Green Development Strategy Project

Seasonal Fishing Timetable

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Abbreviations

Berried- Refers to the carrying of developing eggs on the abdomen of crustaceans.

CPUE- Catch per unit effort

EMFF- European Marine Fisheries Fund

FEK- Fishermen's Ecological Knowledge

LPUE- Landed per unit effort

MLS- Minimum landing size

OFA- Orkney Fisheries Association

1. Executive Summary

This report was conducted through funding from the EMFF to identify the seasonality of the inshore fishery in Orkney to help support the sustainability of the fishing industry. Creel fishing in Orkney is a mixed enterprise with target species including Brown crab (*Cancer pagarus*), Velvet crab (*Necora puber*), Green crab (*Carcinus maenas*) and European Lobster (*Hommarus gammarus*). This makes management of such a diverse, dynamic and fluctuating fishery more complex than others. This report aimed to provide evidence of the requirement for large fishing areas, how specific fishing patterns relate to these, how tides and subsea characteristics influence deployment of gear and connections to home ports, and the importance of economical and logical navigation routes.

Information for this report was collected during face-to-face interviews with individual fishermen who routinely fish or are retired from fishing, in Orkney waters. Those interviewed were asked to provide associated information on their fishing vessel and Fishermen's Ecological Knowledge (FEK). Fishermen have an immense wealth of information and knowledge of the seas they fish in. Fishers can best explain how a fishing ground has changed over the course of a few weeks, years or decades. They can provide intimate fine scale ecological and environmental information that is not otherwise available. Therefore, fisher's ecological knowledge is extremely important in informing science and addressing gaps in the current knowledge and management. During interviews they were asked to provide information on aspects such as species targeted, fishing gear used, fishing seasonality, historical changes, species abundance, biological conditions, subsea characteristics and fishing sites.

In providing a detailed understanding of fishing activities in Orkney waters, this can be used to inform management decisions relating to marine spatial planning relative to different aspects such as fisheries management, conservation or development sites. Competition is for space and by providing up to date evidence, improved knowledge of the distribution of fishing activities and the value of fisheries in inshore waters, it can help ensure best management of these sites. In understanding more of the fishing pattern within Orkney, 'greener' fishing techniques could be adopted to further enhance the sustainably of the shellfish industry

Key words: Fishermen's Ecological Knowledge, Seasonal timetable, Fishing activity, Sustainability

2. Introduction

2.1 Fishermen's Ecological Knowledge

The need for different strategies to help in monitoring and the sustainable management of important fish and shellfish stocks is slowly becoming recognised (Macdonald *et al*, 2014; Johannes, 1981). Greater awareness is becoming accepted towards utilizing fishermen's ecological knowledge (FEK) as a valued source of data within the assessment and management process of fisheries science (MacDonald *et al*, 2014). Fishermen have extensive interaction within the environment they work and can often accurately recognise long-term trends in stock level changes and subtleties in changes to the ecosystem (Drew, 2005; MacDonald *et al,* 2014). Carr and Hayman, 2012, also recommended the use of FEK to fill in knowledge gaps in data poor fisheries. This can prove extremely beneficial as in 2011 the European commission reported that 62% of fish stocks in the EU waters were lacking in biological and ecological information regarding stocks and with inaccurate or missing age-catch data.

Fishermen can often hold memories and facts that are not recorded elsewhere (Damasio *et al*, 2015). Accurate record keeping by fishermen is carried out by the majority, mainly for their own use but also due to regulatory compliance measures required by government agencies. As a result, records can show long-term distribution and abundance data down to individual species for the area they fish in, which can be more indicative of species movement than time-limited scientific sampling processes (Macdonald *et al*, 2014). As such, several studies have been undertaken in different types of fisheries to examine the viability of using FEK in commercial fisheries; Megrim (*Lepidorhombus whiffiagonis*) in the North Sea (Macdonald *et al*, 2014); tropical shrimp trawl fishery in Mexico (Foster and Vincent, 2010); mixed species fishery in Brazil (Damasio *et al*, 2015); Australian Murray crayfish (*Euastacus armatus)* (Zukowski *et al*, 2011); European deep-water fishery (Lorance *et al,* 2011) and lobster (*Jasus frontalis*) stocks in Chile (Eddy *et al*, 2010). The gathering of fishers' ecological knowledge was mainly conducted through interviews and questionnaires with fishermen. Secondary data was also collected through fishers catch data (LPUE and CPUE), historic data and then compared to other regional survey data.

Wider benefits to the fishing community can be achieved through investigating FEK. Many fishermen can often feel that their wide-ranging knowledge which is gathered over many years should be taken into consideration in the managing of stocks (MacDonald *et al*, 2014). By engaging with fishermen within the process of scientific research and management it can act as a bridge through involvement and help to fully invest in relationships and partnerships (Carr and Hayman, 2012; Johannes *et al*, 2000). In doing so it can help strengthen the sense of community and ownership within the fisheries, leading to adaptive co-management opportunities that assist the immediate needs of the fishery (Carr and Hayman, 2012; Johannes *et al*, 2000).

In adopting these principals and engaging with local fishermen it can help address the need for better information on the inshore fishing fleet within Orkney. Fishermen in Orkney can best explain how the fishing grounds they use have changed over the course of weeks, years or decades through first-hand observations and catch records (Carr and Hayman, 2012). Their knowledge can provide detailed, spatially resolved information on commercial inshore fishing in Orkney. In better understanding the reliance on fishing grounds, how these have changed over time, identifying seasonal conditions and the biological condition of catches, this can help inform local management decisions of the local fleet to ensure sustainability into the future (St. Martin, 2007).

2.2 Fishing activity in Orkney

In 2016, the total value of all fish landed by Scottish vessels was £557 million (Scottish Sea Fisheries Statistics, 2017). The value of shellfish landings by Scottish vessels has seen an increase from 2015 to 2016 of 21 percent to £166 million and accounted for 14 percent of landings by quantity (64 thousand tonnes (Scottish Sea Fisheries Statistics, 2017). Orkney in 2016 landed 4,936 tonnes of shellfish which was valued at £9,135,000. Table 1 shows the quantity and value of lobster and crab species landed into Orkney in 2016. This in turn supports a fishing fleet in Orkney waters of 131 actively registered vessels, 199 regularly employed and 93 irregularly employed fishermen (Scottish Sea Fisheries Statistics, 2017). Figure 1 shows Orkney and some of its 70 associated islands. Orkney covers an area of 990km^2 with the largest island being the mainland, covering 523km^2. The isles are then routinely referred to as the North Isles and the South Isles. The South Isles surround Scapa Flow and comprise of Hoy, Graemsay, Flotta, Burray and South Ronaldsay. The North Isles are more extensive and lie to the North of Orkney and include; Shapinsay, Rousay, Egilsay, Wyre, Eday, Westray, Papa Westray, North Ronaldsay, Sanday and Stronsay.

Figure 1. Map of Orkney and its islands.

The inshore fishery amongst Orkney's archipelago is diverse and complex, characterised by strong tidal flows. It is dominated by a mixed fishery fleet of 91 boats, 10m and under. Orkney's mixed fishery is made up of numerous target species including Brown crab (*Cancer Pagarus*), Velvet Crab (*Necora puber*), Green Crab (*Carcinus maenas*), European Lobster (*Hommarus gammarus*), Nephrops (*Nephrops norvegicus*), Whelks (*Buccinum undatumn*), King Scallops (*Pecten maximus*) and Queen Scallops (*Aequipecten opercularis*). King Scallops in Orkney are fished for using both hand diving and dredge fishing methods. In addition there are hand-lines for fin fish such as mackerel with further potential to catch other species such as Cod (*Gadus marhua*) and Haddock (*Melanogrammarus aeglefinus*). However, the main shellfish species landed in Orkney is targeted towards Lobsters, Brown

Crab, Velvet and Green Crab, as seen in Table 1, of which conservation measures exist for these species in the form of various minimum landing sizes (MLS).

Table 1. Quantity and value of commercial species landed into Orkney in 2016, adapted from Scottish Sea Fisheries Statistics, 2017.

	Quantity (tonnes)	Value (£'000)
Lobster (*Homarus gammarus*)	102	1,286
Edible Crab (*Cancer pagarus*)	3,404	4,769
Green Crabs (*Carcinus maenas*)	80	58
Velvet Crab (*Necora puber*)	393	1,210
Scallops (*Pecten Maximus*)	379	1,197
Whelks (*Buccinum undatumn*)	452	410

Further fishing around Orkney waters also includes fishing for whitefish with three Orkney registered whitefish fishing vessels. However, Orkney has no designated landing port or fish market, therefore landings operate at other local registered ports such as Shetland, Scrabster, Fraserburgh and Peterhead or ports on the West Coast of Scotland. The quantity and value of demersal and pelagic fish landed into Orkney can be seen in table 2. Mackerel quantities can be seen to increase in this table from 2014. This was due to the Scottish government launching a trial to expand the fisheries in inshore waters through allocating 10 meter and under vessels in the non-sector access to 1,000 tonnes of North Sea Mackerel (Marine Scotland, 2017).

Table 2. Adapted from Scottish Sea Fisheries Statistics, 2017. Quantity and value of total demersal and pelagic fish landed into Scotland from 2012 to 2016.

	Quantity (tonnes)					Value (£'000)				
	2012	2013	2014	2015	2016	2012	2013	2014	2015	2016
Total demersal	40	33	19	24	6	52	38	61	38	19
Total pelagic (Mackerel)	13	7	41	37	36	20	4	25	17	22

Processing of shellfish in Orkney is conducted through the Orkney Fishermen's Society in Stromness. It was established in 1953 and is one of the foremost processors of Brown crab in the UK. This co-operative handles the largest share of Orkney's Lobster, Velvet and Brown crab catches from the ports of Stromness, Tingwall and Kirkwall, along with the islands of Westray, Sanday, Stronsay, Rousay and Hoy. Westray also has its own processor (Westray Processors Ltd) which was established over 40 years ago for the production of fresh and frozen crabmeat from the local fishing fleet.

2.3 Seasonal Fishing

Fishing as an activity is highly dynamic and changeable and has many factors which influence the fishing activity within an inshore community. Firstly, fishing activity is somewhat limited by the inshore fishery boundary which is 6 miles from baselines as defined by the Inshore Fishing (Scotland) Act 1984. Inshore waters, part of the Territorial Waters (12 miles limit), form part of Scotland as defined in the Scotland Act 1998. While competence for sea fisheries rests at EU level, the UK has exclusive right to fish within 6 miles. Scottish Government are responsible for the regulation of sea fishing within the Scottish zone of British Fisheries Limits. Between 6 and 12 miles, fishing by non-UK vessels is restricted to those with historic rights relating to specific countries.

Secondly, fishing is further influenced by seasonal changes in temporal conditions and spatial abundance. The biology and life cycle of shellfish and fish vary throughout the seasons and can influence the quality of shellfish landed. A typical reproductive cycle of a mature crab begins once the female moults and is mated. Figure 2 shows the reproductive cycle of a mature female Brown crab (O'Dwyer *et al*, 2006). Moulting in crabs is a process whereby the crab produces a new cuticle through swelling as the old skeleton is cast due to an intake in water (Crothers, 1967). This process is a means by which crabs can grow and increase in size throughout their lifespan (Green, 1961). Once this has occurred the female crab will brood her eggs and spawn an egg mass of between 1 and 4 million eggs which are characteristically bright orange in colour and which then develop to reddish brown in colour (O'Dwyer *et al*, 2006). The eggs are carried beneath the female's abdomen for seven to eight months when the eggs are typically released as larvae into the plankton in the spring and early summer. In lobsters the berries are held for a longer period, usually ten to eleven months. During this time when the female is 'berried', she does not actively feed, reduces activity, and relies on body reserves for survival (O'Dwyer *et al*, 2006).

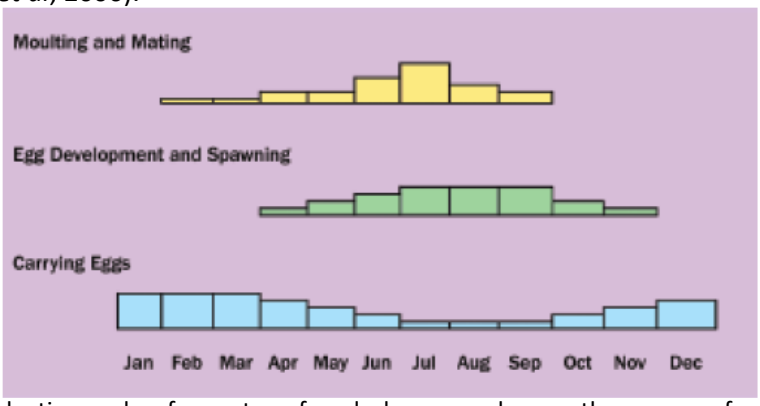


Figure 2. The reproductive cycle of a mature female brown crab over the course of a year, adapted from (O'Dwyer *et al*, 2006).

Not all female crabs will follow this pattern exactly and the timing of each phase of reproduction may be earlier or later than presented (O'Dwyer *et al*, 2006). This is dependent on several factors such as the age and health of the individuals, water temperature, food availability, and behaviour of local populations (Klassen and Locke, 2007). This also varies regionally and between the species of crabs, such as how long they carry their berries for and how many moults they go through.

By understanding the seasonality of the reproductive cycle of shellfish species, it shows how this can affect the quality of the shellfish landed. Figure 3 shows the typical cycle of meat yield from a mature female Brown crab over a year. From figure 3, the volume and quantity of brown and white meat of a female at marketable size varies throughout the course of a year and is directly linked to the reproductive cycle (O'Dwyer *et al*, 2006). However, the exact timing of this is again highly variable and influenced by the same physiological and environmental factors which affect reproduction.

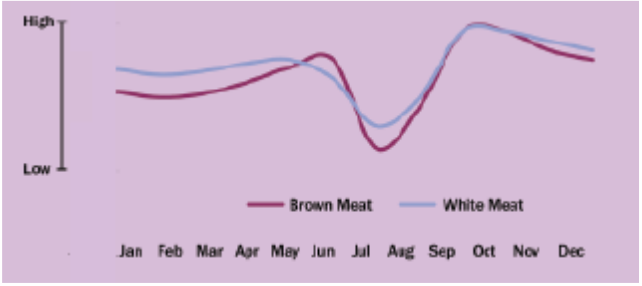


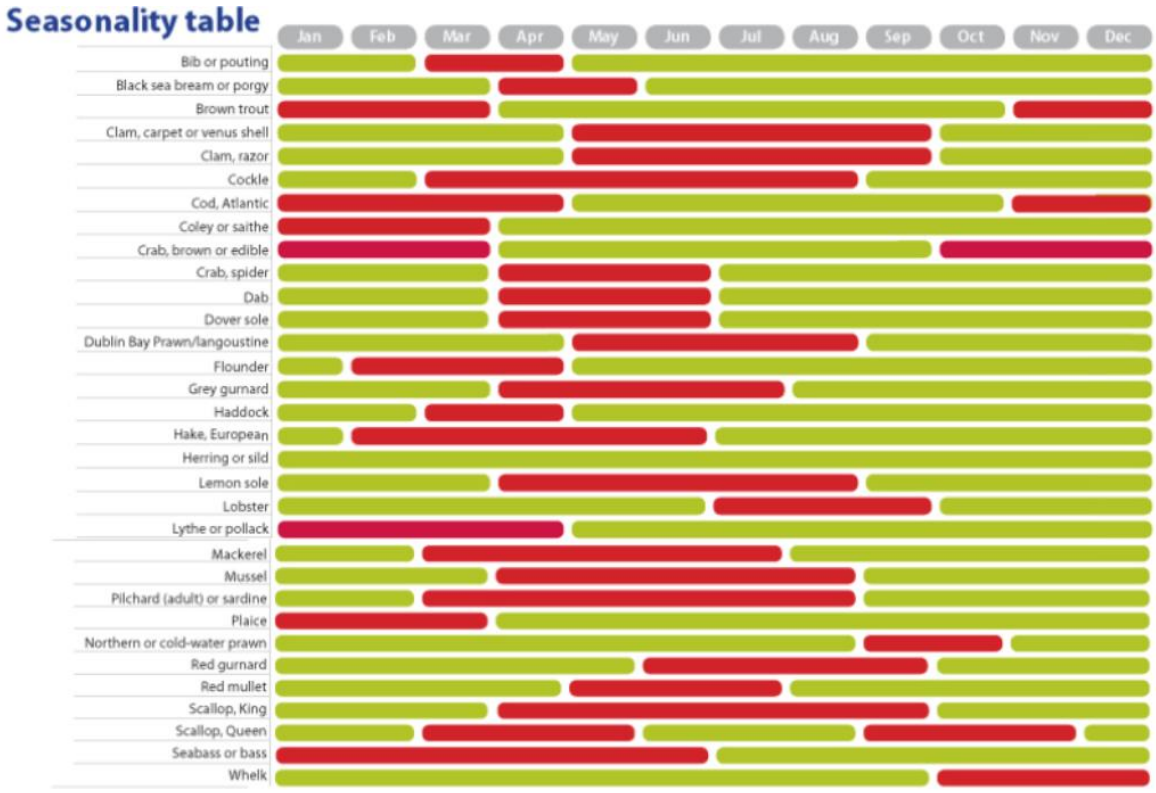
Figure 3. The typical cycle of meat yield from a mature female brown crab. Brown meat yield is shown in purple and white meat yield shown in blue. Adapted from (O'Dwyer *et al*, 2006).

Scallop growth and reproduction, similarly to crustaceans is linked to seasonal cycles in storage and utilisation of energy (Barber and Blake, 1991). Spawning in scallops is again influenced by external and internal factors such as water temperature and age (Le Pennec *et al*, 2003). Spawning usually occurs over the summer months beginning in April or May to September. (Barber and Blake, 1991). A range of environmental conditions are thought to act as a cue for spawning attributed to changes in water masses indicating favourable conditions for larvae, food availability and photoperiodism. Therefore, maximum meat yields are usually obtained just before spawning occurs in the spring and late summer when gonads are the heaviest and energy storage in scallops high (Hardy and Smith, 2001).

Fishing as an activity is also highly affected by abiotic factors such as weather, water temperature, salinity, tidal patterns, turbidity, nutrient availability, subsea characteristics, lunar activity, UV, wind speed and day length. Fishing is then also affected by factors such as distance from port, boat or engine size, gear type and other marine activities within the area.

Many agencies recognise the need for sustainable fishing through identification of the seasonality of species. The marine conservation society has published their 'Good Fish Guide' to allow consumers to take a key role in securing the future of our seas and marine wildlife by making more environmentally responsible choices when buying seafood. Within this guide is a seasonality table which advises the times to avoid buying fish during their breeding or spawning times, shown in red, as seen in table 3. Green indicates the months outside of the breeding season and the best time to enjoy eating them.

Table 3. Marine Conservation society seasonality table advising the best time to buy fish to help sustainability of the fishing industry. Green colours indicate the best time to buy fish, the red best time to avoid fish as this coincides with their breeding or spawning time.



In better understanding the seasonality of the fisheries around Orkney it is hoped that more efficient fishing patterns could be established. This could lead to a more seasonal fishery as seen in the past which would allow the rest and recovery of grounds in the anticipation that better quality crabs and

fishing areas could become established. This would in turn help provide sustainability of the fishery into the future.

2.4 Aims of Report

The present report aimed to provide detailed, spatially and temporal information on commercial inshore fishing activity around Orkney

- Definition of the areas fished and the species fished for;
- Seasonal usage of fishing areas;
- Seasonal biological conditions of species (berried, moulting, spatting, undersized);
- Factors which affect fishing -weather, tide, marine spatial factors.

3. Methodology

3.1 Fishermen's Ecological Knowledge Questionnaire

Initially a target list of 108 vessels in Orkney were to be interviewed. This list was compiled from OFA's members' details and those boats registered in Orkney. This list then focused on fishermen's port locations on the mainland and the isles and vessel type. Those interviewed included current full time, part time and retired fishermen. Currently 30 interviews have been carried out thus far and include the isles of Hoy, Westray, Stronsay, Shapinsay and Rousay.

Data collection for FEK was composed during face-to-face interviews with current individual vessel owners or retired owners (Kafas *et al*, 2014). Prior to the interview, the interview itself was discussed with the intended fishermen including the scope of the project, the type of questions they would be asked and how the information given would be handled and treated. This was done to ensure that the fishermen understood the intention of the project, how their knowledge would contribute to the project and how it would be used. Fishermen were also asked to sign a confidentiality agreement between themselves and OFA. This was to give fishermen a sense of security over the data that they were providing to ensure anonymity and commercial confidentiality of their knowledge over their fishing grounds.

The interview with fishermen was split into three parts; about the fisherman, about the vessel and their FEK. Towards the end of the interview questions they were also asked to give their opinion on certain aspects of the fishing industry. A summary of the questions asked can be seen in Table 4. Fishing areas were sketched onto a hard copy map for species fished presently, historically and seasonally. Historical references referred to changes to the fishery in their working lifetime but also changes seen if their forefathers also fished.

All interview data was stored electronically along with a hard copy and fishing areas mapped using ArcMap 10.5 and MaxSea. Some interviews were recorded but not all given that some interviews were carried out on boats or boat sheds.

Table 4. Summary of data collected during fishermen interviews, adapted from Kafas *et al,* 2014.

Category	Data	Description
Fishermen's information	Age	Fisherman's age
	Fishing Employment	Full time, part time, retired or hobby.
	Years local	Number of years fishing in area
Vessel Information	Vessel details	Name and PLN number
	Length	Overall vessel length
	Age of Boat	Year it was built
	Vessel years fishing	Years fishing with this vessel. Also collected information on past boats.
	Power	Engine kW or horse power. Optimal cruising speed.
	Home and Landing Port	Home port and landing or destination port(s)

	Crew	Average number of crew including skipper
	Fuel	Fuel type, amount used in average trip between summer and winter, price changes. Other and amount of other fuel derivatives used (E.g. refrigeration, lubricant, engine and hydraulic oils).
Fishermen's Ecological Knowledge (FEK)	Gear type	Gear type and parameters e.g. mesh size, creel size, soft or hard eyes.
	Length of trips	How long a typical fishing trip lasts.
	Number of creels	Number of creels in the water
	Species	Species targeted currently and historically
	Effort/ Intensity	Amount of gear hauled per day, soak times, placement of gear.
	Other gear	Quantities of other gear such as fish boxes, keep boxes/nets, rope, net, weights etc. How often these are replaced, and costs associated.
	Bait	Type of fish, bought, price, time spent fishing.
	Seasonality	Months in which fishing takes place for each species. Timing of biological influences such as presence of berries, moulting, spatting, undersized, landing weights etc.
	Fishing Area	Areas and days per area is fished for. Percentage annual vessel earning.
	Historic Fishing Area	Areas which used to be fished or areas in decline
	Subsea characteristics	Areas which is preferred for species. Areas which influence fishing patterns.
	Connection to home ports	Max travel distance in a day
	Characteristics of grounds in area	Nursery grounds, seasonal movement, fishing pressure.
	Environmental conditions	Sea temp, depth, tide, wind intensity and direction and wrecks.
	Biological Condition	Health of fishing area and change over time.

	Fishing Prices	Fishing prices throughout season for species and comparison to past.
	Conflict	Gear conflict, other working users, tourism, marine traffic.
Fishing Opinions	Costs	How do you attempt to reduce costs associated with fishing?
	Gear Reduction	Reduction in the amount of gear as a management measure.
	Seasonal Closures	Closure on species at certain times of year.
	Licences	Changes to licences for the ability to catch fish.
	Diversification	Current limitations to diversification of the inshore fishery.

3.2 Landing data

Landing data was analysed in conjunction with estimates given during interviews. Landing data was collected from those boats which land to the Orkney Fishermen's Society. The data analysed includes Brown, Velvet and Green crabs, Lobster, Scallops and prawns landed by Orkney boats from a variety of port locations. The number of boats fishing throughout this time also varies with people either changing the species they fish for, leaving the industry or changing the processor to whom they choose to land to. The number of boats fishing landing prawns was 3, 9 scallop boats, 18 for Greens, 50 for Velvets, 49 for Brown and 51 for lobsters.

3.3 Observer trips

Observer trips were conducted on a wide variety of Orkney fishing boats to gain better understanding of the fishing industry in Orkney waters. Observer trips are essential for informing on practice in the real-time environment and providing interactions with fishermen in an informal context. These trips allowed for the building of relationships and trust to collect sensitive data that was necessary for this project.

During these trips first-hand biological data was gathered on a variety of shellfish and whitefish species on a range of boat sizes and fishing areas within Orkney. Catch per unit effort (CPUE) was investigated per boat and will be compared throughout the seasons to reflect fishing patterns. Other data collected included bait preference for target species, number of creels and lines sampled per trip and other biological data which was useful. Sampling methods followed that which was carried out by Marine Scotland.

Creel boat shellfish measurements investigated Brown Crabs, Velvet Crabs and Green Crabs. CPUE was investigated by recording the amount of crab per creel and how this is sorted. For example, how many of each species is kept, discarded (small/ soft crab), amount of bycatch. Crabs which were discarded because they were too small were measured for carapace width and size frequency. Landed crabs were also measured for carapace width size frequency to determine landing per unit effort (LUPE). Lobsters were also measured and recorded in the same manner as described above.

Scallop measurements on dive boats included; morphometric (CW, carapace height, carapace depth, age, condition), dive frequency and time, location, landing size frequency and weights. On dredgers information collected also included dredging time, location and amount collected per dredge.

Prawn's morphometric measurements collected include sex, carapace length, claw depth, claw length, claw width, overall length, tail length, abdominal width.

4. Results

4.1 Tidal Movement

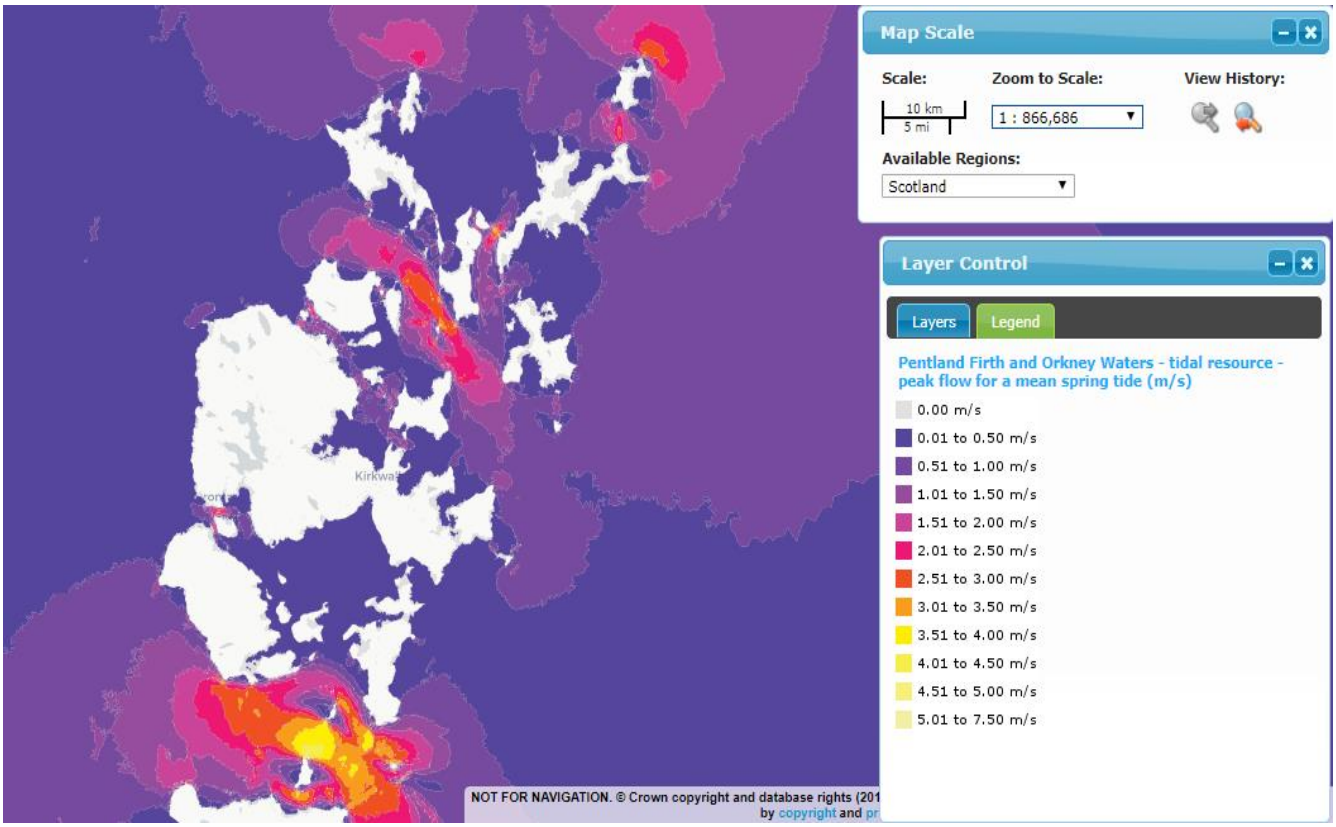


Figure 4. Pentland Firth and Orkney waters, peak flow for a mean spring tide (m/s), adapted from Marine Scotland Maps NMPi.

Tide and weather affect the whole aspect of inshore fishing around Orkney and fishermen report it as the biggest influence in fishing (Figure 4). The tidal range for Orkney is relatively small, no more than three meters, but the strength of the current is probably one of the strongest in the UK and can frequently reach over eight knots. Not only does this affect the routes taken when fishing it also influences fishing activity especially when gear is hauled. In general, the main tidal stream on the flood runs east and the ebb runs west, with many deviations and regional difference amongst the isles. This makes fishing in Orkney highly dynamic but also requires local knowledge built up over a long period of time to understand how to fish these waters effectively. This is clearly demonstrated in Appendix figure 1 whereby the tidal flow can be seen to change in the hours before and after high tide and operates in an irregular fashion around the North Isles. Therefore, fishermen need to have extensive temporal knowledge of the areas that they fish to fish efficiently.

Spring tides usually occur with the new moon or during a full moon and influence fishing patterns. Spring tides result in the largest difference between the high water and low water, increasing access to areas of land previously unreachable during low tides. Due to the large difference in water levels, leaving gear at sea can become more difficult as buoys can become submerged and difficult to locate.

Current speed is slowest at the beginning and the end of a change in tide and accelerates as the water's levels rise or falls. This movement influences the daily fishing activity on when and where creels will be hauled and the travel time and route to the creels' position (Figure 4). As seen in Figure 4, those fishing from Westray to the Stronsay Firth, down the south tip of Eday will face up to 3.51 to 4.00m/s at peak flow for a mean spring tide as water is funnelled between the islands. One of the largest peak flow areas occurs in the Pentland Firth along the south coasts of Hoy and South Ronaldsay. In this area mean spring tide in the middle of the Pentland Firth can reach up to 4.51-5.00m/s, making it a highly challenging area to fish and travel in. Sheltered areas for fishing in Spring tides include Scapa flow, the North Sound, and along most eastern coastlines in Orkney.

4.2 Vessel Density

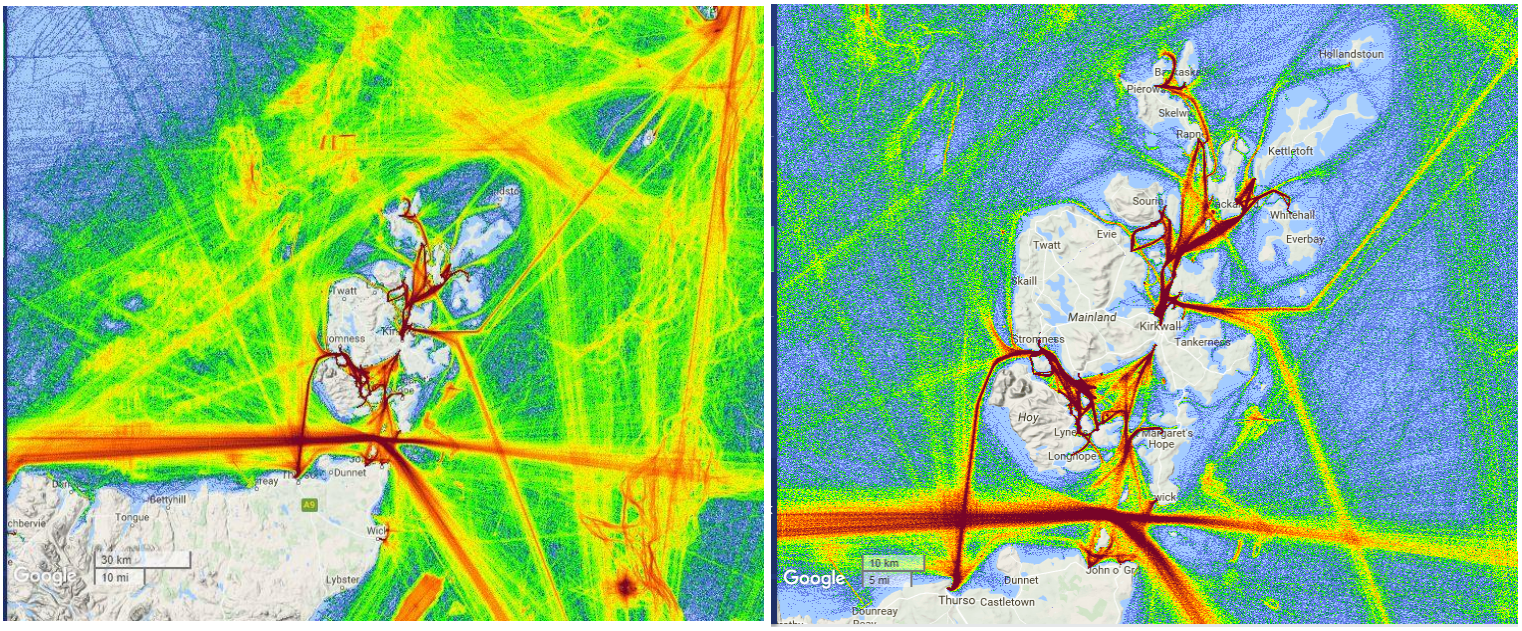


Figure 5. Vessel density (right) and Vessel density shipping routes (left) for 2016 in Orkney using AIS track analysis, adapted from Marine Traffic.

Orkney and the surrounding waters are busy with a range of vessel types which routinely operate and pass through Orkney due to its geographical position in dividing the North Sea and Atlantic Ocean (Figure 5). In Marine Scotland's 2012 Shipping report of the Pentland Firth and Orkney waters, they reported seven vessel types operating within this area. These include tankers (oil/ chemical/gas carrier), bulk/ore carrier, cargo (including RoRo/container vessels), passenger (ferry and cruise ship), offshore (oil and gas and renewables support vessels), tugs and other vessels which were usually transitioning between harbours.

Four passenger ships operate between the Scottish Mainland and Orkney. These include Pentland Ferries' *Pentalina* (operating between Gills Bay and St Margaret's Hope), Serco NorthLink's *Hamnavoe* (Scrabster to Stromness) and *Hjaltland* and *Hrossey* (Aberdeen/Kirkwall/Lerwick route) (Marine Scotland, 2012). A further eight vessels are regular passenger ships servicing as the inter-islands ferries

to the North and South Isles, mainly operating out of Kirkwall, Tingwall and Houton. These passenger ferries operate with very defined tracks and ports of call. This helps make fishing within these routes easier due to routine and known timetables of transport.

The Pentland Firth can be seen to operate as a major shipping route for many vessels transiting east/west through this area (Marine Scotland, 2012). Scapa Flow is another area which operates with high volumes of traffic, servicing mainly for tankers which routinely call at Flotta Oil Terminal, Scapa Bay, Scrabster and Kirkwall. This further adds traffic through Scapa Flow and the Pentland Firth.

Most fishermen commented on having almost no negative interaction with marine traffic or users. As fishermen tend to fish in an inshore capacity with smaller boats, right of way is given to those vessels which are larger. The majority of conflict as sea originates from conflict over gear with trawlers and scallop dredgers operating to the east of Orkney.

4.3 Historic Fishing Activity

In the last century the fishing pattern and activity within Orkney has changed significantly due to many socio, economic and biological factors. Fishing in Orkney has moved away from the fishing and farming lifestyle and is more exclusively one or the other. In the time before WWII, fishing enterprises were more of a part-time activity prosecuted during the summer months to supplement diet through the catching of fish. Most fish were either smoked or salted in barrels such as herring or mackerel in order to last throughout the winter months. Fishing, at this time was exclusively targeted towards lobsters with the use of wooden creels. Most of these creels were made by hand and creel making was a winter time activity as boats were smaller and less durable for operation in rougher weather. This resulted in a seasonal fishery whereby fishing occurred between May and October, leaving lobsters and their fishing grounds to rest during the winter months.

As most fishermen had to hand make their wooden creels, which was both labour intensive and time consuming, the creels were therefore looked after. The fragility of these creels meant that gear was shifted to safe areas more routinely. The number of creels used to fish were much less at this time too, with an estimate of no more than 100 creels used per fishermen. Fishermen today have attributed the decline in fishing to the development of ready-to-order steel creels. These creels are more robust, have a longer lifespan and can be placed in deeper, rougher water without being lost or broken as easily as wooden creels. This has resulted in more time spent fishing as time wasn't needed to make creels and the lobster fishing areas that were previously unfished are now used.

Fishing for lobster during this time was lucrative as they were abundant and easy to catch in inshore waters. There was also no market for the fishing of other shellfish such as Browns or Velvets, the development of these fisheries came later with the creation of factories and the opening of markets in Europe. However, during WWII many fishermen left fishing to join the army resulting in a decrease in fishing effort during this time. Therefore, fishing grounds were rested and fishermen today hypothesise that this helped contribute to the longevity of the lobster fishery, until it became more heavily fished towards the 1970's. At the peak of the lobster fishing, fishermen have commented being able to turn over gear once or even twice a day and retrieve up to on average 30 to 40 lobsters a day during the harvest run.

The development of the processing factory in Stromness in 1953 and in Westray during the 1970's opened up the fishery to the catching of Brown crab then Velvets. Before the factories' establishment shellfish was exported as freight to Scrabster, then by train to Billingsgate, to access markets in Europe such as France, Spain and Portugal. Fishermen attribute this change to the increased drive to fish for species other than lobsters, which had been becoming increasingly more difficult to fish.

Further fishing activities have developed the scallop fishing for King Scallops in Orkney which is conducted through two methods; hand-picked diving or dredging, while Queenies are mainly fished for using dredges. Dredging activity is limited to 8 dredges per side within 6nm, 10 dredges per side out to 12nm and 14 per side out to 200nm. Hand diving is a highly selective method of scallop collection as large individuals are selected on the ground with little disturbance to the benthos and no current restrictions except MLS affects this fishing method.

4.4 Fishermen's Ecological Knowledge

4.4.1 Brown Crab

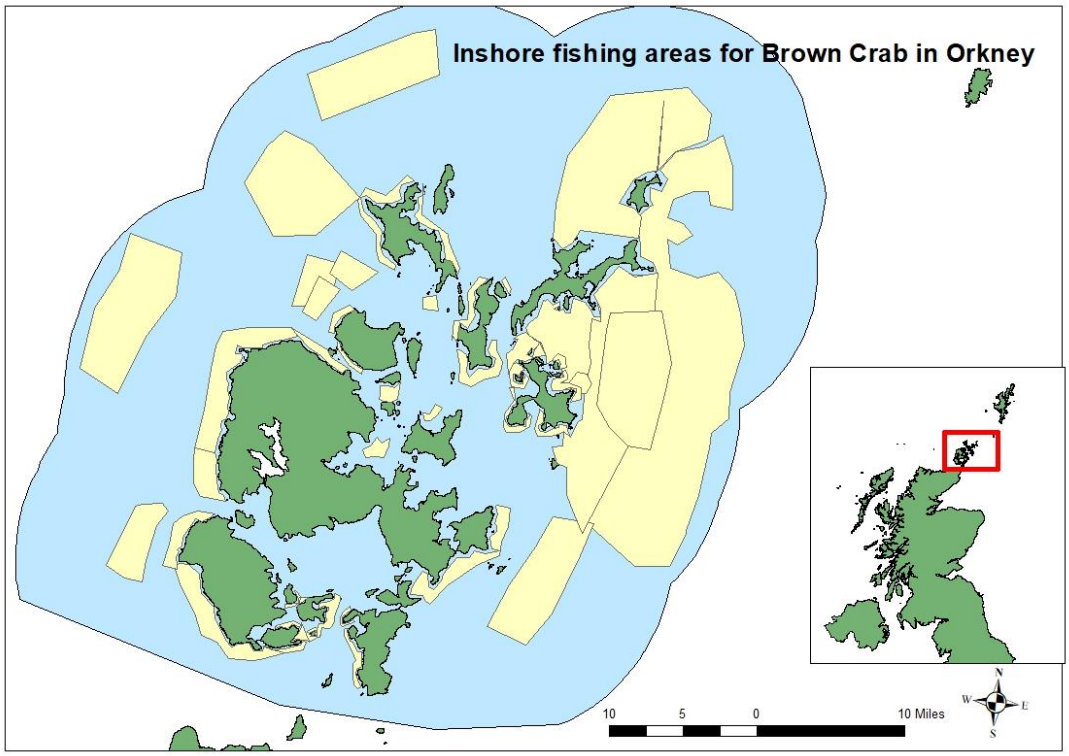


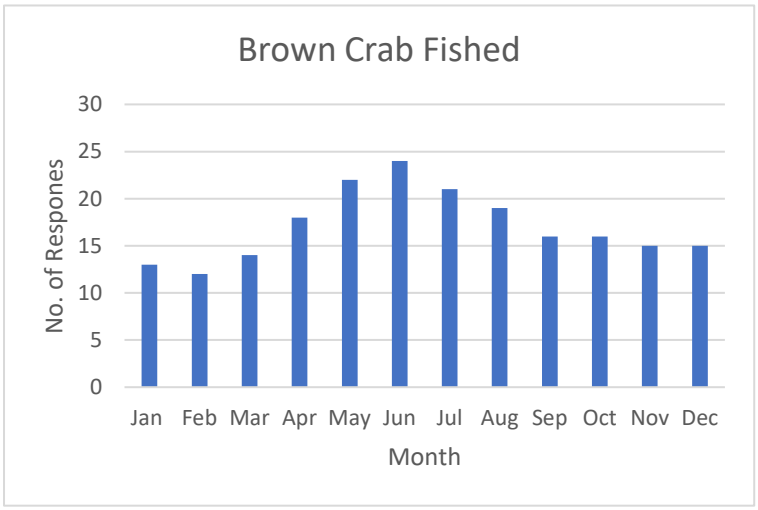
Figure 6. Fishers ecological knowledge of inshore fishing areas for Brown Crab in Orkney.

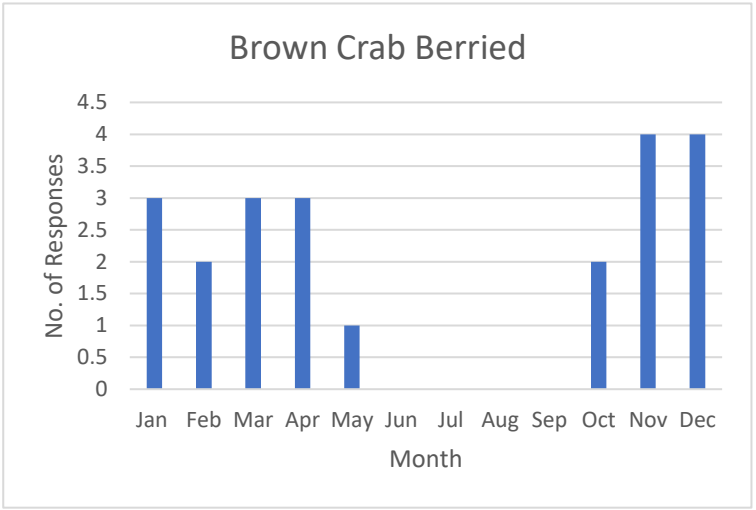
Fishing for Brown crab in Orkney operates extensively around the coastline from very close inshore up to roughly 50 fathoms depth. Inshore fishing areas used throughout the year can be seen in figure 6. Brown crabs are found in a wide range of substrate but are typically found on rocky to mixed sediment/sand environment which is oxygenated and often tidal. Fishermen report that female Brown crabs often prefer sediment in which they can bury when soft or when berried. Fishermen also reported that a higher rate of male brown crabs are caught inshore in comparison to females which tend to be found in water deeper than 20 fathoms.

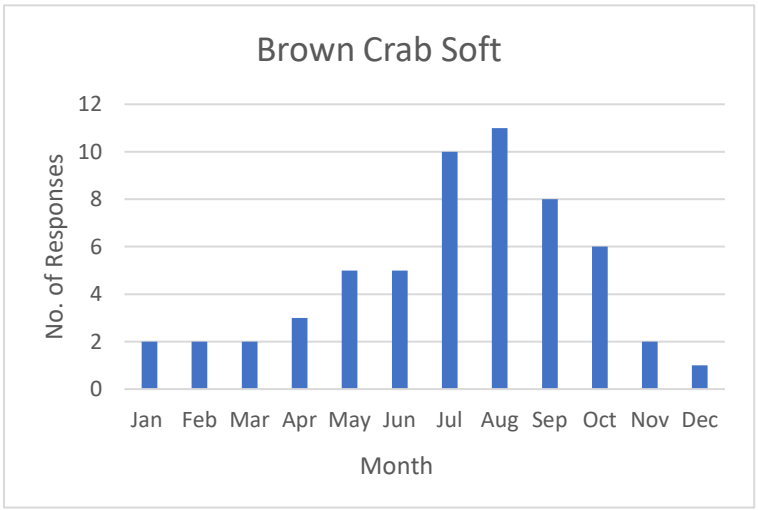
While fishing for Brown crab can occur in close to the shore, those that benefit from this fishery tend to have larger boats which can get out to deeper water areas where they are found more readily. This is usually associated with boats above 10 meters.

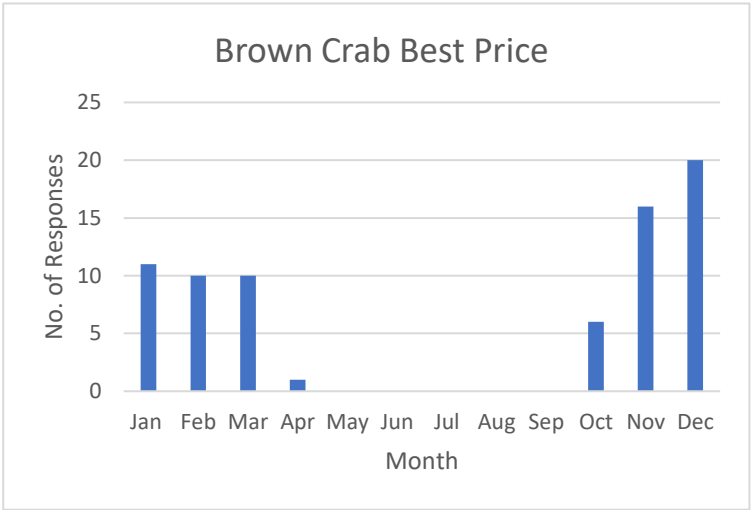
Undersized Brown crabs were described in abundance by most fishermen as mainly close inshore and regional rather than seasonal. However, fishermen often found an increase in undersized juvenile Brown crabs on sandy bottom environments in areas such as the Bay of Skaill.

Migration in Brown crabs was uncertain, but those fishermen on the west coast of the mainland reported that they understand they migrate North to South towards Scapa Flow throughout the course of the year with usually only the female Brown crabs migrating. Similar reports were found on the East coast of the North Isles in Orkney. During May to August, Brown crabs can primarily be found in the North Ronaldsay Firth and round the north of Sanday. However during December to March they migrate further south continuing down to Stronsay.









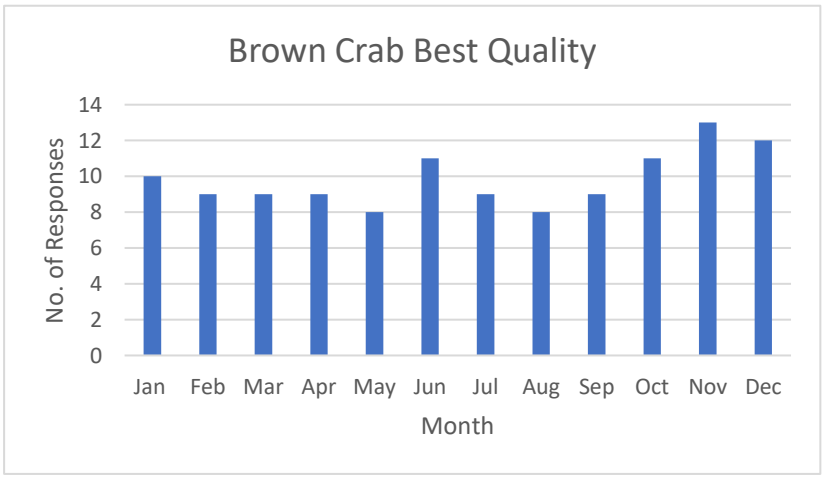


Figure 7. Fishermen's ecological knowledge responses to Brown crab fishing times, presence of berries, soft shell condition, best market price and best quality on average throughout a year.

Fishing activity reported by fishermen can be seen to increase within the summer months of May, June and July (Figure 7). This is generally associated with better, more stable weather and longer hours of daylight which contributes to more fishing and the ability to reach Brown crab fishing areas which are further from ports. Fishing activity during the summer also increases due to a seasonal influence as in colder water temperatures, Brown crabs enter a state of torpor. Fishing for Brown crab will therefore start inshore in the earlier months of summer as the deeper water offshore will take longer to increase in temperature. However, fishermen throughout Orkney have described a slow decline in the presence of Brown crab within the inshore sector (inside 6nm) and an increase in effort to land the same volumes of Brown crab within the past decade.

Berried females were poorly reported among inshore fishermen but those that had caught them saw them more throughout October to May. Fishermen described the lack of catching berried females as due to their behaviour and movement. They advised that it is likely that females migrate further offshore to brood their eggs therefore they are unlikely to catch them close to shore. When the females are berried they are also less likely to be caught in creels as during this time in order to protect their eggs, they bury into soft sediment and become inactive during this time.

'Soft crabs' refers to crabs which have recently moulted their old carapace and are still soft along with an associated decrease in meat quantity. They are also referred to as 'white crab' as the colour of the underside varies during the moult cycle with newly moulted crabs being white or pale in colour. These were mostly reported during July, August and September. Fishermen hypothesise that the moulting cycle coincides with warmer water temperatures which act as a trigger. 'Brown crab quality', refers to the overall condition of the crabs with high meat yield and not recently cast (soft). Better quality crabs were usually landed in the winter months of October, November and December.

Fishermen found that they could get the best prices for their Brown crabs during the winter months. They explained that this is mainly associated with supply and demand. Demand increased during November and December for the Christmas markets but also due to less people out fishing mainly associated with poorer weather. Whereas during summer, more fishermen are out fishing and thus landing more crabs which often which floods the markets and results in a fall in price. Fishermen describe the price for Brown crabs to be on average £2 to £3 per kilogram, with a higher buying price for crabs which have their claws cut. Brown crab prices have been as low as £1 per kilogram for females and £1.20 for males in the summer months and only increasing to £1.80 and £2.20 in the winter months. Currently, newer markets have been established with China which has increased demand for live crabs to be shipped to China, mainly for female crabs. This has had a positive impact on prices, resulting in higher prices of up to £5-6 per kilogram.

4.4.2 Lobster

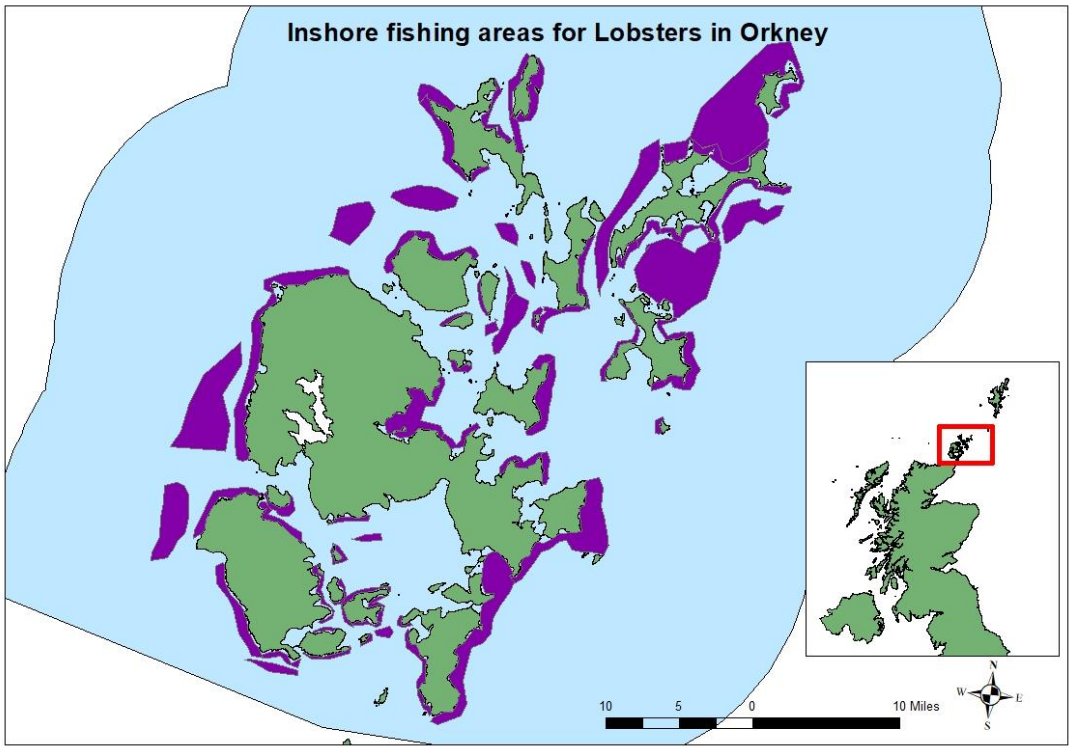
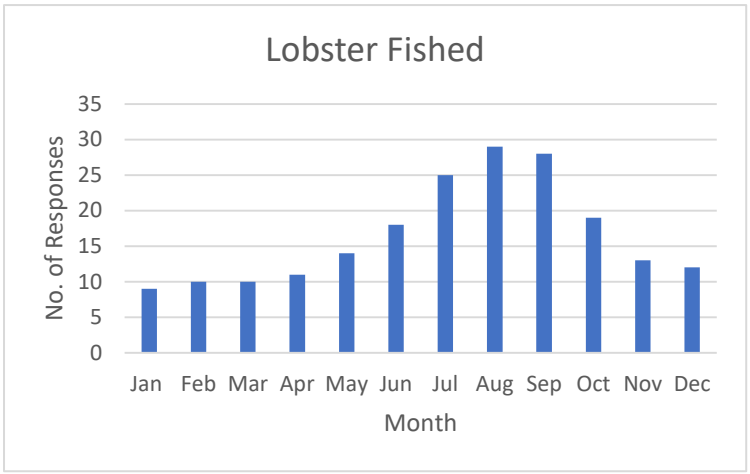
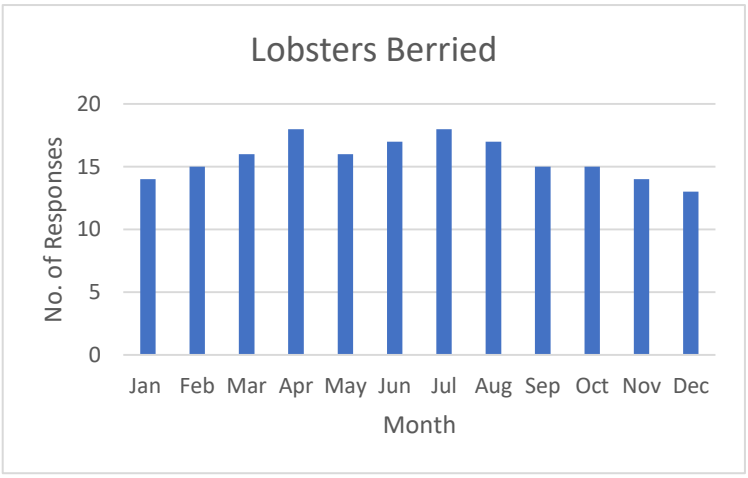


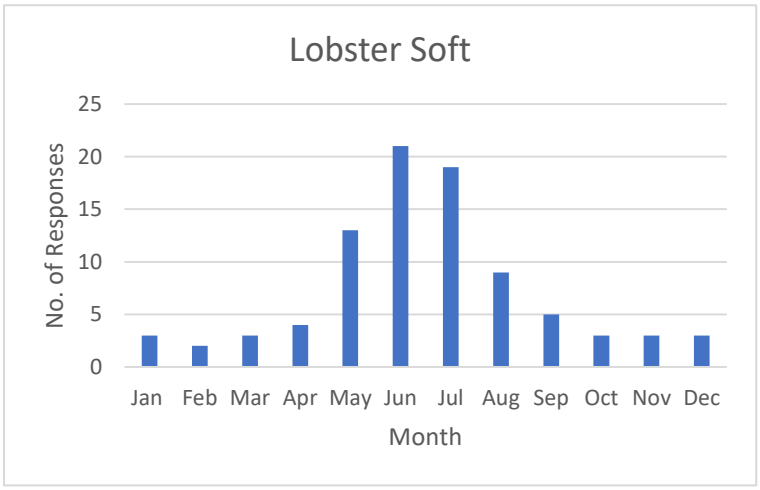
Figure 8. Fishers ecological knowledge of inshore fishing areas for Lobster in Orkney.

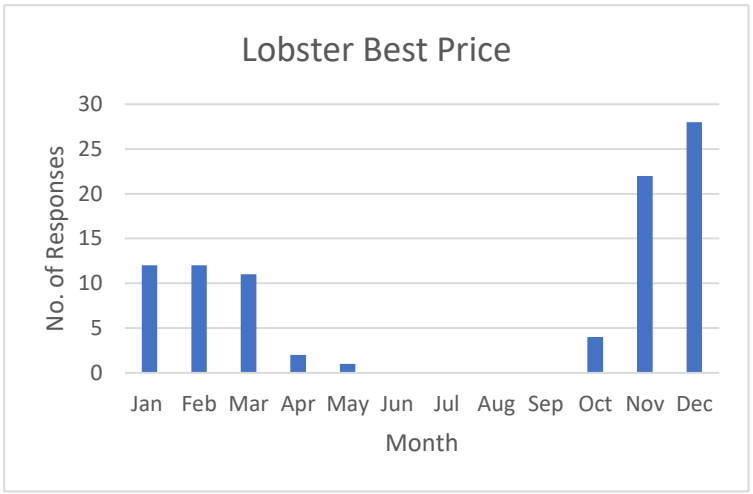
Lobster fishing in Orkney (Figure 8) is carried out in very similar fishing grounds to Brown crab (Figure 6). Lobsters can be found on very shallow inshore grounds, operating at a depth of 5 meters up to 50 meters and are usually found on rocky terrain. Brown crabs and lobsters are more commonly found in areas of good water movement providing rich oxygenated water and a plentiful supply of food. Fishermen also report no marked difference in the ratio of males: females caught. Undersized lobsters are routinely seen within certain fishing areas within Orkney. However, fishermen believe that these juvenile lobsters will not remain in their original nursery grounds as they do not catch them as subsequent adults within the same area. It is understood that the adults will migrate from the inshore to offshore environment with females migrating rather than males. Local fishermen also report lobsters possibly holding territories as the same notched lobster can be caught continuously within the same area.

As previously highlighted the fishing activity for lobsters has changed significantly over the past 50 years. Originally most fishing in Orkney was solely for lobsters and fishing was highly seasonal from May to October. Now very few that aren't hobby fishermen fish exclusively for lobster as the abundance of the species is not there to generate a sufficient income from landings.









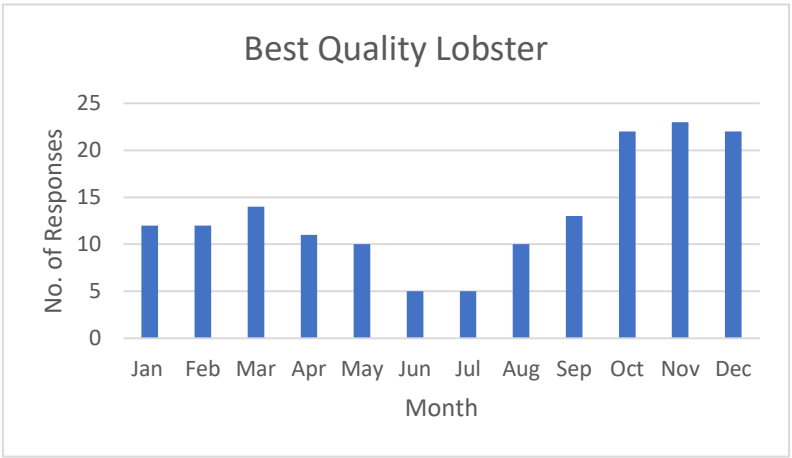


Figure 9. Fishermen's ecological knowledge responses to Lobster fishing times, presence of berries, soft shell condition, best market price and best quality on average throughout a year.

Fishing activity for lobster does occur throughout the whole year but can be seen to increase significantly during the months of July, August and September (Figure 9). Fishermen in Orkney target lobsters during these months as it is referred to as the 'harvest run'. During this period lobsters are highly active on the sea floor and are therefore more likely to be caught. Increased activity level is associated with the recent casting of exoskeletons, which can be seen to occur on average from May to July. After the lobsters have shed their shell increased activity is thought to be related to the

lobsters looking for a mate and the replenishment of energy levels through increased feeding, resulting in more being attracted to bait in creels.

Again, like Brown crabs, fishermen believe that the casting of shells is linked to the warming water temperatures in the summer. Unlike the Brown crab, lobsters have no distinct season for carrying their berries as they can be found throughout the whole year, largely due to the brooding period of these eggs to be ten to eleven months.

The price for lobsters is highest during the months of November and December (Figure 9) and again, similar to Brown crabs the price for this species reduces during the summer period. This is linked to an increase in demand for these lobsters during the festive Christmas period and reduced supply due to poorer weather conditions restricting fishing. The price fishermen can achieve for lobsters is currently between £23 and £25 per kilogram during the peak winter season. During the summer months, the price of lobster significantly declines with lobsters only generating on average £8 to £12 per kilogram. Unlike Brown crab there is no difference in price compared to landed males and females.

The best quality lobsters are similar to Brown crab and are caught in the winter months. These individuals are hard in shell quality, with good meat yield and well sized above the MLS which is conducive to in receiving a better price for these individuals.

4.4.3 Velvet Crab

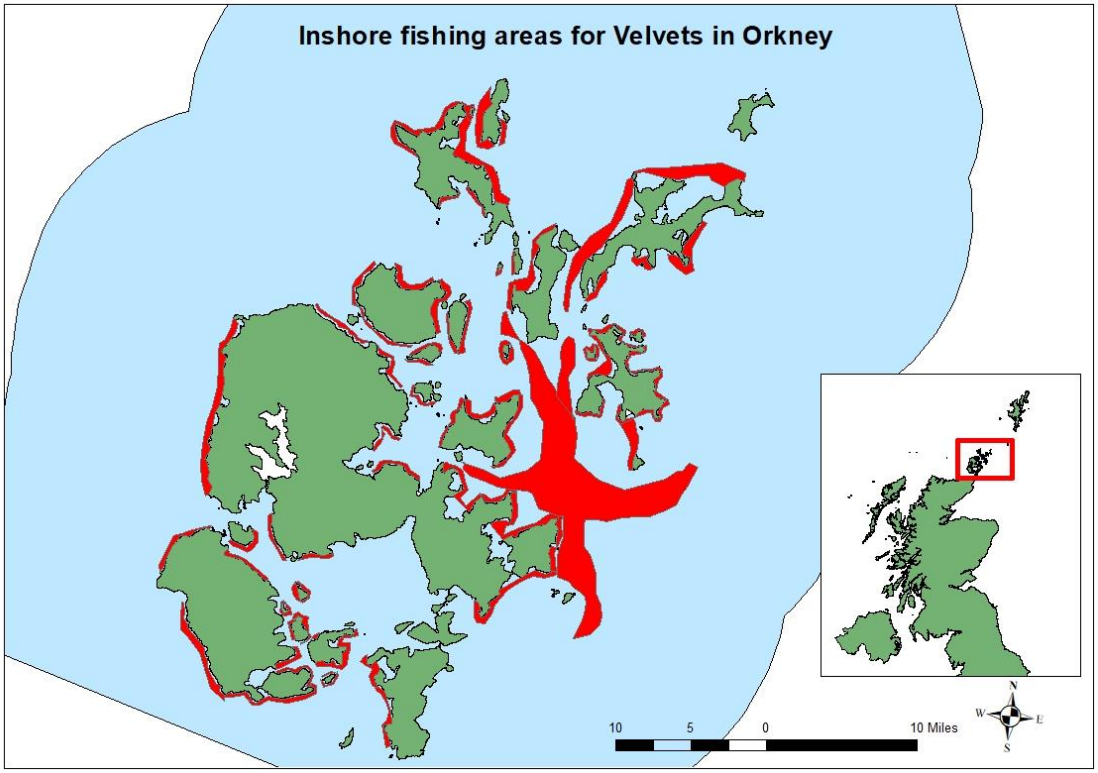
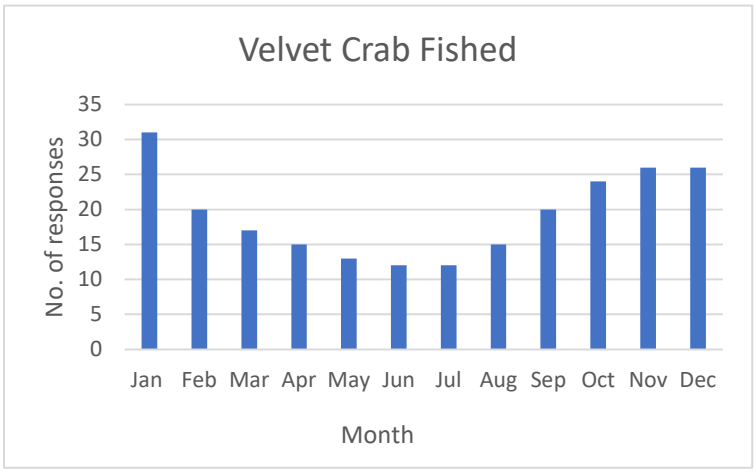
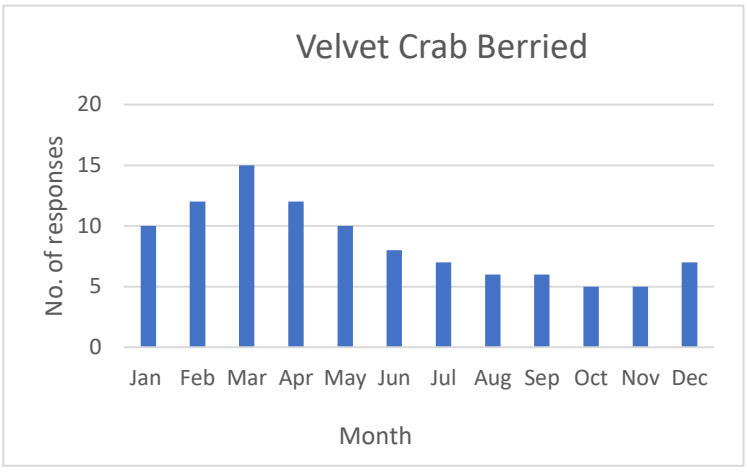


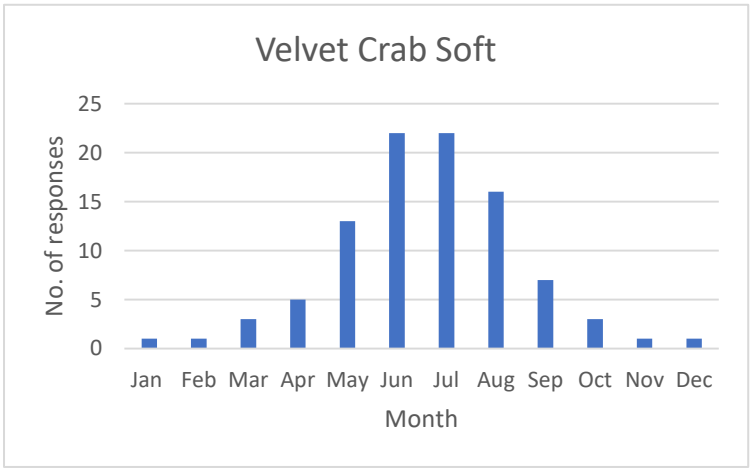
Figure 10. Fishers ecological knowledge of inshore fishing areas for velvets in Orkney.

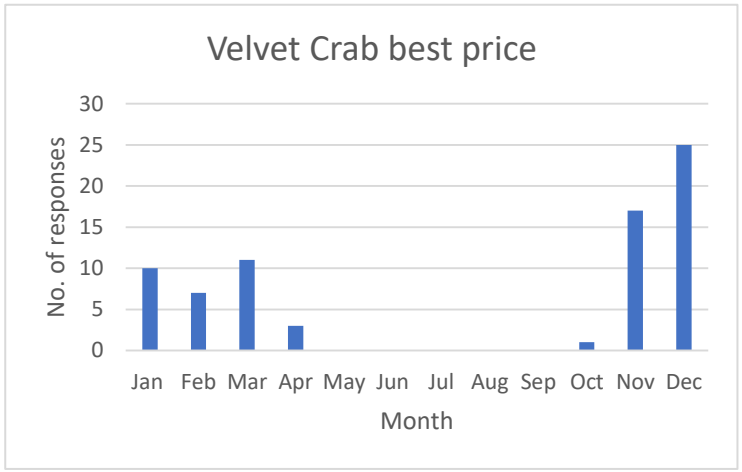
Velvets are dominant around the majority of the coastline within the mainland and isles (Figure 10). Fishing for Velvets around Orkney operates on similar to ground which lobsters are found. (Figure 8). These swimming crabs are routinely found on rocky ground and mixed sediment, mainly characterised by a covering of rocks and kelp used as cover for protection.

Fishermen report good fishing for Velvets in areas of good tidal movement where they are found on the edge of the tide. This can be seen in the Stronsay Firth (Figure 4.) where water flow is funnelled between the islands. This area was a good fishing area from 2009-2012 at a depth of 10 to 30 fathoms which resulted in the area becoming routinely targeted throughout the year. However, this area has experienced a decline in relative abundance of Velvets. This area has now reduced in size and abundance with the existing Velvet fishery being confined to 2- 15 fathom in areas north of Shapinsay, Green Holms, East of the Wide Firth and areas of Sanday such as Hack Ness, Spur Ness and Holm of Elness. Consensus amongst fishermen that use this area attribute the decline to increased fishing pressure on the fishing area throughout the whole year. Decline in Velvets in the Stronsay Firth is also thought to be linked to heavy south east weather in 2011/2012 which may have impacted on Velvet breeding performance.









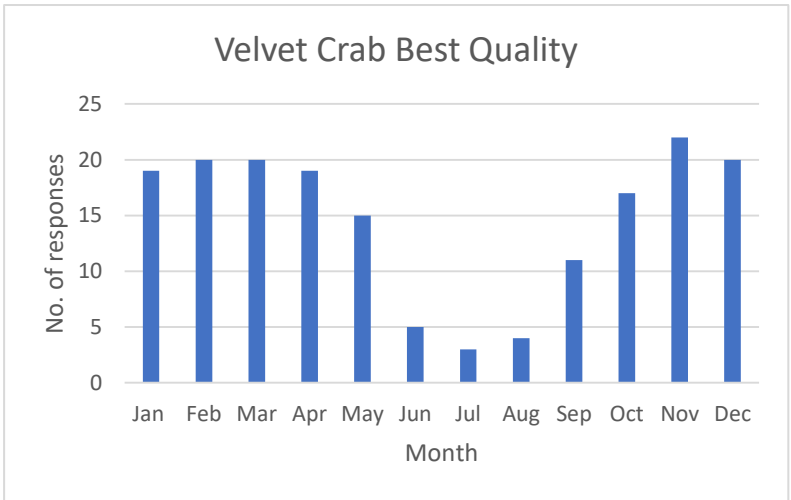


Figure 11. Fishermen's ecological knowledge responses to Velvet crab fishing times, presence of berries, soft shell condition, best market price and best quality on average throughout a year.

Velvet fishing is mainly active during the winter months which starts to increase in September until March (Figure 11). As these species are found in shallow depths this allows the fishermen easy access during the winter time as they do not have to steam to offshore locations to fish for them. They can stay within short distances from their landing ports and within relatively sheltered fishing areas. This is beneficial during the winter time as it provides an income when Brown crab is less fished and allows shorter journey times away from port which works in conjunction with shorter day lengths and poorer weather.

Moulting in Velvet crabs can be seen to happen between May and August time with early individuals casting in April and lasting until September (Figure 11). Females are found to cast after the males which may be the individuals which are casting during April. Casting of carapace is conducted through the summer months in concurrence with increase in water temperature. When Velvets are soft they are subject to high mortality and therefore don't handle well during catching, landing and transportation. If caught during the summer they are put under more stress due to exposure to light, heat differential and longer time out of water as a result of increased fishing hours during summer. This in turn feeds into an increased mortality rate along with poor handling practice as they can often die when placed on their backs.

The presence of berries in Velvets is seen throughout the whole year but the main months are from February to April from where 'berried' declines gradually throughout the year (Figure 11). Fishermen report the seasonality of berries being more distinct as they would not have been seen throughout July to October. But they have seen the timing for this becoming less distinct and defined.

Best quality Velvets are fished during the winter months and decline significantly in June to August. This is in conjunction with the casting of shells during the summer months and represents their poorer meat yield quality and their increased mortality rates.

Best price for Velvets again occurs during the winter months of November and December, again related to supply and demand for these crabs during the festive period and reduced fishing effort in winter. Poorest prices are seen during the summer months when they can reach as low as £2 per kilogram and is associated with a decline in quality during these months along with higher mortality rates post landing. On average throughout the year velvet crab prices range between £4 to £5 per kilogram.

Since the development of the Velvet fishery in the 1980's which initially was prosperous, in the last decade many fishermen have commented on a decline of these crabs. One fisherman commented that originally 300 creels for one week's fishing could land 300kg, now landings would be around only 70-80kg of velvets resulting in 0.2kg on average per creel compared to 1 kg originally. This trend is not abnormal as another fisherman in a different area in Orkney recalls that fishing with 100 creels could catch 2 boxes (40kg) of velvets in 2008/2009 in two days' worth of fishing. Now for the same effort the creels would only catch half this amount of Velvet crabs within the same area of Kirkwall Bay. For a fisherman working off the east coast of Orkney and Stronsay, similar trends have been noted. In the late 1980's for this area 200 creels could land 400kgs, on average 2 kilo per day per creel at the peak of velvet fishing season, usually January/ December. Now 200 creels would land on average only 20 to 30 kg, roughly half a kilogram per creel.

4.4.4 Scallops and Queenies

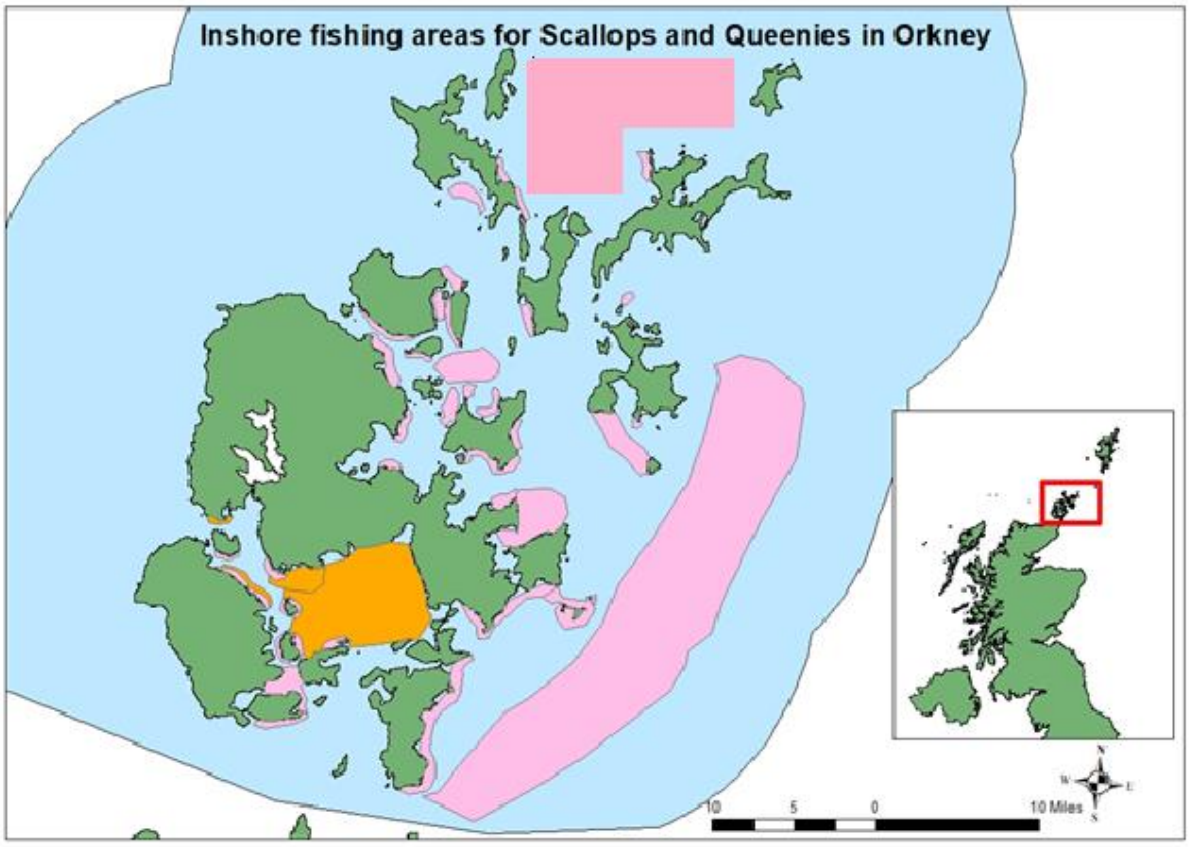


Figure 12. Fishers ecological knowledge of inshore fishing areas for King Scallops (pink) and Queenies (orange) in Orkney.

Scallop fishing for King Scallops in Orkney is conducted through two methods; hand-picked diving or dredging while Queenies are mainly fished for using dredges (Figure 12). Diving for scallops takes places in a depth of 20 meters or less in winter and on average 40 to 42 meters in summer. Some of the deepest depths dived is 52 meters in South Ronaldsay (Figure 12). The North Sound is also a significant scallop site for dredging activities. On average per crew two to three dives are conducted on average per day, with dives lasting between 60 to 90 minutes. King scallops are found on a mix of habitats including sand, gravel and mud which provides a suitable habitat in which to bury. They are usually found on sloping gradients in areas of good current flow which provides food and clean oxygenated water. Hand diving is a year-round activity with on average 15 days a month of fishing trips. This reduces in the winter due to weather and shorter dives due to shorter day light and colder sea temperatures. But diving in the winter can be easier and more lucrative due to better visibility and less seaweed and algae present which in turn allows the scallops to be collected more easily.

The areas in which hand-picked diving takes place is highly isolated and fragmented with very little connectivity between commonly used fishing dive sites (Figure 12). However, the areas that are used are highly dynamic and constantly changing. The Galt Skerry is described as a highly reliable area of fishing with good tidal movement. It was heavily dredged six to eight years ago, yet the area remains healthy in abundance. Yet some areas do not recover as easily, as an area of the west side of Shapinsay which had a 3- month period of good scallop fishing but after which did not recover. Nevertheless, recruitment within the King scallop population is described as good and fast acting with areas quick to recover and recolonize.

The south east of Shapinsay is another dive site in which scallop abundance can increase after a period of large swells and poor weather (Figure 12). However, if an area is too exposed to tidal movement, such as Gairsay, scallops within this area do not thrive due to too much motion. This was seen in the Shapinsay and Auskerry sounds where a spell of SE weather changed the benthos environment which resulted in the scallops within the area being buried by sand and gravel suffocating them as they were not able to move away in time.

Many of the areas on the maps vary in the length of time they can be fished. Some areas may generate a couple weeks of fishing, others months. On average fishing in Scapa Flow can be sustained for five months. The Galt again is another reliable area as it an area which can sustain months of work however some fishermen only select to fish this area in poorer times of fishing. Areas around Westray are reliable enough to be fished for a week on and off at a time.

The main port of departure on the East mainland is Kirkwall and the West Stromness. Divers also operate from South Ronaldsay from Burray, St. Margaret's Hope and Burwick. Fishing areas furthest away from home ports are mainly fished throughout the summer months due to longer day light hours, allowing for more travelling time.

Scallop dredging mainly operates offshore on the East side of Orkney. This is a popular area which attracts many 'foreign' boats (those not local to Orkney) with vessels reported having travelled from the east coast of Scotland and south east of England. As a result, this area is reported as being heavily dredged resulting in a negative change to the benthos. However, given this fishing activity has been carried out within this area frequently for the past 15 years, rejuvenation is thought to have occurred. Local fishermen estimate that it takes on average 5 years for an area to recover once it has been dredged.

In every dive site, generally a mix of sized scallops can be found. However, some nursery areas have been noted within the Eynhallow sound and within the Gault area. It is thought that these small scallops will migrate when they are young as within these areas fewer larger adults are found.

Scallop prices are currently estimated at £2.70 (small)/£3.70 (large) per kilo and have remained high all year around. Prices were lower in 2008 as a result of the financial crash with prices being as low as £3 per kilo. This caused some uncertainty during this time as if prices remained this low fishing for scallops would have become uneconomical due to increasing fuel prices. Scallops generally retain a high price all year round, mainly due to the ability to dive for this species all year round and the species is not as limited in its biological seasonality compared to crab which cast their exoskeleton.

Queenies are primarily caught through dredge fishing. The main fishing areas for these species occurs within Scapa Flow and Hoxa sound, the coastline NE of Hoy and from Orphir to Scapa. These species can be found primarily on muddy to gravel substrate in which they can easily bury. Fishing for these species is only conducted from on average three vessels within Orkney. Prices for Queenies are on average £1.25 per kilo and are landed at a significantly higher size than their legal MLS.

4.4.5 Whelks

Whelks (*Buccinum undatum*), known locally as 'Buckies' are fished for using whelk pots. This fishery is only carried out by roughly six to eight boats within Orkney and is mainly confined to areas of Scapa Flow and the east side of Orkney between the North Isles. The areas fished for Buckies usually occurs on soft bottom ground ranging between 1 and 30 fathom and usually mud or silty sand. Grounds to the east of Orkney can usually be fished for a week before a decline in abundance is seen. The areas used for Buckies are often small and isolated areas with substantial distance between sites.

Boats currently fishing for Buckies target these gastropods from late winter into spring and summer, based mainly on the availability of other species. Better yields of Buckies are usually seen throughout the winter months before spawning occurs from June to August. Fishermen on the east side of Orkney will start targeting them from March to August time while those in Scapa Flow will start earlier in January. Most fishermen will stop fishing for Buckies to start to target Brown crab and lobsters. However, this fishery has been described by fishermen as a 'boom and bust' fishery with good fishing for these species lasting for roughly four years before it collapses and the returns in landings reduce, making it unviable.

Landings when this fishery is described as 'good' can reach up to four tonnes per day. On average one tonne of Buckies were recorded as an average landing weight within the first year of the start of this fishery. Prices for whelks can fluctuate from £1.20 per kilo to 80p. At the lower price of 80p this fishery can still be economical to fish if high quantities can be caught. The price for Buckies is dependent on quantity as well as quality. Undersized Whelks can be seen more often between June to August/ September months and is area dependent as this is not seen in all fishing sites. Recruitment within this fishery as described by current fishermen is slow and takes a long time before large adults are seen again following a decline in catch quantities. No landing data is currently available for this species and shipment of Buckies is by the pallet, handled by merchants and processors on the mainland.

4.4.6 Other species

Prawns (*Nephrops norvegicus)* are fished for using creel pots and trawl gear within Orkney. This fishing activity mainly occurs within Scapa Flow. Fishing for this species using pots is routinely conducted from May to December within this area with only two boats currently fishing for prawns. Trawling within the Flow is only carried out by one boat. Berried female prawns can be seen all year and most individuals cast their shells from May to August. Fishermen comment on the general greater size of prawns landed into Orkney in comparison to other areas within Scotland. Many fishermen therefore have issues in selling larger than average prawns as buyers want consistency within their products and so often reject large individuals.

Winkle (*Littorina littorea*) and dog whelk (*Nucella lapillus)* collecting is conducted on intertidal rock habitats which is characteristically affected by numerous physical variables including wave exposure, salinity, temperature and tides. Harvesting by hand of local Winkles is most successful on rocky shores during periods of the lowest tide where more of the shore is exposed. This is not a commercial enterprise and is typically conducted as either a pastime or a means to provide an additional source of income. Winkles are typically sold to local buyers such as OFS intended for personal consumption or used for bait. This is also true for the collection of razor clams (*Ensis siliqua*), known locally as 'Spoots'. Again, spoots are collected at low tide by hand on muddy to sandy beaches. Some spoots were also previously collected by some divers and through illegal electrofishing. There is some commercial diving for spoots conducted but has declined due to tighter health and safety regulations. Spring tides are the best time for the collection of spoots and winkles as the beds are uncovered by

low tides. Like winkle picking the collection of spoots is mainly a pastime and used for personal consumption or bait. This was a lucrative commercial fishery until 2014, after which widespread fishing took place and stricter regulations and controls came into force.

4.5 Seasonal timetable

Although there is no distinct fishing time as dictated through species movement or management practice, a seasonal influence does exist among the commercial inshore shellfish within Orkney. As seen in figure 13, for the three most commercial shellfish species a seasonality towards fishing efforts can be seen throughout the year based on fishermen's responses. At the beginning of the year fishing efforts are mainly concentrated on Velvet crabs and this slowly decreases throughout the year with the lowest fishing efforts for Velvets occurring during the summer months of May to July, after which Velvet fishing increases again substantially from October. As the fishing for Velvets decreases in spring and summer, the opposite can be said for the Brown crab fishery. Efforts in fishing for Brown occurs from mainly April until August and September with the peak of the Brown crab fishery happening throughout the summer months of May to July. The Lobster fishery can be seen to increase in the months of June to October which allows a period fishing in which the decline of Brown crabs occurs and before the Velvet fishing picks up.

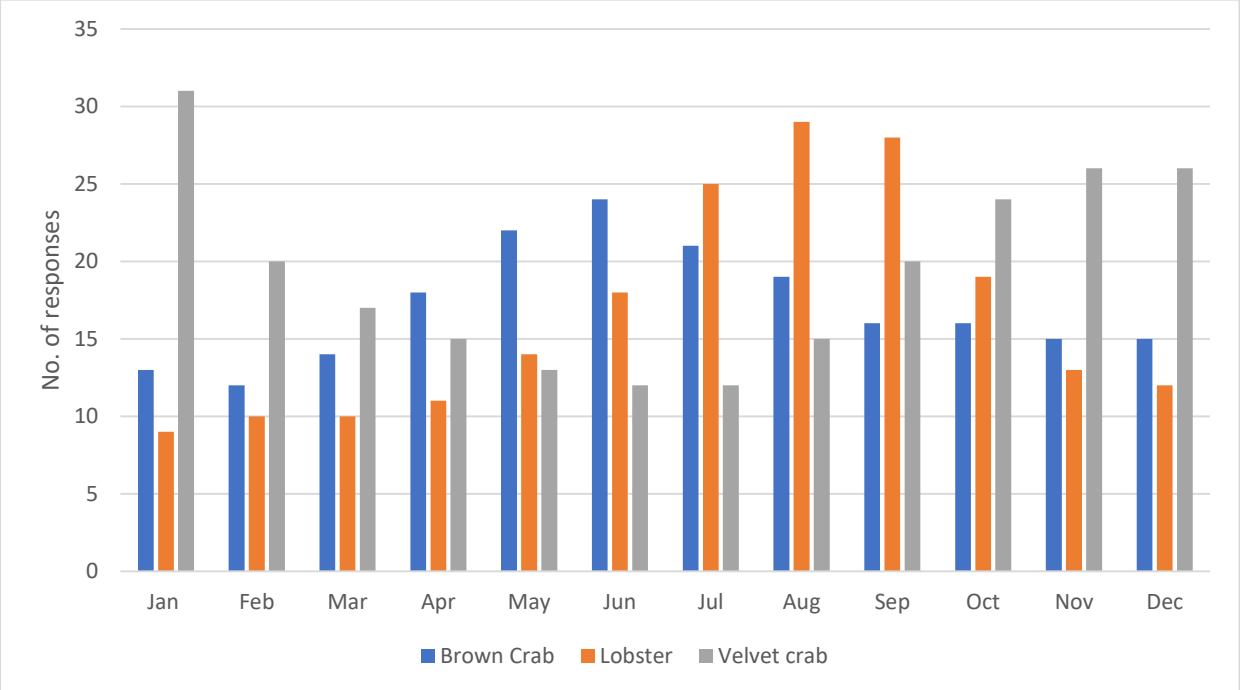
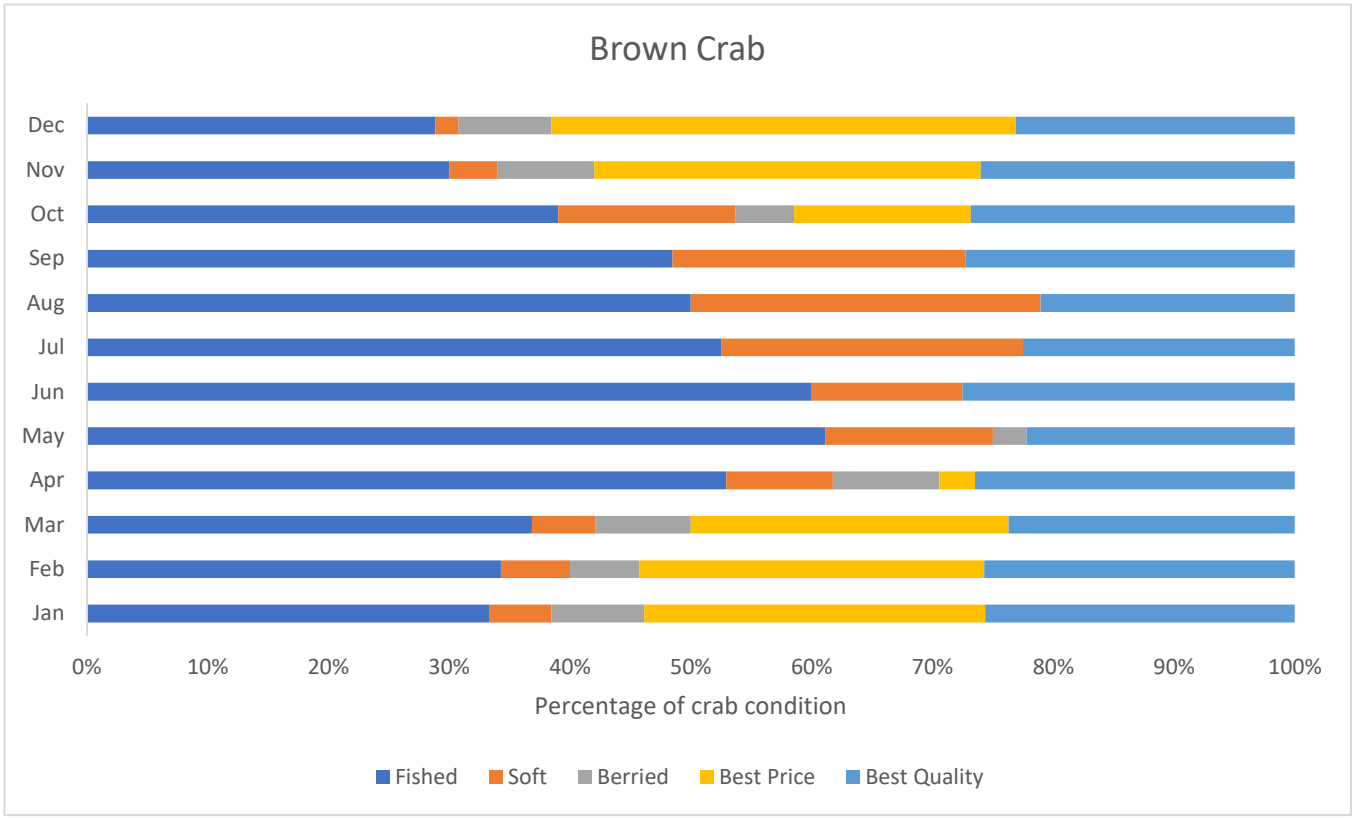
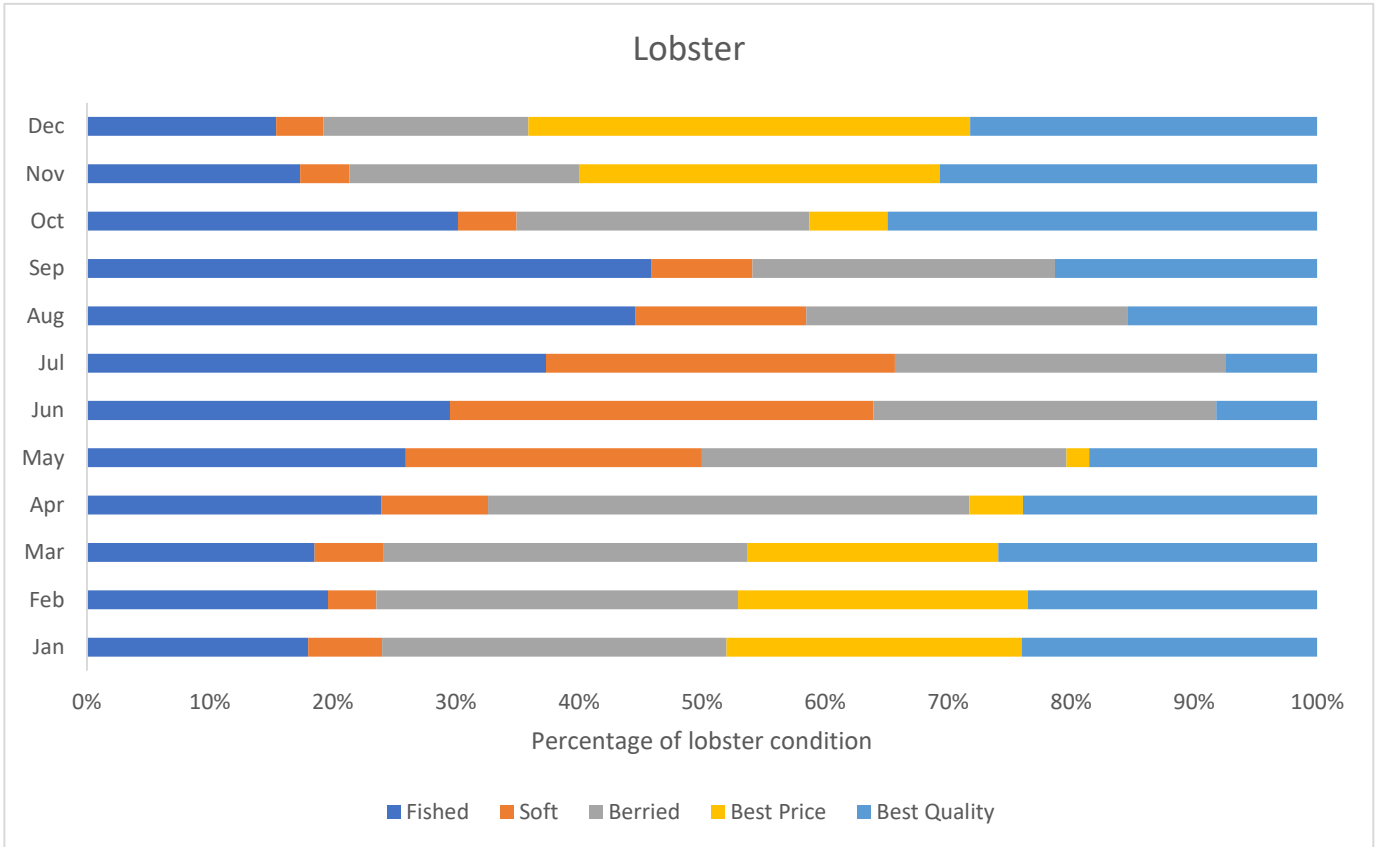
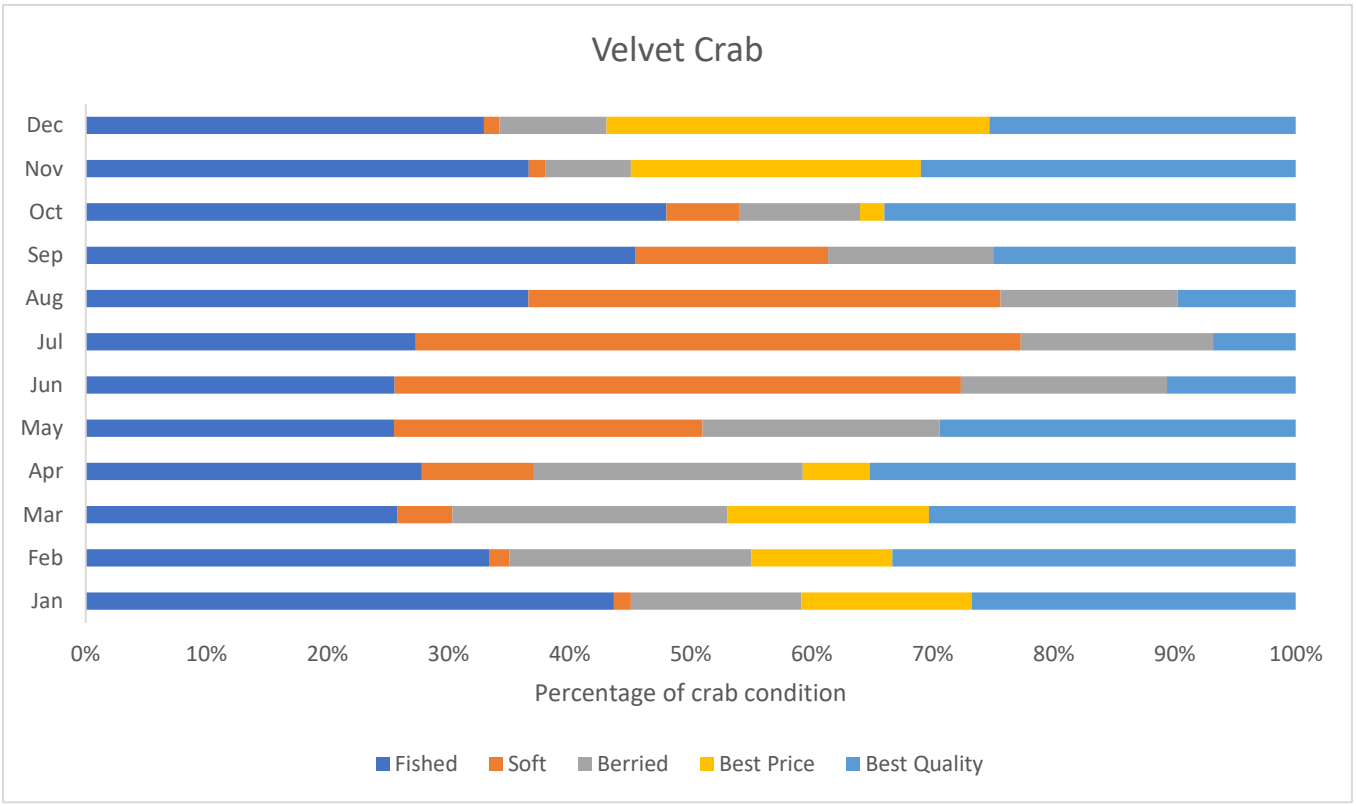


Figure 13. Summary of target fishing time for Brown crab, lobster and velvet crabs in Orkney throughout a typical year in Orkney.

Further representation of this seasonality can be seen within figure 14, based on fishermen responses during interviews in a typical year fishing in Orkney. From these graphs it can be seen that each of the commercial species vary in the biological timings of when they are berried, soft and when they are in their best condition. Less of these seasonal timings are reported for Green crabs. One reason for this is because less attention is paid to this species as they are only fished for exclusively within the winter months when fishing is poor or only large individuals are kept as a bycatch species when targetting other species. Therefore, not much attention is paid to these species by fishermen in regard to their condition or biological timings.


Brown Crab
Dec
Nov
Oct
Sep
Aug
Jul
Jun
May
Apr
Mar
Feb
Jan
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage of crab condition
Fished
Soft
Berried
Best Price
Best Quality


Lobster
Dec
Nov
Oct
Sep
Aug
Jul
Jun
May
Apr
Mar
Feb
Jan
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage of lobster condition
Fished
Soft
Berried
Best Price
Best Quality



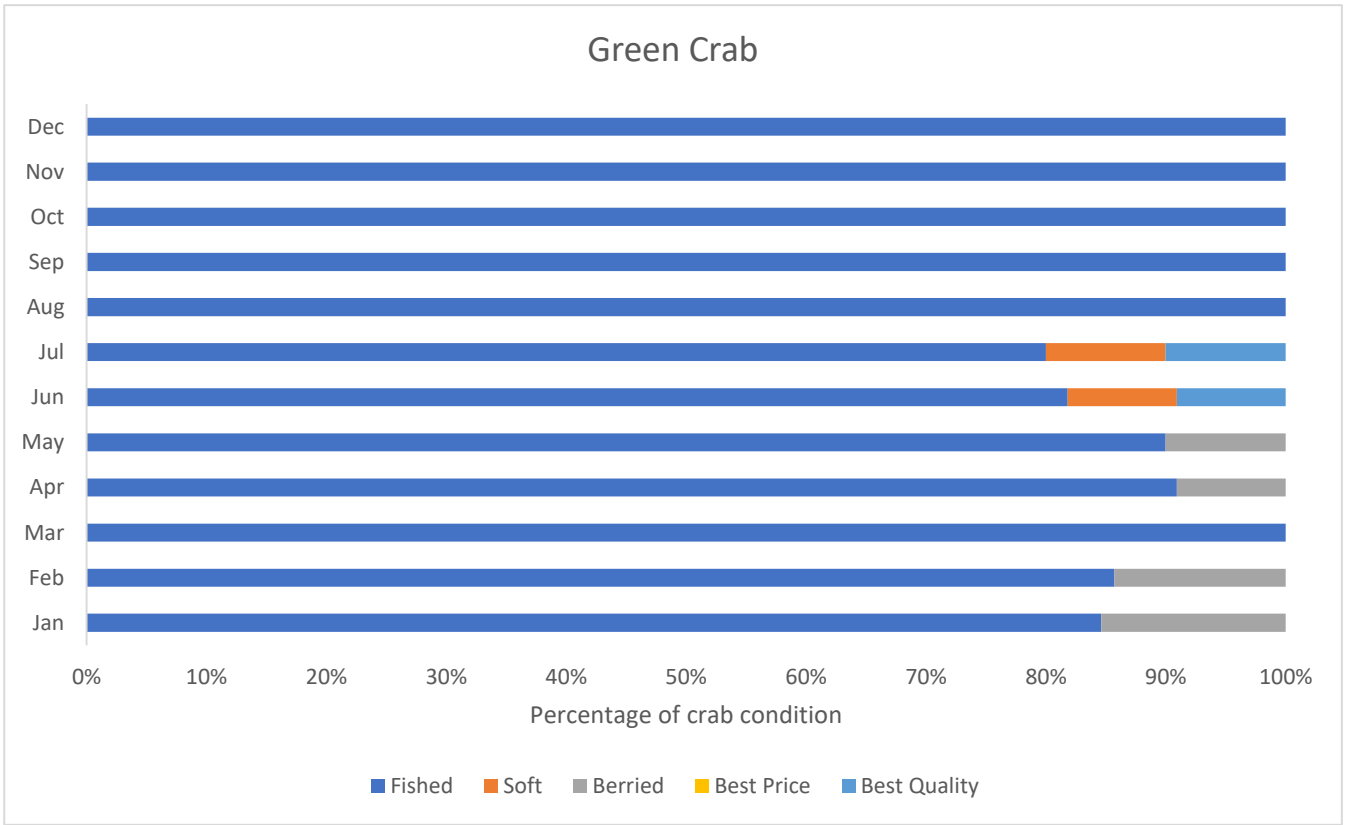


Figure 14. Summary of the months different commercial species (Brown crab, Lobster, Velvets and Green Crabs) are fished for, their condition (soft and berried) and when the best prices and quality are from fishermen responses.

4.6 Landings

4.6.1 Brown Crabs

Purchases of Brown crab landings to OFS, as seen in figure 15, on average is highest in the months of June (146,676 kg) to November (163,679 kg). From 2007 to 2018 the volume of Brown crab landed has fluctuated over time but has on average remained within 65,000kg. The poorest years occurred in 08/09 and 09/10 where landings were as low as 1,022,329 and 1,082,897kg. The largest landings were recorded in 16/17 with weights of 1,800,665kg. From figure 16, it can be seen that the season for fishing for Brown crab can and does fluctuate in terms of when the season starts and ends. In some years fishing can continue throughout the winter allowing the landing of Brown crabs and is usually associated with good weather to allow fishing. Whereas in 2015 the Brown crab fishing did not start until late May and July.

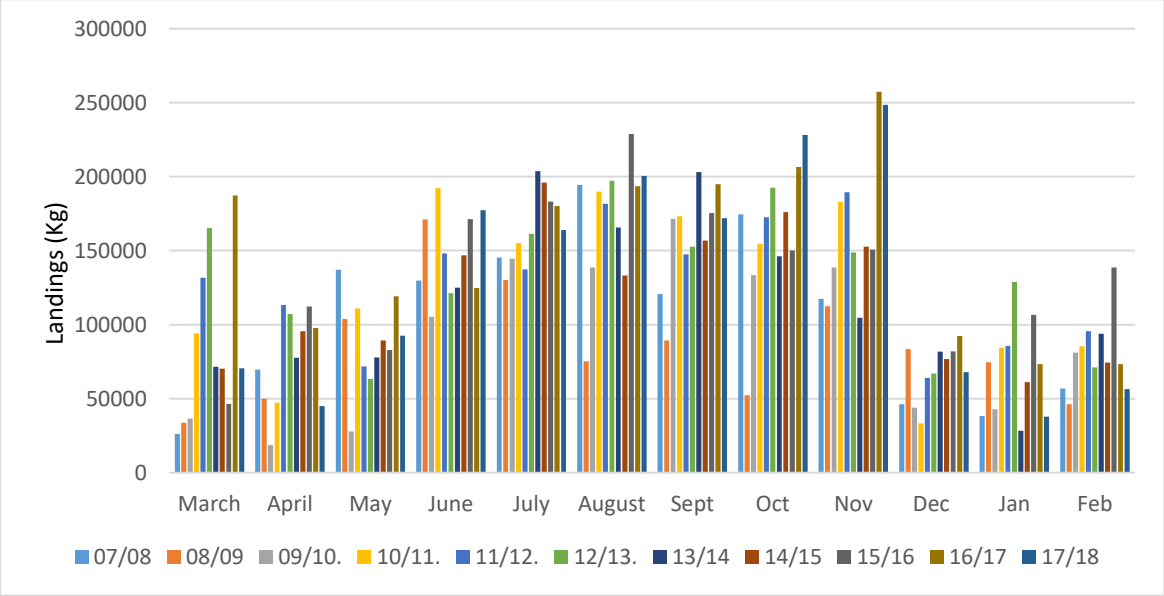


Figure 15. Brown crab landing purchase (Kg) to OFS from 2007 to 2018

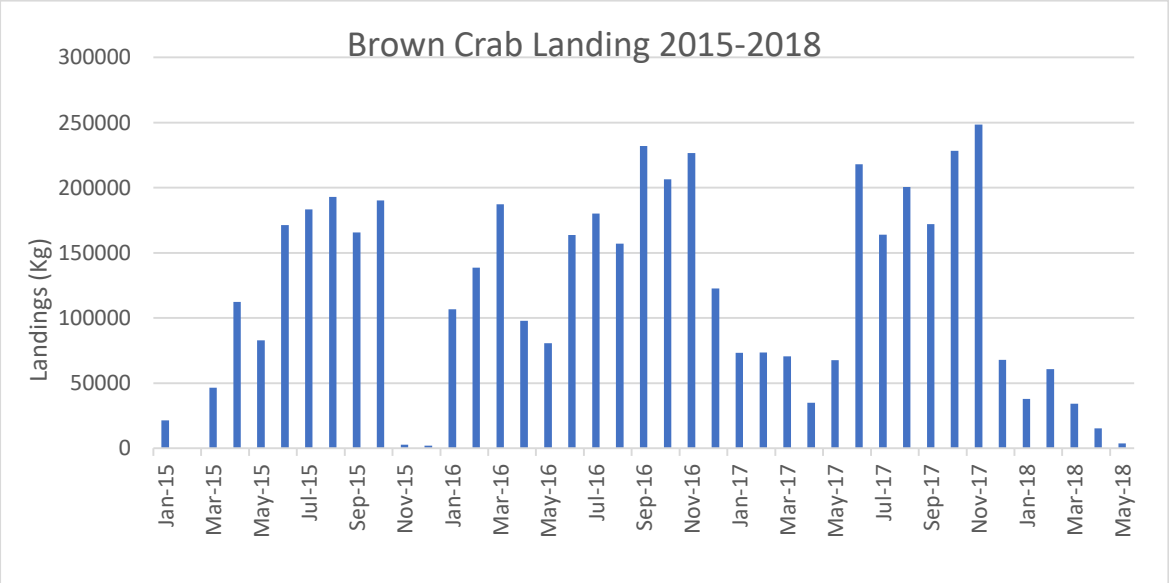


Figure 16. Brown crab landings purchase (kg) to OFA per month from the year 2015 to 2018.

4.6.2 Lobster

Landing of lobster in Orkney is more concentrated throughout the year. This can be seen in figure 17, where the main months for landing on average, occurs during July (3,958kg), August (6,862kg) and September (3,561kg). On average, the weight of lobsters landed from 2007 to 2018 has not varied too greatly as the average is 2580kg and deviates by 1164kg. The best years for fishing for lobster were in 2011/2012 (39,404kg) and 2012/2013 (40,682kg). From figure 18, the seasonality of the landings can be clearly seen throughout the years of 2015-2018, as fishing for lobsters starts within July and decreased from November onwards. The landings for lobsters in comparison to Brown crab are on average 1,403,406kg less per year.

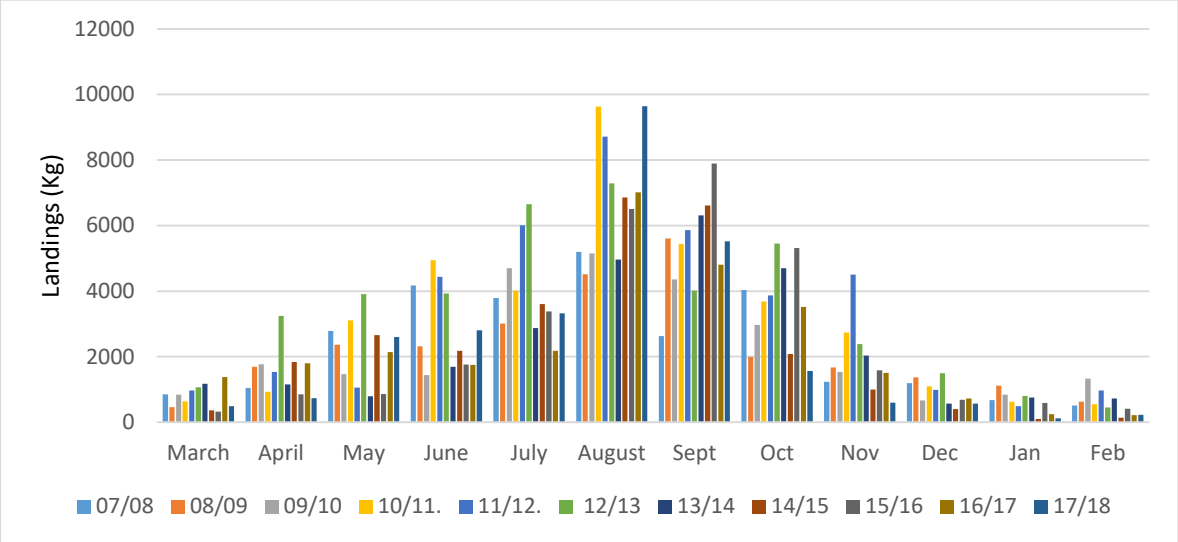


Figure 17. Lobster landing purchase (Kg) to OFS from 2007 to 2018.

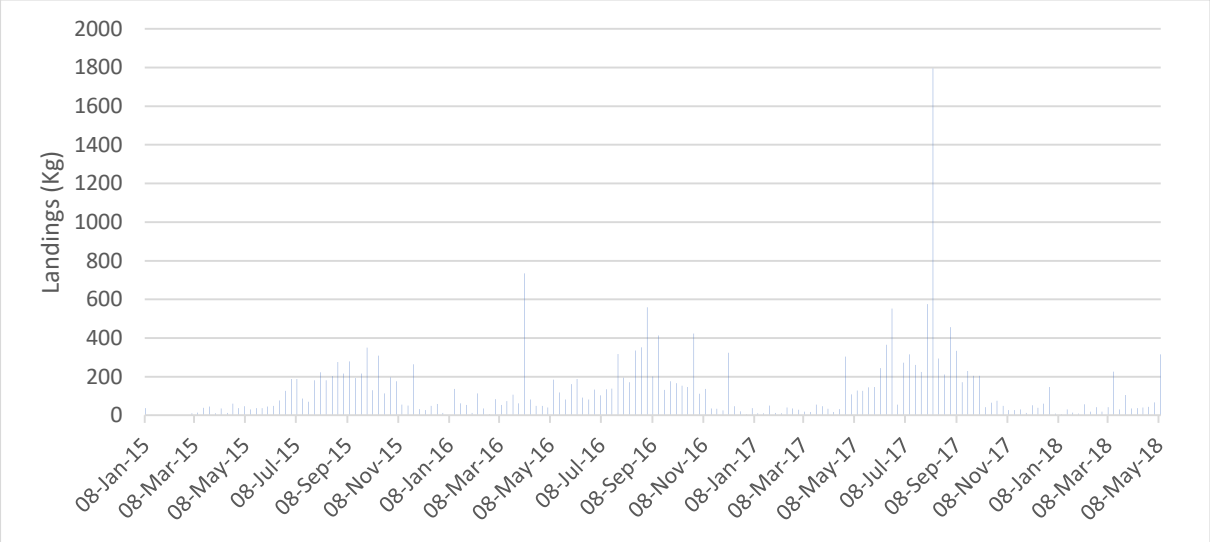


Figure 18. Lobster landing purchase (kg)per month to OFA from the year 2015 to 2018

4.6.3 Velvet crabs

From figure 19 and appendix figure 2 the volume of landings can be seen to vary monthly and yearly from 2007 to 2018. The highest yearly landing of Velvets to OFS was in 2015/2016 with 212,632kg purchased. The lowest ladings were recorded was in 2007/2008 with 87865kg. From the landing data the Velvet fishery appears to have better years for volume of landings than others, as seen in figure 19 and appendix figure 2. On average the years 2008/09, 2010/11, 2013/14, 20015/16 had higher landings in comparison to the others which were followed by either one or two years of lower landings (Appendix fig 2 and 19). Figure 20 highlights the best months for landings which happens in December with an average landing of 61608kg. The landing volume decreases substantially in January and February until May after which it increases from June onwards. The highest landings occur from September to December when fishing efforts increase. The Velvet fishery can be seen to be seasonal as mainly as a winter fishery (Fig 19, 20 and appendix 3).

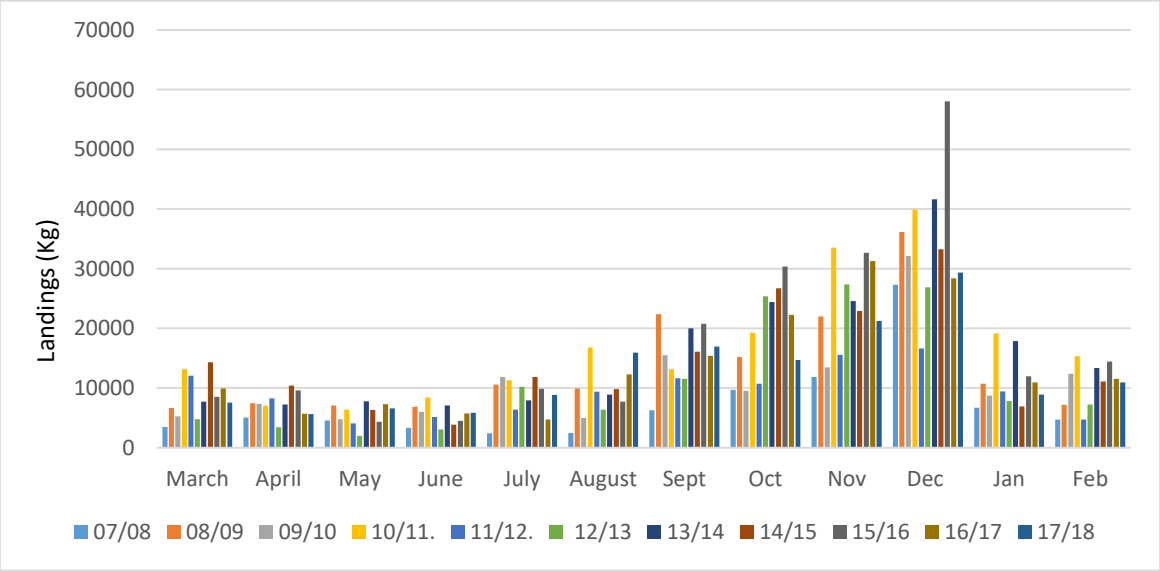


Figure 19. Velvet crab landing (Kg) to OFS from 2007 to 2018.

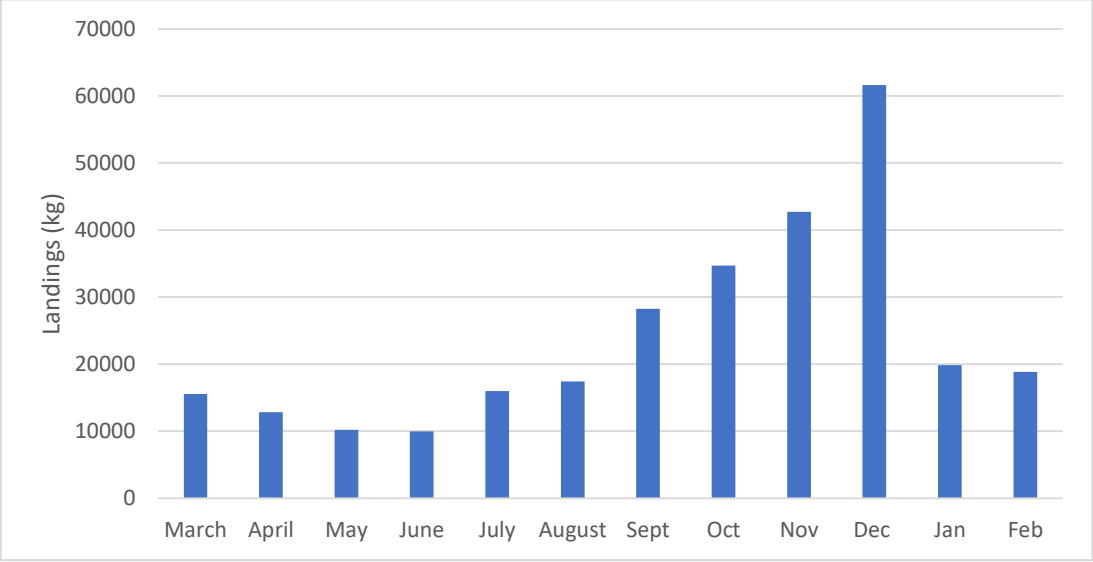


Figure 20. Average Velvet crab landing per month from 2007 to 2008

4.6.4 Green Crab

The landing of Greens in comparison to Lobsters, Browns and Velvets is less seasonal as a target fishery. However, it can be seen from figure 21, that there is some seasonality with fishing effort being concentrated throughout the winter months. Targeting of this fishery mainly starts in September until April, yet this is variable depending upon year. The month of December attracts the highest amount of landing in 2015 with 10581kg, 6279kg (2016) and 2069kg (2017). The lowest months for landings are found in between June to August. The total landings from 2015 to 2017 also varies with 40929kg landed in 2015, 32061kg in 2016 and 57981kg in 2017. In 2017 fishing for Green crabs was at a high rate for most of the months throughout the year resulting in high landings for that year. This trend continued with high fishing rates at the end of 2016 into 2017 when fishing for green crabs at the start of 2017 was higher than at the end of 2017.

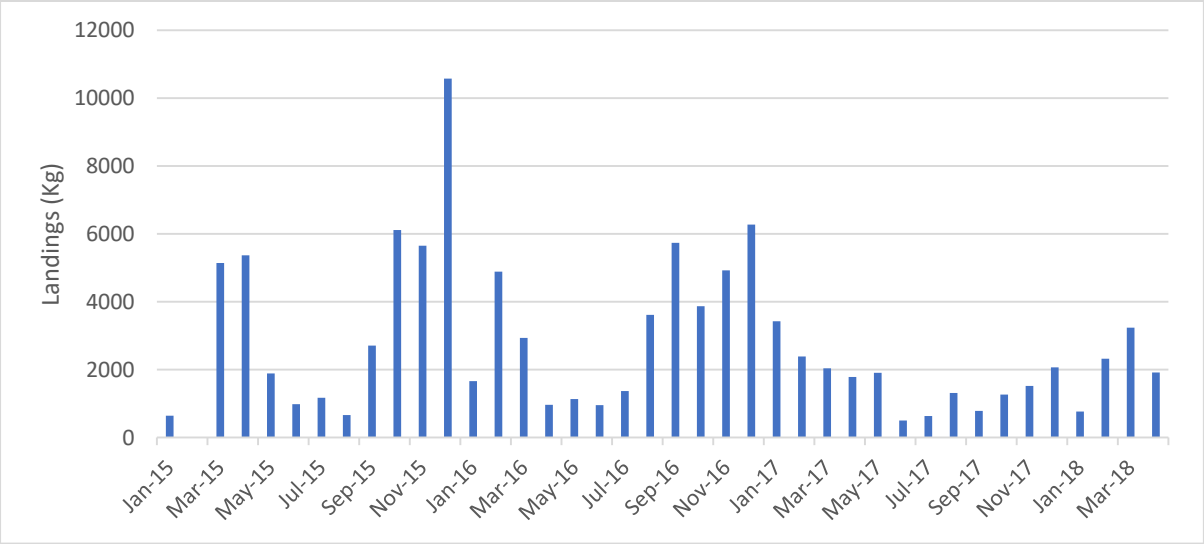


Figure 21. Green crab landing (kg) weights to OFS from 2015 to 2018.

4.6.5 Scallops

Scallop landings, in comparison to the other fisheries, is not exceptionally seasonal as fishing efforts are spread throughout the year (Figure 22 and 23). A significant increase in the volume of scallops landed can be seen between 2016 (2975kg) and 2017 (4853kg) whereby landings increase by 1878kg. In 2018 more scallops were landed in the first 5 months (2998kg) than the total of each of the other years. On average, the majority of scallops are landed in February (1052kg), as seen in figure 23. The rest of the year is consistent ranging in 475kg between the best and worst months. The least productive months appear to be in August (168kg) followed by May (234kg) and January (235kg).

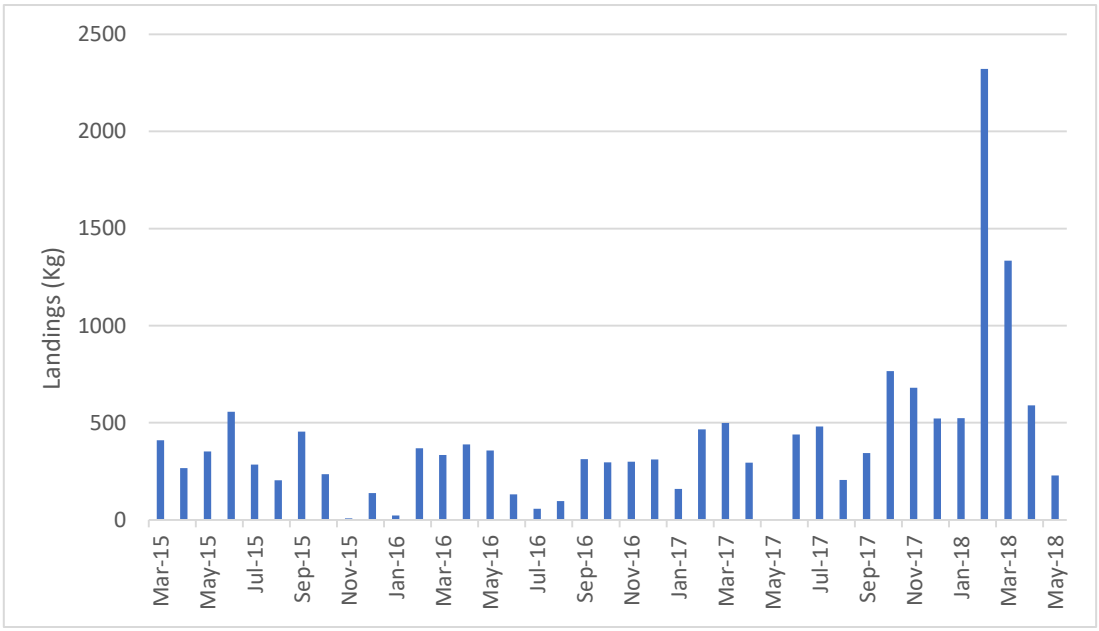


Figure 22. Scallop landing weights (kg) to OFS from 2015 to 2018

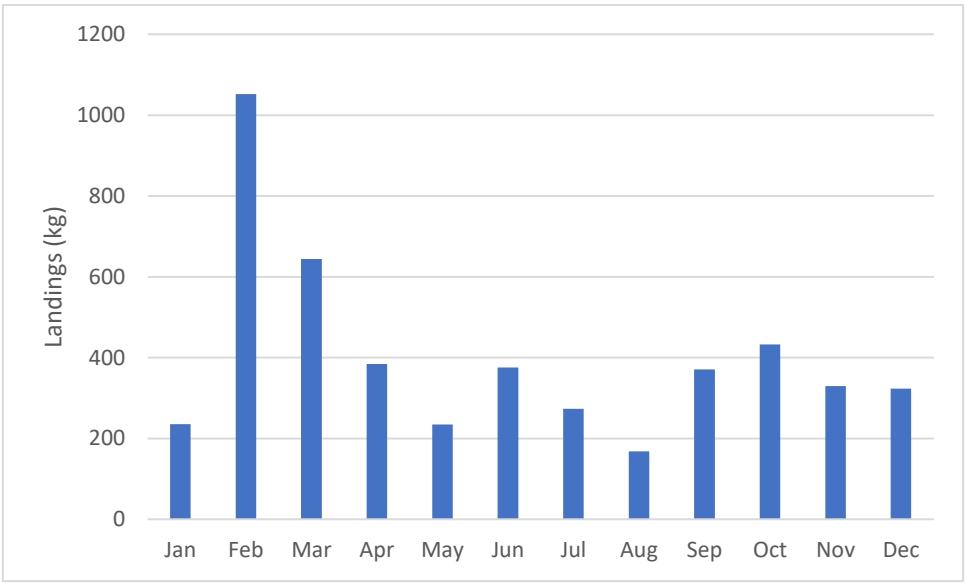


Figure 23. Average scallop landings (kg) per month from 2015 to 2018.

5. Discussion

Fishing for Brown crabs and Velvets was originally lucrative with ease of catching these species after a 1 day stand with less creels being worked. At this time one fisherman could catch enough to make a living using 120 creels on a daily turn-over of creels. Now the same fishermen would require up to 300/400 creels to catch them same amount on a two to three-day stand, often working two to three sets of creels.

With an increased effort in fishing many fishermen have described a cycle of pressure which results from this. The decline in species abundance results in an increase in effort to obtain sufficient landed numbers. One way to increase effort is to increase the number of creels deployed in the water, which leads to an increase in time at sea and fishing of new areas. Often a bigger boat is needed for deck space to hold the creels which in turn is then accompanied with the employment of crew to help. Thus, adding additional costs with crew employment and increased fuel consumption. This further adds more pressure to secure satisfactory landings to meet increased cost expenditures.

Most fishermen have described the waters around Orkney as healthy and believe in the current sustainability measures in place to protect commercial species such as increased MLS, v-notching and returning of berried female crabs. However, consensus is that over-fishing has occurred in Orkney resulting in poorer landing quantities and increased effort. Many also agree that the seasonality of the targeting of species has changed along with the biological characteristics of species. Most fishermen attribute this change in timings of casting and reproduction as an effect of climate change but also increased fishing pressure. The distinctness of the seasons has been less clear cut than when more seasonal fishing activities were being conducted. For example, casting of shells and soft individuals are starting earlier in the year and becoming prolonged. With increased fishing pressure fishermen are fishing for their target species in seasons when previously not routinely targeted, so fishermen would have originally noted a difference to catch characteristics. However, the increase in fishing pressure has occurred in Orkney since the late 1980's so although originally a difference in catch characteristics would have been expected, the continued change observed by fishermen over the last few decades highlights the changes in seasonality that is happening.

Yet many fishermen believe that the fishing industry in Orkney could return to previous levels of catch landing quantities. There are numerous ways in which this could be achieved, one way is to allow fishing activity to return to a seasonal enterprise. A more seasonally targeted shellfish fishery would allow the resting of commercial species during periods of poor quality, for example Velvets during the summer months when soft and when prices are poor. In returning to a seasonal fishery, recovery of grounds would be anticipated with a higher number of crabs being returned instead of landed which would increase the opportunity for more to reproduce. More efficient fishing could also be achieved within this seasonal fishery through better handling practices at sea, the returning of berried lobsters and the avoidance of using other shellfish species as a bait. Fishing using a seasonal timetable could be' best-practice' adopted by all, however this would require co-operation by all fishermen in Orkney. Management measures could also be applied using seasonal closures or days spent at sea for particular species.

Nevertheless, in adopting a more seasonal fishery through these practices, it is anticipated that an initial loss of income would be expected, since fishing effort is already high. Diversification within the inshore fleet is therefore required to allow for this move in order to rest species, but to also provide another source of income. The inshore fishing fleet within Orkney is narrowly focused on the capture of shellfish species mainly due to factors such as limit on fishing quota and licence availability.

Diversification within the inshore fishing fleet could help stabilize coastal communities reliant on shellfish resources and their markets, both of which are susceptible to unpredictable shifts (Cline *et al*, 2016). Abrupt shifts in natural resources and their markets are a ubiquitous challenge to human communities but the ability to safeguard them from a detrimental decline in shellfish stocks through diversification is another reason to help provide sustainability to the Orkney fishing industry (Cline *et al*, 2016). Diversification ultimately provides opportunities to take advantage of emerging opportunities, and changes and buffer against disaster as means to increase resilience within human-natural systems (Cline *et al*, 2016). Inshore fishermen in Orkney have expressed a strong interest in the possibility to fish for other species such as mackerel, herring, cod and haddock. Other species routinely caught within creels also includes octopus, dogfish and wrasse.

The next stages of this project will be to evaluate the feasibility of other fishing activities within Orkney to allow diversification of the inshore fishing fleet to complement a more seasonal timetable. The pathways to change would seek to evaluate the start-up costs of equipment, revenue generation/loss, barriers to diversification as discussed within the final reports of pathways to change. The next stage of research should focus on estimating the species and stock levels for other potential fisheries.

6. Conclusion

In conclusion, the inshore fishing activity within Orkney is a seasonal enterprise. Differences in catch abundance, quality and prices can be seen to vary throughout the year for many of the commercial shellfish species within Orkney, reflecting changes to their biological characteristics. However, the fishing activities are not as seasonally dependent as they have been in the past as described through fishermen's ecological knowledge. This is due to several factors such as development of new markets and species to fish for, increased fishing pressure and environmentally driven pressures on biological timings. Ecosystems dynamics are notoriously variable but general trends identified by fishermen highlight an increase in fishing effort for commercial shellfish. To enhance the sustainability of the industry and allow it to return to a more seasonal fishery may alleviate fishing pressure to allow stocks and grounds to recover. In fishing using a seasonal timetable could be achieved through management measures such as seasonal closures or days at sea. The sustainability of the Orkney fishery would further be enhanced through further fishing opportunities in the ability to fish for other species.

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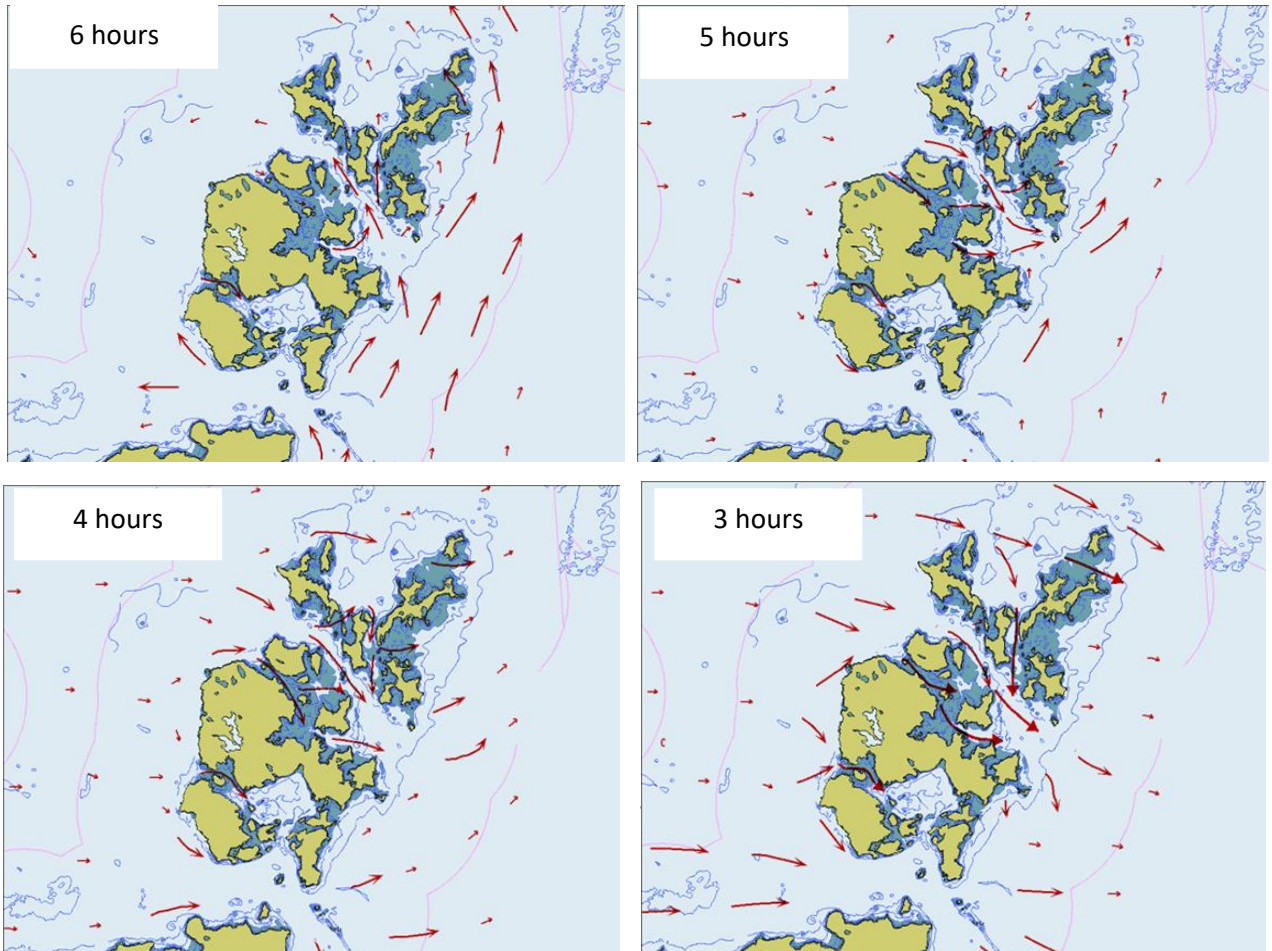
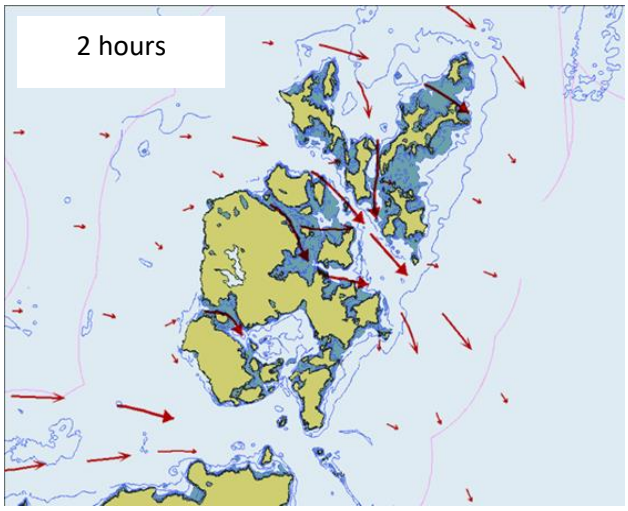
Appendix

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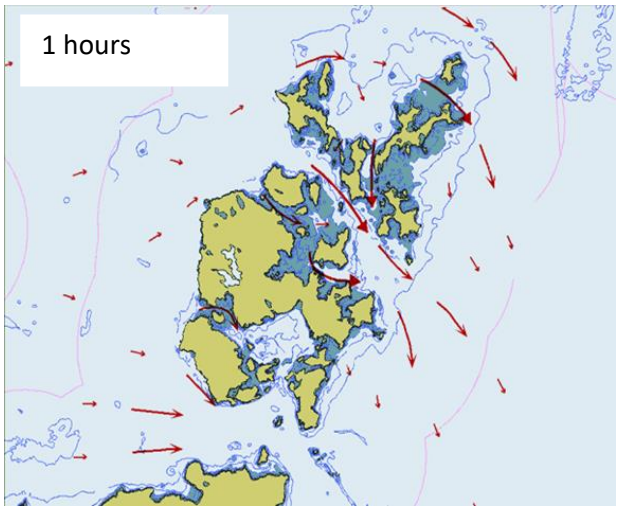
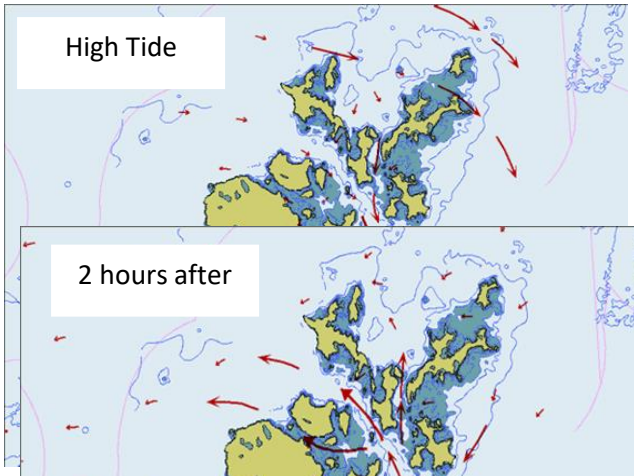
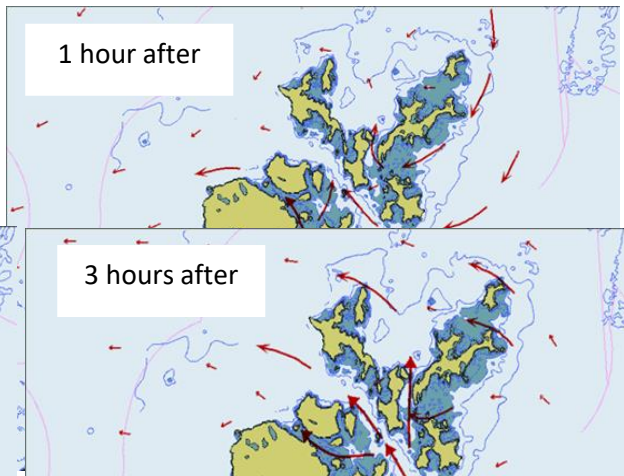

1 hours


High Tide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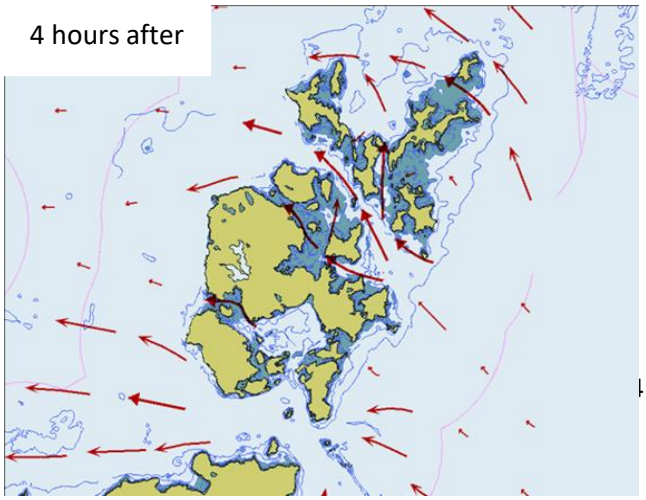
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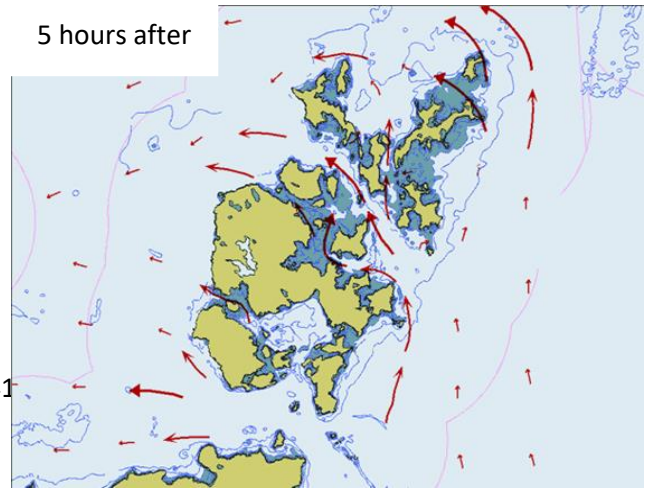
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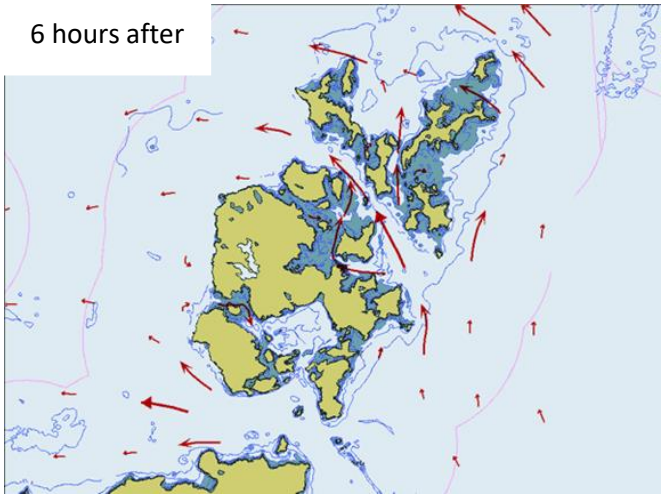

Figure 1. Orkney tidal movement around mainland Orkney and its isles. Red arrow indicated the tidal flow movement direction and intensity in the hours before and after high tide.

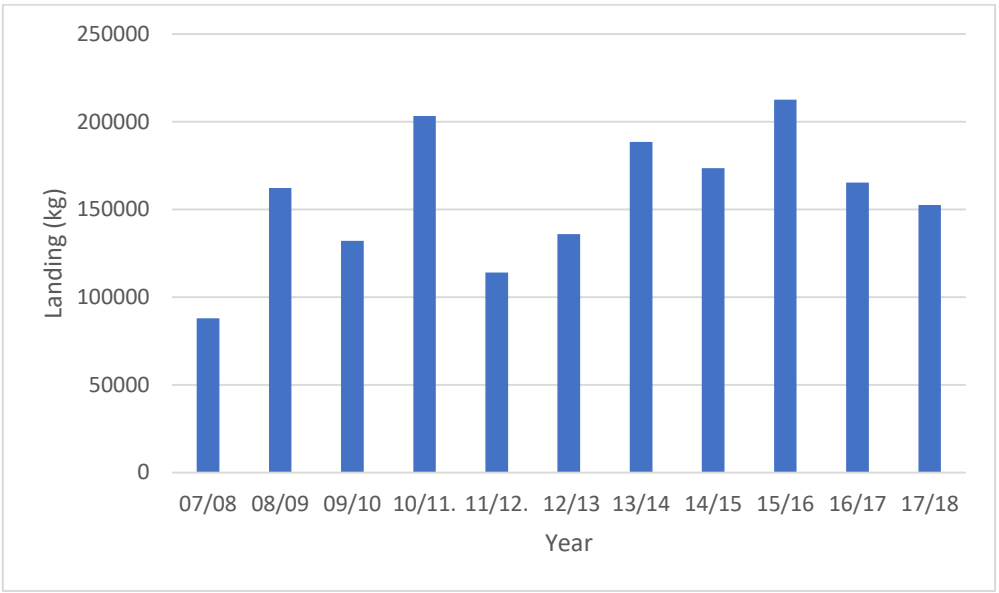

Figure 2. Velvet crab landing purchase (kg) from 2007/08 to 2017/18.

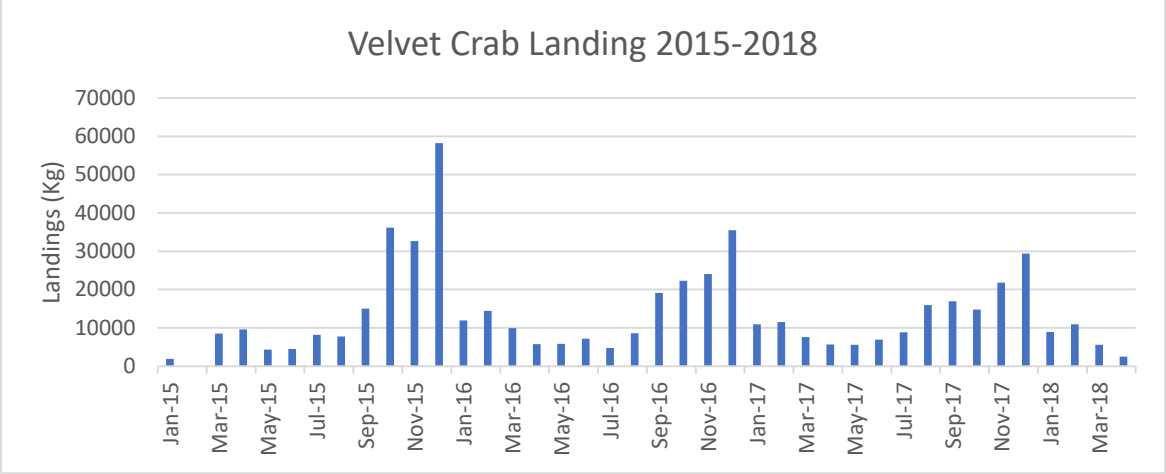

Figure 3. Velvet crab landings (kg) to OFA from the year 2015 to 2018