Title: Assessing bait use by static gear fishers of the Scottish Inshore Fisheries: a preliminary study

Authors names and affiliations: Felicity Spoors[a], Tania Mendo[a], Nicola Khan[a,b], Mark James[a]
[a] Scottish Oceans Institute. East Sands, University of St. Andrews, Fife KY16 LB, United Kingdom
[b] School of Animal, Rural and Environmental Sciences, Nottingham Trent University, Brackenhurst Campus, Southwell NG25 0QF

CRediT authorship contribution statement:
Felicity Spoors: Investigation, Data Curation, Formal analysis, Writing- Original Draft. **Tania Mendo:** Supervision, Methodology, Writing - Review & Editing. **Nicola Khan:** Supervision, Methodology, Writing - Review & Editing. **Mark James:** Conceptualization, Project Administration, Supervision, Methodology, Writing - Review & Editing.

Corresponding Author: Mark James
Email: maj8@st-andrews.ac.uk
Address: Scottish Oceans Institute. East Sands, University of St. Andrews, Fife KY16 LB, United Kingdom

Funding Sources:
This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Keywords:
Coastal fisheries
Bait Biomass
Creel Fishing
Fisher Knowledge
Fisheries Management

ABSTRACT

Approximately 70% of the Scottish fishing fleet target shellfish using baited creels. Bait is an essential component of catch success, but the economic and environmental implications of bait use are unknown. In this preliminary study, a short survey was circulated to members of the Scottish inshore creeling fleet and analysed alongside spatial data from 8 creel fishing vessels. Bait biomass, input into coastal waters through creeling activity, was calculated along with bait types, motivations surrounding the discarding of used bait and the annual estimated spatial concentration. Findings indicate that preferred bait types differ with geographic location and cost the creeling sector approximately £9.8 million annually at the time of the survey, equating to 16.3% of the nominal 2018 shellfish landing value. Data from this research suggests that approximately 13,492 metric tonnes of bait biomass enters coastal Scottish waters through creeling activities annually. Vessel tracks showed fishers returning to certain fishing grounds repeatedly, indicating that bait biomass input is highly localised. Hotspots of fishing activity were calculated to receive up to 75 kg ha^{-1} and 47 kg ha^{-1} of bait biomass per fisher annually when fishing *Nephrops* and crab/ lobster, respectively. Bait discarding occurs most frequently at the fishing grounds with convenience being the main motivation. This study provides a baseline for future studies and prompts the consideration of bait use in the management of creel fisheries.

1. Introduction

The use of bait is a substantial part of catch success in creel fisheries (Chapman and Smith, 1978; Siikavuopio et al., 2017). Various physical properties of bait and its usage, such as moisture content, persistence, rate of diffusion and soak times, can impact catch effectiveness (Dorman et al., 2012; Mackie et al., 1980). As a result, fishers are subject to an unavoidable cost:benefit trade-off when selecting bait type; for instance, more expensive bait types may improve catch substantially. Minimising bait costs while boosting bait-related catch efficiency is key to improving the cost-benefit ratio. Five key determining factors of bait choice are likely to be durability in the creel, availability, oiliness, price and target species, however, it is suggested that bait availability and expense largely govern bait choice (de Rozarieux, 2014; Mackie et al., 1980).

In Scotland, inshore creeling vessels almost exclusively target European lobster (*Homarus gammarus*), brown crab (*Cancer pagurus*), velvet swimming crab (*Necora puber*) and Norway lobster (*Nephrops norvegicus*) within 12 nm of the Scottish coast. Approximately 92 % of creeling vessels are <10 m; this figure increases to ~99 % in vessels <15 m (Marine Scotland, 2019). Operational patterns for the fishery are found to relate to vessel size; larger vessels tend to work larger areas and as a result, fish more creels (Mendo et al., 2019a). Creel-caught landings from Scottish vessels amounted to approximately 16,000 tonnes and were worth over £60 million (nominal value) in 2018 (Marine Scotland, 2019).

Stock assessment reports identify data gaps including information on growth parameters, bycatch discarding, and factors of catchability such as bait types, soak times and creel densities (Mesquita et al., 2017). Aspects affecting catchability directly impact the economic output of a vessel through the altered catch success of target species. Baiting method (mesh bag or perforated container), the quantity of bait per creel and rebaiting frequency also affect catchability (Krouse, 1988). These decisions are based on inherent 'fisher knowledge', gained over a fishing career or by word of mouth. Fisher knowledge has been identified as a largely untapped and valuable data resource for scientific communities (Johannes et al., 2000).

The environmental implications of bait choice on benthic habitats within Scottish inshore fisheries are largely unknown. Bait biomass entering coastal waters from creeling activities come from two sources, the first being retained and consumed within a creel when it is soaked. The second is 'used bait' that has been taken from hauled creels. This used bait is often discarded by fishers into the marine environment.

Parallels may be drawn between the deposition of bait biomass from creeling activity and the widespread practice of discarding deceased non-target and non-quota biomass at sea through EU regulation before the Common Fisheries Policy (CFP) reform in 2013 (European Commission, 2013, 2009). The discarding of marketable biomass was typically associated with industrial-scale bottom trawling activities in the North Atlantic (Zeller et al., 2018). Documented impacts of discarding include artificially inflated scavenging seabird populations (Bicknell et al., 2013; Furness, 2003; Tasker et al., 2000), utilisation by benthic carnivores and demersal fish (Catchpole et al., 2005), habituation of marine predators (Moore, 2003) and altered species interactions (Regehr and Montevecchi, 1997).

Sourcing bait may also have environmental consequences; transportation carries a carbon footprint, which will likely be higher for fishers operating from the Hebridean Islands, shipping bait from the mainland (D Macinnes 2020, *pers. comm.*, 23 June). There is potential for disease transfer to native wildlife and local aquaculture from bait imports (Murray, 2015) and the question of sustainability of baitfish stocks (Rizzari and Gardner, 2019).

The 2017 Creel Fishing Effort Study highlighted a widespread concern over gear saturation with more creels in the water, creating 'creel on creel' conflict between fishers for marine space and leading to overfishing of poorly managed locations (Marine Scotland, 2017). The number of creeling vessels in Scottish waters has been increasing steadily since 2013 (Marine Scotland, 2019). Together, this implies an increased demand for bait and higher levels of biomass entering the marine environment. The demand for bait biomass and its cost to the Scottish inshore fishery is unknown.

In a preliminary study by Saila et al., 2002, creel bait is suggested to be a significant contribution to the increase in populations and landings of American lobster (*Homarus americanus*). Bait biomass input equated to an 80% increase in primary production in the Gulf of Maine inshore fishery. Furthermore, bait consumed within a creel by sub-legal specimens was estimated to account for over 20% of landings due to the impact on growth (Saila et al., 2002). Whilst further study is necessary, if verified, the implications of bait use should be a major consideration in the management of shellfish stocks worldwide. Without knowledge of the demand and spatial use in Scotland, the environmental and economic implications of bait use, both positive and negative, are unknown.

This study aims to establish a baseline for bait biomass and costs in the Scottish inshore creeling sector as well as gain an understanding of bait use by utilising fisher knowledge through a targeted survey. The study was split into four main objectives:

- To identify the different kinds of bait being used across Scotland to identify regional differences in demand.
- To estimate the biomass and the financial costs of bait entering coastal waters as a function of creel numbers.
- To learn of personal motivations surrounding bait discarding practices by tapping into fisher knowledge and allowing for hypothesis formation.
- To use a selection of vessel tracks to estimate the seasonal bait biomass input into areas of highest fishing pressure to provide a basis for understanding possible environmental and economic implications.

2. Materials & Methods

2.1. Survey

This fishery targets crab, lobster and *Nephrops* using baited creels and comprises primarily of vessels <10 m in length. Fishers on the east coast catch only crab and lobster in standard D-shaped or parlour creels. West coast fishers also use D-shaped and parlour creels to catch crab and lobster, along with *Nephrops* which are caught using D-shaped prawn creels

(Marine Scotland, 2017). The surveys were targeted at all members of the Scottish inshore static gear fleet who use baited creels within a 12 nm radius of the coast. A 10 minute, 24-question survey was constructed using Qualtrics^{XM} software version 05/06 2020. A draft of the survey was reviewed by a small number of fishers to ensure that the questions asked were appropriate and that the length would not deter other fishers from responding. It was circulated from the 11th June - 5th August 2020 through various contacts within the sector around Scotland, including Johnshaven, the Western Isles and the Clyde Fishers Association (CFA) to ensure both east and west coast were represented. Contacts subsequently prompted their respective fishing communities to complete the surveys with a prize-draw to incentivise survey participation.

A mixed-mode survey design, suggested to produce a higher response rate, gave fishers the option of completing the survey online through a customized link/ QR code, a hard-copy or a telephone interview (Wallen et al., 2016). Data from telephone interviews were emailed to the participant to approve the response before entry into the database. Consent was obtained before completion and all data were anonymised. Data held were compliant with the UK Government's General Data Protection Regulations (GDPR) (ICO, 2019). Ethical approval for the collection of survey data was granted by the University of St Andrews Research Ethics Committee (UTREC) (Approval Code: BL13442).

Part 1 of the survey focussed on vessel details (home port, vessel plate number and target species) and fishing effort to contribute to the quantification of bait biomass. Details included the number of creels, strings shot per day, days fished, length of high and low season and frequency with which creels are checked and rebaited. Part 2 focused on the details of personal bait use, including bait type, quantity, price, source and discarding practices. The questions were a mix of multiple-choice, short answer, dichotomous and open-ended. Vessel lengths were sourced from the Marine Management Organisation (MMO) Fleet Register.

2.2. Spatial Data Collection

Positional data were collected between February 2018 and July 2020 under the Scottish Inshore Fisheries Integrated Data System (SIFIDS) project (MASTS, 2016). Eight vessels from around Scotland were fitted with solar-powered or vessel electrically powered Teltonika FMB202 and FMB204 waterproof (IP67) trackers. Trackers contained internal high gain Global Navigation Satellite System (GNSS) and Global System for Mobile Communications

(GSM) antennas with integrated high-capacity back-up batteries and had an accuracy of <3 m. The trackers were configured to record positional GNSS data at 60-second intervals as this was found to be the most effective resolution at which to infer fishing activity (Mendo et al., 2019b).

2.3. Survey Data Analysis

All data were analysed using RStudio Version 3.6.1 (RCoreTeam, 2019) with some calculations made with Microsoft Excel ® for Microsoft 365 MSO (16.0.13127.20164). Bait types were grouped into different geographic locations. Fisher's exact testing was used to compare bait preferences for each region and the difference in acquisition (caught or purchased bait). The mass per creel of frequently used bait types was compared using a non-parametric Kruskal-Wallis test to determine if any type would have inflated demand on account of being used in larger quantities per creel.

2.4. Biomass Estimation

The number of creels per string (*CreelStr*) for each fisher were multiplied by the number of strings shot per day (*StrDay*) to give the number of creels shot per fishing day (*CreelDay*) (1).

$$CreelDay = CreelStr * StrDay \quad (1)$$

For each respondent, the bait mass used per creel for the different bait types was averaged (*BaitCreel*). This was multiplied by the number of creels shot per day (*CreelDay*) and by the weekly rebaiting frequency (*RebaitFreq*) to give the amount of bait used by a fisher per week (*BaitWeek*), calculated for high and low seasons separately (2).

$$BaitWeek = BaitCreel * CreelDay * RebaitFreq \quad (2)$$

The amount of bait used per week (*BaitWeek*) was multiplied by the number of weeks fished in high and low season respectively (*WeeksFished*) to estimate the mass of bait per season (*BaitSeas*) (3). The resulting high *(H)* and low *(L)* season values for each fisher were added to give the annual bait used per vessel (*BaitYr*) (4).

$$BaitSeas = BaitWeek * WeeksFished \quad (3)$$

$$BaitYr = BaitSeas(H) + BaitSeas(L) \quad (4)$$

The annual bait used per full-time vessel (where full-time equates to those fishing 52 weeks per year) was averaged (*AveBaitYr*) and was multiplied by the median number of active creel fishing vessels in Scotland, currently estimated at 1,017 (Marine Scotland, 2017) (5). The resulting number is the average bait mass deposited in coastal waters annually (*BaitDeposit*).

$$BaitDeposit = AveBaitYr * 1{,}017 \quad (5)$$

2.5. Estimation of costs

The number of fishing days per week for high and low season (*FDWeek*) were multiplied by the number of creels shot per day (*CreelDay*) to give creels shot per week (*CreelWeek*) (6). This was multiplied by the number of weeks fished in high and low season (*WeeksFished*) to give the number of creels shot per season (*CreelSeas*) (7). Creels shot per season were combined to give the number of creels shot per year (*CreelYr*) (8).

$$CreelWeek = FDWeek * CreelDay \quad (6)$$

$$CreelSeas = CreelWeek * WeeksFished \quad (7)$$

$$CreelYr = CreelSeas(H) + CreelSeas(L) \quad (8)$$

Costs were calculated using the average number of creels shot per day as the price of bait per day was not differentiated between the seasons in the survey. The number of fishing days per year (*FDYr*) was calculated by multiplying the number of fishing days per week (*FDWeek*) by the number of weeks fished for high and low season (*WeeksFished*) (9). To get the average number of creels shot per day (*AveCreelDay*), the number of creels shot per year (*CreelYr*) was divided by the number of fishing days per year (10).

$$FDYr = FDWeek * WeeksFished \quad (9)$$

$$AveCreelDay = CreelYr / FDYr \quad (10)$$

The price paid by a fisher for bait on a typical fishing day (*£BaitFD*) was divided by the mass of bait used per typical fishing day (*MassBaitFD*) to give the cost of bait per kilogram (*£BaitKG*) (11). The cost of bait per kilogram was multiplied by the amount of bait remaining at the end of a fishing trip (*BaitRemain*) to give the price of the remaining bait (*£BaitRemain*) (12).

$$\pounds BaitKG = \pounds BaitFD / MassBaitFD \qquad (11)$$

$$\pounds BaitRemain = \pounds BaitKG * BaitRemain \qquad (12)$$

The price of the remaining bait (*£BaitRemain*) was subtracted from the original price paid by a fisher for bait on a typical fishing day (*£BaitFD*) to give the actual cost of bait used per fishing day (*CostBaitFD*) (13). The cost of bait per creel (*CostCreel*) could then be calculated by dividing the actual cost of bait used per fishing day by the average number of creels shot per day (*AveCreelDay*) (14).

$$CostBaitFD = \pounds BaitFD - \pounds BaitRemain \qquad (13)$$

$$CostCreel = CostBaitFD / AveCreelDay \qquad (14)$$

The cost of bait per creel (*CostCreel*) could then be scaled up to a personal cost-per-year (*FisherCostYr*) by multiplying it by the number of creels shot per year (*CreelYr*) (15). The costs were averaged across all full-time survey respondents who fish 52 weeks per year (*AveFisherCostYr*) and multiplied by 1,017 to give an approximate industry-wide value (*BaitCostYr*) to bait purchased in Scotland for use in the creeling sector (16).

$$FisherCostYr = CostCreel * CreelYr \qquad (15)$$

$$BaitCostYr = AveFisherCostYr * 1{,}017 \qquad (16)$$

2.6. Bait discard motivations

First, the preferred bait discarding site was determined. Participants chose between discarding bait at the fishing grounds, in the harbour or in transit. Fisher’s exact testing determined if the geographic location was a dependent factor in the preferred bait discarding site. Motivations surrounding discarding practice were coded (Table 1) and categorised by discarding site (fishing grounds, harbour and in transit). The percentage of fishers quoting each belief was determined.

Table 1
Descriptors for the codes given to fisher reasons and motivations surrounding the discarding of used bait at either the fishing grounds, in the harbour, or in transit**.**

Code	Descriptor of reasons/ motivations
Attractant	*Believes bait discards will attract new animals to the fishing grounds.*
Convenient	*The easiest solution for getting rid of used bait.*
Feed Birds	*Seabirds consume discarded bait. Beliefs of convenience, the desire to get rid of rotten bait and the belief that there will be no effect on the benthos are*

	inferred.
Feed Benthos	*Believes that benthic organisms will consume discarded bait.*
Feed Stock	*Believes that discarded bait will feed the target species.*
No Discards	*No bait is discarded.*
No Effect	*Discarded bait is believed to have no effect on the benthos.*
No feeding stock	*Believes that fed lobsters will not enter creels.*
None	*No reasons or beliefs were given.*
Preserve fishing grounds	*Believes that bait should not be discarded at the fishing grounds.*
Preserve Harbour	*Believes that bait should not be discarded in the harbour.*
Rotten bad	*Believes rotten bait will not catch anything so bait is discarded to prevent rot.*
Rotten good	*Believes that rotten bait will improve the catch of lobsters and so is retained.*
Safety	*Safety reasons stated, e.g. the discarding of used bait prevents the deck from becoming slippery.*

2.7. Spatial Data Analysis

Positional data were available for eight creeling vessels, 4 from the West Coast and 4 from the East Coast, between February 2018 to July 2020. Data from each vessel were divided by year and further subset into meteorological seasons with spring spanning 01st March – 31st May, summer from 01st June – 31st August, Autumn spanning 01st September – 30th November and Winter from 01st December – 28/29th February the following year. Seasonal data with fishing trips recorded in all three months were considered complete and isolated for the revisit analysis. The SIFIDS project developed an algorithm to infer fishing activity by differentiating creel hauls from that of vessel steaming (Mendo et al., 2019b). This algorithm was applied to the vessels tracks to filter hauling activity only.

Spatial data were visually inspected for errors using the 'leaflet' package in RStudio (Cheng et al., 2019). Coordinates outside the study area, along with duplicated data were removed. Vessels were observed revisiting certain locations within their fishing grounds. To calculate the number of revisits in a season, the function *rasterize()* from the R package '*raster'* (Hijmans, 2020) was used to count the number of fishing trips that occurred within a grid of resolution 100 x 100 m (1 ha). A resolution of 1 ha allowed for the number of revisits to be calculated on a fine spatial scale and for comparison with values given in previous research (Saila et al., 2002). Individual fishing excursions could be identified by a unique trip identification number, which when mapped, permitted the calculation of the number of revisits per 1 ha grid cell. From each seasonal subset and for each vessel, the maximum number of revisits in a season was recorded. The average maximum revisits across each meteorological season was then calculated. The maximum number of revisits enabled the calculation of the concentration of bait entering creeling hotspots per meteorological season.

2.8. Seasonal bait biomass input estimate

The number of *Nephrops* and crab and lobster creels on a string that would fall within 1 ha was calculated (*CreelNumber*). This was multiplied by the average amount of bait used per creel (247.35 g) to give an estimate for the average bait input into that hectare for a single fishing event (*Bait/ha*) (17).

$$Bait/ha = CreelNumber * 247.35 \quad (17)$$

The mass of bait per hectare (*Bait/ha*) was then multiplied by the number of average maximum revisits for each season (*AveMaxRevisit*) to determine the seasonal bait input (*SeasBaitInput*) for a fishing hotspot (18).

$$SeasBaitInput = Bait/ha * AveMaxRevisit \quad (18)$$

Rebaiting was assumed with every revisit and bait mass was assumed equal between *Nephrops* creels and crab and lobster creels. In some instances, vessels were observed returning to the same locations every season, therefore, it was appropriate to sum the seasonal masses (*SeasBaitInput*), yielding an annual figure (*BaitConcYr*) (19).

$$BaitConcYr = SeasBaitInput(Spring) + SeasBaitInput(Summer) + SeasBaitInput(Autumn) + SeasBaitInput(Winter) \quad (19)$$

3. Results

29 survey responses were obtained: 12 surveys (41.4%) from the east coast (E), 12 surveys (41.4%) from the Outer Hebrides (OH) and 5 surveys (17.2%) from the west coast mainland and Inner Hebrides (WMIH). Respondents fished from vessels ranging from 4.78 to 13.41 m in length, with 3 respondents (10.3%) targeting *Nephrops*, 4 respondents (13.8%) targeting lobster, 1 respondent (3.8%) targeting swimming crabs and the remaining 21 (72.4%) targeting various combinations of the above in combination with brown crab. 17 respondents (58.6%) fish 52 weeks per year and the remaining 12 (41.4%) fish between 17 and 44 weeks per year. The 2017 Creel Fishing Effort study revealed that the mean number of creels deployed per vessel by *Nephrops* fishers is 926. West coast crab and lobster fishers deploy an average of 294 creels per vessel and east coast crab and lobster fishers deploy an average of 455 creels per vessel (Marine Scotland, 2017). Trip lengths were found to vary with region.

James et al., 2018 report that vessels from the Outer Hebrides conducted significantly longer trips over greater distances compared to those on the east coast in Fife. The mean trip length of Outer Hebridean vessels was 7.49 h with a mean distance of 36.8 km, compared to a mean of 5.1 h and 24.9 km for Fife-based vessels (James et al., 2018).

3.1. Analysis of bait types

On the east coast (E) (n = 12), mackerel (*Scomber scombrus*) is the most popular bait accounting for 45.2% of the bait types used (Fig 1). A further 29.0% of bait used is fish heads and frames from processing plants. In the OH (n = 12), 31.0% of bait used is mackerel. A further 24.1% of bait used is herring (*Clupea harengus)*. Fishers from the WMIH (n = 5), use a more even spread of bait types, with herring accounting for 21.4% of bait used and haddock (*Melanogrammus aeglefinus*), spotted dogfish (*Scyliorhinus canicula*) and heads and frames each accounting for 14.3% of bait used. A significant difference in bait types was detected between the geographic locations, though with the small sample size for each location, this is an interesting observation that warrants further investigation (Fisher's Exact Test with simulated p-value based on 2000 replicates: p = 0.005 | n = 29).

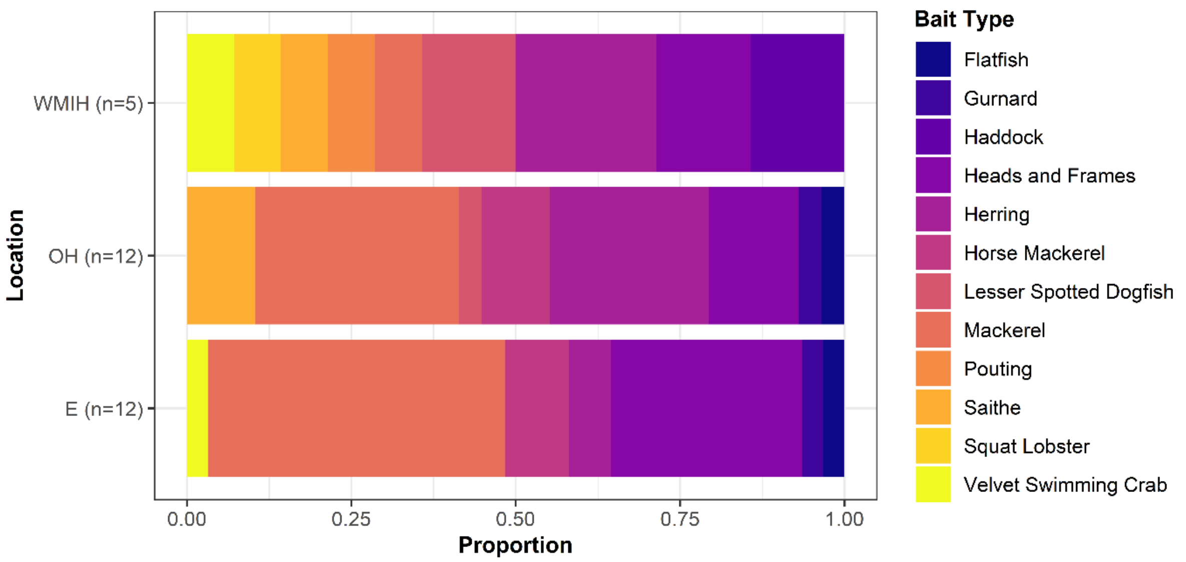

Figure 1) Proportions of each bait type used, categorised by location. (WMIH: west coast mainland and Inner Hebrides | OH: Outer Hebrides | E: East Coast). Fisher's Exact Tests revealed that geographic location is not independent of the bait type preference, therefore preferred bait types differ significantly with region. The limited data available provides an interesting observation and warrants further investigation.

Overall, the most frequently reported bait types were mackerel (62.0%, n = 18), heads and frames (41.4%, n = 12), herring (41.4%, n = 12), horse mackerel (*Trachurus trachurus*) (20.7%, n = 6) and saithe (*Pollachius virens*) (13.8%, n = 4). When the mean amount of bait (g) per creel for each bait type was compared, no significant differences were found between the preferred bait types (Kruskal-Wallis Rank Sum Test: χ^2 = 8.16 | df = 4 | p = 0.086) (n = 25; Fig 2). Because *Nephrops* fishers use D-shaped prawn creels, whilst crab and lobster fishers use a mixture of D-shaped crab and lobster creels and parlour creels (Marine Scotland, 2017), the response of participants identified as exclusive *Nephrops* fishers were explicitly recognised in analysing the results.

No significant differences in bait acquisition were detected between the geographic locations (Fisher's Exact Test for count data: p = 0.21). Consequently, these data were pooled. 46.7% (n = 12) of respondents exclusively purchase bait and the remaining 53.3% (n = 13) acquire bait through a mixture of purchase and catch. No participants reported catching all their bait, though a part-time fisher reported catching 99% of the bait used. Of those that catch bait (n = 16), 56.3% (n = 9) catch mackerel. The remaining 43.8% (n = 7) reported catching either

Figure 2) Bait mass used per creel of the most frequently cited bait types from creel fishers (n = 25). The bold horizontal line shows the median; the lower and upper limit of a box illustrates the first and third quartile respectively. Lower and upper whiskers represent scores outside the interquartile range. Dots outside the whiskers are outliers. Each dot is a fisher response, grouped into bins. Many fishers use multiple types of bait depending on availability. Grey dots are the responses given by fishers targeting *Nephrops* exclusively.

spotted dogfish (*Scyliorhinus canicular)*, haddock (*Melanogrammus aeglefinus)*, saithe (*Pollachius virens)*, velvet swimming crab *(Necora puber)*, pouting (*Trisopterus luscus*) or squat lobster (*Galathea sp.*). The average percentage of bait caught per fisher is 12.8% ± 4.6% (n = 28).

3.2. Biomass and financial cost estimates

The annual bait deposition as a function of creel number for the active inshore creeling fleet was estimated at 13,492 ± 3,402 metric tonnes (mt), with a minimum estimate of 793 mt and a maximum estimate of 47,596 mt. This was based on the average creel fisher using 13,267 ± 3,346 kg of bait per year (range = 780 – 46,800 kg).

The mean cost of bait per creel equated to £0.12 ± £0.02 (range = £0.00 – £0.54) (Fig 3). When scaled up to a fleet level, the annual cost of bait to the industry was estimated at £9,793,421, based on the average active fisher spending £9,629 ± £1,323 (range = £2,496 – £23,028) annually. Fishers who catch large proportions of their bait or have a relationship with processing plants reported a spend of £0.00; all were located on the mainland (n = 4).

3.3. Reasons and motivations for bait discarding

Fisher's Exact testing determined that geographic location is independent of the preferred bait discarding site. Fisher motivations were pooled across geographic locations and instead separated by bait discarding site (Fisher's Exact Test for count data: p = 0.102). 75.9% (n =

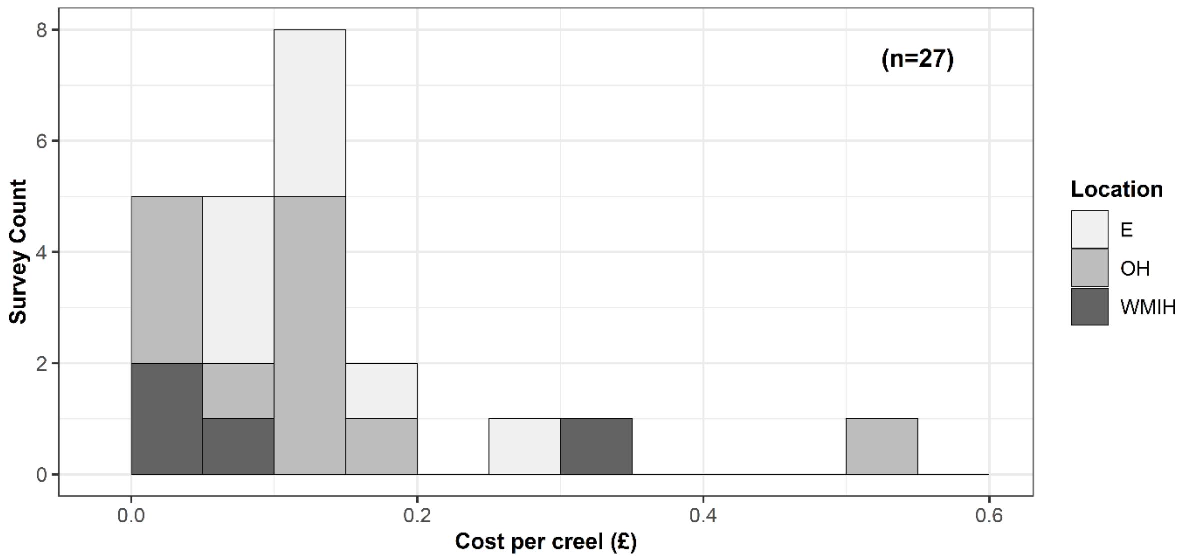

Figure 3) Cost of bait per creel for each of the 27 survey participants that yielded the data necessary to calculate these figures. Costs were split by geographic location. (E = East coast | OH = Outer Hebrides | WMIH = West coast mainland and Inner Hebrides). The mean cost per creel is 12p ± 2p (Min = 0p | Max = 54p).

22) of participants reported that they discard used bait at the fishing grounds. A further 17.2% (n =5) discard bait in transit between the fishing grounds and the harbour. 3.4% (n = 1) discard of used bait within the harbour and 10.3% (n = 3) do not discard any bait on account of having none remaining or because fed lobsters do not enter creels (G Mckie 2020, *pers. comm.,* 8 July). The total percentage exceeds 100% as fishers were able to select multiple answers. The percentages of each reason given were only calculated for those discarding bait at the fishing grounds (n=22; Fig 4) and in transit (n=5). The sole participant that reported discarding used bait in the harbour did not give a reason for doing so. The most quoted reason for discarding bait at the fishing grounds or in transit was convenience (63.5%, n = 14 and 40.0%, n = 2 respectively). Other reasons given for discarding bait in transit included feeding the birds (20.0%, n = 1), no effect (n = 1), preserving the fishing grounds (n = 1), and getting rid of rotten bait (n = 1) (see Table 1 for descriptors).

3.4. Seasonal bait biomass estimations for fishing hotspots

Between February 2018 and July 2020, the eight vessels recorded 997 fishing trips. As the seasons were considered separately for each vessel each year, a total of 33 seasons of data were counted; the average number of maximum revisits per season is reported (Table 2). The spacing of creels per string was given as 12.6 m for *Nephrops* and 21.6 m for crab and lobster

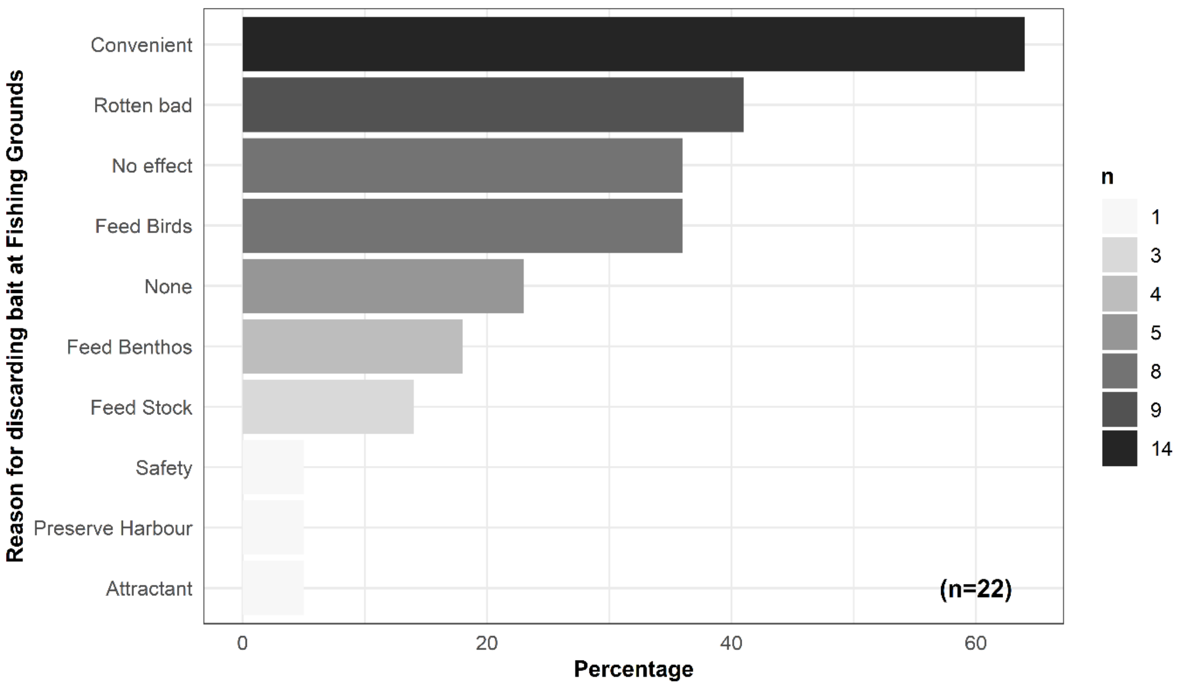

Figure 4) Coded reasons given by 22 survey participants that discard used bait at the fishing grounds. Participants often gave multiple reasons, so the number of fishers (**n**) that gave a particular reason, has been documented with a colour gradient; see the legend on the right for the number of participants giving a particular response. See Table 1 for code descriptors.

strings (D Macinnes 2020, *pers. comm.*, 20 August). The number of creels on a string falling within a hectare was calculated as 8 for *Nephrops* creels and 5 for crab and lobster creels. The estimated bait biomass input into seasonal fishing hotspots for *Nephrops* and crab and lobster creels are reported (Table 3). For those sites revisited every season, the biomass per unit area per year could be up to 75.0 kg ha^{-1} for *Nephrops* hotspots and 46.9 kg ha^{-1} for crab and lobster hotspots.

Table 2
Average number of maximum revisits calculated for each meteorological season based on complete seasonal data subsets from 8 creeling vessels between February 2018 and July 2020. 33 seasons were recorded as each season was considered individually per vessel, per year. For example, this could represent 6 seasons or 2 vessels per season.

Season	Average maximum revisits	Standard error	Number of seasons (n)
Spring	10.17	2.43	6
Summer	12.20	1.96	5
Autumn	8.09	1.12	11
Winter	7.45	0.92	11

Table 3
Mass per hectare estimated values of bait biomass input into creeling hotspots per season for the *Nephrops* and crab and lobster fisheries in Scotland.

Season	Biomass input *Nephrops* (kg ha^{-1})	Biomass input crab and lobster (kg ha^{-1})
Spring	20.12	12.57
Summer	24.14	15.09
Autumn	16.01	10.01
Winter	14.75	9.22

4. Discussion

Survey techniques were combined with spatial data to better understand bait use in the Scottish creeling fleet with a focus on regional bait types, estimates of biomass deposition and cost, discarding motivations and the concentration of bait at fishing hotspots. Despite the limited sample size of 29 fishers, the geographic spread, detail and convergence of responses suggests that this study provides a critical first step for further study into the environmental and economic implications of bait use in the fishery. Bait costs of approximately £9.8 million every year, represent more than 16% of shellfish first sale landing value. Optimising the use of bait could potentially reduce this cost. Approximately 13,500 metric tonnes of bait biomass is being deposited annually in relatively discrete areas within coastal waters which may have localised ecological impacts which deserve further investigation.

Preliminary assessment suggests that bait types differ significantly between geographic location. Clear preferences for mackerel (45.2%) and fish heads and frames (29.0%) were reported on the east coast, with mackerel and herring preferred in the Outer Hebrides. A small sample size for the west coast mainland and Inner Hebrides yielded inconclusive results, though it appears bait types may be more varied. Similar findings were observed in the 2017 Creel Fishing Effort Study, conducted by Marine Scotland. For the east coast fishery, near-equal proportions of mackerel and heads and frames to this study were reported (Marine Scotland, 2017). As their analysis of bait types was partitioned through fishery type rather than location, results for the west coast and the western isles differ; similarities include larger proportions of herring and lesser proportions of heads and frames in both west coast locations. Marine Scotland found herring to be a clear preference for *Nephrops* fishers, likely accounting for the higher proportions seen on the west coast where the *Nephrops* fishery resides. Our results indicate that fishers may use less bait mass in *Nephrops* creels than they do in crab and lobster creels; however, more research is required to determine the differences in bait types and masses per creel between the fisheries.

The differences in bait types due to location observed here were expected; fishers on the mainland have easier access to waste from processing plants than those on the Hebridean islands leading to higher usage of heads and frames (J Riley 2020, *pers. comm.*, 11 July). Mainland fishers potentially have an advantage over their island counterparts in sourcing bait sustainably and economically through the repurposing of fishery waste. Mainland fishers may also have a cost-benefit advantage due to bait transportation costs incurred by island-based fishers.

No significant differences in bait acquisition were detected between the geographic locations. Bait is either solely purchased or purchased and caught. This suggests a high dependence on external sources and sensitivity to market prices. Baitfish supply, availability and therefore sustainability, is crucial for the longevity of the creeling sector. A lack of bait has been cited as a major driver preventing creel fishers from going to sea (Mendo et al., 2019c). This is often overlooked in a fisheries management context, particularly with single-species models which can be ignorant of wider ecological concerns (Hilborn, 2011).

Mackerel was the most frequently caught bait type; likely due to high catch rates during annual mackerel runs, and because licenses are not required for personal use. A mackerel handline license is only necessary when catching 2+ tonnes over 6 months (Marine

Management Organisation, 2020). This is a potential loophole for acquiring bait in an unregulated manner. It is, however, worth considering the environmental and economic benefit yielded from personally catching bait as this reduces the carbon footprint of haulage and nullifies the cost associated with purchase and transport. Research into the monetary value of caught baitfish is needed to determine industry reliance on caught bait and the true values of bait in creeling activities.

When contrasted with discarding practices of other fleets, the annual bait input into coastal Scottish waters is small (13,492 $\pm$ 3,402 metric tonnes); annual discards for Scottish demersal fishing vessels in the West of Scotland were estimated at 30,000 metric tonnes between 1988 and 1993 (Stratoudakis, 1997). With UK fleet-wide discarding from mobile gear, biomass consisted largely of deceased fish that either sink to the seabed to be consumed by benthic scavengers or eaten by seabirds and other marine predators (Bicknell et al., 2013; Bozzano, 2002; Moore, 2003). Conversely, creel bait biomass entering the system is largely pre-consumed in the creel by undersized individuals and non-target species. Undersized individuals and non-target species are then returned to the sea under the assumption that they have high survivability, given in Article 15 of the CFP (European Commission, 2013). Under these circumstances, bait may act as a supplementary food source. In terrestrial systems, supplementary feeding of garden birds is reported to alter behaviour, growth rates, reproductive output, population dynamics and trophic interactions (Robb et al., 2008). Recent research also indicates that increased densities of birds using feeders increases disease transmission (Moyers et al., 2018). Targeted supplementary feeding in coastal waters may be a similar driver for ecological change in the marine environment. A more detailed understanding of the implications is essential; this additional food source may bolster local target species populations or allow undersized individuals to reach minimum landing size (MLS) faster. Indeed, Saila et al. (2002) find that bait may be a substantial contribution to lobster production as a function of increased biomass per unit area. Further research into the proportion of undersized individuals entering Scottish creels and their rate of bait consumption is needed.

The annual cost of bait to the creeling industry is approximately £9.8 million, excluding the additional value of caught bait. Scottish creel-caught shellfish landings were valued at approximately £60 million in 2018 (not adjusted for inflation) (Marine Scotland, 2019). The cost of creel bait equates to around 16.3%, indicating that bait is likely a considerable expenditure for a creel fisher.

Bait was primarily discarded at the fishing grounds, the most cited reason being convenience. An analysis of the motivations surrounding discarding practices revealed some contradictions and offered several hypotheses for future study. Several lobster creelers (n = 8) discard used bait assuming that rotten bait is ineffective. Two respondents retain rotten bait believing it attracts lobsters. If the latter can be empirically proven, lobster fishers may be able to reduce bait costs and biomass, helping to minimise overheads and reduce demand.

Nine respondents believe that discarded bait does not affect the benthos. Four respondents believe that discarded bait feeds the benthos and a further three claim that bait discards feed their target species with one indicating that bait discards may act as attractants, bringing new stock into the area. Conversely, one respondent assumed negative connotations, claiming that lobsters satiated by discarded bait will not enter the creels. The response of the benthos and target species to bait discards is crucial to determine best practice. Whilst nearly all fishers surveyed discard used bait (n=26), many stated that discards consist largely of bones. Nine respondents also reported seabirds consuming discarded bait. Used bait discards are likely a small proportion of the biomass entering coastal waters through creeling activities.

Creel fishers return to some fishing locations, creating localised hotspots of fishing activity. Bait biomass from creeling activities is more concentrated at these localised hotspots. Pre-Landing Obligation, discards from beam trawl fisheries in the North Sea were estimated to be between 5.8 kg ha^{-1} and 40.6 kg ha^{-1} (Garthe et al., 1996). Bait input for Scottish creeling hotspots was estimated at 46.9 kg ha^{-1} for crab and lobster and 75.0 kg ha^{-1} for *Nephrops* annually. Saila et al. (2002) calculated an annual input of 85 kg ha^{-1} in the Gulf of Maine lobster fishery equating it to a very productive fishery yield and a subsidy for secondary productivity. As quantities of bait akin to their findings enter the marine environment in Scotland, it is suggested that creel bait may have wider ecosystem significance by affecting local ecosystem functioning (Saila et al., 2002; Waddington and Meeuwig, 2009). Carbon deposition is of particular interest; organic carbon from bait biomass is deposited on the seabed through the faeces of undersized creel-caught and non-target individuals on their release, and from the discarding of uneaten creel bait. Baiting introduces extra nutrients into the localised marine environment. In an aquaculture context, organic carbon deposited below sea pens from faeces and uneaten feed is associated with anoxic sediments, the formation of bacterial mats, eutrophication and harmful algal blooms (HABs) (Forrest et al., 2007). This nutrient enrichment may damage nearby sensitive habitats such as seagrass beds and their associated epifauna (Lee et al., 2015).

Marine Scotland's Creel Fishing Effort Study highlighted the desire for direct management intervention regarding gear-saturation and fishing effort (Marine Scotland, 2017). The implications of bait use may prompt alternative management strategies for shellfish stocks. One such idea is that of 'sea ranching', which has been cited as a management and conservation measure (Anand and Soundarapandian, 2011). Sea ranching is widely proposed as the release of artificially reared juveniles into the marine environment with the intention of harvest once MLS is reached (Bell et al., 2008). In the UK, Several Orders and Regulating Orders for shellfisheries can be obtained, giving a fisher exclusive management and fishing rights to designated areas of the seabed (DEFRA, 2012). They are principally used for cultivating mussels and oysters but can be extended to other shellfishes including crab and lobster. If bait input positively impacts growth and reproduction of target species, bait could be used as a supplementary food source that effectively "ranches" creel-caught shellfish for more predictable catch success. It is clear from on-going research that some static gear fishers focus their fishing effort in quite discrete areas displaying a pattern of use akin to "ownership" (M James 2020, *pers. comm*., 19 November). This being the case, the ability to perhaps formalise such status would open up the potential for novel approaches to managing fishing activity and effort whilst optimising catch and reducing overall environmental impacts.

The response rate of the survey remains unknown on account of the method of dissemination. Once partitioned, sample sizes restricted the power to confidently determine trends and as such, results should be interpreted with caution. A power analysis is necessary to determine the number of responses required to be representative of the creel fishing sector, however, vessel lengths and target species reported by survey participants were consistent with the broader fishery. Discrepancy between survey results and previous research arises with weeks fished annually; survey responses suggest that almost 60% of creel fishers fish 52 weeks per year. Results of the 2017 Creel Fishing Effort Study indicate that fishing effort, measured by number of creels deployed, reduces substantially over the winter months (Marine Scotland, 2017). We suggest that a combination of weather conditions restricting fishing, particularly in the winter months, together with changes in the catchability of the target species as a function of water temperature and reproductive state for example, that a more realistic duration would be approximately 40 weeks per year for the majority of vessels operating in this sector. The survey may have attracted biased responses from creel fishers concerned over certain aspects of bait use, such as the improvement of the cost-benefit ratio through bait types. Despite the potential bias and limited number of survey responses, the areas identified for future study remain relevant.

4.1. Conclusions

This preliminary research intends to open a dialogue between fisheries scientists, managers and creel fishers concerning bait use and to instigate hypothesis formation for future research. The overarching goal is to create an awareness of the magnitude and possible implications of bait use within the creeling sector and to work towards better practices that maintain or improve catches whilst minimising expenditure and negative environmental consequences. Doing so will likely require careful management and prompts further consideration from management authorities. All findings and subsequent research will inform management strategies that are sensitive to the needs of the creeling communities and environment alike.

Acknowledgements

Thanks to Ivar McBay and Duncan Macinnes, and the group of fishers who commented upon the draft survey and those involved in the Regional Inshore Fisheries Groups who distributed the survey. Also, thanks to the SIFIDS project supported by the European Maritime and Fisheries Fund for the use of fishing vessel track data. We are particularly indebted to all the creel fishers who put their time and thought into answering the creel bait survey, without whom this research would not have been possible.

References

Anand, T., Soundarapandian, P., 2011. Sea ranching of commercially important blue swimming crab Portuns pelagicus (Linnaeus, 1758) in Parangipettai coast. Int. J. Sci. Nat. 2, 215–219.

Bell, J.D., Leber, K.M., Blankenship, H.L., Loneragan, N.R., Masuda, R., 2008. A New Era for Restocking, Stock Enhancement and Sea Ranching of Coastal Fisheries Resources. Rev. Fish. Sci. 16, 1–9. https://doi.org/10.1080/10641260701776951

Bicknell, A.W.J., Oro, D., Camphuysen, K.C.J., Votier, S.C., 2013. Potential consequences of discard reform for seabird communities. J. Appl. Ecol. https://doi.org/10.1111/1365-2664.12072

Bozzano, A., 2002. Fishery discard consumption rate and scavenging activity in the northwestern Mediterranean Sea. ICES J. Mar. Sci. 59, 15–28. https://doi.org/10.1006/jmsc.2001.1142

Bracis, C., Bildstein, K.L., Mueller, T., 2018. Revisitation analysis uncovers spatio-temporal patterns in animal movement data. Ecography (Cop.). 41, 1801–1811. https://doi.org/10.1111/ecog.03618

Calenge, C., 2006. The package adehabitat for the R software: a tool for the analysis of space and habitat use by animals. Ecol. Modell. 197, 516–519.

Catchpole, T.L., Frid, C.L.J., Gray, T.S., 2005. Discards in North Sea fisheries: Causes, consequences and solutions. Mar. Policy 29, 421–430. https://doi.org/10.1016/j.marpol.2004.07.001

Chapman, C., Smith, G., 1978. Creel catches of crab, Cancer pagurus L. using different baits. ICES J. Mar. Sci. 38, 226–229. https://doi.org/10.1093/icesjms/38.2.226

Cheng, J., Karambelkar, B., Xie, Y., 2019. leaflet: Create Interactive Web Maps with the JavaScript "Leaflet" Library.

de Rozarieux, N., 2014. SR668 - Use of discards in bait.

DEFRA, 2012. Shellfisheries: Several Orders and Regulating Orders [WWW Document]. Guidance. URL https://www.gov.uk/guidance/shellfisheries-several-orders-and-regulating-orders (accessed 8.28.20).

Dorman, S.R., Harvey, E.S., Newman, S.J., 2012. Bait Effects in Sampling Coral Reef Fish Assemblages with Stereo-BRUVs. PLoS One 7, e41538. https://doi.org/10.1371/journal.pone.0041538

European Commission, 2013. REGULATION (EU) No 1380/2013 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2013 on the Common Fisheries Policy, amending Council Regulations (EC) No 1954/2003 and (EC) No 1224/2009 and repealing Council Regulations (EC) No 2371/2002 and (EC. Off. J. Eur. Union L354, 40.

European Commission, 2009. GREEN PAPER Reform of the Common Fisheries Policy. Comm. Eur. Communities COM(2009)163 Final 27 pp. https://doi.org/10.2139/ssrn.1743387

Forrest, B., Keeley, N., Gillespie, P., Hopkins, G., Knight, B., Govier, D., 2007. Review of the Ecological Effects of Marine Finfish Aquaculture: Final Report, Cawthron Report.

Furness, R.W., 2003. Impacts of fisheries on seabird communities. Sci. Mar. 67, 33–45. https://doi.org/10.3989/scimar.2003.67s233

Garthe, S., Camphuysen, K., Furness, R.W., 1996. Amounts of discards by commercial fisheries and their significance as food for seabirds in the North Sea. Mar. Ecol. Prog. Ser. 136, 1–11. https://doi.org/10.3354/meps136001

Hijmans, R.J., 2020. raster: Geographic Data Analysis and Modeling.

Hilborn, R., 2011. Future directions in ecosystem based fisheries management: A personal perspective. Fish. Res. 108, 235–239. https://doi.org/10.1016/j.fishres.2010.12.030

ICO, 2019. Guide to the General Data Protection Regulation (GDPR). https://doi.org/10.1111/j.1751-1097.1994.tb09662.x

James, M., Mendo, T., Jones, E.L., Orr, K., Mcknight, A., Thompson, J., 2018. AIS data to inform small scale fisheries management and marine spatial planning. Mar. Policy 91, 113–121. https://doi.org/10.1016/j.marpol.2018.02.012

Johannes, R.E., Freeman, M.M.R., Hamilton, R.J., 2000. Ignore fishers' knowledge and miss the boat. Fish Fish. 1, 257–271. https://doi.org/10.1111/j.1467-2979.2000.00019.x

Krouse, J., 1988. Performance and selectivity of trap fisheries for crustaceans, in: Caddy, J.F. (Ed.), Marine Invertebrate Fisheries: Their Assessment and Management. John Wiley & Sons, Ltd, p. 307. https://doi.org/10.1016/0165-7836(90)90045-w

Lee, S., Hartstein, N.D., Jeffs, A., 2015. Modelling carbon deposition and dissolved nitrogen discharge from sea cage aquaculture of tropical spiny lobster. ICES J. Mar. Sci. 72, i260–i275. https://doi.org/10.1093/icesjms/fsu189

Mackie, A.M., Grant, P.T., Shelton, R.G.J., Hepper, B.T., Walne, P.R., 1980. The relative efficiencies of natural and artificial baits for the lobster, Homarus gammarus: laboratory and field trials. ICES J. Mar. Sci. 39, 123–129. https://doi.org/10.1093/icesjms/39.2.123

Marine Management Organisation, 2020. Handline Mackerel Licence : Conditions (24).

Marine Scotland, 2019. Scottish Sea Fisheries Statistics 2018. The Scottish Government, Edinburgh.

Marine Scotland, 2017. Creel Fishing Effort Study. The Scottish Government, Edinburgh.

MASTS, 2016. Scottish Inshore Fisheries Integrated Data System (SIFIDS) Project [WWW Document]. URL https://www.masts.ac.uk/research/emff-sifids-project/ (accessed 11.26.20).

Mendo, T., Smout, S., Russo, T., D'Andrea, L., James, M., Maravelias, C., 2019a. Effect of temporal and spatial resolution on identification of fishing activities in small-scale fisheries using pots and traps. ICES J. Mar. Sci. 76, 1601–1609. https://doi.org/10.1093/icesjms/fsz073

Mendo, T., Smout, S., Photopoulou, T., James, M., 2019b. Identifying fishing grounds from vessel tracks: Model-based inference for small scale fisheries. R. Soc. Open Sci. 6, 1–12. https://doi.org/10.1098/rsos.191161

Mendo, T., Smout, S., Ransijn, J., Durbach, I., McCann, P., Crowe, S., Carulla Fabrega, A., de Prado, I., James, M., 2019c. Scottish Inshore Fisheries Integrated Data System (SIFIDS): Identifying fishing activities and their associated drivers.

Mesquita, C., Miethe, T., Dobby, H., McLay, A., 2017. Crab and lobster fisheries in Scotland: results of stock assessments 2013-2015. Scottish Mar. Freshw. Sci. 8, 1–90. https://doi.org/10.7489/1990-1

Moore, P.G., 2003. Seals and fisheries in the Clyde Sea area (Scotland): Traditional knowledge informs science. Fish. Res. 63, 51–61. https://doi.org/10.1016/s0165-7836(03)00003-1

Moyers, S.C., Adelman, J.S., Farine, D.R., Thomason, C.A., Hawley, D.M., 2018. Feeder density enhances house finch disease transmission in experimental epidemics. Philos. Trans. R. Soc. B Biol. Sci. 373, 20170090. https://doi.org/10.1098/rstb.2017.0090

Murray, A.G., 2015. Does the use of salmon frames as bait for lobster/crab creel fishing significantly increase the risk of disease in farmed salmon in Scotland? Prev. Vet. Med. 120, 357–366. https://doi.org/10.1016/j.prevetmed.2015.04.020

RCoreTeam, 2019. R: A language and environment for statistical computing.

Regehr, H., Montevecchi, W., 1997. Interactive effects of food shortage and predation on breeding failure of black-legged kittiwakes:indirect effects of fisheries activities and implications for indicator species. Mar. Ecol. Prog. Ser. 155, 249–260.

https://doi.org/10.3354/meps155249

Rizzari, J.R., Gardner, C., 2019. Supply risk of bait in Australia's Southern Rock Lobster Fishery. Mar. Policy 108. https://doi.org/10.1016/j.marpol.2019.103659

Robb, G.N., Mcdonald, R.A., Chamberlain, D.E., Bearhop, S., 2008. Food for thought: supplementary feeding as a driver of ecological change in avian populations. Front. Ecol. Environ. 6, 476–484. https://doi.org/10.1890/060152

Saila, S.B., Nixon, S.W., Oviatt, C.A., 2002. Does Lobster Trap Bait Influence the Maine Inshore Trap Fishery? North Am. J. Fish. Manag. 22, 602–605. https://doi.org/10.1577/1548-8675(2002)022<0602:dltbit>2.0.co;2

Siikavuopio, S.I., Dragøy Whitaker, R., Martinsen, G., Saether, B.-S., Stormo, S.K., 2017. Testing baits prepared from by-product of the shrimp and snow crab industry in the pot fishery for Gadus morhua (Linnaeus, 1758) and Pollachius virens (Linnaeus, 1758). J. Appl. Ichthyol. 33, 1153–1157. https://doi.org/10.1111/jai.13468

Stratoudakis, Y., 1997. A study of fish discarded by Scottish demersal fishing vessels. PhD Thesis. University of Aberdeen.

Tasker, M.L., Camphuysen, C., Cooper, J., Garthe, S., Montevecchi, W.A., Blaber, S.J.M., 2000. The impacts of fishing on marine birds. ICES J. Mar. Sci. 57, 531–547. https://doi.org/10.1006/jmsc.2000.00714

Waddington, K.I., Meeuwig, J.J., 2009. Contribution of bait to lobster production in an oligotrophic marine ecosystem as determined using a mass balance model. Fish. Res. 99, 1–6. https://doi.org/10.1016/j.fishres.2009.04.002

Wallen, K.E., Landon, A.C., Kyle, G.T., Schuett, M.A., Leitz, J., Kurzawski, K., 2016. Mode Effect and Response Rate Issues in Mixed-Mode Survey Research: Implications for Recreational Fisheries Management. North Am. J. Fish. Manag. 36, 852–863. https://doi.org/10.1080/02755947.2016.1165764

Zeller, D., Cashion, T., Palomares, M., Pauly, D., 2018. Global marine fisheries discards: A synthesis of reconstructed data. Fish Fish. 19, 30–39. https://doi.org/10.1111/faf.12233