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Survey Biomass of Redfish (*Sebastes spp.*) 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 redfish 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 *Maniitsoq* (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 redfish catches were weighted and total length measured to the nearest centimetre below. From some of the hauls during the two surveys in 1990 the redfish were length measured or the average weight per fish were estimated. The length distributions of all redfish 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 redfish were examined by the following general linear model (GLM):

log(catch) = a0 + a1(subarea) + a2(depth) + a3(year) + 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. 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):

REDAVG = a0 + a1(subarea) + a2(depth) + a3(year) + error

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

Results

Biomass and abundance

Except in subarea C3, depth 300-400m and subarea W4, depth 300-400m 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 from about 20,000 tonnes and 631 mill. in 1988 to about 12,800 tonnes and 401 mill. in 1990, respectively (Table 4 and 5). The largest reduction is seen in area 'NORTH' and 'WEST' (subarea: N4-N6, W1 and W5). There is increased biomass and abundance estimates in area 'CANADA' from 1988 to 1990.

Length distributions of redfish caught in area 'NORTH' and 'CANADA' during the survey in 1988 shows a marked peak at about 13 cm, whereas in area 'WEST' depth 150-400 m and depth 400-600 m there is marked peaks at about 7 and 13 cm (Fig. 2a-d). Length distributions of redfish caught in area 'WEST' during the survey in 1990 depth 150-400 m shows marked peaks at about 7, 11 and 13 cm, whereas in depth 400-600 m there is marked peaks at about 7, 11, 13 and 18 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 48% of the total variation. The model solution indicate a general increase in the catch rate from north to south, from shallow to deeper water. There is a decrease in the catch rate from 1988 to 1990.

Average weight

Analysis of variance on average weight per fish shows significant effects of subarea ($P<0.01$) and of year ($P<0.05$) but no significant effects ($P>0.05$) of depth (Table 7). The model explains 22 % of the total variation. The model solution indicate a general increase in average weight per fish from north to south. There is a decrease in the average weight per fish from 1988 to 1990.

Discussion

The West Greenland shelf area from the Diskobank region to the Fyllabank region is an important nursery ground for redfish (mainly *Sebastes mentella*). The highest densities of young redfish are observed in trawl fishery around Store Hellefiskbank (NAFO Division 1B) and large quantities of young redfish are by-catch in the shrimp fishery in this area. (Jensen, 1979; Atkinson, 1987; Yamada et al., 1988; Riget et al., 1988; Pedersen and Lehmann, 1989).

The by-catch data presented in this paper confirm that young redfish are highly abundant around Store Hellefiskbank (NAFO Division 1B), and that major nursery grounds for redfish coincide with the distribution area for shrimp.

When comparing biomass and abundance estimates calculated from trawl survey data, it is important that the catch data is collected with similar ships and trawl gear, during the same time period and area 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 redfish. The biomass estimates derived from these surveys are therefore merely indices. However, the decrease in the total biomass and

abundance estimates from about 20,000 tons and 631 mill. in 1988 to about 12,800 tons and 401 mill. in 1990 is an indication for a reduction in the West Greenland redfish populations from 1988 to 1990.

These findings are supported by biomass and abundance estimates derived from the German groundfish survey with R/V *Walther Herwig* which indicate a decline of the fishable redfish populations (*Sebastes marinus*) Southwest of Greenland from 1982 to 1990 (Messtorff and Cornus, 1989 and 1990; Rätz, 1991). In addition biomass estimates from groundfish surveys conducted by Japan Marine Fishery Resource Research Center (JAMARC) in cooperation with Greenland Fisheries Research Institute also indicate a decline of the West Greenland redfish populations (*Sebastes mentella*) from 1987 to 1990 (Due *et al.*, 1991).

Length distributions and average weight data by subarea and depth indicate a gradual migration and growth of young redfish from the northern areas (Division 1A and 1B) westward and south and from shallow to deeper water. Average length and weight data collected during stratified-random bottom trawl surveys off West Greenland at depths between 50-1500 m in 1986, 1987 and 1990 support these findings (Atkinson, 1987; Yamada et al., 1988; Due et al., 1991; Rätz, 1991). According to Zakharov (1966) the marked peak in the length distributions at about 7 cm in the southern part of the survey area (subarea W_1-W_5) probably represents age 1+ redfish. In September-November pelagic redfish fry probably age 0+ (40-68 mm) have been observed drifting northward from Kap Farvel along the West Greenland coast in large quantities (Zakharov, 1966; Pedersen, 1990; Wieland, 1991). Since the 1920's no breeding of redfish have been observed off West Greenland, and it is assumed that the redfish populations in West Greenland waters are recruited from breeding areas in the Irminger Sea southwest of Iceland (Zakharov, 1966; Anon., 1984; Pavlov et al., 1989; Anon., 1990; Magnusson et al., 1990).

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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 redfish (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	
		REDFISH		REDFISH		REDFISH		REDFISH		REDFISH		REDFISH		REDFISH	
		MEAN	IN	MEAN	IN	MEAN	IN	MEAN	IN	MEAN	IN	MEAN	IN	MEAN	IN
DEPTH	YEAR														
200-600	88	0.02	5	0.37	7	0.84	3	2.94	5	20.75	4	6.57	10	0.24	2
	89	0.37	6	0.00	6	0.00	3	0.17	4	2.83	16	.	.	0.00	2
	90	0.29	9	0.00	7	0.00	3	0.06	7	8.75	17	0.21	8	0.52	4

AREA=CANADA

KG PR HOUR		SUBAREA			
		C1		C3	
		REDFISH		REDFISH	
		MEAN	IN	MEAN	IN
DEPTH	YEAR				
200-300	90	.	.	20.09	4
300-400	88	8.27	3	42.94	3
	89	98.73	3	105.60	3
	90	31.85	3	54.20	4
400-600	88	146.25	1	.	.
	89	38.00	1	51.43	3
	90	27.00	1	33.66	4

AREA=WEST

KG PR HOUR		SUBAREA											
		W1		W2		W3		W4		W5		W6	
		REDFISH		REDFISH		REDFISH		REDFISH		REDFISH		REDFISH	
		MEAN	IN	MEAN	IN	MEAN	IN	MEAN	IN	MEAN	IN	MEAN	IN
DEPTH	YEAR												
150-200	88	0.00	3	0.00	4	2.02	4	2.54	7	2.79	4	.	.
	89	0.55	2	0.87	3	0.62	4	2.11	8	0.82	4	.	.
	90	0.00	4	0.00	5	1.56	6	0.61	12	0.51	6	1.70	3
200-300	88	0.49	9	0.65	4	23.27	9	11.46	3	161.49	7	.	.
	89	0.67	4	1.90	5	3.00	10	8.13	3	24.59	7	.	.
	90	0.39	17	10.49	7	2.48	12	0.27	5	2.28	10	10.36	3
300-400	88	42.15	14	44.82	2	83.25	2	94.12	2	91.48	3	.	.
	89	22.61	11	1.70	3	21.97	3	223.25	2	38.82	4	.	.
	90	21.84	26	66.04	3	26.19	9	258.98	4	21.52	5	6.53	2
400-600	88	105.69	1	29.78	2	22.39	8	37.58	3	51.71	4	.	.
	89	39.50	1	28.23	2	4.55	4	35.77	3	42.56	5	.	.
	90	33.52	3	89.49	6	67.42	9	15.79	6	48.32	8	27.49	4

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

AREA=NORTH

BIOMASS IN TONS		SUBAREA													
		N1		N2		N3		N4		N5		N6		N7	
		REDFISH		REDFISH		REDFISH		REDFISH		REDFISH		REDFISH		REDFISH	
		MEAN	IN	MEAN	IN	MEAN	IN	MEAN	IN	MEAN	IN	MEAN	IN	MEAN	IN
DEPTH	YEAR														
200-600	88	1	5	38	7	2	3	58	5	1658	4	671	10	2	2
	89	19	6	0	6	0	3	4	4	331	16	.	.	0	2
	90	91	9	0	7	0	3	1	7	848	17	23	8	5	4

AREA=CANADA

BIOMASS IN TONS		SUBAREA			
		C1		C3	
		REDFISH		REDFISH	
		MEAN	IN	MEAN	IN
DEPTH	YEAR				
200-300	90	.	.	110	4
300-400	88	48	3	419	3
	89	738	3	1473	3
	90	173	3	1451	4
400-600	88	332	1	.	.
	89	153	1	371	3
	90	50	1	187	4

AREA=WEST

BIOMASS IN TONS		SUBAREA											
		W1		W2		W3		W4		W5		W6	
		REDFISH		REDFISH		REDFISH		REDFISH		REDFISH		REDFISH	
		MEAN	IN	MEAN	IN	MEAN	IN	MEAN	IN	MEAN	IN	MEAN	IN
DEPTH	YEAR												
150-200	88	0	3	0	4	37	4	80	7	54	4	.	.
	89	14	2	13	3	17	4	111	8	20	4	.	.
	90	0	4	0	5	29	6	28	12	9	6	20	3
200-300	88	22	9	14	4	866	9	162	3	4941	7	.	.
	89	41	4	58	5	199	10	207	3	944	7	.	.
	90	16	17	253	7	100	12	5	5	82	10	152	3
300-400	88	3284	14	507	2	1898	2	438	2	1529	3	.	.
	89	2525	11	24	3	737	3	1749	2	917	4	.	.
	90	1542	28	969	3	624	9	1598	4	328	5	81	2
400-600	88	713	1	117	2	577	8	507	3	1051	4	.	.
	89	345	1	162	2	172	4	769	3	1302	5	.	.
	90	243	3	482	8	1952	9	230	6	1239	8	225	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)	2428	74%	354	47%	685	48%
CANADA (C_1+C_3)	799	105%	2735	30%	1970	54%
WEST (W_1-W_6)	16800	58%	10326	42%	10206	38%
Total	20027		13414		12863	

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

Area/year	1988 Abundance	1990 Abundance
NORTH (N_1-N_7)	37	5
CANADA (C_1+C_3)	31	82
WEST (W_1-W_6)	563	314
Total	631	401

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: LOGRED

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
MODEL	19	4599.87898668	242.09889298	24.58
ERROR	499	4918.95118026	9.85781780	PR > F
CORRECTED TOTAL	518	9518.83014691		0.0001

R-SQUARE	C.V.	ROOT MSE	LOGRED MEAN
0.483240	51.0004	3.13968431	6.15619011

SOURCE	DF	TYPE I SS	F VALUE	PR > F
SUBAREA	14	2486.86240252	18.02	0.0001
DEPTH	3	1957.86823567	66.20	0.0001
YEAR	2	155.34832846	7.88	0.0004

SOURCE	DF	TYPE III SS	F VALUE	PR > F
SUBAREA	14	2422.62116381	17.55	0.0001
DEPTH	3	1978.01823494	66.89	0.0001
YEAR	2	155.34832846	7.88	0.0004

PARAMETER		ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT		9.43216966 B	10.05	0.0001	0.93826462
SUBAREA	C1	-1.09199731 B	-0.83	0.4054	1.31146129
	C3	-0.00952331 B	-0.01	0.9934	1.15031111
	N1	-7.16482543 B	-6.11	0.0001	1.17314225
	N2	-7.61600115 B	-6.49	0.0001	1.17281891
	N3	-6.55650204 B	-4.62	0.0001	1.42021037
	N4	-7.63769766 B	-6.21	0.0001	1.22980144
	N5	-2.37387073 B	-2.22	0.0266	1.06786183
	N6	-4.39596419 B	-3.71	0.0002	1.18645850
	N7	-3.92901420 B	-2.71	0.0069	1.44743832
	W1	-3.21090846 B	-3.27	0.0012	0.98322625
	W2	-1.41236146 B	-1.37	0.1710	1.03021087
	W3	-0.77530478 B	-0.79	0.4319	0.98576885
	W4	-0.55984758 B	-0.55	0.5799	1.01039437
	W5	-0.47980899 B	-0.48	0.6309	0.99807026
	W6	0.00000000 B	.	.	.
DEPTH	150-200	-5.24932239 B	-11.13	0.0001	0.47186543
	200-300	-2.78088333 B	-6.57	0.0001	0.42308238
	300-400	0.57846263 B	1.37	0.1698	0.41927280
	400-600	0.00000000 B	.	.	.
YEAR	88	1.12638060 B	3.31	0.0010	0.34067182
	89	1.10739401 B	3.23	0.0013	0.34318644
	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: REDAVG

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
MODEL	12	313538.44365169	26128.20363764	3.12
ERROR	131	1095453.47261039	8362.24024893	PR > F
CORRECTED TOTAL	143	1408991.91626208		0.0006

R-SQUARE	C.V.	ROOT MSE	REDAVG MEAN
0.222527	122.2162	91.44528555	74.82257075

SOURCE	DF	TYPE I SS	F VALUE	PR > F
SUBAREA	11	267742.92873804	2.91	0.0018
YEAR	1	45795.51491365	5.48	0.0208

SOURCE	DF	TYPE III SS	F VALUE	PR > F
SUBAREA	11	300793.32368226	3.27	0.0008
YEAR	1	45795.51491365	5.48	0.0208

PARAMETER		ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT		161.82629870 B	5.01	0.0001	32.33079076
SUBAREA	C1	-173.39182448 B	-2.33	0.0212	74.35381444
	C3	-150.34119544 B	-2.42	0.0170	62.17924859
	N4	-91.31203972 B	-1.74	0.0849	52.59336851
	N5	-94.51193355 B	-1.88	0.0617	50.14488140
	N6	-41.33622801 B	-0.82	0.4112	50.14488140
	N7	-111.82629870 B	-1.15	0.2510	96.99237228
	W1	-158.49436436 B	-3.80	0.0002	41.67762882
	W2	-129.82852685 B	-3.13	0.0021	41.43826102
	W3	-146.48750494 B	-4.00	0.0001	36.61273003
	W4	-84.45234063 B	-2.24	0.0267	37.67499568
	W5	-55.58920227 B	-1.52	0.1315	36.61240871
	W6	0.00000000 B			
YEAR	88	40.67410600 B	2.34	0.0208	17.38072400
	90	0.00000000 B			

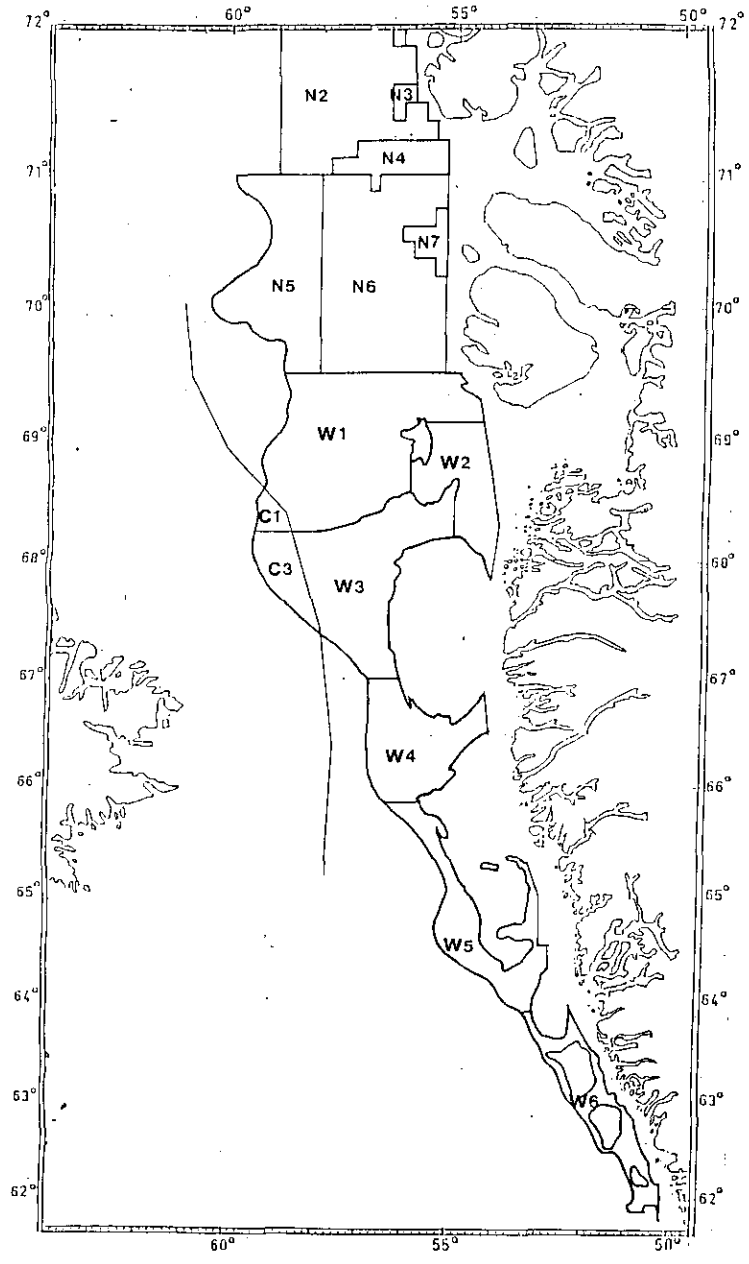


Fig. 1 Area stratification of the yearly stratified-random shrimp-trawl-survey in the main distribution area for shrimp (*Pandalus borealis*) off West Greenland.

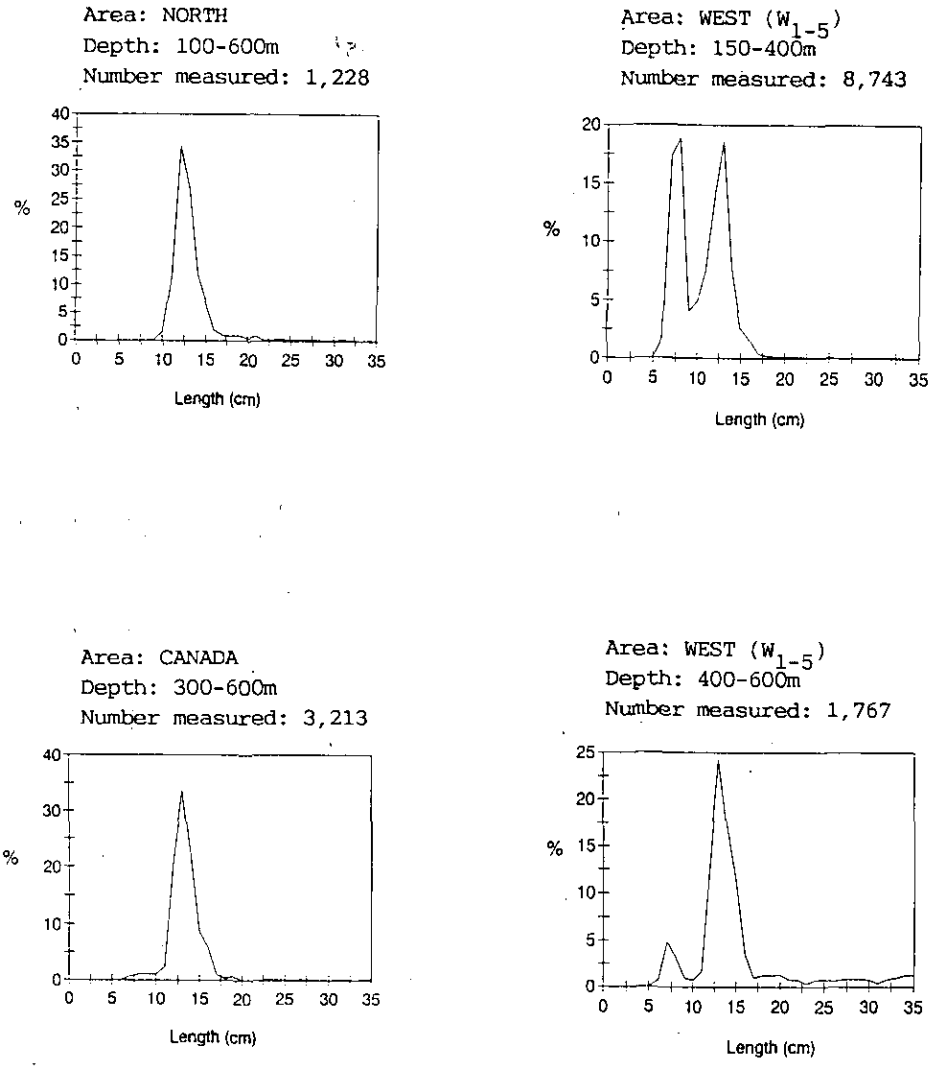
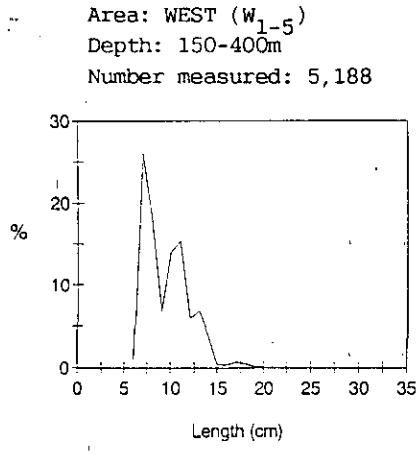


Fig. 2a-d Length distributions of the length measured redfish caught during the survey in 1988 by area and depth. a) "NORTH" (100-600m), b) "CANADA" (300-600m), c) "WEST" (150-400m), d) "WEST" (400-600m).



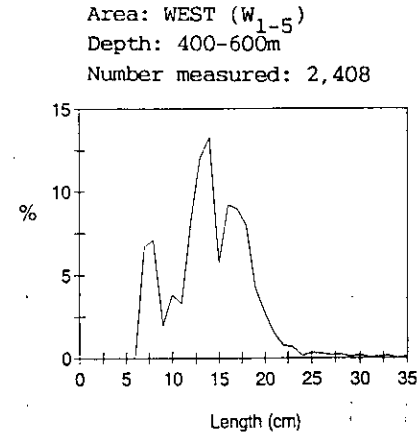


Fig. 3a-b Length distributions of the length measured redfish caught during the survey in 1990 by area and depth. a) "WEST" (150-400m), b) "WEST" (400-600m).