Assessing the Potential for a Demersal Whitefish Trap Fishery to the West of Scotland

FIS025

A REPORT COMMISSIONED BY FIS AND PREPARED BY:

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Contents

Executive Summary

Current awareness of anthropogenic impacts on our environment is going to have an increasingly influential impact on our fishing industry. The need to drastically reduce discards of quota species is being underlined by legislation such as the Landing Obligation. A method of fishing that is capable of addressing these issues, that is economically viable and appropriate for use in our industry is essential. While small-scale trials of fish traps have been undertaken in Scotland, none have studied whether the technique is practical in exposed offshore waters with a view to targeting populations of the large commercial fish understood to be present at depth and on the types of seabed that are not available to mobile gears. This report outlines an assessment of a trial using a model of fish trap specifically designed for use in deep water to the northwest of Scotland.

A total of 16 fish traps were built by the Marine Directorate (MD) to a design robust enough for the task but which also allowed compact storage and transport on a commercial vessel. These were collapsable fish traps that expand into shape when deployed and have an internal structure designed to hold large fish over extended soak periods. They were the product of a long period of trial and design by MD and were deployed from the whitefish trawler *Carina* BF803 a large vessel whose skipper and crew hold tremendous experience and knowledge of working the deeper offshore grounds to the NW of Scotland.

There was a significant hiatus in the project between late October 2018 and April 2019 as a result of issues internal to MD which prevented chartering of vessels. While the project was extended from its original finish date to mitigate this there was nevertheless an impact on the project during this late period from both the severe sea conditions prevalent that winter and a change in commercial economic pressure on *Carina*, and while the overarching objective was met, some of the ancillary objectives were affected. A further hiatus occurred just prior to the final set of fieldwork planned for March 2020 when MD put a hold on staff fieldwork in response to the Covid-19 pandemic. This hiatus lasted until late in 2022 when rules for staff on fieldwork were relaxed.

The traps were deployed in fleets of up to eight for the majority of the project and *Carina* undertook twelve deployments of these over the period August 2018 to March 2020. A further three deployments of fish traps (this time in fleets of fifteen) were undertaken during December 2022. Three semi-automatic fish jigging systems were also deployed twice during December 2022 as a late addition to the study with the

aim of increasing commercial potential during offshore trap fishing. The logistics of operation and the catches recorded are summarised.

This design of trap is assessed as being able to be deployed and retrieved very safely from a modern commercial vessel. The trap design is shown here to be able to operate effectively both at great depths (over 220 m) and on the harshest of fishing grounds that were found over the course of the project, including wrecks and very hard ground seabed. They were operated over the course of this study without sustaining damage, without becoming caught up on the seabed or wreck debris and, during deployments of unexpectedly long duration, they demonstrated their ability to cope very well in extremely harsh winter sea conditions.

The majority of the offshore fish trap deployments found catches were very good to excellent, consisting of large and valuable ling, conger eel, cod, haddock and torsk. Some deployments were forced by contingency to be undertaken close inshore and these proved uneconomic; however in the spirit of the project the analysis includes these. In all some 2024 kg of fish were caught of which over 96% by weight were commercial species.

Where possible, catches from traps were compared to those from trawls undertaken nearby. This provided some evidence (with caution due to limited data) that the traps are able to exploit a localised population of fish that can vary from the trawl in both the species composition and in overall size makeup.

Repeatability was found to be low and variance high and this compromised study of any seasonal effects and of any factors influential on catch rates. Use of underwater cameras in conjunction with the traps was limited by external factors to one deployment and hence gaining insight into fish behaviour is touched on only lightly.

Bycatch (non-commercial species) in the fish traps was found to be low except in cases where lesser spotted dogfish were present in numbers. Capture of undersize quota species was found to be very small (1.1% by number and 0.12% by weight) even when including the inshore deployments. There were zero bycatch observed using jiggers and while there were undersize quota species caught (8.2% by number and 3.1% by weight) some fine tuning of the technique is likely to avoid this.

There were no incidents of marine mammal, cetacean or birdlife capture either entangled in the ropes or held inside the traps themselves.

Despite some poor catches, in particular from the contingency deployments, the traps demonstrate considerable commercial potential and are likely to be a viable option for certain sectors either as an addition to standard fishing practice or as a means to generate income when that standard fishing practice is uneconomic. We suggest that initially the sector most suited for take-up of this method is the large (>12 m) brown crab vessels. Vessels from this sector already possess the space and hardware to deploy and retrieve traps as well as the extensive knowledge of the offshore grounds needed to successfully undertake the fishery.

The market prices used here are conservative and there is potential that premium prices would be achieved if marketed as a low impact and environmentally friendly method of fishing. Current concerns on anthropogenic impacts globally make this an appropriate time to consider this method seriously.

Although these trials were focussed on offshore grounds it is likely that interest in the use of these or other forms of fish traps will arise on grounds further inshore. As quota species below MCRS are more likely to be encountered in these areas, some minimum design standards are needed to ensure use of the fish traps remains consistent with the Landing Obligation and the Future Catching Policy with respect to mitigation of sensitive species bycatch. So called “ghost fishing” of lost static gear is a concern worldwide and the final design should also include biodegradable components to nullify functionality should the fish traps become derelict. Evidence for appropriate minimum design standards will be acquired by MD during trials scheduled for March 2025.

1. Introduction

Demersal trawling is currently by far the principal method utilised for capture of demersal whitefish by the Scottish fishing industry. Discarding in demersal fisheries has been a frequently documented issue particularly within mixed demersal fisheries such those operated within the North Sea and to the west of Scotland. The current sustainable fisheries management scheme, the Landing Obligation, has been designed to address the issue of discarding of commercial species by making it an illegal practice and thus mandatory for vessels to land all their catch for all such quota species. It is thought that the development of novel approaches such as use of fish traps offshore to the west and northwest of Scotland could provide fishers with a sustainable and low impact method that would enable them to target core quota species with minimal bycatch and minimum of undersize fish. The trap fishery could be expected to be most valuable targeting areas of non-trawlable seabed that are understood to be abundant in fish in the deeper whitefish zones on the upper shelf.

Fish traps have proven highly successful in other countries with those such as Norway highlighting double entrance traps as an effective design for increasing cod (*Gadus morhua*) capture (Furevik & Lokkeborg 1994).

2. Project objectives

The main objective of the project is to assess the potential for the development of a baited trap fishery for demersal whitefish in offshore waters to the west of Scotland. As part of this undertaking the project aimed to:

- Establish whether baited fish traps can be successfully deployed at greater depths, in high fish density areas in waters to the west of Scotland.
- Collect data on trap catch composition and catch rates of marketable demersal fish at selected study sites.
- Compare trap catch composition with trawl catch composition in adjacent or comparable areas.
- Evaluate the behaviour of fish in relation to traps.
- Conduct statistical analysis of factors affecting trap catch rates.
- Consider the potential commercial viability of baited traps fishing in the areas studied.

3. Materials and methods

3.1 Vessel

Fish trap trials were undertaken on the Banff registered *Carina* BF803 (Figure 1) a 25 metre whitefish trawler normally working out of the northern ports of Kinlochbervie and Scrabster. *Carina* demonstrated ample room for shooting long fleets of traps safely even when carrying a full complement of trawl gear for normal fishing operations. Importantly *Carina*'s net drum and gantry block were both ideally placed for trouble free hauling of any sort of static gear, facilitated by the excellent visibility from the wheelhouse. The skippers and crew of the vessel are hugely experienced in working the west and northwest fishing grounds and hold a vast bank of knowledge of both the inshore and offshore waters there which has been accumulated over several generations. This information was vital in locating the deployment sites selected for the trials and also in avoiding any gear conflict with other vessels deploying mobile gear. After an initial test deployment, 14 experimental fish trap deployments, and two sets of three jigger deployments were undertaken at various locations over the period of August 2018 to March 2020 and finally during December 2022 (Figure 2).

3.2 Fish traps

Marine Directorate manufactured 16 collapsible traps for the purposes of this study. Over a period of more than a decade previous to this study, continued development and refining of the trap design through use has provided these with particular advantages over other commercially available traps. The traps are triple compartmented with funnelled entrances to both the baited trap section itself and to two interior holding parlours. Entry to the bottom baited section is permitted by any of three entrances adjacent to where the bait is presented. From there the fish then have two options: to proceed horizontally into a side parlour and then upwards into a top (holding) parlour, or directly into the holding parlour. Fish are less likely to escape through the route entered due to the funnelled design of the entrances and are expected instead to move further into the trap to either of the inner parlours, as the route with least resistance (Figure 3). This design concept is intended to move captured fish away from the vicinity of the bait, thus removing a possible inhibitory effect of having large predatory fish adjacent to the bait itself.

The traps are cuboid in design with a base measurement of 150 x 110 cm. They are approximately 20 cm high in their collapsed state (for instance when stowed on deck as in Figure 4), opening up to a full height of 120 cm when submerged and operational. They are comprised of two metal frame sections: a heavy basal section constructed from solid 16 mm mild steel rod and a light central section made from 14 mm tubular aluminium. A total of 6 x 0.450 kg of buoyancy (a combination of plastic floats and tough Styrofoam blocks) is incorporated to lift the uppermost holding parlour section, the walls and top of which are constructed from netting only. 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. The weighting and buoyancy was carefully adjusted during tank trials at Marine Laboratory to give an overall negative buoyancy of 10 kg for each trap. Both the outer retentive layer and the inner compartments are constructed from twisted Courlene netting of 3 mm diameter with an inner mesh size of 60 mm. To aid the process of emptying and rebaiting the traps, an outward opening hinged rectangular door is incorporated into the base section allowing easy removal of catch once the traps are retrieved and suspended off the deck.

3.3 Fish trap deployment

The extensive knowledge and experience provided by the skipper of the *Carina* of the north-western fishing grounds was crucial in selecting deployment where sites the target species (cod, ling *(Molva molva)*, haddock *(Melanogrammus aeglefinus)*, torsk (*Brosme brosme*) and conger eel *(Conger conger)*) would be abundant, whilst also ensuring the fish trap fleets would be safe from conflict with mobile gears should soak times be extended for any reason.

During Deployments 1-12 the traps were deployed in fleets of eight, on branch lines 30 m apart (Figure 5.) along a main line consisting of 20 mm buoyant and abrasion-resistant Seasteel rope. The buoyancy of the main rope reduces the chance of this contacting and snagging on the seabed. Branch lines leading off the main rope to the traps were four metres long and constructed from leaded rope with a lower diameter and breaking strain than that of the main rope. The branch lines were designed with ample length to facilitate easy detachment of the traps during the hauling process. Each trap was connected to the branch rope by 0.8 m of 19 mm chain, which along with the leaded rope used for the branch lines, is intended to offset any effects of tide on the buoyant main rope. Both ends of each fleet of traps terminated with 40 kg end-weights followed by a rope to the surface marked by a dhan (incorporating a radar reflector, a strobe light and a flag) and a marker buoy. During deployments 13-15 the traps were deployed in fleets of 15 to minimise retrieval operations in the poor sea conditions experienced at the time. The longer fleet also provided an opportunity to use something that may be expected to approach the lengths used commercially.

In early phases of design of these traps, attachment to the branch lines was by the conventional method using a bridle fastened to the two leading corners of the trap. Over the course of MD trials on the design this was found to be satisfactory on clean ground, however, it was observed that periodic snagging occurred when working the traps on very rough ground, often with subsequent abrasion damage being noticed on the leading edges. During these trials the use of a bridle was discontinued and traps were attached to the branch lines by only one lower corner (Figure 7). This enabled the traps to be hauled rapidly corner first, thereby, greatly reducing the likelihood of the traps snagging on any challenging seabeds.

Prior to the shooting process traps were laid out in order of shooting on the deck. The Seasteel main rope was laid out, with the weights and traps then being tied on one by one. The sections of main rope between traps were carefully 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 holding rope and the first marker buoy, the dhan and the end rope is at that point payed away over the side of the vessel and streamed off. Once the vessel is fully in position and slowed to around four knots the holding rope is thrown off, releasing the end-weight. From this point onward no crew involvement is required and all can stand clear as, following the first end-weight, the traps self-deploy in sequence finishing with the second end-weight, the end line and the second set of surface markers.

The hauling process required a ‘dummy’ rope to be run from the vessel’s empty net drum on the top deck up to a hanging block on the centre of the gantry. The dhan and marker buoy were grappled from the starboard side, detached and the tails of the dummy rope and end line tied together. The vessel then slowly 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 and detached and then the traps being retrieved one by one and finishing with the second end weight and markers. The drum is stopped once the second surface 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 (Figure 8) 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 individual traps were lifted up by the top section, the hinged door underneath was opened and the catch emptied onto an appropriate section of deck ready for sorting. Once one trap was emptied and sorted the contents were moved away to allow the catch from each individual trap to be recorded separately.

The bait was standardised across all deployments and consisted of Atlantic mackerel *(Scomber scombrus)* and brown crab (*Cancer pagurus*) obtained fresh from the vessels trawl bycatch. Two whole mackerel were tied into the traps as illustrated (Figure 9) - a baiting technique intended to prevent large predatory fish quickly swallowing the bait head first and making multiple fish entries more likely. To increase the release rate of the scent from the bait the mackerel were sliced along the length of their bodies. This also permits a flapping effect of the bait in the tide intended as a visual stimulus to further entice predatory fish. The bait was tied into the lower section of the trap equidistant from each of the three entrances. To additionally encourage shellfish feeders into the traps a 40 mm double white nylon bait bag was filled with crushed brown crab and attached adjacent to the mackerel.

Although camera equipment was carried on several occasions the sea conditions encountered during the winter of 2019-20 and 2022 were such that working with the equipment on deck was rarely feasible and only Deployment 8 (217 m depth on one of *Carina*'s clean ground fish tows) used a camera. It was also intended that jiggers could be used with the traps to understand the benefits of using the two fishing methods in conjunction with each other; however opportunity for this only arose at the end of the project in 2022.

3.4 Jiggers

The jiggers used were a set of three Deep-Drop Diawa Tanacom models, each with five lures (luminous squid and sandeel) on a size 7/0 long bent-shank hooks (the bent shank gives the lures an erratic movement on retrieve) with each set of lures (Figure. 6) lowered on a 1 kg weight. The main line was 90 kg breaking strain braid while lure traces were 70 kg monofilament tied using double T knots to keep the lures clear of the main line. The reels were powered by a 12 volt deep cycle battery and were fully programmable with a range of jigging and retrieval speeds. For safety the jiggers were set to cease retrieving at a depth of five metres from the surface, allowing a switch to manual retrieve from then on. Rods were heavy-duty jigging rods designed to jig effectively with the roll of the vessel and were secured in strong handmade rod holders at equal distances along Carina's starboard. Jigging was undertaken with the vessel at slow drift to allow good ground coverage. To increase chance of success with the range of species understood to be present, the hooks on the bottom three lures in each case were additionally tipped with fresh mackerel strips.

3.5 Data recording

The position, seabed depth and type of ground were logged at each deployment. All catch was removed from the traps and jiggers and sorted by species. All fish were identified and measured total length to the cm below. All invertebrates were identified and counted. For all fish species measured, a whole weight and gutted weight (if applicable to market practice) was estimated for each individual using species and season specific length weight relationships (Coull et al., 1989).

4. Narrative

A fleet of all available (five) traps were prepared and taken aboard the *Carina* during fine weather conditions for a pilot deployment which would serve as a test of the logistics of shooting and hauling the traps whilst also enabling a safety assessment of the working practices. In addition it also allowed some decisions on best practice in processing any catch from the traps. A protocol for deployment was drawn up between the skipper and MD scientists and it was agreed the entire process would be filmed for close study in an effort to highlight any safety issues that would need to be addressed before continuation. The first deployment was undertaken on 28 August 2018 in 550 m depth North West of St Kilda on clean ground at an area where *Carina* hoped to target blue ling (*Molva dypterygia*). Following deployment a trawl was undertaken immediately adjacent to the traps, however, only a small amount of non-commercial fish were captured and, conspicuously, no blue ling. The fleet of traps was recovered on 31 August, however, when hauled there were observed to be a total of only three torsk in the entire five traps, all in various stages of apparent consummation by the scavenging amphipods found to be present in numbers. There was no trace of the bait in any of the traps. While the catch was declared void, the deployment itself was considered logistically successful with shooting of the fleet, locating and grappling of the surface markers and subsequent hauling proceeding without any hitches. The lines and traps were observed to free of any entanglement and examination of each individual trap revealed no damage. There were no major safety issues noted and the deployment and retrieval protocol remained the same throughout the trials from this point on.

Following this an additional 11 traps were constructed at Marine Laboratory in preparation for the next set of deployments which were planned for October 2018. Unfortunately in late October there began a long hiatus in chartered vessel fieldwork at MD for internal reasons. This situation lasted for several months and was further compounded by *Carina* being booked for refit for one month shortly after the block on chartering within MD had been resolved. However, during the next available opportunity (May 2019) *Carina* proceeded out to sea with fish traps on board and deployments were undertaken at Papa Bank; one deployment on relatively clean ground, considered trawlable, at a depth of 128 m and one on shallower but very hard ground which is worked commercially only by Norwegian gill net vessels. The fleet of traps deployed on the hard ground caught moderate quantities of commercial fish (36 kg), the majority of which was cod. Here it was noted that plaice *(Pleuronectes platessoides)* was also caught by the traps although in small numbers. This deployment included the only haddock below Minimum Conservation Reference Size (MCRS) caught during the trials, and one of only seven fish of trap-caught quota species below MCRS over the whole course of the trials. The catch from the clean ground deployment was found to be poor with only 12 kg of mixed species being recorded. It was noted that the fleet deployed on the clean ground recorded significantly more brown crab and fewer fish when compared to those deployed on the hard ground. No accompanying trawls were undertaken by *Carina* in the vicinity of either of these deployments.

In June 2019 a fleet was deployed on the wreck of the *Able* in 90 m depth just 15 miles northwest of Kinlochbervie before *Carina* steamed 60 miles further north to deploy another fleet on the wreck of the *Mars* in a depth of 220 m. Following this *Carina* then steamed to the Faroese sector to fish for three days before returning south and hauling the traps set at *Mars*. Catches there were excellent with nearly 260 kg fish all of which were valuable commercial species consisting largely of ling (figure 9). *Carina* again moved grounds at this point and so did not trawl close to Mars wreck, however the fleet was redeployed a further 60 miles to the northeast in 180 m depth close to an oil pipeline where whitefish densities were known to be high and *Carina* undertook trawling operations nearby. Unfortunately catches with the trawl turned out to be uneconomical, and this resulted in the traps having to be hauled after only a relatively short soak before once again shifting grounds. This fleet again held a substantial catch (180 kg) consisting of all commercial species but primarily large conger eel along with lesser amounts of ling and other species. Logistics prevented a return to the vicinity of the inshore *Able* wreck until the end of the fishing trip giving this fleet an unexpectedly long (11 day) soak time. Catches from here were found to be moderate only with 50 kg of fish of which 30 kg were commercial species such as cod, haddock and whiting *(Merlangius merlangus)*. Considerable numbers of lesser spotted dogfish *(Scyliorhinus canicula)* were present and it was noticeable that in contrast to both the *Mars* wreck and the pipeline there were no large predatory fish encountered from the fleet recovered from the *Able*. No trawling was undertaken in the vicinity of *Able* wreck.

In September 2019 *Carina* loaded the traps for deployment and once again headed for northwestern fishing grounds. Offshore sea conditions, however, were extremely unfavourable and trap deployment was decided against on safety grounds. In line with the agreed contingency undertaken in such circumstances the opportunity was taken to deploy in any shelter that was available; in this case at the mouth of Loch Clash for a short soak deployment while *Carina* landed her catch before steaming to Macduff for repairs. The fleet was set on hard seabed with rocky peaks in 46 m depth and retrieved 12 hours later, however, the catches were poor ~14 kg total weight of which only about half were commercial species. One cod and one saithe under MCRS were caught here.

In October 2019 a fleet was set on an unnamed wreck in 110 m depth some 65 miles offshore to the northwest of Kinlochbervie while *Carina* worked in the surrounding area. The intention was to gradually work north towards the *Mars* wreck over the course of the trip for a further deployment there to gain insight into potential seasonal effect on catches. Trawl catches were uneconomical and with bad weather approaching the decision was made to haul the fleet after only six hours soak time following which *Carina* moved to alternative grounds far to the northeast. Despite the very short soak time the catch was good at 100 kg, of which 80 kg were commercial species with the remaining 20 kg being lesser spotted dogfish. The opportunity was taken to deploy a camera on a single trap on 14 October on one of Carina's tows in 217 m depth. A single trap was utilised to avoid any down-tide bait scent (bait plume) interference from other traps. This deployment recorded two hours of footage which was analysed back at the Marine Laboratory.

In January 2020 *Carina* departed from Scrabster, carrying traps and camera equipment. Again offshore sea conditions remained extremely unfavourable with expected lulls in the weather failing to materialise. With safety in mind the chance was taken for a contingency deployment for a short time only in the shelter of Thurso bay in 51 m depth. The event of respectable captures, particularly of the same species encountered offshore such as ling, would allow this area as a potential site for further camera work on the traps, as the shallower depth held potential for obtaining footage without the need for lights which would contribute to Objective 4. Similar to the deployment at the entrance to Loch Clash however, catches were low (15 kg). Although the catch was comprised almost entirely of commercial species (mainly cod and haddock) it was felt that fish densities were too low to provide any productive camera work. Two cod under MCRS were caught in this deployment.

In Februay 2020, a fleet was deployed again at *Able* wreck in moderate conditions. Conditions deteriorated severely, thereafter, over the course of the trip and as *Carina* did not attempt recovery in the stormy seas experienced. The fleet was left on site for retrieval at the next available opportunity.

In March 2020 *Carina* left Kinlochbervie to work the Nun Bank grounds some 35 miles to the northwest with potential for working grounds at *Mars* wreck a possibility for later on in the trip. The skipper had on previous occasions noted the presence of strong whitefish marks on the sounder over a section of very hard seabed with rocky peaks and outcrops not far from the cleaner grounds commonly trawled, and detoured to see if this was the current case. This was confirmed with very high densities observed on the sounder and the decision was made to deploy on this site during a lull in the less than optimal sea conditions. Due to the harsh nature of the grounds and thus potential for damage or loss, no cameras were attached. Following deployment the anticipated lull that had been forecast turned out to be very short-lived and the decision was made to retrieve the fleet after only a short soak time of 12 hours while *Carina* trawled on the cleaner ground close by. On retrieval over 40 kg of fish were caught, of which nearly all commercial species, with the majority being very large haddock all in excellent condition and of high value. No undersize commercial fish were caught. Notably all traps were retrieved from this rough ground with no hook-ups or any damage incurred. With an extremely unfavourable forecast there was no opportunity of working around *Mars* wreck or of deploying traps there. At the end of the trip there was however a chance to recover the fleet from *Able* wreck which had been in place for 19 days during a period of almost continuous gales. Catches from here were again found to be moderate at 35 kg with cod, conger eel and ling being the most prominent species along with lesser spotted dogfish. Again the fish traps caught plaice and also lemon sole *(Microstomus kitt)*, albeit in small quantities. It was noted that the fish all appeared in excellent condition after an entrapment period of up to 19 days, apart from a conger eel that exhibited some abrasion marks on the head that may have been the result of trying to get through the netting by force.

In December 2022, following a long hiatus in fieldwork as a result of measures set by Scottish Government during the Covid-19 pandemic, *Carina* left Scrabster carrying fish traps and three sets of semi-automatic jigging systems and over the period 16-18 December and carried out three deployments of a single fleet of 15 fish traps and two deployments of full three sets of jiggers working in tandem. The traps were put out twice on very rough grounds to the northwest of Foula; first to the north of Box of wrecks at 150 m depth and second on the edge of Monk Alley at 160 m depth. A final fish trap deployment was made on the wreck of the *Adonis* some 32 nmi further west. Sea conditions were poor, however, deployments and recovery of fish traps were completed safely and without incident. Catches were excellent with 118 kg and 240kg of cod, conger eel, ling and torsk from the fish traps on rough ground and 520kg of the same species from Adonis wreck. Two undersize ling were caught from the north of the Wreck box. Very notably the catch from Adonis consisted fully of commercial species with zero bycatch and zero undersize quota species. During periods of moderate conditions three sets of jiggers each with five hooks were worked, drifting over very hard ground east of Foula Hole for two periods of two hours each. Both drifts resulted in 108 kg of cod, ling saithe, torsk and spurdog all of good commercial size apart from six ling under MCRS. Some large size and thus valuable ling came off the hooks above the waterline before they could be fully brought on board *Carina*.

5. Results

There were 15 deployments of fleets of varying numbers of fish traps undertaken throughout the duration of the project (Table 12). These consisted of: two deployments of 15 traps, ten deployments of eight traps, one deployment of five traps (declared void) and one deployment of a single trap incorporating camera equipment. A further two sets of three semi-automatic jiggers were additionally deployed. The first trap deployment (five traps) took the form of a pilot study taking place in deep water during August 2018, with the primary focus on safety, the catches from which were declared void after loss of both bait and captured fish due to presence of scavenging crustaceans. The following month, at the point where the first proper trip was about to begin, MD put a hold on chartered vessel fieldwork for internal reasons. This situation was only fully resolved in spring 2019 resulting in the next set of deployments being undertaken in May of that year, however, these continued through the summer with some very successful catches being recorded. Meanwhile an extension to the project was secured taking it through the winter of 2019-20, thereby, providing opportunities to reclaim some of the lost time incurred at the beginning. Various factors however including a combination of an extremely stormy winter season, coupled with an alteration in the business plan and economic model operated by the vessel owners, hampered further deployments in areas already fished with the traps. The effect of this was that there were very few repeat deployments in the same grounds and the ability to capture a seasonal element, already compromised by the late start, was lost. An additional effect was that there were several deployments that were undertaken in sheltered waters close inshore rather than offshore, and these though interesting in themselves were frustratingly not successful in a commercial sense. It was noted that soak times were very difficult to plan in advance as the vessel responded to commercial pressure and weather conditions such that it sometimes became necessary to leave the area without the prospect of timely return. This meant that the traps were sometimes picked up after only a short soak (deployment 5 adjacent to a pipeline) or, couldn't be safely picked up (deployment 12 on an inshore wreck) until the next occasion which turned out to be 19 days later. There was no significant damage to any of the individual traps over the course of this study and, bar the initial pilot trip, no faulty deployments and thus there were no catch invalidations.

Overall a total of 19 species of fish were caught for a total weight of 2024 kg. The predominant species in order of total weight followed by total number recorded were: ling (1174 kg, 257), conger eel (254 kg, 50), cod (236 kg, 83), haddock (68 kg, 89), and lesser spotted dogfish (66 kg, 84). Apart from moderate numbers of brown crab (88), invertebrate catch was very low: velvet crab *(Necora puber)* (7), common hermit crab *Pagurus bernhardus)* (1) and red whelks *(Neptunea antiqua)* (4). Of additional interest were the capture of flatfish species, including plaice and lemon sole. Catches were very variable reflecting both the grounds fished and the range of soak times but overall were found to be excellent offshore at wreck sites and on hard ground but of low commercial potential close inshore especially as these deployments were combined with short soak times. An overall summary of the catches is presented in Table 1, while the details of catch at individual deployment level are presented in Table 13.

Table 1

Total numbers and weights caught by species and gear.

Gear	Common Name	Species	Total number	Total live weight
Fish trap	Ballan wrasse	*Labrus bergylta*	4	2.8
Fish trap	Catfish	*Anarhichas lupus*	1	2.2
Fish trap	Cod	*Gadus morhua*	64	168.3
Fish trap	Common dab	*Limanda limanda*	7	1.5
Fish trap	Conger eel	*Conger conger*	50	254.7
Fish trap	Cuckoo wrasse	*Labrus mixtus*	1	0.2
Fish trap	Goldsinny wrasse	*Ctenolabrus rupestris*	1	0.2
Fish trap	Haddock	*Melanogrammus aeglefinus*	89	68.4
Fish trap	Lemon sole	*Microstomus kitt*	4	2.0
Fish trap	Lesser spotted dogfish	*Scyliorhinus canicula*	84	66.2
Fish trap	Long rough dab	*Hippoglossoides platessoides*	1	0.1
Fish trap	Ling	*Molva molva*	217	1061.5
Fish trap	Plaice	*Pleuronectes platessa*	5	2.8
Fish trap	Poor cod	*Trisopterus minutus*	6	0.6
Fish trap	Saithe	*Pollachius virens*	9	7.2
Fish trap	Spurdog	*Squalus acanthias*	1	3.5
Fish trap	3-bearded rockling	*Gaidropsarus vulgaris*	1	0.4
Fish trap	Torsk	*Brosme brosme*	69	152.1
Fish trap	Whiting	*Merlangius merlangus*	25	12.7
		Totals	**639**	**1807.4**
Jigger	Cod	*Gadus morhua*	19	68.6
Jigger	Ling	*Molva molva*	40	113.0
Jigger	Saithe	*Pollachius virens*	3	7.2
Jigger	Spurdog	*Squalus acanthias*	5	18.5
Jigger	Torsk	*Brosme brosme*	6	9.7
		Totals	**73**	**217.0**
		Project totals (fish)	**712**	**2024.4**
Fish trap	Brown crab	*Cancer pagurus*	88	-
Fish trap	Common hermit crab	*Pagurus bernhardus*	1	-
Fish trap	Red whelk	*Neptunea antiqua*	4	-
Fish trap	Velvet crab	*Necora puber*	7	-
		Project totals (invertebrates)	**100**	-

Objective 1 - Deployment at depth

A considerable amount of design went into ensuring the fish traps would deploy in the right orientation and extend fully given the depths these traps were expected to function in. A buoyancy gradient from a very positively buoyant top section to a very negatively buoyant bottom section was built in to facilitate this. Extension and correct buoyancy were tested and perfected at tank facilities at Marine Laboratory prior to full trials. Overall the fish traps were deployed at a wide range of depths ranging from 46 m just outside Loch Clash to 550 m on blue ling grounds west of Lewis. There were eight valid deployments over 100 m depth (110 m, 128 m, 150, 160 183 m, 185 220 m, and 550 m) and a further one which was a camera deployment only in 217 m depth. Despite the nature of the ground in some of these being challenging (rocky peaks, wrecks, pipelines) there were no instances of the fleets becoming stuck, no loss of individual traps, no tangling of main rope or branch lines on retrieval and no significant damage to any of the traps. This reflects both the refinement in attachment method already mentioned and the robust build of the traps which were built with the demanding seabed in mind. With the exception of the very deepest deployment, which was declared void as it seemed apparent that the bait had been scavenged, these also all represent the best catches achieved during the trials. Deployment Number 4 in 220 m depth on *Mars* wreck caught approximately 250 kg of highly marketable large ling. This particular deployment was notable in that the main line was observed to be marked with rust indicating its contact with corroded debris and showing that it had been shot in extremely close proximity to the wreck itself while avoiding hook-ups on retrieval. Deployment Number 5 in 180 m depth adjacent to a pipeline caught 180 kg, all of commercial species with no individuals below MCRS. Deployment number 15 in 185 m at *Adonis* wreck caught 697 kg of mixed commercial species (though with nearly twice as many traps in the fleet as compared to most deployments). Camera footage obtained during Deployment Number 8 in 220 m depth confirmed the traps deploy upright on the seabed as expected.

Although not shot in areas particularly prone to strong tides there was no evidence of the fleets having moved from their shooting position. The end ropes were always rigged over-depth so the marker buoy was always found to be positioned according to the tide in relation to the exact location of the fleets but as the fleets were hauled it was apparent that the traps themselves were close to the original position. All fleets surfaced with no tangling or damage and we are confident the fleets extended, remained in position, and fished very well at the same depth ranges as covered normally by the upper shelf whitefish trawl sector. While the decision was made to neither deploy the traps nor attempt recovery of them in the worst conditions encountered, there were no issues with undertaking either during the moderately poor sea states the vessel normally worked in.

Objective 2 - Catch composition and catch rates

Catches varied a great deal between fish trap deployments. Offshore grounds were targeted, however getting to these was not always possible in winter conditions and some inshore sites had to be introduced out of necessity. Overall the catches in all deployments generally consisted of mixed species of commercial gadoids along with a greater or lesser amount of miscellaneous other species (Table 2) of which only two species, however, were particularly prominent: conger eel and lesser spotted dogfish. The catches by deployment (Table 13) show that conger eel was highly prevalent as expected at oil pipeline (Deployment 5) with 122 kg being caught there, and also at *Mars* wreck (Deployment 4) where 38 kg was recorded, both from fleets of eight traps. In some cases a single species dominated: catches from *Mars* wreck predominantly consisted of large ling while those from Nun Bank predominantly consisted of medium to very large size haddock. Lesser spotted dogfish were only caught in prominent numbers at *Able* wreck (Deployments 6 and 12) and it is noticeable that these deployments at *Able* did not also capture any of the larger predatory fish (ling and cod).

Bycatch (here defined as non-quota species of low or zero commercial potential) was observed to be low overall in both weight and number. Four out of the thirteen valid fish trap deployments contained no bycatch at all. Bycatch species constituted ballan wrasse, cuckoo wrasse, goldsinny wrasse, long rough dab, common dab, poor cod, three-bearded rockling and, most prominently, lesser spotted dogfish. Where lesser spotted dogfish, a moderately sized fish, was a large component of the catch, the bycatch becomes highly significant by weight and this was the case in Deployments 2 (low overall catch), 6 and 12 (both at *Able* wreck). Thus in cases where bycatch was present this ranged from 2.0-57.0% by number and 0.1-43.5% by weight with a mean of 15.7% by number and 3.8% by weight over the thirteen deployments (Table 3).

The results for quota species under MCRS stand out in the case of the fish traps with only seven individuals (three cod, two ling, one saithe and one haddock) recorded as undersize over the course of the study. Of these, the haddock and the two ling came from the offshore grounds while all three of the undersize cod and the saithe came from the contingency deployments inshore. Nine out of the thirteen valid fish trap deployments contained no fish under MCRS. On the basis of individual fish trap deployments the fish under MCRS represent 1.0-1.9 % by weight and 4.5-13.3% by number (Table 4); the highest values of these coming from those where overall catch were particularly low (inshore contingency Deployment 10). As a percentage of the total catch from all 13 valid fish trap deployments combined, these represent 1.1% by number and 0.1% by weight.

Jigging proved successful with 108 kg of commercial species, predominantly cod and ling recorded from each two hour session using three jiggers each with 5 hooks. The catch included a total of six ling under MCRS representing 8.2% by number and 3.1% by weight. There was no bycatch, as defined above, from either of the two jigger deployments.

Table 2

Catch composition. Deployments are grouped into offshore and inshore as regarded by the commercial fishing industry.

Deployment no.	Location	Ballan wrasse	Catfish	Cod	Common dab	Conger eel	Cuckoo wrasse	Goldsinny wrasse	Haddock	Lemon sole	Lesser spotted dogfish	Long rough dab	Ling	Plaice	Poor cod	Saithe	Spurdog	3-bearded rockling	Torsk	Whiting
2	Offshore								*		*			*						*
3	Offshore			*					*		*		*		*				*	*
4	Offshore			*		*			*				*						*	
5	Offshore		*	*		*			*				*		*				*	*
9	Offshore					*			*		*		*						*	*
11	Offshore			*					*		*		*						*	*
13	Offshore			*		*							*						*	
14	Offshore			*		*							*						*	
15	Offshore			*		*							*			*	*		*	
16	Offshore			*									*			*	*		*	
17	Offshore			*									*			*	*		*	
6	Inshore			*	*				*		*	*								*
7	Inshore	*		*			*	*			*		*		*	*				
10	Inshore			*	*				*				*							
12	Inshore			*	*	*			*	*	*		*	*				*		*

Although the data is such that we cannot analyse for soak time we can however provide the weight range caught by deployment type. Using catch rates standardised to a fleet of eight traps the offshore deployments catch rates (total weight followed by commercial weight in brackets) ranged from 12.7 kg (6.9 kg) at Papa Bank clean ground to 379.1 kg (379.1 kg) at *Adonis* wreck. Overall the total weight caught offshore (101 traps in total) was 1691 kg of which 1658 kg (98.0%) were commercially valuable species. For inshore deployments (24 traps in total) catch rates ranged from 14.0 kg (10.9 kg) at Loch Clash to 52.7kg (29.9kg) at *Able* wreck. Overall the total weight caught inshore was 116 kg of which 77 kg (66.7%) were commercial species. As stated already much of the weight of the remaining inshore non-commercial catch was due to the lesser spotted dogfish component.

Table 3

Summary of bycatch and quota species <MCRS by weight (kg) and by number. Percentages are those of total catch weights and numbers. Inshore contingency deployments denoted by *.

deployment no.	gear (no. of traps/hooks)	total catch no.	total wt.	commercial catch no.	commercial catch wt.	bycatch no.	bycatch % no.	bycatch wt.	bycatch % wt.	< MCRS no.	< MCRS % no.	<MCRS wt.	<MCRS % wt.
2	fish traps (8)	15	12.7	10	6.9	4.0	27	5.5	43.3	1.0	6.7	0.2	1.9
3	fish traps (8)	26	39.1	22	36.8	4.0	15	2.2	5.6	0	0	0.0	0
4	fish traps (8)	60	258.6	60	258.6	0	0	0	0	0	0	0.0	0
5	fish traps (8)	29	181.9	28	181.8	1.0	3.0	0.1	0.1	0	0	0.0	0
6*	fish traps (8)	78	52.7	43	29.9	35	45	22.9	43.5	0	0	0.0	0
7*	fish traps (8)	30	14.0	17	10.9	12	40	3.1	22.1	2.0	6.7	0.5	1.5
9	fish traps (8)	44	98.3	19	76.7	25	57	21.6	22	0	0	0.0	0
10*	fish traps (8)	15	15.3	10	14.3	3.0	20	0.7	4.6	2.0	13.3	0.2	1.6
11	fish traps (8)	51	43.4	50	42.5	1.0	2.0	0.8	1.8	0	0	0.0	0
12*	fish traps (8)	36	33.9	20	22.2	16	45	11.7	35	0	0	0.0	0
13	fish traps (15)	44	118.3	42	115.9	0	0	0	0	2.0	4.5	1.2	1.0
14	fish traps (15)	79	241.7	79	241.7	0	0	0	0	0	0	0.0	0
15	fish traps (15)	135	697.4	135	697.4	0	0	0	0	0	0	0.0	0
totals (fish traps)		**642**	**1807.3**	**535**	**1735.6**	**101**	**15.7**	**68.6**	**3.8**	**7.0**	**1.1**	**2.1**	**0.1**
16	jiggers (3 x 5)	35	108.8	33	106	0	0	0	0	2.0	5.7	2.8	2.6
17	jiggers (3 x 5)	38	108.2	34	104.2	0	0	0	0	4.0	10.5	4.0	3.7
totals (jiggers)		**73**	**217**	**67**	**210.2**	**0**	**0**	**0**	**0**	**6.0**	**8.2**	**6.8**	**3.1**
combined totals		**715**	**2024.3**	**602**	**1945.8**	**101**	**14.1**	**68.6**	**3.4**	**13**	**1.8**	**8.9**	**0.4**

Table 4

Details of bycatch and quota species under MCRS**.** Species codes (common name): PCO (poor cod), LSD (lesser spotted dogfish), LRD (long rough dab), BWR (ballan wrasse), GOS (goldsinny wrasse), CUW (cuckoo wrasse), CDA (common dab), TBR (3-bearded rockling), COD (cod), HAD (haddock), LIN (ling), SAI (saithe). Inshore contingency deployments denoted by *.

Deployment	Gear (no. traps/hooks)	Bycatch detail (number caught)	< MCRS detail (lengths)
2	fish traps (8)	LSD (2) PCO (2)	HAD 29cm
3	fish traps (8)	zero bycatch	zero < MCRS
4	fish traps (8)	zero bycatch	zero < MCRS
5	fish traps (8)	PCO (1)	zero < MCRS
6*	fish traps (8)	LSD (34) LRD(1)	zero < MCRS
7*	fish traps (8)	BWR (4) GOS (1) CUW (1) LSD (3) PCO (3)	COD 17cm SAI 32cm
9	fish traps (8)	LSD (25)	zero < MCRS
10*	fish traps (8)	CDA (3)	COD 21cm, 23cm
11	fish traps (8)	LSD (1)	zero < MCRS
12*	fish traps (8)	CDA (1) LSD (14) TBR (1)	zero < MCRS
13	fish traps (15)	zero bycatch	LIN (56cm, 62cm)
14	fish traps (15)	zero bycatch	zero < MCRS
15	fish traps (15)	zero bycatch	zero < MCRS
16	jiggers (3 x 5)	zero bycatch	LIN (2 at 62cm)
17	jiggers (3 x 5)	zero bycatch	LIN (52cm, 54cm, 57cm, 58cm)

Objective 3 - Trap catch compared to adjacent trawl catch

Where appropriate, trawls that were undertaken as close to the deployment as possible were worked up for comparison purposes. Trawls by their very nature cover a large amount of ground to achieve their catch in a way that traps do not and comparisons between the two should be treated cautiously to avoid misleading interpretation. It may be that fish behaviour also has a significant role in the composition of the trap captures, for instance where numbers of very large predatory fish such as ling are captured (Deployments 4, 5 and 9) there may be potential for a deterrent effect on the subsequent entry of smaller species.

Deployment 5 (Oil Pipeline): Two commercial hauls were undertaken on commercial grounds in the vicinity of the trap deployment and while one haul became stuck on the seabed and was hauled back with major damage, the other was successful having a duration of five hours, and was able to pass within 400 m of the traps at its closest approach. The trap deployment was also successful despite a relatively short soak time of 12 hours with a catch equating to approximately 70% conger eel, 22% ling, and 8% mixed commercial species by weight with no fish below MCRS and a negligible amount of non-commercial bycatch (a single poor cod) in the whole trap fleet. This is to be compared to a trawl catch comprising of 20-25% for each of the following species; hake (*Merluccius merluccius*), haddock and saithe (*Pollachius virens)* with the remainder being a mix of other commercial species plus around 7% of non-commercial bycatch (Table 5).

Table 5

Catch comparison of species from Deployment 5 and adjacent trawl.

Deployment 5 Species	Traps wt (kg)	Trawl wt (kg)	Traps wt (%)	Trawl wt (%)
Angler	0	36	0	5
Catfish	2.2	0	1	0
Cod	7.6	47	4	6
Conger eel	121.7	0	67	0
Hake	0	148	0	20
Haddock	3.8	186	2	25
Ling	43.8	68	24	9
Mixed Species Flatfish	0	16	0	2
Saithe	0	173	0	23
Torsk	1.6	0	1	0
Whiting	1.1	21	1	3
Non-commercial	0.09	50	< 0.1	7
Totals	**181.9**	**745**	**100**	**100**

Deployment 11 (Nun Bank hard ground): A series of trawls was undertaken by *Carina* just off the very hard non-trawlable ground at Nun Bank where a fleet of traps was deployed. The catch in these trawls consisted largely of clean haddock in good commercial quantity. A 4-hour tow located within the shortest distance to where the traps were deployed was worked up and compared with the catch from the traps (Table 6). Once again the trap fleet catch, though moderate in overall weight, consisted only of commercial species with haddock contributing to 75% of that, with all species well above MCRS and no bycatch retained. The catch from the trawl exhibited a somewhat similar figure by weight in terms of haddock (83%) however there was a much broader size range (24-57 cm) for the trawl as compared to that from the trap fleet (33-54 cm) including 16.6% by weight under MCRS. The trawl also showed a non-commercial bycatch of 13% by weight. Due to the vastly numerical superiority of the trawl catch as opposed to the trap fleet catch it is not instructive to compare the actual numbers caught directly, however, the numbers at size presented as a percentage of the total number were grouped into 5 cm length classes for both gears and presented in Table 7. Here it is noticeable that the size range for the trawl has its peak in the lower-mid range of the overall length frequency whereas that of the traps peaks close to the largest sizes encountered. While this result should be treated with caution, as it is based both on a single observation and

without the selectivity of these fish traps having been assessed, it could be considered as evidence that in this case the traps are able to fish successfully on a slightly different population (on average larger and higher value) of fish than the trawl did on the more standard grounds close by.

Table 6

Catch comparison of species from Deployment 11 and adjacent trawl.

Deployment 11 Species	Traps wt (kg)	Trawl wt (kg)	Traps wt (%)	Trawl wt (%)
Cod	3.3	0	8	0
Haddock	32.4	928	75	83
Ling	2.4	0	5	0
Mixed Species Flatfish	0	16	0	1
Torsk	4	0	9	0
Whiting	0.4	26	1	2
Non-commercial	0.8	150	2	13
Totals	**43.4**	**1120**	**100**	**100**

Table 7

Percentage caught by size range for haddock – comparison of trap and adjacent haul (Deployment 11).

Size range (cm)	Traps % caught at size range	Trawl % caught at size range
20-24	0	0.6
25-29	0	15.9
30-34	23.3	27.5
35-39	16.3	18.7
40-44	11.6	25.1
45-49	16.3	9
50-54	32.6	2.5
55-59	0	0.6
Totals	**100**	**100**

Deployment 4 (*Mars* wreck): No trawls close by the wreck were undertaken by *Carina* during the course of these trials. After deploying the fleet on the site of the wreck the vessel moved north to fish in Faroese waters, returning after three days to fish on more southern grounds and retrieve the fleet en route. However, the skipper of the *Carina* was able to provide an example from his log book of what a typical haul close to *Mars* during the summer would produce for the vessel. A comparison between this and the catch from the trap fleet is presented in Table 8. The trap fleet showed an 80% catch by weight of large white ling, with the other 20% being all

commercial species with none under MCRS and zero bycatch. A typical close by trawl catch of five hours duration at the same time of year and coming within 300 m of the trap deployment site, would be expected to produce around 20% each of large cod, haddock, saithe and hake with the rest being ling and angler *(Lophius spp)* etc. along with an associated non-commercial 5% bycatch. No saithe or hake were taken at all by the traps during Deployment 4 and no hake at all over the course of the project.

Table 8

Catch comparison of species from Deployment 4 and adjacent trawl (trawl data from vessel logbook).

Deployment 4 Species	Traps wt (kg)	Trawl wt (kg)	Traps wt (%)	Trawl wt (%)
Angler	0	120	0	10
Cod	7.1	234	3	19
Conger eel	38	0	15	0
Hake	0	228	0	18
Haddock	1.8	232	1	18
Ling	209.9	113	81	9
Mixed Species Flatfish	0	26	0	2
Saithe	0	238	0	19
Torsk	1.9	0	1	0
Non-commercial	0	65	0	5
Totals	**258.6**	**1256**	**100**	**100**

While caution must be exercised when looking into these results, overall there is some evidence that the fish traps can prosecute a very localised fishery, catching a completely different makeup of catch to that of a nearby trawl, in the case of the pipeline and also the *Mars* wreck, or a different (high end) length frequency of the same species in the case of Nun Bank.

Objective 4 - Fish behaviour in relation to traps

Use of camera equipment was restricted to the final five trips by which point the vessel was highly proficient in deploying and hauling the fleets. However, equipment setup required a stable working platform and a low risk deployment where the equipment would not be hooked up or towed away. Due to the extremely poor weather conditions experienced in the winter of 2019-2020 the opportunities to deploy the camera equipment were few, hence there was only one deployment made (Number 8) using a camera. This deployment was undertaken in deep water (217 m) on one of *Carina*'s clean ground trawl sites some 40 miles west of Shetland. A single trap was rigged with a GoPro Hero 7 plus auxiliary battery pack and light on a 1 m aluminium bracket attached to the underside of the base. The camera faced the end entrance to the trap, in an effort to establish how fish approach and enter the trap. The trap was deployed along with a single end weight and rope directly on the hauling position of one of *Carina*'s trawls. On retrieval some two hours of clear footage was obtained before the light diminished. Three instances of ling approaching the entrance were seen (Figure 12) where the fish turned to face the light before departing without having attempted an entry to the trap. The trap was observed to be empty of any catch. This was the only combination of good sea conditions and low risk deployment before the end of the project. With this limited data we cannot draw any conclusions with fish behaviour with regards to the effects of lights in association with the traps. To look at general fish behaviour in relation to the trap itself we needed to locate an area of significant target fish species capture ideally shallow enough for no external light source to be necessary. A deployment in Thurso Bay (51 m) was seen as having as potential as just such a site, however catches were lacking in target species. However, we can foresee this being a useful study for future occasions where the economics play a less important role in the project. Importantly the footage was able to confirm that that the trap was orientated correctly on the seabed and performing very much as expected.

Objective 5 - Factors affecting trap catch rates

The variables in the data are considerable and repeatability was found to be low. Soak times ranged from six hours to 19 days (the very long deployments due to circumstances outwith control) and only the *Able* wreck (Deployments 6 and 12) was visited more than once over the course of the trials. As it became apparent during the course of the trials that the variance would be high it became necessary to limit this as much as possible, and ideas such as looking into the effects of a change of bait or incorporating lights into the traps to influence behaviour were put aside as potential for future projects. With a dataset that is moderate in size only and the associated variables high no analysis was made of any of the factors to avoid misleading results. The factors affecting catch rates are poorly understood however those expected to be important include: bait type (as certain species will certainly exhibit bait preferences), the duration that the bait remains attractive and tidal strength and direction as these will both directly influence the bait plume and thus the ability of the bait to attract fish out with the immediate vicinity. We can also anticipate a seasonal effect for species such as cod in some areas and we can postulate a further range of subtle factors such as daylight length amongst many others also playing some part in catch rates.

Objective 6 - Potential commercial viability

The total number and weight of catch for all species from 13 deployments with the traps was calculated. We have included deployments close inshore even though these were not part of the original project plan but have not included Deployments 1 (void) or 8 (camera). The marketable catch used for the valuation estimates consisted of cod, conger eel, haddock, lemon sole, ling plaice, saithe, torsk, spurdog and whiting. Using an average of Shetland and Peterhead market prices from Scottish White Fish Producers Association (SWFPA) online data the price per kilo was calculated based on marketable catch weights in conjunction with average and maximum price, relative to the date the deployments took place and price achieved at market on that day. Average and total maximum value per species and the average daily income per hauled trap is calculated (Table 9). Ling was most prevalent by number with 217 individuals retained across all trap deployments and also the highest in terms of weight (1061 kg) and value (average value £1819 and maximum value £2673). A total of 63 cod were caught by the traps contributing 168 kg to the weight and value (average £508, maximum £937). Moderate quantities of haddock were caught (89) primarily from Deployment 11 at Nun Bank, however, many of these were very large individuals fetching a premium price (average £133, maximum £234). Torsk and conger eel also featured strongly in the catches. Together these species represent exactly those targeted during the development of this project. The daily income per hauled trap based on the grand total of 125 traps and prices achieved at the market was £21.98 and £36.07 average and maximum value respectively over the period of the trials. Note that the analysis necessarily included the data from Deployments 7 and 10 which were the two commercially unsuccessful deployments very close inshore and which, along with the poor catches from Papa Bank and *Able* wreck, have forced the overall average considerably down.

The catch from the jigging systems were valued in the same way (Table 10) aggregating catch from all three jigging systems over both deployments. Again ling were the most prominent species by total number and weight (40 for 113 kg), however, the estimated average and maximum values of these at £194/£285 came second to the 19 cod (68 kg) which gave values of £207 and £382 respectably. Other marketable fish were saithe, torsk and spurdog although all much less significant by weight and number. In terms of value per effort the two jigging drifts combined gave estimated values of £104 and £176 per hour with three jigging systems each using five hooks. The value achieved from each deployment is summarised in Table 11.

Table 9

Summary table of catch from 125 fish traps over period of project; total numbers caught by species, whole weight and post-processed (gutted where appropriate) weight (kg) of marketable, along with average and maximum value achieved at market based on fish prices relative to trap deployment dates.

Species	*Total Number caught*	*Total whole weight*	*Total gutted weight (marketable only)*	*Average value*	*Max value*
Catfish	1	2.20	1.90	£5.02	£5.23
Cod	63	168.23	143.60	£508.34	£937.70
Conger eel	50	254.82	254.82	£150.34	£229.33
Haddock	89	68.40	58.37	£133.08	£234.64
Lemon sole	4	2.00	1.90	£9.03	£28.04
Ling	217	1061.51	937.96	£1,819.65	£2,673.19
Plaice	5	2.80	2.60	£6.08	£9.72
Saithe	9	7.18	5.73	£7.10	£12.31
Spurdog	1	3.50	3.50	£0.88	£0.88
Torsk	69	152.18	140.49	£94.12	£345.59
Whiting	25	12.70	11.20	£13.78	£32.14
Totals (125 traps)	**533**	**1735.51**	**1562.05**	**£2,747.41**	**£4,508.78**
	Average value per hauled trap			**£21.98**	**£36.07**

Table 10

Summary table of catch from jiggers (3 x 5 hooks fished for four hours) in December 2022; total numbers caught by species, whole weight and post-processed (gutted where appropriate) weight (kg) of marketable, along with average and maximum value (£) achieved at market based on historical fish prices relative to trap deployment dates.

Species	*Total Number caught*	*Total whole weight*	*Total gutted weight (marketable only)*	*Average value*	*Max value*
Cod	19	68.56	58.60	£207.43	£382.63
Ling	40	113.03	100.07	£194.13	£285.19
Saithe	3	7.19	6.04	£7.49	£12.99
Spurdog	5	18.50	18.50	£4.63	£4.63
Torsk	6	9.70	8.95	£6.00	£22.02
Totals 3 x 5 hooks / 4 hrs	**73**	**216.98**	**192.16**	**£419.67**	**£707.46**
	Value (3 x 5 hooks) per 1 hour:			**£104.92**	**£176.86**

Table 11

Summary of estimated value per deployment for fleets of eight and 25 traps over period of trials.

Deployment	effort (no. traps)	Average value	Maximum value	Maximum value (25 traps)
2. Papa Bank	8	£13.12	£23.14	£72.31
3. Papa Bank	8	£91.44	£166.26	£519.56
4. *Mars* Wreck	8	£408.67	£613.12	£1,916.00
5. Pipeline	8	£184.86	£287.62	£898.81
6. *Able* Wreck	8	£62.60	£117.15	£366.09
7. Loch Clash	8	£10.43	£16.50	£51.56
9. Unknown wreck	8	£123.46	£189.22	£591.31
10. Thurso Bay	8	£33.81	£59.30	£185.31
11. Nun Bank	8	£81.15	£147.74	£461.69
12. *Able* Wreck	8	£47.24	£92.97	£290.53
13. Box of wrecks	15	£173.48	£290.61	£544.89
14. Monk Alley	15	£355.18	£636.20	£1,192.88
15. *Adonis* Wreck	15	£1,161.99	£1,868.98	£3,504.34
Totals (traps)	**125**	**£2,747.43**	**£4,508.81**	

Economic assessment

FIS025 was not undertaken with the demersal trawl sector in mind for any potential take up of fish traps as an option. From a technical standpoint while also taking into account the skill and knowledge base available, we suggest that the most suitable vessels for uptake would be large the crabbing vessels included in the pots and traps >12 m fleet segment. This is due to large vessel size, the deck layout in many being particularly suitable in terms of self-shooting static fishing gear, the powerful retrieval equipment available on board, the track record of working in the offshore grounds, and not least, the experience and knowledge base inherent to working on these grounds. It is important to note the traps could be an alternative option to generate significant income in times when crab fishing was uneconomic. An initial issue may be the availability of fish quota for this sector and this may need some political input to resolve.

Changes in total revenue, fuel costs, crew share and other associated costs have fluctuated considerably over the protracted period of this study and economic performance data of the Scottish fleet that is available (up to 2022) is unlikely to represent the situation going forward from 2024. The viability will be best assessed on a vessel by vessel basis by the owners themselves with the assistance of the catch rates and information detailed in this report, most notably by the weights recorded from each deployment.

Additional observations

Despite a considerable combined total soak time of 7680 hours using 145 fish traps there were no incidents of marine mammal, cetacean, or birdlife capture either entangled in the ropes or held inside the traps themselves.

6. Discussion

The project, in terms of field work had an extremely slow start due to a halt on all charters undertaken by MD that lasted for several months. Frustratingly this commenced right at the period where the fieldwork would have begun, consequently the project was unable to take advantage of the unusually mild winter conditions experienced during 2018-2019. To compensate for this the project was extended to cover the winter of 2019-20 as opposed to being completed by the original date of November 2019. Unfortunately, this coincided not only with one of the worst winter sea conditions of recent years with the compounding factor that, unlike the winter previously, the economics surrounding commercial fishing did not favour projects of this type. This had the effect of forcing the undertaking of deployments in what can only be described as marginal conditions as and where the chance arose. The situation impaired ability to plan in advance where deployments could be achieved or being able to direct effort to particular areas as the vessel responded in real time both to the sea conditions and also to market forces. This impacted heavily on the intended repeatability during the project and in fact only one site (*Able* wreck) was visited more than once. Soak times were similarly impacted with the same factors being responsible for the large amount of variability into the data. The very end of the project was impacted by the Covid-19 pandemic with MD putting limitations on chartered vessel fieldwork that effectively removed any opportunity to complete the project from between early 2020 and late 2022. With only limited deployments and a large number of variables the data are too sparse to enable any meaningful analysis into the factors affecting catch-rates or any seasonal effect. Fewer truly offshore sites were deployed on than envisaged during the planning stages and the overall results reflect that. However, the project did record some tremendous results on deep non-trawlable areas (Figures 10 and 11). Moreover, these catches came from short fleets of only 8-15 traps, much fewer than might be expected to be worked in a commercial context.

Deployment logistics were pre-planned by MD scientists in collaboration with the skipper of *Carina* and, once finalised and tested, proved to be a simple affair with the traps largely self-shooting as fleets of creels do on many modern creel vessels. Hauling the fleets likewise quickly became a very simple and safe operation even in moderate seas. The traps were designed so that even if one enters the water upside down it will right itself on descent, an important feature during deployment in poor sea conditions. The process of shooting and hauling the traps on-board *Carina* was not at all hindered by the fact that the vessel is a purpose built and working trawler. This serves to show that the compact design and ease of use of the traps can support its potential viability to be used in conjunction with other fishing techniques without interfering with the current fishing practice of the vessel.

Careful consideration was made of weather conditions and the switch was made to contingency deployments in sheltered areas where there were safety doubts. The safety advantages of the long clear deck on *Carina* were very apparent as the lack of any crew contact with the gear following initial deployment of the first weight, surface markers and ropes allowed risk-free shooting.

Soak times varied considerably from six hours to nineteen days, the latter extreme case due to unforeseen circumstances. In all cases the bait was gone on retrieval indicating that soak times need not necessarily be long for successful catches to be obtained.

This design of fish traps, in the configurations used on offshore grounds, are capable of the capture of moderate to large numbers of valuable commercial fish in the highest size ranges. An exception to this was found on the clean ground at Papa Bank where commercial catches were poor and lesser spotted dogfish were prevalent. While a potentially trawlable site, this particular location was also featureless and possibly just represented an area of low commercial fish density at that time. The most successful deployments caught large quantities of predatory “cover-loving” fish such as ling, conger eel and cod with haddock and torsk in lower but still significant amounts. Interestingly the trend at the Nun Bank deployment was for considerable quantities of very large haddock with only very small amounts of other species being recorded. Analysis of trawl catches as close as possible to the trap deployments showed in the case of the pipeline and *Mars* wreck that a considerable component (around 40% by weight) of a typical trawl catch may consist of large size saithe and hake. Both of these are considered bentho-pelagic live fish predators and this is corroborated by the observation of quantities of whole small fresh fish in the digestive tract of those species during processing of the trawl adjacent to the pipeline. As such these are considered unlikely to be caught in traps with the particular bait used. Despite some small saithe being caught in Deployment 7 close inshore, other trials ((MacDonald and Mair, 2017) are in agreement that saithe are rarely caught in traps.

Despite the low number of hooks in each set (five) both jigger deployments produced very good catches of valuable species of top quality, the largest component of which were ling and cod. Most were well above marketable size although six ling <MCRS were caught this should not represent a major issue (see Section 6.1 Selectivity and the landing obligation) and could be much reduced by a switch to larger hooks than used here. Notably there were zero bycatch species caught with this method. The technique shows great promise commercially, and may be used in conjunction with traps, for instance, these can be worked over the duration of the soak period. In the case of trials on board *Carina,* fish were manually hauled aboard the few metres from the waterline to the gunnels resulting in several large and valuable fish being lost off the hooks, however, in a commercial situation this would be resolved by gaffing, netting or simply being closer to the waterline. The chance to look into incorporating the jiggers was only available at the end of this project, however, it is clear that further tuning of the technique would undoubtedly enhance its commercial effectiveness.

The fish caught in the traps were observed to be in similar excellent condition, lively and of top marketable quality, including those from over 200 m depth. Offshore we observed overall bycatch to be very low (9.8% by number and 2.4% by weight) and the capture of quota species under MCRS to be even lower (0.6% by number and 0.1% by weight). The inshore wreck deployments consisted of moderate catches a major component of which however was the relatively large sized bycatch species lesser spotted dogfish; thus overall inshore bycatch figures were higher (40.7% by number and 32.8% by weight) as a result. The figures for capture of quota species under MCRS were also higher (3.3% by number and 0.8% by weight) though again based on very low numbers overall. The deployments close inshore proved disappointing with low catches; however the skipper's opinion was that this would almost certainly be the case for attempts close by with mobile gear as well. It must be noted that these deployments were positioned where it was possible to do so safely rather than targeting any particularly likely fish-holding grounds and in addition neither had particularly long soak times. The only instances of cod under MCRS being reported during the entire project came from these close inshore deployments.

The traps were able to be deployed very successfully at depth on hard and otherwise non-trawlable ground. All deployments with the exception of one, two, and ten were located at sites inaccessible to trawlers due the damage or loss of gear that would be sustained mobile gear on these grounds. Throughout the project there were no occasions when the traps became caught on wrecks or hard ground. In situations where this may arise, however, the end being hauled can be dropped or cut if necessary and the other end picked up allowing the fleet to be hauled from the opposite direction. The branch lines were made deliberately from lower breaking strain ropes to allow loss of single traps, should any become stuck, improving the chances of successful retrieval of the remaining section of the fleets.

It is likely that market prices used here were conservative even at the time and in fact due to the quality of the fish noted above and the environmentally friendly method used premium prices may be achieved with thought as to sales strategy. This would further boost the income generated from the traps, in a similar way to that achieved with cod pots in the Newfoundland markets (Sullivan and Walsh 2010). Targeting niche markets and premium prices for the fish catch could make it a lucrative technique to pursue for some sectors in times where the economics of other forms of fishing were unattractive. Fishers may wish to envisage a phased approach to using the whitefish traps, and starting with a moderate number of traps as a source of additional income seems a potential route for uptake. Due to the nature of commercial crab fishing, skippers will already be aware of areas where their crab creels tend to catch more fish and this prior knowledge also supports indicating them as the fleet most suited to using the fish traps. It would be possible for vessels to deploy a low number of fleets of traps to be hauled at the end of a crabbing day and once knowledge of seasonal variation and area is developed and suitable markets found, judgements can be made on the commercial value of the fish traps as compared to the crab creels. In terms of marketing there is potential on the one hand in establishing short distance supply chains that could be with local restaurants/businesses collecting directly from the harbour and on the other in the growth of markets that publicise a product that is low on energy use, discards, and environmental impact. These markets will be seen as more important than ever with capability for strong growth in the light of climate change and the current publicity of marine micro plastics and other environmental concerns.

The analysis used local market prices for conger eel - one of the largest components of the catches from pipelines and wrecks and a resource that is largely untapped in the north-western waters of Scotland. Prices are variable for this species and may regularly be low on the home market. However, prices on the European market can be very strong and there is currently an extremely lucrative fishery for conger eel operating in the Bay of Biscay (personal discussion – Marine Directorate Compliance staff). This design of traps, worked in conjunction with mackerel bait, seems particularly adept at catching conger eel, a fact noted in previous trials (MacDonald and Mair, 2017). The numbers of conger eels filmed occupying spaces under and around pipelines has been commented on by the oil industry (personal communication), and fishers themselves have witnessed an increase in capture of these in north west and other waters over the past decade so it is possible that this species is highly abundant in the right locations. If this market can be accessed there may be potential for considerable profit. Again this points to the larger crab boats as being able to make the most of this where their “vivier” holding tanks may serve well for holding bulk live conger eel to a point where the economics of reaching the market become viable. A strong price for conger eel would be expected to considerably boost the economics of any potential trap fishery in our waters.

An additional benefit to the suggested large crab vessel sector is that there would be little requirement for vessel adaption to enable the use of the fish traps: the hydraulic haulers in place would be adequate and as the traps are collapsible, deck space would not be an issue either. Storage of fish catches may prove challenging particularly in instances of traps being used on a large scale, however, initially this could be overcome by utilising the vessel’s bait storage area for both fish and an ice machine.

The use of fish traps may also be able to support the fishing industry in general in helping them meet the requirements of climate smart fishing which focusses on making the sector sustainable in terms of social, economic and environmental factors. Due to the nature of fishing with traps, vessels employing this technique would incur far reduced fuel costs in comparison to that of trawlers which are constantly on the move to perform economically. This particular design and configuration of trap fleet demonstrated that it is able to fish passively over periods of severe weather conditions (Deployment 12) when set deep enough to avoid surface swell. This contrasts with the mobile sector which typically performs operations against any unfavourable weather thus requiring even higher energy use. As each trap is negatively buoyant to only 10 kg and the basal area in contact with the seabed is only 1.65 m^2 per trap for this particular design, their impact upon the seabed is expected to be minimal, an assessment in agreement with recent studies in the Bay of Biscay using Norwegian designs (Kopp et al 2020). Unlike mobile demersal gears abrasion against the seabed is minimal and of short duration (hauling only), thus in comparison we can also expect negligible contribution to marine micro-plastics using this technique. The possibilities of sourcing non-plastic material for construction of the covering mesh should be considered as this becomes feasible.

While the large whitefish trawler *Carina* was used as the platform for this study, it is unlikely that use of fish traps would be attractive to the business models of vessels from this sector, relying as they do on regular large volume landings of abundant species.

Retention of <MCRS quota species was very low in these trials, however there were capture of these during the trials - notably in the inshore deployments. While the purpose of these trials was to look into fish trap use on offshore deep-water fishing grounds, some fishers may see opportunities using these on grounds further inshore, where arguably there may be higher densities of smaller target species.

6.1 Selectivity and the landing obligation

These fish traps were covered by 60 mm diamond mesh throughout and are designed with the intent that most fish would end up away from the bait in the buoyant top parlour section. Here there is very little tension on the meshes allowing these to open to a large extent; much more fully than would be expected for the same size of mesh on a trawl for instance, where the lateral tension on the trawl as it is towed closes up the meshes. This feature, along with the extended time period where small fish can encounter these open meshes allows them ample opportunity for escape. As this is a non-mobile gear the fish escape back into their own localised habitat and are not subject to the trauma and decompression issues associated with having been pulled to the surface. In this respect the fish traps can be seen as a highly sustainable way of fishing. While the selectivity properties of the mesh used to cover static gear is currently only poorly understood and gaining scientific understanding of this was outside the scope of this project the results show that only seven quota species fish were under the MCRS, and few "small" fish of any species were retained during the course of the trial. However the catch analysis shows that there is still potential for <MCRS retention and the subject needs further investigation.

Under the current version of the Landing Obligation (Tech Con 1241/2019) use of fish traps is one of the methods with an exemption from the obligation in that live releases of quota species will not count against uptake. To quote the fishing vessel landing obligation guidance published by Scottish Government on 6 Feb 2020 - *If you use pots, traps and creels, then you will be able to return all catches of quota fish to the sea under a high survivability exemption in both the North Sea and North Western Waters. If you decide to retain these fish you must have sufficient quota including those non-sector vessels to be able to land and sell the fish. If you do decide to utilise the exemptions available you must record the approximate volume returned and which exemption is being utilised*. However, we must also note that - *An exemption can be withdrawn/closed if the levels of discard exceed the amounts allowed.* Under the scope of the Future Catching Policy published in 2020 (see Section 7) we may anticipate regulation for selective measures into the design. While the use of the traps is conceptualised with a premium size, condition and value of target species in mind, these fish traps could also be used in areas where a smaller size class of target species is prevalent. It is thus important that some baseline legislation be in place that to mitigate their retention.

It is noticeable that the jiggers produced caught ling under the MCRS for that species (8.2% by number and 3.1% by weight), however, it is likely that this could be markedly reduced or eliminated simply by increasing hook size.

Spurdog were caught at the end of the trials in December 2022 both in the traps and on the jiggers. This may reflect a seasonal change or the recent increase in abundance that has allowed fishers to land this species on a sustainable basis after having been managed as a prohibited species in UK and EU waters for around five years to facilitate stock recovery. Following a recently updated scientific assessment, the International Council for the Exploration of the Sea (ICES) has advised the stock is recovering and limited landings of spurdog can be supported again. Both UK and EU legislation prohibits landings of spurdog over 100 cm in length to discourage the targeting of larger females and provide protection for the breeding stock.

6.2 Other considerations

Ghost fishing of static gear is a concern worldwide and commercial versions of this design should have a very much reduced functionality in the event of them becoming lost. Derelict fish or crustacean traps are considered to have a negative economic and ecological impact and a loss of their ability to catch and retain fish without maintenance should be in-built. Suitable regulation could stipulate size, number and material for degradable panels, these to be constructed from environmentally neutral materials of which jute and bamboo are topical examples.

These traps have been designed with deep offshore waters in mind and there were no incidences of marine mammal capture during this project. There is potential for incidents of this nature if used in shallower waters inshore, where it is possible that seals or other mammals may gain entrance to the traps without preventative measures worked into the design. A size-restrictive collar that fits over the entrance holes has been developed with this in mind.

Cetacean entanglement is an issue that is becoming more prevalent both in Scotland and globally (NatureScot Research Report 1268) and, again while there were no instances observed during these trials some consideration of mitigation measures at this early stage is recommended. NatureScot Research Report 1268 and the Scottish Entanglement Alliance (SEA), with reference to the creel sector, highlights the socio-economic costs to the industry as well as animal welfare considerations and recommends mitigation measures such as negatively buoyant rope and ropeless technology.

This design of trap, the result of a decade of fine-tuning, has been proven to be effective. Where permitted, variants of these traps can be deployed as a sampling tool in sites closed (by legislation or by logistics) to mobile gears. Such sites may include protected areas, decommissioned oil and gas sites, or areas of potential infrastructure where a survey method is needed which can be used both prior to and following installation to allow for comparative assessment of fish populations. Contemporary examples include sites proposed for renewable energy production or for aquaculture e.g. static fishing gear trials at the Hywind floating offshore wind farm: f4acf4706c8b0ab0a270a1950e12cefb38361b6c.pdf (equinor.com).

7. Fish traps and the future catching policy.

In December 2020 the Scottish Government published a ten year Fisheries Management Strategy which set out an approach to deliver responsible and sustainable fisheries management in Scotland Future fisheries: management strategy - 2020 to 2030 - gov.scot (www.gov.scot).

The Future Catching Policy (FCP) is a key component of this Fisheries Management Strategy. It will address long-running operational issues with the landing obligation, which bans the discarding of fish, and will develop new and existing technical rules to increase selectivity across the fleet; whilst dealing with difficult discarding issues by simplifying the over-complicated exemption system. The FCP consultation ran in 2022 and analysis, alongside Scottish government response to this, was published on 14 August last year (2023). Within the response, the Scottish government stated that “under the scope of the FCP we will look at further defining specific technical measures (for fish traps) and how we may undertake improvements within this fleet segment to mitigate sensitive species bycatch”.

8. Summary

Deployment and operation of whitefish traps in deep water upper shelf locations has been proved to be successful and of great potential commercially. The traps and bait combination reported on here are adept at capturing large quantities of valuable fish such as ling, cod, and haddock and also, if the market can be tapped, conger eel. The technique is particularly well suited to fish capture on offshore non-trawlable ground such as wrecks, and around peaks on very hard seabeds. This has a dual advantage in that these locations are unable to be worked by the commercial mobile gear sector and so hold potentially unexploited populations of fish, and also because by the very nature of the locations there is no conflict with mobile fishing gears. The traps can be a commercially viable option for fishers either as an addition to their current standard fishing practice or as a means to generate income when their standard fishing practice is not possible i.e. out of season or when market prices are uneconomic. Using the fish traps in combination with another low energy technique such as jiggers is likely to improve profit beyond that achieved by the traps alone. The technique, in the areas trialled, has demonstrated a low impact on bycatch and undersize quota species. It represents a technique that is low impact on the seabed and local environment as compared to mobile gears and there is great potential for markets keen to publicise these features in the light of the environmental concerns that are rightly being given much consideration today. With the right marketing in place this in turn allows access to not only a potential for premium price on fish caught using this method, but access to markets where demonstrating sustainability and environmental credentials is critical. In terms of fishing grounds available, the skipper of *Carina* is confident that there is an abundance of areas considered unworkable by mobile gears that could be utilised. Studies on the use of selective devices in conjunction with fish traps are, however, needed to provide evidence for minimum standards for future use by fishers, ensuring that their use is in harmony with both the Landing Obligation and the Future Catching Policy whether they are used offshore or inshore. Fish traps could be made very size selective more easily than many mobile fishing gears and this would represent an improvement in the status of an already conservation-friendly gear.

9. Future work

Following initial consideration under the Scottish Government's Future Catching Policy (see Section 7. above) it is essential that minimum standards are set for commercial use of fish traps, both in terms of mitigating retention of undersize quota species and for purposes of simplifying accompanying legislation, a feature vital from a Compliance point of view. Thus some additional studies are required in the immediate future.

Bringing fish up to the surface from depth and immediately releasing them may still have an adverse effect on mortality rates (MD unpublished observations), the degree of which will depend on factors such as species, the water depth and condition of the fish. Thus over time, returning of undersize catch from the surface waters is still expected to have a negative effect on local populations and the ideal solution is to dispense with the need to bring the fish to the surface in the first place. The selectivity characteristics of square mesh in a non-mobile fishing gear are currently not as well studied as they are in mobile gears and the behaviour of fish to static square mesh panels is expected to be quite different. The fish traps used here require adjustments to design to allow the fitting of escape panels, with subsequent selectivity trials providing the evidence necessary to define minimum standards that will be in accordance with the FCP. Trials will initially be carried out using the Directorate’s inshore research vessel MRV *Alba na Mara* and will target populations of smaller size commercial gadoids than encountered during this project. Traps rerigged with netting turned on the square will facilitate fitting of square mesh escape panels and to provide sufficient selectivity data, catches from “test” traps fitted with escape panels constructed from one of three differing sizes of mesh will be compared against those from “control” traps i.e. those lacking any escape panel. Target species will be cod and haddock with the objective being to provide an estimate of most effective mesh size to mitigate retention of individuals <MCRS. The behaviour of target species with regard to the traps as a whole, and to various components of the traps, will be vital for confirmation or update of design, thus concurrent with the selectivity experiments additional traps will be rigged with cameras for collection of behavioural data. As substantial mixed catches may not be as common in static gears as they often are in mobile gears, any experiments will require to be realistic in expectations of capturing enough of the two main target species to provide a result for both. Potentially a follow-up trial may be needed which could provide additional data if needed or assess any design tunings that may arise. In practice the expectation is that the mesh size of escape panel demonstrated to be effective for cod (MCRS 35cm) will provide the evidence to set any minimum standards as this is substantially larger than that for haddock and whiting (30 cm and 27 cm respectively).

Of future interest.

Though not of immediate imperative there are many other factors that would benefit further investigation, one of the principal factors being bait choice. There were no variations in bait type employed over the course of this study with the fresh mackerel/crab combination being used in every deployment. This results show that, as expected, this bait is very appealing to large predatory fish such as ling, conger eel and cod, and also to large haddock. Some exploration of different baits would be informative – in particular squid where both loliginid species (plentiful but also a highly marketable and as such a costly bait) and ommastrephid species (often discarded in Scotland and thus potentially of low cost) could be trialled. Squid is an appealing bait for many demersal fish and may be more successful than mackerel for haddock where this species is in abundance (MacDonald and Mair, 2017, noted that haddock, unlike cod, is not often captured in crab creels and this may be due to a bait effect with commercial crab creels generally being baited with fish). Further baits could be trialled with other species in mind, perhaps taking cues from the angling sector where there is great expertise in matching bait to desired species. The presence of two commercial flatfish species (plaice and lemon sole), was notable while not completely unprecedented (quantities of large common dab (*Limanda limanda*) have been previously caught in traps deployed by MD in the Moray Firth), there may be potential for exploring if the overall design and bait can be customised to the more valuable flatfish species. In addition it would be worthwhile investigating what may be used to attract saithe and particularly lythe (*Pollachius pollachius*) into a commercial trap, the latter especially being a commercially valuable live fish predator species known to inhabit non-trawlable habitat and seabed obstructions.

The behaviour of fish in terms of how they approach and enter the trap has only been very lightly touched on during this study and many more questions on behaviour, each a study in itself, are important in understanding how this gear would function most efficiently in a commercial context. It would be useful to gain some understanding of any inhibitory effects on non-trapped fish merely from the presence of large predators either at the bait or in the holding parlour. In terms of catching power there is potential to further increase the volume of the traps. This may be a useful alteration where catches are high, and would allow design of the interior to move the catch even further away from the bait. We have no clear idea as to how long bait lasts in the presence of certain species such as conger eels or lesser spotted dogfish. Bait protection is something that could be explored both as a means of resisting breakup from target species and others as well as combating destruction from scavenging crustaceans and so prolonging the fishing capability. From both a design and a conservation perspective it would be informative to understand what proportion of each target species escapes from the holding parlours and what proportion do not become trapped at all.

It would be of great interest commercially to explore if a location that initially fishes well for large predators such as conger eel and ling will continue to fish well but for other species such as cod and haddock once numbers of large predators fall off though exploitation. This is a possibility that is supported anecdotally (personal communication from long line fishers). Are the former species quick to arrive at the bait, whereupon the bait is destroyed, leading to the trap becoming ineffective? Or may there be an inhibitory effect at work on other species arising from the presence of these large predators already being in the traps? Information to answer these and other questions like them are likely to become increasingly available as fishers take up the fish traps and apply their own problem-solving powers to making the best of the technique.

10. Acknowledgements

This report proving the effectiveness of a new method of fish capture would not have been possible without the wonderful interest and helpfulness of all aboard the *Carina*. Although the trap work was sometimes an extra duty all crew involved always gave one hundred percent and were enthused about the project at all times. Suggestions and ideas were always being offered and these were taken aboard by myself in any possible future projects and I note the genuine disappointment that was felt by all when the project completion was unavoidably postponed for a seemingly interminable period during the pandemic and after. A great deal of thanks is due to skipper Gary West for his commitment to the project in seeing it through to the end following a two-year hiatus. So much more to investigate but we have made a start here and my thanks to all involved.
Jim Mair

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12. Appendix

Figure 1: *Carina* BF803 was chartered for FIS025.

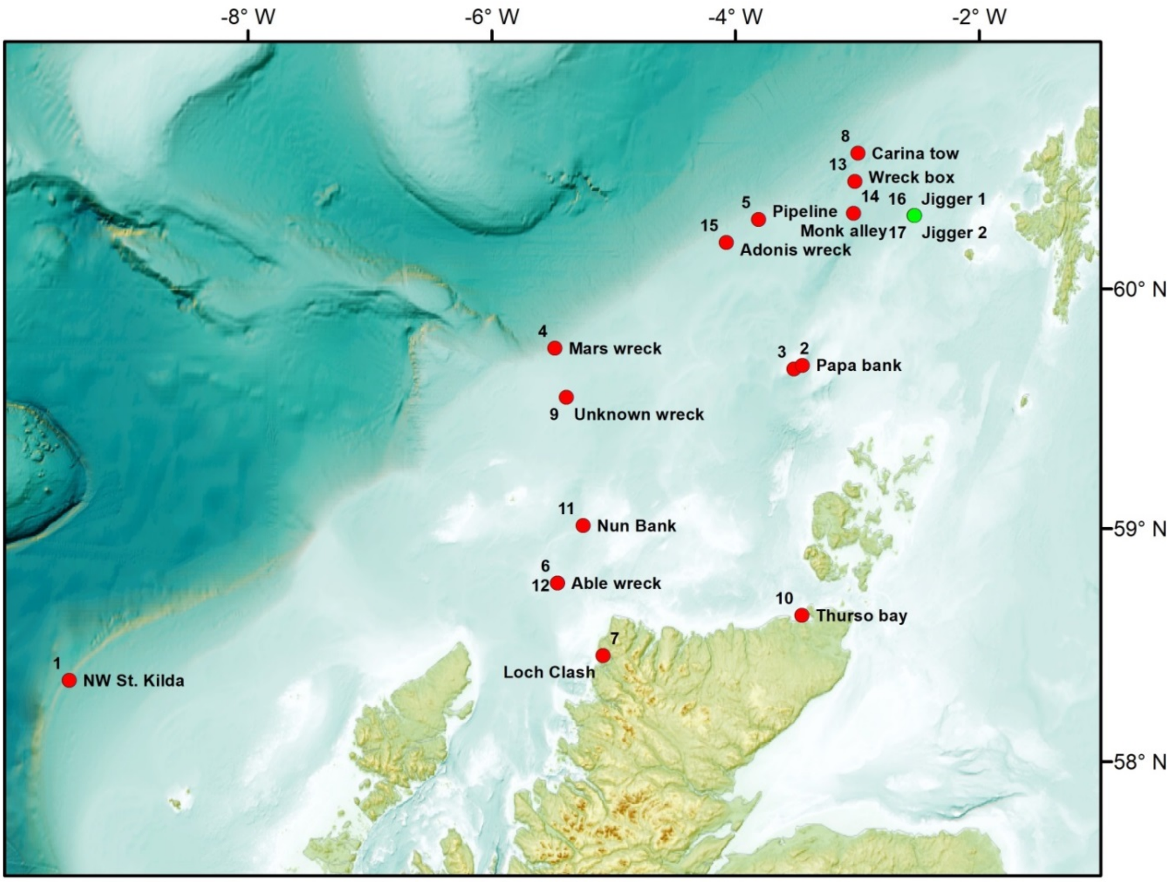

Figure 2: Map of all deployment locations, 1-17 (deployment number ordered by date). Note Jigger 1 and Jigger 2 are in almost the same location.

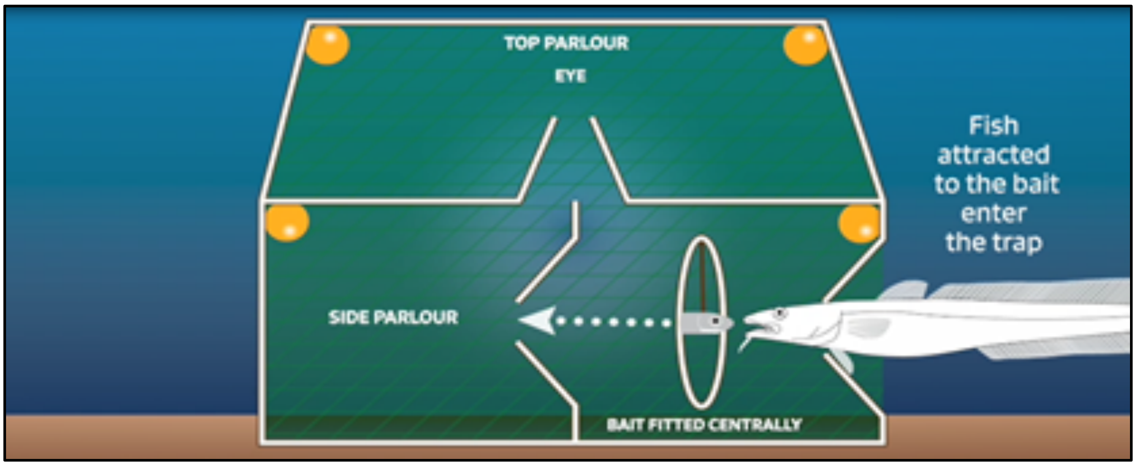

Figure 3: Schematic of triple compartment trap showing the two lower parlour sections where the bait is attached, the parlour sections and the float positions.

Figure 4: Fleet of eight traps compact and stowed on deck of the *Carina.*

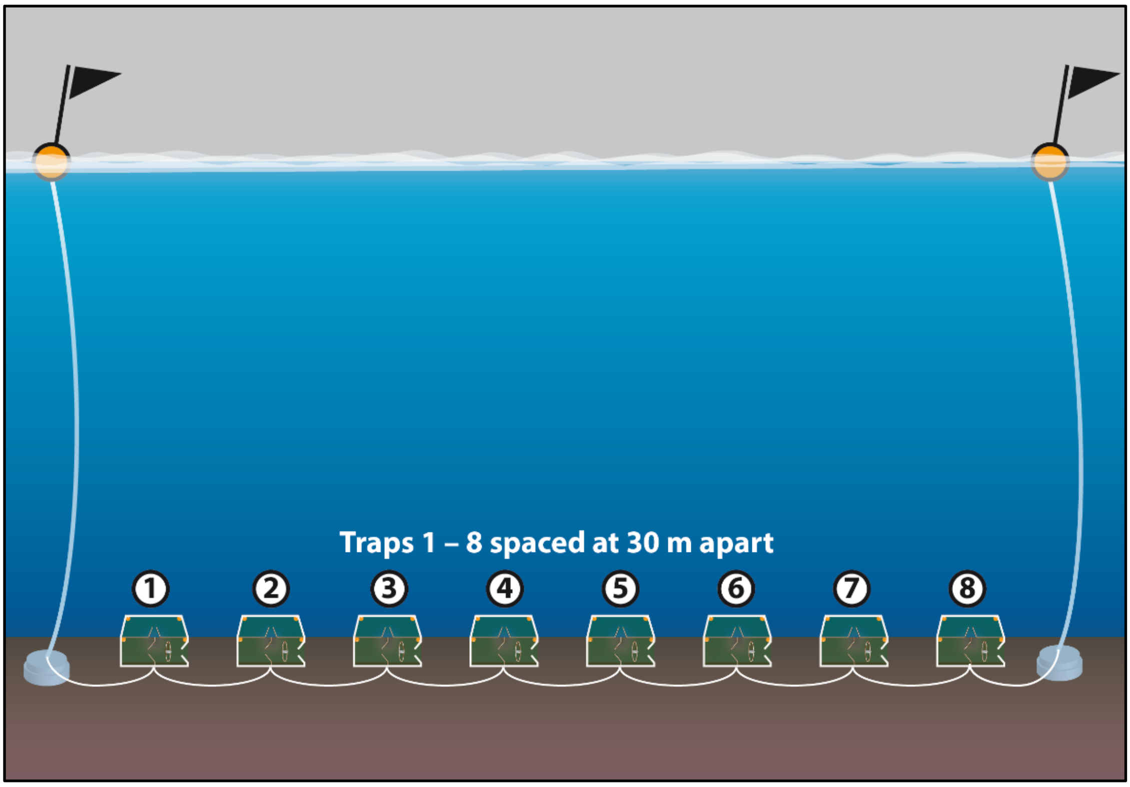

Figure 5: Layout of standard fleet used during FIS025.

Figure 6: Lures used during jigging deployments - lures were used with the bent-shank hook design pictured top left.

Figure 7: Method of attachment – trap attached to branch line by only one lower corner, a change to the original design which utilised a bridle.

Figure 8: Image of trap during the hauling process as it reaches the surface. The fish species observed captured are ling.

Figure 9: Standardised mackerel bait tied into the trap and sliced to create a strong scent release.

Figure 10: Image from Deployment 4 on *Mars* wreck: part of 260 kg fish catch of all commercially valuable species which predominantly consisted of large white ling.

Figure 11: Still from camera footage of Deployment 15 on *Adonis* wreck: another valuable catch - over 697 kg which predominantly consisted of large white ling, cod and torsk. Non-commercial bycatch and quota species under MCRS were both absent.

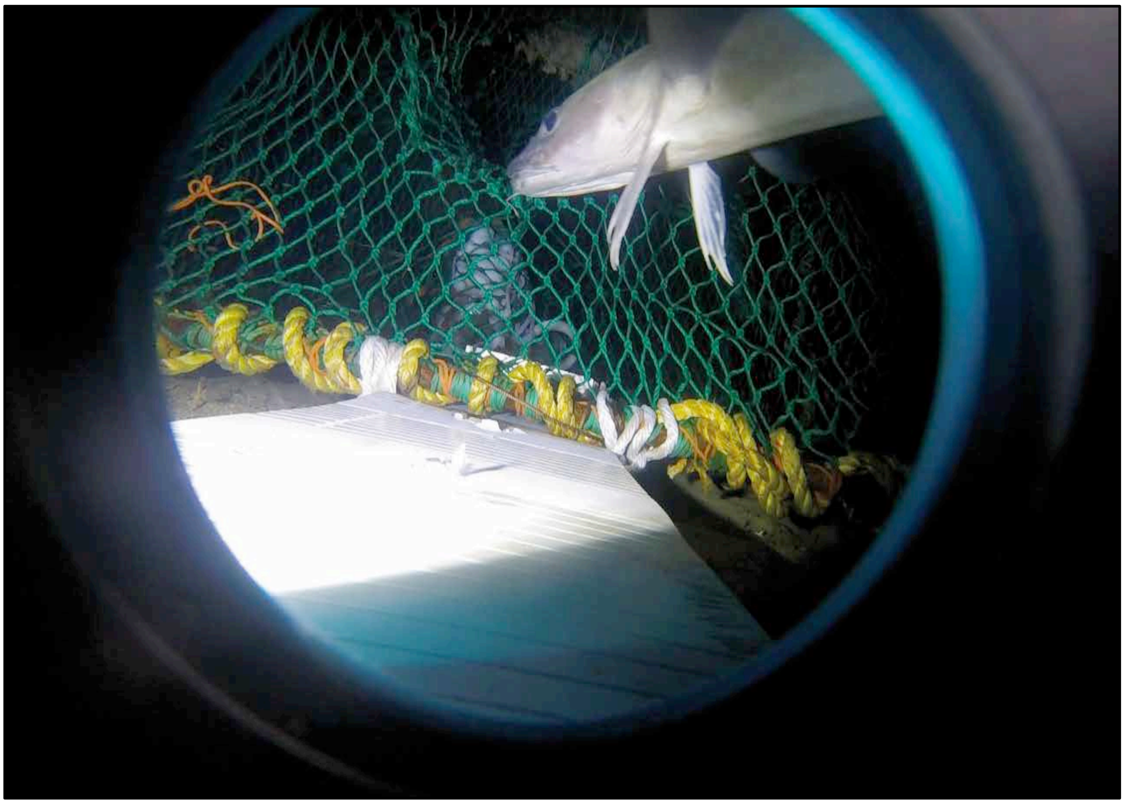

Figure 12: Deployment 8 showing trap in operation, correctly orientated on the seabed. A ling is observed approaching but not using the entrance, possibly as an effect of the light used in the deep (217 m) water

Table 12

Deployment summary

Dep no.	Gear	Date	Latitude	Longitude	Depth (m)	Soak time (hrs)	Soak time (days)	Area	Ground type
1	**Fish traps (5)**	28/08/2018	58° 21.00N	09° 28.00W	550	36	3	Blue ling ground	Offshore Clean Ground
2	**Fish traps (8)**	24/05/2019	59° 41.00N	03° 27.01W	128	24	1	Papa Bank	Offshore Clean Ground
3	**Fish traps (8)**	24/05/2019	59° 40.11N	03° 31.08W	73	24	1	Papa Bank	Offshore Rough Ground
4	**Fish traps (8)**	21/06/2019	59° 45.25N	05° 28.81W	220	72	3	*Mars* wreck	Offshore Wreck
5	**Fish traps (8)**	27/06/2019	60° 16.99N	03° 48.51W	183	12	0.5	Pipeline	Oil Pipeline
6	**Fish traps (8)**	01/07/2019	58° 46.06N	05° 27.50W	91	240	11	*Able* wreck	Inshore Wreck
7	**Fish traps (8)**	04/09/2019	58° 27.50N	05° 05.05W	46	12	0.5	Loch Clash	Inshore Hard Ground
8	**Fish traps (1)**	14/10/2019	60° 33.10N	02° 59.60W	217	6	0.25	Carina tow	Camera Drop
9	**Fish traps (8)**	18/10/2019	59° 33.02N	05° 23.13W	110	6	0.25	Unknown Wreck	Offshore Wreck
10	**Fish traps (8)**	04/01/2020	58° 37.77N	03° 27.23W	51	12	0.5	Thurso Bay	Inshore Clean Ground
11	**Fish traps (8)**	03/03/2020	59° 00.72N	05° 14.91W	70	12	0.5	Nun Bank	Offshore Hard Ground
12	**Fish traps (8)**	03/03/2020	58° 46.06N	05° 27.50W	91	456	19	*Able* wreck	Inshore Wreck
13	**Fish traps (15)**	16/12/2022	60° 26.18N	03° 01.08W	150	12	0.5	North of Box of wrecks	Offshore Rough Ground
14	**Fish traps (15)**	17/12/2022	60° 18.44N	03° 01.61W	160	12	0.5	Monk Alley	Offshore Rough Ground
15	**Fish traps (15)**	18/12/2022	60° 11.34N	04° 04.31W	185	12	0.5	*Adonis* wreck	Offshore Wreck
16	**Jiggers (3x5 hooks)**	16/12/2022	60° 17.91N	02° 31.85W	110	2	0.08	East of Foula Hole	Offshore Rough Ground
17	**Jiggers (3x5 hooks)**	17/12/2022	60° 17.94N	02° 31.59W	130	2	0.08	East of Foula Hole	Offshore Rough Ground

Table 13

Summary of catches by deployment

Deployment	Species	No.	Whole Weight (Kg)	Gut. Weight (kg)	Marketable Gut. Weight (kg)	Size range (cm)
1. North West St. Kilda	-	-	-	-	-	-
2. Papa Bank	Brown crab	34	-	-	-	-
2. Papa Bank	Haddock	6	4.1	3.6	3.4	29-52
2. Papa Bank	Lesser spotted dogfish	4	5.5	-	-	65-70
2. Papa Bank	Plaice	3	1.9	1.8	1.8	37-42
2. Papa Bank	Whiting	2	1.2	1	1	41-42
3. Papa Bank	Brown crab	4	-	-	-	-
3. Papa Bank	Cod	10	22.6	19.3	19.3	40-80
3. Papa Bank	Haddock	6	5	4.3	4.3	37-51
3. Papa Bank	Lesser spotted dogfish	2	2.1	-	-	65-66
3. Papa Bank	Ling	2	6.3	5.5	5.5	68-91
3. Papa Bank	Poor cod	2	0.2	-	-	18-21
3. Papa Bank	Torsk	1	1.3	1.2	1.2	-49
3. Papa Bank	Whiting	3	1.7	1.5	1.5	39-43
4. *Mars* Wreck	Brown crab	1	-	-	-	-
4. *Mars* Wreck	Cod	2	7.1	6	6	67-71
4. *Mars* Wreck	Conger eel	5	38	38	38	120-145
4. *Mars* Wreck	Haddock	1	1.8	1.5	1.5	-59
4. *Mars* Wreck	Ling	51	209.9	185.8	185.8	71-122
4. *Mars* Wreck	Torsk	1	1.9	1.7	1.7	-55
5. Pipeline	Brown crab	4	-	-	-	-
5. Pipeline	Catfish	1	2.2	1.9	1.9	-61
5. Pipeline	Cod	2	7.6	6.5	6.5	57-81
5. Pipeline	Conger eel	8	121.7	121.7	121.7	111-193
5. Pipeline	Haddock	4	3.8	3.3	3.3	42-50
5. Pipeline	Ling	10	43.8	38.8	38.8	70-102
5. Pipeline	Poor cod	1	0.1	-	-	-21
5. Pipeline	Torsk	1	1.6	1.5	1.5	-52
5. Pipeline	Whiting	2	1.1	1	1	39-42

6. *Able* Wreck	Brown crab	4	-	-	-	-
6. *Able* Wreck	Cod	8	10.4	8.9	8.9	41-61
6. *Able* Wreck	Common dab	3	0.5	-	-	24-26
6. *Able* Wreck	Haddock	18	12.2	10.4	10.4	31-59
6. *Able* Wreck	Lesser spotted dogfish	34	22.7	-	-	46-67
6. *Able* Wreck	Long rough dab	1	0.1	-	-	-25
6. *Able* Wreck	Whiting	14	6.8	6	6	34-42
7. Loch Clash	Ballan wrasse	4	2.7	-	-	29-37
7. Loch Clash	Brown crab	19	-	-	-	-
7. Loch Clash	Cod	1	0.1	-	-	-17
7. Loch Clash	Cuckoo wrasse	1	0.2	-	-	-24
7. Loch Clash	Goldsinny wrasse	1	0.2	-	-	-24
7. Loch Clash	Lesser spotted dogfish	3	2.4	-	-	59-61
7. Loch Clash	Ling	2	3.5	3.1	3.1	66-68
7. Loch Clash	Poor cod	3	0.3	-	-	22-23
7. Loch Clash	Saithe	8	4.6	3.9	3.6	32-38
7. Loch Clash	Velvet crab	7	-	-	-	-
9. unknown wreck	Brown crab	2	-	-	-	-
9. unknown wreck	Conger eel	1	3.4	3.4	3.4	-110
9. unknown wreck	Haddock	2	2.8	2	2	49-55
9. unknown wreck	Lesser spotted dogfish	25	21.6	-	-	54-71
9. unknown wreck	Ling	12	65.5	58.4	58.4	76-123
9. unknown wreck	Torsk	2	4	3.7	3.7	-56
9. unknown wreck	Whiting	2	1	0.9	0.9	36-41
10. Thurso Bay	Brown crab	5	-	-	-	-
10. Thurso Bay	Cod	7	6.4	5.5	5.284	21-61
10. Thurso Bay	Common dab	3	0.7	-	-	25-32
10. Thurso Bay	Haddock	6	4.5	3.9	3.9	33-54
10. Thurso Bay	Ling	2	3.6	3.2	3.2	65-70
11. Nun Bank	Brown crab	2	-	-	-	-
11. Nun Bank	Cod	3	3.3	2.9	2.9	42-51
11. Nun Bank	Haddock	43	32.4	28	28	33-54
11. Nun Bank	Lesser spotted dogfish	1	0.8	-	-	-64
11. Nun Bank	Ling	1	2.4	2.1	2.1	-74

11. Nun Bank	Torsk	2	4	3.7	3.7	55-57
11. Nun Bank	Whiting	1	0.4	0.4	0.4	-37
12. *Able* Wreck	Brown crab	4	-	-	-	-
12. *Able* Wreck	Cod	6	6.1	5.2	5.2	36-51
12. *Able* Wreck	Common dab	1	0.3	-	-	-30
12. *Able* Wreck	Conger eel	2	4.3	4.3	4.3	92-101
12. *Able* Wreck	Haddock	3	1.8	1.6	1.6	39-43
12. *Able* Wreck	Lemon sole	4	2	1.9	1.9	31-40
12. *Able* Wreck	Lesser spotted dogfish	14	11	-	-	48-69
12. *Able* Wreck	Ling	2	6.6	5.8	5.8	72-91
12. *Able* Wreck	Plaice	2	0.9	0.8	0.8	29-39
12. *Able* Wreck	3-bearded rockling	1	0.4	-	-	-35
12. *Able* Wreck	Whiting	1	0.5	0.4	0.4	-39
13. N. of Box of wrecks	Brown crab	2	-	-	-	-
13. N. of Box of wrecks	Cod	1	5.5	4.7	4.7	-81
13. N. of Box of wrecks	Conger eel	4	8.1	8.1	8.1	80-102
13. N. of Box of wrecks	Ling	28	83.2	73.7	71.5	56-110
13. N. of Box of wrecks	Torsk	11	21.5	19.8	19.8	52-62
14. Monk Alley	Brown crab	3	-	-	-	-
14. Monk Alley	Cod	9	36.8	31.5	31.5	57-92
14. Monk Alley	Conger eel	17	45.1	45.1	45.1	78-114
14. Monk Alley	Ling	30	107.7	95.3	95.3	65-111
14. Monk Alley	Torsk	23	52.2	48.2	48.2	42-75
15. *Adonis* Wreck	Cod	15	62.4	53.4	53.4	63-92
15. *Adonis* Wreck	Conger eel	13	34.2	34.2	34.2	90-120
15. *Adonis* Wreck	Ling	77	529.0	468.4	468.4	84-142
15. *Adonis* Wreck	Saithe	1	2.6	2.2	2.2	-64
15. *Adonis* Wreck	Spurdog	1	3.5	3.5	3.5	-93
15. *Adonis* Wreck	Torsk	28	65.7	60.7	60.7	49-70
16. E. of Foula Hole*	Cod	8	36.3	31.1	31.1	49-93
16. E. of Foula Hole*	Ling	20	54.4	48.1	45.7	62-102
16. E. of Foula Hole*	Saithe	1	2.3	1.9	1.9	-61
16. E. of Foula Hole*	Spurdog	2	8.0	8.0	8.0	91-93
16. E. of Foula Hole*	Torsk	4	7.8	7.2	7.2	49-62

17. E. of Foula Hole*	Cod	11	32.2	27.5	27.5	61-73
17. E. of Foula Hole*	Ling	20	58.6	51.9	48.4	52-101
17. E. of Foula Hole*	Saithe	2	4.9	4.1	4.1	62-64
17. E. of Foula Hole*	Spurdog	3	10.5	10.5	10.5	90-92
17. E. of Foula Hole*	Torsk	2	1.9	1.7	1.7	-55

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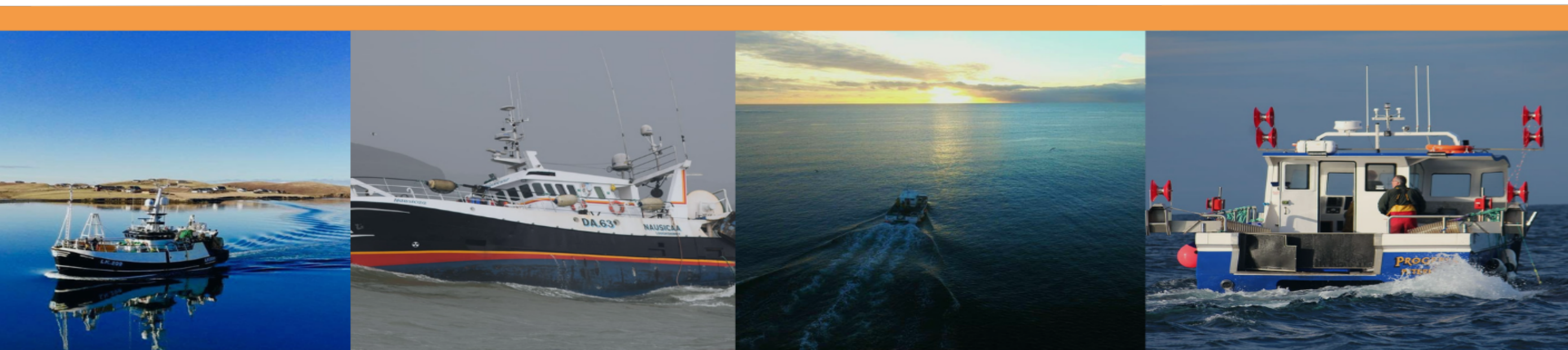

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