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The Fish Capture Process of a Groundfish Survey Trawl

by

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Abstract

Three trawl bags were attached underneath a multi-species groundfish survey trawl to estimate the escapement of Atlantic cod, American plaice, yellowtail flounder, and thorny skate. A total of 27 fishing hauls were made on the Grand Bank off the coast of Newfoundland. The survey trawl reached 50% efficiency beyond 27 cm for all species. Catchability coefficients derived for each species ranged from 0.26 to 0.56. Vulnerability to the fishing trawl was size dependent in cod, plaice, and yellowtail flounder but not thorny skate. Escapement of fish underneath the footgear was enhanced by towing speed of the trawl and the use of large ground gear. Roundfish behavioral reactions to the fishing gear were somewhat more distinctive than flatfishes.

Introduction

Most groundfish surveys carried out in the Newfoundland Region are multi-species directed. On the Grand Banks, the three most important commercial species are Atlantic cod, Gadus morhua, and two flounder species: American plaice, Hippoglossoides platessoides and yellowtail flounder, Limanda ferruginea. It has been known that the survey trawl used caught smaller amounts of young cod and flounders in comparison to adult catches. However, how well the trawl underestimated pre-recruits and its effect on resource assessments was unknown. Investigations have shown that small cod and haddock and plaice can escape underneath the fishing line of the Norwegian survey sampling trawls (Engas and Godø 1986). As well, Main and Sangster (1981) have observed the same actions in cod and plaice off the coast of Scotland.

In order to investigate the escapement of small fish underneath the footgear, three small bag trawls were constructed and mounted underneath the trawl to collect fish that might escape underneath the footgear. Details of construction were followed from a design by Engas and Godø (1976), who carried out similar studies in the Barents Sea.

Materials and Methods

The experiments were carried out in October of 1988 on the Grand Banks, off the coast of Newfoundland aboard the Canadian research vessel W. TEMPLEMAN (Fig. 1). Groundfish surveys currently conducted by the Newfoundland Region of the Department of Fisheries and Oceans use an Engel 145 High Rise otter trawl equipped with steel bobbin footgear with two rubber disc rollers in the bosom (Fig. 2 and 3). The trawl is fitted with a 29 mm nylon codend liner.

The Bag Trawls

The three bag trawls were constructed of 38 mm mesh polyethylene and each was equipped with 20 cm rubber roller footgear. The three bags covered 100% of the fishing area of the footgear of the main trawl and were mounted without gaps (Fig. 4). The headline of the bags was attached to the fishing line of the main trawl and the footgear of the bags was attached by chain to the main footgear (Fig. 5).

The trawl was observed during daylight tows using the underwater remote operated vehicle (ROV) equipped with a video camera. Initial measurements of trawl geometry were made on the first day, only, using "Scanmar".

A total of 27 hauls were completed with each haul being a standard 30 minutes and towed at a speed of 3.5 knots. Fishing was conducted during a 24 hour period at depths of 40 to 160 m. Sampling and measurements of the trawl catches consisted of sorting and weighing of all species of fish. Length measurements were restricted to cod, plaice, yellowtail, and thorny skate and taken to the nearest centimeter. Catches by the bag trawls were treated in the same manner as the main trawl. The trawl net efficiency was measured using Dickson's (1988) formula: net efficiency = catch/(catch + escape). The "escapes" measured were those caught in the bag trawls.

Results

Net Geometry

Using a towing speed of 3.5 knots, the vertical opening of the trawl was measured as 4-6 m and a wing spread of 14 to 16 m, depending on depth, within the range measured during previous trials. Direct observations by the underwater ROV revealed no distortion of the gear. The distance between the fishing line and the bottom was measured to be approximately 45-53 cm and remained the same with the trawl bags attached.

Bag Trawls

Underwater video showed no distortion or change in net geometry of the trawl when the bags were attached. The net efficiency parameter estimates for cod indicate that the efficiency at 50% - i.e., the point where 50% of the number of cod present in the mouth of the trawl enter the net or escape underneath - was approximately 35 cm (Table 1, Fig. 6). Many small cod, 12-29 cm, escaped underneath the fishing line into the trawl bags. Larger cod were found in the main codend ($\bar{x}$ = 57.88) while mean size of cod in the trawl bags ranged from 22.38 to 27.13 cm (Table 5). There were no significant differences in the mean numbers of cod caught in the main codend compared to trawl bags ($p > .05$). However, there was a significant difference in the mean weight in the main codend, indicative of corresponding large fish in the main catch and small fish in the bag trawls ($p < .05$, Table 6).

The 50% net efficiency estimate for plaice was approximately 24 cm (Table 2; Fig. 7). Many small plaice, 4-27 cm, were caught by the bag trawls. As well, substantial numbers of large plaice had escaped underneath the footgear to the extent that net efficiency estimates rarely exceeded 70%. The mean size of plaice in the codend was 36.65 cm, compared to a range of mean values of 20-21 cm in the bag trawls. The main codend caught significantly higher numbers ($\bar{x}$ = 100.20) and weights ($\bar{x}$ = 29.24 kg) than the bag trawls with mean catch of 47.27 fish and average weight of 2.20 kg ($p < .05$) (Table 6).

The 50% net efficiency estimate for yellowtail flounder was approximately 23 cm - close, as one would expect, to that obtained for plaice (Table 3; Fig. 8). Many small yellowtail, 4-27 cm, were caught in the bag trawls and in greater numbers than plaice. Larger yellowtail also escaped beneath the footgear in some quantity, although to a lesser extent than plaice; and their comparable net efficiency estimates were usually much higher. Although the catch numbers of yellowtail in the bags was 3.9 to 1 in comparison to the main codend, there were no significant differences in the overall mean catches by size or weight ($p > .05$; Table 6).

Trawl net efficiency estimates for thorny skate were highly variable, not exceeding 50% over the entire length distribution (Table 4; Fig. 9). Many small and large skate were caught in the main trawl and the bag trawls. The mean length of thorny skate in the main codend ($\bar{x}$ = 52.71 cm) was higher than those found in the trawl bags which ranged from 34.82 cm to 49.63 cm (Table 5). There were no significant differences in the mean catch, in numbers or weight, of the main codend and the trawl bags ($p > .05$) (Table 6).

A non-parametric one way-analysis of variance (Kruskal-Wallis) was used to test for significant difference in the mean numbers of fish caught in the three bag trawls. This test provides insight on common escape patterns or fish reactions to certain parts of the footgear. Mean catches of all four species were higher in the bosom trawl bag while mean catches were similar for the port and starboard mounted trawl bags (Table 7). However, only in cod was there a significant difference in mean catch of the trawl bags, with the bosom trawl bag being significantly higher in catch ($p < .05$). With the exception of cod; plaice, yellowtail, and thorny skate do not seem to show any particular preference for a section of the footgear to escape under.

Discussion

These results on cod and flatfish escapement underneath the footgear confirm observations made by Main and Sangster (1981) on cod and plaice and Engas and Godø (1986) on cod. The survey trawl used in this experiment has low net efficiency for small cod in the size range 6-30 cm and plaice and yellowtail in the size range 4-27 cm. The upper size limit cited here is usually when net efficiency reaches 50%. The net efficiency parameter used here is also known as a catchability coefficient - i.e., the proportion of fish in the path of the trawl that are retained by the trawl (Laevastu and Favorite, 1988). The number of fish in the path of the trawl is the number caught in the main codend plus the number found in the trawl bags, assuming a catchability coefficient of both gears together as 1. Therefore, the calculated catchability coefficient of the survey trawl was .30 for cod, .56 for plaice, .26 for yellowtail, and .35 for thorny skate. From Engas and Godø's (1986) data, catchability coefficient of .54 was calculated for cod in their 1986 experiment. In comparing both gears, it would appear that the survey trawl is less efficient in catching cod than the Norwegian sampling trawl. Korotkov (1984) noted that catchability coefficients are expected to vary from species to species and gear to gear and cited typical values being between 0.1 and 0.4. Catchability coefficients in this study for cod, yellowtail, and thorny skate fall into this range but plaice is above this range. It is interesting to note that the two flounder species, whose distribution overlaps considerably on the Grand Bank, should differ in catchability. It appears that plaice are more vulnerable to the gear than yellowtail flounder and would account for the large catches in the trawl bags of the latter species.

Vulnerability to the gear is size dependent in cod, plaice, and yellowtail flounder but not thorny skate. This 'flatfish,' in comparison to the two flounders, does not show size dependent vulnerability to the gear. Both large and small skate escape under the fishing line of the trawl. The height of the footrope - i.e., the distance from the bottom of a spacer to the ground - is approximately 25 cm; and the distance between two bobbins is 20 cm, giving an effective escape area of 500 sq centimeters. The tendency for fish to escape from the catching zone underneath the footrope is increased as the height of the footrope relative tothe bottom increases (Korotkov 1984).

Underwater observations made during this experiment confirm this escapement underneath the footgear. Escapement behavior was noted in two major patterns. The smallest flatfish and cod which stayed very close to the bottom, while fleeing, were often overtaken by the speed of the trawl. Larger species were often actively seeking escape openings in the footgear. Generally, as fish species are herded closer to the mouth of the trawl, they become concentrated in the area of the bosom rollers and swim in the direction of the tow. One would then expect most escapement to occur in this area of the trawl (Korotkov 1984). Although the mean numbers of each species were highest in the bosom trawl bag, only cod showed a significant difference in catches (hence, escapement) by the bosom trawl bag. Plaice, yellowtail, and thorny skate escaped readily under any section of the footgear. This may be a difference in fish behavior or herding behavior imposed by the trawl. Korotkov (1984) observed directly, via underwater camera, that various fish species react differently in relation to separate elements of the bottom trawl; therefore, he concluded the front part of the trawl has unequal specific and size selective ability.

Conclusions

Net efficiency parameter estimation by size group showed that the survey trawl was very inefficient for young species of cod, plaice, yellowtail, and thorny skate. Catchability coefficients derived for this trawl were much lower for cod, yellowtail, and thorny skate in comparison with plaice. Vulnerability to the fishing gear is size dependent in cod, plaice, and yellowtail but not thorny skate. Escapement of small sizes of various species is enhanced by the fast towing speed and the potential large escape area associated with the bobbin gear of the footrope. Roundfish behavioral reactions to the fishing gear are different than flatfishes.

References

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Table 1. Length frequency distribution of catches of Atlantic cod and their associated net efficiency parameters.

Length Group (cm)	Main Codend	Experimental Bags Port	Bosom	Starboard	Main/Total Bag+Main	Net efficiency %
6-11	5	2	1	0	5/8	63
12-17	1	17	123	10	1/151	1
18-23	9	42	214	5	9/270	3
24-29	25	16	131	3	25/175	14
30-35	8	4	19	1	8/32	25
36-41	11	5	3	1	11/20	55
42-47	7	4	4	0	7/15	47
48-53	17	1	3	1	17/22	77
54-59	66	3	3	1	66/73	90
60-65	50	1	1	1	50/53	94
66-71	22	2	2	1	22/27	81
72-77	11	1	1	0	11/13	85
78-83	6	0	1	0	6/7	86
84-89	7	0	0	0	7/7	100
90-95	8	0	0	0	8/8	100
96-101	5	0	1	0	5/6	83
102-107	5	0	0	0	5/5	100
108-113	2	0	0	0	2/2	100
114-121	5	0	0	0	5/5	100
Total	269	97	507	24	269/897	

Table 2. Length frequency distribution of catches of American plaice and their associated net efficiency parameters.

Length Group (cm)	Main Codend	Experimental Bags Port	Bosom	Starboard	Main/Total Bag+Main	Net efficiency %
4-7	0	39	33	59	0/131	0
8-11	0	280	262	187	0/729	0
12-15	1	184	210	126	1/521	0.2
16-19	18	104	130	69	18/321	6
20-23	96	136	133	80	96/445	22
24-27	341	116	131	71	341/659	52
28-31	410	61	74	47	410/592	69
32-35	465	43	43	28	465/579	80
36-39	416	42	40	40	416/538	77
40-43	327	32	28	41	327/428	76
44-47	212	25	26	21	212/284	75
48-51	123	16	15	14	123/168	73
52-55	92	9	7	11	92/119	77
56-59	57	7	10	4	57/78	73
60-63	53	4	12	4	53/73	73
64-67	17	1	3	2	17/23	74
68-71	3	1	1	0	3/5	60
72-75	3	0	0	0	3/3	100
Total	2624	1100	1158	804	2624/4696	

Table 3. Length frequency distribution of catches of yellowtail flounder and their associated net efficiency parameters.

Length Group (cm)	Main Codend	Experimental Bags Port	Bosom	Starboard	Main/Total Bag+Main	Net efficiency %
4-7	5	28	14	18	5/65	8
8-11	40	483	981	272	40/1776	2
12-15	86	726	2974	473	86/4259	2
16-19	188	473	1946	288	188/2895	6
20-23	293	150	700	65	293/1208	24
24-27	1498	155	591	85	1498/2329	64
28-31	1281	95	372	39	1281/1787	72
32-35	256	11	32	1	256/300	85
36-39	167	9	19	4	167/199	84
40-43	116	4	15	0	116/135	86
44-47	72	3	13	4	72/92	78
48-51	24	0	12	0	24/36	67
52-55	1	1	0	0	1/2	50
Total	4027	2138	8318	1249	4028/15731	

Table 4. Length frequency distribution of catches of thorny skate and their associated net efficiency parameters.

Length Group (cm)	Main Codend	Experimental Bags Port	Bosom	Starboard	Main/Total Bag+Main	Net efficiency %
12-17	0	4	2	1	0/7	0
18-23	10	13	15	18	10/56	18
24-29	10	16	18	17	10/61	16
30-35	17	15	16	10	17/58	29
36-41	29	12	14	4	29/59	49
42-47	24	11	30	5	24/70	34
48-53	17	11	29	0	17/57	30
54-59	26	11	17	1	26/55	47
60-65	20	6	22	4	20/52	38
66-71	27	10	18	2	27/57	47
72-77	25	11	23	4	25/63	40
78-83	6	11	2	1	6/20	30
84-89	4	2	2	0	4/8	50
Total	217	133	208	67	217/625	

Table 5. Comparison of mean length of species caught in the trawl (main) codend with those caught by the experimental bags.

	Main Codend			Experimental Bags Port			Bosom			Starboard		
Species	N	$\bar{x}$	Range	N	$\bar{x}$	Range	N	$\bar{x}$	Range	N	$\bar{x}$	Range
Cod	269	57.88	6-121	97	25.82	8-72	507	22.38	11-97	24	27.13	13-67
Plaice	2624	36.65	13-75	1100	20.38	5-68	1158	20.84	5-68	804	21.07	5-66
Y'tail	4027	27.63	6-52	2137	15.83	6-45	8318	16.79	6-51	1249	15.44	6-45
T. Skate	217	52.91	18-87	133	47.35	16-88	208	49.63	16-89	67	34.82	17-80

Table 6. Results of the Mann-Whitney U statistical test comparing mean catches in the trawl (main) codend with the mean catches in the experimental bags (α = .05).

Species	Gear	Mean Catch	Mean Score	Z Value	P
Numbers					
Cod	Main	11.25	40.28	1.5590	.1190
	Bags	11.02	32.09		
Plaice	Main*	100.20	55.90	2.4852	.0129*
	Bags	47.27	40.74		
Y'tail	Main	222.50	15.10	-0.8897	.3736
	Bags	298.33	18.50		
T. Skate	Main	7.55	36.27	0.0692	.9448
	Bags	7.37	35.88		
Weight (kg)					
Cod	Main*	29.64	53.03	4.9856	.0001*
	Bags	2.20	26.78		
Plaice	Main*	55.67	63.98	4.3279	.0001*
	Bags	8.38	37.59		
Y'tail	Main	55.24	19.40	0.6994	.4843
	Bags	17.27	16.71		
T. Skate	Main	15.98	42.23	1.7001	.0891
	Bags	11.83	33.20		

Table 7. Results of Kruskal-Wallis one-way analysis of variance on comparison of mean bag catches by species (d = .05).

Species	Gear	Mean Catch	Mean Score	K-W test	P
Numbers					
Cod	Port	5.13	23.28	12.10	.0024*
	Bosom*	21.15	31.65		
	Starboard	2.00	14.21		
Plaice	Port	46.78	28.70	1.55	.4612
	Bosom	54.52	35.24		
	Starboard	40.20	34.00		
Y'tail	Port	157.50	11.13	1.00	.6076
	Bosom	516.78	14.33		
	Starboard	178.43	11.71		
T. Skate	Port	7.56	22.28	1.79	.4080
	Bosom	7.86	27.98		
	Starboard	6.09	23.00		

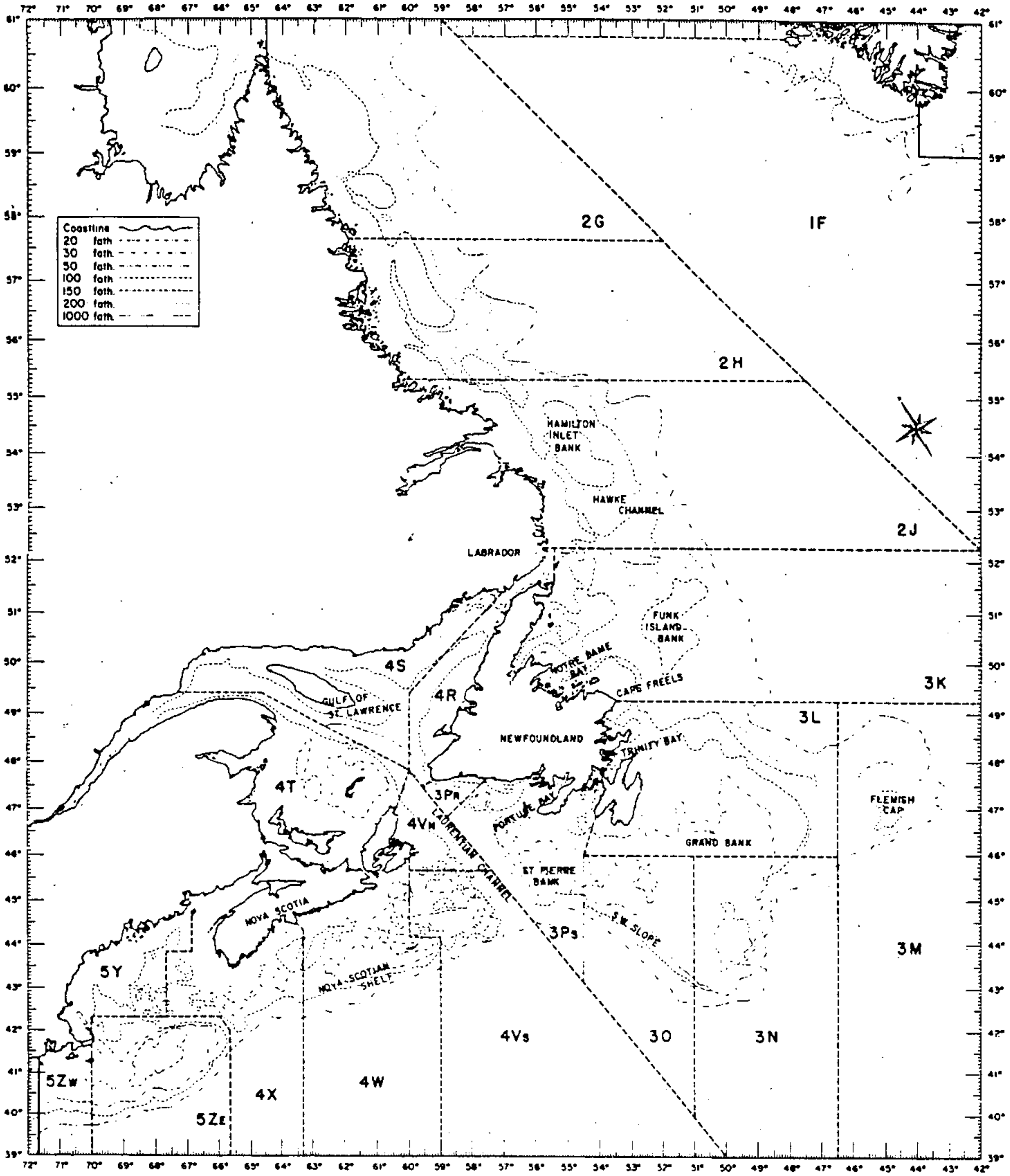


Fig. 1. Chart of the Grand Banks off the Newfoundland coast.

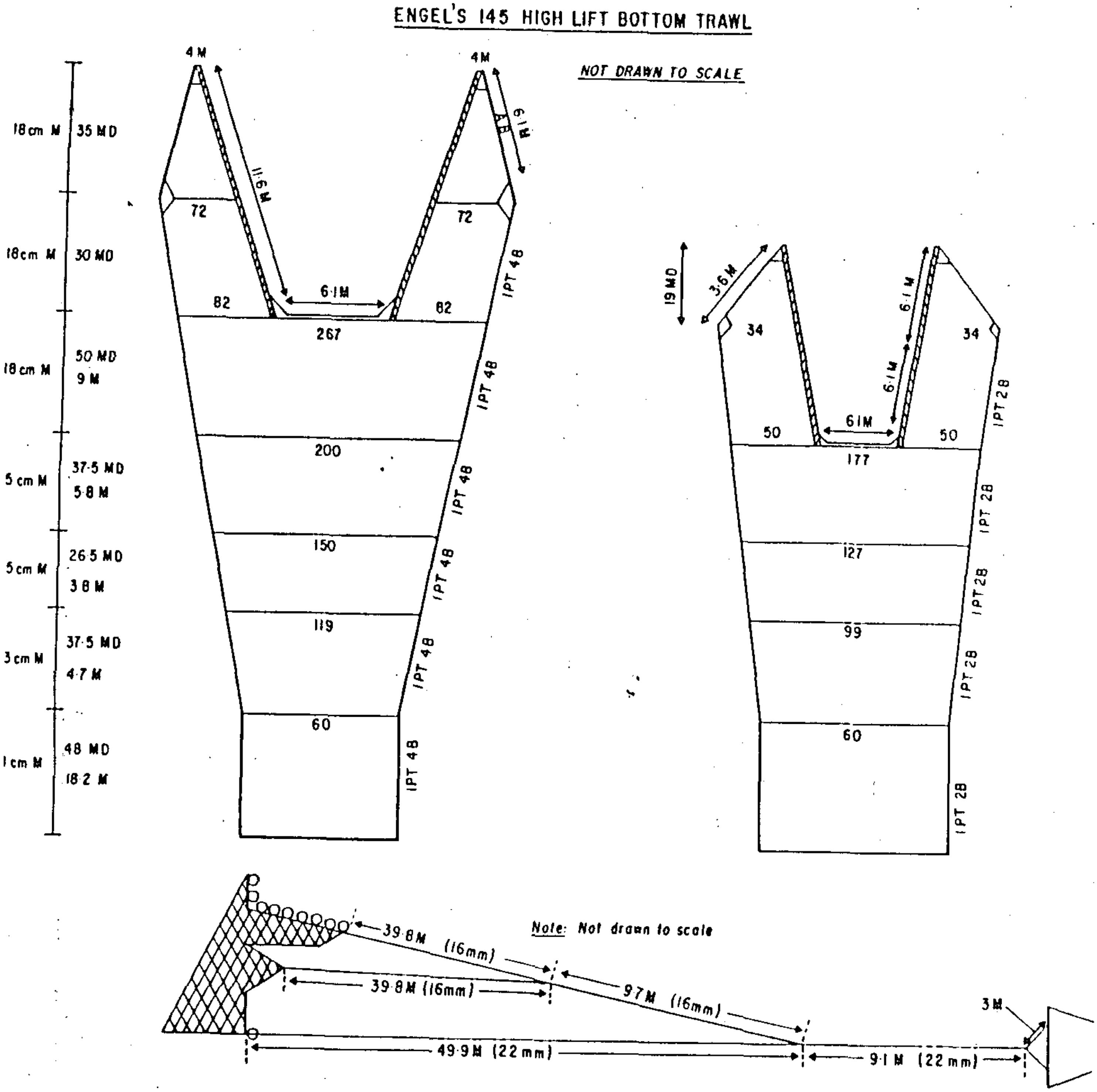


Fig. 2. Schematic diagram of the Canadian survey groundfish trawl used in the Newfoundland Region.

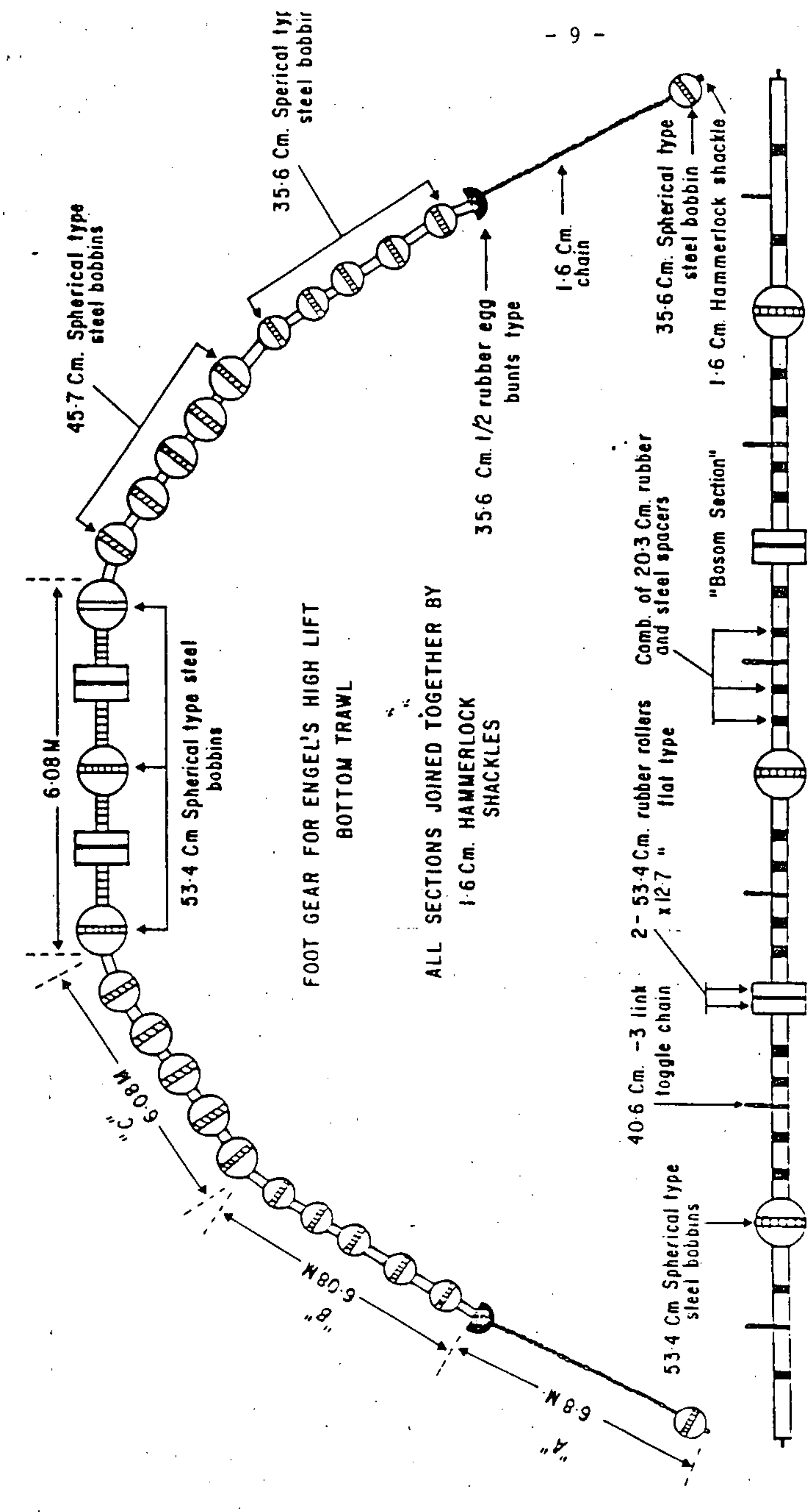


Fig. 3. Schematic diagram of the footgear of the Engel 145 High Rise groundfish

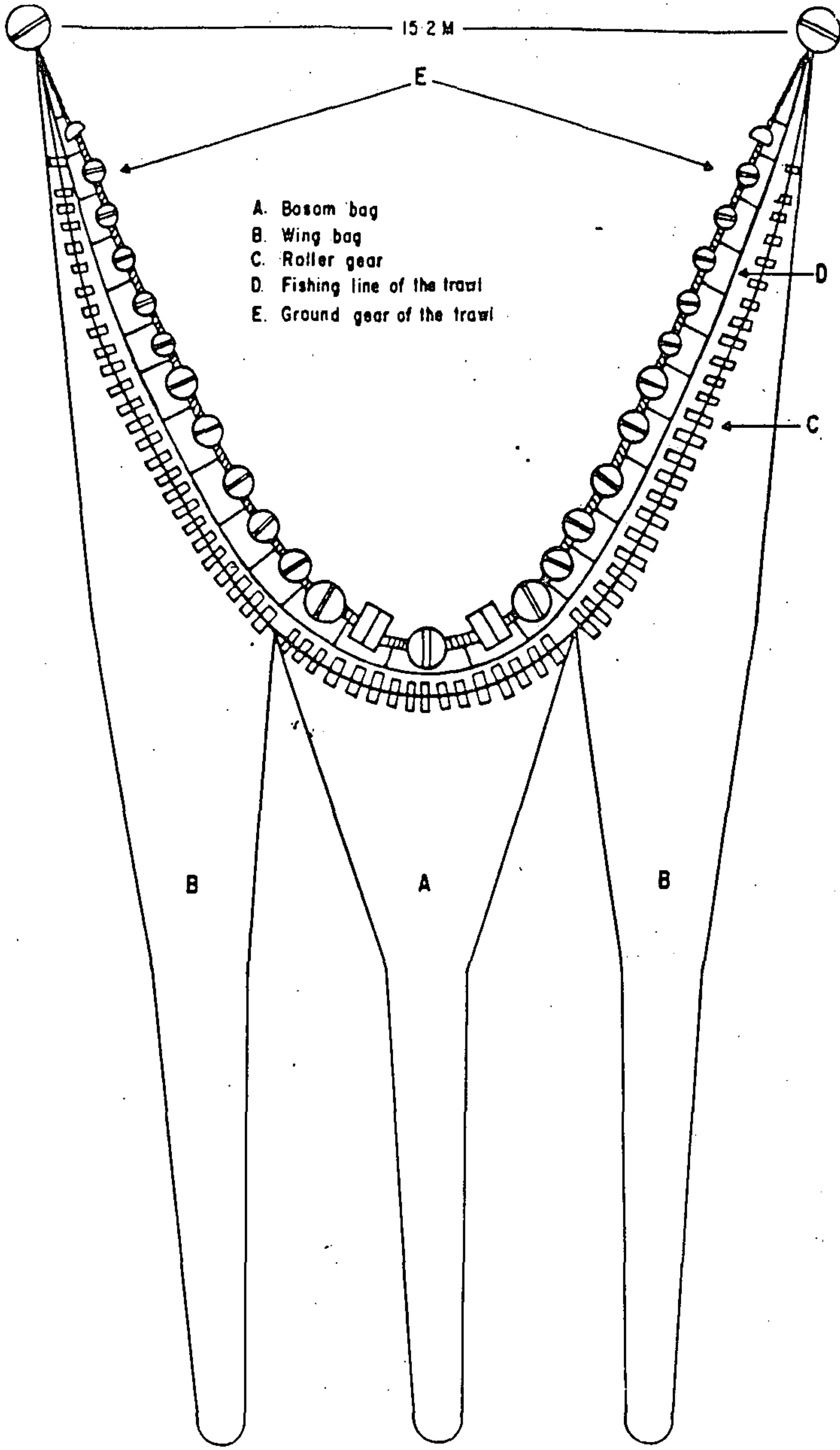


Fig. 4. Schematic diagram of the three trawl bags attached to the main trawl's footgear.

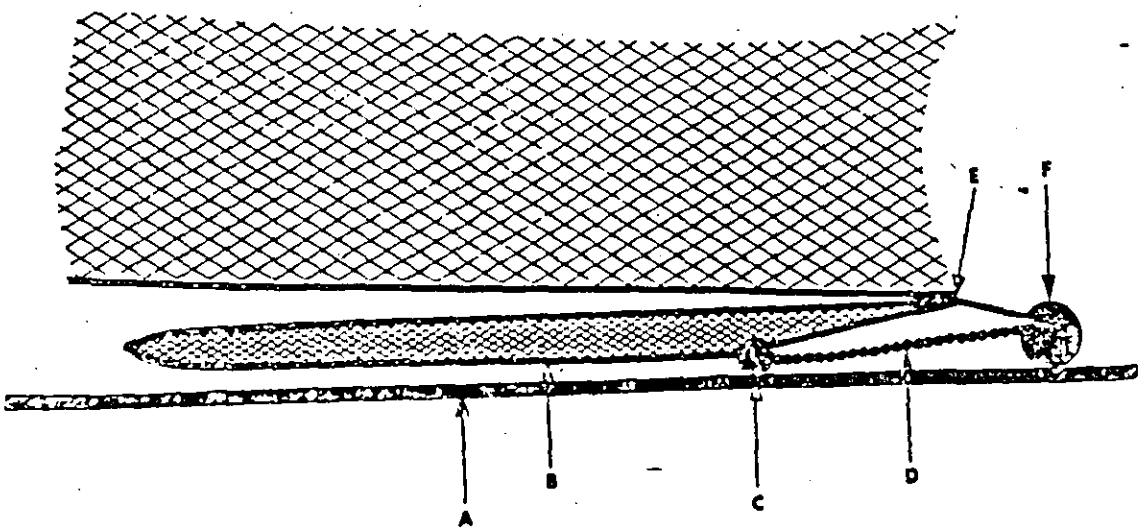


Fig. 5. Schematic presentation of the bags under the trawl from the side.

A - bottom

B - bag

C - roller gear for bottom protection

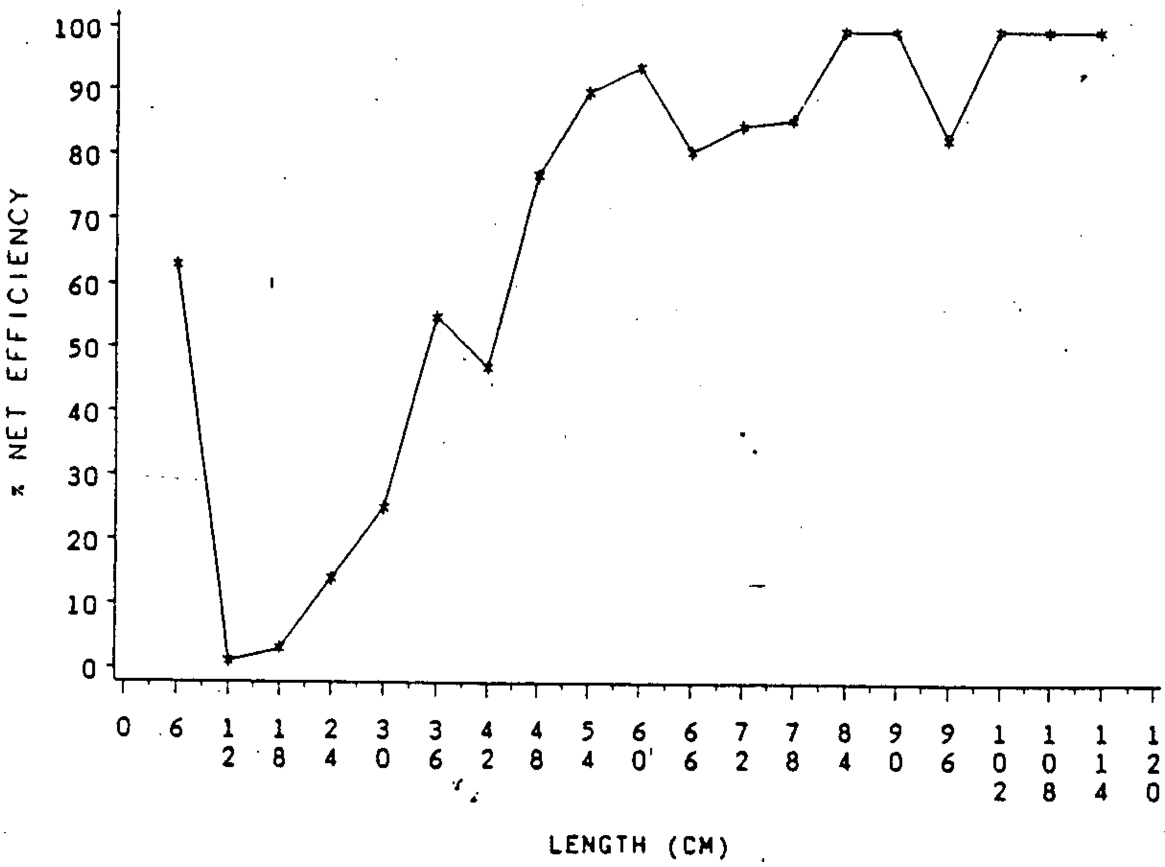
D - chain connection between bobbins and roller

E - headline of the bag/fishing line of the trawl

F - bobbins

(reprinted from Engas and GodØ,1986)

ATLANTIC COD



SPECIES=Atlantic Cod

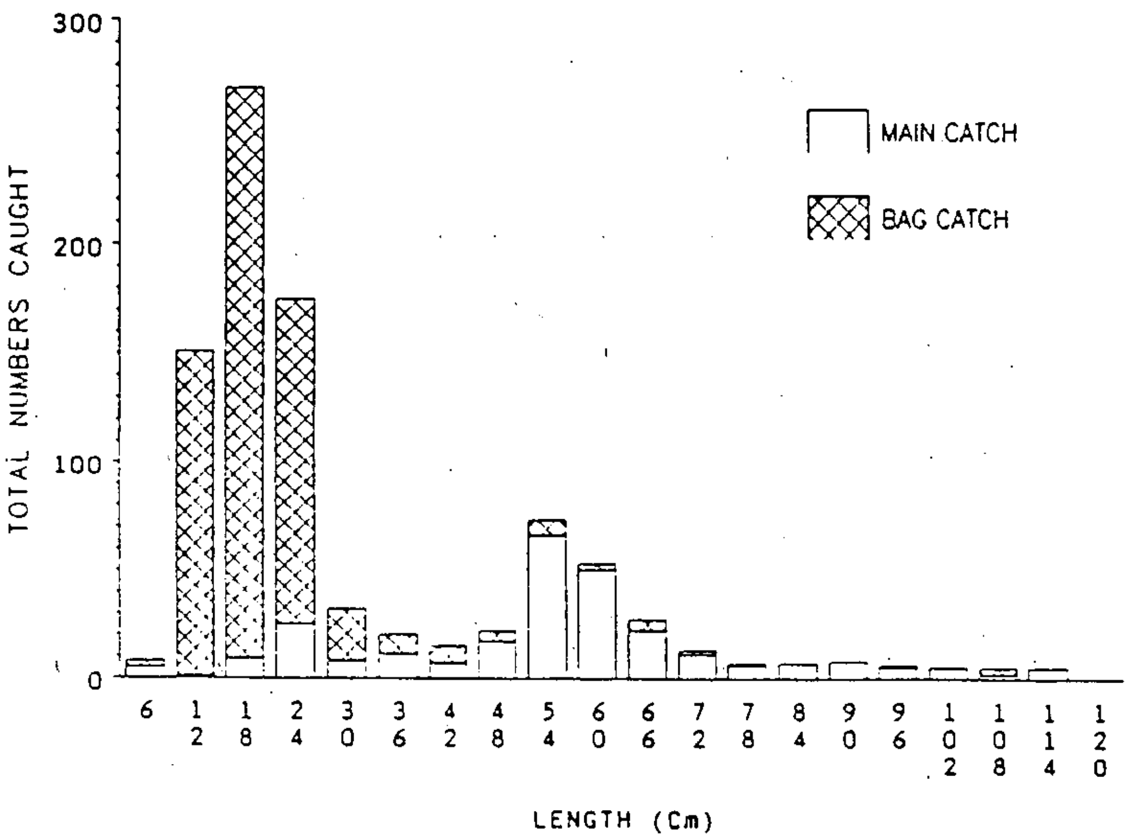
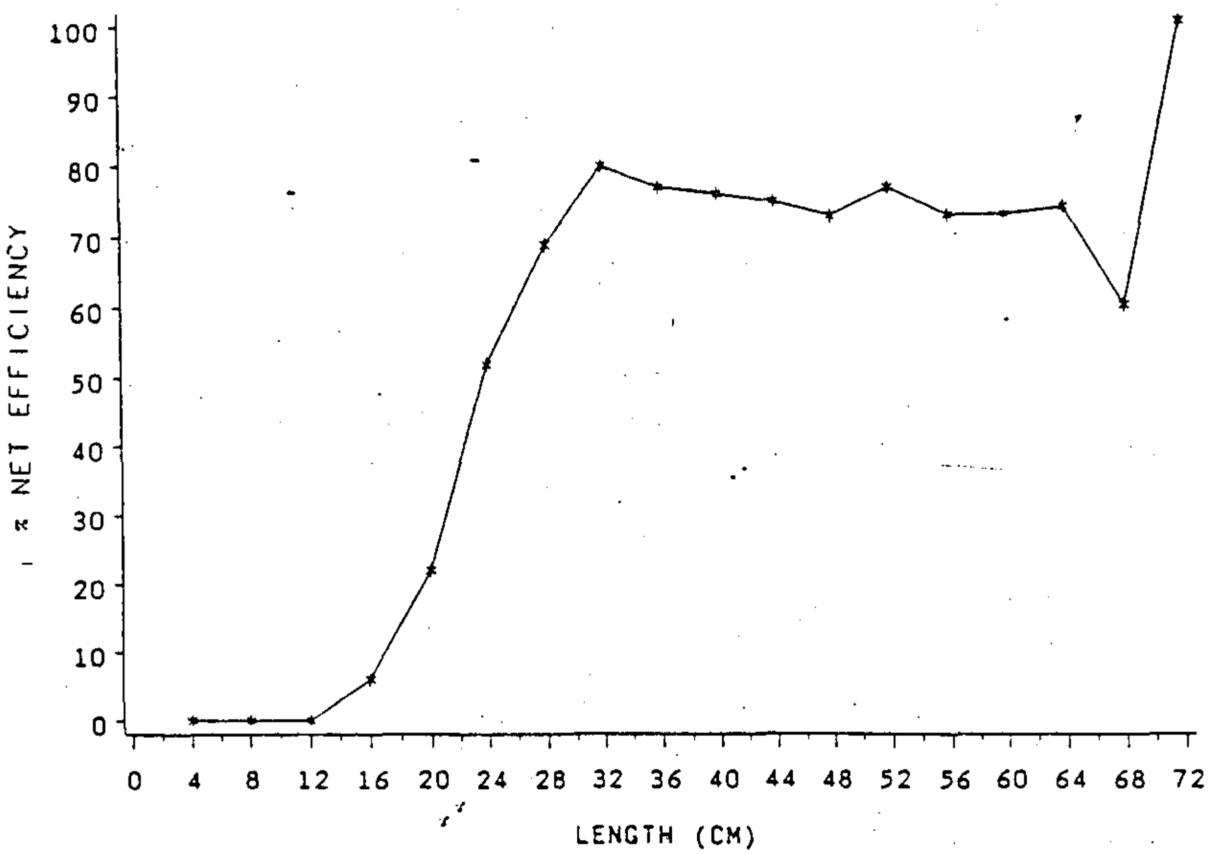


Fig. 6. Length frequency distribution and net efficiency parameter estimates

AMERICAN PLAICE



SPECIES=American Plaice

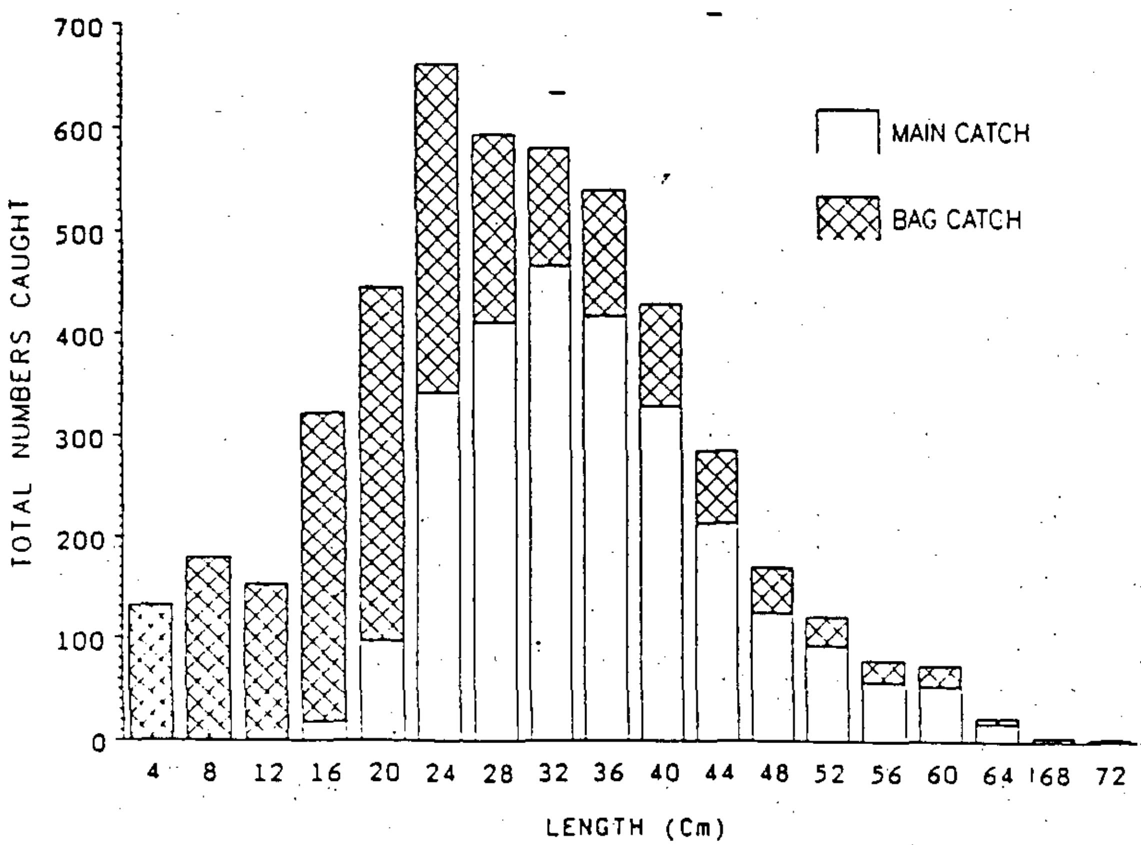
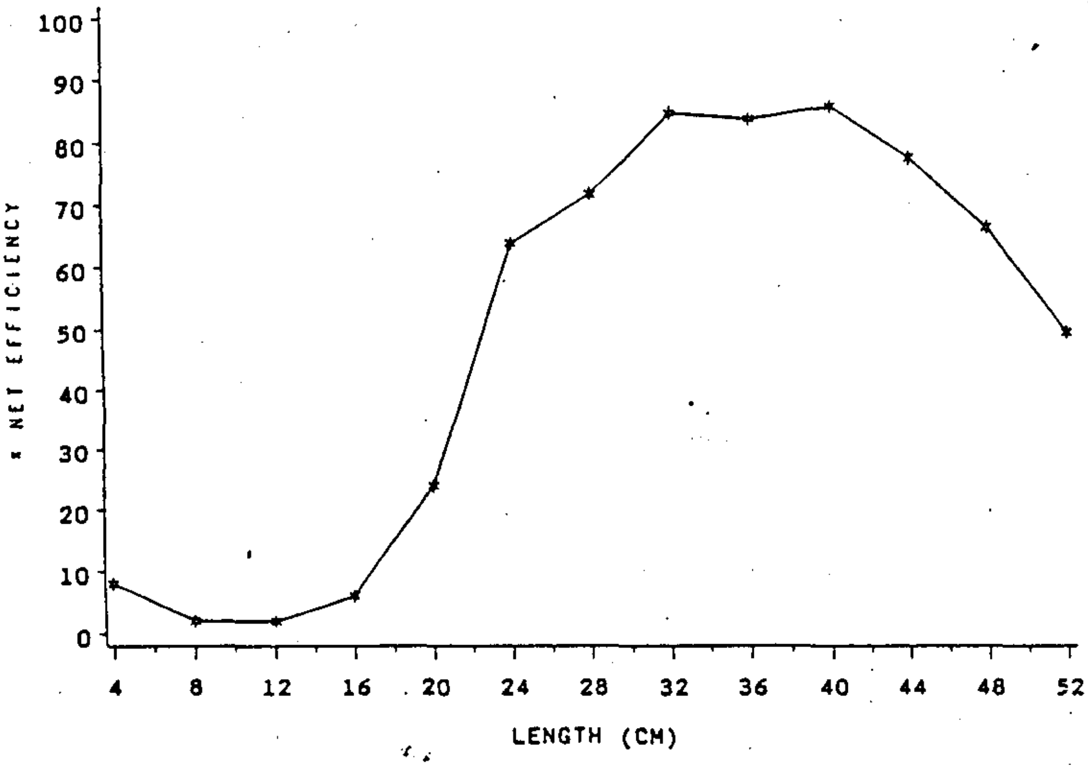


Fig. 7. Length frequency distribution and net efficiency parameter estimates for plaice.

YELLOWTAIL FLOUNDER



SPECIES=Yellowtail Flounder

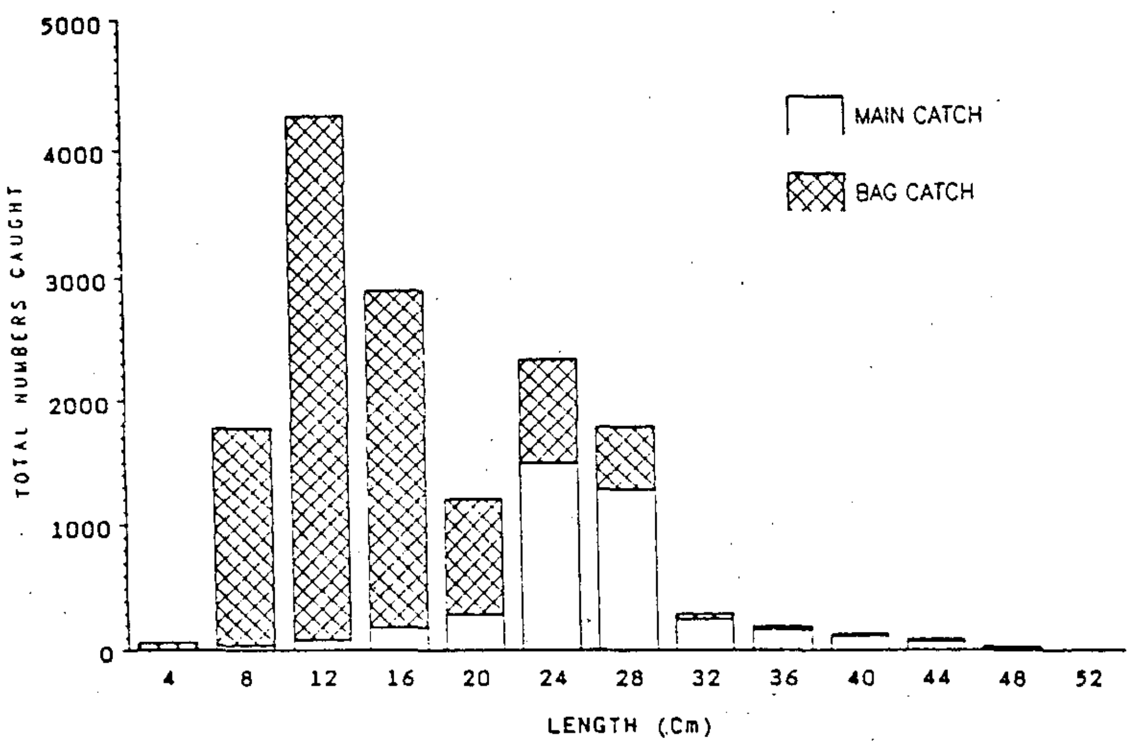
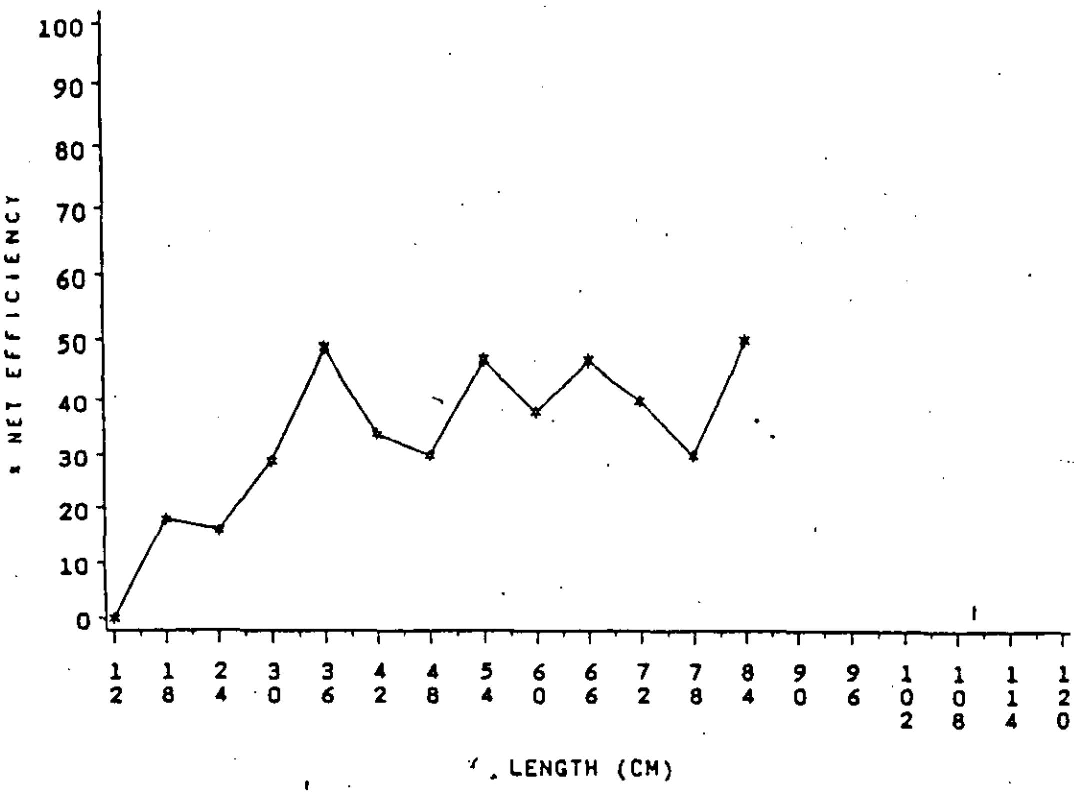


Fig. 8. Length frequency distribution and net efficiency parameter estimates for yellowtail.

THORNY SKATE



SPECIES=Thorny Skate

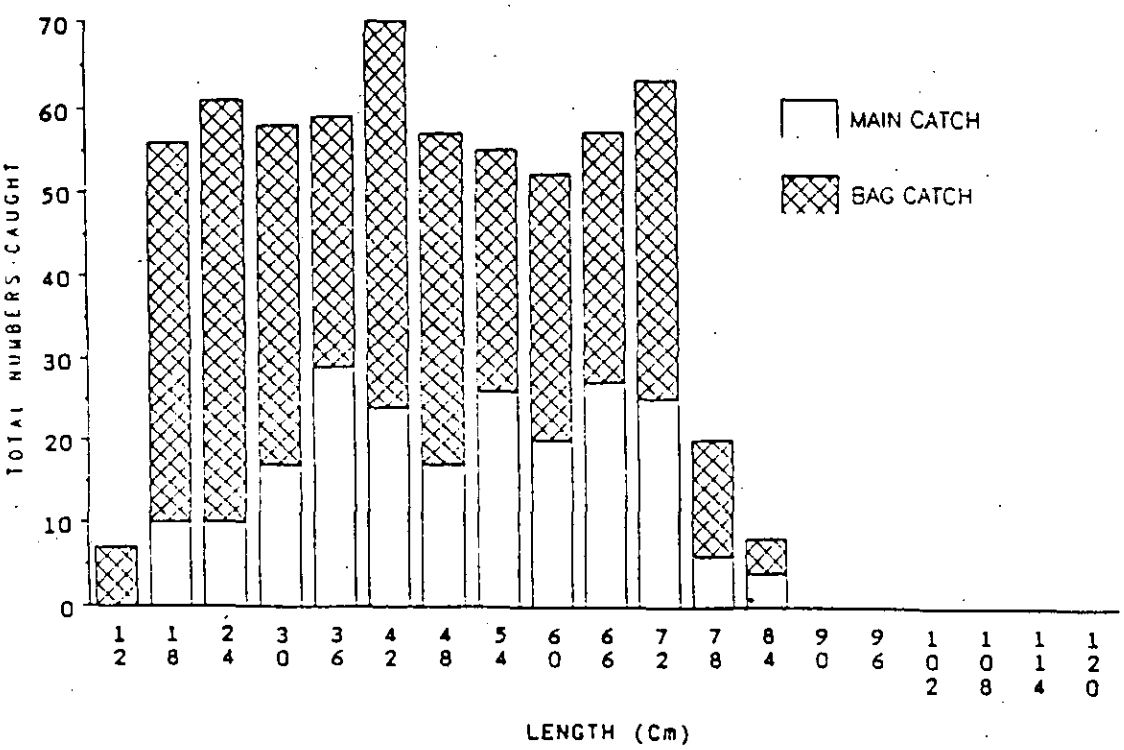


Fig. 9. Length frequency distribution and net efficiency parameter estimates for thorny skate.