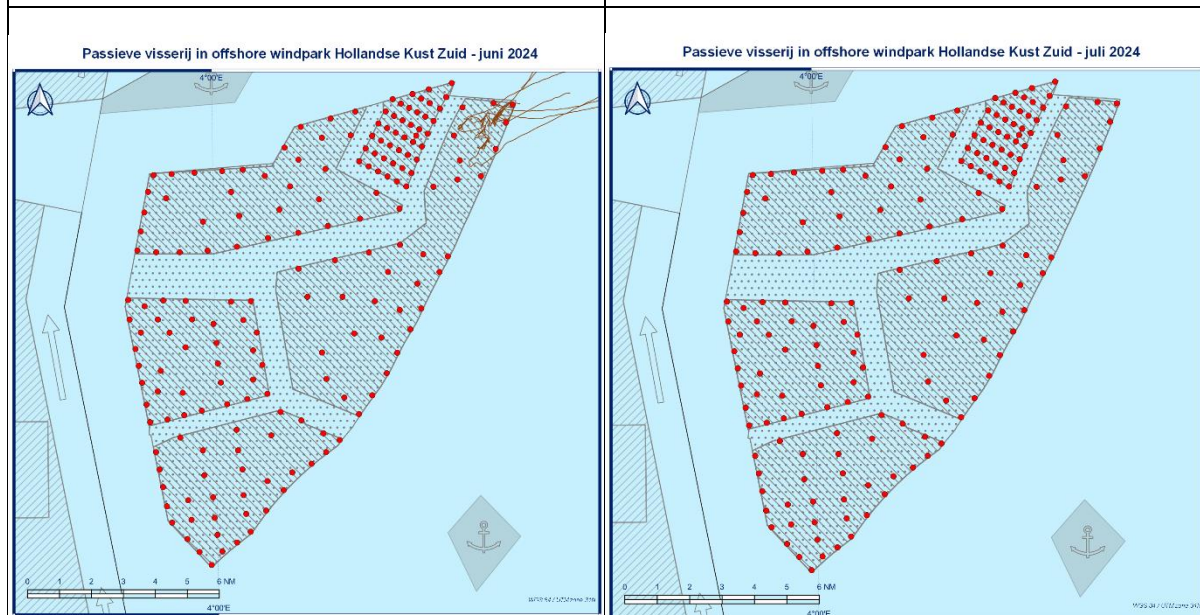


Figure A4.11 Passive fishing trajectories in Hollandse Kust Zuid offshore wind farm, June 2024.

Figure A4.12 Passive fishing trajectories in Hollandse Kust Zuid offshore wind farm, July 2024.

Appendix 5 – Descriptive tables

Table A5.1 Fishing effort, the total catch for sole, as well as important factors such as gear adjustments, relevant observations, weather conditions and bird and marine mammal sightings for all gill net trips in Borssele offshore wind farm. Green means fishing in Borssele II, orange means reference hauls outside the wind farm, blue means fishing in Borssele I.

Date	Trip ID	Fishing effort (hours)	Total marketable sole (grams)	Gear adjustments and observations	Birds and marine mammal sightings
27/04/2024	1	25	790	A lot of damaged nets and pieces of net missing. One anchor was lost. Consulted with researchers in the other wind farm if they experienced similar situations. Not a lot of catch, algal bloom in the water (nets were heavy and slippery).	No sightings.
01/05/2024	2	24	510	Again a lot of damaged nets and pieces of net missing. One steel slag was caught in the net. Skipper fixed the nets before the next trip. Algal bloom in the water, nets were heavy and slippery, not a lot of catch. Call from Coastguard about malfunction in AIS: skipper fixed this. Steel slag observation reported.	1 grey seal, about 15 seagulls.
09/05/2024	3	24	0	Three lines stuck on the seafloor, a lot of damaged nets. One dahn broke and one string broke in half during hauling: tried until dark with a dredge, but no luck. The communication is going well, no issues. It was decided to fish on the old pot locations from the 2023 experiment after the discovery of steel slags. This has been coordinated with Ørsted and approved by LVVN, and RWS	2 harbour porpoises.
10/05/2024	4	23	460	The 3 nets were hauled successfully, but again a lot of damage and heavy nets. Continued dredging for the net lost the previous day and retrieved the string successfully. Decided not to proceed with the experiment but discuss with RWS and Ørsted to see if, and if so, where sharp objects or steel slag is present.	No sightings.

15/05/2024	R1 (5)	24	0	Algal bloom is still ongoing, but the nets were not damaged in any way. The two reference strings were set again outside of the wind farm on two different locations. In consultation with RWS and LVVN, it was decided to conduct reference hauls outside the wind farm to see if any damage occurs there as well. Two nets have been set at two different locations, and were after hauling set again for hauling the next day. The seabed in the wind farm was also examined using an ROV and GoPro cameras. Due to the ongoing algal bloom, the visibility was too low to conduct a succesful survey. There was some catch in the nets.	No sightings.
16/05/2024	R2 (6)	19	830	Algal bloom is still ongoing, but the nets were again not damaged in any way outside of the wind farm. Not a lot of catch. Consulted RWS and LVVN on how to proceed: agreed on expanding the area to Borssele I plots. Adjustments in the permission letter were made and wind farm operators were informed.	No sightings.
18/06/2024	7	21	4150	A few drifts were done with the ROV in Borssele II. Looks like sandy bottom with shells and tube worms at first glance. No indications of steel slag or similar observed so far. Hauling in Borssele I without problems and no damage on the nets. The communication is still going well. More catch in terms of volume and species. The sailing time to Borssele I is about an hour longer than to Borssele II. More macro algae in the nets, the other algal bloom has disappeared.	No sightings.
24/06/2024	8	24	1740	Hauling in Borssele I again without problems and little to no damage on the nets. Few camera transects were done on the seafloor in Borssele II. Algal bloom still absent, very good visibility. Some catch but very little volumes still, diverse in terms of species.	1 harbour seal.
25/06/2024	9	22	1170	Hauling in Borssele I again without problems and little to no damage on the nets. Not a lot of catch, no algal bloom.	No sightings.
26/06/2024	10	22	925	Hauling in Borssele I again without problems and little to no damage on the nets. Not a lot of catch, no algal bloom.	No sightings.
27/06/2024	11	21	2875	Hauling in Borssele I again without problems and little to no damage on the nets. Some catch of target species, no algal bloom.	No sightings.

Table A5.2 Fishing effort, the total catch for sole, as well as important factors such as gear adjustments, relevant observations, weather conditions and bird and marine mammal sightings for all gill net trips in Hollandse Kust Zuid offshore wind farm.

Date	Trip ID	Fishing effort (hours)	Total marketable sole (grams)	Gear adjustments and observations	Birds and marine mammal sightings
31/03/2024	1	27	2130	Communication went well. Asked MCC if we could set nets again when weather stays OK: only possible on locations that were communicated for this trip. No flexible approach possible, but for commercial fishing this is needed. Project leader discussed this with Vattenfall. Some algal bloom, but no damaged nets. Some catch, apparently comparable with catch outside of the wind farm when talking to other commercial fishers. Due to ongoing discussion with MCC about redeploying nets on different locations, nets were not set again.	1 grey seal, 1 songbird and 3 seagulls.
23/04/2024	2	14	4285	Setting and hauling went well: looked like one string was entangled but only one anchor was lifted a bit and took some of the net with it. The rest of the string remained in place. More catch than first time, less bycatch. Catch was brought to the fish auction. Still ongoing algal bloom.	1 grey seal.
27/04/2024	3	17	3500	Comparable catch with last trip, still ongoing algal bloom and the nets were probably very heavy and closed against the seafloor due to spring tide and strong currents. Only little damage to the nets. One line (A107) broke due to strong current and too much pressure on the hauler; hauled from the other side, retrieved all gear. Faster sailing times compared to last trip (2 hours), crew had to wait before entering the wind farm because it was still dark. Call on VHF CH16 from Coast Guard about our intentions: they did not read their email yet and thought it was illegal for crew to enter.	No sightings.
30/04/2024	4	17	6305	Setting and hauling went well, except crew retrieved 1 line and set again because first attempt was too far from fixed position. One Bruce anchor lost at position N52.24.410 E004.12.588. The clip may have come loose when retrieving the net. Position reported to Vattenfall and then to the Coast Guard as a 'dropped object'. No damaged nets, nets were set immediately again. Catch as expected due to ongoing algal bloom. When compared with fishers outside of the wind farm, catch seemed a little higher than what others caught outside of the wind farm. Crew put on lifejackets to make photos from work on board, but that resulted in several almost-accidents since lifejackets are not suitable for this fishery. Decided to take them off again.	1 grey seal.

01/05/2024	5	22	4070	One string was displaced; when setting, the anchor could have been accidentally thrown over lines, causing the anchor to remain suspended and the string not to anchor to the bottom. With the changing tide, the string turned towards the wind turbine and ended up about 80 m away. From now on, crew paid close attention when setting to prevent this: 2 nets (2x50 m) were a total loss; they were replaced for next trip. Catch comparable to day before, still ongoing algal bloom. No damaged nets apart from the two sections as described in the previous column.	1 harbour seal.
09/05/2024	6	20	3215	A lot of bycatch and little sole: one net was full of starfish and benthic species and therefore a lot of rotten and eaten catch. Decided to not use the deeper parts again. Communication is still going very smoothly. Redeployed the strings at the locations that were indicated in the emails, but 1 string was moved from position A105 to position A102 due to the many flatfish and starfish encountered. The crew believes that these numbers are much higher in 'mud holes' (deeper pits than the surrounding area where benthos gather).	2 seagulls.
10/05/2024	7	22	7620	More sole than the day before and less bycatch, very dependent on location. Some places have a lot of dab. The algal bloom is still ongoing. Nets were set at the locations indicated in the email, but crew made a mistake; called Vattenfall and informed them about moving 1 net, and they immediately agreed. Communication is going well.	5 seagulls behind the ship when discarding unwanted catch.
11/05/2024	8	21	8590	Again more sole than the day before, less bycatch. Still a lot of dab in some locations. Algal bloom is still ongoing. Setting and hauling went well, decided not to redeploy the nets due to weather conditions.	1 grey seal.
25/06/2024	9	31	2935	Little catch, a lot of dab in some places. Setting and hauling went well, nets were set again for hauling next day. No more algal bloom. Communication went well.	4 harbour porpoises, 1 harbour seal and 3 seagulls.
26/06/2024	10	17	9965	A lot of catch, and less bycatch. Last day of collecting biological data, before doing video surveys. No more algal bloom. Communication went well.	No sightings.

Appendix 6 – Additional catch data

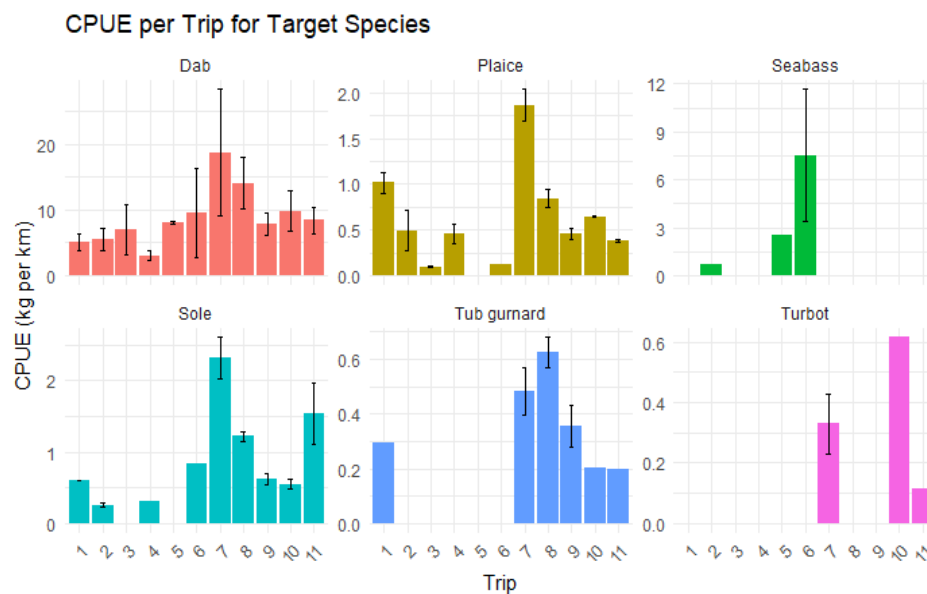


Figure A6.1 CPUE graph for all commercial species caught in Borssele offshore wind farm.

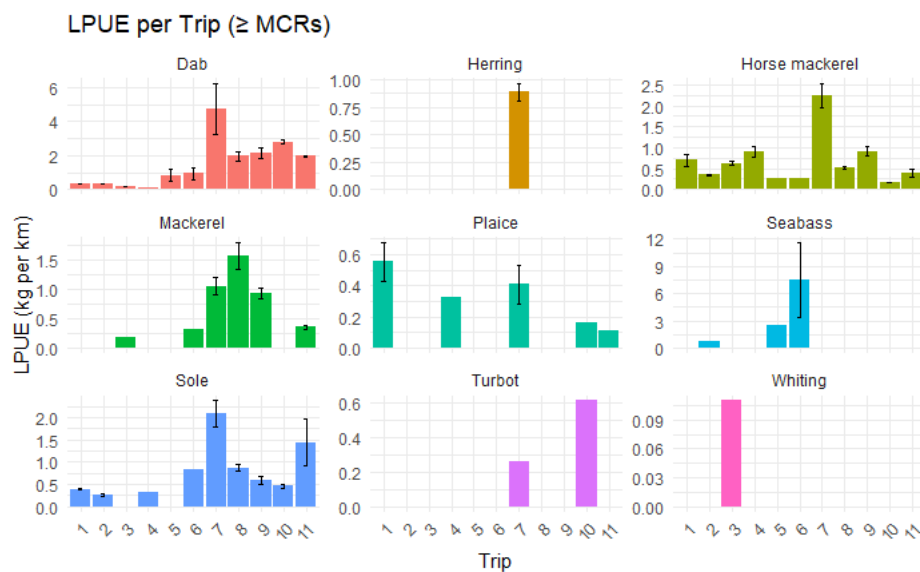


Figure A6.2 LPUE graph for all commercial species caught in Borssele offshore wind farm.

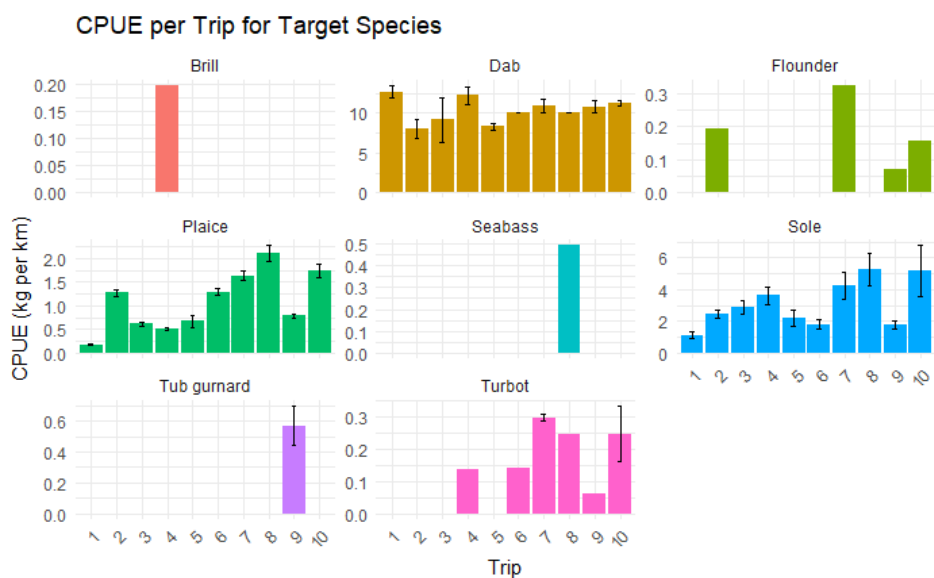


Figure A6.3 CPUE graph for all commercial species caught in Hollandse Kust Zuid offshore wind farm.

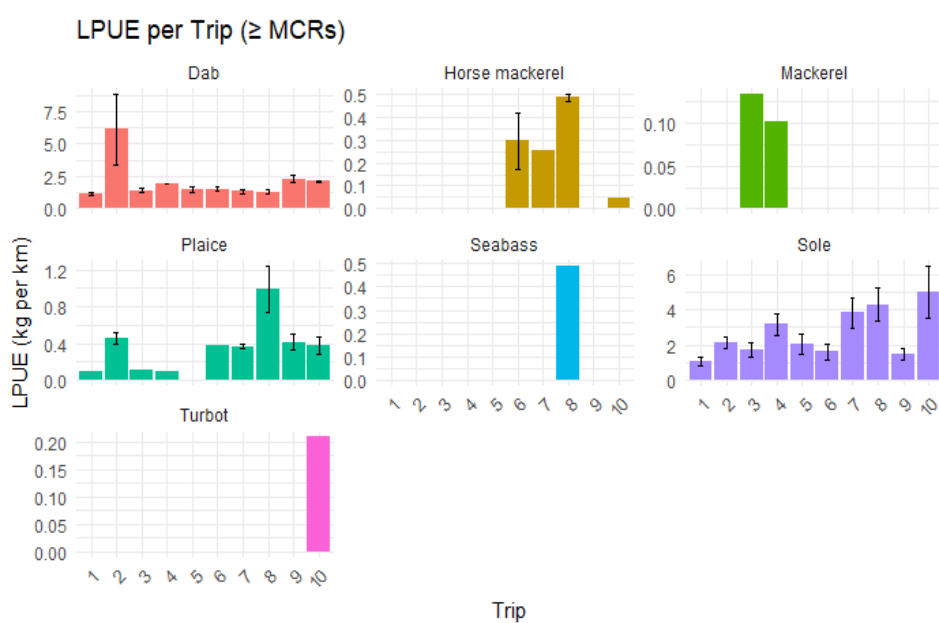


Figure A6.4 LPUE graph for all commercial species caught in Hollandse Kust Zuid offshore wind farm.

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