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PERFORMANCE AND GEOMETRY OF THE FP-120 TRAWL USED DURING UK FISH STOCK ASSESSMENT SURVEYS AROUND SOUTH GEORGIA, SUBAREA 48.3

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Abstract

Methods for calculating the horizontal opening (and, thus, swept area) of a bottom trawl are discussed. *In situ* measurements of the FP-120 trawl used during the 1993/94 UK fish stock assessment survey around South Georgia on the MV *Cordella* are presented. Regression equations for the estimation of horizontal opening from other, more easily measured variables, such as tow speed and trawl depth, are proposed. Biomass estimates for the major fish species around South Georgia are estimated using a new regression equation. The results of this calculation are compared to values obtained from a previous equation. The resulting difference in biomass estimates is of the order of a 10 to 14% increase, depending upon species.

Résumé

Les auteurs examinent différentes méthodes de calcul de l'ouverture horizontale (et, de ce fait, de l'aire balayée) d'un chalut de fond et exposent des mesures *in situ* du chalut FP-120 utilisé pendant la campagne britannique d'évaluation des stocks de poissons autour de la Géorgie du Sud menée en 1993/94 à bord du navire marchand *Cordella*. Ils proposent plusieurs équations de régression pour estimer l'ouverture horizontale à partir d'autres variables plus facilement mesurables, telles que la vitesse et la profondeur du chalutage. D'autre part, à partir d'une nouvelle équation de régression, ils estiment la biomasse des principales espèces de poissons présentes autour de la Géorgie du Sud. Les résultats sont comparés aux valeurs obtenues par une équation antérieure. La différence entre les estimations de biomasse est de l'ordre de 10 à 14% d'augmentation selon les espèces.

Резюме

Обсуждаются методы вычисления горизонтального раскрытия (и, таким образом, протраленной площади) донного трала. Представлены результаты замеров трала FP-120 в (рабочем режиме), применявшегося на борту судна Cordella в ходе съемки по оценке рыбных запасов вокруг Южной Георгии, проведенной Соединенным оролевством в 1993/94 г. Предложены уравнения регрессии для оценки горизонтального раскрытия с помощью других переменных, например скорости и глубины траления, которые более легко поддаются измерению. Биомасса основных видов рыб вокруг Южной Георгии оценена при помощи нового уравнения регрессии. Сравниваются результаты этого расчета с величинами, полученными с помощью использованного в прошлом уравнения. Вытекающее отсюда расхождение в оценках биомассы выражается в 10-14% увеличение, - в зависимости от вида рыб.

Resumen

Se consideran los métodos para calcular la abertura horizontal (y por ende, el área barrida) de una red de arrastre de fondo. Se presentan las mediciones de la red de arrastre FP-120 realizadas in situ durante la prospección del RU con el BM Cordella para evaluar los stocks de peces alrededor de Georgia del Sur durante 1993/94. Se proponen ecuaciones de regresión para la estimación de la abertura horizontal a partir de otras variables más fáciles de medir, como por ejemplo, la velocidad de remolque y la profundidad de arrastre. Los valores estimados de biomasa para las especies ícticas más importantes alrededor de Georgia del Sur son determinados mediante una nueva ecuación de regresión. Estos resultados se contrastan con los resultados obtenidos con la ecuación utilizada previamente. La diferencia en los valores de biomasa estimados dio un aumento del orden de 10 a 14%, dependiendo de la especie.

Keywords: bottom trawl, swept area, South Georgia, biomass, finfish, CCAMLR

INTRODUCTION

Surveys using bottom trawls have been used for over 20 years to make fishery-independent estimates of the stock sizes of commercial finfish around South Georgia. Relative biomass has been estimated using the 'swept-area method' described by Saville (1977). The swept-area method requires a knowledge of the area of seabed covered by the net during each tow. This is normally assumed to be the horizontal distance between the wings multiplied by the distance travelled by the net over the seabed.

The FP-120 trawl (Parkes, 1991) was used during surveys at South Georgia in January/February 1991, January 1992 and January 1994. Previous estimation of the horizontal net opening has relied on theoretical calculations of trawl geometry (e.g., Moderhak and Cielniaszek, 1991), and sea trials carried out by the Sea Fish Industry Authority, SFIA (1985). Moderhak and Cielniaszek (1991) calculated a headline height of 7.2 m and a horizontal opening of 22.8 m. However, trawl geometry has been shown to vary both during and between tows due to a number of factors, including vessel motions, the speed of the trawl through the water, water depth, warp/depth ratio, angle of 'up-pull', door type, sediment type, and ocean currents (Carrothers, 1981; Koeller, 1990; Engås and Ona, 1991; Enerhaug and Karlsen, in press).

Engås and Godø (1986) showed that several aspects of the geometry and performance of the gear can reduce its efficiency for sampling different species and size groups, including excessively high door and wing spreads, and low vertical openings (Engås and West, 1987). Therefore, to standardise trawl performance and reduce variations in catchability between tows, it is desirable to limit changes in trawl geometry. Various measures can be taken to standardise trawl performance, for example maintaining constant tow speed and warp/depth ratio. The effectiveness of these measures can be monitored using acoustic trawl instrumentation attached to the rig during the tow.

If acoustic instrumentation can be used during each trawl event, it may be possible to operate the trawl in such a way that a standard seabed area is swept at every sampling station. Unfortunately, this has not been possible on the South Georgia surveys. The cost of hire and insurance of the equipment may be of the order of only 5 to 10% of the total survey budget. However, around South Georgia the limiting factor is the rough seabed. The region is characterised by an uneven topography which increases the chances of damage to or loss of bottom trawl gear. For example, during the survey undertaken in 1992, the mini-transponder was lost on the first trawl on which it was deployed. Additionally, as trawl monitoring systems are not always readily available, their regular use in scientific surveys can be problematic.

If it is not possible to standardise trawl geometry by using trawl monitoring systems, it is essential for the application of the swept-area method that some alternative estimate of horizontal opening is available for each tow. For example, headline height is often measured using a single transducer mounted in the middle of the headline during the tow. This measurement can be used to estimate the horizontal opening based on an assumed linear relationship between the two variables (Koeller, 1990). Another approach which has been used is to derive empirical relationships between trawl geometry and other, more easily measured variables (e.g., Marteinsson, 1992). Such relationships allow the estimation of the swept area from measurements taken routinely during trawling, such as tow speed, trawl depth and warp length. This approach was used in this study.

MATERIALS AND METHODS

The Trawl

The swept-area method of assessing the standing stock of demersal fish species requires a series of representative samples from known areas of seabed swept by the net. This can be achieved using a trawl with a high likelihood of

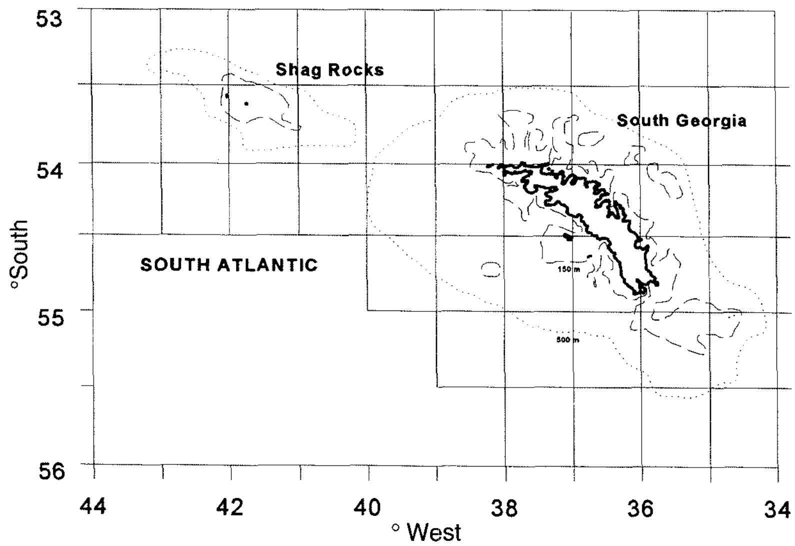

Figure 1: South Georgia and Shag Rocks.

successful sampling, such as a small or scaled-down version of a working commercial bottom trawl.

As mentioned above, the seabed around South Georgia and Shag Rocks (Figure 1) is known to be hard and uneven, thereby making bottom trawling difficult. Trawls with a high degree of contact between the net and the seabed are usually more effective for sampling demersal species, but this very feature makes them prone to severe damage.

The trawl used during the 1991 survey on the MV *Falklands Protector* was developed from the 170 ft Bolt rope trawl used during the previous year's survey on the MV *Hill Cove*. The new trawl (dubbed the FP-120) was rigged with most of the lower wings and part of the upper wings removed in an attempt to avoid the expensive and time consuming trawl repairs experienced previously. Trawl damage in January/February 1991 was found to be much less than in 1990. The FP-120 was used again on the MV *Falklands Protector* in January 1992 (Everson *et al.*, 1992), and on the MV *Cordella* in January 1994 (Everson *et al.*, 1994).

In situ Measurement of Trawl Geometry

For a distance travelled over the ground g and an estimated horizontal opening h, swept area $\hat{S}$ can be estimated at the ith location by:

$$\hat{S}_i = g_i \, h_i \qquad (1)$$

where g_i was derived from positions fixed at the start and end of each tow using a Furuno GPS 500; and h_i was measured *in situ* using trawl monitoring instrumentation manufactured by 'Scanmar' of Norway.

This comprised a ship-mounted monitor, towed hydrophone and trawl-mounted sensors. The system allows *in situ* measurement of various net and water parameters. All sensors are automatically activated in sea water, and transmit their information to the vessel by means of a hydroacoustic link.

Details of the instrumentation used are provided in the appendix. Positions of the sensors on the trawl are shown in Figures 2 (a and b), 3 and 4. The distance sensor and mini-transponder were mounted slightly behind the wing ends to provide basic protection when the trawl became snagged (Figure 2b). The distance measured by the sensors in this position was not considered to be significantly different from the horizontal opening at the wing ends. These sensors can also be mounted in brackets on the trawl doors. This may be preferable, because it provides a more stable measurement of spread; the required modification of the doors, however, was not feasible during this study. The headline height sensor was mounted at the midpoint of the headline. Additional floats were attached to counteract the negative buoyancy of the sensor and to avoid distortion of the headline.

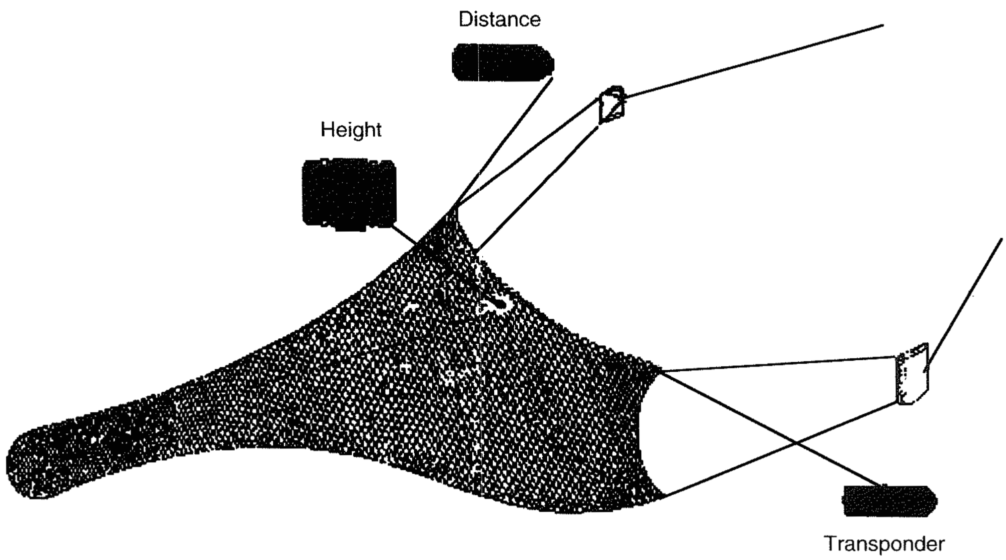

Figure 2a: The positioning of Scanmar sensors on a bottom trawl.

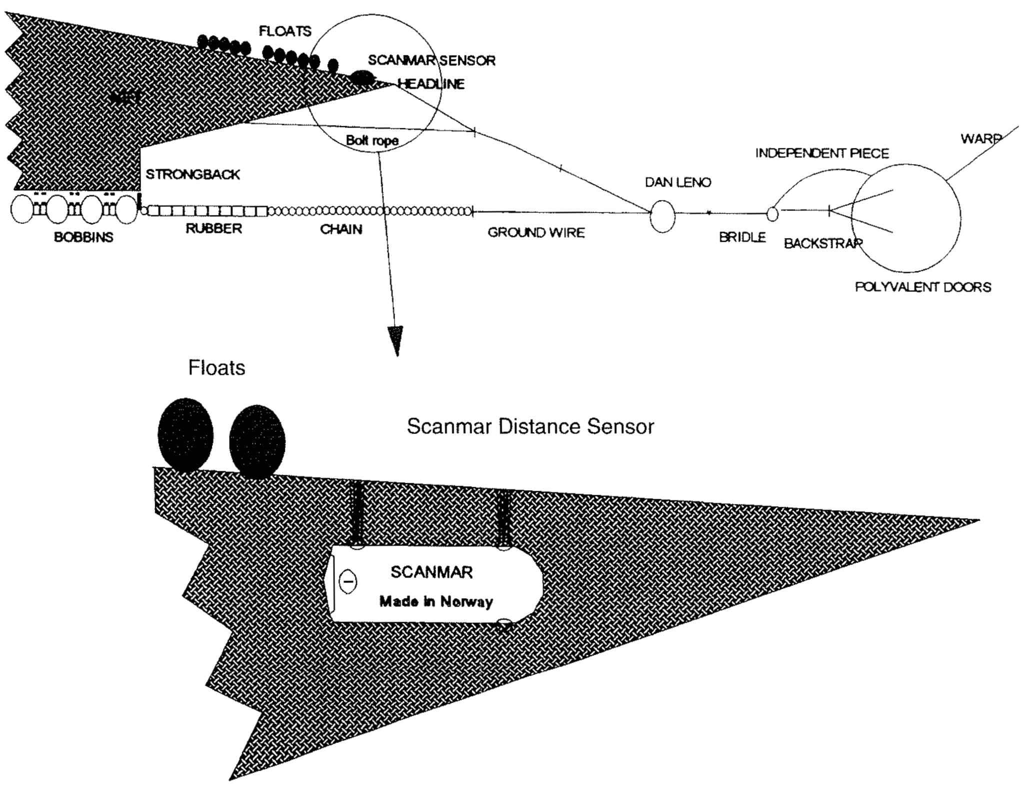

Figure 2b: The positioning of the Scanmar sensor on the FP-120.

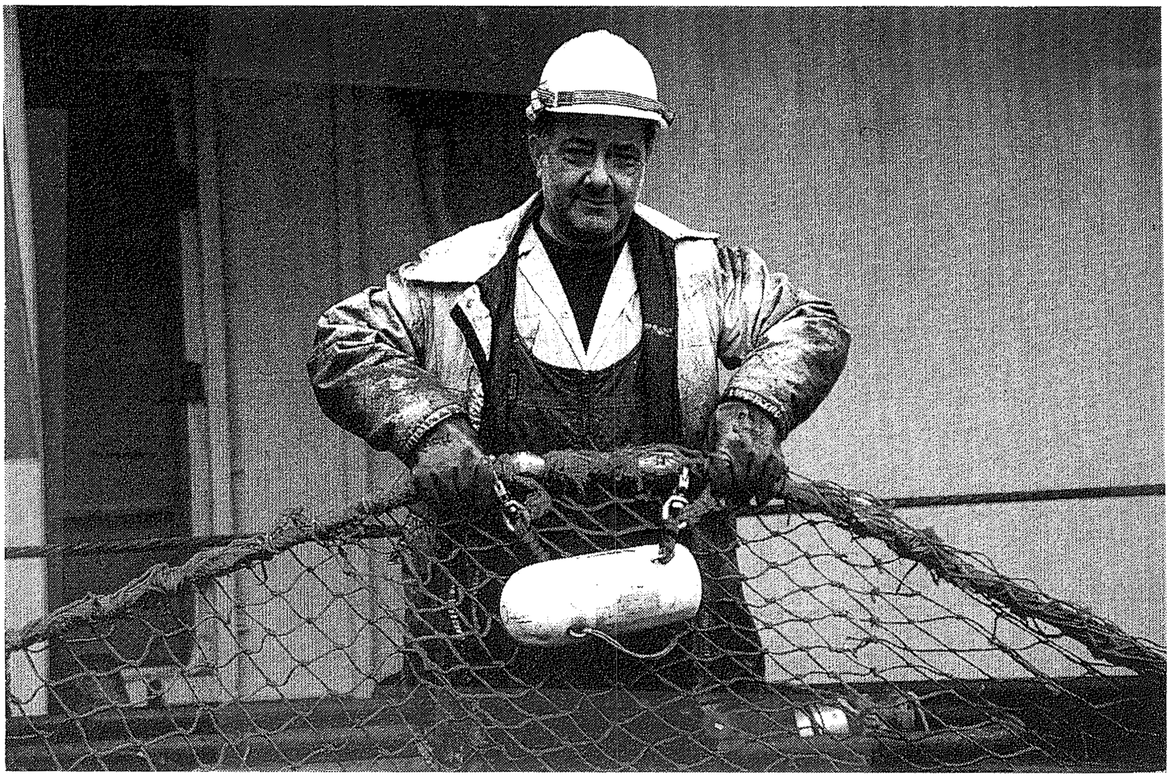

Figure 3: Photograph of the positioning of the horizontal opening sensor on the FP-120.

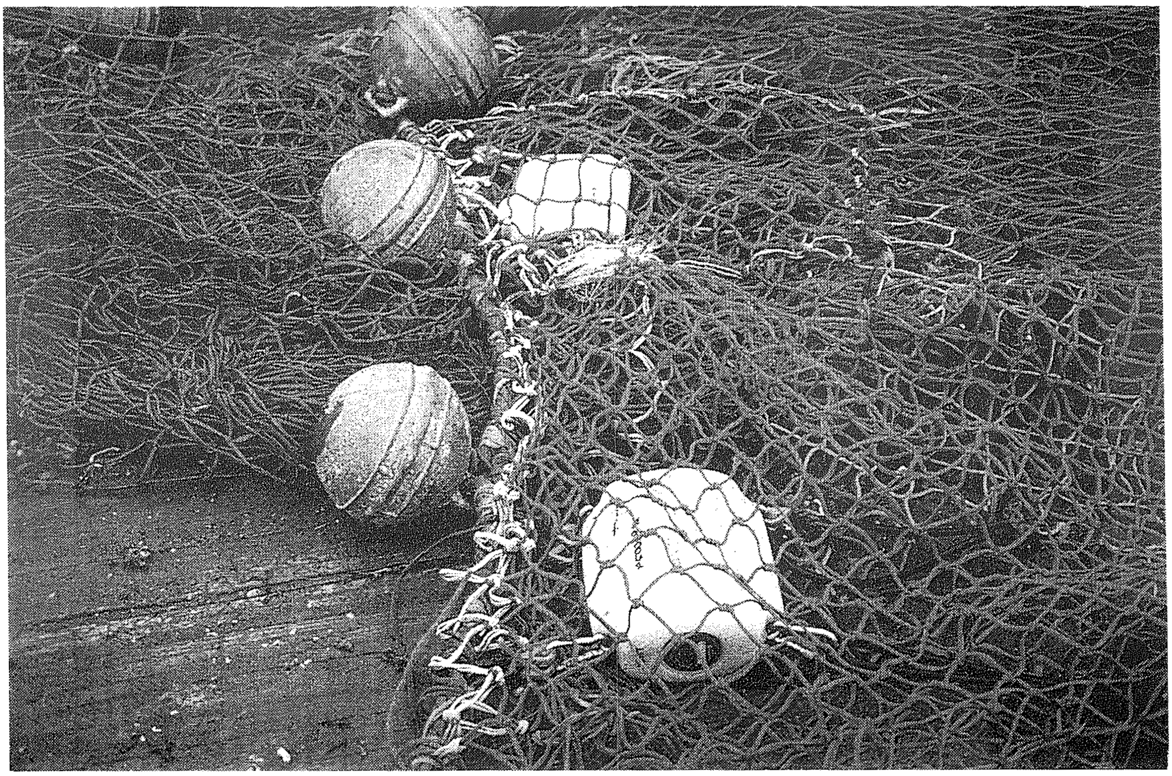

Figure 4: Photograph of the fixing of the Scanmar sensors on the FP-120.

The sensors were deployed at 29 of the 84 stations sampled during the 1994 survey. They provided data on headline height, distance between the wings and water temperature. A laptop PC was used to log the data using a program provided by the suppliers. Most data were logged at 10-second intervals although the first three stations (17, 20 and 21) were logged every 30 seconds and the fourth (22) every 20 seconds.

The hydrophone was deployed from a boom on the starboard side. It was originally intended to put the hydrophone in the water before shooting the trawl. However, due to the proximity of the trawl warps, the hydrophone could not be lowered until the warps had finished paying out, and the trawl began settling onto the seabed. At most stations, the data logger was started before the hydrophone was lowered. Data collection therefore began as soon as possible after the hydrophone was submerged.

The performance of the sensors was monitored during each haul on which they were deployed. It was apparent, particularly in the first few days of the survey, that the positioning of the wing sensors was critical. If the distance sensor was not aligned correctly with the mini-transponder on the opposite wing of the trawl, spurious measurements of the horizontal opening resulted. The mountings of the sensors were checked at the end of each tow, and adjusted as necessary. Generally, the readings from the height sensor were more consistent than those from the wing sensors.

Warp/Depth Ratio

The warp/depth ratio was maintained more or less constant at 3:1 on the advice of the captain and fishing master, based on experience from previous surveys.

Data Analysis and Presentation

Trawl Profiles

Data from the distance and height sensors were plotted against time to provide profiles of the headline height and horizontal opening of the trawl. A standard profile (Figure 5) shows decreasing headline height as the trawl sank to the seabed. Once on the bottom, the headline height and horizontal opening usually settled into a more or less steady pattern. Occasionally the trawl became snagged on an obstacle, detectable on the profile as a sudden change in both the headline height and the horizontal opening (Figure 6). Data points which indicated these type of distortions (amounting to 3% of the total number of data points) were considered to be outliers and were omitted from the calculation of mean values of trawl geometry for each tow. Spurious data resulting from misalignment of sensors and low battery power, denoted by specific codes in the output, were also discarded. In addition, if there were less than 10 minutes of viable data from an individual tow (standard tow duration was 30 minutes), this tow was discarded completely.

Using these criteria, 14 of the 29 tows on which the Scanmar gear was deployed were used in the data analysis (Table 1).

The speed of the trawl through the water was not measured directly. Average tow speed during each haul was calculated from the total distance travelled (measured by the ship's GPS), and the duration. This was assumed to provide the best approximation to the speed of the trawl through the water since current speeds around South Georgia are not very high. The depth of the tow was recorded by the ship's echo sounder (Furuno model 780/782).

Timing of the Start and End of the Tow

Calculation of the area swept by the net at each station requires an estimate of the distance covered over the seabed. This relies on accurate measurement of the time at which the net starts fishing on the bottom and the time when it leaves the bottom.

The surveys in 1989, 1990, 1991 and 1992 did not have the benefit of *in situ* trawl monitoring equipment. On these surveys the captain estimated the time when the bottom trawl arrived on the seabed from the sudden drag of the ground tackle which slows down the ship. The end of the tow, i.e. when the trawl came off the bottom and stopped fishing, was taken as the time when the warps were hauled.

In order to maintain the continuity of the survey time series, the same system was used during the 1994 survey on the MV *Cordella*. The Scanmar height sensor, however, provided the

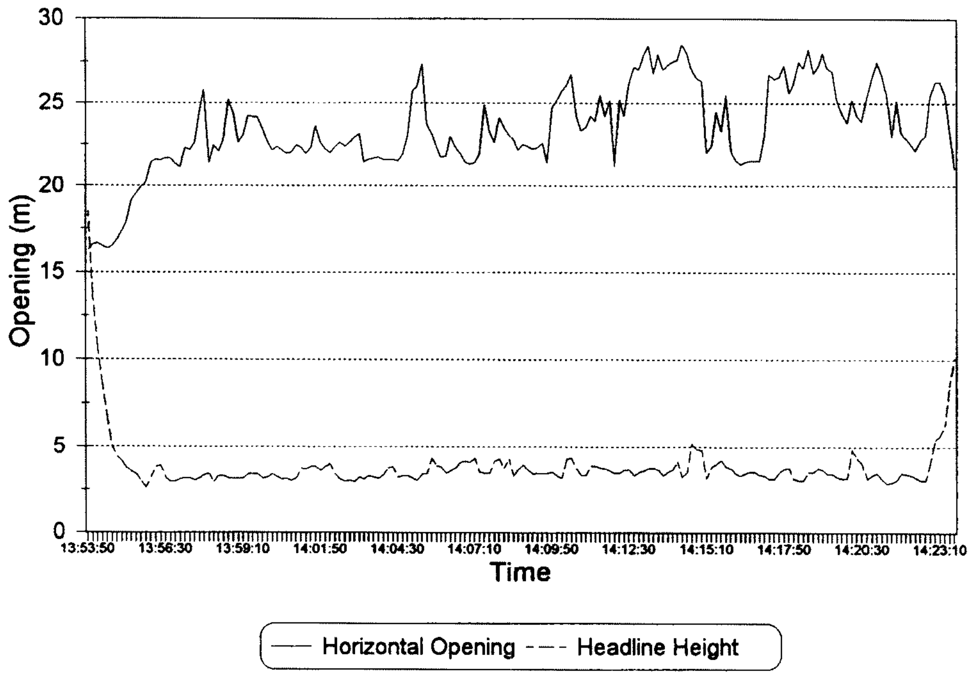

Figure 5: Standard profile of trawl geometry.

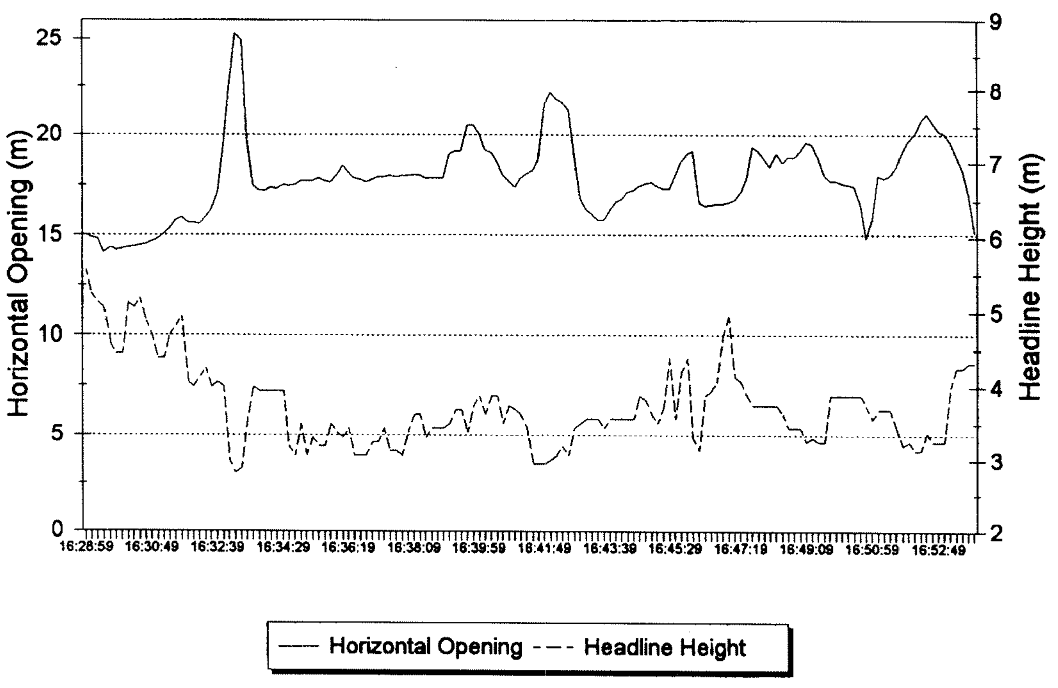

Figure 6: Trawl opening over time at Station 29.

Table 1: Horizontal wing opening and headline height data.

Stations		Horizontal Opening	Vertical Opening
22	No. of Data Points Average Variance	82 18.14 0.17	82 4.05 0.21
24	No. of Data Points Average Variance	121 20.79 0.72	121 3.42 0.39
29	No. of Data Points Average Variance	163 17.62 3.89	163 3.76 0.34
30	No. of Data Points Average Variance	163 19.52 0.58	163 3.59 0.23
34	No. of Data Points Average Variance	62 22.32 1.35	62 3.44 0.15
38	No. of Data Points Average Variance	112 18.02 2.08	112 4.40 0.33
39	No. of Data Points Average Variance	148 16.58 6.32	148 4.36 0.40
42	No. of Data Points Average Variance	83 14.46 11.30	83 4.91 0.37
48	No. of Data Points Average Variance	82 18.99 6.23	82 4.47 0.83
49	No. of Data Points Average Variance	152 18.85 9.31	152 4.54 0.92
50	No. of Data Points Average Variance	153 20.02 6.39	153 4.41 0.62
53	No. of Data Points Average Variance	113 18.42 0.58	113 4.34 0.17
54	No. of Data Points Average Variance	133 18.11 7.03	133 4.32 0.74
55	No. of Data Points Average Variance	61 20.35 9.76	61 4.97 4.34

opportunity to test the information provided by the captain against *in situ* measurements of the distance between the headline and the seabed. The captain was not aware of the information provided by the Scanmar sensors during the survey, except when severe problems with the trawl were indicated.

Only trawl profiles in which the headline sensor provided a clear indication of the time at which the trawl reached and/or left the seabed were used for this analysis. Figure 7, for example, shows the track of headline height at station 30. In this case the trawl was estimated to have reached the seabed at 19:58:40 and left at 20:24:50, (shown by the arrows). At some other stations the data logger was not started until after the trawl had reached the bottom. Only six data sets were used for the start of the tow, and five for the end.

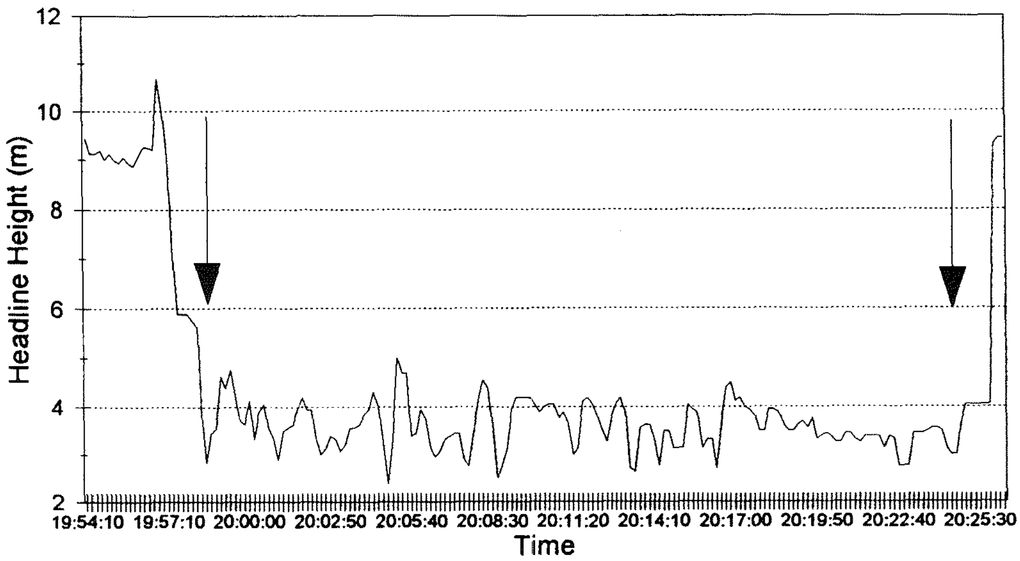

Figure 7: Time of trawl on seabed by headline height.

RESULTS

Modelling of Trawl Geometry

Horizontal Opening and Headline Height

Figure 8 shows the relationship between headline height and horizontal opening:

$$h = 32.3 - 3.13y \qquad (2)$$

where h is the horizontal net opening of the net, and y is the vertical opening. The units of both variables are metres (m).

The R^2 value for this regression was 0.43. The relationship was significant (p, the probability associated with the F statistic, = 0.006). An increase in headline height lead to a decrease in the horizontal opening and vice versa.

Horizontal Opening Against Tow Speed

Figure 9 illustrates the relationship between horizontal opening h and tow speed:

$$h = 34.0 - 3.80w \qquad (3)$$

where w is the mean vessel speed through the water (knots).

When tested, the points at either end of the regression line were not influential. The value of R^2 was 0.526 ($p = 0.012$). According to this regression model, the opening between the wings was reduced with increasing tow speed.

Horizontal Opening Against Maximum Depth

Average measurements of horizontal opening were also plotted against the maximum depth during the tow (Figure 10):

$$h = 16.07 + 0.016d \qquad (4)$$

where d is the depth of deployment of the trawl (m).

$R^2 = 0.342$, however $p = 0.059$, indicating borderline non-significance. This equation suggests that the horizontal opening increased with depth.

Horizontal Opening Against Depth and Tow Speed

The variables maximum depth and tow speed were tested and shown to be independent. A multiple regression of horizontal opening (h) against tow speed (w) and maximum trawl depth (d) was performed:

$$h = 29.36 + 0.01d - 3.09w \qquad (5)$$

The R^2 value for the multiple regression was 0.645. However, on performing the

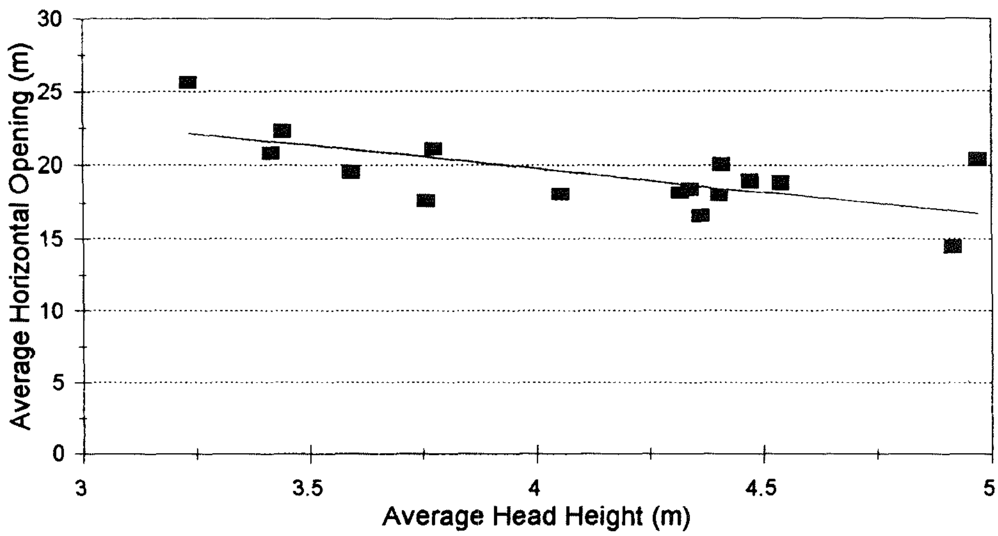

Figure 8: Regression of average head height against average horizontal opening.

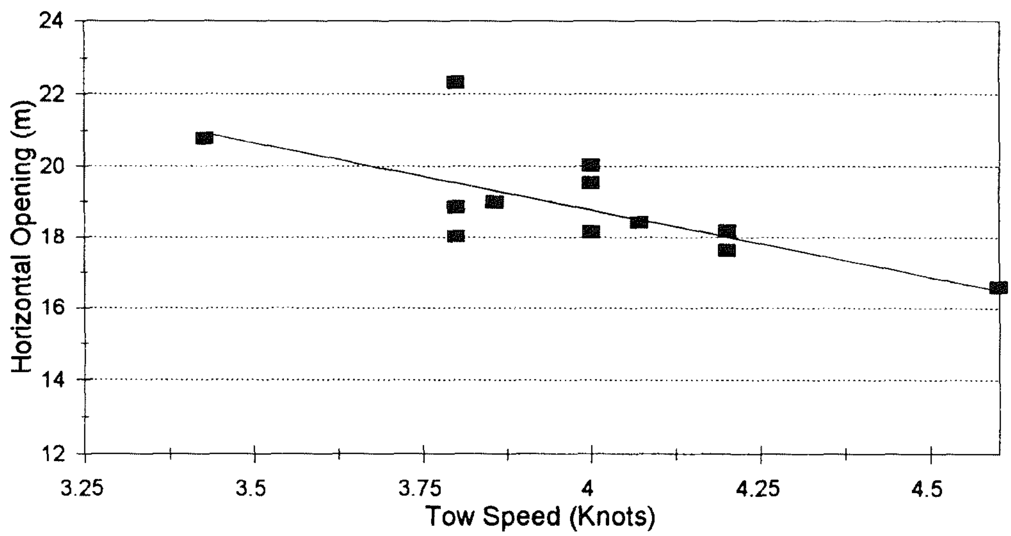

Figure 9: Regression of horizontal opening against tow speed.

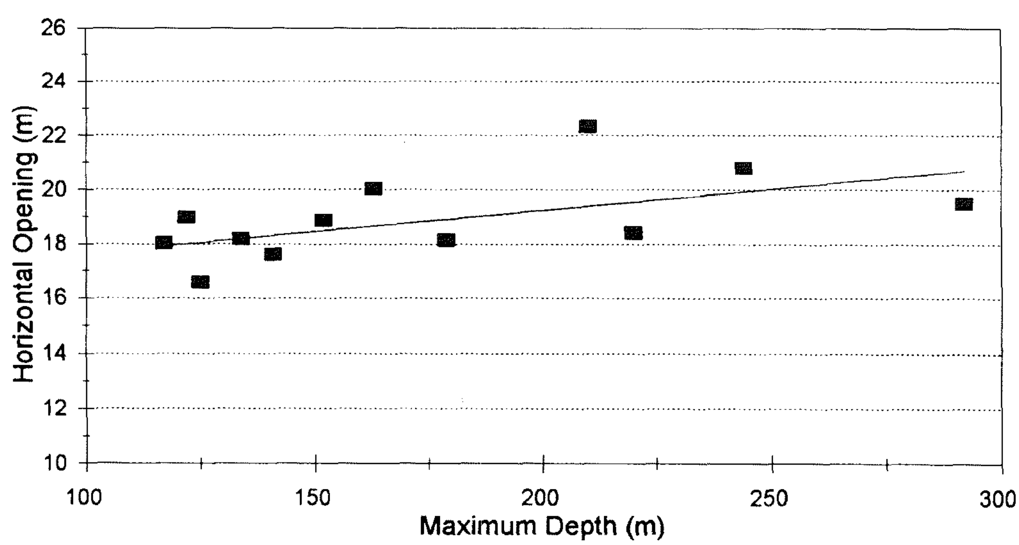

Figure 10: Regression of horizontal opening against maximum depth.

regression stepwise, the speed variable was retained ($p = 0.033$) but depth was rejected with a p value of 0.144.

Equation 3 was considered to provide the most reliable method of estimating the horizontal opening of the FP-120 trawl and was used to calculate revised swept area biomass estimates from the results of the 1994 survey.

Timing of the Start and End of the Tow

Figures 11 and 12 illustrate the time differences between the captain's estimates of when the trawl was on the seabed and the indication from the headline sensor.

The maximum difference between the time when the warps started hauling in (i.e., when the trawl was assumed to leave the seabed), and the time when the headline height indicated that the trawl had actually left the seabed was only 0.8 minutes. However, differences for the time of the start of the tow were greater. In all cases the trawl actually reached the seabed after the apparent drag of the ground tackle indicated to the captain that it had. The average difference was 2.0 minutes, representing a 6.7% error on a standard 30 minute tow. The greatest difference was 3.3 minutes at station 30. It should be noted, however, that times on the bridge were only recorded to the nearest minute.

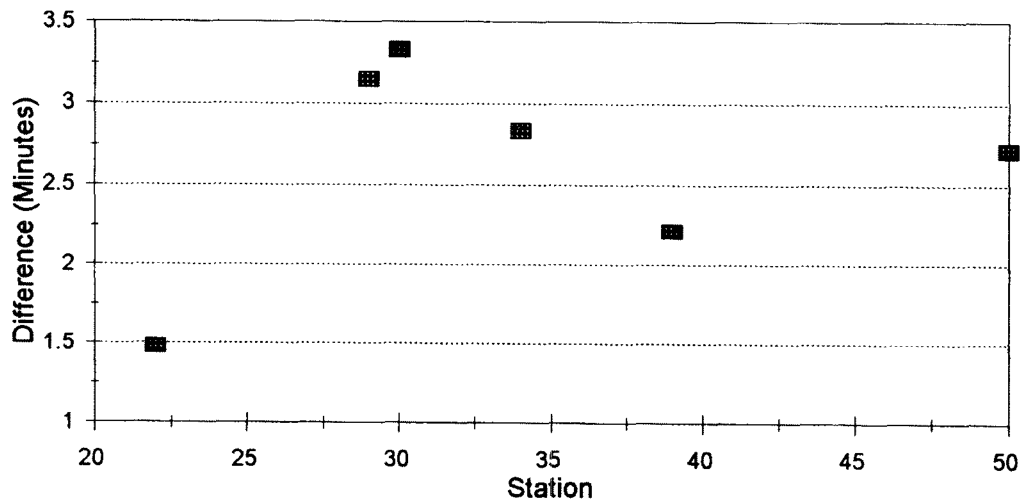

Figure 11: Trawl start times per station (difference between Scanmar and log data).

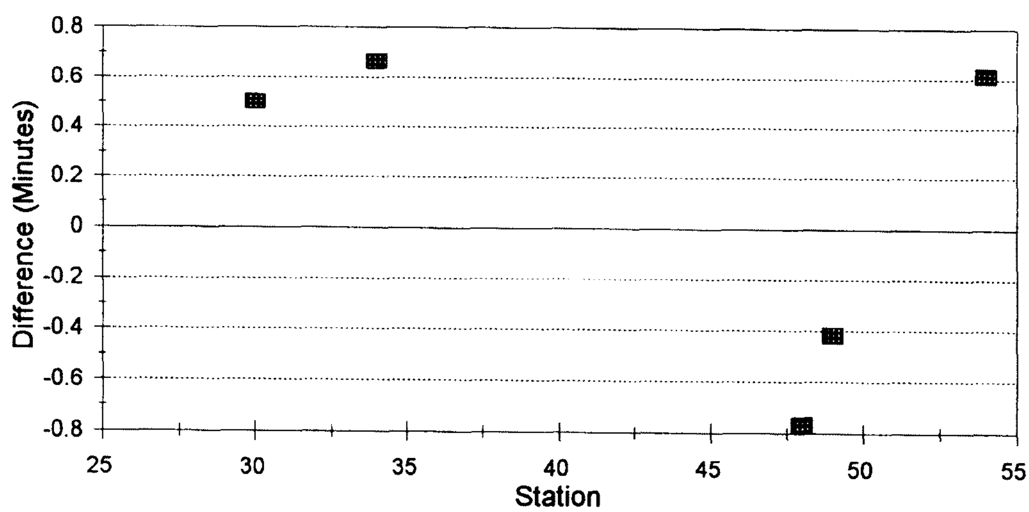

Figure 12: Trawl end times per station (difference between Scanmar and log data).

DISCUSSION

Empirical Formulae

Horizontal Opening and Headline Height

The net opening is basically an oval of fixed circumference. Changes in geometry in the horizontal or vertical plane therefore affect the dimensions of the other. Figure 8 clearly demonstrates this effect during the survey.

The theoretical result of Moderhak and Cielniaszek (1991) does not fit on the regression line of equation 2. The *in situ* measurements indicate on average a headline height of only 3.0 m at a horizontal opening of 22.8 m, rather than 7.2 m as estimated from the theoretical work. The reason for this difference is not clear, but may be related to the rigging of the trawl during the survey (number of floats etc.).

Horizontal Opening Against Tow Speed

Equation 3 is of a similar form to the relationship derived from sea trial data provided by the Sea Fish Industry Authority, which has been used to model the performance of the FP-120 trawl in previous years (SFIA, 1985; Parkes, 1993). The previous regression equation was:

$$h = 25.4 - 1.4w \qquad (6)$$

The two regression lines are compared in Figure 13. They are notably different, particularly at higher tow speeds. These differences probably resulted from a number of factors linked to the use of different vessels with different crews, at different locations, and at different depths.

Horizontal Opening Against Maximum Depth

The relationship between depth and horizontal opening was marginally non-significant. However, previous work has shown a stronger relationship. Godø and Engås (1989) found that trawl geometry showed a considerable depth dependency during trawls in the Svalbard area of Norway. Hagstrøm (1987) found that swept area increased with depth, particularly between 50 m and 100 m, during operations with the 36/47 GOV trawl on the RV *Argos*.

Later studies (e.g., Matuda *et al.*, 1991) showed that the horizontal opening is also related to the warp length, which itself is related to depth. The door spread, and hence the wing opening, will increase with increasing warp length while the doors have sufficient spreading force to counterweight the increasing weight and resistance of the warp wire. Once this balance is exceeded, the wing opening levels out and begins to decrease. The weakness of the relationship between the depth and the horizontal opening during the survey may be due to this non-linear relationship between horizontal opening and

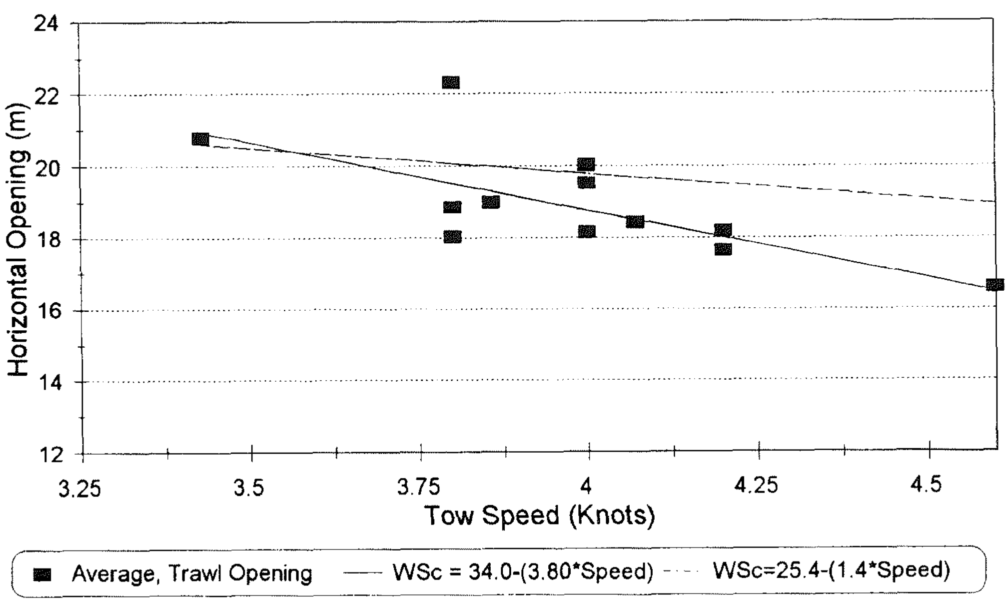

Figure 13: Regressions of horizontal opening against tow speed (old and revised equations).

warp length. No significant relationship between warp length and trawl geometry was apparent during this study, possibly due to the limited data available. Further studies on the effect of warp, depth and the warp/depth ratio on trawl geometry using the FP-120 trawl would be necessary before further conclusions could be drawn.

Timing of the Start and End of the Tow

Timings on the bridge were recorded only to the nearest minute. The differences between times of the start of hauling and the actual times when the trawl left the seabed were therefore considered to be negligible. There were in fact some cases when, according to the recorded times, the trawl left the bottom before hauling started, which is unlikely.

The differences between the estimates of the start of the tow are of greater concern. On each occasion for which data were available the captain estimated that the trawl had reached the bottom and started fishing before the headline sensor indicated that it had. The information from the sensor is likely to be more accurate than the captain's estimate.

Marteinsson (1992) reported on the results of experimental bottom trawls undertaken in Norway, using a 1280# (40 mm) 'Gisund Super' shrimp trawl with 'bobbins' ground gear. The doors reached the bottom (at a depth of 400 m) up to 10 minutes before the Scanmar height sensor registered that the trawl had reached the seabed. The discrepancy observed in this study may, therefore, be due to the drag of the doors, while the trawl was still settling. However, the 'Gisund Super' trawl used half shape rubber bobbins as ground gear, while the FP-120 used steel bobbins. The latter may be heavier in water than the former, possibly reaching the seabed at more or less the same time as the doors. However, it should be noted that this effect may be decreased in sea water.

A 6.7% error in the recording of the time of the start of the tow would have a corresponding effect on the estimates of biomass using the swept-area method. The real concern, however, is the degree to which the error varies between hauls. If the variation is small, then this may be considered to be another component of the systematic bias in the relative biomass estimates from the series of trawl surveys. If the variation is great and is dependent on other factors, such as trawl depth, then the resulting estimates of biomass may be misleading. Only six data points were available from the 1994 survey for this analysis (see 'Timing of the Start and End of the Tow'). Further studies need to be undertaken before the significance of this problem can be fully assessed.

Limitation of Variations in Trawl Geometry

Trawl geometry is very sensitive to changes in construction or rigging and variations in trawl doors. Changes of this type increase the variability of survey indices (Marteinsson, 1992; Parkes, 1991; DeAlteris *et al.*, 1989). This study has shown that the horizontal opening of the FP-120 trawl varies significantly with tow speed (Figure 9). Additionally, a review of the literature has shown that warp length and depth can also affect the horizontal opening. Relative tow speed can be actively controlled, taking into account factors such as current speeds. The amount of warp paid out can also be controlled, but to a lesser extent as it is dependent on depth. Marteinsson (1992) showed that it was possible to reduce the variations in the geometry of the 'Gisund Super' shrimp trawl by shooting extra warp in shallower water, with an estimated ratio of 4:1 being sufficient to decrease the total wing spread variations to 1-2 m. In the trawls around South Georgia, however, warp/depth ratios were maintained around 3:1 to minimise the probability of net damage on the rocky seabed.

Controlling the variability of trawl parameters where possible is a desirable goal (Koeller, 1991). Engås and Ona (1991, 1993) described a method employing a restraining wire between the trawl warps in front of the doors to maintain a constant door-spread at any depth (the 'constraining technique'). However, trawling on rough bottoms, such as around South Georgia, may lead to the problem of varying tension between the warps (Marteinsson, 1992). Engås and Ona have latterly shown that this problem can be partially tackled by attaching the strapping to one of the warp wires with a purse seine ring, leaving the warps free to move independently with varying tension.

Vessel movement may also affect trawl geometry (Enerhaug and Karlsen, in press). For the purposes of this study, this factor was considered to be a component of the random noise in trawl geometry measurements.

Table 2: Comparison of biomass estimates calculated using the previous and revised regression equations.

		Depth(m)											
		50-150			151-250			251-500			Total		
Area	Species	Old	Revised	% Diff	Old	Revised	% Diff	Old	Revised	% Diff	Old	Revised	% Diff
South Georgia	*C. gunnari*	5773	6490	12.42	7394	8324	12.58	977	1101	12.69	14144	15915	13.52
	C. aceratus	920	1049	14.02	7780	8774	12.78	568	644	13.38	9268	10467	12.94
	P. georgianus	1154	1320	14.38	3981	4504	13.14	296	334	12.84	5431	6159	13.40
	N. gibberifrons	4820	5524	14.61	14381	16359	13.75	3089	3497	13.21	22290	25381	13.87
	N. rossii	465	525	12.90	4029	4494	11.54	1842	2127	15.47	6336	7147	12.80
	D. eleginoides	337	385	14.24	1032	1154	11.82	792	908	14.65	2161	2448	13.28
	N. squamifrons	1	2	100.00	75	86	14.67	1063	1231	15.80	1139	1320	15.89
Shag Rocks	*C. gunnari*	403	474	17.62	4176	4725	13.15	21	23	9.52	4600	5224	13.57
	C. aceratus	0	0	-	10	11	10.00	0	0	-	10	11	10.00
	P. georgianus	0	0	-	0	0	-	0	0	-	0	0	-
	N. gibberifrons	28	32	14.29	79	85	7.59	0	0	-	107	118	10.28
	N. rossii	53	60	13.21	0	0	-	0	0	-	53	60	13.21
	D. eleginoides	368	447	21.47	730	780	6.85	669	722	7.92	1767	1950	10.36
	N. squamifrons	0	0	-	23	23	0.00	595	653	9.75	618	677	9.55
	P. guntheri	1558	1903	22.14	2852	3008	5.47	178	197	10.67	4588	5109	11.36

Revision of the Survey Biomass Estimates

The principal result of this study was a revised regression equation for calculating the horizontal opening of the net, based on tow speed. It was not possible to measure the horizontal opening *in situ* at every station. The revised regression (equation 3) was therefore used to calculate horizontal opening (swept area) for input into the algorithm to calculate biomass estimates.

Table 2 presents a comparison between the biomass estimates from the survey calculated using the previous regression (equation 6) and those using the revised version (equation 3). The overall differences were of the order of 10 to 14%. All were increases.

These increases are caused by the decrease in the horizontal opening calculated by equation 3 at speeds greater than 3.58 knots (Figure 13). This includes the majority of tows on the 1994 survey. For a given catch, the estimated density of the fish was higher, leading to an increase in estimated biomass.

CONCLUSION

It is encouraging that it has been possible to use the same design of bottom trawl for surveys at South Georgia over a number of years. This is the first time *in situ* measurements of the geometry of the FP-120 trawl have been made during a survey. The results have shown that the performance of the trawl was significantly different to that which had been assumed from previously available information. As a result the swept area estimates of biomass from the 1994 survey have been revised. The new regression equation may also have application to the surveys in 1991 and 1992 which used the FP-120 trawl, although it should be noted that a different survey vessel was used in these years. From the results of this study it is apparent that more work needs to be done to investigate more thoroughly the geometry of the FP-120 trawl during the surveys. This should focus particularly on the effect of trawl warp length and depth, and also on the potential for reducing variations in geometry between tows.

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Liste des tableaux

Liste des figures

Список таблиц

Список рисунков

Lista de las tablas

Lista de las figuras

APPENDIX

During the survey by MV *Cordella* in January 1994, the following Scanmar gear was used to monitor the distances between various points on the trawl, and thus the trawl's configuration:

• Plasma Display Unit PD-01:	Displays the data selected.
• Towed Hydrophone H45W:	Detects signals from the Scanmar sensors.
• Height Sensor MC6-HT60:	Measures the distance to the strongest echo (1.5 to 60 m). At more than 60 m from the bottom, this would measure the vertical opening. At less than this distance, it would measure the height of the head rope above the seabed.
• Temperature Sensor MC6-T303:	Measured water temperature at operating depth.
• Distance Sensor MC6-A144:	When combined with the mini transponder (below) measured the distance between two points, in this case the distance between the trawl wings (Figure 2).

• Mini Transponder MT144

• Receiver Unit

• Battery Charger BC 220VAC x 2

• Fako 2 Data Logging Software

• IMT-803 Convertor (RS 232)