SeaShare: Hywind Static Fishing Gear Trials

Photo credit: K. Wright

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Summary

Equinor commissioned the Marine Directorate of the Scottish Government to undertake a trial of the use of static commercial fishing gear within the Hywind floating offshore wind farm. This is the first known trial of its kind worldwide, and the Hywind Scotland floating wind farm was the world's first floating wind farm, becoming operational in 2017. The aim of the 'SeaShare' project was to investigate the safety and viability of using static commercial fishing gear within a floating offshore wind farm. Three types of static fishing gear were trialled: fish traps, crab and prawn creels and electronic jiggers. The trial included four trips to sea on board Guard Vessel *Seagull* BF 74 a 30 m ex-commercial fishing vessel with considerable prior experience of working in offshore renewable sites from July to November 2022.

There has been no previous work at the Hywind site or other floating offshore wind farms to understand the risk of gear snagging in a floating offshore wind farm, so testing these areas were a main focus of the trial. Equinor identified three 'fishing trial areas' within the wind farm, based on a minimum distance of 200 m to the wind turbines and the dynamic sections of the export/inter-array cables, and 50 m minimum distance to the remaining subsea infrastructure. A control area was designated outside the wind farm area. These four areas were fished in rotation using all gear types in each rotation within each area.

All gear was successfully operated within the designated 'fishing trial areas' in the Hywind floating offshore wind farm and there were no safety issues, gear snagging or fishing gear lost. The fishing trial areas allowed adequate space to operate the vessel and static fishing gear and were deemed to be safe distances away from the turbines for the vessel and fishing gear in this trial. The commercial viability of these fishing methods was not within the scope of the project. Static fishing was not a prominent fishery in the area prior to the wind farm construction and therefore the catch rates are not representative of a static fishery.

In addition to testing the safety of deploying and hauling static fishing gear in a floating offshore wind farm, catch composition and rates and species biodiversity at the wind farm were also recorded. The most prominent species caught in the trial were Haddock (*Melanogrammus aeglefinus*), Brown crab (*Cancer pagurus*) and Mackerel (*Scomber scombrus*). No Prawns (*Nephrops norvegicus*) were caught using the prawn creels due to apparent lack of suitable Prawn habitat in the Hywind site. Fish and shellfish species caught were largely limited to the targeted commercial fish and shellfish species due to the selectivity of the gear and bait used, and by-catch of other species was minimal. A smaller mesh fish trap was also used to target any other species of interest. There was an increase in Brown crab numbers caught between August and October which was expected based on the species' seasonal behaviour patterns.

This trial has demonstrated that under the right sea and weather conditions, it is possible to fish safely within the Hywind floating offshore wind farm with the static fishing gear tested, within the safety distances to the infrastructure that were used for

these trials, and adherence to standard maritime safety and navigation rules of the sea.

It is hoped that this trial can be replicated in other operational floating offshore wind farms across the world and that the knowledge and experience gained from this trial can help to inform future studies.

This fishing trial will play a major role in helping to understand what types of commercial fishing may be compatible with floating offshore wind and help to facilitate coexistence between the two sectors. The knowledge gained from the trials will also be available to help inform wind farm design, configuration and turbine spacing, and in marine spatial planning for future floating offshore wind farm development.

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1. Introduction

Background

With planned expansion of offshore marine renewable energy installations (MREIs) in the coming years, there is set to be an increasing demand for ocean space across multiple marine stakeholders and thus an increased potential for conflict. To alleviate these potential frictions, a multi-use approach to marine management will become increasingly desirable. An important aspect of this will be promoting the co-existence of offshore wind farms and commercial fisheries. The new ScotWind offshore wind leasing round in Scottish waters has granted option agreements for the potential development of offshore wind in a further 20 sites. Of these 20 potential offshore wind farm sites, 14 are likely to be floating rather than bottom-fixed turbines due to the deeper water conditions at these locations.

There are no legal restrictions to fishing within offshore wind farms in Scottish waters. This differs to the law in some EU countries, for example Germany where fishing in offshore wind farms is legally prohibited. Despite there being no legal restrictions to fishing in wind farms in Scotland, fishers have raised concerns over safety, insurance cover and liability for any damage to wind farm assets or their vessel, and these concerns may prevent them from entering or fishing within wind farms. Floating offshore wind presents a greater potential conflict with commercial fishing than bottom-fixed offshore wind due to the presence of subsea infrastructure such as mooring chains, dynamic cables and anchors which will generally have a larger spatial footprint than bottom-fixed turbines. With the presence of this subsea infrastructure there is an increased risk of snagging fishing gear leading to fishers' concerns over safety.

There has been limited work carried out to understand how fishing may continue within offshore wind farms, for example: a trial with passive fishing techniques within a fixed foundation offshore wind farm in the Netherlands, and several over-trawl surveys carried out in fixed foundation wind farms in Scotland (Beatrice, Moray East and Neart na Gaoithe) to test the safety, as far as reasonably practicable, of fishing over export and array cables (BOWL 2021, Moray East 2022 and Neart na Gaoithe 2022). However there has been no work carried out in floating offshore wind farms.

Hence, Equinor, an offshore wind farm developer, is collaborating with the Marine Directorate of the Scottish Government to examine whether static fishing methods can be used safely and effectively at the Equinor Hywind floating offshore wind farm. The Hywind site is located 15 nautical miles east of Peterhead in north-east Scotland and consists of five floating turbines that have a spar buoy foundation.

The fish traps and jigging methods used in the SeaShare trials have been used in previous projects to investigate the commercial viability of the methods in Scottish fisheries (MacDonald and Mair 2017). A more recent project where the Marine Directorate used the fish traps was the Fisheries Innovation Scotland (FIS) project to 'Assess the potential for a demersal whitefish trap fishery to the West of Scotland'

(FIS025). The FIS project commenced in July 2018 and field work was completed in December 2022 after a long delay due to the Covid-19 pandemic. The final report will be published in summer 2023. The FIS project involved fish traps being deployed from a whitefish trawler, *Carina*, in various deep offshore grounds off the northwest coast of Scotland. The aim of the FIS project was to test the deployment of the fish traps at greater depths and in high fish density areas, and to collect data on trap catch composition and catch rates of marketable demersal fish. The fish traps were deployed in areas unsuitable for trawlers due to high snag risks such as proximity to wrecks, which has similarities to the challenges of deploying the fish traps within floating offshore wind farms. Along with using the same fish traps, lessons learned from the FIS project played a major role in shaping and influencing the 'SeaShare' project.

The SeaShare project aims to contribute to knowledge gaps identified through the Scottish Marine Energy Research (ScotMER) programme. In particular the evidence gap 'FF.05-2022 Coexistence between offshore renewables and commercial fishing' on the ScotMER Fish and Fisheries evidence map[1]. The project significantly improves our understanding of fishing within floating offshore wind farms and provides insight and recommendations for good practice.

Aim, objectives & scientific questions

Aim: To trial the safety and feasibility of static commercial fishing gear within the Hywind floating offshore wind farm.

Objectives:

1. To form an initial assessment of the safety of deployment of static gear (fish traps and creels) and commercial style semi-automated jigging systems in selected areas inside the Hywind floating offshore wind farm.
2. To collect catch and species data from a fleet of fish traps, creels and jiggers in the Hywind floating offshore wind farm.

Research questions:

1. Can fishing be performed in the wind park without damages to fishing equipment or wind farm assets.
    a. What kind of fishing gear used is feasible within Hywind floating wind farm? (jigging, fish traps, creels etc.)
        i. Specification of fishing method tested for each gear type - length of fleets, number of traps/creels per fleet, weighting used etc.
        ii. Soak time
        iii. Catch (species, length, weight, frequency/numbers)
    b. To test the 'fishing trial areas' within the floating wind farm designated by Equinor against the control area.
        i. Do these zones allow adequate space to deploy and haul gear?

[1] Fish and Fisheries ScotMER Receptor Group - gov.scot (www.gov.scot)

ii. Are they a safe distance away from the turbine?
iii. Drifting of gear

2. Using the fishing gear methods in this project, describe in qualitative terms any season changes in catch composition during the SeaShare project?

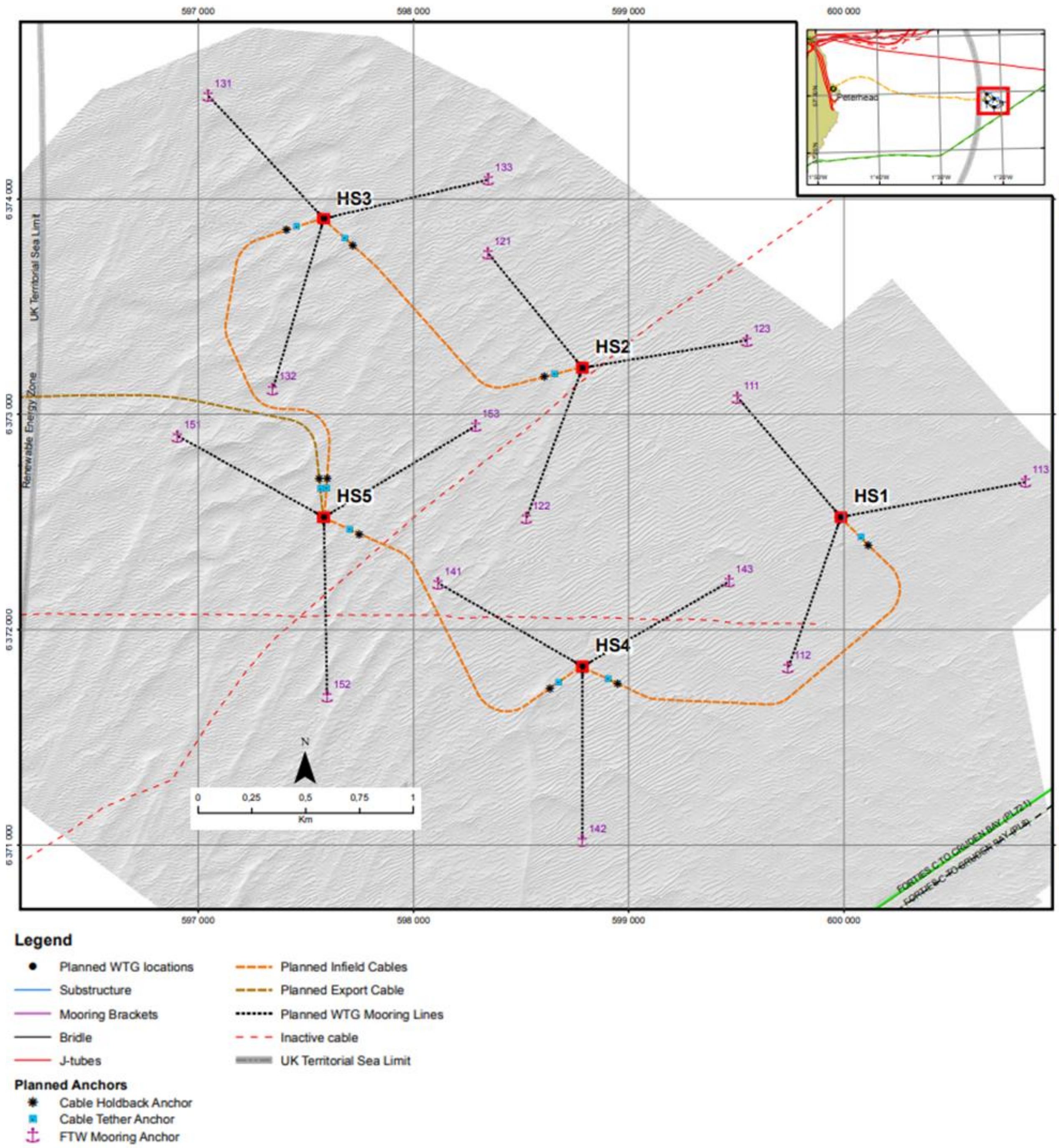

Figure 1. Map presenting the locations of the five turbines and associated subsea infrastructure at Equinor's Hywind floating offshore wind farm.

2. Methods

<u>Site background</u>

The Hywind Scotland floating offshore wind farm, located 25 km east of Peterhead at the Buchan Deep, has been operational since 2017(*Figure 1*). It consists of five floating turbines that have ‘spar buoy’ foundation types (*Figure 2*). The five turbines are located approximately 1350 m apart and are attached to the seabed by a three-point mooring system using three suction anchors per turbine. The mooring lines are free-hanging in the water column and extend out to approximately 700 m – 850 m from the turbine before they touch down on the seabed. (*Figure 3*). The turbines are connected to one another by inter-array cables. These inter-array cables are also partly suspended and extend out to approximately 175 m from the turbines where they are weighted down to the seabed (*Figure 4*).

There are currently several types of floating wind foundation types including: spar, semi-submersible, barge and tension-leg platform (*Figure 2*). Figure 3 presents a diagram of the floating turbine ‘spar buoy’ foundation type, the dynamic cabling, mooring lines and the anchor. The spatial footprint of subsea infrastructure is what makes some types of fishing e.g., mobile fishing challenging within floating offshore wind farms due to potential snagging risk for fishing gear.

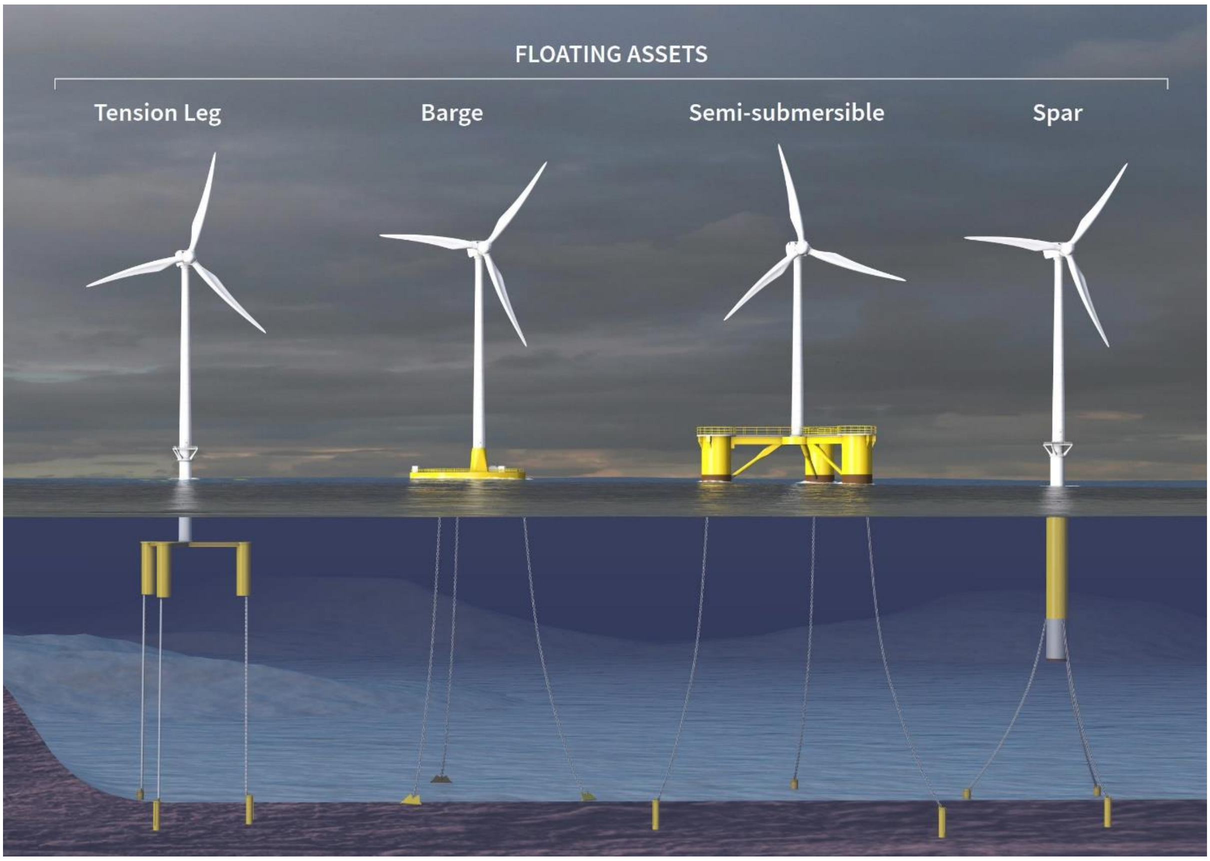

Figure 2. Current types of floating wind foundations (Acteon.com)

Figure 4-4 Mooring arrangement and mooring chain

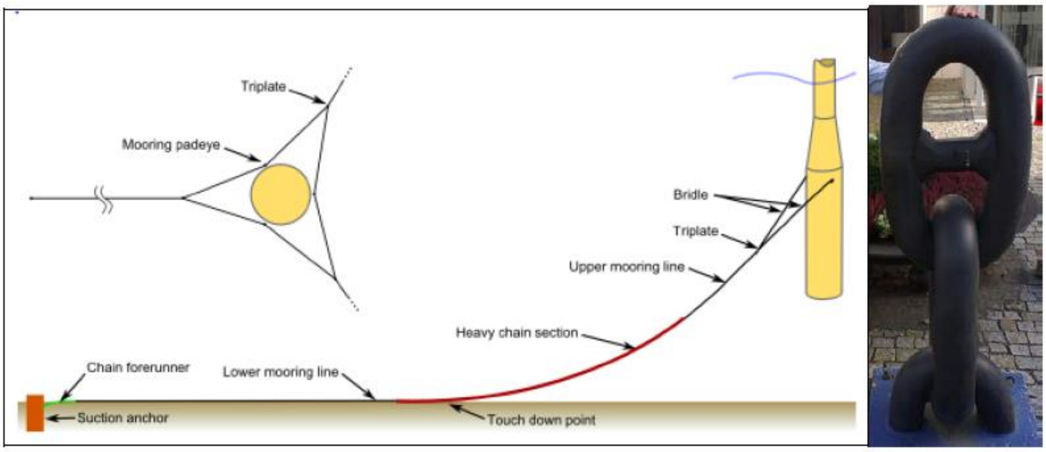

Figure 3. Visualisation of the touch down mooring arrangement, mooring line and suction anchor used at the Hywind wind farm (Equinor.com ES)

Figure 4-5 Schematic of the attachment of the inter-array cable to the WTG showing lazy wave configuration

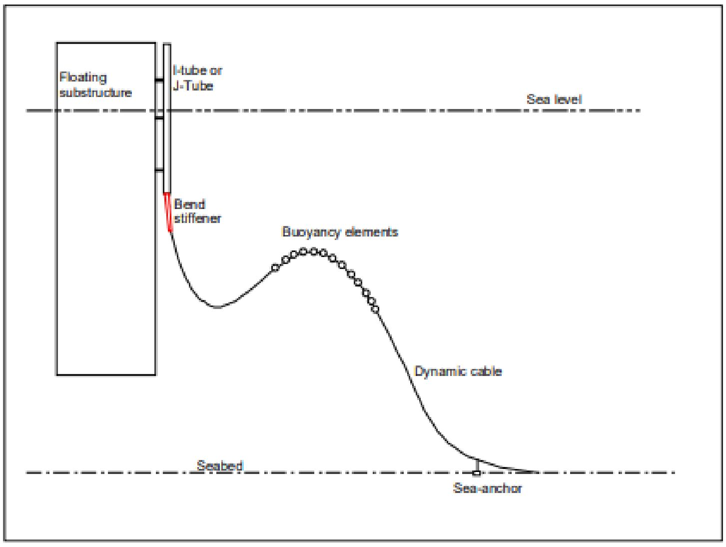

Figure 4. Diagram of the inter-array cables design used at the Hywind wind farm (Equinor.com)

<u>Site environmental conditions, fish species present and fish habitat</u>

Water depths at the Hywind wind farm range between approximately 98 meters and 117 meters, becoming deeper from north to south. The wave direction is mainly from the north with tides moving in a north south pattern, and the site can experience strong tides. The seabed within the turbine deployment area comprises sand and gravel with mega-ripples, apart from some areas of scattered boulders mostly in the southwestern corner (Figure 5). The mega-ripples in the northern wind farm site area are approximately 0.5 m high and superimposed on much larger sand waves with height of 1 to 3 m and a wavelength of up to 250 m. The area outside of the turbine deployment area up to the shore consists mostly of sand and gravel but is generally flatter with only occasional mega-ripples. There are rocky outcrops and boulders along the export cable route corridor. (Hywind ES 2015).

With regards to sediment sampling and particle size analysis, in the turbine deployment area, sediments are largely composed of medium to fine sand, with coarse sand, very fine pebbles and pebbles becoming more predominant towards the middle of the export cable corridor. The total organic matter (%) was low both within the northern wind farm area and along the export cable route corridor where it ranged from 0.75 to 2.1% (MMT 2013)

The majority of the turbine deployment area comprises sandy sediments (biotope "Offshore circalittoral sand" (SS.SSa.OSa)). Seabed imagery indicated a very sparse animal community on the seabed (i.e., epifauna) as well patches of smaller boulder fields (Figure 5).

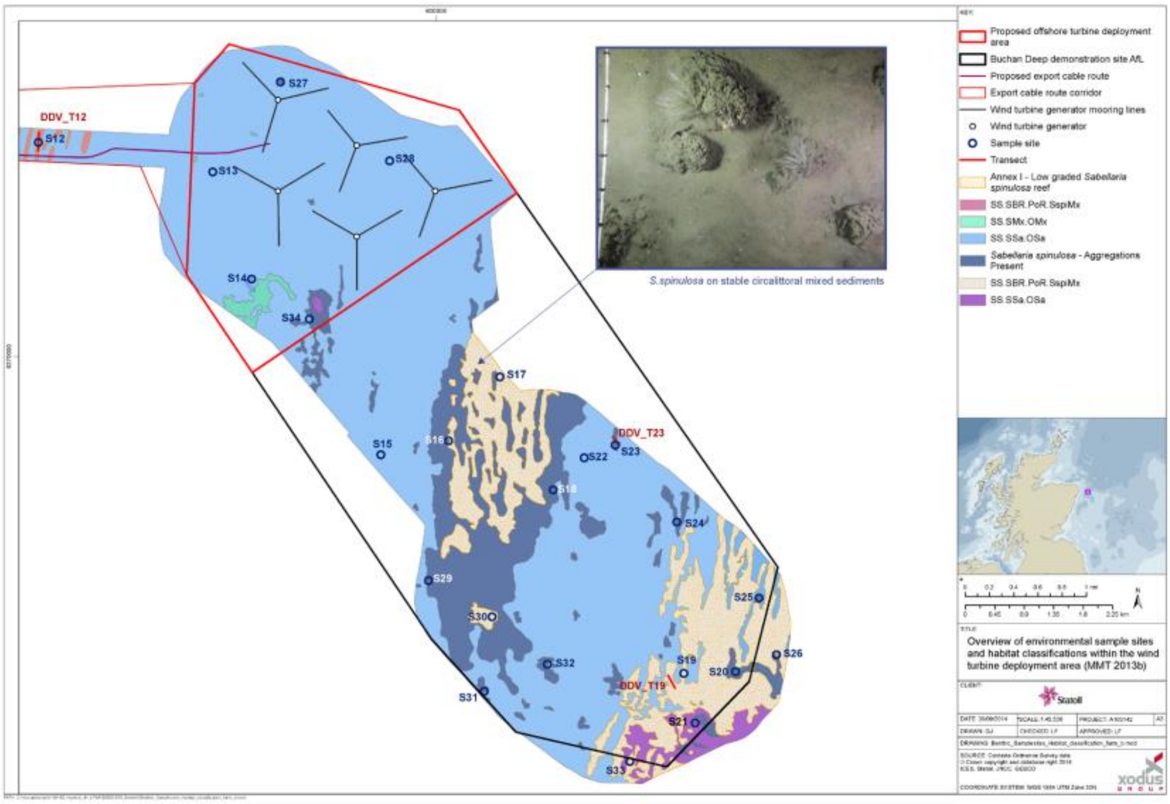

Figure 5. Habitat classifications within the wind farm area (MMT, 2013b in Hywind ES)

Table 1 presents a list of the marine fish and shellfish species reported to be found in the Hywind wind farm area which includes several commercial species.

Herring spawning areas coincide with the turbine area. Herring, Sprat and Mackerel nursery areas are also found in the project area.

High intensity spawning areas for sandeel spawning grounds, and lower intensity spawning areas for Cod, Plaice, Saithe, and Whiting spawning grounds overlapping with both the cable corridor and project area (Hywind ES 2015).

Table 1. List of marine fish and shellfish species reported to be found in the Hywind wind farm area (Hywind ES 2015).

Marine Fish	**Shellfish**
Pelagic	Veined squid (*Loligo forbesi*)
Herring (*Clupea harengus*)	Brown crab (*Pagurus cancer*)
Sprat (*Sprattus sprattus*)	Velvet crab (*Necora puber*)
Mackerel (*Scomber scombrus*)	Scallop (*Pecten maximus*)
Demersal	Norway lobster (*Nephrops norvegicus*)
Raitt's sandeel (*Ammodytes marinus*)	European lobster (*Homarus gammarus*)
Cod (*Gadus morhua*)	
Haddock (*Melanogrammus aeglefinus*)	
Whiting (*Merlangius merlangus*)	
Plaice (*Pleuronectes platessa*)	
Lemon Sole (*Microstomus kitt*)	
Anglerfish (*Lophius piscatorius*)	
Ling (*Molva molva*)	
European hake (*Merluccius merluccius*)	
Norway pout (*Trisopterus esmarkii*)	
Saithe (*Pollachius virens*)	
Spotted ray (*Raja montagui*)	
Common skate (*Dipturus batis*)	
Spurdog (*Squalus acanthias*)	
Tope (*Galeorhinus galeus*)	

Commercial fishing in the turbine area

Mackerel and Herring were commercially exploited in the project area. Low level demersal fisheries targeting Haddock, *Nephrops* and Squid were dominant in the turbine deployment area. There was also a low level of pelagic fishing activity in the turbine deployment area (pelagic activity is greater in the export cable corridor).

Sampling area

The Marine Directorate undertook a two-day trip on board their research vessel, *Alba na Mara*, in June 2021 to familiarise staff with the Hywind site and the fishing methods. The ‘fishing areas’ designated for the test trip on *Alba* in 2021 and Trip 1 of this project were based on more precautionary parameters and were smaller and further away from the turbines than used in later trips within the SeaShare project. After Trip 1 the fishing areas were refined to be based on the safety parameters presented in Table 2. The new areas were larger and closer to the turbines whilst remaining at a safe distance. Figure 6 presents the fishing areas that were used for Trip 1 in a broken outline and the fishing areas that were used for Trip 2 onwards in a solid outline.

The sampling area for the trial was split between inside and outside the wind farm area. Three 'fishing areas' inside the wind farm were designated by Equinor for the purpose of these trials based on various safety parameters such as vessel safety distances from the turbines, array/export cables and mooring lines/anchors (Table 2). A fourth area was designated outside the wind farm area as a control area to compare the ability to fish outside the windfarm to inside the windfarm. The revised Area 1 as seen on Figure 6 was established to avoid an infield cable and there was also an inactive telecoms cable running through Area 2.

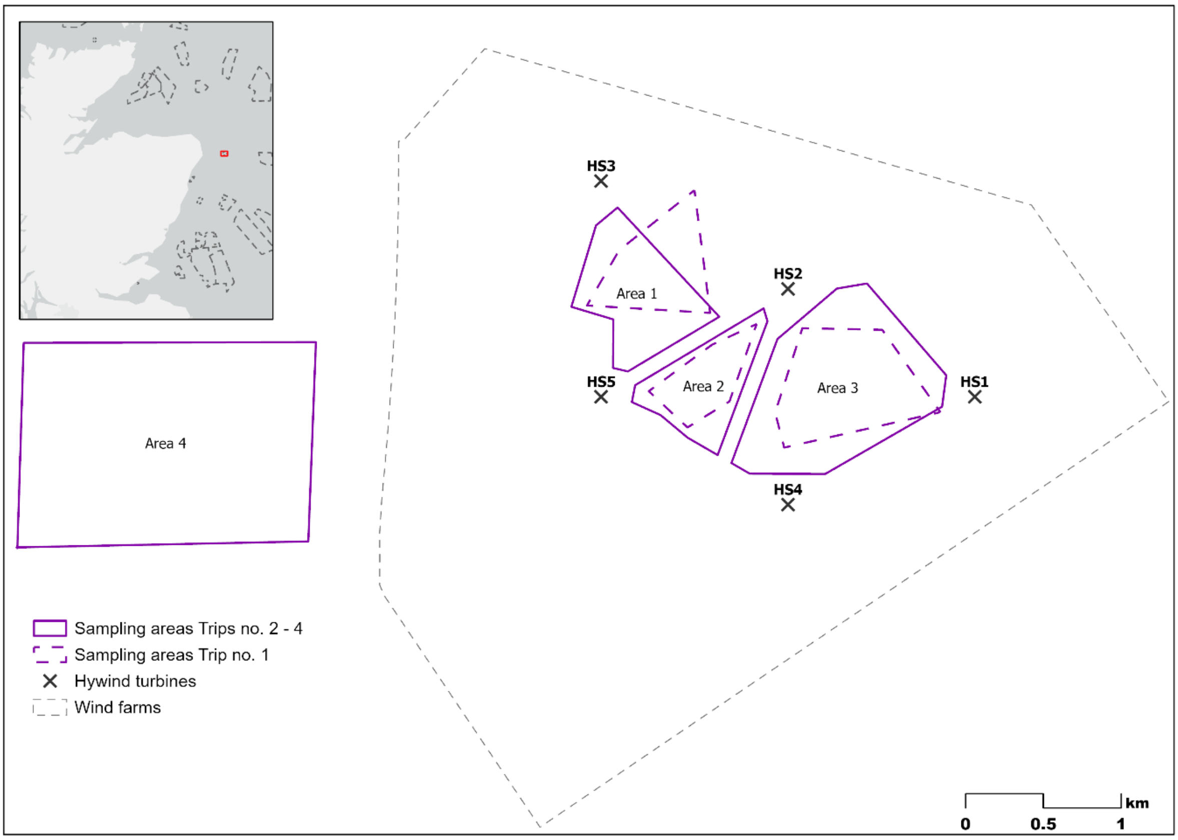

Figure 6. Three 'fishing trial areas' designated by Equinor within the wind farm and fourth area outside the wind farm area as a control.

Table 2. Safety parameters set by Equinor.

Name*	Distance for Vessel*
Wind Turbine Generator	>200 m
Mooring Anchors & Mooring Lines**	50 m
Inter-array cables lying on seabed**	50 m
Dynamic sections of export/inter-array cable**	200 m

** When towing equipment/mooring/anchoring. Distances refer to towed equipment distance from the vessel. For example: if a tow fish is being towed 25 m behind a vessel, to maintain a 50 m safety distance from the mooring line, the vessel should be 75 m away.*

***When vessel is passing in transit no safety distance is required*

<u>Sampling programme</u>

A different location within each fishing area was fished each visit to mimic commercial fishing practices and to avoid ‘fishing out’ a location, i.e., the fishing track was different each time within the ‘fishing area’ to maximize the proportion of each fishing area that was sampled and to provide the ability to adapt to different sea and tidal conditions. Four methods of fishing were trialed (fish traps, crab creels, prawn creels and electronic jiggers). Each day of fishing each fishing area had a different fishing gear deployed (Table 3).

Table 3. Example of the rotational fishing method on each day of the trial

Day 1	deploy fish traps in area 1	deploy crab creels in area 2	deploy prawn creels in area 3	jig in area 4
Day 2	haul fish traps and deploy in area 2	haul crab creels and deploy in area 3	haul prawn creels and deploy in area 4	jig in area 1
Day 3	haul fish traps and deploy in area 3	haul crab creels and deploy in area 4	haul prawn creels and deploy in area 1	jig in area 2
Day 4	haul fish traps and deploy in area 4	haul crab creels and deploy in area 1	haul prawn creels and deploy in area 2	jig in area 3
Day 5	haul fish traps	haul crab creels	haul prawn creels	

The order of gear deployment in each fishing area was influenced by the weather and tide conditions to make sure the best conditions were utilised. The order of gear deployment for each trip are presented in the results section.

A ‘Notice to Mariners’ was distributed to a list of relevant stakeholders including harbours, fisheries representatives, navigation, and sea rescue bodies prior to each trip giving details of the trial and locations of the gear deployed. This was particularly important as the static gear was left in situ overnight to soak both inside and outside the wind farm. The gear was appropriately marked, further reducing any risk of conflict with other fishers in the area.

Vessel selection

The BF 74 '*Seagull*' was selected to undertake the trial (*Figure 7*). The Seagull is 30 meters in length, 8 meters in width and has a draft of 0.6 meters. The vessel is an ex-commercial whitefish trawler that now carries out guard duties for offshore wind farms. This vessel was highly beneficial to the project as the crew had both long-term commercial fishing expertise and experience working in and around offshore wind farms. The Seagull was selected as it had ample deck space (2 decks of roughly 50 m^2 working space each) to store and operate the static fishing gear, had the equipment and ability to safely haul up the static gear (e.g., a rope drum) and had sufficient engine propulsion and manoeuvrability to work safely within the wind farm. The vessel also met strict covid regulations which was an essential element of the vessel selection process at the time of the Covid-19 pandemic.

Figure 7. The Seagull (BF 74) was chartered for the project (photo credit: Kirsty Wright)

Safety on board the vessel

Risk assessments for the project were agreed and circulated to all project members prior to carrying out the fieldwork. A safety brief was given by the skipper to the scientists and crew prior to departure. This included vessel orientation and basic safety procedures. The safety procedures associated with the gear deployment and hauling process were also communicated to everyone on board the vessel.

A record of safety observations for each deployment was maintained by those onboard which included any lost gear, gear snagging or vessel issues. The distance of the vessel to the turbines was closely monitored by the skipper using the live plotter system and the infrastructure/boundary coordinates provided by Equinor.

Static fishing gear

1. **Fish traps**

Triple parlour fish traps were used as part of this trial. They were designed and built by the Marine Directorate’s specialist gear staff and had previously been trialed on board commercial vessels, where they were demonstrated to be both robust and very effective at capturing large demersal whitefish. The fish traps have also been deployed in Marine Protected Areas (MPAs) and adjacent to wrecks, so they are well suited to deploying in sensitive and challenging environments. Cuboid in design, the traps have a base measurement of 150 cm x 110 cm, have a storage height of approximately 20 cm and a full height of 120 cm when submerged and operational. Each trap has three vertical entrances in the first compartment, which is baited. A large funnel entrance leads to the first parlour section and a second large funnel entrance leads from the two bottom sections to an upper chamber. After entering the top panel, fish have at least two entrances to negotiate before potentially escaping (*Figure 8*). Buoyancy (plastic floats and tough Styrofoam) are incorporated to lift the upper parlour section and the walls when submerged. The placement of the buoyancy ensures the traps remain in an upright position as they extend into shape during descent and when in position on the seabed. Figure 9 presents the fish trap in its upright position, ready to be deployed. Weights are also added to the traps to give negative buoyancy and ensure they remain on the sea floor. Each trap is foldable for storage purposes which was an important benefit to maintain deck space.

Two types of triple parlour traps were used:

1. Commercial catch fish traps (large mesh 60 mm, made of twisted coralline material)
2. Biodiversity fish traps (small mesh 20 mm, as used in recent inshore MPA surveys). The biodiversity fish traps are made of knotless material which is used as standard in aquaculture and scientific fish experiments as it does not damage the fish meaning they are caught in good condition.

Table 4 presents further specifications of the two types of fish trap used in this trial.

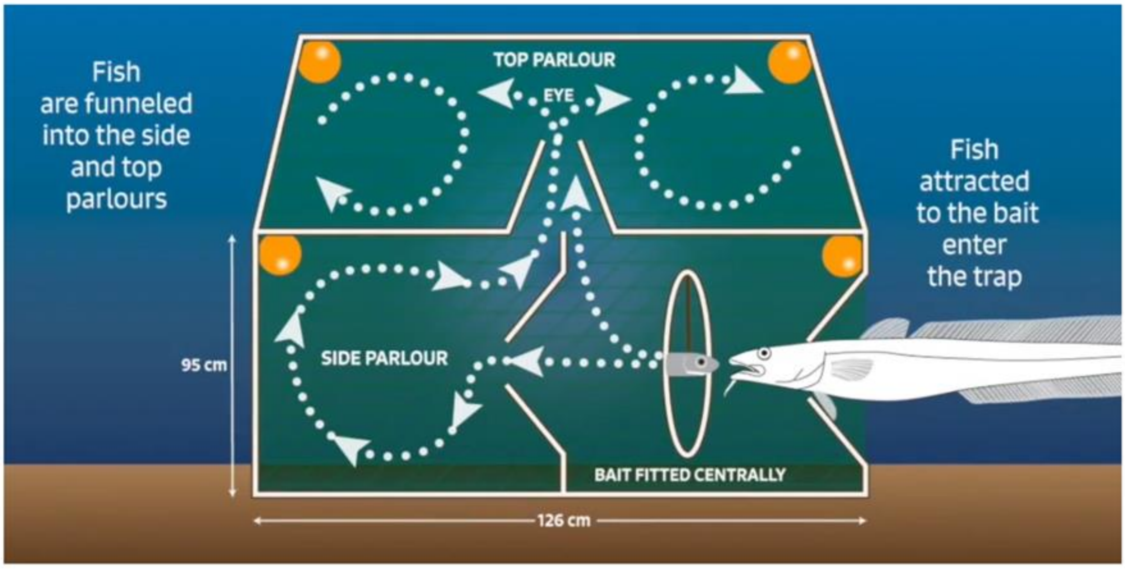

Figure 8. Fish trap design

The traps were fished in a fleet of eight, on branch lines 30 m apart and the trap types were alternated along each fleet. Fleets were suitably weighted to avoid as much as possible drift issues however understanding the potential drift of the gear in this area was part of the trial.

<u>Fish trap deployment and hauling method</u>

Prior to the shooting process, the fish traps were laid out in order of shooting on the deck. The main rope was laid out with the weights and traps then being tied on one by one. The rope was coiled on top of each trap to avoid tangles once deployment was initiated. When approaching the shooting position, the first end-weight is suspended over the side and held there using a short length of 10 mm rope. The first dhan (marker buoy and flagpole) and end rope is shot away, then once the boat is fully in position and slowed to around four knots the holding rope is thrown off and the weight is released. From here onward no crew involvement is required and the traps self-deploy in sequence following the weight, finishing with the last weight, the end line and the surface marker. The position of the first dhan, first weight, second dhan and second weight was logged at each deployment.

The hauling process required a ‘dummy’ rope to be run for the vessel’s empty net drum on the top deck up to the hanging block on the centre of the gantry. The dhan and buoy were grappled from the starboard side, detached and the tails of the dummy rope and end line tied together. The vessel then moved away with care to avoid the end line coming into contact with the propeller. Hauling then begins with the first end weight being brought aboard, detached and the traps then being retrieved one by one, followed by the second end weight. The drum is stopped once the other end marker is brought on-board. The process culminates with the rope being spooled on the net drum and the remaining parts of the gear detached and stored on deck ready for catch processing and redeployment. During hauling operations careful watch on the tension was kept and notes were made of any instances of snagging on the seabed. As each trap surfaced it was observed and checked for tangled branch ropes or other signs that deployment had been suboptimal. Once on deck all traps were checked over for damage and scored as valid or invalid if there was significant damage present that allowed possibility of catch escape. To process the catch the traps were uplifted by the top section, the door opened, and the catch emptied onto the deck ready for sorting. Once one trap was emptied, the contents were sorted into individual buckets labelled per trap, one for fish and one for invertebrates and moved away to prevent any mix up and allow each individual trap catch to be recorded separately.

Table 4. Fish trap specifications

Trap design	**Target species**	**Deployment area**	**Deployment method**	**No. of traps used**	**Bait used**
Commercial catch fish traps (large mesh size)	Commercial gadoids (Haddock, Whiting, Cod, Ling)	Deployed both inside and outside the wind farm area	Self-shooting i.e., no human involvement in deployment for safety	4	Frozen mackerel and squid or fresh mackerel and crab
Biodiversity fish traps (small mesh size)	Fish of all sizes and species	Deployed both inside and outside the wind farm area	Self-shooting i.e., no human involvement in deployment for safety	4	Frozen mackerel and squid or fresh mackerel and crab

Fish trap outputs:

1. Operational safety information and a comprehensive log of each fleet deployment documenting exactly how each deployment and retrieval went and logging any/all incidents.
2. Location points on vessel plotter and GIS map – the location of the first dhan marker, first weight, second weight and second dhan marker will be recorded.
3. For all fish/trap/deployment: total catch weights per species and length frequency.
4. All commercial invertebrates (crustaceans, squid): total catch weights per species and length frequency.
5. All other invertebrates: total catch weight and a count. Photographs taken for identification.

Figure 9. Fish trap

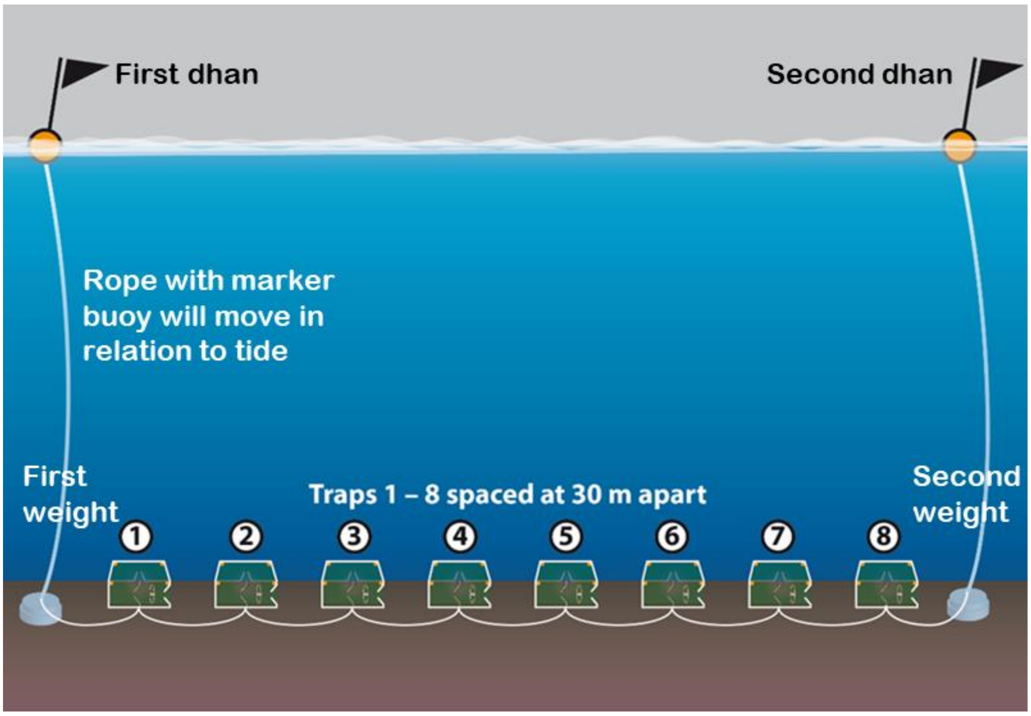

Figure 10. Layout of standard fleet of 8 fish traps used during the trial.

2. Jiggers

A total of three electronic jiggers were used that were designed to target pelagic mackerel. The jigger set up consists of an electronically large fishing reel (deep drop Diawa Tanacom), powered by a 12-volt deep cycle battery and fully programmable with various jigging and retrieval speeds. The jiggers are automatically programmed to stop retrieving at 5 m from the surface, then switched onto manual hand cranking for safety. The jigging line is a thin fishing line and the jiggers have built in break mechanisms in several places in case of gear being snagged. Each jigging trace used 8 size 2/0 hooks with a small white and blue cock hackle, silver tinsel and red heat shrink rubber tubing, imitating small sandeel. Bait was also loaded onto the hooks. Table 5 presents the jigger specifications.

Table 5. Jigger specifications

Jigger	Target species	Deployment area	Deployment method	Bait used
Electronic jigger	Mackerel, commercial gadoids (cod, haddock, saithe, Pollock)	Inside and outside the wind farm area	Jigging drifts as the vessel drifted with the tide	Lures (bottom 3 hooks only) tipped with fresh mackerel strip

Jigger Outputs:
1. Operational safety information and a comprehensive log of each jigging deployment.
2. For all commercial fish/deployment: total catch weights per species and length frequency.
3. Location points on vessel plotter and GIS map – drift points were recorded at a rate of 20 second intervals.

3. Creels

Commercial, heavy build, parlour design prawn and crab creels were trialled as part of the project. They were deployed on a rotational method and left overnight for an approximate 24-hour soak time.

Both crab and prawn creels were fished in a fleet of 20, with the crab creels on branch lines 20 m apart and the prawn creels on branch lines 16 m apart, along a main line. Table 6 presents the specifications of the crab and prawn creels.

The creels were deployed and hauled using the same method as the fish traps described in the fish trap section.

Table 6. Creels specifications

Creel type	Target species	Deployment area	Deployment method	No. of creels used	Bait used
Crab creels	Brown crab	Deployed both inside and outside the wind farm area	Self-shooting i.e., no human involvement in deployment for safety	20	Frozen or fresh mackerel
Prawn creels	Prawns/*Nephrops*/ Norway lobster	Deployed both inside and outside the wind farm area	Self-shooting i.e., no human involvement in deployment for safety	20	Frozen or salted mackerel

Creel Outputs:
1. Operational safety information and a comprehensive log of each deployment of creel fleet.
2. For all commercial shellfish/fleet: total catch weights per species and length frequency.
3. Location points on vessel plotter and GIS map – the location of the first dhan marker, first weight, second weight and second dhan marker will be recorded.

<u>Other equipment</u>

A list of other important equipment used in the trials:

- AIS beacon x6 – 10-mile radius
- Dhan markers – flag poles with a buoy to mark the location of the gear.
- Laptop – the laptop was compatible with GIS and could be used offline. The laptop was plugged directly into the vessel's plotter system so that it could recorded precise GPS locations.
- Freezer – to store bait and fish and invertebrate samples.
- Multiple plastic buckets – to store the catch and separate catch per trap/creel/jigger.
- Sea-going scales – to weigh the catch.
- Callipers – to measure crab carapace length.
- Fish measuring board – to measure the length of fish and other species.

- Handheld GPS logger – an iPhone and GPS location tracker app called 'myTracks' was used to record the vessel tracks each day. This track data was then added to GIS to create a map for each day's deployments.
- Sampling/data sheets on waterproof paper with clipboard and pencil – to record catch data.
- Personal Protection Equipment (PPE) – life jackets, hard hats, rubber boots, protective clothing etc.
- Spare weights, ropes, chains and buoys

<u>Sampling methods</u>

Commercial fish

All fish species were identified (and additionally sexed in the case of elasmobranchs), weighed and total length (tip of the snout to the tip of the longer lobe of the caudal fin) to the cm below (0.5 cm below in the case of herring) measured for all individuals. Figure 11 presents the method of a fish being measured.

Figure 11. Fish (Haddock) being measured on the fish measuring board.

Invertebrates

Commercial crustaceans (brown crab, velvet crab) were identified and sorted by sex and ovigerous (egg carrying) state. A carapace width measurement to the mm below was recorded for each individual (Figure 12).

Figure 12. Brown crab carapace width being measured using callipers.

Fish and shellfish species caught during the project were returned to the sea alive where possible and others were used as bait or for human consumption.

<u>GIS</u>

The GPS location and track of the vessel throughout the trip was recorded using the vessel's plotter system and the 'my Tracks' iPhone and GPS location tracker app. The GPS location of the gear deployed was recorded on the vessel's plotter system and on the GIS laptop. Positions of the static gear were recorded for each deployment and haul and included locations for the first dhan, first weight, second weight and second dhan.

Fish traps and creels – locations recorded

1. First dhan deployed/hauled
2. First weight deployed/hauled

3. Second weight deployed/hauled
4. Second dhan deployed/hauled

Jiggers – locations recorded

1. Starting point of jigging drift
2. Points recorded every 20 seconds along the drift
3. End point of jigging drift

The GPS data from the iPhone app were converted to a GIS format and all of the GIS data were collated into a GIS project. The locations of the gear deployments and hauls were then plotted on maps for each day of the trips.

3. Results

In total, five trips were planned from June 2022 to November 2022 however the first planned trip in June was cancelled due to the Covid-19 pandemic. Trip 1 in July and Trip 4 in November were impacted by adverse weather conditions including thick fog, high winds and high wave swell which made it unsafe to go to sea and work within the wind farm for either some or all the planned time. There were three successful days on Trip 1 and only jigging was possible on day one of Trip 4, meaning that four days were lost. Both Trip 2 and Trip 3 achieved a full rotation of all areas and all gear across five days.

Trip 1

Trip one was undertaken from 25th July to 29th July 2022. Table 7 presents the schedule of the trip including the activities undertaken each day and Figure 13, Figure 14 and Figure 15 present GIS maps displaying the vessel tracks and gear positions for each day of the trip. As previously mentioned, the old ‘fishing area’ shapes were used for Trip 1 as reflected in the maps.

Table 7. Trip 1 schedule

Day 1	Crab creels deployed in Area 4	Prawn creels deployed in Area 3	Fish traps deployed in Area 1	Jigging in Area 2	
Day 2	Weather and conditions were unsuitable to undertake work				
Day 3	Hauled crab creels from Area 4	Hauled prawn creels from Area 3	Prawn creels deployed in Area 4	Crab creels deployed in Area 3	Unable to recover fish traps and carry out jigging due to unsuitable weather/conditions
Day 4	Hauled fish traps from Area 1	Hauled crab creels from Area 3	Hauled prawn creels from Area 4	Jigging in Area 2	

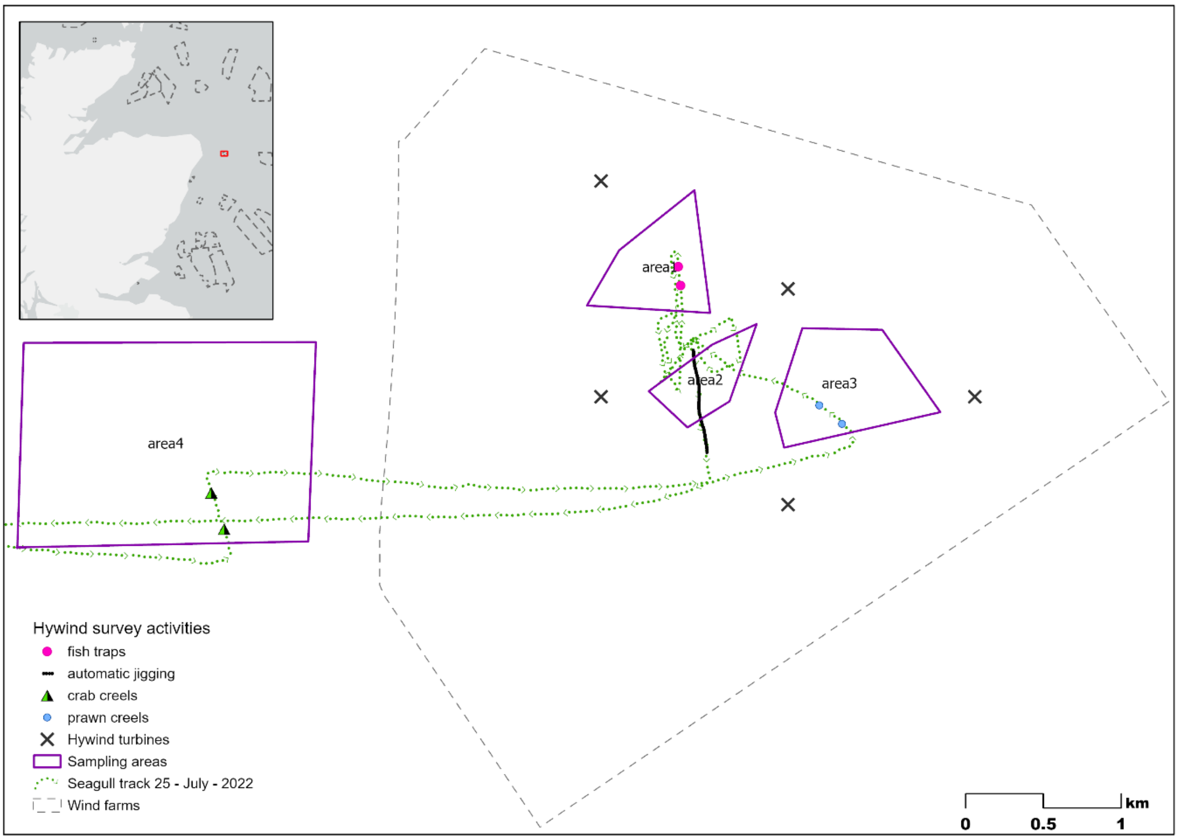

Figure 13. Trip 1, Day 1 GPS tracks and gear positions

On the above and following maps, the black line across the areas is the automatic jigging. The black line is made up of single black dots that are continuously recorded points along the jigging drift to make up the black line.

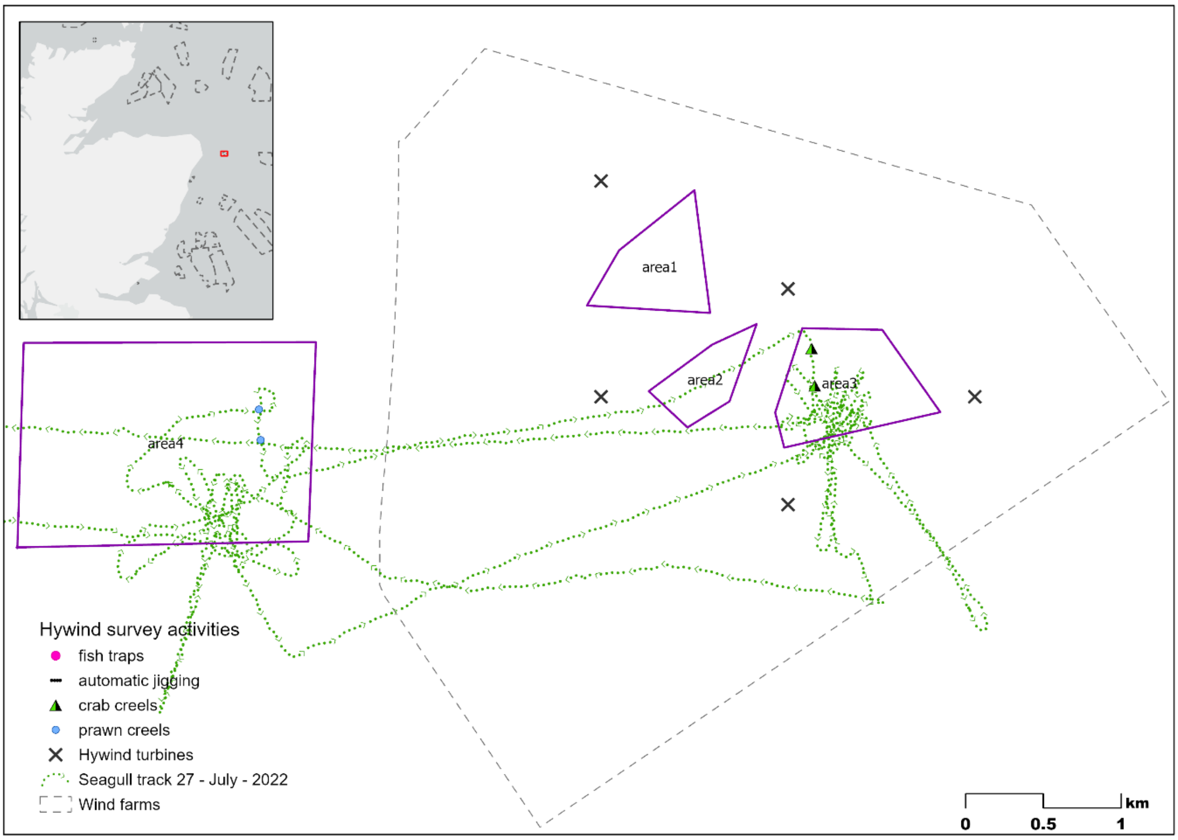

Figure 14. Trip 1, Day 3 GPS tracks and gear positions

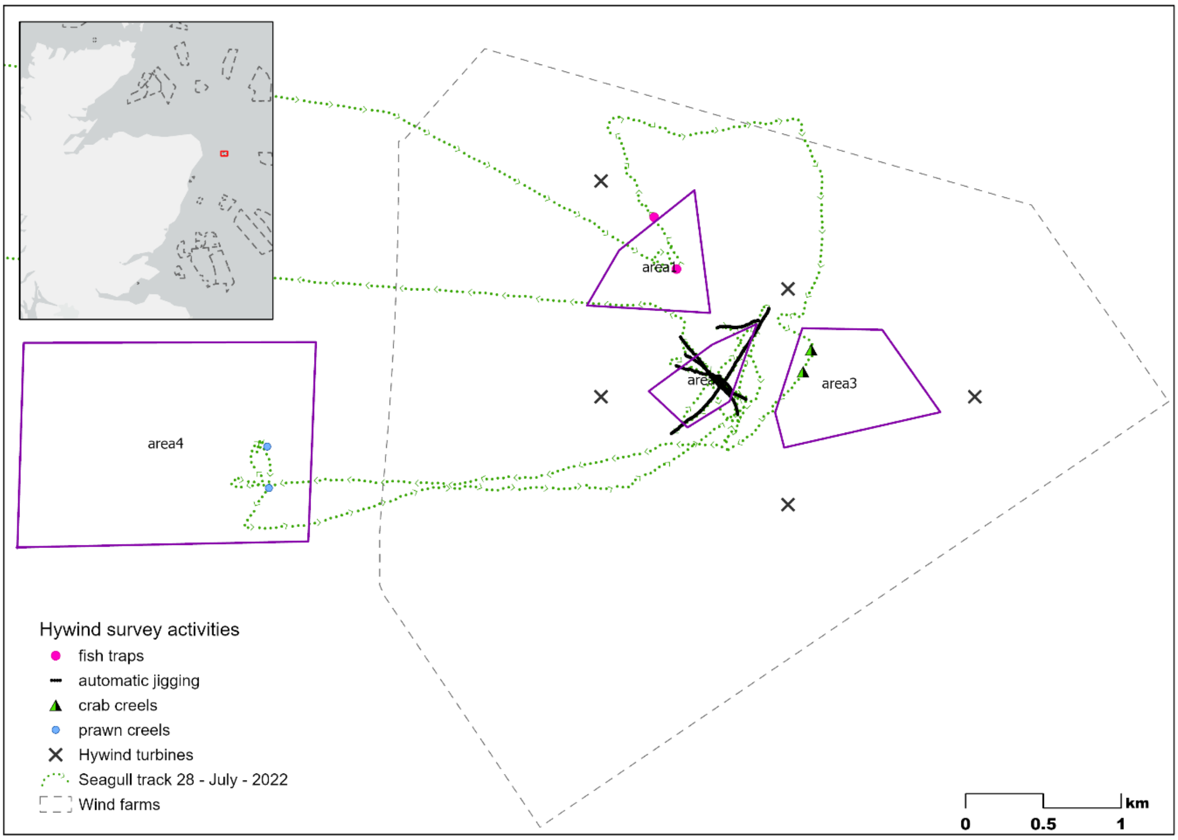

Figure 15. Trip 1, Day 4 GPS tracks and gear positions

Trip 2

Trip 2 was undertaken from 29 August to 2 September 2022. The fishing areas were refined for this trip and the trips following to be based on the safety parameters in Table 2. Table 8 presents the schedule of the trip including the activities undertaken each day and Figure 16, Figure 17, Figure 18, Figure 19 and Figure 20 present GIS maps displaying the vessel tracks and gear positions for each day of the trip.

Table 8. Trip 2 schedule

Day 1	Deployed prawn creels in Area 1	Deployed crab creels in Area 2	Deployed fish traps in Area 3	Jigging in Area 4			
Day 2	Hauled prawn creels from Area 1	Hauled crab creels from Area 2	Prawn creels deployed in Area 2	Crab creels deployed in Area 3	Hauled fish traps from Area 3	Deployed fish traps in Area 4	Jigging in Area 1
Day 3	Hauled prawn creels from Area 2	Hauled crab creels from Area 3	Deployed prawn creels in Area 3	Deployed crab creels in Area 4	Hauled fish trap from Area 4	Deployed fish traps in Area 1	Jigging in Area 2
Day 4	Hauled crab creels from Area 4	Hauled fish traps from Area 1	Deployed crab creels in Area 1	Deployed fish traps in Area 2	Hauled prawn creels from Area 3	Deployed prawn creels in Area 4	Jigging in Area 3
Day 5	Hauled prawn creels from Area 4	Hauled crab creels from Area 3	Hauled fish traps from Area 2				

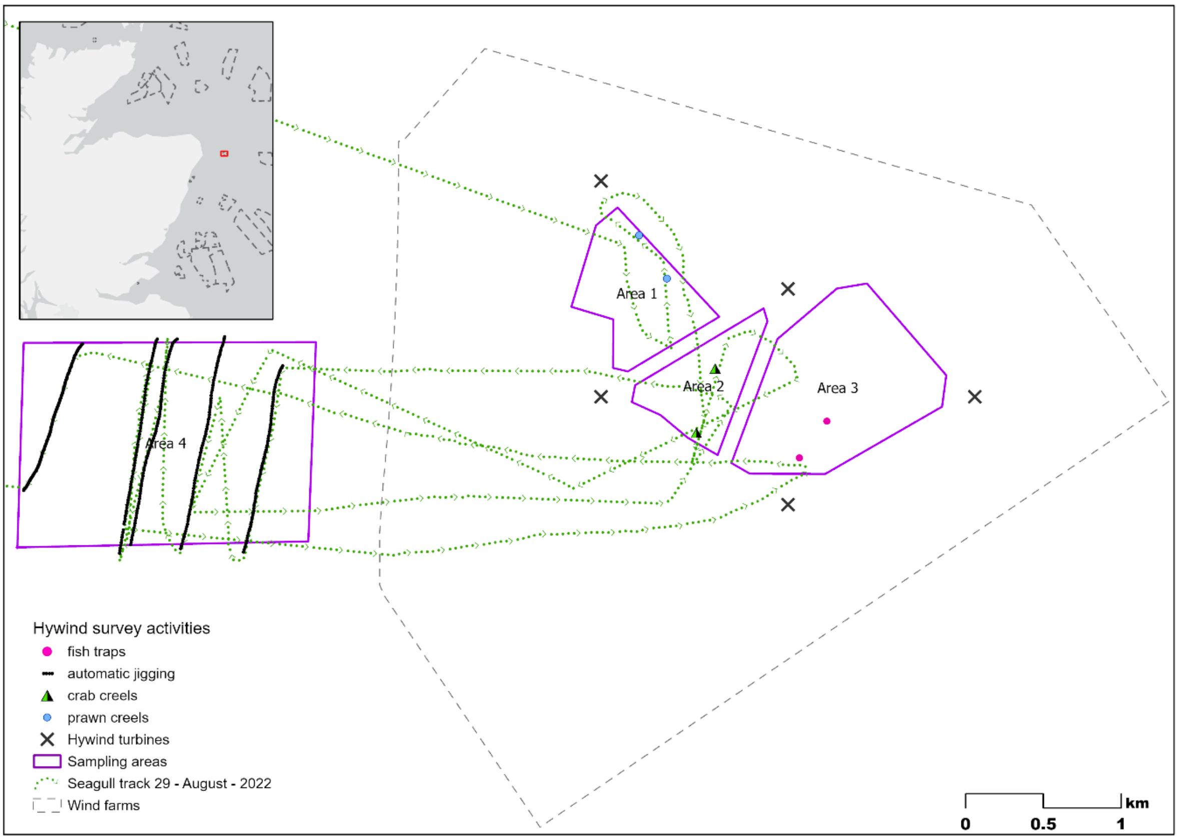

Figure 16. Trip 2, Day 1 GPS tracks and gear positions

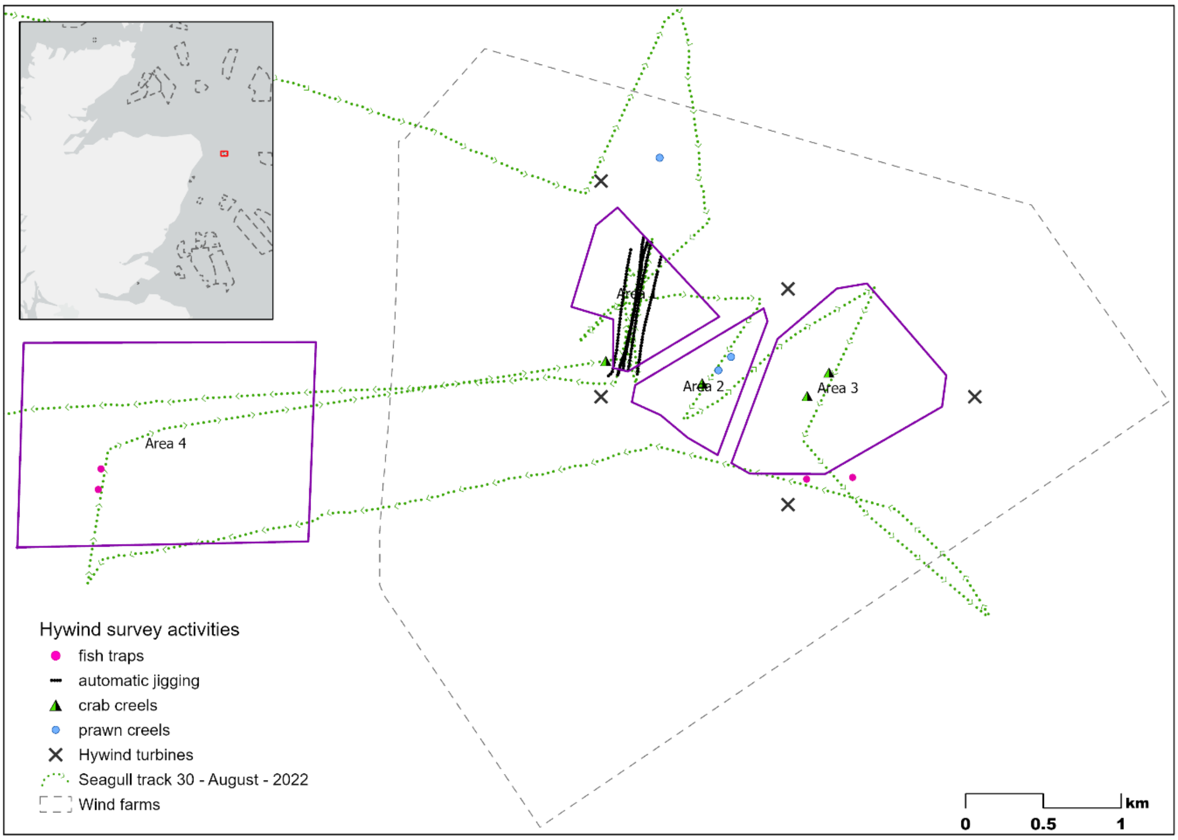

Figure 17. Trip 2, Day 2 GPS tracks and gear positions

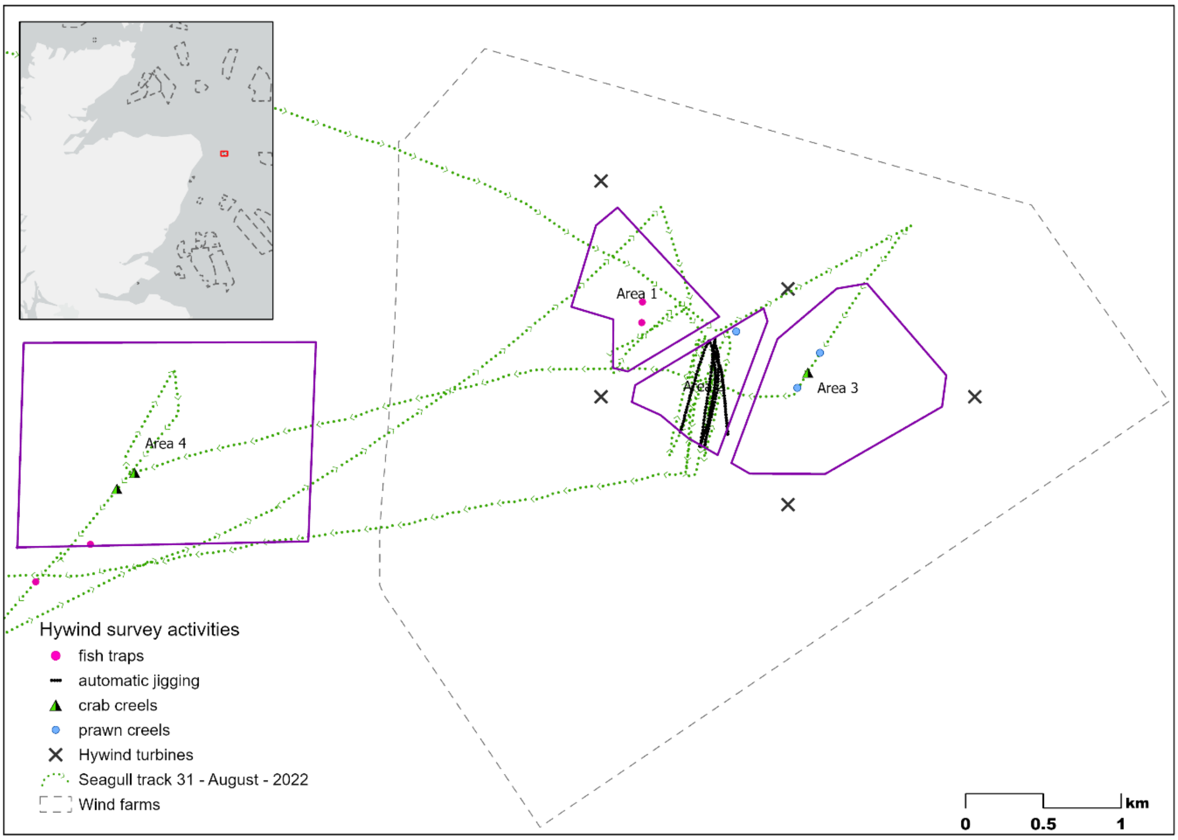

Figure 18. Trip 2, Day 3 GPS tracks and gear positions

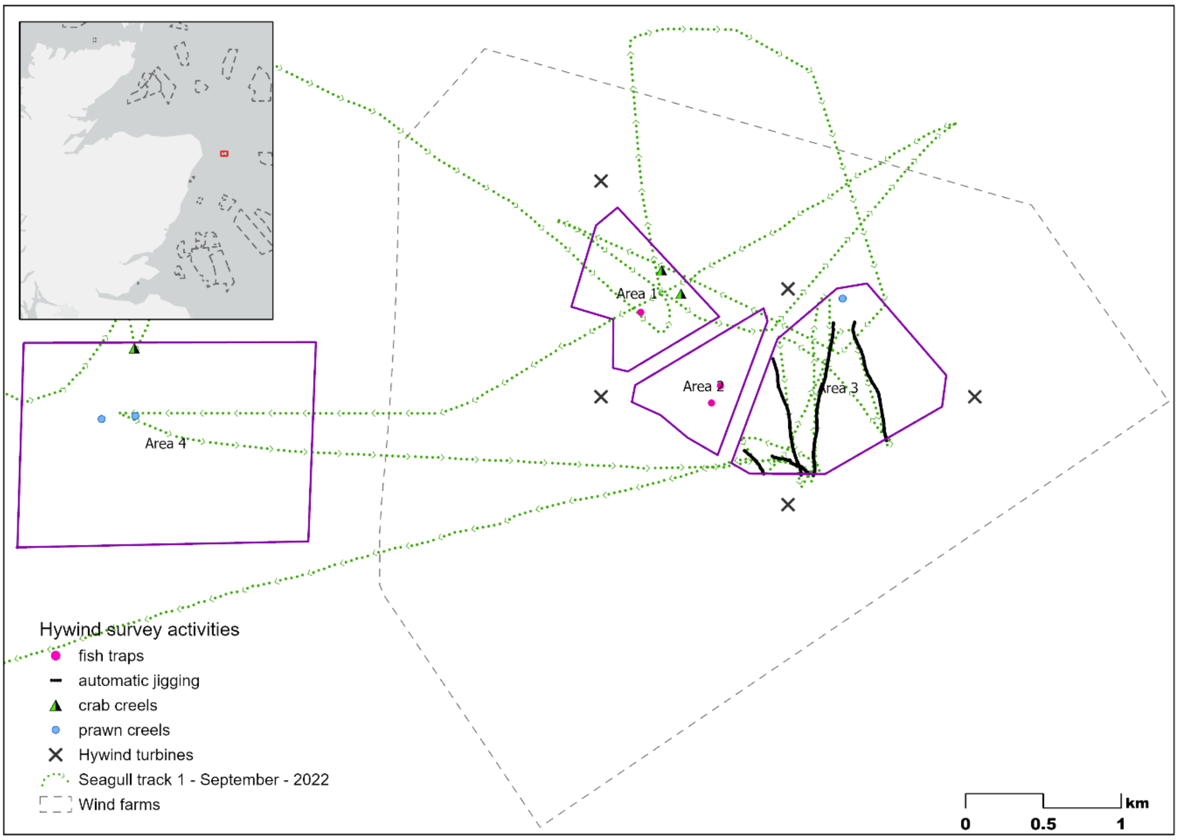

Figure 19. Trip 2, Day 4 GPS tracks and gear positions

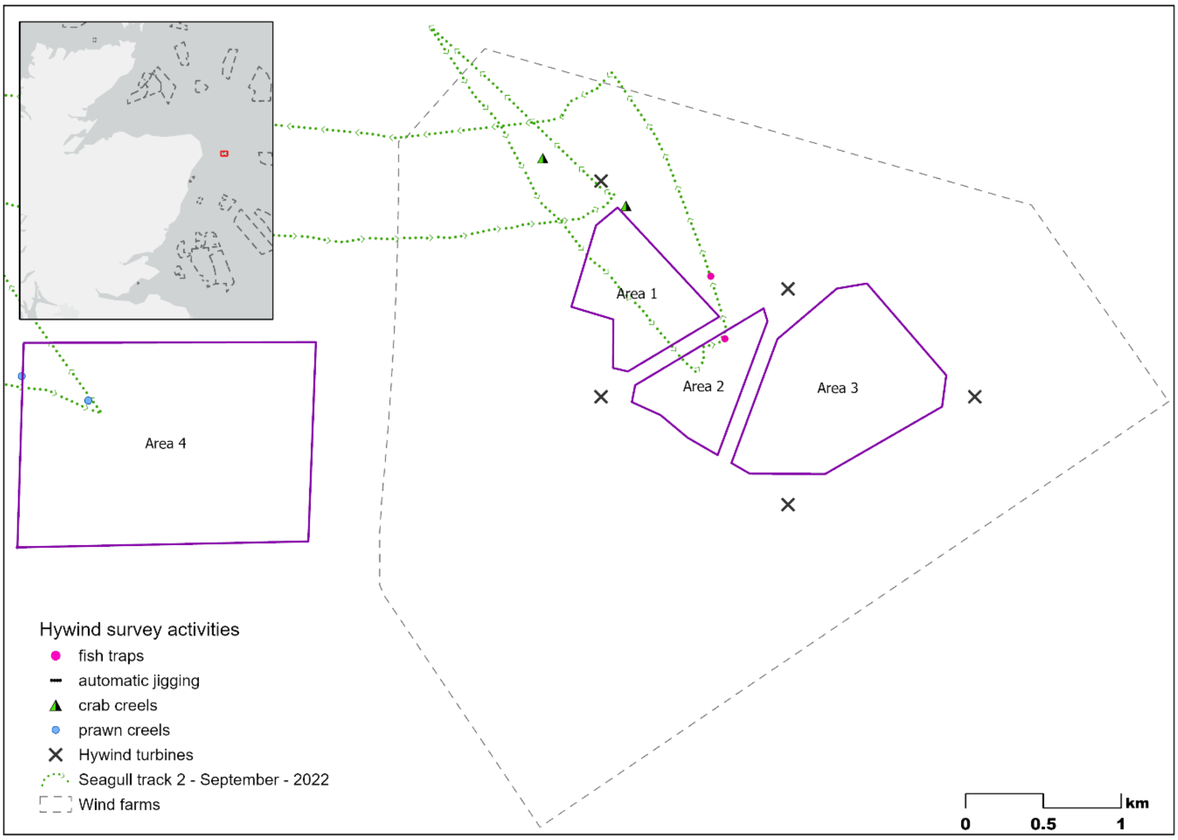

Figure 20. Trip 2, Day 5 GPS tracks and gear positions

<u>Trip 3</u>

Trip 3 was undertaken from 17 October to 21 October 2022. Table 9 presents the schedule of the trip including the activities undertaken each day and Figure 21, Figure 22, Figure 23, Figure 24, Figure 25 present GIS maps displaying the vessel tracks and gear positions for each day of the trip.

Table 9. Trip 3 schedule

Day 1	Prawn creels deployed in Area 4	Jigging in Area 4	Crab creels deployed in Area 3	Fish traps deployed in Area 1			
Day 2	Hauled crab creels from Area 3	Jigging in Area 3	Deployed crab creels in Area 2	Hauled fish traps from Area 1	Hauled prawn creels from Area 4	Deployed fish traps in Area 4	Deployed prawn creels in Area 1
Day 3	Hauled fish traps	Hauled crab creels	Hauled prawn creels	Jigging in Area 1	Fish traps	Prawn creels	Crab creels

	from Area 4	from Area 2	from Area 1		deployed in Area 2	deployed in Area 3	deployed in Area 4
Day 4	Hauled crab creels from Area 4	Hauled fish traps from Area 2	Hauled prawn creels from Area 3	Fish traps deployed in Area 3	Prawn creels deployed in Area 2	Crab creels deployed in Area 1	
Day 5	Hauled crab creels from Area 1	Hauled prawn creels from Area 2	Hauled fish traps from Area 3	Jigging in Area 2			

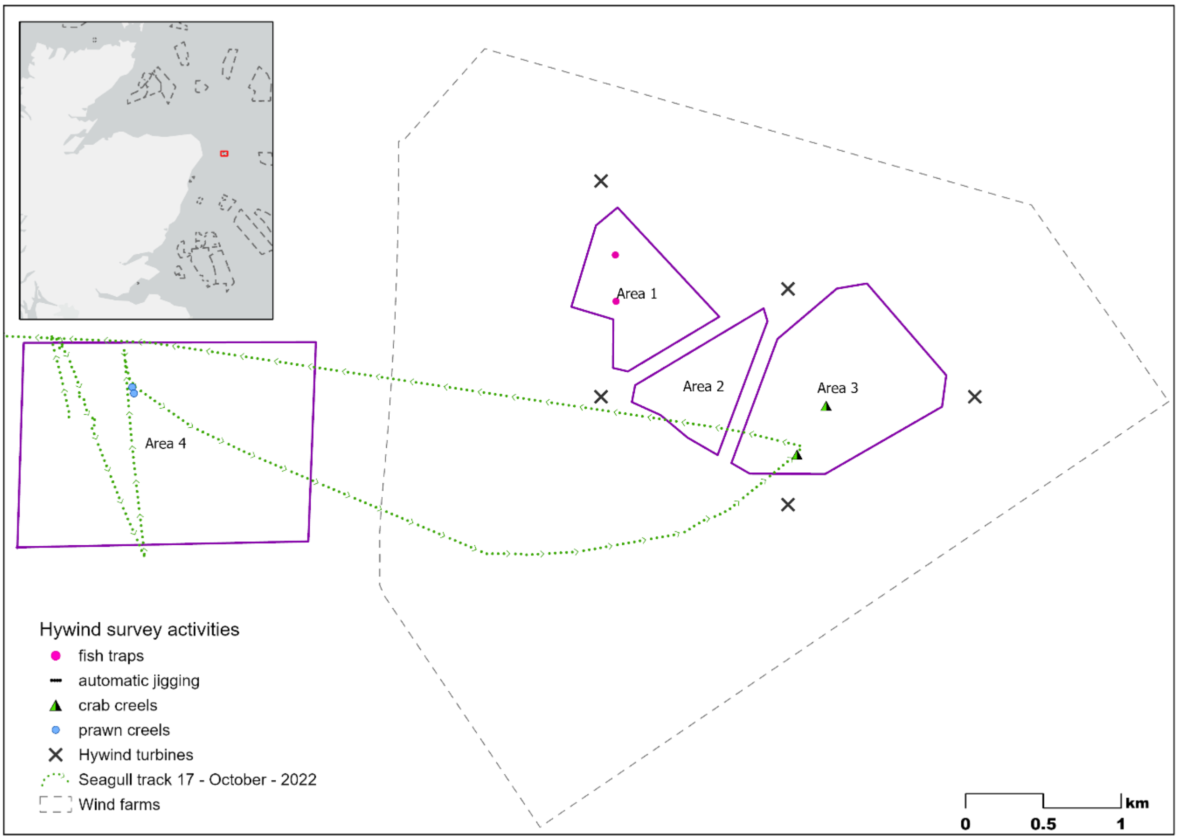

Figure 21. Trip 3, Day 1 GPS tracks and gear positions

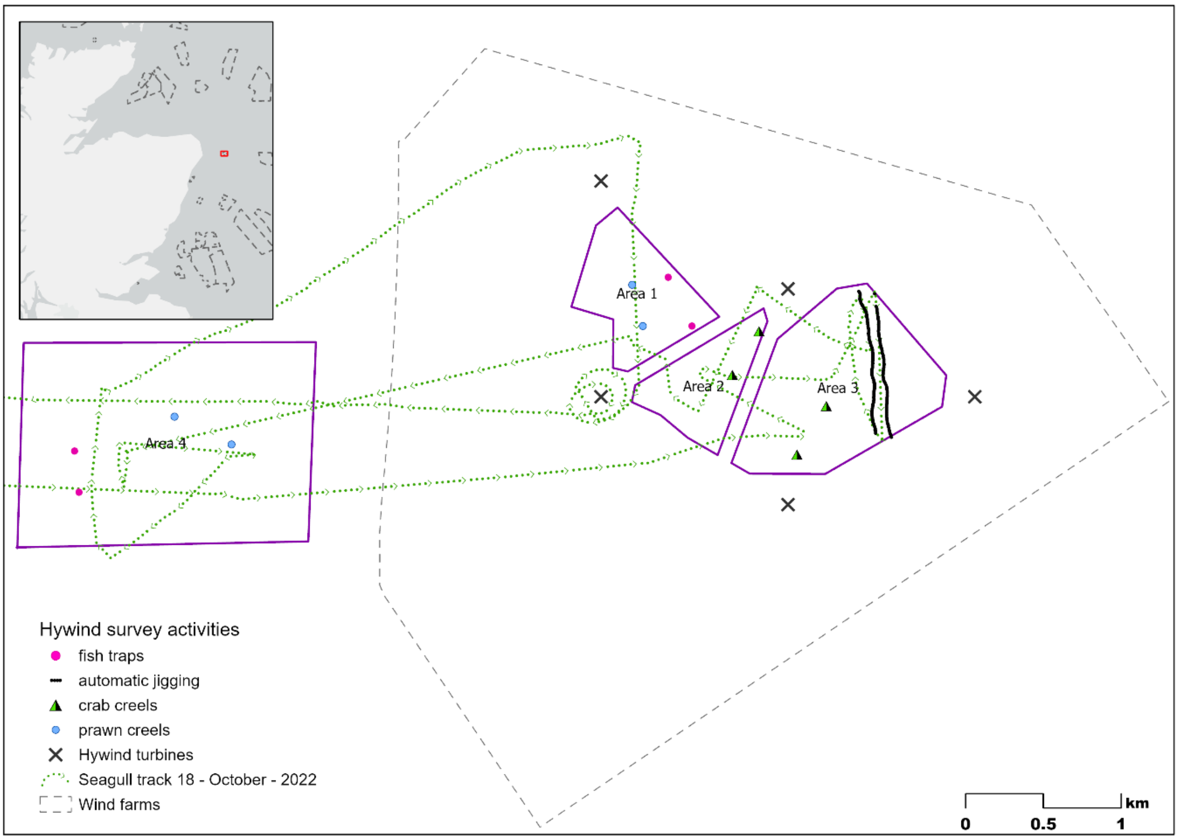

Figure 22. Trip 3, Day 2 GPS tracks and gear positions

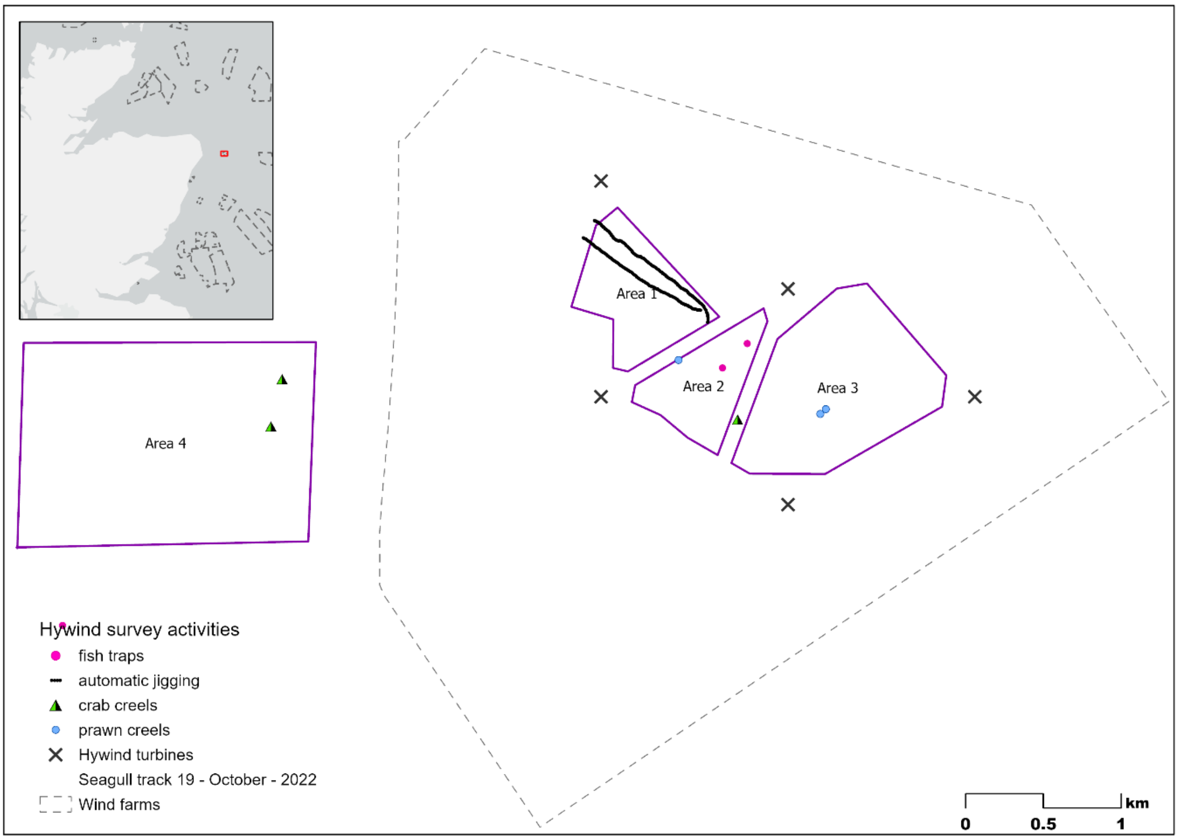

Figure 23. Trip 3, Day 3 GPS tracks and gear positions (no GPS track available)

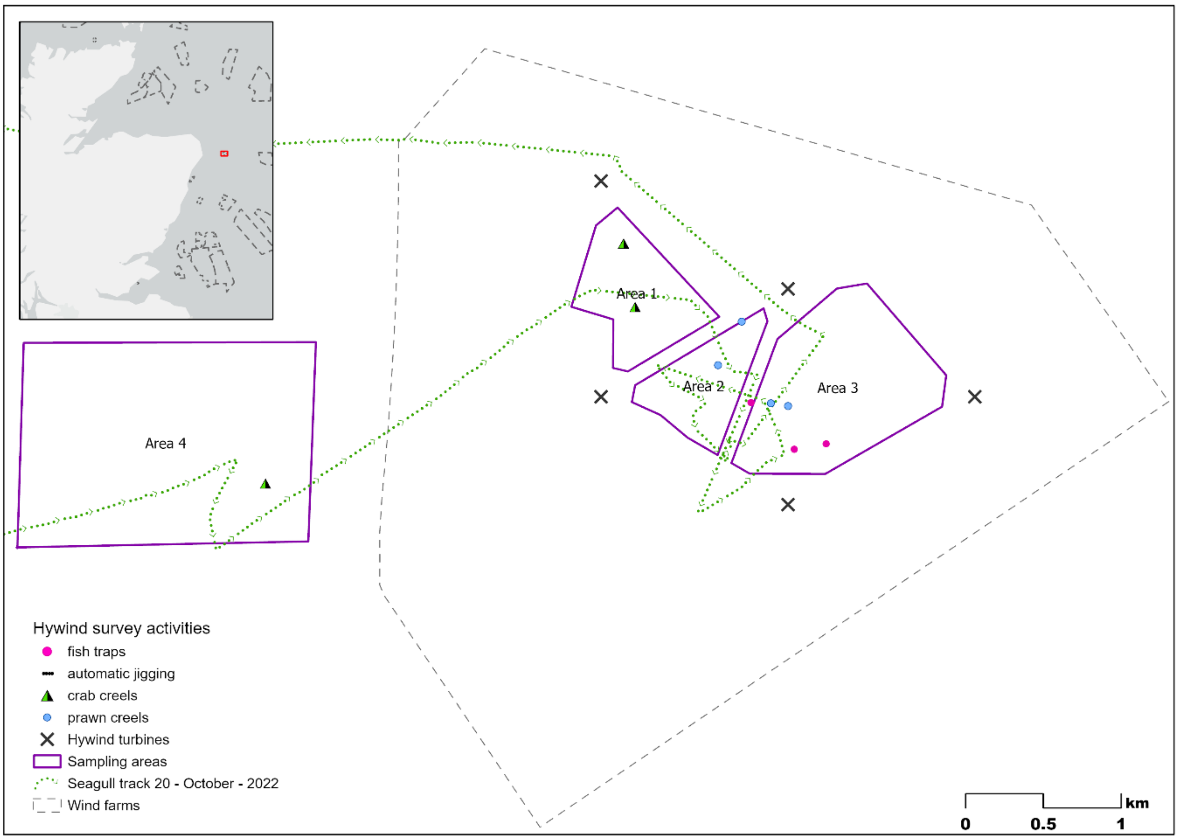

Figure 24. Trip 3, Day 4 GPS tracks and gear positions

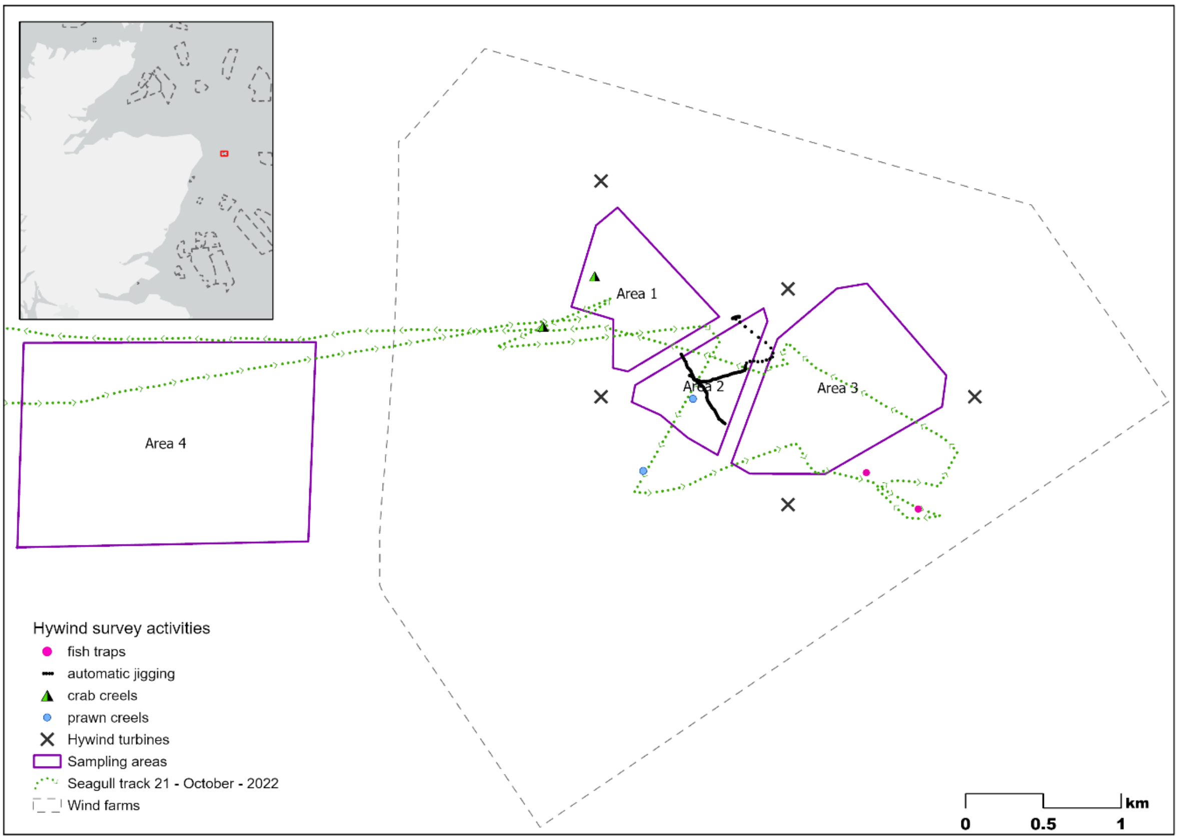

Figure 25. Trip 3, Day 5 GPS tracks and gear positions

Trip 4

Trip 4 was undertaken from 14 November to 18 November 2022.

Unfortunately, the weather and sea conditions were unsuitable during this trip due to a storm which meant that it was only safe for the vessel to go out to the Hywind wind farm on the first day. The conditions on the first day were also not suitable to enter the wind farm safely so the only activity that was undertaken was jigging in the area outside of the wind farm (Area 4) Figure 26.

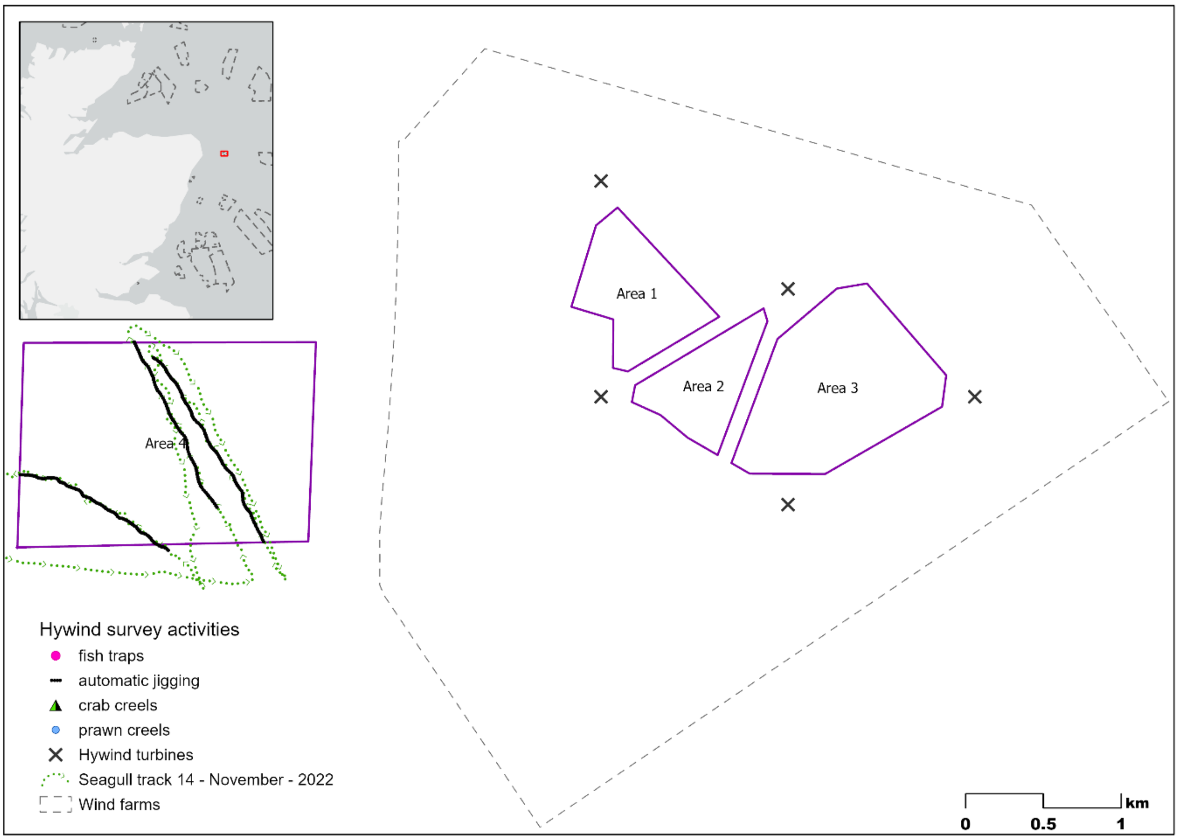

Figure 26. Trip 4, Day GPS tracks and gear positions

Catch composition and catch rates summary

This results section is based on the raw data gathered from the project that has been analysed and presented with the aid of tables and graphs. The results have not been interpretated using statistical methods as this was not the focus of the project.

i. Species summary

Table 10 summarises the species caught during the trial including the total number and weight caught by gear type. The most prominent species by number and weight were Haddock, Brown crab and Mackerel across all gear types.

Table 10. Species catch summary including numbers and weight (kg) of catch per species.

Method	**Common name**	**Scientific name**	**Number**	**Weight (kg)**
Crab Creel	Brown crab	*Cancer pagurus*	**117**	**81.17**
Crab Creel	Whiting	*Merlangius merlangus*	**5**	**1.3**
Crab Creel	Haddock	*Melanogrammus aeglefinus*	**4**	**1.4**
Crab Creel	Lesser octopus	*Eledone cirrosa*	**1**	**0.04**
Crab Creel	Bull rout	*Myoxocephalus scorpius*	**1**	**0.19**
Crab Creel	Lesser spotted dogfish	*Scyliorhinus canicula*	**1**	**1.2**
Crab Creel	Hermit crabs	*Pagurus ssp*	**-**	**12.42**
Prawn Creel	Whiting	*Merlangius merlangus*	**19**	**3.7**
Prawn Creel	Poor cod	*Trisopterus minutus*	**5**	**0.04**
Prawn Creel	Norway pout	*Trisopterus esmarkii*	**4**	**0.08**
Prawn Creel	Haddock	*Melanogrammus aeglefinus*	**2**	**0.8**
Prawn Creel	Ling	*Molva molva*	**2**	**0.77**
Prawn Creel	Bib	*Trisopterus luscus*	**1**	**0.04**
Prawn Creel	Common dab	*Limanda limanda*	**2**	**0.1**
Prawn Creel	Brown crab	*Cancer pagurus*	**2**	**0.06**
Prawn Creel	Cod	*Gadus morhua*	**1**	**0.15**
Prawn Creel	Lemon sole	*Microstomus kitt*	**1**	**0.06**
Prawn Creel	Spurdog	*Squalus acanthias*	**1**	**0.4**
Prawn Creel	Lesser octopus	*Eledone cirrosa*	**1**	**0.01**
Prawn Creel	Round crab	*Atelecydus rotundatus*	**5**	**0.21**
Prawn Creel	Swimming crab	*Portunidae*	**3**	**0.06**
Prawn Creel	Starfish	*Asteroidea spp*	**-**	**0.78**
Prawn Creel	Dog whelk	*Neptunea antiqua*	**-**	**1.46**
Prawn Creel	Red shrimp	*Pandalus borealis/montagui*	**-**	**0.03**
Prawn Creel	Hermit crabs	*Pagurus spp*	**-**	**2.88**
Fish trap	Haddock	*Melanogrammus aeglefinus*	**186**	**79.72**
Fish trap	Brown crab	*Cancer pagurus*	**69**	**54.32**
Fish trap	Whiting	*Merlangius merlangus*	**26**	**6.38**
Fish trap	Poor cod	*Trisopterus minutus*	**19**	**0.91**
Fish trap	Cod	*Gadus morhua*	**7**	**4.52**
Fish trap	Common dab	*Limanda limanda*	**4**	**0.69**
Fish trap	Bib	*Trisopterus luscus*	**3**	**0.61**
Fish trap	Lesser octopus	*Eledone cirrosa*	**1**	**1.37**

Fish trap	Northern stone crab	*Lithodes maja*	**1**	**0.29**
Fish trap	Dog whelk	*Neptunea antiqua*	**-**	**0.01**
Fish trap	Conger	*Conger conger*	**1**	**8**
Fish trap	Lesser spotted dogfish	*Scyliorhinus canicula*	**1**	**0.85**
Fish trap	Swimming crab	*Portunidae*	**1**	**0.01**
Fish trap	Long finned squid	*Loligo sp*	**1**	**0.06**
Fish trap	Bull rout	*Myoxocephalus scorpius*	**1**	**0.12**
Fish trap	Hermit crabs	*Pagurus spp*	**-**	**0.51**
Fish trap	Seasnail sp	*Liparis sp*	**1**	**0.003**
Jiggers	Mackerel	*Scomber scombrus*	**90**	**32.47**
Jiggers	Haddock	*Melanogrammus aeglefinus*	**44**	**20.97**
Jiggers	Whiting	*Merlangius merlangus*	**41**	**11.5**
Jiggers	Cod	*Gadus morhua*	**2**	**0.76**
Jiggers	Grey gurnard	*Eutrigla gurnardus*	**1**	**0.26**

ii. Catch rate

Catch per unit effort (CPUE) has been calculated by deployment and is not scaled to time due to the limited data gathered. The raw CPUE data for fish traps (Table 14), jiggers (Table 15), crab creels (Table 16) and prawn creels (Table 17) can be found in the Appendix.

Fish traps

Catch data from both small and large mesh creels are combined as small fish of all species were rarely encountered in any of the traps or creels.

Figure 27 and Figure 28 present the CPUE for only Haddock and Whiting as these species were the main components of the fish trap catch. The figures show that haddock was the most prominent fish caught in the fish traps by both number and weight.

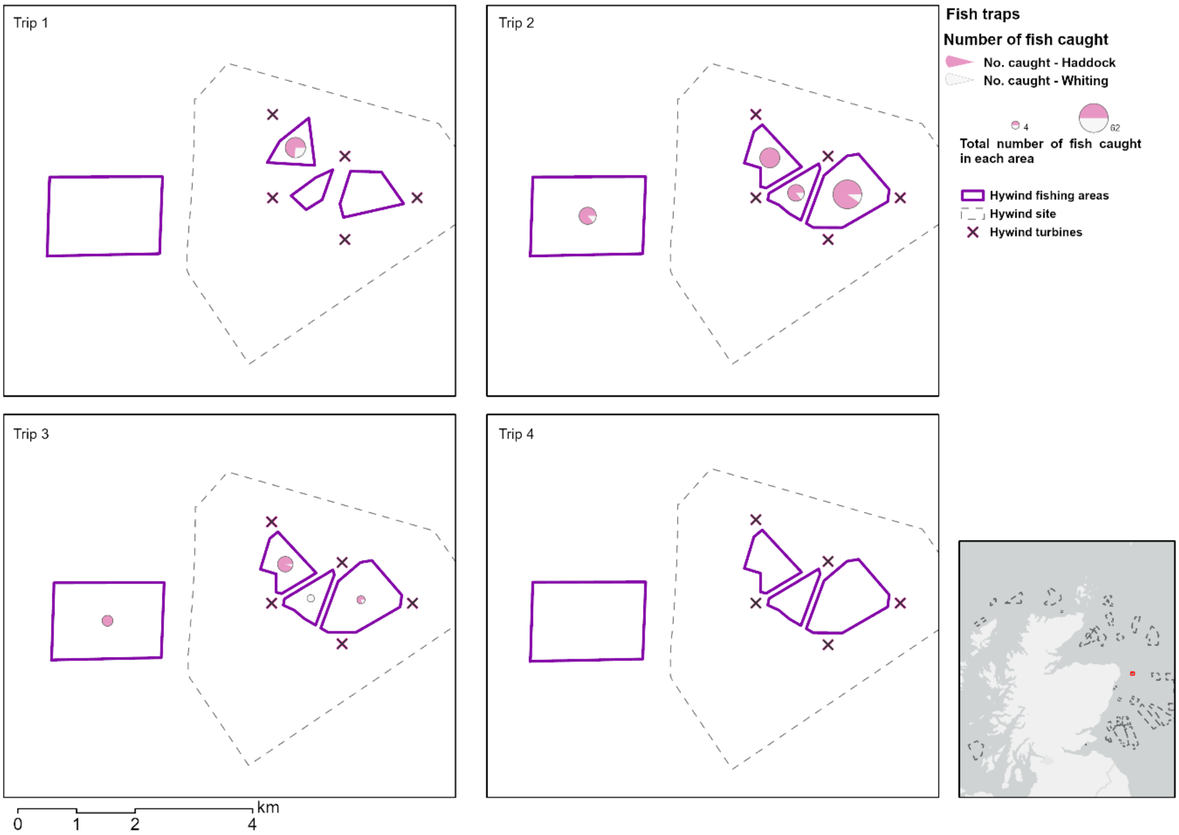

Figure 27. Numbers of fish caught in fish traps per deployment – haddock and whiting.

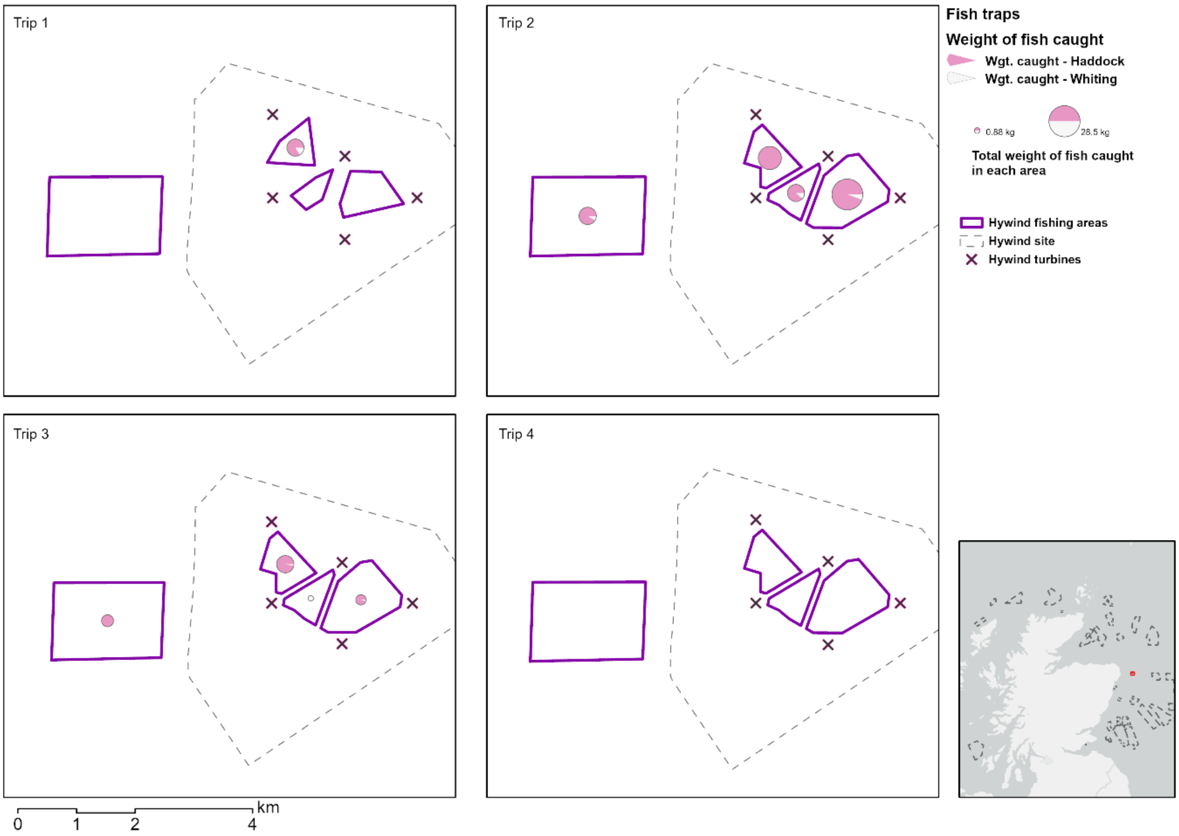

Figure 28. Weights of fish caught in fish traps per deployment – haddock and whiting.

Creels

Figure 29 and Figure 30 present the weight of species using crab creels and prawn creels respectively.

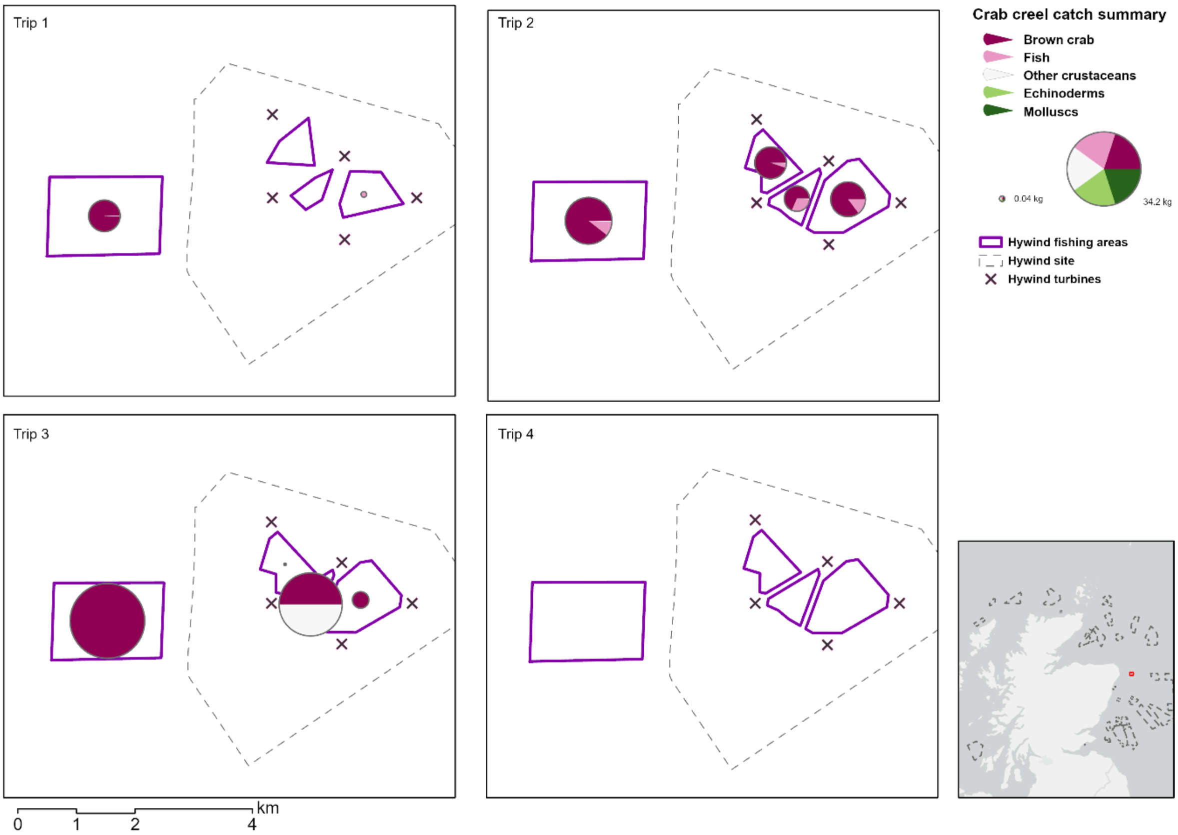

Figure 29. Weight of species caught using crab creels.

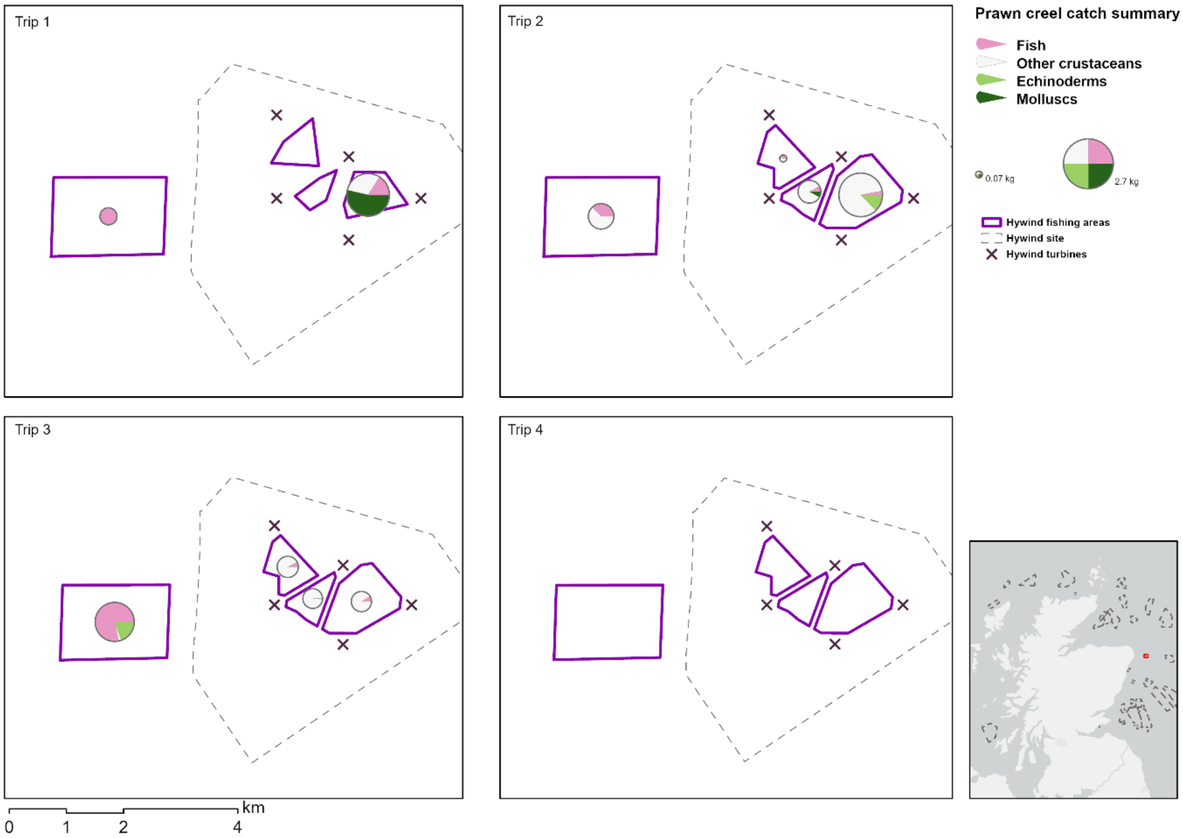

Figure 30. Weight of species caught using prawn creels.

Jiggers

Figure 31 and Figure 32 present the number and weight of fish caught by jiggers per hour respectively.

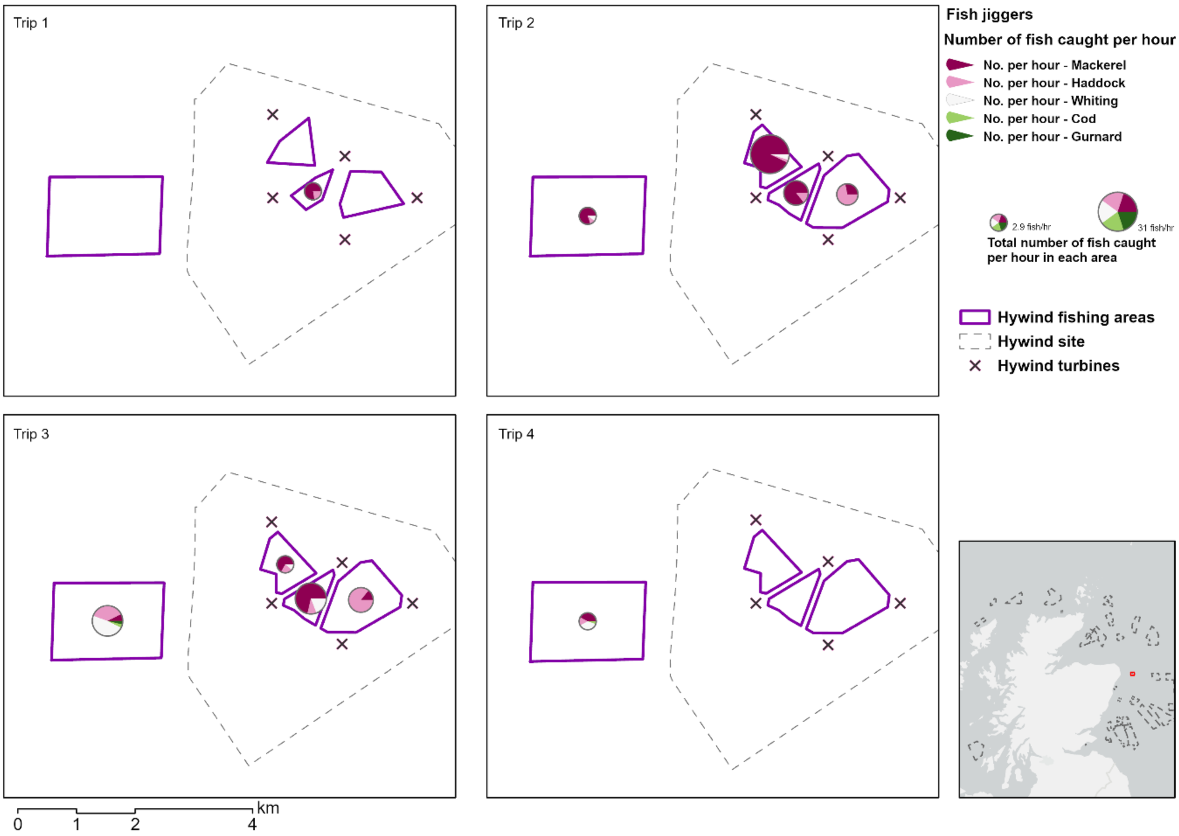

Figure 31. Number of fish caught by jiggers per hour.

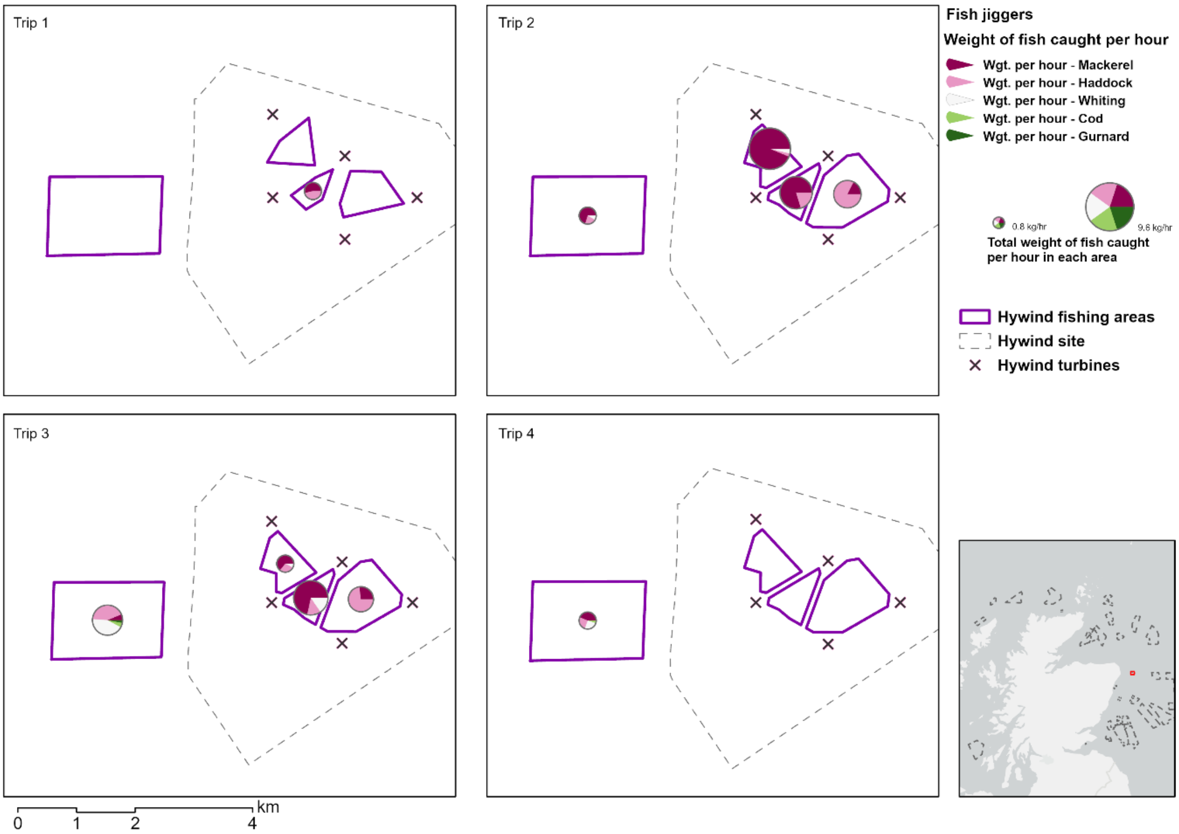

Figure 32. Weight of fish caught by jiggers per hour.

iii. Length frequency distribution

Length frequency distribution bar charts have been plotted to present the range of lengths of commercial fish species (Haddock, Whiting and Mackerel) caught by fish traps and jiggers throughout the trial. The figures below show that most of the commercial fish species caught were above the Minimum Conservation Reference Size (MCRS) for Scottish waters e.g., Haddock is 30 cm, Whiting is 27 cm and Mackerel is 20 cm).

Fish traps:

Figure 33 and Figure 34 present the length frequency distribution for both Haddock and Whiting caught in fish traps.

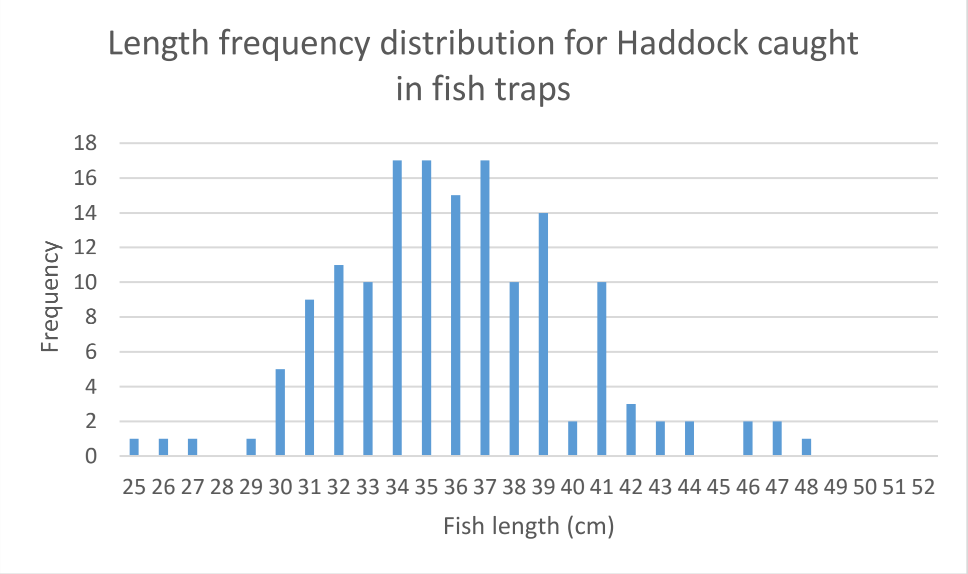

Figure 33. Length frequency distribution for Haddock caught in fish traps.

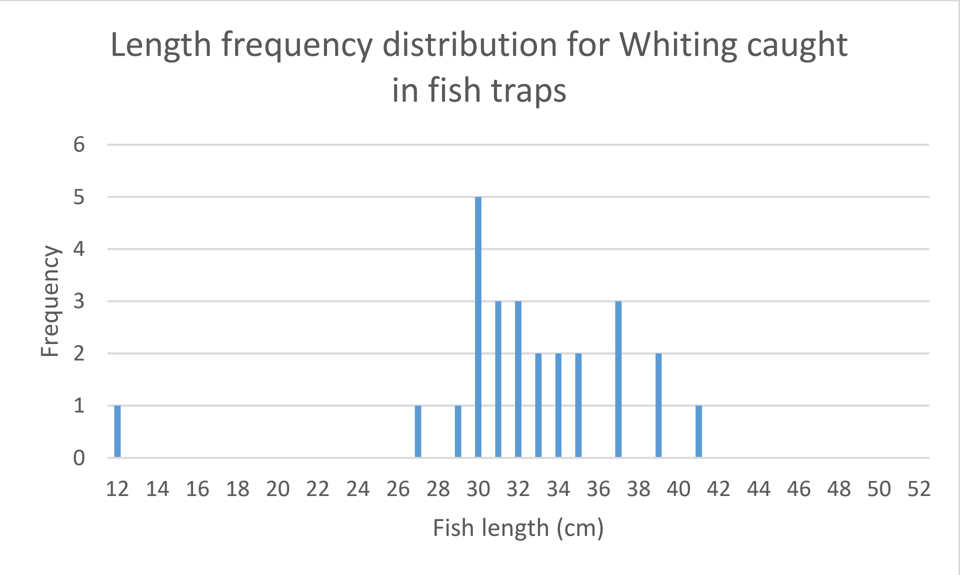

Figure 34. Length frequency distribution for Whiting caught in fish traps.

Jiggers:

Figure 35, Figure 36 and Figure 37 present the length frequency distribution for Haddock, Mackerel and Whiting caught by jiggers.

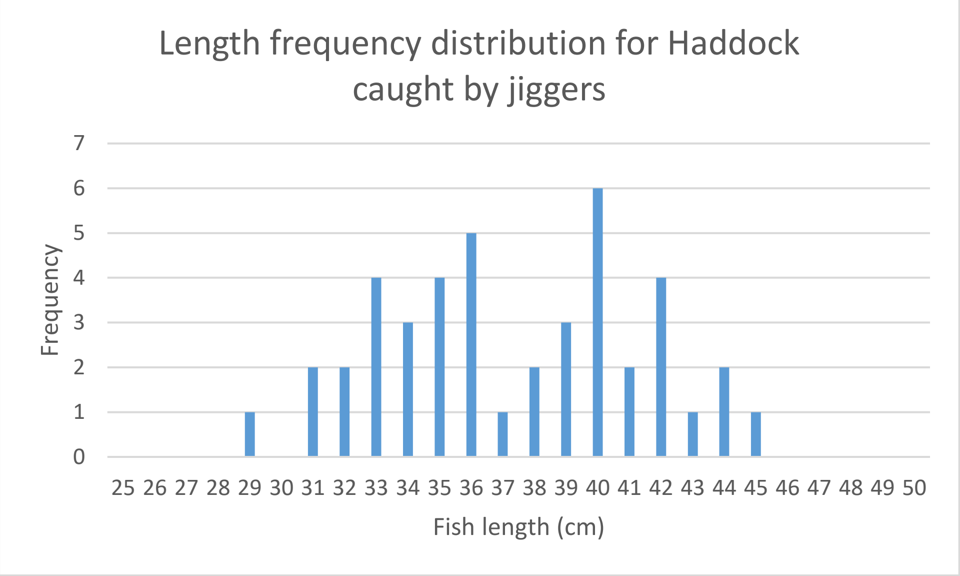

Figure 35. Length frequency distribution for Haddock caught by jiggers.

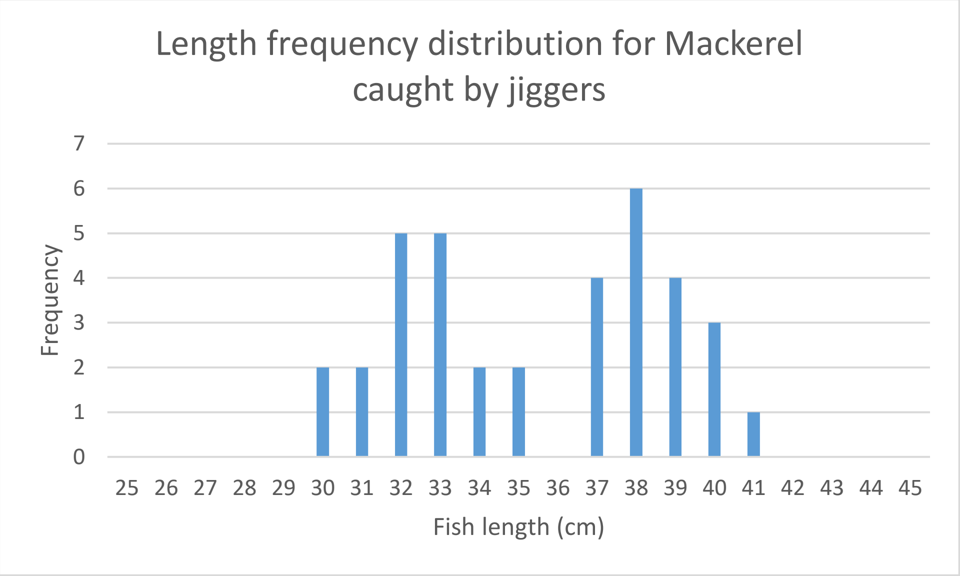

Figure 36. Length frequency distribution for Mackerel caught by jiggers.

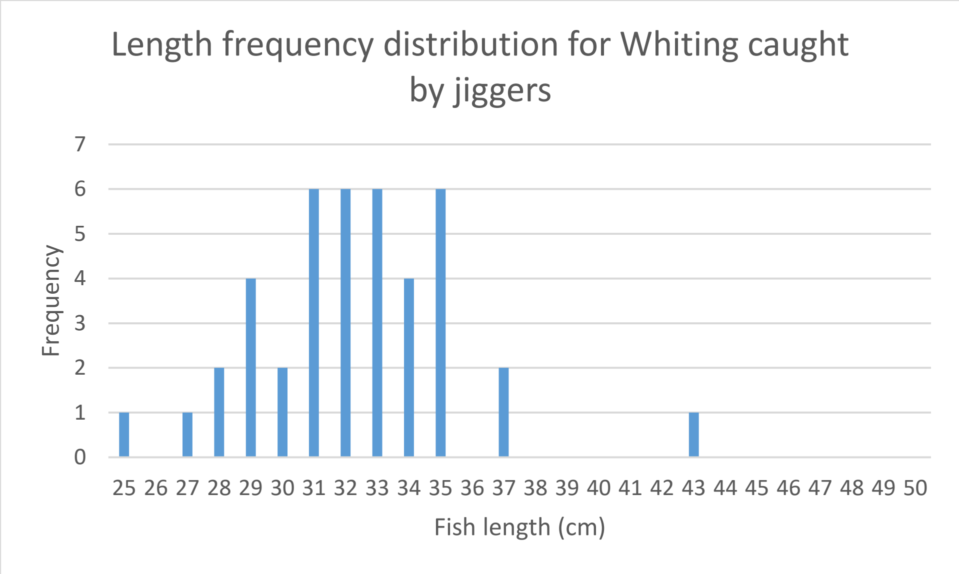

Figure 37. Length frequency distribution for Whiting caught by jiggers.

c

The total number of species of fish caught in all fishing areas per gear type was recorded, with Area 1, 2 and 3 being inside the wind farm area and Area 4 being outside the wind farm area. A comparison has been made between Trip 2 and Trip 3 for Haddock, Cod and Whiting as a full rotation of areas and gear was achieved on these trips (Figure 38).

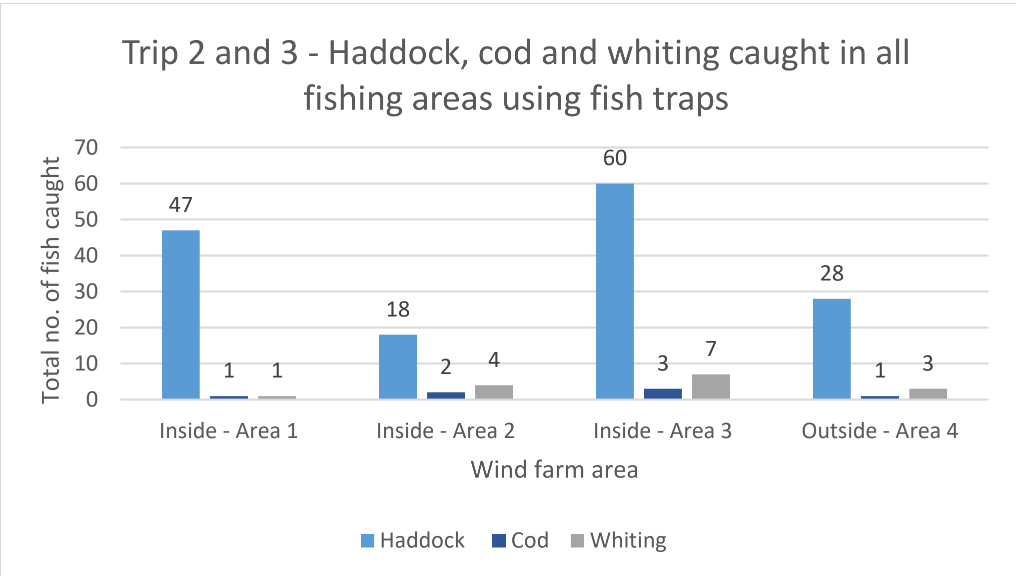

Figure 38. Trip 2 and 3 – Haddock, Cod and Whiting caught in all fishing areas using fish traps.

Figure 39 and Figure 40 for the jiggers have not been combined as five drifts of each area were carried out for Trip 2 and only two drifts of each area were carried out for Trip 3 due to less daylight hours and weather disruptions.

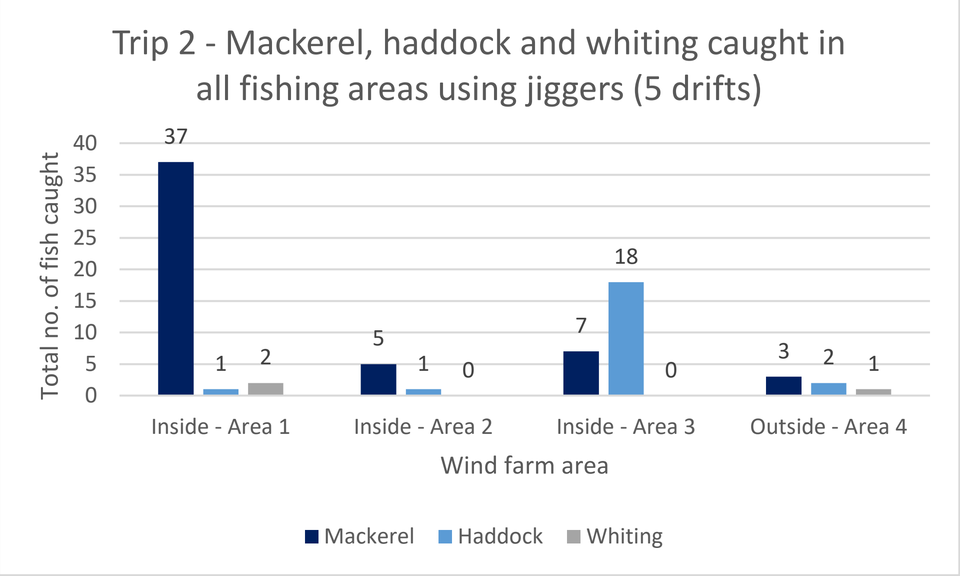

Figure 39. Trip 2 – Mackerel, haddock and whiting caught in all fishing areas using jiggers (5 drifts)

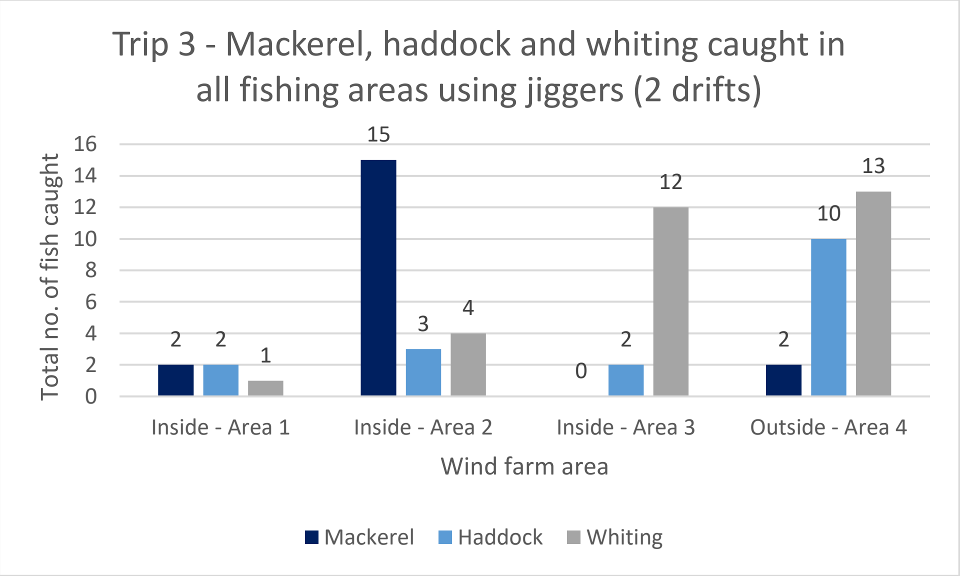

Figure 40. Trip 3 – Mackerel, haddock and whiting caught in all fishing areas using jiggers (2 drifts)

iv. Brown crab catch

Brown crabs were one of the most prominent species in the catch, this is mainly due to the crab creels specifically targeting them. Brown crabs were caught in the crab creels, fish traps and prawn creels, however only two small Brown crabs were caught in the prawn creels as the size of the entrance for the prawn creels is too small to allow entrance to the typical size of Brown crab observed to be present. Table *11* presents the numbers of Brown crabs caught by fishing method.

Table 11. Numbers of Brown crabs caught.

Fishing method	Brown crabs caught
Crab creels	117
Fish traps	69
Prawn creels	2
Total	**188**

The total number of Brown crab caught in all fishing areas by crab creels has been recorded, with Area 1, 2 and 3 being inside the wind farm area and Area 4 being outside the wind farm area.

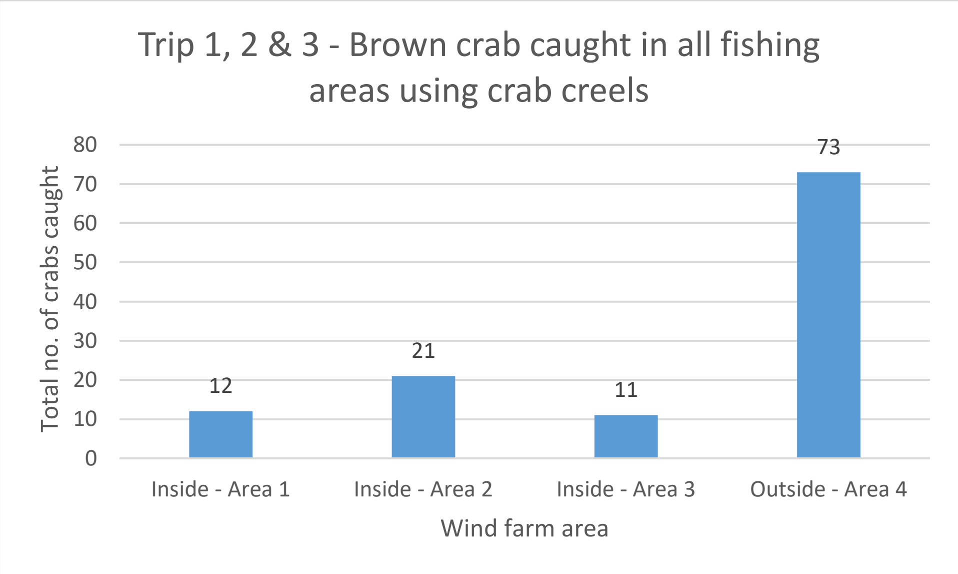

Figure 41. Brown crab caught in all fishing areas using crab creels.

There was an increase in the number of brown crabs caught between Trip 2 in August (51) and Trip 3 in October (125) (Figure 42). Trip 1 and Trip 4 were impacted by adverse weather and would therefore not be comparable, so they were excluded from this analysis.

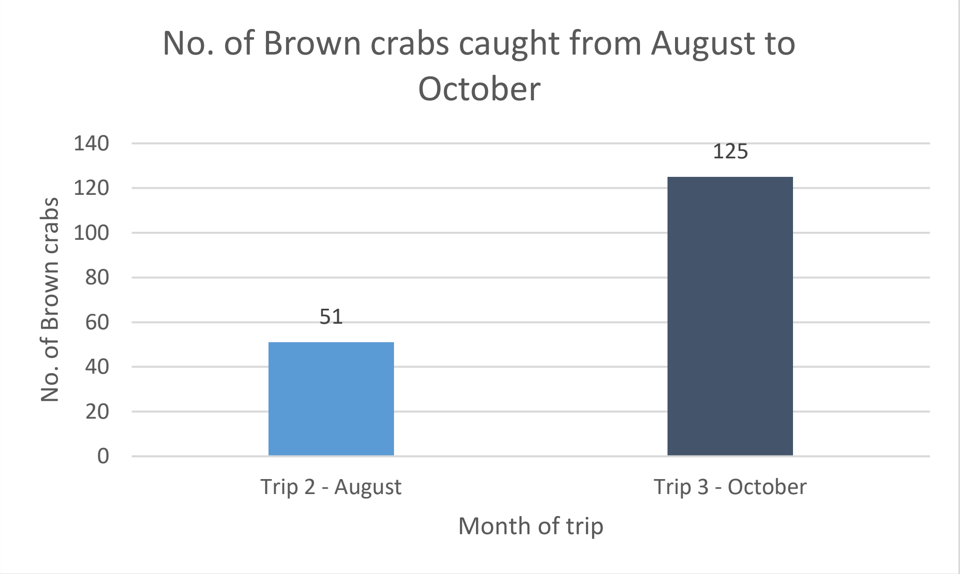

Figure 42. No. of brown crabs caught from August to October using all fishing methods.

More female brown crabs caught than male brown crabs with 154 female compared to 34 male brown crabs (Figure 43).

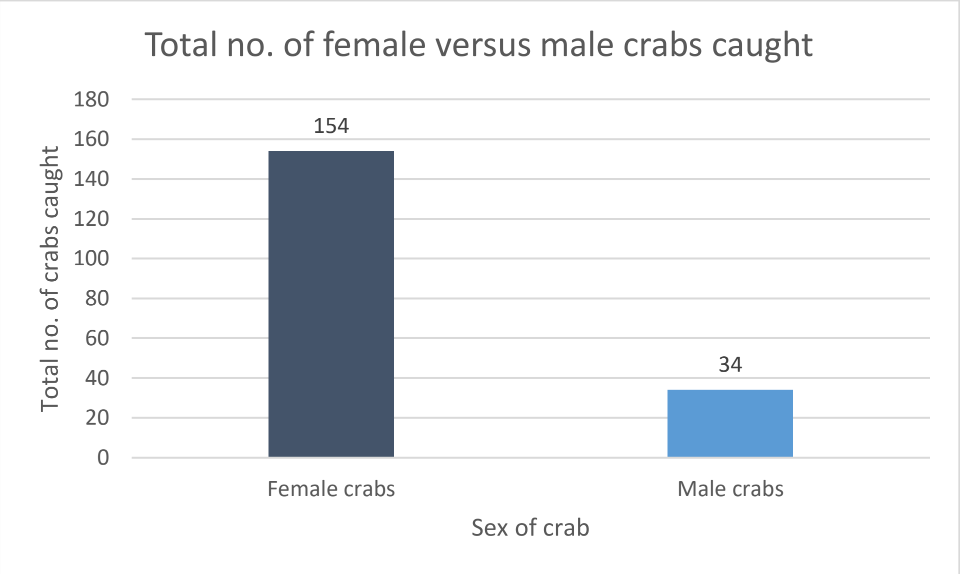

Figure 43. Total no. of female versus male brown crabs caught.

<u>Safety assessment summary</u>

i. Safety considerations

There were no safety issues or concerns raised by either the skipper and crew or the scientists on the trial except adverse weather conditions on Trip 1 and Trip 4 which impacted planned activities (Table 12).

Table 12. List of safety considerations that were assessed in the trial and whether or not any issues arose.

Potential safety issue assessed	**Trip 1**	**Trip 2**	**Trip 3**	**Trip 4**	**Comments**
Vessel operating out with 'fishing areas' risking potential collision and damage to assets	No	No	No	No	Vessel adhered to 'fishing area' boundaries.
Loss of fishing gear which could result in gear entanglement around assets, potential ghost fishing and safety risk to other vessels	None	None	None	None	All fishing gear was successfully retrieved.
Gear snagged or entangled in infrastructure e.g., dynamic cabling, mooring chains and anchors etc.	No	No	No	No	No gear snagged or entangled. The gear was deployed and hauled in a safe and controlled manner.
Damage to fishing gear	None	None	None	None	Once on the deck all gear was inspected for damage which might indicate gear drift, dragging on the seafloor or snagging but there was no damage present.
Vessel drifting near turbines	No	No	No	No	Skipper ensured vessel drifted (whilst in gear) out of wind farm and away from turbines when hauling gear.
Issues with vessel handling or maneuverability in the floating offshore wind farm	No	No	No	No	Skipper ensured vessel drifted out of wind farm and away from turbines when hauling gear.
Static gear drift	Minimal	Minimal	Minimal	Minimal	Minimal movement, weights added – explained further below.
Safety issues onboard vessel involving crew/scientists	None	None	None	None	All crew properly briefed on the correct procedures and followed safety precautions. Static gear deployment was self-shooting and did not involve any human intervention.
Conflict with other sea users	None	None	None	None	Mitigated with timely Notice to Mariners (NtM) and reflective markers on the gear.

Weather/Miscellaneous issues	Weather disruptions	Vessel propeller cut rope during gear retrieval	None	Weather disruptions	On one occasion the rope for the marker buoy and dhan floated behind the vessel during hauling operations where it was cut by the vessel propeller. However, the gear was hauled from the other end and the buoy was retrieved. This periodically happens during fishing operations and didn’t result in any damage to the vessel propeller, it only added on extra time to the hauling process. The skipper did not class this as a safety concern.

ii. Safe working conditions – weather and sea conditions

Safely operating the fishing gear in the floating wind farm area and avoiding any interaction with the floating wind infrastructure was the top priority of this trial.

Safety decisions were made in relation to the weather and sea conditions prior to each trip and were assessed each morning and monitored throughout the day. *Table 13* presents the minimum and maximum range of sea conditions that the vessel was operating in throughout the trial from July to November.

Table 13. Minimum and maximum range of sea conditions throughout the trial

Sea conditions	**Minimum and Maximum range**
Wind speed	2 knots – 30 knots
Tide speed	0.3 knots – 2 knots
Swell height	0.2 m – 2.5 m

Trips 1 and 4 were impacted by adverse weather conditions such as thick fog, high winds and wave swell which would have made it unsafe to enter the wind farm and operate the static gear. On day 2 of Trip 1 the wind speed was above 30 knots and therefore the decision was made to remain in Peterhead harbour for the day as the winds and wave swell were too high for safe working within the wind farm.

4. Discussion

Safety and suitability of the fishing methods in the vicinity of a floating offshore wind farm

The Marine Directorate undertook a two-day trip on board their research vessel, *Alba na Mara*, in June 2021 to familiarise staff with the Hywind site and trial two of the three fishing methods: baited fish traps and automated jigging systems. There were some lessons learned from this trip such as it was better to have shorter fleets of fish traps and creels to be able to deploy them within the designated ‘fishing areas’ and have space for contingency. The fish traps were only left out for several hours and did not catch many fish so longer soak times and ideally soaking overnight was recommended. These lessons were factored into this main project.

Whilst there are no legal restrictions to fishing within wind farms in Scottish waters, temporary or permanent exclusion or advisory zones are implemented during different stages of offshore wind farm construction, operation and decommissioning for safety reasons. These exclusion zones are in place for all vessel activity including commercial fisheries, shipping, and recreational vessels. For example, there tends to be a temporary 500 m safety exclusion zone around turbines during the construction and decommissioning phase, enforced through guard vessels. During the operational phase there is typically an advisory 50 m safety buffer zone around turbines to minimise risks to vessels and turbines. To trial fishing in the Hywind floating offshore wind farm, Equinor designated fishing areas within the wind farm based on safety parameters. The fishing areas designated for the test trip on *Alba* in June 2021 and Trip 1 of this project were based on more precautionary parameters and were smaller and further away from the turbines. However, after Trip 1 the fishing areas were refined to be based on the safety parameters displayed in Table 2. The new areas were larger and closer to the turbines remaining at a safe distance. The new, larger areas allowed adequate space for vessel manoeuvring and static gear deployment.

The refined ‘fishing areas’ allowed fishing activities to be undertaken in closer proximity to the turbines. The closest distance to a turbine was 200 m whilst carrying out jigging on Trip 1. There were no snagging instances for any of the fishing gear used.

This trial has demonstrated that under the right sea and weather conditions, it is possible to fish safely within the Hywind floating offshore wind farm with the static fishing gear tested, assuming that the standard maritime safety and navigation rules of the sea, and the offshore wind farm safety parameters are adhered to. This conclusion has been limited specifically to the Hywind floating offshore wind farm because other floating offshore wind farms may have different turbine technologies, spacing and configurations as well as different geographic, oceanographic or seabed conditions that may influence fishing conditions. Hence it is recommended that similar trials are carried out in other operational floating offshore wind farms worldwide to gain a better understanding of safe fishing within floating offshore wind farms.

This trial was undertaken from a large 30 meter ex-whitefish trawler and this vessel size was selected based on several factors including deck size, hauling equipment, sufficient engine power and that it met strict covid regulations at the time. However, it is recognised that most Scottish static gear vessels are generally much smaller than the one used in this trial. Smaller vessels may have more space to operate within the wind farm although they would be limited by deck space for gear. A recommendation is that a similar trial be carried out using a smaller vessel such as a creel boat.

Consideration of weather and sea conditions played a major role in the safety of the trial and influenced the decision to enter the wind farm area and deploy the static gear. Suboptimal weather conditions may not impact static fishing activity in other areas outside wind farms to the same degree. However poor weather conditions limit fishing activity in wind farms due to the proximity to the turbines and potential safety and gear snagging risks. Trip 1 and Trip 4 were impacted by high wave swell, strong tides or thick fog which made it unsafe to enter the wind farm and to operate the static fishing gear. The decision not to enter the wind farm area was discussed between the vessel skipper and the Marine Directorate staff onboard the vessel and a precautionary approach was adopted. The decision not to enter the wind farm on day two of Trip 1 was due to the wind speed being over 30 knots and therefore the winds and wave swell would be too high for safe working within the wind farm. Faster tidal speed would also cause the vessel to drift faster whilst jigging which could increase the potential risk of jigging line entanglement in any sub-surface infrastructure. The decision to shoot the static gear involved consideration of the forecast for the next few days of the trip whether it would be possible to haul the gear again and the potential for resultant gear loss, longer soak periods and an increased risk of damage to the gear from other sea users. A minimum and maximum range of sea conditions including wind speed, tide speed and wave height were recorded, providing a guide to operating limits for static gear in the Hywind site. If this trial was to be repeated, it would be beneficial to have more flexibility with dates and vessel time to give contingency for adverse weather disruptions. Aside from one bad weather day in Trip 1 and several bad weather days in Trip 4, conditions were largely good.

One of the project objectives was to understand the potential for the static gear to drift, and the risk of it snagging on and fouling subsea infrastructure. This could potentially lead to ghost fishing where fouled gear continues to catch fish and other marine species, resulting in entanglement and death in some instances. It was challenging to measure gear drift as the vessel tended to haul the gear whilst moving out of the wind farm and away from the turbines for safety reasons, which meant that the marker buoy and weight positions changed as a result of the vessel pulling the gear. This is a common safety practice for fishers when hauling static gear. However, the judgement of the crew on board the vessel was that gear always appeared to be in the same position as previously marked on the vessel plotter from the previous day’s deployment positions or positioned in accordance with the prevailing tide. This meant the marker buoys were easy to find and gives confidence of appropriate weighting of the static gear and minimal gear drifting. There were no occasions of gear becoming entangled after leaving the gear to soak for 24 hours overnight however if the gear were to be left for a longer period or if there were significant wind and tides then there may be the possibility of gear drifting and becoming entangled in turbine infrastructure. If this trial were to be replicated it has been recommended that a ‘pinger’ compatible with the vessel’s plotter system is used to locate one or both weights on the seabed, directly after deployment and again just before hauling. This would help to give a more accurate measurement of any movement of the gear.

Catch composition and catch rates

Overall catch rates were low in relation to typical catch rates in more commercial creel fishing areas and fish traps catch rates from other studies such as the FIS project. This ties in with the historic pattern of relatively low level of commercial fishing with mobile gear in the area and the absence of a static fishery prior to the Hywind wind farm construction and was an expected result. Haddock and mackerel were amongst the most prominent species caught in the trial, consistent with low level fisheries in the wider area.

As mentioned above, the fish traps used in this trial have also been used in the FIS project where they were deployed in various deep offshore grounds off the northwest coast of Scotland in December 2022 (results of this project are expected to be available in summer 2023). The fish traps were deployed in areas of high fish density and within very close proximity to wrecks where they caught a large number of fish, for example preliminary results recorded several hundred kg of large ling, cod and conger from a single deployment of 16 fish traps on grounds to the west of Shetland. This provides proof of the efficiency of this gear type when deployed in areas of higher density of target species. The focus of the SeaShare project was to test the efficacy of the deployment of static fishing gear within a floating offshore wind farm, not whether the site was commercially viable for such a fishery.

Most of the commercial fish species caught during this trial were above the Minimum Conservation Reference Size (MCRS) for Scottish waters e.g., Haddock is 30 cm, Whiting is 27 cm and Mackerel is 20 cm. There were very few small or juvenile fish caught using either small or large mesh traps in the Hywind site, which in terms of the former species suggests they may not have been present in significant numbers. While selectivity in static trap gear is not as well researched as mobile gears, the subject is under consideration by the Marine Directorate and formal advice on both mesh size and configuration to minimise catching small fish may be available during late 2023. This should help improve on the already conservation friendly status of this gear.

The main aim of this trial was to test the safety of operating static gear in a floating offshore wind farm. There was also an aim to test the viability of the fishing methods however this was from a safety and practical point of view rather than the commercial viability of the fishing methods. Catch data were collected to inform the use of the static gear. It is hoped that these trials can be replicated in other floating offshore wind farms in the future that may have more active fisheries and that the knowledge and experience from this trial can be used to help inform future trials.

Trips were carried out in July, August, October and November 2022. Originally there was a trip scheduled for September however after the August trip it was decided amongst the scientific staff and agreed with the vessel and Equinor that the August trip would be postponed until October. This was to capture potential seasonal differences in catches, in particular increases to brown crab as they move further offshore towards winter and changes to cod numbers as they come inshore. This trend was observed for brown crab as there was a total of 51 brown crab caught on Trip 2 in August and a total of 125 brown crab caught on Trip 3 in October. However, the expected increase in cod was not observed between the August and October trips although few cod were caught across all trips in general.

There were no prawns caught despite the use of prawn creels. This was an expected result as the area does not have the conditions and ground type suitable for prawns and historically was not a prawn fishing ground. Despite this, the trial delivered its core objective of testing the use of prawn creels in a floating offshore wind farm.

On Trip 2, five jigging drifts were undertaken in each area, and on Trip 3, two drifts of jigging were carried out in each area. This reduction was due to poorer sea and weather conditions throughout Trip 3. However, it was still possible to draw a comparison between trips and look at fish caught per jigging duration.

Environmental knowledge and biodiversity

The diversity of species caught was influenced by the type of gear, lure and bait used as each are typically used to capture specific species. This trial’s focus was commercial fish and shellfish species due to the commercial capture methods used and therefore limited biodiversity information on other marine species can be gleamed from these trials, when compared to benthic grabs and fish video surveys. Nevertheless, this information can be added to baseline data and used to improve the environmental knowledge of the area.

By-catch of non-target species was relatively low however by-catch species to note were Lesser octopus, Long finned squid, Lesser spotted dogfish, Ling, Common dab, Red shrimp, Snailfish, Conger eel and species of starfish.

The single control area used in this project was 470 m from the wind farm boundary and 1751 m from the nearest turbine. This compared with three fishing areas within the wind farm, resulting in substantially more fishing effort in the wind farm than outside. The difficultly in ensuring the control area was similar to the wind farm areas in depth and seabed type, made it challenging to be able to compare fish catch inside the windfarm to outside the wind farm. However, this was not the main aim of the trial, though catch composition and rates for each of the areas are still reported.

Some species of fish such as certain gadoids (Pollock and Saithe in particular) are attracted to hard, man-made structures that represent reef type habitats and aggregate around them (Reubens *et al.* 2014; Fujii 2015; Flávio *et al*. 2023; Methratta & Dardick 2019). It is thought that these structures may offer fish food, shelter and refuge from predators. Predators such as seals and large predatory fish have been shown to hunt around fixed foundation wind turbines (Russell *et al.* 2014). Studies set up to compare fish inside versus outside wind farms have found that overall fish abundance increased slightly in the offshore wind farm but declined in the control area 6 km away (Stenberg *et al*. 2015). Rocky habitat fishes were most abundant close to the turbines while whiting was most abundant away from them. Species diversity was significantly higher close to the turbines. Results indicate that the artificial reef structures provided by a wind farm were large enough to attract fish species with a preference for rocky habitat (Stenberg *et al*. 2015). The SeaShare project was not set up to look at fish aggregation around the floating turbines due to the safety risk of the vessel being close to the turbine however the crew carrying out the automatic jigging reported that more fish were caught using the jiggers when they were closer to the turbine compared to when they were further away from the turbine. In this project, fish caught were recorded per drift and not in relation to distance from turbine so this finding is only based on observation, but this would be a subject worthy of further study.

5. Conclusion

The deployment and safe operation of static fishing gear (fish traps, creels, and electronic jiggers) in the Hywind floating offshore wind farm were successfully demonstrated during this short trial. Apart from periods of adverse weather, there were no safety concerns or issues such as gear snagging or gear loss experienced, and gear drift appeared minimal, due to appropriate weighting. The ‘fishing areas’ that Equinor designated for these trials, based on safety parameters and a minimum distance of 200 m to a turbine and dynamic sections of the export/inter-array cables and 50 m away from all other subsea infrastructure, allowed the safe operation of the static gear and sufficient room to manoeuvre for a 30 m fishing vessel. While the catch sizes were not commercially viable, this was understood in advance to likely be the case as the area was not particularly productive in terms of historical fishing and was not the focus of the project.

This trial has been an informative first step towards understanding the ability to safely fish in a floating offshore wind farm using static gear. This insight will support considerations for good practice to promote coexistence between offshore wind farms and commercial fisheries.

6. Recommendations

This project has identified a range of recommendations:

- Defining 'fishing areas' within a floating offshore wind farm is helpful to aid coexistence with static fisheries. It reduces the risk of fishing gear snagging, vessel safety issues and damage to wind farm infrastructure. Concerns over liability and insurance for fishing within wind farms is a separate matter for the offshore wind sector and commercial fisheries and was not considered by this project. These areas can be uploaded and drawn on the ship's plotter so that Captain, crew and scientific staff have a view of their position relative to the pre-defined fishing areas at all times.
- Accurate surface and sub-surface spatial locations of all floating offshore wind farm infrastructure including mooring chains, dynamic cables and anchors, should be made available to fishers in a format that can be easily uploaded to fishers plotters. These locations could be added to the FishSAFE[2] website for example and be uploaded to their unit and maps for easy access for fishers. The location of all surface and sub-surface infrastructure associated with the Hywind offshore wind farm is available on FishSAFE.
- Good communication between the wind farm control centre and any fishing vessels entering the wind farm. This is not a statutory requirement as there are no legal restrictions to fishing within offshore wind farms in Scottish waters. However, this greatly improves working relationships between the offshore wind and fishing industries, reduces risk of confusion, and may provide a faster rescue response in an emergency situation.
- Given that this is the first trial, and it was relatively short, similar studies should be replicated in other operational floating wind farms to help facilitate coexistence opportunities. Other types of fishing methods local to the wind farm area could also be tested to make the trial more applicable to the fishing fleet. A similar trial using a smaller vessel such as a creel boat should also be undertaken.

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[2] Homepage | FishSAFE

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8. Appendix

Raw CPUE Data

Table 14. Fishtrap CPUE (number and weight/deployment) of main commercial species by area and trip.

Trip	Area	Species	Number/Deployment	Weight/Deployment (kg)
Trip 1	1	HAD	23	14.86
Trip 1	1	WHI	8	2.93
Trip 2	1	HAD	30	16.02
Trip 2	1	WHI	0	0.00
Trip 2	2	HAD	18	7.72
Trip 2	2	WHI	3	1.03
Trip 2	3	HAD	56	26.88
Trip 2	3	WHI	6	1.61
Trip 2	4	HAD	19	8.16
Trip 2	4	WHI	3	0.80
Trip 3	1	HAD	17	8.70
Trip 3	1	WHI	1	0.30
Trip 3	2	HAD	0	0.00
Trip 3	2	WHI	4	0.89
Trip 3	3	HAD	4	3.00
Trip 3	3	WHI	1	0.16
Trip 3	4	HAD	9	4.30
Trip 3	4	WHI	0	0.00

Table 15. Jigger CPUE by number and weight of main commercial species by area and trip.

Trip	Area	Species	Number	Weight (kg)	Duration (min)	No/hr	Wt/hr
Trip 1	2	MAC	7	1.31	186	2.3	0.4
Trip 1	2	HAD	2	1.13	186	0.6	0.4
Trip 2	1	MAC	39	12.25	82	28.5	9.0
Trip 2	1	HAD	1	0.32	82	0.7	0.2
Trip 2	1	WHI	2	0.50	82	1.5	0.4
Trip 2	2	MAC	6	2.65	34	10.6	4.7
Trip 2	2	HAD	1	0.67	34	1.8	1.2
Trip 2	3	MAC	7	1.96	159	2.6	0.7

Trip 2	3	HAD	18	9.23	159	6.8	3.5
Trip 2	4	MAC	8	1.91	99	4.8	1.2
Trip 2	4	HAD	1	0.59	99	0.6	0.4
Trip 2	4	WHI	1	0.23	99	0.6	0.1
Trip 3	1	MAC	6	1.91	100	3.6	1.1
Trip 3	1	HAD	2	0.85	100	1.2	0.5
Trip 3	1	WHI	1	0.22	100	0.6	0.1
Trip 3	2	MAC	15	6.09	71	12.7	5.1
Trip 3	2	HAD	2	1.09	71	1.7	0.9
Trip 3	2	WHI	4	1.32	71	3.4	1.1
Trip 3	3	HAD	2	1.30	75	1.6	1.0
Trip 3	3	WHI	12	3.50	75	9.6	2.8
Trip 3	4	MAC	2	0.55	95	1.3	0.3
Trip 3	4	HAD	10	3.72	95	6.3	2.3
Trip 3	4	WHI	13	3.80	95	8.2	2.4
Trip 3	4	COD	1	0.42	95	0.6	0.3
Trip 3	4	GUU	1	0.26	95	0.6	0.2
Trip 4	4	MAC	8	3.262	129	3.7	1.5
Trip 4	4	HAD	3	1.935	129	1.4	0.9
Trip 4	4	WHI	7	1.92	129	3.3	0.9
Trip 4	4	COD	1	0.361	129	0.5	0.2

Table 16. Crab creel CPUE (weight/deployment) of main commercial species and agglomerated non-commercial bycatch by area and trip. Results not scaled to soak time.

Trip	Area	Species	Weight/Deployment (kg)
Trip 1	4	ECR	6.10
Trip 1	4	Other Crustaceans	0.04
Trip 1	3	Fish	0.20
Trip 2	2	ECR	2.70
Trip 2	2	Other Crustaceans	0.04
Trip 2	2	FISH	1.20

Trip 2	3	ECR	6.37
Trip 2	3	FISH	1.10
Trip 2	4	ECR	12.00
Trip 2	4	Fish	1.33
Trip 2	4	Other Crustaceans	0.09
Trip 2	1	ECR	5.90
Trip 2	1	Fish	0.27
Trip 2	1	Other Crustaceans	0.05
Trip 3	3	ECR	1.70
Trip 3	2	ECR	12.20
Trip 3	2	Other Crustaceans	12.20
Trip 3	4	ECR	34.20
Trip 3	1	Molluscs	0.04

Table 17. Prawn creel CPUE (weight/deployment) of main commercial shellfish species and agglomerated

Trip	Area	Species	Weight/Deployment (kg)
Trip 1	3	ECR	0.06
Trip 1	3	Other Crustaceans	0.42
Trip 1	3	Fish	0.79
Trip 1	3	Molluscs	1.40
Trip 1	4	Other Crustaceans	0.42
Trip 2	1	Fish	0.04
Trip 2	1	Other Crustaceans	0.03
Trip 2	2	Fish	0.63
Trip 2	2	Other Crustaceans	0.06
Trip 2	2	Molluscs	0.06
Trip 2	3	Fish	2.30

Trip 2	3	Other Crustaceans	0.08
Trip 2	3	Echinoderms	0.35
Trip 2	4	Fish	0.59
Trip 2	4	Other Crustaceans	0.35
Trip 3	4	Fish	0.04
Trip 3	4	Other Crustaceans	1.72
Trip 3	4	Echinoderms	0.43
Trip 3	1	Fish	0.56
Trip 3	1	Other Crustaceans	0.05
Trip 3	3	Fish	0.54
Trip 3	3	Other Crustaceans	0.05
Trip 3	2	Fish	0.56
Trip 3	2	Molluscs	0.01