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Report – Decision to fish: Fishers' behaviour within the Northumberland inshore pot fishery

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Client: Northumberland Inshore Fisheries and Conservation Authority

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Tables and Figures

1. Abstract

Successful management requires understanding of fisher behaviour. This study aims to explore decision making in Northumberland inshore pot fishers. Questionnaires were conducted to establish what factors were important to pot fishers, finding that economic factors were of low importance. Weather was found to be important and affected temporal but not spatial distribution. Catch rates and season were also important factors. Landings data for lobster and crab species (*Homarus gammarus* and *Cancer pagurus*) by season were compared for both kg pot^{-1} and £ pot^{-1}, and seasons with high kg pot^{-1} did not always correlate with high £ pot^{-1}. Total £ pot^{-1} was then mapped using GIS and seasons were compared using Monte Carlo simulations analysis. Significant differences between all seasons were found. A clear seasonal pattern can be seen, moving offshore in the winter and back inshore in summer, concentrating value over small patches of ground close to ports.

2. Introduction

2.1. Background and Rationale

Overfishing of marine fish stocks remains a global issue (Boonstra & Hentati-Sundberg, 2014), and this decline requires management to promote sustainable development and prevent total collapse of global fish stocks (Fulton *et al*., 2011). Fisheries management, however, often fails to achieve its goals and this is often due to a lack of understanding of fishers' behaviour (Salas & Gaertner, 2004).

The importance of understanding fishers' behaviour has long been recognised, especially when related to fisheries management issues (Hilborn, 1985). There are two main fisheries components, the fish and the fishers. Management devices are enacted through the fisher component so an understanding and subsequent inclusion of fishers' behaviour into the decision making process would greatly improve management by reducing conflict and unintended consequences of poorly conceived control measures (Fulton *et al*., 2011).

A revised approach to the application of Article 6 of the EU Habitats Directive 92/43/EEC on England's European Marine Sites (EMS) (DEFRA, 2013) requires the assessment of fishery based impacts on EMS designated habitats and features by the Inshore Fishery and Conservation Authorities (IFCAs). Currently the IFCAs are working towards site specific plans for medium risk activities (NIFCA, 2014), and the requirement for continued work toward gathering evidence for the Habitat Regulations Assessment (HRA) process has been identified in the 2014 Joint Annual Work plan for Northumberland IFCA and Natural England, Marine Management Organisation and the Environment Agency (NIFCA, 2014), specifically for potting, netting, and bait gathering activities within the Northumberland IFCA district.

2.2. Aims

The project aims to explore decision making in Northumberland inshore pot fishers. Firstly, research will establish which factors affect movements of fishers, and then how these factors affect spatial distribution. This will be achieved through the following three objectives:

1. Conducting questionnaires to establish what factors are important to Northumberland inshore pot fishers when deciding where to fish, and the relative importance of these factors
2. To relate these factors to variation in the weight and value of species caught
3. To develop an understanding of how these factors change spatial distributions of fishers through GIS data manipulation methods

2.3. Study Area and Fishery

The Northumberland IFCA district stretches from the middle of the River Tyne to the English/Scottish border, and extends from the National Tidal Limit out to six nautical miles. The area contains five main fishing ports: North Shields, Blyth, Amble, Seahouses, and Berwick, as well as, eight smaller fishing locations (Figure 1). Potting is the predominant fishing technique in the NIFCA district with approximately 120 commercial shellfish permits allocated in 2012 (Browne, 2012). Lobsters (*Homarus gammarus*) and brown crabs (*Cancer pagurus*) are the main targeted species (Turner *et al*., 2015) though there are a range of other gears used for a variety of target species (Turner *et al*., 2009). Velvet swimming crabs (*Necora puber*) are also caught, but these are not actively targeted and recent landings have been reduced (Browne, 2012), so data collected will focus on the main two targeted species, lobster and crab. Additionally, some potters fish part time, commonly only working in the summer targeting lobsters (Turner *et al*., 2009).

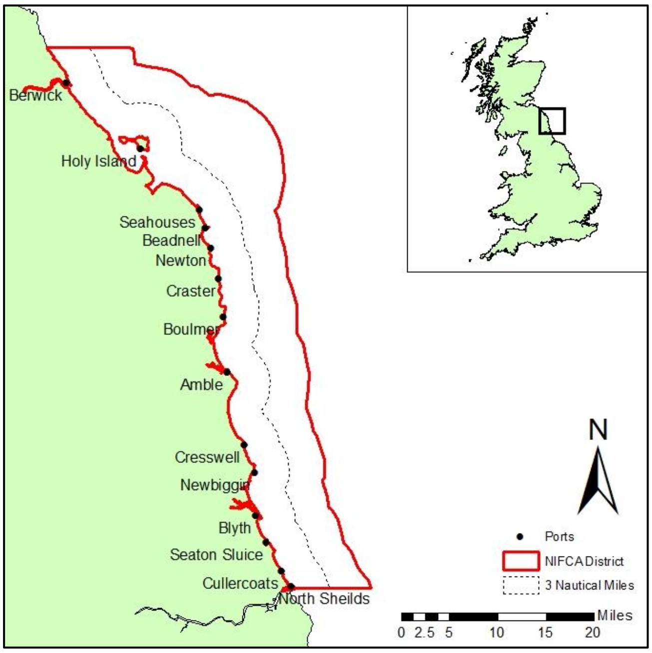

Figure 1: Northumberland Inshore Fisheries and Conservation Authority district, with fishing ports

3. Methodology

3.1. Data collection

3.1.1. Questionnaire

To gather fisher data, nineteen skippers were interviewed over a two day period (2nd and 3rd July, 2015), representing 25 permits (41.67% of active permits) in 7 ports (Table 1). Skippers of boats with a potting license were the targeted population, and had to be considered active by NIFCA enforcement officers. The total number of active permits was estimated to be 60 fishers (NIFCA, 2015, pers. comm.) (Table 1). Initially, an information sheet and consent form (Appendix 1) was presented and discussed before fishers signed their consent to take part. Questionnaires comprised mainly structured questions to ensure a quick survey time of 5 to 10 minutes. Closed questions were a mix of categorical, scaled or one word answers and sections covered general information, seasonality, weather, economics, and decision making (Appendix 2). Questionnaire design was based on results from a literature review completed previously (Appendix 3).

Additional sections which were not directly informing this project were also included for separate projects, and reports have been included in Appendices 4 and 5.

Statistically randomized participant selection was not feasible due to both time constraints and the difficulty in getting fishers to participate. Therefore skippers were approached directly at ports, and NIFCA officers advised which locations would be most likely to have the most fishers present on that day. There were two different interviewers present during the study period. NIFCA officers were present for identification of active pot fishers, but left during the interview to prevent bias. Due to time constraints and weather issues, questionnaires were not completed in all ports, and some ports were under sampled (Table 1). Bad weather reduced availability of fishers at the docks. Questionnaires were undertaken during salmon season and so part time drift net fishers were not available to be included in the survey.

Table 1: The number of interviews completed at each port along with the total number of active fishers

Port	No. of Interviews	Total no. of active fishers
North Shields	1	4
Cullercoats	0	2
Blyth	3	9
Newbiggin	0	2
Amble	5	20
Boulmer	0	1
Craster	0	1
Seahouses	3	11
Holy Island	3	5
Berwick	2	4

3.1.2. NIFCA data

NIFCA provided shellfish landings data, where vessels <10m in length holding a potting permit for the NIFCA district are required to submit monthly logs. These include details on landings (kg), landing port, pot numbers and number of days at sea. Additionally, a record of fishing vessel sightings and related patrol routes were made available. Vessel sighting positions within the district are recorded by NIFCA officers on routine enforcement patrols. Data were obtained for the years 2011-2014, and contained information on vessel name, registration, and geographic position, along with information on their home port and the observed activity. Monthly shellfish prices (lobster and crab) were obtained from NIFCA quarterly reports, and prices for 2014-15 were averaged by season (Spring: March to May; Summer: June to August; Autumn: September to November; Winter: December to February).

3.2. Data Analysis

3.2.1. Questionnaire

Questionnaire data was input into a Microsoft Excel spreadsheet and summarised. Due to a low return rate (41.67%) questionnaire data was analysed descriptively. To ascertain which factors are important to decision making, fishers were asked to rank a series of factors (Appendix 1). These rankings were coded into ‘scores’, where the higher the score the more important the factor. Median and range of scores were then calculated for each factor and compared.

3.2.2. Landings

Data for years 2011 to 2014 were combined and for each record species and season were documented and kg pot^{-1} was calculated using Microsoft Excel. Further analysis was completed using “R”, version 3.0.1, packages ‘stats’ and ‘utils’. All sets of weight data were non-normally distributed (Shapiro Wilks, $p<0.001$), so Kruskal Wallis tests were performed to compare kg pot^{-1} for different species during different seasons, with subsequent Mann Whitney U tests. As catch does not always equal profit (van Putten *et al*., 2012), the Kruskal Wallis test and Mann Whitney U tests were then repeated using the economic value of the kg pot^{-1} (£). Shellfish prices used (Table 2) were those derived from NIFCA data.

Table 2: Seasonal shellfish prices

Season	Crab (£ kg^{-1})	Lobster (£ kg^{-1})
Spring	1.10	10
Summer	1.10	8.2
Autumn	1.30	10
Winter	1.20	15

3.2.3. Sightings

Vessel sightings associated with potting and accompanying patrol routes were geo-referenced using ArcGIS, version 10.2.1, and points outside of the district were removed. Due to a bias in patrol routes to the south of the district, sightings were weighted by patrol effort using the method described by Turner *et al*., (2009):

$$\mathbf{PE = (1\text{-}\mathit{n}/\mathit{N}) + (1\text{-}((D\mathit{max}\text{-}D\mathit{g})/(D\mathit{max}\text{-}D\mathit{min}))}$$

Where n = number of patrols within a grid square; N = total number of patrols; Dmax = maximum distance to patrol route; Dg = grid square distance to patrol route; Dmin = minimum distance to patrol route.

Sightings were then separated into four seasons and a kernel density plot was constructed for each season to create a probability distribution of fishing activity. The kernel density command from the ESRI ArcToolox was used with a smoothing factor of 1500 square map units (Turner, 2015) , Percent Volume Contours (PVCs) were then calculated at 50, 60, 70, 80, 90, 95, and 100%, and the relative landings in £ pot^{-1} km^{-2} were assigned to the contours. The PVCs were converted to raster format for further analysis was using “R”, version 3.0.1, packages ‘raster’, ‘stats’, ‘dismo’, ‘rgdal’, ‘base’, and compared using Monte Carlo simulations analysis (Stephenson, unpublished). 5000 random points were selected with replacement (Manly, 2007), and the values extracted for these points from each map and compared using a paired t-test. This was repeated 10000 times (Jackson & Somers, 1989), and the test statistic from each repetition produced a test statistic distribution. The mean of the distribution was taken, and the associated p value calculated. Where significance was found, the raster for each season was subtracted from the previous season, using the Raster Calculator command from the ESRI ArcToolbox, producing a summary of change.

4. Results

4.1. Questionnaires

When asked to rank the importance of factors involved in decision making, fishers’ responses were variable (Figure 2). Two main groupings are apparent; higher importance factors being weather, catch rates, and season. Economic factors were less important to Northumberland pot fishers’ decision making. Fishers could easily estimate prices for high and low fuel costs, but when asked how this would affect distance travelled all

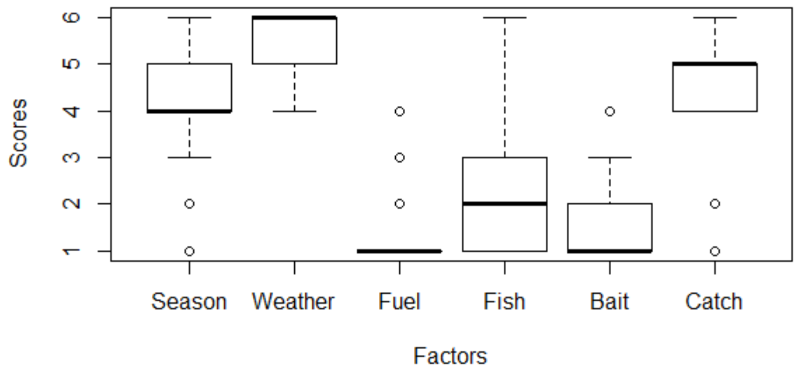

Figure 2: The importance of factors in decision making, where the higher the score the more important the factor.

replied that it would not. When questioned further, fishers explained that they would still go fishing, no matter what costs were associated. Weather was considered an important factor, but when questioned about wind speed most fishers said they only considered it for exiting the harbour, and they would not change fishing location as a response to bad weather. This indicates that weather is an important factor to temporal movement, but not spatial. For these reasons, the responses in fisher behaviour to weather and economics have not been studied further.

Catch rates and seasonality appear to be another important factor. Questions on seasonality were not answered as expected, resulting in a loss of clarity surrounding responses to seasonality changes. Seasonality and catch rates have therefore been chosen as the main focus for study using the landings and sightings data to investigate what species are targeted and when.

4.2. Landings

A significant difference was found between median landings of species (lobster and crab) by season (kg pot^{-1}) (Kruskal Wallis, chi-sq = 473.6359, df=7, p<0.001). Subsequent Mann Whitney U tests were used to investigate where the differences occurred and statistics have been summarised in Table 3.

Table 3: Mann Whitney U tests (U value and p value) results between groups (species by season) for landings (kg pot^{-1}).

Group	Spring Lobster	Summer Crab	Summer Lobster	Autumn Crab	Autumn Lobster	Winter Crab	Winter Lobster
Spring Crab	W=301549 p<0.001	W=324864 p<0.001	W=332878 p<0.001	W=323510 p<0.001	W=312095 p<0.001	W=219965.5 p>0.05	W=307579 p<0.001
Spring Lobster		W=1210020 p<0.001	W=162016 p<0.001	W=219827 p<0.001	W=131054 p<0.001	W=135697 p<0.001	W=206303 p>0.05
Summer Crab			W=36844 p>0.05	W=371896 p>0.05	W=333129 p<0.05	W=247695.5 p<0.001	W=349423.5 p<0.001
Summer Lobster				W=386807 p<0.01	W=333399 p<0.05	W=250349.5 p<0.001	W=399273 p<0.001
Autumn Crab					W=297039 p<0.001	W=227406 p<0.001	W=317032 p<0.001
Autumn Lobster						W=250964 p<0.05	W=410651 p<0.001
Winter Crab							W=139389 p<0.001

The Mann Whitney U's show four statistically separate groups, with the highest landings (kg pot^{-1}) found in Spring and Winter Crab groups (Median = 0.163 $\pm$ 36.533 kg pot^{-1} Range; Median = 0.133 $\pm$ 15.625 kg pot^{-1} Range), followed by Autumn Lobster as a separate group (Median = 0.113 $\pm$ 2.42 kg pot^{-1} Range). The lowest grouping was the Winter and Spring Lobsters (Median = 0.051 $\pm$ 4.01 kg pot^{-1} Range; Median =

0.047 ± 8.00 kg pot^{-1} Range), and above them are a group of Summer Lobsters and Summer and Autumn Crab (Median = 0.104 ± 15.706 kg pot^{-1} Range; Median = 0.097 ± 10.392 kg pot^{-1} Range; Median = 0.081 ± 2.715 kg pot^{-1} Range).

This was then repeated using the economic value (£ pot^{-1}), finding a significant difference between median landings value of species (lobster and crab) by season (Kruskal Wallis, chi-sq = 2295.019.019, df=7, p<0.001). Groupings were again investigated using Mann Whitney U tests, and six significantly different groups were found (Table 4). Lobster values were all in different groups, with the highest being autumn (Median = £1.132 ± 24.200 pot^{-1} Range), then summer (Median = £0.850 ± 80.000 pot^{-1} Range), winter (Median = £0.760 ± 60.275 pot^{-1} Range) and spring (Median = £0.467 ± 80.000 pot^{-1} Range). Crab groups had a lower value per pot per month, with summer and autumn crab being the lowest (Median =£0.106 ± 11.431 pot^{-1} Range; Median = £0.105 ± 3.529 pot^{-1} Range), and spring and winter crab being higher (Median = £0.180 ± 40.187 pot^{-1} Range; Median = £0.160 ± 18.750 pot^{-1} Range).

Table 4: Mann Whitney U tests (U value and p value) results between groups (species by season) for landings kg pot^{-1}.

Group	Spring Lobster	Summer Crab	Summer Lobster	Autumn Crab	Autumn Lobster	Winter Crab	Winter Lobster
Spring Crab	W=113771 p<0.001	W=324864 p<0.001	W=94131 p<0.001	W=309088 p<0.001	W=56524.5 p<0.001	W=213694.5 p>0.05	W=77236 p<0.001
Spring Lobster		W=114162 p<0.001	W=189036.5 p<0.001	W=117921 p<0.001	W=131054.5 p<0.001	W=124875.5 p<0.001	W=155866 p<0.001
Summer Crab			W=91395.5 p<0.001	W=353863.5 p>0.05	W=51255 p<0.001	W=240238 p<0.001	W=74494.5 p<0.001
Summer Lobster				W=97678.5 p<0.001	W=287675 p<0.001	W=110830 p<0.001	W=304477 p<0.001
Autumn Crab					W=58496.5 p<0.001	W=233559 p<0.001	W=80002 p<0.001
Autumn Lobster						W=73806.5 p<0.001	W=347775.5 p<0.001
Winter Crab							W=91450.5 p<0.001

4.3 Sightings

Maps comparing the spatial distribution of value (£ pot^{-1} km^{-2}) were produced. Figure 3 shows that the highest seasonal values are found in summer (Figure 3b) and the lowest in spring (Figure 3a). The highest summer values lie inshore and close to ports. Autumn and winter have similar values, but effort in winter appears further offshore than autumn (Figures 3c,d). Highest autumn values are also inshore and close to ports; though are more dispersed than summer's high intensity patches. Winter's distribution is more widely dispersed (Figure 3d). Spring effort reaches further offshore than summer and autumn, and this is more apparent in the south of the district (Figure 3a). Using the Monte Carlo methods detailed in Section 3.2.3, all raster layers from Figure 3 were found to be statistically different from each other (Table 5). Figures 4a and b, show the largest change in landing value (£ pot^{-1} km^{-2}) surrounds the summer season, with more similarity between autumn to winter and winter to spring (Figures 4c,d). From spring to summer there is a significant increase in £ pot^{-1} km^{-2} (Table 5) evident in well-defined areas close inshore and to ports (Figure 4a).

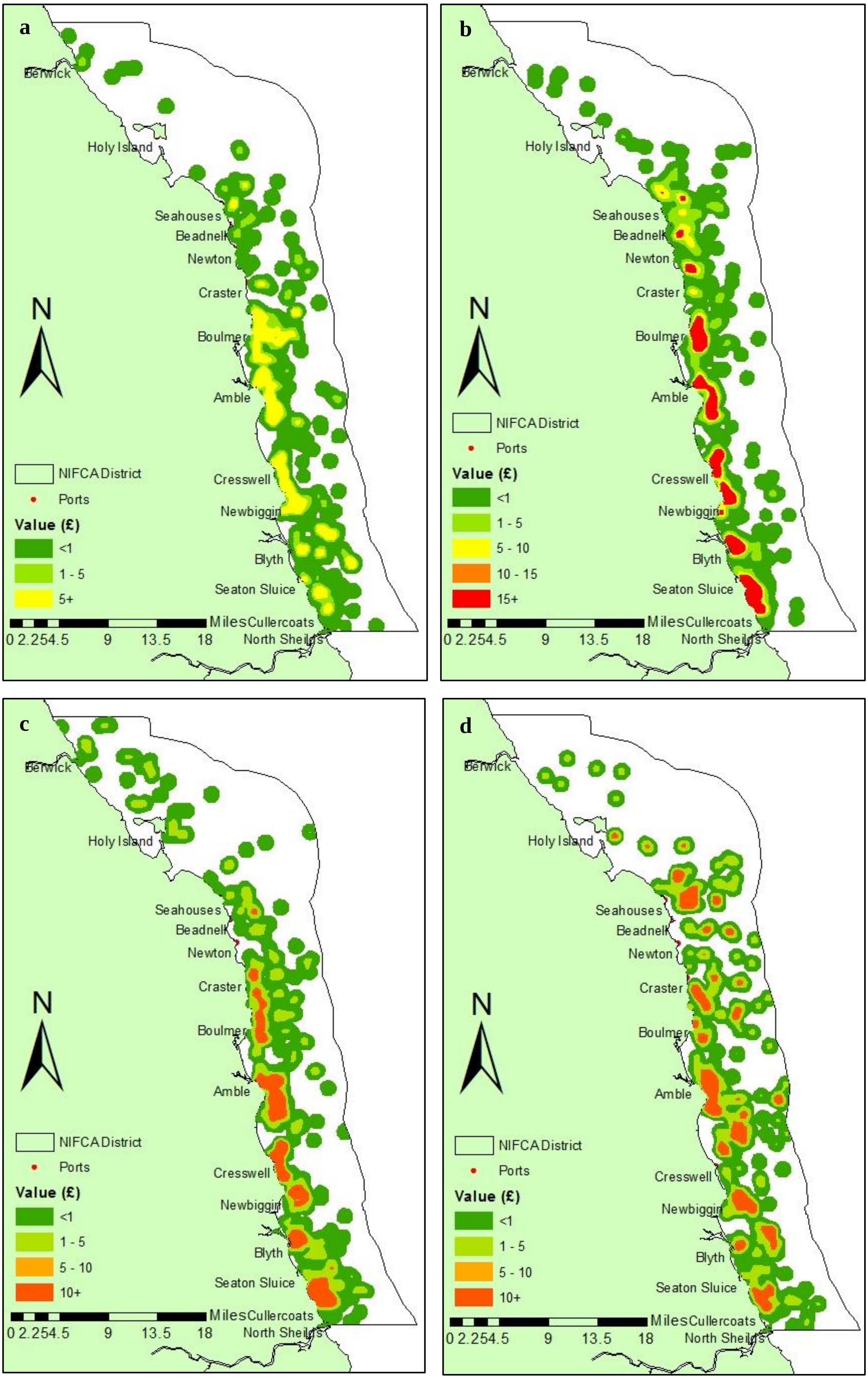

Figure 3: Spatial variation of value in £ pot^{-1} km^{-2} for the Northumberland IFCA district during a) Spring; b) Summer; c) Autumn and d) Winter

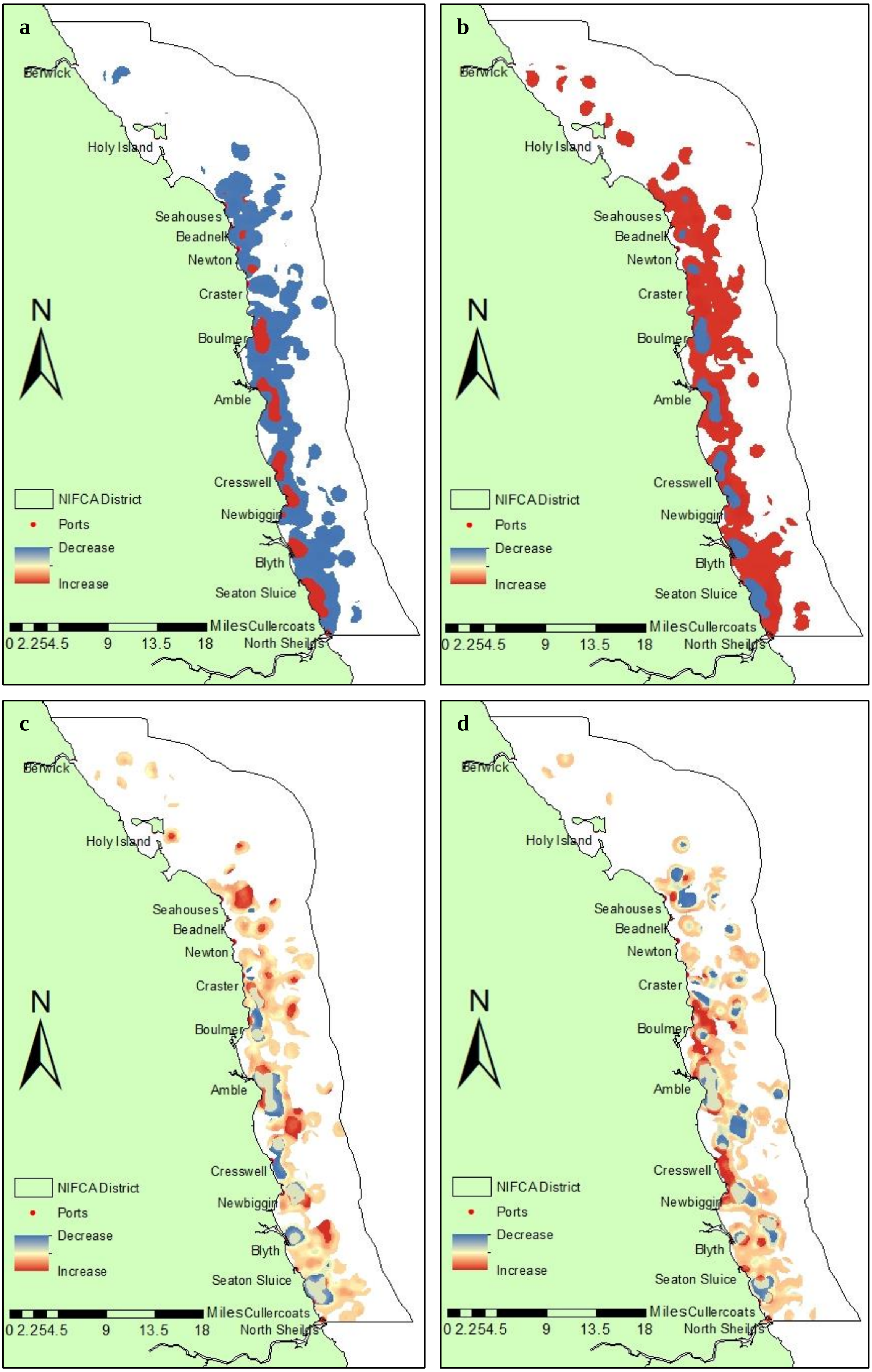

Figure 4: Changes in value between seasons where a) Spring to Summer; b) Summer to Autumn; c) Autumn to Winter and d) Winter to Spring.

Table 5: Monte Carlo simulations analysis test results (Mean T statistic and *p* value), where a positive mean t statistic indicates significant negative change and vice versa

Season	Summer	Autumn	Winter
Spring	T statistic mean = -23.82214, $p<0.001$	T statistic mean = -19.72026, $p<0.001$	T statistic mean = -14.33178, $p<0.001$
Summer		T statistic mean = 24.06444, $p<0.001$	T statistic mean = 23.72634, $p<0.001$
Autumn			T statistic mean = 10.08507, $p<0.001$

Summer to autumn shows an opposite change (Table 5), and an increase in surrounding area (Figure 4b). Autumn to winter does not reach the same intensity of change, but a small increase offshore, and further decrease in the same inshore patches is apparent (Figure 4c), as well as an overall decrease in value (Table 5). Winter to spring also shows lower intensity of change than spring to summer and summer to winter, but there is a clear overall increase (Table 5) mainly inshore (Figure 4d).

5. Discussion

5.1. Questionnaires

Data derived from questionnaires was used to assess what factors were important to decision making (Objective 1). Scores were compared between factors and the lowest scores were found in factors relating to economics (Figure 2, Section 4.1). While the lack of regard for economics seems unusual, it was supported by the other answers provided by fishers. As predominantly inshore fishers, where travel is reduced, resulting fuel costs are low and variation in fuel price causes little change (Tidd *et al*., 2015). In addition, there is no requirement to tow gear, and so relative fuel costs are minimal in terms of profit margins (NIFCA, 2015, pers. comm.).

The indication that weather is an important factor to temporal movement but not spatial, appears to be in opposition to Browne’s (2012) description of fishery movement, where the author indicates that movement offshore is due to a requirement to protect pots from poor weather conditions. However, Andersen *et al*. (2012) found a similar response in Danish gill net fishers, where the effects of weather were temporal and not spatial.

5.1.1. Data Reliability

There will also be issues with the quality of data collected. The subject matter is a sensitive topic for some fishers and often answers are misrepresented, most noticeably in the form of giving an answer more vague than the question required. Finally, as the questionnaire was completed by two different people, there could be variation in how the questions were asked, resulting in differing ways of answering.

Overall, this will not affect the project in a major way. Most questions were categorical, so there were little areas for misinterpretation. Questions affected by poor answering have not been included in data analysis.

However, due to the low return rate (41.67%) and poor geographic spread (Table 1, Section 3.1.1), it is unlikely that the questionnaires accurately represent the viewpoints of the whole of the NIFCA district.

5.2. Landings

Study into seasonal change (Objective 2) in species catch was achieved through a series of Kruskal Wallis and Mann Whitney U tests. Comparing seasonal kg pot^{-1} (Table 3, Section 4.2) and £ pot^{-1} (Table 4, Section 4.2). The lowest median weights of lobsters (kg pot^{-1}) were found in winter and spring, matching seasonal lobster availability (Smith *et al.*, 1999). Conversely, winter and spring crab weights (kg pot^{-1}) were the highest, as with the lack of lobster availability, the fleet focuses solely on crab for this time of year (Browne, 2012). Autumn lobster has the highest weight per pot of the lobster values, again matching seasonal lobster activity (Bennett, 1974). Summer lobster, summer crab, and autumn crab values form a statistically similar group. What would be expected is higher summer lobster kg pot^{-1}, with crab kg pot^{-1} dropping off in summer (Browne, 2012). However, the landing volumes of crab in summer and autumn appear to be maintained, though volumes are not as high as winter and spring. What seems to be happening is that fishers are keeping some pot strings further offshore to target crab to supplement the sometimes variable lobster catches (NIFCA, 2015, pers. comm.) as a risk aversion strategy to diversify sources of income (Salas & Gaertner, 2004).

When considering economic value (£ pot^{-1}), all lobster median values are higher than crab values due to the higher price they fetch (Table 2, Section 3.2.2). Autumn and summer lobsters have the highest values. Winter and spring lobsters had the same kg pot^{-1}, but winter £ pot^{-1} values are higher for winter, due to the inflation of lobster price at Christmas (Table 2, Section 3.2.2). Crab prices per pot are similar in ranking, with summer and autumn reaching higher median £ pot^{-1} over spring and winter. This is most likely to be due to the higher volume landed per pot, as wholesale prices for crab are higher in winter and spring (Table 2, Section 3.2.2). This shows that seasons with the higher catch rates do not necessarily correlate to the most economically important time for fishers.

5.2.1. Data Reliability

Landings data are the most reliable data used, however assumptions were still required. Four years of data were combined as the total numbers of sightings available were too low to conduct seasonal analyses on an annual basis, introducing variation from several sources: variation in fishing effort over time; variation in lobster and crab stocks; catchability; long-term weather conditions; management measures; and the targeting of other species, such as the velvet swimming crab (*Necora puber*). This reduces the certainty that observed patterns can be solely attributed to change in seasonality.

5.3. Sightings

Objective 3 involved mapping seasonal distributions of £ pot^{-1} km^{-2}, comparing seasonal change to ascertain what was targeted where and when. Spring values for £ pot^{-1} km^{-2} are noticeably lower than winter values

(Figures 3a,b). However, spring and winter landings (kg pot^{-1}) for crab (Table 3, Section 4.2) and lobster (Table 4, Section 4.2) are not significantly different, and so difference in lobster price (Table 2, Section 4.2.2) is the most likely reason for the difference in £ pot^{-1} km^{-2}. Lobster prices become inflated over the Christmas period (Table 2, Section 3.2.2), with prices up to £19 kg^{-1} (NIFCA, 2015, pers. comm.).

Value is concentrated between spring and summer into small inshore patches (Figure 4a), with values higher than those of autumns (Figures 3b,c). This does not reflect landings results, where autumn values for lobster (both in kg and £) were the highest (Tables 3,4, Section 4.2). This appears to indicate that while summer values are lower than autumns, they are concentrated over smaller areas of fishing ground. Winter (Figure3d) appears to have the widest distribution offshore. With more suitable crab habitat offshore (Browne, 2012) and low lobster catches (Table 3, Section 4.2), indicating the targeting of crab. Mapping gives an indication of where the most intensely fished grounds are and can be incorporated into spatial management plans.

5.3.1. Data Reliability

Sightings data manipulation required several assumptions. Firstly, sightings do not accurately cover all of the NIFCA district, especially further offshore and toward the North of the district where patrol effort is sparse (Figure 3), data should not be considered reliable above Seahouses. Attaching the landings to the percent volume contours is also not an accurate representation on the spatial distribution of these landings. The allocation is based on probability rather than position, and so the exact extent and worth of grounds will not be entirely accurate. However, this should be suitable for the spatial scale being studied.

6. Conclusions

The range of data sources and analysis has revealed a clear seasonal pattern, with movement inshore from winter to summer, and back out offshore from summer to winter. Areas with high value can be seen, though the distinction between landings volume and value should be noted. An area could be favoured by fishers for high volume or for high value, but are not the same. Fisher responses to weather were temporal but not spatial, and fishers did not consider economics in their decision making.

Further study, with a more in-depth questionnaire should be undertaken to answer if, and how, fishers target high value or high volume areas. A more in depth interview process with fishers could provide better quality spatial data to reveal information on what grounds were associated with which species and catch rates.

7. Acknowledgements

I would like to thank my dissertation supervisor Dr Clare Fitzsimmons, fellow masters student Natalie Wallace, and PhD student Fabrice Stephenson for all of their knowledge and assistance. I am extremely grateful for the assistance from NIFCA staff members and to all the fishers that gave their time to complete the questionnaire.

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Appendix 1 **Project Information Sheet: Decision to fish**

This questionnaire will inform two Masters projects for Newcastle University (School of Marine Science and Technology) for NIFCA. We are trying to find out how and why pot fishers make their decisions on where to fish under different conditions as well as looking at the distribution of lobsters and fishing activity in relation to habitat types.

The questionnaires will take approximately 5-10 minutes, and the questions will cover:

- Vessel characteristics
- Species targeted
- Type of grounds fished under different conditions (ie. season)
- Decision making
- Pot limitation

The data you provide will be compared to NIFCAs vessel sightings, to help provide a deeper understanding of your decision making.

This information from the project will be provided to Newcastle University and NIFCA, however, if you wish to remain anonymous please indicate below.

Data will be stored confidentially and if published, completely anonymous. Your details, boat names and PLNs will only be used to order records and will not be presented with the data.

If you would like to be provided with further information about this project, or to make a complaint, please contact: Morwenna See (m.see@ncl.ac.uk) and Natalie Wallace (N.M.Wallace1@ncl.ac.uk)

I, ____, have:

- Read and understood the project information detailed above;
- Been given the opportunity to ask questions;
- Voluntarily agreed to participate in both the questionnaire and the project;
  Understood the procedures involving data usage and storage to ensure confidentiality and anonymity;

I would like to remain anonymous: Yes No

Signed: ________________________ Date: _____________________

Appendix 2 **<u>Questionnaire: Decision to Fish</u>**

General

Date: ______________________ Time: _____________

Port: _________________________________

Name:____

Age: 18-30 31-50 51-70 70+

Number of years fishing in the NIFCA district: 0-4 5-9 10-14
15-19 20-24 24-29 30+

Vessel Characteristics

How many vessels do you own?: 1 2 3+

Name of vessel:____

PLN:____

Length: _____________________________________

Engine Power: ________________________________

Type:

Trawler/Keel Fast Worker Coble Other

Name of vessel:____

PLN:____

Length: _____________________________________

Engine Power: ________________________________

Type:

Trawler/Keel Fast Worker Coble Other

Is fishing your main source of income? ☐ Yes ☐ No

Do you have any other forms of income? ☐ Yes ☐ No

If yes, when do you decide to switch to this?

____

____

____

____

Seasonal

Please give details of the types of grounds you would fish on under the following conditions. Areas have been split into the minimum and maximum distances you would choose to go from port.

Spring

Minimum	**Maximum**
Nautical Miles Offshore	**Nautical Miles Offshore**
0 1-2 3-4 5-6 6-12 12+	0 1-2 3-4 5-6 6-12 12+
Ground Type	**Ground Type**
Hard Soft	Hard Soft
Species Targeted	**Species Targeted**
Lobster Crab Other	Lobster Crab Other
If other please specify:____________________	If other please specify:____________________

Summer

Minimum	**Maximum**
Nautical Miles Offshore	**Nautical Miles Offshore**
0 1-2 3-4 5-6 6-12 12+	0 1-2 3-4 5-6 6-12 12+
Ground Type	**Ground Type**
Hard Soft	Hard Soft
Species Targeted	**Species Targeted**
Lobster Crab Other	Lobster Crab Other
If other please specify:____________________	If other please specify:____________________

Autumn

Minimum	**Maximum**
Nautical Miles Offshore	**Nautical Miles Offshore**
0 1-2 3-4 5-6 6-12 12+	0 1-2 3-4 5-6 6-12 12+
Ground Type	**Ground Type**
Hard Soft	Hard Soft
Species Targeted	**Species Targeted**
Lobster Crab Other	Lobster Crab Other
If other please specify:____________________	If other please specify:____________________

Winter

Minimum	Maximum
Nautical Miles Offshore	**Nautical Miles Offshore**
0 1-2 3-4 5-6 6-12 12+	0 1-2 3-4 5-6 6-12 12+
Ground Type	**Ground Type**
Hard Soft	Hard Soft
Species Targeted	**Species Targeted**
Lobster Crab Other	Lobster Crab Other
If other please specify:____________________	If other please specify:____________________

Weather

Please give an estimate wind speed (mph) and/or swell height (m) for the following situations:

(Note: if wind direction doesn't affect your choices only complete one)

When would you not leave the harbour?

Wind speed (onshore): __________________________ and/or swell height: ______________________

Wind speed (offshore): __________________________ and/or swell height: ______________________

When would you fish offshore? More than 3nm

Wind speed (onshore): __________________________ and/or swell height: ______________________

Wind speed (offshore): __________________________ and/or swell height: ______________________

Economical

Please give estimates of what you would consider to be high and low values for fuel price, along with the maximum distance you would travel using these fuel prices:

High: ________________ Maximum distance (summer): ________________

Maximum distance (winter): __________________

Low: ________________ Maximum distance (summer): ________________

Maximum distance (winter): __________________

Decision Making

Please rank the importance of the following factors from 1 to 5, where 1 is most important and 5 is least.

☐ Season ☐ Weather ☐ Fuel Price ☐ Fish Price ☐ Bait Price

Are there any other factors involved in your decision making? Please specify what and why:

____

____

____

____

Pot Limitation

Has the introduction of pot limitation (2009) influenced how many pots you have in the sea?

Increase　　No change　　Decrease

Have you purchased an additional vessel due to the pot limitation?　Yes　　No

Are you more selective of where you fish your pots?　Yes　　No

If yes, which criteria are you most selective about?

Habitat type　　Distance from port　　Likelihood of catch　　Other

If other please specify: ____

Has the introduction of pot limitation (2009) increased the number of pots you fish outside the district?　Yes　　No

If the number of pots outside the district has increased:

Approximately how many extra pots per month do you fish outside the district (excluding any pots fished outside the district before 2009)?______________________________

Escape Hatches

How do you feel about escape hatches?

Good　　Indifferent　　Bad

How do you feel escape hatches would make a difference to your landable catch?

Decrease　　No difference　　Increase

Do you think escape hatches would be beneficial to:

Lobster stocks?　　Yes　　No

Your landings?　　Yes　　No

Appendix 2 Literature Review

Decision making in small scale fisheries: A case study for the Northumberland inshore pot fishery

1. Abstract

Fisher behaviour requires study to be incorporated into fisheries management, preventing conflict and unintended consequences of badly thought through control measures. This review aims to evaluate current literature on fisher behaviour to inform a study in the Northumberland inshore pot fishery. The theoretical background reviewed reveals that economic maximisation in fisheries does not always fully represent fisher tactics, especially in small-scale fisheries. Methods of risk aversion should be studied, specific areas being alternative forms of income, seasonal catch rates, and distance from port during poor weather conditions. A review of methods shows that a mixed methods design, including qualitative and quantitative data, helps to best inform studies.

2. Introduction

Continued overfishing of marine fish stocks remains a global issue (Boonstra & Hentati-Sundberg, 2014), and this decline requires management to promote sustainable development and prevent total collapse of global fish stocks (Fulton *et al*., 2011). Fisheries management, however, often fails to achieve its goals and this is often due to a lack of understanding of fishers' behaviour (Salas & Gaertner, 2004). The importance of understanding fishers' behaviour has long been recognised, especially when related to fisheries management issues (Hilborn, 1985). There are two main components to fisheries, the fish and the fishers, and management devices are enacted through the fisher component. An understanding and the subsequent inclusion of fishers' requirements and decision making processes would greatly improve management by reducing conflict and unintended consequences of badly thought through control measures (Fulton *et al*., 2011). Fisher behaviour is highly variable, reflecting the uncertainty of the activity (Salas & Gaertner, 2004). Human behaviour is an extremely complex subject and so studies require a wide range of interdisciplinary knowledge and understanding, from ecology to economics, as well as anthropology and sociology of human behaviour (Branch *et al*., 2006).

The aim of this review is to evaluate current literature on fishers' decision making processes, drawing out implications for the study of Northumberland inshore pot fishers. This will be achieved with three objectives:

1. Assess the underlying theories of decision making in fishers
2. Review current (2010-2015) papers investigating decision making in fishers
3. Incorporate and adapt findings from objectives 1 and 2, as well as related literature, to inform a study of decision making in Northumberland inshore pot fishers

The fleets to be studied are inshore pot fishers, operating within the Northumberland Inshore Fisheries and Conservation Authority's (NIFCA) district (Figure 1). Potting is the predominant fishing technique in the NIFCA district, with approximately 120 commercial shellfish permits allocated in 2012 (Browne, 2012). The study of decision making relates to the revised approach to the application of Article 6 of the EU Habitats Directive 92/43/EEC on England's European Marine Sites (EMS) (DEFRA, 2013), requiring the assessment of fishery based impacts on EMS designated habitats and features by the IFCAs. The requirement for continued work towards the gathering of evidence for the Habitat Regulations Assessment (HRA) process has been identified (NIFCA, 2014) specifically for potting, netting, and bait gathering activities within the Northumberland IFCA district. Information relating to decision making can help to inform where potting is taking place and how this is likely to change. For this purpose, the literature reviewed in this document will focus on a spatial aspect to fisher behaviour.

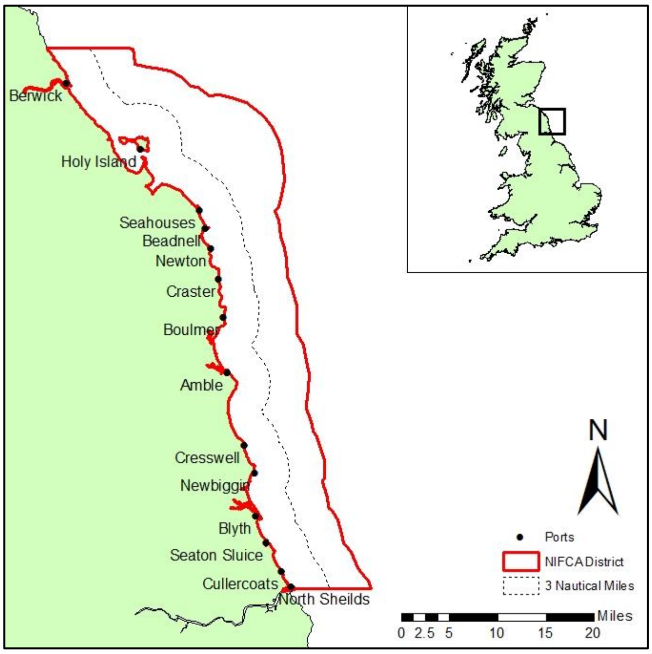

Figure 1: Northumberland Inshore Fisheries and Conservation Authority district, with fishing ports

3. Theoretical background

A logical assumption about fisher behaviour is that the main goal of commercial fisheries is to make money. Profit maximisation is the most common approach to study fisher behaviour (van Putten *et al*., 2012). However, there has been much debate within the literature as to whether this is an accurate assumption (Salas & Gaertner, 2004).

The main arguments against economic maximisation include risk, social factors, and un-objective decision making. Risk, and the perception of risk, has been acknowledged as a key driver of fisher behaviour (Dowling *et al*., 2015). Risks can be both physical and economic (Salas & Gaertner, 2004) and can be seen producing trade-offs between distance from port and high profit fishing grounds (Bastardie *et al*., 2010). Generally, fishers tend toward being risk averse, putting more effort into preventing a loss than maximising profit (Kahneman & Tversky, 1979). Social factors can also impact decisions; constraining time spent fishing through social interactions, leisure time and community ties (Camerer & Fehr, 2006). Decision making is not always rational (Boonstra & Hentati-Sundberg, 2014) and not all decisions are made with perfect clarity (Dawnay & Shah, 2005). Logical decision pathways may be overlooked in favour of habitual behaviour (Durrenberger & Pálsson, 1986) or through hunches and rule of thumb (Tversky & Kahneman, 1974).

These aspects of behaviour lead to the development of fisher ‘tactics’ (Salas & Gaertner, 2004). Attempts have been made at categorising these tactics, mainly for management purposes (Boonstra & Hentati-Sundberg, 2014), but over simplification tends to lead to management which does not accommodate the adaptive and dynamic development of fisher tactics (Salas & Gaertner, 2004). It would be logical to then assess individual fisheries on a case by case basis, incorporating the local socioeconomic and environmental factors rather than making assumptions based on similar fisheries.

4. Review of studies

Recent (2010-2015) peer-reviewed literature was identified with Scopus (http://www.scopus.com), using a mixture of the search terms ‘fisher’, ‘behaviour’, ‘fleet’, ‘dynamics’ and ‘movement’. Papers were then excluded if the study was not marine, commercial, or did not have a spatial aspect included. The 34 papers identified are listed in Table 1. There are two main groupings of papers, those that concerned spatial and temporal distribution and behaviour, and those studying how fisher behaviour changes with external factors. The first group of papers is the larger (59%) compared to the second (41%) (Table 1). The papers cover a range of successes and failures. Romagnoni *et al*. (2015) aimed to predict the spatial behaviour of North Sea fishing fleets. The model used was a combination of food-web models (Ecopath and Ecosim) combined with a spatial model (Ecospace). Modelled results were a poor fit with real data, and this was attributed to a lack of inclusion of human behaviour. Despite complex food web models, the failure was due to extreme simplification of human behaviour, involving only profit and fuel costs. The variability in success in the 34 papers identified is similarly matched with a large variation in methods and their complexity.

Sample sizes used for papers varied from one fisher to international fleet data. Moutopoulous *et al*. (2014) observed the actions of one small-scale fisher in Greece, recording movements and landing’s data. This produced in depth, reliable and accurate data on fisher behaviour, but is constrained by its worth to management being difficult to generalise and to therefore relate to management options. On the opposite end of the scale, a study investigating the tuna purse seine fishery collected data from the Indian, Atlantic and Pacific Oceans and modelled the available data using a Generalised Additive Model (Davies *et al*., 2014). However, the model output was binary, simply showing a presence or absence of fishing effort. This is an example of where generalisation of human behaviour over a large scale reduces the detail of assumptions that can be established using the data set.

Data sources also vary widely, and a range of the types of data used can be seen in Table 1. Most studies in the European Union (EU) use the Vessel Monitoring System (VMS) to provide data on spatial and temporal behaviour. Vessels over 12m in length have to provide data on position, direction and speed at regular intervals through a satellite based system (Council Regulation (EC) No 1224/2009). This same regulation also requires electronic logbooks to be submitted, detailing fishing operation and landings data, though most commercial fisheries require similar records to be kept (Paterson, 2014). For studies not in the EU other methods were employed, such as: observer data (Beitl, 2015); interview mapping exercises (Paterson, 2014) and even a long-term catch log system implemented by the authors themselves (Teh & Teh, 2011; Teh *et al*., 2012). Even within the EU there are gaps in data, where vessels under 12m in length are not required to use the VMS. Horta e Costa *et al*. (2013) studied vessels less than 7m in Portugal, and effort data was derived from twice daily transects of the study area.

Studies involving human behaviour often require data on social factors. Desk based information is available, such as tourism (Giakoumi *et al*., 2011), but most methods employ the use of questionnaires in a mixed methods design, combining qualitative and quantitative data. Data for a large group (quantitative) can be

Table 1: Papers identified from 2010 – present relating to marine fisher behaviour, with a spatial aspect. Papers are sorted by type of study and the types of data used in the studies have been listed.

Type of study	References	Data Sets Used
Spatial/Temporal		
Descriptive	Beitl, 2015, Diogo et al., 2015 Moutopoulos et al., 2014, Paterson, 2014, Rijnsdorp et al., 2011	Catch/Landings data; Fishing grounds; Fishing effort, gear and methods (timing and numbers); Vessel movement Interviews, observations, logbooks, and VMS
Modelling	Andersen et al., 2012, Bastardie et al., 2010, 2013, Carr and Heyman, 2014, Davies et al, 2014, López-Rocha et al., 2014, Marchal et al., 2012, Poos et al., 2010, Simons et al., 2014, Tidd et al., 2012, Wise et al., 2012	Interviews, observations, logbooks, and VMS; Catch/Landings/Catchability data Fishing effort, gear and methods (timing and numbers); Management information Vessel movement; Fishing grounds/Harbours/Habitat Quality; Environmental/Physical factors; Species Abundance and Behaviour Annual operating costs, fuel costs, fish prices, fuel consumption, sales slips
Predictive	Girardin et al., 2015, Ives et al., 2013, Romagnoni et al., 2015	Fishing grounds/Harbours; Environmental/Physical factors; Species Abundance and Behaviour Interviews, observations, logbooks, and VMS Catch/Landings data; Fishing grounds; Fishing effort, gear and methods (timing and numbers); Vessel movement Annual operating costs, fuel costs, fish prices, fuel consumption, sales slips
Behaviour in relation to:		
Closures	Abbott and Haynie, 2012, Bastardie et al., 2015, Giakoumi et al., 2011, Horta e Costa et al., 2013, Teh & Teh, 2011, Teh et al., 2012	Location and catch data; Environmental/Physical factors Production and product values of catcher-processor vessels Logbooks, and VMS; Fishing grounds/Harbours, gear and methods (timing and numbers); Vessel movement Annual operating costs, fuel costs, fish prices, fuel consumption, sales slips, socioeconomics
Economics	Abernethy et al., 2010, Link et al., 2011, Muallil et al., 2013, Poos et al., 2013, Tidd et al., 2011	Annual operating costs, fuel costs, fish prices, fuel consumption, sales slips, socioeconomics; Production and product values of catcher-processor vessels Fishing grounds/Harbours; Environmental/Physical factors; Species Abundance and Behaviour; Logbooks, and VMS
Climate Change	Hamon et al., 2014	Annual operating costs, fuel costs, fish prices, fuel consumption, sales slips Fishing grounds/Harbours; Environmental/Physical factors; Species Abundance and Behaviour; Logbooks, and VMS
Fish Abundance	Murray et al., 2011, Shester, 2010	Annual operating costs, fuel costs, fish prices, fuel consumption, sales slips Catch/Landings data; Fishing grounds; Fishing effort, gear and methods (timing and numbers); Vessel movement; Logbooks, and VMS Fishing grounds/Harbours; Environmental/Physical factors; Species Abundance and Behaviour

enhanced, clarified and validated using qualitative data (Boonstra & Hentati-Sundberg, 2014). Bastardie *et al*. (2010) noted the necessity of including social data in models, particularly the fishers' decision making process. Most questionnaires used a structured or semi-structured approach, a notable exception being Wise *et al*. (2012), who used a series of informal conversations with skippers. The lack of a set of standard questions introduces bias, questions could be asked in a manner that leads the skipper to answer a question in a particular way. Variation between how questions are asked means there are no standard responses that could be compared between skippers with confidence in the data reliability.

The most complicated methodologies were those involving models, a common method with examples in the modelling and predictive sections of the spatial and temporal studies (Table 1), as well as studies involving fisher behaviour in relation to: closures (Bastardie *et al*., 2015); economics (Link *et al*., 2011); climate change (Hamon *et al*., 2014) and fish abundance (Murray *et al*., 2011). Many different types of models are used, the two most common being bio-economic models and Random Utility Models (RUMs). In the past, the economic approach was the most common (van Putten *et al*., 2012), but constraints in assuming economic maximisation and the lack of inclusion of fisher behaviour in models, especially risk (Dowling *et al*., 2015) is an issue. For this reason the use of RUMs has seen a great increase over the last few decades due to their ability to model both monetary and non-monetary attributes (van Putten *et al*., 2012). For example, Andersen *et al*. (2012) included model sections covering knowledge, risk, tradition, fuel price and distance, regulations, weather, and fish price.

Other models used included a predator-prey model (López-Rocha *et al*., 2014) and an Individual Based Model (Bastardie *et al*., 2010). A General Additive Model seen in Davies *et al*. (2014) performed well, presenting an accurate model but it was noted the model would not hold under changing external factors. This was a common source of error among models, where fisher's behaviour created patterns that could not be explained by economic or utility maximisation alone. Beitl (2015) presumed this was inertia to change due to familiarity and tradition, where falling catch rates to below average values did not cause fishers to move away from their preferred fishing grounds.

5. Northumberland inshore pot fishery

The Northumberland inshore pot fishery is a small-scale fishery (Turner *et al*., 2015). Economic maximisation in small-scale fisheries is less established than larger fishery fleets (Salas & Gaertner, 2004), meaning that the relative importance of economics must be evaluated. The majority of vessels within the district are privately owned (NIFCA, 2015, pers. comm.), with an average crew size of one to two people (Browne *et al*., 2012), and so vessel skippers are in charge of decision making. Additionally, as a small-scale fishery, data from the VMS and logbooks will not be available and so substitute data sources must be considered. Turner *et al*. (2015) presents a study of the spatial distribution of potting activity within the NIFCA district, using a method which provides an estimate of fishing effort derived from sightings during enforcement patrols by NIFCA officers. There have been other studies into fisher behaviour in the district, covering knowledge sharing and social networks (Turner *et al*., 2014) and territoriality (Turner *et al*., 2013).

With a potentially smaller drive for economic maximisation, the perception of risk could be similarly increased. Smaller boats and crews are exposed to more physical risk (Bye & Lamvik, 2007) such as weather, and their risk aversion strategies should be studied. Economic risk could also be a factor. As potters, Northumberland fishers have specialised in the type of gear they use, but fishers rarely become completely specialised due to the dangers of relying too heavily on one form of income (Salas & Gaertner, 2004). Therefore, alternative income strategies should be investigated. The main target species are European lobster (*Homarus gammarus*) and brown crab (*Cancer pagurus*), though catch rates vary seasonally (Browne, 2012) and so study into what species are targeted when would be advantageous.

6. Conclusions and Recommendations

This review has described the theoretical aspects to fisher behaviour and examined the different methods they have been studied with, in order to make recommendations to a fisher behaviour study in Northumberland inshore pot fishers. Recommendations cover the relative importance of factors to decision making, along with investigations to determine fishers strategies to reduce risk. Specific areas are alternative forms of income, seasonal catch rates, and distance from port during poor weather conditions. A review of methods shows that a mixed methods design, including qualitative and quantitative data, helps to best inform studies.

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Appendix 4

Pot Limitation

Questionnaires were completed over a two day period (2nd and 3rd June, 2015), throughout the NIFCA district. The sample population were skippers of potting boats, who are actively targeting shellfish. The questionnaires were predominantly structured questions, and a total of 19 people (25 permits) were interviewed, covering 7 ports (Table 1).

Table 1: Number of people interviewed by port

Port	Number of people
Berwick	2
Holy Island	3
Seahouses	3
Beadnell	2
Amble	5
Blyth	3
North Shields	1

There were a total of 6 questions regarding pot limitation, and results can be seen in Figure 1 below.

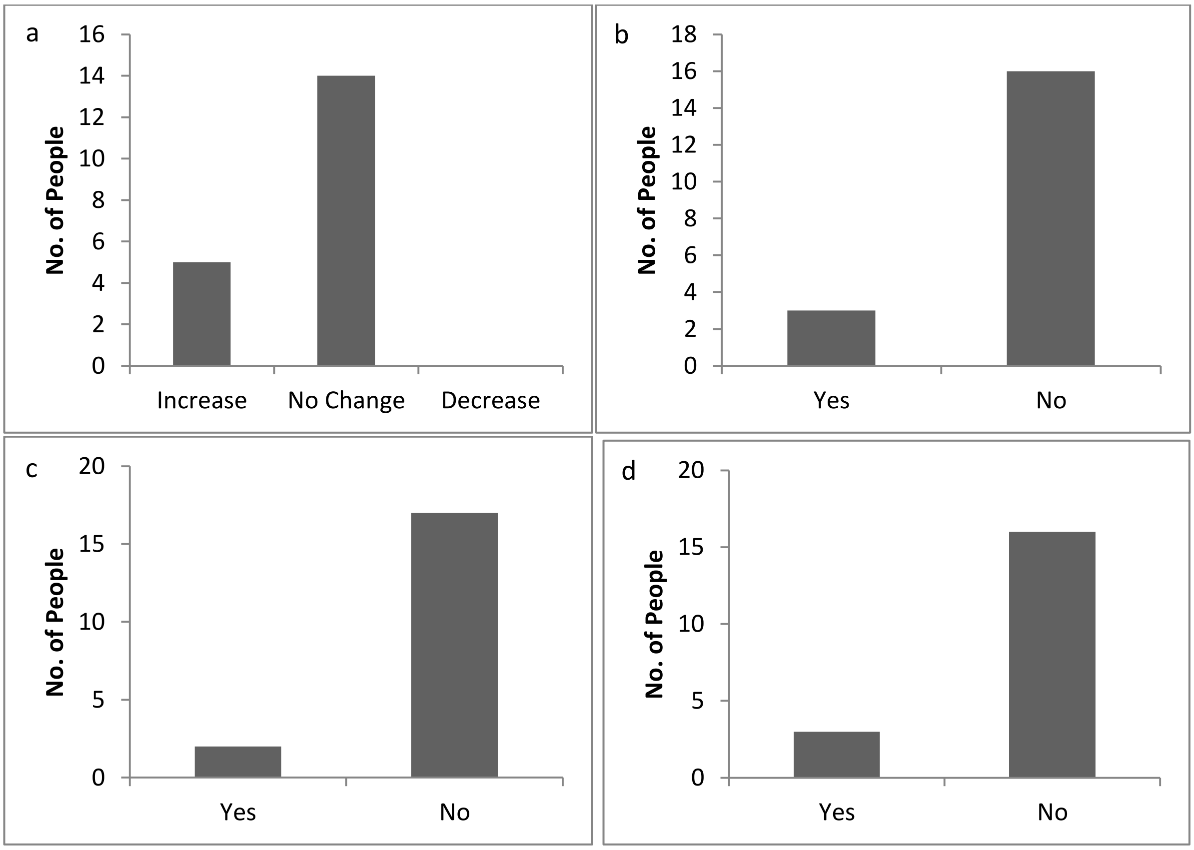

Figure 1: a) Has the introduction of the pot limitation (2009) influenced how many pots you have in the sea? ; b) Have you purchased an additional vessel due to the pot limitation? ; c) Are you more selective of where you fish your pots? ; d) Has the introduction of the pot limitation (2009) increased the number of pots you fish outside the district?

- Figure 1a shows that fishers report that the pot limitation has either caused no change or an increase in the number of pots
- Figure 1b shows that 3 of the people who were interviewed have purchased a new vessel due to the pot limitation
- The majority of people have not been more selective of where they've fished (Figure 1c), but those that did (n=2) cited likelihood of catch, distance from port, and lobster size.
- Similarly, the majority of people have not increased the number of pots they fish outside the district (Figure 1d). There were 3 people who increased the number of pots outside the district, and the numbers cited were 400, 800 and one who couldn't estimate.

Splitting the answers by North and South reveals more information (Figure 2).

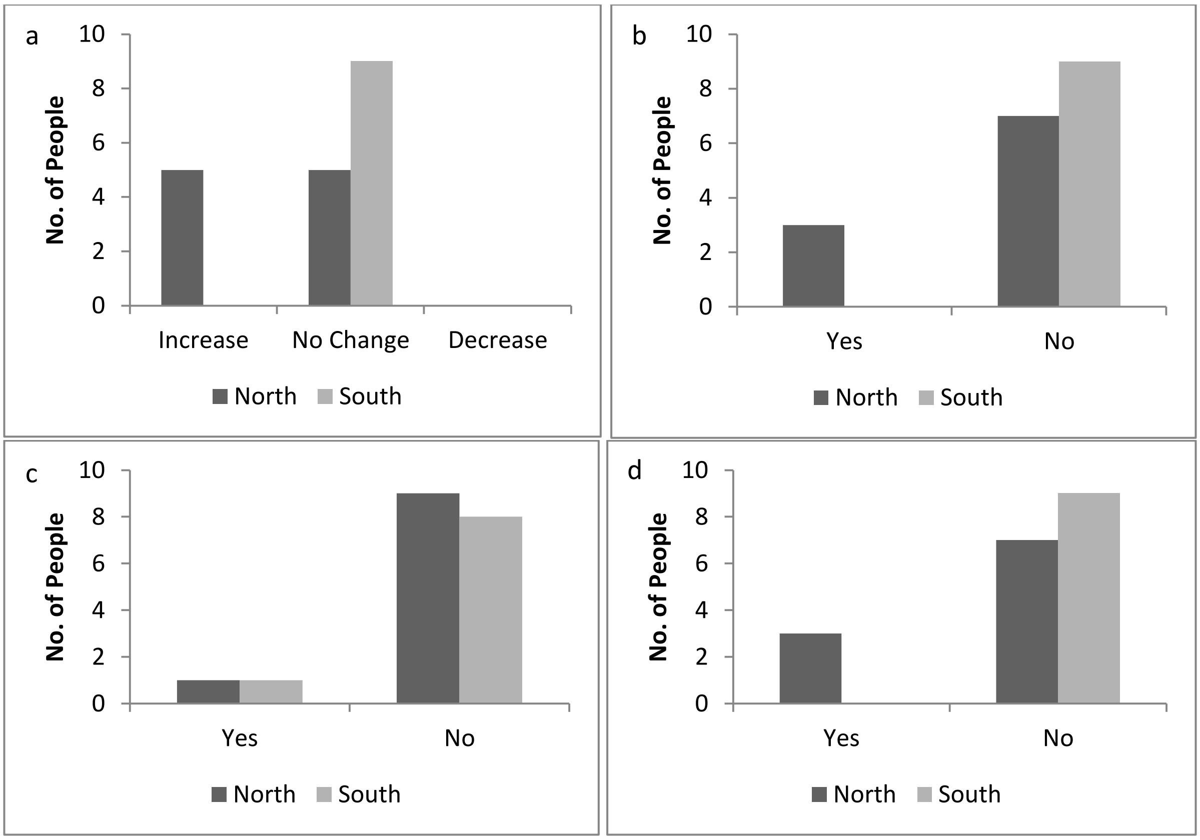

Figure 2: a) Has the introduction of the pot limitation (2009) influenced how many pots you have in the sea? ; b) Have you purchased an additional vessel due to the pot limitation? ; c) Are you more selective of where you fish your pots? ; d) Has the introduction of the pot limitation (2009) increased the number of pots you fish outside the district?

- Splitting by district shows that the effects of the pot limitation have been predominantly seen in the North
    - The only incidences of an increase of pots being fished, and the purchase of an additional vessel was from those questioned was in the North (Figure 1a and 1b)
    - Similarly, of those questioned, only those in the North increased the number of pots fished outside the district (Figure 1d).
- Looking at port level, these increases seen are solely from Seahouses and Holy Island.

Appendix 5

Escape Hatches

Questionnaires were completed over a two day period (2nd and 3rd June, 2015), throughout the NIFCA district. The sample population were skippers of potting boats, who are actively targeting shellfish. The questionnaires were predominantly structured questions, and a total of 19 people (25 permits) were interviewed, covering 7 ports (Table 1).

Table 1: Number of people interviewed by port

Port	Number of people
Berwick	2
Holy Island	3
Seahouses	3
Beadnell	2
Amble	5
Blyth	3
North Shields	1

There were a total of 4 questions regarding escape hatches, and all questions had a very mixed response (Figure 1).

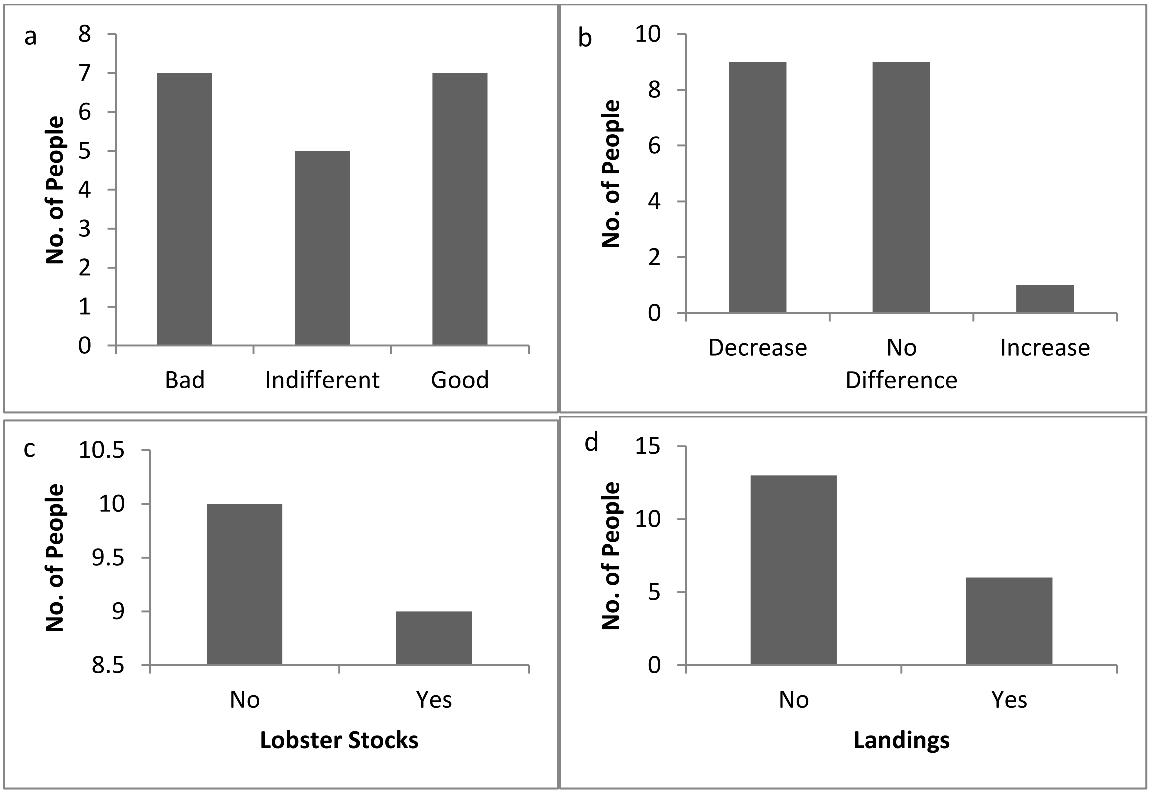

Figure 1: a) How do you feel about escape hatches? ; b) Do you think escape hatches will make a difference to your landable catch? ; c) Do you think escape hatches will be beneficial to a) Lobster Stocks; b) Landings?