fishes

Article

Catch per Unit Effort of Decapod Species, *C. pagurus* and *H. gammarus*, from a Voluntary Marine Reserve

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Abstract: *C. pagurus* and *H. gammarus* are deemed to be declining in abundance in the Berwickshire Marine Reserve from personal communications with local inshore fishers. Fisheries data in the form of catch per unit effort (CPUE) were collected for these two commercially important decapods. Other explanatory variables from fishing activity such as the creel and bait type used, the soak time of the fishing gear, and deployment depth were recorded to provide as much detail as possible to describe the effort applied to catch these decapod species. In this study, CPUE was higher for *H. gammarus* and *C. pagurus* outside the Berwickshire Marine Reserve. General additive models (GAMs) were used to describe the effects of the explanatory variables and showed that soak time (days) and depth (m) significantly affected CPUE for *C. pagurus*, not *H. gammarus*. Sea temperature (°C) showed a negative correlation with the CPUE of both *H. gammarus* and *C. pagurus*; however, a positive correlation was found with the number of *C. pagurus* caught. The data collected in this study provide a foundation in understanding the current abundance of *C. pagurus* and *H. gammarus* in a voluntary marine reserve on the east coast of Scotland, which can be used to inform future changes in fisheries management in Berwickshire.

Keywords: catch per unit effort; *Cancer pagurus*; *Homarus gammarus*; fisheries

Key Contribution: The abundance of *C. pagurus* and *H. gammarus*, described in the form of catch per unit effort, highlights a potential overexploitation of the commercially important species inside the Berwickshire Marine Reserve.

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1. Introduction

Pressure is applied to shellfish fisheries, such as *C. pagurus* and *H. gammarus*, to compensate for recovering finfish fisheries for food security [1,2]. However, it is suggested that *C. pagurus* and *H. gammarus* are deemed "fish to avoid" by the Marine Conservation Society [3]. With contradicting statements, there is a clear need for as much information as possible to fully understand the sustainability status of commercially important species in the Berwickshire region. Personal observations highlighted that many inshore fishers suggest a decline of both *H. gammarus* and *C. pagurus* in the region, which these fishers fully depend on for financial support. *C. pagurus* stocks are currently misunderstood regarding their current level of exploitation [4]. In the region of Berwickshire, based on statistics from Eyemouth Harbour (55.871697, −2.087245), there are around 62 creel fishing vessels under 10 m in length and 3 vessels over 10 m typically fishing for *C. pagurus* and *H. gammarus* [5]. These vessels are below 12 m in length and are regarded as part of the inshore fishing fleet [6,7]. In the 10.3 km^2 Berwickshire Marine Reserve, fishers contribute to 91–97% of the annual value of landings in the U.K., of which in 2019 this contribution was 19% [5,8]. In 2020, the *C. pagurus* fishery for Berwickshire (Eyemouth Harbour) was valued at GBP 567,000, and the *H. gammarus* fishery was valued at GBP 2,565,000 [5]. Although generating valuable annual income to the U.K. economy and to the local economy of Berwickshire, it is believed that U.K.-wide *C. pagurus* and *H. gammarus* fisheries are overexploited or close to overexploited [2].

Catch per unit effort (CPUE) is a common tool for monitoring and reporting fish populations through analysis of commercial landings to provide an abundance index [2,9,10]. If the resultant CPUE is declining, this may indicate a fishery that cannot support the level of fishing it experiences; likewise, an increasing CPUE can indicate the fished stock is recovering and potential increases in fishing activity may be applied with appropriate management [11]. In addition to landings data, morphometric data (wet weight (g) and carapace length/width (mm)), can be added to understand the growth and health of the fished stock [12]. With all forms of fishing, there are variables that can influence the fishers' catch. Pots, or creels, are a form of fishing using various bait types. They can be fitted with panels for undersized or unwanted bycatch to escape and can vary structurally with the inclusion or exclusion of one or more "eyes" (the entrance to a fishing creel). Inter- and intra-specific interactions between individuals within the vicinity of the fishing creel can also influence the individuals that enter and leave a creel [13]. In addition, the season [14], soak time [15,16], and environmental changes can potentially lead to a misinformed calculation of CPUE, abundance, and size distribution for a locale [15,17,18]. To understand such a complex system, these variables should be considered in fisheries assessments, although they currently are not; therefore, interpreting CPUE data fully should be undertaken with caution. Furthermore, collating specific information from individual fishing vessels such as the location of creel hauling, the number of creels per fleet, and soak time for each fleet can provide a full description of the CPUE, particularly for mixed trap fisheries [2]. CPUE is generally standardised using statistical methods such as general linear models (GLMs) and general additive models (GAMs), which allow for descriptions of CPUE with greater detail by considering such variables; however, this still does not provide a full descriptor for abundance in real terms as it cannot correlate well with the statistical output of such tests [19,20].

Marine reserves and other protected marine designations are becoming more apparently used to mitigate the declining biodiversity currently observed worldwide [21–23]. Most of these designations are backed by legislation; however, in the case of the Berwickshire Marine Reserve, it is a voluntary designation. The Berwickshire Marine Reserve is one of three other statutory reserves on the Berwickshire coastline; of these, one is a special area of conservation, the Berwickshire and North Northumberland SAC, and the other prevents the use of mobile fishing gear, the Static Gear Reserve (Figure 1). Therefore, static gear fishing is the primary form of fishing within and outside the Berwickshire Marine Reserve. At present, the only management protocol for this fishery is the current minimum landing size for both *C. pagurus* and *H. gammarus*, which is 150 mm and 90 mm, respectively [24]. The number of creels associated with each inshore fisher is not limited, and therefore, there is an increasing interest in creel limitations, which have started with pilot studies on the west coast of Scotland [25]. Currently, there is no scope for such a limitation in Berwickshire, and anecdotal data from local inshore fishers suggest some vessels are deploying over 1000 creels, with one extreme case of 10,000 creel deployments. Inshore fishing vessels are not required at present to utilise vessel tracking technology, and therefore, monitoring of these vessels' fishing activity regionally is not common practice either. However, this is soon to change with the current inshore modernisation programme detailed in the "Bute House Agreement" and "fisheries management strategy 2020 to 2030 delivery plan" which aims to enhance monitoring activities of the inshore fishing fleet using onboard vessel technology [26] as this sector is poorly reported and understood. The data collected from these monitoring systems will allow areas of fishing activity to be monitored, which can aid the understanding of fishing effort in a more regional context. Without current context and understanding of the CPUE in Berwickshire, the means of assessing the effects of new management or legislation are limited.

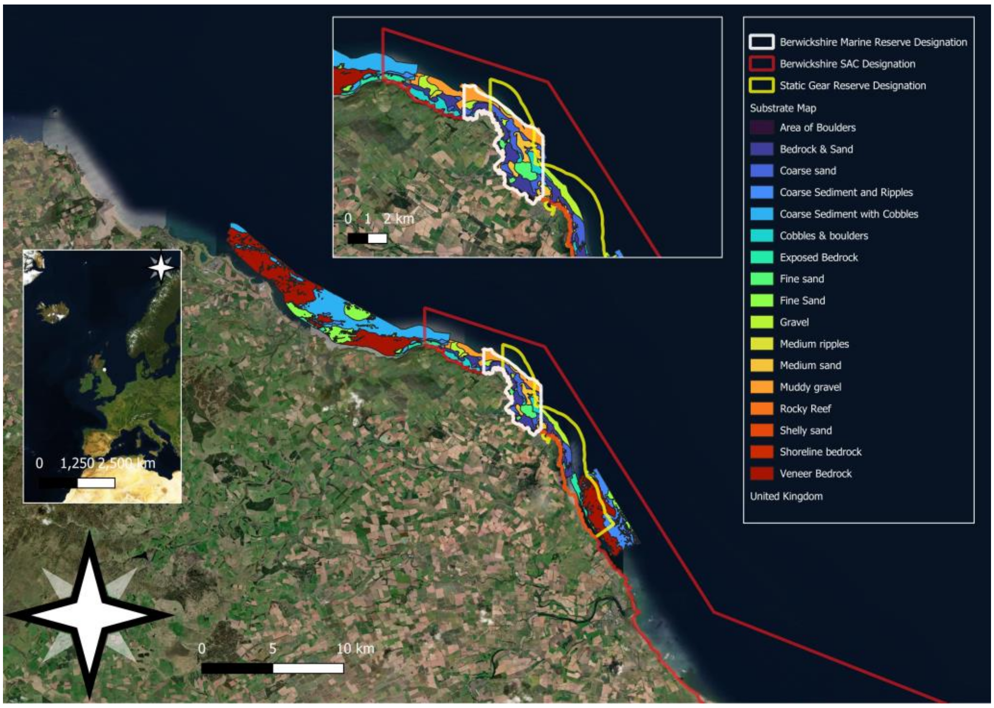

Figure 1. Habitat map of the Berwickshire coastline (55.912714, −2.109902) that includes the mixing of substrate types in and outside the Berwickshire Marine Reserve designation. The habitat map was provided by Blue Marine Foundation.

This study aims to provide information for a data-limited fishery in a voluntary marine reserve to understand the local *C. pagurus* and *H. gammarus* abundance in the Berwickshire Marine Reserve. We incorporate local inshore fishers that conducted independent onboard assessments from 2018 to 2019 to collate information on CPUE for these species. Included in the assessments are bait type, creel type, and environmental variables, such as sea temperature (°C), dissolved oxygen (%), and salinity (ppt) which cover many of the factors that could influence CPUE.

2. Materials and Methods

2.1. Study Area

The Berwickshire Marine Reserve (55.912714, −2.109902) covers an open sea area of 10.3 km^2 (Figure 1) which extends out from the Berwickshire coastline to a 50 m depth contour. Within this designation, the habitat is formed from rocky outcrops interspersed with patches of sand (Figure 1). The BMR is situated within the Berwickshire and North Northumberland Special Area of Conservation (SAC). The SAC covers an area of 652 km^2, from Alnmouth in the south to Fast Castle Head in the north, which includes the St. Abbs and Eyemouth Static Gear Reserve which covers 26 km^2 and extends one nautical mile offshore from St. Abbs Head in the north to the Scotland–England Border in the south. Onboard independent surveys took place within the Berwickshire Marine Reserve, Southeast Scotland, U.K. (55.912714, −2.109902), and outside this designation (Figure 2). In the local area, the fishing season for both species is typically all year round; however, the intensity of fishing activity is greater in the summer months for *H. gammarus* and in the winter and spring months for *C. pagurus*, which can be indicated by the fluctuating annual market value of these decapods.

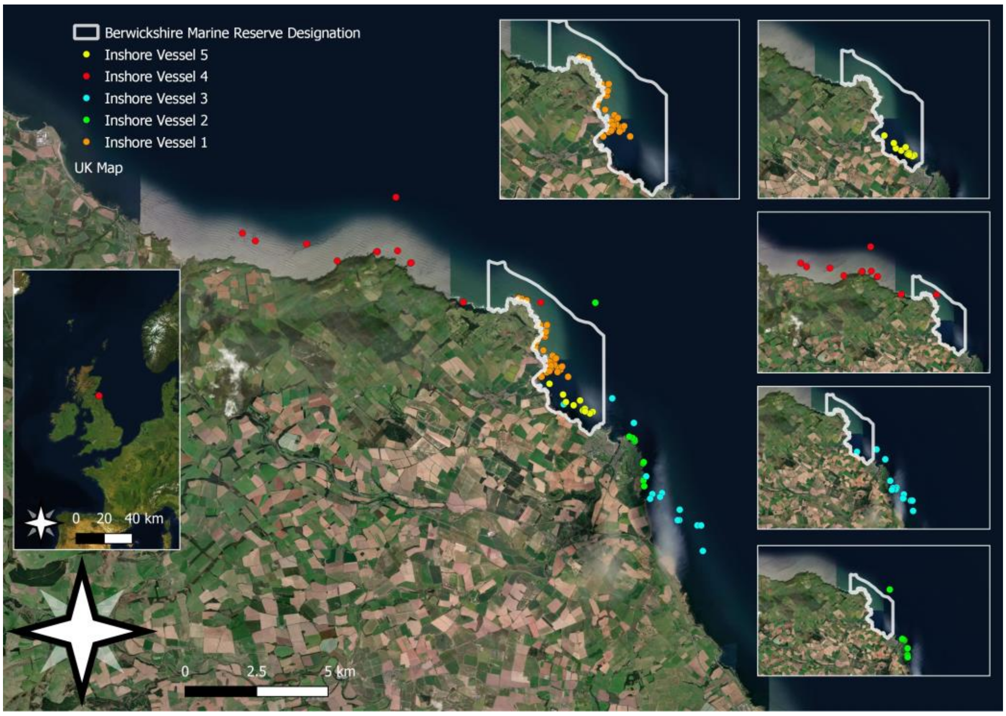

Figure 2. Creel fleet locations from all CPUE surveys between 2018 and 2019. Creel fleets are separated by colour representing each fishing vessel used. The white outline highlights the Berwickshire Marine Reserve designation (55.912714, −2.109902). Orange and yellow dots were categorised as inside the Berwickshire Marine Reserve designation, and red, green, and blue are located along the Berwickshire coast and categorised as outside the marine reserve.

2.2. Onboard Surveys

In the period between 2018 and 2019, catch per unit effort (CPUE) surveys were conducted using 5 local inshore fishing vessels of sizes 12 m or less. The local fishing vessels used were berthed in either St. Abbs Harbour (55.899190, −2.129224) or Eyemouth Harbour (55.871697, −2.087245). Surveys were conducted throughout the primary fishing season, with the number of surveys decreasing towards the winter months due to lower fishing activity in response to adverse weather. Surveys generally occurred between the times of 0600 h–1500 h, with each survey varying in duration from 1 to 8 h. Multiple creels are fished as fleets. The number of creels deployed in each surveyed fleet reached a maximum number of 45, with some surveys including single pots which are known as single enders in the local area. Fleets were deployed in a random method, as fishers deployed fleets as they would during normal fishing activity. The creels used by the local inshore fishers varied from single hard-eye to double soft-eye parlours (Figure 3). The variation between the creel types used is dependent on the entrance, known as the eye, and the number of eyes per creel. Eyes can be either made from netting, termed soft eyes, or from a hard plastic 6-inch ring termed a hard eye. Typically, the rest of the creel structure is built from a 38-inch frame of either plastic or metal and laced with rope made from a nylon material (Figure 3). Each fleet of creels was deployed in a depth range between 5.2 m and 32 m which varied depending on the fishing vessel used and the month of the year. The length of time creels were deployed, known as soak time, was recorded in days and ranged from 1 to 7 days. Creels used in this study were typically not fitted with escape panels as this is common for the area. All vessel names and locations of creel retrievals were recorded using their onboard GPS or by handheld GPS which all onboard surveyors carried. The recording of all CPUE data was conducted by two members of staff from St. Abbs Marine Station and two staff rangers from the Berwickshire Marine Reserve (BMR).

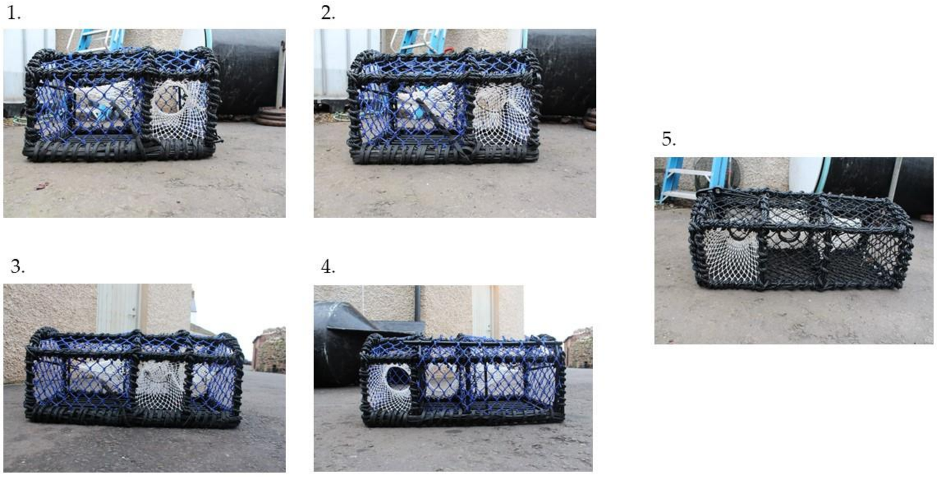

Figure 3. Creel types used from all fishing vessels during the sampling period. No escape panels were used on any of the creels sampled over the survey period. The creels shown in the figure were not used during the study. These are used to present a visual representation of the creels utilised by the local inshore fishers. Image 1 shows a single hard-eye parlour and image 2 is a single soft-eye parlour. Image 3 shows a double soft-eye parlour and image 4 is a double hard-eye parlour. Lastly, image 5 shows a prawn parlour which is smaller in size and is fitted with two entrances.

2.3. CPUE

Catch per unit effort (CPUE) (kg per day^{-1}) was calculated for each onboard survey. For data collected in 2019, landing per unit effort (LPUE) (kg per day^{-1}) and net retrieval per unit effort (NRPUE) (kg per day^{-1}) were also measured. LPUE is the number of individuals of landing size (>85 mm *H. gammarus*; >140 mm *C. pagurus*) or above based on the number of creels hauled, and in contrast, the NRPUE is the number of individuals below the landing size.

$$\text{CPUE} = \frac{\text{Total number of target species per fleet}}{\text{Number of creels per fleet}}$$

$$\text{LPUE} = \frac{\text{Total number of landing sized individuals per fleet}}{\text{Number of creels per fleet}}$$

$$\text{NRPUE} = \frac{\text{Total number of undersized individuals per fleet}}{\text{Number of creels per fleet}}$$

All bycatch was recorded using the common species name and the number of individuals present in each hauled creel. As the number of *Necora puber*, which are deemed bycatch by the inshore fishers, caught was so high, they were included in the CPUE assessments as they can be collected and sold by the local inshore fishers.

2.4. Environmental Data

Environmental data such as sea surface temperature (°C), dissolved oxygen (mg/L), salinity (ppt), and lunar phase (%) were recorded on each day an onboard survey was conducted. These data, except lunar phase, were collected using a YSI ProSolo digital water quality meter probe deployed at sea before each fleet haul. Data were rounded to two decimal places for analysis. Lunar phase data were collected on each onboard survey day from a meteorological website (Willyweather.co.uk accessed on 1 June 2018).

2.5. Statistical Analyses

All statistical analysis was conducted using R Studio (Version 1.1.463–© 2009–2018 RStudio, Inc., Boston, MA, USA) [27]. Data were inspected for normality of distribution and equal variance using the Shapiro–Wilks test and Bartlett's test. Histogram plots were used for visual inspection of normality distribution. Unpaired two-sample t-tests were used to compare the number of individuals caught inside and outside the Berwickshire Marine Reserve designation. To find any differences in the number of individuals caught by year and soak time, Kruskal–Wallis tests were conducted. Pairwise Wilcox tests were used to further the analysis of the Kruskal–Wallis tests to include month as a factor. Kendall rank tau correlations were conducted to consider the effects of environmental variables such as sea surface temperature (°C), salinity (ppt), and dissolved oxygen (mg/L) on the number of target species caught and CPUE. Tau values of above 0 were indicative of positive relationships, and values above 1 were regarded as highly positive. Tau values of below 0 were indicative of negative relationships, with values below −1 regarded as highly negative values.

General additive models (GAMs) were used to model the relationships of CPUE for each target species in relation to the explanatory variables, as shown by the following:

$$\text{CPUE} \sim \text{year} + \text{s(depth)} + \text{s(soak time)} + \text{boundary} + \text{bait} + \text{creel type}$$

The complexity of the models was reduced by comparing the REML scores (restricted maximum likelihood) and R^2 values. Models with a low REML score when compared to the other tests were favoured. The models were fitted with a quasi-Poisson function due to overdispersion in the initial models. Soak time (days) and depth (m) were selected as isotropic smooths (s) based on the models used in [20]. Chi-square tests were then used to assign which variables significantly influenced the CPUE of the target species. Significance was assumed when the *p*-value was <0.05 for all statistical tests.

3. Results

3.1. Catch Composition

From both sampling years collectively, the total number of *H. gammarus* individuals reached n = 3013, the total number of *C. pagurus* individuals reached n = 2117, and the total number of *N. puber* individuals reached n = 3388. These numbers were collected across a total of 23 surveys and 1897 individual creel pots (Table 1). In 2019, the number of undersized individuals (<minimum landing size (<MLS)) was 834 for *H. gammarus* and 427 for *C. pagurus*. The soak time to catch the greatest number of *H. gammarus* (>MLS) was 7 days, although this was deemed insignificant (p = 0.07). However, for those *H. gammarus* <MLS, significance was found for all soak times above 2 days ($p \leq 0.05$). A soak time of 5 days showed significance for the highest number of *C. pagurus* (<MLS) caught ($p < 0.05$). Contrastingly, a soak time of 2 and 3 days proved to be significant compared to 7 days (p = 0.03) when related to the number of *N. puber* caught.

Table 1. Total count of the boats, surveys, and creels used in this project. Data are separated by year and show the total count for each group. Total number of *H. gammarus*, *C. pagurus*, and *N. puber* caught over the surveys is shown.

Year	No. of Boats	No. of Surveys	No. of Creels	No. of *H. gammarus*	No. of *C. pagurus*	No. of *N. puber*
2018	1	8	472	389	567	550
2019	5	15	1425	2624 (834 < MLS)	1550 (427 < MLS)	2838

Note: *N. puber* are not distinguished by a minimum landing size, and therefore, values are not separated similar to *H. gammarus* and *C. pagurus* in the table. MLS is the abbreviation for minimum landing size (minimum landing size 150 mm for *C. pagurus* and 80 mm for *H. gammarus*).

The number of *H. gammarus* (chi-square = 7.36, p = 0.02) and *C. pagurus* (chi-square = 32.37, $p \leq 0.05$) decreased from 2018 to 2019, whereas the number of *N. puber* (chi-square = 83.60, $p \leq 0.05$) increased. The number of *H. gammarus* increased between July (2018: 1.43 ± 0.07, 2019: 1.26 ± 0.05) and August (2018: 1.67 ± 0.06, 2019: 1.35 ± 0.09) (p = 0.01). For *C. pagurus*, in 2018, numbers decreased from July (2.28 ± 0.10) to August (1.66 ± 0.10), whereas in 2019, there was not a large discrepancy (July: 1.10 ± 0.05, August: 1.18 ± 0.13) ($p \leq 0.05$).

For *N. puber*, the number of individuals caught in August differed from those in July and September ($p \leq 0.05$).

3.2. CPUE

CPUE data from 2018 for both *C. pagurus* and *H. gammarus* was highest in prawn parlour creel variations (n = 2.92 and 1.85). The lowest values were recorded in double-eye creels for *C. pagurus* (n = 0.94) and single-eye creels for *H. gammarus* (n = 0.57) (Table 2). The CPUE of *N. puber* was found to be highest in single-eye creels (n = 2.26) and lowest in double-eye variations (n = 0.83). In 2019, CPUE for *H. gammarus* was highest in hard-and-soft-eye creels and lowest in prawn parlours (Table 3). For *C. pagurus*, CPUE was highest in parlours and lowest in prawn parlours (Table 3). For *N. puber*, CPUE was highest in prawn parlours and lowest in hard- and soft-eye creels, respectively (Table 2). In data from 2019, NRPUE was greater than LPUE for all target species. NRPUE was highest for *H. gammarus* (n = 1.29), whereas LPUE was lowest for *C. pagurus* (n = 0.31).

Table 2. CPUE for all target species in 2018–2019 based on pot types sampled.

Year	Creel Type	No. of Pots	No. of *H. gammarus* ≥MLS/≤MLS	No. of *C. pagurus* ≥MLS/≤MLS	CPUE (L)	CPUE (C)	CPUE (V)
2018	Double-Eye	311	293	291	0.942	0.942	0.836
	Single-Eye	146	70	235	0.570	1.520	1.650
	Prawn Parlour	14	26	41	1.857	2.928	1.571
2019	Double-Eye Parlour	109	101/148	36/93	2.284	1.183	1.12
	Double Soft-Eye Parlour	110	66/73	35/21	1.263	0.509	2.8
	Hard- and Soft-Eye	8	7/16	0/7	2.875	0.875	0.25
	Hard-Eye Parlour	329	143/291	57/123	1.32	0.55	2.29
	Parlour	624	335/988	301/749	2.120	1.682	1.639
	Prawn Parlour	44	21/21	1/5	0.954	0.136	3.659
	Soft-Eye Parlour	144	86/302	25/73	2.69	0.68	2.36

Note: CPUE values for *H. gammarus* (L), *C. pagurus* (C), and *N. puber* (V) are presented for each pot type sampled. Values are calculated by the number of individuals caught divided by the number of pots of the specific creel type. The values shown for total number of *H. gammarus* and *C. pagurus* are separated by landing size (≥MLS)/undersized (≤MLS). Numbers of *H. gammarus* and *C. pagurus* in 2018 were grouped and not separated by landing size, as represented in the table.

Table 3. CPUE (2018–19) (mean ± standard error mean) of the target species collected from all creels hauled by the respective fishing vessel.

Year	Vessel	BMR Designation	No. of Pots	CPUE (L)	CPUE (C)	CPUE (V)
2018	Vessel 1	In	468	0.82 ± 0.02	1.12 ± 0.04	1.17 ± 0.04
2019	Vessel 1	In	453	1.00 ± 0.02	0.37 ± 0.01	2.86 ± 0.06
	Vessel 2	In	256	1.28 ± 0.05	1.33 ± 0.05	1.53 ± 0.05
	Vessel 3	Out	47	3.72 ± 0.21	0.17 ± 0.03	1.34 ± 0.13
	Vessel 4	Out	370	2.75 ± 0.04	1.31 ± 0.05	1.47 ± 0.05
	Vessel 5	Out	299	2.16 ± 0.04	1.80 ± 0.07	1.80 ± 0.06

Note: Vessels are also separated by their fishing area inside or outside the Berwickshire Marine Reserve designation.

Regarding CPUE of the target species inside and outside the Berwickshire Marine Reserve, for *H. gammarus*, it was greater outside (2.57 ± 0.03) than inside (1.10 ± 0.02) the designation (t = 41.65, $p \leq 0.05$). This was also the case for *C. pagurus* (outside: 1.44 ± 0.04; inside: 0.72 ± 0.02) (t = 11.30, $p \leq 0.05$). Only the CPUE for *N. puber* was greater inside (2.38 ± 0.04) than outside (1.60 ± 0.04). Regarding the number of these target species, both *H. gammarus* (≥MLS: 1.51 ± 0.04; ≤MLS: 2.39 ± 0.05) and *C. pagurus* (≥MLS: 1.62 ± 0.07;

≤MLS: 2.91 ± 0.18) were higher outside the designation. The number of *N. puber* caught was greater inside (3.59 ± 0.11) the designation than outside (3.30 ± 0.12) (t = −5.13, $p \leq 0.05$).

In the analysis of GAM models of CPUE of both *H. gammarus* and *C. pagurus*, it was found that the simpler model (CPUE ~ year + s(depth) + s(soak time) + boundary) was deemed suitable based on the chi-square test results and REML scores ($p \leq 0.05$) (Table 4). For *N. puber*, the more complex model was deemed more suitable in describing the changes in CPUE (CPUE ~ year + s(depth) + s(soak time) + boundary + bait + pot type) (df = 15.95, $p \leq 0.05$). The outputs from all models can be seen in Table 4. Considering each model, soak time (days) was significant for CPUE for all target species ($p \leq 0.05$) (Figures 4–6). Depth (m) also showed a significant effect on the model and CPUE for all models except for *H. gammarus* (F = 1.87, $p = 0.19$) (Figure 5).

Table 4. General additive model outputs describing the relationship of CPUE of all target species with depth, soak time, bait, creel type, and area in relation to the Berwickshire Marine Reserve designation.

Species	Model	REML	R^2	Deviance	Intercept: *t*-Value	Intercept: *p*-Value
H. gammarus	Model A	−1381.5	0.63	63.9%	−0.30	0.76
	Model B	−1575.7	0.72	71.7%	−6.26	<0.05
	Model C	−879.7	0.52	41.7%	−8.76	<0.05
C. pagurus	Model A	−1141.1	0.63	62.6%	16.27	<0.05
	Model B	−838.2	0.46	46.8%	1.66	0.09
	Model C	−580.83	0.33	31.2%	7.27	<0.05
N. puber	Model A	−547.58	0.18	15.8%	−18.12	<0.05
	Model B	−686.55	0.25	26.1%	−10.69	<0.05
	Model C	−895.07	0.42	42.7%	−0.33	0.73

Note: Results include all data from all 5 fishing vessels across both survey years (2018–19). Significance was set at $p < 0.05$. The models used are as follows: model A: CPUE ~ year + s(depth) + s(soak time) + boundary + bait; model B: CPUE ~ year + s(depth) + s(soak time) + boundary + bait + creel type; model C: CPUE ~ year + s(depth) + s(soak time) + boundary. Best-fitting models were selected based on the REML score (the lower the score, the better the description of CPUE) and R^2 value (the greater the value, the better the fit to the model). Significance was set at $p < 0.05$. Chi-square tests were used to compare and test which models were best for the CPUE data.

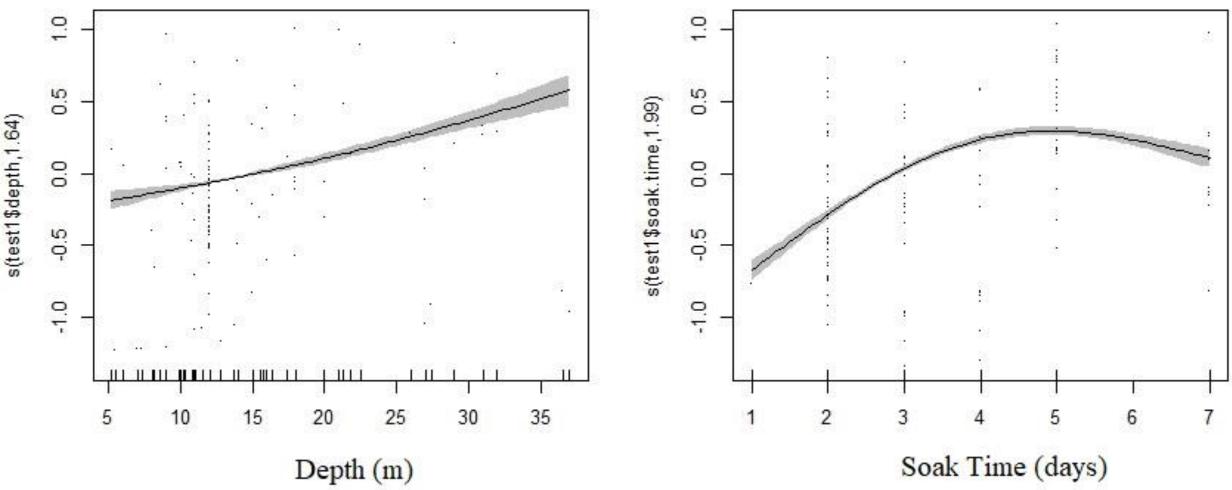

Figure 4. Effects of smoothing parameters depth and soak time on the CPUE of *C. pagurus* following GAM model analysis of data from 2018 to 19. Graphs are produced from the best-fitting model (CPUE ~ year + s(depth) + s(soak time) + boundary). Smoothing parameters were assigned basis functions in the model as s(parameter, k = 3); this set the maximum possible degrees of freedom for the smoothing parameter as 3.

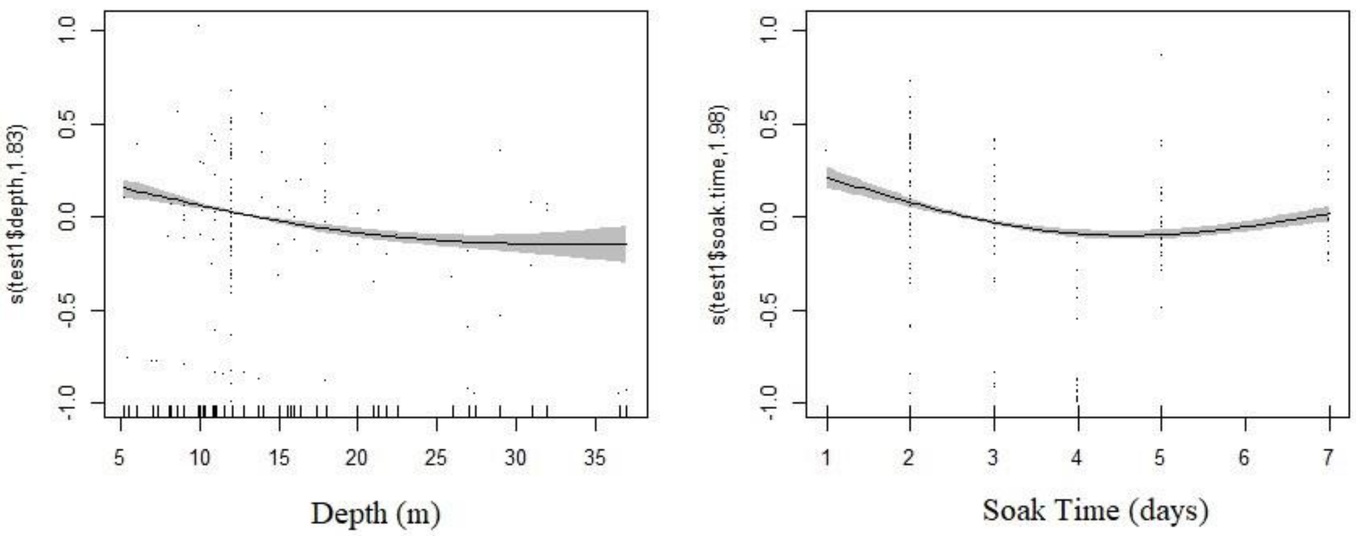

Figure 5. Effects of smoothing parameters depth and soak time on the CPUE of *H. gammarus* following GAM model analysis of data from 2018 to 19. Graphs are produced from the best-fitting model (CPUE ~ year + s(depth) + s(soak time) + boundary). Smoothing parameters were assigned basis functions in the model as s(parameter, k = 3); this set the maximum possible degrees of freedom for the smoothing parameter as 3.

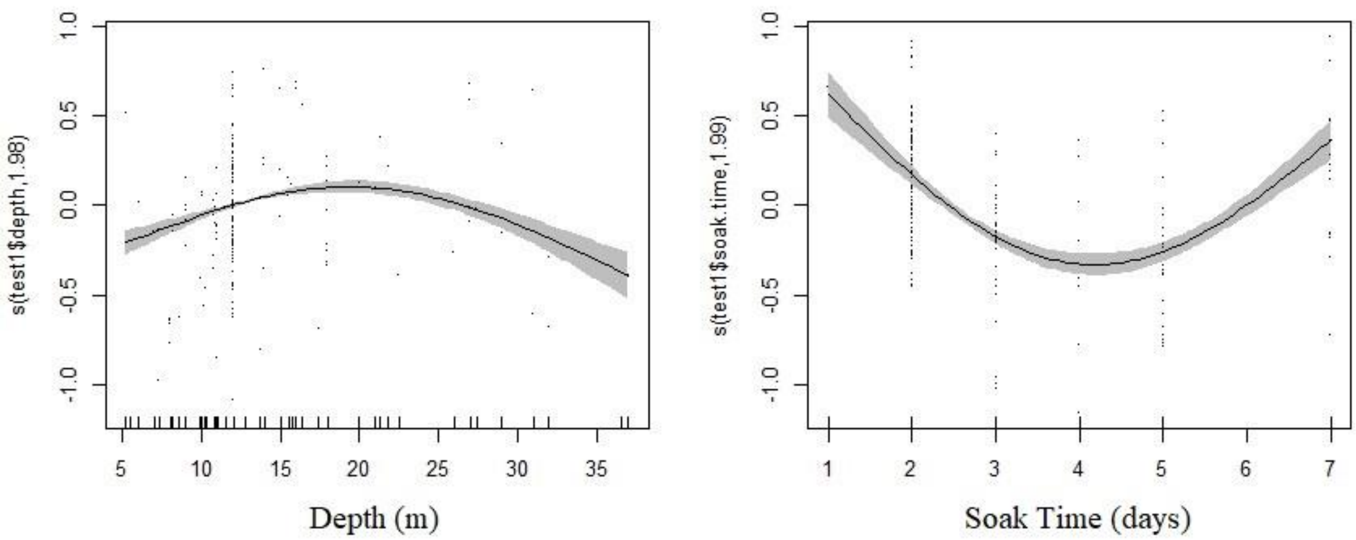

Figure 6. Effects of smoothing parameters depth and soak time on CPUE of *N. puber* following GAM model analysis of data from 2018 to 19. Graphs are produced from the best-fitting model (CPUE ~ year + s(depth) + s(soak time) + boundary + bait + pot type). Smoothing parameters were assigned basis functions in the model as s(parameter, k = 3); this set the maximum possible degrees of freedom for the smoothing parameter as 3.

3.3. Environmental Data

Between the sampling years of 2018 and 2019, August was the warmest month (sea surface temperature) (2018: 15.38 ± 0.26 °C; 2019: 15.08 ± 0.21 °C). The coldest month with respect to sea surface temperature was March in 2018 (4.77 ± 0.29 °C) and February in 2019 (6.15 ± 0.09 °C). April for both years had the lowest recorded salinity (2018: 33.57 ± 0.06 ppt; 2019: 33.68 ± 0.21 ppt), with September recording the highest in 2018 (34.44 ± 0.04 ppt) and October recording the highest in 2019 (34.39 ± 0.03 ppt). A full breakdown of the environmental variables recorded can be seen in Table 5.

Table 5. Environmental variables (sea temperature (°C), salinity (ppt), and dissolved oxygen (mg/L)) recorded by month for each sampling year (2018–2019). Data shown as mean ± sem.

	2018		2019		
Month	**Sea Surface Temperature (°C)**	**Salinity (ppt)**	**Sea Surface Temperature (°C)**	**Salinity (ppt)**	**Dissolved Oxygen (mg/L)**
June	11.80 ± 0.18	34.13 ± 0.02	12.06 ± 0.24	33.91 ± 0.03	9.15 ± 0.06
July	14.80 ± 0.52	34.16 ± 0.05	14.33 ± 0.25	33.88 ± 0.07	8.38 ± 0.06
August	15.38 ± 0.26	33.90 ± 0.30	15.08 ± 0.21	33.86 ± 0.06	8.01 ± 0.25
September	12.75 ± 0.28	34.44 ± 0.04	12.61 ± 0.08	34.22 ± 0.09	8.84 ± 0.17
October	10.88 ± 0.20	34.41 ± 0.04	10.77 ± 0.15	34.39 ± 0.03	8.89 ± 0.09
November	9.99 ± 0.17	34.24 ± 0.04	9.24 ± 0.16	33.78 ± 0.21	9.33 ± 0.07
December	8.40 ± 0.00	34.31 ± 0.00	7.80 ± 0.15	34.00 ± 0.24	9.43 ± 0.05

H. gammarus of sizes above the MLS were not positively or negatively related to environmental factors significantly (Table 6). However, those below the MLS were positively correlated with dissolved oxygen (tau = 0.18, $p \leq 0.05$), salinity (tau = 0.15, $p \leq 0.05$), and lunar phase (tau = 0.11, $p \leq 0.05$) and negatively correlated with sea surface temperature (tau = −0.18, $p \leq 0.05$) (Table 6). *C. pagurus* individuals of sizes below the MLS followed the same trend as the undersized *H. gammarus*; however, there was no significant result in correlation with salinity (tau = 0.05, $p = 0.15$). Those *C. pagurus* individuals above the MLS were positively correlated with sea surface temperature (tau = 0.14, $p \leq 0.05$) and negatively correlated with dissolved oxygen (tau = −0.09, $p \leq 0.05$) and lunar phase (tau = −0.10, $p \leq 0.05$). CPUE of both *C. pagurus* and *H. gammarus* was tested with lunar phase and sea surface temperature (Figure 7), and it was found that there was a weak negative relationship for both species regarding sea surface temperature (tau ≤ -0.5, $p \leq 0.05$) and a weak positive relationship for lunar phase (tau ≥ 0.5, $p \leq 0.05$) (Table 6).

Table 6. Kendall rank correlation outputs (*p*-value and tau value) for abundance counts and CPUE related to environmental variables for *C. pagurus* and *H. gammarus*.

Species		**Individuals ≥ MLS**	**Individuals ≤ MLS**	**CPUE**
H. gammarus	Sea Temperature (°C)	$p = 0.37$ tau = 0.02	$p \leq 0.05$ tau = −0.18	$p \leq 0.05$ tau = −0.61
	Salinity (ppt)	$p = 0.27$ tau = 0.03	$p \leq 0.05$ tau = 0.15	
	DO (mg/L)	$p = 0.05$ tau = −0.05	$p \leq 0.05$ tau = 0.18	
	Lunar Phase (%)	$p = 0.70$ tau = −0.01	$p \leq 0.05$ tau = 0.11	$p \leq 0.05$ tau = 0.46
C. pagurus	Sea Temperature (°C)	$p \leq 0.05$ tau = 0.14	$p = 0.00$ tau = −0.10	$p \leq 0.05$ tau = −0.21
	Salinity (ppt)	$p = 0.84$ tau = −0.00	$p = 0.15$ tau = 0.05	
	DO (mg/L)	$p = 0.00$ tau = −0.09	$p \leq 0.05$ tau = 0.17	
	Lunar Phase (%)	$p = 0.00$ tau = −0.10	$p \leq 0.05$ tau = 0.21	$p \leq 0.05$ tau = 0.34

Note: Significance was set at $p < 0.05$. Negative tau values correspond to negative relationships and positive tau values correspond to positive relationships. The greater the tau value ≥ 1, the greater the positive relationship; and with tau values ≤ -1, the greater the negative relationship. DO denotes dissolved oxygen (mg/L).

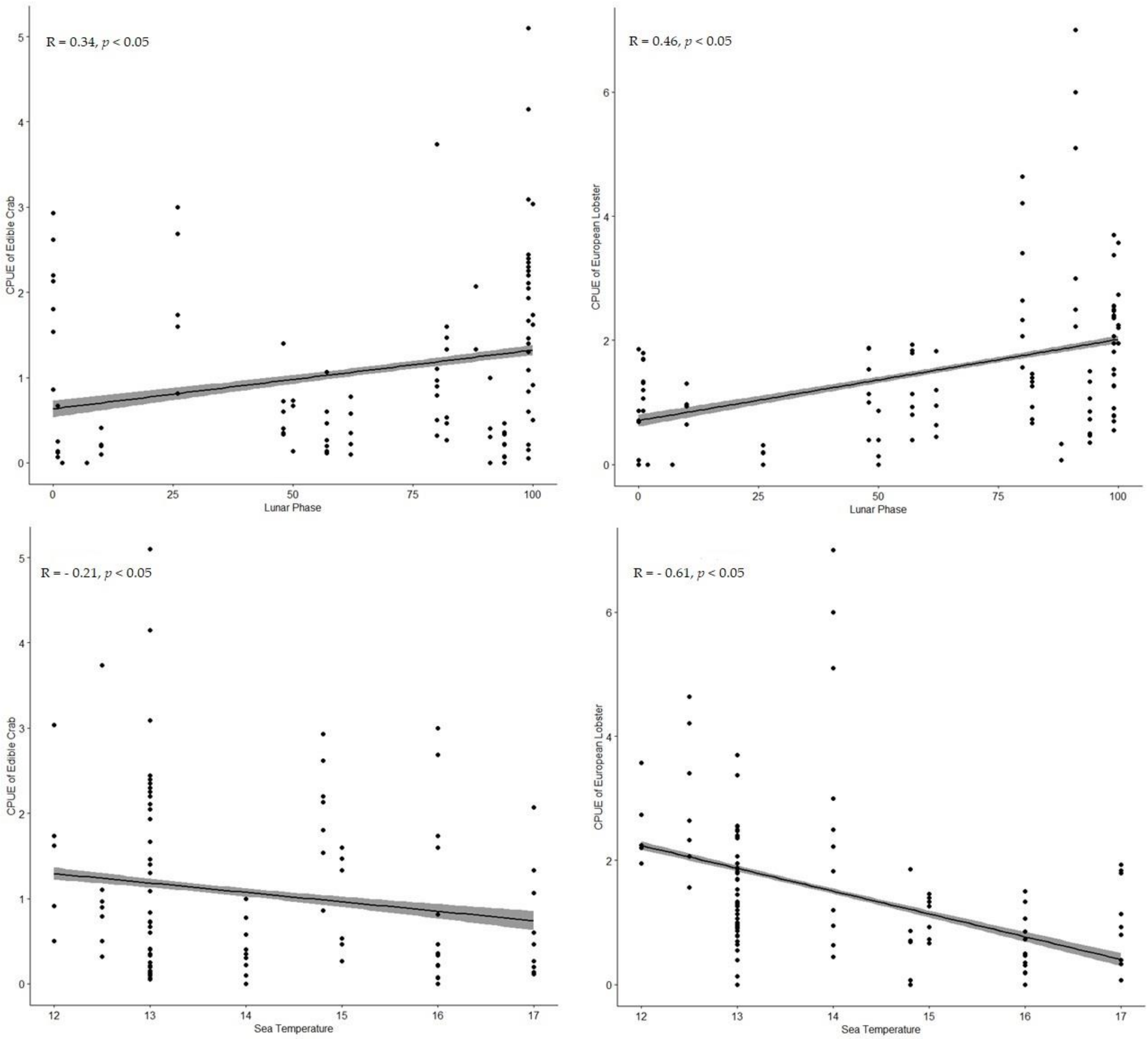

Figure 7. Kendall rank correlation of lunar phase (%) and sea surface temperature (°C) with respect to CPUE of *C. pagurus* and *H. gammarus*. This included undersized and landing-sized individuals. Black dots represent the recorded CPUE for the target species from each survey conducted over the study. A positive correlation for lunar phase (%) is highlighted by the trendline with an R value of 0.34 ($p \leq 0.05$) for *C. pagurus* and 0.46 ($p \leq 0.05$) for *H. gammarus*. Negative correlations for sea temperature are highlighted by the trendline with an R value of −0.21 ($p \leq 0.05$) for *C. pagurus* and −0.61 ($p \leq 0.05$) for *H. gammarus*. Significance was set at $p < 0.05$.

3.4. Bait

The type of bait used by the fishers can be seen in Figure 8, with a greater proportion of mackerel (*Scomber scombrus*) (42.07%) and herring (*Clupea harengus*) (34.35%) used across all fishing vessels. Bait was included in the GAM models, in which mackerel was significantly related to the number of *H. gammarus* ($p = 0.01$) and *C. pagurus* ($p = 0.01$) caught. Herring as a bait source was significant for the number of *C. pagurus* caught ($p \leq 0.05$). Contrastingly, scad (*Trachurus trachurus*) showed significance for the number of *N. puber* caught ($p \leq 0.05$).

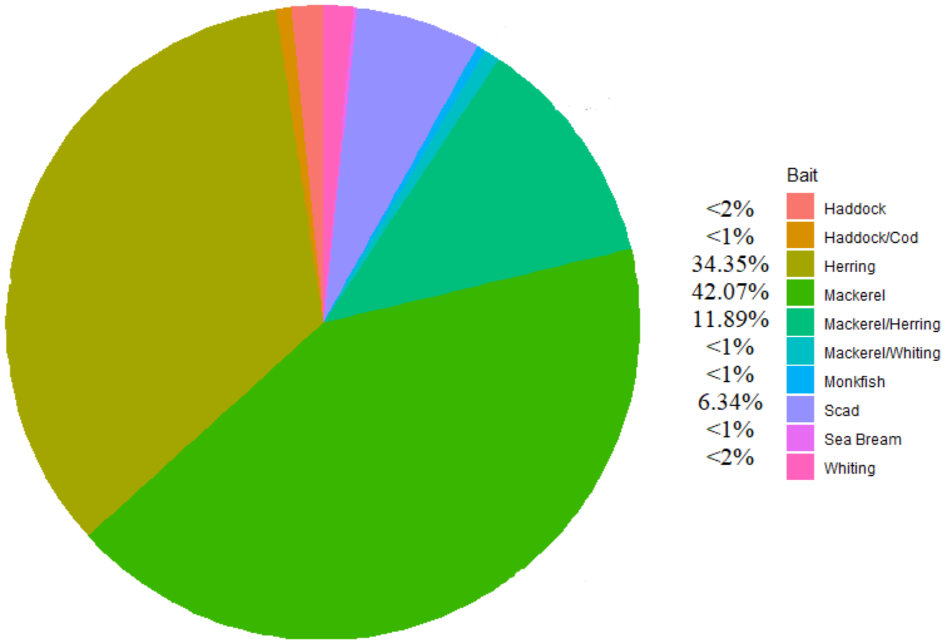

Figure 8. Pie chart of the bait type used across 2018 and 2019. Data are separated by bait type used across all fishing vessels. The data shown are the percentage of creels using the bait types highlighted in the figure.

4. Discussion

4.1. Catch Composition

In the local area, it is a common theory with local fishers that the stocks for both *H. gammarus* and *C. pagurus* are declining (pers. obvs.). Previous studies have implemented the use of logbooks, used by commercial fishers, to collate the information in situ; however, the robustness of this assessment is determined by the number of fishers participating [15,20]. In this study, a low number of fishing vessels (n = 5) were observed independently using onboard observers without the use of fisher logbooks. Logbooks are used to record the annual landings of fishers' catch every time they fish at sea. In this study we did not observe every fishing trip; therefore, it may be assumed that some detail and nuance have been lost from the results, which may have been provided if logbooks were used. It has been addressed that due to the limited number of vessels fishing used in this study, there is potential that the catch could be more uniform than would be representative of the natural stock, a positive intra-cluster correlation [15,28]. However, by utilising fishers with different fishing grounds and fishing fleets of randomised locations, it is perceived that this positive intra-cluster correlation was reduced. Many factors could influence the *C. pagurus* populations regionally, such as habitat variations, mating behaviour, and competition for food and shelter [20]. The influence is based on the sex ratio of caught individuals, which differs seasonally and spatially with *C. pagurus* migrating in the Autumn after emigrating back to inshore grounds to mate and moult [17,20,29]. The habitats outside and inside the marine reserve designation are predominantly rocky outcrops with interspersed sandy patches with the latter increasing in presence outside the marine reserve. Such habitats benefit the female *C. pagurus* who reside in sandy patches to avoid strong currents and to incubate eggs post-mating [20,30,31] (Figure 1). The rocky outcrops may have led to lower numbers of *H. gammarus* and *C. pagurus* caught due to the availability of natural shelter outweighing exploratory behaviour around creels. *H. gammarus* tend to shelter in the late spring as they moult and harden their shell before re-emerging in the late summer [32,33], which coincides with the increase in CPUE in August and July in 2019 shown in this study. The number of *C. pagurus* caught has been shown to be related to sediment type following GAM models in [4] which showed that gravel substrate proved to have higher catch rates than softer sediment. This was not included in our models as the locations of creel pots could not be “ground-truthed” to specific substrate types as the habitat map described in Figure 1 was provided after sampling and analysis. The study presented in [4] also used dredges and trawls, a form of mobile fishing, which is not comparable to static gear fishing which involves the need for food-seeking behaviour using odour cues [34,35].

4.2. CPUE

Although independent observations typically are low in replicates, they are useful in understanding CPUE estimates which are location-specific whilst providing additional biological information such as morphometric measurements and condition indices [20,36]. The CPUE for *C. pagurus* and *H. gammarus* was greater outside the Berwickshire Marine Reserve designation. This study did not focus on the potential “spill-over” effect associated with the Berwickshire Marine Reserve, but it may be suggestive based on the CPUE trend outside the designation. It can be assumed that the effort required to fish for *C. pagurus* and *H. gammarus* is less outside the marine reserve but much greater inside, suggesting overexploitation within the marine reserve. This is contrary to a similar study for the marine protected area (MPA) around the Isle of Arran, Scotland, in which the inverse was found [23]. Inside the reserve, the CPUE for *H. gammarus* was 123% higher within the designation in 2012; with *C. pagurus*, the CPUE was similar both inside and outside the designation [23]. However, in 2013 it was found that the CPUE of *C. pagurus* had declined within the reserve by 49%, equating to a 253% difference between the outside and inside areas of study [23]. Studies outside the U.K. also find increases in abundance inside the designated areas of protection which have also been related to a “spill-over” effect. Spiny lobsters (*Panulirus interruptus*) in California were 124% higher in abundance inside the reserve and 223% higher on the border of the reserve, suggesting a “spill-over” effect over a 10-year sampling period (2008–18) [37]. Furthermore, in Norway, a 245% increase in CPUE for *H. gammarus* was located inside MPAs based on pooled results from 2006 to 2010 [38]. It has been stated that warmer sea temperatures are likely to increase catch due to the metabolic demand of the *C. pagurus* species [20]. In this study, it was found that sea surface temperature correlated with the number of *C. pagurus* caught above the minimum landing size, which was also similar to that of [20]. This contrasts observations with *C. pagurus* fishing occurring typically between April and November, with the highest catches observed in October and November [20]. CPUE of *H. gammarus* also showed a negative correlation with sea surface temperature in this study, but [23] found that temperature had no significant effect on the number of individuals caught. In the Mediterranean Sea, warmer waters (May–August) were associated with higher CPUE for *H. gammarus* [39]. Soak time ranged from 1 to 7 days, with the optimal soak times differing depending on which target species was being caught. It has been suggested that soak time does not linearly affect the end catch [20], which is apparent in Figures 4–6. Other studies suggest that the number of *C. pagurus* landings positively correlates with soak time [36] but also declines with increasing soak time [39]. In the Northern Taiwan Strait, soak times of <48 h saw a greater catch of target crustacean species, whereas soak times of >48 h saw a greater haul of bycatch [40]. In this study, soak time had a significant effect on the CPUE for all target species as a smoothing factor in the GAM models, although the effects of soak time greatly differed depending on species (Figures 4–6). Depth also showed a significant effect on CPUE, except for *H. gammarus*, which has also been shown in [20] with the number of *C. pagurus* caught increasing with depth. However, it has been shown in [4] that the number of *C. pagurus* caught showed a nonlinear decrease with depth (23–84 m); however, this depth range is far deeper than that used in this study (5–37 m) [4]. Creel deployment is typically associated with rocky habitats compared to sand or muddy substrates [6]. Over a 9-year period, the fishing pressure in the rocky inshore area doubled in the Northumberland district, although the creel density was constant [6]. In areas of high fishing density, it has been shown that the number of *C. pagurus* and *H. gammarus* caught declined over a 3-year period by 19% and 35% respectively [41]. Future data surveys should integrate the habitat type on which the fishing equipment is deployed, based on the data provided in Figure 1, also known as fisheries habitat interactions [6].

Creels are not standardised fishing equipment; fishers can adapt and change them in response to fishing needs. Such adaptations can include frame material, net gap size, and number and size of entrances [20]. Predominantly, in this area, the creels are not affixed with escape gaps, which likely increases creel saturation. Such escape gaps can increase the efficiency of the creel by decreasing the undersized catch by 34% whilst increasing commercial catch by 125%, which is further exaggerated with the inclusion of two gaps [42]. Many studies record the efficiency of escape gaps and their ability to reduce the catch of undersized individuals whilst maintaining the commercial catch (those at MLS or above) [13,42–44]. The results in this study showed that CPUE and the number of target species caught greatly varied among the various creel types used. The CPUE of *N. puber* in 2019 was greater in the prawn parlour variations (Table 2), CPUE of *C. pagurus* was greater in parlour creels, and CPUE of *H. gammarus* was greater in hard- and soft-eye creels. From fisher observations, the hard-eye creel variations are dominated by *H. gammarus*, and the soft-eye creels are dominated by *C. pagurus*, although this cannot be confirmed by this study as the number of *H. gammarus* dominantly outnumbered *C. pagurus* in all creel types (Table 2). Other adaptations made to creels can include the entrances, with larger and smaller entrances potentially limiting sized individuals. The entrances for the creels used in this study were not measured, and assumptions on catch limitations by entrance size cannot be made and supported. Typically, the size of entrances on creels ranges from 3.5″ (89 mm) to 6″ (152 mm) in the Berwickshire area, although the industry standard is recorded as 9.8″ (250 mm) [29]. A study looking into the influence of entrance size on crayfish noted that the entrance size had no effect on the range of sizes caught [43]. The entrance sizes ranged from 45 to 85 mm in diameter [43], significantly smaller than those required to meet the landing sizes of both *C. pagurus* and *H. gammarus*. In contrast, it has been documented that the entrance size, if increased, is likely to increase the mean size of the animal caught, in this case, *H. gammarus* [13].

4.3. Bait

The dominant bait type used across all fishing vessels was mackerel (*Scomber scombrus*) (42.07%) and herring (*Clupea harengus*) (34.36%). Both *H. gammarus* and *C. pagurus* are chemosensory species using bimodal sensilla and olfactory systems to respond to chemical stimuli [9,45]. Both herring and mackerel are recognised as oily fish [46] and, it would be assumed, produce a strong chemical stimulus. The chemosensory stimulus is dependent on time, as the degradation and decomposition of the bait will influence the time period at which the fishing gear is most effective, with bait degradation ranging from 4 to 27 days based on values from [47,48]. It could be assumed that bait plumes surrounding the creel pots can vary regionally due to the regional variation in tides and currents [20]. The bait plume influence and the area with which the plume was associated could not be estimated in this study. Strong currents could lead to faster dilution of the bait plume, which could lead to smaller areas of influence that can only be estimated or assumed [9]. When presented with mackerel bait in a closed flume system, scampi (*Metanephrops challengeri*) showed no alterations in their behaviour but showed greater walking speeds in more turbulent water flow influenced by such bait [49]. Contrastingly, free-ranging *H. gammarus* exhibited a decrease in walking speed with decreasing distance to deployed creels; however, the behaviour could not be associated with bait influence specifically [9]. This chemosensory stimulus may influence a deterrence behaviour, as crushed crab added to baited creels led to a decrease in caught crabs by 54% [50].

4.4. Models

The best-fitting models for CPUE of *H. gammarus* and *C. pagurus* were those excluding the factors creel type and bait type. When additional explanatory factors were applied to each model, the deviance explained increased. However, more variables were significant, which seemed to exaggerate the interpretation of the models. The model used was based on that of [20], with the inclusion of bait type and creel type. Both smoothing parameters, soak time and depth, influenced the CPUE for all target species with varying influences. The CPUE of *C. pagurus* seemed to increase up to a period of 5 days before steadily decreasing, whereas that of *H. gammarus* decreased to 4 days before plateauing (Figures 5 and 6). Soak time varied depending on the fishing vessel used and the season. The soak time of static fishing gear can be influenced by the weather, with early termination of fishing periods being dependent on the adversity of the weather. If the creels are heavily saturated, this could likely lead to a decrease in available bait and space, further inhibiting catch. A higher density of *H. gammarus* in the creels will limit the catch of *C. pagurus* [2,51]; in contrast, a higher density of *C. pagurus* would not limit the available space but would reduce the available bait, limiting the attraction of other individuals [52]. The presence of one individual *H. gammarus* within a creel can decrease the CPUE of *C. pagurus* and *N. puber* by factors of 12 and 9, respectively [6]. Similar to the smoothing trend of soak time on the CPUE of *H. gammarus*, CPUE decreased with increasing depth until around 20 m before plateauing. The CPUE of *C. pagurus* increased with increasing depth, whilst that of *N. puber* increased with increasing depth until around 20 m before decreasing. The influence of depth on CPUE is likely linked to bottom sea temperature and sea current, which could be utilised to improve location-specific data [2,20]. *C. pagurus* are well known to migrate further offshore; in particular, females migrate further offshore during the gestation period to bury themselves in finer sediment such as sand for brooding [42,53]. It is documented that the depth range distribution of *C. pagurus* is around 6–40 m [54]. The depth range of *H. gammarus* ideally ranges from 35 to 40 m [40]. *H. gammarus* have expressed depth diel patterns from September to January as a form of inactivity coinciding with the decrease in water temperature [55,56]. The same study showed that all but one individual remained in depths shallower than 30 m for longer and shorter periods of activity [46]. The CPUE of *H. gammarus* was influenced by depths below 30 m (Figure 5) which would suggest a similar trend to [53], but also the limited activity in this species is likely to be associated with site fidelity which is common with this species [57], with activity commonly associated with feeding and territorial behaviour [58] within a few (~3.8 km) kilometres from their shelter [39]. Within a 20 m distance of a deployed creel, *H. gammarus* can remain in this vicinity for up to 17 h, and their presence can reduce the catch of both *C. pagurus* and *N. puber* [2,9].

5. Conclusions

Our study suggests that there is an exploitation of the commercially important species *C. pagurus* and *H. gammarus* inside the Berwickshire Marine Reserve due to the lower CPUE values recorded. A "spill-over" effect for both species may be a factor contributing to the varying CPUE values recorded in and outside the marine reserve, which would require further investigation. With no creel limitation in the region, it may be suggested that the decline inside the marine reserve may be accounted for by creel density saturating any viable fishing ground and subsequently contributing to regional fishing pressure. This would require further investigation through monitoring of vessel activity within the reserve designation gathered with autonomous tracking devices attached to the inshore fishing fleet. The depth and soak time of deployed creels were associated with the CPUE of the target species. This information could be used in relation to a creel limitation. By reducing the creel saturation on fishing grounds at certain depths and decreasing or increasing the length of species-dependent soak times, more targeted fishing activity can take place without affecting the overall catch for fishers. This is an ideal within a complex system, as other factors such as substrate type and bottom sea temperature would need to be considered, which would highlight fishery habitat interactions, improving the resolution of the findings in this study. It is believed that the information provided in this study will be used in future advice and consideration for changes in fisheries management for Berwickshire.

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Institutional Review Board Statement: The research adhered to the legal requirements of the country (U.K.) in which the work was carried out, and all institutional guidelines of St. Abbs Marine Station. Informal ethical review and approval of this research was conducted by authors and trustees of St. Abbs Marine Station using published literature and information obtained from Animals (Scientific Procedures) Act 1986 (ASPA). Animal collection was conducted with the local commercial fishing fleet. The surveys were in accordance with terms of Section 9 of the Sea Fish Conservation Act 1967, Article 25 of Council Regulation No. 2019/1241, the specified crustaceans (prohibition on landing, sale and carriage) (Scotland): order 2017 No. 455 and the undersized edible crabs (Scotland) order 200 No. 228. At present, crustaceans still remain outside the protections of the Animal Welfare Act, the Act which makes it an offence to cause unnecessary suffering to protected animals. Ethical approval should be waived.

Informed Consent Statement: Informed consent was obtained from all inshore fishers prior to the commencement of the study to allow the use of their vessel and the publication of the data collected.

Data Availability Statement: The data collected and analysed in this paper are not available publicly. Readers can inquire and request the raw data files from the first author (blair.easton@marinestation.co.uk).

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References

1. Pauly, D.; Christensen, V.; Guénette, S.; Pitcher, T.J.; Sumaila, U.R.; Walters, C.J.; Watson, R.A.; Zeller, D. Towards sustainability in world fisheries. *Nature* **2002**, *418*, 689–695. [CrossRef]
2. Skerritt, D.J.; Bannister, R.C.A.; Polunin, N.V.C.; Fitzsimmons, C. Inter- and intra-specific interactions affecting crustacean trap fisheries—Implications for management. *Fish. Manag. Ecol.* **2020**, *27*, 445–453. [CrossRef]
3. Mcveigh, K. 'Much of Scottish Crab and Lobster Is "Fish to Avoid", Says Sustainable Seafood Guide', The Guardian. Available online: https://www.theguardian.com/environment/2022/apr/05/much-of-scottish-crab-and-lobster-is-fish-to-avoid-says-sustainable-seafood-guide (accessed on 6 April 2022).
4. Mesquita, C.; Dobby, H.; Pierce, G.J.; Jones, C.S.; Fernandes, P.G. Abundance and spatial distribution of brown crab (*Cancer pagurus*) from fishery-independent dredge and trawl surveys in the North Sea. *ICES J. Mar. Sci.* **2020**, *78*, 597–610. [CrossRef]
5. Marine Scotland, 'Scottish Sea Fisheries Statistics 2019', The Scottish Government, 2020. Available online: https://www.gov.scot/publications/scottish-sea-fisheries-statistics-2019/ (accessed on 26 June 2023).
6. Stephenson, F.; Polunin, N.V.C.; Mill, A.C.; Scott, C.; Lightfoot, P.; Fitzsimmons, C. Spatial and temporal changes in pot-fishing effort and habitat use. *ICES J. Mar. Sci.* **2017**, *74*, 2201–2212. [CrossRef]
7. Breen, P.; Vanstaen, K.; Clark, R.W.E. Mapping inshore fishing activity using aerial, land, and vessel-based sighting information. *ICES J. Mar. Sci.* **2014**, *72*, 467–479. [CrossRef]
8. Kafas, A.; McLay, A.; Chimienti, M.; Scott, B.E.; Davies, I.; Gubbins, M. ScotMap: Participatory mapping of inshore fishing activity to inform marine spatial planning in Scotland. *Mar. Policy* **2017**, *79*, 8–18. [CrossRef]
9. Lees, K.J.; Mill, A.C.; Skerritt, D.J.; Robertson, P.A.; Fitzsimmons, C. Movement patterns of a commercially important, free-ranging marine invertebrate in the vicinity of a bait source. *Anim. Biotelemetry* **2018**, *6*, 8. [CrossRef]

10. Murray, L.; Seed, R. Determining whether catch per unit effort is a suitable proxy for relative crab abundance. *Mar. Ecol. Prog. Ser.* **2010**, *401*, 173–182. [CrossRef]
11. Stamatopoulos, C. 'Sample-Based Fishery Surveys: A Technical Handbook', FAO Fisheries Technical Paper, no. 425, p. 132. 2002. Available online: https://www.fao.org/3/Y2790E/Y2790E00.htm (accessed on 28 June 2023).
12. Harley, S.J.; Myers, R.A.; Dunn, A.; Thorson, J.T.; Fonner, R.; Haltuch, M.A.; Ono, K.; Winker, H.; Carruthers, T.R.; Walter, J.F.; et al. Is catch-per-unit-effort proportional to abundance? *Can. J. Fish. Aquat. Sci.* **2001**, *58*, 1760–1772. [CrossRef]
13. Addison, J.T.; Lovewell, S.R.J. Size composition and pot selectivity in the lobster (*Homarus gammarus* (L.)) and crab (*Cancer pagurus* L.) fisheries on the east coast of England. *ICES J. Mar. Sci.* **1991**, *48*, 79–90. [CrossRef]
14. Hart, P.J.B. Enlarging the shadow of the future: Avoiding conflict and conserving fish. In *Reinventing Fisheries Management*; Pitcher, T.J., Pauly, D., Hart, P.J.B., Eds.; Springer Netherlands: Dordrecht, The Netherlands, 1998; pp. 227–238. [CrossRef]
15. Woll, A.K.; van der Meeren, G.I.; Fossen, I. Spatial variation in abundance and catch composition of Cancer pagurus in Norwegian waters: Biological reasoning and implications for assessment. *ICES J. Mar. Sci.* **2006**, *63*, 421–433. [CrossRef]
16. Fogarty, M.J.; Addison, J.T. Modelling capture processes in individual traps: Entry, escapement and soak time. *ICES J. Mar. Sci.* **1997**, *54*, 193–205. [CrossRef]
17. Bennett, D.B. Factors in the life history of the edible crab (*Cancer pagurus* L.) that influence modelling and management. *ICES Mar. Sci. Symp.* **1995**, *199*, 89–98.
18. Tully, O.; Robinson, M.; O'Keefe, E.; Cosgrove, R.; Doyle, O.; Lehane, B. The Brown Crab (*Cancer pagurus* L.) Fishery: Analysis of the Resource in 2004–2005. *Fish. Resour.* **2006**, *4*, 48. Available online: https://bim.ie/wp-content/uploads/2021/02/bimNo,4,The,Brown,-,Crab,Cancer,pagurus,L,-,Fishery,Analysis,of,the,resource,in,2004-2005,.pdf (accessed on 17 July 2023).
19. Okamura, H.; Morita, S.H.; Funamoto, T.; Ichinokawa, M.; Eguchi, S. Target-based catch-per-unit-effort standardization in multispecies fisheries. *Can. J. Fish. Aquat. Sci.* **2018**, *75*, 452–463. [CrossRef]
20. Öndes, F.; Emmerson, J.A.; Kaiser, M.J.; Murray, L.G.; Kennington, K. The catch characteristics and population structure of the brown crab (*Cancer pagurus*) fishery in the Isle of Man, Irish Sea. *J. Mar. Biol. Assoc. United Kingd.* **2019**, *99*, 119–133. [CrossRef]
21. Pendleton, L.H.; Ahmadia, G.N.; Browman, H.I.; Thurstan, R.; Kaplan, D.M.; Bartolino, V. Debating the effectiveness of marine protected areas. *ICES J. Mar. Sci.* **2018**, *75*, 1156–1159. [CrossRef]
22. Sala, E.; Giakoumi, S. No-Take Marine Reserves Are theMost Effective Protected Areas in the Ocean. *ICES J. Ofmarine Sci.* **2017**, *75*, 1166–1168. [CrossRef]
23. Howarth, L.M.; Dubois, P.; Gratton, P.; Judge, M.; Christie, B.; Waggitt, J.J.; Hawkins, J.P.; Roberts, C.M.; Stewart, B.D. Trade-offs in marine protection: Multispecies interactions within a community-led temperate marine reserve. *ICES J. Mar. Sci.* **2017**, *74*, 263–276. [CrossRef]
24. Marine Scotland. *Consultation on Landing Controls for the Scottish Crab and Lobster Fisheries: Outcome Report*; The Scottish Government: Edinburgh, Scotland, 2017; ISBN 978-1-78652-769-1.
25. Bell, S.; Aird, C.; Blackadder, L.; James, M.; Mendo, T.; Colilles, A.M.; Woulters, J.; Strang, N. *Outer Hebrides Inshore Fisheries Pilot: Year One Report*; The Scottish Government: Edinburgh, Scotland, 2022; ISBN 978-1-80435-440-7.
26. The Scottish Government. Fisheries Management Strategy 2020 to 2030: Delivery Plan. Available online: https://www.gov.scot/publications/scotlands-fisheries-management-strategy-2020-2030-delivery-plan/documents/ (accessed on 26 June 2023).
27. RStudio Team. *RStudio: Integrated Development for R*; RStudio, PBC: Boston, MA, USA, 2020. Available online: http://www.rstudio.com/ (accessed on 13 May 2021).
28. Pennington, M.; Burmeister, L.-M.; Hjellvik, V. Assessing the Precision of Frequency Distributions Estimated from Trawl-Survey Samples. 2002. Available online: http://hdl.handle.net/1834/31044 (accessed on 28 June 2023).
29. Edwards, E. *The Edible Crab and Its Fishery in British Waters*; Fishing News Books Ltd.: Farnham, UK, 1979.
30. Woll, A.K.; Alesund, M. The Edible Crab: Biology Grading Hand-Ling Live Crabs. Handbook. 2006. Available online: File:///C:/Users/MDPI/Downloads/Handbook%20-%20Edible%20crab%202005%20-%20MF.pdf (accessed on 25 March 2022).
31. Hall, S.J.; Robertson, M.R.; Basford, D.J.; Fryer, R. Pit-Digging by the Crab Cancer pagurus: A Test for Long-Term, Large-Scale Effects on Infaunal Community Structure. *J. Anim. Ecol.* **1993**, *62*, 59–66. [CrossRef]
32. Aitken, A. Brown Crab and European Lobster Fisheries in the NWIFCA District the Use of Returns Data to Inform Management, 2018. Available online: https://www.nw-ifca.gov.uk/app/uploads/Agenda-Item-10-Annex-A-TSB-Annex-A-Crab-and-Lobster-Report-Use-of-Landings-Data-08-01-18.pdf (accessed on 27 June 2023).
33. Pawson, M.G. *Biogeographical Identification of English Channel Fish and Shellfish Stocks. Ministry of Agriculture, Fisheries and Food, Fisheries Research Technical Report*; MAFF Directorate of Fisheries Research: Lowestoft, UK, 1995; Volume 99, p. 72.
34. Kaiser, M.J. Directorate-General for Internal Policies Policy Department B: Structural and Cohesion Policies Fisheries the Conflict between Static Gear and Mobile Gear in Inshore Fisheries Study. 2014. Available online: https://www.europarl.europa.eu/RegData/etudes/STUD/2014/529070/IPOL_STU(2014)529070_EN.pdf (accessed on 27 June 2023).
35. The Scottish Government. Changes to Legislation: There Are Currently No Known Outstanding Effects for the Inshore Fishing (Scotland) Act 1984. 1984. Available online: https://www.legislation.gov.uk/ukpga/1984/26/contents (accessed on 28 June 2023).
36. Verdoit, M.; Pelletier, D.; Bellail, R. Are commercial logbook and scientific CPUE data useful for characterizing the spatial and seasonal distribution of exploited populations? The case of the Celtic Sea whiting. *Aquat. Living Resour.* **2003**, *16*, 467–485. [CrossRef]

37. Lenihan, H.S.; Fitzgerald, S.P.; Reed, D.C.; Hofmeister, J.K.K.; Stier, A.C. Increasing spillover enhances southern California spiny lobster catch along marine reserve borders. *Ecosphere* **2022**, *13*, e4110. [CrossRef]
38. Moland, E.; Olsen, E.M.; Knutsen, H.; Garrigou, P.; Espeland, S.H.; Kleiven, A.R.; Andre, C.; Knutsen, J.A. Lobsterand Cod Benefit from Small-Scale Northern Marine ProtectedAreas: Inference from an Empirical Before–After Control-Impact Study. *Proc. R. Soc. B Biol.* **2013**, *280*, 20122679. [CrossRef]
39. Pavičić, M.; Matić-Skoko, S.; Vrdoljak, D.; Vujević, A. Population Characteristics of the European Lobster, *Homarus gammarus* in the Adriatic Sea: Implications for Sustainable Fisheries Management. *Water* **2021**, *13*, 1072. [CrossRef]
40. Naimullah, M.; Lee, W.-Y.; Wu, Y.-L.; Chen, Y.-K.; Huang, Y.-C.; Liao, C.-H.; Lan, K.-W. Effect of soaking time on targets and bycatch species catch rates in fish and crab trap fishery in the southern East China Sea. *Fish. Res.* **2022**, *250*, 106258. [CrossRef]
41. Rees, A.; Sheehan, E.V.; Attrill, M.J. Optimal fishing effort benefits fisheries and conservation. *Sci. Rep.* **2021**, *11*, 3784. [CrossRef] [PubMed]
42. Brown, C.G. The effect of escape gaps on trap selectivity in the United Kingdom crab (*Cancer pagurus* L.) and lobster (*Homarus gammarus* (L.)) fisheries. *ICES J. Mar. Sci.* **1982**, *40*, 127–134. [CrossRef]
43. Brown, P.; Hunt, T.L.; Giri, K. Effects of gear type, entrance size and soak time on trap efficiency for freshwater crayfish Cherax destructor and C. albidus. *Mar. Freshw. Res.* **2015**, *66*, 989–998. [CrossRef]
44. Winger, P.D.; Walsh, P.J. Selectivity, efficiency, and underwater observations of modified trap designs for the snow crab (*Chionoecetes opilio*) fishery in Newfoundland and Labrador. *Fish. Res.* **2011**, *109*, 107–113. [CrossRef]
45. Hallberg, E.; Skog, M. *Chemosensory Sensilla in Crustaceans*; Springer: Berlin/Heidelberg, Germany, 2011; pp. 103–121. [CrossRef]
46. Food Standards Agency. What's an Oily Fish? The National Archives, 24 June 2004. Available online: https://www.food.gov.uk/business-guidance/hsc-nutritional-standards-proteins (accessed on 28 June 2023).
47. Bullimore, B.A.; Newman, P.B.; Kaiser, M.J.; Gilbert, S.E.; Lock, K.M. A Study of Catches in a Fleet of "Ghost-Fishing" Pots. *Fish. Bull.* **2001**, *99*, 247.
48. Putsa, S.; Boutson, A.; Tunkijjanukij, S. Comparison of ghost fishing impacts on collapsible crab trap between conventional and escape vents trap in Si Racha Bay, Chon Buri province. *Agric. Nat. Resour.* **2016**, *50*, 125–132. [CrossRef]
49. Major, R.; Jeffs, A. Orientation and food search behaviour of a deep sea lobster in turbulent versus laminar odour plumes. *Helgol. Mar. Res.* **2017**, *71*, 9. [CrossRef]
50. Chapman, C.J.; Smith, G.L. Creel catches of crab, *Cancer pagurus* L. using different baits. *ICES J. Mar. Sci.* **1978**, *38*, 226–229. [CrossRef]
51. Watson, W.; Jury, S.H. The relationship between American lobster catch, entry rate into traps and density. *Mar. Biol. Res.* **2013**, *9*, 59–68. [CrossRef]
52. Rayner, G.; McGaw, I.J. Effects of the invasive green crab (*Carcinus maenas*) on American lobster (*Homarus americanus*): Food acquisition and trapping behaviour. *J. Sea Res.* **2019**, *144*, 95–104. [CrossRef]
53. Howard, A.E. The Distribution and Behaviour of Ovigerous Edible Crabs (*Cancer pagurus*), and Consequent Sampling Bias. 1982. Available online: http://icesjms.oxfordjournals.org/ (accessed on 28 June 2023).
54. Tonk, L.; Rozemeijer, M. Ecology of the Brown Crab (*Cancer pagurus*) and Production Potential for Passive Fisheries in Dutch Offshore Wind Farms, p. 49. 2019. Available online: http://library.wur.nl/WebQuery/wurpubs/553352 (accessed on 28 June 2023).
55. Moland, E.; Olsen, E.M.; Andvord, K.; Knutsen, J.A.; Stenseth, N.C. Home range of European lobster (*Homarus gammarus*) in a marine reserve: Implications for future reserve design. *Can. J. Fish. Aquat. Sci.* **2011**, *68*, 1197–1210. [CrossRef]
56. Smith, I.; Collins, K.; Jensen, A. Seasonal changes in the level and diel pattern of activity in the European lobster *Homarus gammarus*. *Mar. Ecol. Prog. Ser.* **1999**, *186*, 255–264. [CrossRef]
57. Bannister, R.C.A.; Addison, J.T.; Lovewell, S.R.J. Growth, Movement, Recapture Rate and Survival of Hatchery Reared Lobsters (*Homarus gammarus* (Linnaeus, 1758)) Released into the Wild on the English East Coast. *Crustaceana* **1994**, *70*, 156–172. [CrossRef]
58. Karavanich, C.; Atema, J. Individual recognition and memory in lobster dominance. *Anim. Behav.* **1998**, *56*, 1553–1560. [CrossRef]