Final Report

Project 24: North Sea GOV gear trials

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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.

Catch rate comparisons were made between two commercial fishing boats – the *Our Lass II* fishing soft-ground areas (supported by the FSP) and the *Jubilee Quest* fishing hard-ground areas (funded by the fishing industry with a contribution from Defra), 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 roughly 70% of those on commercial vessels on soft ground stations, with on average of 25% escaping under the net. Patterns of abundance across areas were consistent with those found by commercial vessels on the same habitat.

However, the distribution of cod is not uniform across habitats in the North Sea, with younger cod favouring the higher relief of hard ground stations for its protection from predators. On hard ground tows only fished by the commercial trawler *Jubilee Quest* in these trials, catch rates were significantly higher because of the larger concentrations of cod in such grounds. The affinity of smaller cod for this habitat is also borne out by the smaller mean length of the catches compared with that of the *Our Lass II*. Cod found on hard ground habitats therefore represent a separate portion of the population and cannot usefully be compared with the survey tows in terms of catch rates.

At low densities, an average of 40% of cod would escape underneath the standard GOV gear. This decreased substantially to just ~15% at greater abundance, indicating that the relationship between abundance on the grounds and catches is not linear, as assumed by the assessment.

GOV catch rates for **plaice** were much lower than commercial rates (21%) on soft-ground areas, even when the portion escaping under the net (33%) was included. The reasons for this are not yet clear, but it could indicate that the commercial gear was more efficient at herding plaice owing to the longer sweeps used. 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 70% of the commercial catch rates and the vessel caught more whiting than the commercial vessels.

The conditions in January were hardly ideal for direct observation, nor would the fish been able to see much of the gear as it approached. Fish use a wide variety of sensory organs when exploring their surroundings, and the value of vision in this is unclear, so it seems prudent to re-estimate the escape rate in clearer, brighter conditions when it would also be possible to observes the response to the approaching gear by camera.

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.

To address these specific concerns and to examine spatial distribution issues on the scale of miles rather than on the scale of the North Sea, a complex work package was developed between fishermen and scientists to address the industry concerns. The main focus of the work was the finfish species of commercial importance to the English NS whitefish fleet, i.e. cod, haddock, whiting and plaice.

Catch rate comparisons were made between the commercial sector, represented by the *Our Lass II* (skipper James Locker) fishing soft-ground stations (funded by FSP) and the *Jubilee Quest* (skipper Graham Hall) fishing on hard-ground stations with rockhopper gear (funded by industry and subsidised by Defra), and those achieved by the *Cefas Endeavour* using the soft-ground GOV set-up. Standardised 2-mile tows were carried out to test whether the research gear survey was likely to pick up the same component of the stock as the commercial vessels.

To estimate the rates of escape of the major commercial species from the standard IBTS (International Bottom Trawl Survey) gear, the *Cefas Endeavour* GOV gear was fitted with additional nets behind the ground gear to capture the fish escaping. The aim was to determine the catch rate, and also to see which factors, if any, would influence the rate of escape.

As an adjunct to the main work, an underwater camera was 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 these objectives were agreed by industry, management and science in advance, and this report presents the results. The trials were carried out from 8 to 15 January 2008 near the English coast of the central North Sea.

Objectives of the 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 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 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 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.

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.

Jubilee Quest: Grimsby-based, steel-hulled twin rigger of 19.34 m registered length (21.2 m overall, 347 kW). Built in 1997, she fished two gears during the trials, a Jackson high-lift trawl fitted with rockhopper ground gear, and a low-lift trawl designed by the skipper along the lines of a “Danish scraper” 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 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. The *Jubilee Quest* was employed to investigate the distribution of catches on nearby hard grounds using her rockhopper gear. Because of their smaller engine size, the commercial boats were 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 80 mm codend, 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 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.

Location, time, sea conditions, 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 for each haul.

On the commercial vessels 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 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.

For logistic and operational reasons not all tows were completed by all vessels. Therefore, for the purposes of comparison between vessels only those stations fished by all 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 bi-cubic spline smoothers with 2-3 degrees of freedom. The model assumed a binomial error distribution modelled via a logit link function, hence 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 a lot of 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.

An attempt was made to observe the behaviour of the fish in the mouth of the net and to determine the methods of escape, using a video camera. Unfortunately, however, because of the generally poor weather, turbidity and low light conditions in winter, no observations of value were possible. Therefore, this secondary aim of the project had to be abandoned. If follow-up comparisons become possible at a time of the year when weather conditions are better, it is hoped to repeat at least the escape bag part of the project then.

Results

A total of 22 stations was completed, i.e valid catches for all vessels, catching in all 2748 plaice, 1808 cod, 3925 haddock and 54 073 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. Total numbers by species, percentage of largest by ground and GOV escape rate, indicating the percentage of fish in the escape bags compared with the total measured.

	Numbers		Proportion		
	Caught	Escaped	of largest catch overall	of largest soft ground	GOV escape
Plaice					
Cefas Endeavour	350	191	0.209	0.209	0.353
Our Lass II	1676		1.000	1.000	
Jubilee Quest	531		0.317		
Cod					
Cefas Endeavour	250	82	0.224	0.693	0.247
Our Lass II	361		0.324	1.000	
Jubilee Quest	1115		1.000		
Haddock					
Cefas Endeavour	1036	69	0.678	0.678	0.062
Our Lass II	1527		1.000	1.000	
Jubilee Quest	1293		0.847		
Whiting					
Cefas Endeavour	22053	786	1.000	1.000	0.034
Our Lass II	18221		0.826	0.826	
Jubilee Quest	13013		0.590		

To examine the results on a station-by-station basis, catches of each species made by each vessel were compared. 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

Jubilee Quest caught substantially more cod (1115) fishing on the hard ground than the vessels fishing on the softer ground. Station 20 specifically had a particularly large catch of cod, although it appeared that the general area in the vicinity did not yield many cod. Soft-ground tows were generally more productive for cod in The Wash area than farther north. This was also true in general for the hard-ground tows; it seemed that in such an environment, the patchiness of cod on the ground appeared to allow for good catches in generally less productive areas (Figure 1).

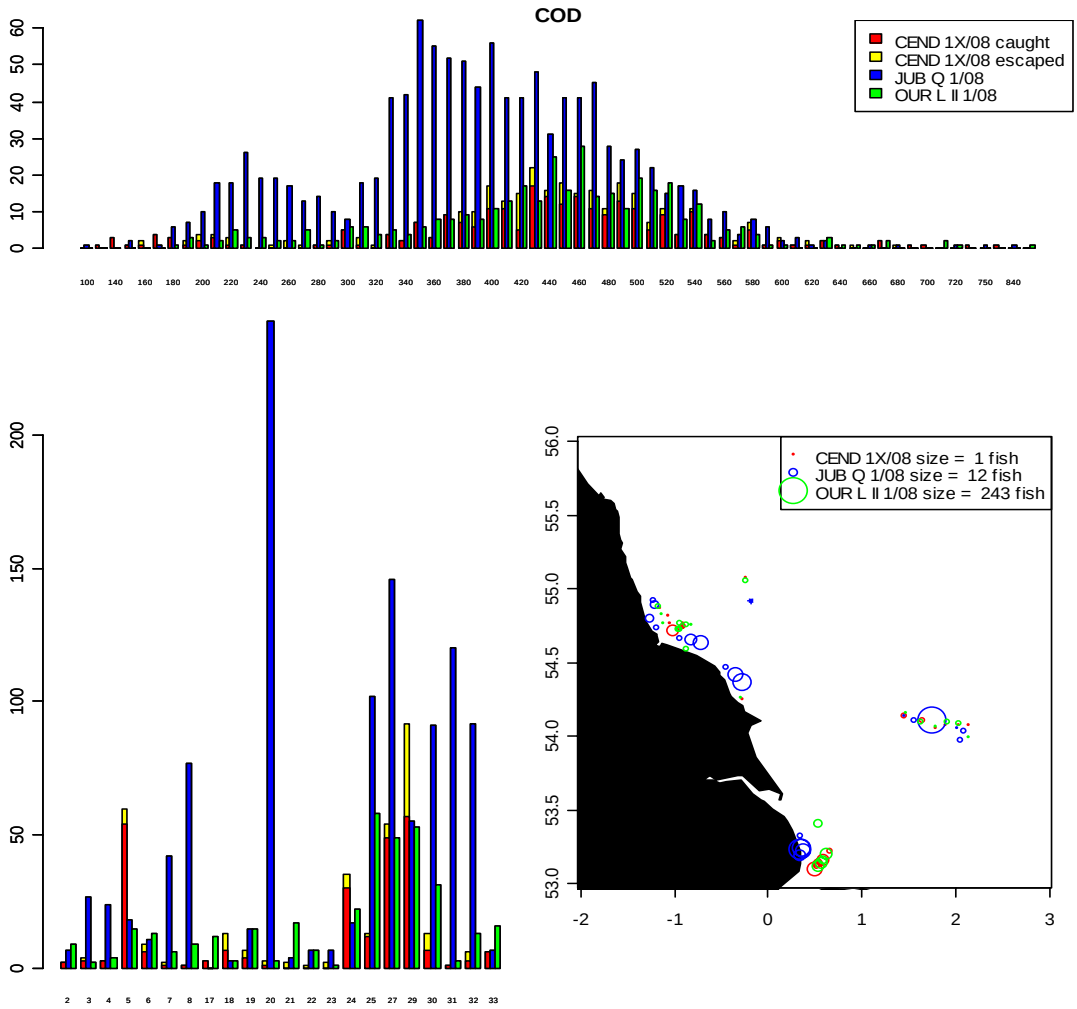

Figure 1. Cod length frequency, numbers per station and distribution of catches for each of the vessels. *Cefas Endeavour* catches are divided into those retained by the standard gear (red), and those caught by the escape bags (yellow). Maps of distributions show only those cod retained in the standard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

On soft-ground stations, comparable numbers of cod were caught by *Our Lass II* (361) and *Cefas Endeavour* (332), although the numbers that would have been retained by the standard GOV gear alone were 30% less than the commercial catches. Nevertheless, trends in abundance of cod over stations taken by the RV are largely reflected in the trends observed also in the *Our Lass II* catches. Links with the stations on adjacent hard ground are more difficult to observe in the data because of the patchiness of the distribution, although excluding Station 20 from the analysis yields some commonalities.

The length frequency distributions indicate that the gear deployed by *Cefas Endeavour* and *Our Lass II* had similar selectivity. The *Jubilee Quest*, however, caught a similar number of larger cod, but also far more smaller cod, up to ~450 mm. This outcome can be explained by the assumed tendency of smaller cod to seek sanctuary in hard-ground areas, whereas larger fish are less segregated in their distribution. It therefore seems likely that the *Cefas Endeavour* and *Our Lass II* sample the same part of the population, albeit at slightly different rates, while the hard ground yields a greater number of smaller cod.

Plaice

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 2).

Our Lass II caught much larger numbers of plaice (1676 for all stations) than the other two vessels when using its scraper net, but in the area of The Wash it was not possible to deploy that net and very few plaice were caught in an alternate high-lift gear at stations 24–30. Plaice catches by *Cefas Endeavour* (overall 541, in GOV 350) were much smaller, more similar to the rates attained by the *Jubilee Quest* on hard-ground stations (531), where abundances are likely to be much 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 all 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.

Cefas Endeavour caught more of the smaller plaice <160 mm than the other vessels 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 boats, although without clear modes it is not possible to distinguish random variation caused by sampling from distinct trends in catchability.

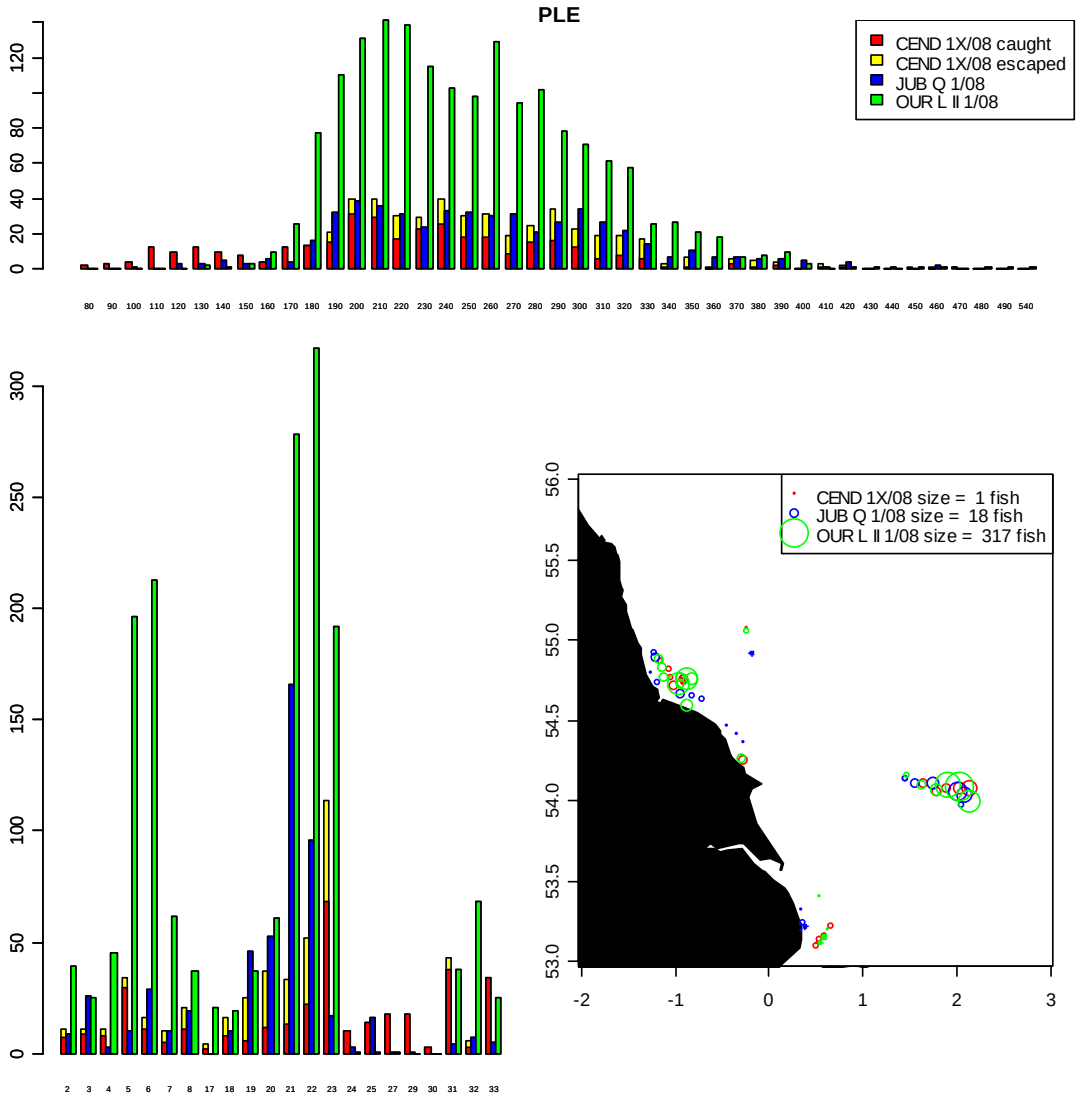

Figure 2. Plaice length frequency, numbers per station and distribution of catches for each of the vessels. *Cefas Endeavour* catches are divided into those retained by the standard gear (red), and those caught by the escape bags (yellow). Maps of distributions show only those plaice retained in the standard GOV gear.

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 caught in The Wash area. 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. There seems too to be very little difference between the abundance of haddock on soft- and hard-ground stations (Figure 3).

Our Lass II caught the most haddock (1572), but all vessels caught similar quantities overall (*Cefas Endeavour* 1036; *Jubilee Quest* 1293). However, most of the *Jubilee Quest* catch came from one very large catch of haddock (>700 fish) at station 20, whereas the *Cefas Endeavour* catches were more uniform across areas.

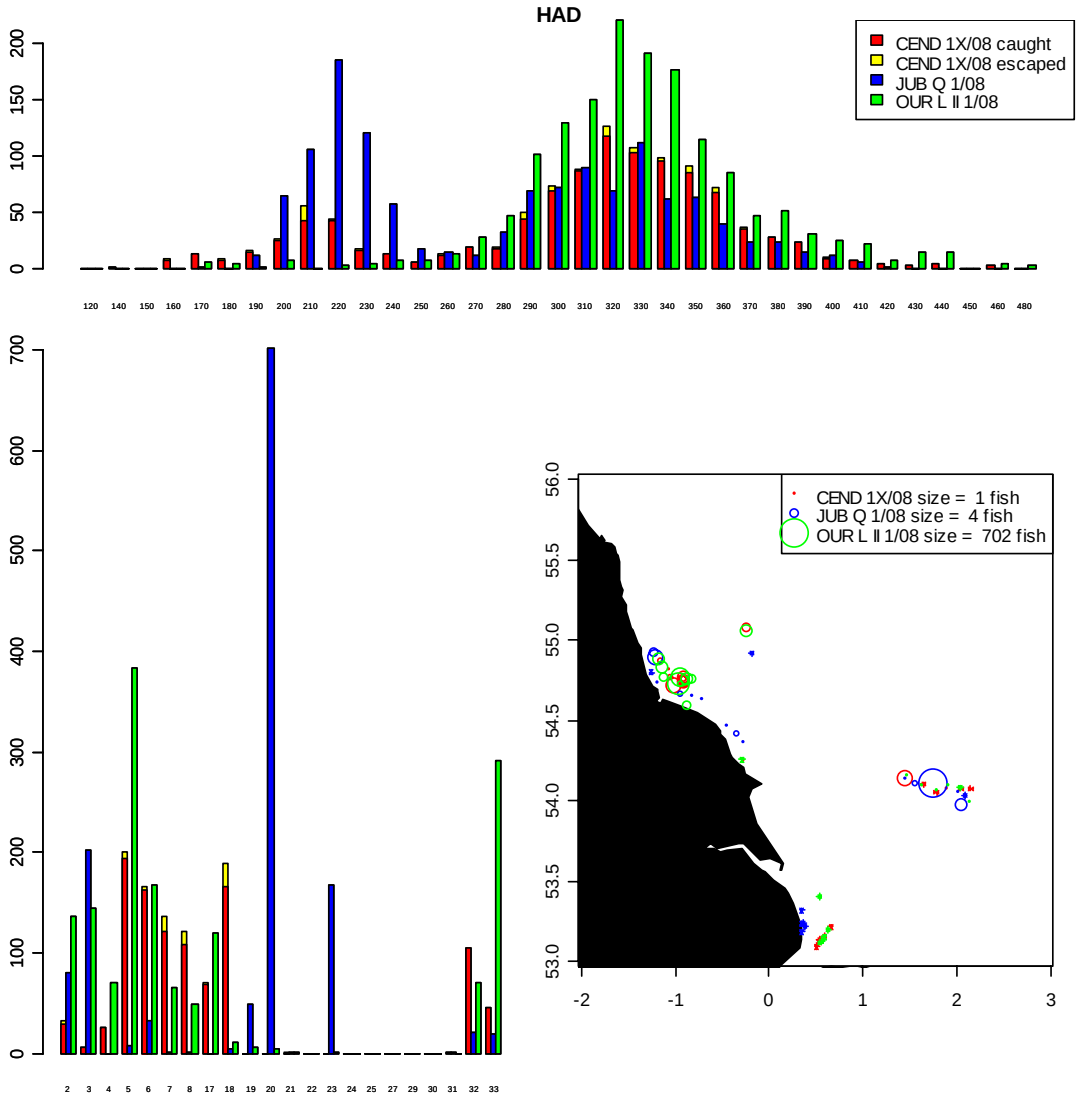

Figure 3. Haddock length frequency, numbers per station and distribution of catches for each of the vessels. *Cefas Endeavour* catches are divided into those retained by the standard gear (red), and those caught by the escape bags (yellow). Maps of distributions show only those haddock retained in the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

Length frequency distributions were broadly similar in range, although they showed substantial differences in the relative selectivities. At a fish size of <260 mm, *Our Lass II* caught few haddock, the GOV (with its smaller mesh codend) a few more, and the *Jubilee Quest* more still. Haddock >250 mm relative distributions in the catches were similar, although the catch rate of the *Our Lass II* was greater. It is therefore likely that a combination of different distribution of the fish and selectivity of the gear is responsible for the differences we observed during the experiment.

Whiting

It appears that, inshore, whiting are more likely to be caught over soft ground, particularly along the Yorkshire coast, whereas offshore the species seems to be more evenly distributed across habitats. However, the larger catches of whiting made by

Jubilee Quest did contain a number of smaller fish not found on other hard-ground stations (Figure 4).

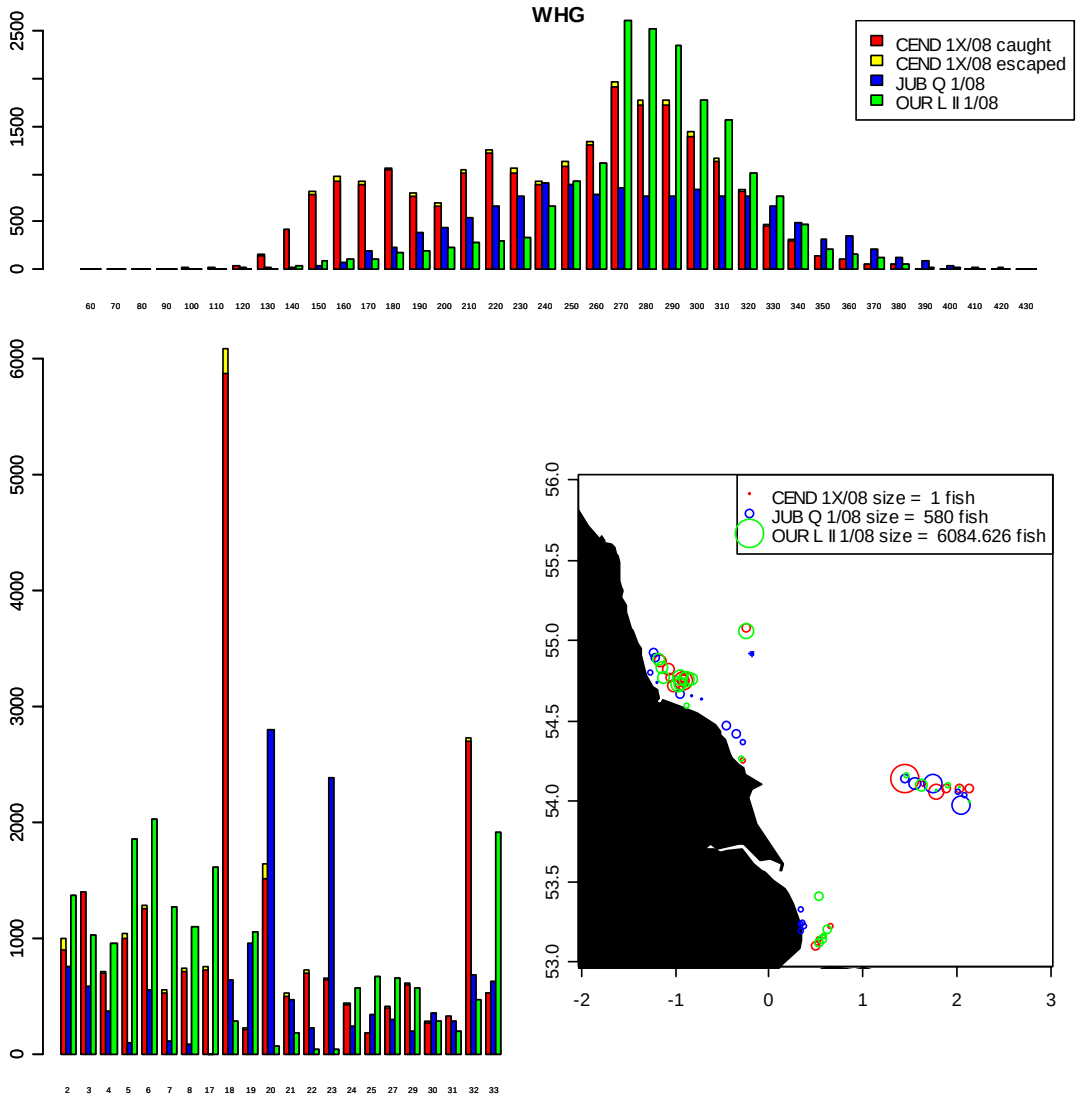

Figure 4. Whiting length frequency, numbers per station and distribution of catches for each of the vessels. *Cefas Endeavour* catches are divided into those retained by the standard gear (red), and those caught by the escape bags (yellow). Maps of distributions show only those whiting retained in the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

Whiting were the dominant species encountered in the trials, *Cefas Endeavour* catching 22 053, although a large number of these were smaller fish preferentially retained by the smaller codend mesh of the GOV, particularly at station 18. Despite great variability between stations, there does appear to be some relationship between the catch rates of this species on soft ground, which is less apparent but likely still present between soft- and hard-ground stations.

Length distributions were very different between the three vessels, and it is not possible to disentangle the effects of habitat and gear from one another, but it seems likely that different parts of the population were being sampled, despite the similarities in catch rates by station between vessels.

Escape rates underneath the GOV

Cod

Some 25% of the cod caught were retained in the escape bags, with both length and the size of the catch affecting the rate of escape at any one station. Retention rates were greater at larger sizes, meaning that most of the larger fish were retained by the standard GOV (Figure 5). Retention rates also increased with the size of catch up to about 35 fish, after which samples became too scarce in this 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 small schools, when they are more likely to enter the GOV.

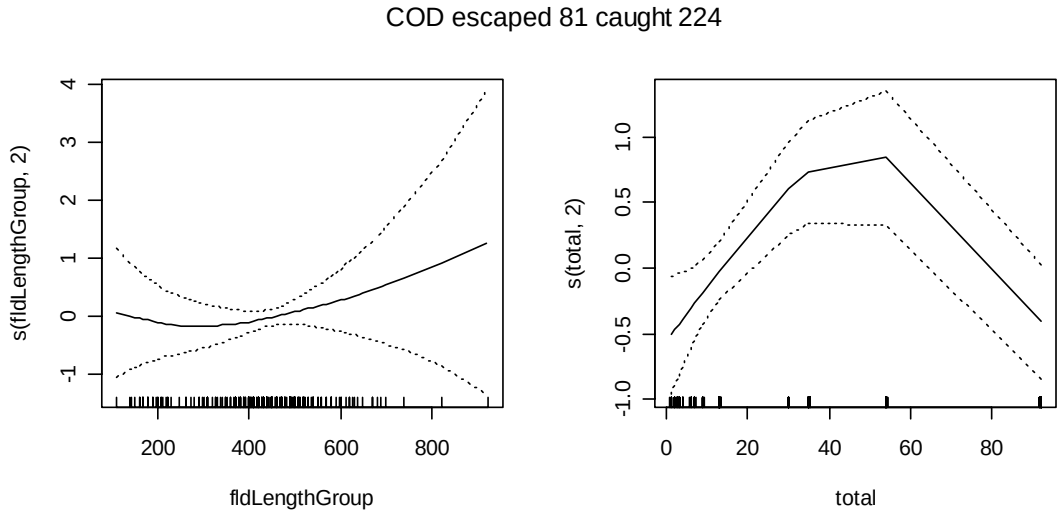

Figure 5. Statistically modelled trends in escape rates of cod with (left) length of escaping cod and (right) the total catch in number of cod. Dashed lines give some indication of the degree of uncertainty around the trend line.

Plaice

Overall, 35% of the plaice sampled by *Cefas Endeavour* were caught in the escape bags, i.e. would not have been retained by the standard gear. Although there is some statistical evidence that the rate of escape is dependent on length, this is mostly an artefact of the difference in codend mesh size (Figure 6).

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 a strong 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 of towing.

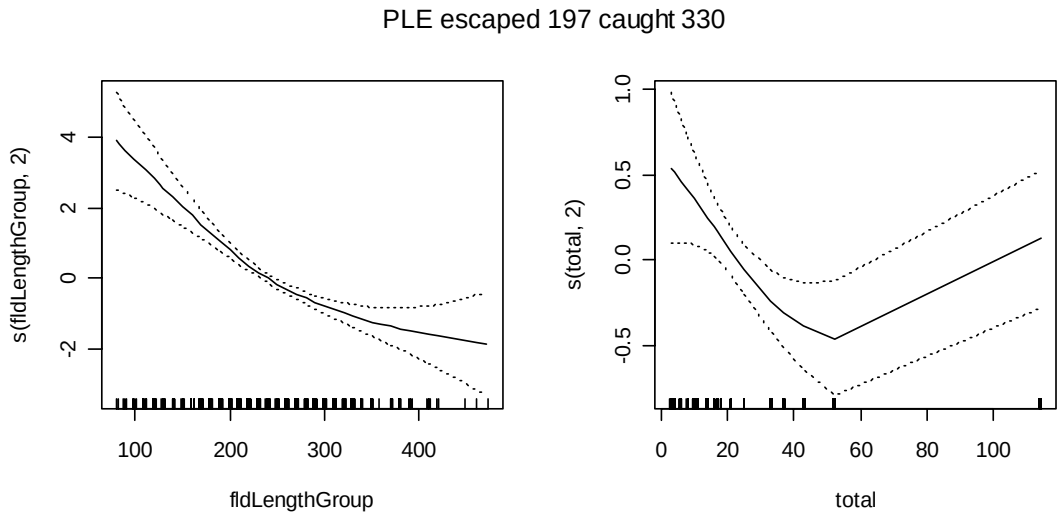

Figure 6. Statistically modelled trends in escape rates of plaice with (left) length of escaping plaice and (right) the total catch in numbers of plaice. Dashed lines give some indication of the degree of uncertainty around the trend line.

Haddock

Only 6% 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%, escaped underneath the GOV. The effects of abundance on whiting are 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. There also appeared to be an effect of water depth on escape rate, greater depth leading to more escapement. This is thought to be linked to gear, with less ground contact at greater depth. However, this possibility was not obvious for the other species during this study, so it needs to be investigated further.

Discussion

Despite the small number of samples available owing to weather and gear constraints, this experiment showed once again the huge 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 the fish, and improve the performance of stock assessments, where appropriate.

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 study has shown that the GOV gear, although not as efficient as the commercial gears, will catch a substantial portion (about 70% of commercial catch rates) of the cod on soft-ground stations, and it appears that most of the cod that do escape, do so underneath the gear (25%). One problem is that the rate of escape is dependent on the number of fish in the catches, so the relationship between catch rate and abundance is not linear, as assumed by the assessment. Over the range of catches seen in this study, the escape rate can vary from as much as 40% for small catches to around 15% at catches of 50 cod per 2-mile tow. This suggests that the relationship between abundance and catches is exponential or sigmoid, depending on what happens with the very large catches, but not asymptotic or linear as assumed by most assessment methodologies. The possible magnitude of this effect on the assessment depends on the variability in catches between stations and will require further examination.

Unfortunately, the conditions under which the trials were conducted were very different from those in August when the traditional survey is conducted. Industry representatives contend that the murky water in January would lead to an underestimation of the escape rate of cod, because they would not be able to perceive the gaps behind the ground gear. Further trials are planned to take place immediately subsequent to the 3rd quarter IBTS survey, which should produce more clement conditions for these trials.

Effects of escapement

What is also clear from these trials is that the abundance of cod on the hard-ground stations is not necessarily similar to that on nearby soft-ground stations. In addition, catches on the hard ground are higher in general, but also potentially more variable. Therefore, it is not always possible to compare commercial catch rates with those of the survey, which may explain some of the differences in opinions between scientists and industry. The fact that the IBTS survey carried out by Cefas in the North Sea is exclusively on soft-bottom stations (because of the historical exploitation of this species over such habitat), ignoring the portion on hard-ground stations does suggest that there may be value to management in evaluating the proportion of the population now found in each habitat.

Plaice

Plaice are generally assumed to be associated with sandy substrata, as found on the soft-ground stations. The largest catch of plaice (1676) was indeed attained over this substratum by the *Our Lass II*. GOV catches were much smaller, more akin to those obtained by the *Jubilee Quest* on the hard-ground stations. However, although the

GOV was much less efficient at capturing plaice, the general trend across stations appeared to be similar for all areas other than The Wash (where a different commercial gear was used). This suggests that the same portion of the population was being sampled, but this cannot be confirmed in the absence of clear nodes in the length frequency information.

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 and may justify the standardisation of the GOV for the purposes of monitoring surveys. The reason for the lower catch rates of plaice in the GOV have not been examined in detail, but are likely to be associated with the much shorter sweeps on the GOV (50 m) compared with the commercial gear used in these trials the *Our Lass II* (180 m). The sweeps effectively increase the area swept for flatfish by quite a significant margin, as well as reducing the over-spread in the gear, which in turn tends to increase the ground contact over undulating ground (pers. obs. Dave Peach). Although for cod only the latter is of importance, for plaice and in fact most flatfish that live in contact with the ground, the herding by the sweeps will account for most of the differences between the commercial and the GOV gear.

Effects of escapement
From a plaice assessment perspective, reduced catchability in general and particularly at larger size of fish does not serve to improve the assessment. Improving the gear would enhance the size of the catches, but because plaice catches are usually quite reasonable for the IBTS survey, it is not certain that this would improve the accuracy or precision of the assessment. Intuitively, having greater numbers of larger fish would also increase the numbers of older fish. This in turn would tend to decrease the variance and increase the number of ages in the tuning data, but the effects cannot be quantified from the available information.

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 caught 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 very 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.

The distributions of haddock and whiting were only weakly correlated between the commercial gears and the GOV. Commercial catch rates of small fish were better on the hard-ground stations, particularly haddock, but the same comparison cannot be made with the GOV, because mesh-selectivity issues cloud the issue as a consequence of having a blinder in the GOV gear.

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 indicated a decline at greater abundance, but this was based on a very small number of samples.

Effects of escapement
During the trials, tows within half a mile of each other could produce very high and very low catches, even using the same gear without any apparent shift in habitat. It is therefore clear that the distribution of these fish is currently extremely 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 (6–7%) 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

Although the study has clearly identified different factors influencing the GOV catch and escape rates of specific species, it has not been possible on the basis of fish behaviour to explain the reasons for the differences. 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 that 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.

To determine the rate of escape with any certainty, it will be necessary to collect additional samples, and some work has been scheduled tentatively for summer 2008. Hopefully, this will also allow for some direct (camera) observation of gear and fish behaviour, and to give some insight to the underlying causes of the relationships that are recorded here. For now though, we have determined some basic parameters satisfying the overall programme objectives:

1. The standard GOV catch rates for cod are roughly 70% of those on commercial vessels, with ~25% of the fish escaping below the net. Trends in abundance across GOV stations are consistent with those for commercial vessels on soft ground. Catch rates on commercial hard-ground stations can be much better and likely contain a different portion of the population. Percentage retention of cod can vary from 60 to 85%, 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 (21%) on soft-ground stations, even when including the portion escaping under the net (33%). The reasons for this are not clear, but it could indicate losses from the experimental gear, or perhaps more-efficient herding by the commercial gear. 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 final years of recruitment in the assessment process and therefore have a significant bearing on the forecast.

The results by objective were:

Objective 1
The study quantified the rate of escape of cod and plaice underneath the ground gear as 0.25 and 0.33, as proposed in the objectives, and in addition indicated that haddock (0.06) and whiting (0.03) escape rates were negligible.

Objective 2
The study provided good evidence that cod catch rates of the GOV gear were similar to those obtained on the commercial vessel fishing on the same soft ground, but considerably different from the catch rates made on the adjacent hard-ground tows. For plaice, survey catch rates were much lower than comparable commercial catches on soft ground, but the pattern across stations suggested that this was merely a scaler in efficiency. Adjacent hard-ground tows yielded similar catch rates to the survey gear catch rates on soft ground, and the distribution of catches across stations was roughly similar to that of the commercial catches. Haddock and whiting catches rates were also similar between survey and commercial gears, although their distribution seems to have been much more patchy, that it would require more samples to be taken to ascertain the degree of correlation between commercial and survey gear across stations.

Objective 3
Because of the poor weather, low light and turbid water, it was not possible to provide direct evidence of the means of escape of fish out of the survey gear. It is hoped that conditions will be better during August when we hope to repeat the trials under more favourable conditions.

Secondary Objectives 1 and 2
Given the conditions it was not possible to attain sufficient numbers of tows on the soft-ground stations using the escape bags. Moreover, on a number of tows the escape

bags were damaged by small rocks, suggesting that the gear may well be susceptible to stones and hard substrata. Therefore we do not consider it good sense to risk the escape gear for the August trips.

Acknowledgements

This work was carried out in cooperation with the skippers and crew of the FV *Our Lass II* (skipper James Locker) and FV *Jubilee Quest* (skipper Graham Hall). Cefas offers sincere thanks to 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, 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 56ºN 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 forth 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 sever southerly gales, Cefas Endeavour headed for Lowestoft and docked at xxxxh 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*
Graham Hall, *Jubilee Quest*

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

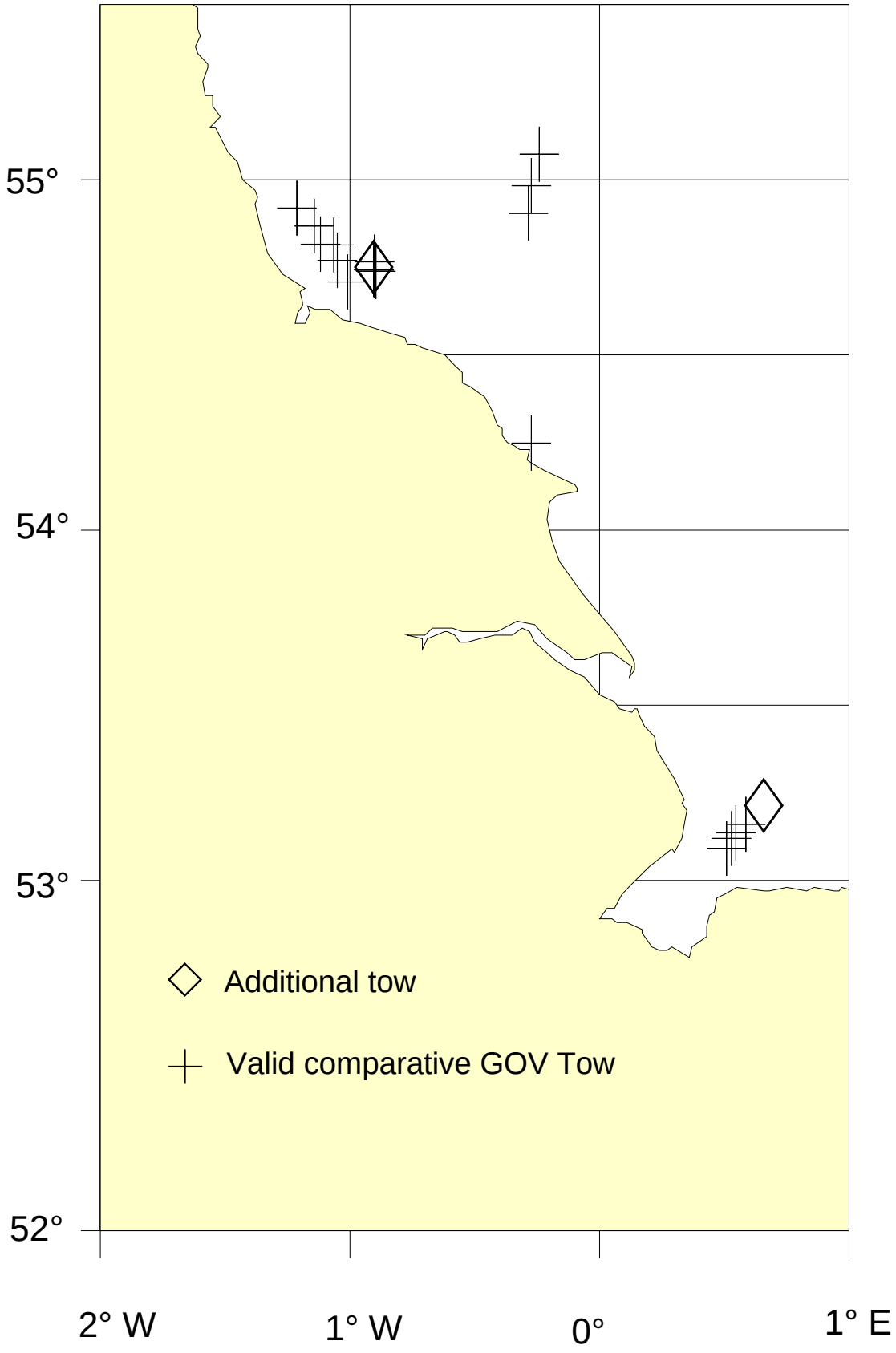

Table 1 Catch weights from GOV and ground gear bags(weight in kg)

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