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The influence of depth and bottom type on area swept by groundtrawl, and consequences for survey indices and population estimates.

by

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Abstract

In this document the variation in swept area for a Western IIA trawl in relation to depth and bottom type is examined, and the impact of using variable spread in calculating survey indices and population estimates is assessed for the 4X cod stock. Door spreads were chosen as the best representative of swept area. The data, collected using SCANMAR spread sensors, indicates that spread varies with depth and substrate type. Using the variable spread results in a great increase in indices for deep strata in comparison with shallower strata. Similarly, indices for older age cod increase in relation to younger ages. However, The impact on population estimates is not as great.

Résumé

Dans le présent document, on examine la variation de l'aire balayée par un chalut Western IIA en fonction de la profondeur et du type de fond, et on évalue les effets de l'utilisation d'un écartement variable dans le calcul des indices des relevés de recherche et les estimations de population de morue du stock de 4X. On a choisi l'écartement des panneaux comme l'élément le plus représentatif de l'aire de balayage. Les données, recueillies au moyen des capteurs du SCANMAR, révèlent que l'écartement varie selon la profondeur et selon le type de substrat. L'utilisation d'un écartement variable se traduit par une hausse considérable des indices lorsqu'on passe de strates peu profondes à des strates profondes. On constate aussi une augmentation des indices ayant trait à la morue d'un certain âge par rapport à ceux qui s'appliquent à la jeune morue.

Introduction

In calculating survey indices, the area swept by the trawl is currently determined by multiplying the length of the tow by a standard tow width. Differences in effective width of the trawl net are thus not taken into account. Both door spread and wing spread of the Western IIa trawl have been shown to vary with depth (Koeller, 1991; Strong, 1992). Thus, using a constant width results in a relative underestimate of swept area in deeper tows, and consequently an overestimate of the fish abundance per unit area in these tows. Since the survey results are used to provide an index, not an absolute abundance estimate, this may not be of great importance as long as fish distribution is consistent. However, distribution does vary between years. Also, if distribution of different age classes varies with depth, the effective weighting of catches which results from using a standard width rather than actual variation in width, will result in proportionally higher indices of abundance for age groups found in deeper water.

Other factors have also been identified as having potential impact on gear spread. In deriving a relation between swept area and depth, Godø and Engås (1989) found that wing spread was consistently higher in the eastern than the western Svalbard surveys. They suggest that this may be due to differences in bottom type. Trawl Door spread has been shown to decrease when the trawl moves from smooth sand to hard rocky substrate (Main and Sangster, 1979). Since the trawl doors will dig in on soft substrate, we may find higher spread in areas of soft bottom.

The tow width which is currently used for the Western IIA trawl is 41 feet. This is an estimate of standard wingspread determined in test tows. However, it is unclear if wingspread is the appropriate parameter to indicate swept width. There is a great deal of evidence that the swept area, defined here as the area from which fish may be captured during a tow, is that bounded by door spreads (Carrothers 1980). Due to net avoidance, not all fish initially in this path will be captured, but herding, both through visual cues such as the sand cloud and bridles (Main and Sangster, 1979, 1981a, 1981b, 1983; Engås and Godø, 1989), and by noise created by the gear (Main and Sangster, 1982; Ona and Godø, 1987; Andrews et al, 1991), should result in this being the area sampled.

The results of studies investigating the effect of sweep length on bottom trawl catch conducted by Engås and Godø (1989), and Andrew et al (1991), seem to support this hypothesis. In both these studies, catch varied with door spread, and not with wing spread. However, in assessing the influence of swept area variation on trawl catches, Godø and Engås (1989) use the wing spreads as their measure of swept area. They assume that swept area will be directly related to wing spring, and that a regression of these two would pass through the origin. This is not the case for a regression of wing spread on door spread (Strong, 1992), and thus the degree of variation in swept area with depth will differ depending on which measure of spread is used to represent swept area.

In this paper consideration is given to which parameter best represents swept width. The influence of depth and bottom type on swept width is then examined, and a relation predicting spread from depth is derived. These predicted spreads are then used to recalculate the survey indices for 4X cod for 1970-1992. These recalculated indices are then compared with the standard indices to determine the influence of variable swept width.

Population estimates were also calculated from the two sets of indices using ADAPT (Gavaris, 1988). Population estimates derived from the two index series are compared, and relations between indices and populations investigated.

Methods

Data on gear geometry were obtained from the Scotia/Fundy SCANMAR database. For this paper, modal spreads (both for door spread and wing spread) have been used. Modes were selected as the more appropriate measure of central tendency because of the nature of the data available. SCANMAR data tends to be negatively skewed, largely due to the inclusion of data recorded during descent and haul back of the net. Thus, the mean is consistently lower than the mode, and is an inappropriate measure of central tendency.

A regression analysis was performed of modal wing spread on modal door spread for 28 sets where both were recorded, to determine if they were directly proportional.

Bottom type was divided into two categories, soft and hard, based on information in the series of publications by the Canadian Hydrographic Survey on surficial geology of the sea bed on the Scotian Shelf and in the Bay of Fundy (King, 1970; MacLean and King, 1971; Drapeau and King, 1972; Fader et al, 1977). Clay and silt surfaces were designated soft, as indicated in these publications, while all sand, gravel, and rock surfaces were designated hard. Door spreads were then compared for the two substrate types. Regression analysis was used to derive an equation relating door spread to depth. Previous analysis of these data (Strong, 1992) had derived separate regression equations for each survey using mean door spread versus depth. An initial attempt to use all data together indicated that there were consistent differences between areas and vessels, so only data from the 4X survey conducted from the Alfred Needler (cruise N139) were used in the final analysis.

Door spreads were calculated, based on bottom type and depth for all tows in the survey series. For this calculation bottom type in strata 71 (Le Have Basin), 83 (George's Basin), and 84 (Jordan and Crowell Basins) and at depths greater than 80 fathoms in strata 70 and 76 (Roseway Basin and those parts of the Le Have Basin less than 100 fathoms deep) were treated as soft, while all other areas were treated as hard substrate. The one area of soft substrate that is overlooked through this division is at the mouth of the Bay of Fundy, overlapping strata 92 and 93. In this area the water depth is generally less than 80 fathoms, and as no function is available to predict spread at these depths on soft substrate (see Results and Discussion), this area has been treated as hard bottomed.

Survey indices were recalculated for the 23 year time series of 4X summer surveys using the calculated door spreads to determine area swept by each tow, and then to recalculate the numbers and weights of cod captured per standard tow unit(1.75 nautical miles long, 41 feet wide). Door spreads were entered in meters rather than translating them to the imperial measures generally used for the survey, since the scaling effect of 0.305 (meters/foot) made the resulting indices roughly comparable to the standard indices.

The population estimates for the constant swept width indices (CI) are the mid-year populations, $\bar{N}_{a,y}$ calculated from this years stock assessment for 4X cod (Gavaris, 1993). These population estimates were calculated using values provided in the 4X cod stock assessment (Gavaris, 1993) as:

$$\bar{N}_{a,y}=N_{a,y}(1-\exp[-(F_{a,y}+M)]/(F_{a,y}+M))$$

Mid-year population estimates were also calculated using the variable swept width indices (VI) following the same formulation used in the 4X cod stock assessment (see Gavaris, 1993).

Results and Discussion

The regression of wing spread on door spread is quite strong, with an R^2 of 89.4%, and both the regression equation and the intercept are highly significant (fig. 1). The significant intercept indicates that wing spread is not directly proportional to door spread, thus the two measures can not be used interchangeably to represent swept area. Thus, as evidence seems to overwhelmingly indicate that the area bounded by door spreads is the area from which a ground trawl may capture fish, door spread has been selected as the only appropriate measure of swept width for calculating the swept area of a tow.

A plot of door spread versus depth with spreads plotted separately for the two bottom types clearly indicates that bottom type has a strong influence on door spreads (fig. 2). At all depths, door spread is always higher from areas with soft surface substrate. Thus, these two groups will be dealt with separately in determining the relation between depth and door spread.

Door spreads from areas with hard substrate clearly increase with depth, but the rate of increase appears to decline as depth increases. Using a Marquardt algorithm the data were fitted to a number of non-linear models. However, based on the mean square residuals and the pattern of residuals, a linear model of door spread versus ln depth (door spread=13.5[ln depth]-6.1) was selected as the most appropriate (fig. 3).

There is some indication that a similar pattern is followed for tows on soft substrate; however, the quantity of data from areas with soft substrate at depths less than 80 fathoms is so low that any detailed analysis below this depth is impossible. Information from the series of publications on surficial geology within the Scotia/Fundy area (King, 1970; MacLean and King, 1971; Drapeau and King, 1972; Fader et al, 1977) indicates that the distribution of soft substrate is restricted almost exclusively to depths greater than 80 fathoms within the 4X area. A regression of door spread on depth for tows on soft substrate at greater than 80 fathoms was not significant. The slope from the equation is almost zero, so for this depth range on soft substrate the mean door spread of 72.5m will be used for all tows.

When expected door spreads are determined based on depth and bottom type, and indices are recalculated using these values for swept width, the result is a relative decrease in survey index for deeper or soft bottom strata in comparison to shallower areas (table 1). Since the swept area increases with depth, the resultant catch/unit area will be impacted more strongly for deep water tows.

A comparison of indices by age group shows that the relative difference between the two varies with age. Older age groups show a greater reduction in numbers in response to the inclusion of gear spread variability than do younger ages (table 2). This result simply reflects that older fish are generally caught in deeper water (Sinclair, 1992), and thus the impact of increasing gear spread with depth is highest for these age groups.

When these data are split into years when the Needler was used as the survey vessel (1983-1992), and years when the A T Cameron or the Lady Hammond were used (1970-1982), it is apparent that the CI/VI ratio is higher in the older data (table 2). This once again indicates that the depth at which fish were captured was greater where the ratio is larger. Since the mean depth of tows is quite similar for the two time periods (76.7 fm for 1970-1982; 75.1 fm for 1983-1992), this may indicate that there has been some shift in fish distribution in relation to depth between the two time periods, or that the A T Cameron fished more effectively than the Needler in deep water.

Results from SPA's are presented in table 3 (a and b). Population estimates derived from the two sets of indices converge in earlier years of the time series, but in more recent years some differences are evident. A comparison of correlations between indices and population from surveys conducted on the Needler shows little difference for VI and CI series (table 4). Similarly, no marked differences were observed in the pattern of residuals from the two series. These results provide no indication of whether one index series is a more accurate reflection of the total population. Correlations between indices and population drop drastically when the entire time series is included, and when only data from before 1983 are used, no consistent correlation is found between indices and population for either series (table 4).

The difference evident in the VI series from the CI series is an overall increase in population estimates in recent years. This, however may be an artifact of the data handling. An increase in population estimate over the CI series indicates that indices are higher in comparison to long term means in recent years for the VI series than for the CI series. This reflects the fact that the CI/VI ratio is higher for years prior to 1983 (table 2).

The depth to gear spread relation on which the VI indices were calculated was derived using data from a survey on the Needler. Whether the same depth:spread relation holds on another vessel or for different gear is far from certain; thus it may be inappropriate to extend the VI series back before 1983. However, The current practice in 4X stock assessments is to use a constant ratio to convert A. T. Cameron trawlable units to Alfed Needler trawlable units, implying that the relative gear performance for the two vessels was constant at all depths. On this basis the same depth to gear spread ratio was used in this paper for both vessels to allow for the inclusion of the full survey series in the VI.

If the depth:spread relation on the Cameron was not the same as that from the Needler, then the CI series will also be effected, since the factor of 0.8 which is used to convert data from pre-1983 into Alfred Needler trawlable units will not be appropriate for all depths. This could result in an artificial inflation or deflation of indices at age in the early time series, which would then bias population estimates in later years by biasing the long term mean.

Conclusions

In the literature, wing spread has generally been used as the measure of swept width for a ground trawl. However, since it has been shown that fish are herded by the doors and ground warps, both through visual and audio cues, it seems apparent that the area sampled by the net is greater than the area swept by the wings, and will be best represented by door spreads. Since door spread varies from roughly 35 m to 75 m over depths trawled during a survey, it is apparent that swept area may vary dramatically with depth. In this paper it is shown that this strongly influences survey indices for some strata, and that its influence on indices increases with the age of the fish. There is also some indication from these data that cod distribution in the 4X area may have been shifted towards deeper water earlier in the time series. This may better be resolved through a direct examination of catch data.

Although the effect of variation in gear spread on survey indices seems fairly clear from these analyses, its influence on SPA results is somewhat equivocal. Differences exist between population estimates made from the two indices, but there is no indication which is more reliable. There is some question about the appropriateness of using the full time series for calculating VI, due to differences in trawl gear and vessel. However, if the relation between depth and gear spread is not consistent for the three vessels, then the use of a single vessel conversion factor for all depths in the CI series may also be inappropriate. The obvious impact of swept area variation with depth on survey indices suggests these outstanding questions warrant further investigation.

Acknowledgments

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Table 1. Survey indices for 1992 by stratum for constant swept width (CI) and variable width (VI) of trawl.

Stratum no.	Depth Range (fm)	CI	VI
470	50 - 100	189491	151741
471	> 100	0	0
472	50 - 100	51451	39504
473	< 50	218327	193377
474	50 - 100	112237	103973
475	< 50	129659	118781
476	50 - 100	1059388	850112
477	50 - 100	224497	191274
478	> 100	19196	13736
480	< 50	883343	815216
481	50 - 100	810144	659319
482	> 100	30299	21382
483	> 100	0	0
484	> 100	0	0
485	50 -100	912360	782853
490	< 50	517722	496748
491	50 - 100	833838	693745
492	50 - 100	994728	782135
493	50 - 100	458068	426646
494	< 50	240489	238166
495	< 50	423406	448098

Table 2. Ratio of CI to VI.

Age	Years		
	1983-1992	1970-1982	1970-1992
1	1.111	1.159	1.137
2	1.126	1.179	1.157
3	1.140	1.208	1.179
4	1.185	1.221	1.204
5	1.217	1.230	1.224
6	1.218	1.225	1.223
7	1.205	1.248	1.230
8	1.190	1.229	1.213
9	1.221	1.274	1.245
10	1.177	1.299	1.249

Table 3a: Cod population numbers in thousands calculated for CI data.

Years	Age							
	3	4	5	6	7	8	9	10
1970	7652	5276	3370	1821	1342	627	368	71
1971	11492	5196	3064	1571	873	719	396	125
1972	10088	7272	2801	1474	803	478	365	225
1973	8034	6003	3711	1217	691	553	257	208
1974	11145	4733	2981	1645	597	337	363	85
1975	13966	6684	2524	1391	716	339	167	234
1976	10880	9535	3586	1423	778	382	204	105
1977	13609	7362	5987	1979	838	423	211	93
1978	12736	8742	4299	3061	970	474	220	107
1979	9600	7910	4840	2091	1314	439	259	115
1980	17074	6328	3800	2261	1024	680	229	146
1981	15071	9736	3512	1628	1075	511	373	119
1982	10783	8324	4410	1758	734	511	229	189
1983	13540	6712	3809	1753	757	309	231	95
1984	6247	7829	3675	1726	764	308	132	110
1985	7007	3393	3805	1662	792	364	156	63
1986	9419	3914	1714	1657	745	376	187	83
1987	5777	5349	1816	800	721	351	184	91
1988	16240	3533	2716	707	362	297	149	75
1989	11357	10125	1875	1311	249	171	137	77
1990	19128	7089	5409	939	635	102	85	73
1991	5311	12173	3833	2652	428	289	39	45
1992	8295	2609	6247	1908	1357	228	147	13

Table 3b: Cod population numbers in thousands calculated for VI data.

Year	Age							
	3	4	5	6	7	8	9	10
1970	7652	5276	3370	1821	1342	627	368	71
1971	11492	5196	3064	1571	873	719	396	125
1972	10088	7272	2801	1474	803	478	365	225
1973	8035	6003	3711	1217	691	553	257	208
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1975	13966	6684	2524	1391	716	339	167	234
1976	10880	9535	3586	1423	778	382	204	105
1977	13611	7362	5988	1979	838	423	211	93
1978	12737	8742	4299	3061	970	474	220	107
1979	9603	7910	4841	2091	1314	439	259	115
1980	17076	6330	3801	2261	1024	680	229	146
1981	15074	9739	3514	1628	1075	511	373	119
1982	10785	8326	4413	1760	735	511	229	189
1983	13540	6713	3810	1755	758	309	231	95
1984	6267	7829	3676	1727	766	309	132	111
1985	7055	3409	3805	1663	793	365	157	63
1986	9466	3955	1727	1657	746	377	188	83
1987	5783	5388	1850	811	722	352	184	91
1988	16331	3538	2748	736	371	297	150	76
1989	11392	10202	1879	1338	272	179	137	78
1990	19347	7119	5472	942	657	121	91	73
1991	5455	12354	3857	2703	431	306	54	50
1992	8587	2731	6396	1928	1399	231	161	26

Table 4: Correlation of CI and VI to population estimates calculated from these indices.

	Correlation of Population to Index			
	1983 to 1992		1970 to 1982	
Age	CI	VI	CI	VI
3	0.741	0.715	0.211	0.276
4	0.908	0.912	0.047	0.032
5	0.847	0.848	-0.343	-0.320
6	0.751	0.755	0.110	0.152
7	0.684	0.656	0.621	0.614
8	0.761	0.781	0.218	0.226
9	0.565	0.518	0.378	0.331
10	0.428	0.498	0.444	0.545

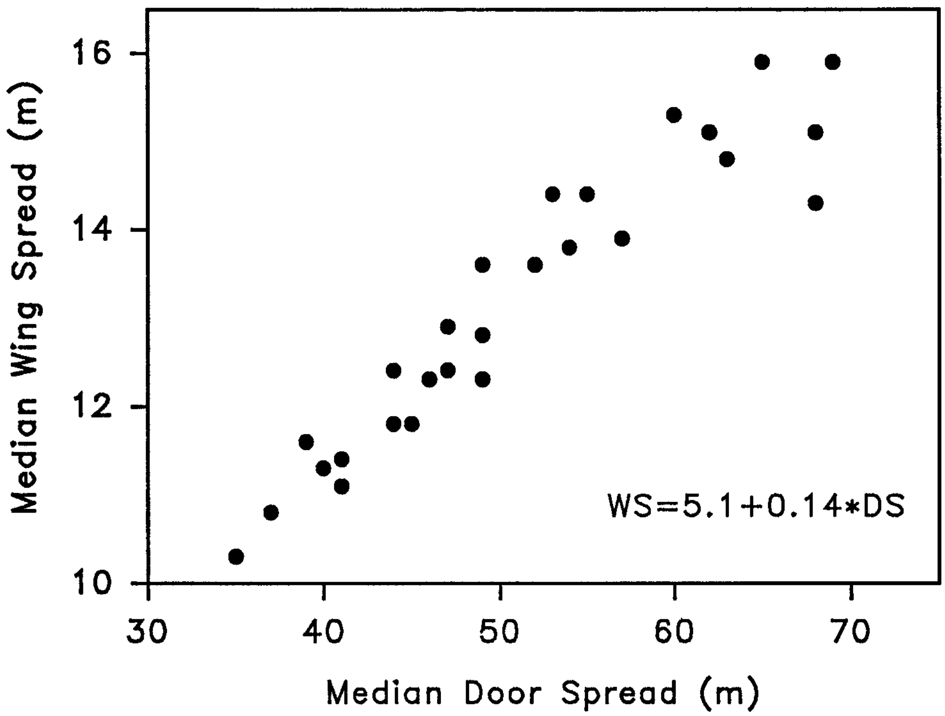

Figure 1: Median wing spread vs door spread for a Western 2A Trawl

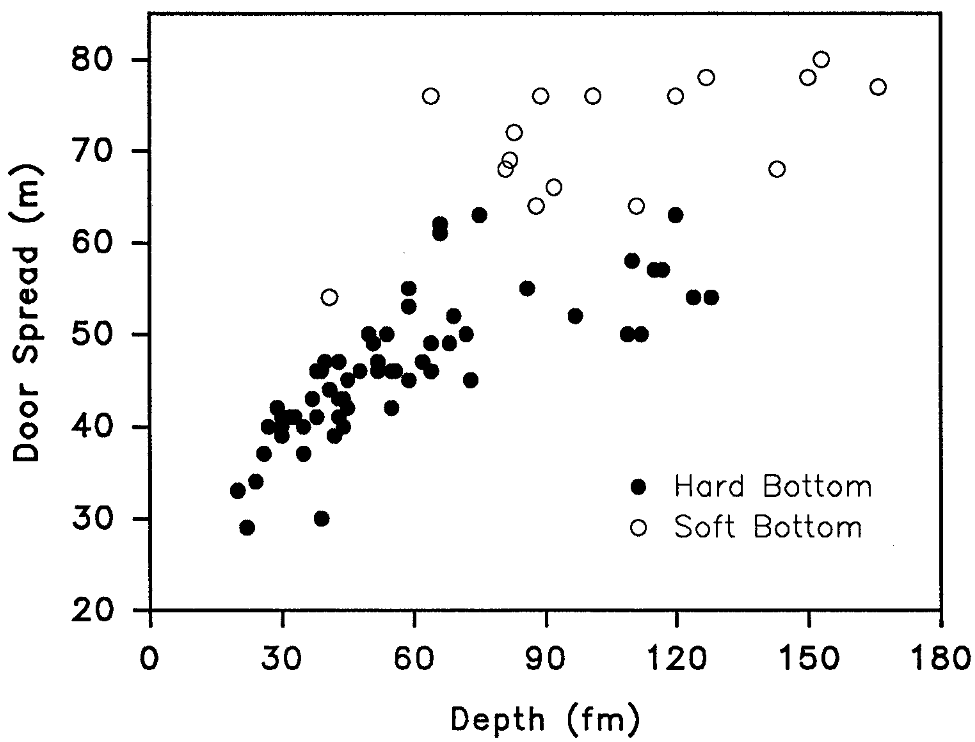

Figure 2: The influence of depth and bottom type on door spread for a Western 2A Trawl.

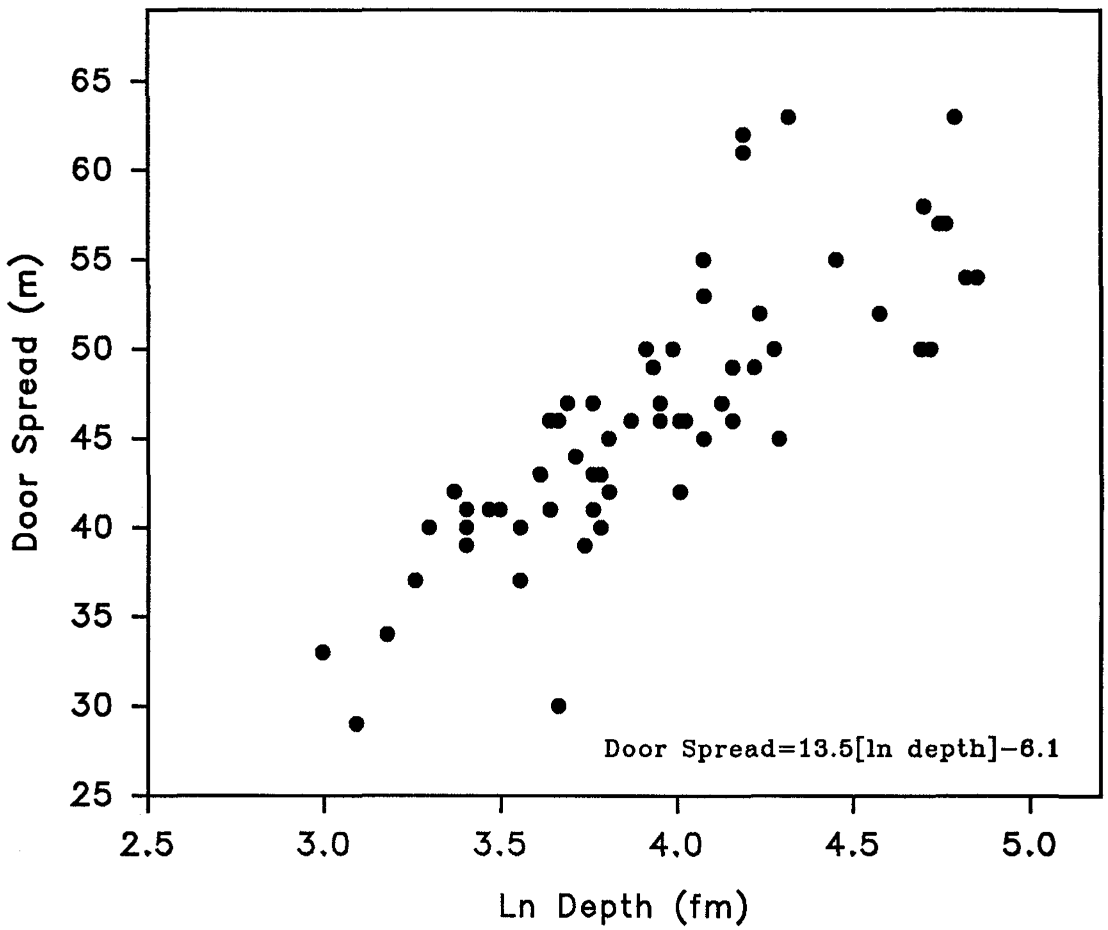

Figure 3: Door spread vs ln depth for a Western 2A Trawl