Jig Fishing Pilot Study in Shetland Coastal Waters

Final Report

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Executive Summary

Jig fishing was last attempted commercially in Shetland in the early 1990s. Although the initiative was considered a success, the metier has not gained precedence over otter trawling. The recent difficulties encountered by the whitefish sector indicated that an evaluation of this approach should be revisited and, following a request from the Shetland Fishermen's Association, the NAFC Marine Centre undertook a pilot study of jig fishing in the inshore waters around Shetland.

In June 2005 six Oilwind jigging machines were fitted to the Centre's fishing vessel *Atlantia* LK328 and in March 2006 they were installed on the Centre's new vessel Atlantia *II* LK502. During the study a variety of commercially available gear was trialled and information on both catches and environmental conditions (e.g. wind and weather, seabed type, water depth, sea temperature and sea state) were recorded. Catch data included positions, fishing times and catch composition.

Fishing trials were carried out over an 18 month period and covered as many areas around Shetland as possible. The highest catch rates were on wrecks to the north of Shetland. During the study, 119 days fishing produced 545 boxes of fish with a value of £29,000. The most valuable species in the catch was lythe (*Pollachius pollachius*) followed by saithe (*Polachius virens*), cod (*Gadus morhua*), ling (*Molva molva*) and tusk (*Brosme brosme*) respectively. Environmental variables such as wind speed, sea depth, seabed type and tide all had significant effects on catch rates.

Market prices fluctuated during the study period and prices received for jig caught fish were rarely higher than those for trawl caught fish. The main running costs associated with jig fishing were fuel and gear although fuel consumption when jigging was significantly lower than while trawling.

Factors needing to be taken into consideration when determining the commercial viability of jig fishing include: initial set up costs, weather restrictions, resistance of localised fishing grounds to intense fishing, quota availability, and marketing and promotion of the catch.

The results of the study indicate that jig fishing could be commercially viable, at least on a seasonal basis. However to reach its full potential a co-operative approach may need to be considered so that issues such as constancy of supply, volume and niche marketing could be addressed in order to achieve higher prices.

Report Layout and Target Audience

This report is aimed primarily towards a readership of interested fishermen, however to justify the interpretation of the data that has been collected there has inevitably been a statistical analysis of that data. Results of statistical analysis have been included for completeness and interpretation of the results are given in the text.

The project divides into a number of sections (background and introduction, fishing gear, fishing operations, experiments, and commercial viability) and as such, and due its length, the report has been laid out to reflect this. Within each of these sections, and as appropriate, there are the standard Materials and Methods, Results and Discussion divisions.

1 Introduction & Aims

Commercial jig fishing, also known as automated handlining, is a method of fishing using hooks with lures which are ‘jigged’ up and down in the water. Jig fishing techniques have been used for centuries by European vessels fishing Icelandic, Newfoundland and North Sea fishing grounds. Many of the techniques used then are still in use today (Sainsbury, 1996). In recent years however, the advent of hydraulic or electric automated jigging machines has eliminated much of the manual labour required to haul fish from great depths. Modern automated jigging machines are equipped with a computerised motor which enables the user to, among other things, program the machine to fish at a specified depth, alter the motion of the gear, and set a bite alarm to sense a specified weight of fish after which the machine will automatically haul.

There are a number of automated handline fisheries throughout the world targeting whitefish species such as Atlantic cod (*Gadus morhua*) and saithe (*Pollachius virens*), pelagic species such as yellowfin tuna (*Thunnus albacares*) and mackerel (*Scomber scombrus*), and cephalopods such as the short-fin squid (*Illex argentinus)*. The vessels engaged in these fisheries range in size from small, under 10 metre, vessels operating two or three jigging machines to large 60 metre vessels operating up to 50 machines.

1.1 Jig fishing in European waters

A number of European and Nordic countries have an active commercial jig fishery. In 2004, over 90 small inshore vessels in the Faroe Islands were reported to be equipped with jigging and long lining equipment, with the main target species being saithe and cod (ICES, 2005a). In Iceland, 308 vessels were engaged in jig fishing in 2004, landing 17,500 tonnes of fish, of which 14,500 tonnes was cod and 2,629 tonnes was saithe (ICES, 2005b). These vessels are mainly less than 10 metres in length. Currently, jig fishing for whitefish in Scotland is only carried out by a small number of inshore vessels. It often supplements other fishing methods such as fishing with crab and lobster pots. In 2005 only 5.8 tonnes of fish, mainly pollack (locally known as lythe) (*Pollachius pollachius*) were landed in Scotland using jigging equipment (Anon., 2006).

1.2 Conservation and the environment

In recent years criticism has been levelled at current fisheries management strategies while greater emphasis has been put on the need to develop more sustainable, conservation orientated fisheries (Hentrich & Salomon, 2006). Non-governmental organisations (NGOs) such as the Marine Stewardship Council (MSC) and the Marine Conservation Society (MCS) actively promote sustainable fisheries and, as consumers become more aware of the source of their fish, they are turning increasingly to products from fisheries which are proven to be sustainable and less damaging to the marine environment (Jaffry et al., 2004). Automated handline fisheries are often advocated as being conservation orientated as, in comparison to trawl fisheries, they have a minimal impact on the ecosystem (Huse et al., 2002). There are a number of studies that provide evidence that line fisheries also select for larger individuals when compared with trawling, thus resulting in reduced discarding of undersized fish (Halliday, 2002, Huse et al., 2000).

Jig fishing for whitefish, which involves allowing the vessel to drift with the engine switched off, has environmental benefits in terms of low fuel consumption when compared to trawling. With current fuel prices, reducing vessel running costs should increase profit margins significantly. The fact that the vessel is drifting means that lines hang almost vertically in the water, so the highly publicised seabird by-catches that occur in some line fisheries (Tasker et al., 2000) are rarely an issue.

1.3 Jig fishing in Shetland

Jig fishing was last attempted commercially in Shetland in the early 1990s (Nicolson, 1999). However, although the initiative was considered to be a success, the metier has not gained precedence over otter trawling. The recent difficulties encountered by the whitefish sector and an imperative need to conserve stocks and reduce discards, combined with advances in jigging machine technology, indicated that an evaluation of this approach should be revisited. In the current environmental and market conditions there is a renewed interest amongst fishermen and early in 2004 the Shetland Fishermen's Association approached the NAFC Marine Centre (then called the North Atlantic Fisheries College) to investigate whether a pilot study could be undertaken. An initial cost for gear, combined with the potential loss of earnings during the development of a new fishery is considered to preclude such attempts by individual fishermen. In 2004 when this study was initiated such was the financial state of the industry that it was estimated that any new venture must start to pay its way within two weeks, thus leaving little time for individual fishermen in the commercial situation to undertake a viable study.

1.4 Study Aims

The study had a number of aims in relation to an investigation into the practical execution and economic viability of jig fishing in inshore waters around Shetland. The first aim was to assess the technical requirements, materials required, and costs incurred when fitting out a vessel for jig fishing. The commercial viability of the method was then to be investigated by undertaking jig fishing trials and, throughout the trials, selectivity and bycatch was to be monitored and recorded, as were a number of environmental variables. Income from fish landings and costs incurred during fishing operations were used to evaluate levels of profitability. The market potential of line caught fish was assessed and compared with fish caught using other methods. A further objective of the study was to appraise the impact of specific handling regimes on the quality of the product. Finally, should the findings of the study be positive, it was intended to develop a management strategy for the implementation of the fishery in Shetland waters.

2 Fishing gear

2.1 Jigging machines

2.1.1 Materials and Methods

In May 2005, phase 1 of the project commenced when two members of the NAFC fisheries development department travelled to Torshavn, in the Faroe Islands to gain information on, and practical experience of, jig fishing for white fish. During this visit they went on fishing trips with local experienced jig fishermen and took part in discussions on the advantages and disadvantages of different gear types. During the visit they also attended the Fish Fair in Torshavn and were able to discuss the project requirements with several jig fishing manufacturers and establish contacts with gear suppliers.

Following this visit six Oilwind electric jiggers were purchased and installed on the *Atlantia* LK328 (a 10m, 120hp, Cygnus GM33 GRP vessel) (Figure 1), after essential modification of the vessel's power supply during June and July 2005. The machines were fitted locally by DH Marine. In January 2006 the *Atlantia* was replaced by the *Atlantia II* LK502 (a 12.3m, 170hp, wooden hulled trawler built in 1999 at Thoms, Cornwall) and the jigging machines were transferred to the new vessel.

Figure 1 Oilwind automated jigging machines.

2.1.1.1 Machine settings

The Oilwind jigging machines have a variety of different motor and jig function settings which allow the user to alter the movement of the fishing gear to suit different environmental conditions, different gear and different target fish sizes.

Reel motor function settings (Table 1) were rarely adjusted as original factory settings were found to be adequate for all conditions. However, reel jig function settings (Table 2) were frequently adjusted, usually to optimise the operation of the gear when targeting specific species of fish. When fishing for saithe on wrecks the jig travel was often set at 5 fathoms or more, causing the terminal gear to be jigged up and down over a greater distance from the wreck. This setting was more effective with saithe as they were frequently found up to 20 fathoms above the wreck. When fishing for ling the machines were adjusted to travel only 2 fathoms to ensure the terminal gear was close to the seabed at all times. The jig pause mechanism was often adjusted to 5 or 10 seconds thus allowing the gear to stop jigging and lie close to the seabed for short periods.

Table 1 Oilwind jigging reel motor function settings.

Function number	Motor function	Description	Setting
0	Jig speed up	Adjusted jig speed when line is hauled. Percentage of max. speed.	30%
1	Bite speed	Hauling speed after a fish is caught. Percentage of max. speed.	20%
2	Bite time	Period of time that bite speed will last. Value is in seconds.	15 secs
3	Speed 1	Hauling speed after bite time. Percentage of max. speed.	75%
4	Speed 2	Used when activating down button. Percentage of max. speed.	99%
5	Max. pulling power	Percentage of maximum possible pulling power with maximum force.	40%
6	Min. pulling power	Percentage of maximum possible pulling power with minimum force.	27%
7	Tangling	Sensitivity for registration of tangling of fishing gear. Pre-set value.	4.5
8	Jig speed down	Speed when paying out line. Percentage of max. speed.	90%

Table 2 Oilwind jigging reel jig function settings.

Function number	Jig function	Description	Setting
0	Weight	Fish sensing mechanism. Low value more sensitive, high less sensitive.	75
1	Distance from bottom	Distance from seabed machine will haul gear before jigging (fathoms).	0.5
2	Jig travel	Distance of jig travel in one jigging motion (fathoms)	5
3	Jig number	Number of jigs before searching for the seabed again	5
4	Drift compensation	Number of jigs before machine automatically hauls gear.	40
5	Program	Two different programmes. 0 for whitefish and 1 for mackerel/squid.	0
6	Waves	Compensates for the rolling motion of the vessel in rough seas.	0
7	Search range	Indicates what depth machine will commence searching (fathoms).	40
8	Jig pause	Length of pause between each jigging period (seconds)	0

2.1.2 Results

The Oilwind jigging machines were found to be fairly hardwearing and reliable although, on occasion, the spring in the arm tended to loosen on a number of them. On one occasion the sensing arm of one of the machines was damaged due to the strain caused as a result of terminal gear becoming fast in a wreck (Figure 2). For the most part, due to their positioning on the vessel, five of the six machines were fished simultaneously. However, this was reduced to three machines when large fish such as saithe were caught. The horizontal movement of the saithe while being hauled on the jigging machines often caused them to get tangled in the gear of the neighbouring machine. On some occasions, the terminal gear on all five machines would come up tangled together with a number of fish attached. Such events reduced fishing time as gear often needed to be removed and replaced.

The Dynema mainline supplied with the machines proved to be very strong and durable and showed no significant effects of wear. The 10 fathom, 300lb shock leader attached to the end of the main line on each machine was replaced twice during the project due to the effects of wear and tear.

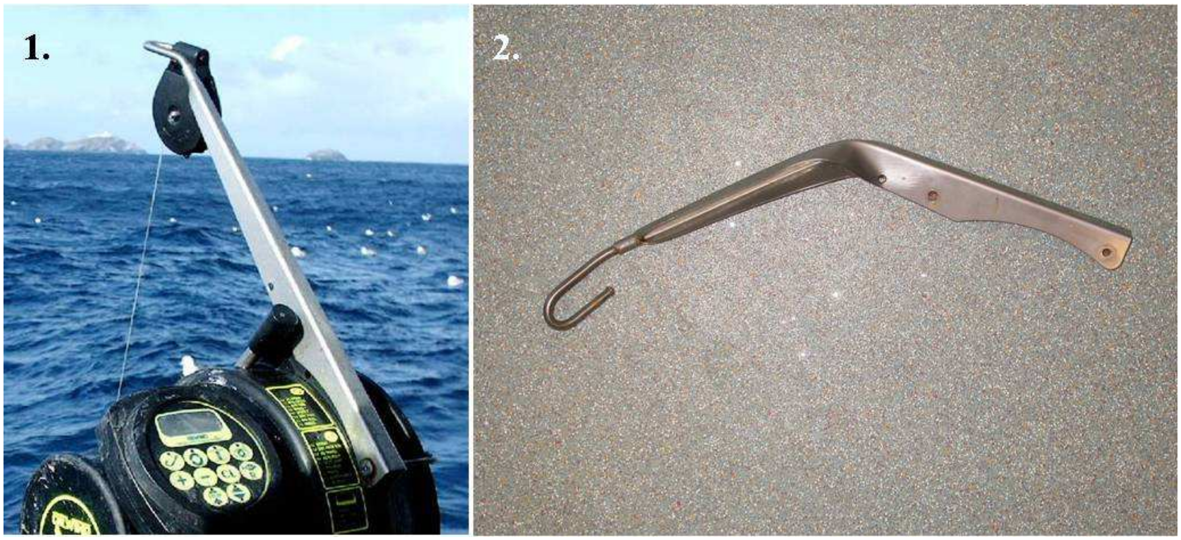


Figure 2 Damage caused to a jigging machine sensing arm which fishing on a wreck.
1. Functional sensing arm operating on a jigging machine; 2. Sensing arm following damage sustained while fishing on a wreck.

2.1.3 Discussion

Three well known brands of jigging machine, Oilwind, Belitronic and Mustad DNG are readily available for use in commercial whitefish jig fisheries. Although Oilwind machines were used in this study, both Belitronic and Mustad DNG are generally regarded as being equally efficient. There is a fairly equal mix of the three different machines currently working within the Faroese jig fishery with no real preference for one specific manufacturer (A. Johnson, pers. comm.). Any decisions on which machines to install would be down to personal preference.

In this study the Oilwind machines were found to be very hard wearing and reliable which is essential for ensuring that costs are kept to a minimum. The computer program controlling the machines was reasonably straightforward to operate and, after gaining experience, users were able to optimise the settings for different species and seabed types. Fish were easily hauled from the seabed on most occasions with the only exception being some of the wrecks in deeper water to the north of Shetland. On some occasions, when there were 5 or 6 large saithe caught on one machine, the motor would struggle to haul the fish to the surface. Another problem encountered when fishing for saithe was being able to calculate what the optimum distance between the jigging machines would be in order to avoid tangles between the terminal gear of adjacent machines. On many occasions the machine nearest the bow of the boat would be tangled with the machine on the stern although, when fishing for these large powerful fish such problems were inevitable and could not be totally avoided. However, when fishing for other species a distance of 5 feet (1.5 metres) between the machines was found to have worked well to keep tangles to a minimum.

The only real problems encountered with the jigging machines during the study were the loosening of the springs under the sensing arm and the damage to one of the sensing arms. Both problems were easily rectified and on both occasions lessons were learned in order to avoid a future recurrence of these problems.

2.2 Gear trialled during the project

2.2.1 Materials and Methods

The six jigging machines were each equipped with 300m (164 fathom) of 400lb Dynema main line, an 18.3m (10 fathom) 300lb monofilament shock leader, and a nylon ring of 40mm inside diameter attached to the end of the leader.

A variety of terminal fishing gear was used throughout the project (Figure 3). The main suppliers of the gear were Oilwind, Teymavirkid Pf., UK Hooks Ltd, Red Gill Fishing Lures Ltd and Sonarlure (Appendix I). The total cost of terminal gear was £2,050. Early on in the project, sinkers (lead in weights of 7lb) were produced by staff at the Marine Centre (Figure 4) thus reducing the number needing to be purchased and significantly lowering the cost to the project.

One of the aims of the project was to determine which, if any, fishing gear yielded higher catches. With this in mind, a number of different types of gear were fished simultaneously. A number of different baits including mackerel (*Scomber scombrus*), buckie (common whelk) (*Buccinum undatum*) and prawns (*Nephrops norvegicus*) were also used. When baiting lures on rigs other than the steel bowed sinker, only the bottom two hooks were normally baited. This was designed to be an extra stimulus to attract bottom dwelling fish such as cod and ling.

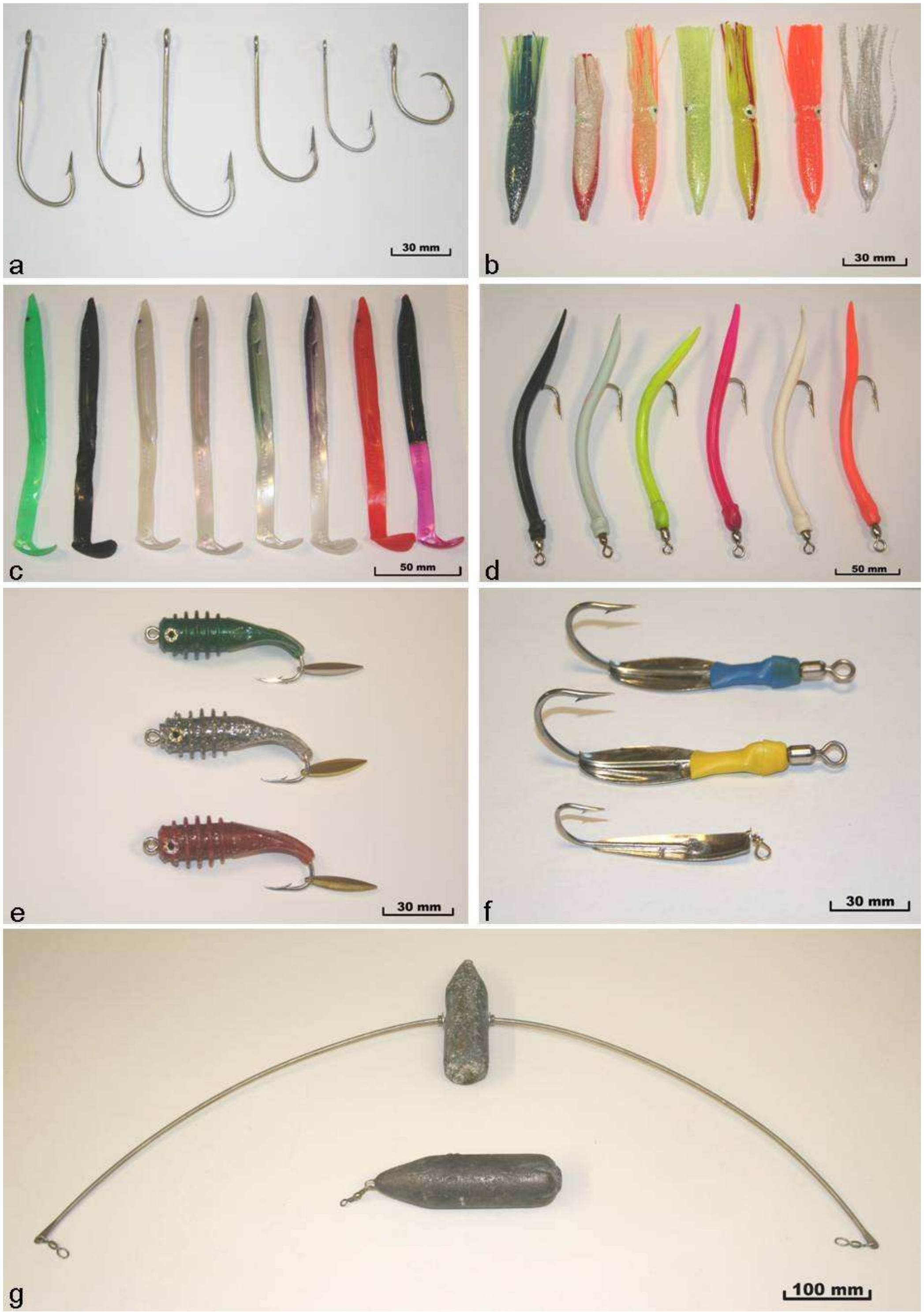


Figure 3 Terminal fishing gear used throughout the project.
a: Mustad rubber eel hooks size 10/0 & 12/0, Mustad O'Shaughnessy hooks size 8/0, 10/0 & 12/0, Mustad E Z Baiter hooks size 13/0; **b**: 5 inch plastic squid in a variety of colours; **c**: 178mm Red Gill rubber eels in a variety of colours; **d**: rubber eel lures in a variety of colours; **e**: sonar lures in green, silver & red; **f**: spoons in size 6, 7 & 8; **g**: 6lb steel bowed sinker and 7lb sinker.

Figure 4 Procedure for producing lead sinkers; 1. apparatus used in the construction of sinkers; 2. lead is broken up into small pieces; 3. lead is placed into melting pot until almost full; 4. an eye with a swivel is placed into the mould; 5. mould is fastened using a G-clamp; 6. lead is carefully poured into bottom of mould; 7. mould is cooled in water; 8. finished sinkers.

2.2.1.1 Lure rigs

A number of different lure rigs were constructed and fished during the project. The most frequently used rigs were the rubber eel lure rig and the Red Gill lure rig.

2.2.1.2 Construction of rubber eel lure rig

Rubber eel lure rigs were constructed from Marlin 250lb (113.1kg / 1.60mm) clear main line with size 3/0 (127lb) black brass barrel swivels attached to the main line using the scaffold knot (Figure 5d). Swivels were attached at intervals of 0.5 fathoms (0.9m) on either side of each lure (Figure 5b). This allowed for the removal of any twists in the line caused by hooked fish. Lures were constructed from Mustad rubber eel hooks size 10/0, coloured PVC or silicone tubing with 6mm inside and 8mm outside diameter, and size 1/0 (175lb) nickel crane swivels. Lures were then attached to loops made in the main line, at approximately 1 fathom (1.83 metres) intervals, using the dropper loop knot (Figure 5a,e).

2.2.1.3 Construction of Red Gill lure rig

Another commonly used lure rig was constructed using Red Gill fishing lures (Figure 3c). These lures were equipped with size 8/0 Mustad O’Shaughnessy hooks (Figure 3a). The rig was constructed from Marlin 250lb (113.1kg / 1.60mm) clear main line with size 2/0 (127lb) three way barrel swivels attached to the main line, by the eye on opposite ends of the swivel, using the scaffold knot (Figure 5d). Swivels were attached at approximately one fathom intervals. The lures were then attached to the remaining eye on the swivel using an 8-10cm length of 1.1mm nylon fishing line and a crimp, which provided rigidity in the snood (Figure 5c). A number of snood lengths between 5 and 10cm were trialled.

2.2.1.4 Construction of other lure rigs

A variety of other lure rigs, made from spoons or plastic squid, were also constructed and fished using one of the above methods. Later in the project the Marine Centre was approached by an American company, SonarLure to trial their ‘sonar lures’ (Figure 3e). Sonar lure rigs were constructed following the same pattern as for the Red Gill lure rig.

2.2.1.5 Construction of rig using steel bowed sinker

Rigs were also constructed using the steel bowed sinker (Figure 3g). This rig was more suited to fishing close to the seabed as the lures were situated below the sinker rather than above it, as with the other rigs. Rigs were constructed from approximately 60cm lengths of Marlin 250lb (113.1kg / 1.60mm) clear main line. A size 2/0 (127lb) three way barrel swivel was inserted into the main line halfway along its length using the scaffold knot. One lure was attached to the end of the rig using the scaffold knot and the other lure was attached to the remaining eye on the three way swivel using an 8-10cm length of 1.1mm nylon fishing line and a crimp. The remaining end of the lure rigs were attached to the swivels on either side of the steel bow using the scaffold knot (Figure 5d).

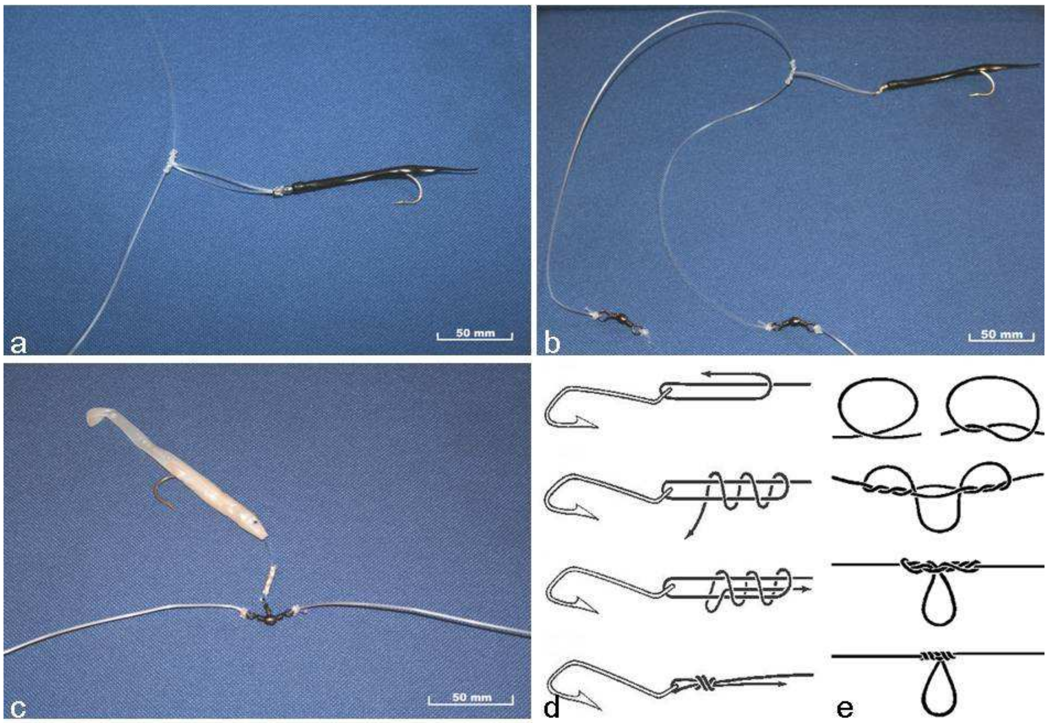


Figure 5 Techniques used in the construction of jig fishing lure rigs.
a: section of a rubber eel lure rig showing a black rubber eel lure attached to a dropper loop constructed from the main line; b. method of construction of a rubber eel lure rig; c. section of a Red Gill lure rig showing a silver Red Gill lure attached to a three way swivel using a crimp; d: illustration of the method used to construct a scaffold knot; e: illustration of the method used to construct a dropper loop knot.

2.2.1.6 Use of Bait

Three different types of bait, mackerel (either frozen or fresh), buckies and prawns, were used. Fresh bait was used when available and supplies of mackerel and buckies were frozen and stored for use at other times. Fresh mackerel baits were prepared by filleting the fish and cutting the fillet into strips of approximately 2-3cm width. Following defrosting, frozen mackerel fillets were often less robust than fresh fillets. To overcome this, frozen mackerel baits were prepared by cutting the head off the fish and cutting the remainder of the fish into steaks each about 2-3cm wide. Buckie baits were prepared by smashing the shell with a hammer, removing the flesh and cutting into sections of 2-3cm width.

2.2.2 Results

One of the most significant findings when working with terminal gear was the need to replace the mainline on the lure rigs on a regular basis. This was because the monofilament tended to lose its transparency after a few days fishing, turning a pale white colour. It was often felt that when the line turned this colour the fishing efficiency was reduced. It therefore became standard procedure to replace the monofilament in the lure rigs when this colour change became apparent. However further investigation, in the form of a comparative experiment, is required to actually test this hypothesis.

A significant cost to the project was the loss of sinkers and other gear loss. This was especially evident in areas where the drift of the vessel was considerable and where there were few fish being caught. Often, when fishing on hard or peaky ground, the length of monofilament between the bottom hook and the sinker would become abraded, reducing its strength, and ultimately resulting in the loss of the sinker. On other occasions when the gear became fast in the seabed, the sinker and a number of hooks would often be lost due to the strain breaking the line. It is assumed that the weakest point in the lure rig mainline was the point at which the line broke and, depending on where this was, it could result in the loss of little or all of the terminal gear. Weak points and resulting breaks in the mainline were often close to knots tied within the mainline. On other occasions when only the sinker was lost, it was chaffing of the section of mainline between the sinker and the bottom hook on the seabed that resulted in line breakages. This was often avoided by replacing the mainline between the sinker and the bottom hook when it became visibly worn.

On most occasions a variety and combination of lure rigs were fished simultaneously. When fishing rigs other than the steel bow rig; rubber eel and Red gill rigs were fished on alternate machines. This often helped to highlight which if any of the gear types was fishing best at any given time.

Differences in the construction of the rubber eel and Red gill lure rigs highlighted a number of advantages and disadvantages of each type. For example, one disadvantage in the construction of the Red Gill rigs (Figure 5) was found when the gear became tangled as crimps, due to their lack of flexibility, caused significant problems making tangles more difficult to unravel. Three way swivels in the rigs were seen to be very successful as they helped keep twists out of the mainline. The main problem identified with the construction of rubber eel rigs was the ease at which the dropper loop was shortened when strain came onto the lure rig. This was especially evident when the gear became fast on the seabed. It was often necessary to replace rigs as the distance between the lure and the mainline was too short (Figure 6) for the lure to work effectively.

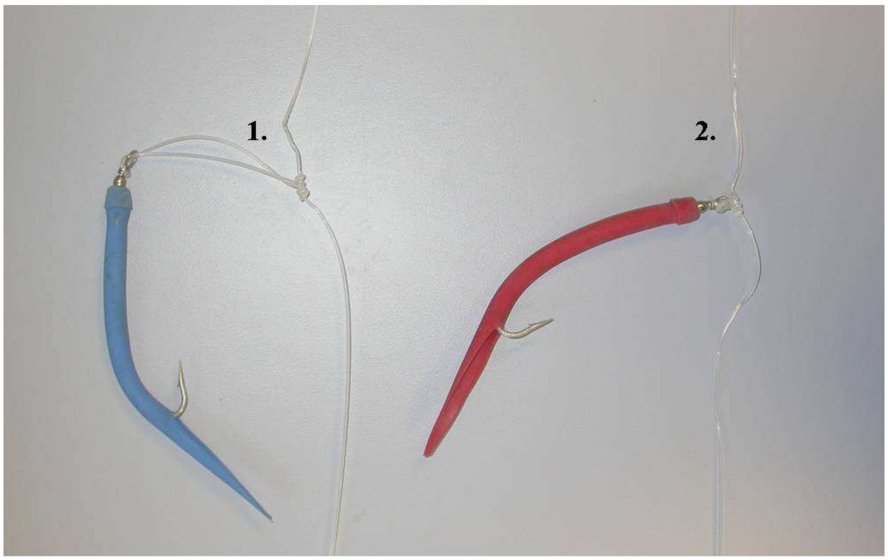


Figure 6 Damage to terminal gear as a result of gear becoming fast in the seabed.
1. A normal sized dropper loop tied into the mainline; 2. A shortened dropper loop as a result of gear becoming fast in the seabed.

2.2.2.1 Mustad rubber eel lures

During most of the project a variety of lure types and colours were fished on a "try and see" basis rather than under a strict protocol. Different grounds and ground types were constantly being explored under ever changing environmental conditions and it was found that the numbers of fish being caught were very variable. As the project developed the most frequently used lures were the Mustad rubber eel lures (Figure 3). Size 10 hooks were found to be more effective than size 12, which were for the most part too big, especially when catching smaller inshore fish. The lures were found to be strong and hardwearing, with the ability to withstand the rigours of catching large numbers of fish.

Two types of tubing were used to make the rubber eels and the PVC, while being more challenging to use in the construction of lures, was found to be more hardwearing than the silicone tubing. The colours in the silicone also tended to lose their brilliance over time. A number of different colours of tubing were used with the predominant colours being black, white, fluorescent red, fluorescent yellow, fluorescent green and pale blue as these were more readily available for purchase. Other colours less frequently used and not as readily available were silver, gold, red, dark blue, green and orange. The average cost for the construction of a rubber eel lure was £0.49.

Coloured lures were often randomly mixed in different arrangements on the lure rigs to optimise the effects of any colour at any given time. On many occasions black was observed to be a successful colour for catching bottom dwelling fish such as cod, ling and tusk. As a result black lures were often attached closest to the sinker to try and increase catches of these species. Observations indicated that fluorescent red was effective for catching lythe while saithe did not appear to show any preference for a specific colour.

Specific catch data was collected between the 26th October and the 8th December 2005 which highlighted a significant difference (χ^2=266, d.f.=5, P<0.01) in the number of fish caught on the different coloured lures. Figure 7 shows that the largest percentage of cod (50%), ling (60%) and tusk (62%), all bottom dwelling fish, were caught on black rubber eel lures while saithe was also caught in greater numbers on black (27%) than any other colour. Lythe were caught more frequently on red rubber eel lures (15%) than any other colour. The green rubber eel lure was found to be the least effective, catching only 5 lythe and no other species (Table 3). Blue and yellow did little better catching only 6 and 10 fish respectively.

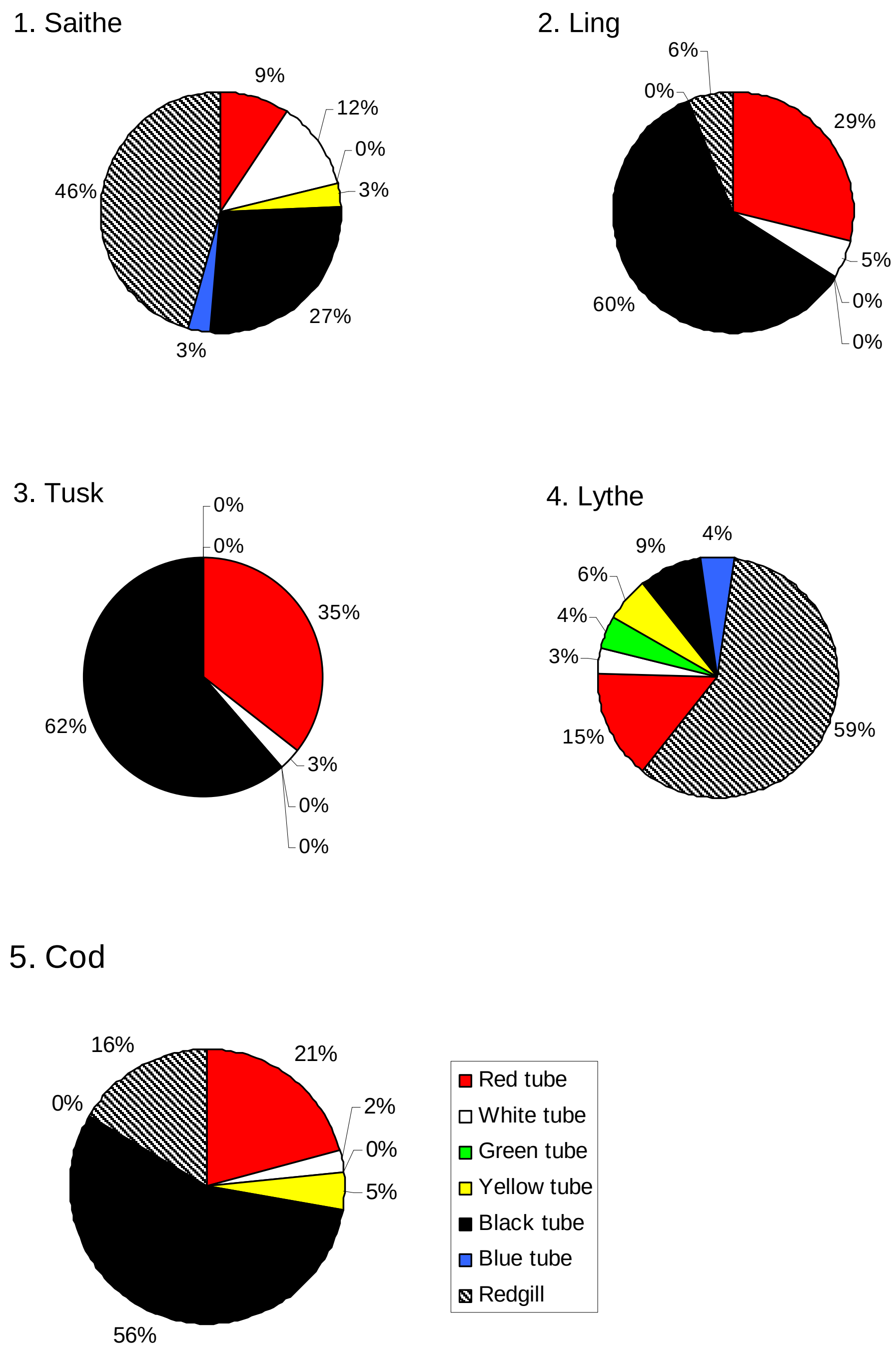


Figure 7 Percentage of total number of fish hooked on each of six different coloured rubber eel tube lures and Redgill lures. NB Data was collected for five species of fish caught between 26th October and 8th December 2005.

Table 3 Number of fish caught on six different coloured rubber eel tube lures and Redgill lures.

Lure Type	Number of fish					Total Fish
	Lythe	Cod	Ling	Tusk	Saithe	
Red rubber eel	17	9	23	11	3	63
White rubber eel	4	1	4	1	4	14
Green rubber eel	5	0	0	0	0	5
Yellow rubber eel	7	2	0	0	1	10
Black rubber eel	10	24	48	19	9	110
Blue rubber eel	5	0	0	0	1	6
Redgill	68	7	5	0	15	95
Total	116	43	80	31	33	303

2.2.2.2 Red Gill lures

Two sizes of Red Gill lure, 178mm and 210mm, were fished with the 210mm generally proving to be too large for the sizes of fish targeted. The main colours of Red Gill fished were the deadly nightshade, blue pearl, red pearl and silver in size 178mm. Lure rigs were often constructed using a mixture of the different colours. Following the success of these colours, lime green, cherry red, black, mackerel and afterburner (black with red tail) were also tried with less success. Initially the manufacturer supplied hooks with the lures but, as they tended to lose their shape when catching bigger fish, they were replaced with Mustad O'Shaughnessy size 8/0 hooks that proved to be more durable. The size 8/0 hook was regarded as the best size for the 178mm lure and the size 10/0 hook was more suitable for the 210mm lure. When contacted, the manufacturer was happy to supply the lures with or without hooks. The average cost for the construction of a Red Gill lure was £1.24. One interesting general observation noted was that the Red Gill lures seemed to fish better during the second half of the summer and the autumn months while, during the spring and early summer they did not fish as well. The reasons for this are unknown.

Specific catch data collected between 26th October and 8th December 2005 gave an indication of the effectiveness of this lure. A total of 95 fish were caught using the Redgill, coming second only to the black rubber eel (Table 3). It proved to be the most successful lure for catching lythe (59%) and saithe (46%) as well as catching small numbers of cod and ling (Figure 7).

One of the problems arising from the use of the Red Gill occurred with the loss of the tail section due to fish biting at it. The tail section provided the movement in the water that attracted fish and when it was broken off the lure no longer fished as effectively, even although the remainder of the lure was often in good condition.

2.2.2.3 Spoon & plastic squid lures

The use of spoons and plastic squid (muppets) was normally restricted to rigs constructed for use with the steel bowed sinker. Spoon lures cost £1.28 each while plastic squid lures were constructed at a cost £1.23 each. Normally these rigs would be constructed with a combination of lures and more often than not they would also be baited for maximum fish attraction. They were found to work especially well when fishing for ling because the lures were kept close to the seabed for long periods of time using the jig pause mechanism. Gear loss tended to be less of an issue when using the steel bowed sinker and when gear was lost it was usually restricted to one or two lures.

2.2.2.4 Sonar lures

Sonar lures were used for a limited period and were not found to fish any better than rubber eels or Red Gill lures. One of the problems encountered with the sonar lures was the brittle nature of the hooks. On a few occasions the point and barb of the hooks were broken off by larger fish, especially saithe (Figure 8). This normally occurred when the hooks, with the fish attached, were lifted clear of the water. This problem was not seen with any of the other hook types used as there was a tendency for them to bend rather than break. Sonar lures were supplied free of charge and are available commercially at a cost of £2.12 each.

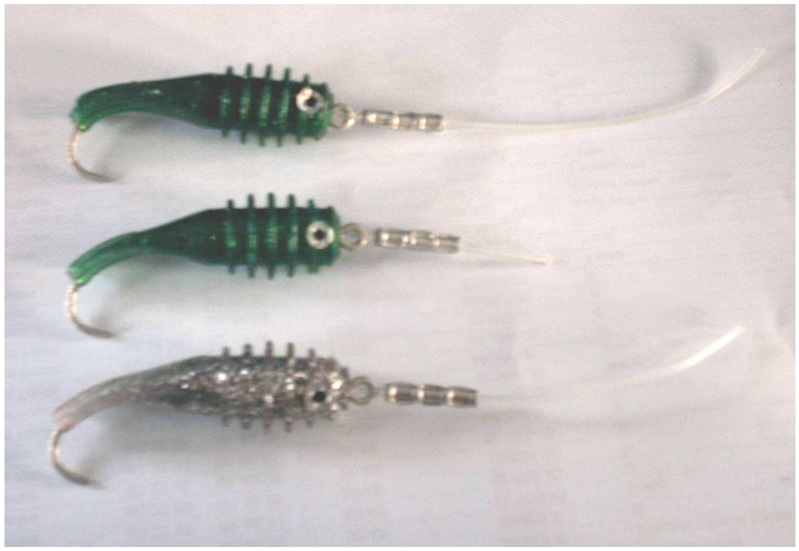


Figure 8 Sonar lures with point of hook broken off. NB Sonar lures were supplied by SonarLure.com. Lure rigs were constructed using a similar pattern to that used for making Red Gill rigs.

2.2.2.5 Bait

Mackerel and buckies were used successfully as bait throughout the study while prawns were quickly ruled out due to the soft flesh being unable to withstand the rigours of the jigging motion of the gear. The buckie was the most resilient bait as its tough rubber-like flesh ensured it stayed attached to the hook for prolonged periods. Fresh mackerel was also relatively resistant to the jigging motion while frozen mackerel tended to break up quite easily and needed to be replaced often.

The use of bait on lures was often observed to increase catches of bottom dwelling fish such as cod, tusk and ling while other species such as lythe and saithe showed a preference for bare lures. Fresh mackerel was observed to be the most effective bait on most occasions although there were times when the buckie fished better.

2.2.3 Discussion

One important lesson learned early on in the study was the need to ensure that the terminal gear was kept in excellent condition. This maximised returns and ensured that the minimum amount of time was spent working with gear while fishing. While this was also an effective way of keeping gear loss to a minimum, well over £800 worth of gear was lost during the study. Wear and tear was always an issue and most of the gear used had a fairly short lifespan. It was therefore essential to have a significant number of spare rigs and sinkers and anywhere between 5 and 20 lure rigs were normally prepared and ready to be used as replacements for lost or damaged gear. Bearing that in mind, anyone wishing to undertake jig fishing would be recommended to have a good supply of spare gear with spare rigs ready to use as replacements for lost gear.

2.2.3.1 Lures

While a variety of lures were tried during this study, the rubber eel lure was the most cost effective option. Materials needed to make the lures are readily available and large numbers of lures can be constructed in a relatively short period of time. In terms of durability, PVC tubing was preferred to silicon and the variety of colours available gives a number of options when constructing lures.

Catch data indicated that different species had preferences for different coloured rubber eel lures with black being the most effective for bottom dwelling species such as cod, ling and tusk. A number of fish species that feed on active prey are known to adopt the strategy of attacking the prey from below (Jobling, 1996). This strategy is related to the visibility of the prey item against the downwelling light. It may be the case that black coloured lures stand out more clearly than any other colour against the light from above making them easier for predators to detect and locate.

Red Gill lures are an effective means of catching species such as lythe and saithe. However, the fragility of the lure meant that they did not need to incur much damage to render them ineffective. As with the rubber eel lures, Red Gill rigs were relatively easy to construct. The four main colours used during this study, silver, blue pearl, red pearl and deadly nightshade, were selected following advice from the manufacturer on which colours have proven to be most effective with other fishermen.

It was observed that there was a variation in the effectiveness of the Red Gill lures at different times of the year and this may be related to fish feeding patterns and prey availability. These lures, which are intended to be imitation sandeels, may have fished more effectively at times of the year when sandeels are more readily available to the target species. There are a number of fish species known to exhibit diet switching behaviour (Gerking, 1994) depending on the availability of different prey types. Further studies are necessary to determine whether seasonal changes have an effect on the performance of different lures. Over a period of time patterns may emerge indicating which lures would be the most effective for a specific target species at different times of the year.

Other lures used in the study were not deployed in the same quantities as the two types mentioned above. This is no reflection on their ability to catch fish, in fact there may be times when spoons, muppets and even sonic lures do indeed out fish rubber eels and Red Gills. Collaboration of findings from vessels involved in the fishery over an extended period of time would be the most effective method of building up a picture of which, if any, lures work best under certain conditions.

2.2.3.2 Bait

The use of bait proved successful for attracting demersal fish such as cod, ling and tusk. On many occasions the presence of bait would have given an extra stimulus to help fish detect and locate lures. Baited hooks have long been used as a method for catching fish and numerous studies have been carried out looking at a variety of aspects related to baits and fish reaction to bait. Lokkeborg (1989, 1999, 2000) and Vabo (2004) carried out studies investigating the behaviour of fish in relation to baited hooks, highlighting how different species react and subsequently respond to bait. Other studies have looked at the use of different sizes of bait in long line fisheries (Johannessen, 1983, Løkkeborg & Bjordal, 1995, Wolla et al., 2001) with the view to finding optimum sized baits. A number of different baits have also undergone field trials. Johnstone (1981) reported that cod and saithe preferred mussel and squid baits to mackerel and salt herring while Lokkeborg, (1991) carried out an experiment using minced herring in a nylon bag. The minced herring produced higher catch rates of haddock, ling and tusk while cod favoured the natural bait.

Each fish species show preferences for different baits and these are likely to be based on their own prey preferences. These preferences may change on a seasonal basis or at various stages in the life cycle.

3 Fishing Operations

3.1 Materials and Methods

3.1.1 Fishing grounds

As many areas as possible around the coast of Shetland, including both Foula and Fair Isle, were fished. In general, the selection of fishing grounds on any given day was largely dependant on weather conditions. Offshore grounds which were deemed to be accessible to inshore vessels in good weather conditions were also fished.

Fishing was mainly limited to areas that are not readily accessible to trawlers such as hard ground, areas of rocky peaks on the sea floor, and wrecks. Selection of specific grounds was based on information passed on by other fishermen, local knowledge, and information gathered from fishermen's chart plotter data. Other grounds were identified using the echo sounder on the *Atlantia* and *Atlantia II* while travelling between known fishing grounds.

Grounds that yielded reasonable quantities of fish were fished more often than unsuccessful grounds. This was, in part, to determine the extent of the fishing grounds and also to evaluate whether species and quantities of fish on the grounds fluctuated over time.

3.1.2 Conducting drifts

During fishing operations, the vessel was positioned so that, depending on the wind and the speed and direction of the tide, it drifted over the target area once the engine was switched off. When fishing on wrecks the vessel was stopped near the wreck, the direction of drift was determined and the vessel was then positioned so that it drifted over the top of the wreck. When the vessel had completed a drift over the wreck, as shown by the disappearance of the wreck from the echo sounder, the vessel was steamed back to the starting position and another drift began. This is shown schematically in Figure 9. The number of drifts undertaken over any one location was largely determined by the amount of fish caught. If few fish were caught the vessel moved on to try another area. A similar approach was used on peaks and hard bottom. After the direction of drift was determined and the vessel moved to a start position, it was allowed to drift over the ground and, when the edge of the peak or hard ground was reached, the vessel was steamed back to the start position.

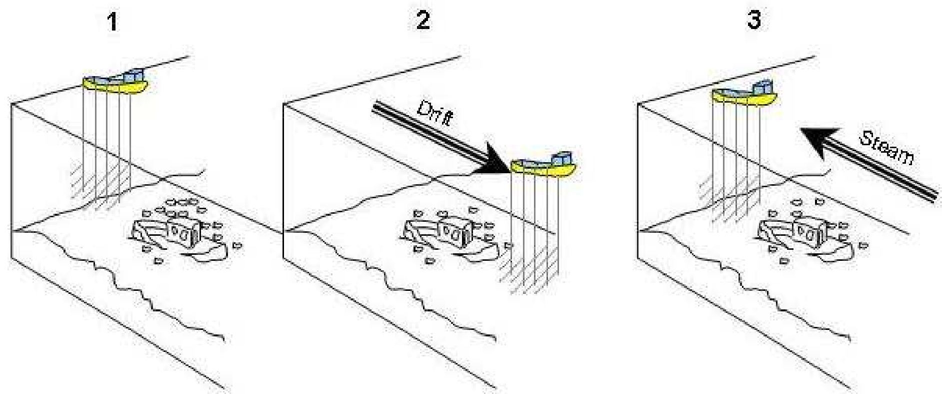


Figure 9 Diagram of drift procedure during jig fishing over a wreck; 1: Position to start drift over wreck, 2: completion of drift over wreck and some fish caught, 3: steam back to starting position prior to repeating procedure.

3.1.3 Bycatch and Selectivity

Records were kept of all species that were caught. Those that were caught infrequently were later grouped as bycatch. Records were also kept of undersize fish and those that were foul hooked.

3.1.4 Handling & storage of fish

When fish were brought aboard the vessel, they were placed in large insulated plastic bins, each with the capacity to hold 150-200kg of fish. Normally, within one hour of being caught, fish were gutted and washed and then boxed in ice in the hold of the vessel following guidelines for storage of fish on small inshore vessels published by Sea Fish Industry Authority's fish technology department (Seafish, 1997). Fish were stored in the hold for between one and three days, depending on the length of the fishing trip. All fish were landed at ports in Shetland and sold through the Shetland Seafood Auction in Lerwick.

3.1.5 Data collection and analysis

A variety of data was collected throughout the project. At sea, environmental conditions including weather, wind speed and direction, sea temperature, sea state, sea depth and type of seabed were recorded. Each time an area was fished the latitude and longitude and any known name of the ground or wreck was recorded; the time of day that fishing began, length of time spent fishing, and the catch were also recorded for each fishing location. (See Appendix II for an example of data sheets). Other data collected included duration of fishing trips, estimates of the amount of fuel consumed, estimates of gear loss costs, total grossing of fish landed from each trip, and average fish prices for each trip. On a number of occasions, when circumstances permitted, specific catch data including numbers of undersized and foul hooked fish were also recorded.

A number of statistical tests were undertaken to explore relationships and differences between catch rates in a number of areas fished during the study and to investigate relationships between catch rates and a number of environmental variables.

3.1.5.1 Fishing grounds

The Kruskal-Wallis test was used to determine if there was significant variation in the catch per unit effort (CPUE), measured as boxes per hour, between the three fishing ground types (hard ground, peaks and wrecks). The Chi-square test was also used to ascertain whether there was a significant difference in the total catch, measured as total boxes, between the three fishing ground types.

3.1.5.2 Depth data

Possible relationships between saithe and lythe CPUE and sea depth were investigated using the Spearman Rank Correlation Co-efficient test. This test was also used to explore changes in total catch, measured as total boxes, and CPUE over a period of time at an area of peaks 15 miles NNW of the Ramna Stacks. Possible relationships between depth and CPUE for both peaks and hard ground were also examined using the same test.

3.1.5.3 Environmental variables

The Kruskal-Wallis test was used to determine if there was significant variation in total CPUE at different stages in the tide cycle at an area of peaks 15 miles NNW of the Ramna stacks. The Mann-Whitney *U*-test for unmatched samples was used to further investigate differences between CPUE and tide cycle at the peaks 15 miles NNW of the Ramna stacks and also a wreck 15 miles north of the Ramna Stacks.

The effects of tide strength on CPUE and total catch, measured as total boxes, as well as the effects of wind speed and direction on CPUE were examined using the Spearman Rank Correlation Co-efficient and Kruskal-Wallis tests. A 1-way ANOVA was also used to investigate variation in catch rates (boxes/hour) during different wind speeds.

The Kruskal-Wallis test was used to determine whether there was significant variation in CPUE during different sea states, CPUE at different times of day, measured as hours after sunrise and hours before sunset, and CPUE during different weather conditions. Finally, the Chi-square test was used to ascertain whether catch rates of a number of lures were significantly different during a fishing period between October and December 2005.

3.2 Results

A total of 1505 hours from 121 days were spent at sea during the 15 months that the project ran. During that time 476 hours were spent actively fishing while the remainder of the time, 1029 hours, was used travelling to and from port, searching for suitable grounds and steaming between fishing grounds. Of the 121 days at sea, there were 26 days with three crew members present, and for the remainder of the time the vessel had a crew of two. Throughout the project the vessel was based in various harbours around Shetland including Lerwick, Scalloway, West Burrafirth, Collafirth and Cullivoe. A number of other small harbours were used for overnight stays. Lerwick, Scalloway and Cullivoe were particularly convenient as essential supplies such as ice, water and fuel were available. When the vessel was based at harbours without those amenities ice was normally transported to the vessel in large insulated bins.

3.2.1 Handling & storage of the catch

The nature of the fishery (short trip duration) and the handling and storage of the catch ensured that it was in prime condition when sold at auction. The condition of the catch benefited from the fish being brought aboard alive and then being gutted, washed, iced and stored as 40kg boxes within 1-2 hours of being caught. Fish were stored in the hold of the vessel for a maximum of three days before being landed, with the majority of fish being landed within one or two days of being caught. This compares to 7 day trips common amongst the local trawler fleet. The majority of the catch was put onto the Scalloway market with the remainder being sold at Lerwick. When the vessel was working out of harbours other than Lerwick and Scalloway, fish were transported to market using the Centre’s pick-up and trailer. On one occasion when the catch was too large for the Centre's transport R.S. Henderson haulage were hired to take the catch from Cullivoe, Yell to Scalloway.

3.2.2 Fishing grounds

A number of areas around Shetland were fished during the project (Figure 10). In total, 570 fishing operations (i.e. one or more consecutive drifts on a given ground on a given day) were carried out over the 15 month period. The operations were categorised according to the following seabed types: hard bottom, peaks, and wrecks. A total of 214 hours were spent carrying out 310 fishing operations on hard bottom, 129 hours were spent carrying out 152 fishing operations on peaks, and 97 operations were carried out during 133 hours on wrecks (Figure 11). There was a highly significant variation (Kruskal-Wallis test: K=39.1, d.f.=2, P<0.001) in the catch per unit effort (CPUE), measured as boxes per hour, between the three ground types, with wrecks yielding the highest CPUE, followed by peaks and then hard ground (Table 4). There was also a significant difference (χ^2=243, d.f.=2, P<0.001) in the amount of saleable fish, measured as total boxes, between the three ground types, with wrecks yielding the greatest amount of fish, followed by peaks and then hard ground (Table 4).

Lythe were by far the greatest contributor to the overall catch with a total of 292 boxes (Figure 12). A total of 204.5 boxes of saithe were also caught. Smaller amounts of other species including cod (17.5 boxes), ling (27 boxes), and tusk (4 boxes) were caught at different times throughout the project.

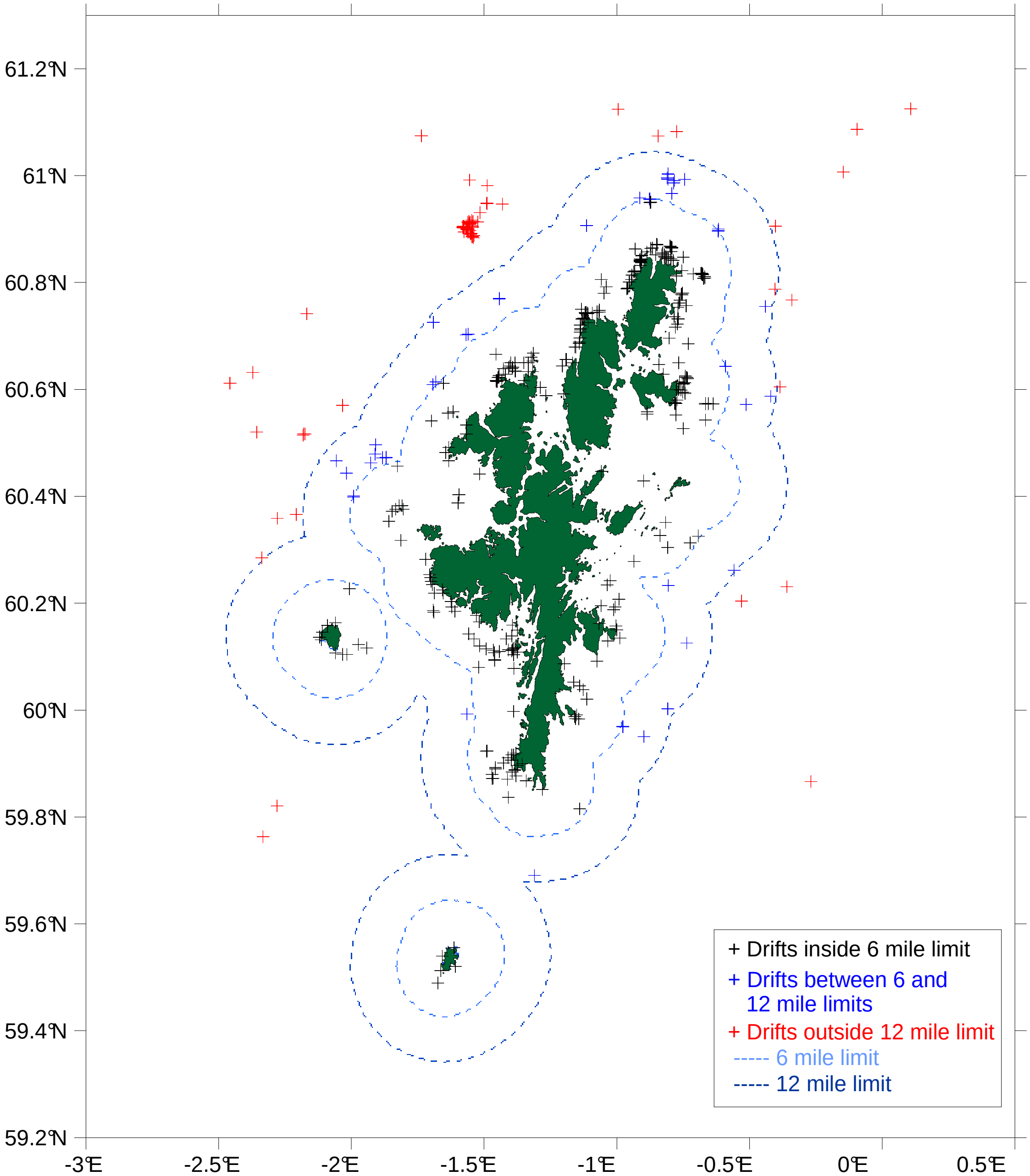


Figure 10 Geographical positions of individual jig fishing operations completed around Shetland.

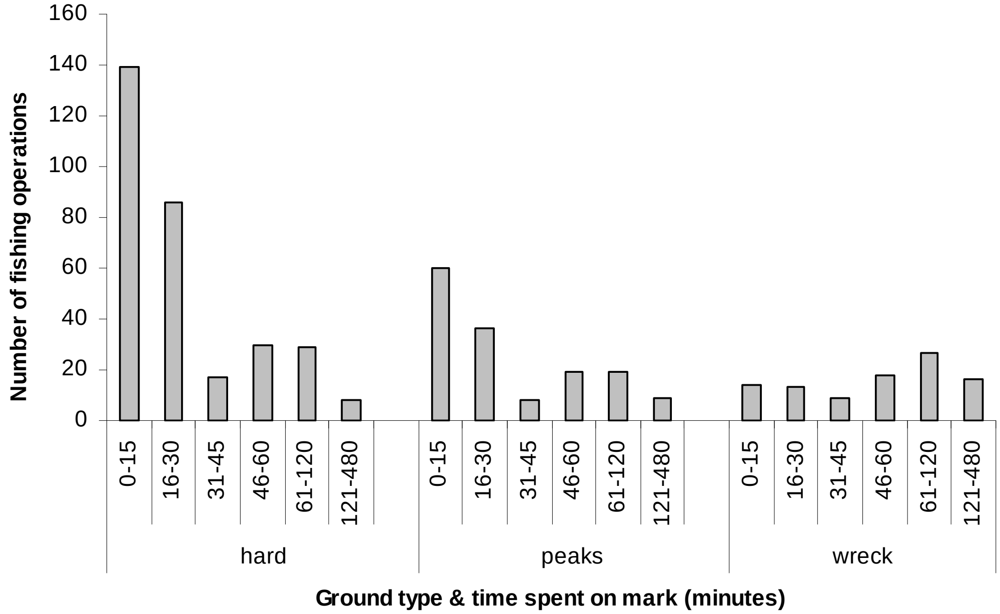


Figure 11 Duration and number of fishing operations on three different ground types around Shetland.

Table 4 Total catch of the five main species, time spent fishing and CPUE for the different ground types fished.

Ground type	Time fishing (hrs)	Boxes of fish per ground type					Total boxes
		Lythe	Saithe	Ling	Cod	Tusk	
Hard	214	35	1	5	11	1	53
Peaks	129	132	2.5	1	5	2.5	143
Wrecks	133	125	201	21	1.5	0.5	349
Total	476	292	204.5	27	17.5	4	545
		Total CPUE (boxes per hour)					
		Lythe	Saithe	Ling	Cod	Tusk	**Total boxes per hour**
Hard	214	0.2	0.01	0.02	0.05	0.00	0.25
Peaks	129	1.0	0.05	0.01	0.03	0.01	1.14
Wrecks	133	0.9	1.5	0.2	0.01	0.00	2.62
Total	476	0.6	0.4	0.05	0.03	0.01	1.15

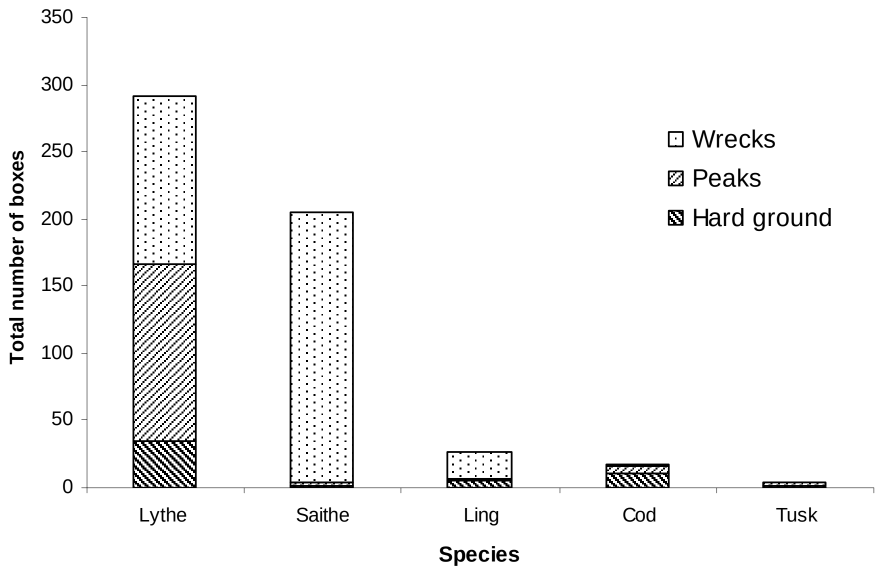
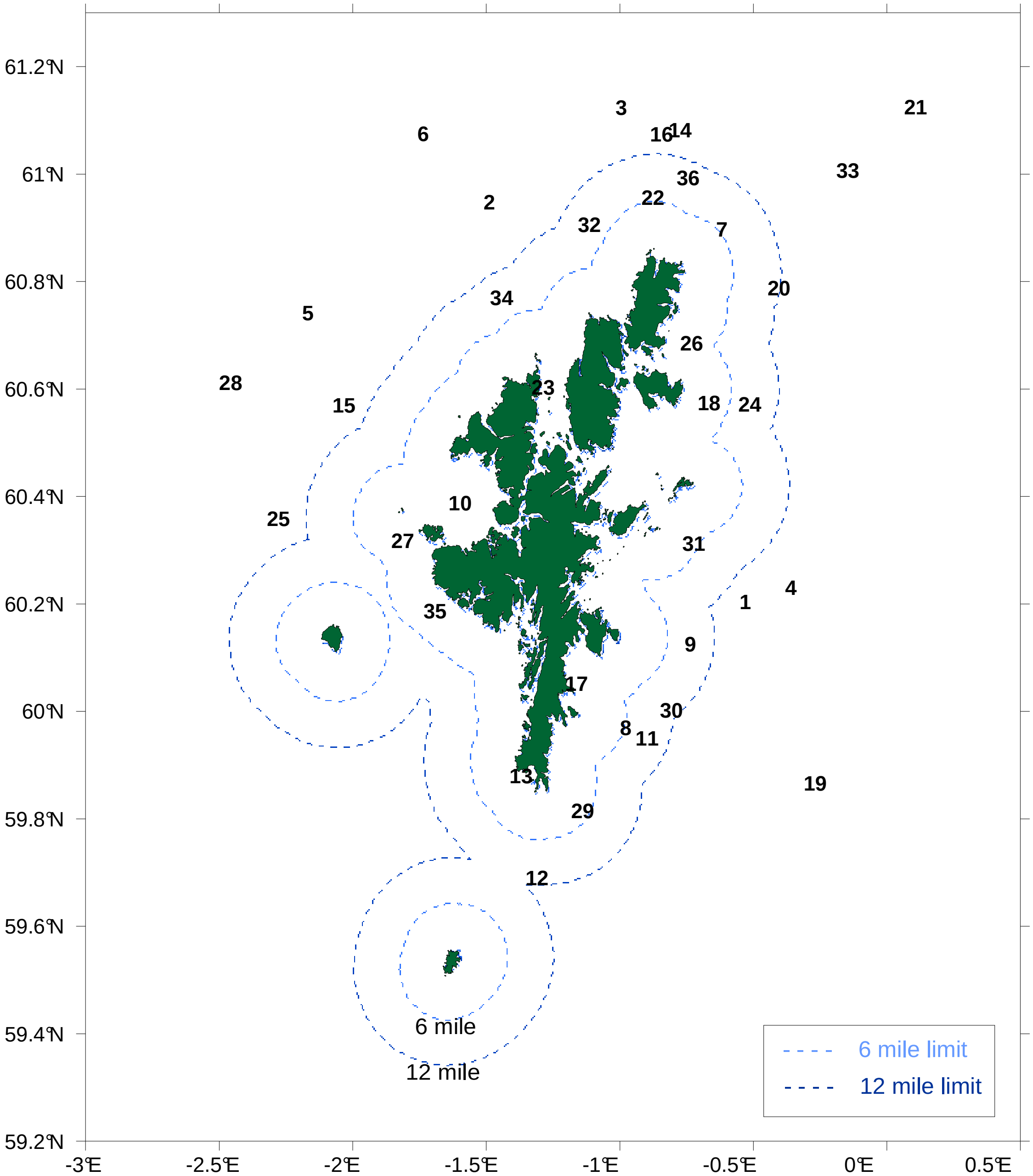


Figure 12 Total catch by species from the three different types of seabed fished.

3.2.3 Wrecks

A total of 36 wrecks (or groups of wrecks) were located and fished. The majority of the wrecks were outside the 6 mile limit to the north and east of Shetland (Figure 13) and lay in depths ranging from 10 to 102 fathoms (18 – 187m). Positions of wrecks shown in Figure 13 are detailed in Appendix III

The time spent fishing on each wreck on any given day varied from 15 minutes to 6 hours with an average duration of 1 hour 23 minutes. Specific drifts would last between 10 and 20 minutes although the time the vessel took to drift over the wrecks varied depending on the speed and direction of the wind and tide. With little tide and wind the drift could be as long as an hour. On many occasions, as the vessel drifted away from the wreck, the shoal of fish would move with the vessel and fishing could continue for a longer period.



No.	Wreck	No.	Wreck	No.	Wreck
1	13 mile E of Lerwick	13	Braer	25	North of Foula Wk
2	15 mile N of Ramna Stacks	14	Buschini	26	Northern Venture
3	15 mile NWN of Muckle Flugga	15	Coal boat	27	Papa Stour Wk
4	16 mile E of Lerwick	16	Coastal Empress	28	Pipeline
5	26 mile NW of Ramna Stacks	17	Day Dawn	29	Quo Vadis
6	27 mile NNW of Ramna Stacks	18	Duniedin + Fetlar - muckle + Fetlar - south Wks	30	River Ayre
7	6 mile ENE of Unst	19	East of Lerwick Wk	31	South of Out Skerries
8	7 mile E of Mousa	20	East of Skaw Wks	32	Submarine
9	8 mile E of Lerwick	21	Glenugie	33	Telstar
10	Argonaut	22	Majestic	34	Unity
11	Barge	23	Morning star	35	Victory
12	Blue Painter	24	north Fetlar Wk	36	Voracious

Figure 13 Geographical positions of wrecks located and fished around Shetland.

3.2.3.1 Total catches from wrecks

The highest catch over a period of time from a single wreck, 15 miles north of the Ramna Stacks (No. 2 on Figure 13), was 84 boxes, 74 of saithe and 10 of lythe (Figure 14). A total of 20.25 hours were spent fishing on this wreck over a number of months giving a total CPUE of 4.15 boxes/hour. The wreck lay in 71 fathoms of water and was located by chance, when travelling from one fishing ground to another. Although this wreck yielded the highest total catch, the CPUE data (Figure 15) indicates that the highest catch rate, 7.1 boxes/hour, actually occurred at the Glenugie wreck, 25 miles NE of Unst (No. 21 on Figure 13). Figure 15 highlights the fact that average catch rates were generally higher to the north of Shetland than the east or south of Shetland.

The largest catch for a single day, twenty-two boxes of saithe and 6 boxes of lythe, came during a four hour fishing period at a wreck 13 miles north of Muckle Flugga known as the Coastal Empress (No. 16 on Figure 13 and Figure 23). Although many wrecks yielded high catches over relatively short periods of time, this was not the case for all wrecks. Of the 39 wrecks sampled, 16 (41%) yielded less than one box of fish. Often wrecks within 4-5 miles of each other would have significant differences in numbers of fish caught and marks of fish visible on the echo sounder. For example, the wrecks 25 and 21 miles northeast of Unst were in similar depths and were similar sizes when viewed on the echo sounder. The wreck 25 miles northeast of Unst had signs of fish when viewed on the echo sounder and 6 boxes of saithe were caught in 30 minutes, one of the highest CPUEs of any wreck (Figure 15). However, the other wreck, only four miles to the southwest, had no marks on the echo sounder and only one ling was caught during the same length of time. A similar pattern was evident in other locations.

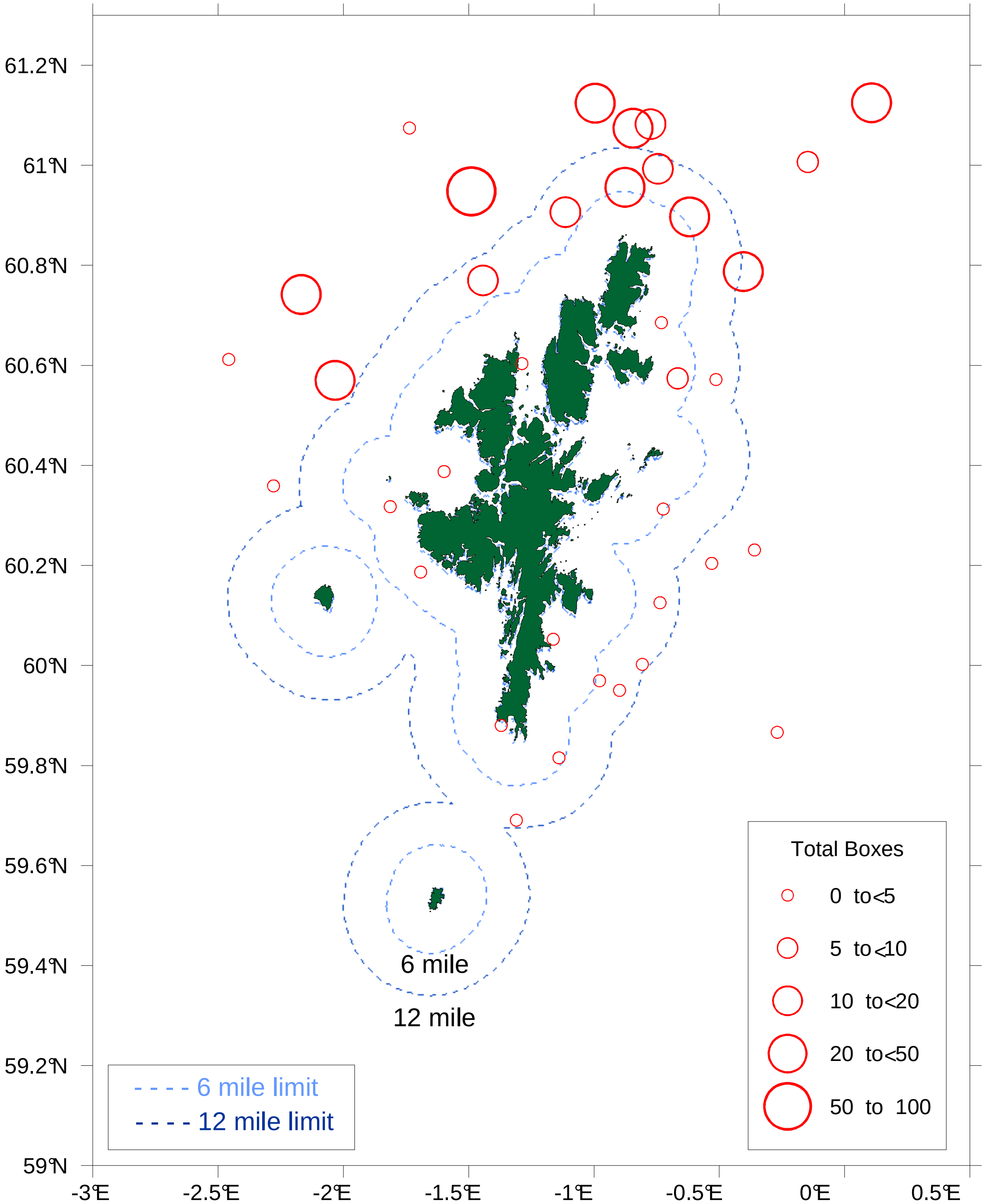


Figure 14 Total number of boxes caught on wrecks fished around Shetland.

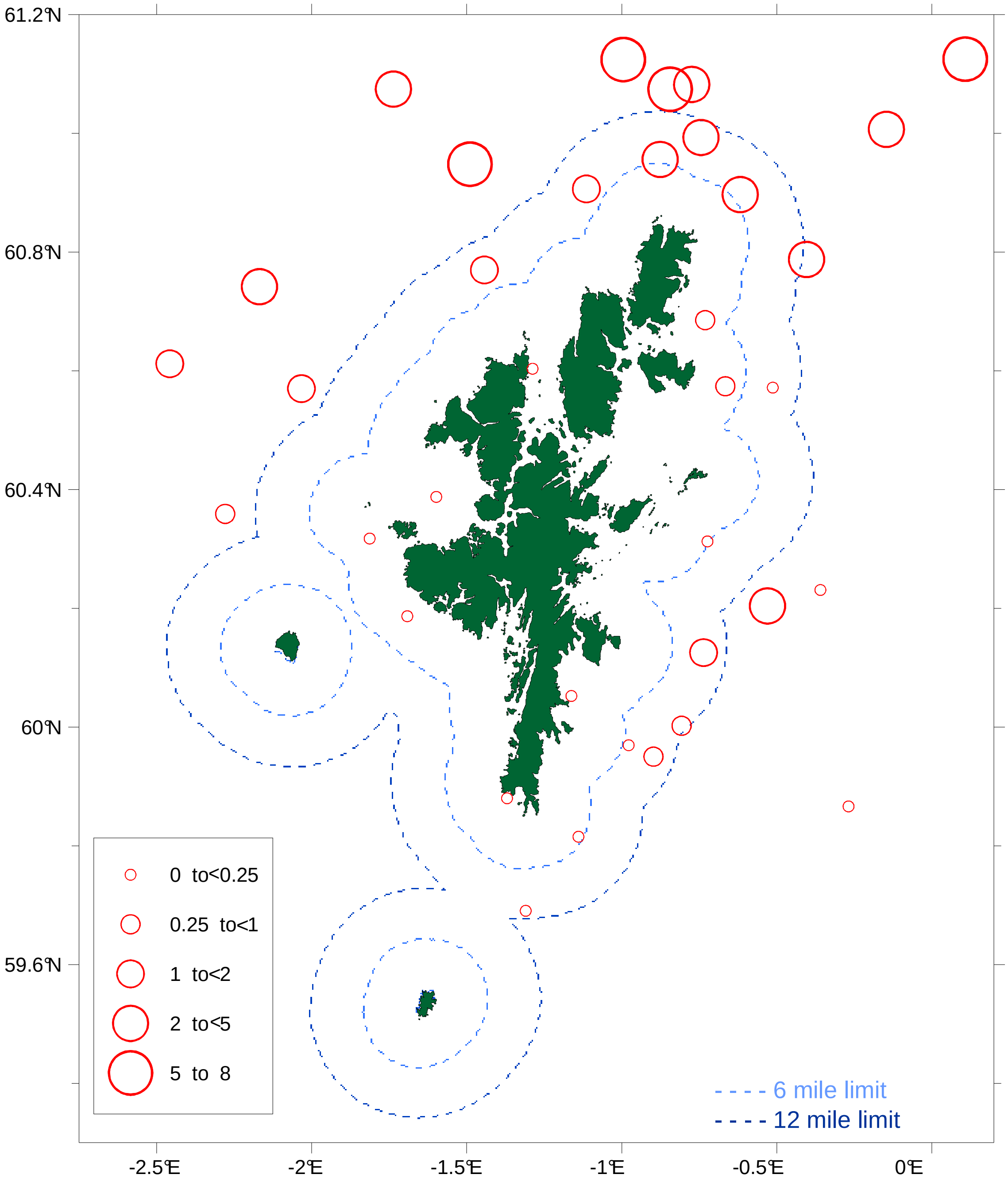


Figure 15 Catch per unit effort (boxes/hour) of wrecks fished around Shetland.

3.2.3.2 <u>Species composition on wrecks</u>

Species composition and quantity of fish caught changed over time on some wrecks. For example, lythe were the main species caught on the Majestic wreck (60°57.36'N, 000°52.53'W) on most occasions although, for unknown reasons, saithe were caught in greater numbers on the 17th August (Table 5). Other wrecks, such as the one 15 miles north of the Ramna Stacks did not have a significant change in species composition in the catch over time (Table 6).

Gear loss was not a significant issue on the majority of wrecks fished. Some more recently sunken wrecks did tend to snag the gear more than those which have been present on the seabed for many years. Little, if any, gear was lost on the wrecks with reasonable quantities of fish present.

Table 5 Changes in catch composition at the 'Majestic' wreck at different dates during 2006.

Date	Time on Mark (Hours)	Catch (boxes)			
		saithe	lythe	ling	tusk
19-Apr-06	3	3	9	-	-
01-Jun-06	1.75	0.5	7.5	-	-
17-Aug-06	1	3	0.5	-	-
18-Sep-06	1.5	1	3	1	1
17-Oct-06	0.75	0.5	0.75	3	-

Table 6 Catch composition over a seven month period in 2006 at a wreck 15 miles north of the Ramna Stacks.

Date	Time on Mark (Hours)	Catch (boxes)	
		saithe	lythe
18-Apr-06	2.5	15	1
16-May-06	6	13	4
06-Jun-06	2	4	1.5
06-Jun-06	1.5	5	1
17-Jul-06	1.25	14	0.5
12-Sep-06	2	11	1
16-Oct-06	1.25	8	1

3.2.3.3 Catch by species on wrecks

The main species caught on wrecks were saithe and lythe (Table 4). Saithe were caught on a number of wrecks around Shetland although the most productive were those north of Muckle Flugga (Figure 16). Lythe were also caught on a number of wrecks around Shetland with the highest CPUEs tending to be from wrecks at the northern end of Shetland (Figure 17). Two wrecks, the 'submarine' (No. 32 on Figure 13) and a wreck 11 miles east of Unst (No. 20 on Figure 13), were an exception to this pattern as they yielded 14 and 3 boxes of good quality ling respectively (Figure 18) and very little saithe (Figure 16) or lythe (Figure 19). Ling were also caught in small numbers on ten other wrecks around Shetland (Figure 19). Cod (Figure 20) and tusk (Figure 21) were both caught in very low numbers. One box of cod was caught on the pipeline west of the Ramna Stacks and a further half box was caught during one fishing operation on the submarine wreck. The only other wreck to yield cod was 16 miles east of Lerwick although only one fish was caught. Tusk displayed a similar pattern with only one or two fish being caught on a total of 6 wrecks (Figure 21).

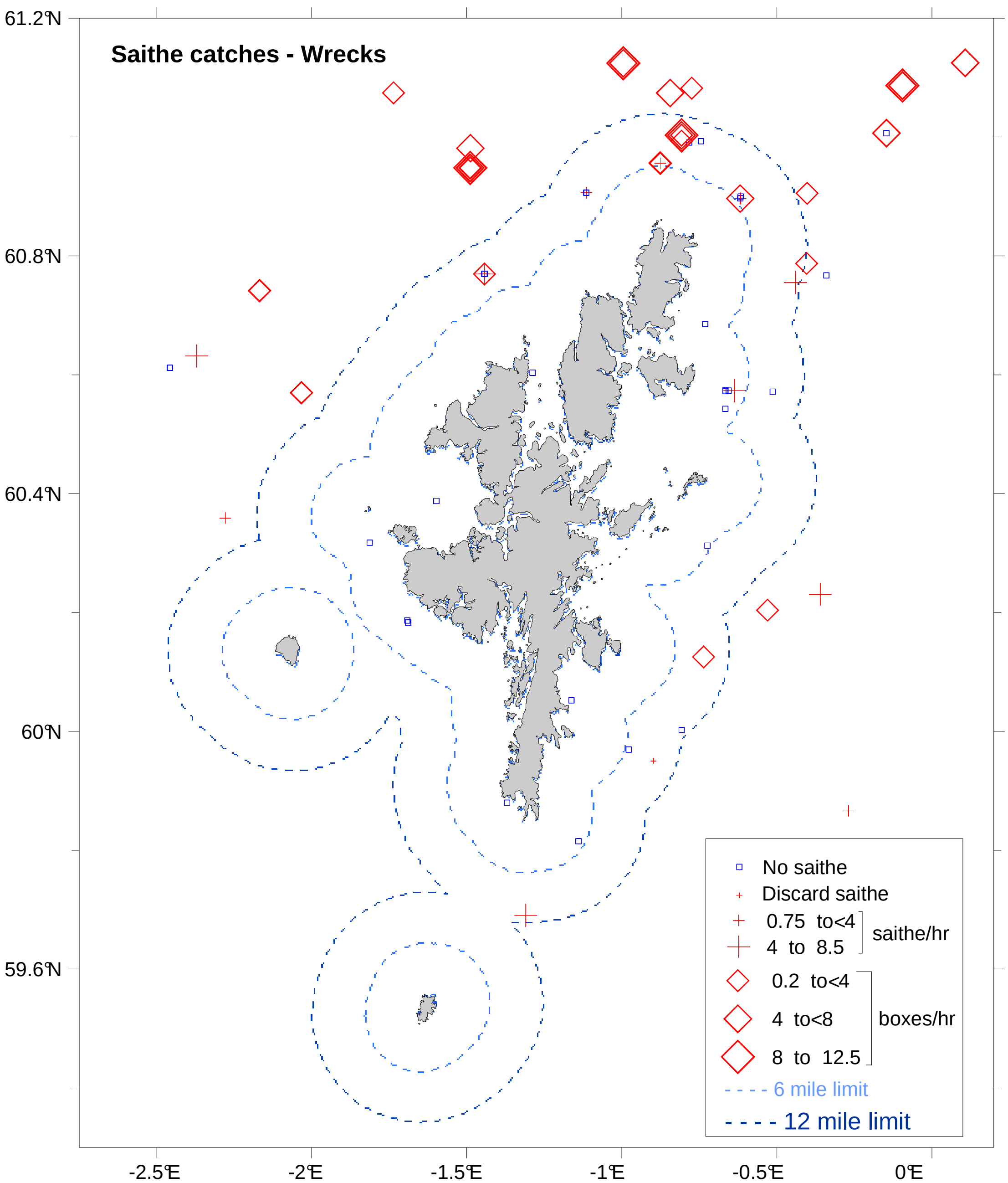


Figure 16 Catch rates of saithe on wrecks around Shetland. NB Catches were recorded as number per fishing operation where catches were <0.25 boxes per operation and in boxes per hour where catch rates were higher.

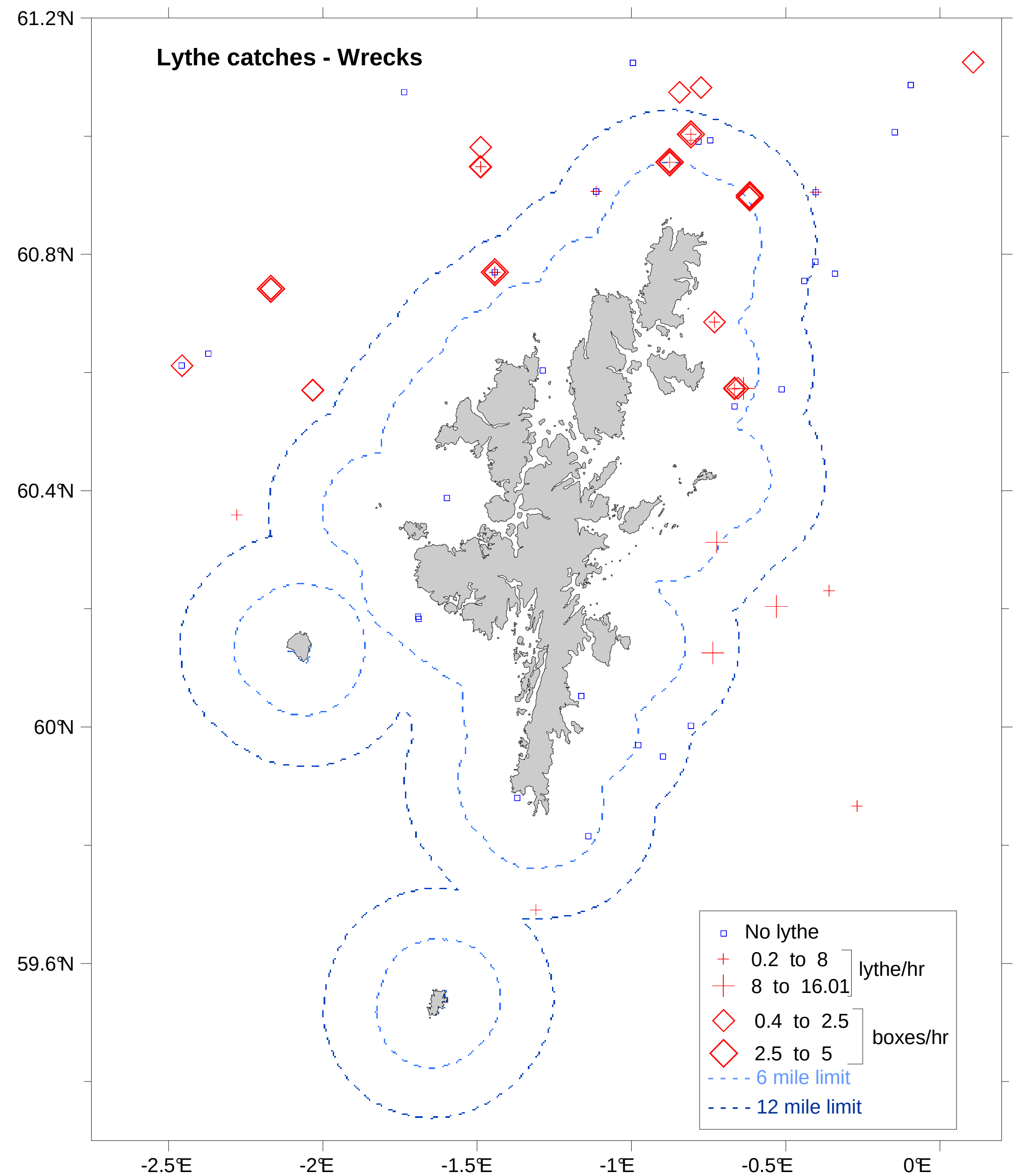


Figure 17 Catch rates of lythe on wrecks around Shetland. NB Catches were recorded as number per fishing operation where catches were <0.25 boxes per operation and in boxes per hour where catch rates were higher.

Figure 18 Ling caught with jigging machines on a wreck in 71 fathoms east of Unst. NB The ling shown were caught using the sinker with steel bow rig. Fish were caught on a variety of lures that were also baited with mackerel.

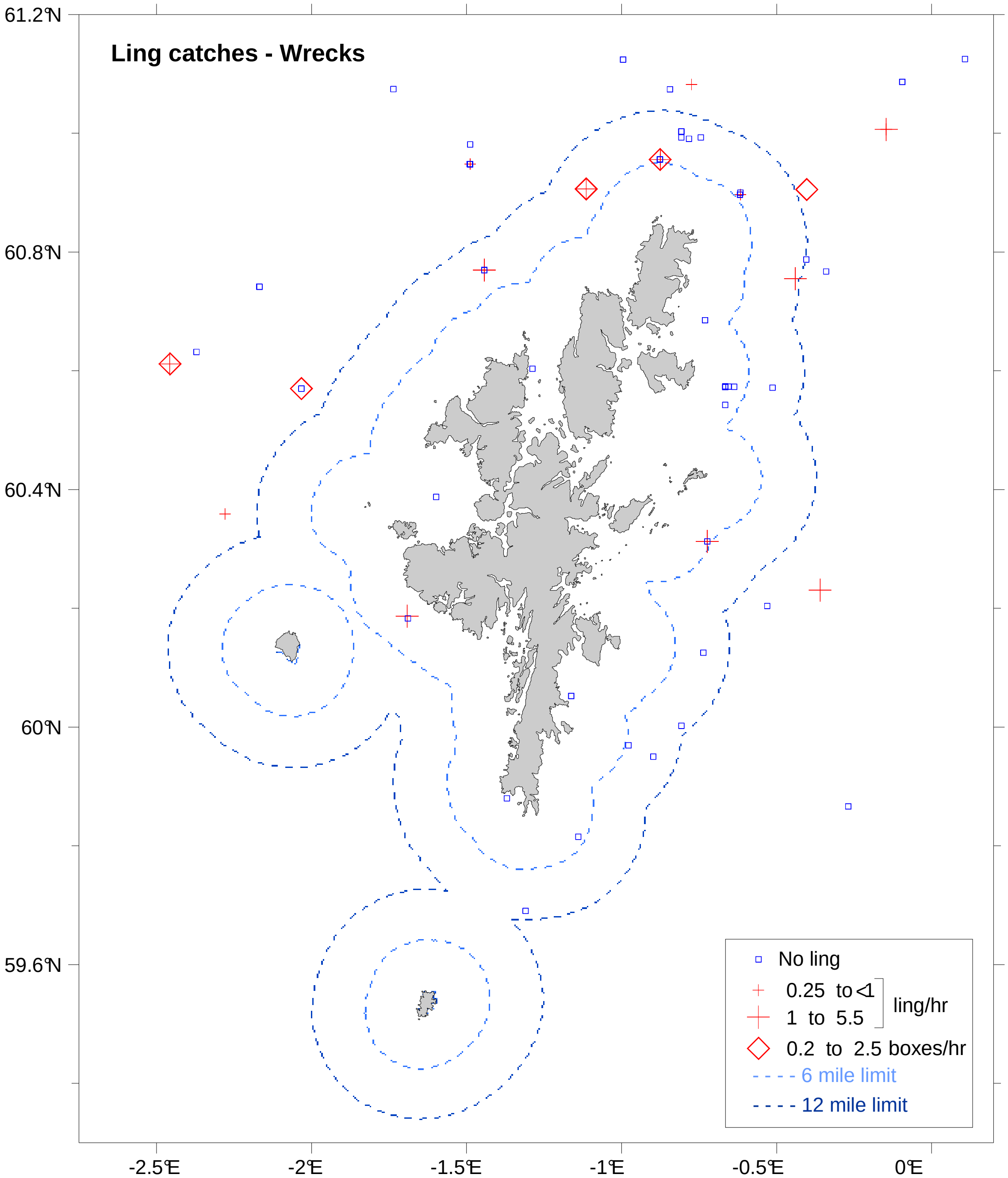


Figure 19 Catch rates of ling on wrecks around Shetland. NB Catches were recorded as number per fishing operation where catches were <0.25 boxes per operation and in boxes per hour where catch rates were higher.

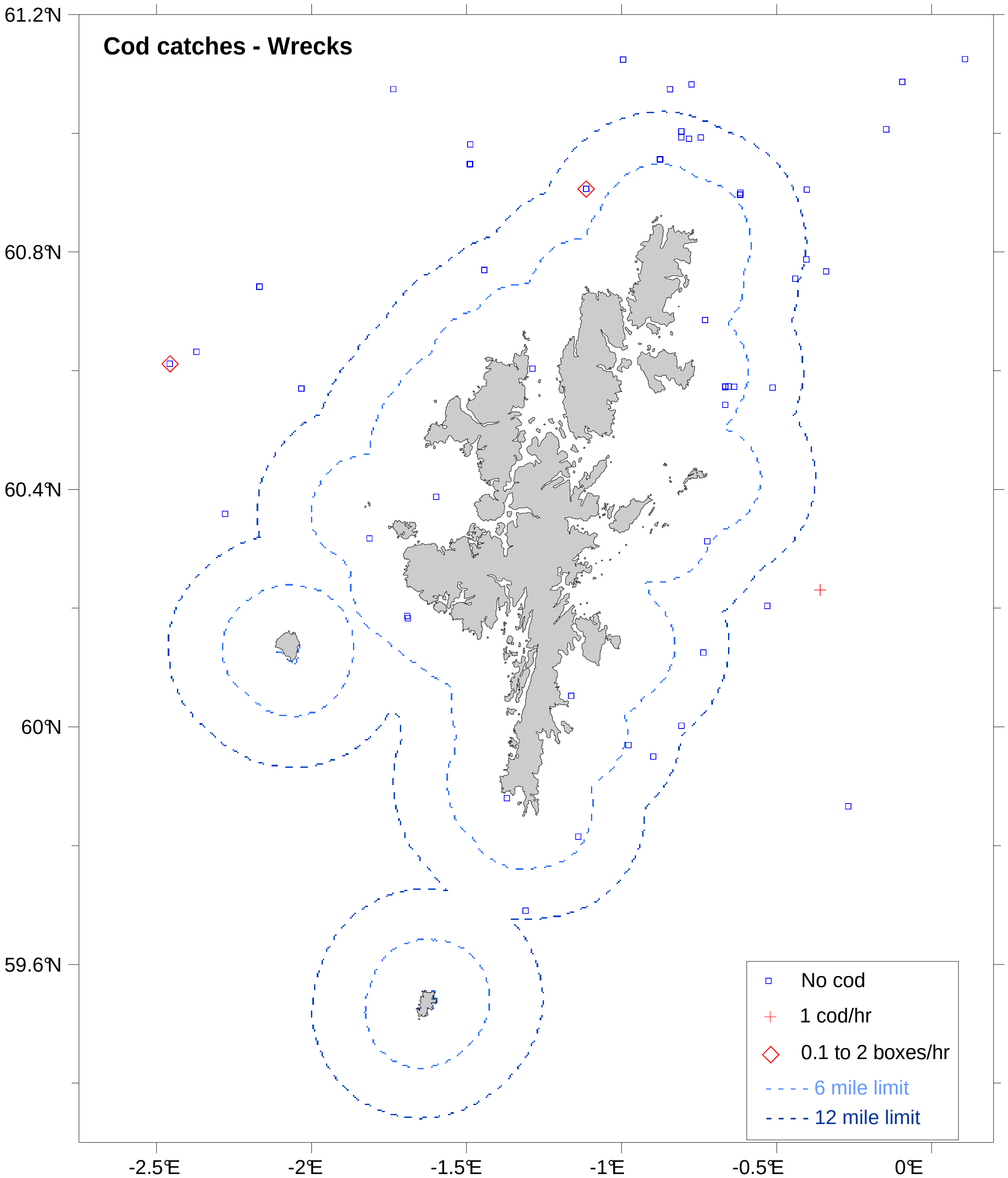


Figure 20 Catch rates of cod on wrecks around Shetland. NB Catches were recorded as number per fishing operation where catches were <0.25 boxes per operation and in boxes per hour where catch rates were higher.

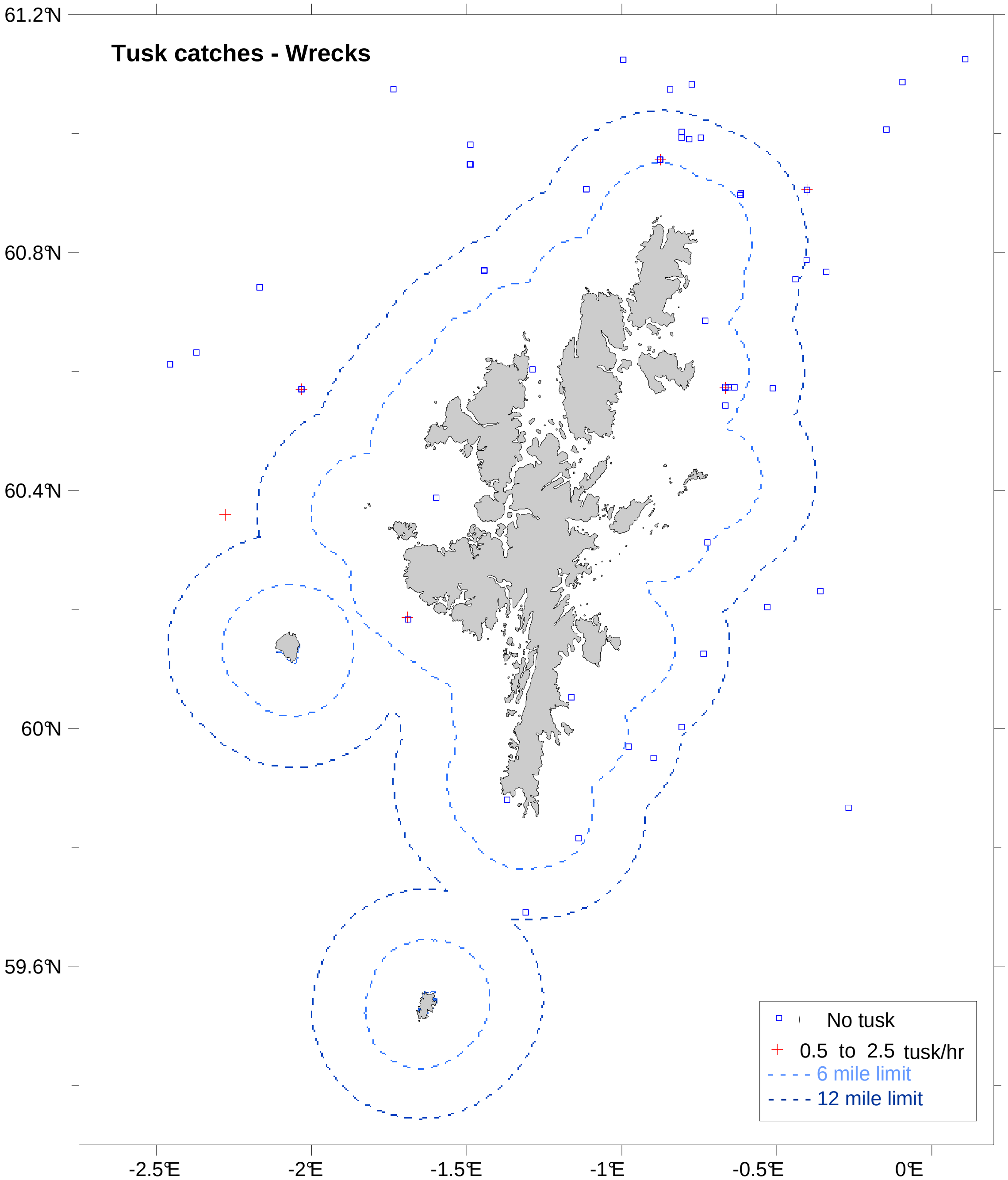


Figure 21 Catch rates of tusk on wrecks around Shetland. NB Catches were recorded as number per fishing operation where catches were <0.25 boxes per operation and in boxes per hour where catch rates were higher.

3.2.3.4 Catches on wrecks in relation to depth

A Spearman rank correlation co-efficient indicated that there was a significant positive correlation (r_s =0.91, n=10, P<0.01) between catch rates of saithe and increasing depth, up to a maximum at approximately 85 fathoms (Figure 22). Lythe catch rates were not significantly correlated (r_s =0.227, n=10, P>0.05) with depth, with CPUE peaking between 50 and 65 fathoms (Figure 22).

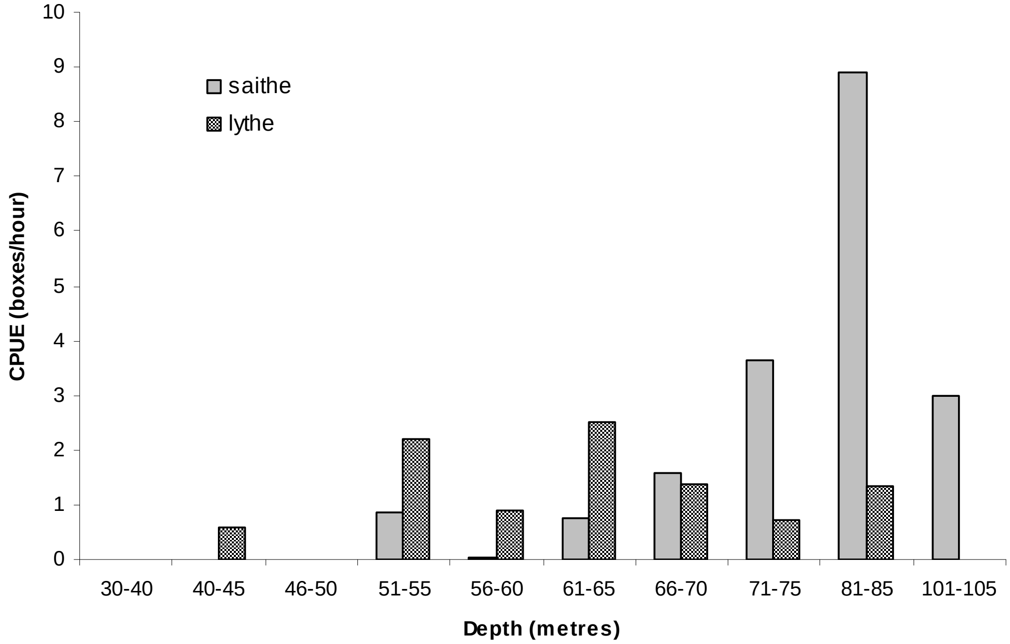


Figure 22 Catch per unit effort (boxes per hour) of saithe and lythe from wrecks at different depths around Shetland.

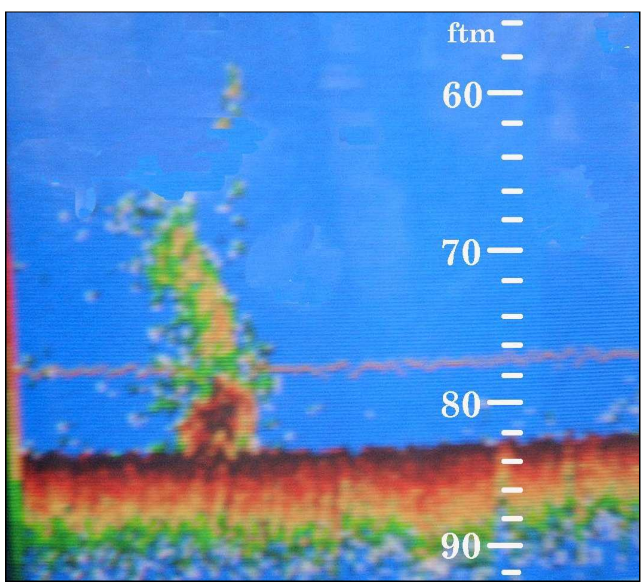
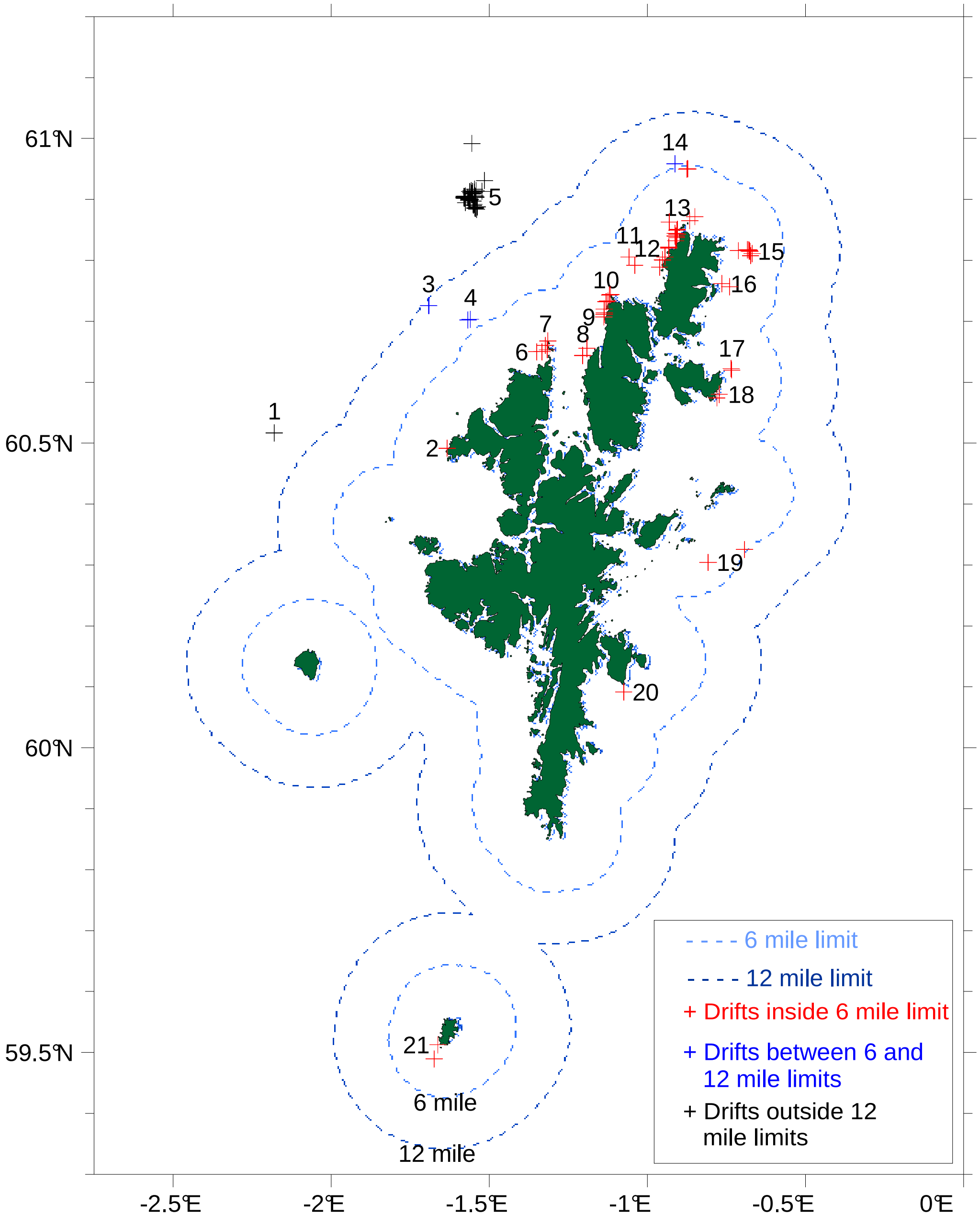


Figure 23 Photo of echo sounder reading showing Coastal Empress wreck and associated fish marks. NB The wreck is sitting on the seabed in 82 fathoms of water. The dense area associated with the wreck extends from the seabed to the 78 fathom mark. Marks of fish, found to be mainly saithe and lythe, extended from the top of the wreck to approximately 20 fathoms above the wreck.

3.2.4 Peaks

Fishing took place on peaky seabed in a variety of locations around Shetland (Figure 24) with the majority of peaky ground being found towards the north of Shetland and within the 6 mile limit. Positions of peaks shown in Figure 24 are detailed in Appendix IV. A total of 26 different locations with peaks were fished. However, only 8 of the 26 locations sampled (30%) resulted in more than one box of fish being caught. Areas of peaky seabed that were fished ranged from shallow inshore areas 5-10 fathoms (9-18m) deep, to offshore areas in depths of 50-60 fathoms (91-110m) for example, those 15 miles north-northwest of the Ramna Stacks (No. 5 on Figure 24). The time spent fishing on each peak varied from 15 minutes to 8 hours with an average duration of 51 minutes (Figure 25). Individual drifts were generally between 30 and 45 minutes in duration.

The effect of wind and tide on drifts over single peaks was similar to that experienced when fishing on wrecks. In places where a number of peaks were present, drifts could be longer as the vessel was able to travel longer distances while staying on suitable grounds. It was also noted that in areas where there were a number of peaks grouped together, fish tended to lie in specific locations within the group. This was especially evident at the fishing location 'East of Skaw' (60°48.94'N, 000°40.71'W) which had a reasonably large area of p eaks although, on each trip, fish were noticeably concentrated in approximately the same place.



No.	Peak	No.	Peak
1	14 miles W Eshaness	12	NW Unst (peaks between Flubersgerdi and Hermaness)
2	Eshaness Light	13	Muckle Flugga
3	12 mile NW Ramna Stacks	14	6 mile N of Muckle Flugga
4	8 mile NW Ramna Stacks	15	East of Skaw
5	15 mile NNW Ramna Stacks	16	Balta Isle
6	Sandsvoe	17	Strandburgh Ness
7	Gruney	18	Funzie Ness
8	Whalefirth	19	Out Skerries
9	Swinga Taing	20	Bard Head
10	Gloup Holm	21	Skaden light
11	Breken		

Figure 24 Geographical locations of peaks fished around Shetland.

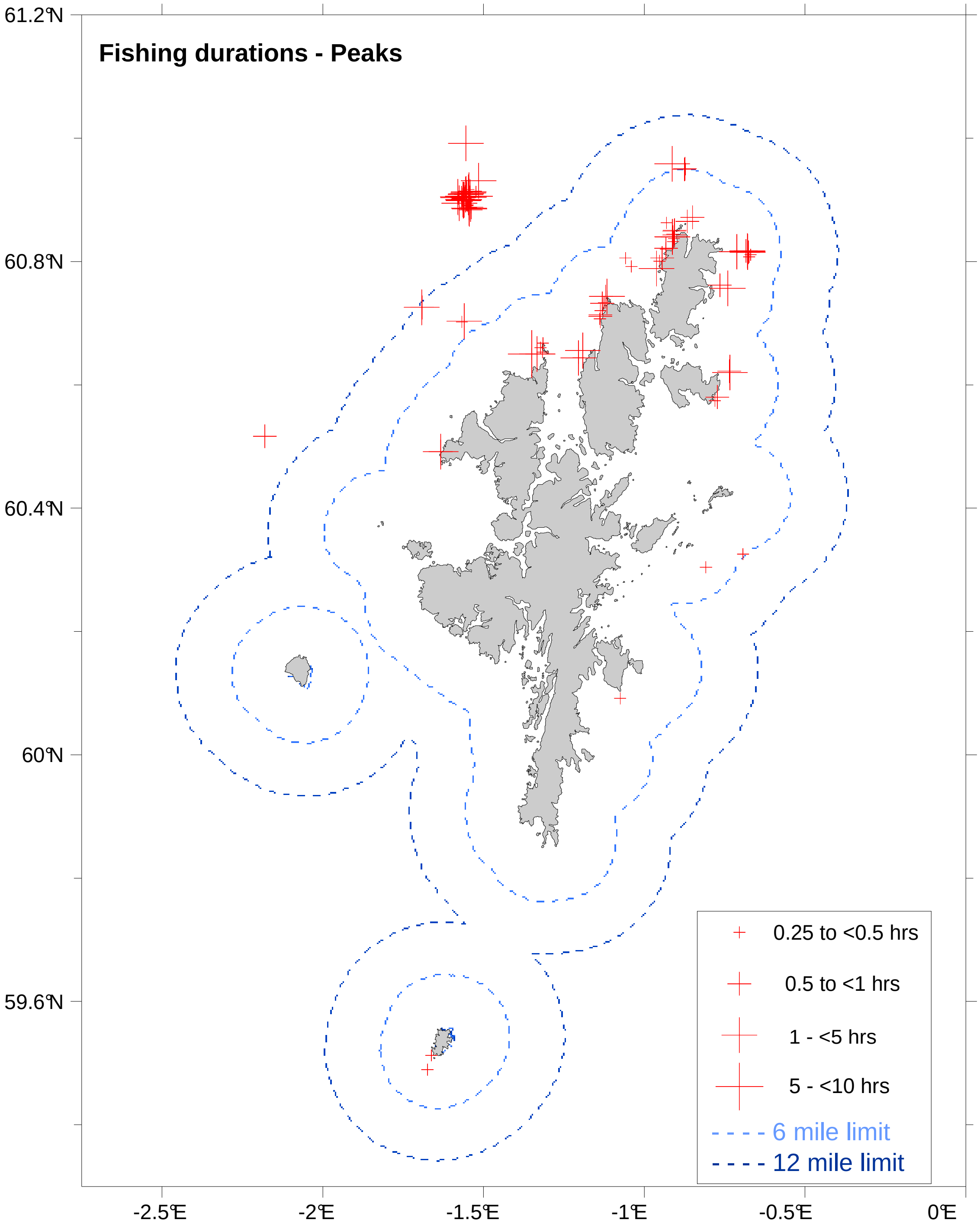


Figure 25 Fishing times during each visit to peaks areas.

3.2.4.1 Total catches from peaks

A total of 143 boxes of fish, comprising of lythe, saithe, cod, ling and tusk were caught on peaky ground (Table 4). As with wrecks, catch rates were generally highest at the furthest north and furthest offshore peaks areas (Figure 26). The most

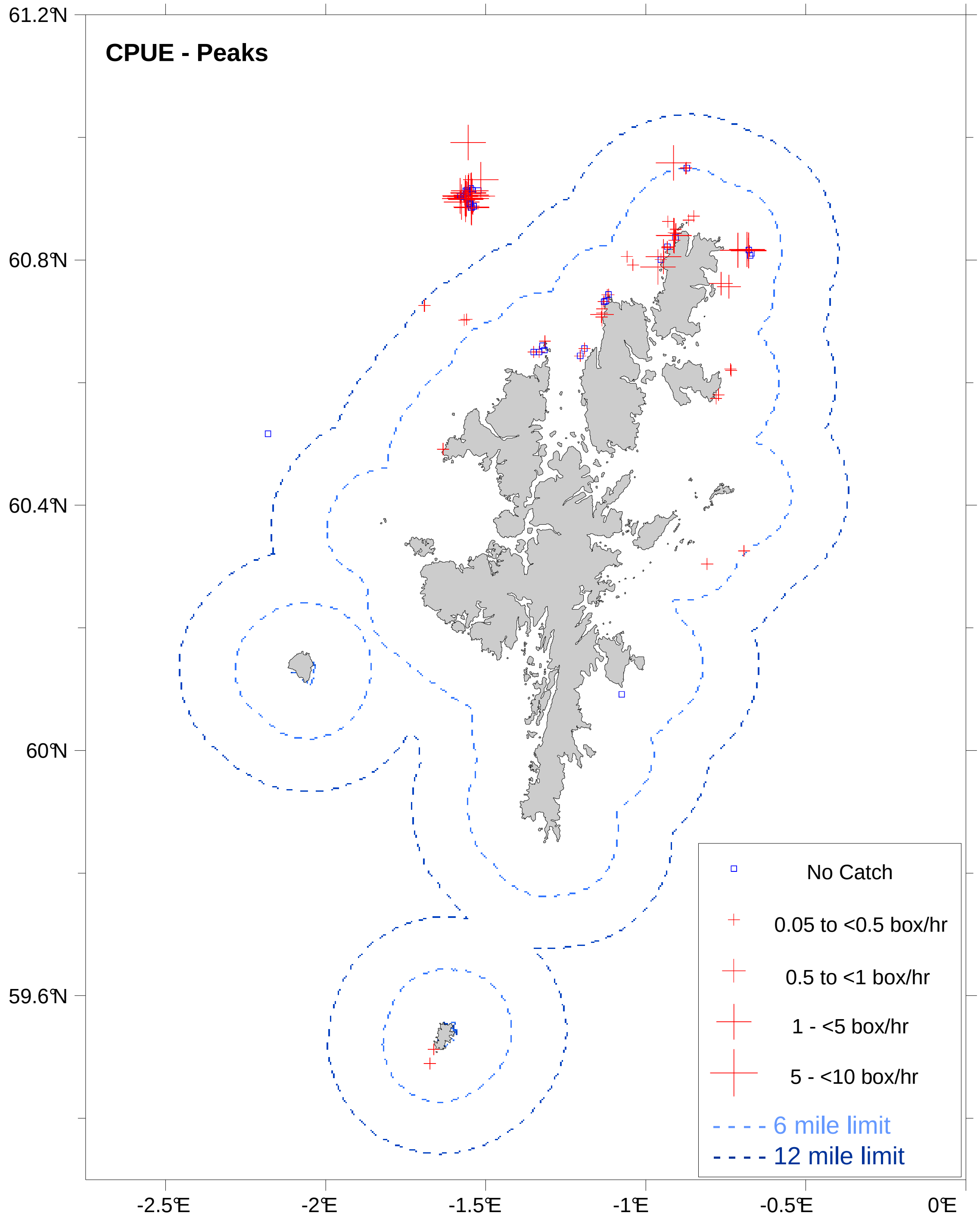


Figure 26 Catch per unit effort (boxes/hour) from peaks fished around Shetland.

successful area of peaks were those located 15 miles north-northwest of the Ramna Stacks where, over a 12 month period, more than 99.5 boxes of fish, mainly lythe, were caught (area No. 5 on Figure 24). Catches in the first few visits to this area were highest and over a period of time they generally declined. Towards the end of

2006 and at the beginning of 2007 there were relatively few lythe caught while significant numbers of small, undersized saithe were caught instead (Table 7). Catch per unit effort during the 4 month period August to November 2005 was significantly higher (Mann-Whitney, $U = P<0.001$) than the 4 month period July to October 2006. The one exception to the general decline in catch rates at this area was on the 14th February 2007 when 5 boxes of lythe were caught in a 1.5 hour period.

The data in Table 7 also highlights the general decline in the total time spent fishing in the area during each succeeding visit. Throughout the study the amount of time spent fishing in an area depended on the amount of fish being caught. This is an inevitable part of the fishers' behaviour in that if no, or very few, fish were being caught then fishing activity was moved to another area rather than persist on an area that was unproductive at that time. Longer periods of time were generally spent in areas yielding higher catches.

Table 7 Catch compositions and total CPUE on the 16 dates that fishing took place at an area of peaks 15 miles north-northwest of the Ramna Stacks.

Date	Time on mark (Hours)	Catch (boxes)					
		Saithe	Lythe	Ling	Tusk	Cod	Total CPUE
10-Aug-05	5	-	11	0.25	0.25	-	2.30
11-Aug-05	6	-	14	-	-	-	2.33
16-Aug-06	8	-	10	-	-	-	1.25
11-Oct-05	7	0.5	11.5	-	-	-	1.71
18-Nov-05	6	0.5	20	-	0.5	-	3.50
18-Apr-06	4.25	-	4.5	-	-	-	1.05
16-May-06	0.5	-	-	-	-	-	0
06-Jun-06	6	-	8	-	-	-	1.33
17-Jul-06	2.75	Discards	-	-	-	-	0
11-Sep-06	2.25	Discards	5	-	-	-	2.22
12-Sep-06	2.75	Discards	3	-	-	-	1.09
21-Sep-06	3.25	Discards	0.5	-	-	-	0.15
16-Oct-06	3	Discards	1.5	-	-	-	0.50
14-Feb-07	1.5	-	5	-	-	-	3.33
22-Mar-07	4	Discards	2	-	-	-	0.50
28-Mar-07	1.5	-	-	-	-	-	0

3.2.4.2 Catch by species from peaks

Lythe was the predominant species caught followed by cod, tusk, saithe and ling. The majority of lythe were caught in a number of areas north of the Ramna Stacks (Figure 27) with a couple of peaks east of Whalsay being the only place south of

Ramna Stacks yielding marketable fish, although this was only one fish from each peak. Cod catches were also confined to the north of Shetland (Figure 28) with the best catches, one box for 1.5 hours fishing, coming from an area of peaks 3 miles east of Skaw on the north-eastern tip of Unst. Catches of ling (Figure 29) and tusk (Figure 30) on peaks were low in all areas although there were small numbers of each species caught in a number of locations. In contrast to catches on wrecks, saithe were one of the least abundant fish caught over peaks (Figure 31). The highest saithe CPUE was 3.5 boxes/hour at an isolated peak 14 miles north of the Ramna Stacks. A number of peaks yielded undersized saithe while the majority of marketable fish caught were generally smaller than those caught on wrecks.

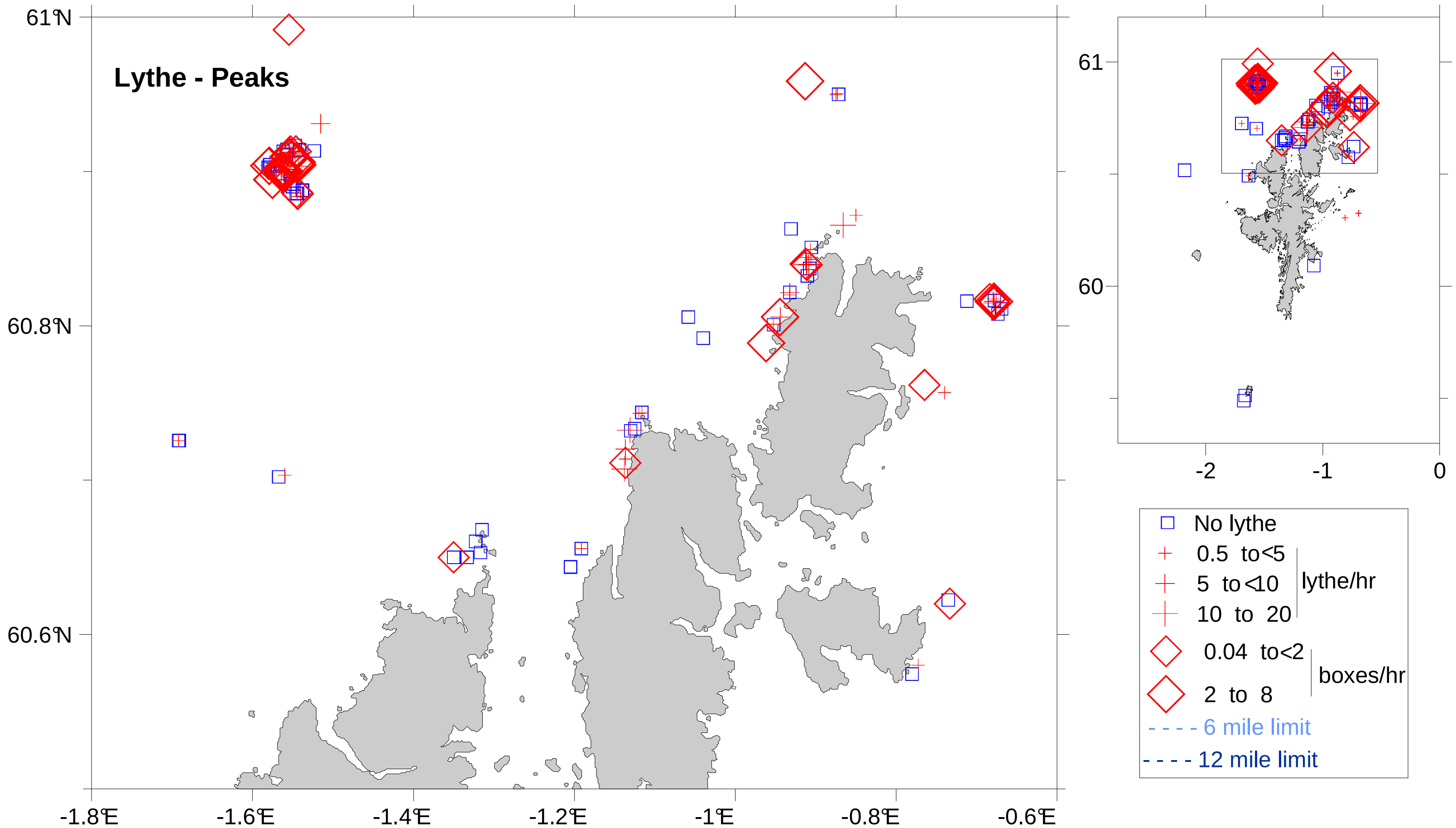


Figure 27 Catch rates of lythe on peaks at the northern end of Shetland.
NB Catches were recorded as number per fishing operation where catches were <0.25 boxes per operation and in boxes per hour where catch rates were higher.

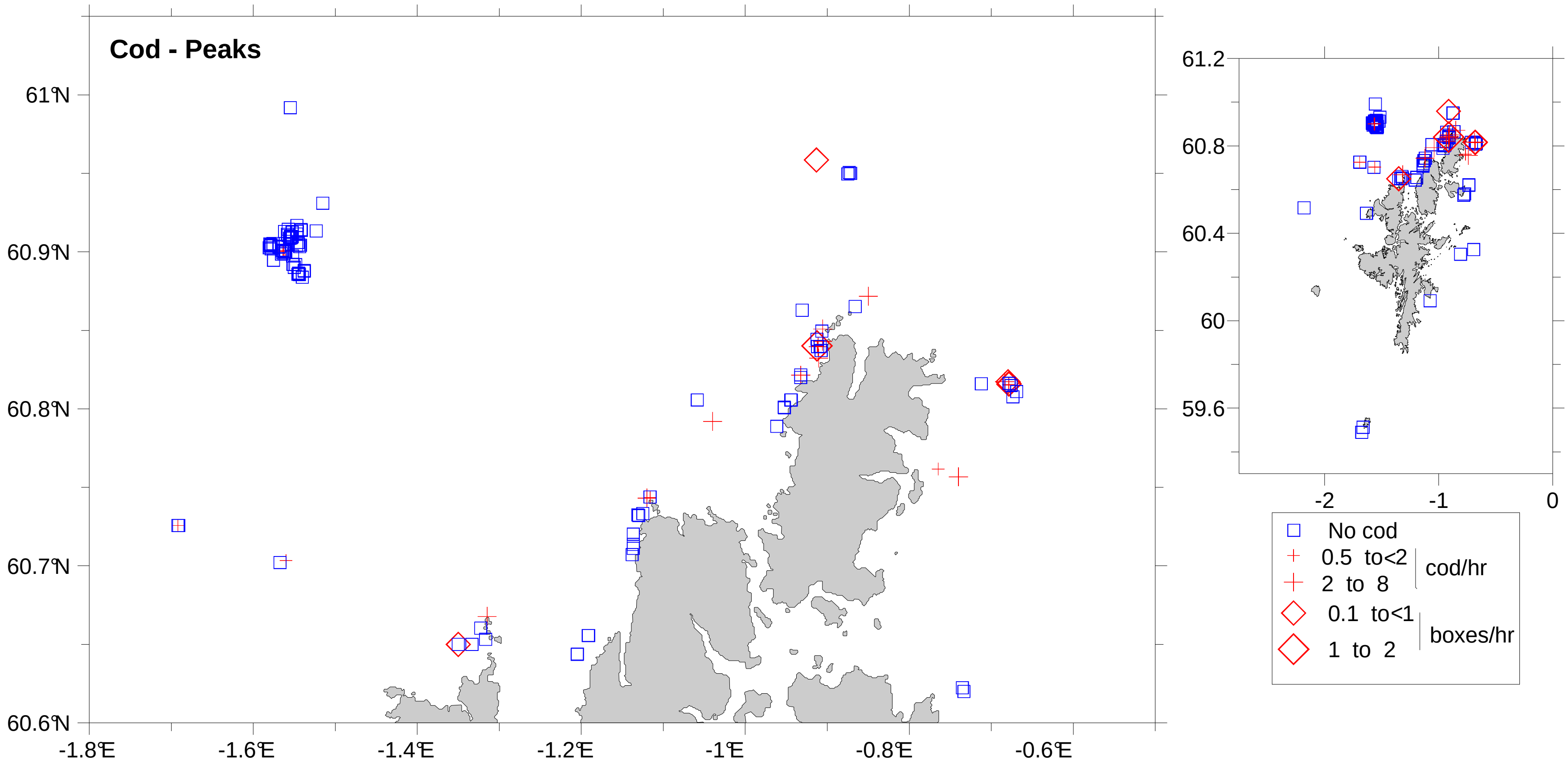


Figure 28 Catch rates of cod on peaks at the northern end of Shetland.
NB Catches were recorded as number per fishing operation where catches were <0.25 boxes per operation and in boxes per hour where catch rates were higher.

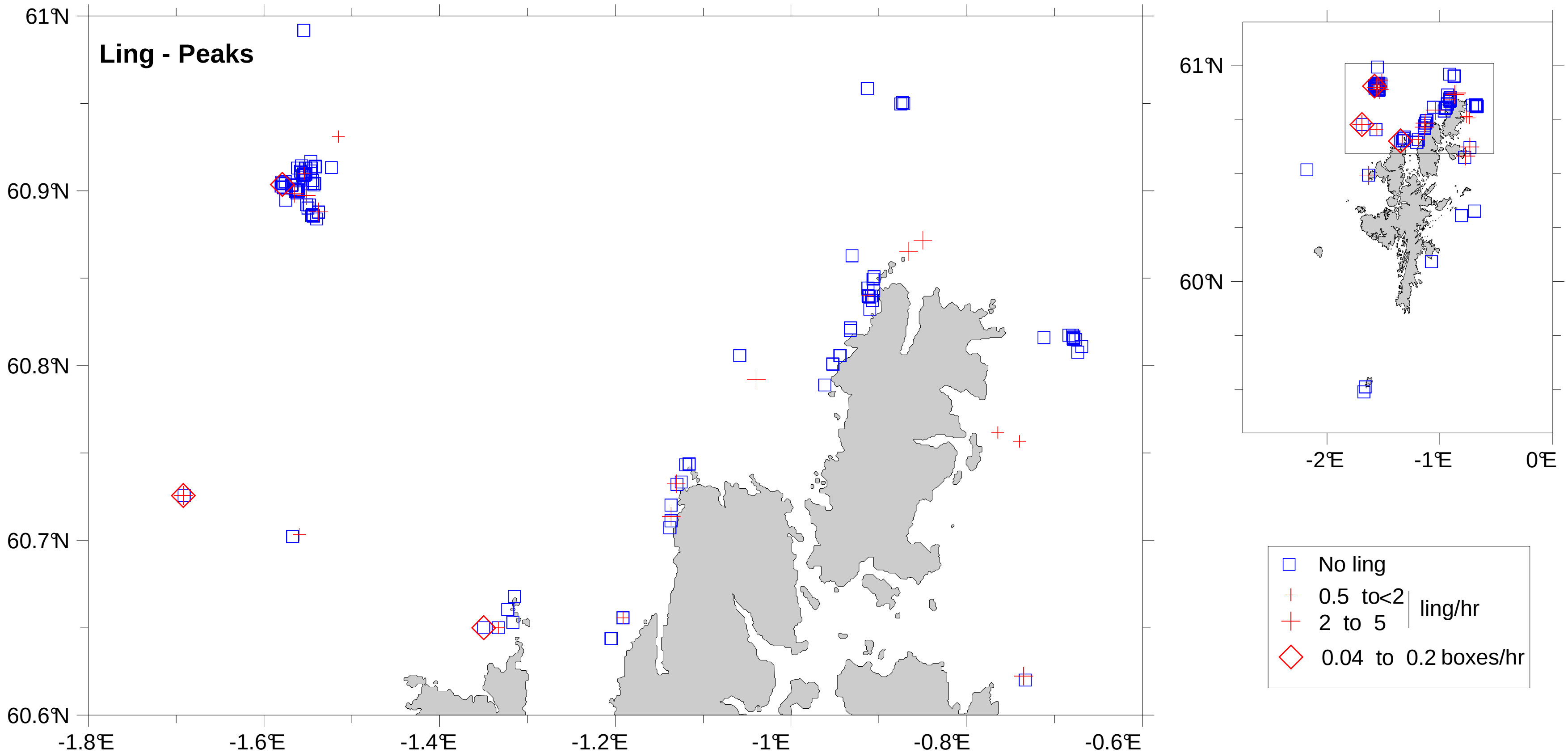


Figure 29 Catch rates of ling on peaks at the northern end of Shetland.
NB Catches were recorded as number per fishing operation where catches were <0.25 boxes per operation and in boxes per hour where catch rates were higher.

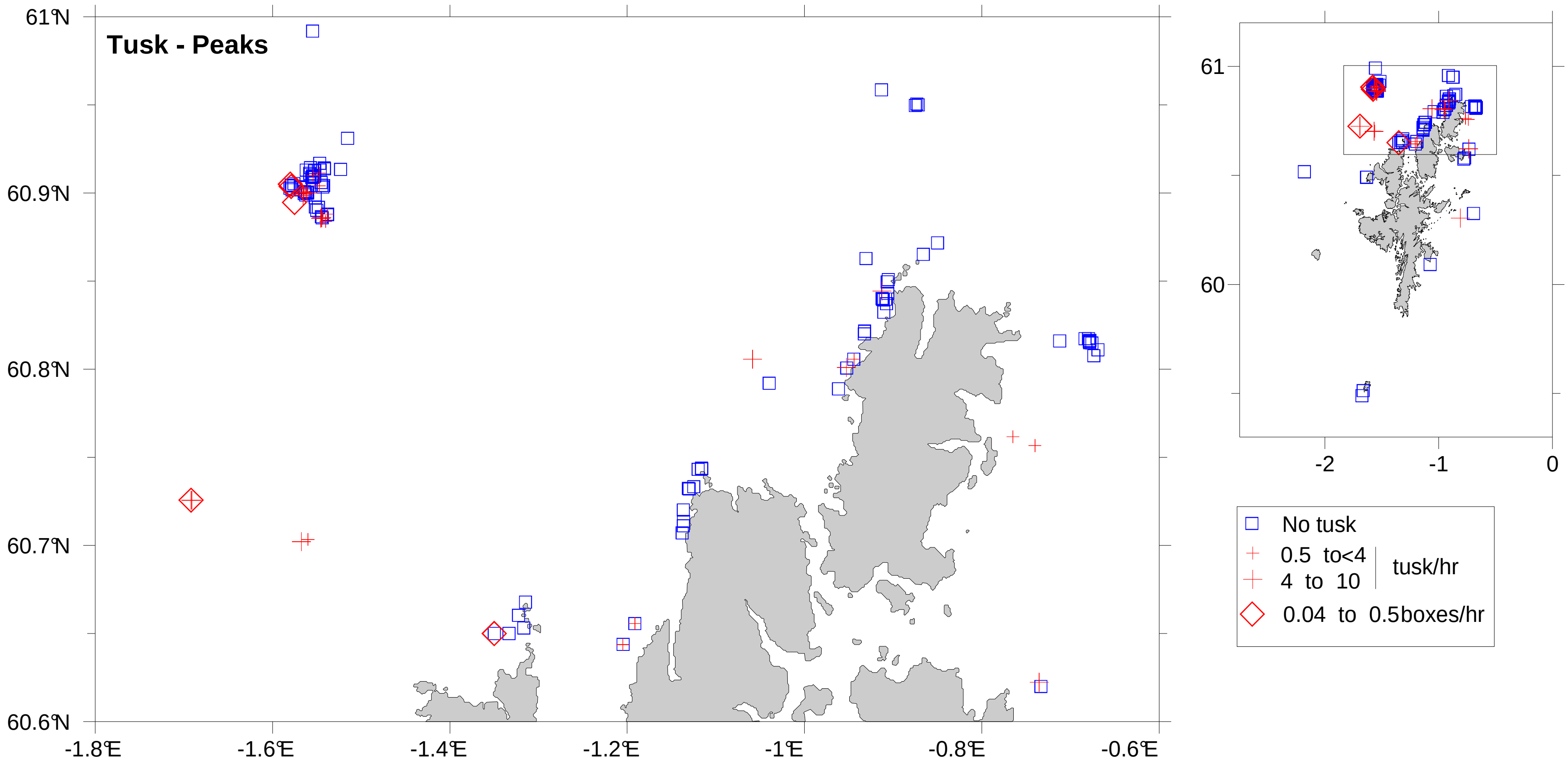


Figure 30 Catch rates of tusk on peaks at the northern end of Shetland.
NB Catches were recorded as number per fishing operation where catches were <0.25 boxes per operation and in boxes per hour where catch rates were higher.

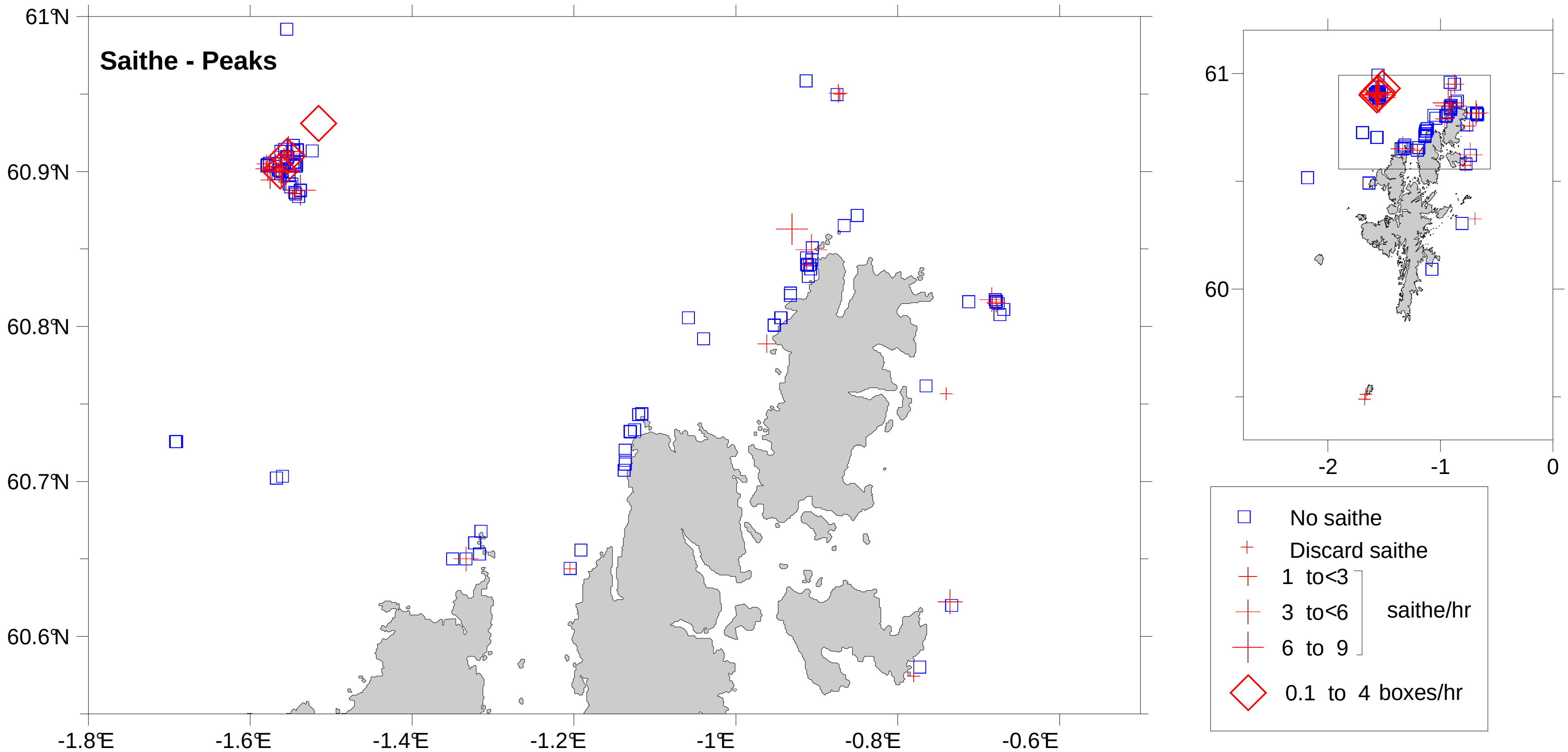


Figure 31 Catch rates of saithe on peaks at the northern end of Shetland.
NB Catches were recorded as number per fishing operation where catches were <0.25 boxes per operation and in boxes per hour where catch rates were higher.

3.2.4.3 Catch by depth from peaks

Catch rates were variable at between zero and seven boxes per hour for individual fishing operations on peaks (Figure 32). When grouped by depth, all depth groups except two yielded less than a total of 2 boxes/hour (Figure 33), the two depth groups with CPUE values greater than 2 boxes/hour were at 41-45 fathoms (2.1 boxes/hour) and at 66-70 fathoms (2.3 boxes/hour). These related to areas East of Skaw (No. 15 on Figure 24) and 15 mile NW of the Ramna stacks (No. 5 on Figure 24) respectively. A Spearman rank correlation coefficient indicated that there was a statistically significant correlation between depth and catch rate (r_s = 0.286, n = 152, P<0.01) with higher catch rates occurring in deeper water.

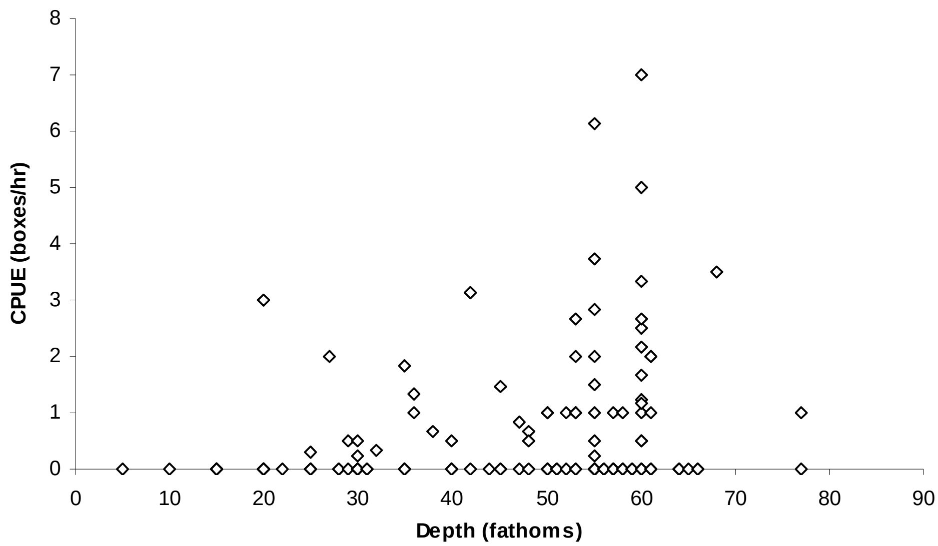


Figure 32 Catch rates shown in relation to water depth for the 152 fishing operations on peaks.

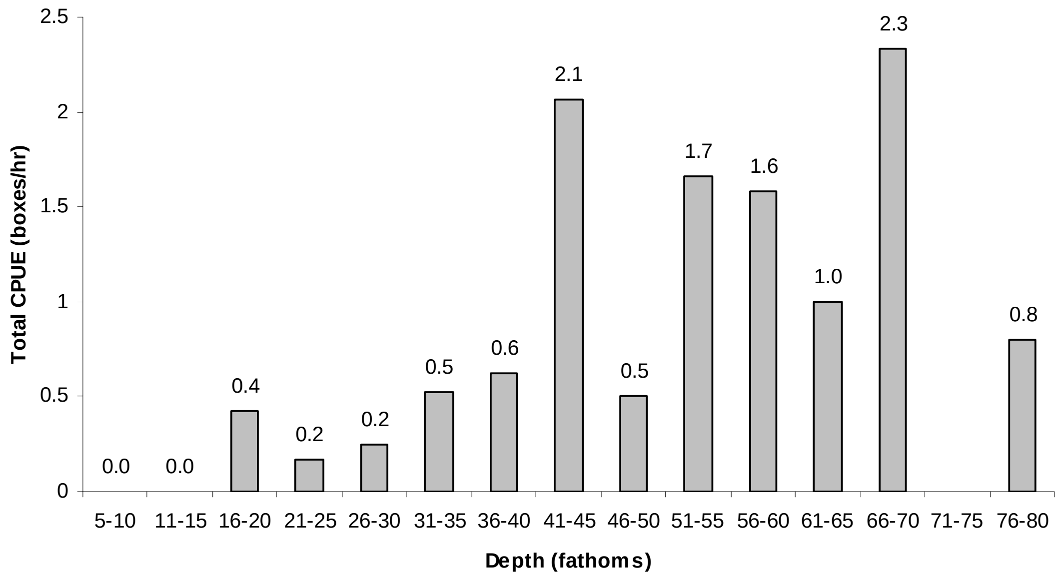


Figure 33 Total catch per unit effort (boxes per hour) at different depths on peaks around Shetland (CPUE values shown above bars).

3.2.4.4 Gear loss from peaks

Gear loss was at times significant when fishing on peaky ground. This was normally exacerbated when wind and tide caused the vessel to drift faster than in optimum conditions. Areas such as Muckle Flugga, where there were large numbers of craggy peaks, became notorious for losing gear due to the strength of the tide around the headland.

3.2.5 Hard ground

One hundred and forty areas of hard ground were sampled in depths ranging from 10-73 fathoms (18-134m). The majority of hard ground that was fished was in inshore areas less than 6 nautical miles from shore.

The time spent fishing on each area of hard ground varied from 15 minutes to 6 hours with an average duration of 41 minutes (Figure 34). Positions of hard ground shown in Figure 34 are detailed in Appendix V. Specific drifts ranged in length from 15 to 90 minutes. If a mark of fish was located during a drift, the vessel was usually driven back to it after fish had stopped taking the lures. On some occasions, if a few fish were steadily being caught, the vessel was left to drift until the edge of the hard ground was reached. This often resulted in locating various pockets of fish over a reasonably large area of seabed. Catch rates on hard ground ranged from 0 – 4 boxes/hr. The highest catch rates tended to be around the north of Shetland.

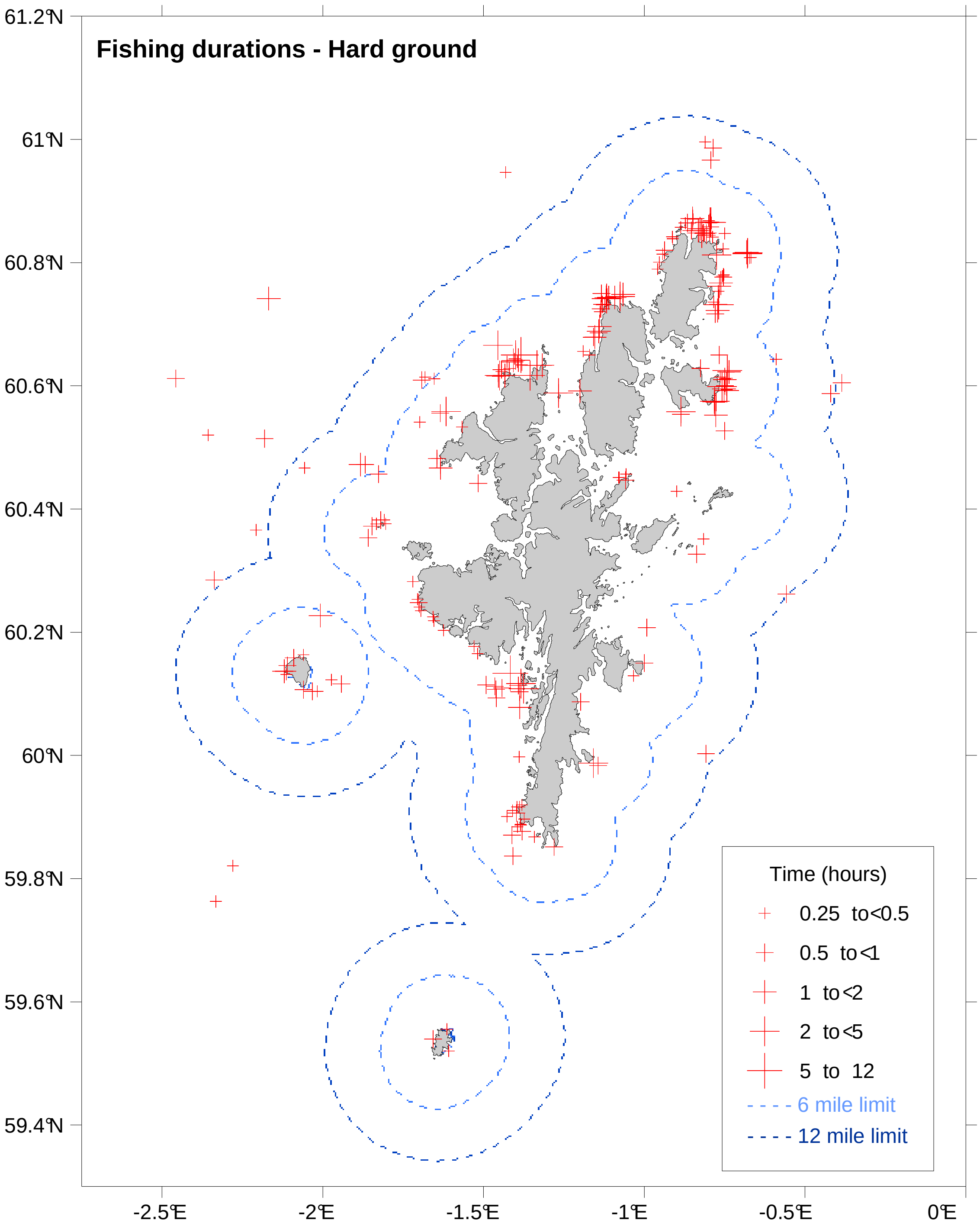


Figure 34 Time spent fishing during each visit to an area of hard ground during the project.

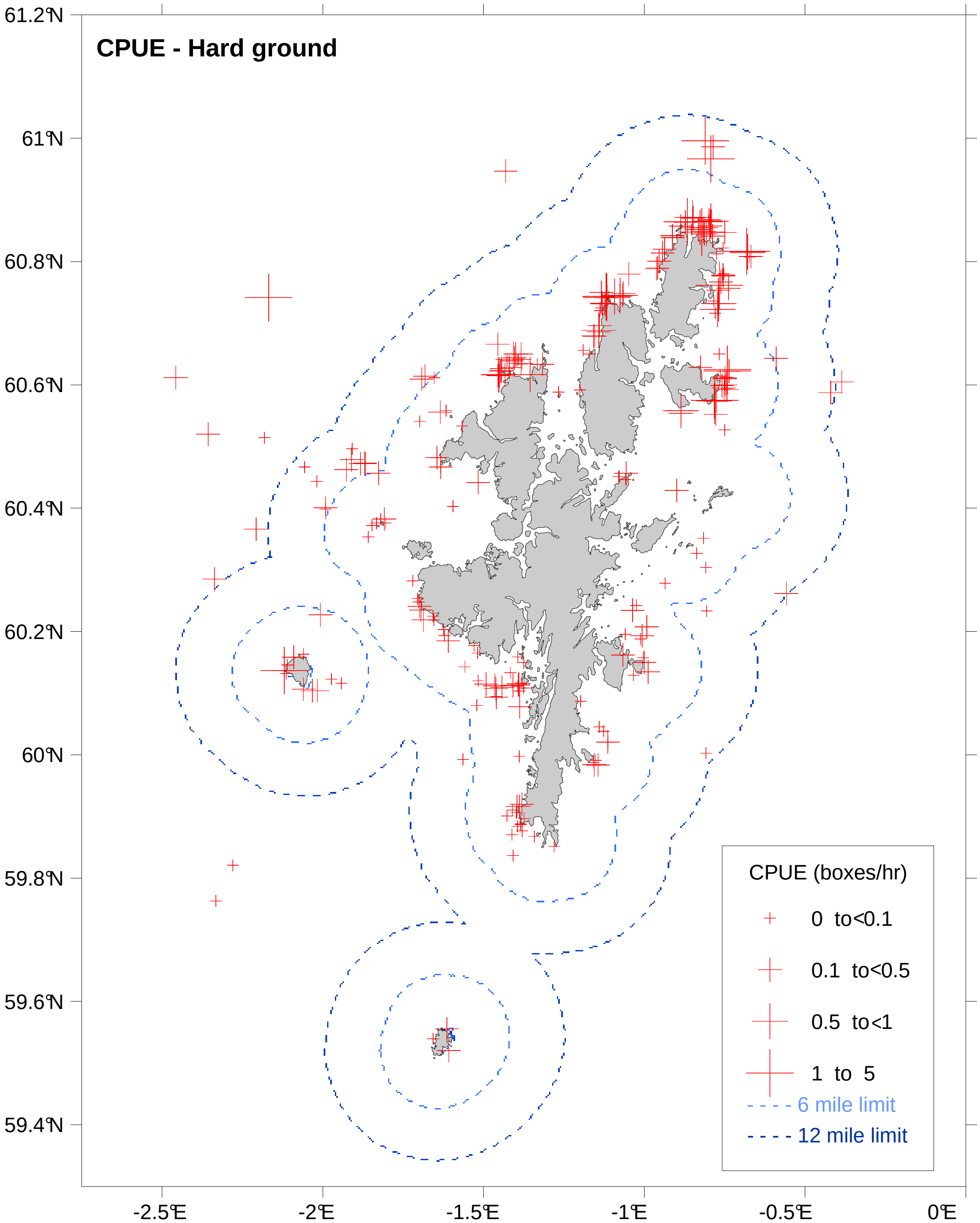


Figure 35 CPUE (boxes/hr) during each of the fishing operations on hard ground around Shetland.

3.2.5.1 Total catches from hard ground

A total of 53 boxes were caught on hard ground. Of the 140 locations fished, no marketable fish were caught on 110 of them (79%) and only 19 of the locations

(14%) yielded one or more boxes of fish. The most successful fishing on hard ground was "East of Skaw" in Unst which yielded 9.5 boxes in 8 hours fishing.

3.2.5.2 Catch by species on hard ground

As was the case on peaky ground, the most abundant species was lythe, followed by cod and ling (Table 4). Lythe catches were mainly restricted to the north of Shetland, especially around Fetlar, Yell and Unst (Figure 36). The highest CPUE for lythe (1.16 boxes/hour) came from Strandburgh Ness, Fetlar. Cod catches on hard ground were, with the exception of a 0.5 box haul at Foula in 30 minutes, mainly restricted to the north-west of Shetland (Figure 37). The inshore areas of Uyea Baas and Muckle Flugga yielded the highest CPUEs of 0.25 and 1 boxes/hour respectively. There were few, if any, cod caught around the south of Shetland. Ling were caught in a number of locations around Shetland although the majority were caught in inshore areas at the northern end of the Islands (Figure 38). The highest CPUE, 0.5 boxes/hour, was from an area of hard ground near Whalefirth, Yell. Catches of saithe on hard ground were very poor with the exception of an area north of Muckle Flugga which yielded 0.5 boxes in 15 minutes and another pieces of hard ground 26 miles north-west of the Ramna Stacks that yielded 0.5 boxes for 1 hour fishing (Figure 39). Undersized saithe were caught in a number of inshore locations especially to the west and south of Shetland. Tusk were not caught in significant numbers on hard ground anywhere around Shetland although the small numbers that were caught were hooked mainly to the north and west of Shetland (Figure 40).

3.2.5.3 Gear loss on hard ground

Gear loss was a problem when fishing on hard ground in areas with a strong tide. As with the peaky ground, if few fish were caught more gear tended to be lost. One of the areas where this was most prevalent was off Gloup Holm, north Yell.

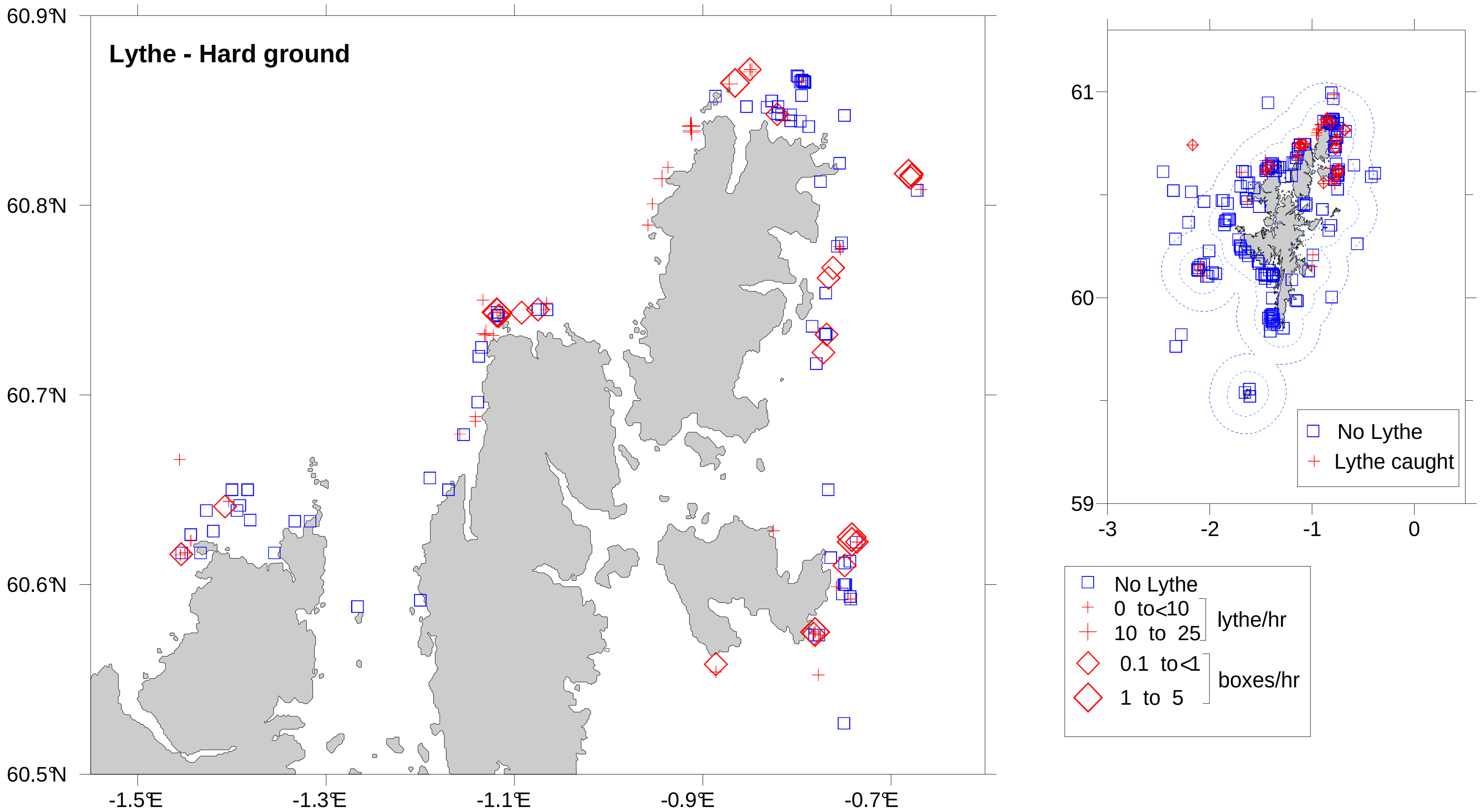


Figure 36 Catch rates of lythe on areas of hard ground around Shetland.
NB Catches were recorded as number per fishing operation where catches were <0.25 boxes per operation and in boxes per hour where catch rates were higher.

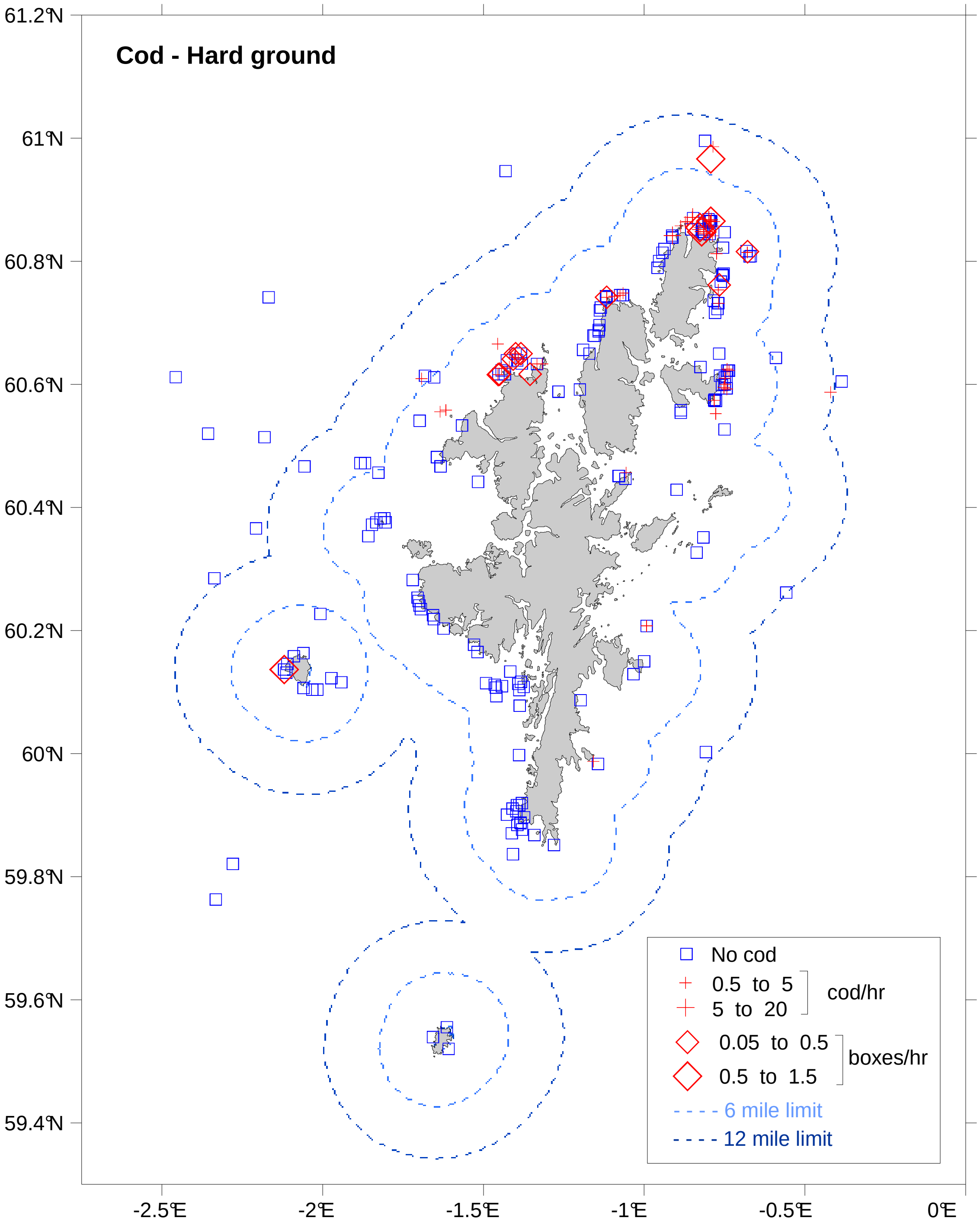


Figure 37 Catch rates of cod on areas of hard ground around Shetland.
NB Catches were recorded as number per fishing operation (+) where catches were <0.25 boxes per operation and in boxes per hour (◊) where catch rates were higher.

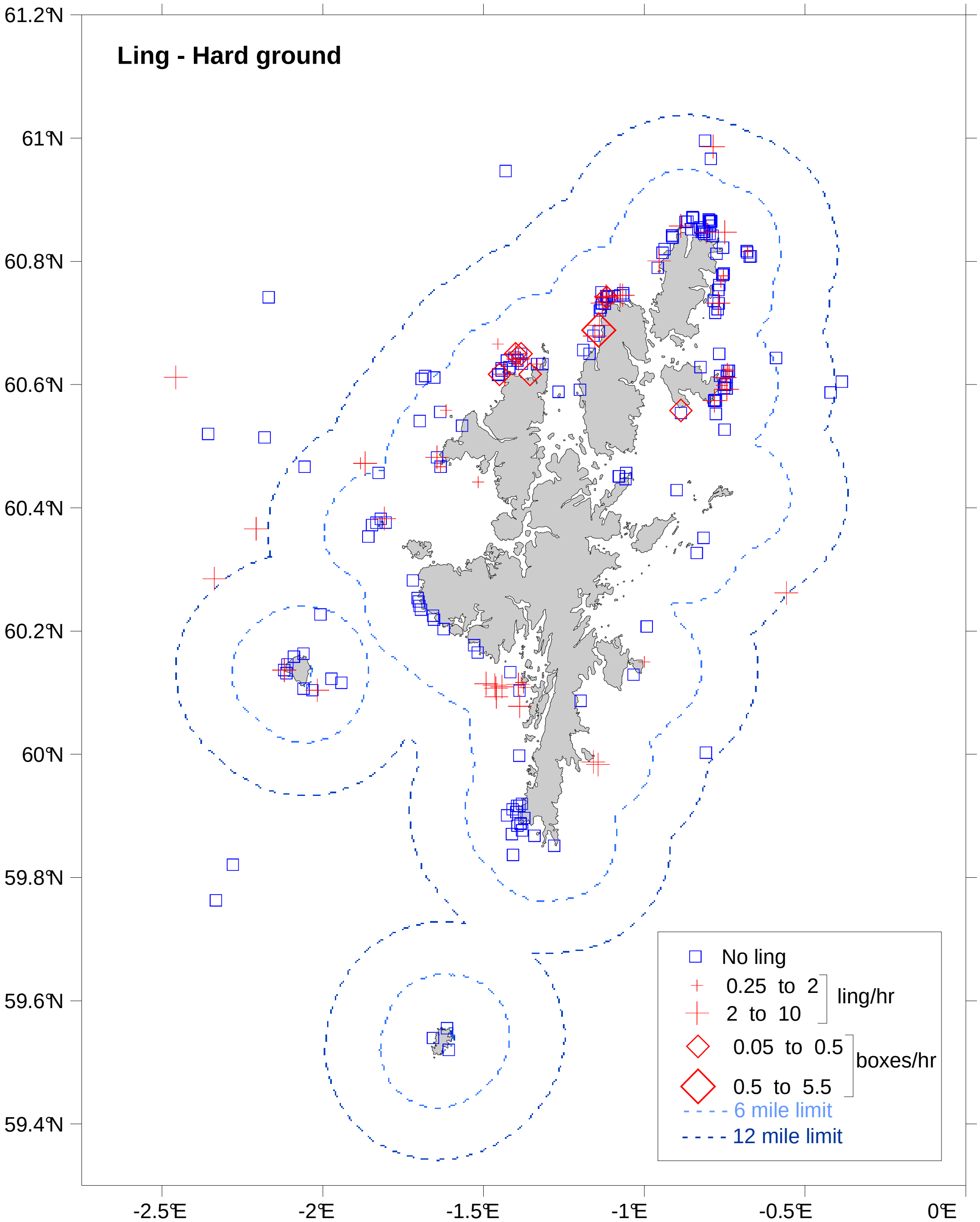


Figure 38 Catch rates of ling on areas of hard ground around Shetland.
NB Catches were recorded as number per fishing operation (+) where catches were <0.25 boxes per operation and in boxes per hour (◊) where catch rates were higher.

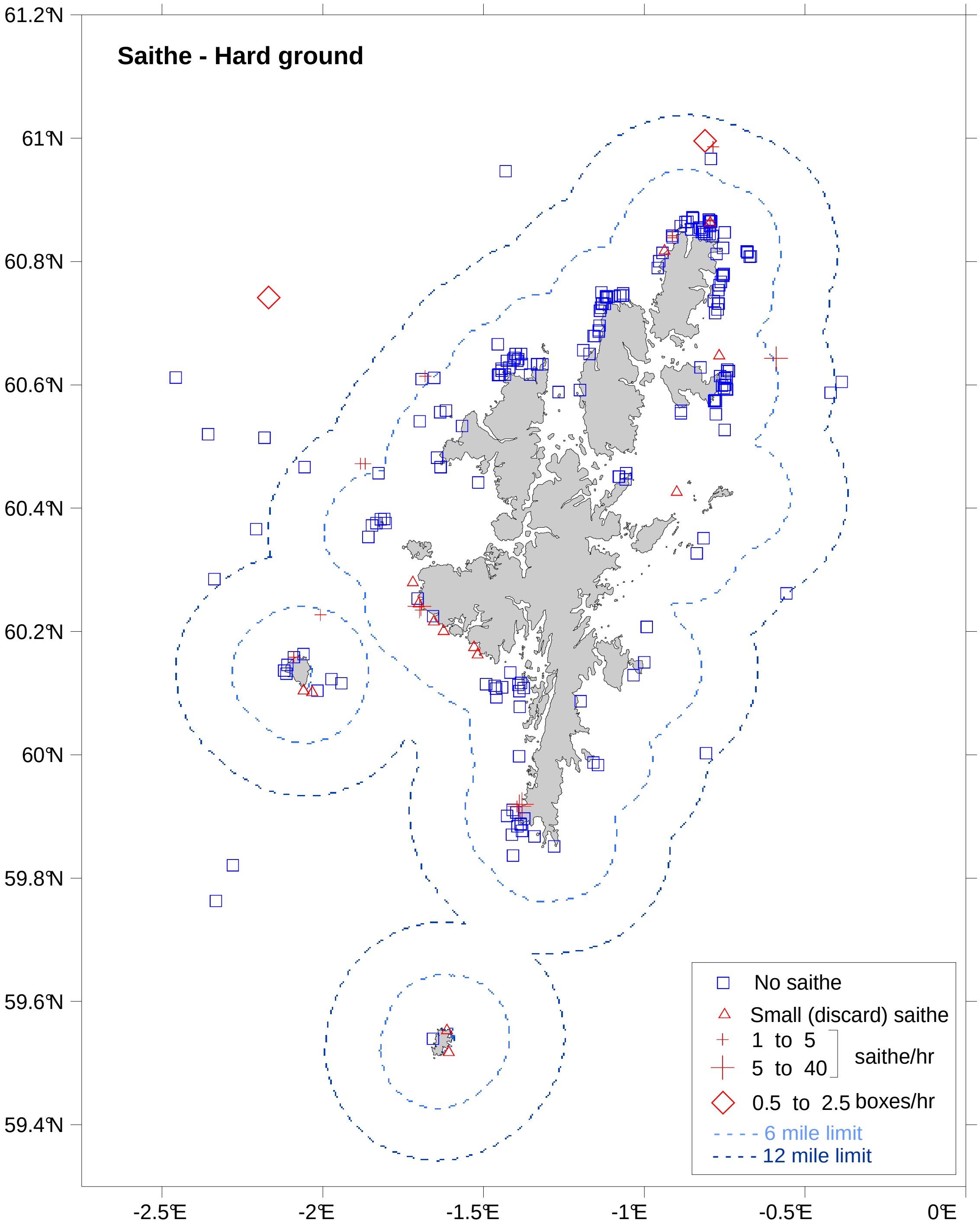


Figure 39 Catch rates of saithe on areas of hard ground around Shetland.
NB Catches were recorded as number per fishing operation (+) where catches were <0.25 boxes per operation and in boxes per hour (◊) where catch rates were higher.

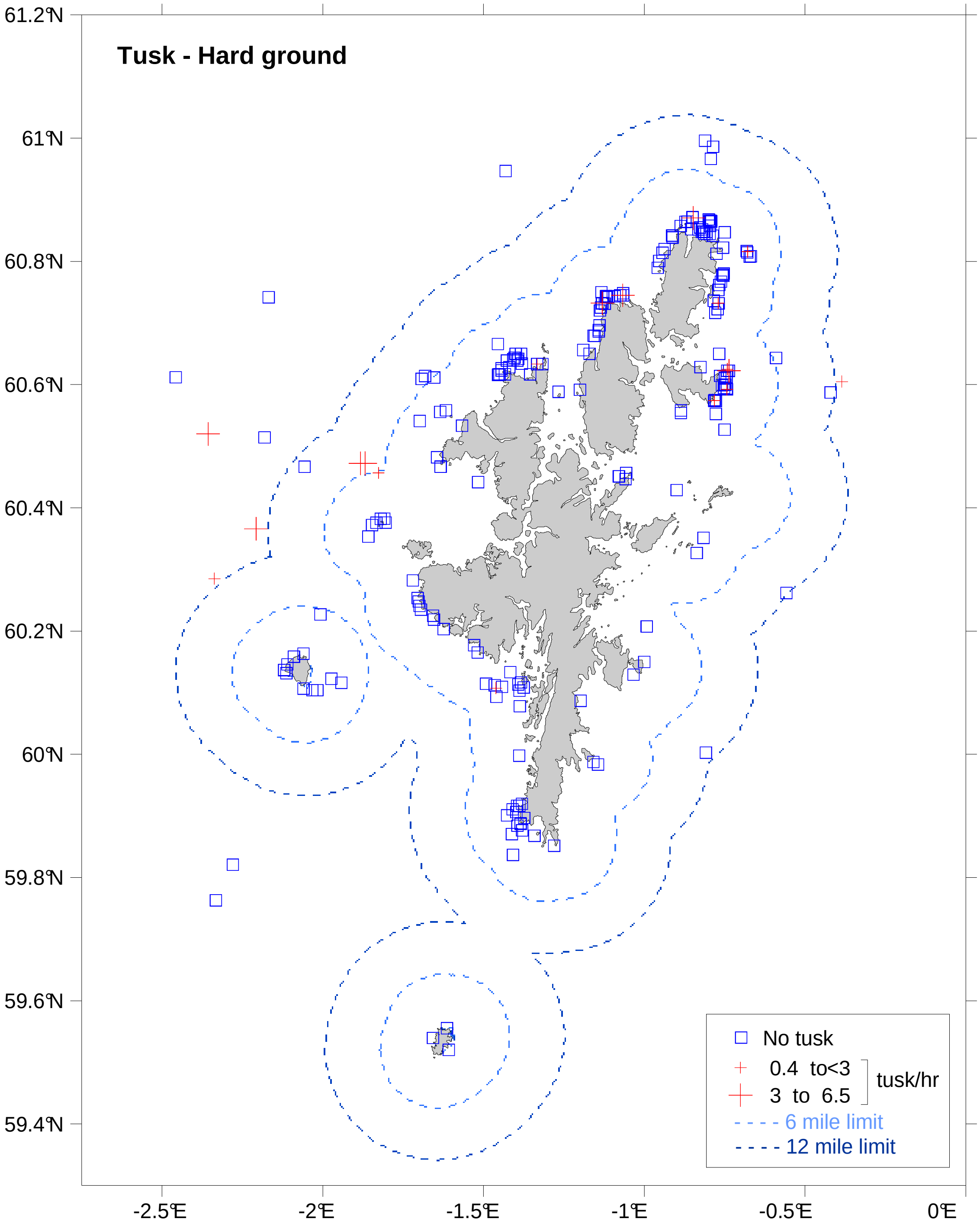


Figure 40 Catch rates of tusk on areas of hard ground around Shetland.
NB Catches were recorded as number per fishing operation (+) where catches were <0.25 boxes per operation and in boxes per hour (◊) where catch rates were higher.

3.2.5.4 Catches from hard ground in relation to depth

A Spearman Rank Correlation test indicated that there was a statistically significant weakly positive correlation between water depth and CPUE (r_s =0.149, n=304,

P=0.009) (Figure 41). Total CPUEs are shown by 5 fathom depth intervals in Figure 42. It was observed that the total CPUE was low (0-0.05 boxes per hour) in depths less than 20 fathoms (37m); this increased to between 0.2 and 0.3 boxes per hour in depths between 20 and 40 fathoms (37-73m) and increased further in the two deeper depth ranges that were fished (46-50 and 66-70 fathoms (84-134m and 121-128m)) where the CPUE was between 0.7 and 0.8 boxes per hour. The amount of fishing at depths greater than 46 fathoms (84m) was limited so further data collection would be desirable to confirm whether the pattern of increased CPUEs with greater depth holds true. Catch rates of 0 boxes/hour for depths 50-55, 55-60 and 71-75 fathoms are considered to be anomalies as there was less than one hour spent fishing in each of these depth groupings, significantly less than other depth groups. When data from these depth groups are removed there is a significant relationship between catch rate and depth (r_s =0.66, n=10, P<0.05).

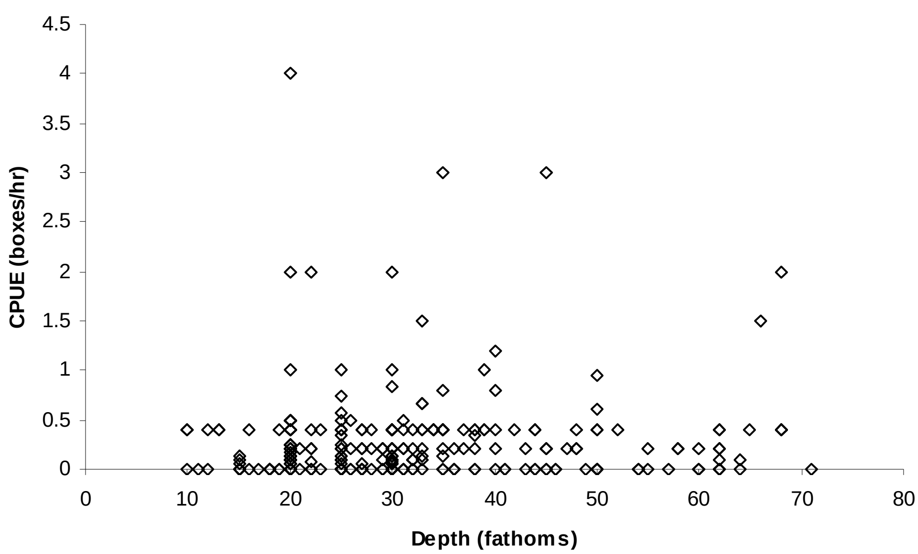


Figure 41 Scatter plot of water depth and CPUE for 304 fishing operations on hard ground.

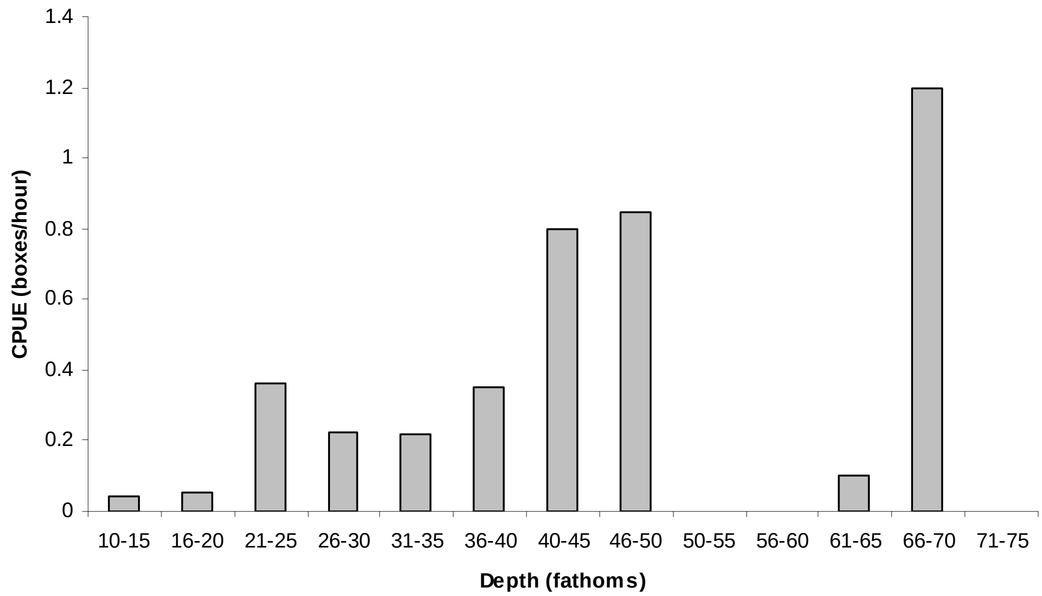


Figure 42 Total catch per unit effort at different depths on hard ground around the Shetland Isles.

3.2.6 Bycatch and selectivity of gear

A number of species which could be classed as bycatch were caught throughout the study. Those species were whiting (*Merlangius merlangus*), anglerfish (monkfish) (*Lophius piscatorius*), haddock (*Melanogrammus aeglefinus*), Norway haddock (*Sebastes viviparus*), mackerel (*Scomber scombrus*) and horse mackerel (*Trachurus trachurus*). Although they were classed as bycatch, species such as whiting, haddock, anglerfish and Norway haddock would have been landed if caught in significant numbers.

The number of foul hooked fish that were caught was relatively low for the majority of target species, as was evident from example data collected between 26th October and 8th December 2005 (Table 8). The overall ratio of fish caught foul hooked was 5.2%. The species with the lowest percentage of foul hooked fish (0%) was tusk while the species with the highest percentage was saithe (18.2%). The proportion of lythe, cod and ling caught foul hooked was 5%, 4.5% and 3.8% respectively. On many occasions hooks were deeply set, known as 'gut hooking', causing damage to vital organs.

Ling and saithe were the only species with undersized fish among the catch between 26th October and 8th December 2005. The total percentage of undersized fish during that time was 17% for ling (63cm minimum landing size) and 36% for saithe (35cm minimum landing size). There were three saithe caught that were both foul hooked and undersized. At other times during the study a similar pattern of relatively large proportions of undersized saithe and ling was seen in a number of inshore fishing locations while undersized cod and lythe were very rarely caught. NB Tusk does not have a minimum legal landing size.

Table 8 Total number of fish caught foul hooked and/or undersized during fishing operations between 26th October and 8th December 2005.

Species	Number of fish	Foul hooked	Undersized*	Undersized & foul hooked
Lythe	120	6	0	0
Cod	44	2	0	0
Ling	89	3	15	0
Saithe	33	6	12	3
Tusk	36	0	-	0
Total	322	17	27	3

*Minimum landing sizes are: lythe-30cm; cod-35cm; ling-63cm; saithe-35cm; tusk-no minimum landing size.

3.2.7 Environmental Variables

A number of environmental variables were observed to have an influence on catch rates throughout the project. Changing environmental conditions often had dramatic effects on the ability to catch fish, often over very short periods of time. Variables which had the greatest influence on the practical execution of the project were tide, wind, sea state and daylight patterns.

3.2.7.1 Tide

The environmental variable which had the most noticeable influence on catch rates was the tide. In this study HW Lerwick was used to compare CPUE because an accurate prediction of high water at each of the areas fished is not available. However, from personal observations while fishing at the peaks 15 miles north-northwest of the Ramna Stacks, where a significant proportion of fishing was undertaken, it was estimated that high water was approximately 2 hours before HW Lerwick.

In many places a steady fishing would suddenly stop when the tide changed. This was especially noticeable in areas such as the peaks 15 miles north-northwest of the Ramna Stacks (Figure 43) and it was found that of the fishing operations when fish were caught, there was a statistically significant difference in CPUE at different stages in the tidal cycle (Kruskal-Wallis test: $K=7.4$, d.f.=2, $P<0.05$). This difference consisted of a noticeable increase in CPUE beginning 2-3 hours before high water (HW) Lerwick (0-1 hours before HW at the peaks) and ending 1-2 hour after HW Lerwick (3-4 hours after HW at the peaks) when compared to the CPUEs 3-5 hours before HW Lerwick (1-3 hours before HW at the peaks) and 2-4 hours after HW Lerwick (4-6 hours after HW at the peaks) (Figure 43). During the period of increased CPUE the tidal stream was travelling in an easterly direction for the first hour, southeast for the second hour and southwest for the third hour (Table 9). For the remainder of the cycle, the direction of flow moves around each remaining point of the compass.

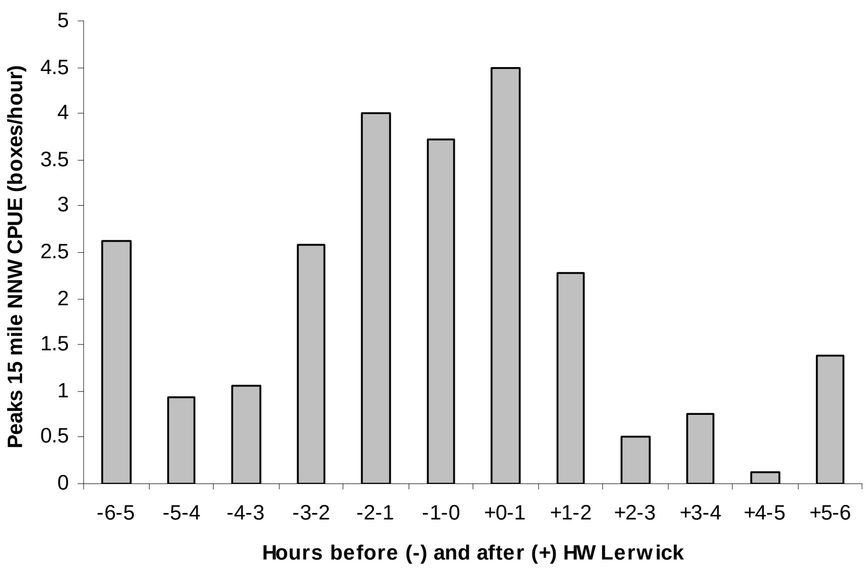


Figure 43 Total catch per unit effort at an area of peaks 15 miles north-northwest of the Ramna Stacks in relation to tide.

Table 9 Direction of current flow at different times in the tide cycle at an area of peaks 15 miles north-northwest of the Ramna Stacks.

Time in relation to HW Lerwick	Direction of flow of tidal current
-6	N
-5	N
-4	NE
-3	NE
-2	E
-1	E
HW	SE
+1	SW
+2	W-SW
+3	W
+4	W
+5	W
+6	NW

While there appears to be a clear relationship between CPUE and the tidal cycle, there is a great deal of variability in the data (Figure 44).

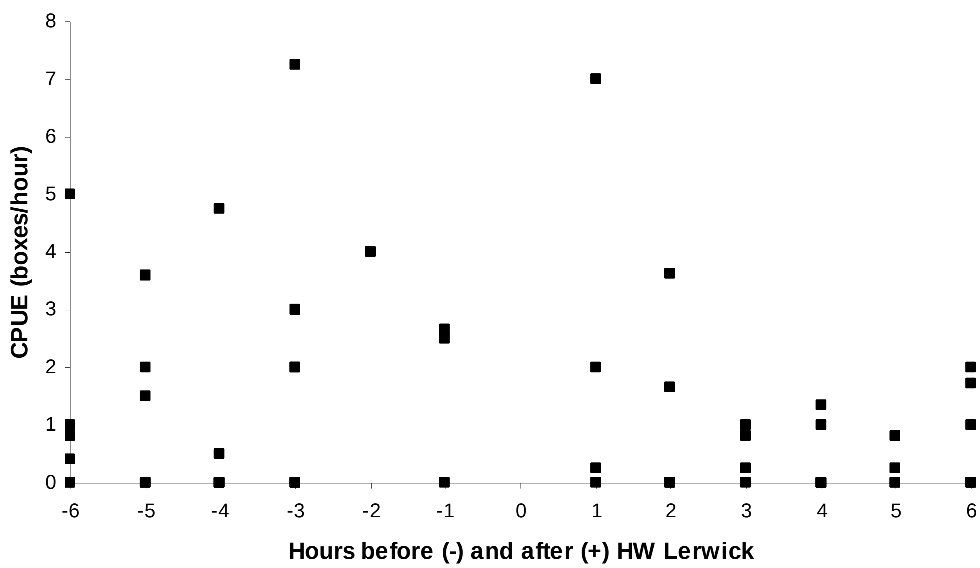


Figure 44 Variability in catch per unit effort at an area of peaks 15 miles north-northwest of the Ramna Stacks in relation to tide.

There was not a clear relationship between tide and CPUE in all fishing locations. An example being a nearby wreck, 15 miles north of the Ramna Stacks, there was no significant difference in CPUE (Mann-Whitney, U = P>0.05) at different stages in the tidal cycle (Figure 45).

There was no significant correlation between the height (metres above datum) of the tide and catch rate (Figure 46) (r_s =0.01, n=570, P>0.05). However, although there was not a significant correlation, there was a significant difference in CPUE between the different tide heights (*K*=18.5, 8d.f., *P*<0.05) with the lowest tide height, 1.6 metres, yielding the greatest catch rate, 2.1 boxes/hour, while the lowest catch rate, 0.6 boxes/hour, occurred during tidal heights of 2.1 metres.

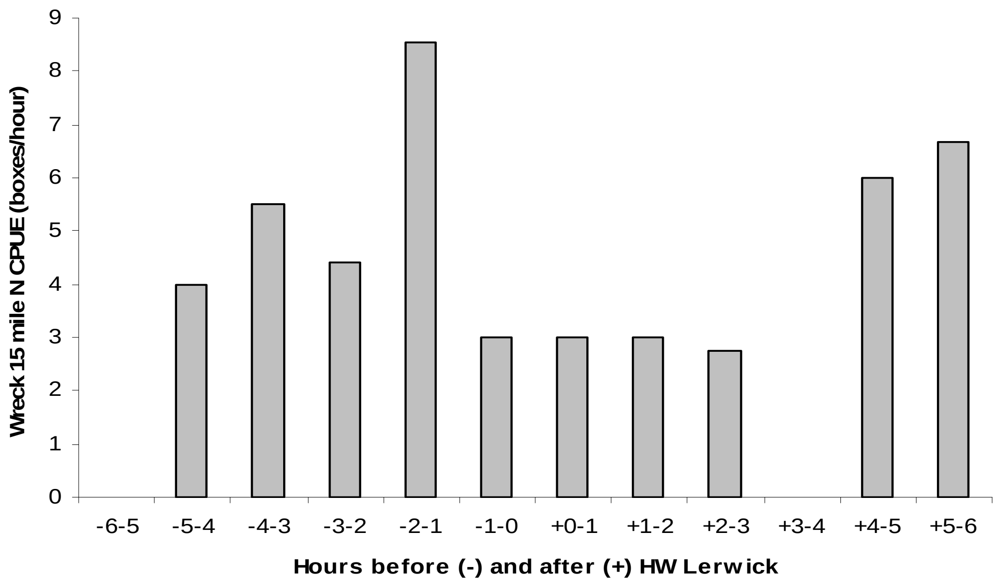


Figure 45 Total catch per unit effort at a wreck 15 miles north of the Ramna Stacks in relation to tide. NB Tidal predictions were taken from Admiralty tide table publications.

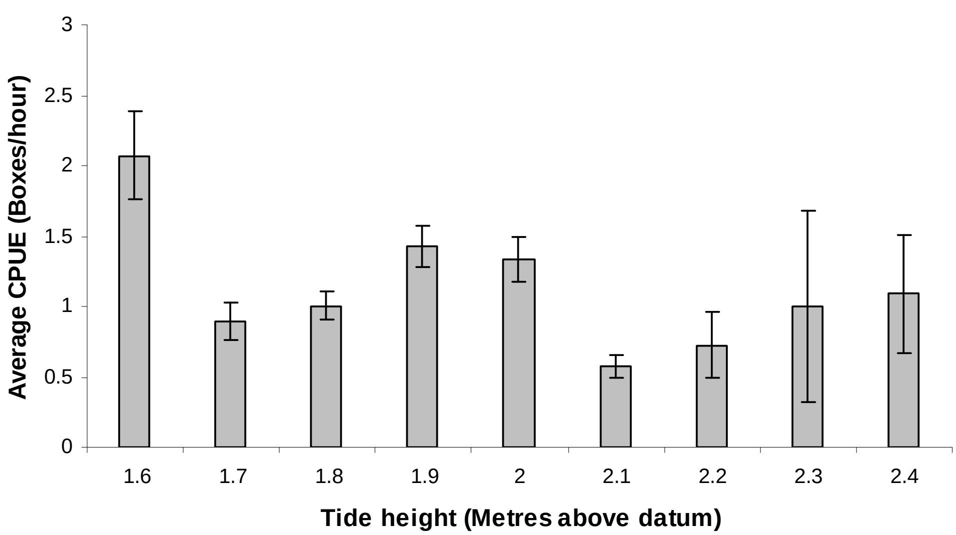


Figure 46 Average catch per unit effort for all species caught during different tide heights. Standard error bars (± s.e.) are also shown. NB Tidal predictions were taken from Admiralty (1986).

The strength of the tide had a big influence on the ability of the vessel to remain on or near fish marks. Coastal areas around headlands were affected the most while offshore areas were less so. Areas such as Muckle Flugga, Gloup Holm, Lamba Ness and others became unfeasible to work during spring tides as the vessel drifted too quickly over the ground to allow for any reasonable fishing to take place. There was also a tendency for more gear to be lost in places with strong tidal currents.

3.2.7.2 Wind

The strength and direction of wind had a significant effect on the speed and direction of travel of the vessel during drifts. In strong winds flowing with the tide the speed of drift increased while a fresh to strong wind blowing against the tide often helped to slow the drift of the vessel. On hard ground, when a steady drift was required a force 3-4 wind with the tide was ideal to help the vessel drift at a reasonable speed over the ground. On wrecks, light winds were more suited as the vessel tended to stay in the same position for longer.

A Spearman rank correlation coefficient indicated that, for the average catch rates for all species combined, there was a statistically significant negative relationship between catch rate and increasing wind speed (r_s =-0.74, n=8, P<0.05) (Figure 47). There is however, an obviously outlying value for the catch rates obtained in Force 1 winds due to a relatively small sample size. The highest average catch rates were observed in calm weather (2.11 boxes/ hour ± 0.86 (standard error)). The higher degree of variation in those catch rates results in the average value not being statistically significantly different to those catch rates obtained in force 2, 3 or 4 winds (1-way ANOVA $F_{3,345}$ = 0.894, P>0.05). There was a steady decrease in catch rates above force 4.

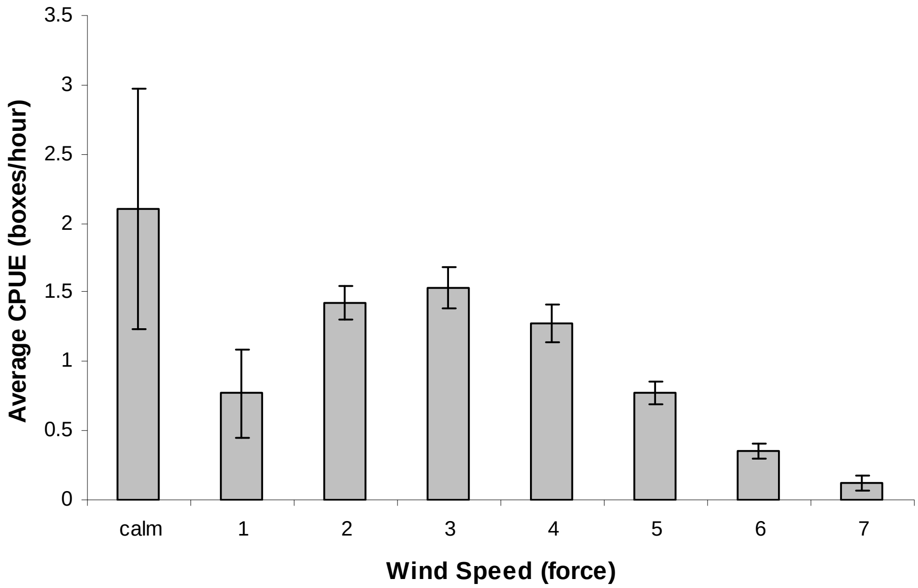


Figure 47 Average catch per unit effort for all species caught during different wind speeds. Standard error bars (± s.e.) are also shown. NB Wind speed was estimated and recorded using the Beaufort scale.

There was a significant difference (K=18.8, 8 d.f., P<0.05) in average CPUE in different wind directions (Figure 48). The maximum average CPUE, 1.96 ± 0.50 boxes/hour, came during variable winds (i.e. calm conditions) while the minimum, 0.69 ± 0.07, came when the wind was blowing from a south-easterly direction. The direction of the wind also played a significant role in deciding where the vessel would fish each day. For example, during moderate to fresh winds from a southerly direction, areas of coastline along the north of the mainland, Yell and Unst could be fished in relative comfort while fresh winds from a westerly direction often resulted in the vessel fishing on the east coast of Unst and Fetlar. Strong winds blowing from the north were probably the least advantageous as the majority of the previously successful fishing grounds were exposed.

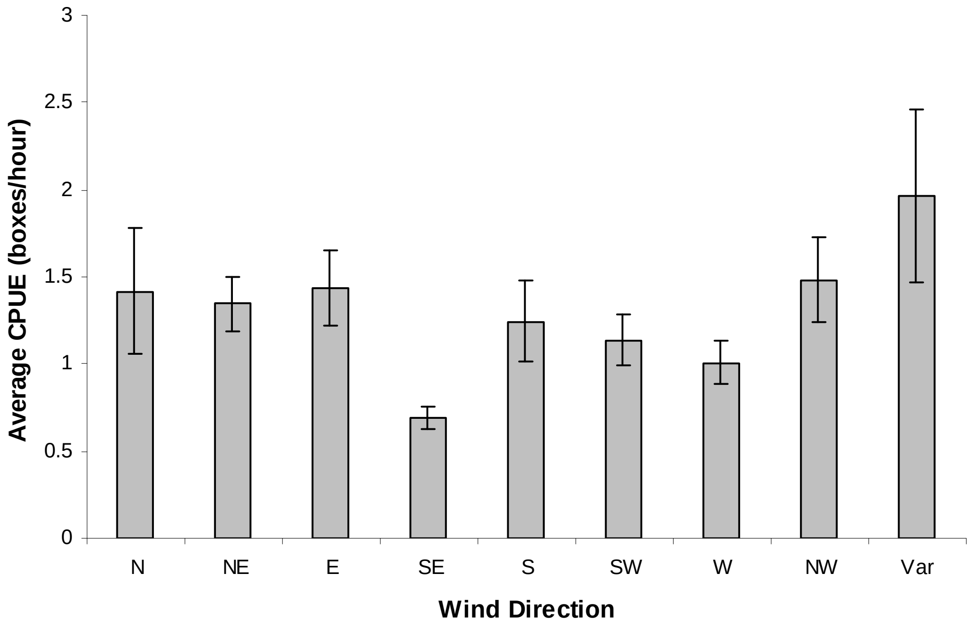


Figure 48 Average catch per unit effort for all species caught during different wind directions. Standard error bars (± s.e.) are also shown.

3.2.7.3 Sea state

Sea conditions often affected the efficiency of the jigging machines. In moderate to rough conditions the bite alarm would erroneously go off with the roll of the vessel. This was sometimes rectified by increasing the weight function (Table 2) to make the machines less sensitive. This could often be a source of frustration as worsening sea conditions exacerbated the situation. On other occasions the bite alarm would go off erroneously due to the loosening of the spring operating within the sensing arm on the machines. In February 2007 the manufacturers were contacted about the problem and they advised that the spring under the sensing arm should be adjusted to the settings outlined in Figure 49. The springs were also replaced by new ones and following these adjustments the machines were less prone to go off in poor sea conditions.

Sea state also had an effect on the hauling speed of the jigging machines, especially when catching large saithe. The downwards movement of the vessel in the ground swell reduced some of the strain on the jigging machines and allowed lines to be hauled more rapidly. On calm days the machines often struggled to haul 5 or 6 large saithe to the surface, often significantly decreasing the actual fishing time of the gear.

There was a significant difference (K=40.5, 8 d.f., P<0.001) in catch rates when fishing in different sea states (Figure 50). The highest average CPUEs came during operations where the sea state was predominantly a westerly swell, 1.90 boxes/hour ± 0.37 (standard error), north-easterly swell, 1.80 ± 0.88 boxes/hour, and south-westerly swell, 1.57 ± 0.24 boxes/hour. Average CPUE was at its lowest, 0.67 ± 0.14 boxes/hour, during rough sea conditions.

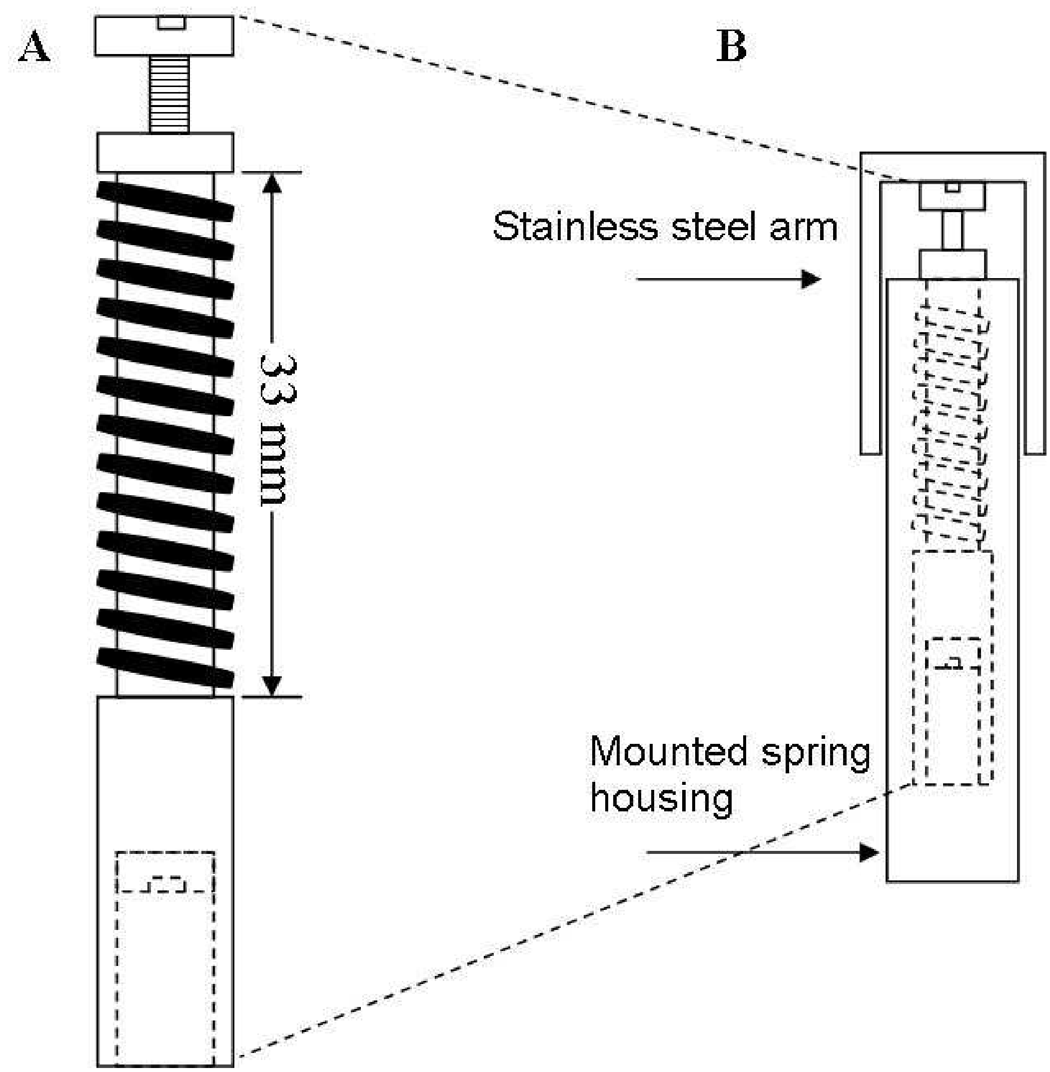


Figure 49 Procedure for adjusting sensitivity of spring beneath jigging machine sensing arm. A: Mounted spring is removed from housing and spring is adjusted to be 33mm in length by tightening or loosening screw on top; B: Mounted spring is returned to housing, the sensing arm is pushed gently until it is touching the top of the spring and the kg (weight) button is pressed to get a weight reading. The weight setting should be 15, if it is less than 15 the screw in the top of the mounted spring needs to be adjusted out, if it is greater than 15 the screw needs to be adjusted in.

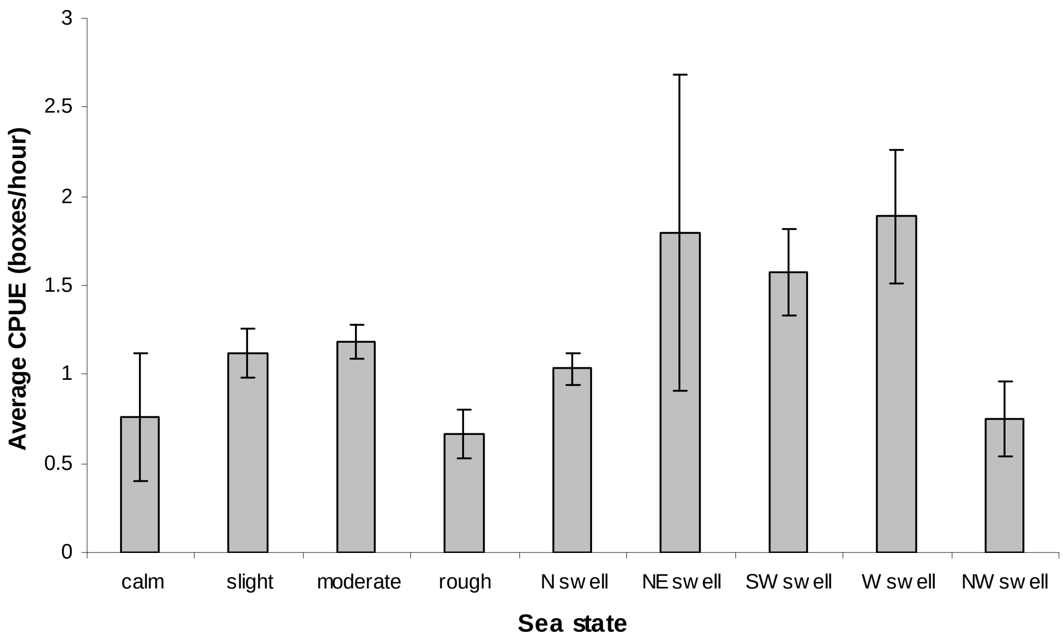


Figure 50 Average catch per unit effort for all species caught in different sea states. Standard error bars (± s.e.) are also shown.

3.2.7.4 Daylight patterns & light conditions

Fishing operations were normally confined to daylight hours. This resulted in longer daily fishing periods during the summer months and a relatively shorter window for fishing in the winter. There was no significant difference between catch rates at different times of day (K=13.7, 18d.f., P>0.05), measured as the number of hours after sunrise or before sunset (Figure 51). The highest CPUE, 1.30 ± 0.49 (standard error) boxes/hour, was in the period 6-7 hours after sunrise while the lowest, 0.23 ± 0.11 boxes/hour, was during a period 2-3 hours before sunset.

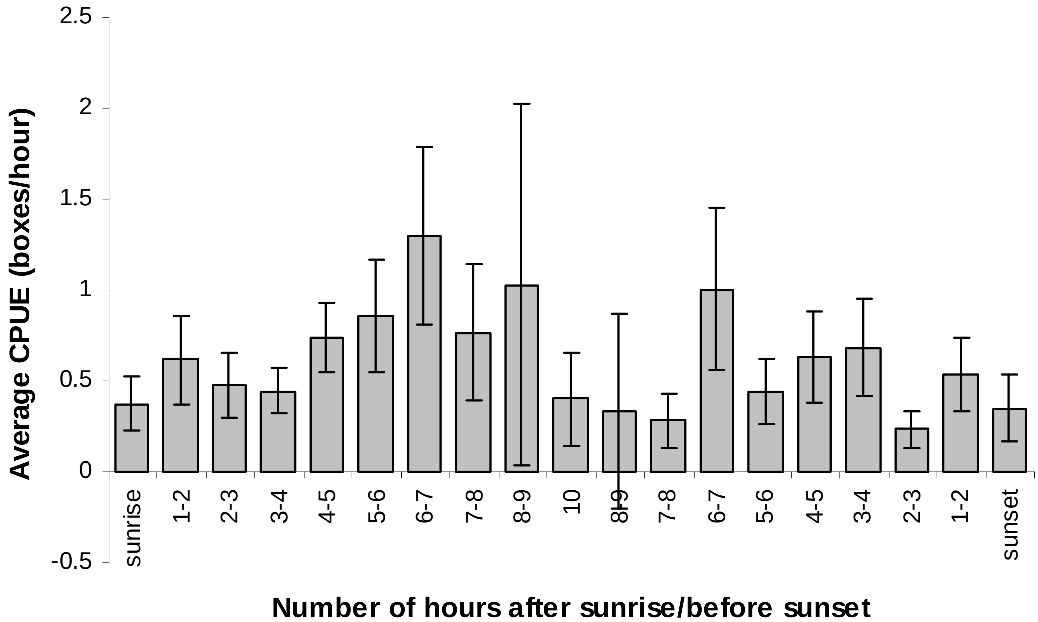


Figure 51 Average catch per unit effort for all species during one hour time periods between sunrise and sunset. Standard error bars (± s.e.) are also shown.

There was a significant difference in catch rates (K=29.5, 6d.f., P<0.01) in differing light levels associated with different weather conditions (Figure 52). The highest overall CPUE, 2.29 ± 0.23 boxes/hour, was during showery weather while the lowest CPUEs were on days with persistent rain, 0.34 ± 0.07 boxes/hour, or snow showers, 0 boxes/hour. Sunny and cloudy weather had similar CPUEs, 1.33 ± 0.13 and 1.56 ± 0.17 boxes/hour respectively. Average CPUE for fog was 0.97 ± 0.17 boxes/hour while during cloudy weather with sunny spells CPUE was 0.68 ± 0.08 boxes/hour.

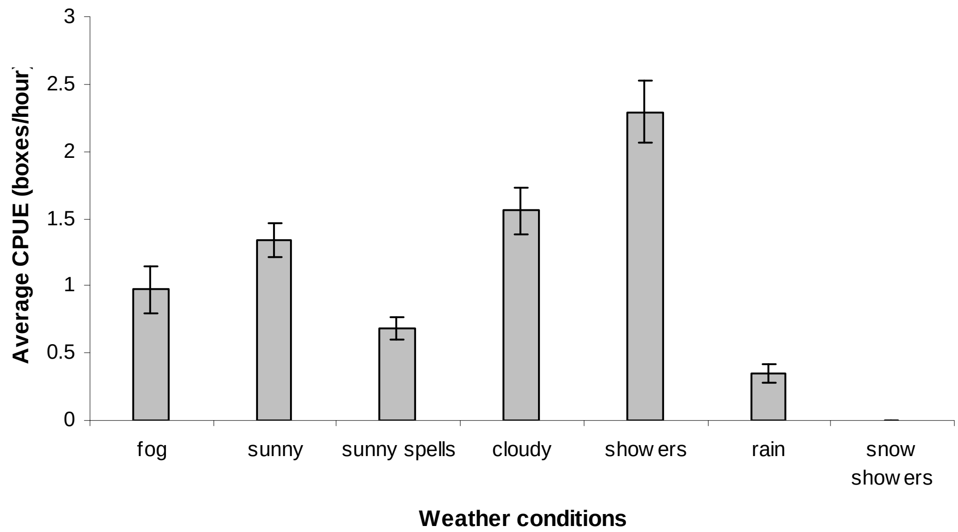


Figure 52 Average catch per unit effort for all species caught during various weather conditions. Standard error bars (± s.e.) are also shown.

3.3 Discussion

3.3.1 Time at sea

Although the *Atlantia* and *Atlantia II* were predominantly involved in the jig fishing pilot study, vessels and staff of the Marine Centre were also engaged in other duties. As a result a full time fishing vessel would probably have had the opportunity to be at sea for more than the 103 days worked during this project. The number of crew required for the effective operation of jigging machines depends on the number of machines being fished. On many occasions, with a crew of two, each crew member was assigned to three machines. While this was adequate in slow or reasonable fishing conditions, things often slowed down when large quantities of fish were being caught. During periods of good fishing it was noted that the fishing operation ran more smoothly with three of a crew, working two machines each.

It was evident early on in the project that the best results were going to come from areas towards the north of Shetland. As a large amount of time was spent fishing in this area, Cullivoe became the favoured harbour for basing the fishing vessel. Cullivoe was an ideal base as it was the closest harbour to the most productive grounds which reduced the travelling time and additionally reduced fuel costs. It also provides all the necessary services including fuel, ice and water. Its position in Bluemull Sound gives the opportunity to travel north to Muckle Flugga and surrounding areas or to travel south to grounds on the east coast of Unst or Fetlar. These options give more flexibility depending on wind strength and direction.

3.3.2 Fishing grounds

One of the most significant findings of the project was the distinct difference in catches between the northern and southern ends of Shetland. The reason for this difference is not clear, although there could be a number of possible explanations. One explanation could be that many of the wrecks and peaks fished at the north end of Shetland are not easily accessible to inshore vessels as a result of weather. While trawlers can tow nets around these areas, the actual areas themselves are protected due to the nature of the seabed. Other factors which may affect the distribution of fish include water temperature, availability of feed, and seabed topography, among other things. A clear understanding of current patterns in fish distribution around Shetland would require further in-depth research.

3.3.3 Seabed type

3.3.3.1 Wrecks

Results indicate that vessels wishing to participate in a jig fishery around Shetland would be heavily reliant on wrecks and peaks to yield the best catches. Wrecks, which yielded significantly more fish than other seabed types in this study, have been shown to have larger fish assemblages and higher species richness than surrounding habitat (Quattrini & Ross, 2006). The recognition of wrecks as areas where numerous species congregate, sometimes in high concentrations, has prompted much debate into the possible use of artificial reefs as fish aggregating devices. Studies have been carried out to investigate optimum design (Baine, 2001), effects on fish production (Grossman et al., 1997) and impacts of artificial reefs on the surrounding ecosystem (Wilding, 2006). The use of such devices around the coast of Shetland, especially around the northern end of the islands, would possibly increase the number of areas available to jig fishermen. However such devices are not guaranteed to attract fish and this point is reinforced by the clear lack of fish on some of the wrecks fished during this pilot study. To make fish aggregating devices successful more research is needed to understand the factors that attract commercial species such as lythe and saithe to these structures.

Although many wrecks were identified during this study there are many more which have not been located due to inaccurate co-ordinates or their distance from the shore. A number of wrecks have been marked on fishing charts in areas north of the Coastal Empress (No. 16 on Figure 13). Periods of good weather would be required to fish on these wrecks due to the long steaming times necessary to reach them. These wrecks are likely to yield catches similar to those in the surrounding area.

3.3.3.2 Peaks

Offshore peaks are also successful areas for catching species such as lythe. As with wrecks these are areas of seabed avoided by trawlers. The location of fish marks in specific areas within groups of peaks indicates that, as with wrecks, a number of environmental and structural factors possibly contribute to the presence of fish in these areas. Inshore peaks, while yielding reasonable quantities of fish, did not match the production of those in deeper water. This suggests that inshore peaks may not have the necessary resources available to sustain large quantities of fish. On the other hand it may be part of a wider issue, namely the lack of inshore fish (within 6 miles of the coast) reported around the coast of Shetland during the last few years.

3.3.3.3 Hard ground

The majority of hard ground fished was inshore. The general lack of inshore fish may also be one explanation as to why catches on hard ground were significantly less than other ground types. The low quantity of fish caught inshore around the south end of Shetland also suggests that any successful fishing on hard ground will be restricted to the northern end of Shetland.

3.3.4 Catch

3.3.4.1 Lythe

Lythe, the greatest overall contributor to the catch, would be the most profitable species to target with jigging machines. Prices are always reasonable and fish appear to be available in large enough quantities in waters at the north of Shetland to enable vessels to turn over a significant profit. Jig caught lythe has the added advantage of being recommended by an environmental organisation. The Marine Stewardship Council (MSC), in its ‘Good Fish Guide’, has advised that in order to ensure sustainability of the species consumers should source lythe (pollack) that is line caught (MSC, 2007).

Lythe are a pelagic to benthopelagic species reportedly found mainly on rocky bottom (Cohen et al., 1990) and are distributed in waters around Britain, Denmark, Faroe, Norway and Iceland (FAO, 2000). Lythe are known to remain within the vicinity of the peak or wreck they inhabit (Sarno et al., 1994) and are less active than saithe, adopting a concealed ambush strategy rather than active foraging (Potts, 1986). The most successful method of catching lythe during this study, which was jigging the terminal gear close to the seabed, is consistent with this behaviour.

Decreases in lythe numbers caught on wrecks in water deeper than 65 fathoms (105 metres) may be due to behaviour traits rather than a lack of fish. The data in Figure 22 shows a decline in lythe catches at the same point as saithe catches rapidly increase. Large marks of saithe often stood well above a specific wreck and on most occasions the hooks were full of saithe and the jigging machine automatically hauled before they reached the wreck. As a result it is considered likely that the terminal gear was rarely dropping to the point on the wreck where the lythe were lying. In the absence of saithe, lythe catches in deeper water may have been significantly higher.

3.3.4.2 Saithe

A number of wrecks to the north of Shetland have the potential to yield good catches of saithe. The large numbers of saithe found in these areas may be due to their proximity to saithe spawning grounds which are to the north and east of Shetland (Figure 53). It is unclear if saithe are permanently resident on specific wrecks, if they move between wrecks or if they migrate away from the area completely. One previous study reported saithe migrating from the Norwegian coast to Faroese and Icelandic waters, sometimes in large numbers (Jakobsen & Olsen, 1987). While evidence of migration is limited, International Bottom Trawl Survey (IBTS) data shows that density in the north-eastern North Sea is markedly higher in summer months than winter months indicating dispersal during the feeding season (ICES, 2007). In order to substantiate whether saithe do in fact move from the wrecks, catch data would need to be gathered and analysed throughout the year.

The coastal waters of Shetland are a major nursery ground for saithe (Figure 53). This explains the frequent capture of small saithe in inshore waters around Shetland. Catches of small saithe can be kept relatively low due to the large size of hooks fished and the ability to move away from any marks which turn out to be small fish.

Saithe are pelagic to benthopelagic species that feed mainly on herring, Norway pout, haddock and sandeel (Du Buit, 1991). On many occasions during the study saithe stomachs were found to contain semi-digested herring and mackerel as well as other species such as garfish (*Belone belone belone*) and Norway pout (*Trisopterus esmarkii*). There was also one instance while fishing on the Coal Boat wreck (60'34.20^{o}N, 002'01.98^{o}W) that a number of the saithe caught were observed to regurgitate small live mackerel which they were obviously feeding on at that time. Unlike lythe they are very active foragers, often moving vertically in the water column and may be found great distances from the seabed during night time (Bergstad, 1991).

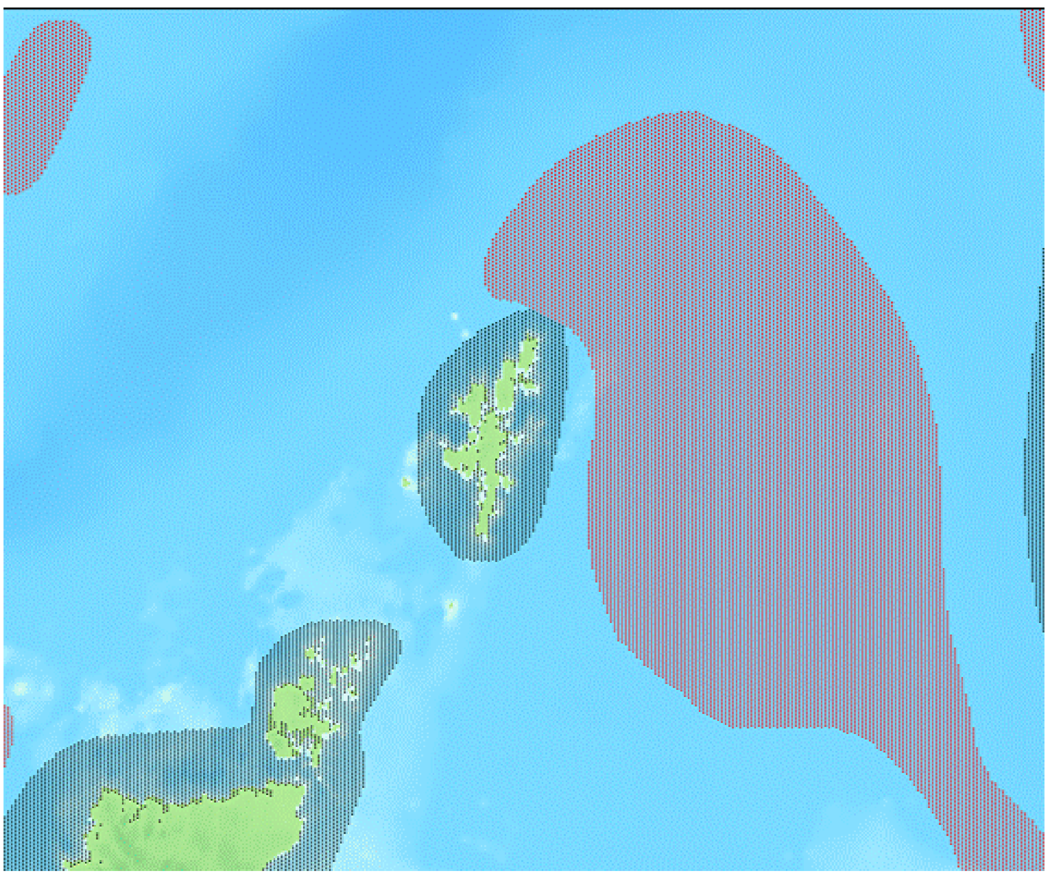


Figure 53 Saithe spawning and nursery grounds in the northern North Sea. NB Red areas indicate saithe spawning grounds; Black areas indicate saithe nursery grounds. Source: CEFAS interactive Spatial Explorer and Administrator (http://www.cefas.co.uk/isea).

3.3.4.3 Cod

The results of this study indicate that the best place to target cod around Shetland would be inshore areas to the north and east of Muckle Flugga, Unst although, even there catches have been fairly low. Current market prices for cod mean that relatively small amounts of fish could yield a significant profit, however there are currently issues associated with locally high abundances of cod and a subsequent mismatch with available quota.

As with lythe, cod have been caught mainly by jigging the terminal gear close to the seabed. This is consistent with the behavioural characteristics of cod, as they are known to spend large amounts of time foraging on or near the seabed (Cohen et al., 1990).

There is currently a great deal of debate centred around the state of cod stocks in the North Sea. The estimated spawning stock biomass of cod has decreased from a peak of over 250,000t in 1970 to around 35,500t in 2001 (ICES, 2006). Although official estimates indicate that stocks have improved very slightly since then, current figures are still below the limit reference point (B_{lim}) of 70,000t. As a result current quota limits restrict vessels' ability to target this species. However, recent reports from fishermen in a number of areas in the North Sea, especially around Shetland, suggest that catches and abundance of cod are presently higher than they have been for many years (Linkie, 2007).

3.3.4.4 Ling

The most successful method of catching ling was to fish the terminal gear baited and tight to the seabed rather than jigging. This is consistent with the life history traits of this species. Ling is a solitary benthic or semi-benthic fish that inhabits rocky or sandy substrates (Cohen et al., 1990). They are reported to occupy a home range area, within which they forage for food (Lokkeborg et al., 2000).

Wrecks such as the Submarine (60'54.37^{o}N, 001'06.87^{o}W), yielding the highest catches of ling, may provide ideal habitat for ling by providing shelter within the wreck while also allowing fish to move off the wreck to search for food. It is unknown why a number of wrecks had significant quantities of ling present on them while none were caught on others. A number of factors such as the size and shape of the wreck along with environmental variables and availability of food may determine the suitability of specific wrecks for species such as ling.

Ling caught on wrecks were generally larger than those caught on inshore grounds. Few small ling were caught on offshore wrecks and this suggests that ling possibly migrate from inshore areas to deeper habitats as they mature.

The results of this study indicate that there are only a few places, mainly wrecks, where ling could be caught in large enough numbers to make it cost effective to specifically target them, and then it is not known how these areas would withstand sustained fishing pressure. In most locations ling catches are such that they would serve as a bycatch to other species such as lythe and saithe.

3.3.4.5 Tusk

Catches of tusk were low throughout the project and this species would probably only rarely be caught in large enough quantities to merit landing it. The majority of tusk were caught from offshore locations and this is consistent with the biology of the species as they are reported to be bottom dwelling fish found mainly in deep water (Cohen et al., 1990). The most successful method for catching tusk was similar to ling, keeping the gear close to the seabed as well as using bait.

3.3.5 Handling & storage of the catch

Handling and storage of the catch during the jig fishing project was kept consistent with nationally recommended practises for the whitefish fleet. Seafood Scotland and Seafish recently issued a scheme aimed at improving fish quality and hygiene prior to landing. Within the scheme some of the objectives include a maximum time fish can be stored in the hold, correct procedures for handling, icing and storing boxes on board the vessel and maintaining high standards of cleanliness (Harman, 2005). Adherence to these standards ensured that the catch was landed and sold in excellent condition.

The benefits of following these recommendations were illustrated in a recent study carried out by Seafish in which the prices received by one vessel, adhering to recommended catch handling procedures, were compared to another vessel which did not follow the recommendations. The vessel adhering to recommended procedures often achieved higher prices for fish at market and on many occasions the differences in price were significant (Ferguson, 2002).

On smaller inshore vessels facilities are not available to handle and store fish in the same manner as in larger vessels. Often weighing at sea is not an option while there is often limited, if any, hold space available to box and store fish. Recent initiatives investigating best handling practises for inshore vessels have indicated that insulated bins are an effective method of storing fish at very low temperatures (Lockley, 2007). The bins are designed to carry slush ice, a mixture of flake ice and seawater and are available in a number of sizes including 100, 220, 310 and 380 litre capacities. The South West Handline Fishermen's Association (SWHFA) has recently been awarded Objective One Fisheries grants for the purchase of insulated bins which normally cost in the region of £230 for the smaller 100 litre version. Studies have shown that slush ice lowers the core temperature of immersed fish below 0˚C in approximately 45 minutes while the same process can take up to 12 hours in fish boxes covered with flake ice (Seafish, 2004).

3.3.6 Bycatch and selectivity of gear

One of the biggest environmental advantages that jig fishing has over other metiers is the relatively low numbers of by-catch and discards. Some fisheries have large amounts of by-catch and, over the years, measures have been introduced to reduce these quantities (Catchpole et al., 2006, Kaimmer & Trumble, 1998, Kerstetter & Graves, 2006). Hook based fisheries such as longlining have also been criticized for seabird bycatch and a number of studies have been carried out to try and devise methods of reducing fatalities (Bull, 2007, Lokkeborg, 1998). There has been a great deal of negative publicity associated with albatross fatalities associated with some longline fisheries in the southern oceans. During this study it was clearly evident that seabird and other by-catch is not an issue when jig fishing.

The low incidence of foul hooked fish (Section 3.2.6) caught on jigging machines ensures that the majority of fish landed are in excellent condition with little or no damage to the flesh. Norwegian studies have shown that the effects of hooks penetrating the flesh of fish result in a significant reduction in the quality of resulting products (Gregersen, 2005). Figures show that in Norwegian coastal fisheries in 2003, 8 million kilograms of cod were landed with serious catch damage. Foul hooking cannot be totally avoided although the use of circle hooks may help reduce numbers damaged.

Low catch rates of undersized fish may have been a result of the size of the hooks used during the study. The numbers of undersized saithe caught is probably due to the coast of Shetland being a recognised nursery ground (Figure 53). This was evident on a number of occasions when marks on the echo sounder turned out to be undersized saithe. However, one of the advantages of fishing with jigging machines is that when a mark is found to be undersized fish, the gear can be hauled after only a very small number of fish are caught and the vessel moved to another location. This allows shoals of small fish to be left relatively untouched. Undersized ling presented a problem as, unlike saithe, almost all the individuals caught did not survive. This problem occurs in many hook fisheries and a number of different styles of hook have been developed attempting to reduce it. The most successful styles found for a variety of fisheries have been a number of different types of circle hook (Bacheler & Buckel, 2004, Beckwith Jr & Rand, 2005, Cooke & Suski, 2004, Willis & Millar, 2001).

Exact survival rates of fish caught and released while jigging is generally unknown. One study on the survival rates of undersized cod in a hand-line fishery estimated a 43% mortality rate with larger fish generally surviving better (Pálsson et al., 2003). Further research could be carried out to determine the survival rates of fish discarded during jig fishing operations and also to investigate whether increasing hook size reduces catches of undersized fish while maintaining catch rates of marketable fish.

3.3.7 Environmental variables

Fish are continually receiving, and responding to, various stimuli from the surrounding environment. These stimuli elicit a variety of responses which can trigger instantaneous or seasonal changes in a number of elements of fish behaviour such as feeding, migration and reproduction (Jobling, 1996). Of particular relevance to this study were the effects of environmental variables on activity, feeding capabilities and feeding motivation. Unlike trawl and other net fisheries, jig fishing relies on the target species being motivated to respond to the deployed gear. Stoner (2004) has outlined the wide variety of environmental variables that may affect fish feeding behaviour at any one time namely, temperature, prey, current, wind, barometric pressure, light, turbidity, bottom type, conspecifics and competitors (Figure 54). Fish responses to changes in environmental conditions were evident on many occasions throughout this pilot study.

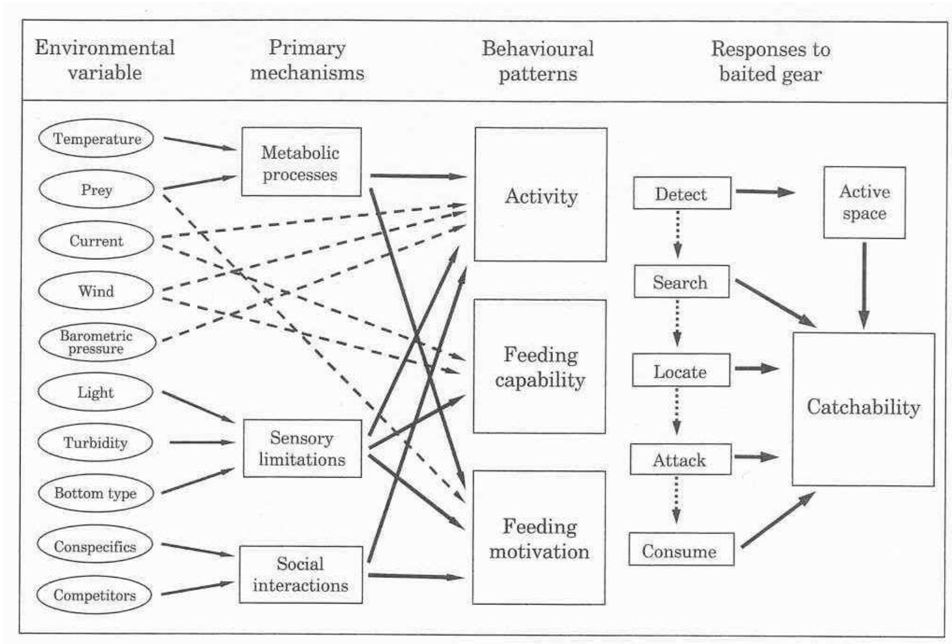


Figure 54 Possible effects of environmental variables on activity, feeding capabilities and feeding motivation of fishes (Stoner, 2004).

3.3.7.1 Tide

Tide had a noticeable effect on catches in some fishing locations. One such location was the peaks 15 miles north-northwest of the Ramna Stacks (Figure 27) where there were significant differences in lythe catch rates at different times in the tide cycle. During their visit to Faroe, NAFC Marine Centre staff were advised by local fishermen involved in the jig fishery that catch rates around Faroe are higher during specific, predictable periods in the tide cycle, especially when the tidal currents were flowing in a west to east direction (A. Johnson, pers. comm.). Previous studies have shown that tide can have direct impacts on the feeding behaviour of fish (Fernö & Huse, 1983) while Lokkeborg (1989) also reported that cod and haddock activity decreases at high current velocities. A number of other fish species are also known to shelter under similar conditions (Gerstner, 1998, Gerstner & Webb, 1998).

This pattern did not hold for all fishing locations e.g. the wreck 15 miles north of the Ramna Stacks (60^{o}56.90N, 001^{o}29.30W). These differences suggest that while tide can play an important role in fish behaviour in some locations, there are many locations where other environmental factors may have a greater influence on behaviour. The wreck 15 miles north of the Ramna Stacks appeared on the echo sounder to be a relatively small structure with a large amount of fish surrounding it. It may have been the case that the effects of intraspecific (within species) and interspecific (between species) competition for food were greater than the influences of the tide on fish behaviour in this area, causing fish to feed whenever the opportunity arose.

3.3.7.2 Wind

The effects of wind speed and direction play an important role in determining the viability of this metier. This is because the most profitable fishing grounds were found to be in offshore, exposed sea areas at the northern end of Shetland and, while there may be significant opportunities to access these grounds during summer months, there will be long periods of time when the grounds will not be accessible to inshore vessels. Sheltered inshore areas may be accessible in fresh winds although catches in many of these areas are limited. This, coupled with the costs incurred as a result of increased gear loss due to the drift speed of the vessel in fresh winds, has the potential to reduce profit levels significantly.

Significant differences in catch rates for different wind directions during this study may indicate preferences in fish feeding behaviour in certain conditions. However a contributing factor to that finding is that some of the more productive fishing grounds could only be accessed when the wind was of a certain direction and below a certain strength. For example, the data shows ‘variable’ wind direction to have had the highest CPUE and during the study ‘variable’ winds were defined as light or moderate and never above force 4. The significant negative correlation between CPUE and wind speed reflects the fact that as wind speed increases the lucrative offshore fishing grounds become less accessible.

Few studies have been carried out on the effects of variables associated with barometric changes such as wind and cloud cover (Stoner, 2004). However, studies carried out on freshwater fish species reported that rainbow trout (*Oncorhynchus mykis*) (Peterson, 1972) and black crappie (*Pomoxis nigromaculatus*) (Guy *et al*., 1992) responded to changes in barometric pressure. Further research is required to investigate the effects of barometric changes on fish behavioural traits such as feeding motivation.

3.3.7.3 Sea state

Moderate or rough sea conditions highlighted a gear defect which became quite problematic over a period of time. When the jigging machines were supplied there were no instructions as to how to alter settings if the gear was not performing correctly. Information from the suppliers suggested that, after the machines were initially calibrated, they would not require calibration in the future. However, when the springs removed from the sensing arm were compared with replacement springs there was a clear difference in the length of the two, with the newer springs being longer and tauter. Therefore it was necessary to replace the springs and re-calibrate the machines to revert them to their original sensitivity.

The significant differences in catch rates during different sea conditions were probably more related to the ability of the vessel to access the best fishing grounds in fine weather. Overall, CPUE was generally higher during days when there was a sea swell running, again this is a reflection of the fact that the best fishing was to the north and west of Shetland and there was often a sea swell in those areas, more so than in the southern and eastern areas.

3.3.7.4 Daylight patterns and light conditions

Diel periodicities in feeding and activity are well known for a number of fish species (Stoner, 2004). Studies have shown that many commercially important gadoid species exhibit patterns in feeding activity related to daylight patterns. Saithe undertake significant vertical migrations that are known to exhibit diel and seasonal differences (Jonsson & Armannsson, 2006). Cod and haddock are known to display a diel rhythm of feeding activity (Lokkeborg & Bjordal, 1989) with cod exhibiting a pronounced increase at dawn and a decrease at dusk (Lokkeborg & Ferno, 1999). Investigations into the feeding behaviour of ling have shown this species to exhibit a crepuscular activity rhythm, i.e. they have higher levels of swimming activity at dawn and dusk (Lokkeborg *et al*., 2000). That study also showed that ling were less active at night, not locating or responding to baits. Little is known about activity patterns of lythe although one study has reported that fish often move to different depths during periods of predation (Potts, 1986).

Jig fishing is traditionally restricted to daylight hours in Faroese waters and, as studies into fish feeding activity indicate, this is probably in response to known fish activity patterns. In the waters around Shetland there is a vast difference in the amount of daylight hours between summer and winter. During the summer the longest day has a daylight period of over 19 hours between sunrise and sunset with very little actual darkness between sunset and sunrise. During winter almost the opposite is true, with less than 5 hours between sunrise and sunset on the shortest day. Vessels involved in the fishery would therefore need to take advantage of the longer days during the summer months to maximise revenue and compensate for lack of fishing time during the winter.

In the marine environment vision plays an important role in fish feeding behaviour (Pitcher, 1993) and changes in light level and intensity have a direct effect on the ability of fish to locate prey. This is especially true when fishing exclusively with lures because the ability of fish to locate lures depends primarily on visual cues, unlike baits where olfactory cues are also employed for detection and location (Stoner, 2004). Studies have shown that a number of species of fish are affected by changes in light levels, with many species including cod and halibut exhibiting increased activity at higher light levels (Marchand et al., 2003, Scherer & Harrison, 1988, Stoner, 2003).

Differences in CPUE in various light conditions during this study were not consistent with the expected patterns of decreasing CPUE with declining light level for cod, saithe and lythe. If this pattern were to hold then CPUE would be expected to be highest during sunny conditions for cod and lowest during rain, snow or fog, which it was not. Catches of ling were not high enough to establish whether they exhibited the expected increase in activity at dawn and dusk. As there are many factors that can affect the catch rates (e.g. weather, tide, lure type and colour) and there is a constant interplay between these factors, much more extensive research would be needed to determine if and how light levels affect catch rates of the species important to jig fishing.

4 Experiments Conducted during the Study

During the course of the study experiments were undertaken to compare catch rates with different lure types, to investigate the effects of lure colour on catch rates, and to investigate the use of pheromones as artificial bait.

4.1 Experiment 1: Comparison of lure types

4.1.1 Introduction and aims

There are a number of different lure types available commercially for jig fishing. It is possible that there could be differences in catch rates from different types of lures so an experiment was devised to test the null hypothesis that there is no significant difference in the number of fish (saithe, lythe and cod) caught on jigging machines fishing with different lure types.

Catch rates of five different lure types (rubber eel, Red Gill, spoon, muppet and sonic lure) were compared (Figure 3). Four of the lure types are those readily available to commercial fishermen while the fifth, the sonic lure, was a newly developed lure being trialled alongside other commonly used lures.

4.1.2 Materials and Methods

4.1.2.1 Gear set-up for comparison of lure types

Five Oilwind fully automatic jigging machines were each equipped with 300m of 400lb Dynema main line, a 10 fathom 300lb monofilament shock leader, and a nylon ring of 40mm inside diameter attached to the end of the leader. Lure rigs, constructed for each of the different lure types, were attached to the nylon ring. Lures on each machine were numbered 1-6 from top to bottom respectively. A 7lb lead sinker was attached to the end of each lure rig.

Rubber eel lure rigs were constructed from Marlin 250lb (113.1kg / 1.60mm) clear main line with size 3/0 (127lb) black brass barrel swivels attached to the main line using the scaffold knot (Figure 5d, page 18). Swivels were attached at intervals of 0.5 fathoms on either side of each lure. Coloured lures were constructed from Mustad rubber eel hooks size 10/0, coloured PVC or silicone tubing with 6mm inside and 8mm outside diameter, and size 1/0 (175lb) nickel crane swivels. The different coloured lures were then attached to loops made in the main line using the dropper loop knot (Figure 3 and Figure 5b) at approximately 1 fathom (1.83 metres) intervals.

Red Gill, muppet, spoon and sonic lure rigs were each constructed from Marlin 250lb (113.1kg / 1.60mm) clear main line with size 2/0 (127lb) three way barrel swivels attached to the main line, by the eye on opposite ends of the swivel, using the scaffold knot (Figure 5d, page 18). Swivels were attached at approximately one fathom intervals. Red Gill lures and muppets were equipped with size 8/0 Mustad O'Shaughnessy hooks while spoons and sonic lures were supplied with hooks (approximately size 8/0) attached. Each of the lures were then attached to the remaining eye on the swivel of their respective rigs using an 8-10cm length of 1.1mm nylon fishing line and a crimp, which provided rigidity in the snood (Figure 5c, page 18).

Lure colours were selected from those readily available to commercial fishermen. Six different coloured rubber eel, Red Gill and muppet lures were randomly assigned to their respective hooks (Table 10). Only three colours of sonic lure, red, green and silver were available for use, requiring each colour to be positioned twice on the rig. The three colours were randomly assigned to hooks 1-3 and the pattern was repeated for hooks 4-6. Spoon lures were only available in silver and as a result each hook was assigned the same coloured lures. Jigging machine motor functions were set at factory settings (Table 1, page 11) while operating functions were calibrated to the settings shown in Table 2.

Table 10 Positions of each of six randomly assigned colours for five different types of lure during an experiment comparing different lure types.

	Lure Type				
Hook Number	Rubber eel	Red Gill	Spoon	Sonic	Muppet
1	**Blue**	**Black**	**Silver**	**Red**	**Silver**
2	**Gold**	**Red**	**Silver**	**Green**	**Orange**
3	**Red**	**Mackerel**	**Silver**	**Silver**	**Green**
4	**White**	**Nightshade**	**Silver**	**Red**	**Yellow & Red**
5	**Black**	**Silver**	**Silver**	**Green**	**Green & Blue**
6	**Yellow**	**Green**	**Silver**	**Silver**	**Red & White**

4.1.2.2 Experimental protocol

To avoid any possible effect of machine or position, the lure rigs were rotated between machines periodically in such a way as to ensure that each lure type was positioned on each reel once and next to each of the remaining lure types twice throughout five rotations. Table 11 below shows the rotation pattern that was devised.

During this experiment the fish caught on each hook on each rig was recorded.

Table 11 Rotation pattern for each of the lure rigs used in the lure preference experiment.

	Machine 1	Machine 2	Machine 3	Machine 4	Machine 5
Rotation 1	**Red Gill**	**Rubber eel**	**Muppet**	**Sonic**	**Spoon**
Rotation 2	**Spoon**	**Muppet**	**Red Gill**	**Rubber eel**	**Sonic**
Rotation 3	**Sonic**	**Red Gill**	**Spoon**	**Muppet**	**Rubber eel**
Rotation 4	**Rubber eel**	**Spoon**	**Sonic**	**Red Gill**	**Muppet**
Rotation 5	**Muppet**	**Sonic**	**Rubber eel**	**Spoon**	**Red Gill**

4.1.2.3 Data analysis

A 2-way ANOVA without replication was used to investigate if the total catch of fish differed between the five different lure types. A 1-way ANOVA was also used to investigate whether catch rates differed between the five lure types for each of the species caught in sufficient numbers (lythe and saithe) and whether there was a hook preference for each of the species caught in sufficient numbers (lythe and saithe). In each case a post-hoc Tukey test was undertaken to distinguish mean differences when the results of the ANOVA indicated a significant difference.

4.1.3 Results

During March 2007 and over a one week period ten hours were spent carrying out a total of five gear rotations in a number of locations at the northern end of Shetland (Figure 55). The time spent fishing at each location ranged from 15 to 90 minutes (Figure 56).

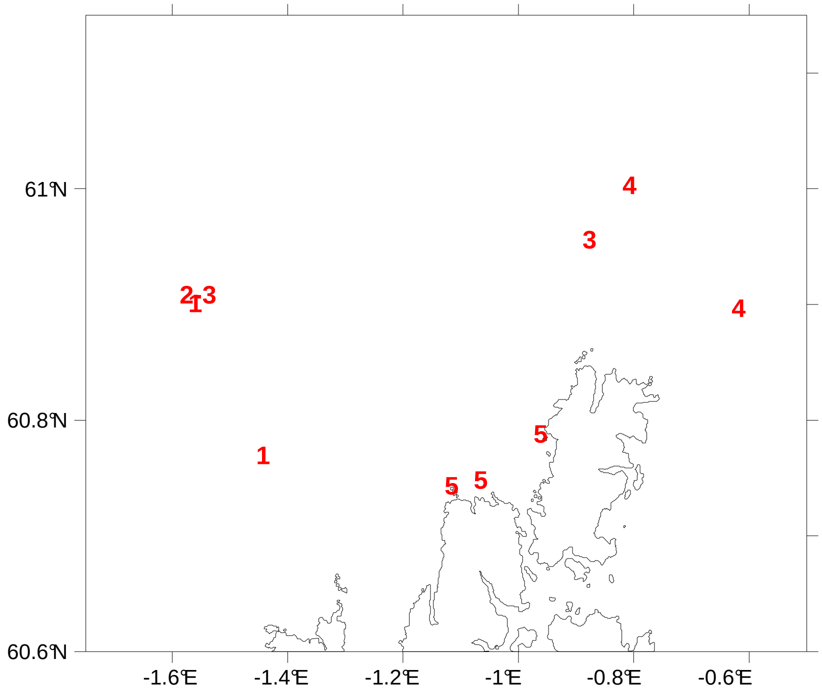


Figure 55 Geographic location of each of the 5 rotations carried out during lure preference trials at the northern end of Shetland.

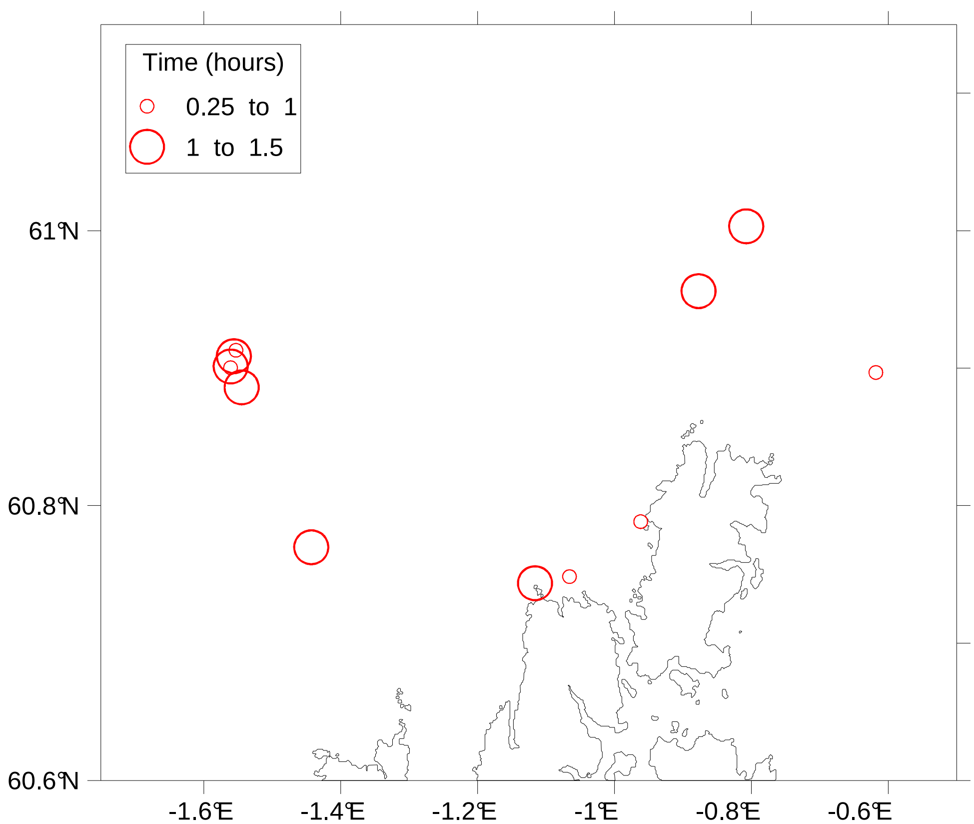


Figure 56 Time spent fishing at each location during lure preference trials at the northern end of Shetland.

A total of 238 fish were caught on the five different lure types during five rotations (Table 12). A 2-way ANOVA without replication indicated that there were no significant differences in numbers of fish caught between each of the machines ($F_{4,16}$ = 0.21, P>0.05) but there were significant differences between the lure types ($F_{4,16}$ = 0.95, P<0.05). The lowest number of fish was caught using the sonic lures.

Table 12 Total numbers of fish caught using each lure type on each machine from the five rotations.

	Lure type					
Machine	**Redgill**	**Rubber eel**	**Muppet**	**Sonic**	**Spoon**	**Total**
1	10	21	3	3	5	42
2	5	15	15	2	19	56
3	7	2	7	10	16	42
4	15	11	11	1	5	43
5	4	7	26	8	10	55
Total	41	56	62	24	55	238

The total catch of each species by each lure type is detailed in Table 13 and are shown by species and location in (Figure 57). A one-way ANOVA indicated that there was a significant difference in the numbers of lythe being caught between lure types ($F_{4,20}$ = 3.20, P<0.05). A post-hoc Tukey test indicated that the significant differences in the numbers of lythe being caught lay between the sonic and muppet and sonic and rubber eel lures. For saithe, a one-way ANOVA found that there was no statistically significant difference in numbers caught between lure type ($F_{4,20}$ = 0.27, P>0.05). Catches of the remaining species were too low to carry out statistical analysis.

Table 13 Number of fish caught on five different lure types during March 2007.

	Lure type				
Species	**Redgill**	**Rubber eel**	**Muppet**	**Sonic**	**Spoon**
Lythe	21	27	28	4	25
Cod	0	0	0	1	0
Saithe	18	28	29	15	28
Tusk	1	1	3	1	0
Ling	0	0	0	0	1
Others	1	0	2	3	1
Total	41	56	62	24	55

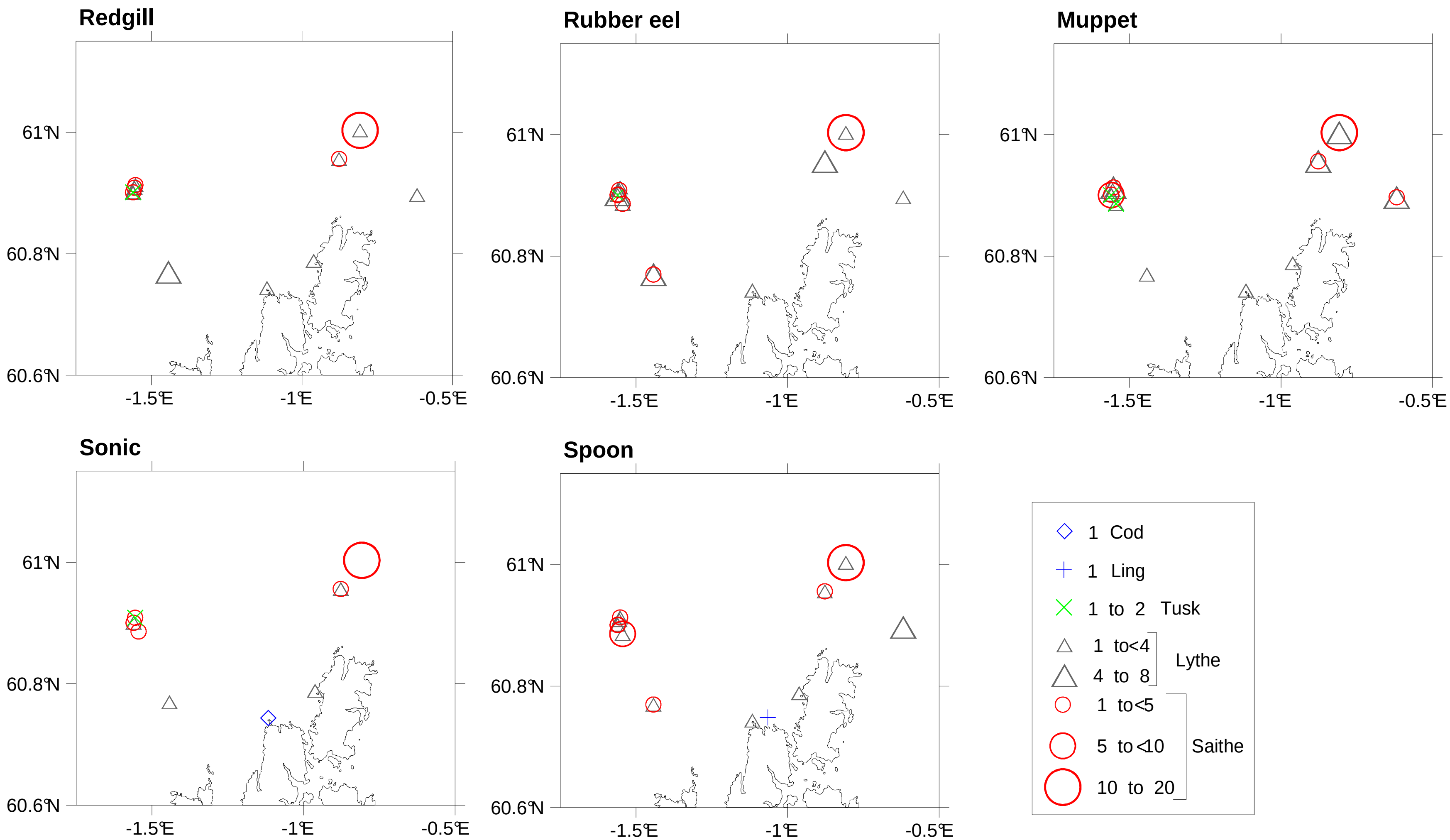


Figure 57 Breakdown of the catch (numbers of fish of each species) for each of the 5 lure types deployed during lure preference trials.

The numbers of fish caught on each hook was recorded throughout the duration of the experiment. Figure 58 shows that regardless of lure type, the few tusk that were caught during the experiment were all caught on hook number 6, the one closest to the seabed. Analysis of data for catches of lythe on each hook using ANOVA's revealed that there was not a statistically significant pattern of hook preference for any of the lure types (Redgill: $F_{5,29}$ = 1.18; rubber eel: $F_{5,29}$ = 0.23; muppet: $F_{5,29}$ = 2.00; sonic: $F_{5,29}$ = 1.14; spoon: $F_{5,29}$ = 0.61, all P>0.05).

Catches of saithe were similarly investigated for hook preferences during the rotations and results of ANOVA's indicated that there were no statistically significant differences in total catches between hooks (Redgill: $F_{5,29}$ = 0.88; rubber eel: $F_{5,29}$ = 0.59; muppet: $F_{5,29}$ = 0.25; sonic: $F_{5,29}$ = 0.83; spoon: $F_{5,29}$ = 0.25, all P>0.05).

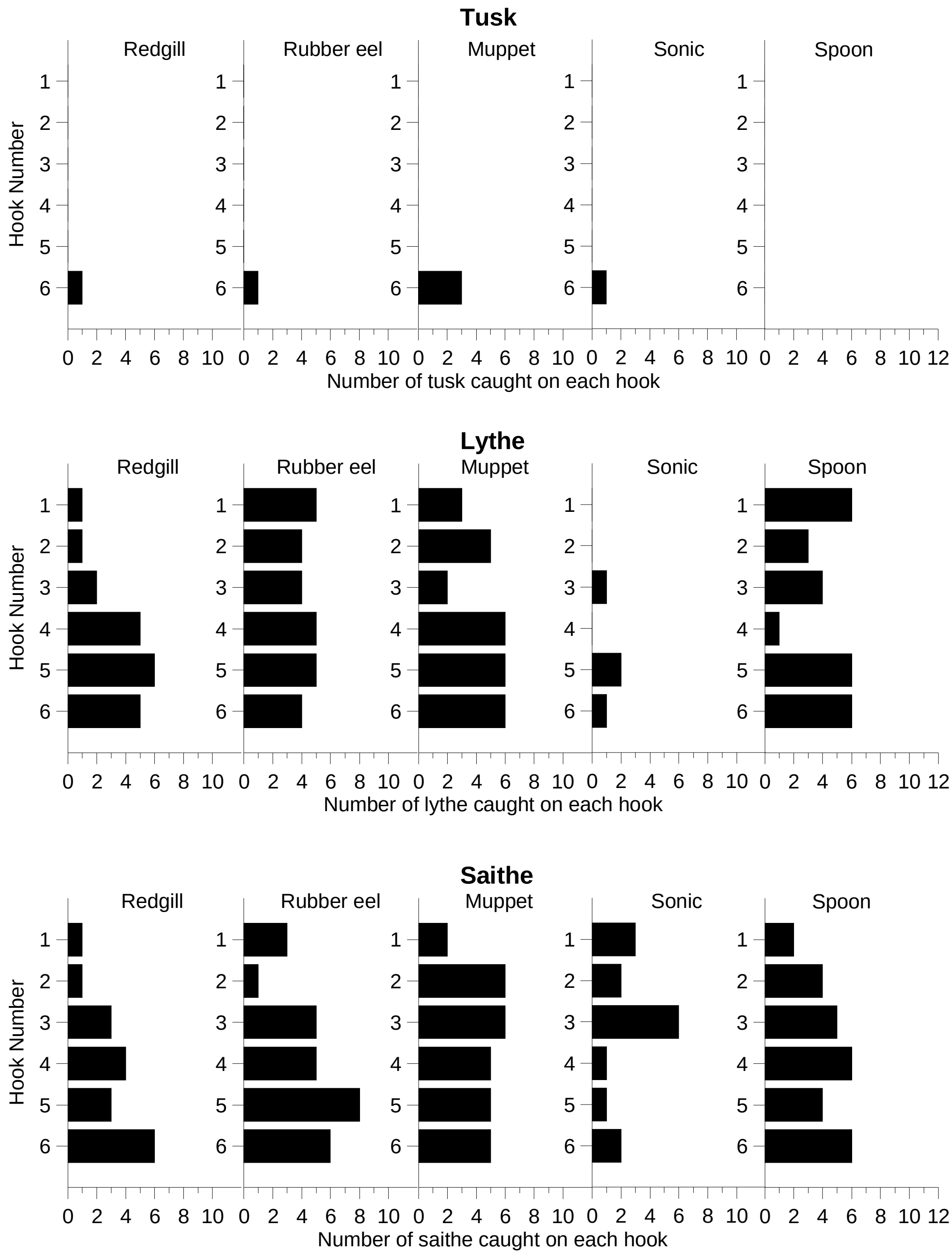


Figure 58 Numbers of tusk, lythe and saithe recorded on each hook number on each of the different lure types during the lure type experiment.

4.1.4 Discussion

During the lure type experiment, for reasons associated with experimental design and analysis, only five commercially available lure types were trialled. A huge number of lure types are available for use by commercial fishermen and a large number of studies could be carried out comparing the effectiveness of each type.

Results from this study indicate that catch rates do not differ between the various lure types trialled here. Red Gill, rubber eel, muppet and spoon lures are commonly used by commercial fishermen in Shetland while the sonic lure is a newly developed lure previously untried in the waters around Shetland. The results indicate that those lures commonly used by commercial fishermen may in fact be the most suitable for species targeted while jig fishing.

Only two species, lythe and saithe, were caught in significant numbers during the trial. These two species are relatively abundant around Shetland especially in areas of hard seabed and wrecks. The low numbers of tusk, ling and cod caught may have been due to the lures not being suitable for catching those species although it is more likely a result of low numbers of fish present on the grounds where the experiment took place.

Each of the five lures used in the study was designed to imitate species that the target fish would normally prey upon. Red Gill and rubber eel lures are designed to resemble sand eels and other small fish. The movement of the eels in the water when being jigged is intended to imitate that of an injured fish, possibly suggesting an easy target to the predator. Muppet lures are designed to imitate small octopus or squid and the jigging motion of the gear provides lifelike movements and jerks which in turn attract predators. Spoon lures are generally silver in colour, providing flickers of light when being jigged in the water. This flickering action is intended to resemble movements of injured fish, thereby attracting predators. Sonic lures are also designed to imitate injured fish and the design of the lure reportedly creates a vibration that fish find difficult to resist.

Lythe, being ambush predators, have a diet which is known to include mainly fish species such as herring, haddock, Norway pout, and poor cod as well as cephalopods and crustaceans (Cohen et al., 1990). All the lures used in this study would therefore be expected to attract this species. Saithe are voracious predators and are known to eat a wide range of prey types including herring, mackerel, whiting, haddock, a number of crustaceans and also cephalopods (Rae & Shelton, 1982). One saithe caught during this study was even found to have a plastic ice-cream wrapper in its stomach. As with lythe, the lures used in this study would all be expected to attract saithe.

Hook preferences exhibited by some of the species caught during this study may be due to one or more factors. For example, the few tusk caught were all captured on the bottom hook regardless of the lure type. This is consistent with their biology as they tend to stay close to the bottom on rough, rock or gravel ground (Cohen *et al*., 1990). Saithe and lythe are pelagic to benthopelagic species and can be found at different levels in the water column (ICES, 2007). This was reflected in the distribution of the total catch of each species between the six hooks on each rig. One other factor which may have affected the distribution of fish on the hooks was the colour of the lures used. Other studies have shown that jig fishing target species such as lythe exhibit preferences for different coloured lures. This may have had an effect on the results of this experiment although spoon lures would not have been affected as they were only deployed in one colour.

While there may have been preferences between different lure types during this experiment it is unclear whether these preferences remain constant. As mentioned above, many predatory fish are known to change prey depending on the availability of certain species at different times of the year (Rae & Shelton, 1982). As a result the effectiveness of different lures may also change throughout the year. Further studies could be carried out at different times of year to determine whether lure preferences change over time. This would possibly reveal the types of lure which would result in optimum catches of each of the target species throughout the year.

4.2 Experiment 2: Comparison of lure colour

4.2.1 Introduction and aims

There are a large number of colours of lure that are available for use in jig fishing. It is possible that the different coloured lures could result in different catch rates of different species and in different conditions. An experiment was devised to test the null hypothesis that there is no significant difference in the number of fish (saithe, lythe and cod) caught on jigging machines fishing with different coloured rubber eel tube lures.

Catch rates of five different colours of rubber eel tube lure (black, fluorescent red, pale blue, white, fluorescent green) were investigated. Colours chosen were based on those readily available and used by commercial fishermen.

4.2.2 Materials and Methods

4.2.2.1 Gear set-up during comparison of lure colours

Five Oilwind fully automatic jigging machines were each equipped with 300m of 400lb Dynema main line, a 10 fathom 300lb monofilament shock leader, and a nylon ring of 40mm inside diameter attached to the end of the leader. Lure rigs, constructed with six equally spaced rubber eel tube lures of one of the specified colours, were attached to the nylon ring. Lures on each machine were numbered 1-6 from top to bottom respectively. A 7lb lead sinker was attached to the end of each lure rig.

Lure rigs were constructed from Marlin 250lb (113.1kg / 1.60mm) clear main line with size 3/0 (127lb) black brass barrel swivels attached to the main line using the scaffold knot (Figure 5d, page 18). Swivels were attached at intervals of 0.5 fathoms on either side of each lure. This allowed for the removal of any twists in the line caused by hooked fish. Lures were constructed from Mustad rubber eel hooks size 10/0, coloured PVC or silicone tubing with 6mm inside and 8mm outside diameter, and size 1/0 (175lb) nickel crane swivels. Lures were then attached to loops made in the main line using the dropper loop knot (Figure 5e, page 18) at approximately 1 fathom (1.83 metres) intervals.

Jigging machine motor functions were set at factory settings (Table 1) while operating functions were calibrated to the settings shown in Table 2.

4.2.2.2 Experimental protocol

To avoid any possible effect of machine or position, the colours were rotated between machines periodically in such a way as to ensure that each colour was positioned on each reel once and next to each of the remaining colours twice throughout the five rotations. Table 14 below shows the rotation pattern that was devised. Each rotation lasted for four hours giving a total of 20 hours fishing time.

During this experiment the fish caught on each hook on each rig was recorded.

Table 14 Rotation pattern of coloured lure rigs for each machine during the experiment.

	Machine 1	Machine 2	Machine 3	Machine 4	Machine 5
Rotation 1	**Black**	**Pale Blue**	**Flr. Green**	**Flr. Red**	**White**
Rotation 2	**White**	**Flr. Green**	**Black**	**Pale Blue**	**Flr. Red**
Rotation 3	**Flr. Red**	**Black**	**White**	**Flr. Green**	**Pale Blue**
Rotation 4	**Pale Blue**	**White**	**Flr. Red**	**Black**	**Flr. Green**
Rotation 5	**Flr. Green**	**Flr. Red**	**Pale Blue**	**White**	**Black**

4.2.2.3 Data analysis

A 2-way ANOVA without replication was used to investigate if the total catch of fish differed between the five different lure colours and the five jigging machines. A 1-way ANOVA was also used to investigate whether catch rates differed between the five lure colours for each of the species caught in sufficient numbers (lythe, saithe and cod) and whether there was a hook preference for each of the species caught in sufficient numbers (lythe, saithe and cod). In each case a post-hoc Tukey test was undertaken to distinguish mean differences when the results of the ANOVA indicated a significant difference.

4.2.3 Results

During August and September 20 hours of fishing were undertaken over a number of days. From this, five different rotations were carried out at a number of locations (Figure 59) with the time spent fishing in each location ranging from 15 to 90 minutes (Figure 60).

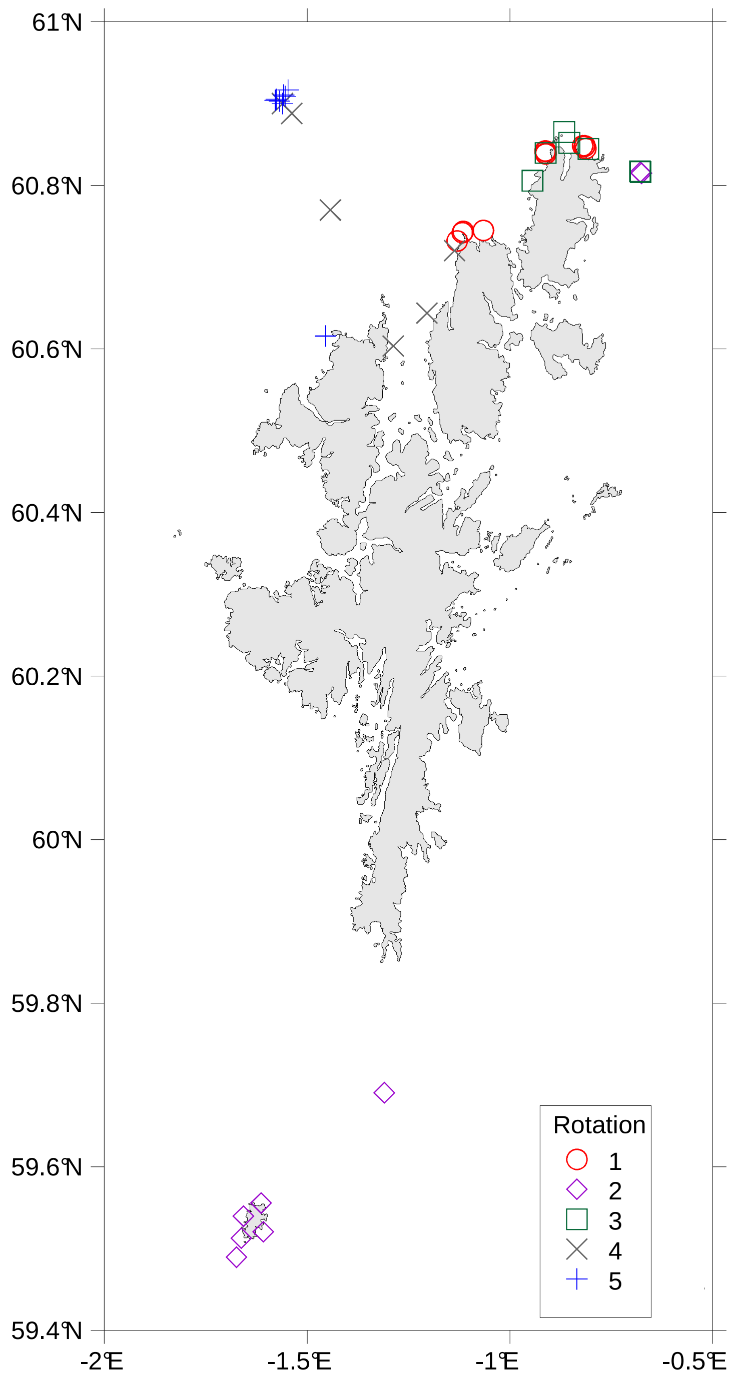


Figure 59 Geographical location of each of five rotations carried out during the lure colour preference experiment.

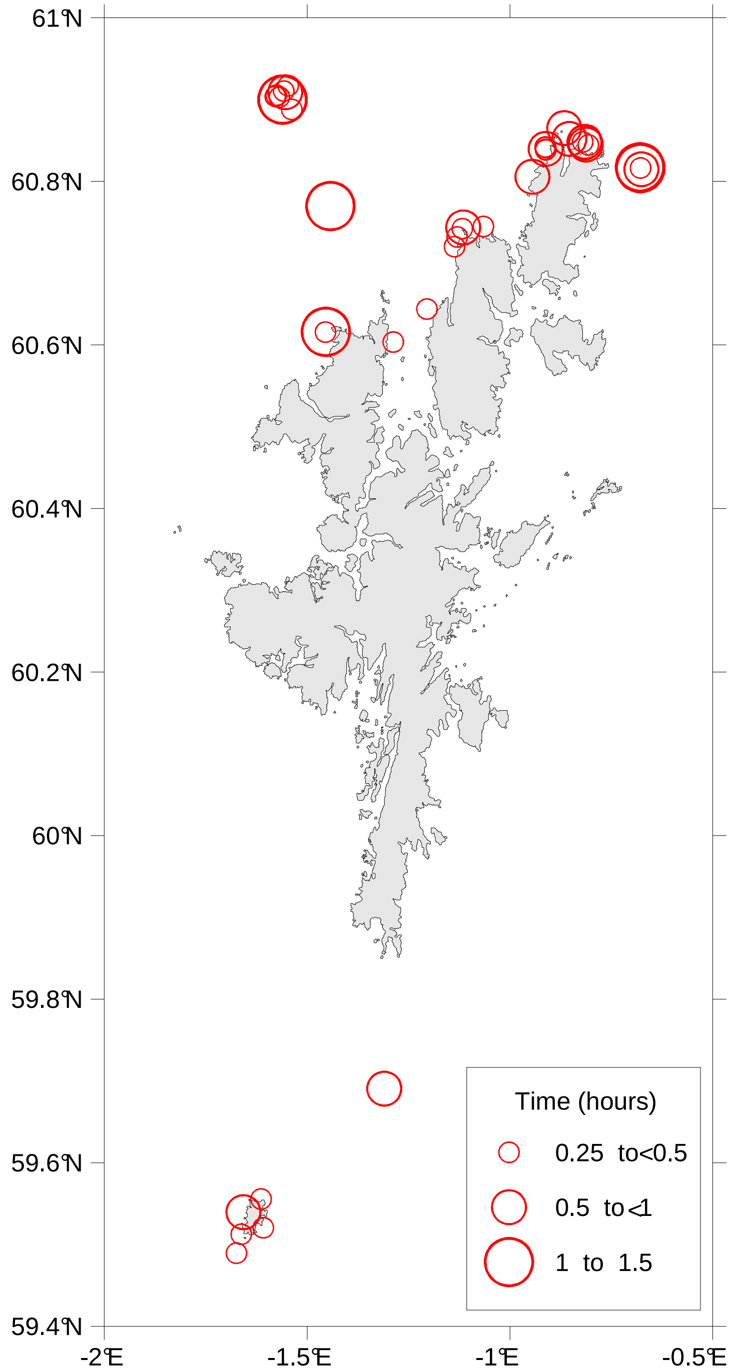


Figure 60 Time spent fishing at each location during lure colour preference experiment.

A total of 492 fish were caught during the five rotations. A 2-way ANOVA without replication indicated that neither the machine number ($F_{4,16}$ = 0.021, P>0.05) nor the lure colour ($F_{4,16}$ = 0.614, P>0.05) were significant factors in the total numbers of fish caught. Although the total number caught ranged from 69 with the fluorescent green lures to 122 fish with the red lures (Table 15), the variability in catches between rotations was high.

One way ANOVAs indicated that there was no significant effect of lure colour on the numbers of either lythe ($F_{4,20}$ = 0.553, P>0.05), cod ($F_{4,20}$ = 0.430, P>0.05) or saithe ($F_{4,20}$ = 0.046, P>0.05) that were caught during this experiment. Catches of ling and tusk were too low to carry out any statistical analysis.

Table 15 Number of fish caught on different coloured lures during an experiment in August-September 2006.

	Lure colour				
Species	**Black**	**White**	**Fluorescent Green**	**Fluorescent Red**	**Pale Blue**
Lythe	54	51	35	72	51
Cod	13	12	9	12	5
Saithe	39	42	25	36	32
Ling	1	0	0	0	0
Tusk	0	1	0	1	1
Total	107	106	69	121	89

The numbers of fish caught on each hook were recorded during most of the duration of this experiment (Figure 61). There were highly significant differences in the catches of cod depending on the position of the hook (1-way ANOVA: $F_{5, 24}$ = 16.05, P<0.0001). A post-hoc Tukey test indicated that catches on hook 6 (closest to the seabed) were significantly higher than those on all other hooks (all P<0.01) and catches on hook 5 were higher than on hooks 2 and 3 (both P<0.05).

A 1-way ANOVA indicated that there was a marginally statistically significant difference in the numbers of lythe caught between different hooks, depending on their position from the end of the rig (1-way ANOVA $F_{5,24}$ = 2.67, P = 0.047). A post-hoc Tukey test indicated that the differences in catches between hook 1 (uppermost hook) and 4 and hook 1 and 5 were the greatest (P = 0.055 in both cases).

There was no statistically significant effect of hook number on catches of saithe (1-way ANOVA: $F_{5, 24}$ = 0.70, P>0.05).

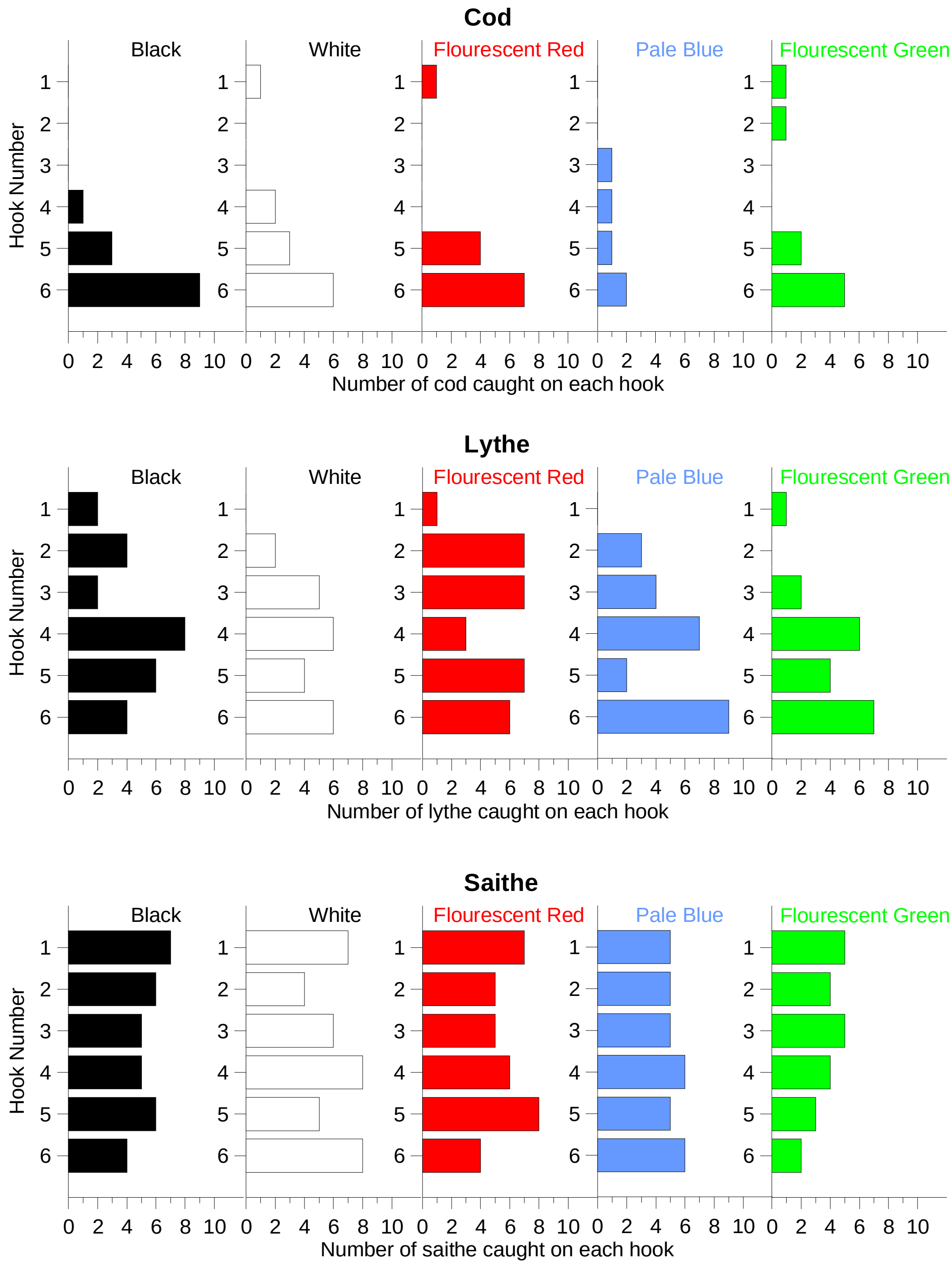


Figure 61 Numbers of cod, lythe and saithe recorded on each hook number on each of the different coloured lures during the lure colour experiment.

4.2.4 Discussion

The results of this experiment indicate that lythe, saithe and cod do not exhibit preferences for different coloured lures. This may indicate that these species exhibit relatively low levels of feed selectivity. Stomach content analyses of saithe and lythe have show that saithe prey on a greater number of species than lythe (Rae & Shelton, 1982). Lythe in the North Sea feed mainly on lesser sandeels, *Ammodytes marinus,* during August and September, the months that this study was conducted (Hoines & Bergstad, 1999). Saithe were shown to have a different diet composition with herring being the most abundant species extracted from stomachs.

Catch rates of coloured lures may be affected by the visual detection abilities of the target species. Species such as lythe, saithe and cod are known to utilise available light while attacking prey. By attacking from below there is the advantage of increased visibility of the prey items against bright downwelling light (Jobling, 1996). Other species such as the dolphinfish, *Coryphaena hippurus*, have been shown to possess visual pigments which provide optimum visibility of prey species in relation to hunting strategies. It may be the case that the fluorescent red lures used in this study matches the sensitivity of the visual pigments within the eye of the lythe providing maximum visibility of this colour in the water column. Another study, investigating the effect of 10 different coloured lures on hooking rates of spotted mackerel, *Scomber australasicus*, found that red lures had the highest hooking rate and were of greatest visibility to the fish (Hsieh *et al*., 2001). Studies on the effects of different coloured monofilament in undersea green lighting also found that red, black, dark green and dark blue were seen as a dark silhouette (Wardle et al., 1991).

During the current experiment only five colours of artificial lure were used. While red may have been the most effective lure for catching lythe at the time of this experiment, August-September, it may not necessarily be the most effective colour at other times of year in different environmental conditions. In order to successfully determine the best colours of artificial lures to use at different times of year, similar studies would need to be carried out on a seasonal basis. Another point to note is that these trials were only carried out on one type of lure, rubber eels. While red may have been the most effective colour for catching lythe on rubber eel lures it may not necessarily be the most effective colour when using other types of lure.

4.3 Experiment 3: Performance of artificial pheromones

4.3.1 Introduction and aims

NAFC Marine Centre were contacted by the Centre for Environment, Fisheries and Aquaculture Science (CEFAS) with a view to undertaking trials of pheromone pastes that were under development. An experiment was devised to test the null hypothesis that there is no significant difference in the number of fish (lythe, saithe and cod) caught on jigging machines fishing with or without artificial pheromones.

4.3.2 Materials and Methods

Five litres each of two different pheromone pastes were supplied by the Centre for Environment, Fisheries and Aquaculture Science (CEFAS). While the exact recipe for the production of the paste was not divulged, one paste was known to be based on a squid recipe while the other was based on a fish recipe. Each paste has an approximate shelf life of nine months.

Prior to obtaining the pheromone pastes, the consistency and texture was not known so a number of possible methods of delivery were investigated. One such delivery method considered the use of commercially available perforated containers known as swimfeeders (Figure 62). These cylindrical plastic containers could be attached to swivels positioned between hooks in the main line of the terminal gear.

As well as attaching swimfeeders to jig fishing gear, they were also trialled in a controlled aquarium environment. One such swimfeeder was filled with fish pheromone paste and placed in front of a Maxi-jet water pump outlet in a 7ft (213cm) x 2ft (61cm) x 1.5ft (46cm) saltwater aquarium containing a number of wrasse (Figure 63). This allowed the pheromone plume to be dispersed throughout the tank.

Another possible delivery method investigated was that of injecting the paste into the cavity found in rubber eel lures between the rubber tubing and the hook. This would allow for slow release of the pheromone from the lure into the water column. The final method to be investigated was the option of simply dipping the lures into the pheromone paste allowing an even and equal distribution of paste on each lure.

Figure 62 Perforated swimfeeders trialled for potential use as a method of delivery of pheromone pastes.

Figure 63 Saltwater aquarium used in swimfeeder trial

4.3.2.1 Gear set-up during pheromone experiment

Three Oilwind fully automatic jigging machines were each equipped with 300m of 400lb Dynema main line, a 10 fathom 300lb monofilament shock leader, and a nylon ring of 40mm inside diameter attached to the end of the leader. Lure rigs, constructed with six equally spaced rubber eel tube lures of one of the specified colours, were attached to the nylon ring. Lures on each machine were numbered 1-6 and coloured orange, pale blue, fluorescent yellow, white, fluorescent red, and black from top to bottom respectively. A 7lb lead sinker was attached to the end of each lure rig.

Lure rigs were constructed from Marlin 250lb (113.1kg / 1.60mm) clear main line with size 3/0 (127lb) black brass barrel swivels attached to the main line using the scaffold knot (Figure 5d, page 18). Swivels were attached at intervals of 0.5 fathoms on either side of each lure. This allowed for the removal of any twists in the line caused by hooked fish. Lures were constructed from Mustad rubber eel hooks size 10/0, coloured PVC or silicone tubing with 6mm inside and 8mm outside diameter, and size 1/0 (175lb) nickel crane swivels. Lures were then attached to loops made in the main line using the dropper loop knot (Figure 5e, page 18) at approximately 1 fathom (1.83 metres) intervals.

Jigging machine motor functions were set at factory settings (Table 1) while operating functions were calibrated to the settings shown in Table 2.

4.3.2.2 Experimental protocol

Three different treatments were applied on a rotational basis (Table 16). For each rotation, treatment one (no pheromone) was always undertaken first in order to avoid traces of the pheromones in the water column affecting the 'no pheromone' treatment. The order in which treatments 2 (fish pheromone) and 3 (squid pheromone) were fished was alternated to reduce the likelihood of traces of one pheromone consistently affecting the results when the other was applied.

Table 16 Rotation pattern during the pheromone experiments.

	Rotation 1	Rotation 2
Treatment 1	**No pheromone**	**No pheromone**
Treatment 2	**Fish pheromone**	**Squid pheromone**
Treatment 3	**Squid pheromone**	**Fish pheromone**

The pheromone paste was applied to each of the lures by dipping the lure into the paste, ensuring an even and equal coverage of the entire lure. One dip into the paste provided enough pheromone coverage on each lure to last for 30 minutes. In the event of a fish being caught the lure was examined and, if necessary, the lure was re-coated in the pheromone paste.

Nine sets of identical lure rigs were constructed, three sets for each treatment. Each rotation began at a designated fishing ground where the vessel was allowed to drift for a relevant period of time. The length of the drift depended on the ground being fished and the speed of drift over the ground. When the first drift (treatment 1) was completed, the vessel was manoeuvred back to the starting point, the lure rigs were removed from the machines, treatment 2 lure rigs were attached, and fishing began again and continued for the same period of time as treatment 1 (Figure 9). When the second drift was completed the same procedure was carried out for treatment 3. Following the completion of the third drift the vessel was moved to a new area of ground and the same procedure was carried out following the arrangement in rotation 2 with the only difference being that treatment 3 was deployed before treatment 2.

4.3.2.3 Data analysis

The F_{max} test was used to test the homogeneity of variance in the total numbers of fish caught between the three treatments and the number of fish of each species (lythe, saithe, cod and ling) caught between the three treatments. The non-parametric Friedman test was used to determine whether there were significant differences in the total numbers of fish caught between each of the treatments. A 2-way ANOVA without replication was used to investigate whether there were significant differences in the number of lythe caught between the three treatments. The Friedman test was used to determine whether there were significant differences in the number of saithe, cod and ling caught between each of the pheromone treatments. Finally, lure preferences were investigated for lythe, saithe, cod and ling using the 2-way ANOVA without replication.

4.3.3 Results

4.3.3.1 Pheromone delivery mechanisms

Following the arrival of the pheromone pastes each method of delivery was trialled. The three methods, swimfeeders, injecting lures with paste and coating lures in paste, were each evaluated, after which the most practical and effective method of delivery was employed for the fishing trials.

Swimfeeders were considered ineffective due to the thick consistency of the pastes. During trials, swimfeeders were attached to fishing gear for up to 8 hours fishing per day with little, if any, of the paste being released from the perforations in the container.

In the controlled aquarium experiment observations of fish behaviour showed that fish gathered around the swimfeeder when it was initially immersed in the tank. General fish behaviour was noted to be relaxed and inquisitive and after a short period of time fish dispersed throughout the tank. The swimfeeder was positioned in the tank for seven days after which the contents were examined and it was evident that all of the paste appeared to be intact inside the feeder with no evidence of dispersal through the perforations.

The second method investigated, injection of pheromone paste into the cavity in rubber eel lures, was found to be time consuming and ineffective. As with the swimfeeders little of the paste appeared to disperse from within the lures during trials. This, along with the impracticality of filling individual lures using a syringe on a constantly moving fishing vessel, rendered this method unfeasible.

The most operable and appropriate delivery method was found to be that of dipping the lures into the pheromone paste. Using this method a consistent and equal coating of pheromone of approximately 2mm on each lure was achieved. It appeared that the pheromone could then slowly disperse into the water column with lures normally needing to be recoated after 30 minutes fishing time or following the capture of a fish. As a result this method was selected for use during fishing trials. One of the problems encountered when using the paste was a result of its greasy consistency. Lures, fishing line and protective gloves eventually became coated in the greasy substance making the line very difficult to work with as it tended to slip though the fingers. This posed a safety risk and on many occasions line slipping almost caused hooks to become embedded in the operator’s hands. The problem was partially eradicated by periodically washing the gloves in a bucket of soapy water.

4.3.3.2 Fishing trials

A total of 16.25 hours were spent fishing during October 2006 and March 2007. Trials were also scheduled for February 2007 although a 4 week period of bad weather resulted in the vessel being unable to go to sea.

During the trials 14 rotations were carried out in a number of locations at the northern end of Shetland (Figure 64). Rotations lasted anywhere between 30 minutes - giving 10 minutes for each treatment (no paste, squid paste, fish paste), and 120 minutes, which gave with 40 minutes for each treatment (Figure 65). The length of each rotation depended on a number of variables such as the speed of the drift of the vessel due to tide or wind and the size of the grounds being fished.

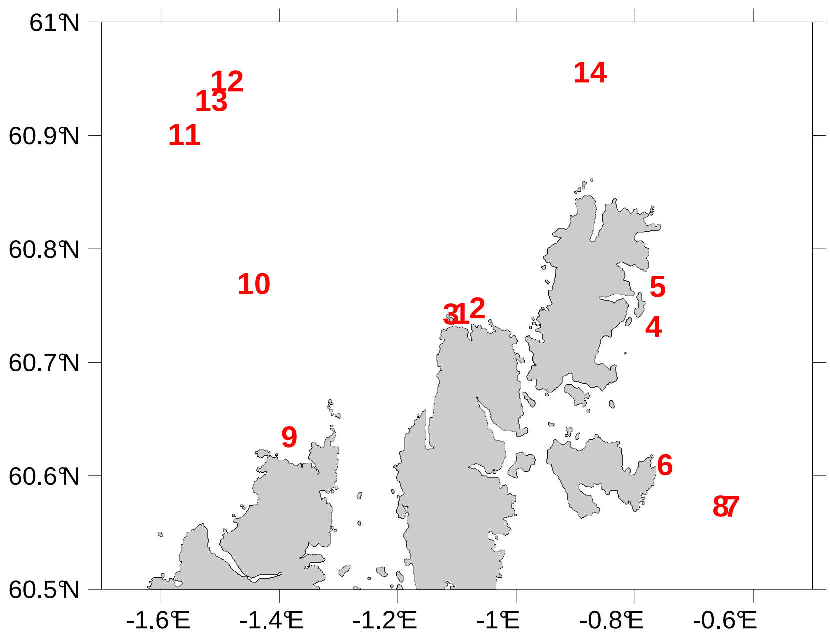


Figure 64 Geographic location of each of the 14 rotations carried out during pheromone trials at the northern end Shetland.

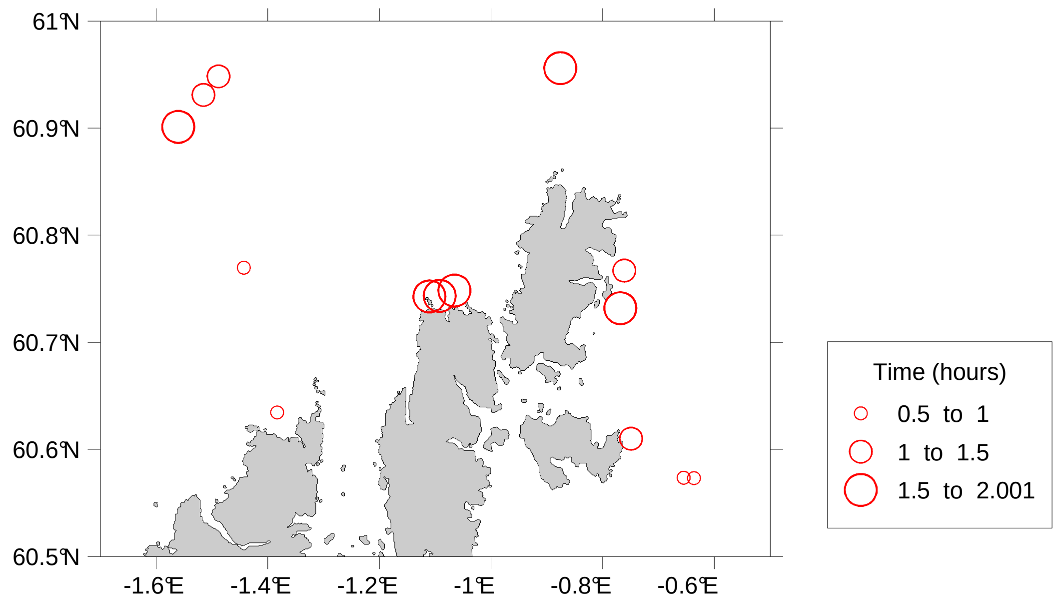


Figure 65 Duration of each of the 14 rotations carried out during pheromone trials.

4.3.3.3 Total catches

A total of 335 fish were caught during the pheromone trials. Catches varied from a total of two fish being caught during rotation nine (45 minutes), to a total of 80 fish being caught during rotation 12 (75 minutes). The highest numbers of fish were caught during rotations 1, 12 and 13 while the lowest numbers of fish were caught during rotations 9, 10 and 11 (Figure 66).

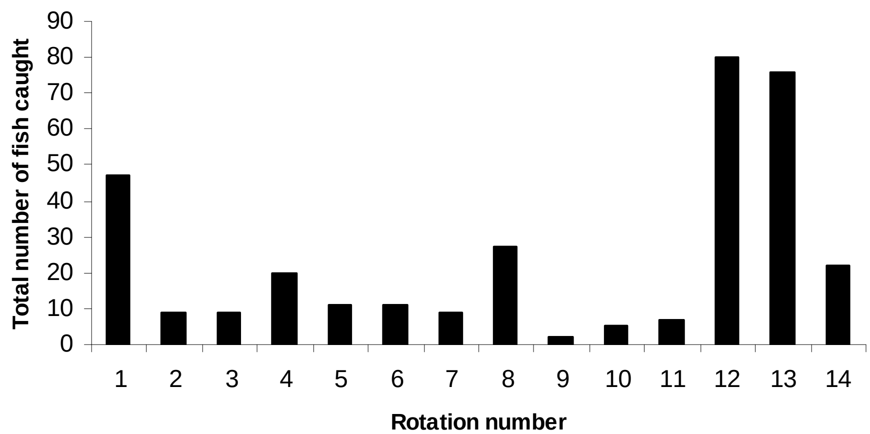


Figure 66 Total number of fish caught during each of 14 rotations completed during the pheromone trials.

Variances were not homogeneous so a non-parametric Freidman test was used to determine if there were significant differences in the numbers of fish caught between the three treatments. Results indicated that a significant difference did exist (χ^2=7.348, d.f.=2, P=0.025) between treatments. A total of 174 fish were caught by treatment 1 (no pheromone) while totals of 82 and 79 fish were caught in treatments 2 and 3 respectively (Table 17).

Table 17 Number of fish caught using three different treatments during pheromone trials.

	Number of fish				
Treatment	Lythe	Saithe	Cod	Ling	Total
1. No pheromone	62	101	6	5	174
2. Fish pheromone	29	48	2	3	82
3. Squid pheromone	27	42	4	6	79

4.3.3.4 Catches by species

A total of 4 species of fish were caught. Lythe and saithe were the most abundant; while small quantities of cod and ling were also caught. The distribution of catches for each treatment is shown in (Figure 67).

An F_{max} test indicated that variances were homogeneous in the catch data for lythe and the resulting 2-way ANOVA without replication indicated that there were significant differences between the treatments ($F_{2, 26}$ = 5.02, P = 0.014) and the rotations ($F_{13, 26}$ = 3.96, P = 0.001). Over the 14 rotations, a total of 62 lythe were caught when no pheromone was used. This was more than twice the number of lythe caught when either the fish pheromone (29 lythe) or squid pheromone (27 lythe) was used. Numbers of lythe caught in each rotation and by each treatment are shown in Figure 68.

Saithe were the most abundant species caught during the pheromone trials with the majority of individuals being caught during rotations 12 and 13 (Figure 69). An F_{max} test indicated that variances were not homogeneous and the resulting Freidman test indicated that there were no statistically significant differences in catches of saithe between the three treatments (χ^2=1.724, d.f.=2, P=0.422).

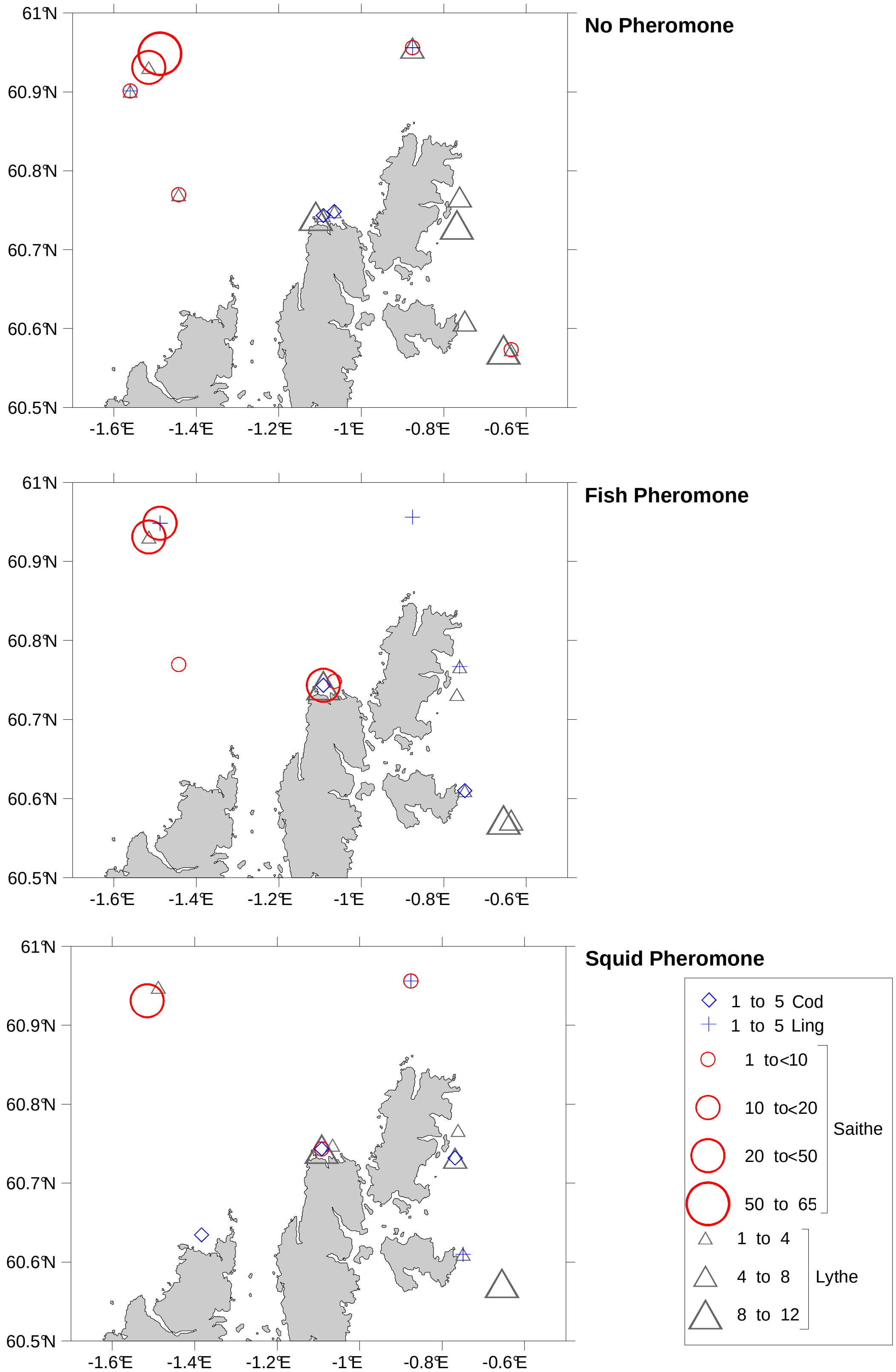


Figure 67 Breakdown of the catch (numbers of fish of each species) for each of the three treatments applied over the 14 rotations carried out during pheromone trials.

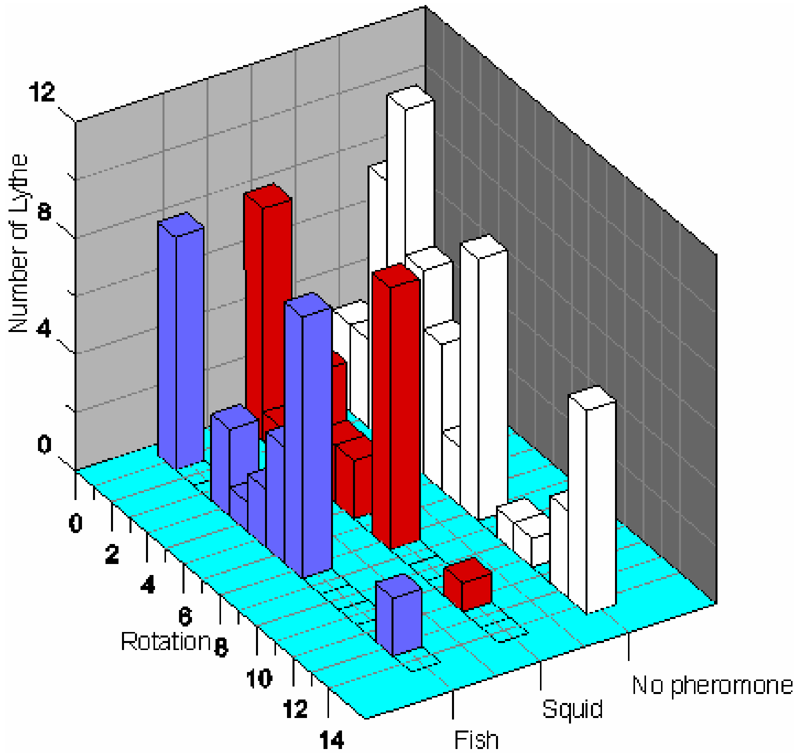


Figure 68 Total number of lythe caught by each treatment during each of the 14 rotations completed during the pheromone trials.

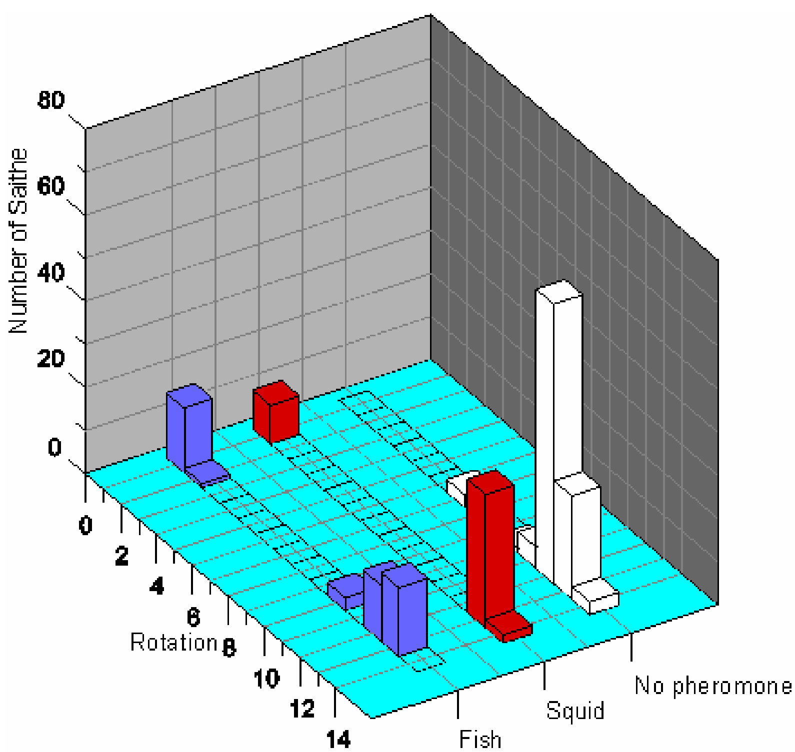


Figure 69 Total number of saithe caught using each treatment type during each of 14 rotations during the pheromone trials.

Only small numbers of cod and ling were caught during the pheromone trials. Of the 10 cod that were caught, 6 were caught with no pheromone, 2 with fish pheromone and 4 with squid pheromone (Figure 70).

Of the 14 ling that were caught, five were caught using no pheromone, three with the fish pheromone and 6 with the squid pheromone (Figure 71). The majority of ling were caught during rotation 14, on the Majestic wreck north of Muckle Flugga (Figure 67). For both cod and ling, F_{max} tests indicated that variances were not homogeneous and the resulting Friedman tests indicated that there were no statistically significant differences in catches between the three treatments (cod: χ^2=0.40, d.f.=2, *P*=0.819; and ling: χ^2=0.125, d.f.=2, *P*=0.939).

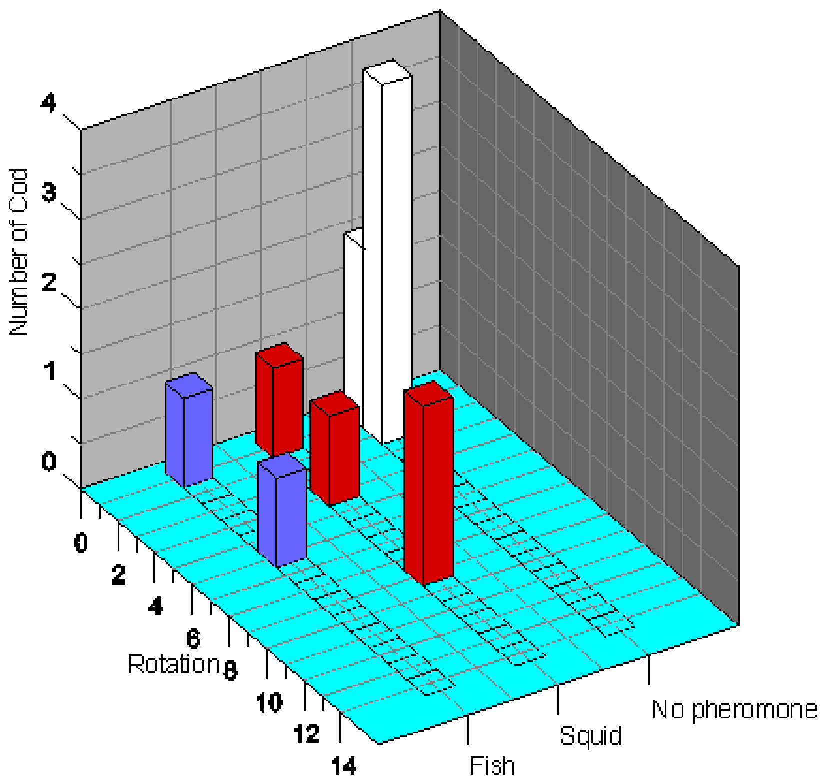


Figure 70 Total number of cod caught using each of the treatments during each of 14 rotations completed during the pheromone trials.

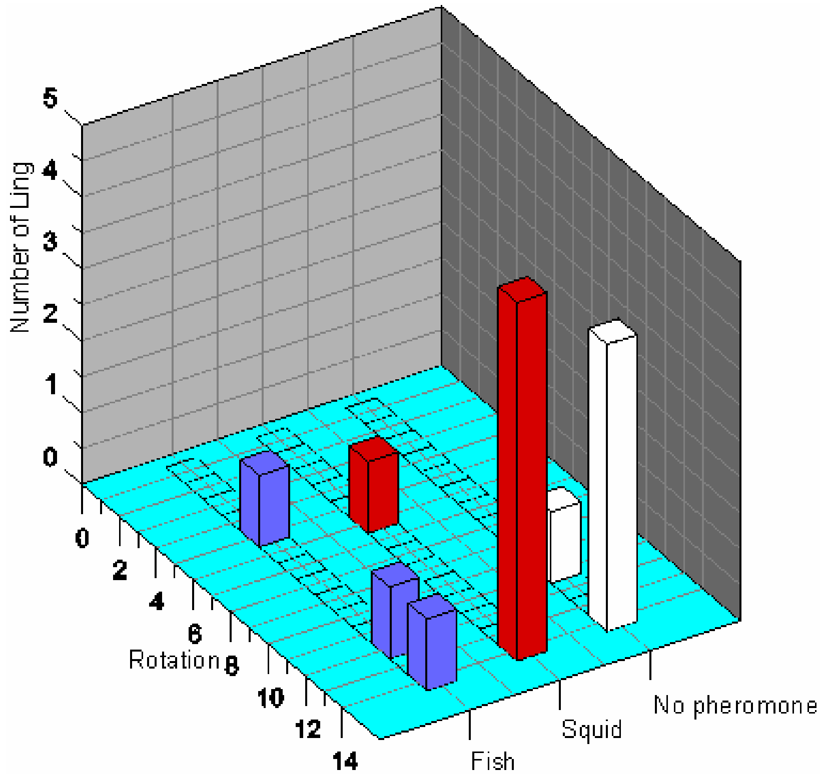


Figure 71 Total number of ling caught by each treatment during each of 14 rotations completed during the pheromone trials.

4.3.3.5 Lure preferences

The numbers of fish caught on the six lures of each rig were recorded throughout the trials and are shown in Figure 72 The relationship between lure number and the total numbers of cod caught were investigated. Results indicate that significant differences existed in the numbers of cod caught between different lures (2-way ANOVA without replication: $F_{5,17}$ = 5.302, P = 0.012). Although the numbers caught were low, the data presented in Figure 72 suggests that cod prefer the bottom lures.
A similar investigation indicated that there were no statistically significant differences in numbers of ling caught between different lure numbers (2-way ANOVA without replication: $F_{5,17}$ = 2.430, P = 0.109). It should be noted that the numbers of ling that were caught were low.
For lythe and saithe statistically significant differences in the numbers being caught on different lures were detected (2-way ANOVA without replication: $F_{5,17}$ = 3.750, P = 0.041 for lythe; $F_{5,17}$ = 8.414, P = 0.002 for saithe). The data presented in Figure 72 suggests that both species have a preference for lures that are lower down the rig, i.e. nearer the seabed

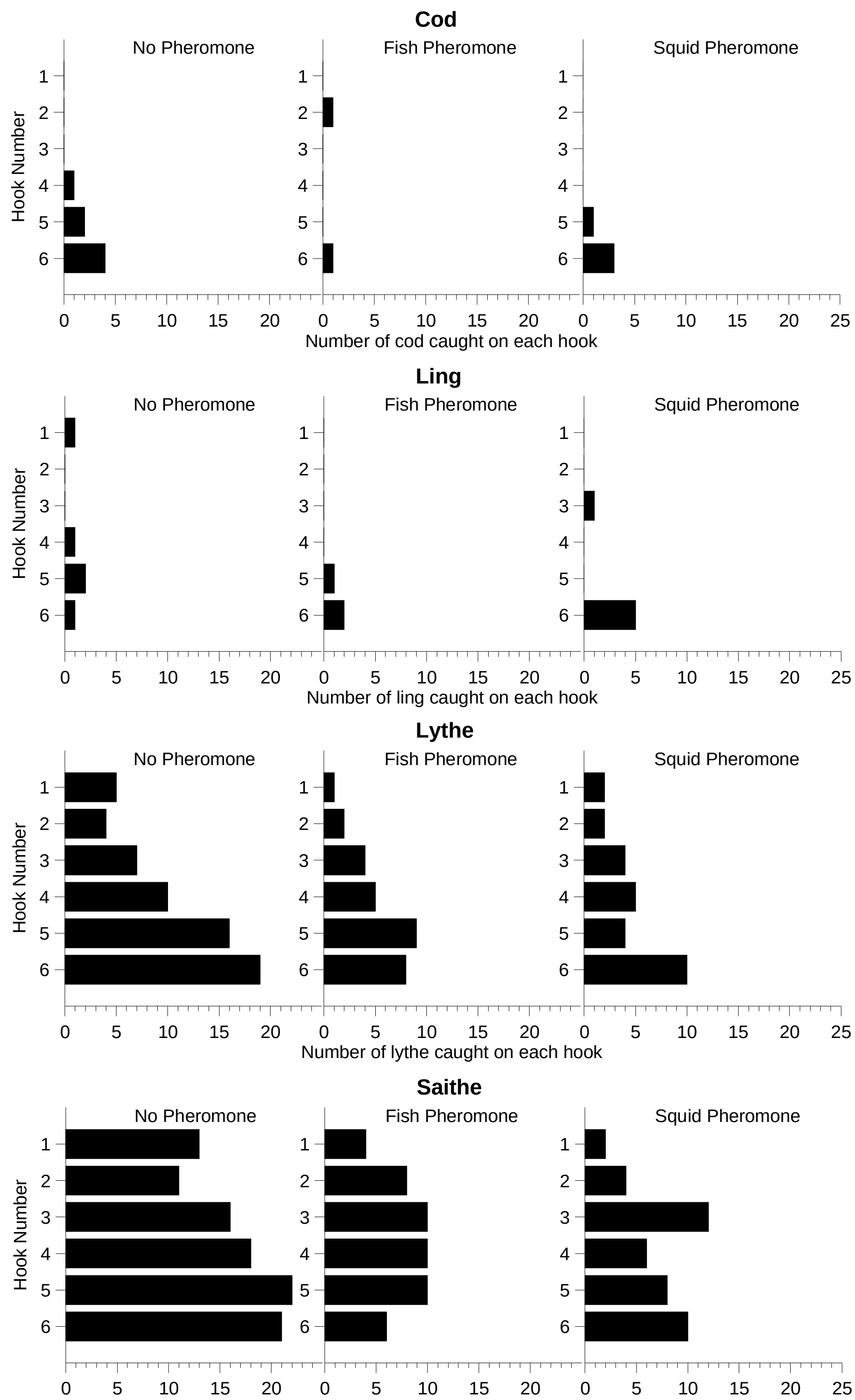


Figure 72 Numbers of cod, ling, lythe and saithe recorded on each hook number on each of the different treatments during the pheromone trials. NB Hook 6 is closest to the seabed.

4.3.4 Discussion

The investigation into the performance of artificial pheromones indicates that the use of pheromone enhanced pastes did not increase catch rates of jig fishing target species such as saithe, lythe, cod and ling around Shetland. On the contrary, total catch rates with the pheromone treatments were significantly below that of the control treatment. This may indicate that the pheromone paste is acting as a deterrent rather than an attractant.

4.3.4.1 Pheromone delivery mechanisms

Only a small number of possible delivery mechanisms were trialled during this study. Each method had advantages and disadvantages although the chosen method, dipping the lures in the paste, was certainly the most practical. The biggest problem encountered when dispensing the treatments was the time consumed equipping the lures with the pheromones. In commercial fishing operations time on the fishing grounds is often limited and as such the time available must be used efficiently. Catches using pheromone pastes, where time is consumed preparing gear for use, would need to be significantly greater than those without the paste to compensate for loss of time.

The method of dipping the lures into the paste, while being the most effective for the time available for this study, is probably not the overall most effective way of dispensing the pastes. If pastes were to be available, at the same consistency as used in these trials, it would probably be more appropriate to design a lure, based on those used by commercial fishermen, which would accommodate and disperse the paste more effectively.

It would also be worth considering altering the consistency of the paste. A diluted substance may disperse into the water column more effectively and may be more appropriate for cold water fishing grounds such as those around Shetland. Controlled experiments could evaluate how well different dilutions dispersed into the water at differing temperatures. This would provide optimum dilutions for any given sea temperature at differing times of the year. Dilutions were not attempted during this study as it was unknown whether the process of dilution would have an effect on the functionality of the pheromones.

4.3.4.2 Catch variation

The reason catches may have been lower with the pheromones may be a direct result of the order in which the treatments were applied. In order for the trial to be unbiased it was necessary for the control treatment 'no pheromone' to be deployed first during each rotation. This ensured that the control was not affected by pheromone residues in the water column. While this proved an effective way of minimising bias in the results it may have introduced other anomalies which directly affected the results. During the jig fishing pilot study it has been noted from personal observations that catches on the same ground tend to decrease with each drift over that ground. This is possibly the result of the removal of feeding fish from the grounds during each drift, leaving less fish to be caught on the next drift. Therefore, any fish caught during the first drift would not be available to the gear during the second drift and fish caught during the first and second drift would not be available during the third drift. The only way to overcome this problem would be to deploy each treatment during drift 1 on a rotational basis although, as mentioned above, this may affect the results of the study due to the possible effects of pheromone residues in the water column on the control treatment.

4.3.4.3 Target species

Catches were mainly restricted to lythe and saithe, two species which rely heavily on visual cues to detect and locate prey. Although these two species are known to rely heavily on visual cues, feeding behaviour would still be expected to intensify with the presence of the pheromones in the water. Cod and ling, few of which were caught during this trial, have been caught in low numbers during the entire jig fishing pilot study. During the overall pilot study the majority of those two species captured were caught using baits such as mackerel and whelks. It was intended to carry out further trials using the pheromones with a variety of baits to determine whether the two combined had an effect on catch rates. However, the apparent lack of bottom dwelling species such as cod and ling in the inshore waters around Shetland made such trials unfeasible. It was considered that studies using baits would have proved ineffective for saithe and lythe as these species were observed to show clear preferences for lures rather than bait.

4.3.4.4 Gear preferences

The gear chosen to undertake this trial was based on that which is available to commercial fishermen. Under normal jig fishing circumstances six lures of varying colours are placed on each rig. During this trial rubber eel lures were selected as they are readily available and have proven to be effective at catching a number of species throughout the jig fish pilot study. The six colours of rubber eel lure chosen and used were, again, those readily available for purchase by commercial fishermen.

The distribution of each species in relation to the hook number on which they were caught is a reflection, in each case, of the individual species' biology. Cod and ling are known to be benthopelagic species, often foraging on the seabed (Lokkeborg et al., 1998, Lokkeborg et al., 2000), which may be why the majority of both these species were caught on hooks nearer the bottom of the lure rigs. Lythe and saithe are both typically pelagic to benthopelagic and can be found at varying depths in the water column (Jonsson & Armannsson, 2006, Potts, 1986). Lythe are known to spend most of their time closer to the seabed (Cohen et al., 1990) while saithe often move great distances vertically in the water column (Bergstad, 1991). This behaviour may explain why lythe catches showed a significant difference between top and bottom lures while saithe catches, although significantly different between the lures, were more evenly distributed between the six lures.

The type and colours of lure used may have had an effect on the results of the study. Different coloured lures may have yielded different results while the use of other commercially available lures such as Redgill, muppet and spoon may have also produced different results. Time restrictions meant that these different combinations could not be properly assessed.

4.3.4.5 Conclusion from pheromone trials

The results of this study have highlighted a number of issues which, if addressed, could make future pheromone enhanced jig fishing trials more successful. The greatest single problem faced was that of effectively dispensing the pheromones into the water column. Trials with different consistencies of paste to determine optimal dispersion in waters around Shetland, along with purpose built lures could significantly alter the outcome of any future studies.

5 Economic Viability

5.1 Materials and Methods

Throughout the study economic data in relation to income and expenditure while jig fishing was recorded. Following each landing the total number of boxes landed, prices received for fish (£/kg) and total vessel grossing were recorded. Prices received for jig caught fish were compared with average market prices on the day of landing to determine whether jig caught fish were achieving their full market potential.

Potential profit margins were calculated by taking into account the various expenses associated with jig fishing, including fuel and fishing gear. Expenditure while jig fishing was calculated by recording fuel consumption, gear usage and other fishing expenses.

5.2 Results

5.2.1 Market prices

There were a total of 50 landings of fish valued at £29,931. Ninety three of the 121 days fishing resulted in enough fish being caught to justify a landing. Total landings varied from month to month (Table 18) with the highest landings, £5,540 for 11 days fishing, seen in May 2006. The average daily grossing was £228.

Market prices of individual species fluctuated greatly over the months (Figure 73). The most profitable species was lythe with a contribution of £20,540 towards the total grossing. Prices for lythe ranged from a low of £1.00/kg in May 2006 to a high of £2.59/kg in November 2006 with an average price of £1.72.kg. Saithe with a value of £5,876 were landed with prices ranging from £0.41/kg to £0.95/kg, the average being £0.60/kg. Cod with a value of £1,817 were sold for prices between £0.98/kg and £3.31/kg, the average price being £1.88/kg. The remainder of the catch was made up of ling with a total value of £1,607 (range: £0.29/kg to £1.68/kg; average: £1.11/kg) and tusk with a value of £95 (range: £0.28/kg to £0.77/kg; average £0.56/kg).

Prices received for jig caught fish were often similar to, or less than the average daily price on the market (Table 19). This was especially noticeable with species such as cod and ling which were landed in small quantities, often less than one box.

Table 18 Monthly jig fishing total and average catch values.

Month	Days at sea	Total Boxes	Total value	Average catch value per day	Average catch value per box
August 05	11	57.75	£3,206.00	£291.45	£55.52
September 05	7	11.25	£532.71	£76.10	£47.35
October 05	10	27.50	£2,115.78	£211.58	£76.94
November 05	8	30.25	£1,933.79	£241.72	£63.93
December 05	3	1.75	£90.54	£30.18	£51.74
April 06	6	45.00	£2,519.09	£419.85	£55.98
May 06	11	118.00	£5,540.13	£503.65	£46.95
June 06	7	62.25	£2,547.74	£363.96	£40.93
July 06	12	42.00	£1,517.90	£126.49	£36.14
August 06	8	24.50	£1,667.00	£208.38	£68.04
September 06	11	46.75	£3,335.26	£303.21	£71.34
October 06	5	31.00	£2,029.25	£405.85	£65.46
November 06	2	4.50	£472.93	£236.47	£105.10
January 07	5	0	£0.00	£0.00	£0.00
February 07	7	15	£753.78	£107.68	£50.25
March 07	5	21	£868.11	£173.62	£41.34
April 07	3	32	£801.96	£267.32	£25.06
Total	**121**	**570.50**	**£29,931.97**	**£236.12**	**£53.06**

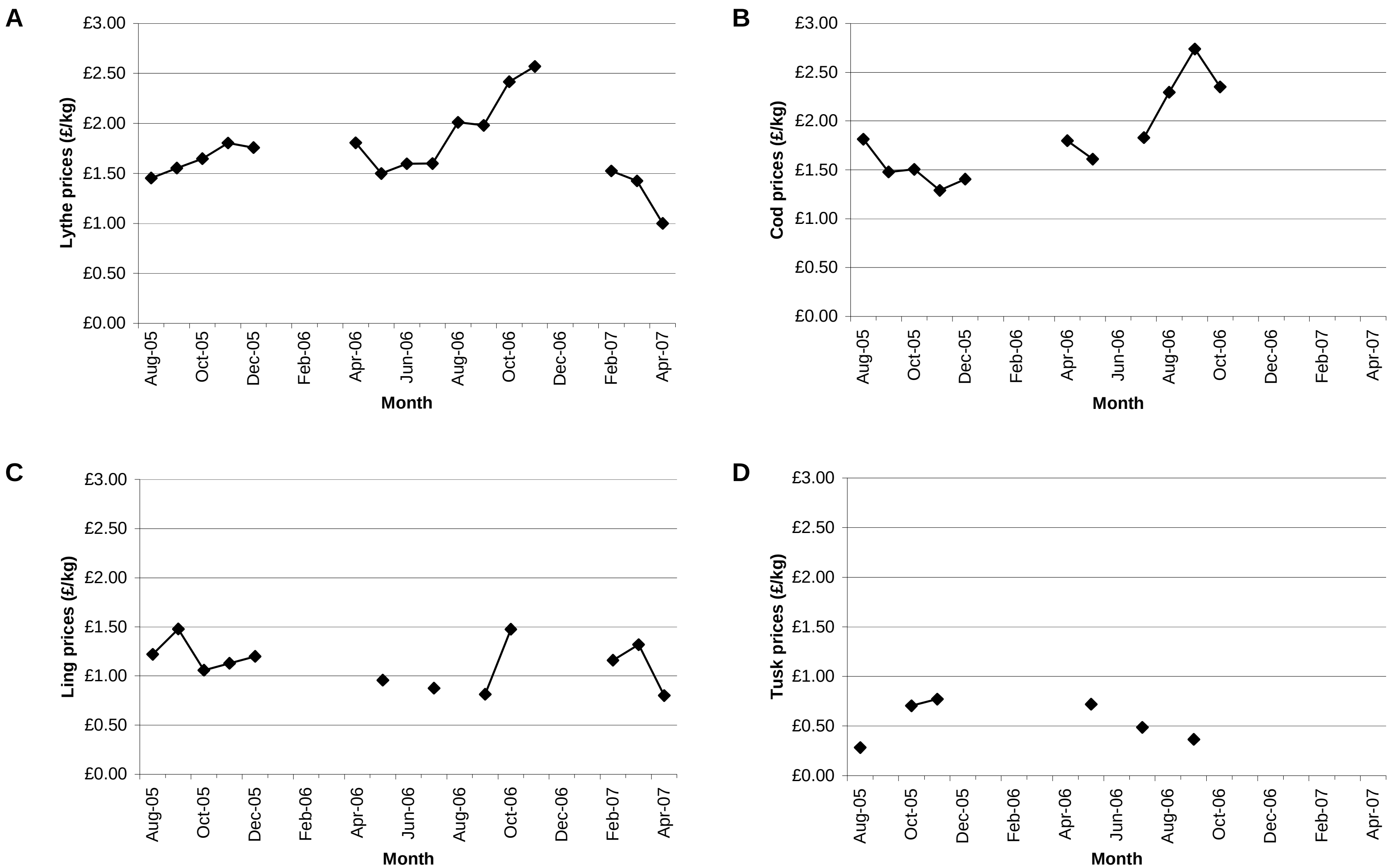


Figure 73 Average monthly prices for jig caught fish sold through Shetland Seafood Auctions (A = lythe; B = cod; C = ling; D = saithe).

Table 19 Comparison of prices of jig caught fish with average daily prices at Scalloway and Lerwick fish markets.

	Cod		**Ling**		**Lythe**		**Saithe**	
Date	Average price	Jig price	Average price	Jig price	Average price	Jig price	Average price	Jig price
05/08/2005	£1.97	£1.76	£1.48	£1.22	£1.55	£1.50	£0.43	£0.42
06/09/2005	-	-	£1.69	£1.68	£1.49	£1.51	£0.58	£0.57
12/10/2005	£1.81	£1.70	£1.66	£1.29	£1.56	£1.63	£0.47	£0.43
19/11/2005	-	-	£1.82	£0.60	£1.96	£2.05	£0.53	£0.49
09/12/2005	£1.41	£1.41	£1.17	£1.20	£1.74	£1.76	-	-
21/03/2006	-	-	-	-	£1.84	£1.84	£0.93	£0.88
11/05/2006	£1.74	£1.61	£1.07	£1.02	£1.15	£1.09	£0.71	£0.66
09/06/2006	-	-	-	-	£1.63	£1.60	£0.55	£0.61
12/07/2006	-	-	£1.16	£0.59	£1.74	£1.74	£0.52	£0.57
24/08/2006	£2.14	£2.08	-	-	£1.88	£1.88	-	-

NB All prices are £/kg. Comparisons are based on the same grade of each species of fish.

5.2.2 Potential profit margins

The main running costs incurred when jig fishing are fuel and gear. During this study fuel consumption varied on a day to day basis depending on the amount of time spent steaming to different fishing grounds. On average, the fuel consumption on the *Atlantia* was 100 litres per day during jigging operations while fuel consumption when trawling was 150 litres per day. On the *Atlantia II* fuel consumption was estimated to be 140 litres per day when jigging and 200 litres a day while trawling.

Due to the nature of the jigging project, a significant proportion of the available time was spent steaming and searching for potential fishing grounds all around Shetland. This reduced the amount of time that was available for fishing and subsequently reduced the potential income from catches while the expenditure (fuel consumption) was increased. In a commercial situation, the proportions of time divided between steaming to and from grounds, searching for grounds and fishing would be different. Once a vessel had identified a number of regular grounds the amount of time spent searching would reduce, as long as the grounds stayed viable, and by travelling directly to fishing grounds the amounts of fishing time would be longer.

Prices for marine diesel fluctuate on a daily basis and prices during the course of the project have ranged from 24.4p to 33.5p per litre. On the NAFC Marine Centre's current vessel *Atlantia II*, daily fuel costs while jigging are in the region of £34-£47 while fuel costs during trawling are between £49 and £67. These figures will vary between different vessels depending on engine size etc. The cost of replacing lost or damaged gear averaged at £15 per day during the study. On many days no gear was lost while on others gear losses could be as high as £60 with the rate of gear loss being highly dependant on the ground being fished, the strength of the tide and the speed of the vessel drifting over the ground. Table 20 highlights some of the other running costs involved including ice, food, landing dues, agent's commission and Association commission.

Although actual profit margins will vary from vessel to vessel, depending on associated expenses, the following example gives an indication of potential profits levels. During May 2006, when catches were at their best, average daily grossing on the *Atlantia II* was £503 (Table 18). At that time fuel prices were relatively high at 32.9p per litre and average daily fuel costs would have been in the region of £46. The total expenses incurred on a daily basis, taking into account each of the items in Table 20, would have amounted to approximately £124. After expenses, an average daily profit of £379 was achieved during May.

Table 20 Average daily expenses incurred by the *Atlantia II* during the jig fishing pilot study.

Expense	**Amount (Total value in £ or % of total catch value)**
Fuel	£34-£47
Gear	£15
Ice	£15
Food	£10
Landing dues	2.50%
LHD limited (agent)	3%
Fishermen's Association (including hire of quota)	2%

5.3 Discussion

5.3.1 Market Prices

Price fluctuations at different times during the study had a marked effect on the vessel's earning ability. The changes in prices of lythe from £1.00 to £2.59 per kg meant that the price for a box of lythe fluctuated between £41 and £106. An average price of £1.72 per kg equates to over £70 per box and a small inshore vessel would only need a relatively low number of boxes to cover costs and start making a profit. On the other hand, saithe would need to be caught in large quantities due to their relatively low price. During the summer months significant catches of saithe would be achievable as the weather would be more favourable for vessels, enabling fishing to take place at wrecks where large quantities of saithe are present. However, availability of storage space on smaller vessels may be an issue.

One of the problems identified in relation to the market potential of jig caught fish was the poor prices received for part boxes. During jig fishing operations, and especially during this study, species such as cod, ling and tusk were caught in quantities less than the standard 41kg box. On almost every occasion that these part boxes were landed, the prices received were significantly less than the market average for that day. One example of such a difference occurred on the 18th September 2006 when a half box of ling achieved a price of £0.29 per kg while the average market price for ling did not go below £1.00 per kg throughout September 2006. In many instances inshore vessels engaged in the fishery catch small amounts, often less than a box, of a number of different species and, in order to maximise profits, prices need to be consistent regardless of the amount landed.

5.3.2 Potential profit margins

Profit margins are dependant on a number of factors and would fluctuate between vessels. Fuel costs while jigging are lower than when trawling and the daily savings made in fuel costs are significant. Lower fuel costs are always highlighted as one of the major benefits of jig fishing over trawling and the results of this study certainly support this argument.

Costs incurred from Association membership will be dependant on factors such as the need to lease quota. During this study the only quota species that was leased for the *Atlantia II* was saithe as lythe are a non-quota species and others such as cod, ling and tusk were caught in low numbers. Vessels under 10 metres will not have this expense as this sector does not have saithe quota limits imposed.

The potential for significant catches, low expenses and reasonable market prices all point to the possibility of considerable profit margins for inshore vessels engaged in jig fishing.

5.3.3 Commercial viability of jig fishing

The results of this study indicate that the potential is there for a jig fishery to be established, albeit most likely on a seasonal basis. However, to determine the commercial viability of jig fishing for whitefish in the waters around Shetland a number of factors need to be taken into consideration.

5.3.3.1 Initial set up costs

For a currently operating vessel, the set up costs involved in preparing a vessel to participate in a jig fishery are substantial. The main costs incurred would include the purchase of jigging machines, which currently retail at between £1,500 and £2,000 each depending on the make and model selected. In order to ensure reasonable returns a vessel would need a minimum of 2 or 3 machines although many smaller vessels often work up to 6 machines at any one time. There are also significant costs associated with preparing a fishing vessel for using jigging machines. These costs include providing an adequate power supply to the machines as well as fitting the machines to the vessel. Other costs include the purchase of a sufficient supply of terminal gear (filament, hooks and lures, sinkers etc).

In order for vessels to participate in a jig fishery they would also need an appropriate license. A Category A license is required for vessels wishing to fish for quota species such as cod and saithe. At the present time Category A licences are available on the market for approximately £200 per vessel capacity unit (L. Tait, pers. comm.). The number of VCUs required by any vessel is calculated by the formula (Length overall (m) X Breadth (m)) + (Engine Power (kw) X 0.45) and therefore will differ between vessels. Typically, vessels between 8 and 10 metres in length would need anywhere between 50 and 100 VCUs depending on the outcome of the above calculation. At current prices a license for a vessel under 10 metres could cost anywhere between £10,000 and £20,000. Vessels greater than 10 metres in length may expect to pay in excess of £20,000 for a Category A license.

The total costs involved in preparing a vessel to enter the fishery, including jigging machines, preparation of the vessel, gear and an appropriate license has the potential to run into the tens of thousands of pounds. As a result a financial assistance scheme is likely to be required to help offset initial costs.

5.3.3.2 Weather restrictions

While catches of saithe and lythe have often been high on wrecks and peaks at the northern end of Shetland, weather conditions have often made these grounds inaccessible. This, coupled with the apparent lack of fish on more sheltered inshore grounds, suggests that with the current availability of fish, jig fishing will only be viable on a seasonal basis.

Long periods of windy weather at different times during the pilot study meant that the vessel was tied up, often for weeks at a time. Summer months provided the best weather to allow vessels to venture further offshore, while during the winter, breaks in the weather were less frequent. Even when breaks in the weather did emerge, sea conditions were usually too poor to consider travelling to offshore areas. As the inshore fleet relies on a steady source of income it may be recommended to undertake jig fishing along with other fishing methods such as creel fishing or gill netting. The combination of two or more fishing methods would maximise returns by allowing vessels to have a source of income while the more lucrative jig fishing grounds are inaccessible. However, it should also be remembered that there has been a significant lack of inshore fish during the course of this study. In future years, increases in inshore fish abundances may provide more opportunities for vessels engaged in jig fishing, especially during periods of windy weather.

5.3.3.3 Resistance of grounds to fishing effort

Little is known about the resistance of localised fishing grounds such as wrecks and peaks to substantial fishing effort. The results of this study indicate that some areas such as the peaks 15 miles NNW of the Ramna Stacks had a steady decrease in catches over time. This suggests that there may be limited movement of fish onto the peaks over the time period studied.

If this is the case then such areas may not be able to withstand sustained fishing activity in the long term. However, changes in catch composition, such as those seen on a number of wrecks during this study indicate that fish do move to and from individual wrecks over time.

In order to better understand the effects of fishing activity on wrecks and peaks more studies would need to be carried out on fish movements in relation to these structures. One study has shown that species such as saithe can migrate over long distances, often crossing national boundaries (Jakobsen & Olsen, 1987). As a result, the potential is there for migrating fish to inhabit wrecks which have been subject to intense fishing activity. The life history patterns of both saithe and lythe, the two species which have been predominantly caught on wrecks and peaks, indicate that there is potential for localised fishing grounds to recover following intense fishing activity.

One further method of reducing effort on known wrecks and peaks could be through the production and use of further artificial reefs as fish aggregating devices (FADs). While these structures may provide a greater number of localised fishing grounds for jig fishermen, the production and placement of such devices does not guarantee that fish will be attracted to them. Studies have shown that only 50% of artificial reefs deployed meet their objectives (Baine, 2001). The present study has also shown that many of the wrecks located at the northern end of Shetland yielded either low or no catches, and so presumably did not have significant quantities of fish present on them. Therefore, in order to maximise the potential benefits of artificial reefs, more would need to be known concerning the optimum design and placement of such structures in order to attract target species.

5.3.3.4 Fish quota

Availability of quota to vessels wishing to engage in jig fishing plays a significant role in determining the commercial viability of this metier. The predominant species in the catch throughout the jig fishing pilot study was lythe. At the present time lythe do not come under quota limits in the North Sea although there are limits imposed in the west of Scotland. Ling are also free from quota restrictions and as a result any vessels fishing for either of these species are not restricted to the amount they can catch. Although these two species non-quota it should be borne in mind that they have minimum landing sizes of 30cm and 63cm respectively (Council Regulation 850/98 Annex XII).

Two of the other species commonly caught on jigging machines, cod and saithe, come under quota restrictions in both North Sea and west of Scotland waters. At the present time the Shetland Fish Producers Organisation quota limits for cod and saithe for the two month period April to May 2007 are set at 80 and 400 boxes respectively. Based on the catches recorded in this study an over-10m jig fishing vessel would not be likely to exceed the cod quota over the two month period; however a saithe quota of 400 boxes could easily be used up before the end of the two months. Catches of saithe during the project have been as high as 11 boxes per hour suggesting that 400 boxes could be caught in a relatively short time if conditions were favourable. This would leave vessels with the option of renting further quota and thus reducing profit margins, or stopping fishing.

Licenses available for vessels under 10 metres are all Category A. As such these vessels are able to fish for those stocks which are considered to be at greatest risk and are subject to quota. Quota limits for vessels under 10 metres which are not members of a producers organisation vary, often significantly, from those available to the over 10 metre fleet. At the present time the under 10 metre quota allocation for cod in the North Sea is 4 tonnes, from 1st January to 30th April 2007. This is significantly lower than that which is available to over 10 metre vessels in the producer's organisation and, if a vessel was to experience an upturn in catches of cod, the quota would soon be used up. As with the over 10 metre fleet, there are no restrictions on catches of ling, tusk and lythe. In contrast to the saithe quotas placed on over 10 metre vessels, there are no such restrictions on landings of saithe by vessels less than 10 metres in length.

At the present time quota limits are considered to be more in favour of jigging vessels within the under 10 metre fleet. The potential for large catches of saithe and lythe and the lack of quota restrictions allows smaller vessels to fish freely for these species. However, if catches of cod were to increase then vessels over 10 metres within the producer's organisation, would benefit as they would have more quota available to target this species than vessels under 10 metres.

5.3.3.5 Market potential

A number of issues arising during the study period have led to suggestions that jig caught fish are not achieving their full market potential in Shetland. The main problem identified is a lack of recognition of jig caught fish on the market. In order to combat this, a number of inshore fisheries in other locations have established fishermen's associations aimed at attaining the full market potential of line caught fish. Two such examples are the South West Handline Fishermen's Association whose members target bass, pollack (lythe) and mackerel, and the Cape Cod Commercial Hook Fishermen's Association, based on the east coast of the United States of America. Both associations have been established in order to increase market prices by raising public awareness of the sustainable methods used to catch fish, the quality of the fish and the ability of consumers to trace fish back to the vessels that caught them.

The South West Handline Fishermen's Association have established a website as a marketing tool to raise public awareness of their products. Fish such as lythe and bass are individually tagged, identifying the vessel on which they were caught. The association has also received Marine Stewardship Council (MSC) accreditation for its sustainable mackerel fishery.

A similar association, with members consisting of inshore vessels targeting whitefish, squid and mackerel on handlines or automated jigging machines, could potentially be established in Shetland. The formation of such an organisation would provide opportunities for increased awareness of line caught fish as well as providing a structure for producing and implementing marketing strategies designed at maximising returns for vessels involved in the fishery. At the present time there are a number of inshore vessels engaged in jig fishing with some fishermen indicating an interest in the creation of such an association or co-operative. Further enquiries are required to ascertain the level of interest in handline fisheries in Shetland and also to establish whether such vessels would be interested in adopting a group approach to marketing their catch. Until the issue of effective marketing is resolved, jig fishing in Shetland waters will not achieve its full potential.

6 Conclusions

The results of this pilot study indicate that jig fishing could be commercially viable, at least on a seasonal basis. However, accessibility to the most successful fishing grounds, found mainly to the north of Shetland, is highly weather dependant and therefore smaller inshore vessels may be restricted in their ability to frequent those grounds.

The range of gear successfully trialled here demonstrates that fishermen can confidently utilize the materials and methods described in this study. The majority of fishing gear deployed during the study was successful at capturing the main jig fishing target species.

The results of the study also suggest that the successful implementation of a jig fishery around Shetland would be highly dependant on a small number of localised fishing grounds. Although significant quantities of fish have been caught in a number of locations, more research is needed to determine how resistant those fishing grounds are to substantial fishing effort.

Over the course of the study, patterns relating to the effects of environmental variables such as tide on catch rates became evident and this information was used to maximise catches where possible. As with any other fishery, knowledge of the numerous factors that affect the fishery will increase over time and, as the user becomes more experienced, this information can be utilized to maximise returns.

Finally, the results of this study highlight the need to market and promote jig caught fish. In order to reach its full potential a co-operative approach may need to be considered so that issues such as constancy of supply, volume and niche marketing could be addressed in order to achieve the higher prices often seen in other line caught fisheries.

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8 Appendices

Appendix Ia Jig fishing gear suppliers contact details.

Name	Address	Telephone	Fax	Email
Oilwind	Box 9 FR-370 Miovagur Faeroe Islands	+298332422	+298333222	Oilwind@oilwind.fo
UK Hooks Ltd	22 Grange Road Shanklin, Isle of Wight PO37 7EJ	01983868687	01983863329	mike@uk-hooks.com
RedGill Ltd	40 Kiln Close Mevagissey Cornwall PL26 6TP	01726843214	01726843214	rgflures@aol.com
Teymavirikid Ltd	Heidavegur (9-11) PO Box 210 FO-620 Runavik Faeroe Islands	+298473000	+298473001	teymavirkid@teymavirkid.fo
Sonarlure	Web address: www.sonarlure.com (USA)	+5614871085		info@SonarLure.com

Appendix Ib Fishing gear supplied by Teymavirkid Pf.

Item	Size	Quantity
Sinkers		
Sinker with steel bow	6 lbs	12
Sinker	7 lbs	42
Fishing line		
Nylon fishing line	1.1mm	200m
Nylon fishing line	1.5mm	200m
Nylon fishing line	1.8mm	300m
Hooks		
Spoon	no. 6	50
Spoon	no. 7	50
Spoon	no. 8	50
Rubber eel hook, 5 pieces	no. 8	6
Rubber eel hook, 5 pieces	no. 9	16
Rubber eel hook, 5 pieces	no. 10	16
Rubber eel hook, 5 pieces	no. 12	16
Other		
Plastic ring	n/a	16
Brass clip	n/a	16

Appendix Ic Fishing gear supplied by UK Hooks Ltd.

Item	Size	Quantity
Hooks		
Mustad O'Shaughnessy	8/0	400
Mustad O'Shaughnessy	10/0	25
Mustad O'Shaughnessy	12/0	25
Mustad Rubber Eel	10/0	600
Mustad Rubber Eel	12/0	100
Mustad E Z Baiter	13/0	25
Fishing Line		
Marlin 1kg spool	250lb	6
Swivels		
Three way barrel swivel	2/0	400
Black brass barrel swivel	3/0	500
Nickel crane swivel	1/0	700
Tubing		
PVC tubing	6x8mm	110m
Silicone tubing	6x8mm	80m
Other		
Oval crimps	1.7mm	600
Plastic squid	5 ins.	40

Appendix Id Fishing gear supplied by Red Gill Fishing Lures Ltd.

Item	Size	Quantity
Red Gill lure with hook	178mm	100
Red Gill lure without hook	178mm	60
Red gill lure without hook	210mm	60

Appendix Ie Fishing gear supplied by Sonarlure.

Item	Size	Quantity
Sonarlure 100s- green	2 ins.	
Sonarlure 100s- red	2 ins.	
Sonarlure 100s- silver	2 ins.	

Appendix If Fishing gear supplied by Oilwind.

Item	Size	Quantity
Dynema mainline	1.1mm	1800m
Shock absorbers	n/a	12
Swivels	3/0	60
Rubber eel lures	no. 9	72
Sinker	7 lbs	12

Appendix II Example of data sheet used during jig fishing pilot study.

Environmental conditions

C = Cod; L = Lythe; Li = Ling; S = Saithe; T = Tusk

Date	Weather	Wind	Sea temp	HW LK	Sea state	General Area	Fishing location	Latitude N	Longitude W	Sea depth	Bottom type	Drift	Time Began	Time spent on mark	Catch

Appendix III Chart positions (WGS84 Datum) of wrecks fished during jig fishing pilot study.

Wreck	Latitude		Longitude	
Argonaut	60.23.26	N	01.35.89	W
Barge wreck	59.57.01	N	00.53.87	W
Blue Painter wreck	59.41.43	N	01.18.59	W
Braer wreck	59.54.00	N	01.21.40	W
Buschini wreck	60.04.94	N	00.46.47	W
Coal Boat wreck	60.34.20	N	02.01.98	W
Coastal Empress wreck	61:04:45	N	00.50.65	W
Day Dawn	60.03.14	N	01.09.75	W
Dunieden wreck	60.34.41	N	00.39.31	W
Glenugie wreck	61.07.50	N	00.05.45	E
Majestic wreck	60.57.36	N	00.52.53	W
Morning Star wreck	60.36.21	N	01.17.26	W
Muckle Wreck	60.34.35	N	00.39.96	W
North of Foula wreck	60.21.54	N	02.16.73	W
North Wreck	60.34.30	N	00.30.79	W
Northern Venture wreck	60.41.12	N	00.43.86	W
Papa Stour wreck	60.19.05	N	01.48.78	W
Pipeline	60.36.71	N	02.27.45	W
Quo Vadis wreck	59.48.92	N	01.08.38	W
River Ayre wreck	60.00.13	N	00.48.43	W
South Wreck	60.32.56	N	00.39.96	W
Submarine wreck	60.54.37	N	01.06.87	W
Telstar wreck	61.00.40	N	00.08.80	W
Unity wreck	60.46.19	N	01.26.56	W
Victory Wreck	60.11.20	N	01.41.50	W
Voracious wreck	61.00.18	N	00.48.44	W
Wreck 11 mile ENE	60.54.32	N	00.24.15	W
Wreck 13 mile E Lerwick	60.12.24	N	00.31.81	W
Wreck 15 mile N Ramna Stacks	60.56.88	N	01.29.30	W
Wreck 15 mile NNW Flugga	61.07.45	N	00.59.71	W
Wreck 16 mile E Lerwick	60.13.85	N	00.21.57	W
Wreck 21 mile NE Unst	61.00.40	N	00.08.80	W
Wreck 25 mile NE Unst	61.05.20	N	00.05.70	E
Wreck 26 mile NW Ramna Stacks	60.44.50	N	02.10.10	W
Wreck 27 mile NNW Ramna Stacks	61.04.47	N	01.44.18	W
Wreck 6 mile ENE Unst	60.53.79	N	00.37.08	W
Wreck 7 mile E Mousa	59.58.16	N	00.58.67	W
Wreck 8 mile E Lerwick	60.07.52	N	00.44.18	W
Wreck Out Skerries	60.18.76	N	00.43.42	W

Appendix IV Chart positions (WGS84 Datum) of peaks fished during jig fishing pilot study.

Peak	**Latitude**		**Longitude**	
Bagi Stack	60.43.21	N	01.08.20	W
Balta Isle	60.45.70	N	00.45.89	W
Bard Head	60.05.50	N	01.04.50	W
Breken	60.47.52	N	01.02.39	W
East of Skaw	60.48.94	N	00.40.71	W
Eigg Stack	60.38.62	N	01.12.30	W
Eshaness	60.31.00	N	02.10.81	W
Eshaness Light	60.29.50	N	01.38.00	W
Flubersgerdie	60.47.33	N	00.57.70	W
Funzie Ness	60.34.81	N	00.46.36	W
Gloup Holm	60.44.00	N	01.07.50	W
Gruney	60.39.00	N	01.20.00	W
Muckle Flugga	60.49.94	N	00.54.63	W
Muckle Flugga	60.56.98	N	00.52.50	W
Orknagable	60.48.04	N	00.57.14	W
Out Skerries	60.19.53	N	00.41.57	W
Peaks 12 mile NW	60.43.54	N	01.41.52	W
Peaks 15 mile NNW	60.54.26	N	01.32.68	W
Peaks 8 mile NW	60.42.20	N	01.33.60	W
Sandsvoe	60.39.00	N	01.21.00	W
Skaden light	59.30.75	N	01.39.75	W
Strandburgh Ness	60.37.20	N	00.44.00	W
Swinga Taing	60.42.43	N	01.08.28	W
Tonga	60.49.20	N	00.55.95	W
Whalefirth	60.38.63	N	01.12.28	W

Appendix V Chart positions (WGS84 Datum) of hard ground fished during jig fishing pilot study.

Hard Ground	Latitude		Longitude	
Bressay	60.11.59	N	01.00.58	W
Bagi Stack	60.43.50	N	01.06.50	W
Blata Isle	60.43.34	N	00.46.76	W
Balta Isle	60.46.02	N	00.45.69	W
Coall Head	60.05.21	N	01.11.87	W
East of 15 mile peaks	60.56.80	N	01.25.87	W
East of Lerwick	60.00.16	N	00.48.48	W
East of Skaw	60.48.47	N	00.40.33	W
East of Skaw	60.50.49	N	00.47.24	W
Eigg Stack	60.39.00	N	01.10.00	W
Eshaness	60.28.91	N	01.38.68	W
Eshaness	60.30.86	N	02.10.87	W
Eshaness	60.31.20	N	02.21.40	W
Eshaness	60.32.46	N	01.41.90	W
Fethaland	60.38.00	N	01.20.00	W
Finnie	60.34.40	N	00.46.60	W
Fitful Head	59.50.20	N	01.24.50	W
Fitful Head	59.52.23	N	01.24.70	W
Fitful Head	59.52.60	N	01.22.80	W
Fitful Head	59.53.05	N	01.23.66	W
Fitful Head	59.54.05	N	01.25.61	W
Fitful Head	59.54.64	N	01.24.58	W
Fitful Head	59.54.98	N	01.23.31	W
Fitful Head	59.55.18	N	01.22.82	W
Flubersgerdie	60.47.37	N	00.57.49	W
Football Pitch	60.36.84	N	01.40.90	W
Fund	60.37.70	N	00.49.50	W
Funzie Ness	60.33.14	N	00.46.63	W
Funzie Ness	60.34.40	N	00.46.87	W
Gluop Holm	60.43.22	N	01.08.27	W
Gloup Holm	60.44.50	N	01.07.00	W
Haaf Gruney	60.39.00	N	00.46.00	W
Helliness	60.02.72	N	01.08.41	W
Hoo Stack	60.14.53	N	01.01.50	W
Hosta	60.36.00	N	00.46.00	W
Lady's Holm	59.52.06	N	01.20.49	W
Lunna Ness	60.26.80	N	01.03.50	W
Markamouth	60.41.77	N	01.08.34	W
Matta Taing	60.16.93	N	01.43.19	W
Mousa	60.01.25	N	01.06.79	W
Muckle Bard	59.59.25	N	01.09.50	W
Muckle Flugga	60.49.20	N	00.56.21	W
Muckle Flugga	60.50.31	N	00.54.71	W
Muckle Flugga	60.50.70	N	00.48.78	W
Muckle Flugga	60.51.10	N	00.49.90	W
Muckle Flugga	60.51.12	N	00.51.21	W

Hard Ground	Latitude		Longitude	
Muckle Flugga	60.51.30	N	00.49.60	W
Muckle Flugga	60.51.45	N	00.53.19	W
Muckle Flugga	60.51.47	N	00.47.70	W
Muckle Flugga	60.51.87	N	00.51.94	W
Muckle Flugga	60.51.88	N	00.47.48	W
Muckle Flugga	60.52.22	N	00.50.86	W
Muckle Flugga	60.57.99	N	00.47.57	W
Muckle Holm	60.35.30	N	01.16.00	W
Muckle Ossa	60.33.50	N	01.37.00	W
Muckle Ossa	60.32.00	N	01.34.00	W
Muckle Ossa	60.33.34	N	01.38.09	W
Ness of Hillswick	60.26.50	N	01.31.00	W
North Haaf	60.07.99	N	01.32.28	W
North of Foula	60.21.96	N	02.12.45	W
North of Foula	60.17.10	N	02.20.23	W
North Shoals	60.13.62	N	02.00.44	W
Norwick	60.48.75	N	00.46.50	W
Noss	60.12.45	N	00.59.53	W
Noss	60.09.00	N	01.00.00	W
Noss	60.07.75	N	01.02.00	W
Noup	60.51.92	N	00.47.55	W
Noup	60.50.84	N	00.44.97	W
Out Skerries	60.25.73	N	00.53.94	W
Oxna	60.06.50	N	01.22.50	W
Oxna	60.08.00	N	01.25.00	W
Perie Bard	59.59.00	N	01.08.62	W
Pipeline	60.36.71	N	02.27.45	W
Pobie Bank	60.35.24	N	00.25.21	W
Pobie Bank	60.36.29	N	00.23.12	W
Ramsness	60.33.48	N	00.53.16	W
Rump	60.09.91	N	01.31.10	W
Sandsvoe	60.38.00	N	01.19.00	W
Sandsvoe	60.38.50	N	01.23.50	W
Sandsvoe	60.39.00	N	01.23.00	W
Sandsvoe	60.39.00	N	01.24.00	W
Sharks Teeth	60.09.50	N	02.05.40	W
Sheep Rock	59.31.22	N	01.36.49	W
Skelda Ness	60.05.60	N	01.27.60	W
Skelda Ness	60.06.20	N	01.23.30	W
Skelda Ness	60.06.44	N	01.27.67	W
Skelda Ness	60.06.87	N	01.29.52	W
Skerry of Eshaness	60.28.00	N	01.38.00	W
Skroo light	59.33.33	N	01.36.82	W
South Ness	60.06.24	N	02.01.01	W
South Ness	60.06.40	N	02.03.59	W
South Ness	60.06.96	N	01.56.53	W
South Ness	60.07.36	N	01.58.39	W
South of Foula	59.49.25	N	02.16.78	W

Hard Ground	Latitude		Longitude	
South of Foula	59.45.78	N	02.19.96	W
St Ninians Isle	59.59.86	N	01.23.35	W
Strandburgh Ness	60.31.61	N	00.45.00	W
Strandburgh Ness	60.36.60	N	00.44.96	W
Strandburgh Ness	60.36.85	N	00.45.84	W
Strandburgh Ness	60.37.34	N	00.44.22	W
Strandburgh Ness	60.38.59	N	00.35.40	W
Strem Ness	60.09.80	N	02.03.60	W
Sumburgh Head	59.51.09	N	01.16.82	W
The Kame	60.08.75	N	02.06.60	W
Tind	60.35.54	N	00.44.56	W
Tind	60.35.93	N	00.45.48	W
Tonga	60.48.84	N	00.56.59	W
Upskud	60.44.60	N	01.05.53	W
Upskud	60.44.61	N	01.07.11	W
Upskud	60.44.70	N	01.04.50	W
Upskud	60.44.70	N	01.04.00	W
Uyea Baas	60.36.94	N	01.27.29	W
Uyea Baas	60.37.00	N	01.27.00	W
Uyea Baas	60.37.00	N	01.21.00	W
Uyea Baas	60.37.00	N	01.26.00	W
Uyea Baas	60.38.04	N	01.22.84	W
Uyea Baas	60.38.34	N	01.25.63	W
Uyea Baas	60.39.00	N	01.24.00	W
Uyea Baas	60.39.95	N	01.27.33	W
Vaila	60.10.62	N	01.31.75	W
Ve Skerries	60.21.20	N	01.51.50	W
Ve Skerries	60.22.32	N	01.50.81	W
Ve Skerries	60.22.56	N	01.48.25	W
Ve Skerries	60.27.40	N	01.49.60	W
Ve Skerries	60.28.00	N	02.03.40	W
Ve Skerries	60.28.33	N	01.52.10	W
Walls	60.12.19	N	01.37.44	W
Wats Ness	60.14.88	N	01.42.10	W
Wats Ness	60.13.12	N	01.39.25	W
West Sandwick	60.35.50	N	01.12.00	W
West Side	59.32.37	N	01.39.43	W
Wester Hoevdi	60.08.20	N	02.07.20	W
Wester Skerry	60.04.68	N	01.23.23	W
Whalefirth	60.39.37	N	01.11.39	W
Whalefirth	60.40.74	N	01.09.24	W
Whalefirth	60.41.31	N	01.08.48	W
Whalsay	60.21.08	N	00.48.94	W
Whalsay	60.19.60	N	00.50.20	W
Whalsay	60.15.71	N	00.33.47	W

Appendix VI Breakdown of prices received for jig caught fish landed at Lerwick and Scalloway markets.

Trip Date	Cod				Ling				Lythe				Tusk				Saithe			
	Boxes	Kg	Value	£/Kg	Boxes	Kg	Value	£/Kg	Boxes	Kg	Value	£/Kg	Boxes	Kg	Value	£/Kg	Boxes	Kg	Value	£/Kg
1-2/08/2005									7.00	287.0	£432.05	£1.51					3.00	123.0	£51.15	£0.42
3-4/08/2005	2.00	82.0	£145.99	£1.78	0.75	30.8	£37.50	£1.22	6.25	218.8	£323.17	£1.48								
8-9/08/2005									3.00	123.0	£150.00	£1.22								
10-11/08/2005									22.50	828.5	£1,149.36	£1.39	1.00	41.0	£11.61	£0.28				
16-17/08/2005	2.25	92.3	£213.16	£2.31					9.00	369.0	£585.84	£1.59								
18/08/2005									2.00	70.0	£108.04	£1.54								
02/09/2005																				
05/09/2005					1.00	41.0	£69.01	£1.68	2.25	92.3	£138.92	£1.51					3.75	153.8	£75.98	£0.49
06/09/2005																				
12/09/2005																				
21-22/09/2005	1.25	51.3	£69.51	£1.36	1.00	41.0	£59.64	£1.45												
29/09/2005	0.25	10.3	£15.16	£1.48	0.75	30.8	£39.75	£1.29	1.00	41.0	£65.65	£1.60								
10-11/10/2005	0.25	10.0	£17.00	£1.70	0.75	32.0	£41.24	£1.29	12.75	552.8	£900.91	£1.63	0.75	35.0	£24.66	£0.70	1.00	41.0	£17.72	£0.43
17-18/10/2005	2.00	81.0	£126.35	£1.56	2.50	102.5	£130.20	£1.27	0.75	29.0	£42.09	£1.45								
19-20/10/2005																				
24/10/2005																				
26/10/2005	0.75	27.0	£34.00	£1.26	0.25	10.2	£6.25	£0.61	5.75	235.7	£438.58	£1.86								

Trip Date	Cod				Ling				Lythe				Tusk				Saithe			
	Boxes	**Kg**	**Value**	**£/Kg**	**Boxes**	**Kg**	**Value**	**£/Kg**	**Boxes**	**Kg**	**Value**	**£/Kg**	**Boxes**	**Kg**	**Value**	**£/Kg**	**Boxes**	**Kg**	**Value**	**£/Kg**
31-01/11/2005	1.25	49.0	£77.04	£1.57	1.25	52.0	£61.99	£1.19	2.50	101.0	£200.28	£1.98								
02-03/11/2005	0.25	10.3	£10.05	£0.98	1.25	51.3	£69.95	£1.36	0.50	20.5	£27.85	£1.36	0.75	35.0	£27.00	£0.77				
18/11/2005					0.50	16.0	£9.65	£0.60	20.25	830.3	£1,700.49	£2.05					0.50	20.5	£10.02	£0.49
21-23/11/2005	0.25	10.3	£13.50	£1.32	0.50	20.5	£27.83	£1.36	0.50	20.5	£37.45	£1.83								
29/11/2005																				
6-8/12/2005	0.50	18.0	£25.32	£1.41	0.75	28.0	£33.60	£1.20	0.50	18.0	£31.62	£1.76								
10/04/2006																				
11-12/04/2006	1.00	40.0	£72.00	£1.80					1.00	40.0	£71.00	£1.78								
19-20/04/2006									23.00	897.0	£1,647.48	£1.84					20.00	830.0	£728.61	£0.88
28/04/2006																				
8-10/05/2006	1.00	30.8	£49.50	£1.61	1.00	41.0	£41.68	£1.02	6.00	246.0	£267.78	£1.09	1.00	20.5	£14.82	£0.72	2.00	70.5	£40.43	£0.57
15-17/05/2006					0.50	20.0	£17.90	£0.90	18.00	738.0	£1,318.59	£1.79					17.50	707.5	£488.73	£0.69
22-23/05/2006									25.00	1025	£1,425.91	£1.39								
24-25/05/2006									13.00	533.0	£920.67	£1.73					33.00	1353.0	£954.46	£0.71
31-1/06/2006									9.00	369.0	£635.94	£1.72					4.00	164.0	£126.82	£0.77
05/06/2006																	8.00	328.0	£266.72	£0.81
06-08/06/2006									12.00	492.0	£785.52	£1.60					29.00	1189.0	£689.31	£0.58
27-28/06/2006									0.50	20.5	£30.15	£1.47					0.75	30.8	£13.28	£0.43
10-11/07/2006					0.25	10.0	£5.90	£0.59	4.00	164.0	£284.60	£1.74					4.00	164.0	£93.92	£0.57
13-14/07/2006					2.5	102.5	£106.45	£1.04					0.5	20.5	£10.01	£0.49	1.00	41.0	£16.95	£0.41

Trip Date	Cod				Ling				Lythe				Tusk				Saithe			
	Boxes	Kg	Value	£/Kg	Boxes	Kg	Value	£/Kg	Boxes	Kg	Value	£/Kg	Boxes	Kg	Value	£/Kg	Boxes	Kg	Value	£/Kg
17-18/07/2006									0.50	20.5	£30.78	£1.50					19.00	779.0	£371.34	£0.48
19-20/07/2006	1.00	41.0	£75.02	£1.83	0.50	20.5	£20.50	£1.00	7.00	287.0	£434.84	£1.52								
24/07/2006																				
26-27/07/2006									0.75	30.8	£50.65	£1.65					1.00	41.0	£16.94	£0.41
31-01/08/2006																				
7-8/08/2006																				
16-17/08/2007	1.00	41.0	£106.04	£2.59					4.00	164.0	£350.80	£2.14					6.00	246.0	£162.06	£0.66
21-23/08/2006	1.50	61.5	£122.91	£2.00					12.00	492.0	£925.19	£1.88								
01/09/2006																				
5-6/09/2006	2.00	82.0	£271.46	£3.31					3.50	143.5	£260.81	£1.82								
11-12/09/2006									11.75	481.8	£940.00	£1.95					12.00	492.0	£379.95	£0.77
15/09/2006	0.50	20.5	£33.90	£1.65					1.00	52.0	£107.65	£2.07								
18/09/2006					0.50	17.0	£5.00	£0.29	5.75	235.0	£472.06	£2.01					1.00	41.0	£21.09	£0.51
21/09/2006									1.75	71.0	£142.40	£2.01								
25-26/09/2006	1.75	71.0	£230.63	£3.25	0.50	20.5	£27.33	£1.33	5.25	215.0	£435.66	£2.03	0.50	20.0	£7.32	£0.37				
27/09/2006																				
05/10/2006	0.50	20.0	33.03	£1.65					3.00	123.0	285.00	£2.32								
16-17/10/06	0.50	25.0	£76.19	£3.05	7.00	287.0	£423.27	£1.47	6.00	246.0	£603.48	£2.45					13.00	533.0	£506.78	£0.95
25/10/2006									1.00	41.0	£101.50	£2.48								
30/10/2006																				
2-3/11/2006									4.50	184.0	£472.93	£2.57								

Trip Date	Cod				Ling				Lythe				Tusk				Saithe			
	Boxes	Kg	Value	£/Kg	Boxes	Kg	Value	£/Kg	Boxes	Kg	Value	£/Kg	Boxes	Kg	Value	£/Kg	Boxes	Kg	Value	£/Kg
14/02/2007									6	252.0	£327.03	£1.30								
19/02/2007					6	246.0	£285.66	£1.16												
21/02/2007									1.75	71.0	£124.40	£1.75					1	41.0	£16.69	£0.41
22-23/03/2007									6.5	266.0	£417.20	£1.57					3	123.0	£91.29	£0.74
26/03/2007																				
28-29/03/2007					1	41	£54.03	£1.32	1	41	£52.33	£1.28					9.5	389.5	£253.26	£0.65
02-04/04/2007					1	41	32.87	£0.80	7	287	285.76	£1.00					24	984	483.33	£0.49