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Effect of deviation from vessel target speed over ground, trawl speed through water and time of day on catch rates of several fish species in North Sea surveys

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Abstract

Effort in trawl surveys is standardised by using a common gear, towing time and vessel speed. Such standardisation should result in fairly constant distance trawled and area or volume swept. Protocols for the North Sea International Bottom Trawl Survey (IBTS), for example, establish hauls of 30 min duration at a target speed of 4 knots over ground with a standard GOV (Grande Ouverture Verticale) trawl.

To evaluate primarily the effect of departures from the target speed and of trawl speed through water a fishing experiment was performed within IBTS condition. The experiment consisted on 30 hauls performed on the Walther Herwig III in a small area in northern North Sea during 5 days in November 1997. Speed over ground and through water were calculated from the distance travelled between shooting and hauling positions and measurements of current speed and direction continuously recorded by a current meter set few meters above the sea bottom. Here we analyse the variation of catch rates of Norway pout (*Trisopterus esmarki*), haddock (*Melanogrammus aeglefinus*), whiting (*Merlangius merlangus*), dab (*Limanda limanda*) and grey gumard (*Eutrigula gurnadus*) with speed over ground and through water, and area and volume swept by the gear, together with time of day to account for diel fluctuations. For the analysis we use generalized additive models.

Catch rates of fish closely related to the seabed increased significantly with speed over ground while rates of more pelagic fish increased with speed through water. Most affected were small haddock and whiting which doubled in numbers within the 3.9 to 5.2 knot target speed experienced during the experiment. Catches of large haddock were stable. Area swept affected small haddock and whiting and volume small haddock only. Catch rates except those of adult whiting varied with time of day typically within twofold between day and night.

Introduction

Increasing interest for fishery-independent data for assessment emphasises the value of surveys in the North Sea. Scientific assessment of fish populations subjected to exploitation is a current priority for fisheries management, and in the North Sea this has become critical as most stocks are overexploited. For the assessment of ground fish species, some research surveys in the region are carried out within the frame of the International Bottom Trawl Survey (IBTS) program that covers the entire North Sea at least in winter since the late 1960's. Effort in these surveys is standardised (ICES 1999). The IBTS manual recommends a target speed of 4 knots and to report the actual ground speed and distance trawled as well as the values of several gear parameters. The manual also recommends that current speed and direction at fishing depth should be reported but this information is not often delivered since it is not mandatory.

Procedures to treat catch data to calculate abundance indices from scientific surveys for assessment vary. In the North Sea, raw data from IBTS are used by the International Commission for the Exploration of the Sea (ICES) to calculate indices for groundfish species. On the other hand, in the spirit of improving data quality, in NAFO (North Atlantic Fisheries Organization) area Div. 4VWX for example, abundance indices for assessments of groundfish species are calculated using "corrected" catches (Halliday and Koeller 1981). These indices are calculated by the Canadian Atlantic Fisheries Scientific Advisory Committee adjusting the catch by tow by multiplying the numbers of fish caught by 1.75/distance travelled (1.75 naut. miles corresponds to the distance normally travelled during a standard set at 3.5 knots for 30 minutes). To investigate if a similar procedure would be appropriate in the North Sea data were collected during a fishing experiment.

Here we report on the analysis of variation of catch rates, during the fishing experiment performed within IBTS conditions, with vessel speed over ground, equivalent to distance travelled, trawl speed through water, area and volume swept, and time of day. For the analysis we used generalized additive models GAMs (Hastie and Tibshirani 1990). GAMs have been used in analysis of catch data for example by Swartzman et al. (1992). The method allows to investigate variables that may explain the observed variance without imposing restrictions of a pre-set functional form. This flexibility was considered advantageous as the analysis includes the effect of time of day which is nonlinear. Time of day was included as a covariate, because catches of several species are known to fluctuate within 24 hr (Adlerstein and Trumble 1993, Ehrich and Gröger 1989, Pitt *et al.* 1981, Wieland *et al.* 1998). For the analysis we selected species that are representative of pelagic and demersal types in the North Sea, thus associated to the sea bottom in different degrees and that could react differently to variation of the covariates.

Material and Methods

Data collection

Catch data and information on vessel performance and gear geometry as well as information on environmental conditions were collected on 30 hauls during a fishing experiment conducted by the German fisheries research vessel "Walther Herwig III" between the 22nd and the 27th of November 1997. The experiment took place within a reduced area in northern North Sea around 58°N; 1°W (Fig. 1). The area was selected on the basis of previous German Groundfish Surveys which indicated optimal characteristics for the investigation of the variables of interest, i.e. haddock and whiting were abundant and fairly evenly distributed and environmental parameters like sediment type and depth, that could influence catch rates, and temperature and salinity were known to be homogenous. Also, distribution of benthos fauna was known to be uniform. The experiment was performed in a short period of 5 days to minimise biological variability. Also, standard protocols as during IBTS regular hauls were observed to evaluate the variation of the variables of interest within normal survey conditions. Hauls were performed with a standard GOV (Grande Ouverture Verticale) trawl according to protocols in the IBTS manual, that establish a constant tow duration of 30 min at a speed of 4 knots (ICES 1999). Starting time was defined as the moment when the winch had stopped at a predefined warp length. At this moment the gear normally had reached the bottom. The haul back process begun 30 minutes later. Haul positions were chosen at random (Fig. 1). For each haul towing direction, target speed and shooting and hauling positions were determined by satellite navigator (GPS). Aboard the vessel, normally the whole catch was sorted out by species or by species groups. For each species, or group, fish were weighted and either all fish or a sub-sample were counted and measured. Sub-samples of about 200 to 400 individuals were taken from the abundant species like whiting and haddock for length measurements.

During this experiment special effort was allocated to obtain information on water current characteristics at fishing depth and to measu're gear geometry. Current measurements were obtained to calculate the speed of the trawl through water which differs from that of the vessel depending on the direction the vessel travels relative to the direction and speed of the water current at fishing depth. Current speed and direction were constantly measured with a current meter set a few meters above the sea bottom at about the centre of the survey area. Gear geometry was monitored and the spread of wings and doors and the headline height were simultaneously measured with wireless distance and height sensors (SIMRAD, Norway).

Data selection

Data from 27 over the 30 hauls performed during the fishing experiment were selected for the analysis. Data from 3 hauls conducted during day hours at a ground speed less than 3.7 knots were not included because tows of similar conditions were not performed at night. Species considered in the analysis are: Norway pout (*Trisopterus esmarkii*), haddock (*Melanogrammus aeglefinus*), whiting (*Merlangius merlangus*), grey gumard (*Eutrigla gurnadus)*, and dab (*Limanda limanda*).

To guide the appropriate aggregation level for the analysis in relation to fish size, we compared the length frequency distribution of each species within hauls. Whiting and haddock presented a bimodal length distribution with peaks at 15 and 25 cm (Fig. 2) and some hauls were dominated by small or large fish. Accordingly the analysis for these two species was performed separately for catch rates of fish smaller and larger than 20 cm. Fish smaller than 20 cm were 0 group fish and fish larger than 20 cm mostly 1 and 2 year old. For other species the length composition did not vary and analysis was performed for the total catch.

Data Analysis

Catch rates by species were modelled as a function of a covariate representing either vessel ground speed, trawling speed through water or area and volume swept, plus time of day. Ground speed in knots GS was calculated as twice the distance between shooting and hauling position travelled in hauls of 30 minutes duration. Distance D in nautical miles was calculated based on the geodesic distance between shooting and hauling positions. Trawl speed through water TSW in knots was calculated as

$$TSW \quad GS \quad \cos(VD - CD) *$$

51.4

where *VD* and CD are the vessel and current direction in radians, CS is the current speed at fishing depth in cm/sec and 51.4 is to convert cm/sec in knots. Swept area1 *SA1* was calculated as the distance *D* in meters times the wingspread of the GOV trawl, and swept area2 *SA2* in m^2 as the distance *D* times the doorspread. Volume swept 1 *VS1* in m^3 is the product of the distance *D* and an estimate of the area of the net opening. This area was calculated assuming an ellipse shape for the opening which remains constant during tows.

$$VS1 \quad \pi * a * b * D$$

where a =wingspread/2, b= headline height/2 and D is the distance travelled in meters

The effect of covariates described above on catch rates was analysed using routines to fit GAMs and generalized linear models GLMs (McCullagh and Nelder 1989) contained in the S-Plus programming environment (Becker et al. 1988) based on Hastie and Tibshirani (1990) and functions developed by Venables and Ripley (2000). Separate models were run for speed over ground and through water, areas and volume swept. All covariates were first introduced as continuos smooth variables and were modelled non-parametrically using scatterplot smoothers described in Chambers and Hastie (1992). The logarithmic-link was used to relate the expected catch rates to the predictors according to

$$\log(\mu) \quad \partial \quad \sum^{2} f_j(X \quad + \varepsilon$$

where the errors are independent of the X_js, $\mu=E(Y/X_1,X_2)$ is the mean catch rate, and f_j are univariate smooth function for (X_1) time of day and (X_2) corresponding to either ground speed, speed through water, area or volume swept. When nonlinearity was not significant the smooth variable was replaced by a linear term. The probability distribution of Y is modelled with a quasi likelihood, using an appropriate relationship between, mean catch rate and variance for each species. This relationship was determined by regressing the logarithm of the mean catch rates (by 4 hr time and 0.2 knots speed intervals) against the logarithm of the variance.

Explanatory variables were assessed using *F* tests according to whether or not they explained a significant portion of the corresponding model deviance. Analysis of deviance was stepwise. The nonlinearity and appropriate degrees of freedom of the smooth variables were assessed within the analysis of deviance by jointly increasing and decreasing them until no significant fit improvement was obtained at a 95% confidence level. Models introducing the time of day term as a day/night factor were used to estimate a coefficient for the relationship between day and night catches.

Results

Environmental parameters during the fishing experiment were homogeneous as expected and weather conditions were fair and stable. Bottom temperature varied from 10.62 to 10.84 °C and salinity from 35.18 to 35.22‰. Bottom current moved in northerly direction with speed varying from 3 to 32 cm/sec. Weather conditions, 2 in a scale from 1 to S. did not change within the 5 days of the survey with mostly cloudy skies and constant south east winds of about 18 meters/sec.

The distance travelled by the vessel in 30 min. hauls varied from 1.7 (from I .9 included in the analysis) to 2.6 nautical miles (Fig. 3). Estimated speed over ground varied from 3.39 (3.9 in the analysis) to 5. IS knots while speed through water ranged between 3.55 and 5.29 knots.

The difference between these two variables was between -0.59 to +0.56 knots. Ground speed deviated up to around 30% from the targeted speed. With respect to gear parameters, wingspread varied from 18 to 22 m, doorspread between 100 and 122 m and headline height between 3.9 and 4.7 m (Table 1). The trawl geometry measurements show no unstable bottom contact conditions. The area of the net opening was estimated to be between 63 and 71 m^2. Area swept by the wings was in the range of 64567 to 99761 m^2, area swept by the doors between 314654 and 479853 m^2 and the volume between 210088 and 325946 m^3.

Frequency distribution of the catch rates and rate levels varied between species. Catches were highest for haddock and whiting larger than 20 cm with levels up to around 3000 fish per tow and were lowest for grey gurnard with levels up to 200 fish (Fig. 4). No zero catches occurred of the selected species. The distribution of catch rates varied from fairly normal to skewed (Fig. 5). Accordingly, the slope of the regressions between the logarithms of the mean catch rates and the variance varied from not significantly different from zero to around 2. Catch rates of large haddock were modelled with a quasi likelihood model with a constant variance, of small haddock with a variance proportional to the mean μ and that of large and small whiting, dab, grey gumard, and Norway pout with a variance proportional to μ^2. Check of the residuals indicated adequate fits.

Analysis of deviance indicate that catch rates except those of large whiting vary significantly with time of day ($p<0.05$) (Table 2). This variable explained up to 55% of the total variation of the large haddock catches. The variation of catch rates with time of day is significantly non linear except for small whiting and 3 degrees of freedom were found appropriate to model the effect on catch rates for each species. Rates of Norway pout, and of small and large haddock tend to be higher during the day while catch rates of dab, grey gumard and small whiting are higher at night (Fig. 6). Highest difference was for grey gurnard for which the time of day coefficient indicates that night catches are more than double the day catches (Table 3).

Results from the analysis of deviance also indicate that the variation of the catch rates with speed over ground was significant and the effect of this term is linear-in the model for small haddock ($p<0.01$), small whiting ($p=0.05$) and dab ($p=0.05$)(Table 2). The effect of ground speed explains up to 18% of the catch rate variation of small haddock. The effect of speed through water is linear in the model and significant at the 95% level for small haddock and Norway pout and at the 90% level for small and large whiting, explaining up to 12% (small haddock) of the catch rate variation. The variation of catch rates with area swept by the wings was significant for small haddock ($p=0.01$) and small whiting ($p=0.05$) and the area swept by the doors only for small haddock ($p=0.04$). The volume affected significantly catches of small haddock only ($p=0.02$). In the case of large whiting it was observed that S consecutive hauls conducted during the first 2 sampling days had consistently high rates (Figure 4). In the case that this was due to a strong biological association such as a feeding "hot spot" situation, the effect from the variables investigated would be masked. An analysis excluding these stations was conducted and results still indicated non-significant effects of time of the day and vessel ground speed, but a significant effect of trawling speed through water ($p=0.06$) (Table2).

Since variation of catch rates with the speed. area and volume covariates was found to be linear (in the log-link scale). estimates for the slopes of the effects could be obtained ('Table 3). Fitted values for speed covariates are presented in Figures 7 and S. Slopes range from low values for the effect of speed over ground for species found off the sea bottom to high values for species more closely associated with the seabed. The reverse is true for the effect of speed through water. Steepest slopes in both cases are for small haddock and whiting which can be found on and off the bottom. For the effect of ground speed, slopes for small whiting and haddock, grey gumard and dab are between 0.63 and 0.86. Thus, the catch roughly doubles within the speed range from about 4 to 5 knots included in the analysis, equivalent to a distance trawled of around 1000 meters in 30 min. Slopes for Norway pout and large whiting and haddock were negligible. For the effect of the speed through water, slopes for small haddock and small and large whiting and Norway pout are around 0.5, and for large haddock, dab and grey gurnard insignificant. In terms of the variation of catch with area swept by the wings and doors highest values were respectively for small haddock (0.0004) and whiting and for grey gumard (0.000009) and small haddock and whiting, same as for the highest slopes of the variation with vessel ground speed were observed. Finally the highest slopes for the effect of the area swept (0.00001) was for small haddock and whiting.

Discussion

Results suggest that using a unique, non species specific, factor to correct raw data to estimate abundance indices assuming that catch is proportional to distance travelled or area swept in tows of fixed duration is dangerous and can lead to further bias. We found that these variables affect. species differently. In the study fish closely associated with the seabed were most affected so that catches of dab, grey gumard and small haddock and whiting, varied by around a factor of two within a target speed range from 4 to 5 knots, a distance of about 1 km in 30 min. On the other hand the increase in catches of large whiting and haddock and Norway pout was not significant. The effect of the deviation from the target speed among the species differs because the reaction to the fishing gear is determined partially by the fish size or shape, their distribution in the water column and their behaviour (Engås 1996, Godø 1990, Fréon *et* al. 1993). Thus, to correct the data for obtaining representative catch data, more detailed species specific studies considering spatial and temporal variation of the speed effects should be carried out. Nevertheless, in the first place emphasis should be given to avoid having to correct data by maintaining the target speed prescribed in survey protocols.

Several facts can account for the lack of effect of trawling or vessel ground speed variation on catches of haddock larger than 20 cm. One is that increasing speed triggers reactions that counteract the effect, Reaction to surveying vessel has been observed, for example by Olsen *et* al. (1982) among, pelagic and demersal species, which is magnified when vessel speed increases. One possibility is that rising speed increases avoidance reaction to vessel noise. Several studies have revealed avoidance reaction to noise for these species (Ona 1988, Ona and Chruickshank 1986, Olsen 1990, Ona and Gods 1990). Further. increasing speed intensifies the noise produced by survey vessels which increases the fish reaction time to the gear (Neproshin 1979). The author shows that a school reacts more or less intensively depending on the speed of the vessel (i.e. noise level). where at low speeds the escape reaction appears at about 20 m in front of the vessel and at high speed at up to 100 m. Furthermore large haddock have been observed to rise and escape over the headline in substantial numbers (Main and Sangster 1981). Thus, it is likely that at high speed, hence noise level, these fish have higher chances to escape than at lower speed given their behaviour and swimming capabilities. Another possibility is that increasing trawling speed decreases the height of the net aperture making the escape over the headline more likely. So in fact speed in this case would decrease catchability for these fish but the catch will remain the same because of the longer distance trawled. Another explanation for finding no relationship between speed or distance and catch relates to the distribution pattern of large haddock in schools. If the number of fish caught depends on the trawling direction relative to the shape of the fish aggregation, the number of hauls in this experiment might have not been sufficient to detect the effect.

Finally, biological associations occurring at short time scale could mask other effects on catch rates.

Maintaining the target vessel speed does not guarantee that catches are not biased by variation of the trawling speed through water. Results show that within IBTS conditions catch rates of species with pelagic habits can be affected by bottom current characteristics. This is reasonable when considering the fish distribution in the water column in relation with gear performance. Catch rates of Norway pout, unaffected by variations of the vessel speed over ground increased significantly with trawling speed through water. Catch rates of small haddock and small and large whiting, fish that can be found off as well as near the bottom, were also significantly affected. Unfortunately, maintaining constant speeds through water and over ground is impractical. Correcting the data to account for deviation from trawl speed through water has the same problems as discussed in the case of the effect of deviations from vessel ground speed.

The results of our analysis of the effect of area and volume swept on catch rates are deceptive and only showed a significant increase of small haddock and whiting numbers with area, and an increase of small haddock with volume, for about 50% increase of these parameters. This is probably because our estimates of area and volume swept are inadequate. Koeller (1991) describes variation of catch and gear geometry in Scotian Shelf groundfish surveys and states that the true effective swept area by a gear is practically always unknown. The effective width of the trawl can be more than the wingspread due to door and sweepline herding but less than doorspread due to escapement over the sweeplines. A further problem is that the shape of the trawl is modified during trawling. This affects our estimate of the volume swept that assume a rigid ellipse form and also modifies the contact area between the net and the seabed making estimates of area swept also suspicious.

Recommendation in the IBTS manual that tows should be limited to daylight is endorsed by observed variations up to 2 folds between day and night catches. Despite this advice 18% of 1990-1998 records in the IBTS database are from night hauls. In this study, catch rates of all 5 species analysed but large whiting were found to change within 24 hours. These results arc in line with most findings in previous studies in the North Sea (Wieland *et* al. 1998, Ehrich and Gröger 1989) and in the Barents Sea (Engås and Soldal 1992, Michalsen *et al. 1996.* Aglen *et* al. 1999). For large whiting nevertheless Wieland et al. (1998) report that catches of 1 and 2 year old fish were higher during the day than at night. Further, Aglen et al. 1999 report a pelagic distribution of large haddock during the day when we found higher bottom trawl catch rates to occur. Differences in these results are not surprisin g since diel catch rate fluctuations may be due to seasonal and spatial variations in the fish vertical distribution or reactions to the fishing gear not strictly related with light. This opens questions about correcting data collected at night for ‘estimating indices without appropriate knowledge.

In this study the trend was that catch of species closely associated with the seabed increased at night while catch of more pelagic fish Increased during the day. It could be that all species arc somehow higher in water column at night. Thus, species that during the day are in close contact with the seabed can escape in high numbers under the trawl while they are more vulnerable at night as they arc off the bottom. Wash (1989) found that the bottom trawl was more efficient at night in catching fish of demersal habits. Dahm & Wienbeck (1996) demonstrated that losses of grey gurnard of around 40% occur beneath the GOV traw I. while losses of haddock, whiting and Norway pout. not discriminated by size. were under 10% . More pelagic species. also higher in water column at night would escape the gear from above the headline.

In this study the effects on catch rates of speed and distance travelled cannot be differentiated. Nevertheless, one aspect to notice is that the highest effect is for small whiting and haddock up to 20 cm which suggests that speed affects catch rates. Stronger effect of speed with decreasing fish size is in line with the relationship between fish size and swimming speed and fish endurance. He (1993) summarises findings in the literature concerning swimming capacity of commercial marine fishes in relation to fishing gear. The author points out that selectivity of trawls occurs mainly during herding, swimming with the trawl at the mouth area and at the cod end which are all related to swimming behaviour and capacity. The author presents a model that predicts that small fish would be able to escape a slow but not a fast towed gear.

We think that results from this study are rather preliminary to determine factors to correct the catch data. This because the effect of vessel and trawling speed are bound to be species and size specific and could vary with season and site depending on fish behaviour. Thus, further research along the lines of this study is needed to evaluate these changes. At the present, our results stress the importance of complying with IBTS protocols, and could be used to establish criteria to select data for estimating abundance indices.

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Table 1. Summary of vessel and gear performance during the fishing experiment. Dist is the distance travelled by the vessel, GS the ground speed, TSW trawling speed over ground, Wings and Doors correspond to the spread of the trawl, ASW1; ASW2 are the area swept by the wings and doors respectively and Vol the volume swept by the wings.

	Dist (Sea miles)	GS (knots)	TSW (knots)	Wings (m)	Doors (m)	Headline (m)	ASW1 (m^2)	ASW2 (m^2)	Vol (m^3)
Min	1.70			18.3	100.7	3.9		347[illegible]59	
Max	2.59			22.1	122.4	4.7		540[illegible]96	
Mean	2.08			20.6	110.6	4.2		427[illegible]85	
Std.dev.	0.174			0.83	4.50	0.18		433[illegible]1.3	

Table 2: Analysis of deviance from GAMs of catch rates as smooth function of time of day and linear functions of either vessel ground speed *GS*, trawling speed through water *TSW*, area swept based wing spread *AS1 or* on door spread *AS2*, or swept volume *SV*. Var is the model variance function. Columns *GS* to Time of day are probabilities for each term and the percentage of the deviance explained.

Species	Catch Rate #/30 min	GS	TSW	AS1	AS2	SV	Time of day
Norway pout*	μ=610	0.77	0.05	0.77	0.74	0.17	<0.001
Var=μ^2	sd=320	<1%	9%	<1%	<1%	4%	41%
Large whiting	μ=1153	0.95	0.16	0.99	0.98	0.99	0.23
Var=μ^2	sd=623	<1%	5%	<1%	<1%	<1%	19%
Large whiting*	μ=894	0.86	0.06	0.50	0.45	0.75	0.3
Var=μ^2	sd=348	2%	16%	3%	3%	<1%	20%
Large haddock	μ=1251	0.44	0.26	0.81	0.65	0.61	<0.001
Var= cte	sd=649	1%	2%	>1%	>1%	<1%	55%
Small haddock	μ=782	<0.01	0.04	0.01	0.04	0.02*	<0.001
Var=μ	sd=568	18%	12%	15%	13%	14%	34%
Small whiting	μ=644	0.05	0.10	0.05	0.09	0.18	0.05
Var=μ^2	sd=371	13%	8%	12%	9%	5%	14%
Grey gurnard	μ=71	0.24	0.97	0.63	0.96	0.70	<0.001
Var=μ^2	sd=57	2%	<1%	<1%	<1%	<1%	30%
Dab	μ=84	0.05	0.57	0.15	0.37	0.16	<0.001
Var=μ	sd=66	7%	<1%	3%	1%	3%	32%

*Selected hauls

Table 3. Slope of the effect of vessel ground speed *GS*, trawl speed through water *TSW*, swept area 1 *AS1*, swept area 2 *AS2*, and swept volume *SV* and coefficient of the time of day effect introduced as factor in a generalized linear model for each species. Significant at **95%, *90%.

Species	Slope GS	Slope TSW	Slope AS1	Slope AS2	Slope SV	Night Coeff.
Norway pout	0.09	0.46 **	0.000004	0.0000007	0.0000005	-0.52
Large whiting	0.08	0.39	0.0000001	0.00000004	0.000000003	==
Large whiting +	0.05	0.47**	0.000008	0.0000001	0.000001	==
Large haddock	0.12	0.19	0.0000002	0.0000004	0.000001	-0.76
Small haddock	0.86**	0.60**	0.00004**	0.000005**	0.00001**	-0.70
Small whiting	0.78**	0.46*	0.00003**	0.000005*	0.00001	+0.20
Grey gurnard	0.63	0.05	0.00001	0.000009	0.000004	+0.70
Dab	0.67**	0.19	0.00002	0.000004	0.000009	+0.97

+Selected data excluding 8 hauls

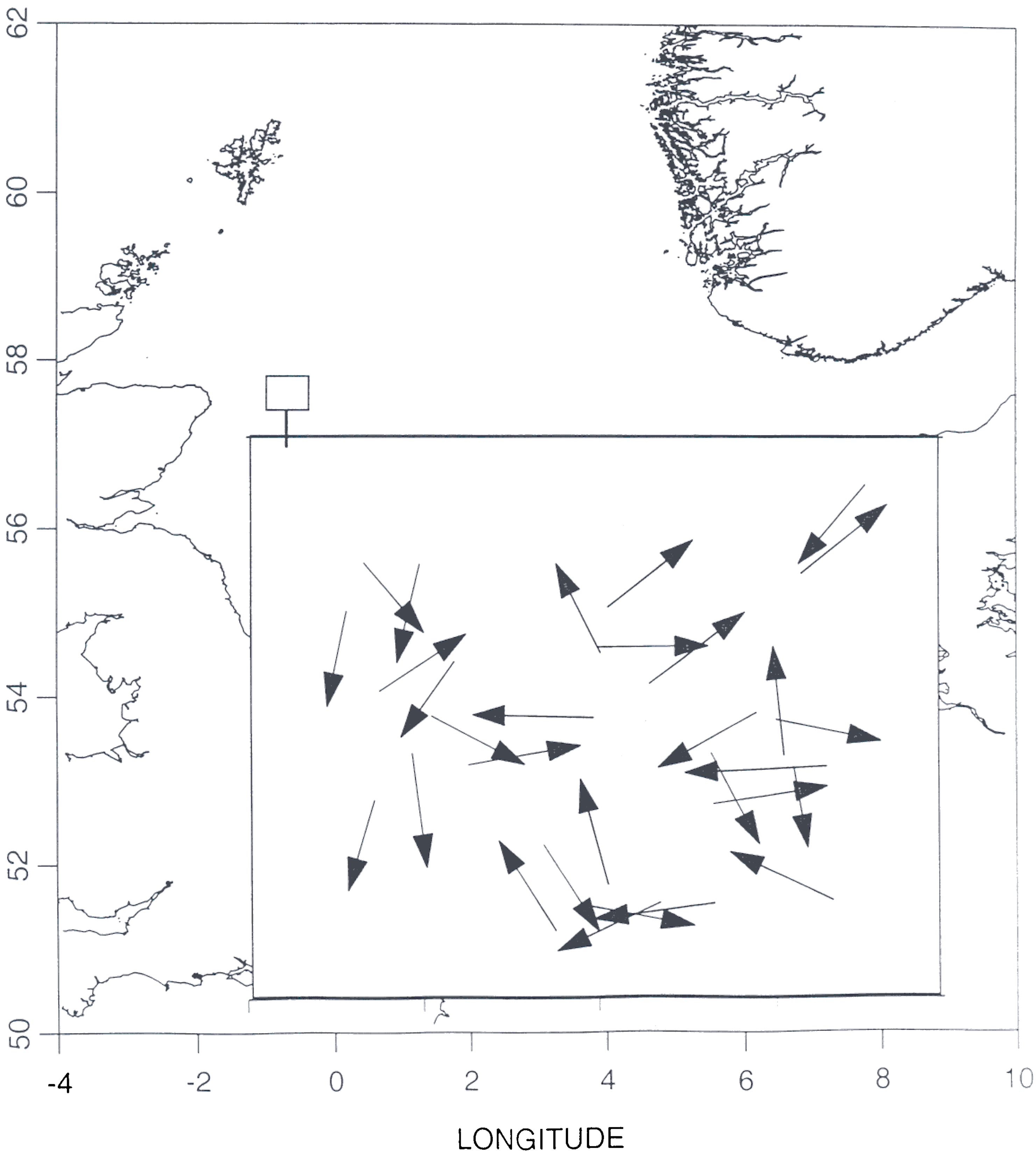
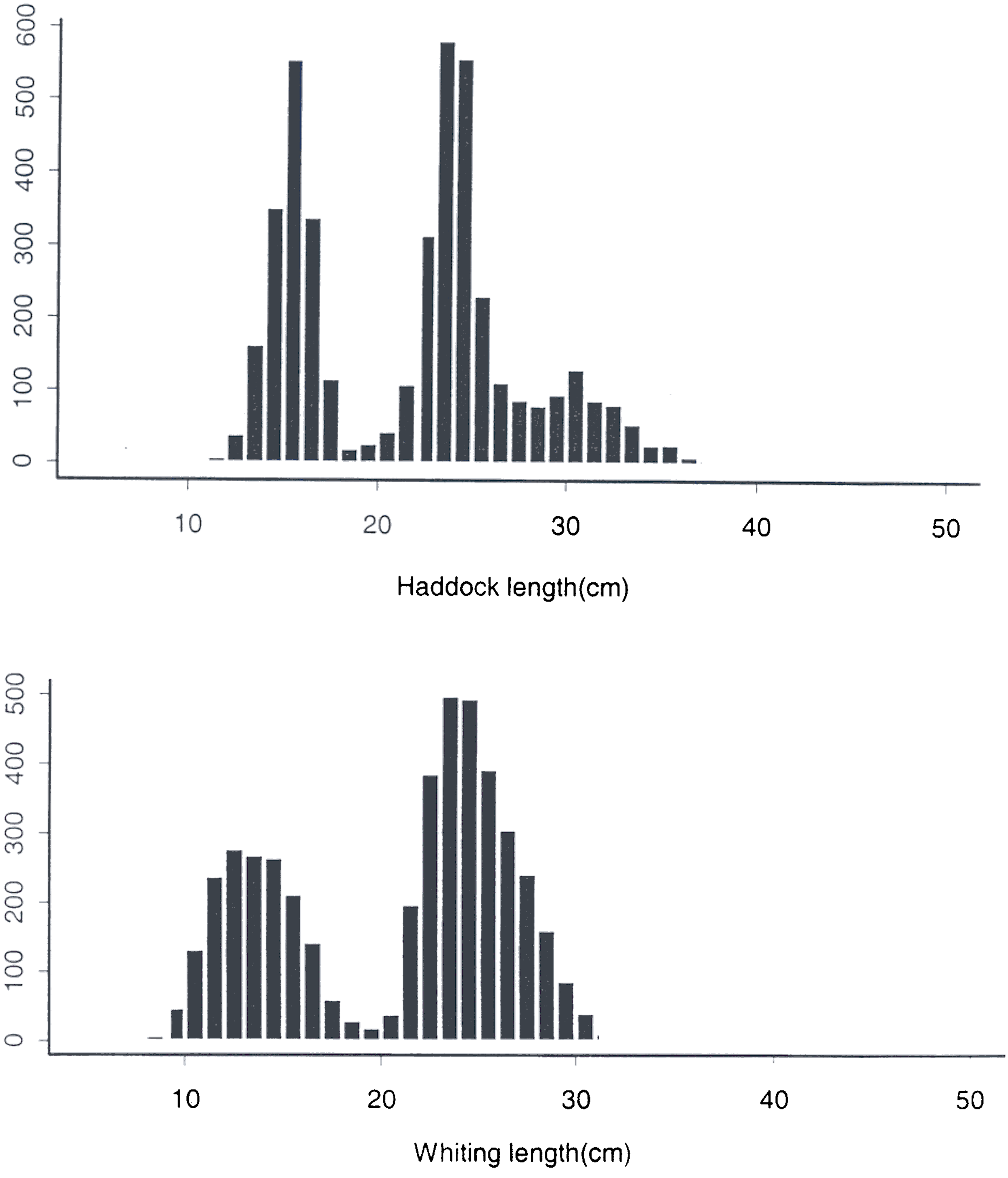


Figure Position of the hauls during the shing experiment and location of the study area



'igure 2. Bimodal length composition of haddock and whiting catches.

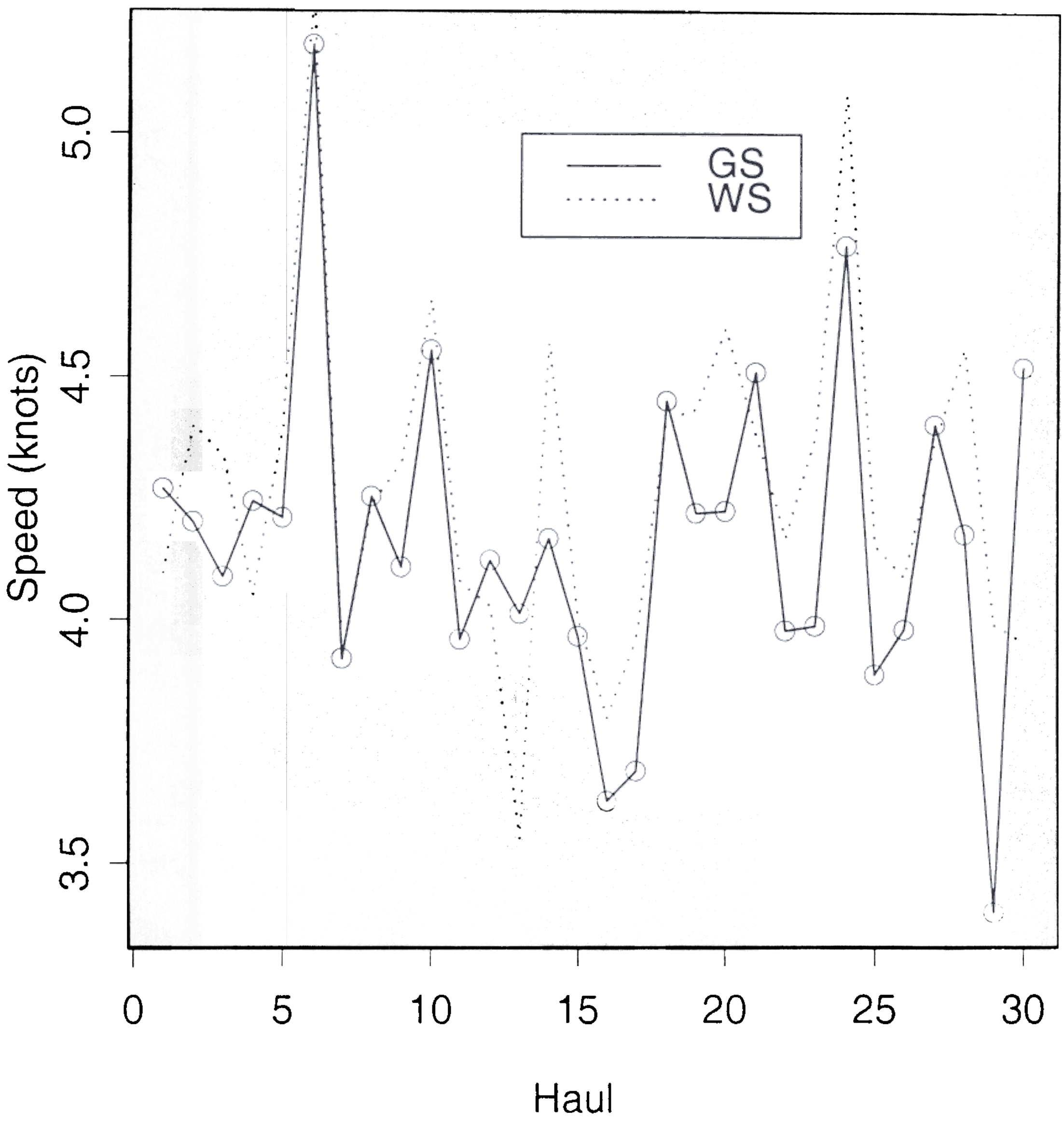


Figure 3. Vessel speed over ground (GS) and trawl speed through water (WS) in the 30 hauls performed during the survey.

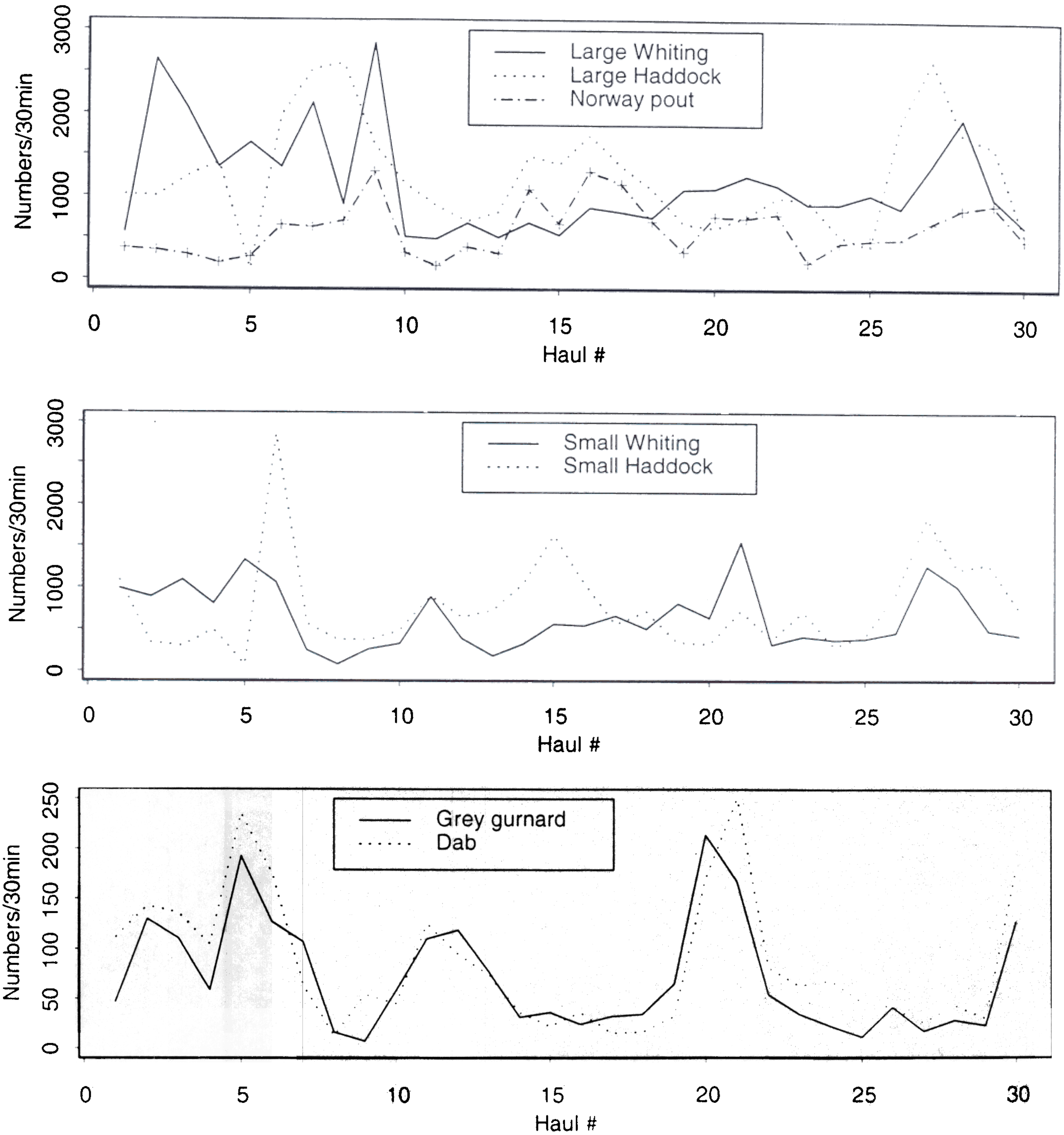


Figure 4. Variation of the ate ate sp in the analy s in the 30 hauls during the survey

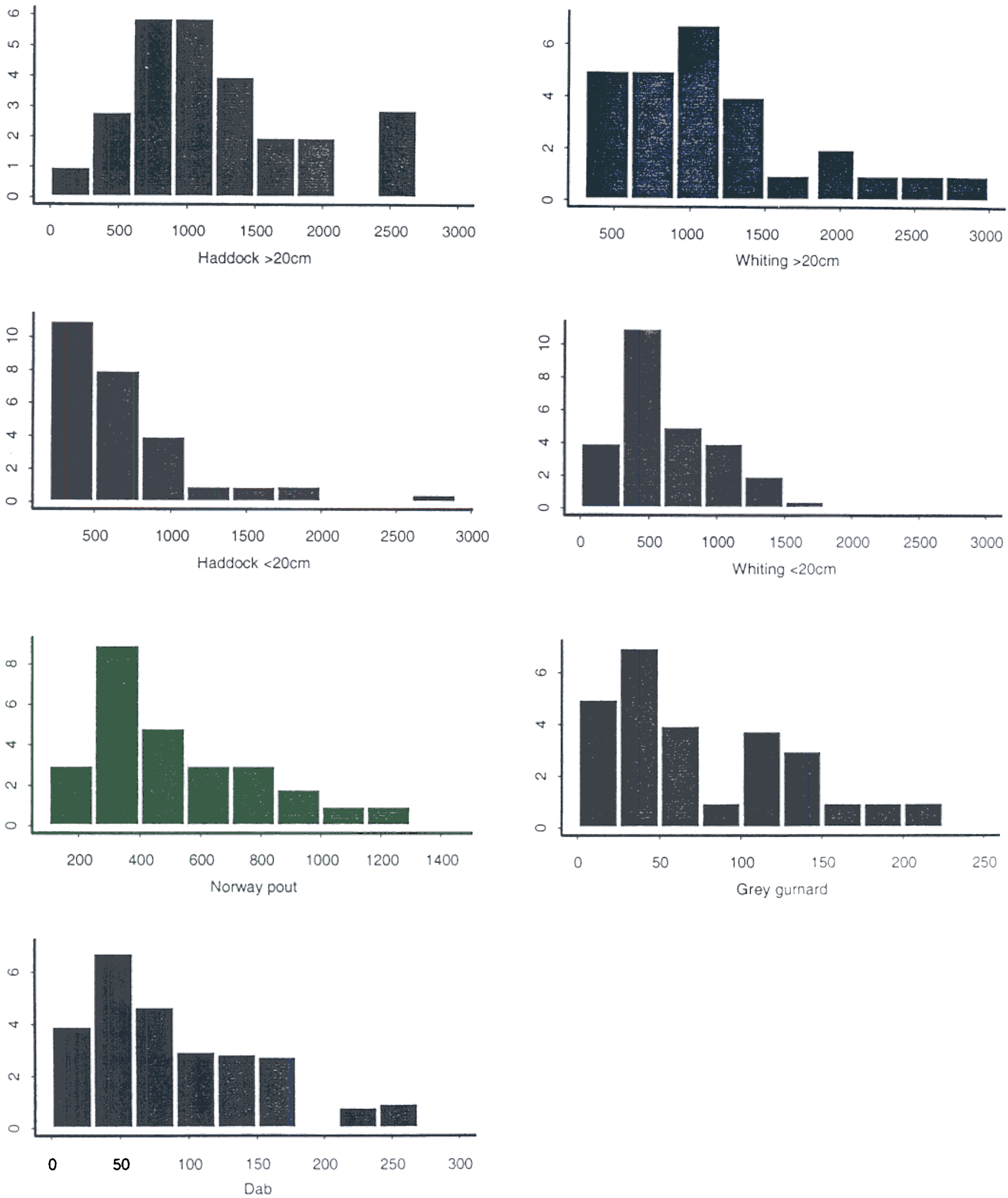


Figure 5. Distribution of catch rates of haddock and whiting smaller and larger than 20cm Norway pout, grey gurnard and dab.

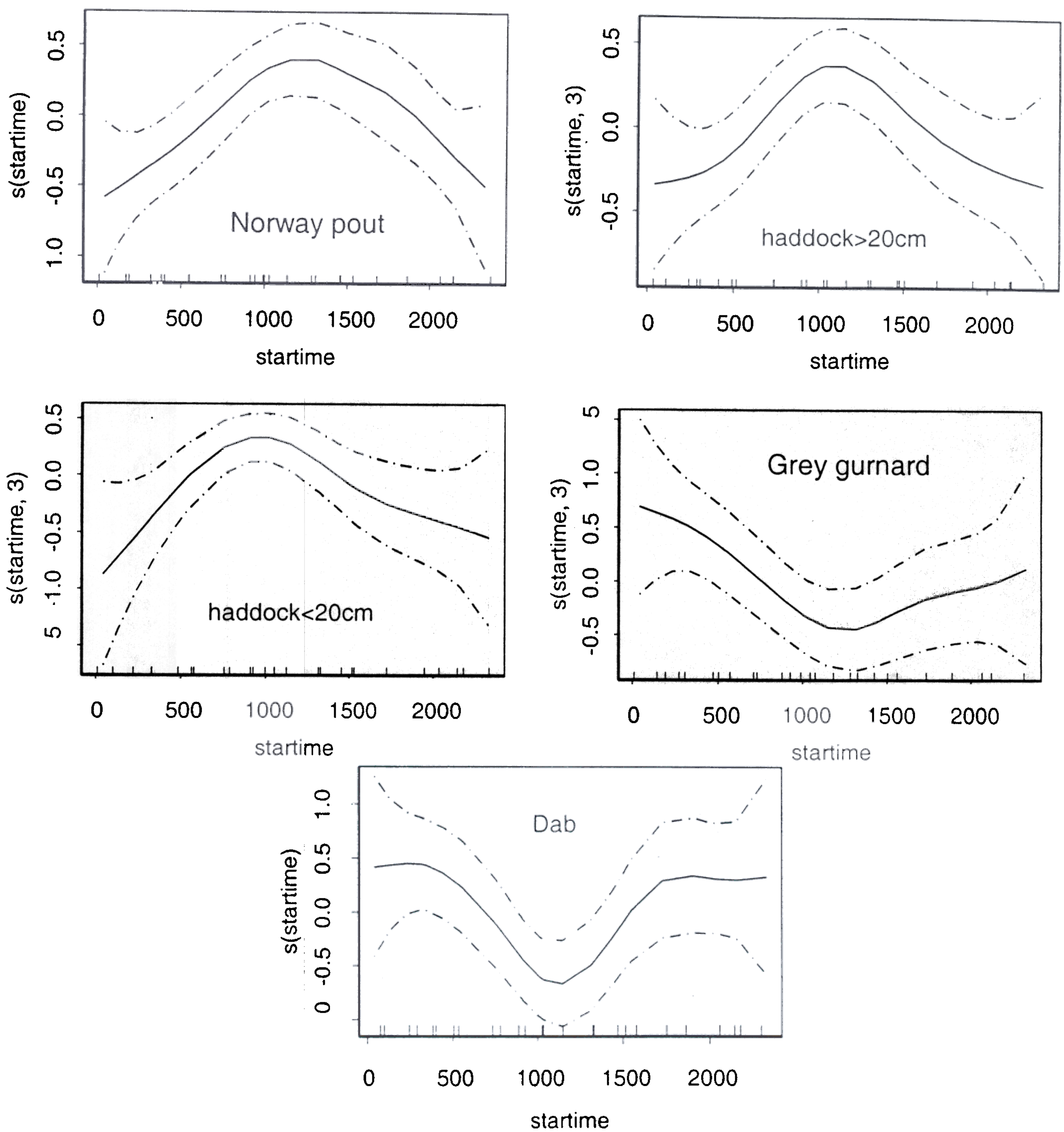
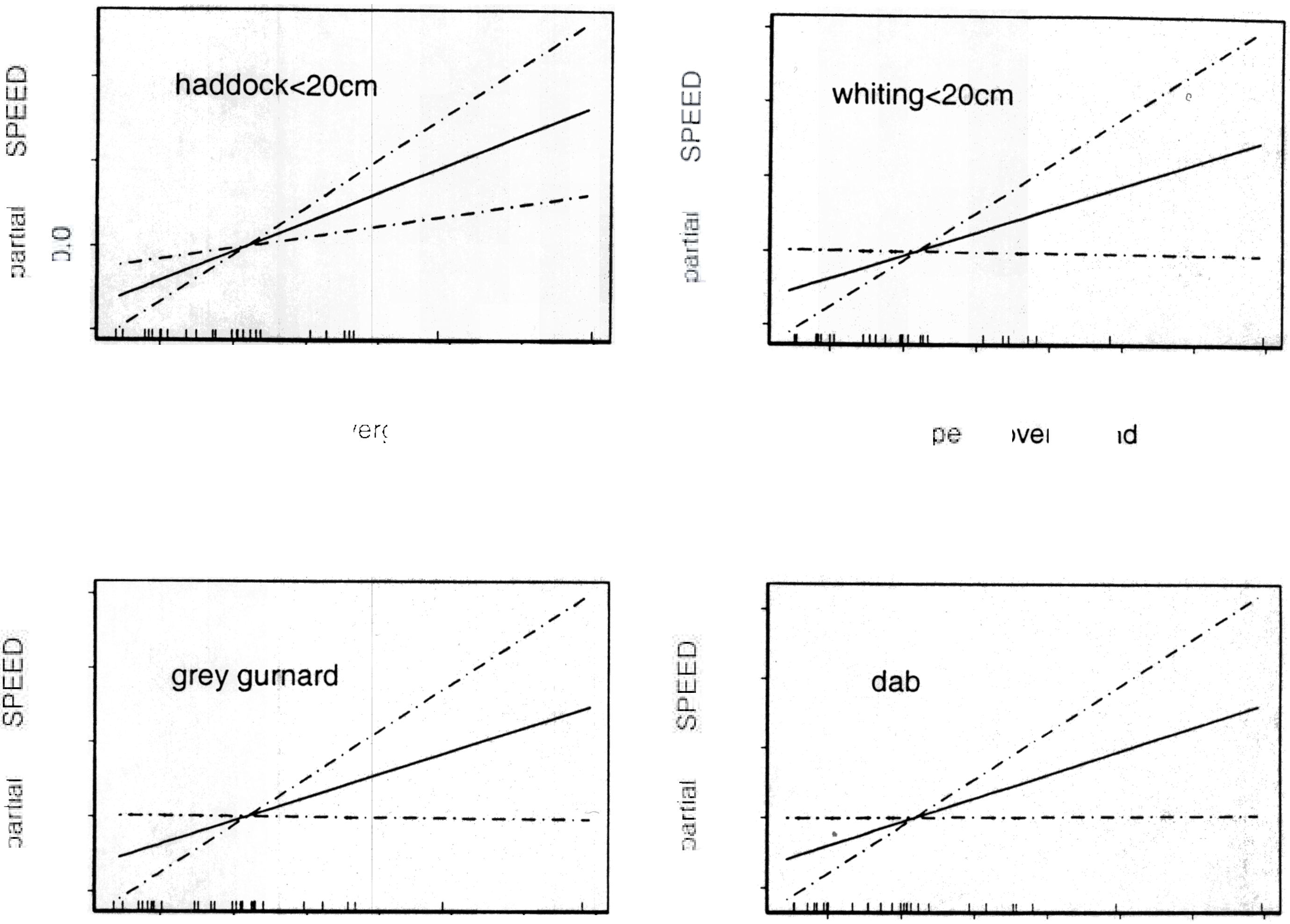


Figure 6. Fitted values from GAMs for the significant variation of catch rates of Norway pout, haddock and smaller and larger than 20cm, grey gurnard and dab as a function as time of day incorporated as a smooth variable accounting for the linear effect of speed over ground or speed through water (depending which variable explained more of the variation). Broken lines indicate approximate 95% confidence bands.



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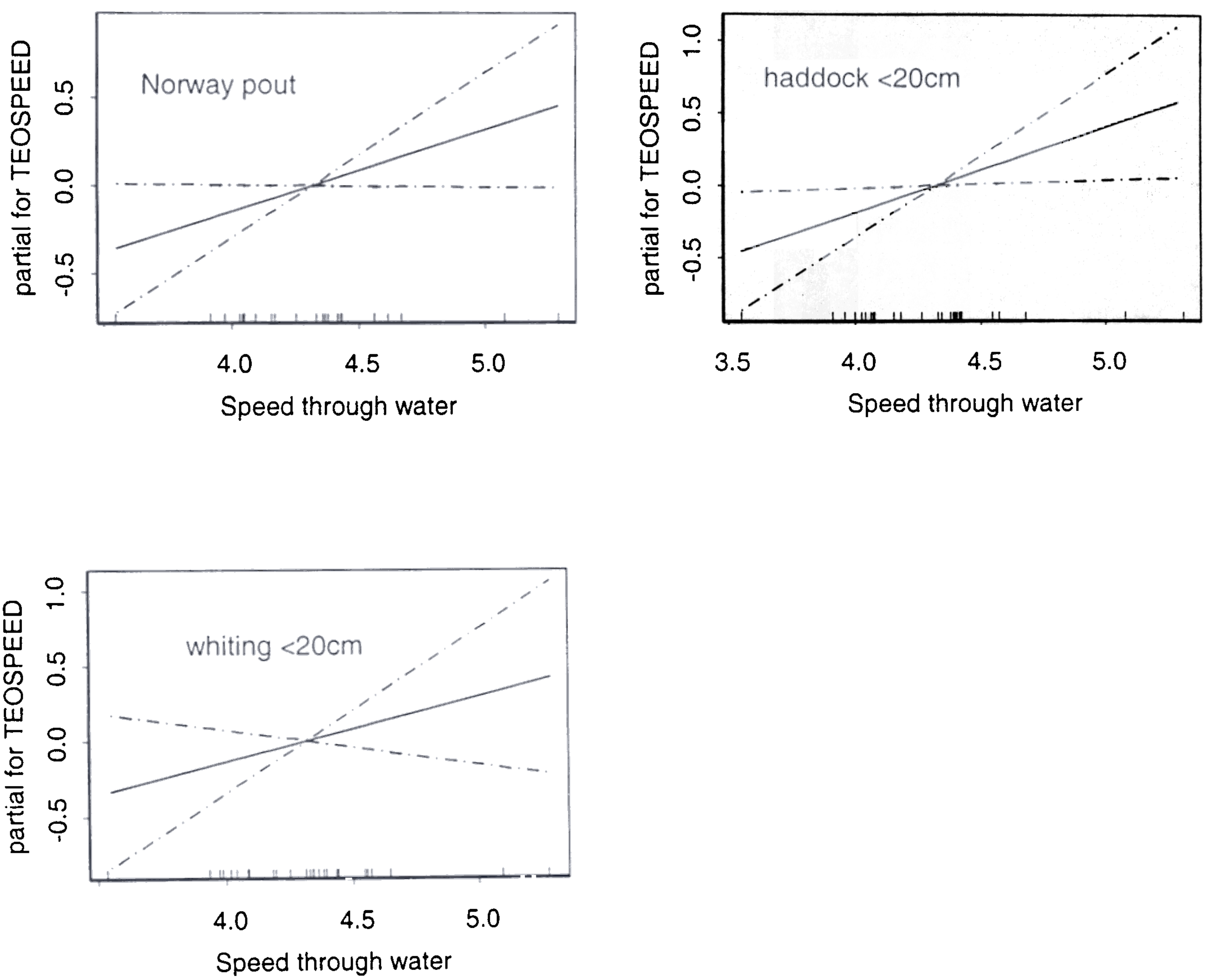

Figure 8. Fitted values from GAMs for the significant variation of catch rates for Norway pout haddock and whiting smaller than 20 cm with speed of trawling through water accounting for time of day incorporated as a smooth variable.