

Final Report

***Project 24X: North Sea GOV gear
trials continuation***

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Summary

The UK fishing industry has argued that the international bottom trawl survey (IBTS) carried out in English waters on the *Cefas Endeavour* using the GOV gear is not representative of the numbers of fish, especially cod, in the North Sea. They are particularly concerned with the set-up of the ground gear and fear that a large proportion of fish escape underneath the gear and between the fishing line and the ground gear.

During two periods, one in January 2008, the other in September 2008, catch rate comparisons were made between a commercial fishing boat – the *Our Lass II* fishing soft-ground areas – and those achieved by the *Cefas Endeavour* using the soft-ground GOV gear. Standardised 2-mile tows were carried out to test if the survey was likely to catch the same portion of the stock as the commercial vessels. The rate of escape of the main commercial species from the standard GOV trawl was assessed by fitting additional nets behind the ground gear to capture escaping fish. The aim was to determine not only the escape rate, but also the factors, if any, that influenced escape.

Standard GOV catch rates for **cod** were 15% of those of the commercial vessel ranging from over 80% in January to a meagre 8% in September, with an average of 17% escaping under the net (20% in January, 14% in September). This suggests that ground contact of the gear and the net itself is not a problem, but rather that it is the sweeps, bridles and the resulting towing angle that is the root cause of the difference in catch rates at the time of the survey. It was possible to confirm the consistent ground contact along a good portion of the fishing line visually using a camera set-up. Patterns of abundance across areas were consistent within season with those found by the commercial vessel fishing the same habitat.

During the September survey, an average of 25% of cod would escape underneath the standard GOV gear at low densities. This decreased to just ~15% at greater abundance, indicating that the relationship between abundance on the grounds and catch is not linear, as assumed by the assessment, although the difference is substantially smaller than estimated in January.

GOV catch rates for **plaice** were much lower than commercial rates (29%) on soft-ground areas, even when the portion escaping under the net was included (39%). Unlike cod the large difference in catch rates was obvious during both periods of sampling, which is at least consistent with the idea that plaice are less affected by water clarity and depend more on tactile stimuli. This outcome will not distort the assessments, but it might be possible to decrease uncertainty with larger catches of older fish.

The standard GOV gear sampled haddock and whiting adequately. *Cefas Endeavour* catch rates of haddock were roughly 60% of commercial catch rates, and the RV caught more whiting than the commercial vessel.

Introduction

The Fisheries Science Partnership (FSP) was established in 2003 to build relationships between fishermen and scientists, and to involve fishermen in the co-commissioning of science. The UK's Department for Environment, Food and Rural Affairs (Defra) funds the FSP, and about ten projects per year have been carried out since 2003/04, comprising a mixture of time-series surveys, fishing gear selectivity studies, and examination of spatial patterns of catch compositions. Reports for FSP projects already completed are available on the FSP page of the Cefas website (www.cefas.co.uk).

Industry proposals for FSP projects have typically been developed at a port/regional level, refined and agreed with Cefas and approved by the FSP Steering Committee. Charter vessels are selected through an open tendering process, and are given dispensations from the relevant quota and effort controls and to fish in non-UK waters where appropriate. In the case of the GOV comparative trials, the concern driving the comparison is a general distrust by industry of the results of the ICES North Sea cod assessment, and specifically the survey tuning information used therein.

In line with these concerns Cefas conducted a study as part of the 2007/08 FSP program (Project 24) comparing the catch rates and escape probabilities of four finfish species commercially important to the English NS whitefish fleet. Having shown that there are differences for plaice and cod between commercial and research catch rates, not only on adjacent hard ground habitat, but also in direct comparison on the same grounds, and that there is some escapement underneath the ground gear, it was deemed important to quantify these differences better.

This study builds on the dataset obtained during the first (January 2008) study by obtaining additional samples from both a commercial and a research vessel fishing side by side on the soft grounds. In addition, the study provides information at a more appropriate time of year, September, when the main IBTS survey is carried out by Cefas and the water is generally less turbid than in January. We examine the effect of this on both the catch rates and the escape rates of the survey gear.

As an adjunct to the main work, an underwater camera was again fitted to the selvedge of the trawl to monitor the behaviour of different species in the mouth of the trawl, and to determine the potential routes of escape of the major commercial species.

All objectives were agreed by industry, management and science in advance, and this report presents the results. The original trials were carried out from 8 to 15 January 2008, and the additional tows from 3 to 6 September 2008, immediately following the IBTS survey.

Objectives of the programme

Primary objectives

- 1) To better quantify the rate of escape of cod and plaice underneath the ground gear and through the gaps between the fishing line and ground gear of the GOV trawl as used in the North Sea groundfish survey (ground gear A, for soft-ground stations).

Using additional bags underneath the gear to capture escapees, the aim is to develop quantitative models that describe the effects of length of cod, abundance of cod and a number of environmental co-variables including time of the year (taken as a proxy for water clarity) on the rate of escape from the GOV.

2) To calibrate the catch rates on the research vessel to commercial catch rates using commercial gear and practices.

3) To determine the means of escape visually from images recorded by a camera mounted on the gear, and to describe the ground contact and behaviour of the gear more generally.

Methods

Vessels and gear

Our Lass II: Whitby-based, steel-hulled twin rigger of 20.15 m registered length (21.5 m overall). Built in 2007, she is equipped with a 480 kW power unit and carried two trawls for the purpose of the experiment, a “prawn scraper net” and a “fish-tail hopper” net.

Cefas Endeavour: Cefas-owned and Lowestoft-based multidisciplinary research vessel of 73.91 m (overall) powered by a 3240 kW diesel-electric plant. For the trials she was equipped with an IBTS standard GOV net, with three additional bags designed and built by Jackson Trawl (Peterhead) fitted to the fishing line of the GOV, but having their own independent ground gear.

The gears and vessels are of different design, and they use different doors, towing angles, net sensor and ground-gear configuration, so the results are not strictly comparable. However, for the purposes of the trial, the gear used on *Our Lass II* and *Cefas Endeavour* was selected to be as similar as possible, using 8-inch ground gear. The two gears were deployed side by side on soft ground, with alternating shooting order between the two boats. Because of their smaller engine size, the commercial vessel was unable to maintain the standard required survey towing speed of 4 knots, so all tows were standardised to 2 nautical miles.

The commercial gears used 80 mm codend mesh, and the *Cefas Endeavour* used a 50-mm codend mesh with a 20-mm blinder in order to keep catchability consistent with the IBTS standard. However, the escape bags were deployed with a codend of 80 mm mesh, because they were likely to pick up large quantities of benthos with a 20 mm blinder and thus to cause backwash, given that the escape bags were just 1/3 of the length of the GOV.

Sampling

The aim of the original survey in January was to sample a number of different grounds with different catch compositions and different densities of cod and other commercial species. Three areas were identified which could be sampled in the somewhat inclement conditions during January. These were Skate Hole, the Yorkshire coast between Hartlepool and Filey, and parts of The Wash near Skegness. During the

September trip we concentrated on obtaining as many as possible additional samples with reasonable numbers of cod to allow for comparison of the catch rates and determination of the effects of time of year on the escape probability. This could best be achieved by remaining on a single site, Baymans Hole, a traditional fishing ground for the whitefish fleet in September.

Location, time, sea condition, and gear parameters were recorded for each haul on all vessels, and sampling of catches was restricted to species of commercial importance, all fish or a representative subsample of these species being measured after each haul.

On the commercial vessel, the catches were sorted by the crew into retained and discarded portions and measured by an observer. On the research vessel, catches from each of the escape bags and from the GOV were worked up separately. Commercial species were weighed by species, and all other organisms were weighed and recorded as benthos, and one otolith per 1-cm length group per station was collected for each of plaice, cod, haddock and whiting during the January trip, though only cod otoliths were collected during September.

For logistic and operational reasons not all tows were completed by both vessels. Therefore, for the purposes of comparison between vessels only those stations fished by both vessels were used. To examine the rate of escape below the net, all *Cefas Endeavour* tows were included where all four codends contained valid samples (i.e. no damage to or fouling of the codend).

A statistical analysis was carried out between the components retained in the GOV proper and those caught in the escape bags, and the factors that affect the rate of escape for each species. A generalized additive model (GAM) was used to determine the effects of the independent variables on the probability of an individual fish being caught or escaping underneath the gear, using local regression smoothers. The model assumed a binomial error distribution modelled via a logit link function, so assuming that each fish acted individually. However, given the relationship with total catch size, this seems highly unlikely, so the interpretation of the results is more complicated than just comparing significance values. To avoid carrying statistical detail in this report, we present here only a summary of those findings that are independent of the violations of the assumptions of the model. An exhaustive discussion of the analysis will be targeted at a peer-reviewed scientific publication later.

During January it was not possible to observe the net directly using camera gear, because of the low light conditions then. In September lighting was better, the water was clearer and we had a better camera. Ten tows were observed with the camera mounted at different locations in the selvedge of the net.

Results

A total of 40 samples was used in this analysis, 26 from January and 14 from September, all of which were completed successfully by both vessels, catching in all 3247 plaice, 4713 cod, 8638 haddock, and 110 295 whiting. For these hauls, the number of individuals of each species caught by each vessel is listed in Table 1, with the *Cefas Endeavour* catches split between those found in the codend and those retained in the escape bags.

Table 1. Seasonal for numbers by species, percentage of largest and GOV escape rate, indicating the percentage of fish in the escape bags compared with the total measured.

		<u>January</u>		<u>September</u>		<u>Total</u>
		Numbers	RV catch compared to commercial catch escape compared to total observed	Numbers	RV catch compared to commercial catch escape compared to total observed	Numbers
Plaice						
<i>Cefas Endeavour</i>	Caught	559	0.26	125	0.21	684
	Escaped	198		34		
<i>Our Lass II</i>		1712	0.33	619	0.20	2331
Cod						
<i>Cefas Endeavour</i>	Caught	336	0.20	274	0.14	610
	Escaped	83		43		
<i>Our Lass II</i>		384	0.88	3593	0.08	3977
Haddock						
<i>Cefas Endeavour</i>	Caught	1258	0.06	1919	0.00	3177
	Escaped	87		9		
<i>Our Lass II</i>		1906	0.66	3459	0.55	5365
Whiting						
<i>Cefas Endeavour</i>	Caught	33759	0.06	25759	0.00	59518
	Escaped	2180		78		
<i>Our Lass II</i>		31297	1.08	17222	1.50	48519

To examine the results on a station-by-station basis, catches of each species were compared between vessels. The length frequencies for all stations combined were also examined to see if the same portion of the population was being sampled, or if there were significant differences in the selectivities of the gears. The results of these comparisons are given below.

Catch rate comparisons

Cod

Our Lass II caught substantially more cod (3977, compared with 610 on *Cefas Endeavour*), most of the difference coming from the September trip where RV catch rates contributed just 8% of commercial catches, whereas in January the ratio was close to 0.88 (Table 1, Figure 1). The length frequencies which were broadly similar between the two vessels also changed substantially, with a greater proportion of the increased catch rates represented by cod of length 250–450 mm. In fact the commercial length frequencies from September indicate greater similarities with the hard ground catches from January provided by the *Jubilee Quest* in the previous study. This would suggest that different portions of the population are sampled by the two gears.

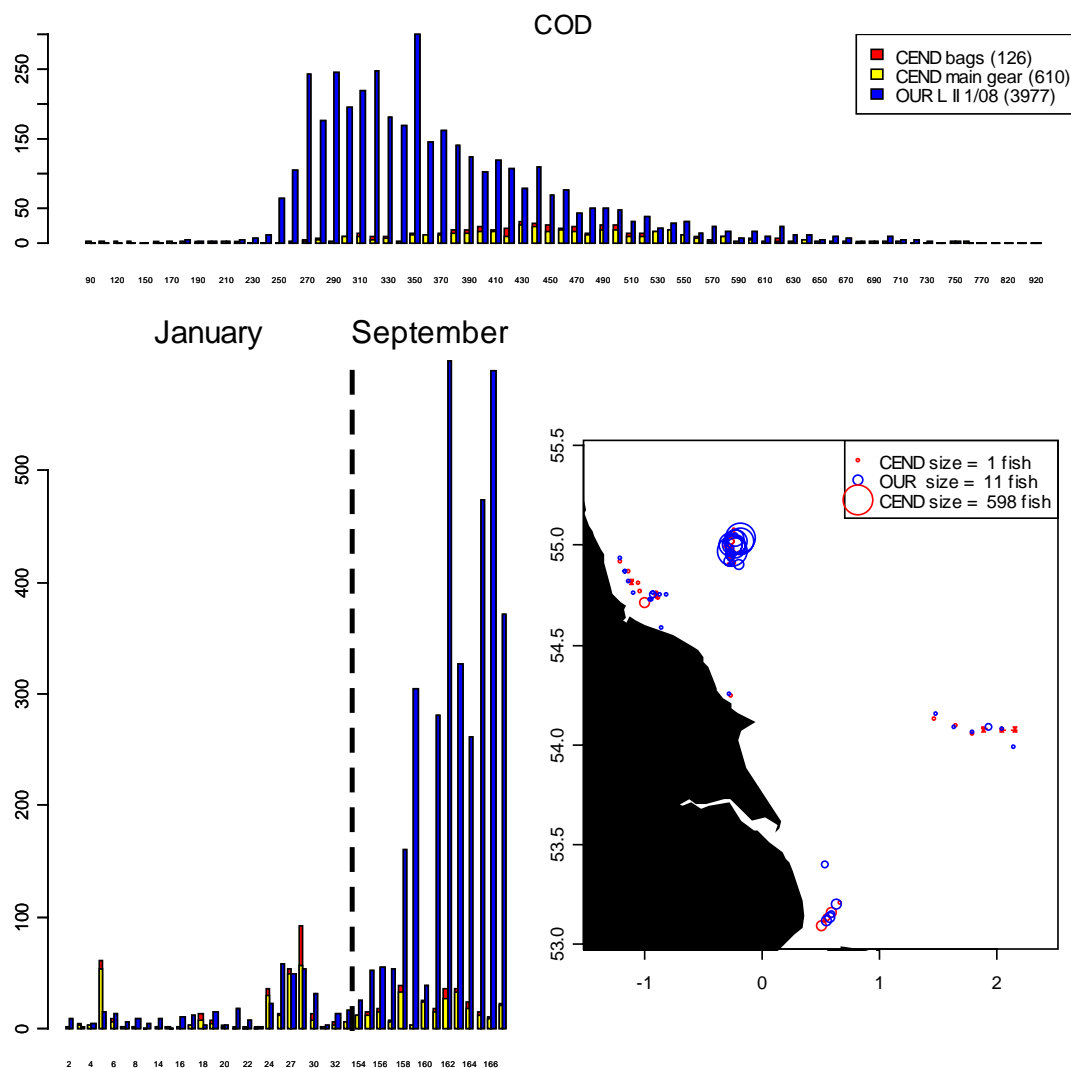


Figure 1. Cod length frequency, numbers per station and distribution of catches for both vessels in 2008. *Cefas Endeavour* catches are divided into those retained by the standard gear (yellow), and those caught by the escape bags (red). Maps of distributions show only those cod retained in the standard GOV gear.

Nevertheless, trends in the abundance of cod over stations covered by the RV are largely reflected in the trends observed in the *Our Lass II* catches when examined separately between the two periods (Figures 1 and 2).

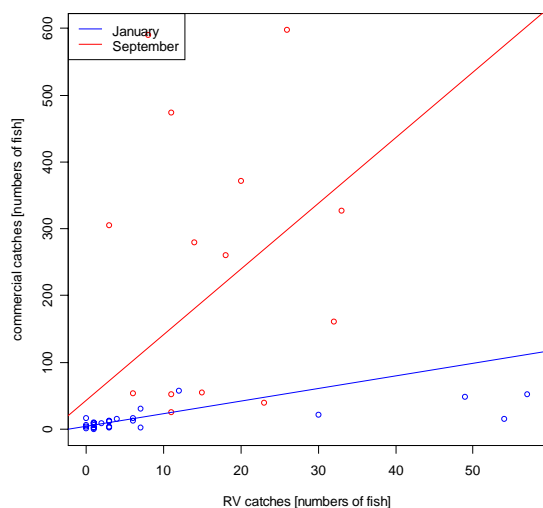


Figure 2. Correlation between RV and commercial cod catches by station. Lines are robust regressions of the estimated relationship for each season. The significant difference in the slopes reflects the seasonal difference in the commercial catch rates. The fit is poorer in September (red) than in January (blue).

Plaice

Our Lass II caught many more plaice (2330 for all stations) than the research vessel (684, with 232 escapees) except at stations 24–30, where it was not possible to deploy the scraper gear used during the rest of the gear trials. During the January cruise, the catch rates at stations 1–23 indicated some good station-by-station correlation despite the much higher catch rates of the commercial gear (Figure 3). The trend is more poorly represented in the September samples, where both RV and commercial sample sizes were lower.

The escape rate of plaice from the standard GOV was about 35%. Catch rates, although quite different in scale, followed broadly similar trends between both vessels across all stations, suggesting that proportionally representative components of the resident population were being sampled, except on those stations where *Our Lass II* had to employ the high-lift gear.

Plaice were most abundant offshore in the Skate Hole, and apparently least abundant in The Wash area. From an ecological perspective and specifically from published literature, one would expect them to be more numerous on soft-ground stations. This appears to be the case, although the statement is not borne out fully by the research vessel catches (Figure 3).

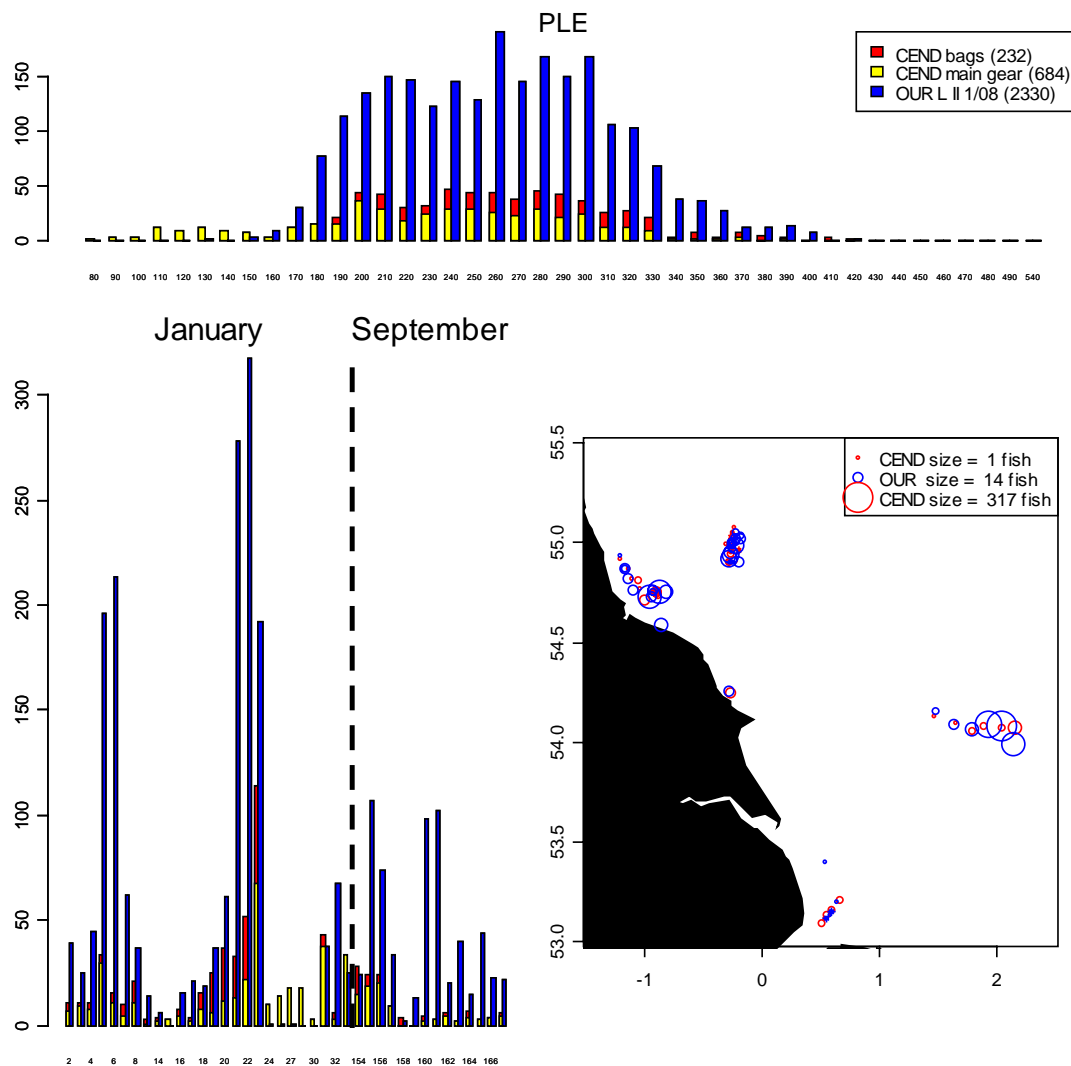


Figure 3. Plaice length frequency, numbers per station and distribution of catches for each of the vessels in 2008. *Cefas Endeavour* catches are divided into those retained by the standard gear (yellow), and those caught by the escape bags (red). Maps of distributions show only those plaice retained in the standard GOV gear.

Cefas Endeavour caught more smaller plaice <160 mm owing to its use of a smaller mesh codend. The apparent 100% retention rate for these smaller fish is likely to be associated with the larger meshes in the escape bags. For larger plaice, the length frequencies were broadly similar between vessels, although without clear modes it is not possible to distinguish random variation caused by sampling from distinct trends in catchability.

Haddock

The distribution of haddock decreased from north to south across the stations sampled, with consistently large catches off the Yorkshire coast and very few haddock caught in The Wash area (Figure 4). These trends are apparent by area, although there seems to be little relationship between the catches of the different

vessels across individual stations, suggesting that the species is encountered sporadically only, because of its patchy distribution.

Our Lass II caught more haddock (5365), but the RV catches were at least similar in magnitude (3177, with 96 escapees), with most haddock taken during September. When looked at seasonally, RV catch rates were similar to commercial rates in January, but lower in September.

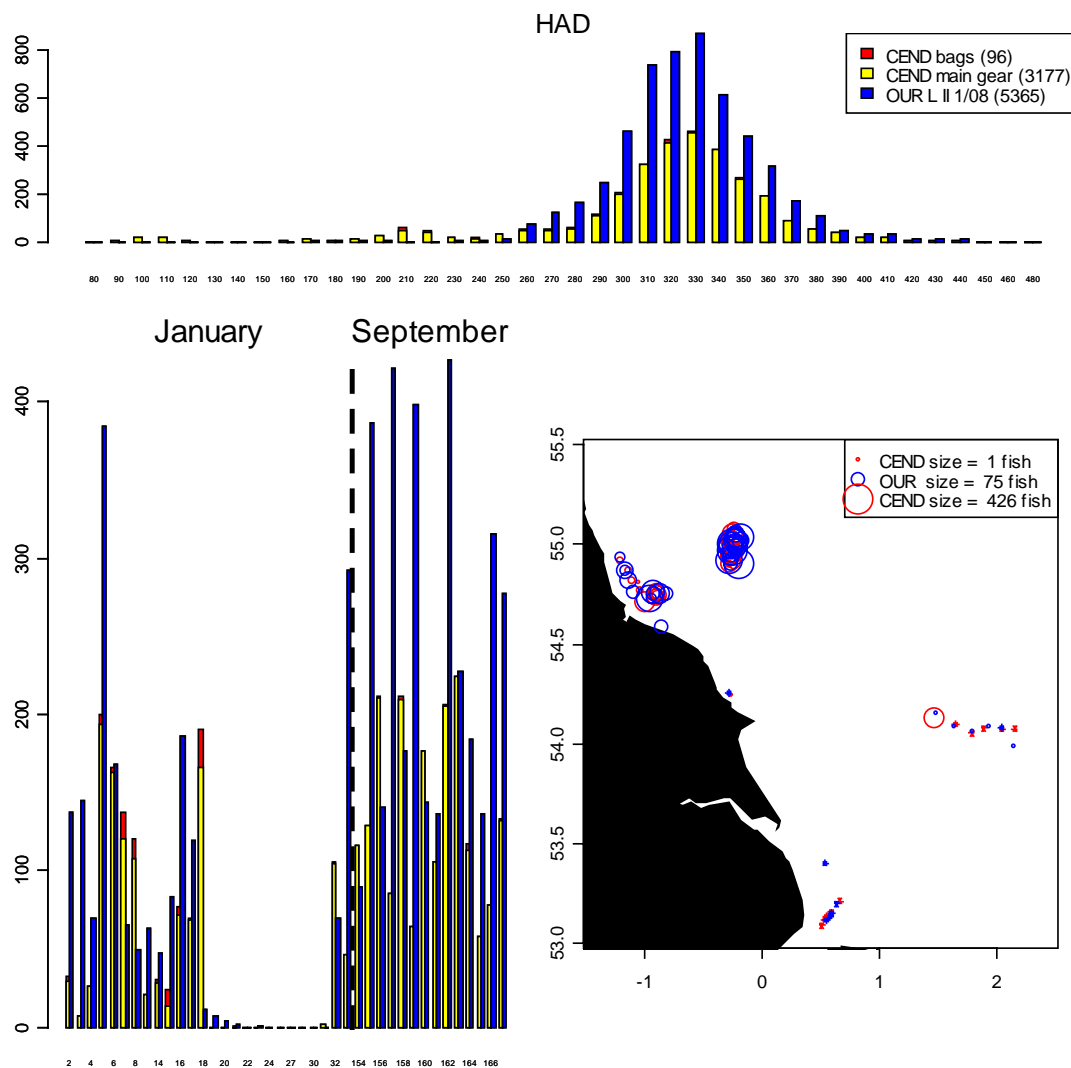


Figure 4. Haddock length frequency, numbers per station and distribution of catches for each of the vessels in 2008. *Cefas Endeavour* catches are divided into those retained by the standard gear (yellow), and those caught by the escape bags (red). Maps of distributions show only those haddock retained in the standard GOV gear.

Length frequency distributions were broadly similar at lengths >250 mm. At smaller sizes the GOV outperformed the commercial gear mainly as a consequence of the smaller mesh size.

Whiting

Whiting is the only species that was caught in larger numbers by *Cefas Endeavour* (59518 with 2258 escapees) than *Our Lass II* (48519). Overall catch rates in September were similar to those in January, although more sporadic earlier in the year (Figure 5). The correlation between RV and commercial catch rates across seasons indicates different relative catch rates between seasons, with the GOV showing greater relative performance during September.

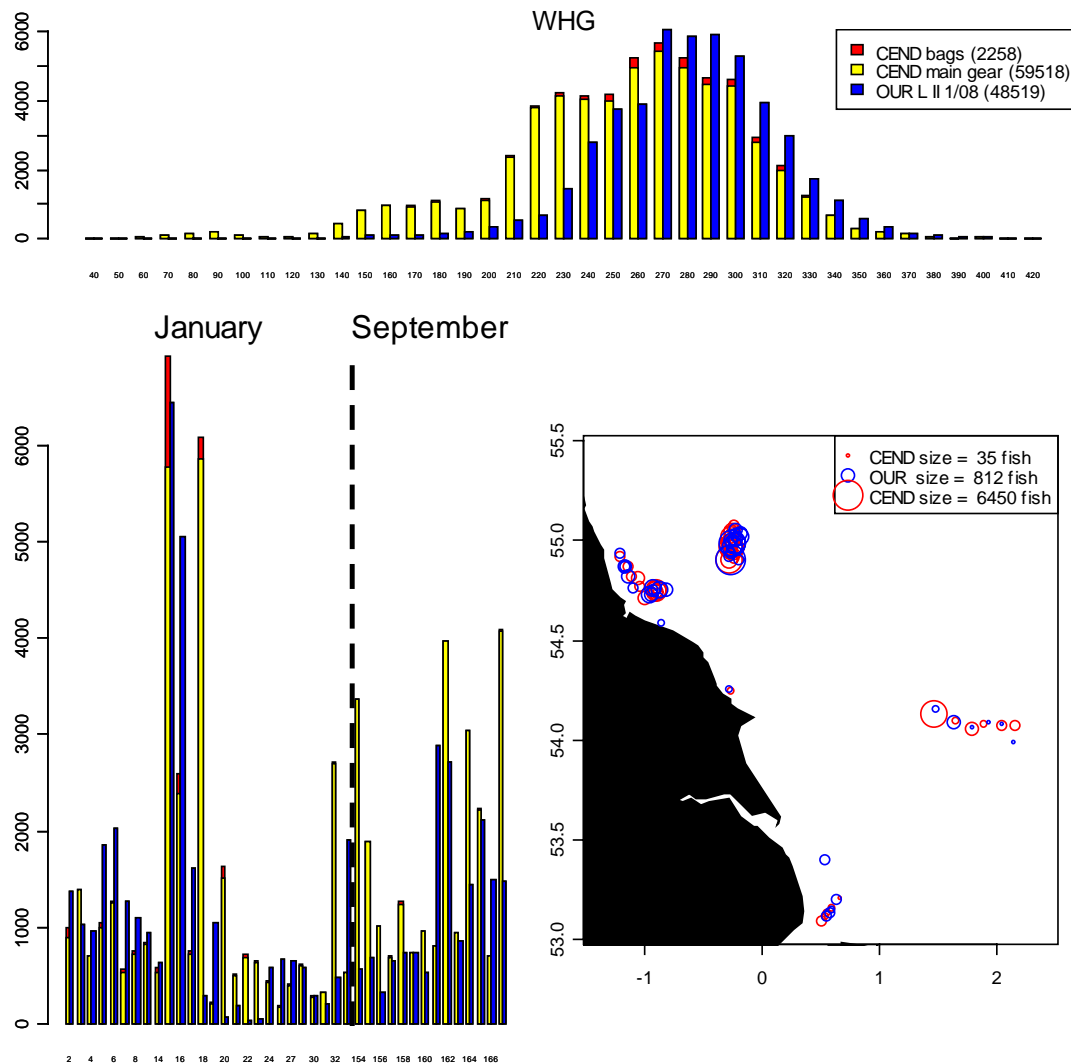


Figure 5. Whiting length frequency, numbers per station and distribution of catches for each of the vessels in 2008. *Cefas Endeavour* catches are divided into those retained by the standard gear (yellow), and those caught by the escape bags (red). Maps of distributions show only those whiting retained in the standard GOV gear.

Whiting dominated the fish catch in the trials, with >110 000 specimens collected. Their length frequencies indicate that catch rates and selectivities at lengths >250 mm are comparable, with the GOV showing greater selectivity at smaller sizes. It is difficult to ascertain whether the same populations are being sampled, owing to some very large samples influencing the length frequency samples.

Escape rates underneath the GOV

Cod

Some 17% of the cod caught were retained in the escape bags overall, with the escape rate decreasing from 20% in January to 14% in September. The model reflected this difference, indicating a seasonal effect on the escape rate along with both length and the size of the total cod catch. Retention rates were greater at larger sizes, meaning that most of the larger fish were retained by the standard GOV (Figure 6). Retention rates also increased with the size of catch up to about 35 fish, after which samples became too scarce in the analysis to be certain of any effect. This suggests that, as individuals, cod are more likely to escape underneath the net than when they are in schools, when they are more likely to enter the GOV.

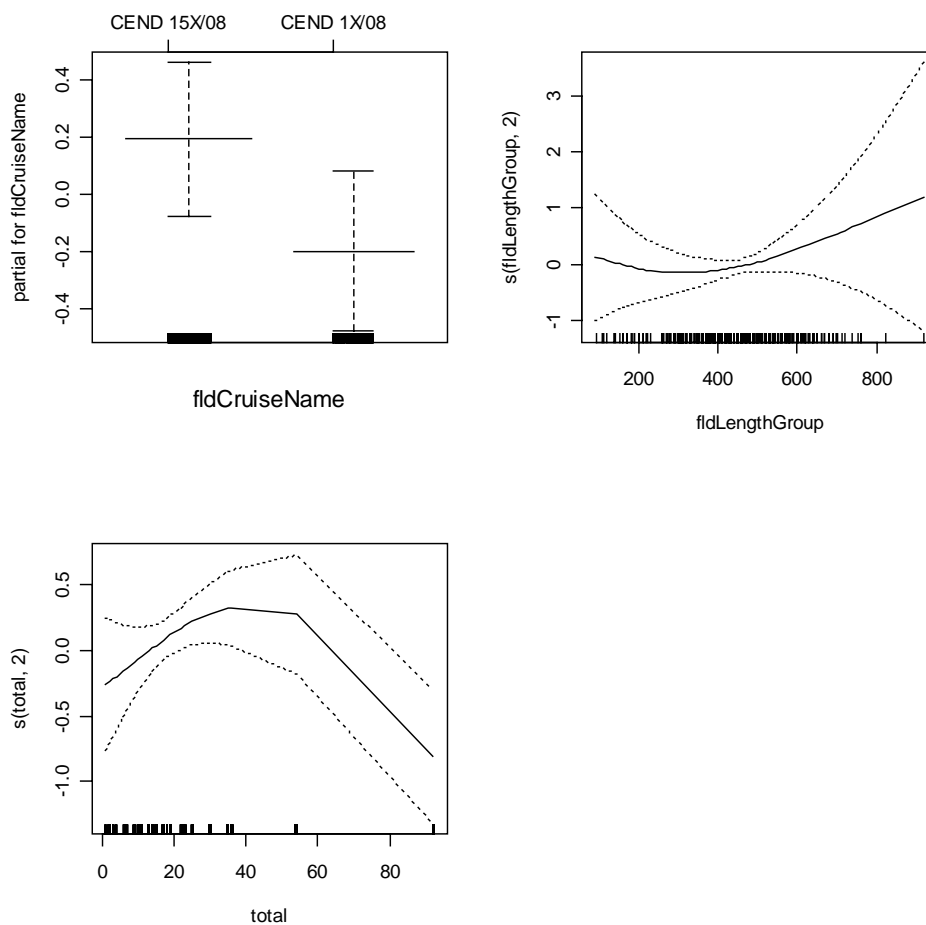


Figure 6. Statistically modelled trends in escape rates of cod with seasonal effect (top left), length (top right) and the total catch in number of cod (bottom left). Higher values indicate a greater chance of retention in the main gear, lower values a greater chance of escape. Dashed lines give some indication of the uncertainty around the trend line.

Interestingly, the shape of the spline effects is almost identical to those developed for the January data in the previous report. Even when just using the September data independently, the spline functions remain almost identical, so giving greater

confidence in the validity of the results than suggested by the confidence limits shown in the plots.

Plaice

Overall, 25% of the plaice sampled by *Cefas Endeavour* were caught in the escape bags, i.e. would not have been retained by the standard gear. There was a decrease in the escape rate between January (26%) and September (21%). There is some statistical evidence that the rate of escape depends on length, but part of this is an artefact of the difference in codend mesh size between the bags and the main gear, with the latter retaining smaller fish not seen in the bags (Figure 7).

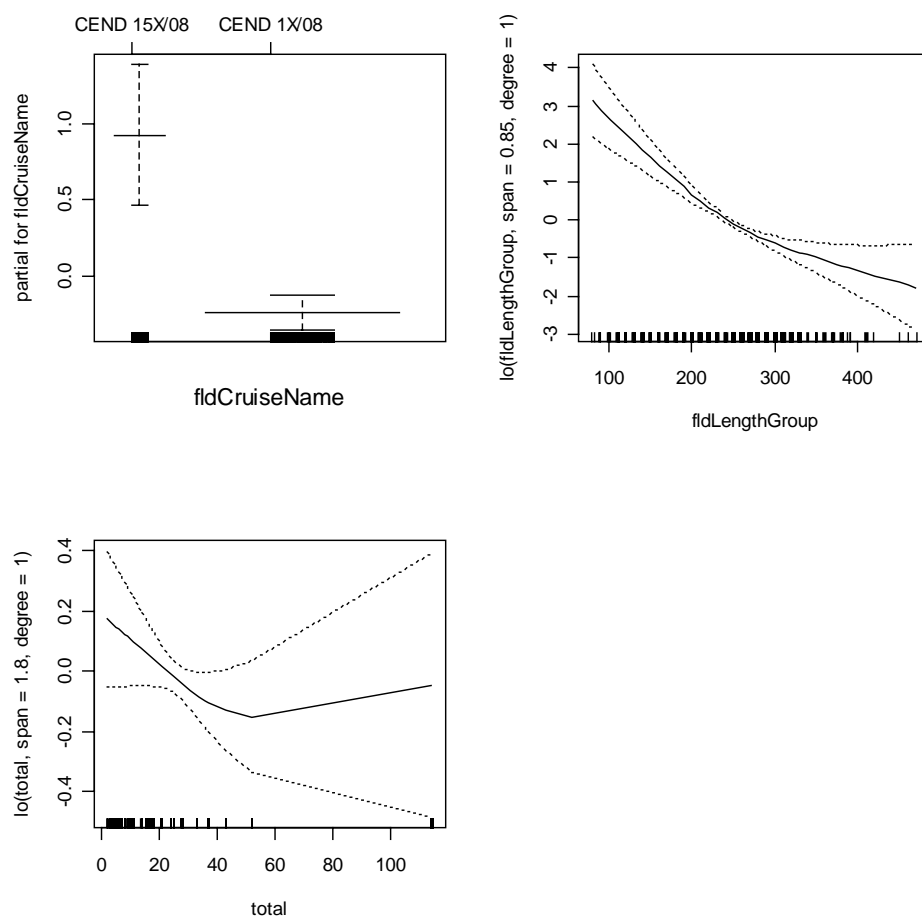


Figure 7. Statistically modelled trends in escape rates of plaice with seasonal effect (top left), length (top right) and the total catch in number of plaice (bottom left). Higher values indicate a greater chance of retention in the main gear, lower values a greater chance of escape. Dashed lines give some indication of the degree of uncertainty around the trend line.

Escapement represents a substantial portion of the fish available to the trawls, which in itself is not problematic if indices of relative abundance are being investigated, provided the proportion taken is constant. However, in this case there is an indication of a link between abundance and catch rate, suggesting that a greater proportion of

plaice escape as abundance increases, at least up to catches of about 50 fish per two miles towed.

Again these results are similar to those provided in the previous report on the January data alone.

Haddock

Only 3% (6% in January, <1% in September) of haddock escaped the GOV by diving underneath the net. Similar to cod, there seems to be an effect of an increasing rate of capture with increasing abundance, up to a point, after which it is not clear what happens because of the small numbers of samples with large catches. Unlike cod, there seems to be no effect of length on the escape rate, although few large haddock were encountered.

Whiting

Very few whiting, just 3%, (6% in January, <1% in September) escaped underneath the GOV. The effect of whiting abundance on catch rates is similar to that found in the other whitefish species, with the escape rate still increasing at catches of >2500 individuals. There seems also to have been an effect of length on escape rate, with larger fish more likely to escape. Some of this was almost certainly caused by the difference in the mesh size in the codends, but the effect appeared to continue up to a length of 400 mm, where both meshes should have, in theory at least, a 100% retention rate.

Camera observations

Extensive footage of the gear on the ground was reviewed. Unfortunately, it was not possible to situate the camera in a position to observe the behaviour of fish ahead of the footrope. The available footage did show the gear having good ground contact all the way into the wings and producing a sizeable sediment cloud, obscuring the possible route of escape between the ground gear and the fishing line. It also demonstrated that it was most effective to position the fishing line directly behind the ground gear so that the gap was a horizontal one with little chance of fish observing it until they had passed over the ground gear.

A small number of fish, identifiable as gadoids only because of the high speed of swimming and gear operation, were observed. These were seen to be actively swimming into the net, i.e. facing in the direction opposite to the direction of tow.

Discussion

This study has provided an important scientific insight into the interaction between fish and trawl gear, underlining the value of cooperation between industry and scientists in such work. Eventually, it is hoped that the knowledge gained can be fully integrated into our understanding of the fishery and fish behaviour, and improve the performance of stock assessments, where appropriate. For now, a number of

significant conclusions can be drawn helping us to understand the difference in perceptions of the state of the stocks between industry and scientists.

Cod

The GOV gear and the North Sea IBTS survey in general has been a point of contention between scientists and fishermen for some time. This direct comparison of commercial and RV catches has given some insight as to the origins of the different opinions and may offer some suitable explanations to these problems. A major issue for the industry currently is cod management, and fishermen have pointed to the ground gear of the GOV as one of the major confounding issues in the different perceptions of industry and scientists on the state of the stock. The original study indicated that the difference in catch rates between commercial gears and the GOV was attributable to the difference in the habitats sampled. This latest study, however, indicated that although comparable during winter, GOV catch rates on similar habitat were much lower than commercial catch rates (<10%) in September.

Reduced catch rates during autumn were, however, not associated with greater escapement underneath the ground gear due to improved visibility. Contrary to this expectation, escapement decreased by roughly 6% rather than increasing. One speculative explanation for this may be a difference in the herding effect. During winter, when water is turbid everywhere, disturbance of the sediment by the sweeps and direct observations of the bridles is unlikely to be effective, so the differences in the set-up of the two gears is minimal. During less turbid summer months the sediment cloud thrown up by the doors and the guiding of the bridles is much more discernible to visual predators such as cod. Consequently, the longer bridles on the commercial gear and the steeper towing angle increase the effective size of the net at that time of year.

The industry feel, the much lower relative catch rates in September confirm their concerns that the GOV gear as used on the survey is much less effective than the current commercial gears explaining some of the differences in the perception of the state of the stock between scientists and industry. Scientists have always argued that the set up of the ground gear is unlikely to be a major factor in the catchability of the net, which was also shown to be the case. These results indicate that only cooperatively do we have the knowledge and expertise to understand the processes involved in the interaction between fish and fishers. In fact, neither scientists nor industry suspected that the escape rate of cod, and other species, is lower during the summer when the waters are clearer than during the winter, so we have all learned something.

The study has shown that the GOV gear cod catches can be linearly related to the catches of the commercial gear within a season, but that cross-season comparisons are impossible, likely due to differences in the effectiveness of herding. Because the RV survey is always carried out at the same time of year, this should not bias assessments of the stock by itself. Improved catches could certainly increase the accuracy of the assessments, because better indications of year-class strength would be possible, particularly for older, scarcer ages. However, indications of the length frequency information indicates that the main difference in selectivity between the gears occurs

between 250 and 450 mm fish length, a range indicative of younger more abundant ages.

Effects of escapement

The results of the escape analysis indicate, as in the January study, that as catches increase, there is greater probability of an individual being retained. At low population numbers we would thus expect cod to be underrepresented in the survey data. The trend with total catch size presented has remained virtually unchanged from the previous study. Because the overall escape rate is estimated to be smaller in September and the model is multiplicative, this has reduced the variability in escape rate with changes in total catch size from the ~25% reported previously to closer to 10%. This indicates less bias in a survey carried out in September than one conducted in January.

Plaice

Plaice were most abundant offshore and least abundant in the area of The Wash, consistent with a distribution over sandy sediments. *Our Lass II* outfished *Cefas Endeavour* by 3.5× for this species, and as for cod, the difference between catch rates was greater during September. The between-season difference in catch rates was, however, much less pronounced than in cod, possibly because plaice behaviour is less visually stimulated than cod. Being most frequently positioned on the sediment, plaice are more likely to be guided by vibrations and physical contact from the sweeps than by visual cues from bridles and sediment disturbance, so water clarity will play a smaller role in the herding. The difference in the length of sweeps of the GOV (50 m) than of the commercial gear used in these trials on *Our Lass II* (180 m), and the associated difference in the towing angle, could then explain the consistent difference in catch rates.

The fact that the commercial gear used in The Wash by *Our Lass II* caught virtually no plaice does suggest that capture efficiency is strongly gear-dependent, so the result may justify the standardisation of the GOV for the purposes of monitoring surveys.

Effects of escapement

From a plaice-assessment perspective, reduced catchability in general and particularly at larger size does not necessarily serve to improve the assessment. Improving the gear would enhance the size of the catches, and more importantly increase the number of larger fish, which may serve to increase the number of ages and increase the precision of estimates at the older ages that are included in the assessment. However, because plaice catches are usually quite reasonable for the IBTS survey, there may not be much gain at all.

The non-linearity of the escape rate with abundance, although problematic, is not as serious as the cod situation from an assessment perspective, because the declining catch rate at greater abundance can imply an asymptotic relationship between catch rate (cpue) and abundance, which is included as an option in the current assessment methodology, XSA.

Haddock and whiting

Haddock and whiting were the most abundant commercial species during the trials. Spatially along the coast, they are more abundant in the north, and catches were smallest in The Wash. The largest catches were made offshore in the skate hole. The GOV is highly efficient at capturing these species, whiting in particular. The GOV net design is such that the height of the opening reduces upward escape of demersally orientated species, similar to high-lift commercial gears. Seasonal differences in the relative commercial to RV catch rates were small compared with plaice and cod.

The distributions of haddock and whiting were only weakly correlated on a station-by-station basis between the commercial gears and the GOV, but they did show reasonable correlation on an area-by-area basis, suggesting that the fish are sporadically distributed on a fine scale, as expected of schooling fish. Catch rates for these species were generally comparable between the gears, and overall only some 3% of catches escaped underneath the ground gear, less so during September than during January, as for cod and plaice.

The statistical analyses indicated that whiting were more likely to escape at greater depth (presumably because of the net geometry) and at larger size, although the latter effect will have been overestimated because of the difference in mesh selectivity between the GOV and the escape bags. In addition there was an indication of an effect of total catch of both haddock and whiting, similar to that observed for cod. At greater abundance, there was initially an increase in the percentage of fish retained, up to 100 and 3000 fish for haddock and whiting, respectively. There was a clear saturation effect for larger catches of haddock (asymptotic), whereas whiting catches declined at greater abundance, but this was based on a very small number of samples.

Effects of escapement

During the trials, tows within a half mile of each other could produce very high and very low catches, even using the same gear and without any apparent change in habitat. It is therefore clear that the distribution of these commercial fish is currently very patchy, probably associated with a weak schooling behaviour. Consequently, the assessment tuning information gathered on these species must be very much influenced by the large catches at some individual stations. This will introduce variability rather than bias into the assessment, but it will also tend to bias the important recruitment estimates for the final year, because there is no other source of information available for that cohort.

From an assessment perspective, the patchy distribution causes the error to be over-dispersed compared with that assumed by the assessment, which could make the assessment overly sensitive to large outliers. The relationship between escape rate and abundance from a theoretical standpoint is as undesirable as the one for cod, but the magnitude of the effect is likely to be influenced by the very low escape rate (<1% at the time of the survey) in the first place. For now and with the information currently to hand, therefore, it is possible to identify only potential weaknesses in the survey information with regards to the assumptions in the assessment, and not necessarily the direction or the magnitude of the effect.

Conclusions

The study has identified different factors influencing the GOV catch and escape rates of specific species and suggests some reasons for these differences. Commercial gears are more effective at capturing cod and plaice, but it has to be remembered that the GOV gear is a compromise for capturing a wide variety of fish over as large an area as possible, and as such it performs well overall. For individual assessments, such as those for plaice and cod, it may be possible to improve the precision and accuracy of abundance estimates by exploring the interaction between gear and fish further, and by modifying the gear and/or the assessment process. However, such action may not be desirable for a survey with multispecies, multi-stock objectives.

Camera observation of the net indicates that ground contact of the GOV is generally good and that the gap between the ground gear and footrope is not a major hindrance to a successful survey and assessment. In order to determine precisely the cause of the differences in the catch rates between gears, it will be necessary to observe the behaviour of fish outside the direct path of the net, something not tried in these experiments.

For all species, the effect of increasing catchability with increasing stock size was smaller at the time of the September survey than during January, but the magnitude of the effect on the assessment needs to be investigated.

This study has determined some basic parameters satisfying the overall programme objectives:

1. In January the standard GOV catch rates for cod are >80% of those on commercial vessels, with 20% of the fish escaping below the net. In September the GOV captures just ~8% of those fish caught by the commercial gear, but the rate of escape underneath the ground gear also decreases to about 14%. Percentage retention of cod can vary from 75 to 85% during the time of the survey, depending on abundance on the ground; the current ICES assessment assumes that catch rates are not affected by abundance.
2. GOV catch rates for plaice are much lower than commercial rates (25%), even when including the portion escaping under the net (39%). It seems more likely that this is due to a difference in the effectiveness of herding, because losses from the GOV gear are much smaller than this difference. This effect will not bias the assessments, but it might be possible to decrease uncertainty if larger catches of older fish are made.
3. Haddock and whiting are sampled adequately by the standard GOV gear, but their distributions are patchy over very small spatial scales, leading to an over-dispersed frequency distribution, which may affect the accuracy of the assessment, particularly of the final years of recruitment. Consequently the effect would be most felt in the forecast, rather than in the assessment itself.

In the opinion of the industry:

1. The differences in the cod catches by the two vessels in the latest survey prove beyond doubt that the gear and set-up used by the *Cefas Endeavour* does not provide a true reflection of the absolute biomass of cod during September.
2. The sweep length and the trawl doors are not compatible and overspread the gear so that the sweep angle is too shallow.

3. However, industry members also acknowledge that despite a much lower catch rate than might be expected from commercial vessels, in relative terms the trend line (percentage increase and decrease) in cod stock size would be similar to trends in commercial catch rates.
4. Remaining issues are the small correction for GOV escape rate with increasing catch rates and past changes in gear geometry caused by a change of research vessel and gear deployed which could be significant.
5. The results underline the importance of continuing industry and scientific cooperation in understanding the interaction between GOV and fish on the ground.

The results by objective were:

Objective 1

The study quantified the rate of escape of cod and plaice underneath the ground gear as 0.17 and 0.25, respectively, as proposed in the objectives, and in addition indicated that haddock (0.03) and whiting (0.03) escape rates were negligible.

Objective 2

The study showed that GOV catch rates of cod were much lower in September than those of the commercial gear, whereas they were more comparable during January. For plaice, survey catch rates were much lower than comparable commercial catches at both times of the year. Haddock catch rate differences also increased in September, but whiting, the only species that was more abundant in RV catches, was more readily caught by the GOV in September. The distribution of both haddock and whiting seems to be more patchy, but correlated well across habitats in general.

Objective 3

The camera footage obtained indicated that ground contact of the gear was good, although it was not possible to observe much of the interaction of fish with the ground gear because the sediment thrown up by the ground contact obscured the view. Also it was not possible to mount the camera in such a way that it was possible to observe the fish in the area ahead of the ground gear.

Acknowledgements

This work was carried out in cooperation with the skippers and crew of the FV *Our Lass II* (skipper James Locker). Cefas sincerely thanks the skippers and their crews for their contributions to the programme, and also acknowledges with thanks the contributions made by the Cefas staff in sampling and entering and collating data. Thanks are also due to Fred Normandale and Joe Horwood for their individual inputs to this research initiative, especially related to their detailed knowledge of the issues important to fisheries and the management of stocks in the North Sea. Dave Reid and Rob Kynoch of the FRS Marine Laboratory, Aberdeen, are thanked for the provision of gear plans and expertise on the use of escape bags, as well as for sharing their knowledge of the behaviour of fish in relation to fishing gear.

Appendix 1: Detailed operational plan

2007/08 NFFO-CEFAS Fisheries Science Partnership

Detailed work plan for Programme: GOV gear comparison.

Objectives of programme

Primary objectives

- 1) To quantify the rate of escape of cod and plaice underneath the ground gear and through the gaps between the fishing line and ground gear of the GOV trawl as used in the North Sea ground fish survey (ground gear A, for soft ground stations). Using additional bags underneath the gear to capture escapees, the aim is to develop quantitative models that describe the effects of length of cod, abundance of cod and a number of environmental co-variables on the rate of escape from the GOV.
- 2) To calibrate the catch rates on the research vessel to commercial catch rates using commercial gear and practices.
- 3) To determine the means of escape visually from images recorded by a camera mounted on the gear, and to describe the ground contact, and behaviour of the gear more generally, over a number of different soft bottom habitats.

Secondary objectives

- 1) If primary objectives have been completed with cruise time remaining, it is hoped to re-rig the escape bags to the GOV gear used to fish on hard ground stations (ground gear D), in order to test the ability of the bags to withstand hard ground stations and to start quantifying routes of escapement for this gear / habitat combination.
- 2) To quantify differences in catch rates between the GOV gear, and the commercial gear on soft ground stations with those obtained by a second commercial vessel operating on adjacent hard ground stations.

Vessels and gear

Vessels, fishing gear and deployment: The fishing vessel Our Lass II will provide the direct comparison to the Cefas Endeavour, whilst the Jubilee Quest will provide a comparison between the catch rates on soft ground stations and hard ground stations. Commercial vessels (Our Lass II, Jubilee Quest) will be using 80mm codends, while Endeavour will use the standard 50mm codends with a 40mm mesh liner. The bags fitted underneath the GOV will use 80mm codends again with a 40mm mesh liner fitted.

Operational plan

Fishing operations will take place in the UK sector of the North Sea south of the 56°N line. A small number of tows will be conducted on Endeavour alone on her way down from Aberdeen where she is in dry dock prior to this trip. This will allow crew and

staff to get used to the deployment of the more complicated gear set up. At the moment the plan is to start comparative fishing at Stations 13 (54 N 55.44; 0 W 18.01) and to move south or east from there as weather conditions dictate, probably ending up somewhere near the southeast corner of the UK EEZ. The aim is to collect as many samples as possible, whilst covering as wide a range of conditions as possible, with regards to the length composition and densities of cod.

Sampling is to be conducted mainly between 7am and 7pm and in favourable weather conditions (less than force 7), with additional work to be conducted only under the agreement of all parties (commercial charter captain / observer on the commercial vessel, SIC and fishing skipper on Endeavour) to ensure successful completions of the primary aims.

Comparative trials will alternate the order in which Endeavour and Our Lass II will operate to limit bias through disturbance. Tows will be carried out in parallel and in a straight line, with one boat slightly ahead of the other. The tow distance is to be standardized to 2 nautical miles, with Endeavour towing at 4 knts and Our Lass II towing at it's normal operational speed of around 3 knots. Operations on the Jubilee quest will also be standardised to 2 nautical mile tows, but because they are towing in adjacent areas on hard ground stations timing is not as critical, but certainly should be within 30 minutes of the start of operations on the direct comparison.

The skippers on all vessels will record relevant parameters for each haul:

- Time and position (lat/long) when the net touches down at the start of the tow and when it lifts off at the end of the tow.
- Water depth and warp out;
- Trawl door spread
- Headline height
- The commercial vessels logsheets should be annotated with FSP programme 2 to identify the trips which are off quota so that they will not be entered onto the BSDB

On commercial vessels crew will sort the catch into retained and discarded portions and assist the observer in recording relevant parameters for each haul:

- Total landed catch of each species
- An estimate of the quantities discarded, by species
- Representative length frequency distribution of landed and discarded cod, plaice, haddock, and whiting. (Other commercial species as time allows).

On Cefas Endeavour, hauls will be worked up separately from each of the escape bags and the cod end.

- Total catch of each commercial species
- Representative length frequency distribution of catches of all commercial species.
- A representative sample of otoliths will be collected for cod and plaice.

Appendix 2 Cruise Report

Cefas LOWESTOFT LABORATORY, LOWESTOFT, SUFFOLK NR33 0HT

2008 RESEARCH VESSEL PROGRAMME

REPORT: RV CEFAS ENDEAVOUR: SURVEY 1X

STAFF

B Harley (SIC)
S Kupschus
G Course
M Parker-Humphreys
R Humphreys
S McCully
D Brown
R Ayers

Arnold Locker (Fishing Industry representative)

DURATION: 6 January – 15 January

LOCATION: North Sea

AIMS

1. To estimate escape rates using additional bags that close the gab below and behind the fishing line on the standard GOV survey gear (Cefas Endeavour) and to compare the standard catch rates with commercial vessels fishing along side using commercial gear on soft bottom habitats (tows in parallel) and hard ground habitats (in the vicinity). Samples for age will be collected for cod, plaice and haddock and for other species as time allows.
2. To determine the behaviour of fish in response to the standard GOV gear and to investigate means of escape a low light level camera will be installed on the net to make video recordings for later evaluation.

Additional aim

If time allows additional tows using the Poly Rockhopper GOV may be carried out.

NARRATIVE (all times GMT)

Cefas Endeavour sailed from Aberdeen at 2130h on the 7 January and headed southeast to Swallow hole to do a shakedown tow and tighten the windings on the winch after the dry dock. The standard GOV, fitted with three ground gear bags was successfully deployed in Swallow Hole, however, weather started to deteriorate and no more tows were possible that day. The vessel steamed southwest towards the Yorkshire coast throughout the rest of Monday, ready to rendezvous with the FV Our Lass II and the FV Jubilee Quest the following morning. The FV Our Lass II fished a

commercial soft groundgear net in parallel with the Cefas vessel and the FV Jubilee Quest fished in close proximity but on hard ground stations with a commercial hard ground gear. With the weather having moderated enough to fish, the gear was deployed at 0729h on 8 January and two successful tows were carried out. On the third and fourth tow of the day, the low light camera was attached to the selvedge, in an attempt to show movement of fish in the bosom of the groundgear (Figure 1). Unfortunately, due to the amount of sediment in the water following the storms, no footage was usable. The camera was removed and three more tows were successfully carried out that day. That night the weather deteriorated again and the vessel headed further inshore to anchor overnight. The following morning, the weather was still poor and Endeavour stayed anchored until lunchtime when we steamed northwest and were able to fish two stations on 9 January. With the weather forecast still being poor, fishing continued in the same area and on 10 January completing three more stations before the weather conditions prevented further sampling. On the second tow of the day, the camera was attached again but again no clear footage was obtained. The forecast for the following day was good so the vessel steamed east overnight to Skate Hole and 6 valid tows were completed. On the third tow that day the camera was attached again, but again no useful footage was obtained as there had not been sufficient time for the sediment to settle. With weather being good, we steamed overnight to the Wash the gear was deployed and in the deepwater channel. On the second tow of the day, 10 minutes before the end of the tow, the Scanmar readings changed. We continued the tow and on hauling the belly of the GOV was torn and the centre groundgear bag had a large metal mast in it. Damage was done to the centre bag and the GOV. This took 3 hours to mend and fishing commenced again at 1416h. On the final tow of the day, the headline sensor reading started to give readings well outside the expected readings, so the decision to cut the tow short to 1nm was taken. No damage was found, however a string of abandoned lobster pots were found on the starboard door and in the GOV net but the hauled was deemed valid. The Jubilee Quest transferred some fishing position data obtained in Scarborough just after dark and Cefas Endeavour steamed north towards Scarborough overnight to fish off Filey and Scarborough the following day, with the information given. At 0824h the first tow of the day was fished. The tow yielded very little roundfish and the decision to steam back to the Hartlepool grounds was made. Two successful tows were carried out over the grounds fished on Tuesday 8 January, however on the third tow of the day, all three cod-ends of the groundgear bags were damaged, and no fish were found in those nets. Due to the time needed to repair the nets, the vessels steamed south to wait off Whitby, in order to drop Arnold Locker off at first light on Monday 14 January. The FV Our Lass II and FV Jubilee Quest finished their charter with Cefas on the evening of Sunday 13 January and, after dropping Arnold Locker off, and with the forecast for Tuesday being severe southerly gales, Cefas Endeavour headed for Lowestoft and docked at xxxh on Tuesday 15 January.

RESULTS

AIM 1: 24 valid comparative tows fished alongside the two fishing vessels and 2 additional tows were fished (Figure 2). SCANMAR equipment was used to monitor headline height, wing width and door spread. At each station, the catch of all commercial species was weighed with the remainder of the catch being grouped together and a total weight of this taken. All commercial fish, or representative samples, were measured. Table 1 lists the commercial finfish species caught that were

sampled for length and shows the total weight of these commercial finfish species compared by GOV and ground gear collection bags and table 2 shows the same species giving total numbers. Data was recorded using the Cefas Electronic Data Capture System. Further analysis will be carried out on return to the Lowestoft laboratory. Samples of otoliths for age determination were taken as specified in standard instructions and table 3 shows the total number of biological samples taken during the survey. For information, figures 3-7 shows the length weight relationship for cod, haddock, whiting, plaice and sole for the biological samples collected.

AIM 2: The low light camera was attached to the net on four of the 26 tows, in an attempt to determine the behaviour of fish in response to the standard GOV gear. Unfortunately due to the low ambient light and the amount of sediment in the water no useable video footage was obtained.

Due to weather no additional time was available to try the ground gear bags on the hard ground rig.

This survey is part on a fishing industry partnership and further reports will be available from the two fishing vessel involved in the program. Our thanks go to Arnold Locker, the skippers (Graham Hall, James Locker) and crews of the FV Jubilee Quest and FV Our Lass II for the co-operation and the information given to allow the smooth running of this program.

B Harley
14 January 2008

DISTRIBUTION

Basic list +
B Harley
S Kupschus
G Course
M Parker-Humphreys
R Humphreys
S McCully
D Brown
R Ayers
Arnold Locker, *Our Lass II*

Figure 2. Plot of shooting positions from Cefas Endeavour 1x/08 survey

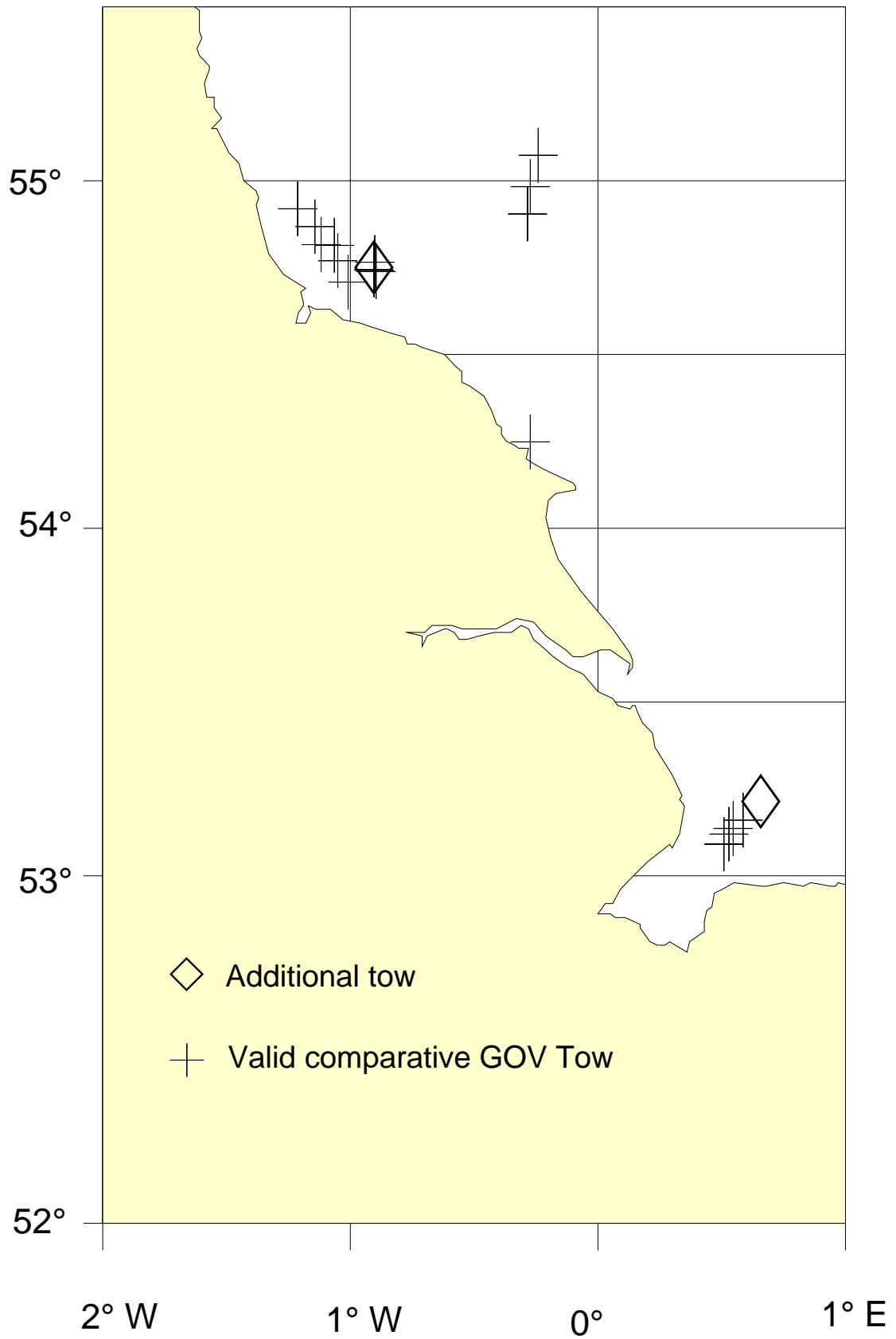


Table 1 Catch weights from GOV and ground gear bags(weight in kg)

Species	Standard IBTS GOV	Centre Ground Gear Bag	Port Ground Gear Bag	Starboard Ground Gear Bag	Grand Total
Brill	2.20	1.63		1.62	5.45
Cod	271.02	52.58	16.34	9.61	349.55
Cuckoo Ray	8.71	6.22	2.65	1.35	18.92
Haddock	337.92	11.88	10.06	2.05	361.90
Plaice	45.63	25.87	10.52	12.60	94.61
Sole	16.56	2.96	1.70	1.07	22.29
Thornback Ray	93.01	8.89	6.58	0.91	109.39
Turbot	4.00				4.00
Whiting	4750.71	210.17	97.12	52.75	5110.74

Table 2 Catch numbers from GOV and ground gear bags

Species	Standard IBTS GOV	Centre Ground Gear Bag	Port Ground Gear Bag	Starboard Ground Gear Bag	Grand Total
Brill	3	2		2	7
Cod	223	49	18	13	303
Cuckoo Ray	16	13	7	4	40
Haddock	1051	49	29	6	1135
Plaice	329	113	38	45	525
Sole	144	9	3	3	159
Thornback Ray	85	12	6	1	104
Turbot	3				3
Whiting	30816	1195	598	363	32972

Table 3 Biological samples

Species	Number collected
Whiting	634
Plaice	358
Cod	297
Haddock	244
Starry Ray	132
Spotted Ray	117
Sole	97
Thornback Ray	91
Cuckoo Ray	36
Blonde Ray	1
Saithe	1
Grand Total	2008

Appendix 3 Extract from the IBTS North Sea Groundfish Cruise Report by Brian Harley

FSP survey narrative. On the evening of 2 September, Sven Kupschus was picked up by searider from Whitby in order to take part in the FSP comparative gear trials survey with the *FV Our Lass II*. Arnold Locker joined Endeavour at 0700h the following morning and the vessels steamed to grounds off Hartlepool to start the trials part of the survey. The GOV was rigged with the ground gear bags as before and the new low light camera was attached to the net for the first haul. The haul yield some cod but the skipper of the *FV Our Lass II* advised that we moved further offshore to Baymans Hole as greater numbers of cod had been reported by the industry in that area. Three successful tows were carried out at Baymans Hole before dark that night yielding good catches of cod. Fishing continued in the vicinity of these grounds, but and on the second tow of the following day the net was hauled with significant damage to the main gear and experimental bags whilst straying onto hard ground. The repair took 5 hours, after which there was sufficient light only for two more tows to be completed that day. The following day 6 tows were completed without further incidence and it was decided to extend the trial by one day to equal the number of tows conducted during the January trials. However, on attempting to shoot the net on the morning of 6 September, the Endeavour's net drum failed and it was not possible to fix the problem in time to continue fishing. The survey was curtailed and the vessel steamed towards Whitby to drop Arnold Locker off, before heading back to Lowestoft to dock at 1430h on 7 September. The *FV Our Lass II* continued fishing commercially for the remainder of the day before returning to Whitby the following morning. Results from this part of the survey will be presented in a further report at a later date.