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Survey Biomass of Greenland halibut (*Reinhardtius hippoglossoides*) off West Greenland (NAFO Subareas 0+1), July-August 1988, 1989 and 1990

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Introduction

A yearly stratified-random shrimp trawl survey in the main distribution area for shrimp (*Pandalus borealis*) off West Greenland was initiated in July 1988 by Greenland Fisheries Research Institute (Carlsson and Kanneworff 1991). This paper presents estimates of biomass, abundances and size distributions for Greenland halibut based on by-catch data collected during the shrimp trawl survey in July 1988, July-August 1989 and July-August 1990.

Materials and Methods

Survey design

The shrimp surveys were carried in the offshore area of West Greenland between 61°52'5N to 72°30'N and from the 3-mile limit to the 600 meter depth contour line (Fig. 1).

The surveys were conducted with four commercial shrimp trawlers of about similar size. In July 1988 with M/Tr *Elias Kleist* (722 GRT), in July-August 1989 with M/Tr *Sisimiut* (722 GRT), in July-August 1990 with M/Tr *Manilitsoq* (722 GRT) and M/Tr *Auveq* (695 GRT), respectively.

The four trawlers used similar trawling gear (Skjervoy 3300/20 with bobbin gear and a double-bag with 44 mm mesh-size in the cod-end). The trawl-doors used were in 1988 and 1990 of the *Perfect* type, while in the 1989-survey *BMV* doors were used. The *BMV* doors gave a smaller wing spread. During the trawl operations in 1989 and 1990 the wing spread was measured by means of SCANMAR equipment to an average of 17.2 m and 28.1 m, respectively. In the 1988-survey the wing spread was estimated to 26.5 m, lacking suitable equipment to measure the actual wing spread.

The standard trawling haul was about 60 minutes at a mean towing speed of about 2.4 knots throughout the surveys. In order to minimize the influence of vertical shrimp migrations the trawl operations were planned to be carried out only during daytime (hours: 0900-1900 UTC). Due to time constraint it became necessary to work on a 24-hour schedule in the last part of the surveys in 1989 and 1990.

In the area between 61°52'5N and 69°30'N (named 'WEST' and 'CANADA') the stratification was based on the depth contours and divided in subareas which were further divided in four depth strata. The area between 69°30'N and 72°30'N (named 'NORTH') was divided in separate shrimp grounds defined by the effort distribution in the commercial shrimp fishery. Due to scarce information on the bottom topography this area was not divided in depth strata. The size of the strata by subarea in square kilometres are given in Table 1.

The number of hauls per strata were allocated proportionally to strata sizes. However a minimum of two hauls per stratum was always scheduled. Within the strata the trawling sites were chosen at random according to Doubleday (1981).

Biomass and abundance

The mean biomass with standard deviation by subarea, depth-stratum and year was calculated by means of the swept area method and assuming a catchability coefficient of 1.0. From most of the hauls in 1988 subsamples of the Greenland halibut catches were weighted and total length measured to the nearest centimetre below. From some of the hauls during the two surveys in 1990 the Greenland halibut were length measured or the average weight per fish were estimated. The length distributions of all Greenland halibut in each haul were weighted by effort and pooled by area.

Abundance estimates by area were calculated simply by dividing the estimated biomass by the mean weight per fish weighted by strata area.

Catch distribution

The catch rates (kg/hour) of Greenland halibut were examined by the following general linear model (GLM):

$$\log(\text{catch}) = a0 + a1(\text{subarea}) + a2(\text{depth}) + a3(\text{year}) + \text{error}$$

where subarea, depth and year were included as class variables.

The computer procedure "GLM" in the statistical computer package (SAS Institute Inc., North Carolina) was used.

Log(catch) was assumed to be normally distributed and this was justified as the standard deviation is proportional to the mean. The distributions are, however, not strictly log normal because several of the trawl catches were zero. Therefore, the delta distribution might be more correct. To avoid to take the log of zero 1 gram was added to all catch rates.

Average weight

Average weights per fish in grams were examined by the following general linear model (GLM):

$$\text{GHLAVG} = a0 + a1(\text{subarea}) + a2(\text{depth}) + a3(\text{year}) + \text{epsilon}$$

where subarea, depth and year were included as class variables.

Results

Biomass and abundance

Except in subarea C3 there is a general decrease in the mean catch per hour and calculated mean biomass by subarea, depth-stratum and year from 1988 to 1990 (Table 2 and 3). The total biomass and abundance estimates decreases significantly from about 12,000 tonnes and 141 mill. in 1988 to about 4,600 tonnes and 36 mill. in 1990, respectively (Table 4 and 5). The largest reduction is seen in area 'NORTH' (subarea: N2, N4-N6) and 'West' (Subarea: W1).

Length distributions of Greenland halibut caught in area 'NORTH', 'CANADA' and 'WEST' during the survey in 1988 shows marked peaks at about 12, 18 and 25 cm (Fig. 2a-d). Length distributions of Greenland halibut caught in area 'WEST' during the survey in 1990 also shows marked peaks at about 12, 18 and 25 cm (Fig. 3a-b).

Catch distribution

Analysis of variance on the logarithmic transformed trawl-survey catches (kg/hour) shows significant effects ($P<0.01$) of subarea, depth and year (Table 6). The model explains 42% of the total variation. The model solution indicate a general decrease in the catch rate from north to south, from deep to shallow water and from 1988 to 1990.

Average weight

Analysis of variance on average weight per fish shows significant effects of depth ($P<0.01$) and of subarea ($P<0.05$) but no significant effects ($P>0.05$) of year (Table 7). The model explains 31 % of the total variation. The model solution indicate a general increase in average weight per fish from north to south and from shallow to deep water.

Discussion

Greenland halibut is most frequent on grounds with rich stocks of deep sea prawns (*Pandalus borealis*), and it is an important fish species in by-catch from the prawn fishery (Smidt, 1969). Small Greenland halibut have long been known to occur in rich quantities on nursery grounds in the Disko Bay, off the West Greenland coast north of 66° N and in several fjords of South Greenland at depths between 200-600 m (Jensen, 1935; Smidt, 1969; Riget and Boje, 1988). According to Smidt (1969) the stock of young Greenland halibut is very dense on the localities west of Disko compared with other localities, and the vast shallow areas (about 200-250 m in depth) northwest, west and southwest of Disko can be regarded as very important nursery grounds from where the older stocks in the fjords of Disko Bay, Umanak district, and more northern districts are recruited. According to Riget and Boje (1989) little attention have been paid to Greenland halibut on the continental slope and they propose that a stepwise migration and growth occur down the continental slope to the deeper part of the Davis Strait were the Greenland halibut mature and spawn.

The by-catch data presented in this paper confirm that major nursery grounds for Greenland halibut coincide with the distribution area for shrimp (*Pandalus borealis*). Average length and weight data by subarea and depth also

indicate a gradual migration and growth of Greenland halibut down the continental slope to the deeper part of the Davis Strait as proposed by Riget and Boje (1989). Average length and weight data collected by Japan Marine Fishery Resource Research Center (JAMARC) in cooperation with Greenland Fisheries Research Institute during stratified-random bottom trawl surveys off West Greenland at depths between 50-1500 m in 1987-90 extent and support these findings (Yamada et al., 1988; Yatsu and Jørgensen, 1989; Due et al., 1991).

When comparing the biomass estimates calculated from the trawl survey data, it is important that the catch data is collected with similar ships and trawl gear, during the same time period etc. This has not completely been fulfilled during the three years shrimp trawl surveys off West Greenland, 1988-90. For instance were the trawl-doors used in 1988 and 1990 of the *Perfect* type, while in the 1989-survey *BMV* doors were used. The *BMV* doors gave a smaller wing spread and a horizontally higher net opening. The effects of differences in ships and gear used between years is unknown as is the catchability for Greenland halibut. The biomass estimates derived from these surveys are therefore merely indices. However, the decrease in the total biomass and abundance estimates from about 12,000 tonnes and 141 mill. in 1988 to about 4,600 tonnes and 36 mill. in 1990 is an indication for a reduction in the stock size from 1988 to 1990.

References

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Table 1 Stratum areas in squarekilometers.

AREA=NORTH

AREA IN KM2	SUBAREA						
	N1	N2	N3	N4	N5	N6	N7
	AREA KM2	AREA KM2	AREA KM2	AREA KM2	AREA KM2	AREA KM2	AREA KM2
DEPTH							
200-600	3649	11789	367	2249	9607	15926	1159

AREA=CANADA

AREA IN KM2	SUBAREA	
	C1	C3
	AREA KM2	AREA KM2
DEPTH		
200-300		660
300-400	655	1192
400-600	312	623

AREA=WEST

AREA IN KM2	SUBAREA					
	W1	W2	W3	W4	W5	W6
	AREA KM2	AREA KM2	AREA KM2	AREA KM2	AREA KM2	AREA KM2
DEPTH						
150-200	2363	1499	2215	4204	1995	1095
200-300	5213	2477	4810	1736	3454	1491
300-400	9239	1453	2714	745	1797	1300
400-600	752	559	3361	1915	2806	884

Table 2 Mean catch of Greenland halibut (kg/hour) and number of hauls by subarea, depth-stratum and year.

AREA=NORTH

KG PR HOUR		SUBAREA													
		N1		N2		N3		N4		N5		N6		N7	
		GRL. HALIBUT		GRL. HALIBUT		GRL. HALIBUT		GRL. HALIBUT		GRL. HALIBUT		GRL. HALIBUT		GRL. HALIBUT	
		MEAN	N	MEAN	N	MEAN	N	MEAN	N	MEAN	N	MEAN	N	MEAN	N
DEPTH	YEAR														
200-600	88	7.15	5	16.19	7	6.52	3	43.24	5	9.71	4	15.27	10	0.54	2
	89	4.45	6	2.25	6	1.63	3	7.07	4	2.04	16	.	.	0.00	2
	90	7.04	9	0.51	7	15.25	3	8.47	7	4.07	17	2.29	8	3.69	4

AREA=CANADA

KG PR HOUR		SUBAREA			
		C1		C3	
		GRL. HALIBUT		GRL. HALIBUT	
		MEAN	N	MEAN	N
DEPTH	YEAR				
200-300	90	.	.	1.97	4
300-400	88	2.26	3	13.34	3
	89	1.67	3	6.40	3
	90	5.31	3	23.81	4
400-600	88	33.00	1	.	.
	89	0.10	1	21.63	3
	90	2.00	1	38.22	4

AREA=WEST

KG PR HOUR		SUBAREA													
		W1		W2		W3		W4		W5		W6			
		GRL. HALIBUT		GRL. HALIBUT		GRL. HALIBUT		GRL. HALIBUT		GRL. HALIBUT		GRL. HALIBUT			
		MEAN	N	MEAN	N	MEAN	N	MEAN	N	MEAN	N	MEAN	N		
DEPTH	YEAR														
150-200	88	0.00	3	0.23	4	0.16	4	0.47	7	0.04	4	.	.		
	89	0.55	2	0.13	3	0.15	4	0.19	8	0.00	4	.	.		
	90	0.28	4	0.02	5	0.23	6	0.10	12	0.00	6	0.39	3		
200-300	88	10.91	9	2.37	4	4.45	9	0.93	3	0.70	7	.	.		
	89	4.77	4	3.78	5	0.38	10	0.67	3	0.37	7	.	.		
	90	1.42	17	1.81	7	1.34	12	0.36	5	0.09	10	2.00	3		
300-400	88	28.51	14	39.30	2	12.49	2	60.06	2	1.40	3	.	.		
	89	8.66	11	1.73	3	13.07	3	5.45	2	3.90	4	.	.		
	90	12.10	26	6.92	3	11.07	9	3.43	4	0.44	5	0.92	2		
400-600	88	17.54	1	43.43	2	49.94	8	53.81	3	25.30	4	.	.		
	89	1.60	1	18.22	2	2.87	4	1.47	3	5.72	5	.	.		
	90	1.40	3	53.20	6	25.93	9	16.08	6	4.74	8	5.96	4		

Table 3 Mean biomass of Greenland halibut (tonnes) and number of hauls by subarea, depth-stratum and year.

AREA=NORTH

BIOMASS IN TONS		SUBAREA													
		N1		N2		N3		N4		N5		N6		N7	
		GRL. HALIBUT		GRL. HALIBUT		GRL. HALIBUT		GRL. HALIBUT		GRL. HALIBUT		GRL. HALIBUT		GRL. HALIBUT	
		MEAN	N	MEAN	N	MEAN	N	MEAN	N	MEAN	N	MEAN	N	MEAN	N
DEPTH	YEAR														
200-600	88	227	5	1494	7	24	3	838	5	793	4	1687	10	5	2
	89	207	6	332	6	8	3	174	4	240	16	.	.	0	2
	90	214	9	41	7	44	3	144	7	327	17	262	8	39	4

AREA=CANADA

BIOMASS IN TONS		SUBAREA			
		C1		C3	
		GRL. HALIBUT		GRL. HALIBUT	
		MEAN	N	MEAN	N
DEPTH	YEAR				
200-300	90	.	.	11	4
300-400	88	11	3	130	3
	89	12	3	87	3
	90	29	3	236	4
400-600	88	75	1	.	.
	89	0	1	157	3
	90	4	1	217	4

AREA=WEST

BIOMASS IN TONS		SUBAREA													
		W1		W2		W3		W4		W5		W6			
		GRL. HALIBUT		GRL. HALIBUT		GRL. HALIBUT		GRL. HALIBUT		GRL. HALIBUT		GRL. HALIBUT			
		MEAN	N	MEAN	N	MEAN	N	MEAN	N	MEAN	N	MEAN	N		
DEPTH	YEAR														
150-200	88	0	3	3	4	4	4	13	7	1	4	.	.		
	89	14	2	2	3	4	4	10	8	0	4	.	.		
	90	6	4	0	5	5	6	5	12	0	6	5	3		
200-300	88	422	9	54	4	160	9	13	3	24	7	.	.		
	89	298	4	116	5	24	10	17	3	14	7	.	.		
	90	56	17	43	7	58	12	6	5	3	10	24	3		
300-400	88	2081	14	459	2	277	2	318	2	19	3	.	.		
	89	950	11	25	3	430	3	45	2	98	4	.	.		
	90	888	26	100	3	260	9	23	4	7	5	12	2		
400-600	88	118	1	167	2	1249	8	794	3	479	4	.	.		
	89	14	1	114	2	109	4	34	3	212	5	.	.		
	90	10	3	274	6	797	9	241	6	121	8	47	4		

Table 4 Total biomass estimates (tonnes) and confidence intervals (%) by area and year.

Area/year	1988		1989		1990	
	Biomass	C.V.	Biomass	C.V.	Biomass	C.V.
NORTH (N_1-N_7)	5068	56%	961	45%	1073	44%
CANADA (C_1+C_3)	216	120%	256	63%	497	72%
WEST (W_1-W_6)	6656	26%	2528	27%	2992	22%
Total	11940		3745		4561	

Table 5 Total abundance estimates (mill.) in 1988 and 1990 by area.

Area/year	1988 Abundance	1990 Abundance
NORTH (N_1-N_7)	47	5
CANADA (C_1+C_3)	1.6	2
WEST (W_1-W_6)	92	29
Total	140.6	36

Table 6 Analysis of variance (ANOVA) on log(catch) with a three factor model (subarea, depth and year). The ANOVA table and the parameter estimates togther with their calculated standard errors are given.

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: LOGGHL

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
MODEL	19	3115.71280184	163.98488431	19.56
ERROR	499	4182.47629326	8.38171602	PR › F
CORRECTED TOTAL	518	7298.18909509		0.0001

R-SQUARE	C.V.	ROOT MSE	LOGGHL MEAN
0.426916	47.9511	2.89511934	6.03765384

SOURCE	DF	TYPE I SS	F VALUE	PR › F
SUBAREA	14	952.29970008	8.12	0.0001
DEPTH	3	2005.54109611	79.76	0.0001
YEAR	2	157.87200564	9.42	0.0001

SOURCE	DF	TYPE III SS	F VALUE	PR › F
SUBAREA	14	492.22823450	4.19	0.0001
DEPTH	3	2031.16812354	80.78	0.0001
YEAR	2	157.87200564	9.42	0.0001

PARAMETER		ESTIMATE	T FOR H0: PARAMETER=0	PR › |T|	STD ERROR OF ESTIMATE
INTERCEPT		6.99060701 B	8.08	0.0001	0.86517872
SUBAREA	C1	0.43091005 B	0.36	0.7217	1.20930532
	C3	1.71663862 B	1.62	0.1062	1.06070790
	N1	1.48337591 B	1.37	0.1709	1.08176061
	N2	1.04521724 B	0.97	0.3343	1.08146246
	N3	2.86078363 B	2.18	0.0294	1.30958342
	N4	1.89596073 B	1.67	0.0952	1.13400634
	N5	0.73756413 B	0.75	0.4541	0.98449656
	N6	0.16288144 B	0.15	0.8817	1.09403959
	N7	0.69630232 B	0.52	0.6021	1.33469045
	W1	1.45210481 B	1.60	0.1099	0.90663808
	W2	1.73750070 B	1.83	0.0680	0.94996265
	W3	1.75573813 B	1.93	0.0540	0.90898077
	W4	1.19253709 B	1.28	0.2011	0.93168994
	W5	-1.18488648 B	-1.29	0.1985	0.92032581
	W6	0.00000000 B	.	.	.
DEPTH	150-200	-6.05591641 B	-13.92	0.0001	0.43492516
	200-300	-3.63150708 B	-9.31	0.0001	0.39012648
	300-400	-0.88224892 B	-2.28	0.0229	0.38661364
	400-600	0.00000000 B	.	.	.
YEAR	88	1.35793699 B	4.32	0.0001	0.31413527
	89	0.37093265 B	1.17	0.2417	0.31645401
	90	0.00000000 B	.	.	.

Table 7 Analysis of variance (ANOVA) on average weight per fish - reduced model. The ANOVA table and the parameter estimates togther with their calculated standard errors are given.

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: GHLAVG

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
MODEL	17	4285365.43355024	252080.31962060	4.10
ERROR	149	9154379.59323769	61438.78921636	PR > F
CORRECTED TOTAL	166	13439745.02678790		0.0001

R-SQUARE	C.V.	ROOT MSE	GHLAVG MEAN
0.318858	111.6278	247.86849178	222.04911061

SOURCE	DF	TYPE I SS	F VALUE	PR > F
SUBAREA	14	2395780.61247631	2.79	0.0010
DEPTH	3	1889584.82107393	10.25	0.0001

SOURCE	DF	TYPE III SS	F VALUE	PR > F
SUBAREA	14	1532618.17815505	1.78	0.0462
DEPTH	3	1889584.82107393	10.25	0.0001

PARAMETER		ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT		641.18730084 B	5.03	0.0001	127.39125547
SUBAREA	C1	-1.91746926 B	-0.01	0.9914	177.50718745
	C3	-274.62361663 B	-1.70	0.0908	161.35186263
	N1	-201.03965664 B	-1.18	0.2391	170.07373856
	N2	-274.07778976 B	-1.77	0.0783	154.59848013
	N3	-226.93027397 B	-1.03	0.3035	219.76683143
	N4	-334.24789822 B	-2.12	0.0356	157.64548011
	N5	-124.59760668 B	-0.83	0.4085	150.32101675
	N6	-346.01637893 B	-2.25	0.0260	153.87155149
	N7	-199.55343990 B	-0.92	0.3585	216.67470221
	W1	-296.66842736 B	-2.20	0.0291	134.64028539
	W2	-386.43952496 B	-2.56	0.0116	151.16825842
	W3	-284.57352568 B	-2.14	0.0338	132.86856095
	W4	-104.03952419 B	-0.75	0.4564	139.33738786
	W5	-157.32880040 B	-1.15	0.2507	136.42270476
	W6	0.00000000 B	.	.	.
DEPTH	150-200	-305.15440488 B	-3.55	0.0005	85.91525292
	200-300	-280.64436393 B	-5.09	0.0001	55.10279701
	300-400	-226.26146514 B	-4.10	0.0001	55.21009731
	400-600	0.00000000 B	.	.	.

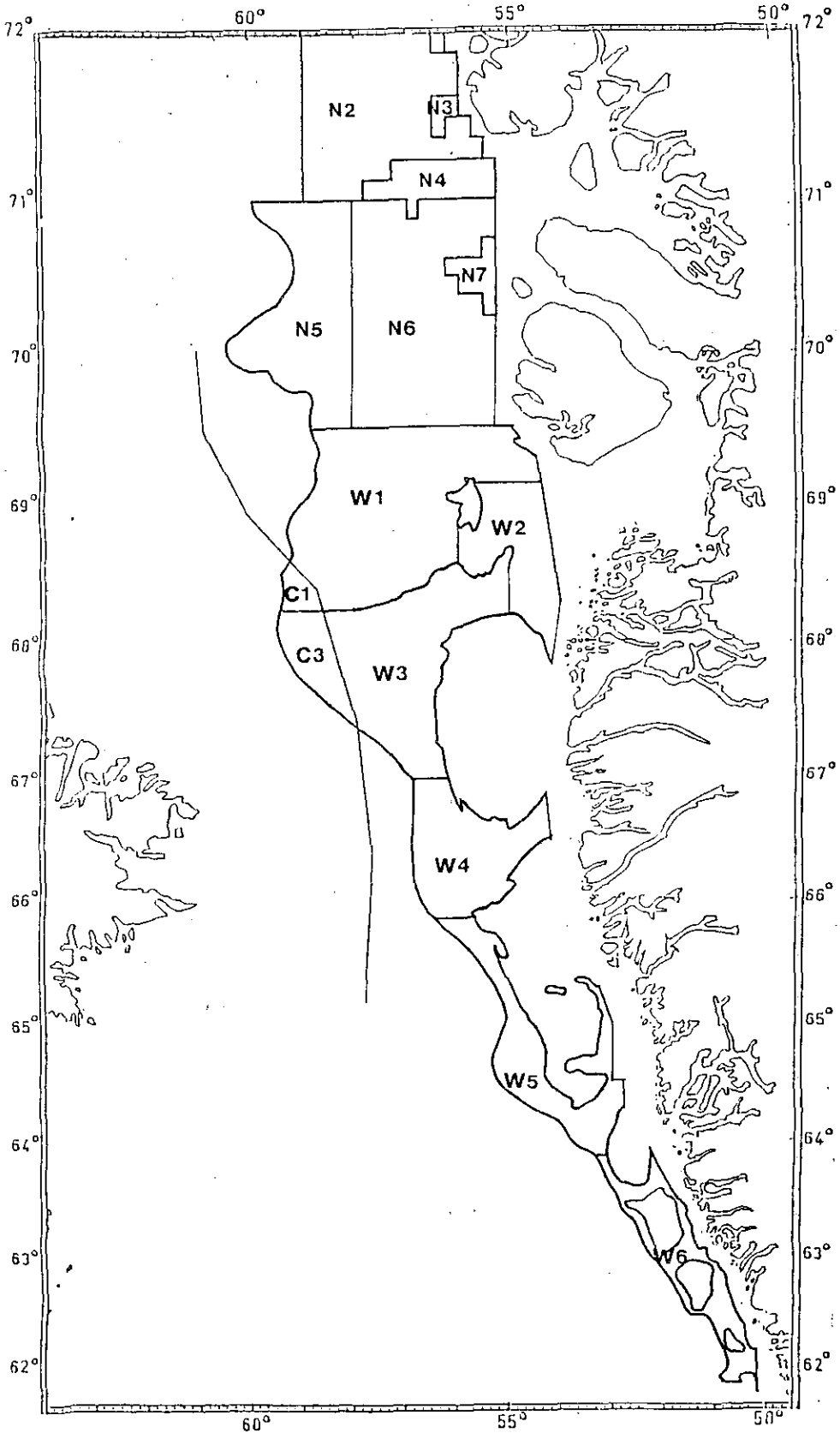
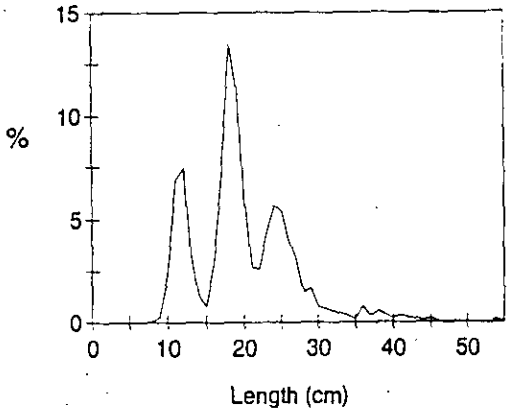
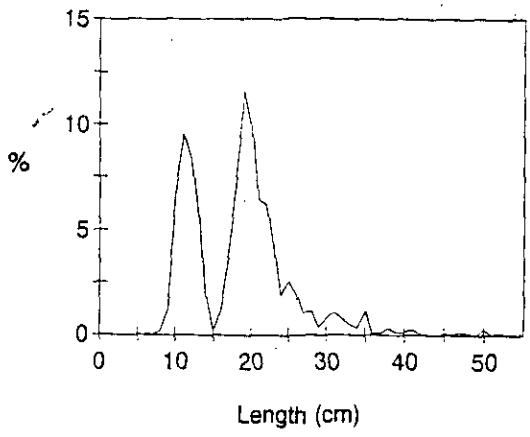


Fig. 1 Area stratification of the yearly stratified-random shrimp-trawl-survey in the main distribution area for shrimp (*Pandalus borealis*) off West Greenland.

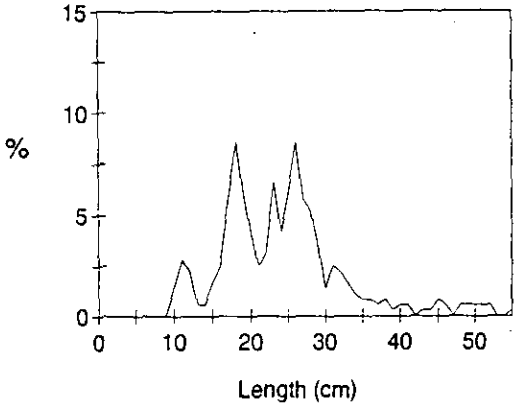
Area: NORTH
Depth: 100-600m
Number measured: 1,709



Area: WEST (W_{1-5})
Depth: 150-400m
Number measured: 4,286



Area: CANADA
Depth: 300-600m
Number measured: 461



Area: WEST (W_{1-5})
Depth: 400-600m
Number measured: 1,338

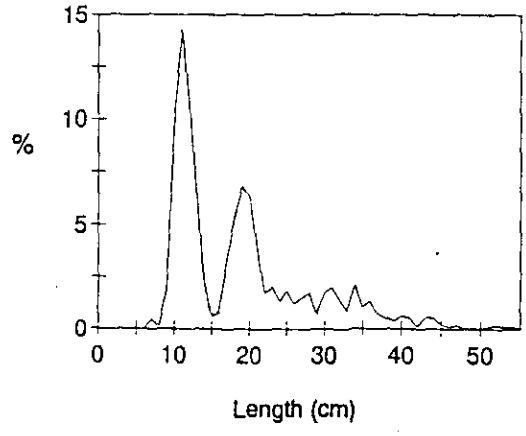
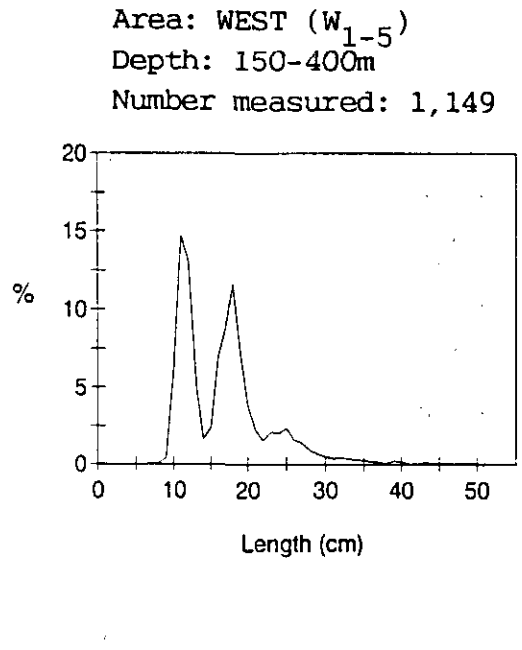


Fig. 2a-d Length distributions of the length measured Greenland halibut caught during the survey in 1988 by area and depth. a) "NORTH" (100-600m), b) "CANADA" (300-600m), c) "WEST" (150-400m), d) "WEST" (400-600m).



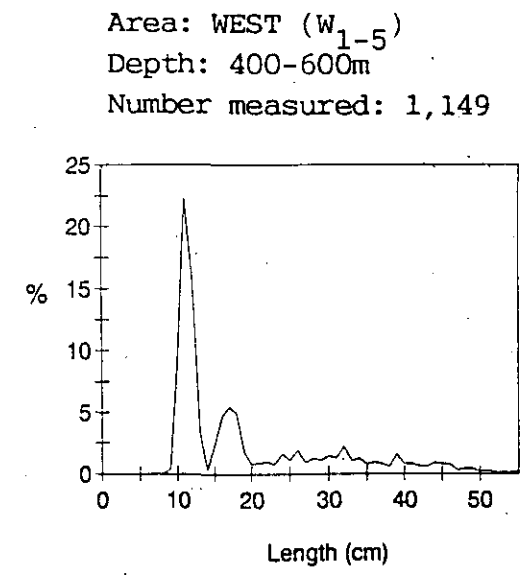


Fig. 3a-b Length distributions of the length measured Greenland halibut caught during the survey in 1990 by area and depth. a) "WEST" (150-400m), b) "WEST" (400-600m).