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Preliminary Analysis of Controlling the Geometry of a Bottom Survey Trawl Using the Restrictor Rope Technique: Effect on Trawl Performance and Catchability of Groundfish

by

Stephen J. Walsh and Barry R. McCallum

Northwest Atlantic Fisheries Centre, Dept. of Fisheries and Oceans
P. O. Box 5667, St. John's, Newfoundland, Canada A1C 5X1

Abstract

Experiments were carried out to investigate the use of a restrictor rope to physically control the door spread of a bottom survey trawl. The alternate haul method was used to compare differences in trawl performance and geometry with the trawl doors unrestricted and restricted with a rope attached to each trawl warp ahead of the doors. Catches from these alternate hauls were used to evaluate the effect of the restrictor rope technique on catchability of groundfish species. The restrictor rope technique was effective in minimizing trawl width variation at bottom depths ranging from 43 to 1244 metres and had no obvious effect on the magnitude of catches and size composition.

Introduction

Bottom trawls are flexible structures with variable catching efficiency. They are commonly employed in annual demersal surveys by many countries to assess the stock size of various commercial and non-commercial species. The prime objective of a bottom trawl survey is to maintain a constant catchability and minimize the sampling variability by standardizing all operations. Survey catch rates, i.e. average catch per tow, are considered proportional to the true stock density only if factors such as vertical distribution, fish behaviour reactions to the trawl and the performance of the trawl are constant over time (Byrne et al. 1981). Although standardization of survey trawl construction, repairs and fishing protocols can minimize some of the bias and variability in the survey hauls, a major area of uncertainty is the effect of the changes in catchability on estimates of abundance due to changes in trawl geometry and performance (Carrothers 1981; Byrne et al 1981; Walsh et al. 1993).

The use of trawl acoustic instruments have allowed researchers to monitor trawl performance, identify gear malfunctions and estimate variability in trawl geometry (see for example Wathne 1977; Engås and West 1987; Stewart and Galbraith 1987; Walsh and McCallum 1995). In calculating survey abundance indices the area swept by the trawl is the product of the distance towed by the spread of either the trawl doors or trawl wings, depending on choice by stock assessment biologists. Door spread and wing spread and hence swept area have been shown to vary with depth, speed, bottom type, currents and the amount of trawl warp deployed (scope ratio) (Wathne 1977) Main and Sangster 1979; West 1981; Godo and Engås 1989; Rose and Walters 1990; Koeller 1991). Although swept area increases with depth and violates the basic assumption of constancy in trawl performance and geometry in annual surveys, no effort has been made to incorporate this variability in trawl width directly into calculation of time series estimates of abundance.

Koeller (1991) found that door spread was highly correlated with scope ratios and suggested that a constant swept area could be achieved at each depth by using scope values derived from prior experiments to achieve constant door spread. Although a promising technique, delays in achieving a constant door spread could result in the trawl actively fishing longer than planned and hence result in an increase in tow duration. Recently Engås and Ona (1991) introduced a technique which limited door spread, maintained constant bottom contact and reduced variability in trawl geometry with depth. In their experiments the authors restricted the door spread in both the Norwegian Campelen 1800 survey trawl, used in demersal surveys of the Barents Sea, and the GOV survey trawl, used in the International Bottom Trawl Surveys of the North Sea, by using a rope attached to between the main trawl warps, 150 m in front of the doors (Engås and Ona 1993).

Minimizing trawl width variation by standardizing door spread with a restrictor rope should achieve a constant swept area regardless of bottom depth. Thus the variance around the average catch per tow should only reflect changes in abundance and not gear performance. However, there is evidence in the literature to suggest that both catch and size composition are affected by door spread because of corresponding changes in sweep herding [bridle] angle and sand cloud herding, both which increase with increasing door spread (Main and Sangster 1981; Korotkov 1984; Strange 1984; Rose and Walters 1990; Engås 1994). Therefore changes in catchability could be expected due to size and species specific fish behaviour reactions to sweep angles and door sand clouds in a restricted versus an unrestricted trawl. These differences in trawl geometry could bias the results. If that occurred then the time series data collected with an restricted trawl would invalidate the old time series collected using an unrestricted trawl due to a bias created in trawl efficiency.

The purpose of this paper is to evaluate the success of minimizing trawl width variability by use of a restrictor rope to control door spread over all depth ranges. Specifically, it will test the hypothesis that the should be no difference in the magnitude and size composition of catches between a restricted trawl and an unrestricted trawl.

Materials and Methods

Bottom trawl surveys are conducted by the Northwest Atlantic Fisheries Centre (NWAFC) on the Labrador-Newfoundland Shelf in bottom depths ranging from 40 m to 1250 m (Walsh and McCallum 1995). The experiment was carried out onboard the Canadian research trawler F. R. V. *Gadus Atlantica* in July of 1994 on the southern Grand Bank off Newfoundland's east coast. A three bridle Campelen 1800 shrimp trawl rigged with 4.3 m^2, 1400 kg polyvalent trawl doors, 40 m bridles and 6.1 m sweep wires was used for all hauls. The trawl was equipped with a 35.6 m rockhopper footrope composed of 355 mm diameter rubber disks. Trawl construction is of 4.0, 3.0 and 2.0 mm diameter polyethylene twine varying in mesh size (knot centre) from 80 mm in the wings to 60 mm in the square and the first bellies and 40 mm in the remaining bellies, extension and codend. A 7.0 m long knotless nylon liner of 12.5 mm mesh size was used in the codend (Figs. 1 and 2).

For restricted tows a 8.4 m, 30.0 mm diameter polyethylene rope fitted with a 38.0 mm "D" shackle on one end and a BOSS 220 S purse shackle on the other was attached to the warps 150 m ahead of the trawl doors (Fig.3). One end of the rope was fixed in place (at 150 m) on the Port warp while the other end was free to slide along the Starboard warp. The rope was positioned 150 m in front of the doors to prevent its contact with the bottom and avoid affecting fish near bottom as suggested by Engås and Ona 1993. Both trawl warps were marked at 25 fathoms (45.7 m) intervals over the first 200 fathoms and at 50 fathoms (91.4 m) intervals over the remaining 2286 m. The trawl was measured using the NWAFC Survey Trawl Checklist (McCallum & Walsh 1995) prior to the beginning of the experiment and after any significant gear damage and repair to ensure standardization of rigging.

SCANMAR hydroacoustic trawl instrumentation was used during each set to measure trawl opening, door spread, wing spread and trawl speed through the water. Calibrated depth sensors were mounted on the square of the trawl and in the middle of the restrictor rope. On selected sets SCANMAR hydroacoustic load cells were used to measure towing loads ahead and behind the trawl doors. Four load cells, two Port and two Starboard were shackled between the warp and the trawl door and the backstrops and the sweep wire. All data was automatically logged at 15 second intervals using two copies of SEATRAWL data acquisition software running simultaneously under WINDOWS 3.1 . On some hauls either a ISIT or CCD underwater camera was mounted on the headline to confirm proper trawl configuration.

The alternate haul method was used to compare trawl geometry and catchability at 53 stations ranging in depth from 43 m to 1244 m. Due to gear damage or malfunction only 41 paired hauls were used in this analysis. At each station, the trawl was fished alternately with and without the restrictor rope, the order being randomized from station to station. The trawl was towed at an average speed of 1.54 m/sec. (3.0 knots) over the ground as determined by GPS receiver and the course heading was identical. The following scope ratios were used: 3.5:1 for hauls < 100 m, 3:1 for hauls between 101 and 500 m; 2.5:1 for hauls between 501 and 1000 m; and 2:1 for hauls >1000 m bottom depth. Information on bottom depth was recorded on the echosounder and bottom temperatures were measured by a trawl mounted CTD unit.

Catch

After each fishing haul the catch was sorted by species and numbers and weights were recorded. Catch rate data was calculated for the following commercial species: thorny skate, *Raja radiata*; capelin, *Mallotsus villosus*, Atlantic cod, *Gadus morhua*, sand lance, *Ammondytes dubius*; redfish, *Sebastes sp*., American plaice, *Hippoglossoides platessoides*; yellowtail flounder, *Pleuronectes ferruginea*; and Greenland halibut, *Reinhardtius hippoglossoides*. All commercial groundfish species were measured to the nearest centimetre and grouped into 4 cm categories for analysis.

A paired "t" test was used to test the null hypothesis that there was no significant differences in catch rates of a restricted versus unrestricted trawl. Statistical analysis was performed using SAS.

Results

Restrictor rope technique

The restrictor rope and its attachment to the main warps presented no operational problems to the normal shooting and hauling of the trawl. Underwater camera observations of the footgear and examinations of trawl door shoe wear showed no differences between restricted and unrestricted hauls in terms of trawl and door performance. Warp tension data was collected from restricted and unrestricted hauls but the analysis is not complete.

Trawl geometry and performance

Fishing depths ranged from 43 m to 1233 m. The majority of paired hauls were completed in depths of 43 m to 800 m with one additional paired set at 1233 m. At these depths, the unrestricted door spread increased from 51.9 m to 68.3 m while the restricted door spread increased from 37.6 m to 50.6 m (Table 1; Fig 4.). A similar trend was observed in wing spread with depth, increasing from 13.4 m to 17.9 m in the unrestricted trawl and from 12.2 m to 17.9 m in the restricted trawl (Fig. 5). This increasing relationship between wing spread and depth and door spread and depth is more obvious in unrestricted hauls than restricted hauls. Variation around the estimate of mean unrestricted door spread ($\bar{x}$= 51.9 m, CV = 12.9 %) was twice that of the estimate of mean restricted door spread ($\bar{x}$ = 45.1 m, CV = 6.5 %). There was minimal variation in the estimate of mean trawl opening of both the restricted and unrestricted trawls (Table 1).

Regression of wing spread against door spread showed that there is a better predictive relationship in the unrestricted trawl (r^2 = .61) than in a restricted trawl (r^2 = .40) (Fig. 6). Consequently sweep (bridle) angles also showed a similar trend being smaller and less variable in a restricted trawl ($\bar{x}$=18.0 ^{0}, CV=8.6%) than in a unrestricted trawl ($\bar{x}$=21.3 ^{0}, CV=15.4) (Table 1, Fig. 7).

Catch

The catches consisted of a mixture of shallow water species on top of the bank and deep water species along the shelf edge. Consequently most species were not represented at each of the 41 station and catches of some commercial species were low (Table 2). None of the target species were caught deeper than 755 m. Bottom temperatures in the experimental area ranged from 0.1^0 to 6.0^0 C.

In order to directly compare the catch rates from the alternate hauls 'zero' catches were added where appropriate. There was no significant difference in the catch rates between an unrestricted trawl and a restricted trawl for any of the 8 target species (p >.05) (Table 2).

Size composition

Length data was available only for the six commercial demersal species. Length and Cumulative length frequencies (%) of each species were calculated and graphically presented to compare differences in size composition of catches of a restricted versus and an unrestricted trawl. There was little difference in the average length and length range for the six groundfish species (Figs. 8-10).

Discussion

The technique of using a restrictor rope to regulate door spread can greatly reduce variability of door spread with depth and thus minimize trawl width variability. Although door spread is affected by bottom type, bottom contact and currents these effects are standardized within pairs of hauls by the alternate hauls method. The tendency of door spread and wing spread to increase with depth is well known (Main and Sangster 1979; West 1981; Godø and Engås 1989; Rose and Walters 1990; Koeller 1991). This is predominately due the magnitude of otter board ground shear forces dictated by the amount of warp required to achieve and maintain bottom contact for a given fishing depth (Crewe 1964). By physically restricting the spread of the trawl warps to 8.4 m, 150 m ahead of the trawl doors, we have tried to achieved a relatively constant door spread with minimal variation across the depths tested. However, we were moderately successful in shallow depths, ie. less than 100 m. Here, approximately 41% of the restricted hauls had a mean value at 41.6 m (CV= 4.1 %) and 59% had a mean value of 45.9 m (CV=5.5%), close to the overall mean of 45.1 m. We suspect that this may be related either to difference in bottom hardness in shallow water, in the experimental area, or insufficient trawl warp scope ratio's used at in the lower end of the shallow depth range as described in the protocols of the Northwest Atlantic Fisheries Centre (Walsh & McCallum 1995). Further analysis will look at bottom type and also the warp tension data and should help clarify this situation. A similar departure in door spread trend in shallow water was identified in the Norwegian experiments (Engås & Ona 1993).

Sweep angles are normally in the range of 12^0 to 20^0 (Engås 1994) and high sweep angles are expected to reduce sweep efficiency, i.e. poor herding of small fish, and hence low catchability (Main and Sangster 1981; Strange 1984; Rose and Walters 1990; Engås 1994). In our experiments, the range of sweep angles in the unrestricted trawl increased from 17^0 to 28^0 ($\bar{x}$ = 21^0) and the bridle angle in the restricted trawl ranged from 14^0 to 21^0 ($\bar{x}$ = 18^0). These differences had no detectable effect on the magnitude of the catches in 6 groundfish and 2 pelagic species or the size composition of the catches of the six groundfish species. Although catches of some species were low (skate, cod, Greenland halibut), it is predicted that the trend seen in the data would remain with higher catches.

Conclusions

Controlling door spread by the restrictor rope can reduce bias and variability in trawl performance over wide depth ranges. This results in a more standard net geometry in the Campelen 1800 survey trawl used at

NWAFC. Similar results were recorded for the Norwegian Campelen 1800 survey trawl and the GOV survey trawl used in IBTS. Another advantage of restricting trawl geometry to reduce variability is that in surveys were more than one vessel are used, eg. the NWAFC fall surveys, and the same trawl and riggings are standardized then it should be possible to standardize fishing power of the research vessels. This would imply a standardization of fishing power in this survey trawls. The IBTS Working Group of ICES (Anon 1994) concluded that this standardization of fishing power would bias their time series indices with the GOV trawl. However, our experiment shows that there is no detectable differences in catch and size composition and the new indices derived using a restrictor rope will not bias and invalidate the old time series.

Additional comparative tows are required to evaluate the restrictor rope technique at NWAFC on both vessels and could be achieved with minimal interuption to the present surveys, if extend over a few years.

Acknowledgements

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Table 1. Comparison of gear geometry for unrestricted and restricted trawls. CV = coefficient of variation * 100

	Unrestricted					**Restricted**				
	Hauls	$\bar{x}$	**CV(%)**	**Min.**	**Max.**	**Hauls**	$\bar{x}$	**CV(%)**	**Min.**	**Max.**
Doorspread	41	51.9	12.9	42.6	68.3	41	45.1	6.5	37.6	50.6
Wingspread	40	15.5	7.4	13.4	17.9	41	14.3	8.8	12.2	17.9
Opening	40	4.8	12.5	3.8	6.1	41	5.0	10.6	4.2	6.5
Sweep Angle	40	21.3	15.3	16.6	27.9	40	18.0	8.6	13.6	20.7

Table 2. Testing for significant difference in mean catches (numbers) of eight species using paired "t" test of data from 41 alternate hauls of unrestricted tows and restricted tows (p=0.05). CV=coefficient of variation * 100.

Species	**Stations**	**Unrestricted** $\bar{x}$	**CV(%)**	**Restricted** $\bar{x}$	**CV(%)**	**Paired t value**	**Probability**
Skate	30	7.2	101.6	6.3	90.2	0.81	.4280
Capelin	20	567.4	179.6	765.3	175.2	-1.08	.2917
Cod	21	10.9	284.2	9.3	324.2	1.09	.3000
Sand lance	18	1867.7	150.2	5164.3	282.6	-1.18	.2559
Redfish	12	4631.0	178.2	2315.2	102.3	1..31	.2201
A. plaice	36	131.6	140.8	116.1	124.8	0.87	.3930
yellowtail	22	339.4	120.8	351.3	184.5	-0.40	.6966
G. halibut	16	19.1	136.1	14.2	137.8	1.04	.3168

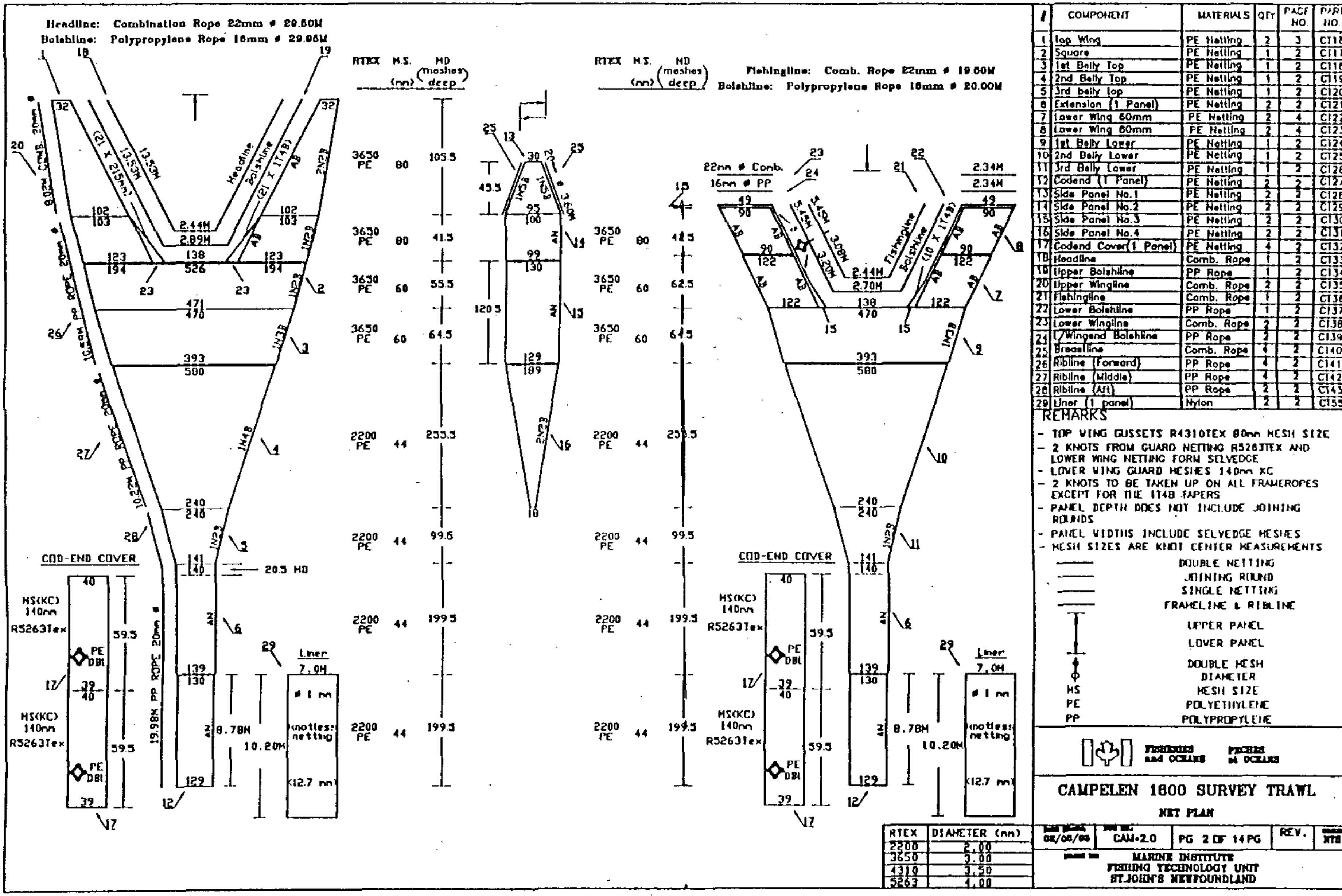
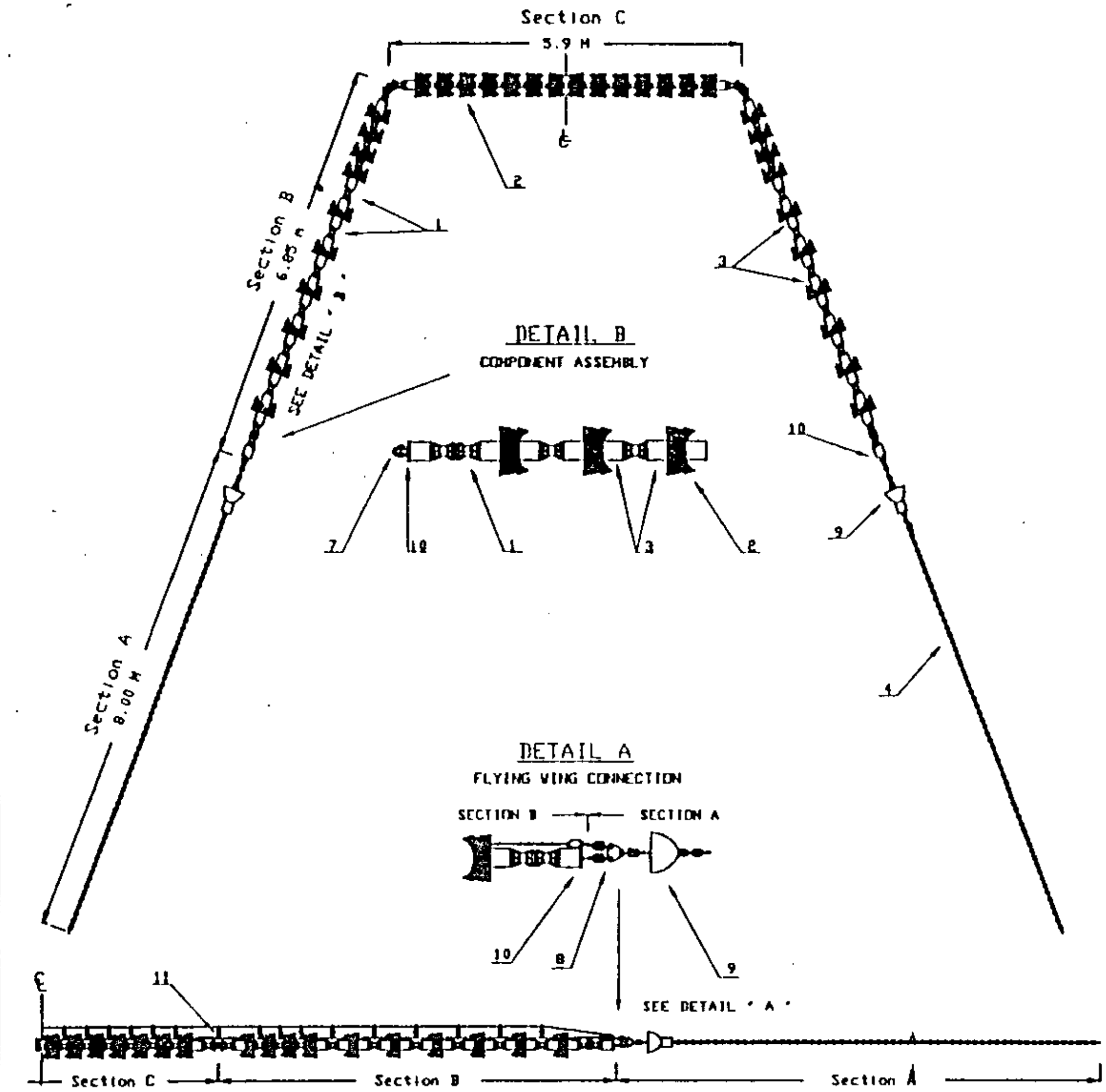


Fig. 1 Trawl plan of the Campelen 1800 survey trawl.



DRAWING NOTES:

- GROUND GEAR IS SYMMETRICAL ABOUT CENTERLINE.
- LENGTHS FOR SECTION B & C ARE MEASURED FROM CENTRE HAMMERLOCK TO CENTRE HAMMERLOCK.
- LENGTH OF SECTION A IS MEASURED FROM CENTRE HAMMERLOCK TO END OF CHAIN (SEE DETAIL A).

#	COMPONENT	WEIGHT (KGS) (IN SEAWATER)		NUMBERS				Page NO.	PART NO.
		UNIT	TOTAL	TOTAL	SECT. A	SECT. B	SECT. C		
1	8" (200mm) Iron Spacer	5.29	206.31	39	0	2x12	1x15	8	C144
2	14" Rockhopper Sets of 3 Disk	0.55	56.1	34X3	0	2x10	1x14	9	C145
3	7" (178MM) Rubber Spacer	0.43	14.62	34	2X1	2x15	1x2	10	C146
4	5/8" (16mm) Mid Link Chain	4.96/M	74.30	14.98	2x7.49m				C112
5	5/8" (16mm) Mid Link Chain	4.96/M	66.96	13.5m		2x6.75m			C113
6	5/8" (16mm) Mid Link Chain	4.96/M	28.76	5.80m			1X5.80m		C114
7	5/8" (16mm) Hammerlock	1.0	12	10	2x4	2x2	0		C148
8	Delta Plate (368mm)	4.76	9.52	2	2	0	0	11	C149
9	14"(356mm) Rubber Bunt Bobbin	4.98	9.96	2	2	0	0	12	C150
10	6" (152mm) Washer	0.42	3.36	8	2x1	2x2	1x2	13	C151
11	15.5" (393mm) Bobbin Chain	0.58	19.14	33	0	2x10	1x13	14	C152
	TOTAL WEIGHT		501.03						

FISHERIES and OCEANS PECHES et OCEANS

CAMPELEN 1800 SURVEY TRAWL

GROUND GEAR

DATE DRAWN	DWG NO.		REV.	SCALE
02/08/93	CAM-3.0	PG 7 OF 14 PG		NTS

DRAWN BY: MARINE INSTITUTE FISHING TECHNOLOGY UNIT ST.JOHN'S NEWFOUNDLAND

Fig. 2 Footgear details of the Campelen 1800 survey trawl.

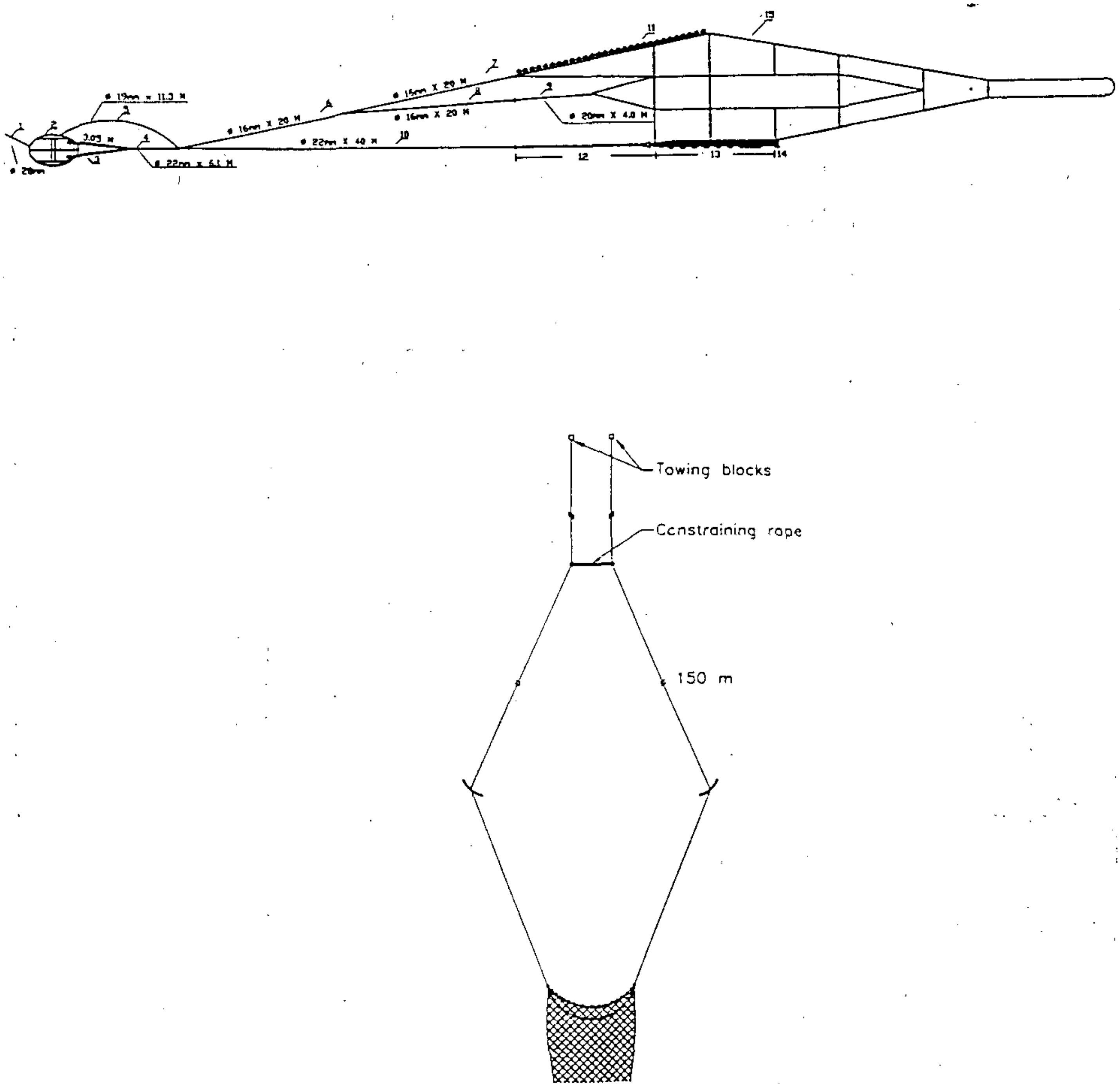
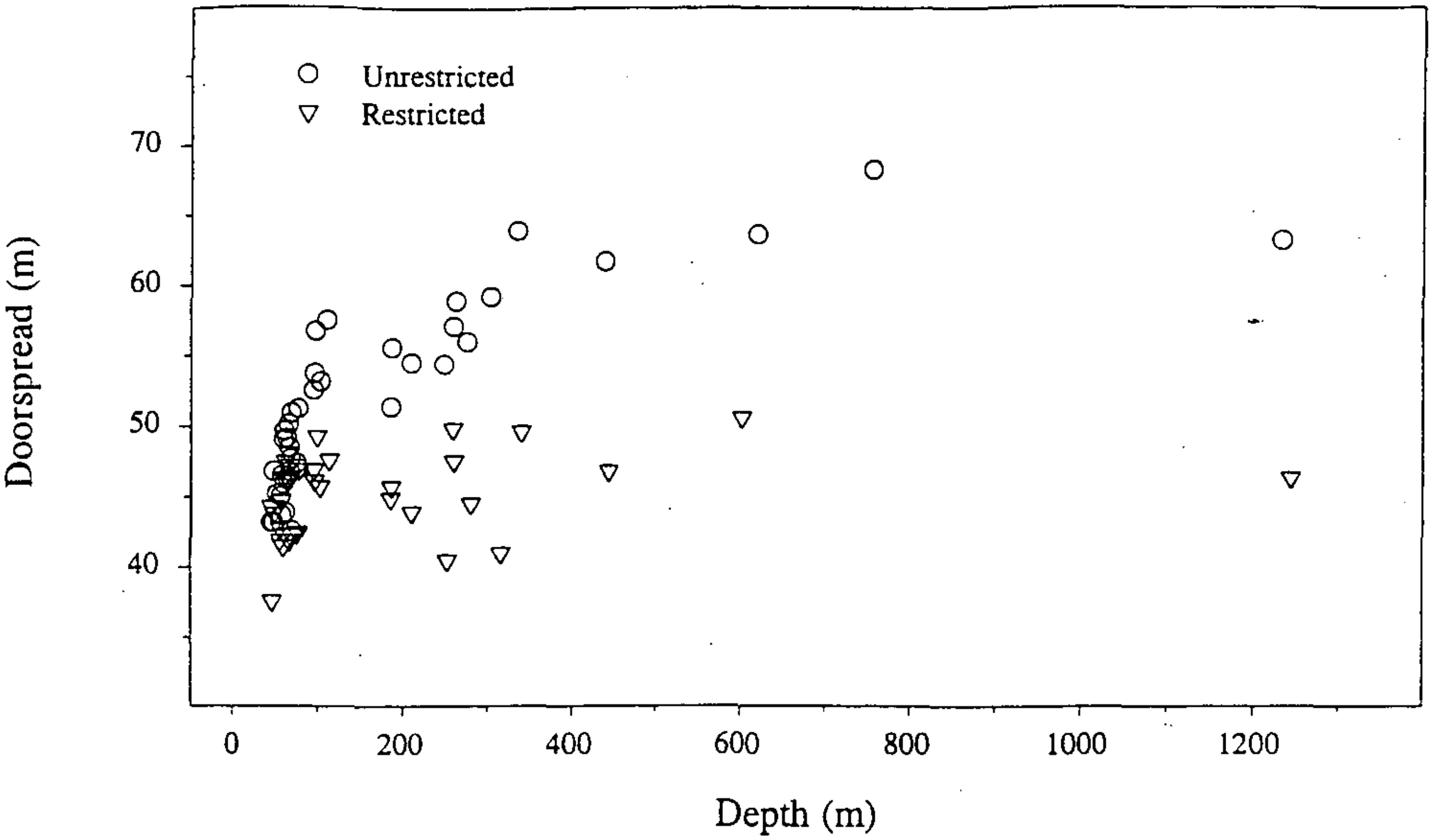


Fig. 3 Rigging diagram and technique used to restrain door spread (reprinted from Engas and Ona 1991).



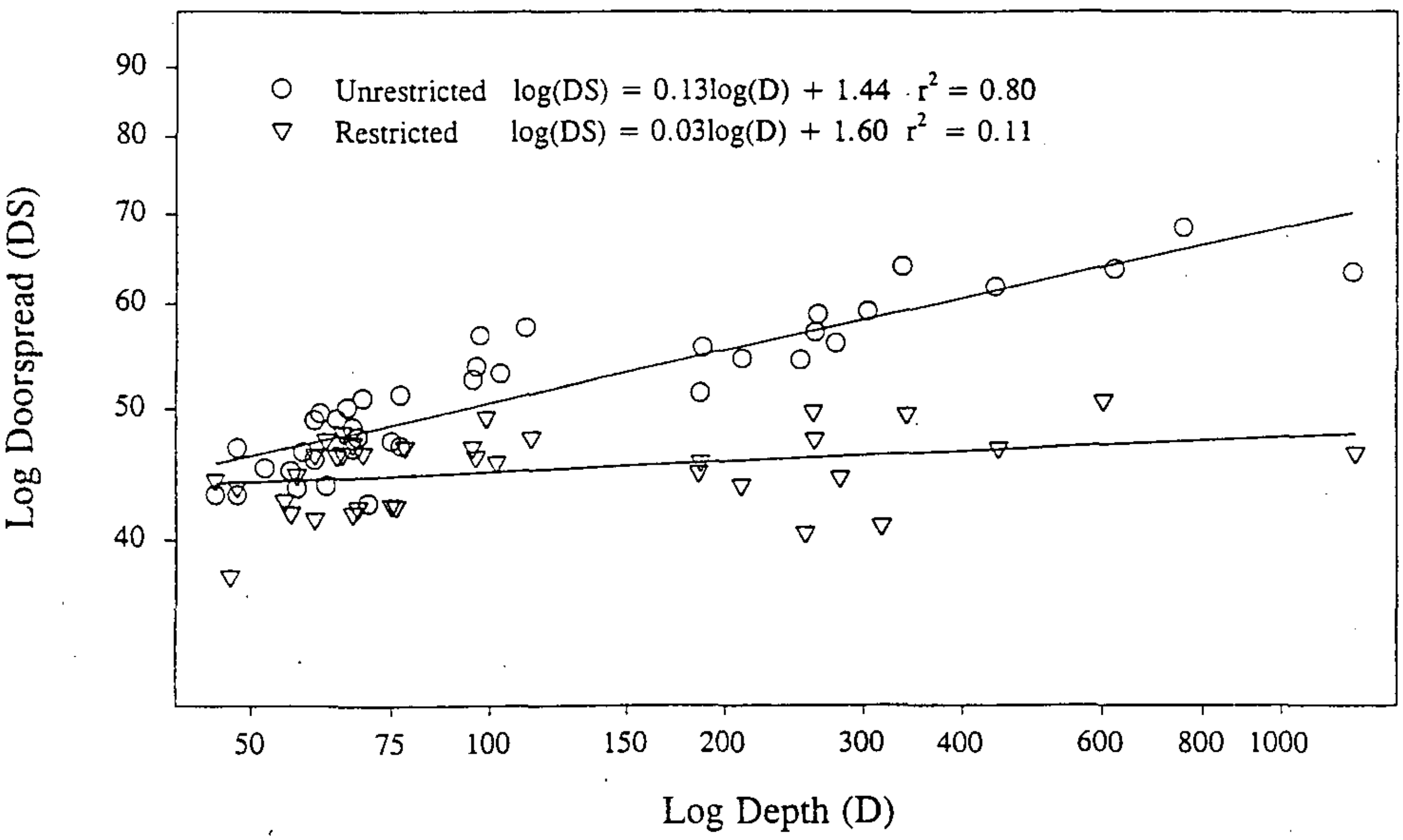


Fig. 4 Relationship of unrestricted and restricted door spread with depth.

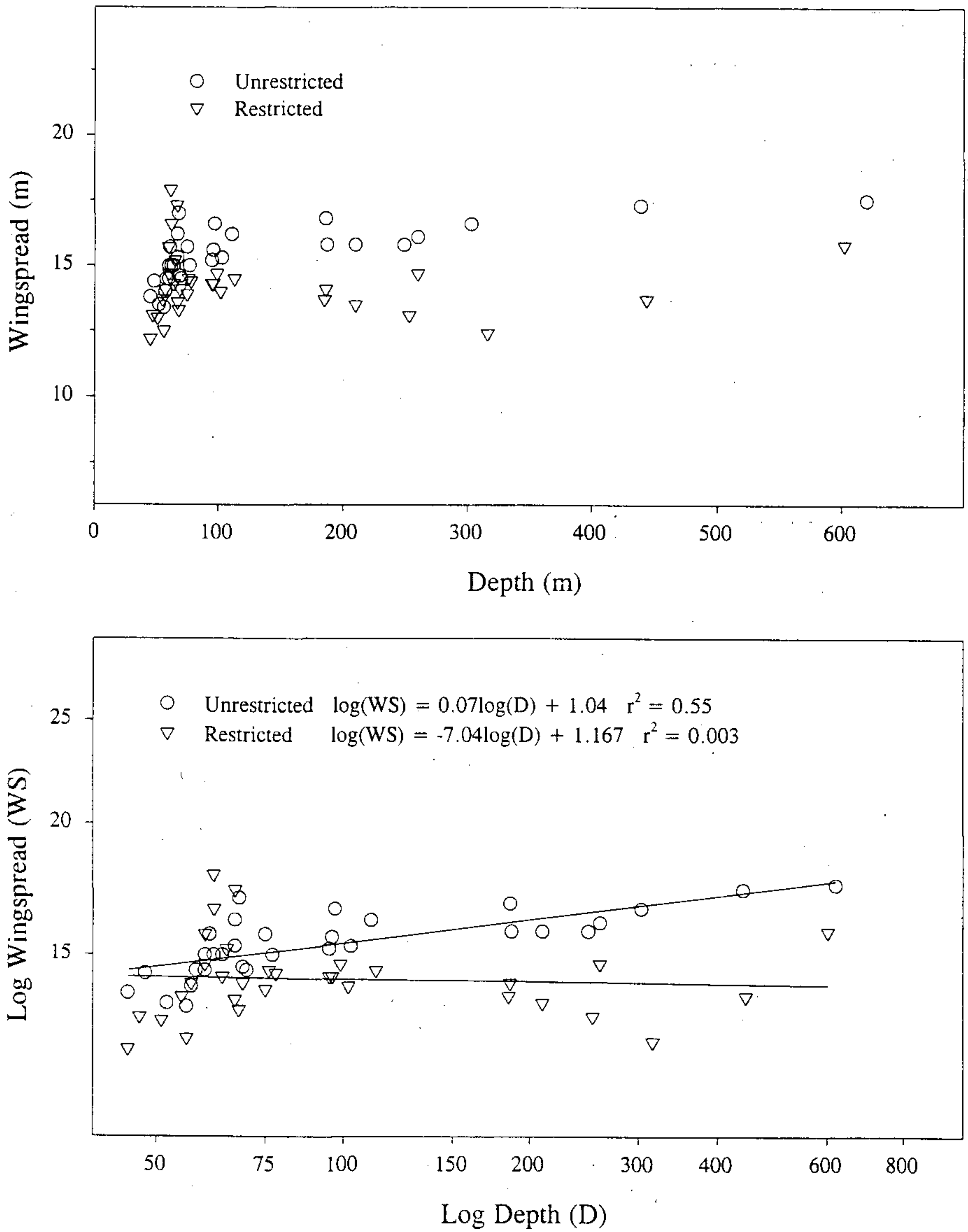
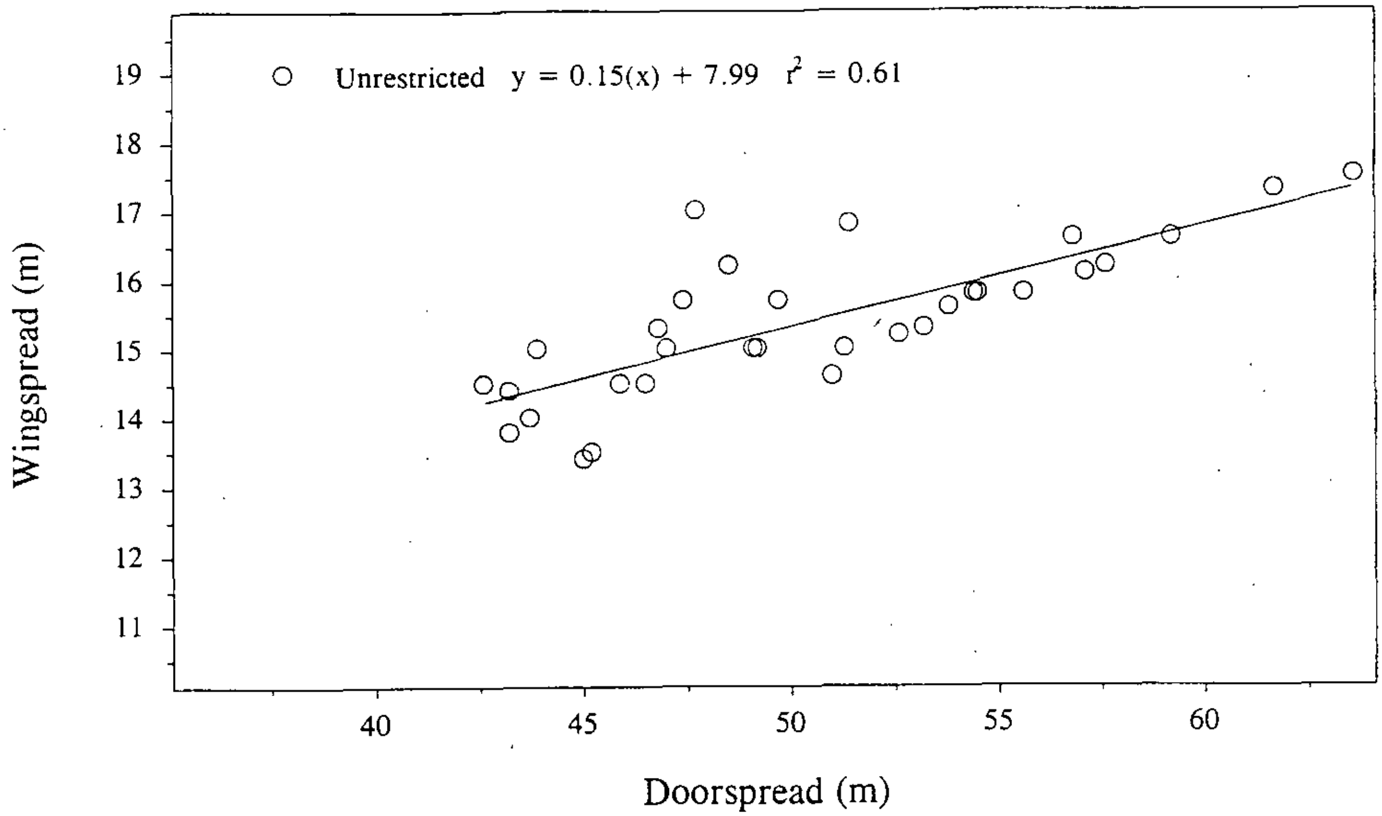


Fig. 5 Relationship of unrestricted and restricted wing spread with depth.



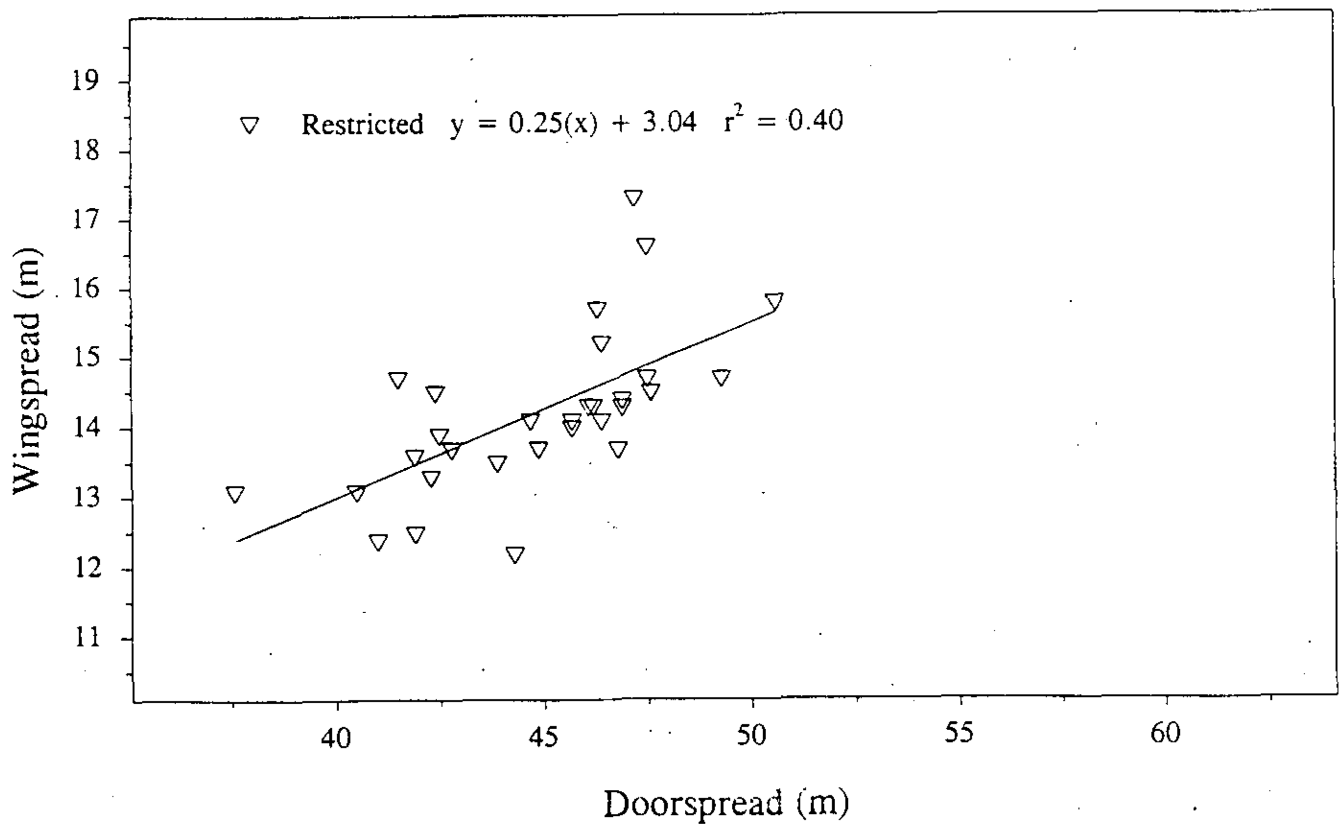
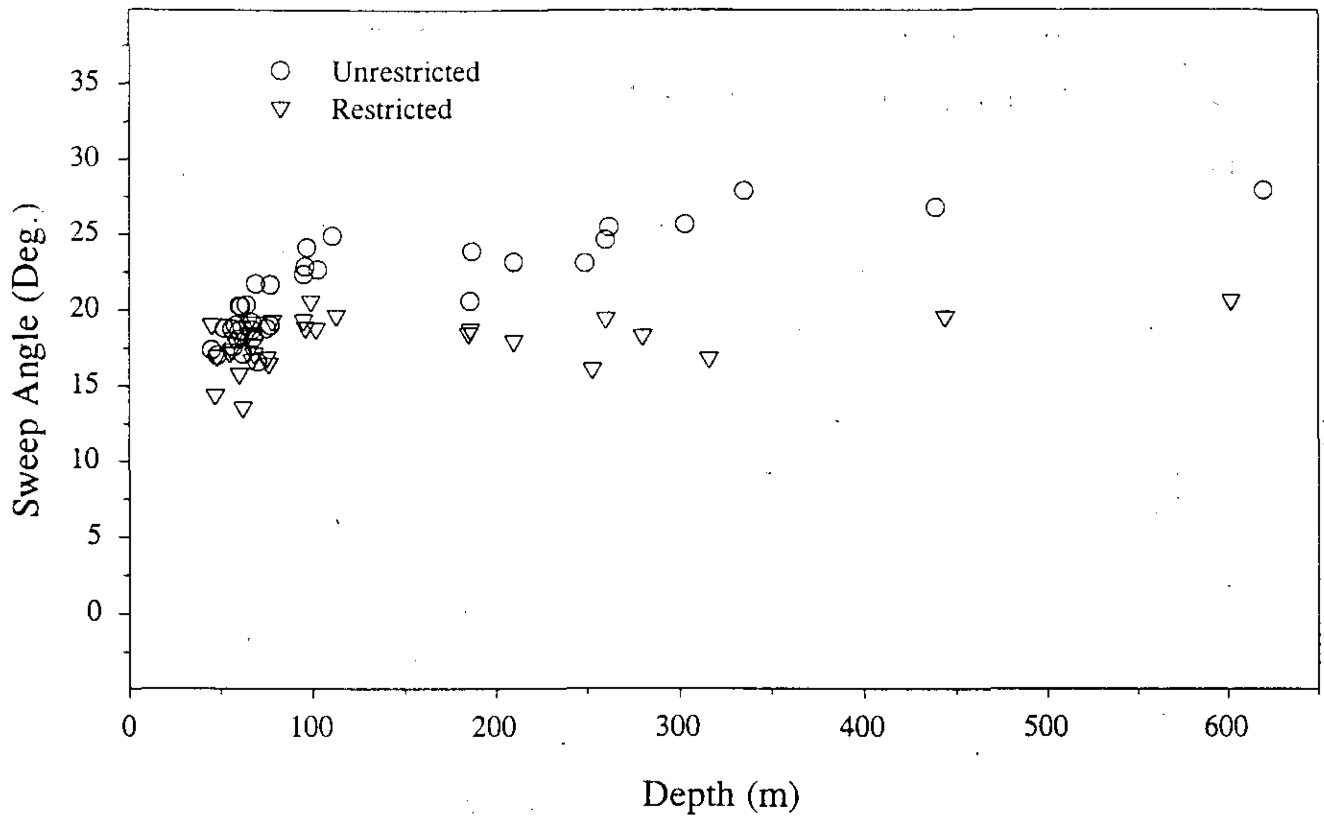


Fig. 6 Relationship between wing spread and door spread for unrestricted and restricted trawl hauls.



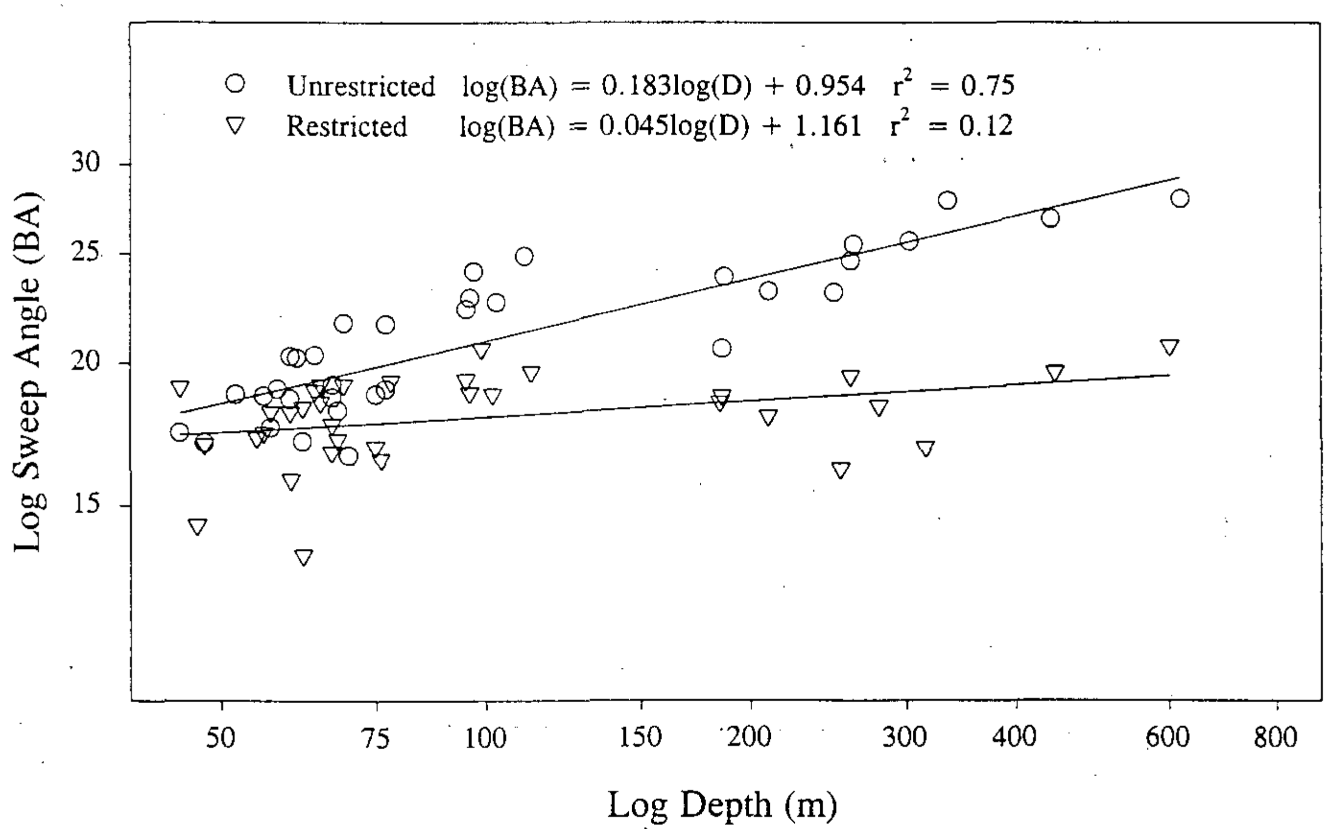


Fig. 7 Relationship of unrestricted and restricted sweep angles with depth.

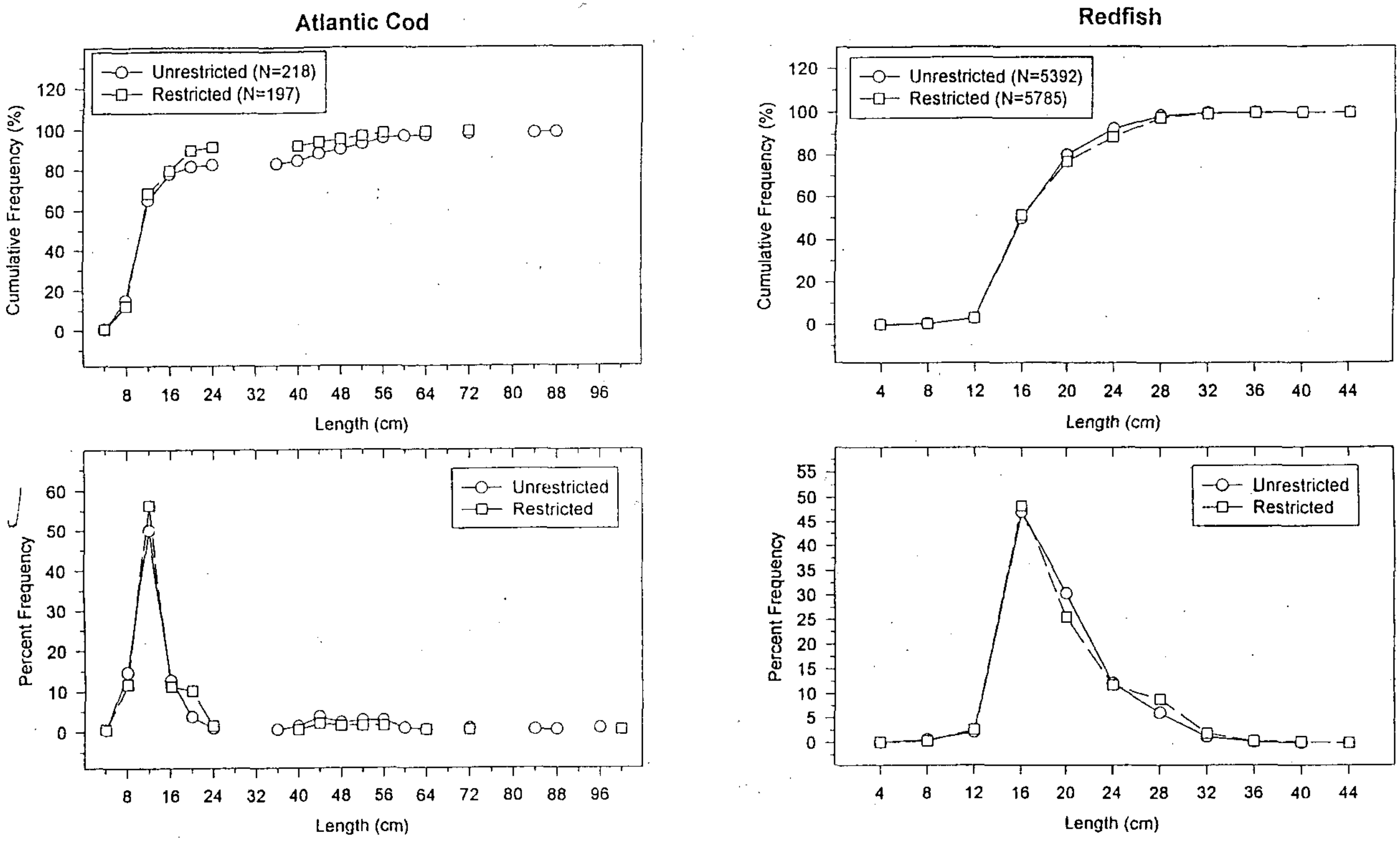


Fig. 8 Length frequency distribution of Atlantic Cod and Redfish from the unrestricted and restricted hauls.

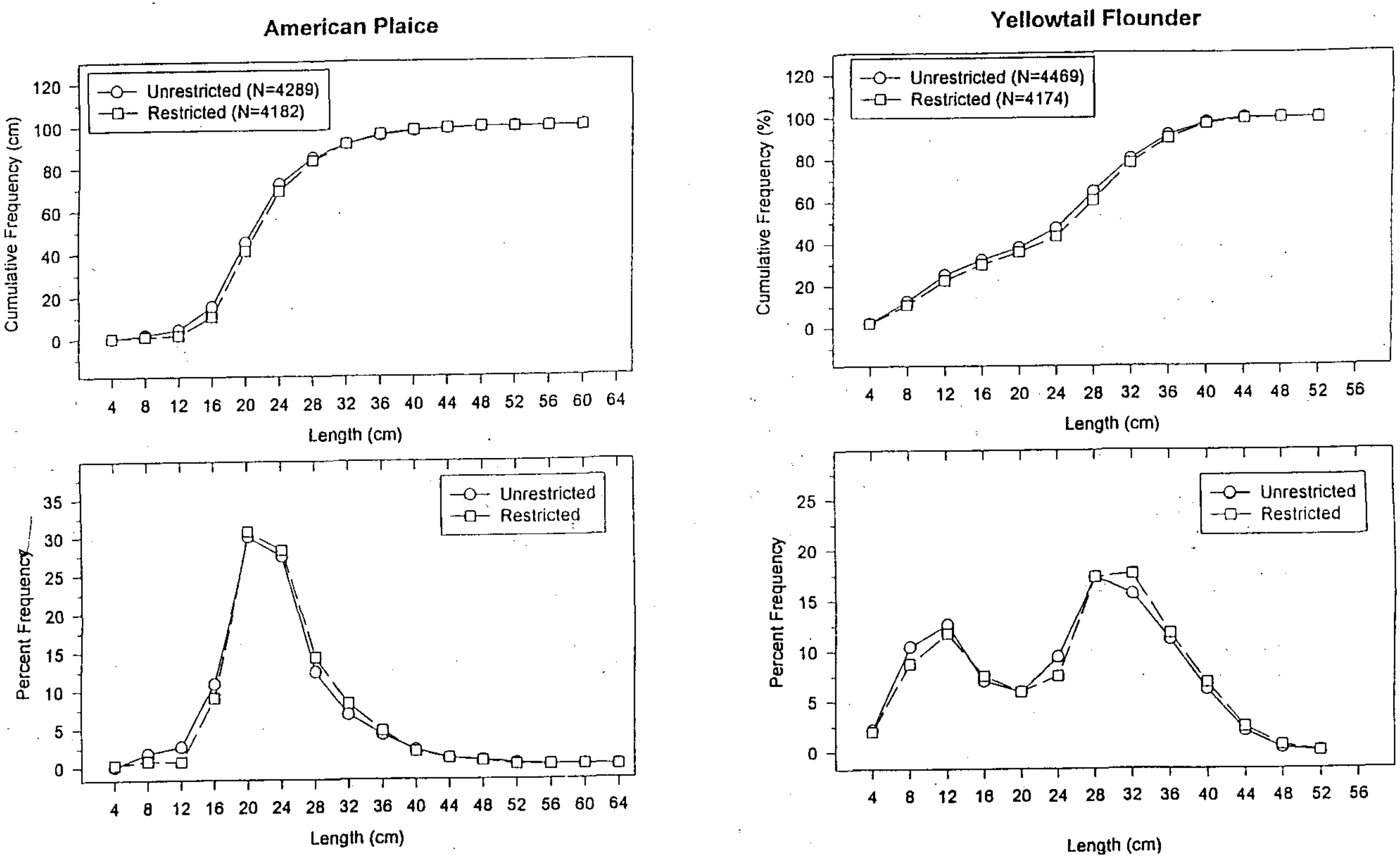


Fig. 9 Length frequency distribution of American Plaice and Yellowtail Flounder from the unrestricted and restricted hauls.

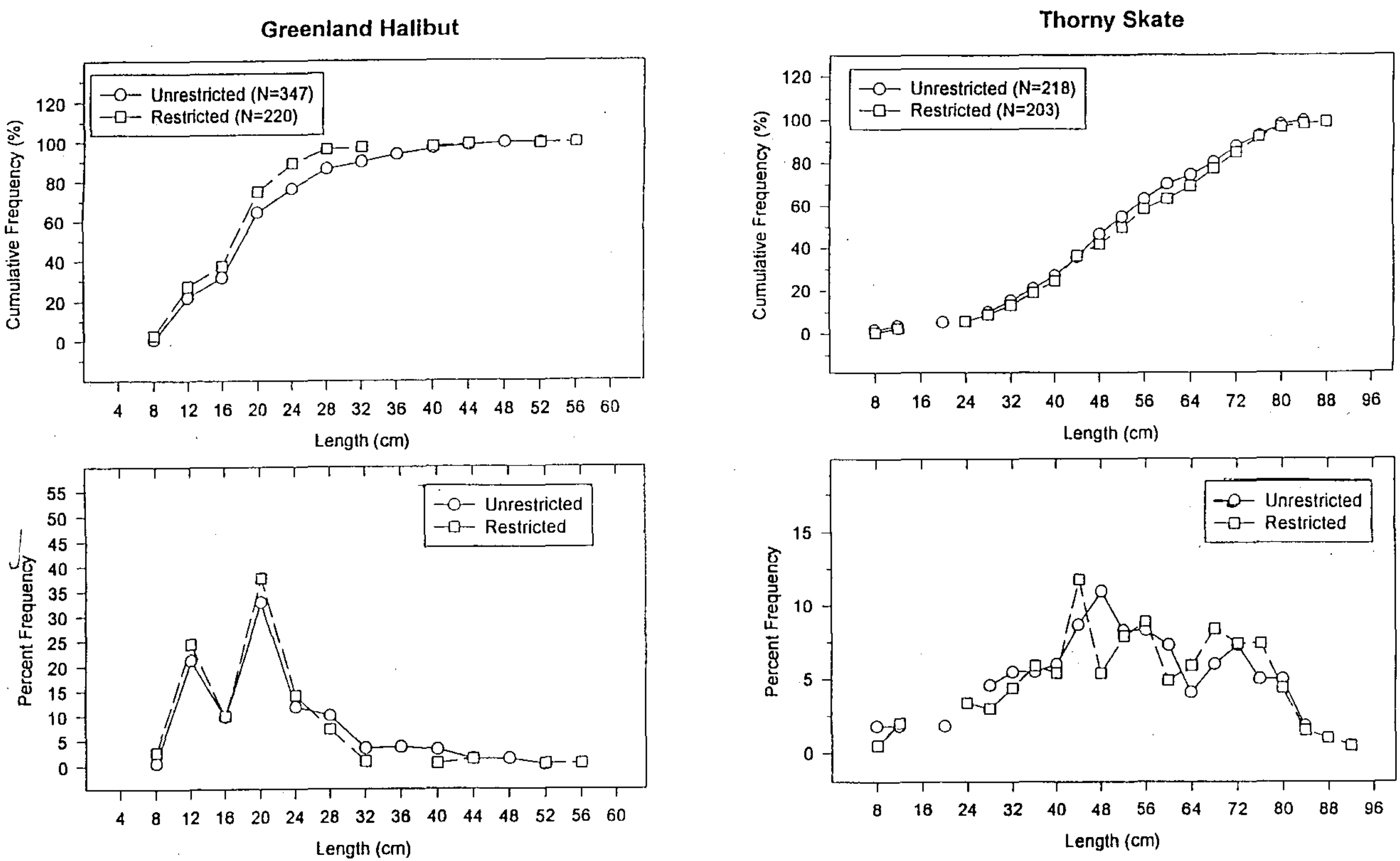


Fig. 10 Length frequency distribution of Greenland Halibut and Thorny Skate from the unrestricted and restricted hauls.