COMPARISON OF THE CAPTURE EFFICIENCY OF 0-GROUP FISH IN PELAGIC TRAWLS

by

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ABSTRACT

In 1992 and 1993 experiments were carried out during the international 0-group fish surveys in order to study the capture efficiency of two pelagic trawls. The catches of the standard sampling trawl were compared with those of a special 0-group fish trawl under construction. The results support and strengthen the conclusions arrived at in earlier works; Catches of 0-group cod and haddock in the standard sampling trawl show largely skewed length distributions, the smaller fishes being undersampled relativly to the larger ones, and the new trawl caught 0-group cod in the length range 5-10 cm 3-4 times more efficient than the standard sampling trawl. A significant density dependent catch efficiency is, however apparent for both trawls.

INTRODUCTION

The standard pelagic trawl (ST) used in the annual investigations of 0-group fish in the Barents Sea and adjacent waters is a commercial type trawl designed for small vessels catching spawning capelin in the winter fishery. In recent years the capture efficiency of this trawl for 0-group fish has been investigated and compared with that of various versions of an experimental trawl (ET) particularly designed at the Institute of Marine Research for catching 0-group fish (Godø *et al.* 1993, Godø and Valdemarsen 1993).

During the 0-group surveys in 1992 and 1993 comparative trawlings were conducted with the standard trawl and two versions of the experimental trawl (one version each year) at locations with relatively high density of 0-group fish, mainly cod. Acoustic recordings of the 0-group fish scattering layers were sampled and processed for all comparative trawl hauls. The present paper includes the analyses of the material and a discussion of the results.

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MATERIAL AND METHODS

Field sampling and postprocessing

Locations, dates and vessels as well as the number of trawl hauls carried out appear from Figure 1.

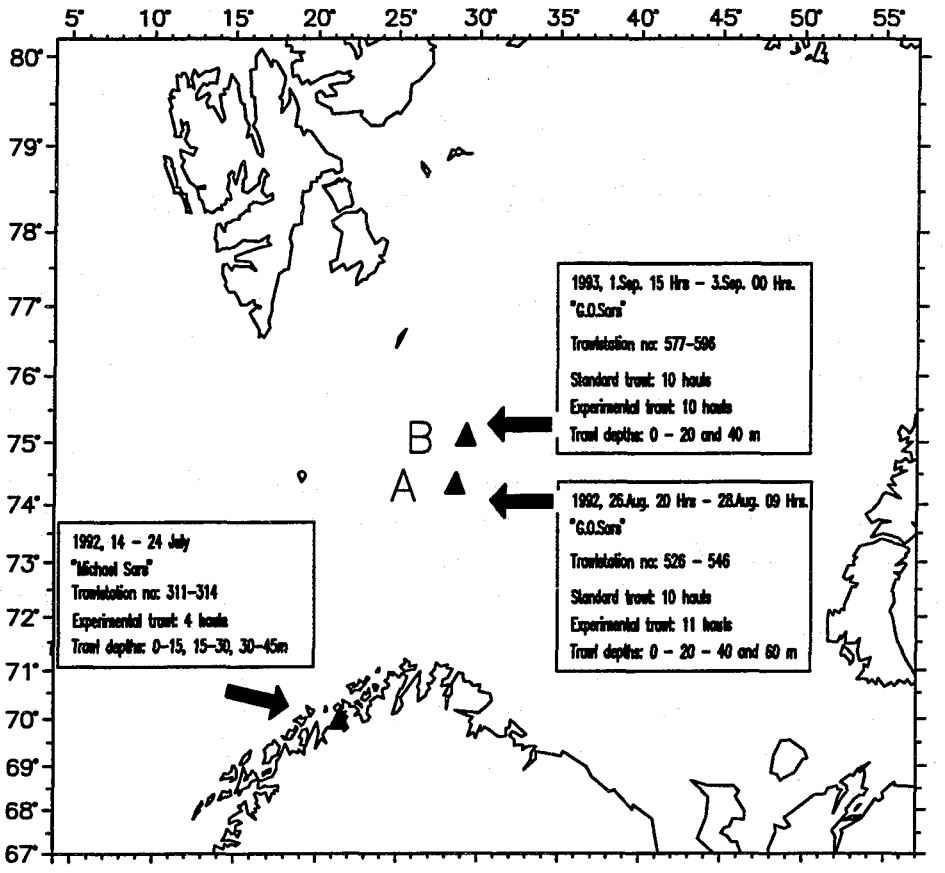

Figure 1. Location and particulars of trawl experiments in 1992 and 1993.

Area back scattering values, s_a, were sampled continously and analyzed with the BEI-system (Knudsen 1990, Foote *et al.* 1991). 0-group herring was separated (Nakken *et al.* 1995) and mean S_A-values of 0-group fish were established within 10 m depth intervals for every trawl haul. Trawl catches were sampled and analyzed according to the standard procedure adopted for the 0-group surveys.

The investigations in 1992 were carried out with the standard 0-group trawl and with an experimental trawl consisting of three equal small trawls on the top of each other (Godø and Valdemarsen 1993). The two trawls were used alternately, all haulings starting in the same position and being in the same direction. Each haul was conducted as a standard 0-group haul; i.e. 10 minutes towing with the headline in each of four depths, 0-20-40 and 60 m, starting at the surface.

In order also to cover low to medium density situations for cod, 28 selected stations worked during the western part of the 1992 international 0-group survey, using the standard sampling trawl are added to the experiments in the analysis of catch efficiency for this trawl. Similarly,

4 stations worked with the experimental trawl from R/V "Michael Sars" in Ullsfjord, 1992, on a low density layer of pure cod 0-group are included in the analysis of catch efficiency.

In 1993 a different version of the experimental trawl, described by Valdemarsen and Misund (1995), was compared with the standard trawl. Trawlings were carried out as standard 0-group hauls with the headline in 50-40-30-20-10 and 0 m, 5 min. towing in each depth. Each trawl was towed two hauls in succession back and forth along the same line.

Computations

In order to obtain comparable figures both the acoustic data and the trawl catches were converted to surface or column densities, ρ_A (number per unit area) as follows:

Acoustics. The density, ρ_A (number per nm^2) was estimated applying the usual equation:

$$\rho_A = \frac{S_A}{<\sigma>} \tag{1}$$

were S_A (m^2/nm^2) is the scattering by 0-group fish during trawling,
$<\sigma>$ is the mean back scattering cross section of the specimens of 0-group fish.

The commonly accepted relationship between the back scattering cross section of cod and fish length

$$10log\frac{\sigma}{4\pi} = 20logL - 68 \tag{2}$$

which gives

$$<\sigma> = 2.0 \cdot 10^{-6} \cdot \overline{L^2} \tag{3}$$

was used to compute $<\sigma>$ from the length distributions in Figure 2.

Trawlcatches. The density, ρ_A (number per nm^2) was estimated by dividing the trawl catch, C (number) with the swept area, A (nm^2):

$$\rho_A = \frac{C}{A} \tag{4}$$

The swept area was defined as the volume filtered by the trawl during the total tow (all depths) divided by the depth extension of the observed water column:

$$A = \frac{D \cdot a}{d} \tag{5}$$

were
- D: total distance towed (nautical miles)
- a: filtering area of trawl mouth (Ona, 1989, Godø and Valdemarsen 1993, Valdemarsen and Misund 1995)
- d: depth extension of observed water column (m).

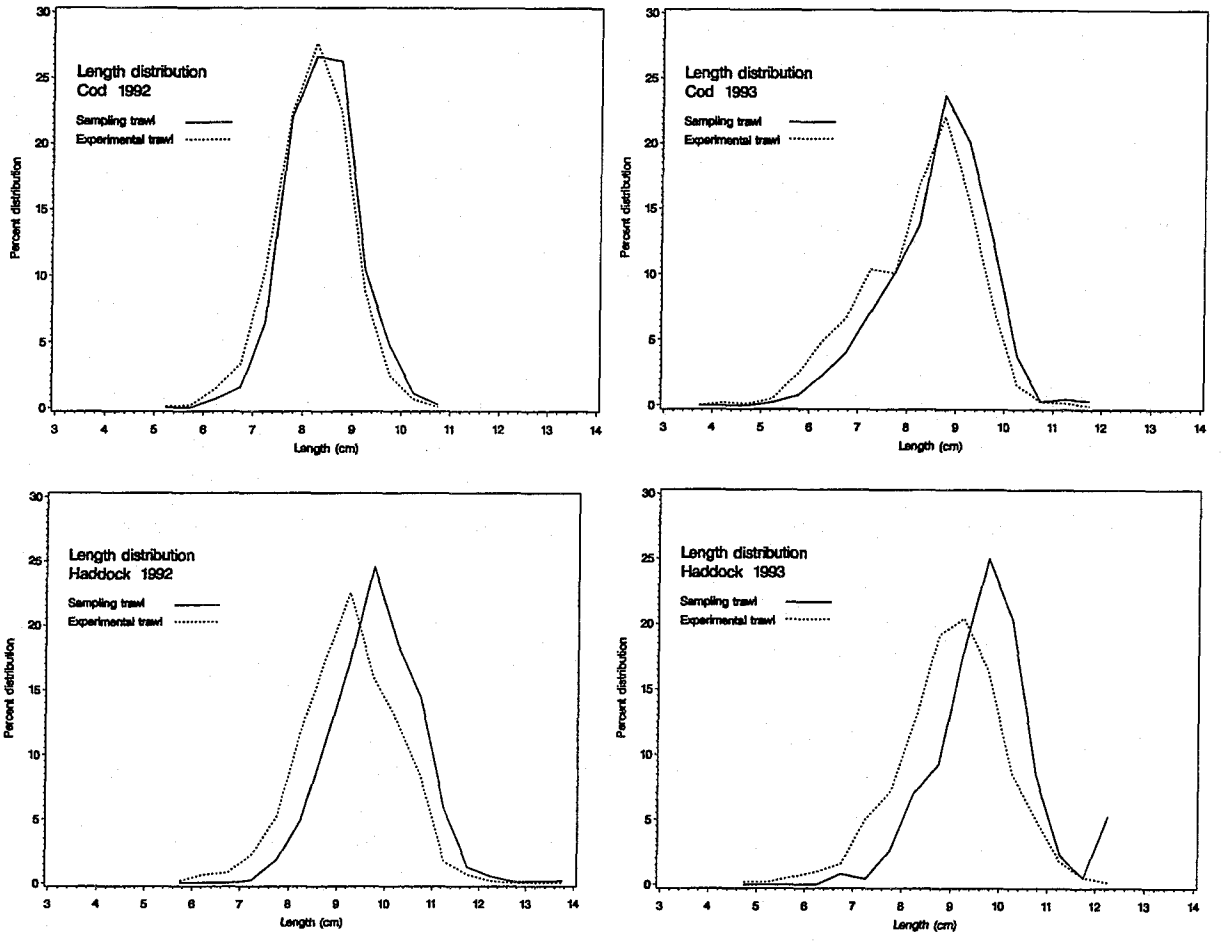

Figure 2. Length distributions of 0-group cod and haddock in the two experiments.

Table 1. Average length (mm) of 0-group cod and haddock at location A, 1992.

	STANDARD TRAWL (10 hauls)	EXPERIMENTAL TRAWL (11 hauls)			
		Total	Upper	Middle	Low
Cod					
All hauls	84	81	82	80	83
Lower value (1 haul)	81	78	78	73	79
Upper value (1 haul)	87	84	85	85	85
Haddock					
All hauls	98	94	93	95	95
Lower value (1 haul)	95	85	79	86	80
Upper value (1 haul)	100	96	100	99	96

Length selection. The length distributions of both 0-group cod and haddock differed between the two types of trawls in both experiments (Figure 2). Mean lengths of catches with the standard trawl were higher than those of the experimental trawl both years (Tables 1 and 2). In order to study and quantify these differences in length selection the following method was used (Millar 1991: The volume density (ρ) of fish in each length group (5mm) was calculated and averaged over 10 hauls for each trawl.

$$\rho = \frac{1}{10} \sum_{j=1}^{10} \frac{C_{j,L}}{D \cdot a} \qquad (6)$$

Where $C_{j,L}$ is the catch in number in haul j and length group L.

Table 2. Average length of 0-group cod (mm) at location B, 1993.

	STANDARD TRAWL (10 hauls)		EXPERIMENTAL TRAWL (10 hauls)	
	Cod	Haddock	Cod	Haddock
All hauls	87	95	79	90
Lower value (1 haul)	84	92	63	84
Upper value (1 haul)	89	97	87	95

The probability that any random fish in the sum of catches will occur in the catch of the standard sampling trawl is then

$$P_L^{(st)} = \frac{\rho_L^{(st)}}{\rho_L^{(st)} + \rho_L^{(et)}} \qquad (7)$$

We chose the following function as model for this probability

$$P_L^{(st)} = k \frac{e^{a+bL}}{1 + e^{a+bL}} \qquad (8)$$

and carried out 4 sets of maximum likelihood analyses in order to estimate k, a and b; for cod and haddock in each of the two years (A and B). The estimates of k, a and b are the values that maximize the expression:

$$\sum_L \left[\rho_L^{(st)} \cdot \log P_L^{(st)} + \rho_L^{(et)} \cdot \log (1 - P_L^{(st)}) \right] \qquad (9)$$

RESULTS AND DISCUSSION

The 1992 experiment

Catch numbers by species are given in Tables 3 and 4. 0-group cod was predominant in the catches of both trawls. 0-group herring was caught in much larger numbers in the standard trawl than in the experimental trawl (Table 3). The back scattering values of 0-group fish appear from Table 4 together with the catches of 0-group cod and haddock. It is seen that the variation in catch numbers of both trawls were much larger than the variation in back scattering values; the range being 2:1 for back scattering values and about 15:1 and 10:1 for the standard- and experimental trawls respectively.

Table 3. Summary of catch per haul (numbers) at location A, 1992. Occ. is the number of hauls with catch.

0-group	STANDARD TRAWL (10 hauls)			EXPERIMENTAL TRAWL (11 hauls)		
	Average	Range	Occ.	Average	Range	Occ.
Cod	9583	1677-25997	10	5599	973-10236	11
Haddock	221	54-418	10	65	22-138	11
Saithe	12	1-29	10	7	0-29	9
Herring	2368	0-13635	8	24	0-144	8
Others						
1+Herring	77	0-381	5	-	-	10
Jellyfish (liters)	75	11-147	10	62	127-170	11

Table 4. Values of back scattering in 0-100 m, S_A, and catch per haul (number) of 0-group cod and haddock in 1992.

St. No.	Time GMT	D. (n.m)	S_A m^2/nm^2	STANDARD TRAWL (a = 480m2)		EXPERIMENTAL TRAWL (a = 71m2)				
				Cod	Haddock	Cod;	Upper	Middle	Lower	Haddock
526	20	2,0	667	1815	112					
527	21	1,3	524			*8410	4789	2930	691	* 138
528	23	2,0	453			2777	533	650	1541	56
529	01	2,0	704	1677	54					
530	03	2,0	505			3780	940	1714	1126	47
531	05	2,0	506	3145	92					
532	08	1,8	442			4812	333	2158	2321	86
533	10	2,0	627	13336	248					
534	11	2,0	753			973	463	232	278	22
535	13	2,0	621	17600	342					
536	14	2,0	450			2733	506	1286	941	33
537	16	2,0	762	11186	160					
538	18	2,0	509			10236	1290	2962	5984	67
539	20	2,0	574	5746	193					
540	22	2,0	393			7057	3216	1874	1967	99
541	00	2,0	389	6057	290					
542	01	2,0	407			6869	1519	3711	1639	46
543	03	2,0	409	9270	299					
544	05	2,0	488			5562	1487	2361	1714	30
545	07	2,0	512	25997	418					
546	09	2,0	445			4642	1156	940	2546	88

* Data excluded from computations. Trawling depth not sufficient due to too small weights.

Figure 3 shows the vertical distribution of the 0-group fish scattering layer during the experiment. A certain tendency of diurnal variation can be observed; the scatterers were concentrated in a very dense layer of limited vertical extension during the afternooen and spread out into larger parts of the water column in the morning. With variations in distribution as shown in Figure 3 large variations in catches are to be expected even though the average density in the water column are fairly constant, particularly when the vertical opening of the trawl is less than the difference between the towing depths.

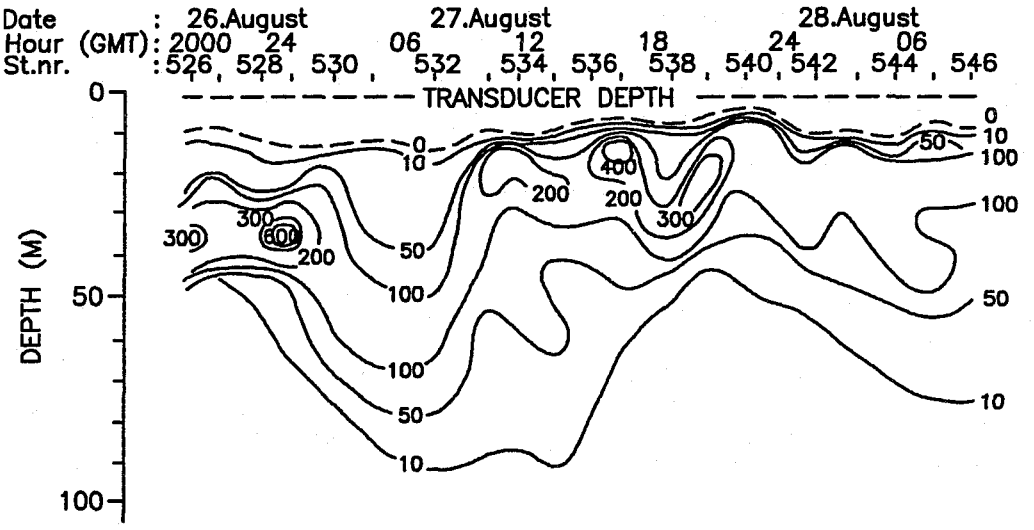

Figure 3. Distribution by depth and time of 0-group fish (mainly cod) back scattering at location A, 1992.

Table 5. Estimated densities (10-6· number per nm^2) of 0-group cod for each trawl haul at location A, 1992.

STANDARD TRAWL				EXPERIMENTAL TRAWL			
		Swept area				Swept area	
St.No.	Acoustics	Cod	Haddock	St.No	Acoustics	Cod	Haddock
526	4,2	0,26	0,02	528	2,9	2,75	0,06
529	4,5	0,25	0,01	530	3,5	3,75	0,05
531	3,2	0,46	0,01	532	3,1	5,30	0,09
533	4,0	1,96	0,04	534	5,2	0,96	0,02
535	3,9	2,58	0,05	536	3,1	2,71	0,03
537	4,8	1,64	0,02	538	3,5	10,14	0,07
539	3,6	0,84	0,03	540	2,7	6,99	0,09
541	2,5	0,89	0,04	542	2,8	6,81	0,05
543	2,6	1,35	0,04	544	3,4	5,51	0,03
545	3,2	3,81	0,06	546	3,1	4,60	0,09
Average (10)	3,7	1,40	0,032	Average (10)	3,4	4,95	0,058
Range (10)	2,5-4,8	0,25 3,81	0,01 0,06	Range (10)	2,7-5,2	0,96 10,14	0,02 0,09
Average (8)	3,7	1,25	0,031	Average (8)	3,2	4,80	0,059
Range (8)	2,6-4,5	0,26 2,58	0,01 0,05	Range (8)	2,8-3,6	2,71 6,99	0,03 0,09

Estimates of fish density (numbers per unit area) are given in Table 5 for each trawl. On an average the densities estimated from the catches of the standard sampling trawl were about 30-40 percent of the "acoustic" density while the average density estimated from the catches of the experimental trawl exceeded the average "acoustic" density by about 50 percent.

When comparing the average densities for the two trawls it seems that the experimental trawl caught 0-group cod 3-4 times more efficient than did the standard sampling trawl.

The 1993 experiment

Catch numbers by species are given in Tables 6 and 7. Also this year 0-group cod dominated in the catches of both trawls. By comparing Tables 3 and 6 it appears as if the version of the experimental trawl used this year caught both haddock and herring more efficient than the version used in 1992 when the catches of the standard trawl are used as reference.

Table 6. Summary of catch per haul (numbers) at location B, 1993. Occ. is the number of hauls.

0-group	STANDARD TRAWL (10 hauls)			EXPERIMENTAL TRAWL (10 hauls)		
	Average	Range	Occ.	Average	Range	Occ.
Cod	1041	293-2180	10	664	49-1988	10
Haddock	66	12-174	10	59	0-122	9
Saithe	3	0-8	8	+	0-2	2
Herring	551	288-3292	4	156	0-901	6
Others						
1+Herring	47	0-260	7	22	0-176	7
Jellyfish (liters)	100	40-180	10	41	20-60	10

Both the acoustic back scattering values and the catches were on an average significantly lower than in 1992 (Tables 4 and 7) and the back scattering showed a much more pronounced variation. The range in back scattering values over the experiment was 50:1 and considerably larger than the range in catches, 7:1 for the standard sampling trawl and about 27:1 for the experimental trawl. The estimates of fish density (Table 8) show results in accordance with those obtained in 1992 (Table 5) when the estimates from the trawl catches are compared. The experimental trawl seem to have caught 0-group cod and haddock 3-4 times more efficient than the standard sampling trawl. However, in 1993 both trawls generated much lower average densities than did the acoustics and using the trawl estimates as reference it appears as if the acoustic method was several times more "efficient" in 1993 than in 1992. A possible reason for this apparent discrepancy might be that high density fish concentrations are herded by otterboards and sweep lines to a much greater extent than low density concentrations. If so, then the actual "mouth area" of the trawls might have been larger than estimated in 1992, when fish densities were much higher than in 1993.

When summarizing the results on trawl efficiency for both trawls (Figures 4a and b) the indicated density dependency, or apparent "increased mouth area for high densities" is significant for both trawls. The experimental trawl has a higher efficiency than the standard trawl for high densities, but at low densities its catch efficiency is low and variable.

Table 7. Towing distance D, back scattering in 0-100 m, S_A and catch per haul (number) of 0-group cod and hadock in location B, 1993.

St. No.	Time GMT	D. (n.m)	S_A m^2 / nm^2	STANDARD TRAWL (a = 480m²) Cod	STANDARD TRAWL (a = 480m²) Haddock	EXPERIMENTAL TRAWL (a = 100m²) Cod	EXPERIMENTAL TRAWL (a = 100m²) Haddock
577	15	1,5	813	1457	113		
578	18	1,1	263			1988	120
579	19	1,2	173	309	174		
580	04	1,2	352			23	75
581	06	0,8	266			191	59
582	07	1,2	162	516	39		
583	08	1,2	124	781	12		
584	10	1,0	267			49	24
585	11	1,0	206			103	52
586	12	1,5	229	1464	99		
587	13	1,3	399	1172	56		
588	14	1,1	97			544	51
589	16	0,9	129			579	122
590	17	1,3	16	293	13		
591	18	1,5	35	1005	57		
592	19	1,0	194			1558	51
593	20	1,0	147			652	16
594	21	1,5	255	2180	32		
595	22	1,5	594	1228	63		
596	00	0,8	78			547	21

Table 8. Estimated densities (10^{-5}· number per nm^2) of 0-group cod and haddock for each trawl haul at location B, 1993.

STANDARD TRAWL				EXPERIMENTAL TRAWL			
		Swept area				Swept area	
St.No.	Acoustics	Cod	Haddock	St.No	Acoustics	Cod	Haddock
577	60,2	2,2	0,2	578	19,5	20,1	1,2
579	13,4	0,6	0,3	580	27,3	2,1	0,7
582	12,7	1,0	0,1	581	20,8	2,7	0,8
583	12,7	1,5	+	584	27,2	0,5	0,3
586	17,5	2,3	0,2	585	15,7	1,1	0,6
587	28,3	2,1	0,1	588	6,9	5,5	0,5
590	1,1	0,5	+	589	9,1	7,1	1,5
591	2,5	1,5	0,1	592	14,1	1,7	0,5
594	17,0	3,4	0,1	593	9,8	7,2	0,2
595	43,0	1,9	0,1	596	5,7	7,6	0,3
Average (10)	18,8	1,7	0,1	Average (10)	15,6	5,6	0,7
Range (10)	1,0-54,9	0,5-3,4	+-0,3	Range (10)	5,7-27,3	0,5-20,1	0,2-1,5
Average (8)	16,6	1,6	0,1	Average (8)	15,4	4,4	0,5
Range (8)	2,2-39,9	0,6-2,2	0,1-0,2	Range (8)	6,9-27,2	1,1-7,6	0,3-1,2

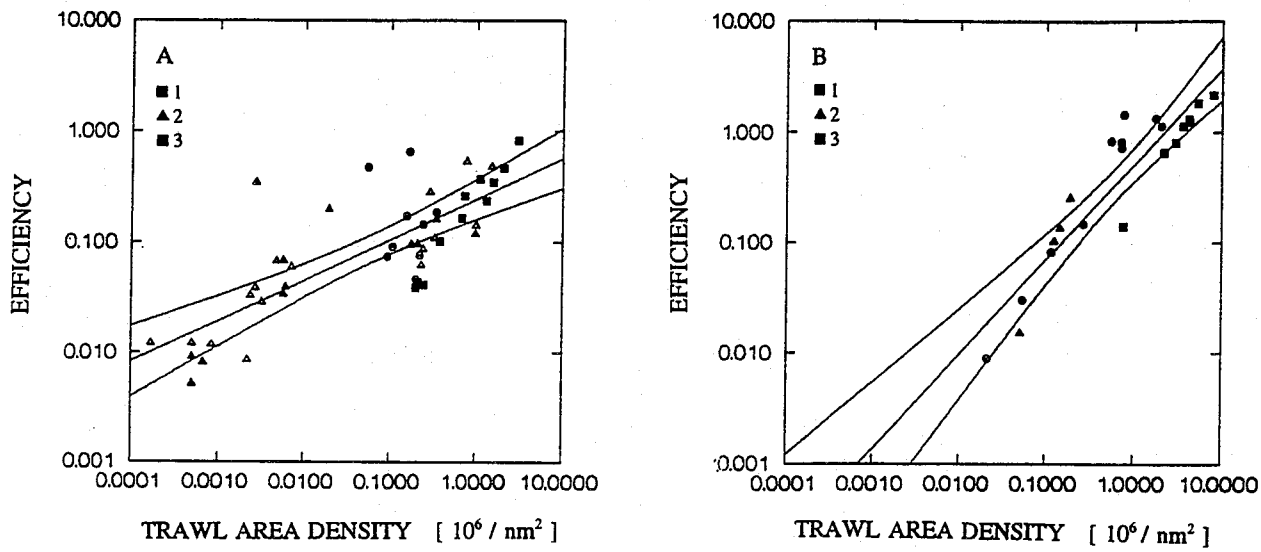

Figure 4a. Standard trawl efficiency (trawl area density/acoustic area density) as a function of trawl area density 1: 1992 experiment, 2: 1993 experiment, 3: stations from 0-group survey 1992.

Figure 4b. Experimental trawl efficiency (trawl area density/acoustic area density) as a function of trawl area density 1: 1992 experiment, 2: 1993 experiment, 3: stations from Ullsfjord.

Accordingly, 0-group abundance will be underestimated with both trawls in years with low abundance, and when the 0-group is well dispersed. In years with high, or spatially aggregated 0-group abundance, however, the experimental trawl is more efficient than the standard trawl, and also seems to be less variable. The results obtained are most likely due to density dependent herding, either in front of the mouth area in the sweeping zone of the trawl, or inside the trawl itself. As differences in efficiency for size and density are undesirable effects in sampling trawls, this should be further studied in order to reduce the effect.

Length and species selection

The results of the selection studies for 0-group cod and haddock are given in Figure 5. The horizontal line at P=0,5 means equal catch efficiency of the two trawls, i.e. that the estimate of fish density for the standard trawl equals that of the experimental trawl. Hence the intercept between the solid curve and this line indicate the fish length for which the two trawls generate equal fish densities. For fish lengths less than that corresponding to the intercept the standard sampling trawl is less efficient than the experimental trawl. It appears that for 0-group cod both versions of the experimental trawl were more efficient than the standard sampling trawl over the whole length range observed. For haddock, however, particularly the 1992 data set indicate that at lengths above 11 cm the standard trawl became more efficient than the sampling trawl, probably because these rather large fishes avoided the small mouth area of the experimental trawl that year. The ratio fish density standard sampling trawl/fish density experimental trawl by length can be read directly from the figures by the dotted curve. It shows that for lengths of 0-group cod and haddock in the range 5-11 cm the catching efficiency of the standard sampling trawl changes significantly, from a few to 10 percent for the lower lengths and 80-100 percent of the larger length of that of the experimental trawl.

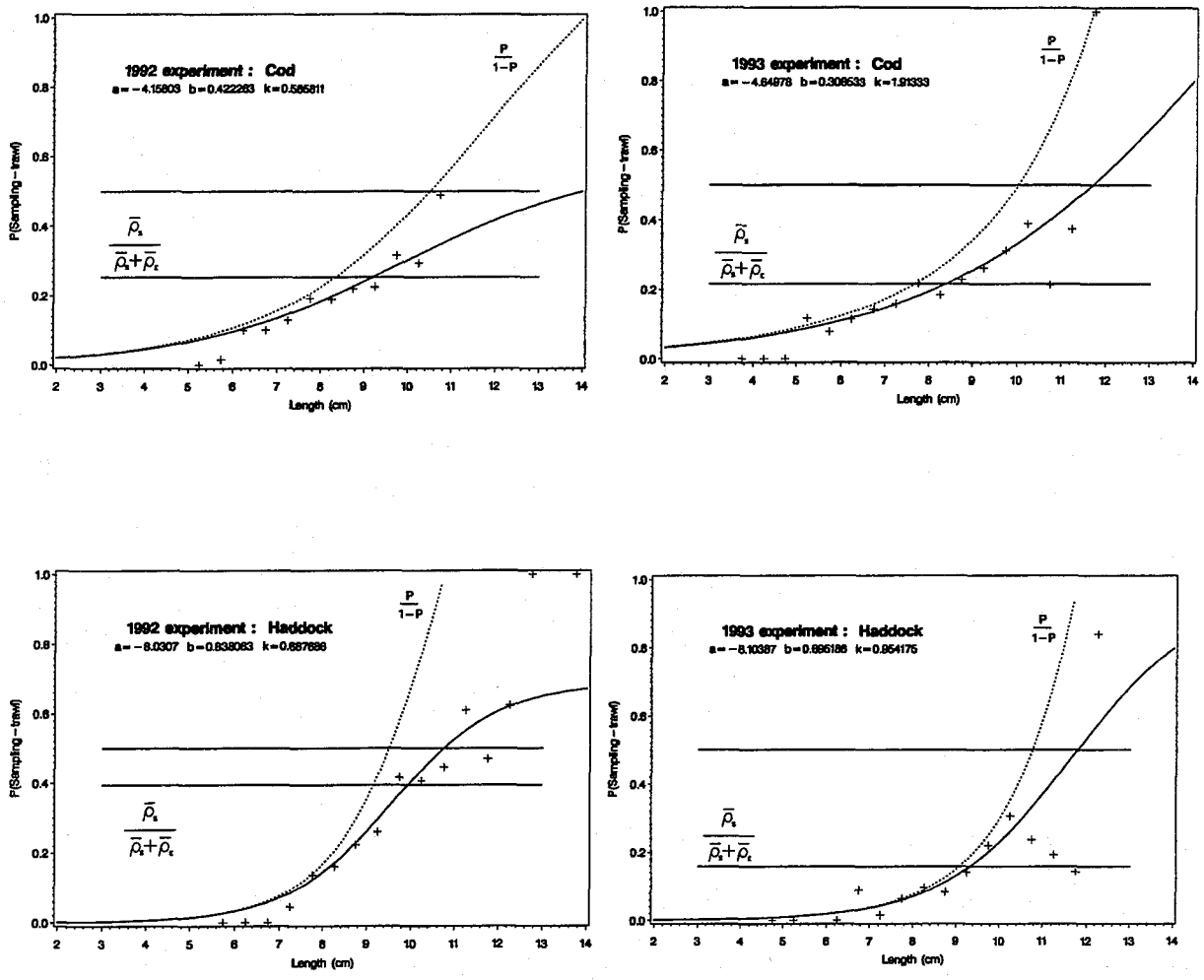

Figure 5. Length selection of standard sampling trawl relative to experimental trawl. Solid curve: Model fitted by maximum likelyhood estimation to observations +. Dotted curve: Fish density in standard sampling trawl relative to that in the experimental trawl, (ρ_{ST}/ρ_{ET}). Upper horisontal line: Probability P=0.5 means equal fish density in the two trawls. Lower horisontal line: Average fish density (all lengths) in standard trawl relative to the sum of average densities in the two trawls.

In Figure 6 is presented the correction factor (multiplier) to be used on the density estimates or catch rates of the standard sampling trawl in order to make them directly comparable with the estimates or catch rates of the experimental trawl (The choice of 9 cm as reference for both species is arbitrary). The curves for the two experiments coincide both for cod and haddock while there seem to be a significant difference in the selection pattern of the two species.

The main results of this study support and strengthen the conclusions of earlier works (Godø *et al.* 1993, Godø and Valdemarsen 1993) that the standard sampling trawl used in the 0-group surveys have a lower catch efficiency of small sized than on larger sized 0-group cod and haddock. The trials with the new experimental trawl were quite promising as they indicate that a trawl which may yield "unbiased" length distributions of 0-group fish can be constructed in near future.

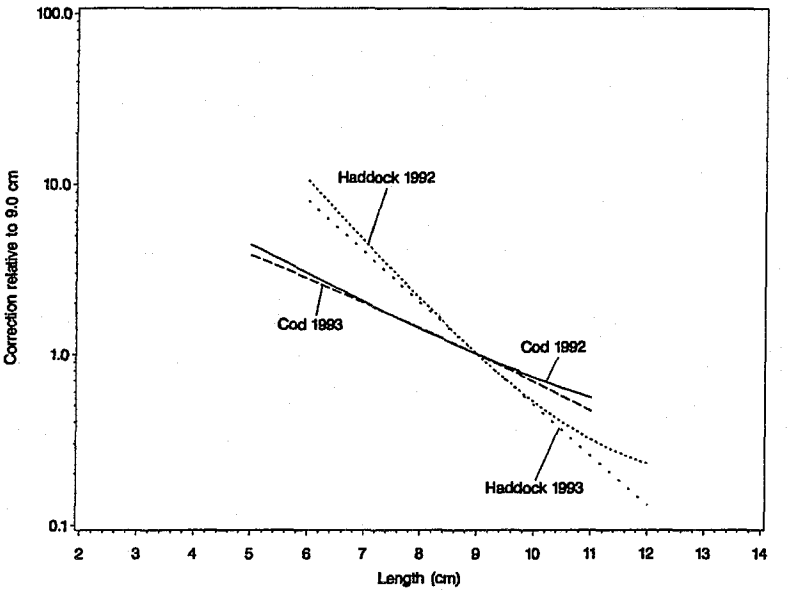

Figure 6. Correction factor (multiplier) to be used for density estimates based on the standard sampling trawl in order to have these comparable to those of the experimental trawl. The choise of 9 cm as a reference point is arbitrarily.

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