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A Preliminary Investigation of the Efficiency of Canadian and Spanish Survey Bottom Trawls on the Southern Grand Bank.

by

Stephen J. Walsh[1], Xabier Paz[2] and Pablo Durán[2]

[1]Northwest Atlantic Fisheries Center, DFO P.O. Box 5667, St. John's, Newfoundland Canada, A1C 5X1. [2]Instituto Espanãol de Oceanographia, Aptdo.1552,36280 Vigo Spain

Abstract

Preliminary analysis of the capture efficiency of the bottom trawls used by Canada and Spain in surveys of the Grand Bank was conducted using a variant of the logistic model to analyse a series of comparative fishing data. Within the Canadian comparative data of the old and new survey trawls, the new survey trawl was less efficient for larger cod and yellowtail flounder but not so for American plaice. However, there is some uncertainty in capture probability for larger fish because of a sparse catches in the data. The Spanish survey trawl is more efficient than the new Canadian survey trawl because of the use of longer sweep lines, which increase catchability in plaice and yellowtail flounder. The logistic model did not fit the data well, in particular for yellowtail flounder. Further analysis is suggested which may offer more insight into modelling and interpretation of the capture efficiency of these survey trawls.

Introduction

In the fall of 1995, Canada changed its survey trawl from the Engel 145 High Rise otter trawl which was in use for surveys on the Grand Bank since 1984, to a new Campelen 1800 shrimp trawl. Several experimental fishing experiments were carried out to derive conversion factors for all NAFO species (Warren *et al*., 1996). In 1995, Spain began new bottom trawl surveys using a Pedreira otter trawl in the Regulatory Area of Div. 3N and 3O to develop a time series for gadoids and flatfish in that area. Beginning in 1999 Spain began carrying out comparative fishing experiments to estimate the selectivity and efficiency of their survey trawl.

The carrying out of comparative fishing experiments to convert a bottom trawl survey time series is often plagued by less than ideal conditions, for example, vessel and weather problems reduced the number of successful tows and insufficient quantities of fish in the population may reduce the accuracy of conversions of small or large fish. In addition, when a new survey trawl is introduced there is, occasionally, an obvious change in the directional trend of the abundance index, which may or may not have biological meaning. For example, in the Canadian surveys of Grand Bank yellowtail flounder (*Limanda ferruginea*), a trawl gear change was introduced in 1984 spring survey and the converted indices showed the biomass increased by 74% over the previous estimate in 1982 (no survey in 1983). Again, in 1996 spring survey, a new survey trawl was introduced and the biomass increased by 148% over the 1995 estimate. There are often other criticisms for some of the shortcomings in the survey indices when a new survey gear is introduced, i.e. the survey is not tracking the population as well as the old gear. For example, in Div. 3LNO cod (*Gadus morhua*), the new gear doesn't appear to catch large cod as effectively as the old gear and this may change the shape of the partial selectivity curve, i.e. a change in catchability (q) in the catch-at-age model output (Stansbury *et al*., 2001). In Div. 3LNO American plaice (*Hippoglossoides platessoides*), the catch-at-age (SPA) model calculated survey catchabilities greater than one (1) with the new gear but less than one with the old gear (J. Morgan 2001, pers. comm.). Generally, the catchability coefficient (q) of most groundfish stocks is less than 1, however, there are several cases where q is above 1, including Div. 3NO cod and 3LNO plaice (Harley and Myers 2001). This implies that that are more fish in the path of the trawl than predicted by a q of 1, i.e. significant herding is apparent. Changes in survey gears may introduce changes in q, which may not be captured in the time series conversion.

Recent research on survey data has shown that, compared to the total variability of the survey, the measurement error associated with the survey trawl is small (2-5% in terms of variance of catch per towed distance) (Hjellvik *et al*., 2001). In addition Korsbrekke *et al*. (2000) have demonstrated that survey based assessments are more accurate than commercial catch at-age models (tuned with survey data) for the Northeast Arctic cod. Reductions in errors (bias and variance) in survey abundance indices should be a priority and it is with this intention that the Northwest Atlantic Fisheries Centre (NAFC) in Newfoundland has begun to evaluate the success of the NAFC standardized trawl program (McCallum and Walsh, 2001). In addition at NAFC, investigations have begun into the incorporation of Scanmar trawl geometry data to calculate swept area estimates of abundance. The Instituto Espanãol de Oceanographia, in Vigo had recently undertaken programs to investigate the accuracy of their survey indices. In 1999, the Institute began carrying out comparative fishing to estimate the efficiency of its Pedreira survey trawl in an alternate haul experiment with a Campelen 1800 shrimp trawl. In 2000, these comparative studies were continued and expanded to include side-by side comparative fishing with the NAFC survey vessel towing its Campelen trawl. In 2001, the Spanish-Canadian comparative fishing trials also included a new Spanish research vessel, *R/V Vizconde de Eza*, which will replace the *R/V Playa de Menduiña*. This resulted in a 3-way comparative fishing experiments to develop conversion factors for the Spanish Campelen trawl and a fishing power conversion for the new research vessel (Román *et al*., 2001).

A fundamental aspect of carrying out annual surveys is an understanding of the catchability of the bottom trawls used. Changes in catchability can be attributed to changes in gear performance, fish availability (i.e. vertical migration) to the gear or vulnerability of the fish (i.e. escapement and herding) to the gear (Parrish, 1963). This paper reports on a preliminary investigation of the capture efficiency of the survey trawls used in assessing groundfish resources on the Grand Bank.

Material and Methods

Data sources

The data for determining the efficiency of the survey trawls come from comparative experiments carried out by Canada and Spain.

Canadian comparative fishing

One hundred and eighty (180) NAFC comparative fishing hauls between the old standard survey trawl, Engel 145 High Lift otter trawl and the new standard trawl, Campelen 1800 shrimp trawl, were examined based on the 1996 side-by-side comparative fishing experiments between the *CCGS Wilfred Templeman* and the CCGS *Alfred Needler* (Warren *et al*., 1997). These experiments were carried out on the Grand Bank, NAFO Div. 3LNO. Differences in size selection and efficiency of the Campelen and Engel trawls for catching cod, American plaice and yellowtail flounder were explored. The Engel trawl was towed for 30 minutes and the Campelen trawl was towed for 15 minutes during all paired tows. Full descriptions of both trawls are found in McCallum and Walsh (1997).

Spanish comparative fishing

In 1999, Spain conducted alternate haul experiments using two bottom trawls aboard the *R/V Playa de Menduiña* in the NAFO Regulatory Area of Div. 3N and 3O. The catches from 17 sets of hauls using a Pedreira otter trawl (Fig. 4 and 5) equipped with 15 cm diameter rubber disc footgear were compared to catches from a Campelen 1800 shrimp trawl, equipped with a 35 cm diameter rockhopper footgear. Both trawls were rigged with 255 m ground warps (Table 2), (Paz and Duran, 1999). Each trawl was towed for 30 minutes. Differences in catch rates of American plaice and yellowtail flounder for catching were explored. There was insufficient cod catches to include in the analysis and length frequency data of other species were unavailable at the time of the analysis, Canada-Spain comparative fishing

In 2000, comparative fishing was carried out between the Canadian Campelen (6.1 m ground warps) towed by the *CCGS Wilfred Templeman* and the Spanish Pedreira otter trawl, towed by the *C/V Playa Menduiñ* during side-by-side tows (Román *et al*., 2001). These experiments were carried out in the NAFO Regulatory Area of Div. 3N and 3O. Both trawls were towed either for 15 minutes or 30 minutes to replicate the survey tow times of each country. Differences in size selection and efficiency of the Campelen and Pedreira trawls for catching American plaice and yellowtail flounder were explored. There was insufficient cod catches to include in the analysis.

Method of analysis

Size selective trawl efficiency (E) of the survey gears was estimated by assuming that catches of one gear represents the population size composition (small mesh trawl) and the other the test gear (larger mesh trawl) in a manner similar to the calculation of codend selectivity using the trouser trawl method (Walsh *et al*., 1992). We used the following form:

$$\text{Efficiency}_{l\ \text{ength}} = CL/(CL+CS)$$

where CL is the catch in the large mesh trawl and CS is the catch in the small mesh trawl for each 2 cm interval.

A probability variant of the logistic curve was fitted to the selectivity data which conditions on the total number of fish caught of length *l* and assumes that the that there is an unequal catch at length between the two trawls, i.e. no 50:50 split (Millar and Walsh, 1992). It takes the form of:

$$S(l) = p \exp(a+bl)/[(1-p) + \exp(a+bl)]$$

where a and b define the curve and p is the estimated split proportion in the large mesh.

Results

Survey gears

Figures 1-5 give the specifications of the two present bottom trawls used in surveys of the Grand Bank by Canada and Spain. For specifications on the NAFC old standard survey trawl see McCallum and Walsh (1997). A summary of the main characteristics is presented here. The 'old Canadian standard' survey trawl, Engel 145 High Rise otter trawl, was rigged with 36-53 cm diameter combination steel and rubber bunt bobbins footgear, 65 m sweep lines, 1253 kg oval doors and with a mesh size of 180 mm in the forepart of the trawl tapering to 130 mm in the codend which included a 30 mm liner. The 'new Canadian standard' survey, Campelen 1800 shrimp trawl, is rigged with 35 cm diameter rubber rockhopper disc footgear, 46 m sweep lines, 1400 kg oval doors and a mesh size of 80 mm in the forepart of the trawl tapering to 44 m in the codend which has a 13 mm liner. The Spanish Pedreira otter trawl is rigged with 15 cm diameter rubber disc (no bobbins) footgear, 267 m sweep lines, 800 kg oval doors and a mesh size of 150 mm in the forepart of the trawl tapering to 35 mm in the codend (no liner used). The Spanish Campelen 1800 shrimp trawl is constructed exactly like the Canadian version but is used with 295 m sweep lines, 800 kg oval doors and no codend liner. These differences in sweep lines (Table 1), mesh sizes, trawl door sizes and footgear will affect selectivity and catchability in terms of differences in herding, effective swept area, and escapement at the footgear and in the body of the trawl (Engås, 1994; Walsh, 1997).

Canadian comparative fishing

Figures 6-8 show the results of selectivity and efficiency of the old and new Canadian survey trawls from the 1996 comparative fishing experiments for cod, American plaice and yellowtail flounder. Capture (Efficiency) probability ø(*l*) for each species increases monotonically with size but in neither case does it reach an asymptote of unity. The Engel was less efficient at capturing small cod, plaice and yellowtail flounder than the Campelen and this may be reflective of differences in footgear size with more escapement underneath the large bobbin gear on the Engel when compared to the Campelen.

The results of the analysis of cod showed that there was a good fit in the data up to approximately 55 cm (Fig. 6). From 65 cm onward the Engel is slightly more efficient than the Campelen (asymptote of 0.57) but the logistic curve may be underestimating the capture efficiency (probability) of large fish because the data is sparse for large cod, i.e. no length group beyond 65 cm had more than a total of 13 fish caught and in most cases the total catch was only 2 to 4 fish.

Analysis of plaice showed a good fit in the data up to 42 cm with a constant capture efficiency (0.44) from that point onward (Fig. 7). This indicates that the Engel is less efficient for plaice than the Campelen. However, the logistic curve may be underestimating the capture efficiency of the largest individuals due to sparse data. For fish larger than 59 cm, the total catch for each length group was less than 10.

Analysis of yellowtail flounder showed the best fit of the logistic curve to the data (Fig. 8). From 32 cm and beyond the Engel was slightly more efficient at capturing medium to large yellowtail flounder (asymptote of 0.57). The logistic curve may be underestimating or overestimating the efficiency for the largest yellowtail flounder again due to sparse data, i.e., total catches for last 4 length groups ranged from 7-22 fish.

Spanish comparative fishing

Figures 9 and 10 show the results of the catch (kg) of American plaice and yellowtail flounder for each pair of fishing hauls from 1) side-by side comparisons of the Campelen and Pedreira trawls between NAFC (Canada) and Spanish research vessels and 2) alternate hauls of the Campelen and Pedreira trawls by the Spanish vessel, each trawl equipped with 240 m sweeps (Table 2). Cod were not present in the catches in sufficient quantities to make a direct comparison; nevertheless, they were generally higher for the Pedreira trawl. In the side-by-size comparisons between the Canadian Campelen and the Spanish Pedreira trawls the overall catches of American plaice and yellowtail flounder in the Pedreira trawl often exceeded that of the Campelen trawl by a factor of 10 (Fig. 9 and 10 top panel). However when the Spanish Campelen was rigged with 295 m sweeps, instead of the 46 m used on the Canadian version (see Table 2), and the catches were compared to that of the Spanish Pedreira trawl with 267 m sweeps in the alternate haul experiment, the catches of the Pedreira were less than 2 times that of the Campelen (Fig. 9 and 10, lower panel). Length frequency data were not available at the time of the analysis.

Canada-Spain comparative fishing

Figures 11 and 12 shows size selectivity and efficiency of the trawls for American plaice and yellowtail flounder derived from the side-by-side comparative fishing of the Canadian Campelen and the Spanish Pedreira trawls [1]. Capture probability almost approaches unity for plaice but not yellowtail flounder. The Pedreira trawl is less efficient than the Campelen only for the smallest of the flatfish. The Pedreira catches at length often exceeded those of the Campelen by a factor of 2 and is probably indicative of the smaller footgear and longer sweep lengths used on the Pedreira when compared to the Campelen trawl. These longer sweeps should increase the herding of fish into the trawl mouth and the smaller footgear should reduce escapement of fish underneath the trawl.

In the American plaice analysis, there was a constant efficiency from 40 cm onward (asymptote of 0.89). The logistic curve may be underestimating the efficiency of the largest plaice due to sparse data (Fig. 11). For yellowtail flounder, the logistic curve shows a constant capture efficiency from 13 cm onward (asymptote of 0.58). However, the curve showed a poor fit to the data and may underestimate the capture efficiency of the Pedreira for fish beyond 13 cm (Fig. 12).

Discussion

The logistic model is widely used to model codend selectivity and assumes that selectivity increases monotonically with fish size to an asymptote of unity. This would imply that fish of a certain size cannot escape. The analysis here of survey data indicates that an asymptote is less than unity which implies escapement of larger fish or that because of sparse data for larger fish the form of capture efficiency is not been well described. Munro and Somerton (2001) concluded that the logistic model should be modified with an additive parameter for a variable asymptote or one that

[1] Earlier draft at the June 2001 NAFO meeting had an error in the formulation of the logistic model that has been corrected here.

showed the capture probability increasing to a maximum then decreasing with increasing fish length. There may be some indication of both conditions in plaice and yellowtail flounder analyses, however, the estimates of capture efficiency in larger fish in the Canadian comparative series for cod and flatfish should be considered uncertain. Poor fit of the present model may also represent uncertainty evident in the Canada-Spain comparative data for yellowtail flounder. Further exploration of parametric and non-parametric methods are needed.

Surveys generally have problems with bias and precision, that is a bias survey estimate may be precise but its estimate may be lower or higher than the true population (Kimura 1989). The shortfall in accuracy is an estimate of the catchability coefficient q, hence, in most cases, survey abundance indices are treated as relative not absolute estimates. Recent comparative fishing experiments to derive conversion factors for the Canadian/NAFC time series, and experiments to evaluate selectivity and efficiency of the Canadian and Spanish survey trawls have offered some insights. It is evident from the data analyzed here that trawls with the longer sweep length will increase the catch rates of cod and flatfish than those trawls equipped with shorter sweep lengths, i.e. an increase in herding effect and a q greater than 1. Recently, there have been several experiments that showed that bridle herding plays a significant role in the catchability and size selectivity of survey trawls (Engås and Godø, 1989; Ramm and Xiao, 1995; Somerton and Munro, 2001). Somerton and Munro (2001) have shown that bridle/sweep herding is quite common and are modeling the estimate along with an estimate of escapement under the footgear to derive a more precise estimate of the catchability coefficient for flatfish. Godø and Engås (1989) have shown that herding is significant in Northeast Arctic cod and Norway has corrected their time series based on a fish size dependent effective fishing width (Jacobsen *et al*., 1997). In the Canadian and Spanish survey time series there has been no experimental measures of herding carried out as of to-date. Certainly herding would appear to account for the large catch rates differences in the experimental comparisons with the Spanish Pedreira and Campelen trawls and in the biomass indices for plaice and yellowtail flounder. Doorspread estimation may be a more effective width parameter estimate in American plaice and yellowtail flounder than wingspread and if such is the case then survey estimates of stock size maybe overestimated. Further investigations of effective swept area through experimentation and modeling are necessary.

Conclusions

The analyses presented here, which examined capture efficiency in survey trawls used by Canada and Spain are considered preliminary. Further modelling of capture efficiency that takes in to account variable asymptotes is necessary. Examination of the length-based capture efficiency data from the Spanish comparative fishing results with their Pedreira and Campelen trawls should be added to the analysis along with the 2001 results of the Canadian-Spanish comparative fishing.

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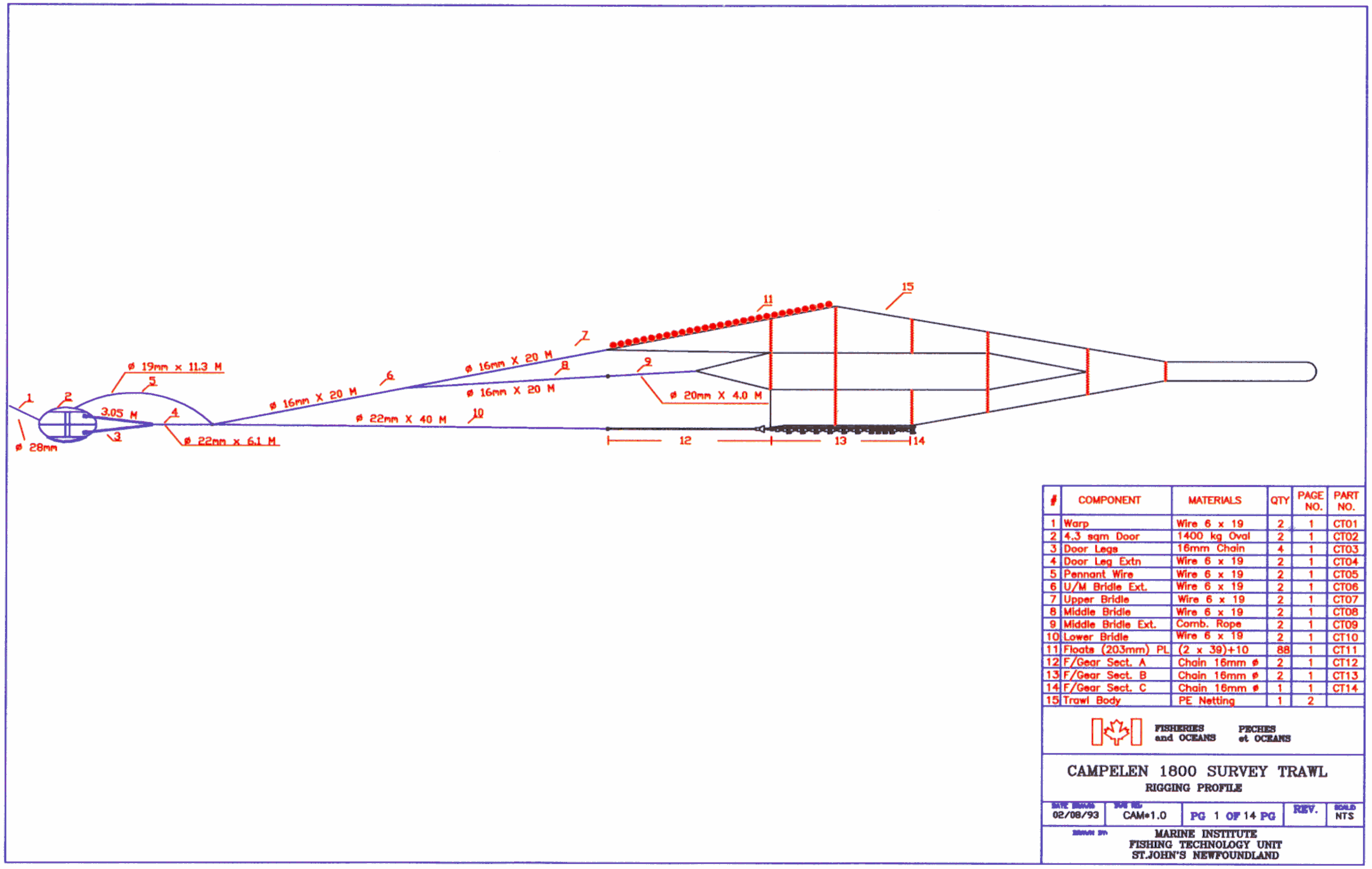
Table 1. Sweep length of each survey trawl.

Gear Parameter	Canadian Engel 145 High Lift otter trawl	Canadian Campelen 1800 shrimp trawl	Spanish Pedreira otter trawl	Spanish Campelen
Ground warps	15.2 m	6.1 m	255 m	255 m
Bridles	50 m	40 m	12 m	40 m
Total sweep length	65.2 m	46.1 m	267 m	295 m



#	COMPONENT	MATERIALS	QTY	PAGE NO.	PART NO.
1	Warp	Wire 6 x 19	2	1	CT01
2	4.3 sqm Door	1400 kg Oval	2	1	CT02
3	Door Legs	16mm Chain	4	1	CT03
4	Door Leg Extn	Wire 6 x 19	2	1	CT04
5	Pennant Wire	Wire 6 x 19	2	1	CT05
6	U/M Bridle Ext.	Wire 6 x 19	2	1	CT06
7	Upper Bridle	Wire 6 x 19	2	1	CT07
8	Middle Bridle	Wire 6 x 19	2	1	CT08
9	Middle Bridle Ext.	Comb. Rope	2	1	CT09
10	Lower Bridle	Wire 6 x 19	2	1	CT10
11	Floats (203mm) PL	(2 x 39)+10	88	1	CT11
12	F/Gear Sect. A	Chain 16mm ø	2	1	CT12
13	F/Gear Sect. B	Chain 16mm ø	2	1	CT13
14	F/Gear Sect. C	Chain 16mm ø	1	1	CT14
15	Trawl Body	PE Netting	1	2	

Fig. 1. Rigging profile of the Campelen 1800 shrimp trawl used in annual surveys of the Grand Bank

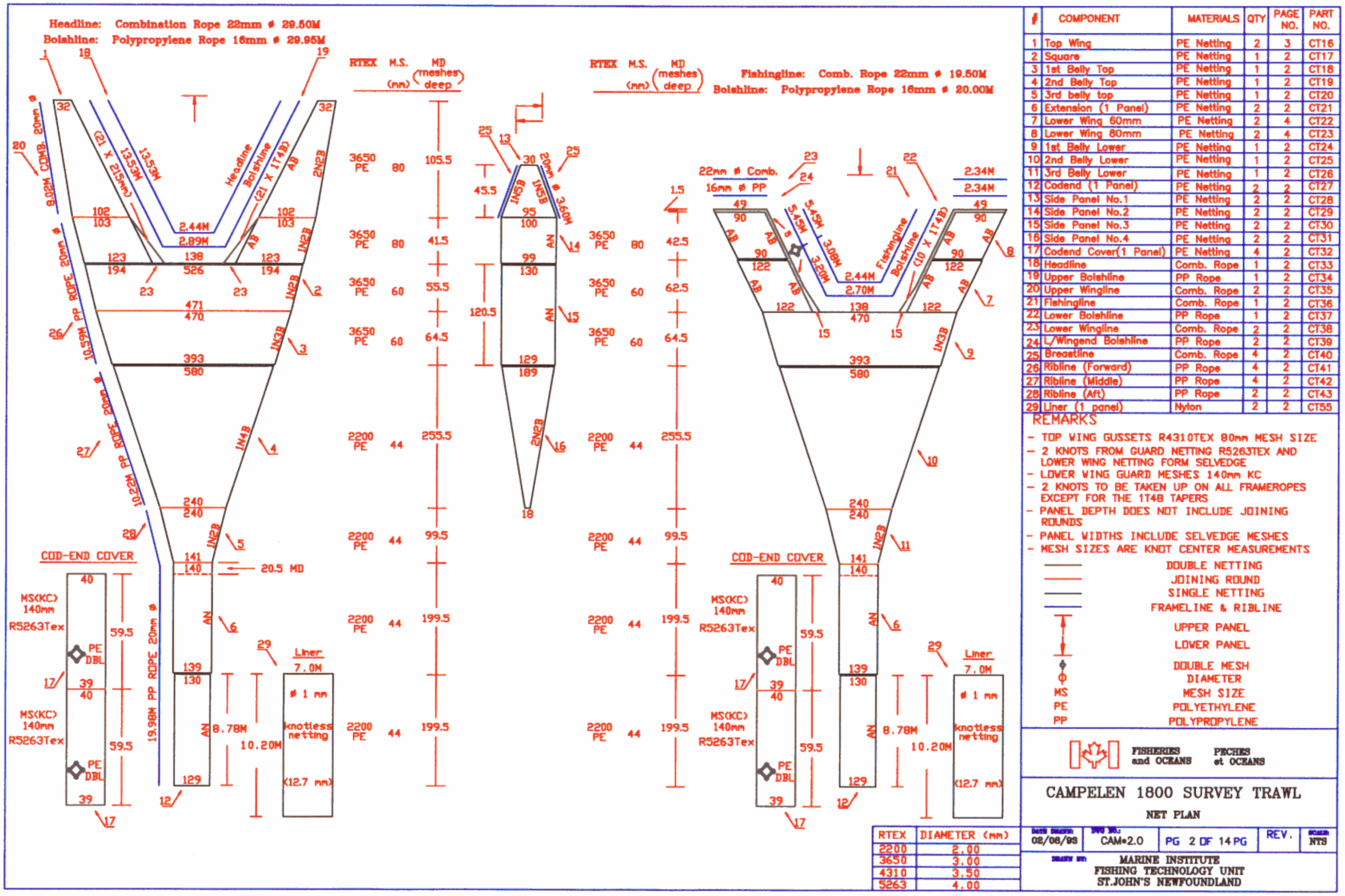
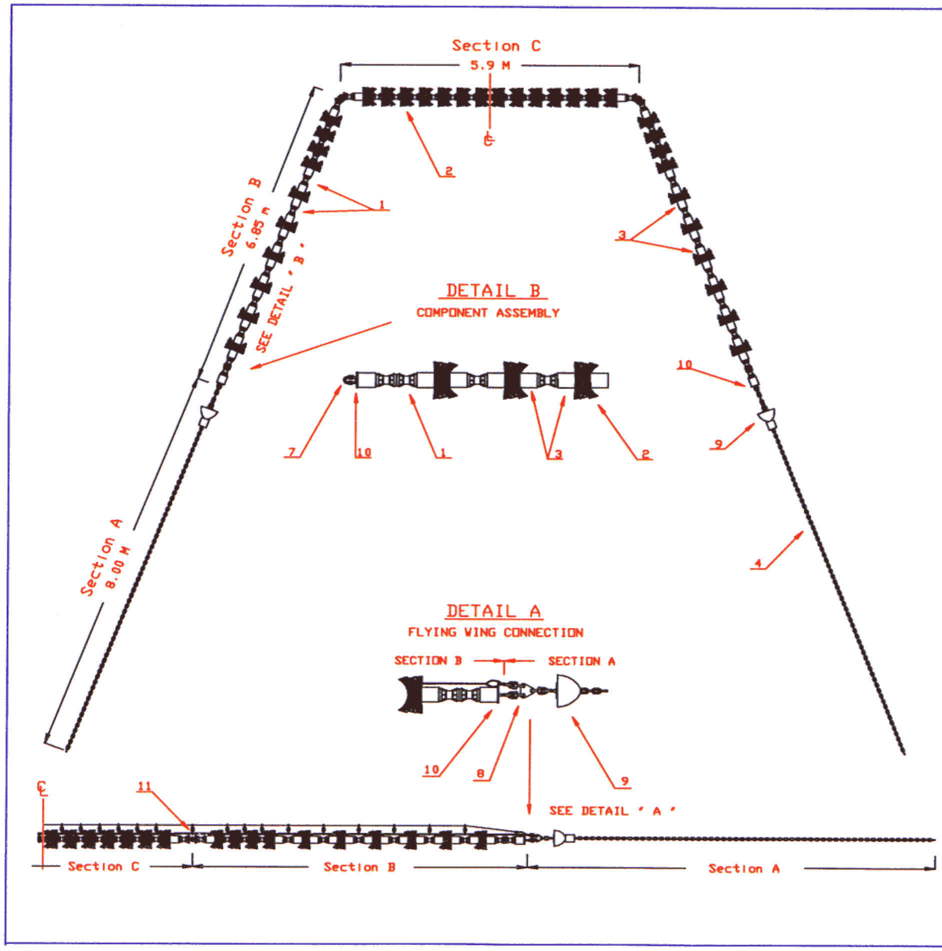


Fig. 2. Schematic diagram of net plan for the Canadian Campelen 1800 shrimp trawl.



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	CT44
2	14' Rockhopper Sets of 3 Disk	0.55	56.1	34X3	0	2x10	1x14	9	CT45
3	7' (178MM) Rubber Spacer	0.43	14.62	34	2X1	2x15	1x2	10	CT46
4	5/8' (16mm) Mid Link Chain	4.96/M	74.30	14:98	2x7.49m				CT12
5	5/8' (16mm) Mid Link Chain	4.96/M	66.96	13.5m		2x6.75m			CT13
6	5/8' (16mm) Mid Link Chain	4.96/M	28.76	5.80m			1X5.80m		CT14
7	5/8' (16mm) Hammerlock	1.0	12	10	2x4	2x2	0		CT48
8	Delta Plate (362mm)	4.76	9.52	2	2	0	0	11	CT49
9	14'(356mm) Rubber Bunt Bobbin	4.98	9.96	2	2	0	0	12	CT50
10	6' (152mm) Washer	0.42	3.36	8	2x1	2x2	1x2	13	CT51
11	15.5' (393mm) Bobbin Chain	0.58	19.14	33	0	2x10	1x13	14	CT52
	TOTAL WEIGHT		501.03						

FISHERIES and OCEANS PECHES et OCEANS

CAMPELEN 1800 SURVEY TRAWL
GROUND GEAR

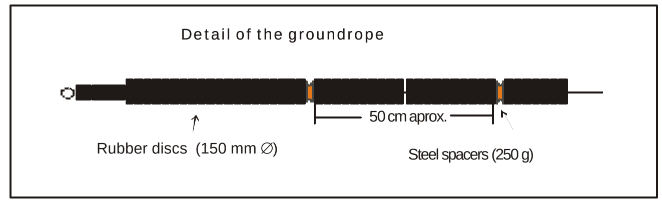
DATE DRAWN:	DWG NO.:		REV.	SCALE:
02/08/93	CAM*3.0	PG 7 OF 14 PG		NTS

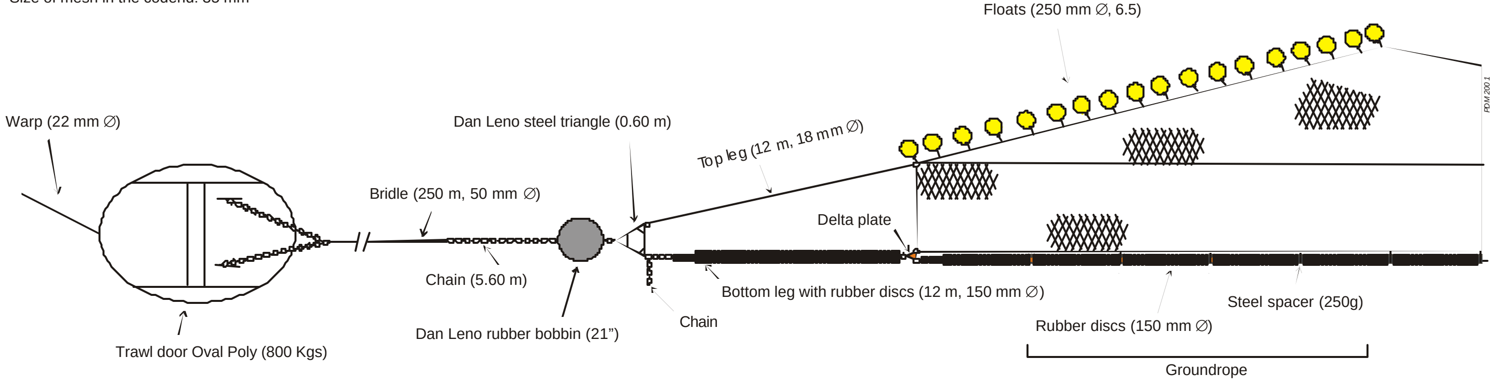
DRAWN BY: MARINE INSTITUTE FISHING TECHNOLOGY UNIT ST.JOHN'S NEWFOUNDLAND

Fig. 3. Schematic plan of the rockhopper footgear of the Canadian Campelen 1800 shrimp trawl

Comparative fishing SPAIN-CANADA (2001 May 21-23)
Spanish Vessel: B/C PLAYA DE MENDUIÑA
Net used : Type “PEDREIRA”
Main characteristics of the gear:

Headline: 39.90 m
Groundrope: 53.10 m
Stimated vertical opening : 2.90 m
Stimated horizontal opening (between dan lenos): 19.20 m
Groundrope with rubber discs & steel spacers
Doors: Oval Polivalent (800 Kgs)
Warp: 22 mm ∅
Bridles: 250 m (50 mm ∅)
Size of mesh in the codend: 35 mm





Rigging Profile

Fig. 4 Rigging profile of the Spanish Pedreira survey trawl used on the Grand Bank.

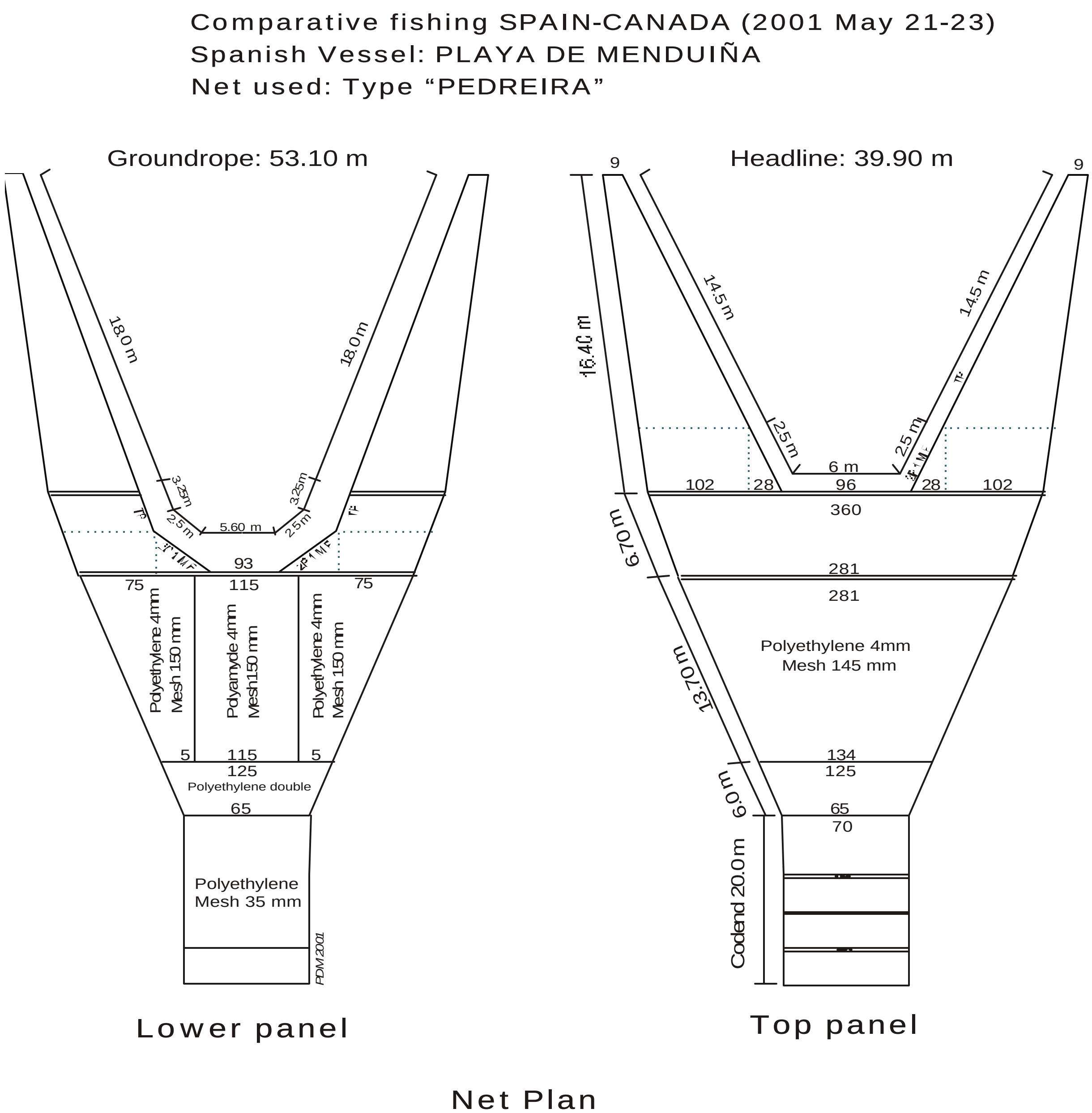


Fig. 5. Schematic of the net plan of the Spanish Pedreira survey trawl

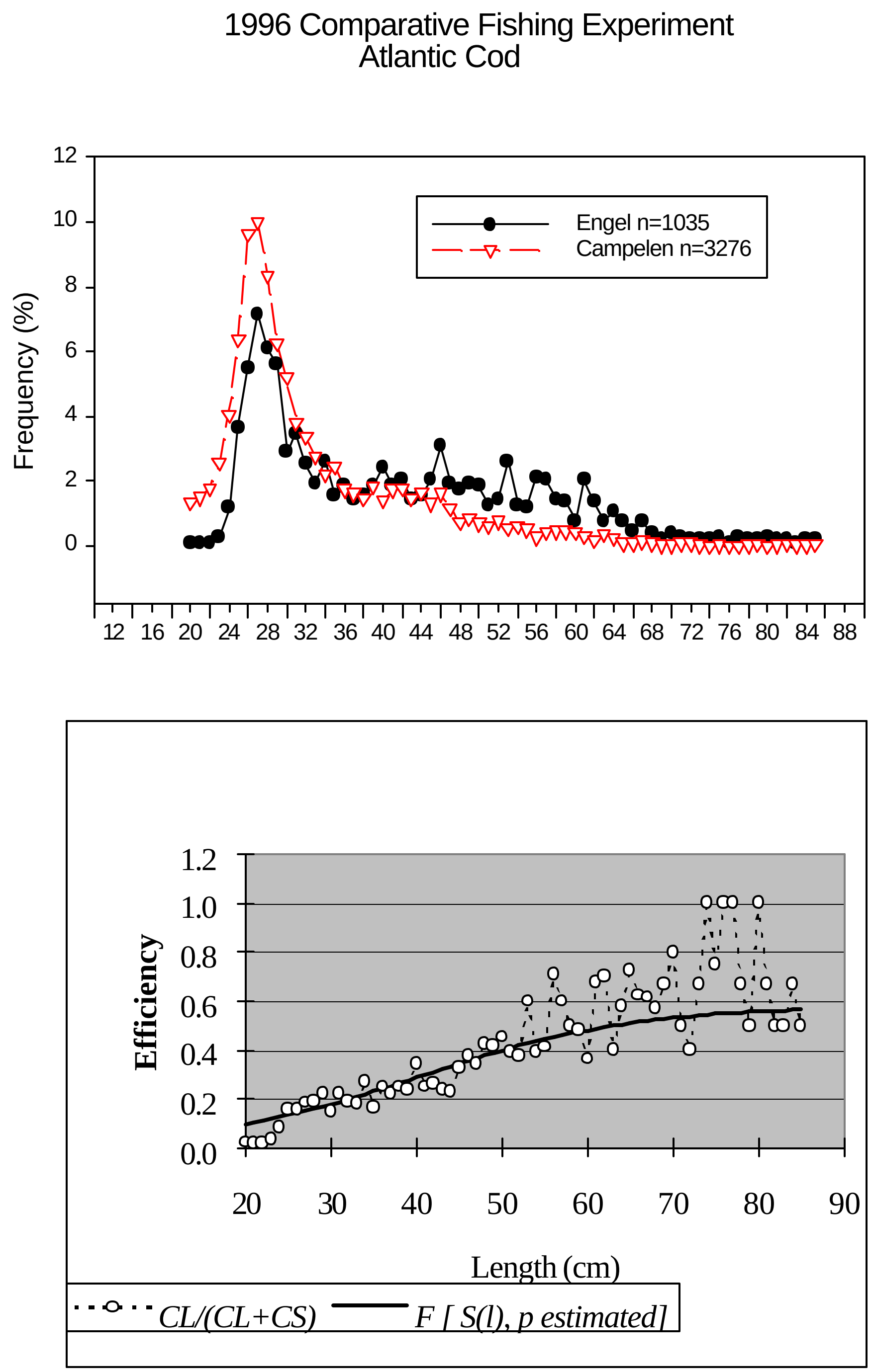


Fig. 6. Top panel: length frequency of catches of cod in both survey gears. Bottom Panel: The proportion of the catch in the Engel Trawl as a function of the Campelen catches, i.e. Efficiency = CL(CL+CS) and F[S(*l*). p estimated} is the fitted logistic curve

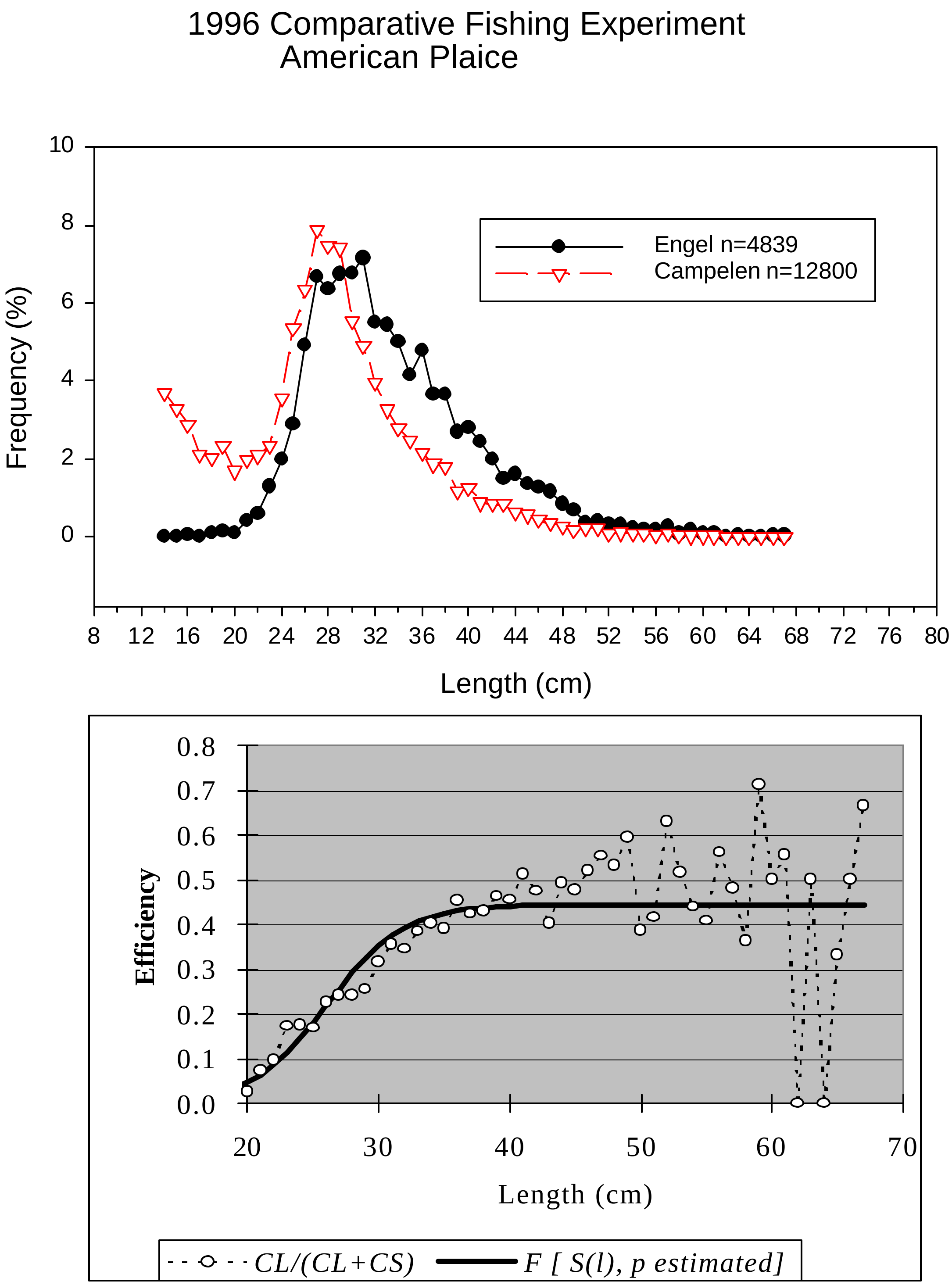
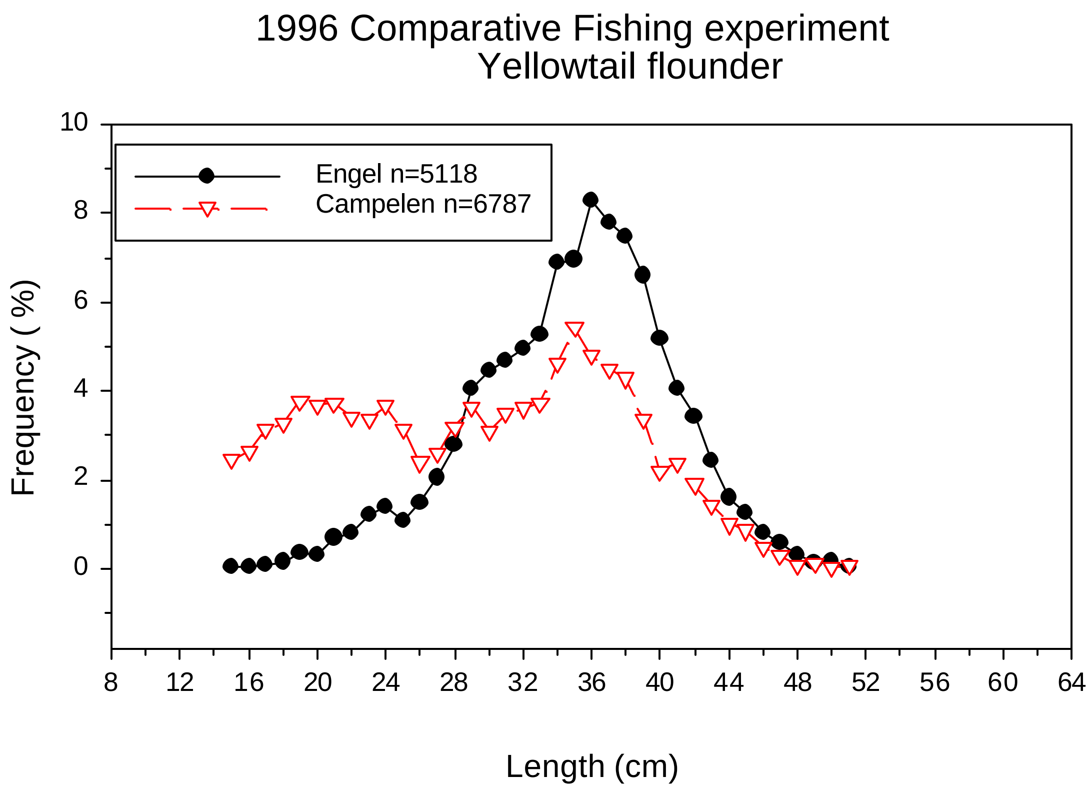


Fig. 7. Top panel: length frequency of catches of plaice in both survey gears. Bottom Panel: The proportion of the catch in the Engel Trawl as a function of the Campelen catches, i.e. Efficiency = CL(CL+CS) and F[S(*l*). p estimated} is the fitted logistic curve



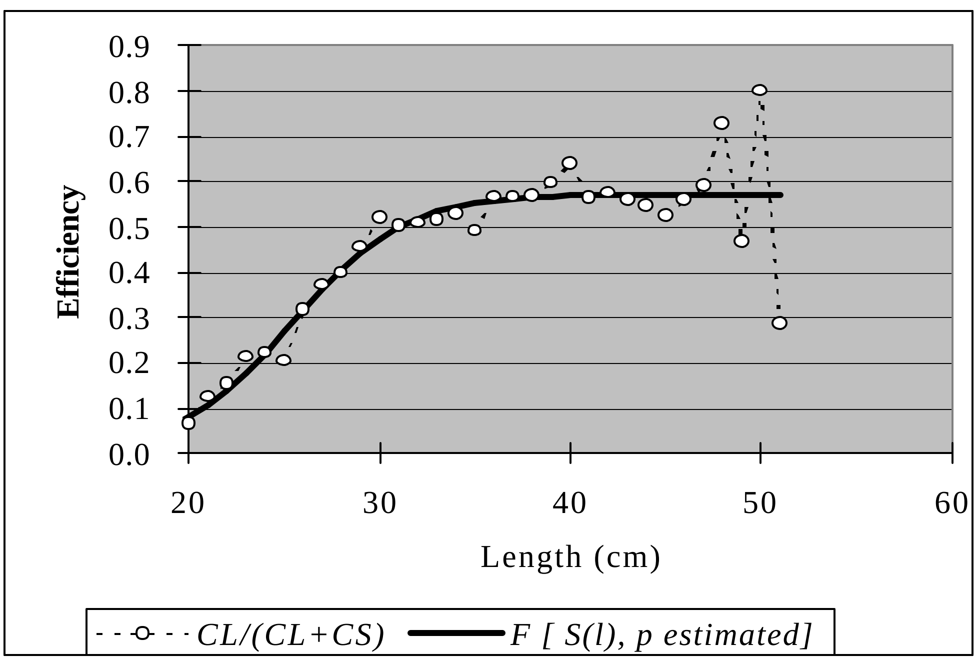


Fig. 8. Top panel: length frequency of catches of yellowtail in both survey gears. Bottom Panel: The proportion of the catch in the Engel Trawl as a function of the Campelen catches, i.e. Efficiency = CL(CL+CS) and F[S(*l*). p estimated} is the fitted logistic curve

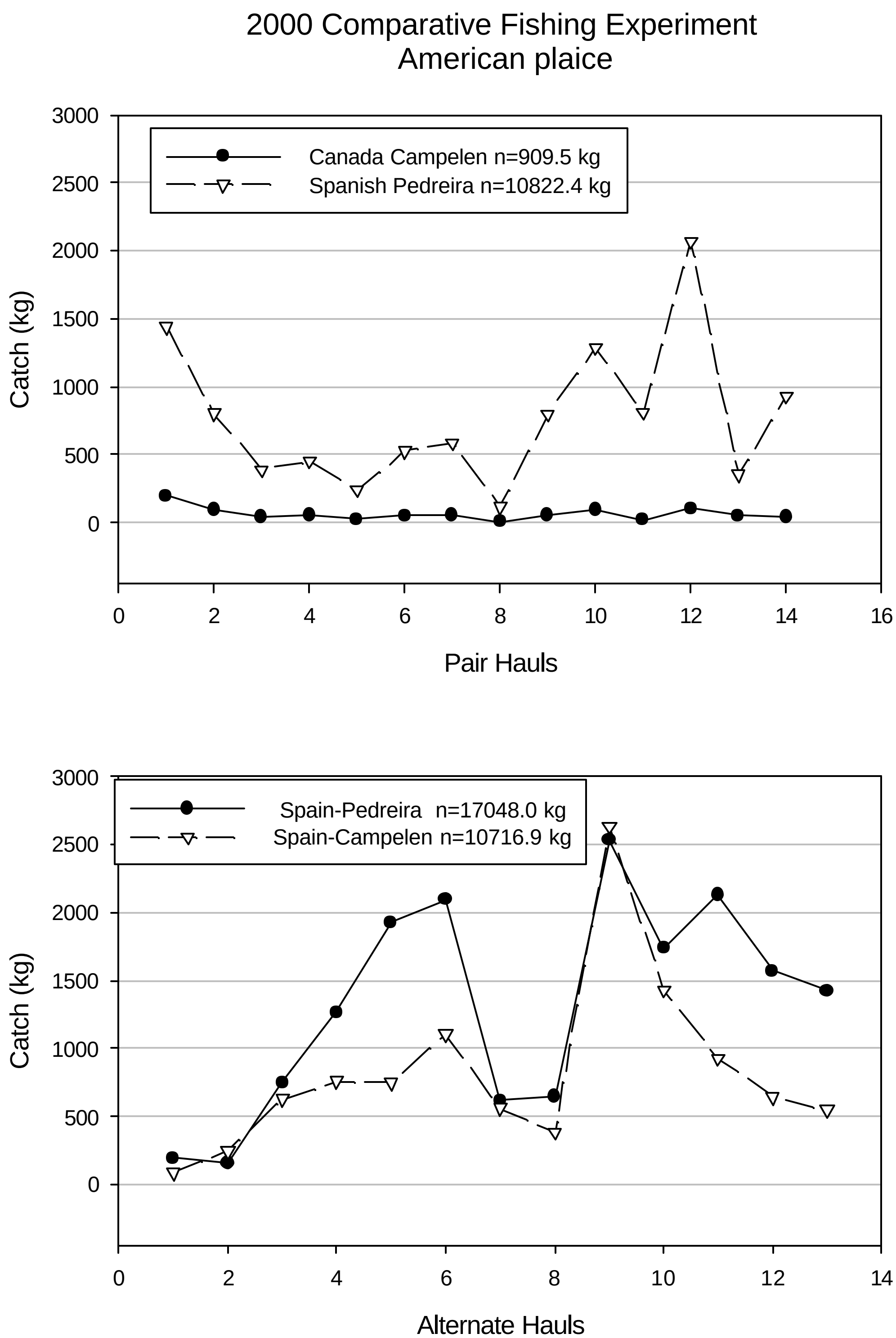


Fig. 9. (Top Panel) Catches of American plaice from comparative fishing between Canadian Campelen trawl and the Spanish Pedreira trawl using parallel hauls and two vessels. (Bottom Panel) Results of comparative fishing between Pedreira trawl and Campelen trawl both rigged with 200 m ground warps and using the alternate haul method.

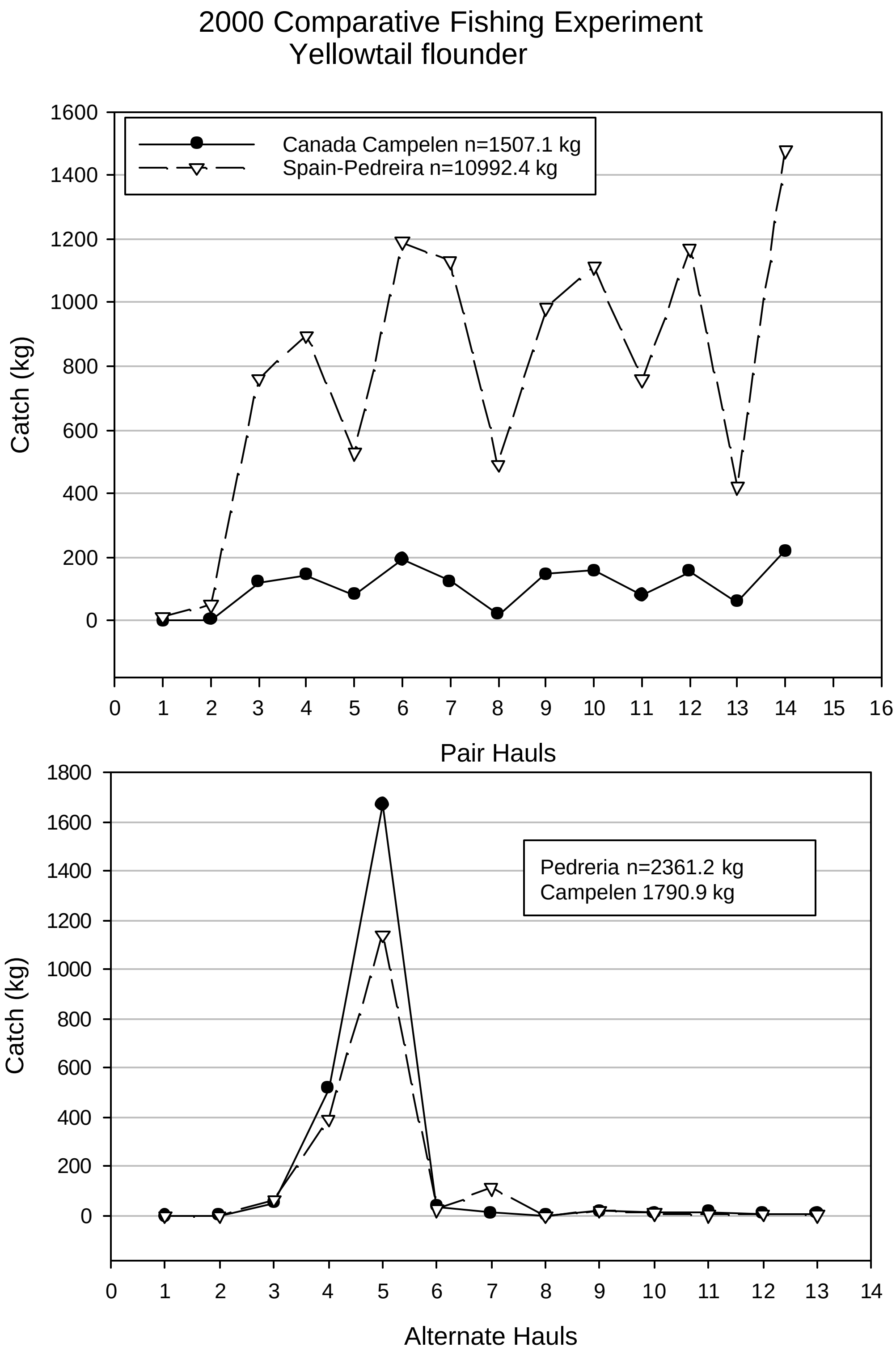


Fig. 10. (Top Panel) Catches of yellowtail flounder from comparative fishing between Canadian Campelen trawl and the Spanish Pedreira trawl using parallel hauls and two vessels. (Bottom Panel) Results of comparative fishing between Pedreira trawl and Campelen trawl both rigged with 200 m ground warps and using the alternate haul method.

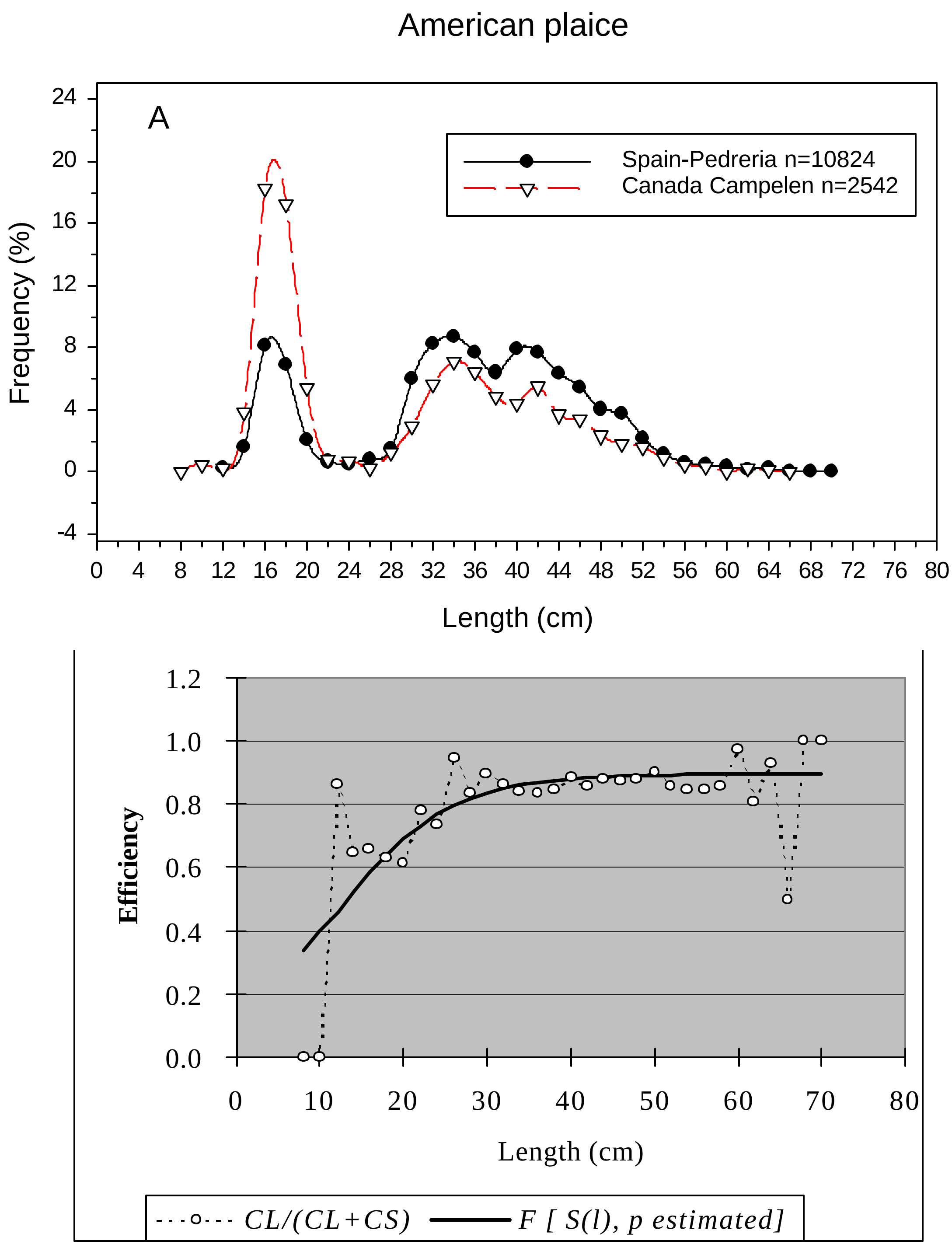


Fig. 11. Top panel: length frequency of catches of American plaice in both survey gears. Bottom Panel: The proportion of the catch in the Pedreira trawl as a function of the Campelen catches, i.e. Efficiency = CL(CL+CS) and F[S(*l*). p estimated} is the fitted logistic curve.

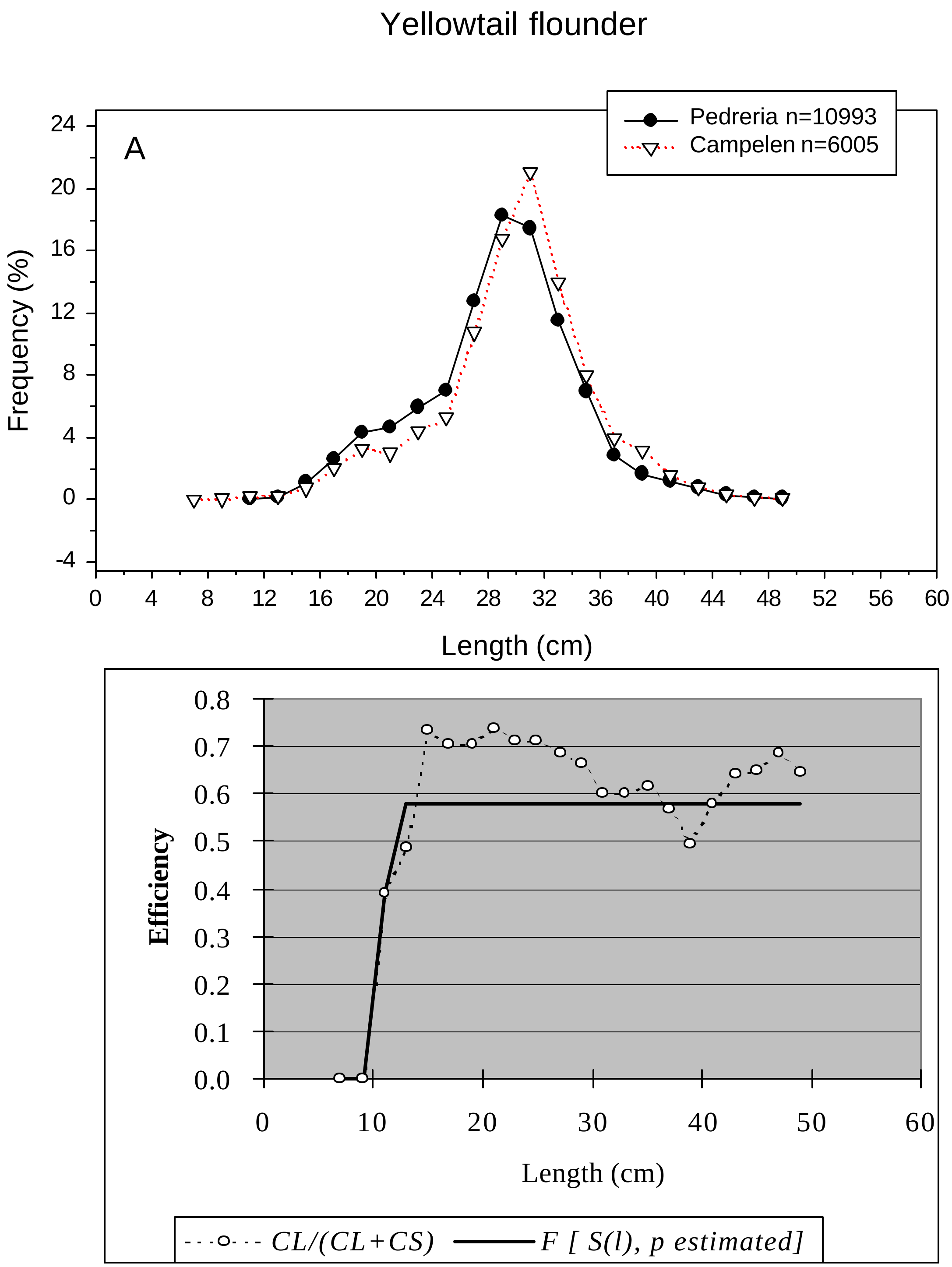


Fig. 12. Top panel: length frequency of catches of yellowtail flounder in both survey gears. Bottom Panel: The proportion of the catch in the Pedreira Trawl as a function of the Campelen catches, i.e. Efficiency = CL(CL+CS) and F[S(*l*). p estimated} is the fitted logistic curve.