Appendix 2. Estimating amount of static creel gear in Scottish waters, and associated cost of transition to negatively buoyant groundline

Glossary of Terms

Buoyant/floating rope
Rope which floats in the water column (usually mainly polypropylene)

Crab
The main species caught in Scottish inshore creeling are *Cancer pagurus* (brown crab) and *Necora puber* (velvet crab)

Creel
A pot or trap that sits on the seabed for catching *Nephrops*, crab, lobster or other target species such as shrimp and wrasse

Endline
The ropes at either end of the fleet which run from the seabed to a surface marker buoy, also known as the **riser** or simply **ends**

Fleet
A number of creels spaced along a line with surface markers at each end

Groundline
The rope that runs along the length of the fleet to which the creels are attached by stoppers; also known as **backrope** or **backline**

Lay
The way that the fibres in a rope are twisted together at the manufacturing stage which influences the handling of the rope, how easy it is to splice and its resistance to abrasion.

Lobster
Homarus gammarus

Negatively buoyant rope
Rope which is slightly denser than seawater so lies on the seabed. Also known as **sinking** or **leaded** rope

Prawn
(in the context of this project) *Nephrops norvegicus*, langoustine. The term ‘Nephrops’ is used in this report for this target species

Stoppers
The short ropes which attach each creel to the groundline, also known as droppers, tails, gangions, leg ropes, beckets, straps, strops, snoods

Vivier vessel
A vessel with a hold that can contain live crustaceans immersed in or misted by water.

1.1 Objectives

The aim of the study was to estimate the amount of static creel gear currently in use in Scottish waters in order to provide data and methods both for this project and to inform other assessments to further the wider understanding of creel gear in Scotland. Specifically, the main quantity of interest is the length of groundline, in order to estimate the costs for any transition from floating rope to negatively buoyant rope to reduce entanglement risks. These estimates are part of a socio-economic analysis examining various options for a transition. As part of estimating groundline we also estimated the number of creels. A suggested option for implementing negatively buoyant groundline has been to target outreach on a regional or gear-type basis, prioritising the areas or gears with the highest risk of entanglement. Thus, we needed methods for estimating gear that could be applied to any chosen boundaries and gear-type and not necessarily based on areas covered by Fisheries Districts or Regional Inshore Fisheries Group.

Some previous estimates of creel fishing gear are available. These include interview studies in 2013 for the Scotmap inshore fisheries mapping project[1], the Marine Scotland Science 2017 Creel Fishing Effort Study and online questionnaires from Ellie MacLennan's PhD. The 2017 Creel Fishing Effort Study covered a limited number of areas but with a high proportion of fishers interviewed. Another source of data is from participants who attended workshops held by the Scottish Entanglement Alliance (SEA) around the Scottish coast during January and February 2025. These workshops with fishers explored their views on the practicality of possible future implementation of negatively buoyant groundline in Scottish creel fisheries, but also asked about the gear that they used, using structured questions (see Appendix 2).

We received 51 completed or partially completed questionnaires, mostly from workshops, but also from other contacts who did not attend a workshop, but with whom we spoke at one-to-one meetings. The locations and dates of the workshops are listed in Table 1 and the fishing harbours of those who filled out questionnaires are shown in Figure 1.

Table 1. Locations and dates for first set of workshops

Arbroath	08/01/2025
Craignure, Mull	14/01/2025
Lerwick, Shetland	21/01/2025
Kirkwall, Orkney	23/01/2025
Troon	06/02/2025
Lionacleit, Benbecula	12/02/2025
Tarbert, Harris	13/02/2025
Ullapool	17/02/2025
Fraserburgh	20/02/2025

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[1] Kafas, A., McLay, A., Chimienti, M., Gubbins, M. (2014) ScotMap Inshore Fisheries Mapping in Scotland: Recording Fishermen's use of the Sea. Scottish Marine and Freshwater Science Volume 5 Number 17. Edinburgh: Scottish Government, 32p. DOI: 10.4789/1554-1

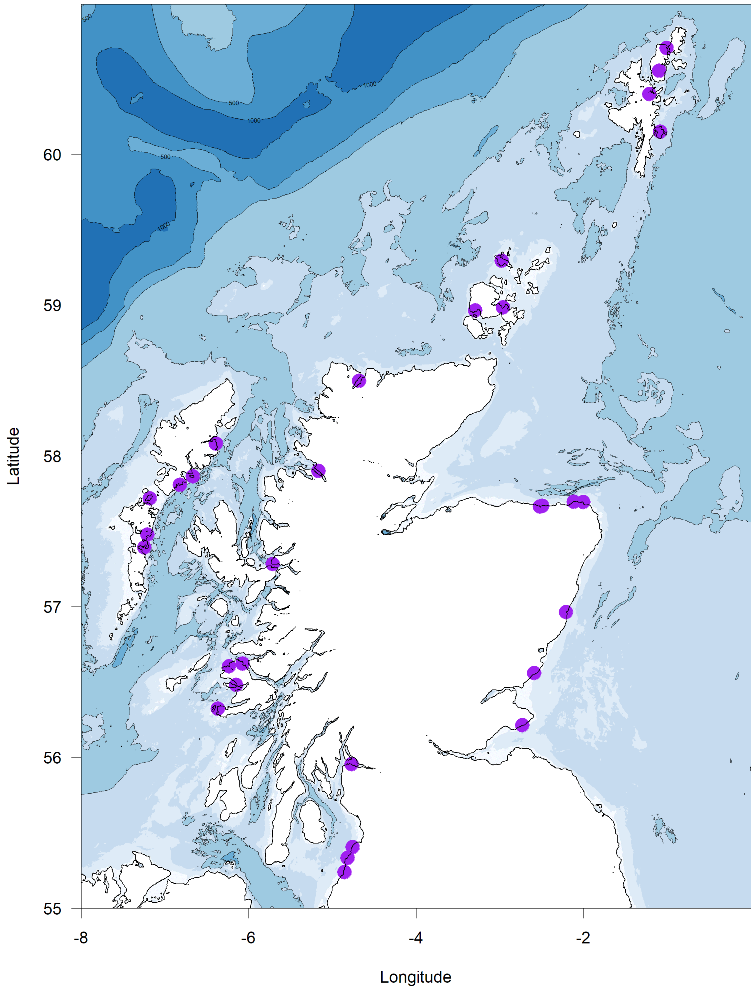

Figure 1. Fishing harbour locations of fishers who completed a questionnaire with details of their gear.

In addition to the data on how much gear was used by individual vessels gathered at the workshops, data from the Marine Directorate on the number of vessels fishing with creels were available alongside publicly available data on the weight and value of landings in the UK fisheries statistics.

The main fishery target species of concern from an entanglement perspective are Nephrops (prawn/langoustine) and, to a less extent, brown crab, because gear targeting these species tends to be set in deeper water, especially in the case of Nephrops. Creel gear targeting Nephrops is different from that targeting crab and lobster. Most fishers use the similar gear for lobster, brown crab, and velvet crab. Hence we generated separate estimates for Nephrops gear and for lobster, brown crab, and velvet crab (LBV) combined.

The estimates from the 2017 Creel Fishing Effort Study were used to validate our estimates for the comparable areas covered. That study adopted a similar approach to dividing gear into Nephrops or LBV.

An important consideration for any estimates of the costs of negatively buoyant line is how often rope needs replaced. This is affected by the type of fishing and the ground being fished. The fishers at the workshops provided information on how often they replace the floating line currently in use. We do not yet have equivalent data on the life expectancy for negatively buoyant line. Thus, all our cost calculations are based on the assumption that negatively buoyant line will need to be replaced at the same time interval as floating, although work is ongoing to assess longevity.

1.2 Methods

Of the shellfish tonnage in 2023 (Scottish fisheries statistics[2]) brown crab, lobster, velvet crab and Nephrops accounted for 90% of landings comprising 98% of the value.

Fisheries data were taken from UK fisheries statistics with additional data on the numbers of vessels by landing port provided by the Marine Directorate. Data on the number of vessels were combined for groups of landing ports by the Marine Directorate to avoid any confidentiality and data protection issues, so that each port grouping contained around five or more vessels.

This resulted in 27 groupings of landing ports where we had data on live weight of catch, landed value, number of vessels operating out of that port grouping, and information on the gear (including numbers of fleets per vessel, numbers of creels per fleet and spacing between creels) from the workshop questionnaires.

For each port grouping where we had questionnaire data from at least one vessel, we took the average gear for the vessels where we have data and multiplied by the number of vessels landing into that group of ports (data provided by the Marine Directorate). This gave an estimate of the total amount of gear by port group. Lobster, brown crab and velvet (LBV) were combined, and separate estimates were made for Nephrops gear (see above). The data on the number of vessels showed some duplication where the same vessel reported landings in more than one port grouping. To correct for this, we multiplied the number of vessels in each port grouping by the number of vessels registered to a district (assumed to have no duplication) divided by the sum of the vessels landing at each port grouping within the district.

We then conducted linear regressions of the total amount of gear (number of creels and length of groundline) in a port group as a response to the reported live weight and landed value in the 2024 fisheries statistics for that port group. The aim of the regressions was to derive an overall average relationship for the amount of gear needed to achieve a certain weight or value of catch.

The estimate for each area could then be generated based on multiplying the average length of groundline or number of creels per ton of catch/value of catch by annual totals.

Another approach was to use the number of vessels and the average amount of gear per vessel. This approach requires consideration of the size of vessels and the different amounts of gear that are worked, but was used to compare estimates of creel numbers with those from landings.

Results

A key assumption of the methods is that the fishers who filled out questionnaires were representative of the vessels in that area. In terms of the distribution of vessel size the questionnaires were similar to Scotland as a whole (Table 2) with the exception that none of the largest 15-24m vessels were represented by questionnaire data. Such vessels tend to be vivier boats which make multi-day trips further offshore.

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[2] https://www.gov.scot/publications/scottish-sea-fisheries-statistics-2023/documents/

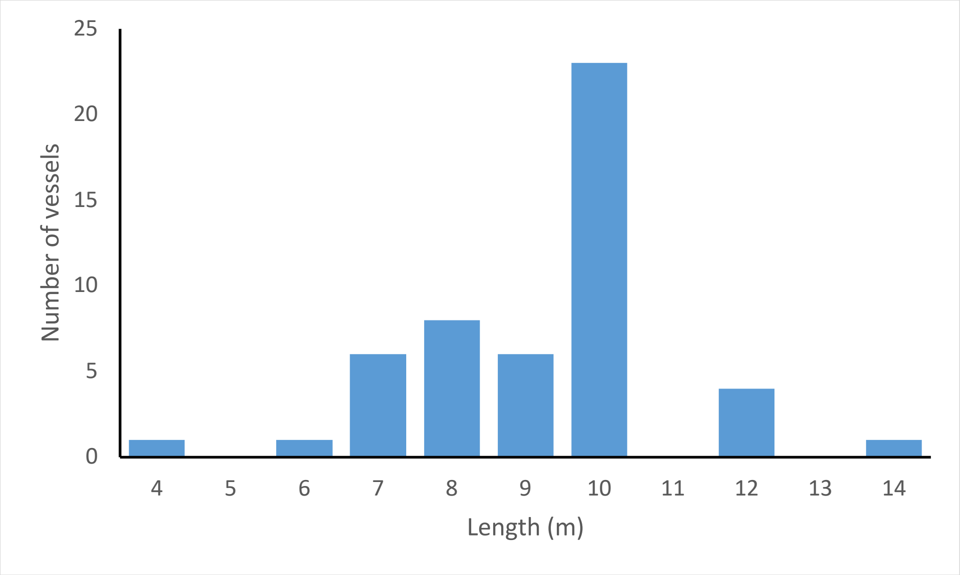

Figure 2. Number of completed questionnaires by vessel length category.

The number of completed questionnaires by vessel length category is shown in Figure 2. Five out of 51 (9.8%) of vessels were in the 'Over 10' category. This compares to 92 out of 882 (10.4%) of creel vessels (Scottish fishery statistics 2023 Table 43) for the Scottish fleet as a whole. From the questionnaires, 56% were singlehanded, 31% had one crew and 13% had two crew.

Table 2. Numbers of vessels by length category for Scotland as a whole and those that filled out questionnaires

Main fishing method	**10 metres and under**	**Over 10 metres to 12 metres**	**Over 12 metres to 15 metres**	**Over 15 metres to 24 metres**	**Total number of all vessels**
Creel fishing (2023 data)	790	73	11	8	**882**
Questionnaire sample	46	4	1	0	**51**

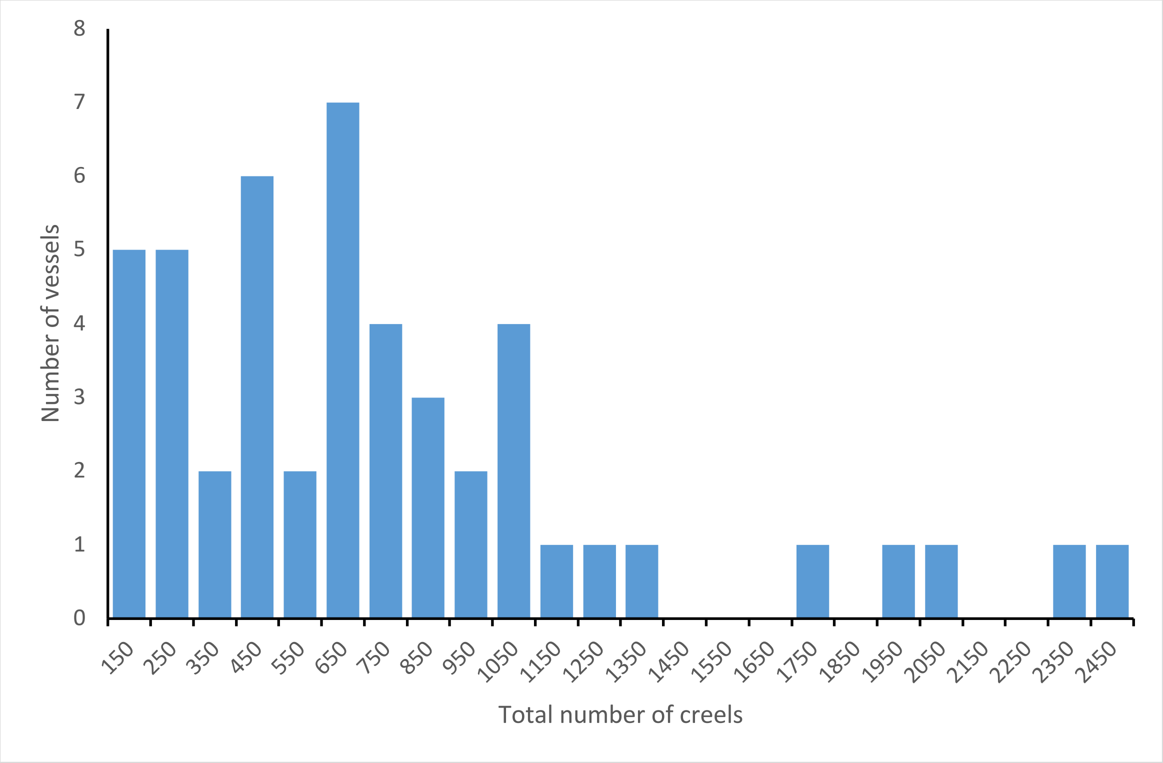

Figure 3. Total number of creels per vessel from the questionnaires (48 vessels).

Total creel numbers and groundline per vessel from the questionnaires were available for 48 vessels (mean = 731 (sd = 563), median = 618). The mean estimate of total groundline per vessel was 14178m (sd=12224), median = 11520.

Of the 48 vessels in the questionnaires, 15 vessels fished for some Nephrops although only one vessel fished solely for Nephrops (Table 3). Some areas of the west coast of Scotland have a higher proportion of vessels that only target Nephrops (e.g. Inner Sound east of Skye). Fishers in this area had been involved with previous trials (Calderan et al. 2025) and so the area had not been included in the workshops.

Table 3. Summary of data from the completed questionnaires

	Nephrops		Lobster		Brown crab		Velvet crab	
n	15		47		41		33	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Number of fleets	13.5	5.8	20.2	15.2	18.4	14.7	18.0	12.1
Number of creels per fleet	52.0	17.0	20.4	9.6	24.4	10.9	20.7	8.1
Length of line between creels (m)	13.4	2.0	23.0	8.4	24.2	8.2	22.5	9.4
Stopper length (m)	1.7	0.6	1.8	0.6	1.9	0.6	1.9	0.6
Total groundline length per fleet (m)	690.6	270.5	458.6	290.3	580.0	328.8	465.7	291.7
Ratio of total stopper length to groundline	0.13	0.05	0.09	0.04	0.08	0.03	0.10	0.05
Ratio of endline to groundline	0.41	0.14	0.32	0.37	0.32	0.31	0.34	0.57
Average of minimum depth (m)	44.3	31.6	7.3	9.8	17.7	14.1	6.8	10.7
Average of maximum depth (m)	134.0	54.6	47.0	29.6	68.3	34.8	43.8	35.1

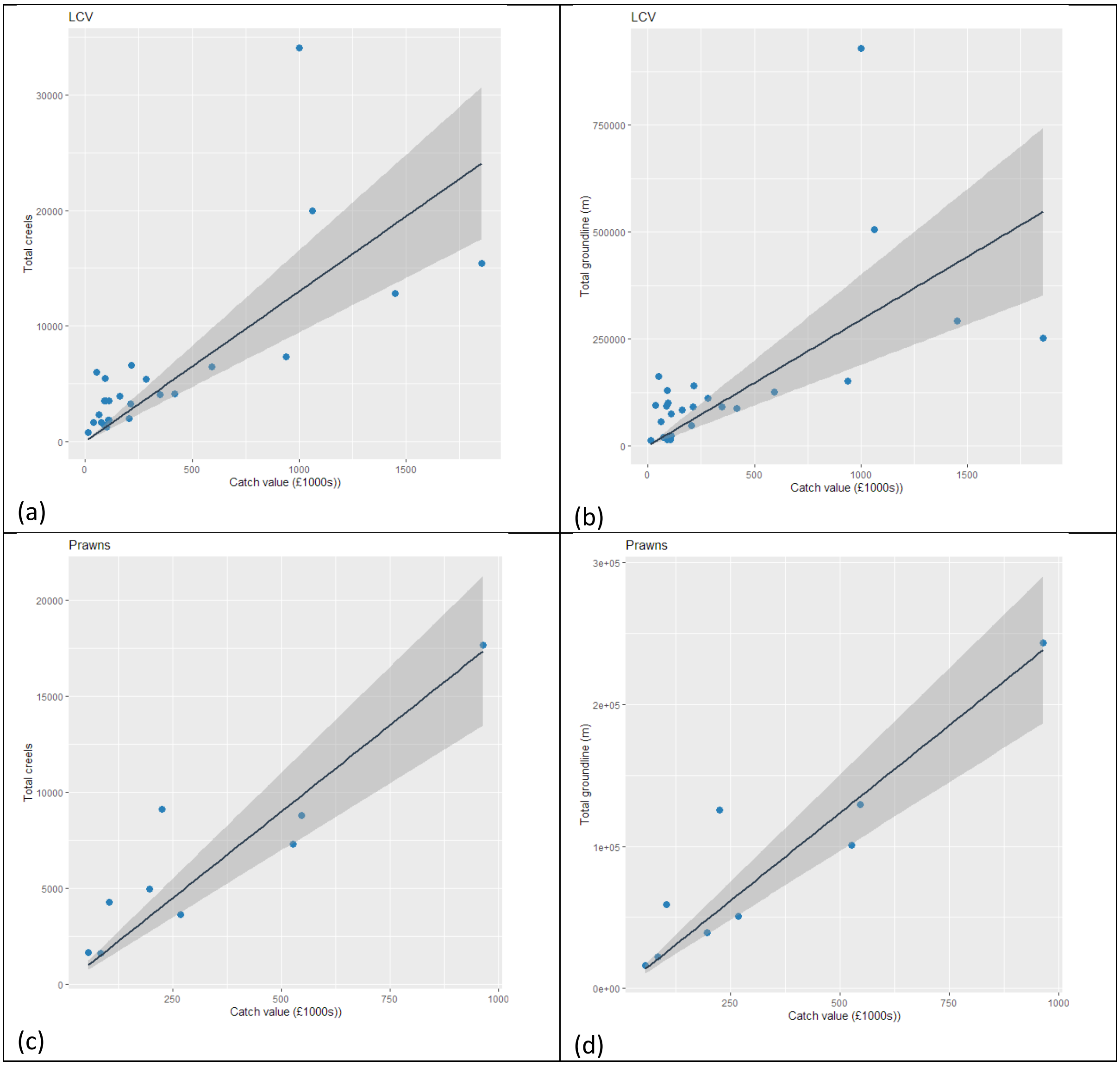

Figure 4. Regressions of gear as a function of catch value for each port grouping. Dark shading indicates 95% CI.

The estimates from the regressions of the number of creels and length of groundline (in metres) for each £1000 of catch and tonne of catch are given in Table 4. The relationship with catch value was slightly better than with catch weight so value was chosen as the predictor variable (Figure 4).

Table 4. Regression estimates of total creels (TC) and total groundline (TG in metres) for each £1000 of catch and tonne of catch, from each port grouping

Regression	Estimate	Std. error	Confidence interval	R^2
LBV TC ~ Value	12.980	1.722	9.434496 - 16.52591	0.6823
LBV TG ~ Value	294.90	51.17	189.5052 - 400.2958	0.5533
LBV TC ~ Weight	53.707	7.586	38.08367 - 69.33024	0.6539
LBV TG ~ Weight	1248.9	215.1	805.9334 - 1691.946	0.5572
Nephrops TC ~ Weight	156.50	27.83	92.32159 - 220.671	0.7729
Nephrops TG ~ Weight	2150.3	376.8	1281.318 - 3019.316	0.7781
Nephrops TC ~ Value	18.003	1.752	13.96398 - 22.04262	0.9208

Nephrops TG ~ Value	247.24	23.23	193.6818 - 300.8031	0.9258

Table 5. Estimates of amount of gear based on landed value by district

District	Landed value in 2024 (£1000s)	Total LBV creels	Total Nephrops creels	Total LBV groundline (km)	Total Nephrops groundline (km)	Nephrops proportion of catch value
Aberdeen	2920	37889	0	861	0	0.0
Anstruther	1683	21843	0	496	0	0.0
Ayr	1176	14170	1519	322	21	0.1
Buckie	671	8701	0	198	0	0.0
Campbeltown	5143	31633	48708	719	669	0.5
Eyemouth	3626	47061	0	1069	0	0.0
Fraserburgh	1807	23461	0	533	0	0.0
Kinlochbervie	535	5889	1466	134	20	0.2
Lochinver	667	431	11400	10	157	1.0
Mallaig	581	2627	6816	60	94	0.7
Oban	5409	35134	48643	798	668	0.5
Orkney	5109	66128	0	1502	4	0.0
Peterhead	1405	18237	0	414	0	0.0
Portree	5400	10871	82130	247	1128	0.8
Scrabster	2426	31481	0	715	0	0.0
Shetland	1779	22968	0	522	2	0.0
Stornoway	6312	47208	48147	1073	661	0.4
Ullapool	2394	6531	34038	148	468	0.8
Total for Scotland	**49043**	**432264**	**282867**	**9821**	**3892**	

Table 5 gives a total estimate for the number of creels in Scotland in 2024 as 715,000. We estimate an average of 733 creels per vessel. We estimate a total groundline length for Scotland as 13,700 km with an average of 14km per vessel.

In addition to the amount of gear fishers provided information on the frequency with which they replace their rope (see Appendix Q3.1)

Table 6. Responses to the numbers in years for midpoint of each 2-year category for rope replacement.

Target species	n	Min	Max	Mean	Median
Lobster/Velvet crab/Brown crab	46	3	9	5.4	5
Nephrops	13	5	9	7.15	7

There were 38 valid responses to the question of the main reason for buying new rope (see Appendix Q3.2). A valid response was when the two responses added up to 100%.

The responses (n=38) to the two options were;

a) Rope is worn out or damaged (min=30%, max=100%, mean = 80.1% (sd=26.5), median = 80%)
b) Gear has been lost and a new fleet needs to be made up (min=0%, max=70%, mean = 19.3% (sd = 19.4), median = 10%)

1.3 Comparison with 2017 Marine Scotland Science Creel Fishing Effort Study

The Creel Effort Study[3] had more intensive effort in terms of interviews (198 vessels) but also concentrated in specific geographic areas. This allows for a level of validation of our approach by comparing our estimates for the areas covered by the 2017 Creel Effort Study. That study divided vessels into those fishing for Nephrops and those fishing for crab and lobster.

Table 7. Comparison of estimates of the average number of creels per vessel from the 2017 Creel Fishing Effort Study and this study.

Area	**Average Nephrops creels per vessel from 2017 study**	**Estimate of Nephrops creels per vessel from this study**
West coast (Figure 1 of 2017 study) ports with more than 10% in value of nephrops	1009	1040
	Average LBV creels per vessel from 2017 study	**Estimate of LBV creels per vessel from this study**
West coast (Figure 1 of 2017 study) ports	359	430
East coast (Figure 1 of 2017 study) ports	542	588

Comparison of creel numbers suggest our estimates of the average per vessel are all within 20% of the 2017 Creel Effort Study for the areas that were covered in 2017. For west coast Nephrops and east coast LBV our estimates were within 10%.

1.4 Comparison with other interview data

Interviews with creel fishers were conducted by Ellie MacLennan as part of a separate project but also providing information on the number of creels per vessel (Table 8).

Table 8. Average creels per vessel from interview data

2. Area	**Number of vessels**	**Average creels per vessel**
Highland	31	930
Eilean Siar	11	1134
Moray and Aberdeenshire	22	319

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[3] https://www.gov.scot/binaries/content/documents/govscot/publications/research-and-analysis/2017/08/creel-fishing-effort-study/documents/00523958-pdf/00523958-pdf/govscot%3Adocument/00523958.pdf

Argyll and Bute	17	969
Orkney and Shetland	12	601
Angus, Fife, Lothian and Borders	15	550
Ayrshire, Dumfries and Galloway	9	1033

The average of 733 creels per vessel from this study is similar to Ellie MacLennan's recent interview data (mean 766 creels per vessel).

1.5 Gaps in coverage

The main gaps in areas covered by the workshops are the areas of the west coast and islands south of Isle of Mull to the Mull of Kintyre (SW RIFG), and east coast south of the Firth of Forth. That area of the west coast accounts for around 11% of the total landed value of creel caught crab, lobster and Nephrops for Scotland with a relatively high proportion (54%) of Nephrops. The value of landings on the east coast south of the Forth is dominated by lobster (78%) and accounts for around 7% of the total landed value of creel caught crab, lobster and Nephrops for Scotland. Creels targeting lobster tend to be in shallow water and have lower entanglement risks. Thus, the east coast south of the Forth is generally lower priority although the 2017 Creel Effort Study did show some offshore effort (presumably for crab). In the west, both Oban area south to Luing and Tayvallich and nearby ports have large landings including a substantial proportion of Nephrops. Having assessed these gaps in workshop data from the southwest, we made a supplementary effort to engage with fishers from these areas, adding 14 new vessels from the Argyll and Islands/southwest area to the project. These skippers have provided information and are trialling negatively buoyant rope.

1.6 Discussion of gear estimates

One of the two main conclusions from the 2017 Creel Fishing Effort Study was that effort monitoring should continue and total effort deployed in Scottish inshore waters quantified. We have specifically focussed on estimating effort from the perspective of the requirements of a potential transition to the use of negatively buoyant groundline. However, our methods also provide an estimate of the total numbers of creels in Scottish waters. Although these have considerable uncertainty, the comparison with the estimates from the limited areas but covered in more detail in the 2017 study did not indicate any substantial bias.

For the whole of Scotland, the estimates of average creel numbers per vessel of 733 from this study and 766 from 117 online responses suggest that the sample of vessels used in this study were adequately representative.

2. Estimating costs of different scenarios for transition to negatively buoyant groundline

2.1 Methods

The estimated costs of transition were estimated for the first ten-year period and then subsequent ten-year periods. In all cases it is assumed that a full transition has been achieved at the end of the first ten years i.e. the costs for the second period are just for the replacement of rope as it wears out.

The parameters used for the estimation are defined in Table 9.

Table 9. Parameters for cost estimates (figures are given in the table for constants throughout the study, other parameters are estimated for each scenario)

G_c	Total length of groundline in crab/lobster gear (m)	
G_n	Total length of groundline in Nephrops gear (m)	
L_c	Average life expectancy of crab/lobster groundline	
L_n	Average life expectancy of Nephrops groundline	
F	Average cost of a 220m coil of floating rope (ex VAT)	£40
W	Average cost of a 220m coil of negatively buoyant rope (ex VAT)	£80
S_c	Average spacing of crab/lobster creels	23.0m
S_n	Average spacing of Nephrops creels	13.4m
C	Average cost in terms of time for re-rigging each creel	£20 (Based on £1000 for a 50 creel fleet)
E_m	Estimated number of entangled minke whales over 10 year period	
E_h	Estimated number of entangled humpback whales over 10 year period	
E_b	Estimated number of entangled basking sharks over 10 year period	
P_m	Proportion of minke whale entanglements in groundline	0.83
P_h	Proportion of humpback whale entanglements in groundline	0.50
P_b	Proportion of basking shark entanglements in groundline	0.76
R_{cm}	Minke whale entanglement rate in crab/lobster gear (whales per km of line) similar Rch and Rcb for humpback and basking sharks	
R_{nm}	Minke whale entanglement rate in nephrops gear, similar R_{ch} and R_{cb} for humpback and basking sharks	

For the scenarios where rope is replaced at the end of its life expectancy there are no additional labour costs or costs for rope disposal.

The extra cost K for the negatively buoyant rope over each ten-year period is given by

$$K = \left(\frac{G_c}{220} \times (W - F)\right) \times \frac{10}{L_c} + \left(\frac{G_n}{220} \times (W - F)\right) \times \frac{10}{L_n}$$

The number of entanglements avoided is based on the estimates over ten years for the scenario area from the SEA interview data using the methods of Leaper et al. (2022) and the observed proportion of entanglements in the groundline.

For the first ten-year period the entanglements avoided are assumed to be proportional to the negatively buoyant line that has been replaced. It is assumed that there will be a period of L years where the line is being replaced followed by 10 - L years where all the line has been replaced. Giving the total number of megafauna entanglements avoided for the first ten-year period A_1, as:

$$A_1 = ((E_m \times P_m) + (E_h \times P_h) + (E_b \times P_b)) \times \frac{1}{10} \times \left(\frac{L}{2} + (10 - L)\right)$$

And for each subsequent ten-year period A_2, as:

$$A_2 = ((E_m \times P_m) + (E_h \times P_h) + (E_b \times P_b))$$

Where the transition to negatively buoyant rope is different for crab/lobster gear and Nephrops gear these equations are modified according to the proportion of risk estimated for each gear type. Thus A_{1cm} would be

$$A_{1cm} = (E_m \times P_m) \times \frac{1}{10} \times \left(\frac{L}{2} + (10 - L)\right) \times \frac{G_c \times R_c}{(G_c \times R_c) + (G_n \times R_n)}$$

and similarly for A_{2cm}, A_{1nm} and A_{2nm}, etc. giving

$$A_1 = A_{1cm} + A_{1nm} + A_{1ch} + A_{1nh} + A_{1cb} + A_{1nb}$$

For the scenarios where rope is replaced straight away the extra costs are assumed to be the total cost of the negatively buoyant rope to replace all the existing floating rope regardless of its age, and then the ongoing extra cost of the negatively buoyant rope when it is due for replacement. In addition there are the costs of the extra labour to change over the rope that did not need to be replaced. There may also be additional disposal costs (because some floating line would be being disposed of early than expected), but these have not been included.

$$K_{rope} = \left(\frac{G_c}{220} \times W\right) + \left(\left(\frac{G_c}{220} \times (W - F)\right) \times \left(\frac{10 - L_c}{L_c}\right)\right) + \left(\frac{G_n}{220} \times W\right) + \left(\left(\frac{G_n}{220} \times (W - F)\right) \times \left(\frac{10 - L_n}{L_n}\right)\right)$$

and

$$K_{labour} = \left(\frac{G_c}{220 \times S_c} + \frac{G_n}{220 \times S_n}\right) \times C$$

Giving total cost K as:

$$K = K_{rope} + K_{labour}$$

Cost per individual megafauna entanglement avoided is Q

$$Q = \frac{K}{A}$$

All options were calculated with three rope replacement interval scenarios (short, medium and long). The medium scenario is based on the average value given in the workshop questionnaires (see Table 10).

Table 10. Assumptions regarding rope replacement intervals for estimates of costs.

Rope replacement interval (years)	Crab/lobster	Nephrops
Short	3	5
Medium (average from workshop questionnaires)	5.4	7.15
Long	7	10

2.1.1 Cost of negatively buoyant rope

The costs of rope are related to the diameter, materials, quality, lay and manufacture. Different types of fishing look for different characteristics in the rope, and fishers can be quite particular about their preferred rope.

Table 11. Costs (excluding VAT) for different negatively buoyant rope (n=15) quoted by six suppliers during 2025

Diameter	Min	Max	Mean	Number of coils distributed during project	Relative proportions of each diameter	Example price difference between negatively buoyant and floating (same supplier)
10mm	£59	£113	£82	163	0.23	£30.67
12mm	£80	£123	£101	377	0.54	£37.50
14mm	£100	£178	£137	155	0.22	£40.83

It is possible that the higher prices quoted by some suppliers just reflected a limited current demand for negatively buoyant rope and so we use the prices at the lower end of the range, which was the main supplier used for the project who handled larger quantities. The price difference for the 12mm rope between negatively buoyant and floating (£37.50) was very similar to the average price difference (£36.60) for all the coils distributed through the project. We understand that the relative proportions of different rope sizes distributed through the project are reasonably representative of Scotland as a whole. Thus, the price difference for a coil of 12mm rope is a good estimate of the average total.

Costs were calculated in line with options discussed with fishers at the workshop of the subsidy required to make negatively buoyant rope (i) cost neutral, (ii) 10% cheaper than floating equivalent and (iii) 25% cheaper than floating equivalent.

For our calculations we used an average price difference per coil of £40. This resulted in an average subsidy of £44 a coil to make negatively buoyant rope 10% cheaper than its floating equivalent, which 82% of workshop attendees indicated would be a sufficient subsidy to incentivise them to switch over (see Appendix 1) (£50 to make it 25% cheaper).

Using the amount of groundline estimated in Table 5, we calculated the total annual cost based on the number of coils required (assuming a standard 220m coil) and the replacement rates for the ‘short’, ‘medium’ and ‘long’ scenarios in Table 10. The ‘medium’ scenario is our best estimate with the estimates for ‘short’ and ‘long’ giving an indication of maximum and minimum values.

2.1.2 Discounted (net present value) calculations

Costs were calculated over a 10-year time horizon and presented as discounted (net present value) estimates. We consider this from a public sector appraisal perspective, using the Green Book discount rate of 3.5%, and from a private industry perspective, using a higher rate of discount (7.5%) to reflect the higher costs of raising capital for a private operator and the greater degree of risk-spreading and risk pooling for the public sector. VAT is not included in either of these sets of calculations since from a public sector appraisal perspective this is a transfer payment; and since private firms can reclaim VAT.

The discounted 10-year totals (*PV*) for public sector and industry were calculated from the first year annual cost estimate (C_1) where *r* is the discount rate (i.e. 1.035 or 1.075) according to;

$$PV = C_i \left(\frac{1 - \left(\frac{1}{r}\right)^{10}}{1 - \left(\frac{1}{r}\right)} \right)$$

2.2 Results

We initially calculated costs for the situation where fishers transitioned to negatively buoyant rope straight away (i.e. regardless of whether the old rope needed replaced or not). This option would require considerable extra work for fishers and so we included an estimate for labour costs. Consultation with fishers indicated a typical labour cost for re-rigging a fleet of creels at £20 a creel. Using this estimate, the total cost estimate for an instantaneous transition to negatively buoyant rope for the whole Scottish creel fleet would be between £20.1M and £24.2M, depending on the rope replacement intervals from Table 10. This option was considered to be prohibitively expensive and also impractical from the fishers' perspective in terms of time away from fishing. Thus, all further calculations were based on a phased transition, in which vessels adopt negatively buoyant rope fleet-by fleet when their existing floating rope reaches the end of its operational life. For this option there is no extra work or additional rope disposal because floating rope is only replaced at the end of its life. All costs were based on the assumption that negatively buoyant rope lasts as long as floating.

From the workshop discussions (Appendix 1), we had ascertained that 67% of fishers would actively switch to negatively buoyant rope if it was cost neutral, 82% if it was 10% cheaper than floating equivalent and 84% if it was 25% cheaper than floating equivalent.

The costs to fishers and the subsidy required are given in Table 12 assuming a situation with 100% uptake. The costs assuming the maximum uptake based on feedback at the workshops are given in Table 13.

Across all scenarios modelled, cost-neutral and cost-incentive transitions for Scotland's crab/lobster and Nephrops fisheries, the total present value (PV) costs provide a comparison of the financial implications of switching from floating to negatively buoyant rope over a 10-year period.

In the cost-neutral scenarios, assuming 100% uptake (Table 12), the private cost to fishers remains the same as continuing to use floating rope, while the public cost to government ranges from £2.2 million to £5.1 million for crab/lobster creel fisheries, and from £609,000 to £1.2million for Nephrops fisheries, depending on rope replacement frequency. This model eliminates the financial barrier to switching but requires moderate public investment and had only modest support from fishers (67% would switch).

In the cost-incentive scenarios, where fishers are financially rewarded for switching (paying only 75% or 90% of the floating rope cost), their PV costs decrease significantly. In the case of a 10% subsidy, crab/lobster fishers' costs drop to between £1.69million to £3.95million, while the government assumes a higher cost burden of £2.42 million to £5.64 million. In Nephrops fisheries, fishers' costs fall to between £470,000 and £940,000, with government contributions rising to £670,000 to £1.34 million (Table 12). However, these figures are assuming 100% uptake. In the case of the maximum uptake of 82% for this level of subsidy indicated by fishers at the workshops the subsidy contributions would be £1.98million to £4.62million for the crab/lobster fishery and between £549,000 and £1.10million for the Nephrops fishery (Table 13).

Although the feedback received suggested that a Scotland wide scheme would be the most effective, supported by fishers and easiest to administer, further regional engagement could encourage uptake. This could be focussed on priority areas and fisheries. Table 14 provides estimates of the reduction in risk entanglements avoided (minke whales, humpback whales and basking sharks) and the subsidy cost of each entanglement avoided for the scenarios costed in Table 13. In addition we performed the same calculations for the 10% cheaper scenario if uptake only occurred in the Nephrops fishery.

Our best estimate of the subsidy required to make negatively buoyant rope 10% cheaper than its floating equivalent, for both crab/lobster and Nephrops creel fisheries throughout Scotland, for a 10-year period, is £3.34million. This would reduce entanglement risk by an estimated 67% (Table 14).

Table 12. Costs of subsidised negatively buoyant rope assuming 100% uptake

	Crab/lobster			**Nephrops**		
	Short	**Medium**	**Long**	**Short**	**Medium**	**Long**
Cost neutral						
Year1 cost for fishers if same price as floating	£595,203	£330,669	£255,087	£141,516	£98,962	£70,758
10 year PV value cost to fishers (7.5% discount rate)	£4,391,939	£2,439,966	£1,882,260	£1,044,233	£730,233	£522,117
Year1 public subsidy cost for negatively buoyant to be same price as floating	£595,203	£330,669	£255,087	£141,516	£98,962	£70,758
10 year PV value subsidy cost (3.5% discount rate)	£5,123,325	£2,846,292	£2,195,711	£1,218,129	£851,838	£609,064
Negatively buoyant 10% cheaper than floating						
Year1 cost for fishers if same price as floating	£535,683	£297,602	£229,578	£127,365	£89,066	£63,682
10 year PV value cost to fishers (7.5% discount rate)	£3,952,745	£2,195,970	£1,694,034	£939,810	£657,210	£469,905
Year1 public subsidy cost for negatively buoyant to be same price as floating	£654,724	£363,735	£280,596	£155,668	£108,859	£77,834
10 year PV value subsidy cost (3.5% discount rate)	£5,635,657	£3,130,921	£2,415,282	£1,339,941	£937,022	£669,971
Negatively buoyant 25% cheaper than floating						
Year1 cost for fishers if same price as floating	£446,403	£248,001	£191,315	£106,137	£74,222	£53,069
10 year PV value cost to fishers (7.5% discount rate)	£3,293,954	£1,829,975	£1,411,695	£783,175	£547,675	£391,587
Year1 public subsidy cost for negatively buoyant to be same price as floating	£744,004	£413,336	£318,859	£176,895	£123,703	£88,448
10 year PV value subsidy cost (3.5% discount rate)	£6,404,156	£3,557,864	£2,744,638	£1,522,661	£1,064,798	£761,330

Table 13. Costs of subsidised negatively buoyant rope assuming indicative scenarios of rates of uptake based on feedback at workshops

	Crab/lobster			**Nephrops**		
	Short	**Medium**	**Long**	**Short**	**Medium**	**Long**
Cost neutral (67% uptake)						
Year1 cost for fishers if same price as floating	£398,786	£221,548	£170,908	£94,816	£66,305	£47,408
10 year PV value cost to fishers (7.5% discount rate)	£2,942,599	£1,634,777	£1,261,114	£699,636	£489,256	£349,818
Year1 public subsidy cost for negatively buoyant to be same price as floating	£398,786	£221,548	£170,908	£94,816	£66,305	£47,408
10 year PV value subsidy cost (3.5% discount rate)	£3,432,628	£1,907,015	£1,471,126	£816,146	£570,732	£408,073

Negatively buoyant 10% cheaper (82% uptake)						
Year1 cost for fishers if same price as floating	£439,260	£244,033	£188,254	£104,439	£73,034	£52,220
10 year PV value cost to fishers (7.5% discount rate)	£3,241,251	£1,800,695	£1,389,108	£770,644	£538,912	£385,322
Year1 public subsidy cost for negatively buoyant to be 10% cheaper	£536,874	£298,263	£230,089	£127,648	£89,264	£63,824
10 year PV value subsidy cost (3.5% discount rate)	£4,621,239	£2,567,355	£1,980,531	£1,098,752	£768,358	£549,376
Negatively buoyant 25% cheaper than floating (84% uptake)						
Year1 cost for fishers if same price as floating	£374,978	£208,321	£160,705	£89,155	£62,346	£44,578
10 year PV value cost to fishers (7.5% discount rate)	£2,766,922	£1,537,179	£1,185,824	£657,867	£460,047	£328,933
Year1 public subsidy cost for negatively buoyant to be 25% cheaper	£624,964	£347,202	£267,842	£148,592	£103,911	£74,296
10 year PV value subsidy cost (3.5% discount rate)	£5,379,491	£2,988,606	£2,305,496	£1,279,035	£894,430	£639,517

Table 14. Estimated risk reduction and cost of public subsidy per entanglement avoided

	Negatively buoyant cost neutral (67% uptake)	Negatively buoyant 10% cheaper (82% uptake)	Negatively buoyant 25% cheaper (84% uptake)	Negatively buoyant 10% cheaper (82% uptake in nephrops fishery only)
Estimated proportion of entanglement avoided	0.54	0.67	0.68	0.34
Estimated entanglements avoided	327	400	410	203
10 year PV for public subsidy	£2,477,747	£3,335,713	£3,883,036	£768,358
Cost per entanglement avoided (PV/E)	£7,578	£8,336	£9,473	£3,794

2.3 Summary of expected funding requirements

Our best estimates of indicative costs of the subsidies that would be required for the crab/lobster and Nephrops fisheries combined for the scenarios of negatively buoyant rope being cost neutral, 10% cheaper or 25% cheaper compared to its floating equivalent are based on:

a) our mean estimates of life expectancy of the rope (the medium scenario)

b) an uptake of 67%, 82% and 84% for the respective scenarios

Taking the relevant figures from Table 13 for these assumptions gives first year public subsidy costs of £288,000 for cost neutral, £388,000 for 10% cheaper and £451,000 for 25% cheaper.

In addition to the subsidy costs there would be additional costs for administration of the scheme and some support for further engagement to encourage uptake, particularly in the areas identified as the highest entanglement risk. These additional costs would mean that a total budget of around £450,000 could be required to fund the 10% cheaper scenario including administration and engagement.

3. Discussion

A socio-economic analysis needs to look at the direct economics of different implementation options but also put this into context of UK and Scottish policy and spending on other comparable support for reducing environmental impacts from economic activities, and the preferred fishing practices in the Scottish inshore fleet.

Mandatory regulation of the use of negatively buoyant rope would be a challenge due to the difficulties of monitoring compliance; any regulation without financial support would have a negative effect on fishers, and likely attract strong opposition. In addition, as noted by Bellanger et al. (2025) 'there is growing recognition of the need to explore alternative approaches that encourage behavioural change through the creation of an appropriate set of incentives towards bycatch reduction.' The basis of the work of the Scottish Entanglement Alliance is that initiatives are fisher-led, and any enforcement would contradict this approach.

The average extra costs to fishers of switching to negatively buoyant rope, replacing rope just when it was due for replacement but without a subsidy, as a fraction of total landed value (gross revenue) were 1.6% for the short life expectancy case, 1.0% for the medium and 0.7% for the long. Since the estimates of the amount of gear in use are related to the landed value, these proportions were similar for all the scenarios. With fishers' profit margins often quite small, a 1% fraction of gross revenue can result in a substantial loss of income and business viability.

At least in the short term, the way to achieve a reduction in entanglement risk is through a level of subsidy. The costs required could be put in context by examining other similar economic situations where the Scottish Government provides levels of annual subsidy for ongoing nature conservation projects. Subsidies for agri-environmental measures may also provide comparative examples, in particular because most of these measures are voluntary and their success depends on farmers' willingness to participate (Schulze et al. 2024). Payment for environmental services (PES) has been found to be effective in many terrestrial examples but has been less used in the context of fisheries (Develey and Gonçalves, 2025).

In the absence of a monetary estimate of the benefits of avoidance in damage to wildlife populations, we have examined a cost-effectiveness measure, expressed as the present value (PV) of costs per predicted avoided entanglement (E) for different scenarios. Choosing an option with a lower PV/E implies a more cost-effective conservation option and this could be achieved through encouraging the most uptake in the highest risk areas. Focussing on low PV/E options would maximise the predicted environmental gain for a given budget.

Some indications of the direct economic value of whales can be inferred from whale watching. For example, Ryan et al. (2018) estimated that 51,200 people went whale watching on boats in the west of Scotland in 2015, generating an estimated £2.3 million and £3.7 million of direct and indirect revenue, respectively. Whale watching also occurs outwith the west coast as part of more general wildlife tourism. In addition, basking shark watching is an important activity on the west coast. Hence these estimates of the contribution of whale watching are likely to be under estimates of the total economic contribution of wildlife tourism associated with whales and basking sharks. Nevertheless, the indirect contribution from whale watching, predominantly for minke whales, of £3.7m can be compared to a population estimate for the west coast of 700 individuals from the SCANS-IV survey in 2022 (Gilles et al, 2023). This suggests an average annual contribution of for each individual minke whale of just over £5000 from whale watching alone, which is similar to the costs of each entanglement avoided.

Establishing a credible eco-labelling scheme for products caught using negatively buoyant rope could also provide an economic incentive towards a transition. This has been explored in the case of the public's willingness to pay in Ireland for more sustainable salmon from aquaculture (van Osch, 2017). Many studies have demonstrated that some consumers are willing to pay a premium for products that are procured in a higher animal welfare manner. Establishing a "low impact" label for creel fishers could create such a differentiated market, which, so long as the label was credible and matched consumer preferences, and could deliver higher revenue streams to fishers who switch to negatively buoyant rope. However, monitoring such a scheme would be complex and difficult in a similar way to enforcing any regulation. It could also potentially disadvantage fishers for whom negatively buoyant rope is not practicable because of the bottom type and conditions where they fish. In addition, there is very little market for Scottish caught shellfish products within Scotland and so any consumer schemes would rely on customers in Europe being prepared to pay for changes that reduced environmental impacts in Scotland, a long way from the consumers themselves.

Further scenarios could be presented for limited areas with particularly high densities of minke whales or basking sharks. These situations will have a lower predicted cost per entanglement avoided (PV/E). One issue with this approach is that the distribution of these species shows considerable inter-annual variability and may also be shifting with climate change and substantially higher sea temperatures. Predicting future high-density areas is therefore very difficult. Any implementation of negatively buoyant line that just targets current high-risk areas will need to take inter-annual variability and the potential for long term changes into account. However, gear which is consistently high-risk (Nephrops and deep-water brown crab) due to the depth at which it is set/amount of rope in the water could be targeted for early implementation.

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