Not to be cited without
permission of the authors[1]

Canadian Atlantic Fisheries
Scientific Advisory Committee

CAFSAC Research Document 92/58

Ne pas citer sans
autorisation des auteurs[1]

Comité scientifique consultatif des
pêches canadiennes dans l'Atlantique

CSCPCA Document de recherche 92/58

Variability of trawl performance on Scotia-Fundy groundfish surveys

by

M. Strong

Department of Fisheries and Oceans
Biological Station
St. Andrews, New Brunswick E0G 2X0

[1]This series documents the scientific basis for fisheries management advice in Atlantic Canada. As such, it addresses the issues of the day in the time frames required and the Research Documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

Research Documents are produced in the official language in which they are provided to the Secretariat by the author.

[1]Cette série documente les bases scientifiques des conseils de gestion des pêches sur la côte atlantique du Canada. Comme telle, elle couvre les problèmes actuels selon les échéanciers voulus et les Documents de recherche qu'elle contient ne doivent pas être considérés comme des énoncés finals sur les sujets traités mais plutôt comme des rapports d'étape sur les études en cours.

Les Documents de recherche sont publiés dans la langue officielle utilisée par les auteurs dans le manuscrit envoyé au secrétariat.

ABSTRACT

The performance of the Atlantic Western IIA groundfish trawl is evaluated by the analysis of trawl mensuration data collected during four standard groundfish surveys of the Scotian Shelf. Net geometry is estimated using a wireless mensuration system by SCANMAR Ltd. to monitor the variation of door spread, wing spread, headline height and trawl speed. Other variables, including vessel speed, fishing depth, warp to depth ratios, gear construction, fishing practices and other factors are assessed for their impact on gear behavior. Results indicate that with increased fishing depth, an increase in gear spread and a decrease in headline height occur with this trawl.

RÉSUMÉ

On évalue le rendement du chalut à poisson de fond Atlantic Western IIA, en analysant des données de mesure recueillies lors de quatre campagnes d'évaluation courantes du poisson de fond sur la plate-forme néo-écossaise. La géométrie du filet est étudiée au moyen d'un système de mesure sans fil de SCANMAR Ltd., qui détermine la variation de l'écartement des panneaux et des ailes du chalut, de la hauteur de sa corde de dos et de sa vitesse. On établit également les effets d'autres variables sur le comportement du chalut, notamment la vitesse du bateau, la profondeur de pêche, le rapport funes-profondeur, les composantes du chalut, les méthodes de pêche et d'autres éléments. Il s'avère que l'écartement de l'engin augmente et que la hauteur de la corde de dos diminue lorsque la profondeur de pêche s'accroît.

INTRODUCTION

Standard bottom trawl groundfish surveys are conducted in the Scotia-Fundy Region, employing an Atlantic Western IIA otter trawl. Information collected on these surveys is used by the Canadian Atlantic Fisheries Scientific Advisory Committee (CAFSAC) for several stock assessment applications, primarily the estimation of relative abundance, resulting in an index of population trends as described by Smith (1988). Abundance indices are based upon catch per species per standard survey set. A standard survey set in the Scotia-Fundy Region is defined as the area swept by a trawl when towed at a constant speed of 3.5 knots for a duration of 30 min, targeting a distance towed of 1.75 naut mi.

Currently, for purposes of data analysis, tows are generally standardized for a distance towed of 1.75 naut mi if the tow is completed in a time window of 20-40 min. To determine swept area (the product of the lower wingspread and distance towed), swept width has traditionally been assigned a constant value of 41 ft for the Western IIA (Carrothers 1988), as no technical means of determining this variable has been available until recently.

The use of a "SCANMAR" system to interactively display and record trawl dimensions has recently been initiated as protocol on standard surveys; thus, the estimation of absolute swept area and volume for each tow is now possible. SCANMAR data from four standard surveys is presented in this report, and the variability of trawl performance during individual tows and among tows is described. The sources of variation for each net dimension monitored are evaluated as controllable or non-controllable, and means of minimizing the controllable sources of variation through fishing practices are discussed.

The variability in performance of the Western IIA, as determined from manually recorded SCANMAR data, is described by Koeller (1991), and discussions of how variability may be reduced are included. Questions of how groundfish survey methodology may be improved with the application of gear mensuration technology and through fishing practices are dealt with by McKone et al. (1990), and will not be examined in depth in this report. The question of how SCANMAR data may be applied needs further evaluation, and changes in traditional survey protocol should await the recommendations of international and inter-regional workshops on the problem.

This report uses electronically logged SCANMAR data to describe the variability in the performance of the Western IIA when following traditional fishing practices. Also, the effects on gear geometry of changes in vessel speed and varying warp to depth ratios are examined from gear trials performed on the J.L. HART using a Concord trawl. To conclude, a series of short-term recommendations are made for the Scotia-Fundy gear mensuration program.

METHODS

Monitoring of the Atlantic Western IIA on standard surveys

SCANMAR sensors were deployed on Atlantic Western IIA groundfish gear on standard groundfish surveys conducted on the ALFRED NEEDLER and LADY HAMMOND. As many stations as possible were monitored, excluding sites where rough bottom presented high risk for gear loss.

Data were logged at 20-s intervals on a shipboard computer using "Fako II" software. Tows were performed according to section 2.2.1 of the Marine Fish Division Manual for Groundfish Bottom Trawl Surveys, Scotia-Fundy Region (Strong and Gavaris 1992). An unwritten guideline maintained all warp:depth ratios at 3:1.

Prior to each survey, trawls were inspected and measured to ensure that they complied with the documented specifications for the Western IIA. Also, specifics of gear damage and repairs were logged when tear-ups occurred, to verify that the rig, dimension and materials of replaced components were to specification.

Data were edited in accordance with criteria established by SCANMAR personnel to remove codes indicating lost signals, obvious outliers resulting from reflected signals, and values introduced by noise. Values logged prior to door touchdown and subsequent to door liftoff were also removed. Files requiring excessive editing were considered extraneous and were excluded from the analyses. The edit specifications used for the SCANMAR data in this report are described in Table 1.

Experimental gear trials using a Concord trawl on the J.L. HART

SCANMAR gear was deployed on a "Concord" groundfish trawl on the J.L. HART in October 1990, and door spreads and headline heights were logged at 15-s intervals to estimate trawl geometry. Nine experimental sets were conducted to assess the impact on trawl dimensions of changes in warp:depth ratios at a constant speed and at a series of depths, and of varied warp:depth ratios and speed at a constant depth. Vessel speed was logged manually from a Loran C receiver at 1-min intervals.

RESULTS

Results of trawl mensuration prior to standard surveys

The specifications for the Atlantic Western IIA were documented by Carrothers (1988). This trawl is used for standard surveys by both the ALFRED NEEDLER and

LADY HAMMOND. Deviations from the documented specifications are listed below for the trawls inspected on each vessel.

The ALFRED NEEDLER's WIIA trawl

1) The sweepline extensions on the NEEDLER are 21 ft in length instead of the prescribed 34 ft.

2) The belly extensions on the NEEDLER's WIIA have only 39 meshes instead of the required 42, making these panels shorter than the specifications. This was done to simplify the taper and facilitate replacement of these panels. Consequently, the belly extension riblines are also shorter.

3) The codend on the NEEDLER's trawl is of the correct length but uses 3.0-in. mesh instead of the prescribed 3.5-in. mesh. To achieve the correct length, the codend is 95 meshes deep instead of 75.

4) The standard rig of this trawl includes a 19-ft fishing line used for removable wedges of netting which close in the lower wing area for flatfish capture on smooth bottoms. Due to tear-ups and fouling of the footgear, this gear has never been used on either vessel.

The LADY HAMMOND's WIIA trawl

1) The lower riblines for the codend on the HAMMOND's trawl are made of 0.63-in. combination wire instead of the prescribed 0.88-in. pre-stretched polyethylene. They were also found to be 12 in. shorter than specified.

2) The liner used on the HAMMOND's gear on H231 was found to be 1.5-in. mesh knotted polyethylene instead of the 1.25-in. knotted nylon (herring seine material) required for the upper half. The lower half was made of 1-in. knotted nylon instead of the 0.75-in. knotless required.

3) The main warp on the HAMMOND is the required 1.13 in. diameter; however, both warps drop to 0.88 in. diameter after 350 fath on the starboard side, and after 200 fath on the port side. Potentially, unequal forces on each door may result when fishing depths beyond 67 fath (at 3:1 scope) are encountered.

4) The codend on the HAMMOND's gear was found to be of the correct 3.5-in. mesh, but was 91 meshes deep instead of the prescribed 75.

Results of SCANMAR monitoring on standard surveys

The performance of the SCANMAR gear is summarized in Table 2. Data from stations that were shallow and of rough bottom demonstrated the highest instance of lost signals, reflected signals and noise. A number of data files were not used as data logged suggested sensors were deployed with low batteries (signal values would improve dramatically in subsequent sets after recharging).

Summary statistics of mensuration data by set for all standard groundfish surveys since 1990 are available from the author, as well as the raw and edited data and software used for analysis. The following relationships were investigated from data gathered on the surveys indicated:

1) Regressions of simultaneously logged values of wing spread and door spread from tows performed on N133 and H231 revealed strong linear relationships from each survey, but of different slopes (Fig. 1). Changes in door spread were found from the examination of time plots to translate quickly into changes in wing spread as in Fig. 2. Although time plots of wing spread and door spread revealed a generally linear relationship, many tows exhibited incidents where the two values would diverge (Fig. 2, between tow times of 6 and 9 min).

   The high within-tow variance of gear spread experienced during the tow depicted in Fig. 2 was a common problem during many tows from the surveys examined; yet, factors such as trawl speed (relative to the water column) and fishing depth could not be found attributable. The frequency of door spread variance by percentage of sets fished is depicted in Fig. 3 for N139 and H231, and it was found that high variance tows were experienced more frequently on H231.

2) Headline height was found to decrease with increased door spread in N139 (Fig. 4).

3) Relationship of mean door spread to depth and warp out for N139, N148, H231 was found to increase with mean fishing depth per tow for the three surveys examined. All relationships demonstrated the same slope, with all intercepts falling within a range of 10 m (Fig. 5).

4) Mean headline height per tow from N139 and H231 was found to decrease with mean tow depth (and warp deployed) for both surveys examined (Fig. 6). The gear on the NEEDLER demonstrated greater headline heights at all fishing depths than that of the LADY HAMMOND.

5) Relationships of trawl dimensions to trawl speed H231 - No relationships could be found between trawl speed and door spread, wing spread and headline height.

6) Extreme changes in bottom profile appear to impact on door spreads during the N139 survey (Fig. 7, 8). However, other sets with dramatic changes in bottom profile demonstrated no changes in spreads with time.

Results of experimental tows using the J.L. HART and a Concord trawl

1) At a constant speed of 2.5 knots and a constant fishing depth of 17 fm, door spreads were found to decrease with decreased warp to depth ratios. Door spreads with time at varied warp to depth ratios are depicted from set 3 in Fig. 9.

2) Door spreads were found to increase with increase in vessel speed for all warp to depth ratios tested. The door spreads at four warp to depth ratios and speeds from 1-5 knots are shown in Fig. 10. It appears that maximum spreads occurred between 2 and 2.5 knots, and then slightly lower asymptotic values were reached for each ratio by about 3 knots. A dramatic loss of spread below 2 knots was observed at all ratios.

3) An increase in door spread was observed with depth for all warp to depth ratios tested. Maximum spreads of 28-30 m were approached at all warp to depth ratios tested when depths exceeded 125 m, or when warp to depth ratios exceeded 3.5:1. A plot of doorspread values observed at four depths and several warp to depth ratios is shown in Fig. 11.

DISCUSSION

Quality of SCANMAR data

The quality of doorspread data on some tows was poor due to the need for sensor recharging. Bad data will also result from weak mini-transponders as battery life expires (when voltage drops to approximately 3 volts). However, the main sources of bad data logged on N139 were due to noise (signals other than SCANMAR), lost signals and reflected signals. Poor spread data appeared more frequently on shallow tows. This was due to a higher incidence of reflected signals. The 950-kg Portuguese "Euronet" doors are known to lean outward with little warp, and signals between the spread sensors can be reflected from the surface instead of being transmitted directly. Also, rough bottom can block signals, or cause intermittent reflection of signals.

A high incidence of lost and reflected signals in the data collected from the NEEDLER surveys for this report implied that the hull-mounted receivers might be at fault. Deployment of a remote hydrophone for signal capture on survey H231 provided significantly better data (less noise and fewer missing values). Consequently, this procedure will be used for data collection on surveys in the future.

Controllable sources of variation in trawl performance

Maintenance of trawl to specifications

In order to maintain consistency in gear performance between sets, surveys and surveys by different vessels, strict maintenance of the gear to documented specifications is necessary. Efforts to do so have been bolstered in recent years through training of personnel in net mensuration, and with the new protocol of regular gear inspections and documentation.

The correct specifications of the Atlantic Western IIA are described by Carrothers (1988). The differences found in the dimensions, rig and materials in the trawls used by the ALFRED NEEDLER and LADY HAMMOND for standard surveys are likely a large factor in the differences found in gear performance. Ascertaining the effect on trawl geometry of any one difference, however, is difficult to detect. One might assume that shorter sweepline extensions on the NEEDLER would limit door spread, yet door spreads were found to be greater on the NEEDLER survey N148 than on the LADY HAMMOND survey H231.

Other differences, such as smaller codend mesh on the NEEDLER's trawl, may not impact on net geometry, but might affect the gear's efficiency in fish capture, as a consequence of backwash from the trawl opening due to reduced water flow through the trawl.

The task of maintaining trawls to specification is complicated by a number of problems. The greatest difficulty is maintaining consistency in replacement components when changes in suppliers occur over time. Each new supplier tends to introduce changes in the dimension and type of material used in construction. For example, "deep sea" headline floats from one company may have thicker walls than floats of the same diameter from another company, resulting in different buoyancy values. The other main problem is maintaining consistency between vessel crews in net mending practices between watches, surveys and vessels.

Only with the current training courses in gear mensuration, regular trawl inspections and careful purchasing practices of replacement components, can greater consistency in gear performance result.

Fishing practices

Adjustment of warp deployed by fishing depth. Warp out is clearly a variable that can be modified to achieve a desired gear configuration. Warp lengths were recorded by set for N133, N139, N148 and H231, and examined to see if fishing practices varied by watch or by depth. However, constant scopes of 3:1 were observed. Ironically, the practice of maintaining a constant warp to depth ratio to reduce variability has resulted in variation of spread with depth. Unfortunately, recording warp length has not been required on standard surveys, although 3:1 scopes have been a rough guideline on the ALFRED NEEDLER since 1981. However, adherence to 3:1 scopes since 1981 is questionable, considering the latitude found during N123 (Koeller 1991), where scopes from 2.4:1 to 3.2:1 were observed.

Controlling vessel speed and trawl speed. As towing speeds are not routinely logged more frequently than every 5 min on standard surveys, it is difficult to relate changes in vessel speed over bottom to changes in trawl dimension. However, examination of time plots of trawl dimensions by set reveals a number of trends. A typical aberrant profile of door spread is depicted from set 03, N139 (Fig. 12). It appears that an initial increase in spread occurs immediately after touch-down of the doors. Increased drag reduces vessel speed which results in loss of spread. Increased vessel speed restores spread, and spread is maintained within a controlled range of values during the remainder of the tow.

Although no relationships could be found between trawl speed (relative to the water column) and net dimensions from standard survey data, time plots of trawl speed and door spread of sets from H231 reveal that a minimum critical speed exists to maintain the stability of the doors. Changes in trawl speed from about 3-5.5 knots do not appear to impact on door spread as in the case of set 44 on H231 (Fig. 13). However, when trawl speed is dropped below 3 knots for 3 min, collapse of one or both doors is precipitated causing the corresponding loss of spread. This effect is supported by findings from experimental tows on the J.L. HART, where dramatic loss of spread occurs below a towing speed of 2 knots over bottom using a Concord trawl (Fig. 10).

Speed, therefore, is a very important factor impacting on net geometry. The frequency of recorded towing speeds from our standard surveys can be used to evaluate how often tows may have been affected by inadequate speed. A comparison of the performance of the NEEDLER and HAMMOND in Fig. 14 shows that greater control was exercised on the NEEDLER with a standard deviation of only ±0.25 knots, whereas the HAMMOND's standard deviation was ±0.65 knots, lending many more opportunities for speed to fall below critical levels.

Non-controllable sources of variation in trawl performance

<u>Bottom type</u>

A number of variables that have not been assessed for their influence on gear performance need consideration. As door spread is dependent upon door performance, factors such as bottom type are crucial. One cannot assume a constant bottom type for a particular depth, or even for the duration of a single tow. A soft substrate may cause doors to entrench to a greater extent than on a hard substrate, resulting in greater spreading forces. Rough bottom with obstacles such as sand humps and boulders may cause erratic door performance, and a corresponding fluctuation in door spread.

<u>**Bottom current speed and direction**</u>

Bottom current speed and direction relative to the direction of tow also need consideration, as one cannot assume the water column to be stagnant. Examining the frequency of mean vessel speed per tow compared with the mean trawl speed per tow from H231 (Fig. 15) reveals very different distributions. Although recorded vessel speed over bottom from Loran bearings suggests a high frequency close to 3.5 knots, this translates into a much broader distribution of trawl speed values relative to the water column. It is reasonable to assume that this effect is a consequence of towing with and against the current. The trawl speed distribution is noted to have a negative skew, which suggests a bias in the choice of tow direction which favors towing into the current, resulting in higher values of trawl speed relative to the water column.

Although determining the speed and direction of bottom currents prior to performing a tow on standard surveys is possible using Doppler current profilers, it is not feasible due to time and cost constraints. However, if stations to be trawled are known to have strong currents of predictable direction, pre-planning of the cruise track might serve to optimize the timing of such tows relative to the tide so as to minimize the effect on trawl performance. Also, tows adversely affected by strong bottom currents, as determined by comparing vessel and trawl speeds, can be removed for use in assessment work.

Current options for the application of SCANMAR data

<u>**Controlling variability of trawl behavior during a tow**</u>

Swept width can be modified to some extent by changing vessel speed and warp deployed on an interactive basis in response to SCANMAR readouts. However, the success of such manoeuvres remains subject to the skill of the wheelhouse personnel on watch. For example, increasing spread by increasing warp out may result in gear speed relative to the bottom dropping below what is required to maintain door stability, resulting in door collapse and loss of spread. Headline height can likewise be maintained as a consequence of doorspread control, subject to the varying skills of the wheelhouse personnel.

Controlling variance in catch associated with variance in gear performance between tows

Improving precision of tow duration and accuracy of distance towed. Tow time (the time of door touch-time to door lift-off) could be more precisely recorded if the tow start and end times were recorded from the times logged when the SCANMAR depth sensor indicates the gear has reached and departed from the bottom. The times of door touchdown and lift-off are usually the same as these values and can be found at the points when spreads increase or decrease dramatically.

It was evident on a number of deep tows that the gear had not settled on the bottom at the recorded start time, and remained on the bottom after the recorded end time. It is recommended that SCANMAR monitoring continue after the initiation of haul-back to assess how long gear remains on the bottom during deep tows.

Maintaining a constant swept width and trawl opening. Warp to depth tables can be developed and used to achieve a single swept width for a range of depths. However, the feasibility of doing this must be tested. Paying out more warp at shallow stations to achieve the spreads found at deeper stations may result in instability and aberrant door performance. The option of using less warp on rough bottom to allow the doors to ride over obstacles would be removed, and a higher incidence of gear damage may result.

Paying out less warp at deeper stations to achieve less spread will likewise affect the aspect of the doors, and studies of door "polish" should be done to assess door stability for the scope proposed at each depth.

Another option in controlling door spread involves installing a wire between the warps to limit spread as proposed by Engas and Ona (1991), but impacts on door performance and catch must first be evaluated.

Maintaining a constant net mouth area. If a simple index of net mouth area were considered to be a product of the upper wing-end spread and the headline height, no relationship of area to fishing depth can be found from tows of N139. As headline height decreases with increase of spread, total area tends to remain unchanged.

However, the impact on catch may be substantial. A widely spread trawl of low profile will likely target more fish species dwelling close to the bottom such as flatfish, and a narrowly spread trawl with a high profile may target more species found higher in the water column such as pollock and redfish. The extent to which differences in trawl opening at different depths affect the catching efficiency of target species is currently unknown (Godo and Engas 1989).

Selection of tows suitable for use in stock assessment based on known gear performance

Currently, all tows with the exception of tear-ups are used in stratified analysis for assessment purposes. If criteria can be established based upon gear speed and configuration to accept or reject a tow as being valid, bad tows could be rejected for use in assessment purposes.

Adjustment of swept area per tow based upon collected data

Exercising this option for the application of SCANMAR data would require successful SCANMAR coverage of all stations per standard survey. Currently, the feasibility of providing good quality data for all tows is being evaluated, considering the constraints presented by hardware performance and bad fishing bottom.

The practice of adjusting abundance indices in direct proportion to swept area assumes linearity between catch, gear spread and towed distance, and is probably erroneous (Koeller 1991). The error of this adjustment would likely only become significant for large variations in spread.

If this approach were to be used by Scotia-Fundy, it would have to be assumed that the dimension of wing spread alone accounts for the efficiency of the trawl (due to the convention of using wing spread in stratified analysis) which, when considering the loss of headline height with increased wing spread, is unlikely. Alternatively, if door spread values were to be used in swept area adjustment, the impact on catch of herding action by the ground warps as their scope changes with door spread, would first have to be evaluated per species.

Short-term recommendations for the Scotia-Fundy gear monitoring program

1) Continue data collection to assess variation of trawl performance following traditional fishing practices on all standard surveys. Improve the quality of data and increase coverage of SCANMAR monitoring on standard surveys.

2) Define the limits of acceptable trawl dimensions for a standard tow. Criteria for correct trawl performance could be developed based on the observed variance in trawl geometry from standard surveys.

3) Examine impact on abundance indices by deleting tows where observed trawl behavior does not fall within the limits defined in 2).

4) Perform experimental tows to develop a warp to depth table that could be used to reduce variation of spread of tows of different depths.

5) Position logging from Loran C should be initiated to improve the accuracy of start and end tow times and distance towed.

6) Encourage reference to the SCANMAR database by assessment personnel so that they may evaluate questionable data on the basis of gear performance by tow.

7) Discrepancies in gear construction from the specifications documented by Carrothers (1988) should be reviewed. Differences in rig that are evaluated long standing and necessary should be documented to establish a new standard configuration. Protocols should be established for the introduction of any changes in the future.

ACKNOWLEDGMENTS

The figures and word processing of this document were prepared by Frank Cunningham and Brenda Best, and much helpful input was given by John Neilson, Joe Hunt and Don Clark in writing of the text. Many thanks to all involved.

REFERENCES

Carrothers, P. J. G. 1988. Scotia-Fundy groundfish survey trawls. Can. Tech. Rep. Fish. Aquat. Sci. 1609: 27 p.

Engas, A., and E. Ona. 1991. A method to reduce survey bottom trawl variability. Int. Counc. Explor. Sea C.M. 1991/B:39.

Godo, O. R., and A. Engas. 1989. Swept area variation with depth and its influence on abundance indices of groundfish from trawl surveys. J. Northw. Atl. Fish. Sci. 9: 133-139.

Koeller, P. A. 1991. Approaches to improving groundfish survey abundance estimates by controlling the variability of survey gear geometry and performance. J. Northw. Atl. Fish. Sci. 11: 51-58.

McKone, D., S. Walsh, and P. A. Koeller. 1990. Improving the performance of groundfish survey trawls - a discussion paper on possible research directions. Available from: St. Andrews Biological Station, St. Andrews, N.B., E0G 2X0.

Smith, S. J. 1988. Abundance indices from research survey data. Can. Atl. Fish. Sci. Advis. Comm. Res. Doc. 88/61: 16-43.

Strong, M. B., and S. Gavaris. 1992. Marine Fish Division Manual for Groundfish Bottom Trawl Surveys, Scotia-Fundy Region, Draft 2.2. Available from: St. Andrews Biological Station, St. Andrews, N.B., E0G 2X0.

Table 1. SCANMAR data edit parameters.

Variable	Description	Acceptable value range
Ltspeed	Long track trawl speed	1 and 6 knots
Ctspeed	Cross track trawl speed	-3 and 3 knots
Wing spread	Spread of upper wing ends in meters	1 and 25 m
Door spread	Spread of doors in meters	1 and 90 m
Clearance	Clearance of footrope from bottom in meters	1 and 3 m
Opening	Height of headline above footrope in meters	1 and 12 m

Table 2. Summary of Scanmar data collected 1991 standard surveys.

Cruise	Dimension	Sets deployed	Sets good data	Performance (%)
N133	Wing spread	18	16	89
	Door spread	18	15	83
	Headline	8	0	0
N139	Door spread	112	81	72
	Headline	112	32	28
	Depth	12	11	91
N148	Door spread	106	87	82
	Trawl speed	25	0	0
H231	Wing spread	71	70	99
	Door spread	30	27	90
	Headline	87	81	93
	Trawl speed	77	77	100
J096	Wing spread	1	1	100
	Door spread	9	9	100
	Headline	8	8	100

Notes:
1) Headline sensor operated erratically on N133/N139 due to faulty batteries and were replaced for J096.
2) Wingspread sensors lost on Set 71 N133 and replaced for N139.
3) Depth sensor lost on Set 17, N139.
4) Trawl speed sensor malfunctioned N148.
5) Headline sensor malfunctioned N148.
6) Headline sensor lost H231.
7) Wing end mini-transducer damaged H231.

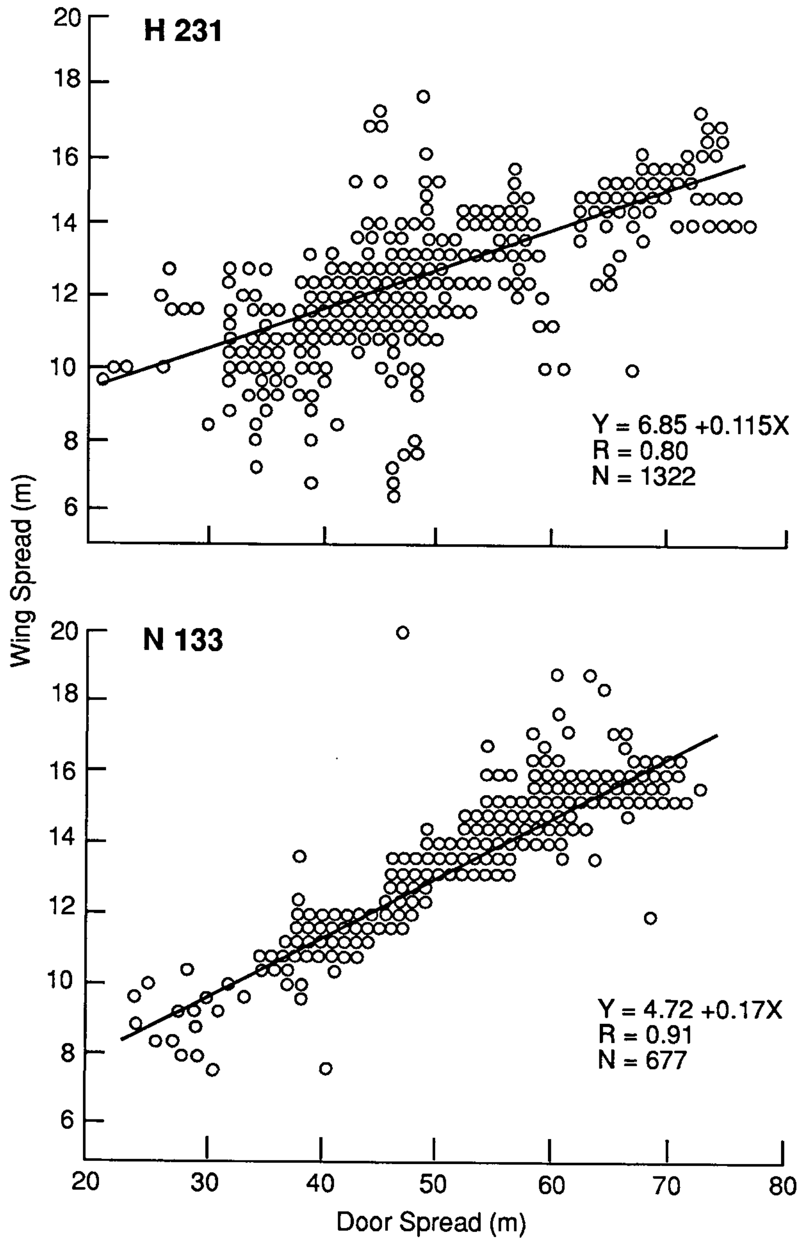

Figure 1. Simultaneously logged values of door spread and wing spread from H231 and N133.

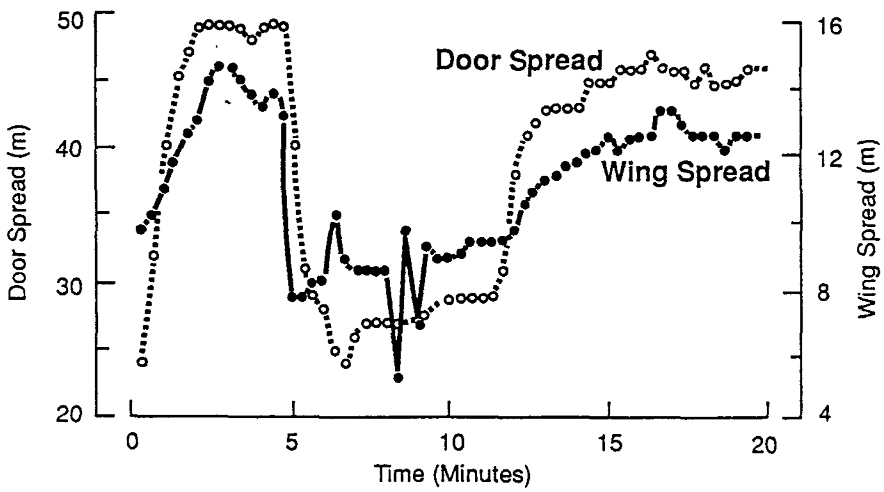

Figure 2. Door spread and wing spread with time from set 68, N139.

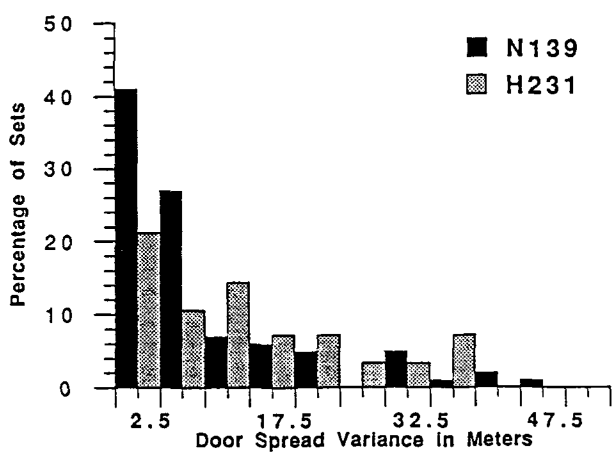

Figure 3. Frequencies of door spread variance observed on N139 and H231.

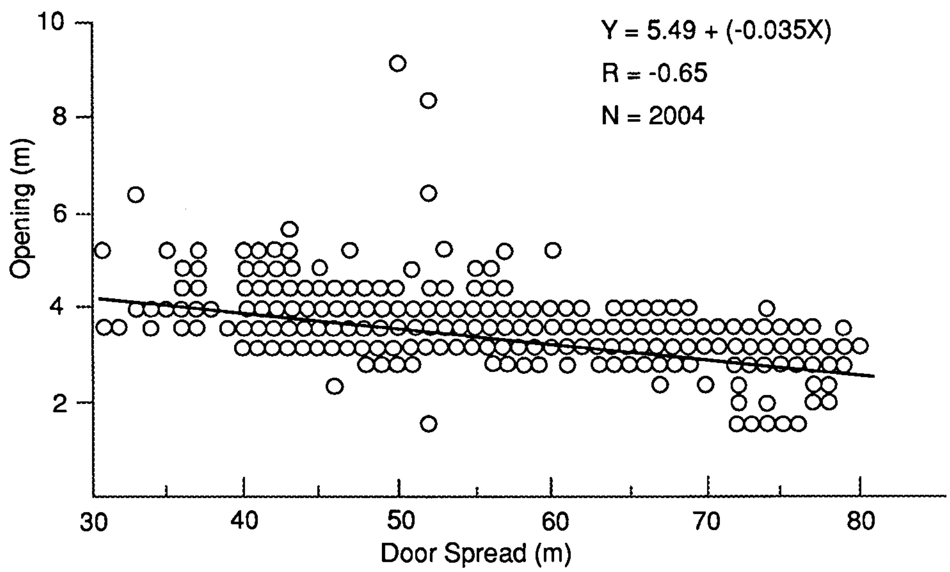

Figure 4. Simultaneously logged values of trawl opening and door spread from trawl opening - N139.

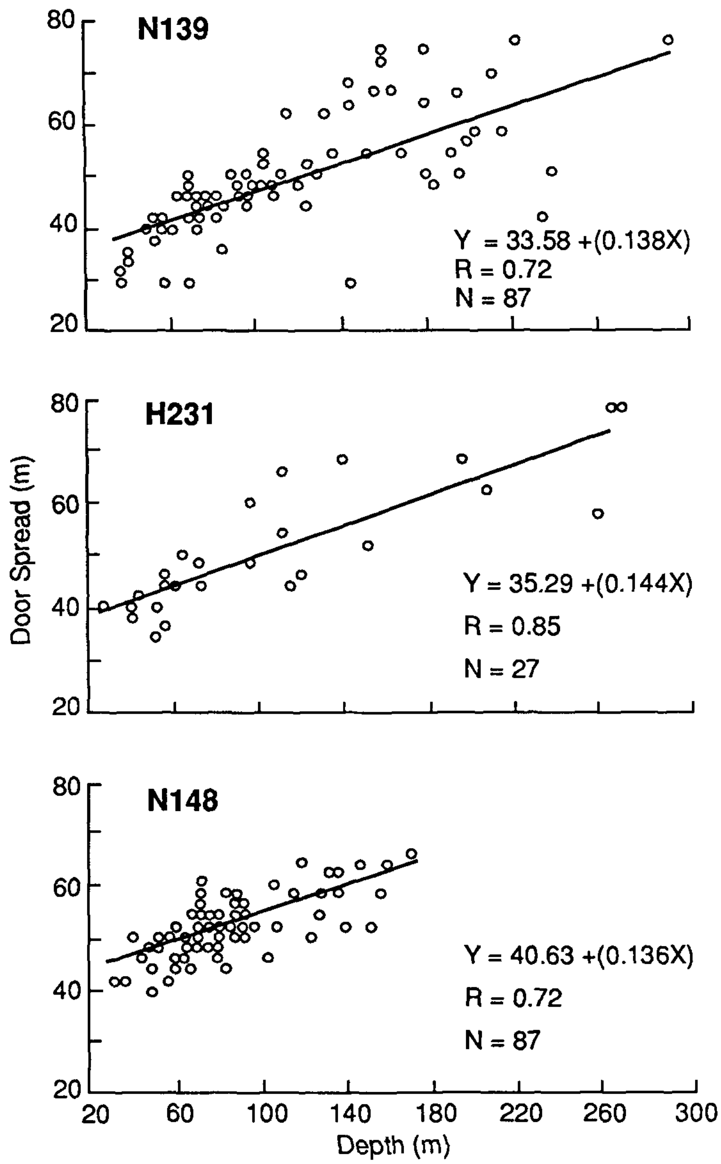

Figure 5. Mean door spreads per tow from N139, H231 and N148.

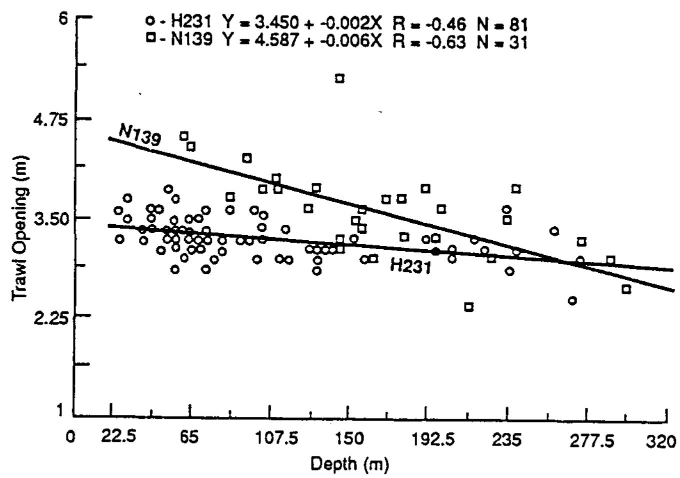

Figure 6. Mean trawl opening per tow by mean depth per tow from N139 and H231.

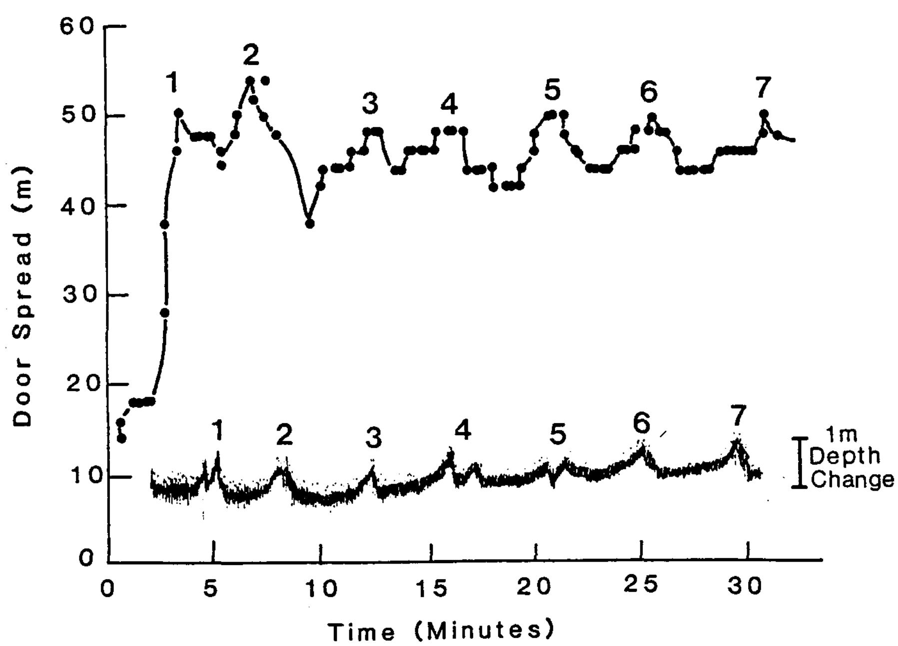

Figure 7. Door spread and bottom profile from set 56, N139.

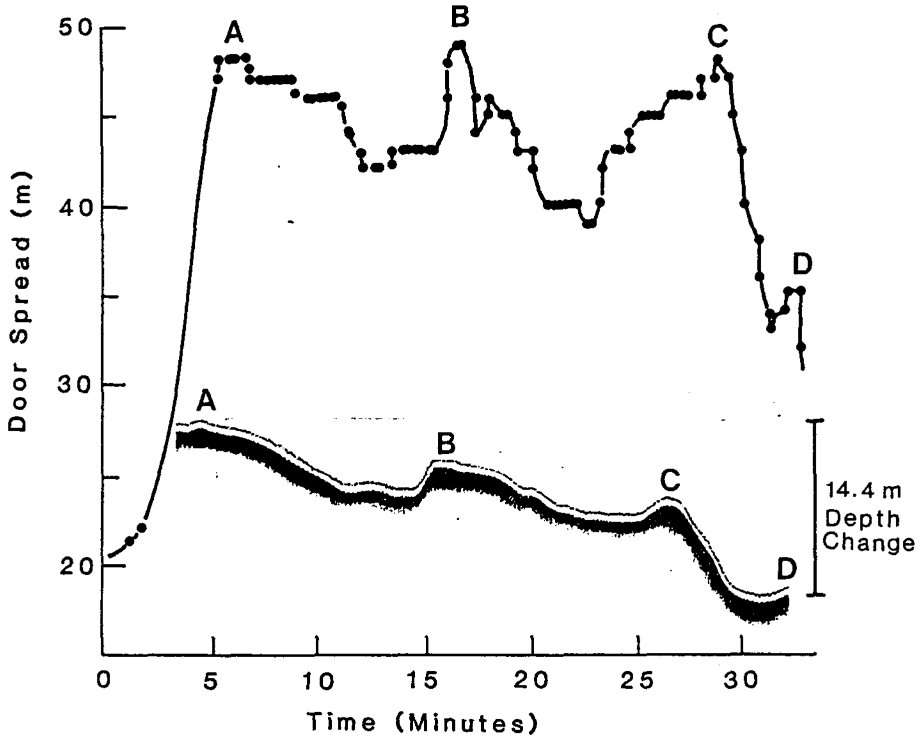

Figure 8. Door spread and bottom profile from set 134, N139.

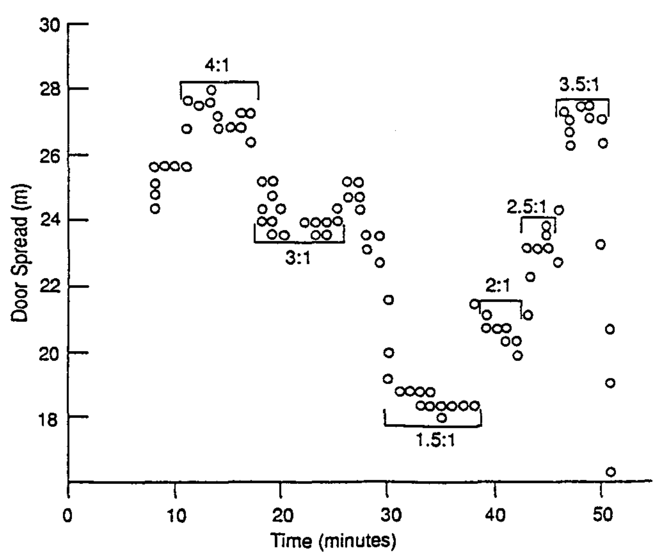

Figure 9. Door spreads at varied scope and constant depth and towing speed for the Concord trawl.

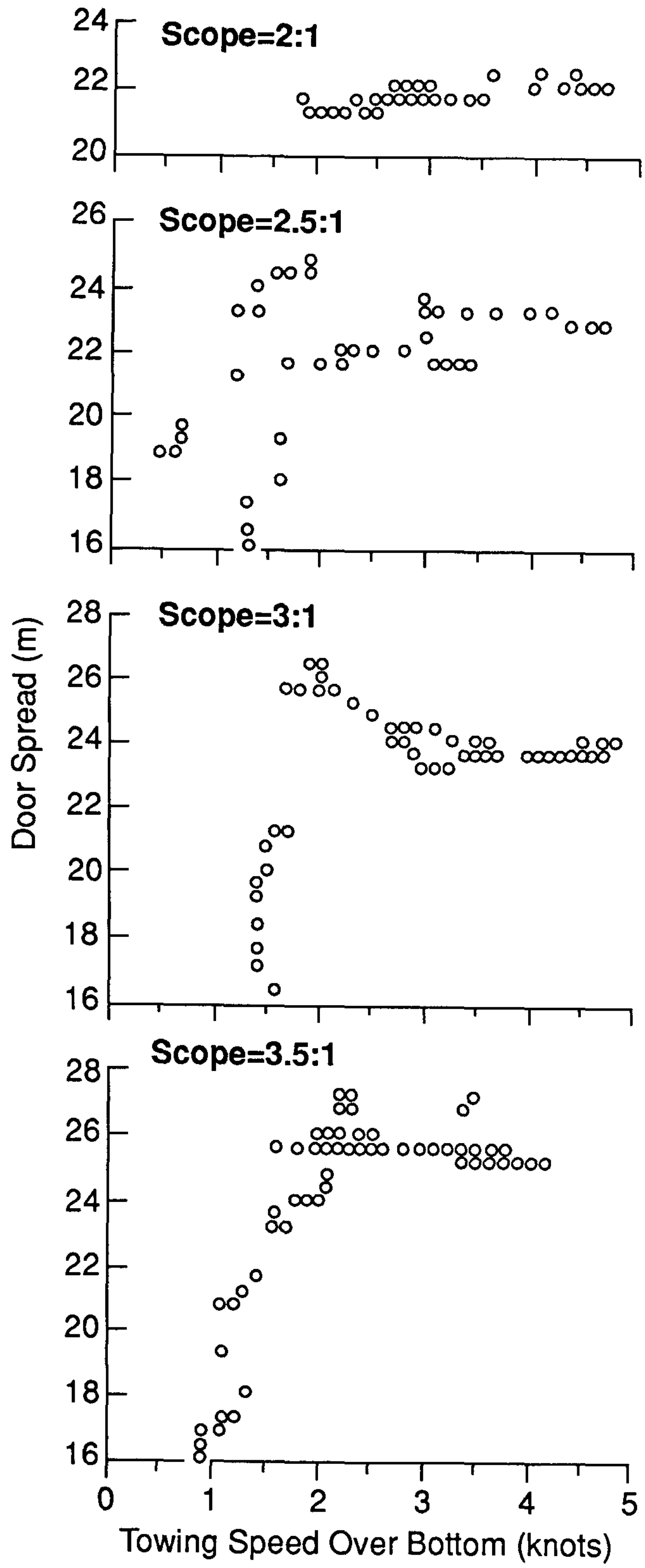

Figure 10. Door spreads at varied scope and towing speeds over bottom using a Concord trawl.

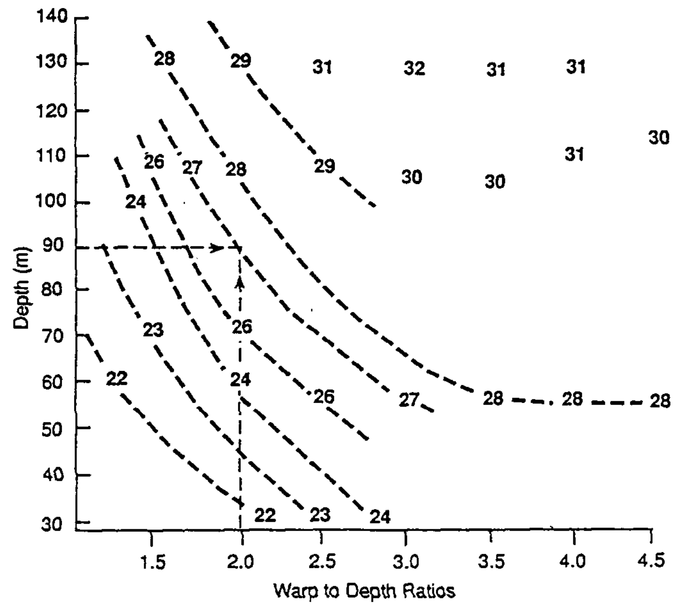

Figure 11. Door spreads (m) observed for the Concord trawl at varied scopes and fishing depths. A scope of 2:1 will yield a spread of approximately 27 meters at 90 meters of fishing depth.

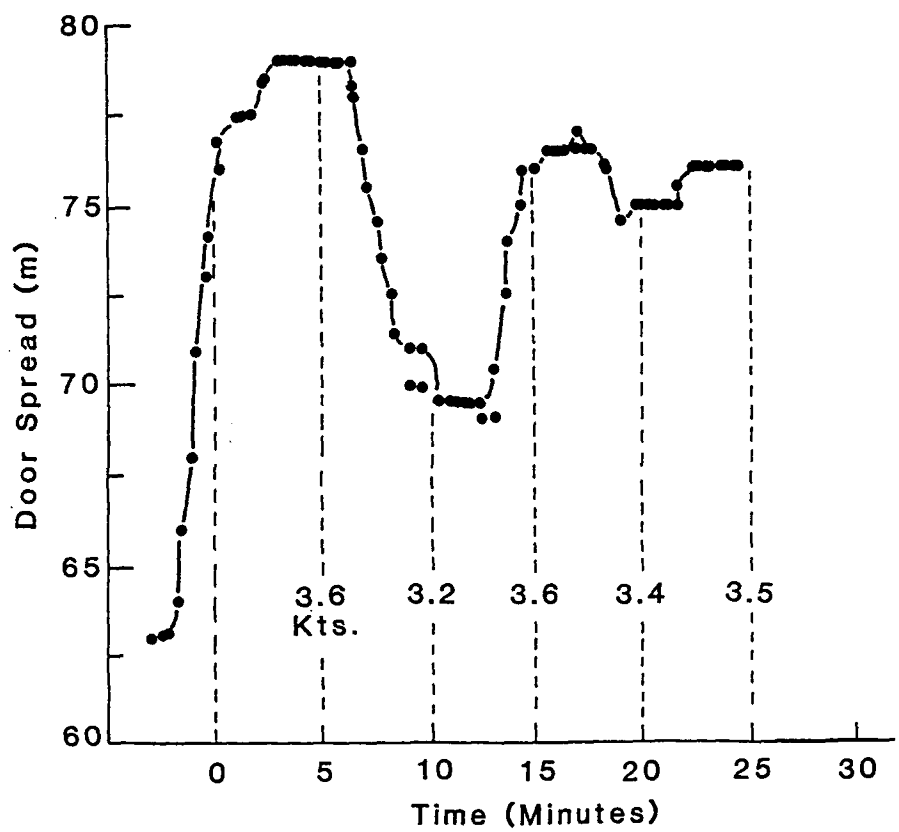

Figure 12. Door spread and recorded towing speed with time from set 3, N139.

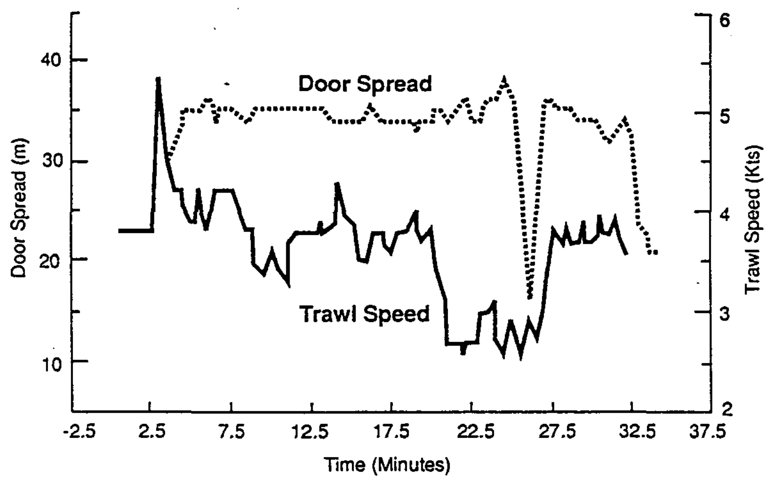

Figure 13. Door spread and recorded towing speed with time from set 44, H231.

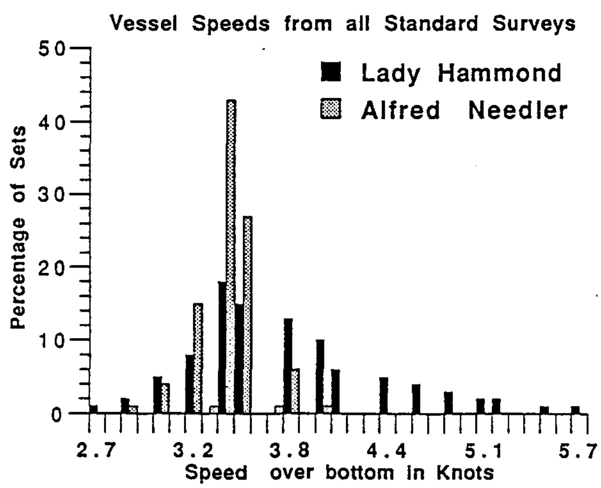

Figure 14. Frequencies of mean vessel speed over bottom per tow bottom trawl surveys by the "Lady Hammond" and "Alfred Needler".

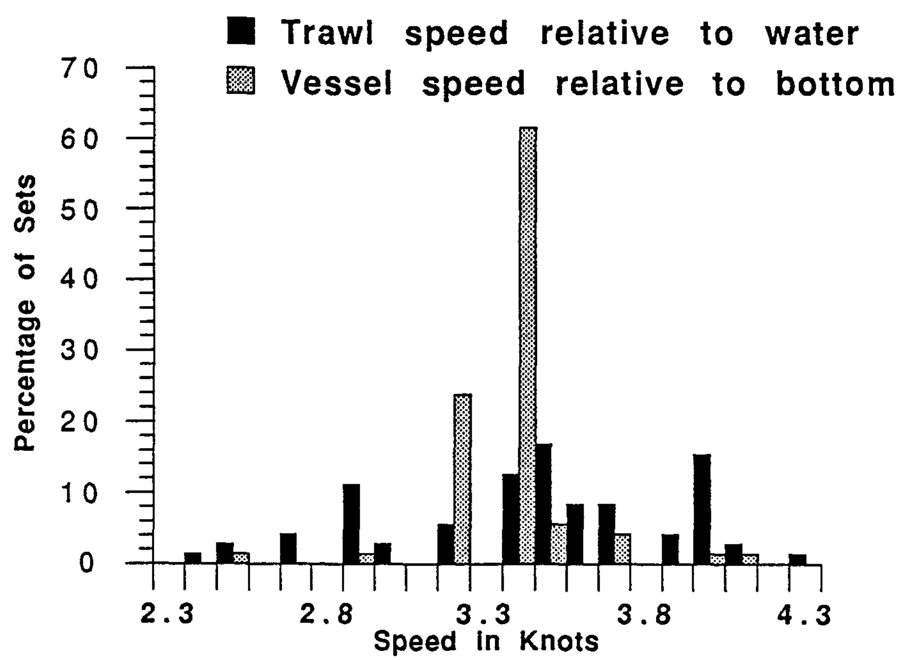

Figure 15. Frequencies of mean trawl speed relative to the water per tow and mean vessel speed relative to the bottom from H231.