INVESTIGATING THE USE OF SINKING GROUNDLINE IN SCOTTISH CREEL FISHERIES TO REDUCE ENTANGLEMENT RISKS TO MARINE MEGAFAUNA

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1. Entanglement in groundline in Scottish creel fisheries

1.1. Creel configurations

The Scottish Entanglement Alliance (SEA) report in 2021 found entanglement in creel gear to be of much greater risk to marine megafauna in Scottish waters than had previously been recognised (MacLennan et al. 2021). For minke whales (*Balaenoptera acutorostrata*) and basking sharks (*Cetorhinus maximus*), the majority of entanglements occurred in the rope between creels, the groundline (83% and 76% of entanglements where the position in the gear was known for minke whales and basking sharks respectively). For humpback whales (*Megaptera novaeangliae*), 50% of entanglements were in the groundline (Leaper et al. in prep.). For most whale entanglements in creel fisheries in other areas, the proportions occurring in groundline and endline are not known. However, in the Republic of Korea, 97% of entangled minke whales were in groundline (Song et al. 2010). In the recently-established octopus (*Octopus vulgaris*) fishery in South Africa, of seven Bryde's whale (*Balaenoptera edeni brydei*) entanglements where the position in the gear was known, four were in groundline (Segre et al. 2021). Groundline is generally made of buoyant polypropylene rope, and therefore floats in arches in the water column between creels when they are on the seabed. These loops can entangle sharks and whales, generally by the mouth, tail, or flipper (Johnson et al. 2005). As creels are usually not attached directly to the main groundline, but toggled via leg ropes (also known as stoppers/droppers/branch lines/gangions/tails), which can themselves be several metres long, the height of any arches of rope floating between creels is further increased. Additionally, the full length of the groundline may float at least the length of the leg ropes off the seabed. Figure 1. is an example of a creel fleet configuration from a 16.5m Scottish offshore creeling vessel. In this example, 100 creels are spaced approximately 25m apart, toggled onto 9m-length leg ropes.

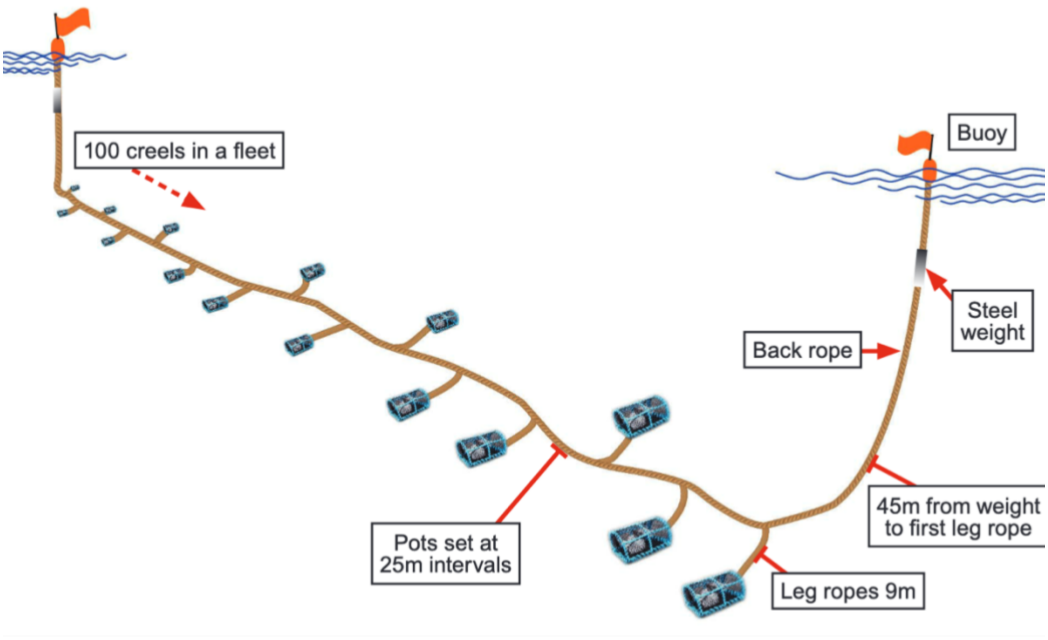

Figure 1. Schematic of a creel configuration from a 16.5 m offshore creeling vessel in Northern Scotland (MAIB 2018)

However, whereas the schematic in Figure 1. might imply that the groundline lies flat on the seabed, in fact it will float in loops rising from one creel to the next, as shown in Figure 2.

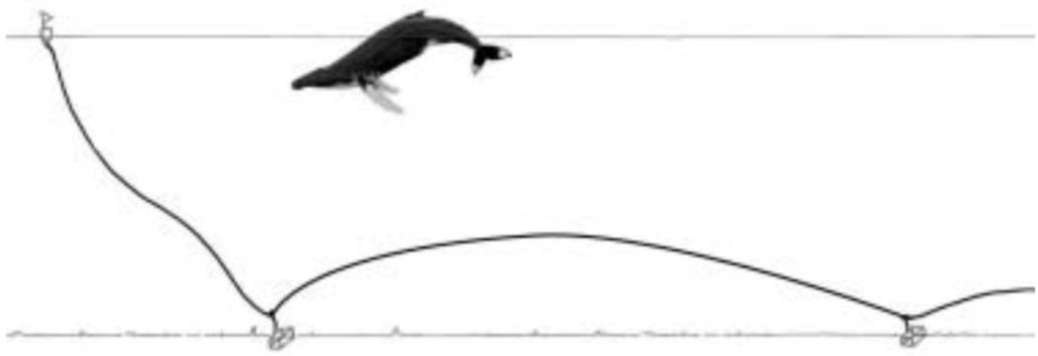

Figure 2. Schematic drawing of a lobster trawl creel in Massachusetts with floating groundline, showing the elevated groundline reaching 16 ft (approx. 5m), vertically suspended leg ropes and the 90 ft (approx. 27 m) distance between traps (from McKiernan et al. (2002))

Therefore in the case of the creel configuration shown in in Figure 1., groundline could be floating in arches about 20 m above the seabed. On a smaller inshore vessel (12 m), with a configuration of 55-60 creels with 14-15m spacing between creels and 2m leg ropes, arches might be about 9m above the seabed (B.Philp pers. comm.).

1.2. Rope types used in creel fleets

Groundlines typically comprise three (or four)-strand twisted ropes constructed of either polypropylene fibres, which float, or polyester/nylon fibres, which sink. Sinking line is often combined with varying proportions of floating materials (polypropylene, polyethylene, or a co-polymer of the two called 'Polysteel'). Lead can also be added to a positively buoyant rope to make it sink (Ludwig et al. 2016). In addition to ropes which float or sink, 'neutrally buoyant' line is also available, which is of similar density to seawater, and is designed neither to float in arches nor be in direct contact with the seabed (McKiernan et al. 2002).

Creel fisheries have generally used polypropylene floating groundline. It is cheaper than sinking line, and there is less risk of chafing or snagging on rocky bottoms (McKiernan et al. 2002, Laist 2017). If the buoy lines on a trawl are lost, floating line can be easier to retrieve using a grapple, and also provides a target that can be detected by boat echosounders, which can be used to locate the floating arch of rope (McKiernan et al. 2002).

However, in order to address the entanglement risk in Scotland posed by floating loops of groundline, changing to sinking or neutrally buoyant line must be considered, and its potential disadvantages investigated and addressed. Although entanglements do also occur in endline/risers (Moore 2019, MacLennan et al. 2021), ropeless gear which operates without risers is still a developing technology involving considerable expense, change in fishing practices and high levels of cooperation between fisheries. However, replacing floating groundline and leg ropes with non-buoyant line so that it remains on or close to the seabed could be accomplished with fewer (although not trivial) changes to Scottish creel fishing practices. Moreover, as these changes to groundline have already taken place in other pot fisheries, there are opportunities to learn from their experiences. For example, this mitigation technique has already been implemented in the US east coast trap fishery as part of a suite of measures to reduce entanglements of critically endangered North Atlantic right whales (*Eubalaena glacialis*). There is therefore the chance to learn from this implementation in order to inform trials of sinking ground line in Scotland.

2. Sinking groundline in US east coast trap fishery

2.1. Introduction of sinking groundline

On the US east coast, entanglement in fishing gear is a major cause of mortality for North Atlantic right whales (Knowlton et al. 2012). Trap fisheries (targeting lobster, crabs and some fish species) use both single traps and 'trawls' of up to around 40 traps joined together and marked with a buoy at either end for longer trawls. The lobster fishery is a high-value industry, with several million traps set within right whale habitat on the Canadian and US east coasts (Laist 2017). Right whale entanglement in fishing gear on the US east coast began to be recognised in the 1970s, and since that time, the range of mitigation strategies discussed and implemented has been complex. In 1994, under Section 118 of the Marine Mammal Protection Act (MMPA), the National Marine Fisheries Service (NMFS) was tasked with establishing Take Reduction Teams (TRTs) to formulate Take Reduction Plans to address bycatch in problem fisheries. The 'Atlantic Large Whale Take Reduction Team', which was responsible for North Atlantic right whales and comprised fishers, fisheries managers, marine scientists and conservationists first met in 1996, in order to reduce right whale entanglement-related deaths and serious injuries. At this time, the state of Massachusetts and NMFS were also carrying out an assessment of how to reduce entanglements. Amongst their proposals was a requirement for lobster fishing in winter and early spring (when right whales were expected to be present) to use sinking groundline, measures which came into effect in January 1997 (McKiernan et al. 2002, Laist 2017). Although this was also considered by NMFS as a possible measure across a wider area, there were protracted disagreements within the TRT, and the final rule published by NMFS in 1999 required very little in the way of gear modifications, and only in restricted critical habitat areas. Only in the Cape Cod Bay area was there a requirement for sinking ground line year-round (which was required by the state of Massachusetts) (Laist 2017).

However, although the status of the North Atlantic right whale population continued to deteriorate, entanglements continued and disagreements on mitigation measures persisted with the TRT, more funding was directed towards testing gear modifications. 'Neutrally buoyant' groundlines became a favoured option (see section 1.2.), although some lobster fishers – mostly from Maine – still thought that the line would abrade against rocks and result in gear loss. The Maine coastline comprises rocks, boulders and ledges, with strong tides and currents, all of which make non-floating rope harder to use due to chafing and catching under rocks, resulting in a greater risk of gear loss (Ludwig et al. 2016). At that time, it was estimated that it would cost a lobster fisher with 800 traps about $5000 to replace their groundlines. (Laist 2017).

In 2002, the Marine Mammal Commission recommended that sinking or neutrally buoyant line be required by all trap fisheries along the East Coast by January 2004. From 2002 to 2005, NMFS spent $2million on workshops and studies on gear modifications of all types, including different types of rope, and reducing the amount of rope used. Tests of neutrally buoyant groundline showed that line actually needed to be slightly denser than neutral to avoid floating loops of line. It therefore still risked abrasion and snagging. There was also still uncertainty as to how right whales behaved in relation to the seabed, and the mechanism of entanglement in groundline, which had not been established. Maine lobster fishers argued for exemptions to a floating groundline ban in areas where lines were likely to snag, but also suggested 'low profile' groundlines, whereby weights would be placed at intervals along floating groundline (Laist 2017).

However, although Maine's rocky coastline was considered to make sinking groundline problematic, in Massachusetts the seabed is less rocky, and it was not considered to be such a problem; the Massachusetts Lobstermen's Association (MLA) agreed to using non-floating groundline. A gear buy-back program funded by the International Fund for Animal Welfare (IFAW) and a congressional appropriation to NMFS was initiated to financially assist fishers in making the shift. IFAW's contribution was $300,000, and the congressional appropriation was $685,000, and in 2004 the scheme began. Nearly $1million was distributed via vouchers for lobster fishers to buy line slightly denser than seawater and hand in an equal amount of floating line. The vouchers covered 75% of the cost of new line, the balance being made up by fishers. In the following year, around 300 Massachusetts lobster fishers (about 25%) participated in the program, on average paying $1000 to $1500 each. By the end of 2005, 3250 miles of floating groundline had been replaced, and state lobster fishing regulations changed to mandate sinking groundlines in all traps as of January 2007 (Laist 2017).

Although the TRT continued to disagree on wider measures, sinking or neutrally buoyant groundline was still considered to be an important measure that should be in place by 2008 (Laist 2017). However, many Maine fishers maintained their opposition, stating that this was too tight a timescale to enable research on snagging and abrasion, and asking that Maine state waters be exempt from the rule. Nonetheless, the MLA received $2million in government funding for a floating groundline buy-back program similar to what had been arranged in Massachusetts. When plans for the new rule on groundline were released in 2007, defining groundline as "the line connecting traps in a trawl" and sinking groundline as line "that has a specific gravity greater than or equal to 1.030, and…does not float at any point in the water column" (NMFS 2007), there was a large exemption area in Maine (70% of the waters within 3 miles of the coastline), exempting approximately 1 to 2 million traps – almost 50% of those set along the east coast (Ludwig et al. 2016, Laist 2017). This was justified by claims that "right whales are unlikely to spend substantial amounts of time in the coastal waters of Maine", that adopting the exemption "would provide an adequate level of protection to endangered large whales" (NMFS 2007), and that there was no evidence that right whales swam near the seabed there (Ludwig et al. 2016, Laist 2017). This proposal by NMFS was opposed by the Marine Mammal Commission, on the grounds that there was a lack of evidence for their claims, and no other alternatives had been considered. It was also opposed by Maine lobster fishers who still thought the exemption area was too small, and should be expanded offshore. However, NMFS refuted the objections from both sides, and the final rule was published in 2007, requiring sinking groundline in non-exempt areas, to be deferred to October 2008 to allow fishers to make the change (Laist 2017). The MLA continued to request more exemptions and more implementation time, and it was agreed to delay until April 2009. An additional $3million was appropriated by Congress for the purchase of new line in Maine. There were 24 exchange events in 2009 and 2010, where $2.3 million was provided to 2,000 lobster fishers, and approximately 1 million kg of floating line was collected and recycled (Ludwig et al. 2016, Laist 2017). It took six years for the sinking groundline rule process to conclude. In the end nearly half of all lobster traps were exempted. The risk reduction has thus far not been quantified (Werner & McLellan-Press 2016, Laist 2017).

2.2. Issues reported from sinking groundline implementation in US fisheries

As described in Section 2., the process of implementing sinking groundline in the US east coast trap fisheries was not straightforward. Maine lobster fishers particularly objected to the new regulations, and extensive questionnaires, anecdotal reports and workshops have detailed their operational issues with sinking groundline (Ludwig et al. 2016). These were primarily that in areas with rocky bottoms, strong tides and currents, sinking groundline chafes, in particular between the first and second traps where the groundline first makes contact with the bottom and may be subject to movement caused by wave action on the vertical line. It therefore does not last as long, making it more likely to fail and result in gear loss (Ludwig et al. 2016). Other problems were reported: that it handles poorly on deck, snags more often and therefore increases tension when hauling, has reduced stretch under tension, results in intense noise when running through the hauler, and is difficult to assess for signs that it is nearing the end of its operational life. Some of these difficulties in handling resulted in injuries or vessel damage in addition to gear loss and increased expense (Ludwig et al. 2016).

Although some lobster fishers stopped fishing in areas where they reported higher gear loss due to the snagging and chafing of sinking line, others also modified their gear. This brought about some unintended consequences. Lobster fishers who tried to minimise groundline by fishing with shorter trawls introduced more vertical lines into the water column, increasing the entanglement risk from vertical line (McCarron & Tetreault 2012, Ludwig et al. 2016). Furthermore, other mitigation measures such as the 2015 vertical line rule which required 'trawling up' in some areas (using more traps in a trawl) increased the amount of groundline, and also resulted in the use of stronger line as a result of the increased load and a consequent rise in the severity of entanglements (McCarron & Tetreault 2012, Knowlton et al. 2016, Hayes et al. 2018).

In response to these issues, studies were carried out in the US with the aim of improving the performance and operational life of sinking groundline. These documented fishers' experiences and challenges with the line, and also involved experimental deployments and sea-trials of traps, and trials in machine-testing facilities (Ludwig et al. 2016). The trials focussed on issues such as the profiles of various line types underwater (floating, neutral, sinking and 'low profile'), their different breaking strengths, the mechanisms by which chafing occurs, how the configuration of hauling systems might be modified, the effects of tide and currents, gear losses attributed to line wear, and how regional differences in bottom type might require different operational approaches to improving non-buoyant groundline performance (see Ludwig et al. 2016 for table of studies).

These studies demonstrated that the service life of groundlines is influenced by many factors, and that the problems experienced by lobster fishers in the US fishing on hard and soft bottom are different (Allen et al. 2008, Allen 2012). In soft-substrate areas, sediment accumulating in the rope was identified as a possible cause of wear, whilst chafing on hard bottoms was more prevalent in rocky areas. Machine-testing trials found that surface abrasion was more problematic than internal abrasion by sediment, and that hauler specification (including angles, material and smoothness of the sheaves, spacing of sheaves and size of hauling drum) had considerable impact on the longevity of line (Allen, 2012).

2.3. Results and recommendations from US studies on groundline performance

The studies on issues with sinking groundline use resulted in suggestions and recommendations for improving the operational efficiency of sinking line, although several of these require further research, as they might have drawbacks as well as benefits, or only be applicable in certain fishing areas. These are summarised by Allen (2012) and Ludwig et al. (2016), and include:

- Using wider diameter line to increase strength.
- Using 4-strand rather than 3-strand rope.
- Knotting rather than splicing to reduce chafe.
- Leaving new coils of line outside and fishing sinking line on vertical line for several seasons before rotating to groundline to increase tightness of lay and harden rope.
- Avoiding blended-fibre ropes: trials by Allen (2012) demonstrated that most blended-fibre ropes (combining polyester and polypropylene), deteriorated more that Polysteel floating rope, even without sediment in the hauling simulator. This appeared to be due to the hauling process causing a loss of strength in blended fibre ropes, possibly due to the difference in size and elasticity of the different fibres, and those fibres abrading against each other. Allen (2012) therefore suggested that sinking ropes should be made entirely of polyester, or of polypropylene with an added lead strand or other heavy material to provide the weighting.
- Modifying hauler specification by, for example, using larger diameter haulers, sheaves with a smooth surface, closely-spaced sheaves, changing the surface angle of the sheaves, using a

splitter with a reverse curve on the edge that meets the rope, keeping the splitter in good condition.

- Setting trawls parallel to the tide to decease snagging and rope movement.
- Using a heavier end trap to reduce movement caused by the vertical line.

2.4. Efficacy of sinking groundline in reducing entanglement

There is no clear evidence that the implementation of sinking groundlines in the US east coast trap fisheries has reduced serious injuries and mortality of right whales to sustainable levels (Brillant & Trippel 2009, Knowlton et al. 2012, Van der Hoop et al. 2012, Werner & McLellan-Press 2016, Moore 2019). Part of the problem with assessing how effective the measure has been is that, whilst groundlines were known to entangle some right whales (Johnson et al. 2005), in the majority of cases it is not clear in which part of the gear the entanglement occurred, and so the extent to which groundlines were the cause of entanglement both before and after the implementation of sinking groundline measures is uncertain (Knowlton et al. 2015, Brillant & Trippel 2009).

There have been some studies on the profiles of different line types in the US east coast fisheries, and their likely entanglement risks. McKiernan et al. (2002) and Lyman & McKiernan (2005) demonstrated that neutrally buoyant line has a lower vertical profile than floating line, but is actually similar in performance to sinking line, in that it is actually negatively buoyant, and is usually in contact with the seabed. Floating groundline was shown to be continuously elevated above the substrate, the maximum height usually being at the midpoint between leg ropes, on average 16 ft (4.9m) above the seabed when traps were spaced 90 ft (27 m) apart. This elevation was contributed to by the leg ropes also being elevated (McKiernan et al. 2002). Neutrally buoyant line was observed either in contact with the seabed or very close to it, and sinking line was in continuous contact with the substrate. These studies concluded that neutral line appears to provide the same level of risk reduction as sinking line, as it is actually negatively buoyant, and both were likely to reduce the probability of whale entanglements.

Part of the uncertainty about risk reduction also comes from a lack of knowledge as to how close and how often right whales approach the seabed; there is evidence that they do swim at or near the seafloor, but it is unclear how often this happens and at what elevation groundline poses a risk to them (Brillant & Trippel 2009, Baumgartner et al. 2017, Laist 2017, Hamilton & Kraus 2019). The use of sinking groundlines likely reduces the risk of entanglements for whales swimming near the seafloor, but may not eliminate the risk for whales making contact with the sediment. There is also some evidence that some humpbacks in the Gulf of Maine and Stellwagen Bank targeting sandlance forage at or near the seabed (Hain et al. 1995, Ware et al. 2014), and that sinking groundline may not entirely eliminate their risk of entanglement (Werner & McLellan-Press 2016, Recht 2019). However, although there is considerable uncertainty regarding whale underwater behaviour, it should be assumed that any reduction in line in the water column is beneficial (Brillant & Trippel. 2009).

3. Sinking groundline: implementation in Scottish creel fishery

3.1. Rationale for implementation trials in Scotland

Although the efficacy of sinking groundline implementation in US east coast fisheries remains uncertain, the expected risk reduction in Scottish waters is higher. Whilst the part of the gear in which right whales become entangled on the US east coast is often unknown, this information is available for many entanglement cases in Scotland, due to the interview data from creel fishers collected as part of the SEA project. The evidence is particularly strong for minke whales and basking sharks, as they are generally not strong enough to escape from or swim off with gear and die *in-situ*, making the mechanism of entanglement clear. As noted in Section 1., in entanglements where the position in the gear was known, 83% of minke whales, 76% of basking sharks and 50% of humpback whales were entangled in the groundline (MacLennan et al. 2021). Bottom feeding has not been documented in any of these species in Scottish waters, and it is therefore a reasonable assumption that the mechanism by which they become entangled in groundline is buoyant line floating in loops in the water column. As previously discussed (Section 1.), although entanglement in risers does also occur in Scottish fisheries, mitigation with ropeless gear is more difficult in many ways than addressing floating groundline.

Furthermore, although it may be unclear how much risk reduction sinking groundline has brought to the NE US coast, the gear trials that have taken place as part of the implementation, and the recommendations from fishers for successfully working with sinking line will be of direct benefit in trials in Scottish waters. The gear exchange and voucher schemes can also inform any similar process in Scotland, if initial trials find sinking groundline could be effectively introduced.

3.2. The Nephrops creel fishery in Scotland

On the west coast of Scotland a large proportion of creel vessels target *Nephrops norvegicus* (known variously as Norway lobster, Dublin Bay prawn, langoustine or scampi, but referred to here as Nephrops).

3.2.1. Nephrops habitat and creeling effort on the Scottish west coast

The Nephrops fishery accounts for a large proportion of entanglements (53% of minke whales and 45% of humpback whales reported during the SEA project) (MacLennan et al. 2021). For initial trials of sinking groundline it would therefore make sense to start with vessels targeting Nephrops, as it is a high-risk fishery. Furthermore, Nephrops inhabit seabeds with soft substrates. Experience from the US suggests that soft substrate is less problematic for sinking groundline implementation (see Section 2.). Figure 3. shows the Nephrops habitat on the west coast overlayed with positions of creels, indicating likely areas where sinking groundline trials might take place.

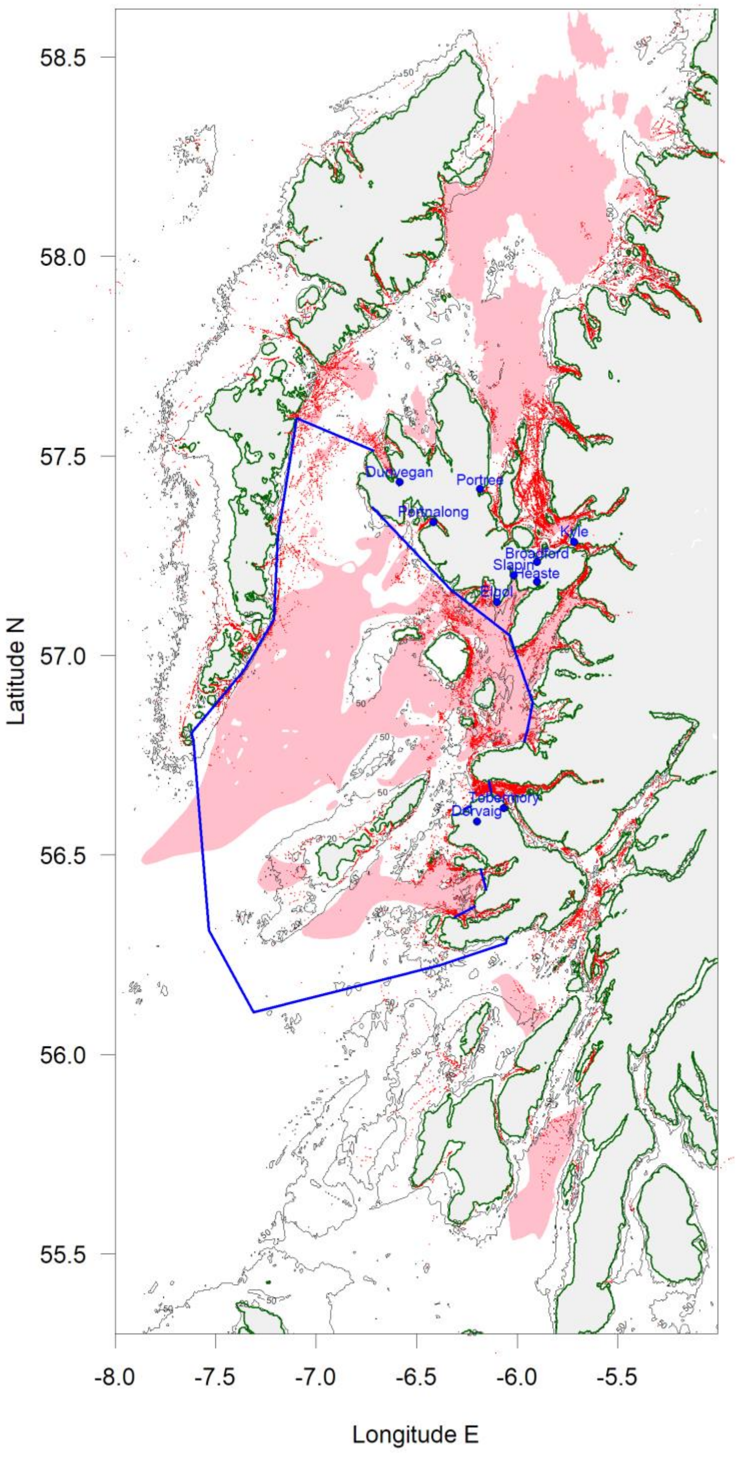

Figure 3. The west coast of Scotland Nephrops fishery. Red dots indicate observed distribution of creels (from Leaper et al. in prep), pink area shows areas of Nephrops habitat from Marine Scotland data[1]. The boundary of the Sea of the Hebrides MPA is shown in blue. Harbours where fishers participated in the SEA project are shown in blue.

[1] hiip://marine.gov.scot/maps/334

3.2.2. Nephrops catches in relation to vessel size on the Scottish west coast

The issues associated with sinking groundline may vary with vessel size. Smaller vessels tend to fish with 10mm groundline, while larger vessels use 12mm, and these lines might behave differently. Larger vessels are also more likely to self-shoot rather than deploy creels by hand, which also might affect the performance of line. Therefore trials of sinking groundline need to consider a mix of smaller (≤ 10m) and larger (>10m) vessels.

Reported Nephrops landings are given in the UK Sea Fisheries Statistics[2], The most recent statistics for catches are from 2020, and data for harbours with greater than 5 tonnes total live weight for vessels fishing with pots and traps are shown for vessels ≤ 10m (Table 1) and >10m (Table 2). These data will enable the selection of vessels from high effort, and therefore high-risk areas.

Table 1. Nephrops catches in 2020 for vessels ≤ 10m using pots and traps

Harbour	Total Sum of Live Weight (tonnes)	Total Sum of Value (£)
Broadford	89.4	964872
Kyle	40.4	398583
Stornoway	38.2	324373
Tarbert	36.2	396767
Portree	36.2	350411
Ullapool	35.1	358714
Tayvallich	34.5	306482
Oban	32.8	332140
Kilchoan	26.0	254917
Sleat	25.2	197953
Shieldaig	24.9	337109
Stockinish	23.5	193143
Gairloch	23.4	263334
Kylesku	22.2	264362
Crinan	20.8	196326
Ulva Ferry	19.2	190150
Achiltibuie	19.1	227751
Dunoon	18.7	171164
Port Appin	18.5	209922
Lochinver	15.7	172971
Lochmaddy	15.0	128648
Dunvegan	13.6	152058
Leverburgh	12.4	97531
Scalpay	12.2	112249
Greenock	8.1	81888
West Loch Tarbert	8.0	51770
Campbeltown	7.9	68309
Erribol	7.8	68936
Mallaig	7.2	69201
Fort William	6.9	71277
Strathaird	6.6	64411

[2] hiips://www.gov.uk/government/collections/uk -sea-fisheries-annual-statistics

Uig	6.6	63304
Glenuig	6.4	71393
Cuan	6.3	68001
Balvicar	5.4	49092
Portaskaig	5.0	59376

Table 2. Nephrops catches in 2020 for vessels >10m using pots and traps

Harbour	Total Sum of Live Weight (tonnes)	Total Sum of Value (£)
Tarbert	48.7	533787
Stockinish	36.6	312559
Portree	34.3	390329
Oban	30.0	328024
Kallin	29.9	200780
Tayvallich	28.3	277729
Balvicar	25.0	271584
Kylesku	22.3	235948
Gruinard - Aultbea	20.4	190142
Scalpay	16.4	157437
Campbeltown	15.5	142824
Stornoway	15.2	83979
Leverburgh	11.9	117626
Luing	11.9	123359
Shieldaig	11.0	129258
Tobermory (Isle of Mull)	10.3	120169
Achiltibuie	10.0	115793
Dunvegan	9.9	103306
Lochinver	7.6	84495
Uig	7.4	59981
Ullapool	7.4	109160
Fort William	7.1	80797
Gairloch	6.0	65305
Kilchoan	5.8	56195
Bunessan	5.2	61487
Broadford	5.1	58505

3.2.3. Amount of gear per vessel targeting Nephrops on the Scottish west coast

In order to conduct trials, it is necessary to establish how much line will be required for replacing floating line with sinking line. The SEA interviews asked fishermen how many creels they set and how much total line they used. These responses provide a good indication of the likely requirements for sinking groundline, although there is some variation between fishers. For the purposes of the trials, it is not the intention to replace all groundline on all the creels on the vessels involved. Some floating line will be retained during trials, and different configurations of groundline will also be trialled to enable comparisons. These might include:

- Manual vs self-shooting creel deployment (≤ 10m and >10m)

- Creel fleets with both sinking groundlines and sinking risers, vs fleets with only sinking groundlines
- Creel fleets with both sinking groundlines and sinking leg ropes, vs fleets with only sinking groundlines, or only sinking leg ropes.

Figure 4. shows the number of creels per vessel from the SEA interview, with the median being 1000 creels.

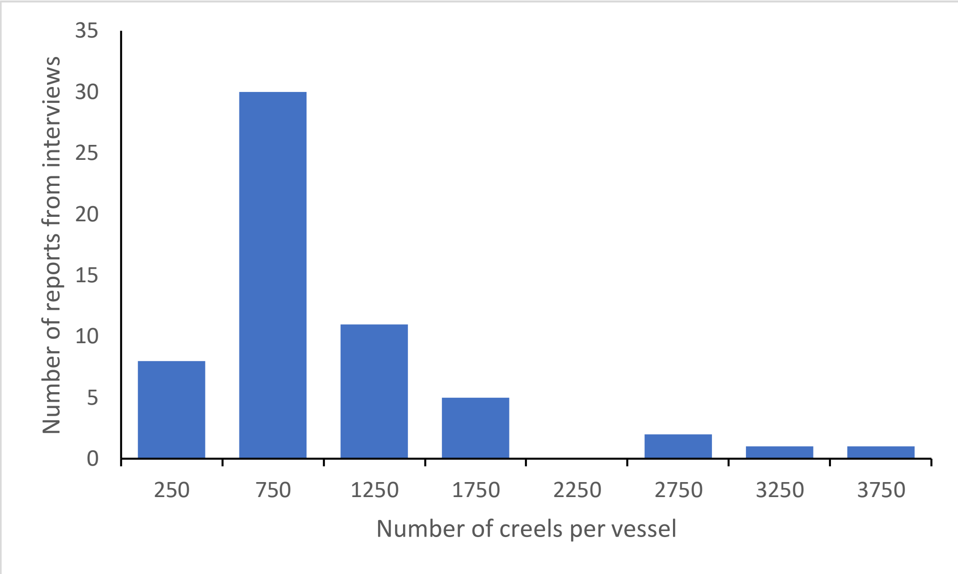

Figure 4. Number of creels per vessel from 58 interviews during the SEA project with vessels fishing primarily for Nephrops. Median = 1000 creels. 55% of vessels fished between 750 and 1250 creels.

Median length of gear was 20km, with 59% of vessels reporting between 10 and 30km. Linear regression of the total length of line against the number of creels per vessel showed a strong correlation with an approximate relationship of 20m of line per creel (Figure 5). Some outliers were removed for this analysis because the aim is to estimate the amount of line for 'typical' vessels. A total of 20m of line would be consistent with 14m of line between creels, 2m leg ropes on each creel, and creels set in fleets of 60 with 120m of line on each end. This is the setup described to us by one individual (B.Philp pers. comm.). These data will enable the line requirements for the trial to be estimated once the vessels involved in the trial have been confirmed, and the configurations to be tested have been agreed upon.

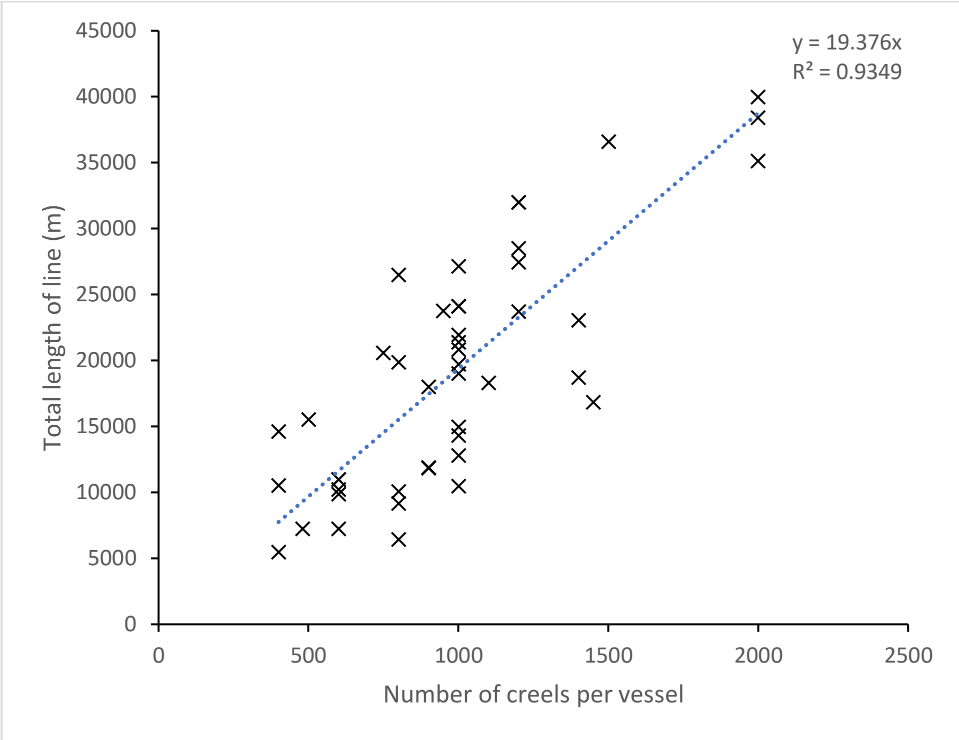

Figure 5. Reported total length of line against number of creels per vessel (some outliers removed).

3.3. Potential disadvantages of sinking groundline on Scottish coasts

In addition to operational trials of how workable sinking line might be for Scottish creel fishers, research would also be useful to ascertain that the use of sinking groundline between creels does not cause any more impact to benthic habitats and species than existing creel fishing practices. Whilst creel fishing is generally assumed to have little impact on benthic habitats (Eno et al. 2001, Stevens 2020), there have been few studies. However, survey methodologies have been developed (including using cameras, ROVs, photographs and divers) which could be expanded to also consider any differences in impact between floating and sinking groundline (Eno et al. 2001, Stephenson et al. 2017, Schweitzer et al. 2018). The footprint of creels and lines is small; the potential for greater impacts on benthic habitats occurs during setting and retrieval, when creels are dragged across the seabed (Stevens 2020). Creels set in rocky habitats may damage benthos such as corals, sponges, sea whips, crinoids and other large emergent epifauna by crushing or breaking them, whilst in soft sediments, emergent epifauna such as cnidarians and ascidians may be damaged (Stevens 2020). Stephenson et al. (2017) studied creel impacts on rocky bottom habitats off the coast of Northumberland, and found that creeling was unlikely to cause changes in benthic community structure, but that study used single creels rather than fleets, so would not have detected any damage from dragging a fleet. Eno et al. (2001) and Schweitzer et al. (2018) found a low likelihood that creels would actually land on benthic organisms, but a much higher risk of damage when they were dragged. Although Eno et al. (2001) found the impacts found were minor and/or temporary, the long-term cumulative impact was not assessed. These impacts will be highly variable depending on the recruitment and regrowth of the benthic species involved (Stevens 2020). It is unclear how sinking groundlines would increase any impacts already occurring, as the creel itself is likely to cause the most damage as it is dragged. Nonetheless, research on this potential impact would be useful in the assessing the viability of switching to sinking groundline.

4. Acknowledgments

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5. Literature cited

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