Marine Management Organisation

Catch Quota Trials: Western Haddock Final Report 2014

December 2015

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Contents

Figures

Tables

1. Executive summary

This report provides the results of the Southwest haddock fully documented fishery scheme for 2014. This trial was in two parts: firstly, testing REM as a tool to fully document fisheries and to verify skipper's records; secondly, to test net selectivity. The participant vessel (a twin-rig otter trawler) was fitted with Remote Electronic Monitoring (REM) with CCTV as an appropriate means to audit compliance with the scheme rules. The key driver of the trial was to establish the potential to avoid haddock becoming a choke species in this mixed demersal fishery.

The vessel owner was awarded extra quota for haddock, anglerfish and megrim. For anglerfish and megrim, all catches had to be landed and counted against quota. For haddock, the skipper was obliged to retain and land all fish caught in the trawl which was modified to improve selectivity. However, catches of juvenile haddock caught in unmodified control nets were allowed to be discarded provided it was fully documented. This was to ensure there was not a disproportionate quota penalty whilst gear comparisons were made.

Results showed that REM was able to monitor the full fishing and processing operations and allow for independent estimates of catches and discards to be made from CCTV analysis. A high correlation was found between skipper's catch estimates and CCTV observer estimates for all three species studied. Data confidence was good for haddock as the system had been set up in order to specifically measure haddock discards. However, data confidence was lower from megrim and anglerfish. Greater confidence can be achieved with more recent technology that is now available to provide improved resolution and processing operation coverage.

Unmodified trawls showed a clear pattern of increasing haddock discards during each season (spring – autumn) in 2014. In addition, there was a clear peak in haddock catches at night time in the Autumn. Therefore, the unmodified nets had very poor selectivity for haddock. This data supports the ICES Advice that suggests a strong 2013 year class will become available to the fishery in 2014/2015 and that heavy discarding would be likely to result.

The skipper tested different combinations of nets in order to determine which had the best selectivity. The main aim of this was to reduce juvenile haddock bycatch and to reduce haddock catches above the minimum size in order to remain within the annual quota limitation. The lowest catches of haddock were realised using a reduced cover net (allowing mature fish to avoid capture) with two square mesh panels (from which juvenile fish can escape). In addition, this also produced the lowest unwanted catch rate for megrim and a low unwanted catch rate for anglerfish. Therefore, this gear type appears to be effective in reducing discards of all three species.

Other methods of avoiding unwanted catch were also introduced. Fishing took place in more easterly grounds in 2014, avoiding to some extent juvenile haddock which was more abundant further west. In addition, fishing at nightwhen the highest haddock catches are taken was reduced.

This report also considered how behavioural and technical modifications affected by-catches of squid and boarfish. The more selective gear reduced squid catches by between 10 and 29%. However, squid catches peaked during daylight hours and as such if the skipper continued to avoid fishing at night, the overall losses would be minimised. Large catches of boarfish blocked nets and were difficult to handle. These catches were almost exclusively taken at night, thereforethe avoidance of night fishing would also appear to reduce unwanted catches of boarfish.

The trials have shown that avoiding fishing at night is an effective tool for reducing overall haddock catch, and specifically juveniles. However, economically the avoidance of fishing at night resulted in a loss of revenue as overall catches were reduced. Temporal avoidance of haddock catches along with the associated fuel savings therefore have to be balanced against the loss of revenue in the mixed fishery as a whole.

By adopting the various avoidance and selectivity measures fishing operations were maintained for the full year whilst remaining within quota limits without discarding. In addition, the combination of gear modifications and behavioural modifications led to a vast reduction in the catch of juvenile haddock. This suggests that, in 2014 haddock would have not been a choke species using these measures although the participant vessel owner does have access to more haddock quota than others operating from south west ports.

Looking forward to 2015, for which analysis is already well advanced, this picture looks to be slightly changed. In 2015 it has proven more challenging to operate a discard free fishery within the reduced quota limits. The skipper has also reported a new year class coming into the fishery in numbers which would correspond with ICES stock predictions. He believes that this is making it more difficult for him to mimimise haddock catches and stay within the quota with large quantities of Grade 4 fish being caught. More detail on this will be reported in the 2015 report.

2. Introduction

The aim of this trial was twofold, firstly to build upon previous reports assessing the impact of a discard ban on ICES Area VIIb-k haddock in the context of a mixed demersal trawl fishery. Secondly, to continue gear selectivity trials in order to determine the best gear configurations to reduce catches of undersize haddock and to maintain overall haddock catches within allowable catch limits (i.e. haddock discards). In addition discards of other potential choke species, megrim and anglerfish, were studied. Finally, the potential for an incidental reduction in squid catches from gear modified for haddock selectivity was tested.

The previous REM report (Roberts *et al*., 2014) covered the whole of 2013. The previous gear selectivity report covered several trips from 12th May to 27th July 2014 (Roberts and Course, 2014). This report provides a follow up report to the 2013 REM report, covering all available data for 2014. In addition, it expands upon the gear selectivity report, including data from 29th April to the 9th December of 2014; i.e. all data available for that year.

Additional VIIb-k haddock, megrim and anglerfish quota was made available for the 2014 trial under Article 14 of Council Regulation (EU) 43/2014 which permits Member States to allocate additional quota to vessels participating in trials of Fully Documented Fisheries (FDF). The participant vessel was fitted with a Remote Electronic Monitoring (REM) device in accordance with Article 15 of Council Regulation (EU) 43/2014.

The vessel is a twin rig trawler which allows a simultaneous comparison between two different trawls; the combination of trawls varied throughout the year and is set out in Table 1 below. The aim of using different net combinations was to test the selectivity of different gears. When a Square Mesh Panel (SQMP) was fitted in the codend, it was 30 meshes deep by 10 meshes wide. When a SQMP was fitted in the stocking, it was done in accordance with the Celtic Sea SQMP regulation (Commission Implementing Regulation (EU) No 737/2012). All nets used in the trial had a reduced cover with 19x8 meshes less.

Date(s) in use	Control gear (reduced cover trawl, both with and without square mesh panel modifications)	Date(s) in use	Test gear (reduced cover trawl with square mesh panel modifications)
29/04/14 – 02/06/14	Unmodified	29/04/14 – 16/06/14	Square mesh panel in codend
03/06/14 – 16/06/14	Square mesh panel in stocking		
17/06/14 – 23/06/14	Square mesh panel in codend	17/06/14 – 30/06/14	Square mesh panel in codend and stocking
25/06/14 – 28/07/14	Unmodified	01/07/14 – 28/07/14	Square mesh panel in codend
02/09/14 – 15/09/14 (second haul of trip)	Square mesh panel in stocking	02/09/14 – 15/09/14 (second haul of trip)	Square mesh panel in codend and stocking
15/09/14 (third haul of trip) – 09/12/14	Unmodified	15/09/15 (third haul of trip) – 09/12/2014	Square mesh panel in stocking

Table 1: Type of gear used at given time of year

The skipper was required to retain all species for which Fully Documented Fishery (FDF) quota was made available. Therefore, all haddock, megrim and anglerfish were retained and counted against the vessel's quota. Any undersize fish landed was not permitted to be sold, or to be used for human consumption. However, uses such as pot bait were acceptable.

Juvenile haddock caught with the less selective control gear was allowed to be discarded provided it was fully documented. This concession was made in the interest of establishing the efficacy of gear modifications without imposing a disproportionate quota penalty.

2.1 Haddock TAC and ICES Advice

The UK Total Allowable Catch (TAC) for Haddock in Area VIIb-k increased every year from 2010 to 2012. However, it then decreased year-on-year with the 2014 TAC set at 948t. In 2015, this trend continued with a decrease to 834t. This has the

potential to increase discard rates in the absence of improved selectivity and avoidance behaviours across the non-FDF fleet.

The 2014 ICES Advice (ICES, 2014a) reports high catches of haddock becoming a problem for the fishing industry as the reduced TAC did not cover bycatch in many vessels. In addition, ICES reported increased high grading in the three years prior to 2014 due to restrictive quotas, although the belief was that this issue would be less prevalent in 2014 as lower availability of haddock meant that less were available to catch. Fishing mortality also continued to be above the Maximum Sustainable Yield level (F_{MSY}) in 2014. This highlights the fact that this stock is not currently being fished at a level sustainable in the long term and that more selective gear types or behaviour modifications are needed to reduce discards.

2.2. Anglerfish and Megrim TAC and ICES Advice

The 'Anglerfish' stock combines two different species – *Lophius budegassa* and *Lophius piscatorius*. Given the uncertainties around these two species, ICES has been unable to predict F_{MSY} for either (ICES, 2014b and c). Based on the available evidence, ICES has predicted that biomass for both stocks is generally increasing but variable. This was reflected in 2014 by the highest TAC in the previous five years of 6027t. However, ICES has advised that the majority of catches of anglerfish are immature and that discarding has increased in recent years (ICES, 2014b and c). Therefore, ICES has recommended an increase in the sampling of discards for this species. The information gathered in this trial can therefore provide valuable supporting evidence on both discards and gear selectivity for this species.

The megrim TAC has remained mostly constant over the last five years with only a slight reduction in 2014. The 2014 UK TAC was 2492t. Fishing mortality has decreased and spawning stock biomass has increased, therefore there is a good prognosis for the stock. However, lack of data means that there is significant uncertainty around the assessment. Therefore, any data which can aid our understanding of megrim catches and discards is a useful tool in increasing our knowledge of this stock.

2.3 Participant vessel fishing patterns

One application to participate in trials was received for the 2014 trial, with the participant vessel being the same as in previous year's trials. This vessel is a 20 metre long twin-rig otter trawler. The vessel uses 106mm codend mesh to target a mixed demersal fishery in the Celtic Sea. The vessel relies on a diverse range of species including quota species such as haddock, megrim and angler as well as a range of non-quota species such as lemon sole.

Figures 1 and 2 below show the top ten species in the 2013 and 2014 catches by landed weight. The three main species by weight; haddock, anglerfish and megrim; are the Fully Documented Fishery (FDF) stocks for this trial. The top ten species dominate the catch, comprising 89% in 2013 and 83% of 2014.

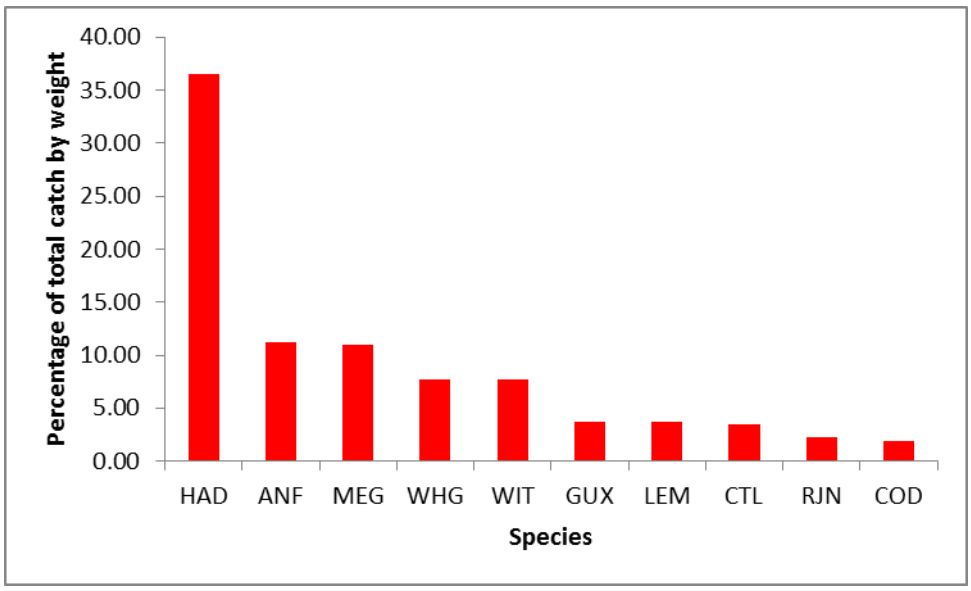

Figure 1: Top ten species in 2013 landed catch by weight

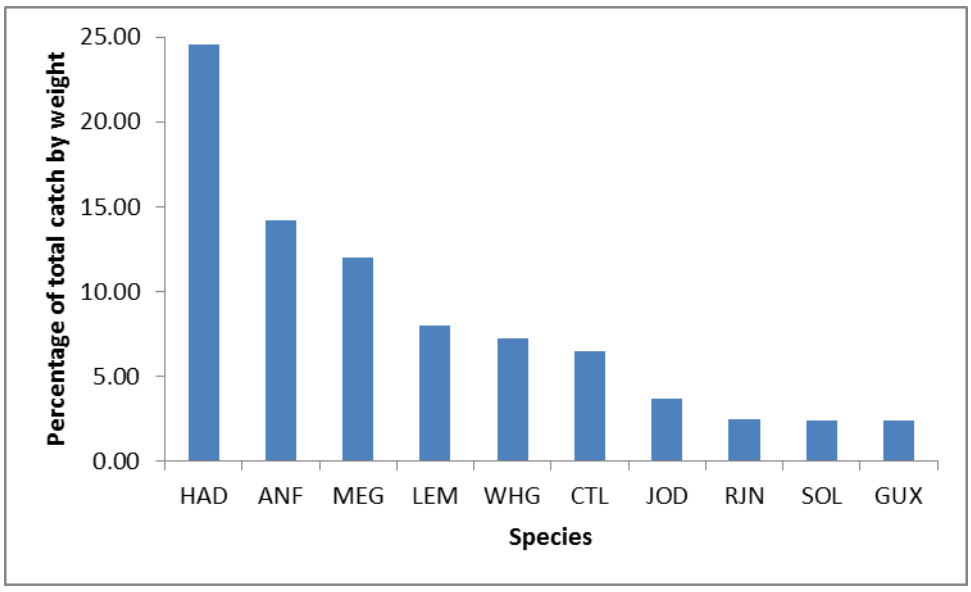

Figure 2: Top ten species in 2014 landed catch by weight

Figures 3 and 4 below show the top ten species in the 2014 catch by income from landings. These ten species comprise 87% of the vessel's income in 2013 and 89% in 2014. Haddock and Anglerfish are shown to be the highest earning species in both years, as well as having constituted the greatest weight. It is interesting to note the differences in the fish species. For example, megrim was only the fifth biggest earning species in 2014 despite being the third in terms of weight. This shows the relatively lower prices for fish such as megrim compared to lemon sole which was fourth in terms of weight but third in terms of income.

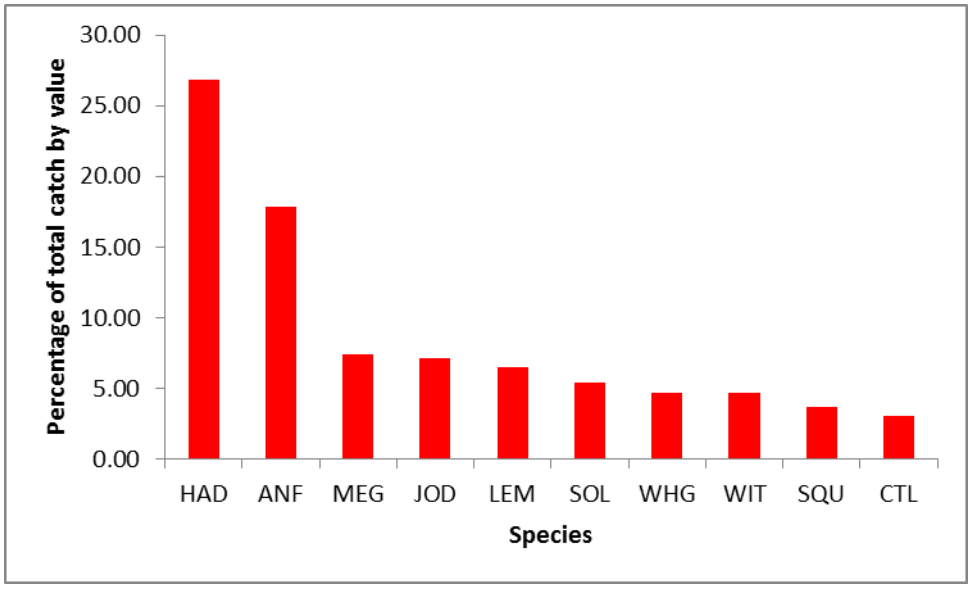

Figure 3: Top ten species in 2013 landed catch by value

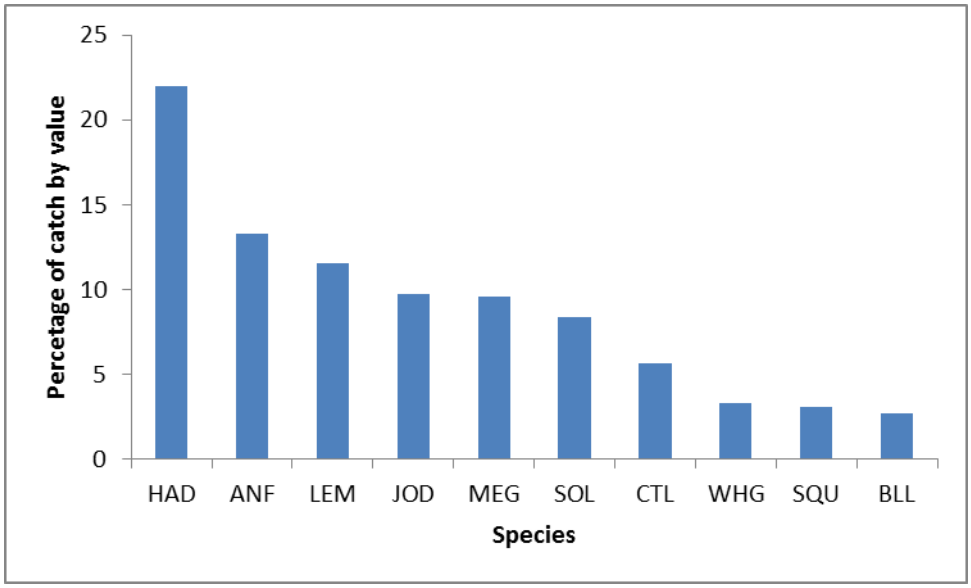

Figure 4: Top ten species in 2014 landed catch by value

Figures 5 and 6 below show that the spatial fishing pattern in 2013 and 2014 are broadly similar. However, the vessel worked further to the west during 2013 and a more confined range in 2014.

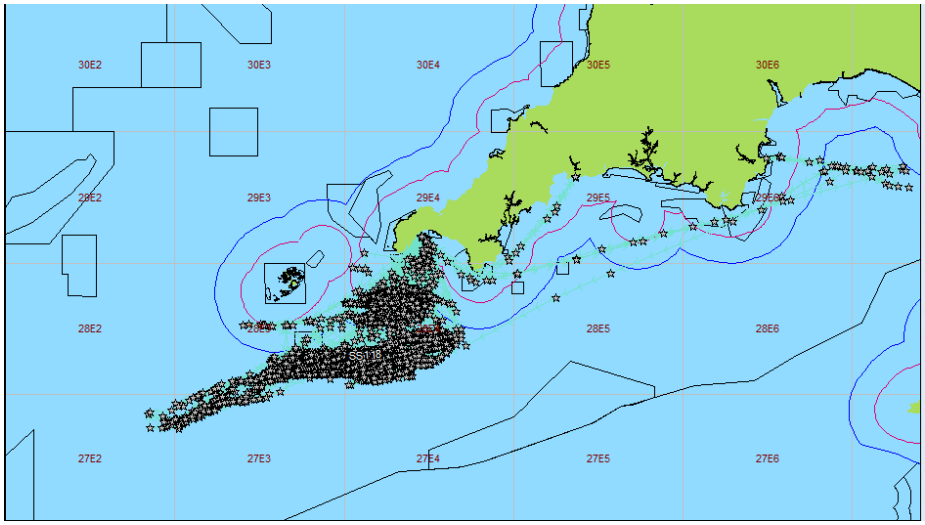

Figure 5: VMS location of the participant vessel during 2013 trial

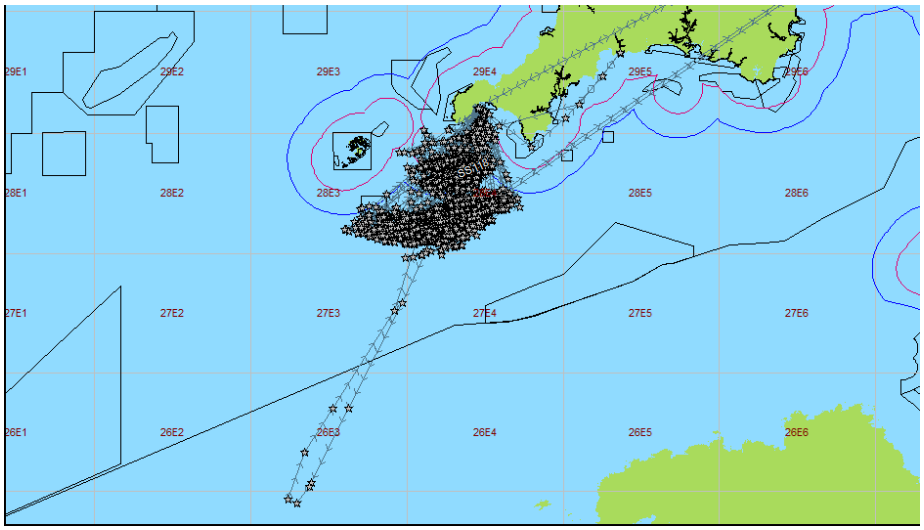

Figure 6: VMS location of the participant vessel during 2014 trial

Figure 7 below shows the haul locations fished by the vessel in 2014, exact positions of the end of each haul are taken from the GPS which is linked into the vessel's REM system.

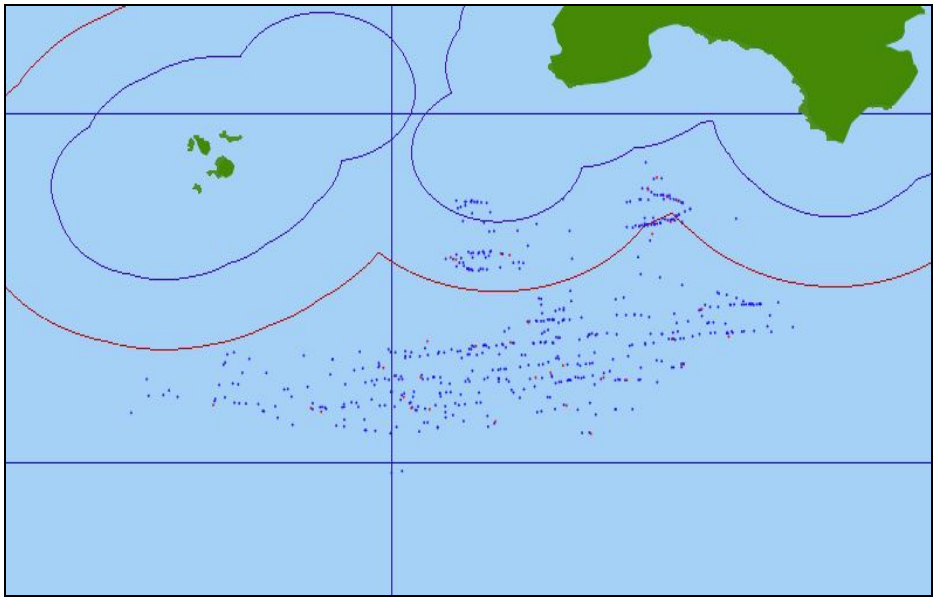

Figure 7: EM location of hauls fished by the participant vessel during 2014. The Hauls shown in red were analysed.

2.4 Species discard rates and additional quota incentives

The vessel was allocated the following FDF quota: 48.3t of ICES area VIIb-k haddock, 7.9 of VII anglerfish, and 16 tonnes of VII megrim. The allocations were undertaken in line with the STECF discard rates for 2012 and the catch of each species in the previous year. The vessel's allocation of VIIb-k haddock was limited by the 5% cap for maximum additional haddock allocations at 5% of the 2014 quota set out in Council Regulation (EU) 43/2014.

The discard rates used, maximum potential quota available, and the relevant scheme rules are set out in Annex I.

3. Methods

The participating vessel was fitted with Remote Electronic Monitoring (REM) equipment from Archipelago Marine Research Ltd (AMR). The REM system fulfils the requirements of Article 15 of Council Regulation (EU) No 43/2014 in that vessels allocated additional FDF quota must have certain on board monitoring in place. This report covers data from April 2014 to December 2014. Data for January until March 2014 is included in the previous report available here: https://www.gov.uk/government/publications/catch-quota-trial-final-report-2013-western-haddock

The vessel skipper also completed haul sheets for every haul with his estimates of retained marketable and retained unmarketable (i.e. would have been discarded in a non-capped fishery) haddock, anglerfish and megrim. Haul time and date was recorded. Haul time was the time at which the winch was started in order to haul in the net. Retained fish were recorded in gutted weight (for haddock and megrim) and

tail weight (for anglerfish). Retained unmarketable fish of all species were weighed in order to understand the weight, and weights were rounded to the nearest 0.5kg. However, weights of retained marketable fish were estimated.

Standard live weight conversions were applied by multiplying the gutted or tail weight by a constant factor. Gutted haddock were multiplied by 1.17, gutted megrim by 1.06 and anglerfish tails by 3. These factors were introduced by EU Commission Regulation 409/2009 of May 18 2009 and have been used as standard conversions across the EU fleet since 2010. Discarded fish from the unmodified gear were recorded in live weight. Comparative estimates of haddock discards from test and control gears were also recorded. Finally, from September until December the catches of squid in both the test and control nets were recorded.

3.1. Video analysis

The participating vessel was fitted with an REM system supplied by Archipelago Marine Research Ltd (AMR). The REM system includes a GPS, sensors (drum rotation and pressure) and CCTV cameras. The data from these are stored on a removable hard drive for later analysis by onshore observers.

A common set of standards were used to measure data quality. The 'camera working' and 'camera performance' definitions are in Annex II of this report. This ensured that all worked to the same standards and enabled monitoring of the quality of data being collected.

In all 6.4% of hauls were analysed from data received between April 2014 to December 2014. These hauls were evenly spaced across trips and chosen at random using an online random sequence generator (https://www.random.org/sequences/). Hauls were reviewed for any haddock, megrim or anglerfish that were discarded; i.e. were seen to go over the end of the discard belt or be tipped overboard; and for retained haddock, megrim and anglerfish, which was split into both marketable and unmarketable categories. The the full processing operation was reviewed in order to obtain an independent and complete picture of the catch. In addition, all weights were estimated independently before comparison with skipper's records to avoid any bias.

The weight of haddock, megrim and anglerfish was estimated for all categories in each selected haul. For retained portions of the catch, the crew sort the fish into five stone baskets. Using data collected at sea over three full fishing trips an average basket weight has been calculated for each species. As only a few haddock records were available, therefore cod records from similar fishing activities were also included to create an average weight for round-fish. The weights found were 30.3kg for full baskets of haddock, 38.2kg for full baskets of anglerfish and 32.25kg for megrim. These baskets were counted throughout the processing event as they were filled, leaving estimates of part filled baskets at the end for each species, this was preferably achieved using the overview camera looking at through the side of the basket as viewing from above can make baskets appear fuller than they are.

Standard conversions were then used to account for gutting and tailing to show live weights, which were 1.17 for haddock, 1.06 for Megrim and 3 for anglerfish, used

throughout Europe and produced by the European Commission. Undersized haddock caught using modified gear was discarded at the end of sorting, due to the conditions of the trial. This haddock was sampled using basket estimates as although it was possible to count this fish and convert to a weight, it would have taken extra time and not improved accuracy.

When a fish was either discarded before being sorted or retained but not collected in a basket, a weight estimate was gained by using the length to weight ratio. An electronic caliper tool was used to measure the length of the fish for larger fish and small haddock and megrim were estimated at just below minimum landing sizes of 30cm and 25cm respectively. Standard weight conversions were used (weight = aL^b,) (CEFAS, pers. Comm.) to then convert these lengths to weights. These weights were calculated as 0.25 for haddock and 0.1 for megrim.

As anglerfish does not have a minimum landing size all fish falling off the discard belt had to be estimated for length. These lengths were then converted to weights using the same standard conversion (CEFAS, pers. Comm.) Once all weights were collected they were exported into an access database where they could be compared to the skippers estimates.

3.2. Analysis of haddock catch

Skipper's estimates of retained unmarketable fish were used in order to compare variation by time and by season when unmodified nets were used. Where 'time' was the time at which the net was hauled as recorded by the skipper. In order to do this, live weights of retained unmarketable and retained marketable fish were summed by four hour time periods (e.g. 00:01 – 04:00) and by season. The percentage of retained unmarketable fish compared to the retained marketable weight was then calculated for each period. A histogram was then plotted showing the discard rate by season and by time. Winter was excluded as the data for this report starts in April and there are few hauls in December – therefore plotting this time period could skew the data.

A comparison was made of retained unmarketable fish for the different types of gear used (gear types and dates of use are shown in Table 1 of this report). Scatter plots were made showing the quantity (kg) of retained unmarketable haddock for each set of control and test gear for each haul. In addition, the maximum quantity of unmarketable haddock from a single haul for each net type was compared.

In addition, using the video data, a discard rate was calculated. This discard rate was the number of haddock which were not retained but returned to the sea, contrary to the terms of the scheme. The total number of haddock seen to be discarded were counted for every haul which was analysed. This figure was then raised to provide an estimate for the total number of hauls.

The skipper's estimates of retained unmarketable and retained marketable haddock were verified using video analysis data. When the data was plotted, it was clear that there was a linear relationship between the two datasets. Therefore a regression line was plotted and an R^2 coefficient of determination calculated.

Finally, the quantity of retained unmarketable haddock for each of the main areas in which the vessel fished was compared. That is for ICES rectangles 28E4 and 28E3. The relative percentage in each was calculated.

3.3. Analysis of megrim and anglerfish catches

Skipper's estimates were used in order to compare the quantity of retained unmarketable megrim and anglerfish from different test nets (megrim and anglerfish from control nets were not recorded). The retained unmarketable weights were summed by gear type. The retained unmarketable as a proportion of the retained marketable catch was then calculated for each gear type.

A discard rate was then calculated for the number of fish of each species which was returned to the sea. As megrim and anglerfish were species for which Fully Documented Fishery (FDF) quota was provided, any return of this species to the sea was contrary to the terms and conditions of the scheme. The total number of each species seen to be discarded were counted for every haul which was analysed. This figure was then raised to provide an estimated total for all hauls in the year.

The skipper's estimates of both retained unmarketable and marketable megrim and anglerfish were then verified using quantities estimated from video analysis. A scatter plot of the data showed a clear linear relationship between the two datasets. A regression line was therefore plotted and an R^2 coefficient of determination calculated.

3.5. Examination of unwanted boarfish catches

Boarfish were caught in high numbers in some catches. These fish are all discarded as there is no market for them. In addition, the quantity and difficulty of handling the boarfish meant that for hauls containing this species, the skipper was unable to make records of other discards.

3.6. Analysis of squid catches

Skipper's estimates were used to compare squid catches between modified and unmodified gear. The aim of this was to understand the potential financial impact through the loss of squid if using nets modified to improve selectivity for haddock.

From the 9th of September until 9th December the skipper recorded the catches of squid in both the modified and unmodified net by haul. This time period was chosen as it covers the peak of the squid catching season for offshore vessels. The catch per month was summed for each net type and a histogram plotted to show the comparative data. In addition, the percentage difference between the catches in each net in a given month was calculated in order to understand numerical differences. Finally, the average market price of squid landed each month was calculated from monthly landings data provided by the MMO statistics team.

4. Results

4.1. Comparison of skipper's estimates with video analysis data

The catches of the three Fully Documented Fishery (FDF) species from skipper's records, landed weight and estimates from video analysis were compared. Figure 8 below shows that final figures were similar for all three species. The largest difference was for megrim with the video analysis estimate being 2.6% more than the landed weight and the skipper's estimate 0.9% less than the landed weight.

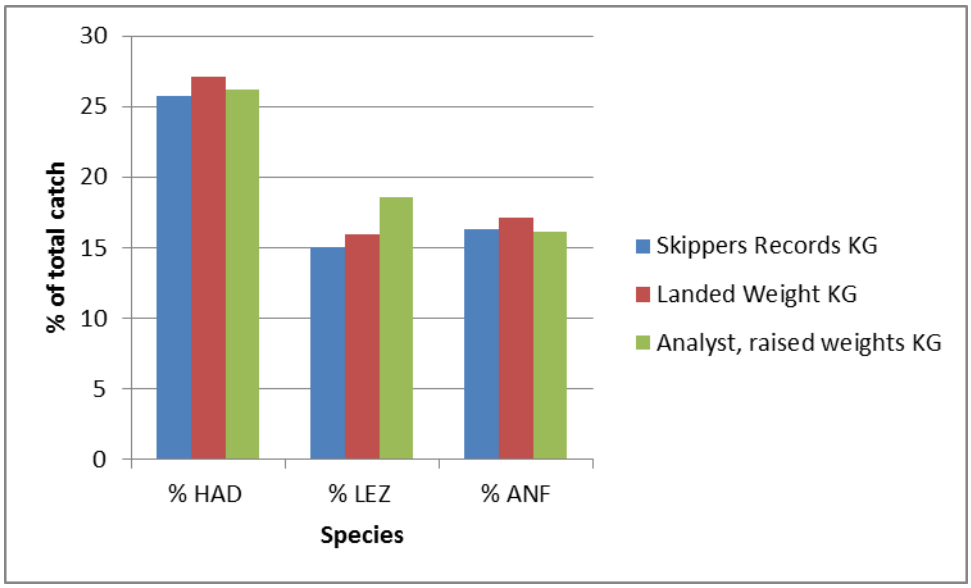

Figure 8: Comparison of skipper's records against landed sales weights and raised weights.

4.2. Haddock catches

Haddock discard rates using unmodified gear were analysed for seasonal and temporal patterns. It is clear from Figure 9 that discard rates increased throughout 2014, with Autumn consistently having the highest discard rates across all times of day. In Spring and Summer, there was no clear variability in discards from hauls at a given time of day. However, in Autumn, there was a clear increase in discard rates from hauls taken at night (i.e. between midnight and eight a.m.).

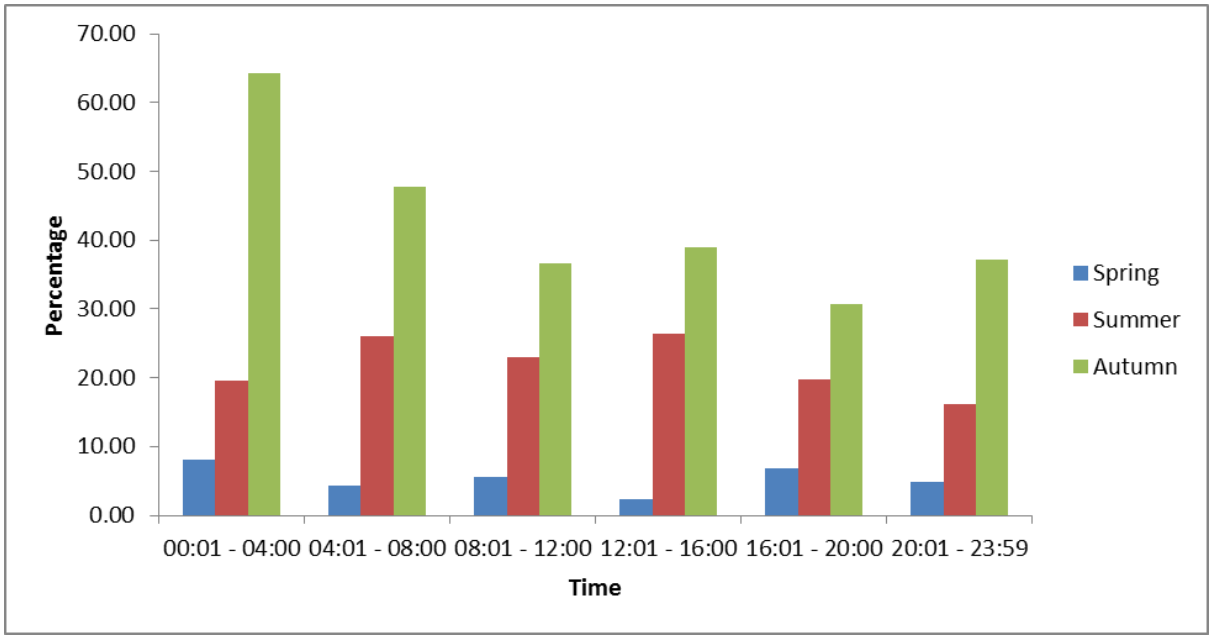

Figure 9: Haddock discard rates from unmodified nets by time and by season

To counter the increased level of unmarketable haddock caught at night fishing effort was reduced during hours of darkness . In table 2 night was defined as hauls started after 8pm and before 5 am. As tows generally last for 5 or more hours 5 am was used as these tows may last into mid morning.

	Hours fished	Percentage of fishing time
Day 2014	1724 hours and 9 minutes	26.26%
Night 2014	982 hours and 31 minutes	14.96%
Total 2014	2706 hours and 40 minutes	41.21%
Day 2013	2453 hours and 35minutes	37.36%
Night 2013	1407 hours and 40 minutes	21.43%
Total 2013	3861 hours and 15 minutes	58.79%

Table 2: Time the vessel was fishing split between night and day. As a percentage of total fishing time during both 2013 and 2014.

The selectivity of different types of gear was then compared. The figures used were taken from the skipper's own records. Figure 10 below shows the vessel using a net with a square mesh panel (SQMP) in the cod end at the same time as an unmodified net with no SQMP. It can be seen from Figure 10 that the addition of the codend SQMP significantly improved selectivity. The maximum retained unwanted haddock in a single haul was 25kg for the codend SQMP, compared to 113kg for the unmodified net. Overall, the net with the codend SQMP retained 2.6 times less unmarketable haddock being retained.

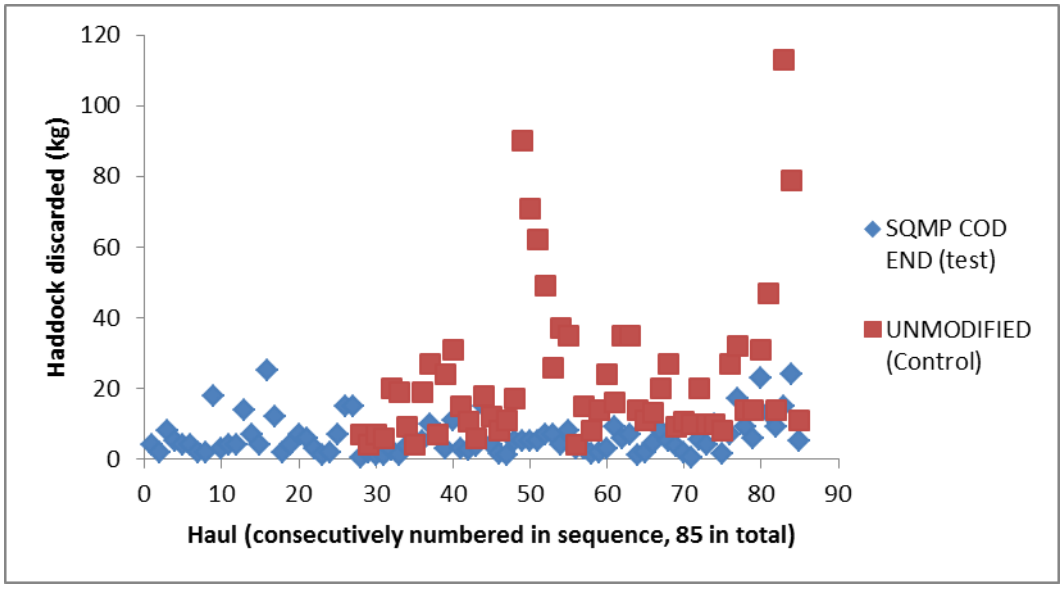

Figure 10: Unmarketable retained haddock from test gear (square mesh panel in the cod end) and control gear (an unmodified net) for hauls from 29/04/14 to 02/06/14

Figure 11 below shows the use of one net with a SQMP in the codend (test net) alongside another with a SQMP in the stocking (control). Although the difference in discards is not as marked as in Figure 10, there was still an improvement in selectivity using a SQMP in the codend. The maximum discard in a single haul with the SQMP in the codend was 46kg compared to 100kg for a SQMP in the stocking. Overall, the SQMP in the codend was more than twice as effective as a SQMP in the stocking in terms of total unmarketable fish.

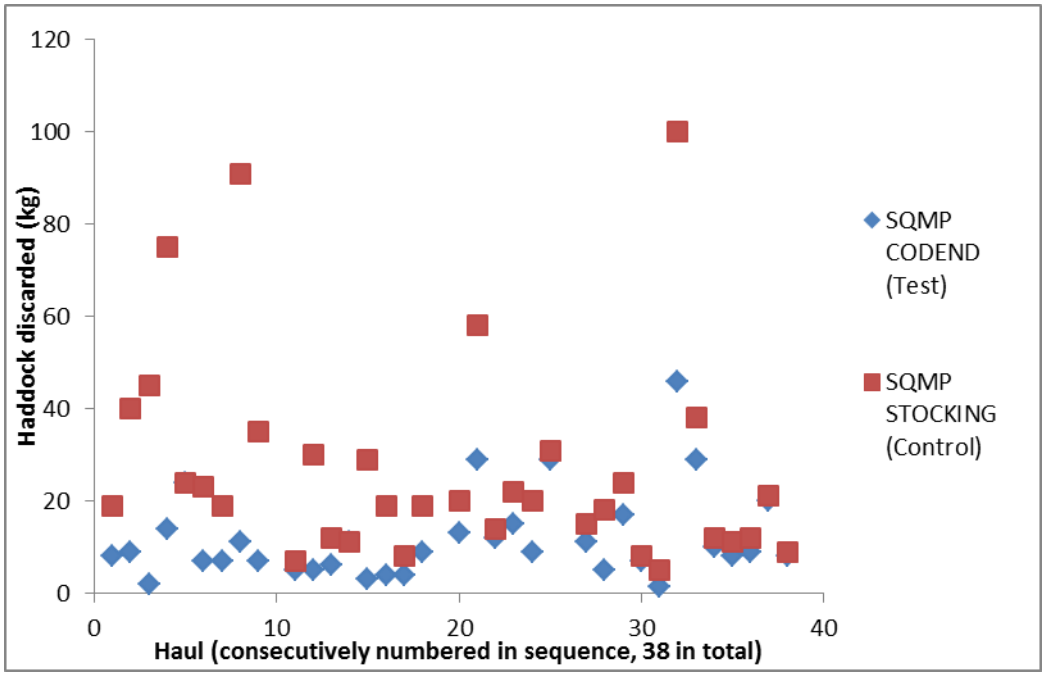

Figure 11: Unmarketable retained haddock from test gear (square mesh panel in the cod end) and control gear (square mesh panel in the stocking) for hauls from 03/06/14 to 16/06/14

Figure 12 shows the comparison of one net with two SQMPs, one in the codend and and one in the stocking, with a net with a single SQMP in the codend. The figure shows that both nets are relatively selective and there are not high levels of unmarketable fish in either. However, the net with two SQMPs was consistently more selective. In fact, for six out of eighteen hauls, one hundred percent of the haddock catch consisted of marketable fish. The maximum discard from the SQMP in the codend only was 27kg; it was 11kg for the net with two SQMPs. Overall, the net with two SQMPs was much more selective, with a 3.7 times decrease in the total weight of unmarketable catch.

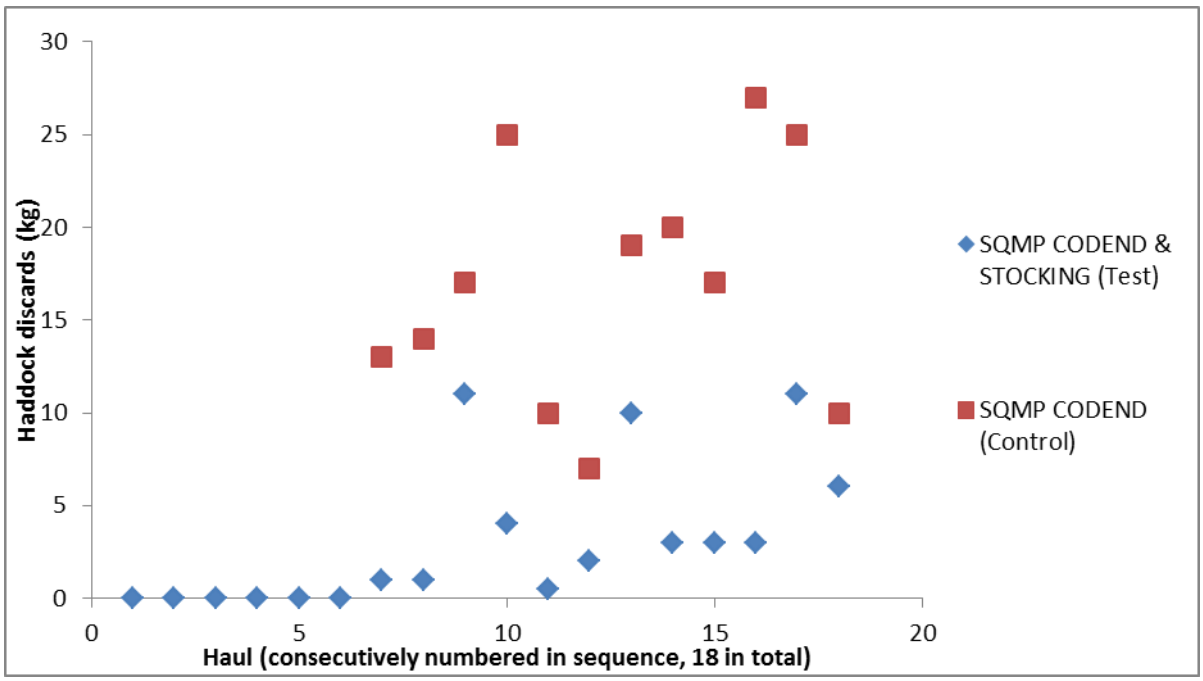

Figure 12: Unmarketable retained haddock from test gear (square mesh panel in the cod end and stocking) and control gear (square mesh panel in the codend) for hauls from 17/06/2014 to 23/06/2014

The control gear in Figure 13 is an unmodified net. This was compared with a net with two SQMPs (one in the cod end and one in the stocking). The net with two SQMPs was consistently more selective for juvenile haddock than the unmodified net which is the one currently used by other fishermen working in this area. The maximum discard in a single haul from the unmodified net was 71kg, with only 12kg for the net with two SQMPs. 312.5kg less of haddock was discarded using the net with two SQMPs, out of a total of 450.5kg for both.

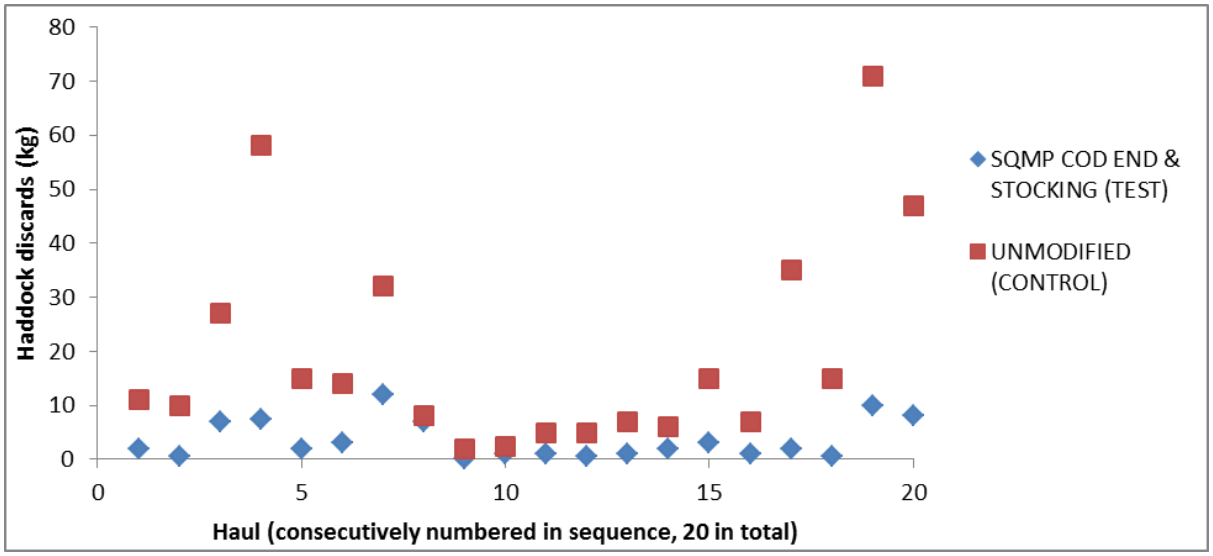

Figure 13: Unmarketable retained haddock from test gear (square mesh panel in the cod end and stocking) and unmodified control gear for hauls from 25/06/14 to 30/06/14

Figure 14 shows the use of a SQMP in the codend compared with an unmodified net. The test net (a single SQMP in the codend) was consistently more selective than the unmodified control net. The maximum discard from a single haul was 252kg for the unmodified gear and 84kg for the SQMP in the codend. Overall, there was a more than five fold decrease in the quantity of unmarketable fish caught in the net with a SQMP in the codend. This demonstrated a much greater selectivity than for an unmodified net.

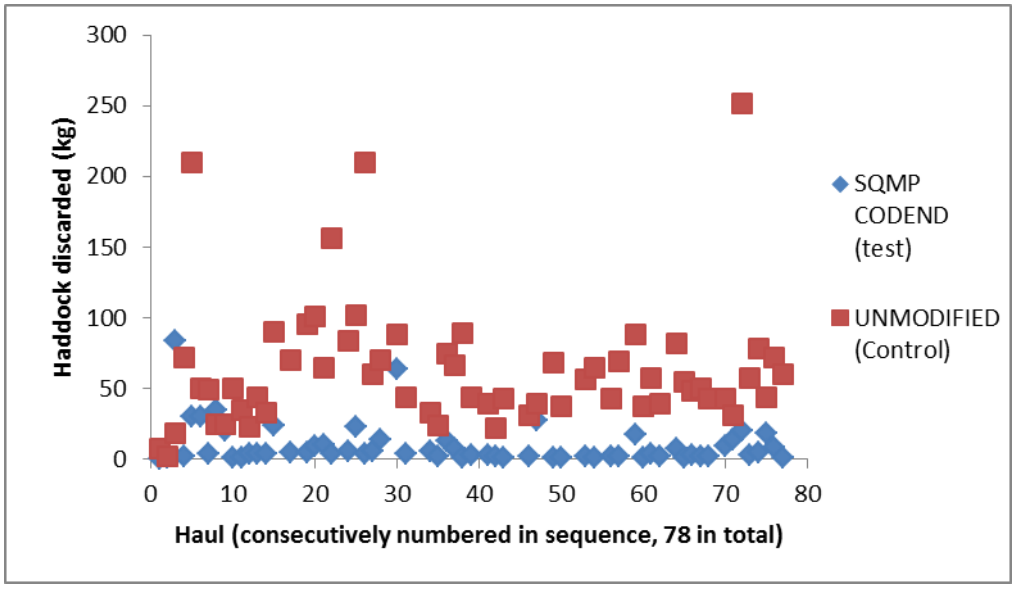

Figure 14: Unmarketable retained haddock from test gear (SQMP in codend) and unmodified control gear for hauls from 01/07/14 to 28/07/14

Figure 15 below shows the comparison between gear with a single SQMP in the stocking and gear with two SQMPs (one in the stocking and one in the codend). It

can be seen from the figure that the test net with two SQMPs was consistently more selective for juvenile haddock than the control net with a SQMP in the stocking.. The gear with two SQMPs was found to be much more selective for haddock with an almost 6 fold decrease in the catch of unmarketable haddock. The maximum unmarketable catch for a single haul was 89kg for a SQMP in the stocking only and 22kg for a net with two SQMPs.

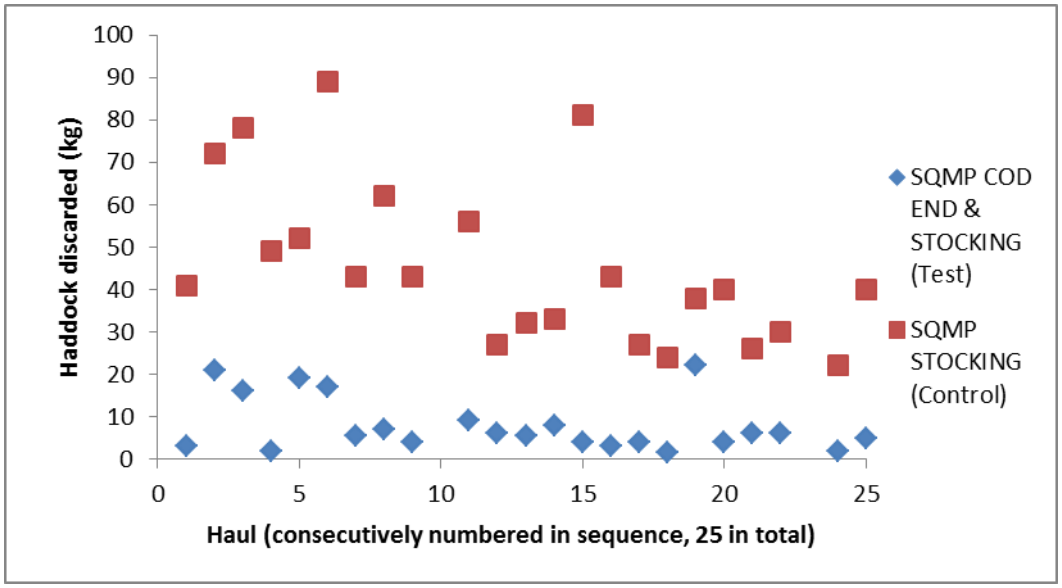

Figure 15: Unmarketable retained haddock from test gear (SQMP in codend and stocking) and control gear (SQMP in stocking only) for hauls from 02/09/14 to 15/09/14

Figure 16 below shows the comparison of the test of unmodified gear against gear with a SQMP in the stocking. It can be seen from the figure that the net with the SQMP are consistently less than for the unmodified gear. The maximum unwanted catch in a single haul was 227kg for the unmodified control and 140kg for the SQMP in the stocking. In total, there were 5549kg of discards recorded from the test net and 13255kg from the control net.

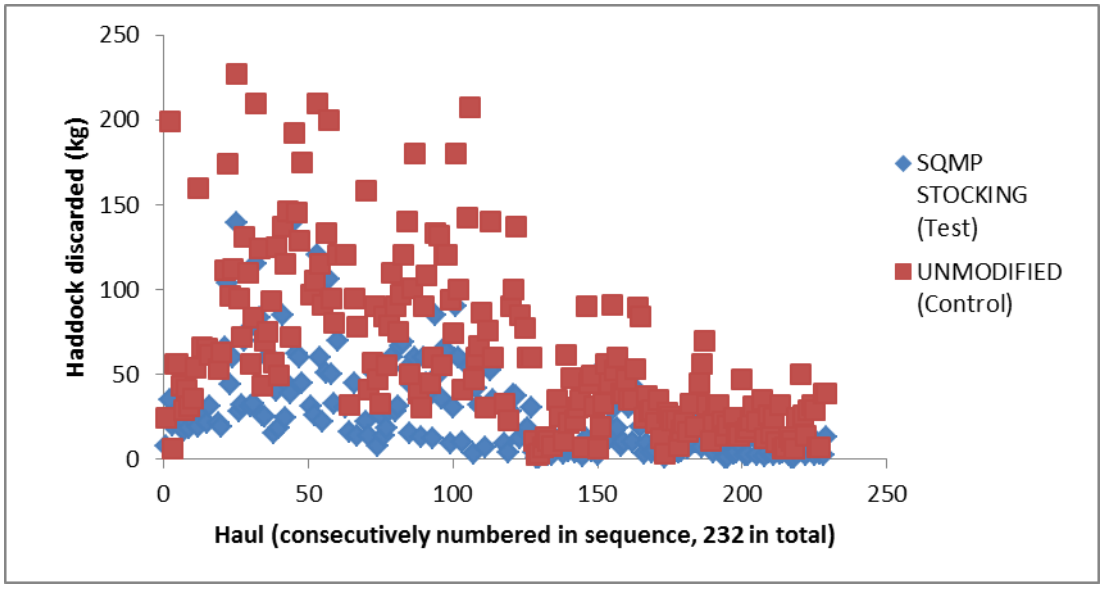

Figure 16: Unmarketable retained haddock from test gear (SQMP in stocking only) and unmodified control gear for hauls from 09/09/14 to 09/12/14

The overall picture for each modified net was compared. The net with a SQMP panel in both the cod end and the stocking was shown to be the most selective for haddock. This is shown in Table 3 below. The total weights for both retained and discarded haddock were taken from the skipper's submitted data for the entire recording period and the percentage caught with each net variation shown. As the net variations were fished for different periods of time it cannot be stated which net caught the highest volumes of fish per effort.

Gear Type	% of total haddock market weight (for full trial period)	% of total haddock retained unmarketable weight (for full trial period)	% of haddock catch which is unmarketable
SQMP cod end only	50.4	20.6	3.33
SQMP cod end and stocking	14.3	4.1	2.35
SQMP stocking only	35.2	75.1	17.34

Table 3: Retained unmarketable haddock percentage by gear type

A discard rate was calculated for haddock which were returned to the sea. As haddock were a Fully Documented Fishery (FDF) species, this is contrary to the scheme terms and conditions. The low levels of discards as a percentage of the total catch, as shown in Table 4 below, suggest that any discards are likely to be accidental. The estimation method used is likely to provide an overestimate of

discard quantities as weight calculations assume fish are just below the minimum landing size, whereas in reality there are likely to be a range of smaller sizes.

Species	No. hauls fished	No. hauls sampled	Discard quantity – raised (kg)	Discard Rate %
HAD	522	33	162.9	0.17

Table 4: Haddock discard rate at sea

A comparison was undertaken between video estimates and skipper estimates for all haddock retained and recorded, both marketable or unmarketable. The plotted values are shown in Figure 17 with a regression line showing the relationship. The R-squared value was 0.9, showing a strong correlation between the two estimates.

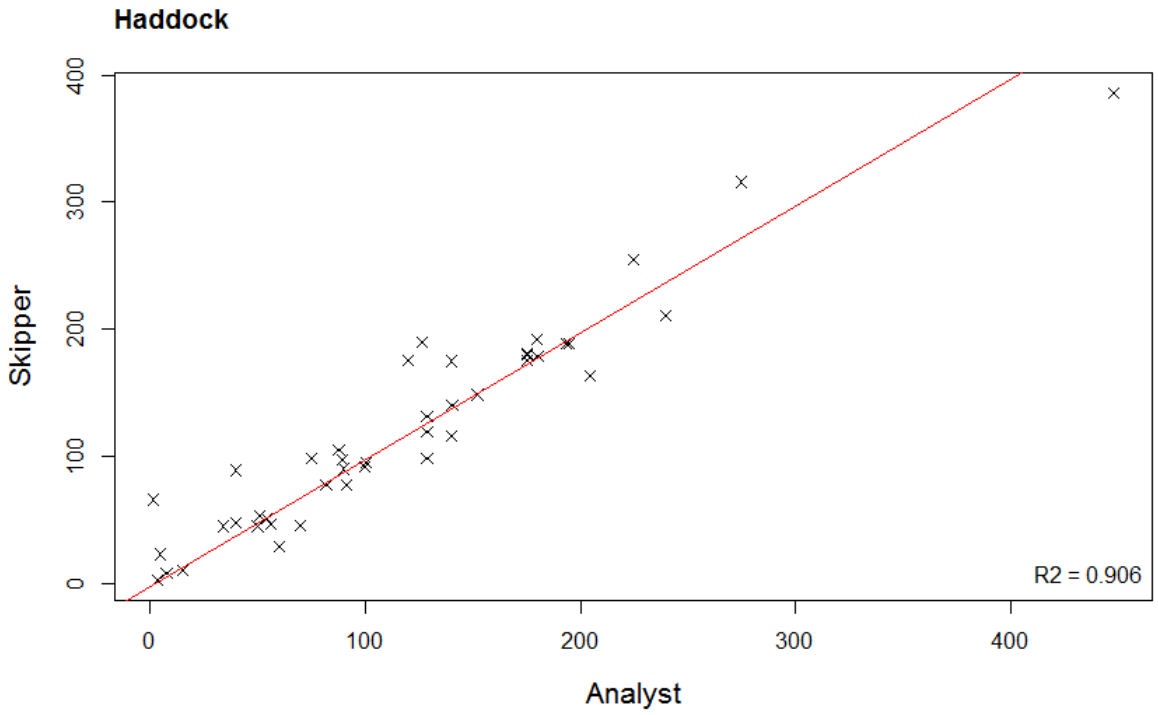

Figure 17: shows the correlation between the video analysis estimates and the skippers records for Haddock.

Figure 18 below shows the relationship between skipper's and video analysis estimates for marketable and unmarketable retained haddock. The dotted lines show the full range of values. The coloured boxes denote the range from the lower 25 percent of values (1st quartile) to the upper 25 percent (3rd quartile). The thick vertical line within the coloured boxes gives the mean value for each dataset.

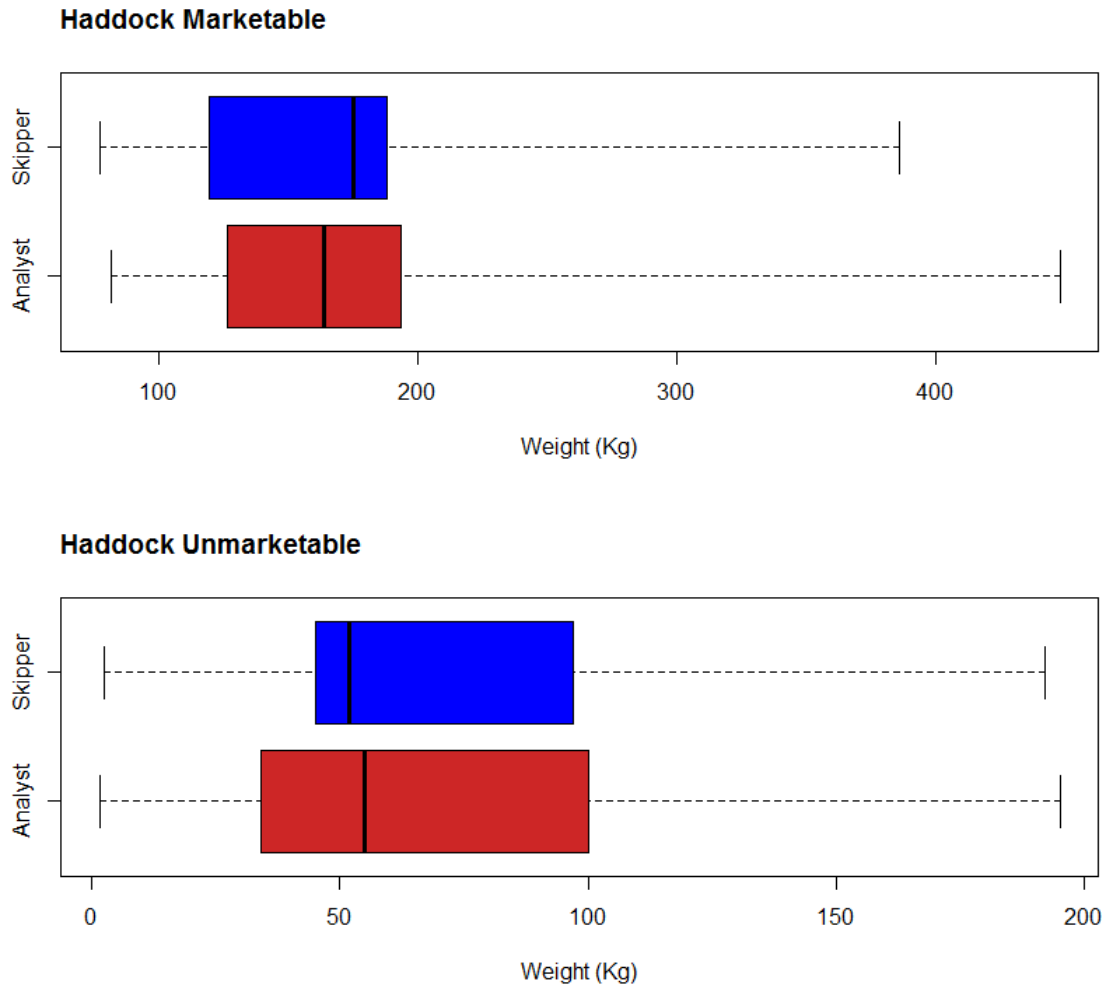

Figure 18: shows a comparison between the Haddock recorded by the skipper and from video analysis for both Marketable and Unmarketable.

Finally, the catches of retained unmarketable haddock for the study period were compared. The skipper's records show that when the vessel did fish further to the west, the amount of unmarketable haddock catch was nearly 50% higher than it was further east. The figures are shown in Table 5 below.

Statistical rectangle	28E4	28E3
% of unmarketable haddock	31.23	45.59

Table 5: Percentage of undersized Haddock caught in the two statistical areas fished

4.3. Megrim catches

The quantity of retained unmarketable megrim for different types of net were calculated using skipper estimates. The nets with either a SQMP in the cod end or two SQMPs were the most selective, as shown in Table 6 below.

Gear type	% of total megrim market weight (for full trial period)	% of total megrim retained unmarketable weight (for full trial period)	% of megrim catch which is unmarketable
SQMP cod end only	48.1	27.6	2.3
SQMP stocking only	15.8	9.7	7.0
SQMP cod end and stocking	36.1	62.6	2.5

Table 6: Megrim retained unmarketable catch rate by gear type

In addition, a discard rate for non-retained megrim was calculated from video analysis. That is, the number of megrim which ended up going back into the sea. This discard rate was much lower than the retained unmarketable. This suggests that the skipper and crew were in compliance with the scheme and that any discards were accidental.

Species	No. hauls fished	No. hauls sampled	Discard quantity – raised (kg)	Discard Rate %
LEZ	522	33	285.5	0.50

Table 7: Megrim discard rate at sea.

A comparison was undertaken between video estimates and skipper estimates for all megrim recorded, both retained marketable and retained unmarketable. The plotted values are shown in Figure 19 with a regression line showing the relationship. The R-squared value was 0.94, showing a strong correlation between the two estimates.

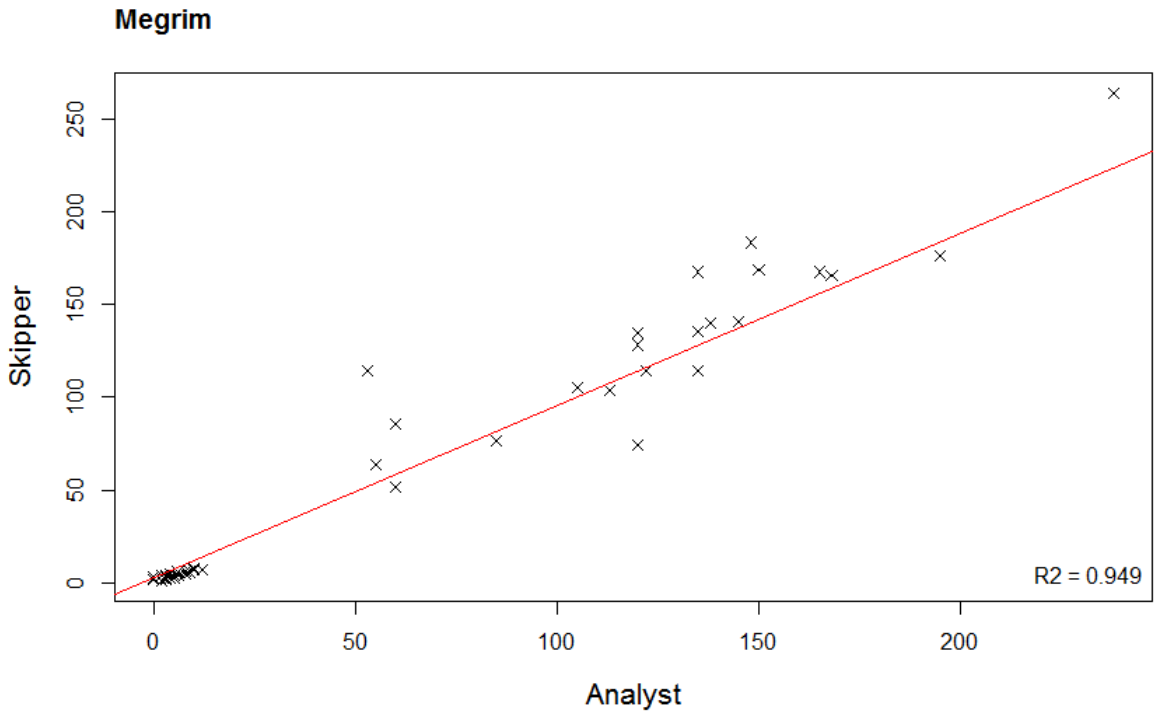

Figure 19: shows the correlation between the video analysis estimates and the skippers records for Megrim.

Figure 20 shows the relationship between skipper's and video analysis estimates for retained marketable and unmarketable megrim. The dotted lines show the full range of values. The coloured boxes denote the range from the lower 25 percent of values (1st quartile) to the upper 25 percent (3rd quartile). The thick vertical line within the coloured boxes gives the mean value for each

dataset.

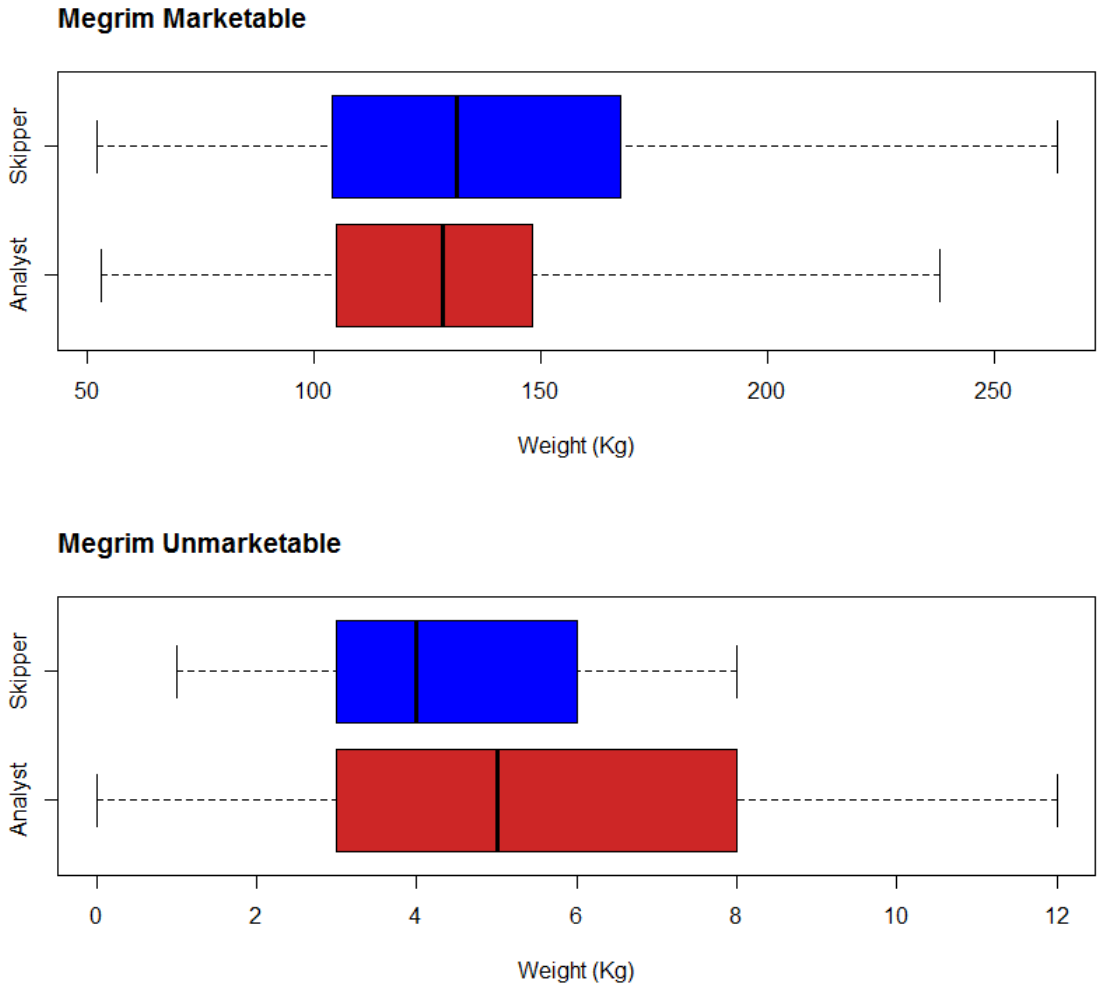

Figure 20: shows a comparison between the Megrim recorded by the skipper and obtained from video analysis for both Marketable and Unmarketable.

4.4. Anglerfish discards

The quantity of landed marketable and retained unmarketable anglerfish for different types of net were calculated using skipper estimates. There did not appear to be any significant difference between net types as shown in Table 8 below. It is unlikely that, due to the body shape of anglerfish, the use of SQMP would have any impact on the selectivity of a net.

Gear type	% of Market weight (kg)	% of Retained unmarketable rate (kg)	Retained unmarketable discard rate (%)
SQMP cod end only	27.5	7.3	0.1
SQMP stocking only	60.6	85.2	0.6
SQMP cod end and stocking	11.7	7.3	0.3

Table 8: Anglerfish discard rate for retained unmarketable fish by gear type

The discard rate for anglerfish was calculated from the CCTV audit. That is, the number of anglerfish which ended up going back into the sea. The discard rate is shown in Table 9

Species	No. hauls fished	No. hauls sampled	Discard quantity – Raised (kg)	Discard Rate %
ANF	522	33	103.6	0.17

Table 9: Anglerfish discard rate

A comparison was undertaken between video estimates and skipper estimates of all anglerfish, both marketable and unmarketable. The plotted values are shown in Figure 21 with a regression line showing the relationship between the two. The R-squared value was 0.9, showing a strong correlation between the two estimates.

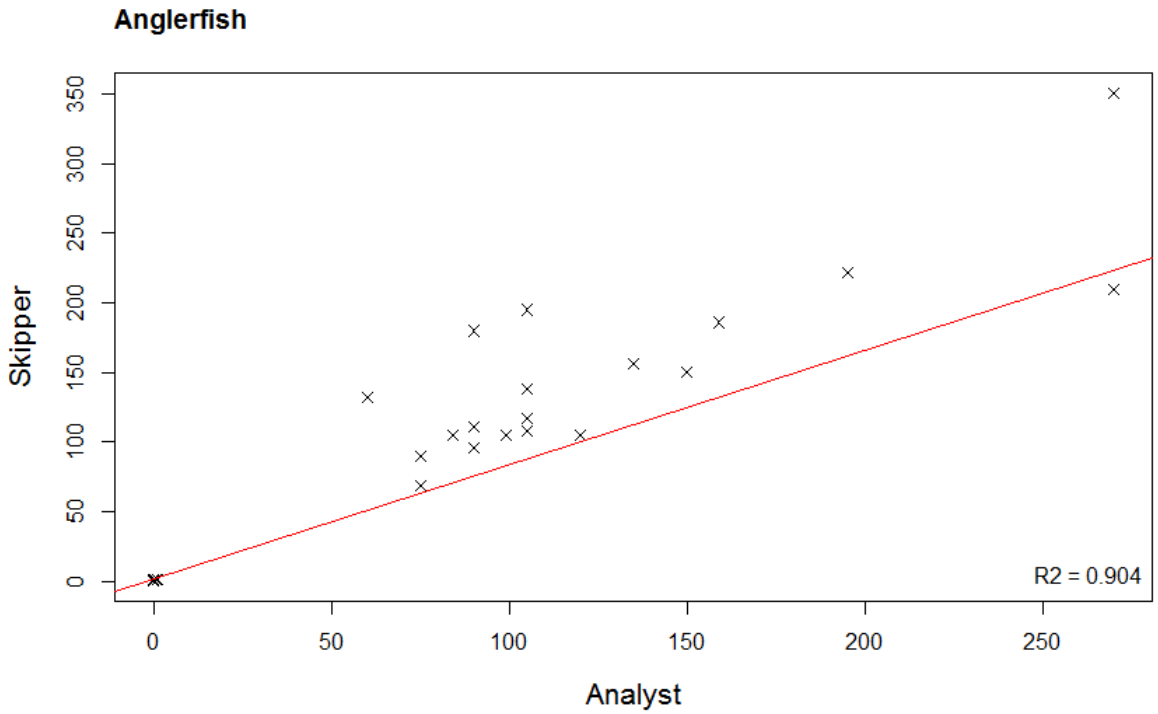

Figure 21: Correlation between video analysis estimates and skipper's records for Anglerfish.

Figure 22 below shows the relationship between skipper's and video analysis estimates for retained marketable and unmarketable haddock. The dotted lines show the full range of values. The coloured boxes denote the range from the lower 25 percent of values (1st quartile) to the upper 25 percent (3rd quartile). The thick vertical line within the coloured boxes gives the mean value for each dataset. There were insufficient catches in order to produce a graph for the video analysis estimate of unmarketable anglerfish due to the fact that numbers and quantities of unmarketable anglerfish were so low.

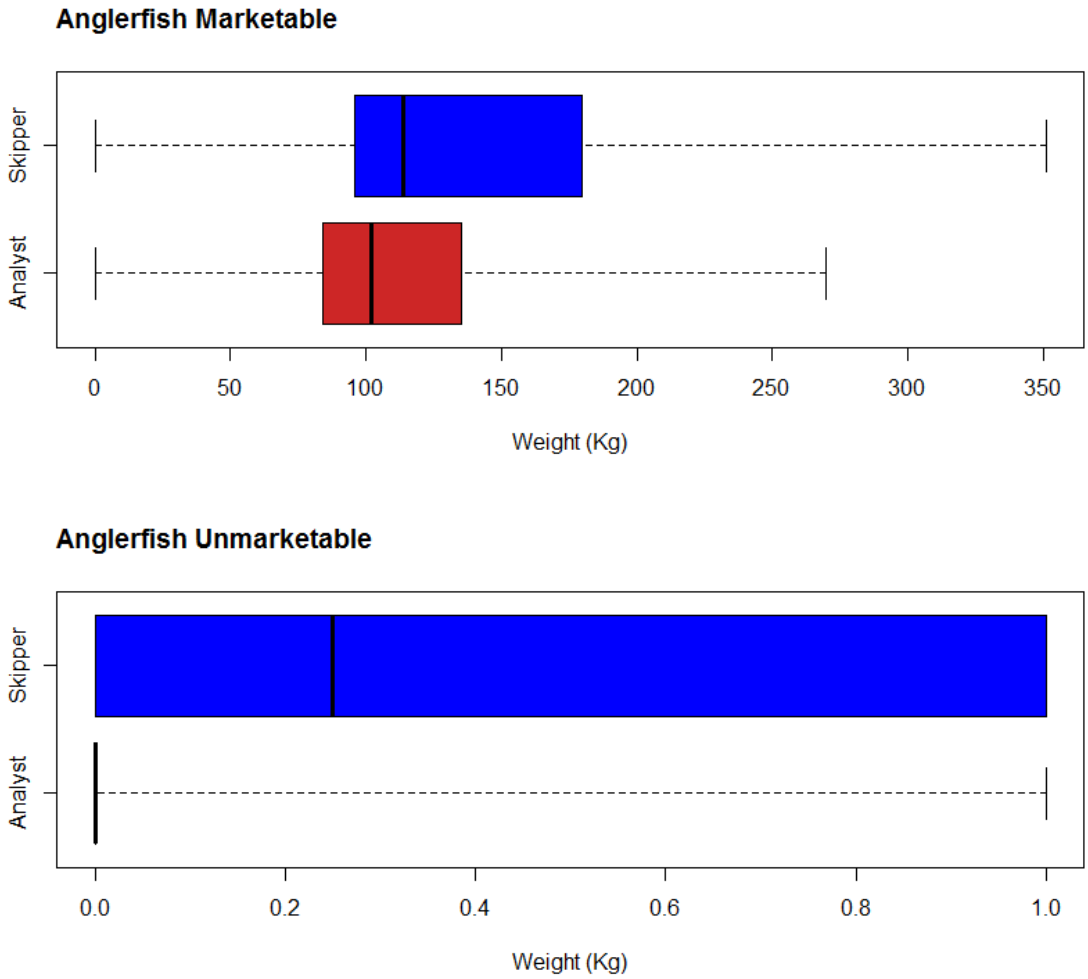

Figure 22: Comparison between the Anglerfish recorded by the skipper and video analysis for both Marketable and Unmarketable.

4.5. Boarfish catches

The skipper was unable to record any data for hauls with large quantities of boarfish due to handling issues. The occurences where the skipper had recorded a large haul of boarfish were examined for any pattern in this occurring. In addition, for one randomly selected haul with a significant quantity of boarfish, the the number of boarfish were counted in order to give an estimate of quantity. In that haul, there were a total of 2784 boarfish, estimated to weigh 108.5kg. This was calculated using the average weight of 0.39g found using the mean male and females weights found in a recent study by White *et al* (2010).

A screenshot from this haul is shown in Figure 23 below. The boarfish can cover most of the belt and more importantly can block up the net while fishing which is likely to increase the catch of undersized fish of other species.

Figure 23: Example of crew sorting a haul with a large boarfish catch

Figure 24 shows the times at which hauls containing large quantities of boarfish were recorded by the skipper. In total, there were twenty three occasions on which these hauls were recorded. Figure 23 shows that there is a clear pattern in that 70% of these hauls were between midnight and 8a.m. and 96% were between 8pm and 8am. The haul records were also examined for any evidence of seasonality, but no clear pattern was found.

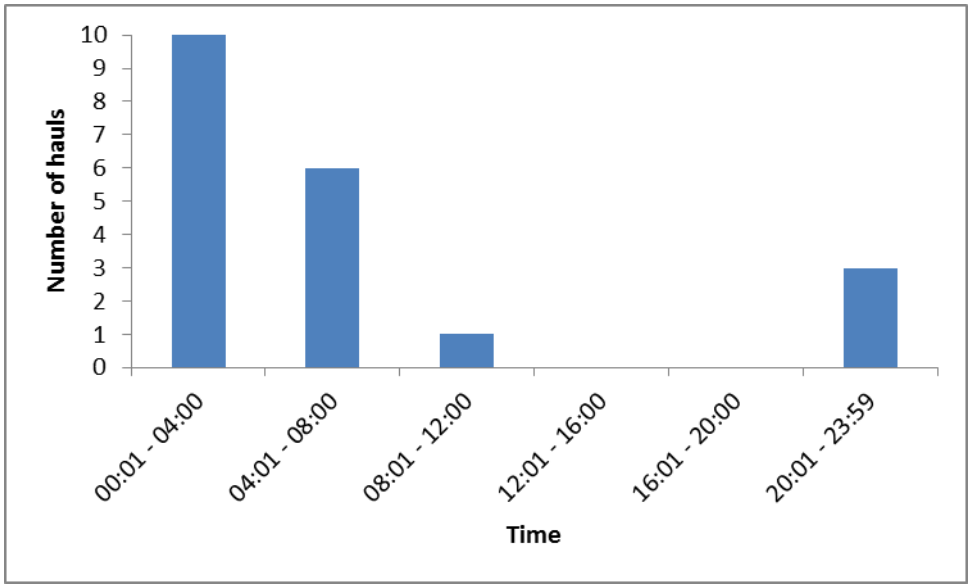

Figure 24: Hauls recorded by skipper as having large quantities of boarfish, shown by time of haul

4.6. Squid catches

The total monthly catch of squid was consistently higher in unmodified gear compared to modified gear (with a square mesh panel in the stocking) as shown in Figure 25 below. The actual percentage difference in the weight of catches is shown in Table 10 along with the percentage difference in income calculated using average landing prices for each month. Overall, it can be seen that the use of the modified net modified with the square mesh panel in the stocking has the

unintentional side effect of being less efficient at catching squid. This also reduces the potential income from squid landings.

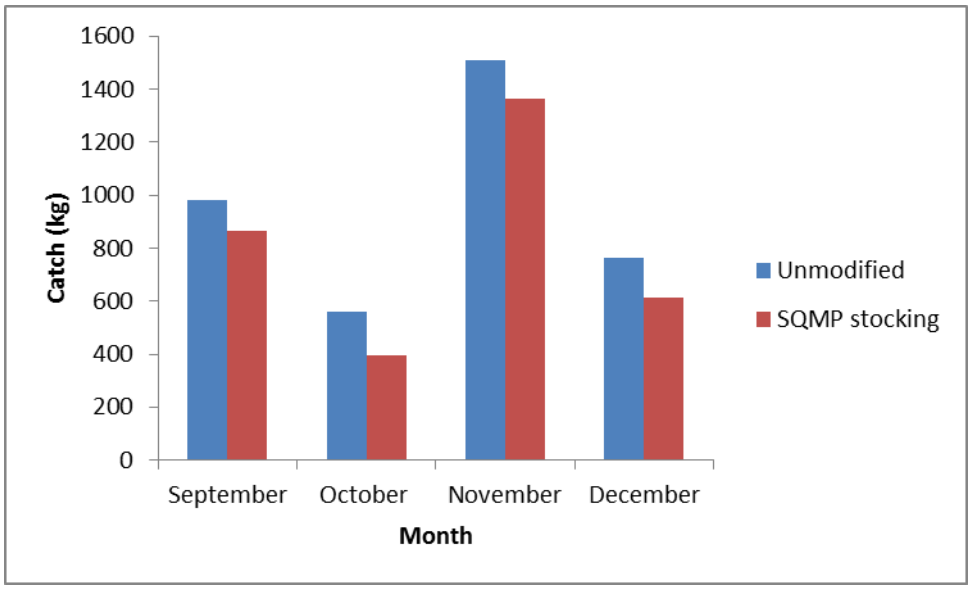

Figure 25: Difference in catch of squid in unmodified net and net with square mesh panel (SQMP) in stocking

Month	Catch unmodified	Catch SQMP stocking	Percentage increase in catch for unmodified	Average price per kilogram (£)	Amount of potential loss in earnings using modified gear (£)
September	979.5	865	12	4.5	515.20
October	559	397.5	29	4.9	791.35
November	1511	1361	10	3.45	517.50
December	761	611.5	20	2.64	394.68

Table 10: Difference in catch of squid and income with unmodified net and net with square mesh panel (SQMP) in stocking

In addition, a histogram of squid catches over time was plotted, shown in Figure 26. Although the catch in the unmodified gear remains consistently higher, there is a clear diurnal pattern. Catches are higher in daylight hours and lower during the night.

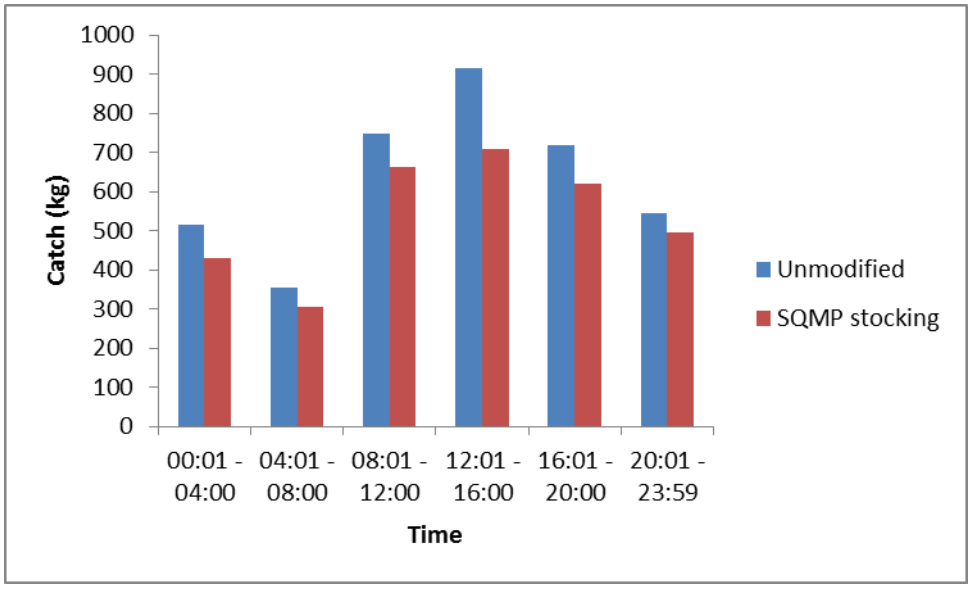

Figure 26: Changes in squid catch over time using different gears

4.7 Data confidence

As part of the data analysis process, a confidence level was given to each haul. Out of a total of 33 hauls analysed, 23 were assigned a confidence level. This is because this process was introduced during the year when some analysis had already been undertaken. The confidence levels assigned to the 23 hauls are shown in Table 11 below.

Confidence level	No. of hauls	Percentage of hauls
High	4	17.4
Medium	12	52.2
Low	7	30.4
Unusable	0	0

Table 11: Video analysis confidence in each haul.

It should, however, be explained that the data confidence picture is not as simple as it may appear from Table 11. On fifteen of the low and medium confidence hauls the reason was due to being unable to clearly see the undersized retained megrim and anglerfish as it was put into the fishroom, thus making weight estimates much harder. However, it was much easier to see the haddock proportion of the catch for these same hauls and a high confidence level could have been attributed if its was that species alone. The REM system was originally set up for analysing haddock catches and discards only, therefore, some adjustment may be necessary to improve megrim and anglerfish data.

5. Discussion and conclusions

5.1 Gear selectivity in the 2014 trial

Unwanted haddock catches in unmodified nets showed a strong seasonal and temporal pattern. The proportion of undersize haddock in the catch increased throughout the year. There was no clear change in discard rates between day and night in spring and summer. However, there was a peak in nocturnal discard rates in autumn. Work by Engás *et al*. (1988) found a significantly higher proportion of smaller haddock (less than 40cm) in night time catches using demersal gear. It was suggested that this was due to differences in vertical migration.

The pattern of squid catches indicates that for both gear types used squid is more available during daylight hours. Cephalopod species such as squid show a diurnal migration pattern where they are deeper in the water column during the day and migrate towards the surface at night (Wearmouth *et al*., 2013). Therefore, for a vessel such as this which is fishing demersally, it would be expected that the availability of squid to the gear would increase during the day when squid tend to be closer to the bottom.

Catches of undersize haddock in unmodified nets showed a strong peak during night time in the autumn which corresponds with the squid season. The results from the squid analysis show that catches peak during daylight hours. The skipper of the study vessel has reduced fishing at night due to high catches of juvenile haddock. These results suggest that this change in behaviour may have dual benefits, particularly for those vessels with more restricted haddock quota.

The net with two SQMPs, one in the cod end and one in the stocking, and the reduced cover was the most selective for haddock. The lowest weight of unwanted haddock consistently came from this gear type. If one square mesh panel only was used, a greater reduction in unwanted catch was achieved by putting it into the cod end (as compared to the stocking). This is in line with the results of our 2013 study where two net combinations with two SQMPs had the greatest impact on reducing juvenile haddock catches (Roberts and Course, 2014).

For megrim, there was a significant increase in unwanted catch when using a net with a SQMP in the stocking only. However, there was minimal difference in selectivity for nets with either two SQMPs or one in the cod end alone. Megrim are soft-bodied and unwanted catch is mostly comprised of damaged fish. As such, there is unlikely to be an exemption from the Landing Obligation on the basis of proven high survival, although there may be a case for a de minimis discard allowance. For anglerfish, unwanted catch was minimal with any of the three test net configurations. Therefore, considering data for all three Fully Documented Fishery (FDF) stocks, the net with two SQMPs is the best in terms of minimising discards.

There is however one particular issue with all net configurations. Large catches of boarfish were occasionally taken suggesting that the nets were not fully selective for these. The skipper reported that the vessel did not wish to catch these as they were difficult to handle (small and spiny fish), and there is no available market for them

(pers. Comm. 08/10/15). A study by Campos and Fonseca (2004) found that a greater percentage of boarfish escape from gear with SQMPs when mesh size was increased from 70mm to 100mm. However, the boarfish did not seem to show active escape behaviour to the same degree as other fish such as whiting, suggesting that more complex measures would need to be put in place to encourage boarfish to escape the net (Campos and Fonseca, 2004). Therefore, the use of SQMPs alone, as used here, is unlikely to be sufficient to reduce boarfish catches significantly.

When the boarfish issue was examined further, it became clear that the large concentrations of boarfish were caught primarily between midnight and 8am. Therefore, avoiding fishing at night has the potential to greatly decrease the amount of boarfish caught. Boarfish are a stock for which there is significant uncertainty, both in terms of stock assessment and species biology (Stange, 2016 [early access]). From the start of 2016, boarfish have been subject to the landing obligation for vessels using pelagic gear and subject to de minimis provisions. However, boarfish will not be subject to the demersal landing obligation until 2019. Given the high levels of uncertainty around the stock and the potential for high levels of discards in demersal fisheries, there is a need to consider the implications of unintended catches of this species.

5.1.1. Impact of the use of selective gear – skipper's comments

The report's findings were presented to one of the two vessel skippers. He was asked to provide us with his comments as to what impact the trial had had on his vessel and business. Overall, the skipper felt that the results of our analysis concurred with what he had witnessed on a first-hand basis. However, he did also highlight some issues that the vessel had had in trying to comply with the scheme.

The skipper was clear that the avoidance of fishing at night was solely to avoid large catches of juvenile haddock and therefore remain within the terms of the scheme. The skipper felt that this benefit did not outweigh the perceived significant economic loss from megrim, anglerfish, gurnard, whiting, cuttlefish, sole and plaice night time catches. This was due to the fact that, in his opinion, catches of these species do not vary significantly diurnally. The business had found it difficult to compensate for this 'loss' of income, particularly with the decrease in the UK haddock quota.

In terms of the haddock catch, the skipper also felt that the use of reduced cover nets was important. He was of the opinion that using reduced cover nets was useful in reducing haddock catch. However, he also felt that the loss was mainly larger, economically viable, haddock. The 2013 report (Roberts and Course, 2014) partly supported this assertion, finding a total haddock catch reduction of 37% from cover reductions. The report however does not break this down into lengths. There is no comparative data available for this, the 2014, report as only reduced cover nets were used.

5.2 Comparison of 2014 data with 2013 report

The 2013 report found similarly to the 2014 report that the net with a reduced cover and two SQMPs was the most selective for haddock with a discard rate of only 2.35%. The unmodified gear in 2014 consistently had much higher discard rates for

haddock, particularly in autumn and winter where discard rates were always higher than ten percent and as high as a maximum of 65.25% (Figure 8 of this report). Therefore, the most selective gear is still leading to a vast reduction in the catch of undersized haddock.

The 2014 report has shown that avoiding fishing at night will also reduce catches of juvenile haddock and there is clear evidence of the skipper doing so. In addition, the vessel fished closer to port and less often in the west during 2014 compared to 2013 (as shown in Figure 27 below). The verified skipper's records show that when the vessel did fish further to the west in 2014 the amount of unmarketable haddock catch, i.e. juvenile haddock was nearly 50% higher than it was further east.

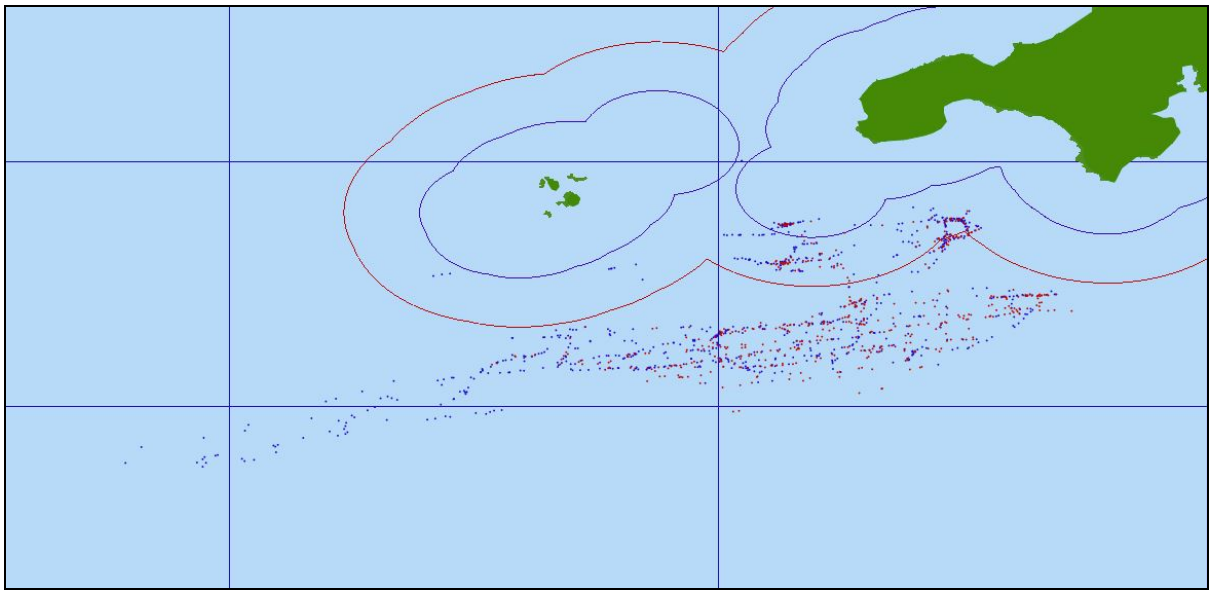

Figure 27: The hauls from the vessel, 2013 are shown in Blue and 2014 are shown in Red.

Using evidence from both the 2013 selectivity (Roberts and Course, 2013) and 2014 reports, measures taken by the skipper to reduce haddock discards are having a clear and positive effect. As such, it should be considered further as to whether some these measures (e.g. use of gear with proven improved selectivity) could be implemented across more of the fleet.

Although there were clear positive results from the continuing reduction in juvenile haddock caught, the increase in the discards still needs to be considered. Looking at the seasonal variation shown in Figure 8, where discards increased each season, it is reasonable to assume that the slight discard increase from the highly selective gear is due to what appears to be a rapidly increasing availability of juvenile haddock throughout the year. This is in line with ICES advice which predicted that heavy discarding will occur in 2014 and 2015 due to a strong 2013 year class becoming available to the fishery (ICES, 2014a).

The 2013 selectivity report (Roberts and Course, 2013) focused primarily on haddock, and did not cover any other species in detail. It did however report that the skipper felt that using more selective nets did not result in a significant loss of

anglerfish and megrim catches. This report has not confirmed this assertion. However, it has shown that the most selective net combination for haddock also reduced megrim (mostly damaged fish) discards and that all test nets had a low amount of anglerfish discards. Therefore, the use of the more selective nets by this vessel could also benefit these other commercial species by reducing discarding.

In terms of the use of REM, both the 2013 REM report (Roberts *et al*., 2014) and this report concur that it has proven a useful and efficient tool. REM has been used successfully in both reports to validate skipper's records with a high correlation between these and observer estimates. In addition, the REM set up allows the complete processing operation to be reviewed. This allows estimates to be made which are independent of those from the skipper. REM can provide more extensive cover of fishing operations and is relatively cheaper than using observers (Kindt-Larsen *et al*., 2011). Our study confirms this picture of REM as a cost-efficient and accurate tool to verify skipper's estimates.

In terms of data confidence, the REM footage, as might be expected, was found to provide better confidence for the analysis of the species for which it was set up (i.e. haddock). Using the system for other species such as megrim and anglerfish still produced good correlation with skipper's results but the analyst had less confidence. There are two potential solutions to this. Firstly, if in future we are aware that multiple species are required to be monitored, the system set-up will be designed with this specifically in mind. Secondly, the system onboard the test vessel is now five years out of date and technology has moved on significantly. The system used in this trial is only able to accommodate four cameras, three of which would have to be analogue. Newer systems can have up to eight separate cameras, all of which may be digital. Therefore, investment in new systems will provide much better coverage of fishing operations and better quality footage enabling analysis of multiple species (or even the full catch) with confidence. In addition, newer systems given their better data potential have far greater possibilities for providing scientific data.

6. References

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ICES. 2014b. Advice June 2014, Celtic Sea and West of Scotland Anglerfish (*Lophius budegassa*) in Divisions VIIb-k and VIIIa,b,d

ICES. 2014c. Advice June 2014. Celtic Sea and West of Scotland Anglerfish (*Lophius piscatorius*) in Divisions VIIb-k and VIIIa,b,d

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Annex I – Excerpt from 2014 scheme application pack setting out available quota

Additional quota

At the 2014 total allowable catches (TACs) and quota negotiations the UK has negotiated for an additional percentage of quotas for a range of species specifically for use in this catch quota trial. In 2014, an additional 1% of UK quota for VII megrim, hake and anglerfish has been negotiated, along with an additional 5% for Celtic sea haddock (VIIb-k). Alternative incentives may be possible by utilising scientific quota(s).

Additional quota will be allocated to vessels based upon the Scientific, Technical and Economic Committee for Fisheries (STECF) approved UK discard rates as shown in Table 1. Furthermore, any additional quota allocated to vessels participating in this scheme will be based on **75%** of what might typically be discarded from the current landings based quota regime. Therefore, under this catch quota scheme you are asked to bid for up to the amount which you see regularly discarded from your vessel, bearing in mind that you are limited to a maximum of 75% of the discard rate.

Table 2 describes the maximum percentage (of previous years' landings, less any 2013 catch quota allocation) incentive on offer for the various stocks and gear types. If you want to get an initial estimate of the maximum quota receivable please contact MMO or use the calculation provided in Annex B (back page) of this document.

The 2012 discard rates for proposed Western water stocks by gear type are set out in Table 1. This shows the proportion of total catch that is assessed to be discarded.

Table 1: Western waters 2012 discards rates

Gear	ANF	HAD	HKE	LEZ
Sample area	7b-k (xd)	7b-k(xd)	7b-k (xd)	7b-k (xd)
ALL	9.2%	39.0%	9.6%	14.8%
BT2	27.8%	43.3%	16.5%	21.1%
TR1	12.3%	58.0%	15.8%	23.5%
TR2	17.45%	76.89%	33.4%	30.8%

Table 2: South West maximum additional quota by stock based on 75% discard rate. Subject to the availability of quotas these percentages can be used to calculate individual vessel maximum allocations as a proportion of landings made in 2013.

Gear	ANF	HAD	HKE	LEZ
	VII	VIIb-k	VII	VII
BT2	29%	57%*	15%	20%

TR1	11%	104%*	14%	23%
TR2	16%	249%*	38%*	33%*

* 30% if capped.

Definition of gear codes

- TR1 equal to or larger than 100mm
- TR2 equal to or larger than 70mm and less than 100mm
- BT2 equal to or larger than 80mm and less than 120mm

The additional quota available will be allocated on the basis of a vessel's track history of landings. Actual additional quota receivable will be based on a proportional allocation for the total duration of the trial.

Applicants are asked to submit a bid, up to the percentages shown in Table 2, required for them to operate catch quota management. Contact MMO about how to calculate the additional quota. This bid should be based on what you have observed your vessel discarding for the stock for which you are bidding for catch quota, the gear type in use and a plan to reduce fishing mortality.

Please note that all catches of catch quota stocks (including undersized fish) will count against the vessel's quota and must be landed. No discards of those stocks are permitted.

Annex II – Camera Working and Performance Definitions

	Complete	Incomplete	No video data
Camera Working	Video is recorded for entire event	Video present intermittently for fishing event	No video data for entire fishing event

Camera Performance	View	Clean	Focused	Lighting
High	Camera view shows area necessary for all species identification and or catch handling.	No water spots, moisture, scratches or debris on the camera dome that interfere with species identification or view of catch handling.	Focus is sharp and in the right area.	Light levels are ideal for species identification and view of catch handling
Medium	Camera View is a bit off but shows enough area for adequate species identification and following catch handling.	Water spots, moisture, scratches or debris on the camera dome make it challenging to identify all species and watch all catch handling but view is adequate.	Focus is adequate but identifying fish species is occasionally challenging as is following catch handling.	Lighting is adequate. Glare or shadow occasionally make it challenging to identify species and follow catch handling during the majority of the event.

Camera Performance	View	Clean	Focused	Lighting
Low	Camera View shows a lot of "useless" area, making catch handling difficult to follow or unable to identify all species. View should be readjusted.	Water spots, moisture, scratches or debris on the camera dome obscure several areas of camera view making species identification and catch handling challenging throughout most of the event.	Focus could be greatly improved. Identifying most fish species is challenging. Difficult to follow catch handling.	Glare or shadow makes it difficult to positively identify species and follow catch handling for the majority of the event.
Unusable	Camera view does not show enough or any of the area necessary to identify species and follow catch handling.	Water spots, moisture, scratches or debris on the camera dome block large areas of camera view, making species identification and following catch handling impossible.	Focus is so poor that species cannot be identified.	Camera image appears over exposed 'washed out' by light glare or pitch black from no light, unable to assess anything in picture.
Unknown*	?	?	?	?

* 'Unknown' refers to the fact that this cannot be assessed because the status is unknown. It is mostly used for when a particular camera is broken and showing a blank screen.