Centre for Environment Fisheries & Aquaculture Science

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English Fisheries Data Enhancement Project

Applying Remote Electronic Monitoring to improve estimates of commercial catches - a focus on haddock 7.b-k caught in otter trawl fisheries

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Example of the view using REM of the catch sorting area used to validate the skipper's estimates of catches

Executive Summary

The reformed EU Common Fisheries Policy (CFP) came into force on 1st January 2014 with a ban on discarding (so-called Landing Obligation) for certain regulated species. This discard ban is being phased in, and will cover all quota stocks in EU waters by January 2019. It is anticipated the move from a landing-based quota to a catch-quota system will motivate changes in fishing behaviour and practices, so that unwanted catches should be avoided. The CFP allows for quota adjustments (so-called uplift) to be made for those stocks under the Landing Obligation (LO), recognising fish that otherwise would have been discarded will now to be landed. These adjustments are being made based on the estimated discards of the concerned stocks, which are derived from a sample of less than 2% of all fishing operations, and then extrapolated to the fleet level. Because estimates may not be representative of true discard patterns, the fishing industry have claimed that discard data deficiencies are the highest risk in the transition to the LO, and insufficient uplift in quota could stop vessels from fishing (Catchpole *et al*., 2017a).

Based on consultations with the fishing industry, it is considered that the haddock ICES 7.b-k stock is the most likely choke species for English southwest otter trawl fisheries under the implementation of the Landing Obligation. There is a widespread perception from the fishing industry that there is a mismatch between the quota (TAC) and catches of haddock in the Celtic Sea and Western Channel, and this is generating a high level of discards, which are thought not to be reflected in official discard estimates. The extension of the Landing Obligation to haddock 7.b-k is considered to cause a choke point, and a cessation of fishing activity, because current estimates of discard rates are not accurate. These concerns led to the initiation of a series of meetings between UK government, enforcement agents, scientists and the fishing industry which started in March 2017. At these meetings it was agreed that there was benefit in collecting additional data on catches and discards in this fishery to inform on future management options.

This report describes the methods that have been developed and applied to deliver an enhanced data collection programme, specifically designed to generate more reliable data on discards of haddock in the Celtic Sea English otter trawl fishery. The methods are intended to deliver the following aims:

- Generate robust discard estimates an enhanced data collection programme for the English southwest otter trawl fishery, with a specific focus on haddock;
- Evidence the potential to avoid catching haddock through modified fishing;
- Compare new estimates with those generated from ongoing data collection programmes;
- Make these data available to fisheries managers and scientists to inform on potential improvements to discard estimates, stock assessments and quota uplift;
- Develop the application of Remote Electronic Monitoring (REM) systems to enable an assessment of modified trawl designs and generate estimates of catch and discard levels.

Preliminary data are presented to illustrate the information that will be generated and the outputs that can be produced. The preliminary results indicate high discard rates of haddock, where 80% of the haddock total catch is being discarded. This is based on skippers' results, validated by independent analysis of Remote Electronic Monitoring data, and is consistent with the ongoing Cefas Observer programme. The results of the programme will be available no later than October 2018.

Introduction

Background

The reformed EU Common Fisheries Policy (CFP) came into force on 1st January 2014 with a ban on discarding (also known as the Landing Obligation) for certain regulated species. This discard ban is being phased in, and will cover all quota stocks in EU waters (and those with a Minimum Landing Size in the Mediterranean) by January 2019. The principle of the Landing Obligation (LO) is to provide a limit on total catch, whereby all catches of regulated species are landed, and once any of the quotas associated with a fishery are reached, fishing activities cease. It is anticipated that the move from a landing-based quota to a catch-quota system will motivate changes in fishing behaviour and practices, so that unwanted catches should be avoided.

The CFP allows for quota adjustments to be made for those stocks under the Landing Obligation, recognising fish that otherwise would have been discarded will now to be landed. These adjustments are being made based on the contribution by those fleets under the Landing Obligation to total catches and discards of the concerned stocks. Estimates of discards are used to 'uplift' the quotas to reflect total catch, and these estimates are derived from Member State scientific observer programmes. The discard data are sampled from less than 2% of all fishing operations, and then extrapolated to the fleet level and therefore may not be representative of true discard patterns. Furthermore, where no data exist, fill-ins are used from data gathered in related fisheries, so if an estimate is largely derived from such filled-in data it may be less accurate (Catchpole and Santos, 2014).

In a system with extensive mixed fisheries such as the EU, a LO will be particularly challenging, due to the potential for 'choke' to occur from many species. In such fisheries it will be difficult to avoid the most restrictive species, for which, once the quota has been met fishing must cease, while maintaining catches of others (Catchpole *et al*., 2017b). This problem will be exacerbated if the estimated discard levels are far from reality. This would mean the quotas, when adjusted to include estimated discard levels, would not be sufficient to cover the actual discards and the fleet would need to avoid more fish to prevent a choke situation. The fishing industry have claimed that discard data deficiencies are the highest risk in the transition to the LO, and insufficient uplift in quota could stop vessels from fishing (Catchpole *et al*., 2017a).

English Celtic Sea and Western Channel otter trawl fishery

Based on consultations with the fishing industry and an assessment of discard data and quota availability, it is considered that the haddock ICES 7.b-k stock is the most likely choke species for English southwest trawl fisheries under the implementation of the Landing Obligation. In 2016, otter trawls accounted for 83% of landings and 88% of discards of the haddock 7.b-k stock (ICES, 2017). However, haddock is not targeted in the Celtic Sea and Western Channel otter trawl fishery but is taken as an incidental by-catch in a highly mixed fishery. The main target species include lemon sole, squid and cuttlefish.

There is a widespread perception within the fishing industry that there is a mismatch between the available quota (TAC) and catches of haddock in the Celtic Sea and Western Channel, and this is generating a high level of discards, which are thought not to be reflected in official discard estimates. The extension of the Landing Obligation to haddock 7.b-k (by January 2019 at the latest) will likely cause a choke point, because current estimates of discard rates are not reflecting reality in the fishery. These discards are believed to include substantial quantities of mature and marketable fish. The Cefas Observer programme shows that, in 2015, only 3% of haddock caught by TR1 (70-99 mm cod-end) and TR2 (≥100 mm cod-end) in the stock area were under the minimum conservation reference size MCRS (<30 cm). Therefore, most discards of haddock are driven by a quota shortage.

More selective gear configurations have been trialled to avoid unwanted haddock (Catchpole *et al*., 2015a; Catchpole *et al*., 2015b), but because the unwanted fish are mature and relatively large compared with target species, the options available to improve selectivity are limited, and rely on behavioural differences between the many species caught simultaneously in this fishery. Spatial avoidance is also a limited option because of the widespread abundance of haddock on the main fishing grounds of the English fleet, although there is anecdotal evidence that fine-scale spatial and temporal avoidance strategies are already being adopted by the fishing fleet. The EU relative stability shares for this stock are approximately, 67% for France, 22% for Ireland, 10% for UK and 1% for Belgium.

ICES advice on haddock stock ICES 7.b-k

The latest ICES advice states that, the TAC has been restrictive in recent years, which has resulted in increased discarding of fish over MCRS (ICES, 2017). Total discards have increased in 2016 and are above the level of the landings for the first time since 2011. Despite the introduction of square-mesh panels since 2012, the assessment does not show evidence for changes in selectivity. In the main study area for this report (ICES 7.e) there is no legal requirement for square-mesh panels. The mixed-fisheries analysis carried out by ICES shows that haddock will be the limiting species for over half the fleets (64%) in 2018. In scenarios where haddock is fished at F_{MSY} in 2018, it is the most limiting stock for the majority of the fleets. Fishing mortality (F) has been above F_{MSY} for the entire time-series and the advice based on an F_{MSY} approach is for a 24% TAC reduction in 2018. The current estimate of discard rate for the stock is 57%, based on an estimated total catch of 17,931 tonnes with 10,337 tonnes of discards.

Collaborative working to enhance catch data accuracy

The perceived mismatch between the TAC and observed abundance of haddock on fishing grounds is widely believed will create a serious choke in the mixed fishery in the Celtic Sea and Western Channel when the landing obligation is implemented from 2019. Based on current data, the quota uplifts are not considered sufficient, even if available flexibilities are applied, to avoid the early cessation of fishing. These concerns led to the initiation of a series of meetings between UK government, Cefas scientists, the Marine Management Organisation, and the fishing industry which started in March 2017. At these meetings it was agreed that there was benefit in collecting additional data on catches and discards in this fishery to inform on future management options. The agreed aims of the work are to:

- Generate robust discard estimates from an enhanced data collection programme for the English southwest otter trawl fishery, with a specific focus on haddock;
- Evidence the potential to avoid catching haddock through behavioural and fishing gear modifications;
- Compare these data with current estimates and estimates generated from ongoing data collection programmes;
- Make these data available to fisheries managers and scientists to inform on potential improvements to discard estimates, stock assessments and quota uplift;
- Develop the application of Remote Electronic Monitoring (REM) systems to enable an assessment of modified trawl designs and generate estimates of catch and discard levels.

This report describes the methods being applied to deliver these aims and some example results. The data collection commenced in July 2017 and will continue into 2018. The full results of the programme will be available no later than October 2018.

Example of the view using REM of the catch sorting area used to validate the skipper's estimates of catches

Materials and Methods

A recently published approach 'Guidelines for Industry-Science Data Collection' (Mackinson *et al*., 2017) provides a step-by-step guide to gathering useful and useable scientific information which was applied to undertake this work. The principal of the approach is that by working in partnership, it benefits both industry and science because the value of science to management is better understood and accepted when the scientific knowledge is co-created.

There are two main components to the work:

- Enhancing monitoring to improve estimates of catches and discards for haddock
- Assessing the performance of selective trawls to minimise unwanted catches of haddock and so assess the potential to avoid catching unwanted haddock using gear modifications

For both of these it was agreed that Remote Electronic Monitoring (REM) technology would be applied. This is the first time that REM, including integrated CCTV cameras, is being used on board vessels in this fleet. This represents a step-change in the willingness to take up this technology and is a demonstration of the seriousness of the concerns of the fishing industry and the commitment to generate robust and representative data. The method requires the skipper to generate data on catches and this is then validated by independent data derived from REM technology. Here we describe the methods and protocols to collect the data developed for these two components in turn, and then describe the method to determine how representative these data are of other vessels in the fleet.

Enhanced monitoring and evaluating selective trawl designs

There are currently three vessels with REM technology installed. The vessel operators applied to take part in the enhanced data collection programme in a tendering process. Two of the vessels are taking part in selectivity gear trials as part of the ongoing monitoring programme. For the period of the trials, these two vessels receive a charter fee but no scientific quota was made available to these. The third vessel is taking part only in the catch monitoring component, and has been awarded access to scientific quota (sole, monkfish, megrim and plaice), although not for haddock. Once the vessels had been selected, REM systems were installed in a configuration that was tailored to each vessel.

The MFV Swiftsure will use a coverless wing-trawl as the modified trawl against a standard trawl with the potential to investigate different areas of cover at the front end of the trawl. The principle is to utilize the behavior of haddock when at the mouth of the trawl, which rise up and can escape over the trawl when the cover section is removed. The vessel operates a single otter trawl, and the modified trawl and standard trawl will be fished alternately on each tow for 30 fishing days. The vessel will also undertake ongoing monitoring after the selectivity trials using a trawl as normal.

The MFV Spirited Lady will use a wing-trawl with 100 mm diamond cod-end with square mesh strip of 110 mm mesh in cod-end above the rings as the modified trawl against a standard wing-trawl with 85mm diamond cod-end. The vessel operates a twin-rig otter trawl so the modified trawl will be

towed simultaneously alongside standard trawl and catches compared for 30 days of fishing. The rigs will be swapped at agreed intervals to ensure the results are not biased towards one of the rigs.

REM systems

Details of the individual vessel REM system set-ups are provided in Annex I. Archipelago systems are used on all vessels, and comprise the EM Observe™ monitoring system (video cameras, gear sensors, and GPS) and EM Record™ data logging software (producing a record of all fishing operations). Two of the vessels are using the Version 5 System, with 5-6 digital cameras recording at 5 frames per second, GPS, and rotation sensor on the net drum. One vessel is using an earlier version (4.5) of the same system, with a mix of digital and analogue cameras. EM Interpret™ data review software is being used for the review process to synchronizes all the data.

Protocols for skippers

The detailed protocols for the collection of the data by skippers, for both the enhanced monitoring and to assess modified trawl designs is given in Annex II. The protocols describe the responsibilities of the skipper in maintaining the REM systems to enable continuous monitoring and the methods to report the catch so that it can be independently validated from the camera (REM) footage. At the current time, only data for haddock (*Melanogrammus aeglefinus*) and cod (*Gadus morhua*) are being reported by the skipper. The participating skippers must record their estimates of discarded and retained catches either on paper haul sheets or directly on the EMI™ (Electronic Monitoring) system in a consistent format.

Protocols for REM analyst

The detailed protocols for the analysis of the REM data are provided in Annex III. Three protocols are provided, for the analysis of data from the selectivity trials for both single rig and twin rig trawlers and for the analysis of data from ongoing monitoring; i.e. during normal fishing operations. All protocols enable estimates to be made of discards and retained catch weights to be calculated from the REM data, so that comparisons can be made with skippers' estimates. The main comparative data are estimated weights; however, length data will also be generated to illustrate the length classes of the retained and discarded catches. For the selectivity trials, there is a higher resolution of analysis, with more of the hauls analyzed to generate length measurements so that the effect of using the modified trawl on the size of fish caught can be assessed.

A sample of discarded haddock presented so length measurements can be taken by the analyst

Deriving estimates of discards and retained catches

The data generated from skippers is provided by haul as weight estimates by species - retained and discarded. The equivalent estimates are calculated from the data generated by the REM analyst. For the discard fraction, a random sample of each species is taken, the lengths of fish are measured using known calibration parameters, and the total number in the sample is recorded. The mean weight per fish in that sample is derived by applying length-weight coefficients. The proportion of the total discard fraction represented by the sample is determined. When all of the sorted catch is visible this can be estimated by volume; in other cases, it may be based on the sorting time in which the sample was taken, relative to the total sorting time. The total weight of the discarded fraction of each species is calculated by applying a raising factor, based on the proportion of the discards sampled, to the calculated weight of the sample. The same process may be applied to the retained fraction, or where the total retained fractions are clearly visible, estimates can be taken directly based on known weight to volume relationships for the different species.

Validating the skippers' data

The data generated by the skippers was compared with the data from the REM analyst. To validate skippers' discard and landings estimations a regression model was devised to describe how the skipper's estimates relate with the REM analyst estimates. In recognition that the skippers' estimates of the discards and landings may have multiplicative errors; i.e. for larger amounts the skipper may make larger absolute errors, the model input data is discards/landings estimates on the logarithmic scale. The regression model treats the REM analyst estimate of discards as the truth. To validate the model, the data are split into a training set (skipper and REM) and a testing set (uses skipper to predict the REM analyst). The model is fitted using the training set and used to predict the REM values for the testing set. The regression model is applied to all of the skipper's data to generate estimated, median, lower and upper confidence limits. A similar approach has been used in

other studies to describe biomass, e.g. (Cook, 2013; Nielsen and Berg, 2014) and landings, e.g.(Spence *et al*., 2016).

As more REM and skipper's data are generated, the expectation is that the level of confidence in skipper's estimates will increase. A further step will be to relax the assumption that the REM data provides the true discarded amounts by including uncertainty in the REM data; e.g. the length-weight coefficients (Froese *et al*., 2014). Using our model, we will then be able to predict, with robust measures of uncertainty, what the true discards were in the absence of the REM. We also intend to explore approaches to decrease the uncertainty of the estimates; e.g. elicit the skippers' beliefs about upper and lower bounds of the discards for a single haul.

How representative is the data from the participating vessels of the wider fleet

To evaluate how representative of the fishery are the Cefas Observer programme sampled trips and REM vessels, the hauls' positions are plotted against the total number of trips of the population by ICES rectangle, using the same fishing gear (otter trawlers), in the same fishing period, so far between July and September 2017. At this stage a visual comparison can be made to illustrate the representativeness of the spatial coverage. The intension is to explore methods to combine these data so that the estimates generated are applied more precisely when and where the fleet was fishing.

Comparing estimates

Estimates of discards and discard rates generated by the skipper are compared with estimates derived from the scientific observer programme. Since 2002, the Cefas observer programme has collected data on catch and discard from English registered fishing vessels, as required by the EU Data Collection Framework. Vessels are selected for sampling using a randomly generated list each quarter, and the allocation of sampling effort to metiers is stratified in proportion to the total effort in the same quarter in previous year. Estimated haddock discards and landings are generated from trips sampled during the same period as the skipper's data were derived, between July and September 2017. The sampling methods and protocols for the observed trips are summarised in Annex IV. Preliminary and illustrative haddock discard estimates are presented based on the method used to provide data to ICES stock assessment groups. Estimates are provided for Celtic sea haddock stock (ICES 7.b-c, e-k) for English otter trawlers in quarter 3 of 2017. Only otter trawlers, using cod-end mesh size 70-99 mm were sampled in this quarter.

Assessing the modified trawls

For 30 days, which are agreed between the skipper and Cefas, two of the vessels, MFV Swiftsure and MFV Spirited Lady III, will generate comparative data on the standard and modified trawls. Where possible length data will be used to assess the differences in selectivity and estimated catch weights will be compared. The analysis will demonstrate the utility of the two selected designs, square-mesh (BACOMA style) panel in the cod-end, and a coverless trawl, in avoiding the capture of unwanted haddock. For this period the skippers will collect information on the full catch (all species), and this will be validated by REM, so that the economic performance of the trawl can be assessed. At the time of writing, there are no results to present on this aspect of the project.

A sample of retained haddock from MFV Swiftsure laid out for the analyst to take length measurements

A sample of discarded haddock from MFV Spirited lady III laid out for the analyst to take length measurements

Preliminary Example Results

In this results section we present only example and preliminary data from the project to illustrate the data that will be generated, and the outputs that will be available in 2018. Illustrative data are provided on retained and discard estimates of haddock only when using standard trawls.

Example skippers' data (only standard trawls used)

Table 1 Summary of the data generated from each vessel

Vessel	ICES Area	Period Start	Data currently available to	Number of Hauls	Haul duration (hr:min:sec))
1.MFV Swiftsure II	7.e	31/07/2017	07/09/2017	165	04:16:23
3.MFV Crystal Sea	7.e	04/07/2017	01/08/2017	77	05:12:07

At this time, the skipper of MFV Swiftsure II has provided data from 165 hauls and the skipper of MFV Crystal Sea 77 hauls, the mean haul duration for the vessels is around 4.25 and 5.25 hours (Table 1). The skipper's data from the MFV Spirited Lady III was not processed in time to include in this report.

Table 2 Skippers' estimates of retained and discarded catches of haddock

	Discards (kg)				Retained (kg)			
Vessel	**Haul Mean**	**Haul StdDev**	**Haul Median**	**Range**	**Haul Mean**	**Haul StdDev**	**Haul median**	**Range**
1	15	71	0	0-508	20	105	0	0-953
3	469	455	315	56-2400	76	55	60	15-278

The skippers of the two vessels reported a mean discard quantity of 15 kg and 469 kg per haul (Table 2). For vessel 1, MFV Swiftsure, haddock were discarded from 9 in165 hauls, whereas for vessel 3, MFV Crystal Sea, haddock was discarded from all hauls from this period. The maximum quantity of haddock discarded from a single haul was substantial from both vessels; namely, 508 kg and 2400 kg respectively.

Table 3 Haddock discard rates calculated from skippers' data

Vessel	Mean Haul Discard Rate	Min Haul Discard Rate	Max haul Discard Rate	StdDev of Haul Discard Rate	Total Discard (kg)	Total Retained (kg)	Overall Discard Rate
1	0.40	0	0.69	0.23	2,432	3,242	0.43
3	0.84	0.48	1	0.04	34,728	5,194	0.87

The overall discard rate for vessels 1 was 0.43, i.e. 43% of the total haddock caught during this period was discarded (Table 3). For vessel three, the discard rate was higher at 0.87. in total, these two vessels discard more than 37 tonnes of haddock, 81% of their haddock catch.

Illustration of skipper data validation

Figures 1 using preliminary results to show the relationship between the REM analyst and skipper's discards and landings estimates, respectively. The linear regressions showed a high correlation between the REM analyst and skippers estimates for both, discards and landings. In this case data from all three vessels are combined, later it will be possible to analyse the vessels separately.

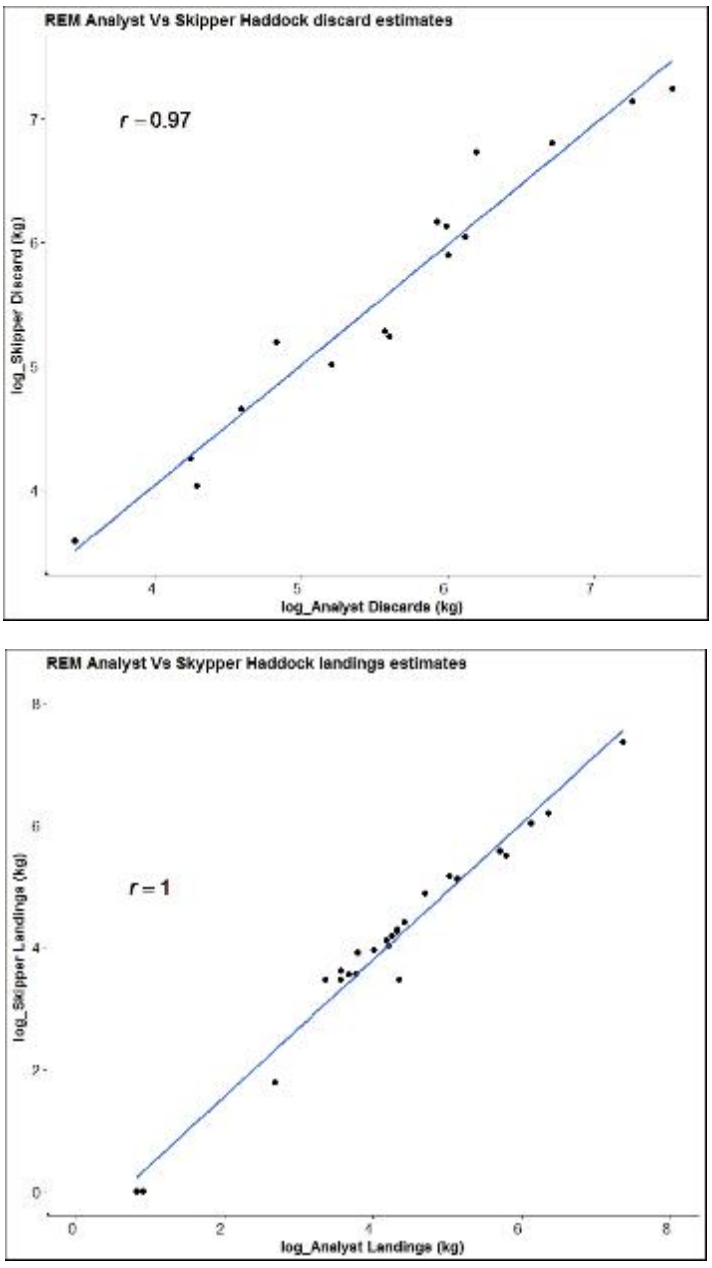

Fig 1 - Comparison of haddock discards (top) and landings (bottom) estimates from skippers and REM analyst.

Preliminary outputs of the regression model have been used to predict haddock discards from skipper's estimates, based on the relation between the REM analysts and skipper's data. The regression model generates estimated landings and discard amounts with a median, lower and upper confidence limits (CLs).

Based on the skippers' estimates, and how close these corresponded to the REM analyst estimates, haddock discard quantities for the period July to September were 33,518-38,853 kg (90% CL) for the MFV Crystal Sea, and 2,129-2,500 kg (90% CL) for the MFV Swiftsure II (Table 4).

	Skippers' estimates haddock Discards (kg)				Skippers' estimated haddock landings			
Vessel	Total discards	Low CI 5%	Median	Upper_ CI 95%	Total landings	Low CI 5%	Median	Upper_ CI 95%
Crystal Sea	34,729	33,518	35,832	38,852	5,194	5,086	5,626	6,376
Swiftsure II	2,432	2,129	2,500	2,974	3,223	2,615	3,459	4,727

Table 4 Validated skippers' estimates of retained and discarded catches of haddock, with confidence intervals (CIs) based on the correlation with REM analyst estimates.

The discard rate for haddock on the Crystal Sea for the period July to September, based on validated skippers' data and the correlation with analyst estimates was 85-88% (90% CL), while the discards rates for Swiftsure II was 34-50% (90% CLs) (Table 5). When taking both vessels together the overall discard rate is around 80%; that is of the total haddock catch, 80% is discarded. As the programme progresses the size composition of the haddock discards will be analysed and differences in catches and discard rates between vessels will be investigated, looking at spatial and technical differences between vessels.

	Discard rate (%)			
Vessel	Total discards	Low CI 5%	Median	Upper_CI 95%
Crystal Sea	87%	85%	86%	88%
Swiftsure II	43%	34%	42%	50%

Table 5 Validated skippers' discard rates for haddock, with CIs based on the correlation with REM analyst estimates.

Representativeness of the Cefas Observer programme and REM vessels

Here we illustrate the type of information that will be presented in 2018. Figure 2 shows the number of trips by rectangle, made by English otter trawlers fishing in ICES 7.e,f,g,h, between July and September 2017, and the haul positions of the three REM vessels and Cefas Observer sampled trips. Most of the otter trawls fishing effort was in ICES area 7.e, off Plymouth and Lyme Bay. However, most of haddock landings are from SW edge (ICES rectangle 28E4). REM vessels operated in two distinct areas that correlated where most of the effort took place. The Cefas Observer programme sampled trips, also overlap where most of the effort of the English otter trawl fleet took place.

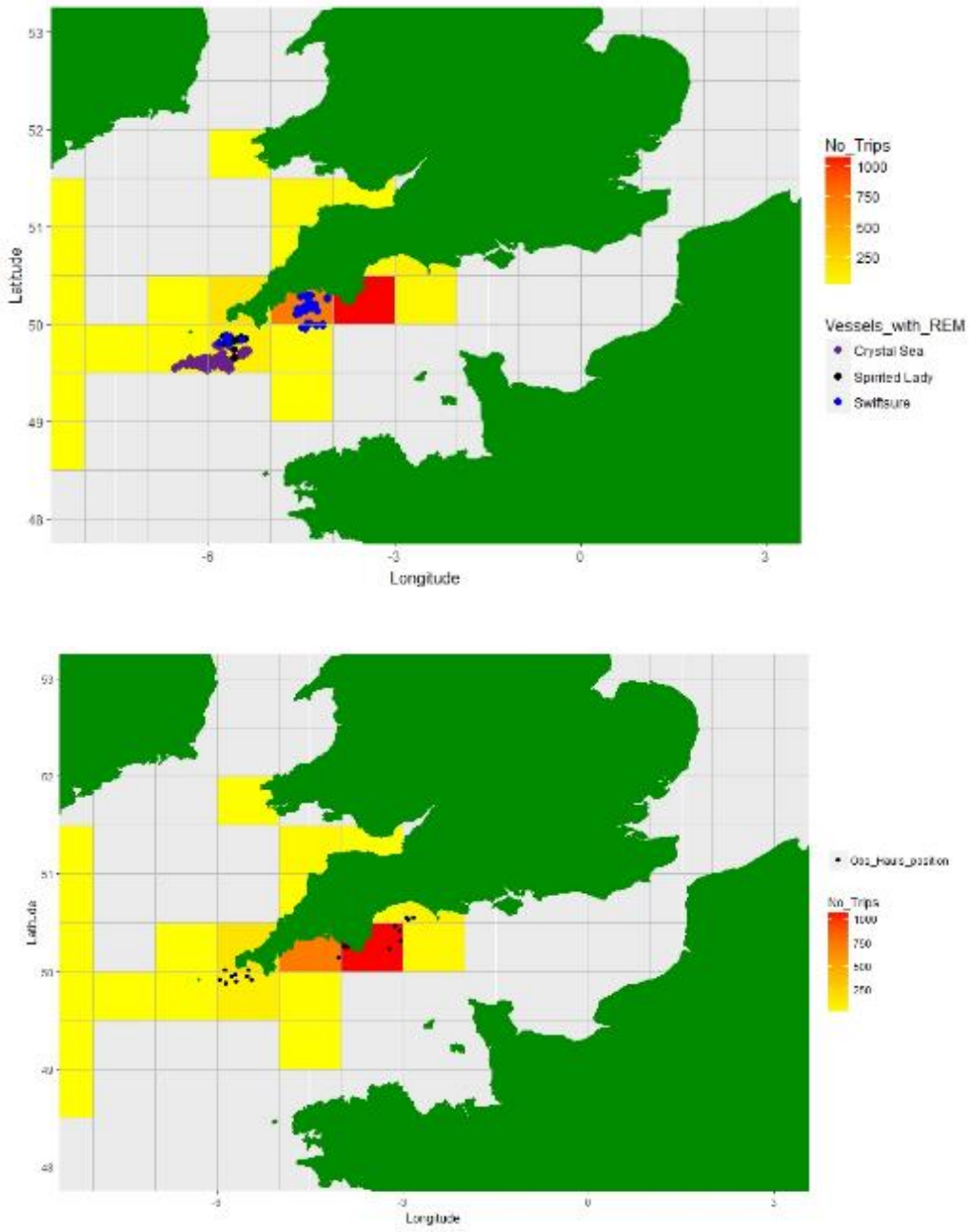

Figure 2. Number of trips of otter trawlers by ICES rectangle, in quarter 3, 2017 and haul locations for each REM vessel (top) and for Cefas Observer programme sampled trips (bottom).

Figure 3 shows the total haddock landings by rectangle, made by English otter trawlers fishing in ICES 7.e,f,g,h, between July and September 2017, and the hauls positions of the three REM vessels and Cefas Observer sampled trips. The location of the hauls from the REM vessels and observed hauls correlate with rectangles where haddock landings were highest.

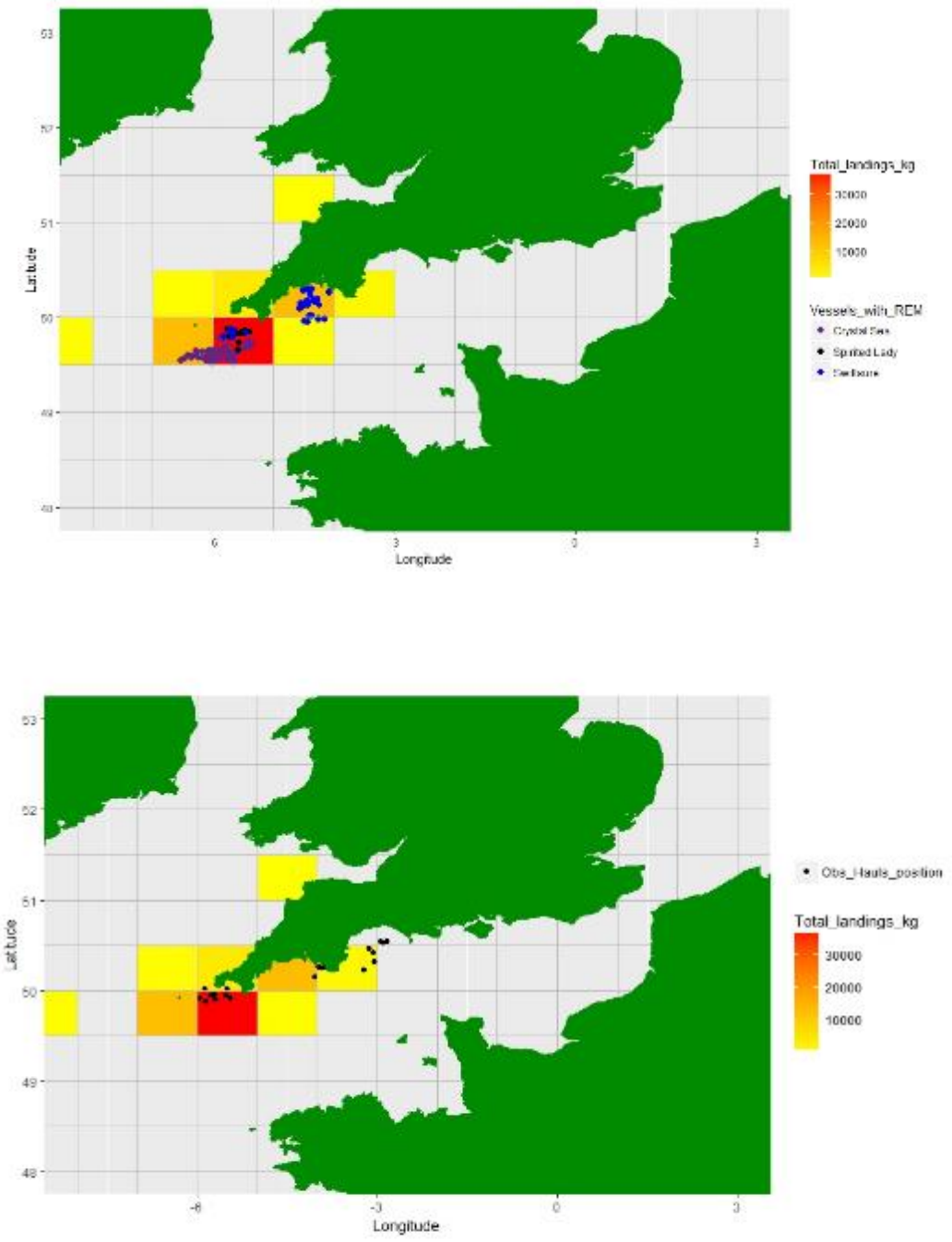

Figure 3. Haddock landings from otter trawlers, by ICES rectangle, in quarter 3 2017 and haul locations of REM vessels (top), and Cefas Observer programme sampled trips (bottom), during the same period.

Comparing estimates

A motivation for this work was the industry's perceived difference between the discard estimates derived from the scientific observer programme and their own experiences during fishing. Here we provide an illustration of how we can compare between the REM and observer programme, the discard rate and the estimated total haddock discard and catch quantities generated by the English otter trawl fleet. Within the same period as the skippers' data was generated so far, July to September, four trips were sampled in the Cefas observer programme, and data generated from nine hauls (Table 6). The mean discard quantities per haul range from 16 kg to 77 kg, and the discard rate from 63% to 100%.

Trip	Year	Qtr	metier	Hauls fished	Hauls sampled	Mean discard per haul (kg)	Mean retainer per haul (kg)	Mean Haul discard rate
1	2017	3	OTB_DEF_70-99	3	1	77	0	100
2	2017	3	OTB_DEF_70-99	2	2	16	3	84
3	2017	3	OTB_DEF_70-99	3	3	40	2	96
4	2017	3	OTB_DEF_70-99	3	3	38	22	63

Table 6 summary data from the Cefas observer programme for trips sampled in Celtic Sea otter trawl fishery in July to September 2017.

When compared with the validated skipper estimates, there are data from 230 more hauls from the skipper, demonstrating the benefits of the enhanced monitoring programme using REM and skipper's data (Table 7). The discard rates from the new enhanced data collection programme and the ongoing observer programme are comparable for the initial period. It is the discard rates that are applied to the official landings data so generate a total discard quantity and inform on total catches and will influence the level of uplift with the implementation of the Landing Obligation. in the first few months it has been observed that there are differences in the total amounts of discards generated per vessel, with one vessel, MFV Crystal Sea generating more catches and discards, than other vessels.

Year	2017
QTR	3
ICES Division	107E
Metier	OTB_DEF_70-99
Observed number hauls	9
Validated skippers' data hauls	239
Observer mean discard estimate per haul (kg)	45
Skipper mean discard estimate per haul (kg)	154 kg
Observer discard rate (%)	87%
Skippers discard rate (%)	80%

Table 7 Comparative data on haddock discards and discard rates from the Cefas observer programme and the enhanced data collection programme in July to September 2017.

Conclusion

This report describes the methods that have been developed and applied to deliver an enhanced data collection programme, specifically designed to generate more data on discards of haddock in the Celtic Sea English otter trawl fishery. The methods are intended to deliver the following aims:

- Generate robust discard estimates from an enhanced data collection programme for the English southwest otter trawl fishery, with a specific focus on haddock;
- Evidence the potential to avoid catching haddock through behavioural and fishing gear modifications;
- Compare these data with current estimates and estimates generated from ongoing data collection programmes;
- Make these data available to fisheries managers and scientists to inform on potential improvements to discard estimates, stock assessments and quota uplift;
- Develop the application of Remote Electronic Monitoring systems to enable an assessment of modified trawl designs and generate estimates of catch and discard levels.

Here we present example, preliminary data from the project from the period July to September 2017, to illustrate the data that will be generated and the outputs that can be produced. The preliminary results indicate high discard rates of haddock, whereby 80% of the haddock total catch is being discarded. This is based on skippers' results, validated by independent analysis of Remote Electronic Monitoring data, and is consistent with the ongoing Cefas Observer programme, conducted as part of the EU Data Collection Framework (DCF). The full results of the programme will be available no later than October 2018.

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Annex I REM vessel set-ups

MFV Spirited Lady III REM set-up

Spirited Lady III SU516	Version 5 System Digital Cameras 5 Frames per second GPS, Rotation Sensor on the Net Drum	**Primary Use**
Camera 1 – Set above the Starboard Pound CALIBRATED		- Assess the bulk catch from the Starboard Net - Assess discarded Catch, measure discarded Haddock
Camera 2 – Set above the Fish room hatch CALIBRATED		- View Washer to count baskets of retained fish - Count baskets of retained fish into the fish room - Calibrated hatch – used to measure retained skates and Rays, Monkfish and other large fish before processing.
Camera 3 – Overview Camera, located above the wheelhouse NOT CALIBRATED		Provides an overview of the deck area. - Assess bulk catch - View hauling and shooting operations - Assess retained catch from each cod-end.

Camera 4 – Located over the fish washer CALIBRATED		- Measure retained fish
Camera 5 – Set above the Port Pound CALIBRATED		- Assess the bulk catch from the Port Net - Assess discarded Catch, measure discarded Haddock

MFV Swiftsure II REM set-up

Swiftsure II FY221	Version 5 System Digital Cameras 5 Frames per second GPS, Rotation Sensor on the Net Drum	**Primary Use**
Camera 1 – Set above the fish room hatch. CALIBRATED		- Assess the fish going into the fish room - Measure retained Monk - Retained Haddock are presented by skipper/crew for measuring
Camera 2 – Starboard Stern Overview NOT CALIBRATED		- Assess bulk catch in starboard pound - Observer hauling and shooting operations
Camera 3 – Stern Pound View CALIBRATED		- Discards are presented to the camera for identification and measuring - Discarded haddock are presented for measuring
Camera 4 – Shelter Deck Overview NOT CALIBRATED		- Provides an overview of sorting process - Provides estimates of volumes

Camera 5 – Port Stern Overview NOT CALIBRATED		- Assess bulk catch in starboard pound - Observer hauling and shooting operations
Camera 6 – Located above the fish washer. NOT CALIBRATED		- Provides an overview of retained catch processing - Count/assess number of baskets of retained fish

MFV Crystal Sea REM set-up

Crystal Sea SS118	Version 4.5 System Digital and analogue Cameras 5 Frames per second GPS, and Rotation Sensor on the Net Drum	**Primary Use**
Camera 1 – Processing area, view of baskets discarded samples – analogue NOT CALIBRATED		- Assess the quantity of fish collected in a sample - Assess duration of sample collection.
Camera 2 – Processing overview - analogue NOT CALIBRATED		- Provides an overview of sorting process
Camera 3 – Discards View analogue CALIBRATED		- General Discards including haddock and cod are discarded off belt down shute. Used for identification and measuring
Camera 4 – Fishroom view. Analogue NOT CALIBRATED		- Provides view of retained fish for identification and weight estimate of retained fish.

Camera 5 – Processing belt – measuring-digital CALIBRATED		- Measuring discarded and retained samples, identifying species sampled.
Camera 6 – Located above the processing deck. Digital CALIBRATED		- For measuring large fish – skates and rays. Not used in Haddock project to date.

Annex II Skippers' Data Collection Protocol

Skipper Responsibilities

1. The remote electronic monitoring system must remain switched on at all times.
2. Camera Lenses must have an unrestricted field of view and should be cleaned **before each haul** (wipe a clean cloth over the lenses), or more often if dirt or water obscures the camera view.
3. Sorting and handling of catches should be carried out in full view of the cameras and in accordance with the agreed protocol below.
4. Hard drive collection will be pre-arranged between the skipper and Cefas (Sam Elliott 07795 283 885) and will occur every week during the selectivity trials.
5. In the event of equipment failure, the skipper must notify Cefas and the MMO at the earliest opportunity.

Enhanced Monitoring: Skipper Protocol

For each trip, complete the haul sheets provided for COD and HADDOCK

Catch sorting

Retained catch

1. Sort the retained catch into orange baskets in view of the cameras; record an estimated weight and volume for the HADDOCK and the COD on the haul sheets.
2. In turn, spread all or no more than half a basket of the retained HADDOCK and COD on the hatch and leave for at least 20-30 seconds so the analyst can get measurements from the calibrated camera.
3. If more than one basket of HADDOCK or COD is being retained only spread one basket on the hatch.

Discarded Catch

1. Sort the unwanted HADDOCK and COD separately into blue baskets, present the baskets to the camera and record an estimated weight or volume for each on the haul sheets. Keep to one side.
2. After clearing the catch, tip a basket of discard HADDOCK back into the empty calibrated pound so the analyst can get measurements from the calibrated camera; spread out the fish and leave for 20-30 seconds before discarding.
3. Where catches of HADDOCK are very large (more than 5 baskets) and it is impractical to separate out all the discarded HADDOCK, take 2 random baskets of discards from the pound and separate the HADDOCK from that. Proceed as above with recording and measuring.

Selectivity Trials: Skipper Protocol

For each trip, complete the haul sheets provided. **The catch from the modified and standard nets will need to be sorted separately**; the catch from the standard net should be noted on the front of the haul sheet and the catch from the modified net should be noted on the back of the haul sheet.

Catch sorting

Retained catch

Sort the retained catch into orange baskets in view of the cameras; record an estimated weight and volume for the HADDOCK and the COD on the haul sheets.

1. In turn, spread all or no more than half a basket of the retained HADDOCK and COD from the standard net on the hatch and leave for at least 20-30 seconds so the analyst can get measurements from the calibrated camera. Repeat this for the HADDOCK and COD catch from the modified net.
2. If more than one basket of HADDOCK or COD is being retained from each side, only spread one basket on the hatch.
3. Record an estimated weight and volume for all other components of the retained catch from both the standard and modified nets on the front and back of the haul sheets.

Discarded Catch

1. Sort the unwanted HADDOCK and COD separately into blue baskets, present the baskets to the camera and record an estimated weight or volume for each on the haul sheets. Keep to one side.
2. After clearing the catch, tip a basket of discard HADDOCK back into the empty pound so the analyst can get measurements from the calibrated camera; spread out the fish and leave for 20-30 seconds before discarding.
3. Where catches of HADDOCK are very large (more than 5 baskets) and it is impractical to separate out all the discarded haddock, take 2 random baskets of discards from the pound and separate the haddock from that. Proceed as above with recording and measuring.
4. Once the HADDOCK and COD have been removed, estimate a volume of the bulk discards and record on the haul sheet
5. Collect a random sample of the discards (1 basket) from both the standard and modified nets – keep to one side. When the HADDOCK discards have been cleared from the pound (step 2), tip the basket of discards in the pound; spread out the fish and leave for 20-30 seconds before discarding.

The participating skippers must record their estimates of discarded and retained catches either on paper haul sheets or directly recorded on the EMI™ (Electronic Monitoring Interpret) in a consistent format that includes the haul times and numbers.

Annex III REM Analyst Protocols

Hard drives on vessels to be swapped at least once per month, but preferably fortnightly. These will then be backed-up on password-protected servers. On retrieval of a disk, enter it on the disk tracking form and name the disk according to the associated nomenclature.

Disk should be named consecutively as follows, ***PLN_Disk Number_Year.*** For Example: ***FY221_1_17***. If a copy of the disk is taken, it should also be entered onto the disk tracking form and the name suffixed with C. For example, ***FY221_1_17C.***

When the disk is first used, the sensor data should be annotated and saved independently of the image processing data. Each trip on the disk should be annotated as ***PLN_Disk Number_Trip Number_Trip Start Date***. For example: ***FY221_1_1_30-07-2017***

There will be an initial "data integrity" audit for all hard drives received, this will be done within two working days of receipt of data. Where quality of the data is low or unusable, or equipment needs fixing, feedback will be provided to the skipper or an engineer will be engaged as required. The scoring system for the data integrity check is as follows:

Data Integrity checks - 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.
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.

Prior to undertaking any measurements of fish, the system for measurement will be calibrated and record of the calibration kept. This calibration will be undertaken once per calendar year as a minimum or upon movement or replacement of any camera.

The hauls should be auto-numbered and assigned a gear type.

Analysis for Ongoing Monitoring

There will be a random audit of approximately twenty percent of hauls. This will be done using a random haul selector spreadsheet. If data for any of the selected twenty percent of hauls is marked as “unusable”, a note will be made in the EMI comments and the next haul selected as a replacement. Protocols are provided for the different sorting methods used on the vessels:

For vessels which use conveyor belts for sorting

For sampled hauls, an estimate of retained cod and haddock will be obtained from viewing the number of boxes of each species entering the fish room.

Due to the quantities of haddock sometimes involved, a count of the discarded haddock viewed in a ten-minute period during the processing time will be made. The start and end times of the processing operation will be determined and recorded by the analyst for each haul analysed so that they can scale up the figures for total processing time. The analyst will pick a start minute at random for analysis using a random number generation spreadsheet provided then perform a count of all visible haddock being discarded over 10 minutes. If there is less than 10 minutes left until the end of processing, the analyst will take the remaining count from the start of the haul.

For cod, a total count will be made for the full processing operation.

One full orange basket of retained and one full blue basket of discarded haddock and cod should be randomly sampled for each haul. These should then be retained until the end of processing and emptied separately on the processing belt. The fish should be spread out to allow measuring and left there for at least ten seconds before they are stowed or discarded as appropriate.

The analyst will annotate retained fish, discards and length measurements in EMI as follows:

Retained catch
The analyst will enter an estimated live weight in kilogrammes of haddock and cod based on the fullness of a box. It will be necessary to carry out a box weight calibration exercise to verify this.

The analyst will record retained cod or haddock as fate “retained general”, with an actual weight per box (e.g. not raised up) when annotating the retained weights.

In addition, the analyst will undertake measuring of the sample baskets of retained cod and haddock and record them on EMI. The analyst will then enter the measurements for the retained as “retained - sample” but they will also enter a length measurement on this record.

Discarded fish
Haddock
To sample haddock, if significant fish numbers are being discarded, a 10 minute sample period will be selected at random from the time the processing belt is running. For that 10 minute period, the

number of haddock being discarded will be counted. If there are relatively small quantities of haddock, a complete count will be made.

The analyst will record discarded haddock as either fate “discarded - general” or “discarded - damaged” when annotating the count. “Discarded – damaged” will only be used where a fish is seen by the analyst to have specific damage.

In addition, where possible the analyst will undertake measuring of all of the fish in the blue sample baskets of discarded haddock and record them on EMI. The analyst will record these haddock as fate “discarded - sample” or “discarded – sample - damaged” and add a length measurement to the annotation. If no length measurement is possible the fish will be annotated as a fish count only and labelled as fate “discarded - sample” or “discarded – sample - damaged”. Weight in kilogrammes of the discarded sample will also be estimated by the analyst.

Cod

The analyst will count all cod seen to be discarded for the processing period from the sampled haul.

The analyst will record discarded cod as either “discarded” or “discarded damaged” when annotating the count. In addition, the analyst will undertake measuring of all of the cod in the sample baskets of discarded cod and record them on EMI. The analyst will record these cod as fate “discarded - sample” or “discarded – sample - damaged” and add a length measurement to the annotation. Where a cod cannot be length measured a fish count will be entered as fate “discarded - sample” or “discarded – sample - damaged”. Weight in kilogrammes of the discarded sample will also be estimated by the analyst.

For vessels which use pounds for sorting

For sampled hauls, an estimate of retained cod and haddock will be obtained from viewing the number of boxes of each species entering the fish room.

Discarded haddock and cod will be sorted separately and into blue baskets. The length data depends on the skipper laying out all, or a proportion, of the discarded haddock and cod in turn in view of the hatch camera or pound camera.

One full orange basket of retained and one full blue basket of discarded haddock and cod should be randomly sampled for each haul. These should then be retained until the end of processing and emptied separately on a hatch or in the pound. The fish should be spread out to allow measuring and left there for at least ten seconds before they are stowed or discarded as appropriate.

The analyst will annotate retained fish, discards and length measurements in EMI as follows:

Retained catch

The analyst will enter an estimated live weight in kilogrammes of haddock and cod based on the fullness of a box. It will be necessary to carry out a box weight calibration exercise to verify this.

The analyst will record retained cod or haddock as fate “retained general”, with an actual weight per box (e.g. not raised up) when annotating the retained weights.

In addition, the analyst will undertake measuring of the sample baskets of retained cod and haddock and record them on EMI. The analyst will then enter the measurements for the retained as “retained - sample” but they will also enter a length measurement on this record.

Discarded catch
The analyst will enter an estimated live weight in kilogrammes of discarded haddock and cod based on the fullness of the blue baskets. Discarded cod or haddock will be annotated as fate “discard general”, with an actual weight per basket (e.g. not raised up) when annotating the discard weights.

For discarded cod and haddock which have been laid out for measurement by the master or crew, the analyst will undertake measuring of all available fish and record them on EMI. The analyst will record these haddock as fate “discarded - sample” and add a length measurement to the annotation.

Analysis of Selectivity Trials

The analysis of selectivity trials is performed at a higher resolution that the ongoing monitoring analysis to have higher levels of confidence in any observed differences between the gears. Here we provide protocols for trawl selectivity trials, in which either single, or twin rigged trawls are used to generate comparative catch data.

Catch comparison with single rig vessel

Random Selection
To ensure that data are recorded consistently for different gears the same number of modified and standard hauls should be analysed. For each trip, hauls will be randomly selected for analysis using the random haul selector. If the haul which is randomly selected is fishing with the standard net, the next haul using the modified net should also be analysed, and vice versa. If the haul selected occurs at the end of the trip, the previous haul in which the other net is used should be selected.

A minimum of one modified and one standard haul should be analysed from each trip.

Number of Hauls per Trip	Analyse - Modified Net	Analyse - Standard Net	Total hauls analysed/ trip	Min-Max% Sampled
2-4	1	1	2	50%-100%
6-9	2	2	4	44%-66%
10-13	3	3	6	46%-60%
14-17	4	4	8	47%-57%

Catch Analysis
Catch Analysis for each randomly selected haul should include:

- Estimate the weight bulk catch (Add an estimated total catch annotation – BULK, Weight (kg)

For example: Bulk catch estimate is based on total number of baskets of bulk catch converted to weight using the nominal weight 35 kg per basket.

Retained Catch

- Record an estimated weight of each retained species including Haddock (retained- general). where possible, record the number of individuals – particularly if numbers are low i.e. <1/10th Basket.
- Where species are laid out on the hatch in the calibrated area, lengths should be taken and length weight conversion used to determine the weight of the retained catch.
- The crew will present a sample of retained haddock for measuring in the calibrated area – lengths should be taken and recorded as retained -sample.

The crew present a sample of the retained haddock, the weight of the sampled haddock and the estimated total weight are recorded separately and the RF can be determined.

Discarded Catch

The crew will sort the catch and separate the discarded haddock from the remaining discards.

- Estimate the total weight of mixed discards (excluding the haddock) – annotated as Estimated total catch – MIX DISCARDS, Weight
- Estimate the weight of discarded haddock annotate as catch item, discarded-general
- Estimate the weight of discards which are not put into baskets, but discarded during sorting – annotated as catch item, discarded-general
  i.e. LSD - I use the estimated bulk minus the volume of discards and volume of retained catch.
- The crew will present the discarded haddock to a calibrated camera (hatch or aft pound) lengths should be taken and annotated as discarded - sample
- View all footage to ensure all discards have been presented, if other discards are observed, either adjust the estimates if possible, or annotate that an unknown quantity of discards are not included in the estimate and the data should be excluded.

When a sub-sample of the total discarded haddock is presented, the weight of the sampled haddock and the estimated total weight are recorded separately and the RF can be determined.

Catch comparison with twin rig vessel

Random Selection

For each trip, hauls will be randomly selected for analysis using the random haul selector.

Number of Hauls per Trip	Total hauls analysed/ trip	Min-Max% Sampled
2-6	2	33%-100%
7-12	4	33%-57%
13-18	6	33%-46%
19-24	8	33%-42%

Catch Analysis

To ensure that data are recorded consistently for different gears the same number of modified and standard rigs should be analysed. For each randomly selected haul, the modified net and the standard net should be analysed and annotated separately. View the video and analyse the modified net, save the annotations file (suffix with MODIFIED). Reload the EMI file and sensor Processed

annotations file and view the video, analysing the standard net. Save the image processed file with the suffix STANDARD.

For each randomly selected haul, catch analysis should be carried out for both the modified and the standard net in turn and should include;

- Estimate the weight bulk catch (Add an estimated total catch annotation – BULK, Weight (kg)

For example: Bulk catch estimate is based on total number of baskets of bulk catch converted to weight using the nominal weight 35 kg per basket.

Retained Catch

- Record an estimated weight of each retained species including Haddock (retained- general). where possible, record the number of individuals – particularly if numbers are low i.e. <1/10th Basket.
- Where species are laid out on the hatch in the calibrated area, lengths should be taken and length weight conversion used to determine the weight of the retained catch.
- The crew will present a sample of retained haddock for measuring in the calibrated area – lengths should be taken and recorded as retained -sample.

The crew present a sample of the retained haddock, the weight of the sampled haddock and the estimated total weight are recorded separately and the RF can be determined.

Discarded Catch

The crew will sort the catch and separate the discarded haddock from the remaining discards.

- Estimate the total weight of mixed discards (excluding the haddock) – annotated as Estimated total catch – MIX DISCARDS, Weight
- Estimate the total weight of discarded haddock annotate as catch item, discarded-general.
- Estimate the weight of discards which are not put into baskets, but discarded during sorting – annotated as catch item, discarded-general
- The crew will present the discarded haddock to a calibrated camera (hatch or aft pound) lengths should be taken and annotated as discarded – sample. Each haddock which is suitably presented should be measured – for haddock which cannot be measured i.e. individuals outside the calibrated area, or those not fully visible, a count should be made and added as an annotation.
- View all footage to ensure all discards have been presented, if other discards are observed, either adjust the estimates if possible, or annotate that an unknown quantity of discards are not included in the estimate and the data should be excluded.

When a sub-sample of the total discarded haddock is presented, the weight of the sampled haddock and the estimated total weight are recorded separately and the RF can be determined.

Annex IV Observer sampling protocols to estimate catches

The data collected by the Cefas observers followed the normal Cefas sampling programme protocol. Once at sea, the sampling scheme is a multistage process in which discards are estimated from a fraction of a haul, and typically >60% of the hauls are sampled during a trip. In each sampled haul all the species are sampled; length measurements are registered for all fish, crustaceans and cephalopods species. When is not possible to sample the whole haul catch, the observer estimates the volume measured relative to the total catch to obtain a raising factor that is used to estimate the total catch of the haul. For each trip, numbers-at-length were raised to the haul, based on an estimated proportion of the total catch volume sampled, then to the trip, based on the proportion of sampled hauls and fished hauls. The length based data was converted to biomass, using length-weight relationships for each species collected during various scientific trawl surveys (Cefas, unpubl. data).

Centre for Environment Fisheries & Aquaculture Science

Cefas

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