Executive Summary

This report outlines the results of the succorfish project undertaken by Orkney Sustainable Fisheries Ltd (OSF) as part of the Orkney Shellfish Research Project (OSRP) from 2013 -2016. This project looked to address key issues relating to the spatial and temporal extent of the fishing activity within and surrounding Orkney, and the overlap between Orkney creel fishermen and the emerging marine renewables sector. Exploratory analyses were also conducted investigating the development of fine scale Orkney fisheries management areas and the role of environmental drivers in dictating fishing aggregations.

Spatial and temporal information on the Orkney inshore fishery was collected through the use of 21 GPRS succorfish units retrofitted to 10 vessels <10m Total length (TL) and 12 Vessels >10m<12m TL. The allocation of succorfish units ensured adequate coverage between different components of the inshore fleet. GPRS units provided an output (ping) every 10 minutes comprising of a GPS location (Longitude/Latitude) and fishing speed (knots). Records were filtered according to speed with all speeds <5knots used as a proxy for fishing activity. Amalgamated quarterly heat maps were created using this speed filtered information producing fine scale fishing density at fishing density/0.160km².

Overall fishing density ranged from 0- 61 pings/0.160km2, with fishing density influenced both spatially and temporally. Fishing density within quarter 1 (January – March) was heavily restricted to inshore areas and inter-island fishing grounds. Over this time period fishing densities ranged from 1 – 24pings/0.160km2, with overlap predominantly occurring with the marine renewable tidal sites. Fishing density in quarter 2 (April – June) ranged from 0-31/0.160km2. Over this time period expansion of the fishery occurred into offshore areas up to the 6nm limit, with such areas associated with the brown crab fishery. Overlap with wave lease sites was recorded. Fishing density within quarter 3 (July – September) ranged from 0 – 35/0.160km2, with fishing activity recorded further offshore outside of the 6nm inshore limit. High density areas were also recorded inshore, with these areas associated with the lobster fishery. These high density areas are documented to overlap considerably with renewable wave sites. Fishing density within quarter 4 (November – December) ranged from 0 – 29/0.160km2. Within this time frame retraction of the fishery occurred, identifying important inshore fishing grounds associated with the winter velvet fishery. Over this time period overlap with marine renewables shifted from wave to inshore tidal sites.

The concept relating to the development of new fine scale inshore Orkney fisheries management areas, similar to those used by the North Atlantic Fisheries College and the Shetland Shellfish Management Organisation was explored. Initial development was based on previous analytical divisions developed by
Orkney Fisheries Association, resulting in the creation of 10 regional management areas. These areas incorporated the creation of two separate areas encompassing Scapa Flow and Kirkwall bay respectively. These management areas were purely speculative and explored the feasibility and level in which Orkney could be managed in the future.

Exploratory analysis was conducted investigating spatial and temporal changes in the fishery relating to environmental drivers, specifically habit distribution. Heatmaps were produced by compiling daily landing records submitted via the OSRP logbook programme or daily merchant landing records overlaid with participating succorfish vessel data, creating capture densities in Kg/0.160km². Heatmaps were produced for three of the commercial targeted species within the creel fishery: brown crab, European lobster and velvet crabs

**Brown Crab**
Capture densities ranged from 0 - 420kg/0.160km² for brown crab, with capture densities influenced by the seasonal expansion and contraction of the fishery. High capture densities were recorded between habitat boundaries of sand/missed sediment and rocky reef habitat. With high densities areas attributed to key biological processes that occur within the fishery such as annual stock migrations and sex associated stock division.

**European Lobster**
European Lobster capture densities ranged from 0 - 38kg/0.160km2, with density heavily seasonally dependant, with the occurrence of the fishery limited to annual peak sea surface temperatures. High capture densities were recoded within rock reef habitat, low capture densities were recorded in mixed/sand habitat also.

**Velvet Crab**
Capture density ranged from 0 - 160km2, with capture density highly seasonal, with high densities coinciding with the contraction of the winter fishery. The fishery was identified as heavily habitat dependant, with capture densities restricted to rocky reef habitat only.

The results of this study present regional estimates of fishing density with the inshore Orkney creel fishery. Providing the first evidence relating to the extent at which overlap occurs at a spatial and temporal scale with inshore marine renewable sites. The role of environmental drivers were explored identifying their role in influencing the seasonal and overall spatial extent of differing fisheries, with aspirations to develop this avenue of research further. New management areas were hypothesised; demonstrating potential levels in which the fishery could be managed in the future, incorporating known
spatial management frameworks and historic spatial divisions to better manage the inshore fishery at a localised scale.

Recommendations surrounding future work are discussed including the participation within new Scotland-wide initiatives collecting spatial inshore fisheries data. The development and further analysis relating to commercial species capture densities and environmental drivers have been highlighted with similar research proposed by participating fishers. Further considerations relating to localised inshore fisheries management and the implementation of smaller management areas are also proposed
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Project Background

The Orkney shellfish research project (OSRP) has come to the end of its four year project (2013 – 2016). The project encompasses a number of objectives aimed to address the needs of two important sectors: Inshore fisheries and marine renewables.

Specific objectives of the project relating to the fishing sector were:

- To assess the status of Orkney crustacean stocks in relation to sustainability criteria;
- To provide monitoring data and biological understanding to support the development and implementation of a harvest strategy and management systems for sustainable fishing in the context of marine spatial planning for renewable energy and other activities in Pentland Firth and Orkney waters;
- To satisfy shellfish consumers of Orkney’s commitment to sustainable fishing.

Objectives relating to the marine renewable energy industry:

- To determine key areas providing value to the Orkney creel fishery in terms of catch rates and the magnitude, composition and quality of catches;
- To describe spatial patterns of space use by the Orkney creel fishery in terms of fishing effort, navigation, relocation of gear during bad weather and seasonal and inter-annual patterns of variability;
- To determine locations of critical habitat for crustacean species targeted by the Orkney creel fishery, particularly in terms of spawning areas and movement and migration patterns of brown crab.

This report outlines the results collected over the past 4 years specifically relating to the tracking of succorfish vessels and the outputs associated with the analysis of data collected. This programme was instigated to provide information relating to the spatial and temporal spread of fishing activity; highlighting important fishing areas and the overlap with the marine renewable energy sites.

The report is comprised of the following sections:

1. Overview
1. Overview

Increasing pressure is being put upon historic marine users to demonstrate usage of marine space, with emerging marine users now jostling for access into previously uncontested areas. The role and importance of inshore fisheries is incontestable with vessels <10m total length (TL) representing 72% of all registered fishing vessels in Scotland (Scottish government, 2015). Currently there is no statutory requirement for vessels <10m TL to carry any AIS or GPRS related system, meaning that very little information is known about the spatial or temporal spread of this economic and socio-economically important industry. The lack of historical evidences is of increasing importance to both marine renewables and inshore fisheries.

The role of this project was to address the needs of the marine renewable industry and that of the inshore fishing sector, gathering information on the spatial extent of the fishery and how it interacts with current and proposed marine renewable energy lease sites. The importance of inshore fisheries at a national level is again amplified at the local Orkney scale, with 68% of its fishing fleet comprising of vessels <10m TL. These further increases with the inclusion of vessel ≤ 12m TL; accounting for 80% of all registered Orkney vessels (Scottish Government, 2015).

Previous projects have looked at trialling AIS systems on vessels <10m (James et al, 2015), gathering geographical positioning data and the feasibility of using AIS in this way. This project demonstrated positive up-take however some concerns still exist regarding the public nature of locational information. In regards to this in partnership with The Crown Estate, Orkney Sustainable fisheries Ltd (OSF) and Marine Scotland Planning. 21 GPRS succorfish devices were initially installed on vessels of varying size all ≤12m TL within the Orkney inshore fleet. Installations of these units occurred within 2013, with devices active until the end of 2016. Over this time frame a total of 21 billion GPS recordings were taken, accounting for 11,66 days at sea. GPRS devices provide a secure connection from which GPS locations are recorded and stored, making positional information private and accessible by the data owner, approved parties and device provider.
2. Seasonal and Temporal Fishing Extents

2.1 Overall 2013 – 2016

A total of 21 vessels participated within the succorfish project, a component of the OSRP. Succorfish units were distributed across a number of different vessel size classes (Table 1) ensuring adequate coverage within and around the Orkney Island (Table 2). The distribution of units among differing vessel sizes allowed the comparison and the inclusion of differing target behaviours associated with vessel size. Typically larger vessels are capable of operating further offshore and in more adverse weather conditions, highlighting important fishing grounds that would be lost if only vessels <10m TL were only retrofitted.

Table 1 Number of participating vessels retrofitted within succorfish GPRS Units per size class

<table>
<thead>
<tr>
<th>Size Class</th>
<th>Number of Vessels</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;10m Total Length</td>
<td>10</td>
</tr>
<tr>
<td>&gt;10m ≤ 12m Total Length</td>
<td>11</td>
</tr>
</tbody>
</table>

Table 2 Distribution of participating vessels retrofitted with succorfish units according to ICES rectangle. Bracketed numbers denote fishers operating across multiple rectangles.

<table>
<thead>
<tr>
<th>ICES Rectangle</th>
<th>Number Vessels</th>
</tr>
</thead>
<tbody>
<tr>
<td>46E6</td>
<td>3 (4)</td>
</tr>
<tr>
<td>46E7</td>
<td>(3)</td>
</tr>
<tr>
<td>47E6</td>
<td>(9)</td>
</tr>
<tr>
<td>47E7</td>
<td>5 (8)</td>
</tr>
</tbody>
</table>

2.2 Data Preparation

Data used to analyse fishing distribution was recorded by succorfish units. Information provided per vessel included a GPS locations (ping) every 10mins, and current speed in knots (knts). To obtain fishing speed filtered data points were filtered in accordance to a speed of <5 knts as a proxy for fishing activity (Kafas et al, 2012). Vessels were also equipped with a number RFID tags attached to the first and last creels on a number of ropes. This provided information relating to actual gear deployment, allowing for cross validation with speed filtered data. Harbour areas were given a 1.5km buffer zone to exclude points.
that did not represent fishing activity but occurred at similar speeds, e.g. port manoeuvring. Heat maps were produced using a grid representing fishing activity (pings) at 0.160km² (Appendix 1).

2.3. Fishing Density Combined

Fishing activity within and around Orkney operates both within the 6 nautical mile (nm) and out to the 12nm limit, with varying levels of fishing intensity occurring within these limits (Appendix 1).

However the majority of Orkney’s fishing activity occurs within the 6 nm limit or commonly referred to as the inshore fisheries limit. The concentration of fishing effort within this limit can be linked to a number of factors. Firstly the inshore fishery is heavily dominated by vessels <10m TL (68% of registered Orkney vessels; Scottish Government, 2015), this restricts the extent in which vessel can operate on a daily basis, causing high concentrations within these areas. Secondly in the case of Orkney, a mosaic of habitat types occur within the inshore 6nm limit, providing the opportunity to target a number of different species within relatively small geographic distances (Appendix 3), resulting in a mixed crustacean fishery. This mixed fishery is further highlighted within identified commercial species hotspots, with a high degree of species overlap within certain areas (See section 8). These hotspot areas were mirrored through high succorfish ping densities (Appendix 1) within and surrounding the Northern Orkney isles, particularly surrounding Eday, Stronsay and Sanday.

Fishing activity outside of the 6nm limit was typically dominated by vessels >10m ≤ 12m TL (12% of registered commercial vessels in Orkney; Scottish Government, 2015), with these larger vessels capable of accessing highly productive areas further offshore. A number of inshore viviers¹ also operate within the Orkney inshore fleet, enabling vessels to stay out for several days at a time. In contrast to fishing density recorded within the 6nm limit, fishing activity further offshore was dispersed across far greater distances, providing an explanation as to why fewer high density areas were recorded. However it is important to note that not all vessels operating within these areas were retrofitted with succorfish units, therefore absolute high density areas cannot be identified.

Differences in targeting behaviours also occurred with the separation of fishing activity between these two limits, with the fishery that operates within the 6nm employing a mixed fishery model (brown crab, lobster and velvet crab), whilst those outside of the 6nm typically specialise in targeting brown crab in large volumes. Changes in targeting behaviour of these larger vessels occurs over annual temporal time

¹ Viver vessels relates to a vessel typically >10m total length that are fitted with recirculating sea water tanks allowing the on-board storage of live crustaceans for extended periods
The constriction of fishing extent in winter months due to bad weather forces these larger offshore vessels to move inshore and target velvet crab alongside smaller vessels that operate inshore year round.

2.3.2 Quarter 1

The extent of fishing activity within Orkney during Q1 (Jan – Mar) illustrates a fishery that is significantly restricted and limited by environmental conditions, specifically weather fronts (Appendix 4A). The fishing activity that does occur is restricted to more sheltered inshore areas, evident within the distribution and density of fishing effort record (Appendix 2A). During this time period the target species for the fishery changes, with landing compositions dominated by velvet crab with a small amount of brown crab. This change in targeting behaviour is documented within the voluntarily OSF logbook programme with velvet crab making up the largest landings percentage during this time period. (See Logbook & Observer report: Coleman & Rodrigues, 2017). It is important to note however that further offshore fishing still occurred in some locations with these areas typically still being used to target brown crab. Accessing these areas however is purely limited to suitable opportunistic weather windows and larger vessel >10m TL. During this time period, overlap with fishing activity and renewable energy sites exists primarily with inshore tidal sites, with these overlaps largely due to ideal velvet crab habitat types situated within high flow, nutrient rich areas. Key overlap areas are highlighted specifically within the Fall of Warness site, Westray Firth and Stronsay Firth.

2.3.3 Quarter 2.

Expansion of the fishery occurred within Q2 (April – June), with greater fishing activity taking place within more exposed areas (Appendix 2B). High concentrations of fishing effort were recorded off the West Mainland, North Hoy and off East Mainland. Low levels of fishing activity still occurred within the inter-island areas. Similar hotspots were identified around Stronsay as there were within Q2, whilst overall fishing pressure decreased within the northern isles. Observed changes in fishing patterns and distribution can be attributed to changes in fishers’ targeting behaviour, with the onset of the brown crab fishery occurring within late Q2. This movement of gear in Q2 coincides with the beginning of the annual mass migratory behaviour that is exhibited in female brown crab. During this time-period, females move into shallower inshore water from deep offshore locations to moult and breed, resulting in the subsequent movement of fishing gear from inshore sheltered areas to capitalize on this stock movement. Interaction and overlap of fishing activity with inshore renewable energy sites is seen to reduce within this quarter due to the relocation of gear to more exposed locations. This however saw an increase in the interaction of the fishery with designated wave sites specifically along the west mainland, with increased overlap
exhibited within the EMEC Billia Croo wave-test site within Q2. In comparison limited overlap is exhibited within the inshore tidal lease sites over the same time period.

2.3.4. Quarter 3.

Fishing density and distribution in Q3 was similar to that of Q2, however slight changes in fishers’ behaviour is recorded (Appendix 2C). In Q3 further expansion of fishing effort is recorded off the west coast of Orkney, coinciding with the peak brown crab fishery which typically occurs in July/Aug/Sept. These changes in fishers’ behaviour can be attributed to the onset of the lobster fishery which starts in middle to late Q3. The timing and length of this fishery is heavily influenced by water temperature with it influencing key biological characteristics of this species. This causes slight annual variation in the fisheries length. Targeting behaviour over this quarter is still heavily dominated by brown crab, with it being the highest record species in landings compositions (see market sampling report; Rodrigues & Coleman, 2017). The overlap with the inshore fleet and renewables exists primarily within wave-test sites due to their close proximity to the shore and their overlap with key lobster habitat.

2.3.5 Quarter 4.

Fishing distribution and density began to decline and a retraction of the fishery is observed within Q4, a reverse trend to that of Q3 (Appendix 2D). This contraction subsequently results in higher fishing densities recorded within sheltered areas and between islands. These changes in fishing distribution can be attributed to two drivers: seasonal weather fronts and species market value. Changes in environmental conditions begin to occur within Q4, with the onset of winter weather fronts reducing the access to more exposed grounds, resulting in the gradual movement of gear into more sheltered winter locations. During this distribution shift, the market value of previously poor species (velvet crab) begins to increase, influencing fishing distribution and intensity. Greater fishing effort is targeted toward this species with high fishing density recorded in sheltered areas, especially surrounding Eday, Scapa Flow, Shapinsay and Kirkwall Bay. Overlap with renewable energy sites is similar to that of Q1, with increases in fishing activity recorded within sheltered locations resulting in increased overlap with tidal sites. High fishing densities are recorded up to the site boundaries of the Fall of Warness and Eday

2.3.6 Billia Croo Wave Test Site

In the case of the Billia Croo wave test site, varying levels of fishing activity were recorded within and surrounding the site. The site itself overlaps with historically important lobster fishing grounds, with medium to high levels of fishing activity (15 -62 pins/0.160km2) still occurring within the shallower section of the site closer to the shore (Appendix 3A). In comparison to the surrounding area however,
lower levels of fishing activity occurred within the site compared to the high levels of fishing activity supported in adjacent areas. Reasons behind the lower level of recorded fishing activity could be attributed to undocumented fishing activity within the site by vessels not fitted with GPRS units. Additionally, access and the deployment of gear within such areas are heavily restricted due to it being an active renewable test site.

2.3.3 Fall of Warness Tidal Test Site

Recorded fishing density surrounding the Fall of Warness tidal test site illustrated that significant fishing activity occurs within the area adjacent to the tidal site (Appendix 3B). The creation of the tidal test site excluded fishing activity. With adjacent areas demonstrating high levels of fishing activity (31-46 pings/0.160km2) this illustrates the potentially high productive nature of the site. Differences however exist between that of the Billia Croo and the Fall of Warness sites. This relates specifically to the technology deployed at each location. In the case of Billia Croo, wave devices are large floating structures, easily visible and gear can be placed amongst or around such devices with limited risk. In comparison with tidal sights, devices are submerged and fitted with large tidal turbine blades. These factors make gear deployment and fishing activity highly dangerous to fishermen. In comparison to the Fall of Warness site, the neighbouring Lashy Sound and Westray south sites are currently vacant. Low to medium fishing activity was recorded within these sites (0 -31 pings/0.160km2). It is therefore recommended that the nature of the fishery that occurs within Lashy Sound and Westray South be identified in case of future exclusion due to the deployment of tidal devices.

3. Orkney Habitat Classification

3.1 Overview & Current Management Areas

The classification of habit types and the extent of habitats has a significant effect on the distribution of target species and subsequent fishing effort and distribution. Therefore having greater information relating to environmental parameters can provide useful insight into seasonal fishers’ behaviour.

Seasonal changes in fishing patterns have been well documented within fisheries worldwide, with distribution influenced by a number of biotic and abiotic factors. Within the inshore creel fishery seasonal patterns within gear deployment and primary target species is known to occur within Orkney (Coleman & Rodrigues, 2016; Coleman & Walker, 2015). The fishery is seen to contract and expand annually, with the primary forces behind this behaviour being environmental conditions restricting the deployment of gear onto more exposed grounds within winter months (See section1: Seasonal and temporal fishing
extents). Additionally economic variables will also influence the distribution of fishing activity such as catch value and variation in market demand.

To provide insight into environmental drivers surrounding fishing distribution and target species distributions, OSF looked to compare landings composition to known habitat extents. Broad scale seabed habitat distribution information is freely available through the European Marine Observation and Data Network (EMODnet; [http://www.emodnet-seabedhabitats.eu/webGIS](http://www.emodnet-seabedhabitats.eu/webGIS)) and Joint Nature Conservation Committee (JNCC). This data catalogue comprises of a number of different amalgamated resources including habitat maps collated from surveys, modelled distribution maps of specific habitats and data sets relating to specific habitats listed as important under EU and international legislation.

Currently Orkney is managed under four ICES rectangles. These areas encompass all aspects of the fishery, within and out-width the 12nm limit (Appendix 4) and incorporate a number of different habitat types, with the spatial distribution of these habitats having a distinct effect on the concentration of fishing effort for a specific species. Variation in catch composition across ICES rectangles has been discussed with previous OSF work (Rodrigues & Coleman, 2017, Coleman & Rodrigues, 2016), specifically in relation to greater quantities of velvet crab and lobster landed by vessels operating within ICES 47E7 compared to all other ICES rectangles.

### 2.2 Habitat Distribution

Distribution of habitats around Orkney is seen to influence the landing compositions from those areas. A greater coverage of shallow aphotic and photic reef habitat is distributed within ICES 47E7 (Appendix 6). This type of habitat is essential for the lobster and velvet crab fishery, with the highest recorded landings occurring within this areas, 52.2% of landed lobster sampled and 60% of velvet crabs in 2015 coming from fishers operating within ICES 47E7 (Coleman & Rodrigues, 2016).

Brown crab landings are mirrored by the distribution of habitat types. With a large fishery occurring off the west of the Orkney where habitat type rapidly changed from offshore shallow sands and mixed coarse sediment types (Appendix 4) to hard rocky bottoms inshore. Biological processes make this area a highly productive fishery, with annual female brown crab migratory routes transcending these areas on mass. Economic variables also play an important role in influencing the distribution and landings compositions of an area e.g. homeport location, steaming time, fuel and bait cost. For example, fishers operating out of the port of Stromness and Tingwall have considerably less steaming time to access brown crab grounds located along the west mainland compared fishers from Orkney’s other major ports. These influencing variables result in the specialised fisheries playing to the strengths of regional habitat and species distributions. For example highly productive inshore velvet fisheries exist year round within the inter-
islands with vessels accessing this fishery based out of Kirkwall. Similar highly productive fisheries are found within some parts of ICES 47E6 and 47E7, with vessels operating out of Westray while a small number of inshore viviers operate out of Kirkwall targeting brown crab across similar habitat types.

3.3 Theoretical Management Areas
Currently Orkney is managed according to ICES rectangles however this provides low regional resolution (ICES rectangles; Appendix 6). It is therefore recommend that the future management of Orkney be governed by small scale management areas that provide greater resolution on fisheries behaviour and target species distribution.

The formation of these new management areas are currently speculative, with Orkney having been subdivided into distinct areas through previous research work carried out by Orkney Fisherman’s Association (OFA V-notch Project; Chapman, 2002; Bell 2013). The division of Orkney into these areas was purely arbitrary and was never intend to be used within a management context. However they provide the basis from which more regional scale management areas could be based, providing finer scale resolution of fishing distribution and the associate landed composition of vessels operating within them. Localised management areas are already enforced within some areas around the British coast, with a successful model developed and implemented by the Shetland Shellfish Management Organisation (SSMO). Its assessment areas are divided into 103 0.5 degree squares with 6nm, providing localised regional reporting squares (Appendix 5). This scale subsequently allows specific information on landings and fishing distribution to be analysed and monitored. A similar model and the development of similar assessment areas could be developed for and implemented within Orkney.

The modification of previous OFA areas used by Bell (2013) into 10 distinct management zones would allow greater assessment of fishing patterns and analysis of regional depletion of stocks (Appendix 7). These zones are specifically altered from Bell (2013) with the incorporation of existing ICES assessment areas. Using the spatial extent of ICES rectangles allows data to be transferred into the national Marine Scotland assessment framework if required for national stock assessment. Overall the production of new management zones is founded by the division of ICES rectangles into 2 smaller areas per existing ICES rectangle, an additional two unique inshore zones are proposed: Zone 4 & 7. Zone 4 is a highly productive inshore sheltered area and experiences high levels of sustained exploitation year round for both lobster and velvet crab stocks due to the dominance of shallow biogenic reef habitat (Appendix 6). However any localised stock depletion within this area is lost under current management areas, with it being encompassed by two ICES rectangles. Similarly the creation of Area 7 is a key protected inshore area during winter months. It is also an important area for the emerging whelk fishery (Buccinum undatum)
and sustains a small scale Nephrop fishery (Nephrops norvegicus) due to the habitat types found within this zone (Appendix 6).

As previously stated, the outlined management areas are purely theoretical, before any implementation both governmental and fisher consultations would be required. This would ensure that the zonal divisions would be appropriate.

4. Commercial Species Hotspots

4.1 Overview
Speed filtering of succorfish data as a proxy for fishing activity provides an insight into temporal and spatial changes in fishing distribution however it provides little information relating to fishing practise apart from inferences. To overcome this limitation, historical daily landings records can be assigned to GPS points collected via the succorfish programme or similar devices. The assignment of recorded landings and spatial information provides further indication of targeting behaviour, high resolution temporal and spatial changes and the identification of commercially important hotspot areas (CIHA).

The identification of CIHA in this way provides valuable information for both fishers and fishery managers, with the identification of highly profitable areas and subsequently areas of key importance to the fishery. Within a fishery management context, they provide an indication of the movement patterns of stocks and subsequently changes in fishers’ targeting behaviours. Furthermore their identification can be used to appropriately reimburse fishermen if they are subsequently excluded from identified areas.

4.2 Methodology
High resolution CIHA can be created through the use of landings records, with clear changes in targeting behaviour identified.

Daily landings data was extracted from logbooks/merchants records, providing daily kg for each commercially targeted species for that vessel. Succorfish GPS data were speed filtered to remove points that did not represent fishing activity (See section 2: Speed filtering). The total number of speed filter points for that day was totalled, with the total daily GPS pings divided by each species total reported landed weight (kg; equation 1).
Following division of landings and assignment to GPS points, data was mapped within R studio (RStudio, 2015) using package Mapplots (Gerritsen, 2014). Initial amalgamated heat maps of all years was produced to ascertain the density in which data could be displayed effectively; subsequent quarterly maps were produced per specie. Heat maps produced displayed CIHA’s of total landings² per Kg at 0.160km², providing high resolution area identification.

4.3 Results

Heat maps were successfully produced for three of the primary target specie (brown crab, lobster and velvet crab; Fig), no heat maps were produced for green crab due to the lack of targeting within the logbook reference fleet or those within the succorfish project.

4.3.1 Brown Crab

Seven key areas were identified from brown crab heat maps; five off the west coast Of the Orkney Mainland, one off south coast of Hoy and one off the Orkney east coast (Appendix 7).

Overall

The distribution of CIHA fall in line with known fishing patterns of participating fishers through previous succorfish density analysis (Appendix 8; Coleman & Rodrigues, 2016). Important brown crab grounds are highlighted as occurring along the west coast of the Orkney mainland, both inshore <30m and at greater depths of 80m+. The identification of these inshore areas is contrary to previous understanding, with such areas mainly associated with the main west coast lobster fishery. The identification of these areas could be due to the targeting of predominantly inshore male crab during earlier proportions of the year (Q2: Rodrigues & Coleman, 2017), with large quantities extracted from this area during this time period. Additionally high capture densities in this area could also be associated with consistent small quantities of brown crabs caught alongside lobster landings, having a large cumulative effect. Following the production of CIHA, these were overlaid with predictive habitat areas (EUSeaMap, 2016) providing additional insight into the distribution of hotspot areas subject to environmental conditions (Appendix 9). In this case, high density areas for brown crab occurred typically on the borderline between two habitats types, predominantly when habitat changes from offshore sand/mixed sediment to inshore reef habitats,

² Total landings represent all amalgamated landings records for all vessels within the resolution of the heatmap.
with all hotspots highlighting this relationship. The reasons behind these aggregations at habitat boundaries can be attributed to the movement of females into these areas prior to moulting and mating with male crab. Similar relationships have been defined within previous tagging studies undertaken around the coast of Hoy, with such areas likened to key mating/lekking habitat (Jones et al, 2010). Differences in geographical targeting behaviours are evident within Orkney. In the case of brown crab, a large fishery exists along the West Mainland of Orkney and Western tip of Hoy, due to large annual female stock migration occurring within this region (Coleman & Rodrigues, 2016). Resulting in this species dominates the targeting behaviour and gear placement of west coast fishers. In comparison, East Coast fishers experience reduced brown crab migrations, potentially being fed by stocks within the North Sea or spill-over from Western Atlantic stocks (Mason, 1965), and with no key CIHA for brown crab highlighted.

Further breakdown and identification of brown crab CIHA was undertaken quarterly identifying temporal and spatial changes in key brown crab densities.

**Q1**

Expansion and distribution of key brown crab capture areas indicate that the fishery is restricted within Q1, with the lowest levels of catch per 0.160km² recorded. Low density hotspots are identified similar to those areas identified within the overall CIHA (Appendix 10), with key hotspots again identified off East Hoy (ICES 46E6 and west mainland (ICES 46E6/47E6). Low level of capture density are also incidentally recorded within sheltered areas, with these low levels being a by-product of the velvet crab fishery over this time frame.

**Q2**

Brown crab CIHA are seen to expand within Q2, with the expansion linked to increase in favourable weather and the expansion of the brown crab fishery. Areas highlighted off both the West coast of Hoy and West mainland, with the highest capture densities recorded within this quarter. Differing to Q1 (Appendix 11). High capture density areas are still restricted predominantly to inshore areas and within 3nm, indicating that male crab comprise 60% of landings contribution, with this relationship exhibited within previous years market sampling (Coleman & Rodrigues, 2016). CIHA areas are highlighted on the East coast where brown crab fishery expansion is again documented. Low levels of capture are highlighted within 47E6&46E6 (Appendix 11), with the movement of fishing effort into the borders between reef and mixed/sand habitat. The movement of gear to these initial low profit/density areas can
be attributed to the preparation and securing of fishing ground prior to the annual female migration that occurs within Q3.

Q3

CIHA within Q3 illustrates further expansion and the identification of high density areas. In contrast to previous quarters, high levels of interaction previously recorded along inshore west mainland areas was reduced, with fishing effort now displaced further offshore on predominantly sand/mixed sediment (Appendix 12). Fishing effort centred on these areas due to them yielding a higher percentage of female brow crab due to annual migratory behaviour over this time period (Coleman & Rodrigues). Similar fishing activities are recorded around the south of coast Hoy (ICES 46E6), between hard and soft sediment habitats. In contrast brown crab on the east mainland is recorded as occurring at lower densities, with the fishery predominantly occurring inshore, with catches from this area being heavily male dominated as a result of the habitat type in which the fishery occurs (Coleman & Rodrigues, 2016)

Q4

CIHA recorded within Q4 illustrate the peak of the brown crab fishery, with highest observed number of high capture areas (Appendix 13). Two noted high capture areas are again noted off the west mainland (Appendix 14A) and west Hoy (Appendix 14B). In both cases high capture density areas are recorded further offshore and away from inshore reef habitat, and this can signify the fishery following the bulk of the female stock, which is now positioned offshore, ready to migrate westwards. This behaviour is mirrored in area B (Appendix 14B) with high density recorded away from reef habitat and on more mixed and sand substrate, surrounding the boundary of four differing types of habitat. In comparison to previous years, contraction within the fishery begins to occur with far greater capture rates of brown crab recorded inshore. High capture rates are identified within Scapa Flow and inter islands, this change in spatial distribution signifies seasonal changes in targeting behaviour of the fishery.

4.3.2 European Lobster

The identification of European lobster CIHA are limited close inshore and within 3nm. Three occur in similar key areas to that of brown crab however occur over different temporal scales. Of those areas identified, high lobster capture densities are recorded along the west mainland (ICES 47E6), west and south coast of Hoy (ICES 46E6) and the east coast of the Orkney mainland (ICES 46E7) (Appendix 15). When combining CIHA with habitat maps, the relationship between lobster density and distribution of these hotspots becomes more apparent. In this case lobster capture density is distributed across biogenetic reef habitat close inshore (Appendix 16; Galparsoror et al, 2009). Habitat preference has been recorded in
previous OSF work, with peak adult lobster density found to occur within 10 – 20m depth, with capture rate declining with depth and preferable habitat type (Coleman, 2015). Low levels of lobster captures are highlighted further offshore on typically mixed/sand habitat. These low level capture rates within these areas can be attributed to the foraging movements of lobsters. Foraging behavioural movements in European lobster are known to occur nocturnally, with individuals moving from shelter providing reef habitat to open mixed/sand foraging habitat (Skerrit, 2014). Under the current habitat maps large amounts of preferable lobster habitat is situated around and within the Orkney Islands. It is important to note that the identification of areas in this case is severely limited by the number of participating fishers within both the logbook scheme and succorfish programme simultaneously. With blank areas being areas in which fisher participation did not occur, not an indication of no fishing activity.

Q1

In the case of CIHA identified in Q1, lobster capture density is limited with capture rates ranging from 0 – 3.6 per 0.160km² (Appendix 17). Of those CIHA identified a number are highlighted on both inshore biogenic reef habitat and some occurring on mixed/sand habitat, the highest capture density rates however occur within biogenic reefs during this time period. High lobster capture rates within biogenic reef habitat can be attributed to limited lobster movement. Low interaction rates during this period can be linked to reduced movement within the species due to low water temperatures, with its activity and key biological processes significantly influenced this environmental variable (Lizárraga-Cubedo et al., 2015). Similarly over this time period, the extent of the fishery is impacted by adverse weather conditions and the subsequent relocation of gear off prime exposed lobster grounds and onto sheltered inshore waters during this time period (See section: 2.3.2 Quarter 1).

Q2

In Q2 slight increases in lobster capture density are recorded 0 -9.2kg per 0.160km² (Appendix 18). Increases over this time period can be attributed to increase in fishing effort, with the expansion of the fishery post the onset of the main brown crab targeting season. The movement of gear to take advantage of the brown crab fishery is evident with increases in low captured density on mixed/sand habitats. High areas of capture density, following a similar trend to Q1, with high interaction occurring inshore and on reef habitat, typically along the west mainland and west Hoy. In comparison limited fishing interaction and capture density is recorded along the East coast (ICES 46E7) and within the northern isles (47E7). Slight increases in capture density during this time period can also be attributed to gradual increases in water temperature, increasing overall lobster movements and the interaction of the species with the fishery.
Q3

Capture densities within Q3 are seen to increase, however the location and the extent of these capture hotspots mirror those of previous quarters (Appendix 19). Differences are observed in the depth range in which capture density occurs, specifically along the west mainland, with fishing activity hugging the shoreline (Appendix 21A). High capture densities are also recorded along the south west coast of Hoy (Appendix 21B) and east mainland (Appendix 21C). Reductions in capture density are observed off the west coast of Hoy, with fishing effort decreasing within these areas. Reductions close inshore can be attributed to the movement of effort further with fishers targeting the brown crab stock in these areas, with lobster occasionally caught. Increases within capture density overall within this time frame can be attributed to peaks in water temperature, resulting in increases in overall lobster movement and subsequent interaction with the fishery.

Q4

Q4 sees a gradual decline in lobster capture density (Appendix 20) compared to that of Q3 (Appendix 19). This gradual decline can be attributed to the overall contraction of the fishery. In the case of the fishers operating along the west mainland, further effort is now recorded within Scapa Flow, with greater brown crab capture densities also recorded during this time period (See Section: 4.3.1 Brown Crab (Appendix 12)). Similar trends are observed along the East Mainland with further fishing effort now recorded within more sheltered locations, indicating changes in environmental conditions influencing the targeting behaviour of the fishery. In comparison high capture densities are still recorded along the south west of Hoy, reasons behind the extended nature of this fishery could be attributed to its slightly sheltered location compared to west/east coast, or overall lower fishing intensity allowing the extension of the fishery latter into this quarter.

4.3.3. Velvet Crab

Overall

The distribution of velvet crab capture density illustrates a pattern that is remarkably different from brown crab and European lobster. This difference relates to the distribution of the fishery, with velvet crab capture limited solely to biogenic reef habitat, with limited interaction across any other habitat types (Appendix 22). In the case of CIHA, important areas are highlighted as occurring within Scapa Flow and along the East Mainland and within the inter islands situated in 46E7 and 47E7. Identification of heat maps are similar to that of lobsters, with both species inhabiting similar habitat and routinely caught alongside gear targeting lobster (Appendix 23). Based on these habitat requirements, further CIHA would
be forecasted to occur within other inshore biogenic reef habitat, with this relationship mirrored in the high landings occurring within these areas. However the identification of these areas is limited by the number of participating fishers within the corresponding OSRP programmes from which data is extracted.

Q1

Capture density with Q1 illustrates a fishery that is highly retracted, with it occurring predominately close to port or mooring locations and at limited frequency. In contrast however high capture densities are observed within the limited CIHA highlighted (Appendix 24), specifically around the East mainland. Low levels of capture density are observed within Scapa Flow and around the south of Hoy. Little to no capture interaction is documented along the west coast mainland, with these fishing grounds too heavily exposed to winter storms to support fishing gear deployment during this time frame. Compared to the other primary target species, a similar trend is observed with limited interaction compared to other quarters, with fishing activity and its extent severely reduced during Q1.

Q2

Q2 capture density of velvet crab was seen to shift from within the inter-island chain (ICES47E7) further south along the east mainland extending down to South Ronaldsay (ICES46E7) (Appendix 25). In comparison to the previous quarters slightly reduced capture densities are observed, this in turn can be attributed to changes in fishers’ targeting behaviour. With the shifting of gear to preferable brown crab and lobster grounds, indicated by high capture densities of both brown crab and lobster over the same time frame. Medium to low level (7.3 -22 kg per 0.160km² are recorded around the east coasts of Sanday and Stronsay (47E7). Continued low levels of capture densities are observed within Scapa Flow and along the south coast of Hoy, highlighting the importance of this species to smaller vessel that relay on this fishery year round.

Q3

Capture densities within Q3, continued to illustrate a limited fishery, indicating geographical differences in fishers’ targeting behaviour (Appendix 26). Targeting behaviours off west mainland (47E6) are seen to target primarily brown crab and lobster during Q3, with capture densities of 0 per 0.160km² recorded. In comparison over the same time period areas are highly profitable and important to the East coast fisheries. High capture densities are continued to be recorded along the east mainland and South Ronaldsay and along the south west coast of Hoy.
Q4

Capture density distributions within Q4 begins to demonstrate the retraction of the fishery (Appendix 27). High density areas are documented around Shapinsay and the West mainland. Low recapture densities are recorded around the south west coast of Hoy, within Scapa Flow, Cava and Flotta. These areas represent sheltered aspects of the winter fishery, with velvet crab being an important component of this. During Q4, the highest capture densities are recorded across this species, indicating that a greater proportion of fishing effort is now targeted toward this species.

5. Future Scope

The value of understanding the distribution of fishing behaviour is greatly enhanced by understanding the distribution of target species due to key environmental conditions. The inclusion of these key environmental variables such as habitats provides a valuable insight into temporal changes in fishing activity and behaviours of the target species. Presenting future opportunities to use such techniques in stock monitor health through landings and targeting behaviour.

The production of the initial species heat maps represents significant steps in understanding the extent and behavioural movements of Orkney inshore fishery. The inclusion of this data in future stock assessments and statistical analysis allows a holistic view of the fishery separate to that of inferences and purely fishery dependant data. Initial heat maps were produced using amalgamated data. Future maps and re-analysing of the data will be conducted using average catch per-region per year and quarter. This will provide further information relating to the value of a given area, strengthening the information presented.

The subsequent production of CIHA maps past the initial OSRP is limited, due to the end of the succorfish unit contract, so collection of GPS data will now cease. Future projects looking at mapping inshore fisheries distribution using succorfish or similar AIS technology is scheduled to commence in 2017. OSF will look at participating within these projects to continue the work presented here.

OSF will also look to further develop new regional scale management areas, building upon the ideas presented here and the current model implemented within the Shetland Shellfish Management Organisation.
References


Appendix 1 Total recorded fishing density of vessel retrofitted with Succorfish GPRS devices (2013-2016)
Appendix 2 Recorded fishing density within and surrounding EMEC Billia Croo Wave test Site (2013 – 2016)

Appendix 3 Recorded fishing density within and surprising Fall of Warness Tidal Site (2013 - 2016)
Appendix 4: Total recorded fishing density of vessel retrofitted with Succorfish GPRS devices per quarter (2013-2016)
Appendix 5 Current Shetland Shellfish Management organisations management and reporting squares.
Appendix 6 Predictive primary habitat mapping within Orkney management area
Appendix 7 Theoretical localised management areas for Orkney Inshore Fisheries
Appendix 8 Identified brown crab commercial important specie hotspots areas around the Orkney islands
Appendix 9 Identified brown crab commercially important species hotspots in relation predicted habitats around the Orkney Islands.
Appendix 10 Identified brown crab commercially important species hotspots in relation predicted habitats around the Orkney Islands: Quarter 1
Appendix 11 Identified brown crab commercially important species hotspots in relation predicted habitats around the Orkney Islands: Quarter 2
Appendix 12 Identified brown crab commercially important species hotspots in relation predicted habitats around the Orkney Islands: Quarter 3
Appendix 13 Identified brown crab commercially important species hotspots in relation predicted habitats around the Orkney Islands: Quarter 4
Appendix 14

Identified brown crab commercially important species hotspots in relation predicted habitats around the Orkney Islands: Quarter 4: A) CIHA identified off West mainland B) CIHA identified off the West coast of Hoy
Appendix 15 Identified European lobster commercially important specie hotspots around the Orkney Islands
Appendix 16 Identified European lobster commercially important species hotspots in relation predicted habitats around the Orkney Islands.
Appendix 17 Identified European lobster commercially important species hotspots in relation predicted habitats around the Orkney Islands: Quarter.
Appendix 18 Identified European lobster commercially important species hotspots in relation predicted habitats around the Orkney Islands: Quarter 2
Appendix 19: Identified European lobster commercially important species hotspots in relation predicted habitats around the Orkney Islands: Quarter 3.
Appendix 20 Identified European lobster commercially important species hotspots in relation predicted habitats around the Orkney Islands: Quarter 4
Appendix 21 Identified European lobster commercially important species hotspots in relation predicted habitats around the Orkney Islands: A) Hotspots identified along inshore west mainland. B) Hotspots identified along south west coast of Hoy. C) Hotspots identified off East Mainland.
Appendix 22 Identified velvet crab commercially important specie hotspots around the Orkney Islands
Appendix 23 Identified velvet crab commercially important species hotspots in relation predicted habitats around the Orkney Islands.
Appendix 24 Identified velvet crab commercially important species hotspots in relation predicted habitats around the Orkney Islands: Quarter 1.
Appendix 25 Identified velvet crab commercially important species hotspots in relation predicted habitats around the Orkney Islands: Quarter 2
Appendix 26 Identified velvet crab commercially important species hotspots in relation predicted habitats around the Orkney Islands: Quarter 3
Appendix 27 Identified velvet crab commercially important species hotspots in relation predicted habitats around the Orkney Islands: Quarter 4