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An Update of the Status of Redfish in NAFO Subarea 2 and Div. 3K

by

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ABSTRACT

Canada has dominated this fishery since implementing a 200 mile fishery zone in 1977. Canadian landings in 1984-86 increased two-fold over the 1983 level in response to improved market conditions. Catches for 1984 and 1985 from the Division 3K were among the highest on record from this component of the stock and constituted more than 90% of the total catch in those years. Catch rates have generally been between 1.0 and 1.5 t/hr since 1959 but declined in recent years from the highest value on record in 1984. Results from an equilibrium general production analysis indicate a yield at 2/3 effort maximum exploitable yield (MEY) of about 25,000 t.

RESUME

Le Canada a dominé la pêche à cette espèce depuis la mise en oeuvre d'une zone de pêche de 200 milles en 1977. De 1984 à 1986 les débarquements ont doublé par rapport à ce qu'ils étaient en 1983 en réponse à des conditions améliorées du marché. Les prises pour 1984 et 1985 dans la division 3K étaient parmi les plus élevées jamais signalées pour cette composante du stock et représentaient plus de 90 % des prises totales pour ces années. Les taux de capture se sont généralement établis à entre 1,0 et 1,5 t/h depuis 1959, mais ont diminué au cours des dernières années par rapport aux valeurs maximales signalées en 1984. Les résultats d'une analyse de production généralisée à l'équilibre indiquent un rendement équivalent aux 2/3 du rendement maximal exploitable, soit environ 25 000 t.

Introduction

Historical nominal catches of redfish from this stock have fluctuated between 14,000 t and 40,000 t since 1965 (Table 1, Fig. 1). Over this same time period the catches reported for Div. 3K have generally constituted >50% of the total for SA 2 and Div. 3K and >80% since 1983. Canada has dominated this fishery since the inception of the 200-mile fishery zone in 1977 (Table 2). Preliminary data for 1985 and 1986 indicate landings have almost doubled the 1983 level as a result of increased Canadian catches in response to improved market conditions (Table 2). Japanese landings for 1986 again increased from the 1984 value due to landings of 2900 t associated with the Resource Short Plant Program (RSPP).

Catches from Div. 2GH have been in the range of 150 t (Table 3a) since 1983 and are generally taken in the latter part of the year because of ice cover in the first half. Catches from Div. 2J have been just over 2,000 t (Table 3b) since 1983 and are spread more evenly throughout the year. Data for 1984 and preliminary data for 1985 show catches from Div. 3K have been greater than 20,000 t up considerably from the 1983 value (Table 3c) and that fishing is spread over the whole year.

Analytical assessments of this stock have not been fruitful to date due to the relatively short time series of available data coupled with low fishing effort values and hence low fishing mortalities.

Methods and Results

A multiplicative model (Gavaris 1980) was again used to derive a standardized catch rate series (using STANDAR V1, Anon. MS 1986) on catch and effort data from ICNAF/NAFO Statistical Bulletins for the period 1959-84, preliminary NAFO data for 1985 and preliminary Canadian data for 1986. From this data base only those data where redfish comprised >50% of the total catch were selected. To reduce potential biases, country-gear-TC and month category types with <5 data points and all catch or effort data <10 units were deleted prior to analysis. In past assessments when employing the multiplicative model grouping of similar category types was done a posteriori, the statistical validity of which has since been questioned. To this end the model was employed using the same groupings as were used in the 1986 assessment (Power and Atkinson MS 1986). However, in that paper the category groupings were erroneously tabled. The correct groupings and their parameter estimates are provided in Table 4. An unweighted regression was chosen because the amount of pro-rating of effort data prior to 1984 could not be determined. The regression results are listed in Table 5 and the regression is highly significant ($p<.01$) with an r-squared value of .38. Type 1 represents country-gear-TC combinations, type 2 represents month combinations and type 3 represents division groupings. The predicted catch rate series (Table 6, Fig. 3) shows that the catch rates have generally been in the range of 1 to 1.5 t/hr from 1959 to the present. From 1976 to 1981 the catch rates were stable around 1 t/hr, then steadily increased to the highest value on record in 1984. Preliminary data for 1985 and 1986 indicate catch rates are declining. Standardized effort has been in the range of 9800 to 19000 hrs since 1980 (Table 6, Fig. 2).

The standardized catch rate and effort data were used in a Schaefer equilibrium general production analysis with effort data lagged 6, 8, and 10 years (Gulland 1961). Only catch and effort data from 1961 onwards were used because catches in 1959 (186,837 t) and 1960 (129,773 t) imply that effort exerted in these years greatly exceeded the long-term average annual effort. As was determined in last year's assessment (Power and Atkinson MS 1986) the above lag periods did not show any significant serial correlation of residuals from a regression of CPUE on effort while an unlagged regression did. However, as was pointed out in that document, it could not be determined which lag period was most appropriate. The three regressions of CPUE on lagged effort were all highly significant with p-values <.01 (Fig. 4, 6, and 8). It had been pointed out in the previous year's assessment of this stock (Power and Atkinson MS 1986) that the 1983-85 points strongly influenced the relationship between CPUE and lagged effort and subsequently the equilibrium general production model was not considered to be appropriate. However, the 1986 data point is in the same general position as the 1983-85 points (upper left) for all three regressions. Since the 1986 value tended to confirm the values for 1983-85, the relationships derived including all these 4 values were considered reasonable. The results of the general production curves (Fig. 5, 7, and 9) derived from the regressions are as follows:

	MEY (t)	Effort at MEY (hr)	Yield at 2/3 effort at MEY (t)
6-year lag	26,597	23,040	23,642
8-year lag	27,246	20,687	24,220
10-year lag	29,634	18,926	26,342

Catch and standardized effort data from 1961 to 1986 were analyzed by a non-equilibrium version (SURPROD V1, Anon MS 1986) of the Schaefer general production model (Rivard and Bledsoe 1978). Initial estimates of virgin stock biomass(B_∞) and maximum exploitable yield (MEY) were derived from the equilibrium runs and set at 550,000 t and 28,000 t respectively. Models were run with input catchability coefficient (q) fixed at 3, 5, 7, and $9X10^{-6}$. Convergence occurred (based on change in RSS<.00001) for $q = 7X10^{-6}$ (Table 7) while convergence (based on change in RSS<.00001, change in each parameter <.00001 and orthogonality offset <.001) occurred with q fixed at $9X10^{-6}$ (Table 8). Using as input the estimates of B_∞ and MEY from these converged runs, the model was rerun iterating for B_∞, MEY, and q. Both runs also converged (Tables 9 and 10) but the final estimate of B_∞ was only 170,000 t. This was considered to be unrealistic for the following reasons: (1) the reported catch for 1959 alone at 186,000 t was above this value, and, (2) the minimum estimate of the biomass from the fall surveys in recent years plus the commercial catch is about 170,000 t. It was concluded that the data do not fit the model's assumptions concerning stock dynamics (i.e. logistic growth) realistically. From the runs that did converge the q-values for the years 1983-85 are higher than predicted by the model (Fig. 10). Further analysis with the years 1983-86 removed did not yield satisfactory results. Examination of the values of annual q from Fig. 10 also indicates a gradual increasing trend from the late 1960's on.

Commercial length frequencies available from the 1986 fishery (Fig. 11-16) were combined (Gavaris and Gavaris 1983) as shown in Fig. 17. One age/length key

constructed from otoliths collected from the 1986 fishery was applied to the length frequency and estimated numbers caught at age with their associated weight at age is shown in Table 11. The weight-length relationships used were:

$$WT\ (males) = 0.01659FL^{2.9548}$$
$$WT\ (females) = 0.01372FL^{3.0210}$$

The strong year-classes of the early to mid 1970's were dominant in the fishery as 12-18 year old fish. Catch and weight at age matrices are listed in Tables 12 and 13. Paloheimo Z's as described by Ricker (1975, p. 171-2) were calculated on the 1956-60 year-classes from 1976 to 1985 as these were the only year-classes which could be successfully followed through the catch at age data series. CPUE at age was calculated by dividing the catch number at age by the standardized effort from the multiplicative model. The results are as follows:

Year	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
CPUE	.301	.523	.264	.178	.920	.267	.161	.340	.341	.188
Z		-.55	.69	.39	-1.64	1.23	.51	-.75	.00	.60

Average Z across the series was .05. However, the yearly estimates fluctuate greatly and are not considered reliable estimates of total mortality.

SPA was not attempted for this assessment because CAFSAC has previously noted that SPA is inappropriate for species such as redfish where there is no convergence in the population matrix.

Research survey results from 1978 to 1986 indicate mean number and weight per tow have been at about the same level since 1984 (Table 14). Biomass estimates have also been at the same level (around 140,000 t) over the same period. Mean numbers caught per tow at age (Fig. 18) indicate the population is mostly represented by ages 11-19 which correspond to the early to mid 1970's year-classes. There is no evidence of any relatively strong year-classes following these. Paloheimo Z's were calculated using mean numbers of redfish caught at age from the 1978-86 surveys by dividing the sum of ages 11-26 in year X+1 by the sum of ages 10-25 in year X (Table 15). The average of the Z values calculated in this way was 0.31, however, the Z values fluctuated greatly and were considered unreliable.

Conclusions

After increasing from a value of 1.00 in 1979 to the highest value on record in 1984 the standardized catch rate declined from 1.78 in 1985 to 1.42 in 1986. This decline is consistent with the decline in biomass between 1983 and 1986 as indicated by the research surveys. These surveys are conducted in November-December period of each year and can be considered to be representative of the biomass at the beginning of year t+1.

It was noted previously (Power and Atkinson MS 1986) that the present TAC of 35,000 t is the MEY value derived from an unlagged relationship of CPUE on effort which was significant only because of the position of the 1973 point. It is, therefore, quite possible that this is an inappropriate estimate. During the period that this quota has been in effect the average annual catch has only been about 19,500 t. Although the 1984 catch rate reached an historic maximum, perhaps due to catches averaging only about 16,000 t over the previous four years, the catch rates decreased again in 1986 and this may be reflective of the catches, averaging over 26,000 t in 1984 and 1985.

The equilibrium model suggests a yield at 2/3 effort at MEY of about 25,000 t. The data also suggest that the 1986 point is approximately on the equilibrium curve. The regressions of CPUE on effort are greatly influenced by the 1983-86 points although the effects of the year-specific actual catch rates (shown to be poorly predicted in the non-equilibrium model) would be somewhat dampened through the lagging procedure.

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Table 1: Summary of nominal catches (t) of redfish in SA2 + Div. 3K.

Year	2G	2H	2J	3K	Total		TAC
1959	-	23	52,519	134,065	186,837	a	
1960	-	56	82,800	46,861	129,773	a	
1961	-	542	25,052	29,861	55,455		
1962	-	155	7,576	11,925	19,657	a	
1963	245	16	5,873	17,510	23,644		
1964	120	938	16,001	23,044	50,154	a	
1965	851	1,735	15,367	16,748	40,425	a	
1966	197	4,678	9,135	18,720	32,730		
1967	24	3,327	13,699	9,112	26,162	a	
1968	670	3,156	4,937	10,103	18,881	a	
1969	55	180	5,838	13,785	19,883	a	
1970	85	393	6,482	10,010	16,970		
1971	471	1,079	5,084	12,672	19,306		
1972	22	637	8,879	10,495	20,033		
1973	192	742	10,545	27,486	38,965		30,000
1974	85	429	5,943	23,688	30,145		30,000
1975	67	383	14,096	11,013	25,559		30,000
1976	89	1,606	14,412	9,858	25,965		30,000
1977	99	770	6,509	10,161	17,539		30,000
1978	29	554	11,804	16,759	29,146		30,000
1979	14	256	16,659	13,801	30,730		30,000
1980	2	47	4,423	10,047	14,519		35,000
1981	24	203	4,241	13,174	17,642		35,000
1982	-	583	7,048	10,352	17,983		35,000
1983	-	158	2,166	12,987	15,311		35,000
1984	49	81	2,329	21,230	23,689		35,000
1985*	-	134	859	28,307	29,300		35,000
1986*					26,633		35,000
1987							35,000

* Provisional.
a Totals include unallocated catch in Subarea 2.

Table 2: Nominal catches (t) of redfish in Subarea 2 + Division 3K by country and year.

Country	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985*	1986*
Canada	445	3,894	3,498	22,052	26,587	7,785	13,416	11,134	9,297	17,367	21,526	18,964
Cuba	-	-	-	-	43	-	-	-	-	-	-	-
GDR	2,447	1,729	1,305	2,909	543	1,102	720	425	626	485	98	134
Iceland	-	2	-	-	-	-	-	-	-	-	-	
Japan	-	-	4	255	-	9	4	2,662	-	1,218	3,601	4,149
Norway	-	9	-	-	-	1	-	-	-	-	-	-
Poland	4,219	3,950	2,269	625	302	870	635	24	1,406	366	66	366
Portugal	2,971	823	845	378	544	266	393	456	183	437	107	
Romania	-	-	312	-	-	-	-	-	-	-	-	-
Spain	26	-	134	37	-	44	-	-	-	-	-	-
USSR	13,575	14,881	8,014	2,685	2,578	4,208	2,474	3,073	3,722	3,690	3,689	2,955
Denmark	-	-	-	-	-	-	-	-	-	-	-	-
FRG	1,837	647	803	157	68	148	-	180	77	111	204	-
France	4	11	110	22	3	7	-	9	-	2	9	-
UK	35	19	245	26	62	79	-	20	-	13	-	-
Others	-	-	-	-	-	-	-	-	-	-	-	65
TOTAL	25,559	25,965	17,539	29,146	30,730	14,519	17,642	17,983	15,311	23,689	29,300	26,633

* *Provisional.*

Table 3a: Nominal catches (t) of redfish in Divisions 2GH by month and year.

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1975	33	42	145	24	11	7	126	36	4	17	1	4	450
1976	232	35	94	4	-	30	85	159	175	416	426	39	1,695
1977	48	3	12	8	-	54	38	140	306	194	49	17	869
1978	224	1	-	-	-	-	5	55	33	9	98	158	583
1979	93	-	-	-	11	-	-	35	22	81	23	5	270
1980	9	-	10	-	1	-	1	-	14	12	-	2	49
1981	22	-	-	-	-	2	28	97	19	32	15	12	227
1982	33	-	-	-	-	29	-	1	300	5	106	109	583
1983	-	-	-	-	-	-	37	-	22	7	87	5	158
1984	-	-	-	-	-	-	-	74	6	14	20	16	130
1985*	-	-	-	-	-	-	114	20	-	-	-	-	134

* Provisional.

Table 3b: Nominal catches (t) of redfish in Division 2J by month and year.

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1975	3,736	1,586	2,155	1,636	810	651	1,345	1,538	210	109	158	162	14,096
1976	2,206	485	-	2	55	73	1,495	7,208	1,827	392	63	606	14,412
1977	217	512	588	54	25	135	914	1,469	1,467	336	619	173	6,509
1978	669	217	418	177	6	1	353	3,994	3,614	1,577	527	251	11,804
1979	137	277	36	-	20	68	2,026	4,452	6,071	3,336	204	32	16,659
1980	43	357	91	59	246	6	13	464	2,784	38	106	216	4,423
1981	206	65	75	12	-	29	1,398	1,886	11	55	114	390	4,241
1982	27	294	191	63	197	410	1,134	2,395	2,188	123	14	12	7,048
1983	37	225	96	93	-	34	403	269	41	18	250	700	2,166
1984	-	-	34	14	2	114	34	1,871	46	80	67	67	2,329
1985*	-	-	-	2	-	27	482	296	14	28	-	10	859

* Provisional.

Table 3c: Nominal catches (t) of redfish in Division 3K by month and year.

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1975	1,142	2,570	2,588	1,633	212	259	617	932	433	151	341	135	11,013
1976	2,260	1,920	929	561	187	307	1,019	604	357	88	304	1,322	9,858
1977	214	1,624	754	382	245	347	3,699	1,103	1,180	377	163	73	10,161
1978	295	589	4,294	2,565	1,757	412	377	597	1,847	469	1,652	1,905	16,759
1979	134	954	1,874	1,800	1,747	951	450	2,107	1,431	2,073	115	165	13,801
1980	112	209	1,154	1,671	1,087	140	196	1,400	693	509	1,845	1,031	10,047
1981	139	342	501	1,085	630	3,405	3,212	1,998	713	120	416	613	13,174
1982	73	136	112	576	1,187	370	1,010	2,031	424	634	2,214	1,585	10,352
1983	447	1,073	2,558	1,354	972	751	627	3,772	532	548	40	313	12,987
1984	924	1,327	1,761	2,920	2,704	936	1,164	2,764	2,165	2,962	863	740	21,230
1985*	1,535	2,378	2,609	2,638	2,060	1,656	1,609	4,960	2,500	1,724	2,803	1,835	28,307

* Provisional.

Table 4: Parameter estimates from the analysis of catch/effort for redfish in SA 2 + Div. 3K using a multiplicative model.

Country-Gear-TC	Estimate	Month	Estimate
USSR OTB 4	-0.522	Jun.	-0.359
CAN(N) OTB 4	-0.100	Oct.	
		Nov.	-0.212
POL OTB 7		Dec.	
GDR OTB 5	0.000		
GDR OTB 6		May	-0.122
		Jul.	
CAN(M) OTB 4	0.148		
		Jan.	
CAN(MQ) OTM 4		Mar.	
CAN(N) OTB 5		Apr.	0.000
GDR OTB 7	0.324	Aug.	
POR OTB 7		Sep.	
USSR OTB 7			
		Feb.	0.115
CAN(M) OTB 5			
CAN(MQ) OTB 5		____	
CAN(MQ) OTM 5		Div.	
CAN(N) OTM 5	0.523	____	
ICE OTB 5			
JPN OTB 6		2H	-0.268
USSR OTM 7			
		2J	0.000
POR OTB 6	0.728	3K	
JPN OTB 7			

Table 5: Regression of multiplicative model for redfish in SA 2 + Div. 3K.

multiple r..... 0.617
multiple r squared..... 0.380

analysis of variance

source of variation	df	sums of squares	mean squares	f-value
intercept	1	4.318e1	4.318e1	
regression	38	8.953e1	2.356e0	9.665
type 1	6	3.105e1	5.175e0	21.227
type 2	4	8.851e0	2.213e0	9.077
type 3	1	1.548e0	1.548e0	6.351
type 4	27	3.250e1	1.204e0	4.937
residuals	599	1.460e2	2.438e⁻1	
total	638	2.787e2		

Table 6: The predicted catch rate for redfish in SA 2 + Div. 3K.

	ln transform		retransformed			
year	mean	s.e.	mean	s.e.	catch	effort
1959	0.2334	0.0174	1.415	0.186	186837	132087
1960	0.0229	0.0256	1.141	0.182	129773	113706
1961	0.4557	0.0593	1.730	0.416	55455	32057
1962	0.3287	0.0443	1.535	0.320	19657	12805
1963	0.3184	0.0133	1.543	0.178	23644	15321
1964	0.4502	0.0136	1.760	0.205	50154	28492
1965	0.2845	0.0138	1.491	0.175	40425	27107
1966	0.0994	0.0234	1.233	0.188	32730	26538
1967	0.1020	0.0085	1.246	0.115	26162	21000
1968	-0.1024	0.0191	1.010	0.139	18881	18690
1969	-0.4064	0.0305	0.741	0.129	19883	26828
1970	-0.1556	0.0533	0.942	0.215	16970	18023
1971	0.1081	0.0259	1.243	0.199	19306	15537
1972	0.0827	0.0261	1.211	0.195	20033	16539
1973	-0.4498	0.0280	0.711	0.118	38965	54841
1974	0.1972	0.0370	1.351	0.258	30145	22315
1975	-0.4447	0.0513	0.706	0.158	25559	36208
1976	-0.0677	0.0153	1.048	0.129	25965	24778
1977	-0.0337	0.0108	1.087	0.113	17539	16142
1978	-0.0464	0.0084	1.074	0.098	29146	27135
1979	-0.1140	0.0099	1.003	0.100	30730	30634
1980	-0.0624	0.0109	1.056	0.110	14519	13753
1981	-0.1618	0.0118	0.955	0.104	17642	18465
1982	0.1159	0.0110	1.262	0.132	17983	14253
1983	0.3234	0.0145	1.550	0.186	15311	9879
1984	0.4740	0.0102	1.806	0.182	23689	13118
1985	0.4622	0.0107	1.784	0.184	29300	16423
1986	0.2355	0.0118	1.421	0.154	26633	18736

Table 7. Results from the non-equilibrium general production analysis of catch and effort data from 1961-1986 with input values of B_∞ = 550,000 t, MEY = 28,000 t, and q fixed at 7 x 10^{-6}.

APPROXIMATE STATISTICS FROM LINEAR THEORY

	EST. PAR.	STD. ERR.	T-VALUE
B_∞	2.63488E5	3.30329E4	7.97654E0
MEY	2.36158E4	3.46499E3	6.81555E0

CORRELATION MATRIX OF THE ESTIMATED PARAMETERS

1.000000	-0.906153
-0.906153	1.000000

VARIANCE OF RESIDUALS.....	42342994.071261
R SQUARED.....	0.621123
R-BAR SQUARED.....	0.605337
DURBIN-WATSON STATISTIC.....	1.852235
ORTHOGONALITY OFFSET.....	0.111041

YEAR	BIOMASS	ADJ. LEVEL	YIELD	PRED. YIELD	RESIDUALS
1961	261,040	95,126	55,455	53,130	2,325
1962	217,686	200,856	19,657	19,165	492
1963	213,643	187,038	23,644	22,316	1,328
1964	207,386	114,705	50,154	38,711	11,443
1965	186,850	122,311	40,425	33,714	6,711
1966	173,625	125,436	32,730	30,983	1,747
1967	164,299	155,850	26,162	23,778	2,384
1968	162,710	168,536	18,881	21,158	-2,277
1969	163,804	123,843	19,883	29,782	-9,899
1970	156,434	172,199	16,970	19,771	-2,801
1971	159,308	185,852	19,306	17,481	1,825
1972	164,256	180,349	20,033	19,072	961
1973	167,322	0	38,965	56,868	-17,903
1974	133,178	148,628	30,145	20,909	9,236
1975	135,611	72,329	25,559	33,016	-7,457
1976	125,909	135,102	25,965	21,956	4,009
1977	127,279	182,529	17,539	14,894	2,645
1978	135,812	122,157	29,146	25,649	3,497
1979	133,658	102,941	30,730	28,231	2,499
1980	128,927	195,650	14,519	12,979	1,540
1981	139,422	169,772	17,642	18,433	-791
1982	144,446	192,904	17,983	14,896	3,087
1983	152,814	216,925	15,311	11,014	4,297
1984	164,562	199,137	23,689	15,444	8,245
1985	171,227	180,986	29,300	19,785	9,515
1986	173,150	168,284	26,633	22,591	4,042
1987	172,189				

Table 8. Results from the non-equilibrium general production analysis of catch and effort data from 1961-1986 with input values of B_∞ = 550,000 t, MEY = 28,000 t, and q fixed at 9 x 10^{-6}.

APPROXIMATE STATISTICS FROM LINEAR THEORY

	EST. PAR.	STD. ERR.	T-VALUE
B_∞	2.30713E5	5.00602E4	4.60872E0
MEY	2.36648E4	1.80371E3	1.31200E1

CORRELATION MATRIX OF THE ESTIMATED PARAMETERS

1.000000	-0.445448
-0.445448	1.000000

VARIANCE OF RESIDUALS.....	40856589.562451
R SQUARED.....	0.634423
R-BAR SQUARED.....	0.619191
DURBIN-WATSON STATISTIC.....	1.916796
ORTHOGONALITY OFFSET.....	0.000000

YEAR	BIOMASS	ADJ. LEVEL	YIELD	PRED. YIELD	RESIDUALS
1961	203,031	70,083	55,455	52,719	2,736
1962	165,824	166,550	19,657	19,099	558
1963	166,011	153,943	23,644	22,625	1,019
1964	162,926	87,946	50,154	39,215	10,939
1965	144,878	94,886	40,425	33,812	6,613
1966	133,829	97,737	32,730	30,896	1,834
1967	126,319	125,487	26,162	23,740	2,422
1968	126,150	137,062	18,881	21,294	-2,413
1969	128,381	96,284	19,883	29,998	-10,115
1970	121,926	140,404	16,970	19,953	-2,983
1971	125,611	152,861	19,306	17,845	1,461
1972	131,227	147,840	20,033	19,665	368
1973	134,759	0	38,965	57,073	-18,108
1974	100,997	118,898	30,145	20,428	9,717
1975	104,008	49,283	25,559	32,086	-6,527
1976	95,066	106,556	25,965	21,203	4,762
1977	96,886	149,829	17,539	14,575	2,964
1978	105,698	94,746	29,146	25,306	3,840
1979	103,820	77,213	30,730	27,686	3,044
1980	99,385	161,800	14,519	12,829	1,690
1981	110,096	138,189	17,642	18,527	-885
1982	115,246	159,295	17,983	15,175	2,808
1983	123,761	181,212	15,311	11,427	3,884
1984	135,715	164,982	23,689	16,258	7,431
1985	142,183	148,421	29,300	20,935	8,365
1986	143,596	136,832	26,633	23,878	2,755
1987	142,066				

Table 9. Results from the non-equilibrium general production analysis of catch and effort data from 1961-1986 with input values of B_∞ = 263,448 t, MEY = 23,616 t, q = 7 x 10^{-6} and fixing the shape of the curve at n = 2.

APPROXIMATE STATISTICS FROM LINEAR THEORY

	EST. PAR.	STD. ERR.	T-VALUE
B_∞	1.70661E5	5.90446E4	2.89037E0
MEY	2.50001E4	1.94013E3	1.28858E1
q	1.44843E-5	5.38552E-6	2.68949E0

CORRELATION MATRIX OF THE ESTIMATED PARAMETERS

1.000000	-0.166201	-0.771487
-0.166201	1.000000	0.623510
-0.771487	0.623510	1.000000

VARIANCE OF RESIDUALS..... 40972513.227430
R SQUARED..... 0.648662
R-BAR SQUARED..... 0.618111
DURBIN-WATSON STATISTIC..... 1.957906
ORTHOGONALITY OFFSET..... 0.002051

YEAR	BIOMASS	ADJ. LEVEL	YIELD	PRED. YIELD	RESIDUALS
1961	124,908	34,055	55,455	51,233	4,222
1962	96,509	116,121	19,657	18,633	1,024
1963	102,181	105,396	23,644	22,985	659
1964	103,136	49,252	50,154	39,567	10,587
1965	88,140	55,156	40,425	33,213	7,212
1966	79,900	57,581	32,730	29,985	2,745
1967	74,708	81,188	26,162	23,222	2,940
1968	76,187	91,035	18,881	21,354	-2,473
1969	79,674	56,345	19,883	30,197	-10,314
1970	74,267	93,878	16,970	20,235	-3,265
1971	78,801	104,475	19,306	18,671	635
1972	85,103	100,204	20,033	21,089	-1,056
1973	89,006	0	38,965	56,858	-17,893
1974	56,238	75,583	30,145	19,038	11,107
1975	59,731	16,361	25,559	29,714	-4,155
1976	52,178	65,084	25,965	19,460	6,505
1977	54,335	101,897	17,539	13,964	3,575
1978	63,015	55,037	29,146	24,866	4,280
1979	61,481	40,121	30,730	26,827	3,903
1980	57,540	112,080	14,519	12,739	1,780
1981	68,126	91,994	17,642	19,225	-1,583
1982	73,273	109,949	17,983	16,263	1,720
1983	81,855	128,594	15,311	12,762	2,549
1984	94,052	114,787	23,689	18,643	5,046
1985	99,930	100,699	29,300	24,015	5,285
1986	100,153	90,839	26,633	27,024	-391
1987	97,477				

Table 10. Results from the non-equilibrium general production analysis of catch and effort data from 1961-1986 with input values of B_∞ = 263,448 t, MEY = 23,616 t, q = 9 x 10^{-6} and fixing the shape of the curve at n = 2.

APPROXIMATE STATISTICS FROM LINEAR THEORY

	EST. PAR.	STD. ERR.	T-VALUE
B_∞	1.70528E5	5.92369E4	2.87875E0
MEY	2.49984E4	1.96736E3	1.27066E1
q	1.44877E-5	5.38978E-6	2.68800E0

CORRELATION MATRIX OF THE ESTIMATED PARAMETERS

1.000000	-0.143130	-0.758068
-0.143130	1.000000	0.622883
-0.758068	0.622883	1.000000

VARIANCE OF RESIDUALS.....	40972509.856746
R SQUARED.....	0.648662
R-BAR SQUARED.....	0.618111
DURBIN-WATSON STATISTIC.....	1.957701
ORTHOGONALITY OFFSET.....	0.000000

YEAR	BIOMASS	ADJ. LEVEL	YIELD	PRED. YIELD	RESIDUALS
1961	124,877	34,113	55,455	51,229	4,226
1962	96,468	116,038	19,657	18,631	1,026
1963	102,135	105,331	23,644	22,981	663
1964	103,086	49,283	50,154	39,559	10,595
1965	88,094	55,177	40,425	33,207	7,218
1966	79,861	57,598	32,730	29,980	2,750
1967	74,675	81,165	26,162	23,219	2,943
1968	76,158	90,995	18,881	21,352	-2,471
1969	79,647	56,364	19,883	30,195	-10,312
1970	74,244	93,833	16,970	20,234	-3,264
1971	78,779	104,412	19,306	18,671	635
1972	85,080	100,148	20,033	21,088	-1,055
1973	88,980	0	38,965	56,854	-17,889
1974	56,219	75,569	30,145	19,037	11,108
1975	59,718	16,449	25,559	29,715	-4,156
1976	52,171	65,088	25,965	19,462	6,503
1977	54,333	101,838	17,539	13,967	3,572
1978	63,018	55,058	29,146	24,871	4,275
1979	61,485	40,168	30,730	26,833	3,897
1980	57,545	112,004	14,519	12,742	1,777
1981	68,134	91,952	17,642	19,229	-1,587
1982	73,280	109,876	17,983	16,267	1,716
1983	81,858	128,489	15,311	12,765	2,546
1984	94,048	114,706	23,689	18,645	5,044
1985	99,913	100,642	29,300	24,015	5,285
1986	100,125	90,799	26,633	27,022	-389
1987	97,441				

Table11: Estimated numbers of redfish caught at age (000's) (including their average weight and length) in the commercial fishery in SA 2 + Div.3K in 1986.

	average		catch		
age	weight	length	mean	std. err.	c. v.
* 6	0.064	16.379	2	0.66	0.39
* 7	0.110	19.467	35	10.24	0.29
* 8	0.154	21.907	298	44.82	0.15
9	0.187	23.389	590	85.07	0.14
10	0.216	24.559	1669	179.32	0.11
11	0.233	25.220	2657	261.55	0.10
12	0.262	26.195	4415	363.50	0.08
13	0.293	27.208	6242	483.81	0.08
14	0.329	28.270	7889	538.84	0.07
15	0.356	29.034	6475	499.65	0.08
16	0.401	30.155	4468	405.93	0.09
17	0.451	31.355	4283	356.92	0.08
18	0.506	32.540	3631	307.59	0.08
19	0.510	32.679	2706	265.44	0.10
20	0.561	33.719	2076	216.00	0.10
21	0.603	34.546	1659	176.53	0.11
22	0.623	34.896	1308	160.90	0.12
23	0.672	35.762	1051	131.95	0.13
24	0.732	36.739	838	110.35	0.13
25	0.786	37.590	684	94.66	0.14
26	0.804	37.893	791	95.24	0.12
27	0.815	38.093	685	88.17	0.13
28	0.827	38.372	644	81.05	0.13
29	0.836	38.524	588	75.45	0.13
*30	1.139	42.270	3069	101.97	0.03

* for the ages flagged by * there was an age length key with only one age determination for some length. Since the variance formula has n_1 in the denominator it cannot be evaluated for this length. Consequently this variance component is not included in the variance for the flagged ages. This is generally not a serious problem since it occurs when few fish are caught at that length.

Table 12. Estimated numbers of redfish caught at age (000's) in SA 2 and Division 3K, 1976-1986.

age	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
6	7	22	4	240	28	44	1	1	2	0	2
7	30	102	400	2159	301	199	224	13	14	48	35
8	136	219	1241	5678	1669	607	998	351	60	220	298
9	1265	612	3297	8798	996	1398	2252	955	1058	679	590
10	2067	843	4071	9251	869	1819	3678	1155	3124	3694	1669
11	3866	1569	4495	6700	839	1536	3920	1271	3713	6542	2657
12	5580	1930	5806	4011	1031	1047	3967	2051	3982	7702	4415
13	7818	2241	6207	7374	1549	1348	4122	2090	5015	8953	6242
14	8652	3315	6267	6646	1889	1409	3479	2352	4591	7814	7889
15	8615	3162	5265	6571	2050	2138	3765	1855	4472	6445	6475
16	2700	2776	5331	6075	1727	1887	3135	1624	4002	5058	4468
17	1826	2504	3969	5544	1753	2302	3052	1641	2666	4296	4283
18	946	1812	2250	1796	1032	1920	2049	1398	2700	4072	3631
19	757	1778	1488	1241	793	1470	1537	1206	1693	2752	2706
20	1128	1638	1495	1391	10058	1308	1044	912	1851	1492	2076
21	968	895	1084	1412	669	1019	1060	956	1671	1545	1659
22	885	940	950	789	532	1001	627	710	1365	1138	1308
23	1100	555	591	573	503	1093	498	613	1044	988	1051
24	1005	618	883	599	748	1004	517	823	1183	835	838
25	684	598	828	930	521	828	324	771	956	680	684
26	678	514	746	569	524	903	369	560	954	822	791
27	512	435	509	590	505	540	341	597	758	583	685
28	632	418	535	589	389	749	256	565	806	620	644
29	284	200	139	283	415	580	226	492	652	532	588

Table 13. Estimated weight at age (kg) of redfish caught in SA 2 and Division 3K, 1976-1986.

age	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
6	0.10	0.10	0.10	0.10	0.11	0.09	0.10	0.10	0.10	0.08	0.06
7	0.14	0.14	0.14	0.14	0.17	0.11	0.14	0.14	0.12	0.12	0.11
8	0.17	0.17	0.17	0.17	0.18	0.16	0.17	0.16	0.17	0.14	0.15
9	0.20	0.20	0.20	0.20	0.22	0.20	0.21	0.19	0.20	0.19	0.19
10	0.24	0.24	0.24	0.24	0.24	0.22	0.25	0.22	0.23	0.22	0.22
11	0.28	0.28	0.28	0.28	0.28	0.24	0.27	0.25	0.25	0.24	0.23
12	0.32	0.32	0.32	0.32	0.29	0.28	0.30	0.28	0.27	0.26	0.26
13	0.36	0.36	0.36	0.36	0.31	0.32	0.33	0.30	0.31	0.29	0.29
14	0.40	0.40	0.40	0.40	0.36	0.35	0.36	0.33	0.35	0.32	0.33
15	0.44	0.44	0.44	0.44	0.42	0.40	0.41	0.37	0.37	0.36	0.36
16	0.48	0.48	0.48	0.48	0.46	0.44	0.45	0.41	0.40	0.40	0.40
17	0.52	0.52	0.52	0.52	0.53	0.49	0.49	0.48	0.44	0.44	0.45
18	0.56	0.56	0.56	0.56	0.57	0.54	0.56	0.52	0.48	0.47	0.51
19	0.60	0.60	0.60	0.60	0.60	0.59	0.60	0.57	0.51	0.51	0.51
20	0.63	0.63	0.63	0.63	0.67	0.63	0.65	0.60	0.57	0.54	0.56
21	0.67	0.67	0.67	0.67	0.65	0.70	0.69	0.64	0.63	0.61	0.60
22	0.70	0.70	0.70	0.70	0.75	0.73	0.71	0.67	0.68	0.63	0.62
23	0.73	0.73	0.73	0.73	0.79	0.76	0.80	0.72	0.70	0.72	0.67
24	0.76	0.76	0.76	0.76	0.75	0.81	0.79	0.74	0.74	0.76	0.73
25	0.79	0.79	0.79	0.79	0.77	0.82	0.85	0.80	0.77	0.80	0.79
26	0.81	0.81	0.81	0.81	0.95	0.84	0.86	0.80	0.83	0.82	0.80
27	0.84	0.84	0.84	0.84	0.93	0.93	0.87	0.83	0.83	0.85	0.82
28	0.87	0.87	0.87	0.87	0.92	0.92	0.88	0.82	0.86	0.84	0.83
29	0.89	0.89	0.89	0.89	1.00	0.89	0.90	0.90	0.87	0.86	0.84

Table 4: Numbers and weights of redfish caught per standard tow and total estimated biomass from Canadian research cruises in Divisions 2J and 3K (coefficients of variation shown in brackets).

Year	No. Sets	No. per Tow	Wt. per Tow (kg)	Total Biomass (t)
1978	118	707.5 (0.39)	215.4 (0.27)	657,320 (0.27)
1979	197	163.5 (0.24)	69.0 (0.26)	210,513 (0.26)
1980	203	163.4 (0.24)	77.2 (0.33)	235,532 (0.33)
1981	171	388.7 (0.48)	156.9 (0.43)	478,660 (0.43)
1981a	169	136.3 (0.20)	65.4 (0.22)	199,364 (0.22)
1982	230	182.8 (0.33)	68.6 (0.33)	209,166 (0.33)
1983	199	615.7 (0.45)	199.0 (0.38)	601,135 (0.38)
1983a	197	232.2 (0.18)	94.6 (0.16)	285,618 (0.16)
1984	201	113.7 (0.20)	47.0 (0.21)	139,381 (0.21)
1985	230	116.1 (0.28)	45.1 (0.27)	137,468 (0.27)
1986	160	94.3 (0.54)	48.5 (0.58)	143,038 (0.58)

a Excluding 2 large catches

Table 15. Mean numbers of redfish caught at age (sexes combined) per standard tow during Canadian research surveys to NAFO divisions 2J+3K, 1978-1986 showing total mortality coefficients (Paloheimo Z's) between years.

Age	1978	1979	1980	1981	1982	1983	1984	1985	1986
1	0.62	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	2.35	0.08	0.01	0.01	0.05	0.01	0.00	0.03	0.05
3	7.31	0.44	0.22	0.01	0.03	0.07	0.15	0.02	0.02
4	13.12	3.16	0.24	0.17	0.10	0.06	0.52	0.14	0.14
5	34.27	5.94	2.11	0.09	0.19	0.09	0.39	0.48	0.63
6	29.14	9.60	5.12	1.66	0.41	0.24	0.29	0.32	1.20
7	27.11	12.45	11.42	8.91	5.12	0.91	0.76	0.57	0.63
8	59.57	16.78	14.50	14.20	12.18	51.40	1.02	1.49	0.75
9	99.13	24.84	16.61	52.21	23.75	136.30	6.17	3.50	1.37
10	74.52	16.72	8.92	56.27	11.49	132.14	9.80	7.99	1.62
11	72.79	13.70	10.99	35.37	16.19	95.35	12.89	10.16	3.87
12	37.98	14.25	10.46	37.90	14.98	81.06	10.33	13.96	6.46
13	44.71	21.30	10.80	32.67	13.67	63.54	7.19	13.31	8.74
14	31.21	15.94	7.24	17.36	20.12	53.35	9.25	10.72	9.98
15	35.81	10.39	9.17	19.69	11.12	42.05	9.97	11.41	11.45
16	27.23	6.67	11.74	29.82	7.53	33.45	8.54	10.55	8.64
17	13.09	8.74	5.67	20.74	8.68	20.20	8.23	6.67	6.96
18	8.52	5.26	7.26	14.71	5.04	11.21	5.97	4.39	7.20
19	8.56	5.67	4.01	13.31	4.09	11.52	4.59	4.45	5.35
20	11.73	1.75	4.91	5.37	3.01	8.55	3.00	3.33	2.49
21	10.37	2.48	1.96	4.69	4.60	6.92	2.54	2.38	2.52
22	5.88	2.06	1.95	3.43	2.17	5.57	1.91	1.88	1.71
23	5.37	1.15	1.92	2.75	2.46	5.50	1.62	0.95	2.24
24	4.45	1.46	2.30	1.82	3.11	4.21	1.11	1.57	1.35
25	8.96	1.64	0.57	1.47	1.59	3.75	1.08	0.90	1.05
26	6.63	2.02	1.49	1.96	1.38	3.81	0.83	0.53	1.02
27	4.04	1.81	1.49	2.02	2.03	2.68	0.82	0.64	0.61
28	4.75	1.32	1.69	1.92	1.37	1.76	0.59	0.59	1.07
29	1.89	1.15	0.40	1.32	0.90	1.76	0.36	0.51	0.48
30+	16.17	7.31	8.21	6.71	5.57	10.31	3.71	2.69	4.71
Total Over Ages									
10-25:	401.18	129.18	99.87	297.37	129.85	578.37	99.02	104.52	81.63
11-26:		114.48	92.44	243.06	119.74	450.04	90.05	97.06	81.03
Z		1.25	0.33	-0.89	0.91	-1.24	1.86	0.02	0.25

Average Z (1978-1980) = 0.31

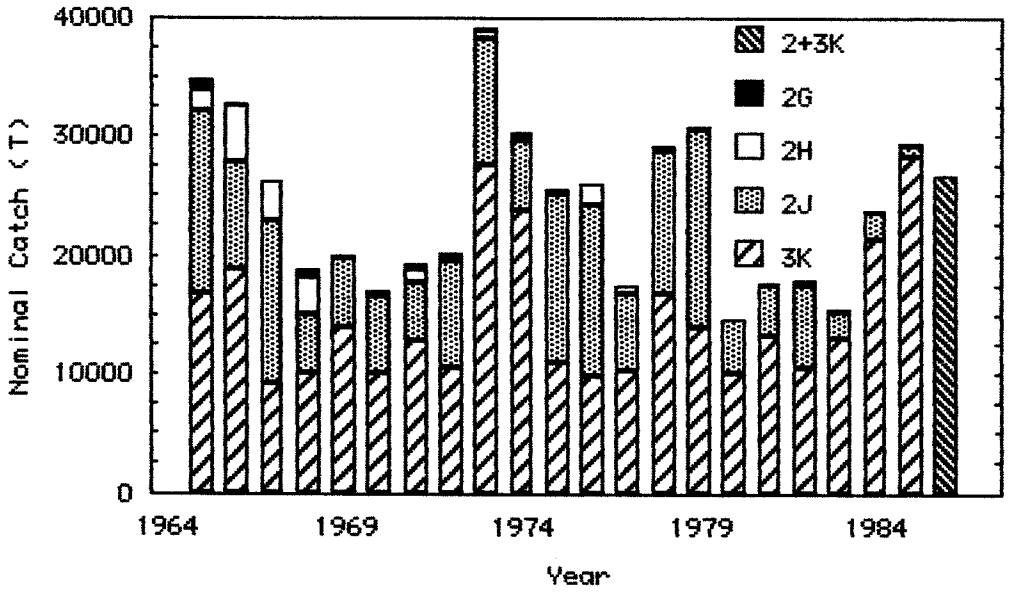

Fig. 1: Nominal catches of redfish from SA 2+ Div. 3K, 1965-1986 (1985 and 1986 are provisional, 1965 does not include an unallocated catch of 5724 t from SA 2).

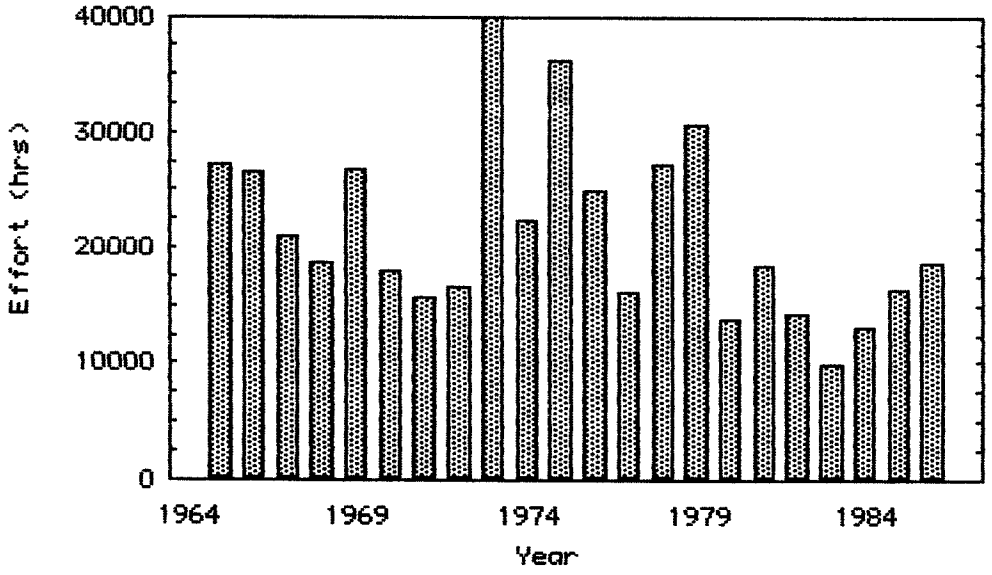

Fig. 2: Standardized effort for redfish in SA 2 + Div. 3K, 1965-1986 (1985 and 1986 are provisional)

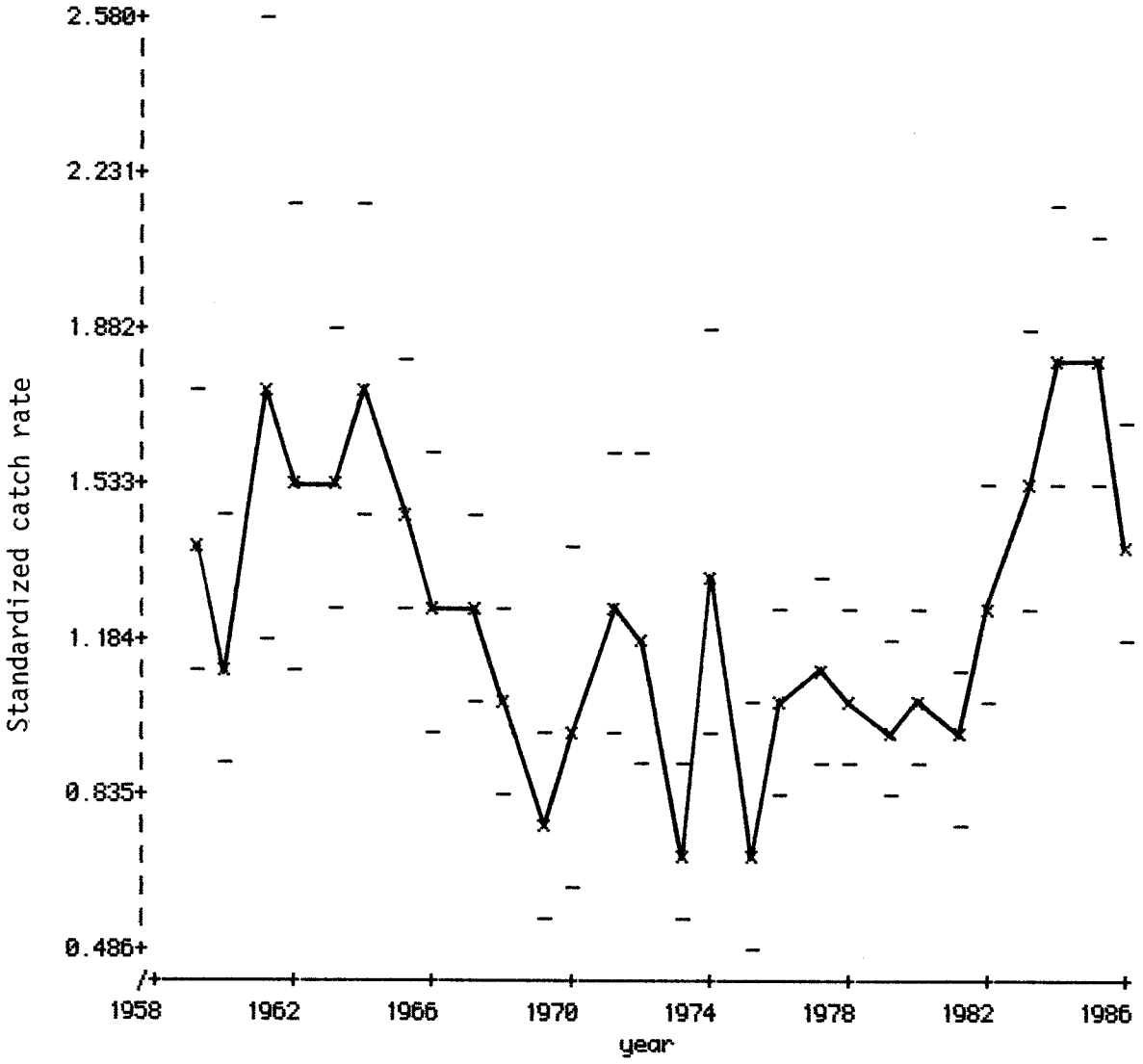

Figure 3: Plot of catch rates for redfish in NAFO Subarea 2 + Division 3K in the period 1959-1986 as derived using a multiplicative model (1985 and 1986 are preliminary).

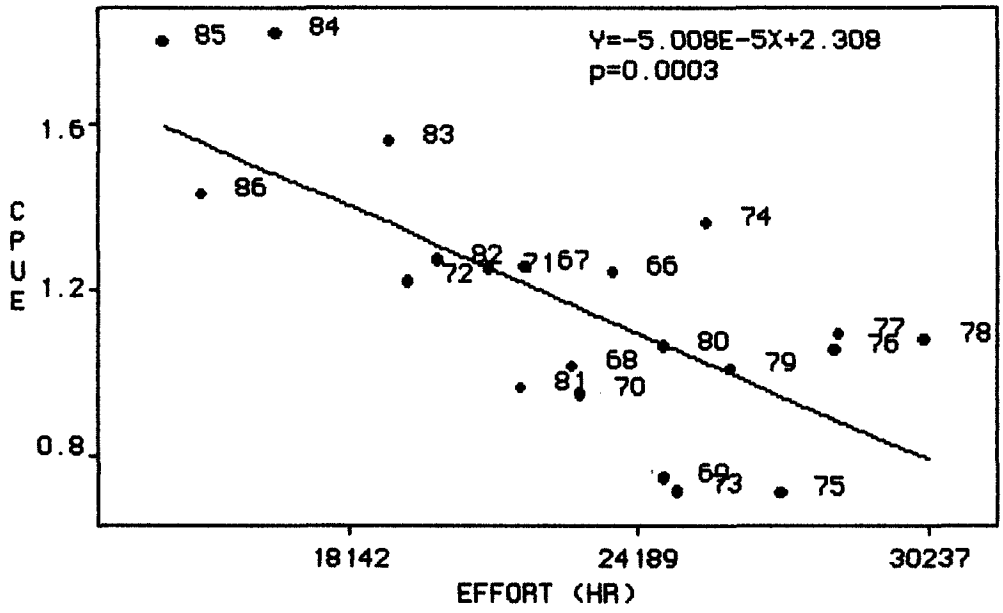

Figure 4: Regression of standardized CPUE on standardized effort for redfish in NAFO Subarea 2 + Division 3K with data lagged 6 years.

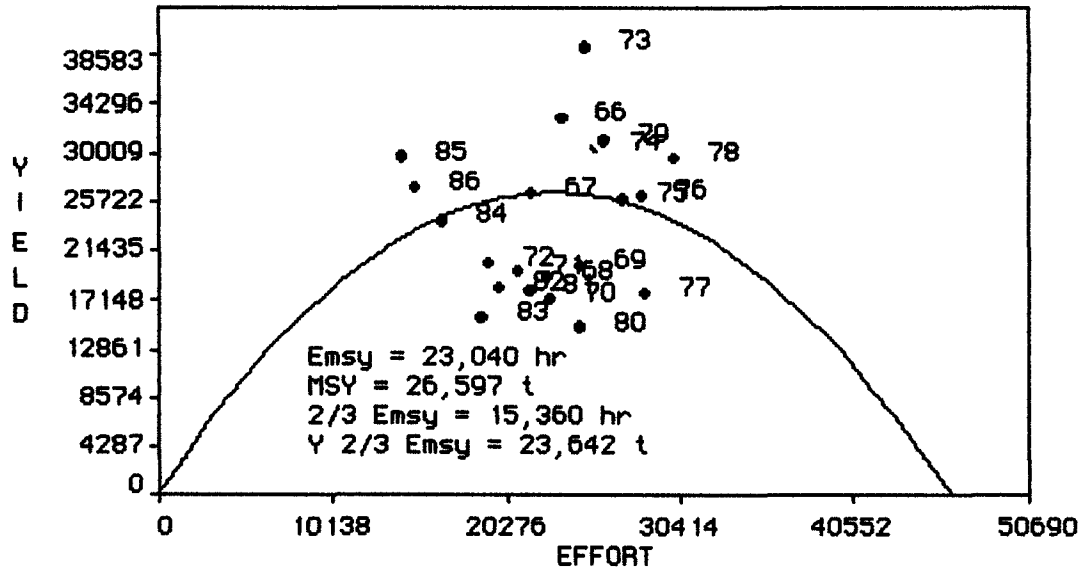

Figure 5: Schaefer general production curve derived from the regression above.

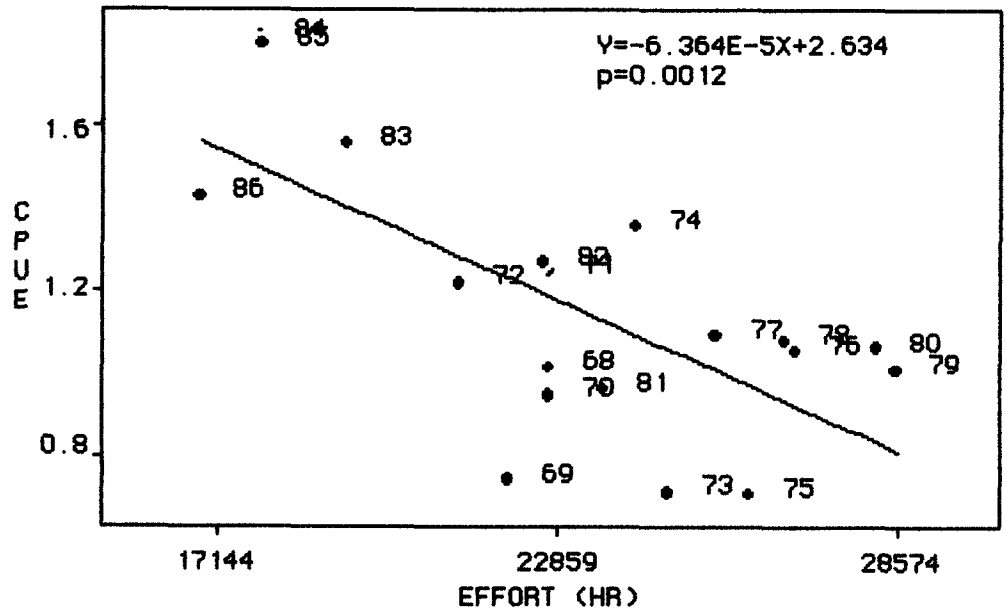

Figure 6: Regression of standardized CPUE on standardized effort for redfish in NAFO Subarea 2 + Division 3K with data lagged 8 years.

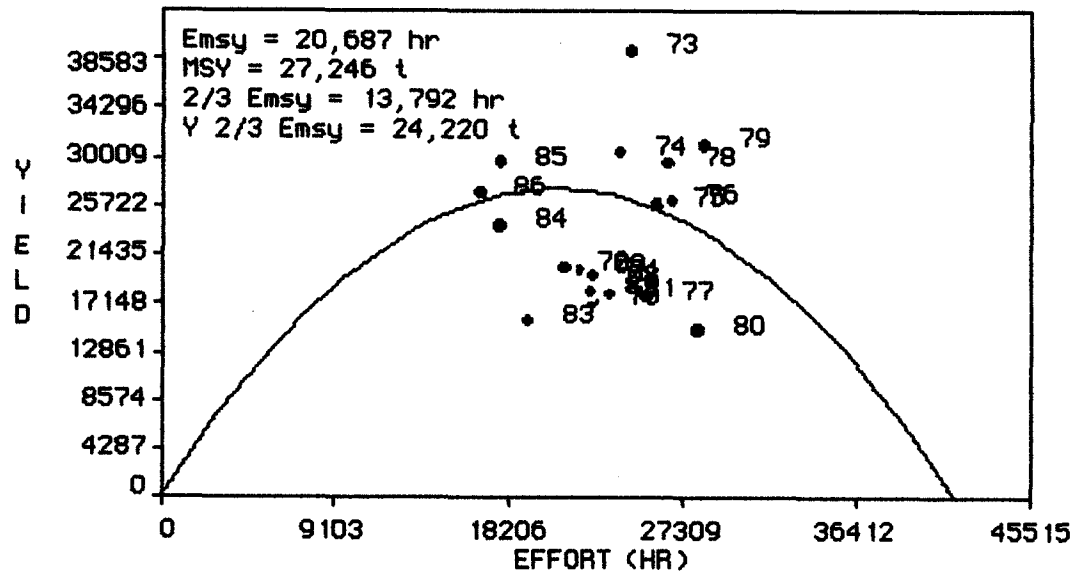

Figure 7: Schaefer general production curve derived from the regression above.

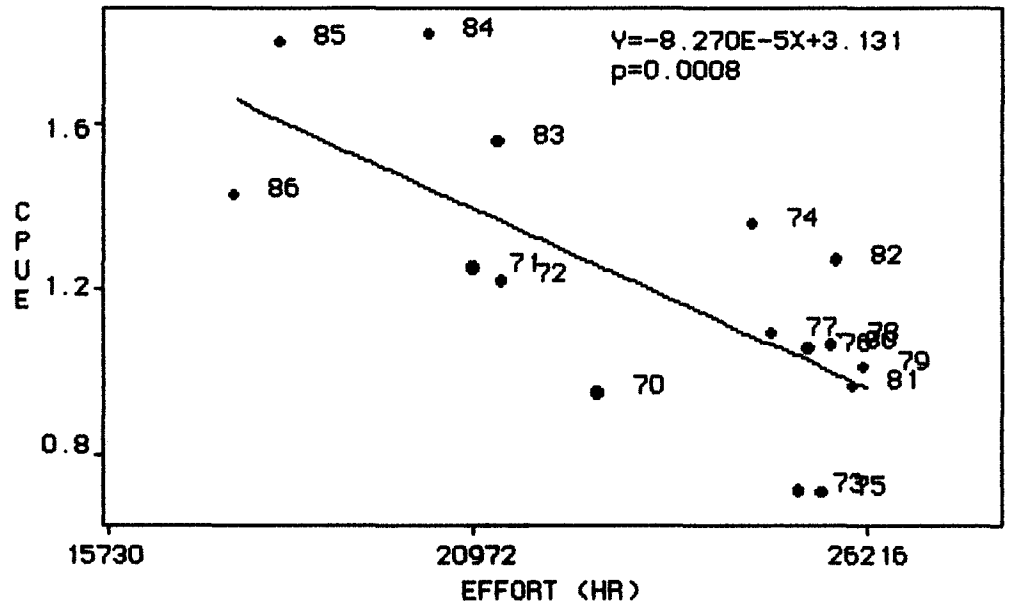

Figure 8 : Regression of standardized CPUE on standardized effort for redfish in NAFO Subarea 2 + Division 3K with data lagged 10 years.

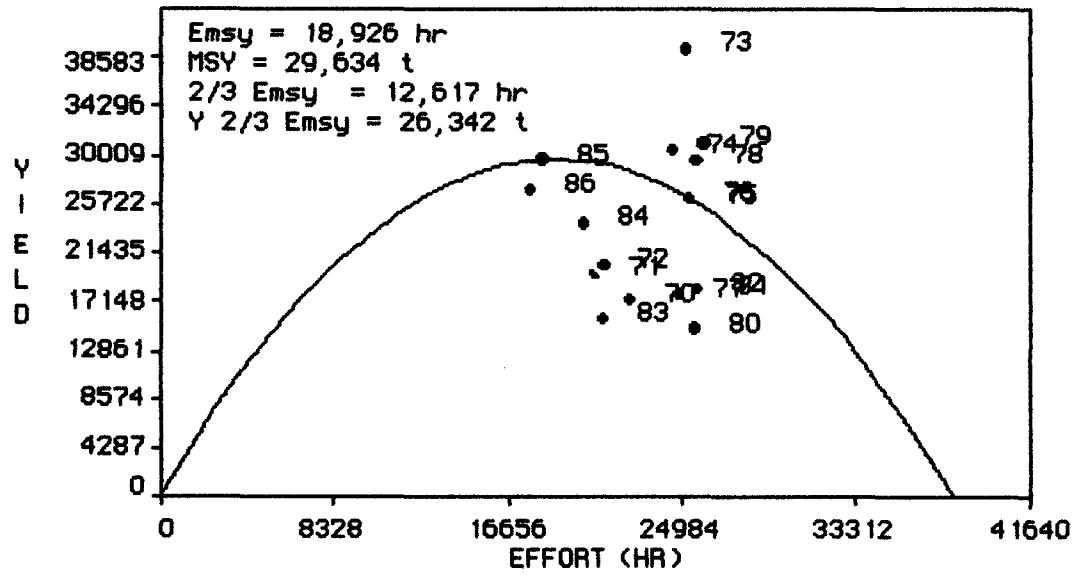

Figure 9 : Schaefer general production curve derived from the regression above.

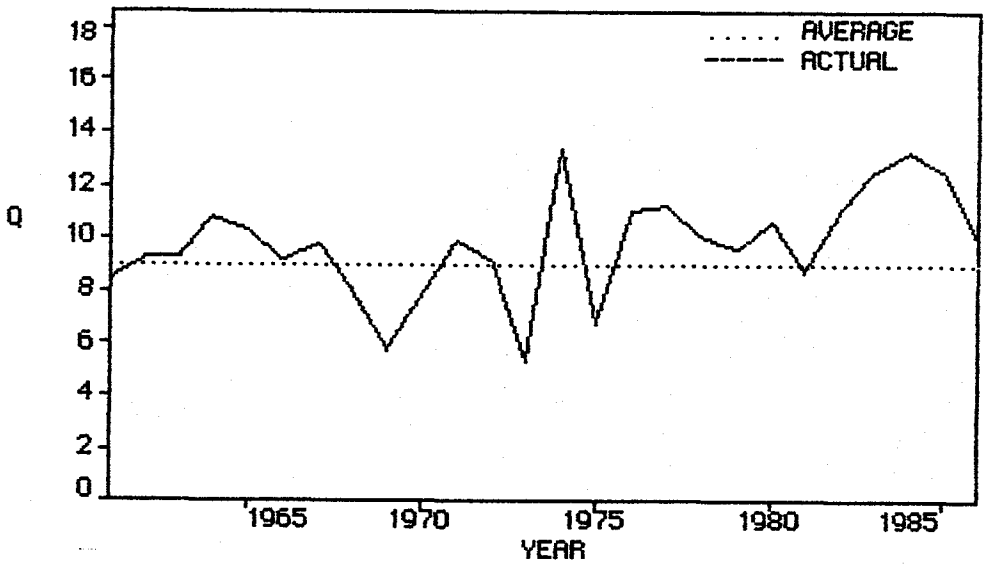

Figure 10. Average and actual q values (q X 10^{-6}) from non-equilibrium general production analysis with input parameters of B =550,000 t, MSY=28,000 t and q fixed at 9 X 10^{-6}.

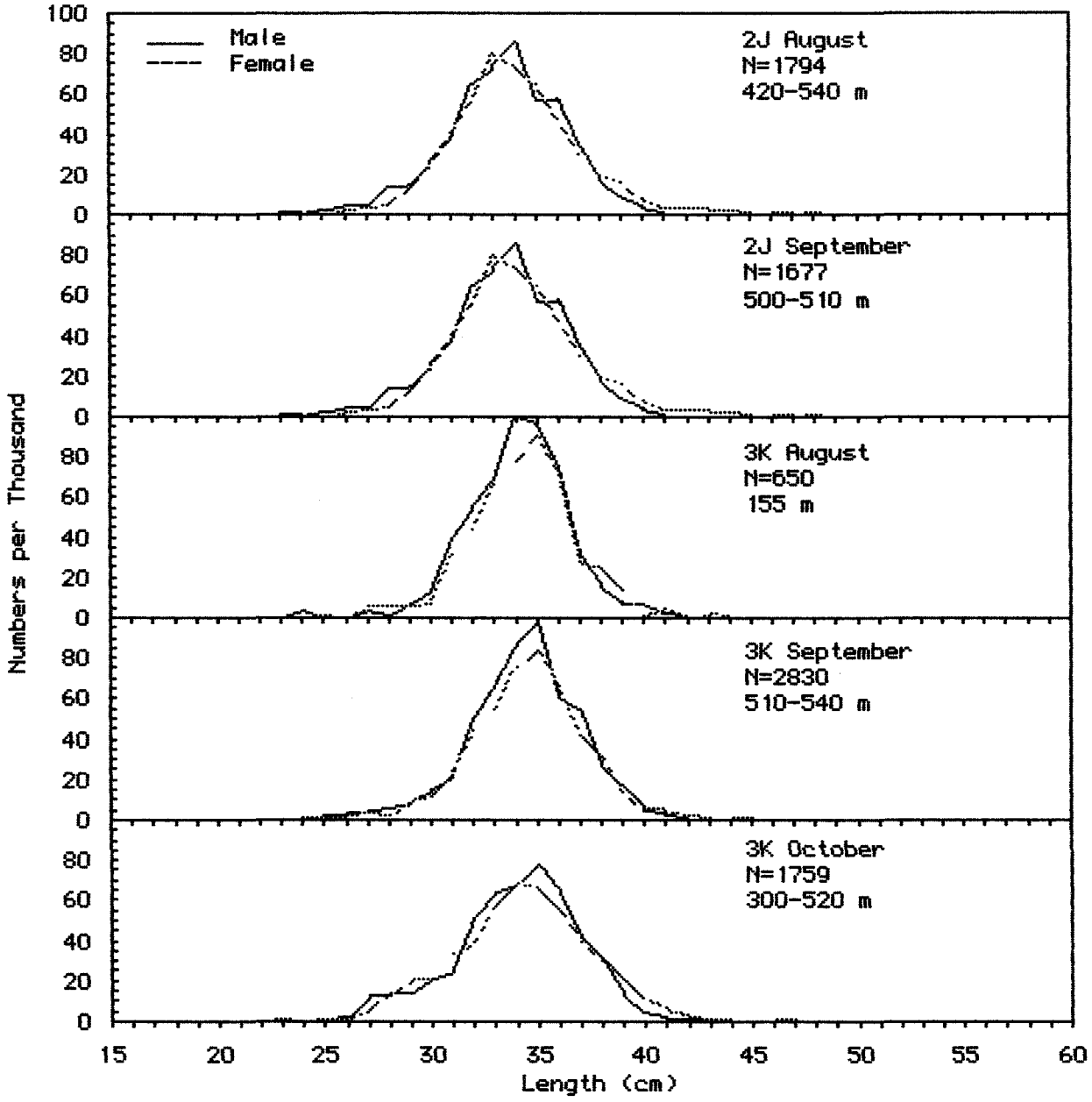

Fig.11: Commercial length frequencies of redfish caught by Poland in NAFO SA 2 and Division 3K in 1986 (sea sampling).

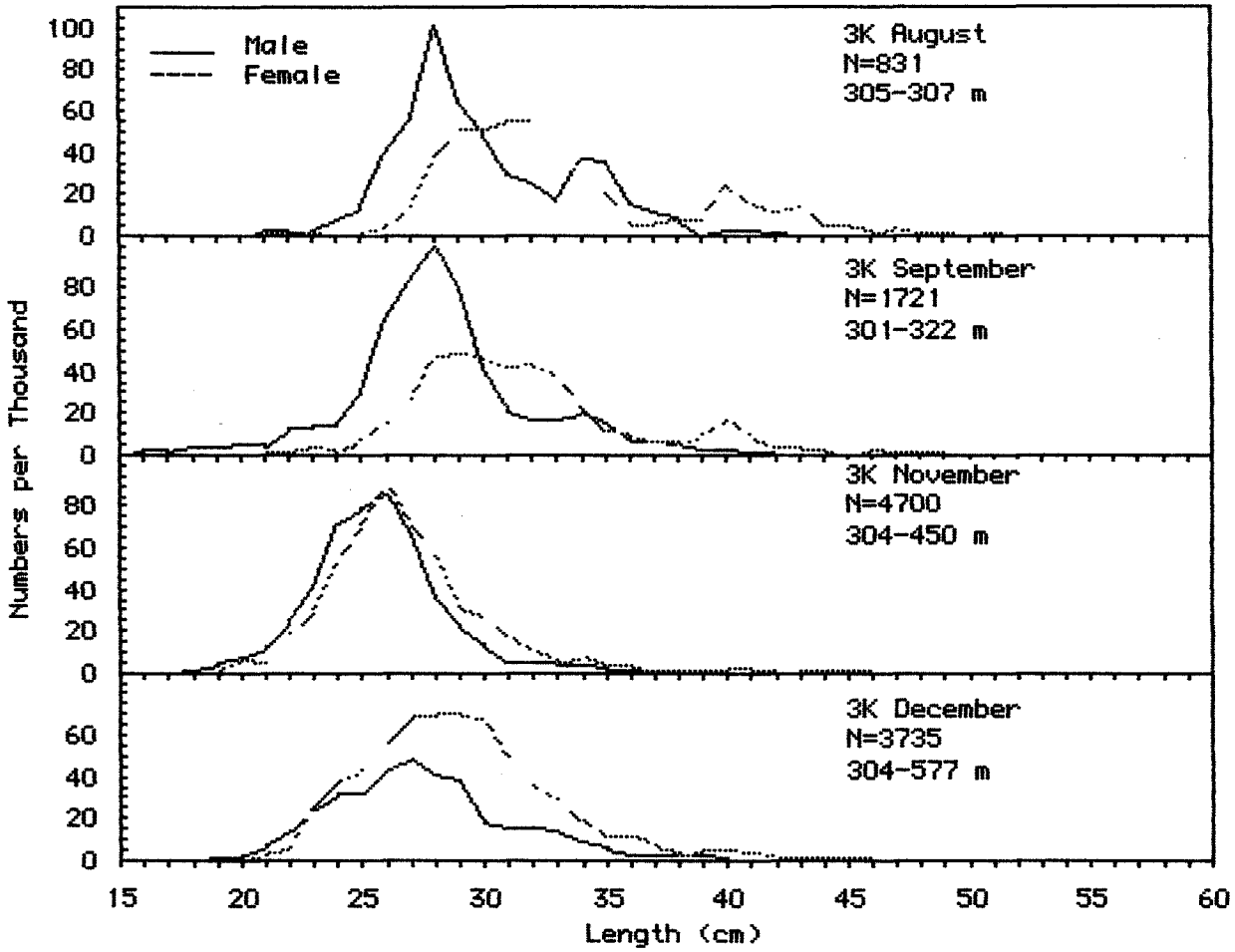

Fig. 12: Commercial length frequencies of redfish caught by Japan in NAFO SA 2 and Division 3K in 1986 (sea sampling).

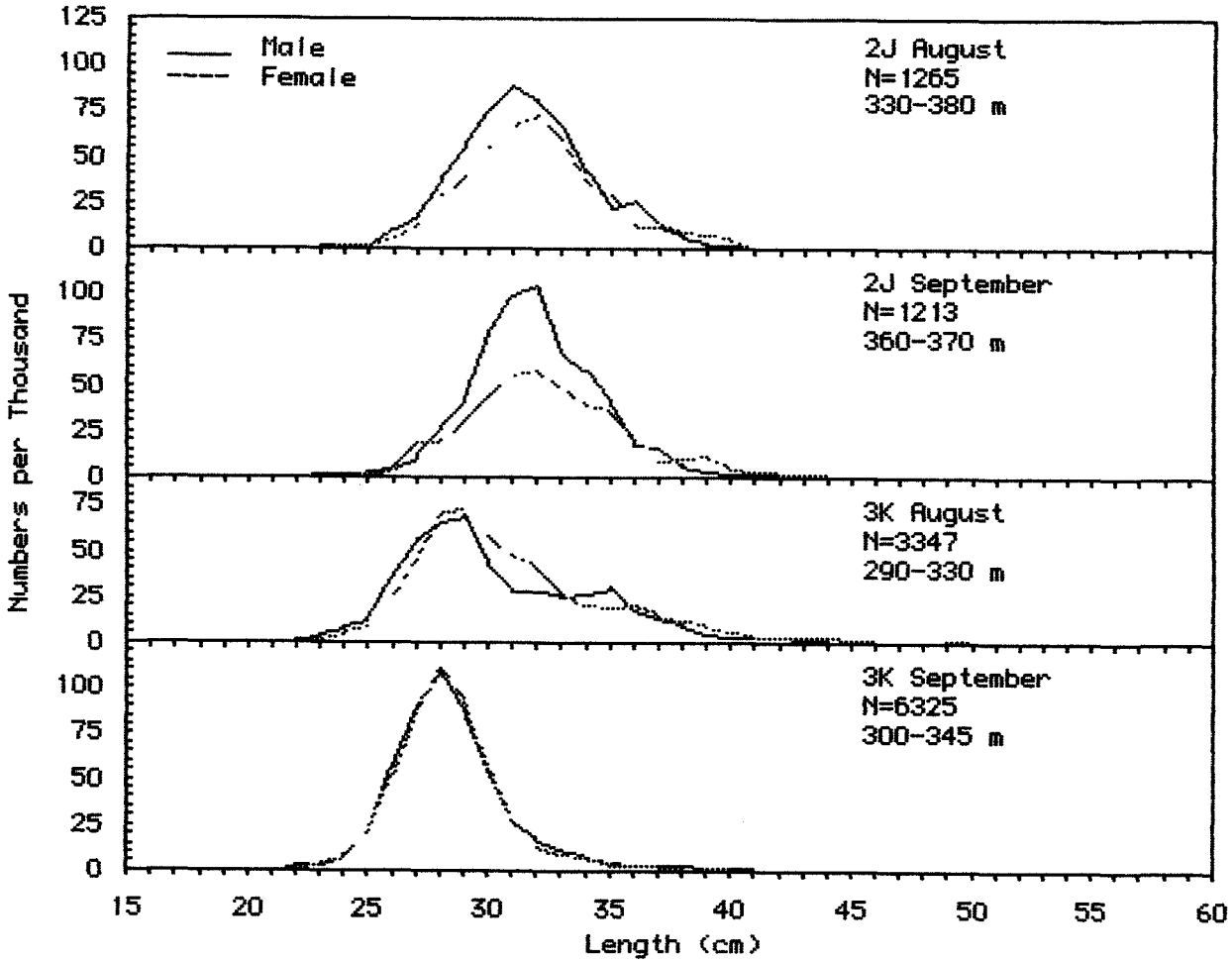

Fig.13: Commercial length frequencies of redfish caught by USSR in NAFO SA 2 and Division 3K in 1986 (sea sampling).

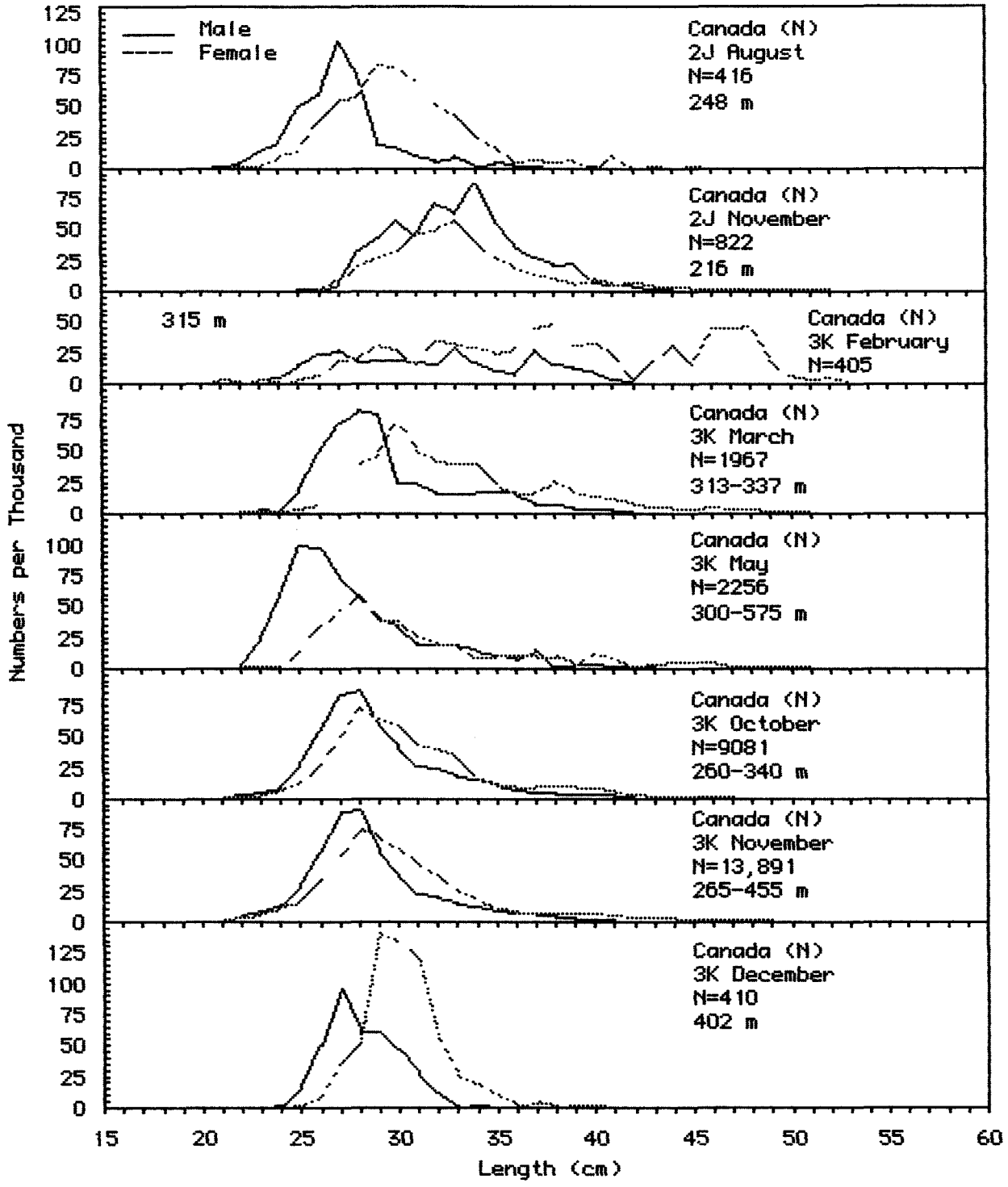

Fig.14: Commercial length frequencies of redfish caught by Canada in NAFO SA 2 and Division 3K in 1986 (sea sampling).

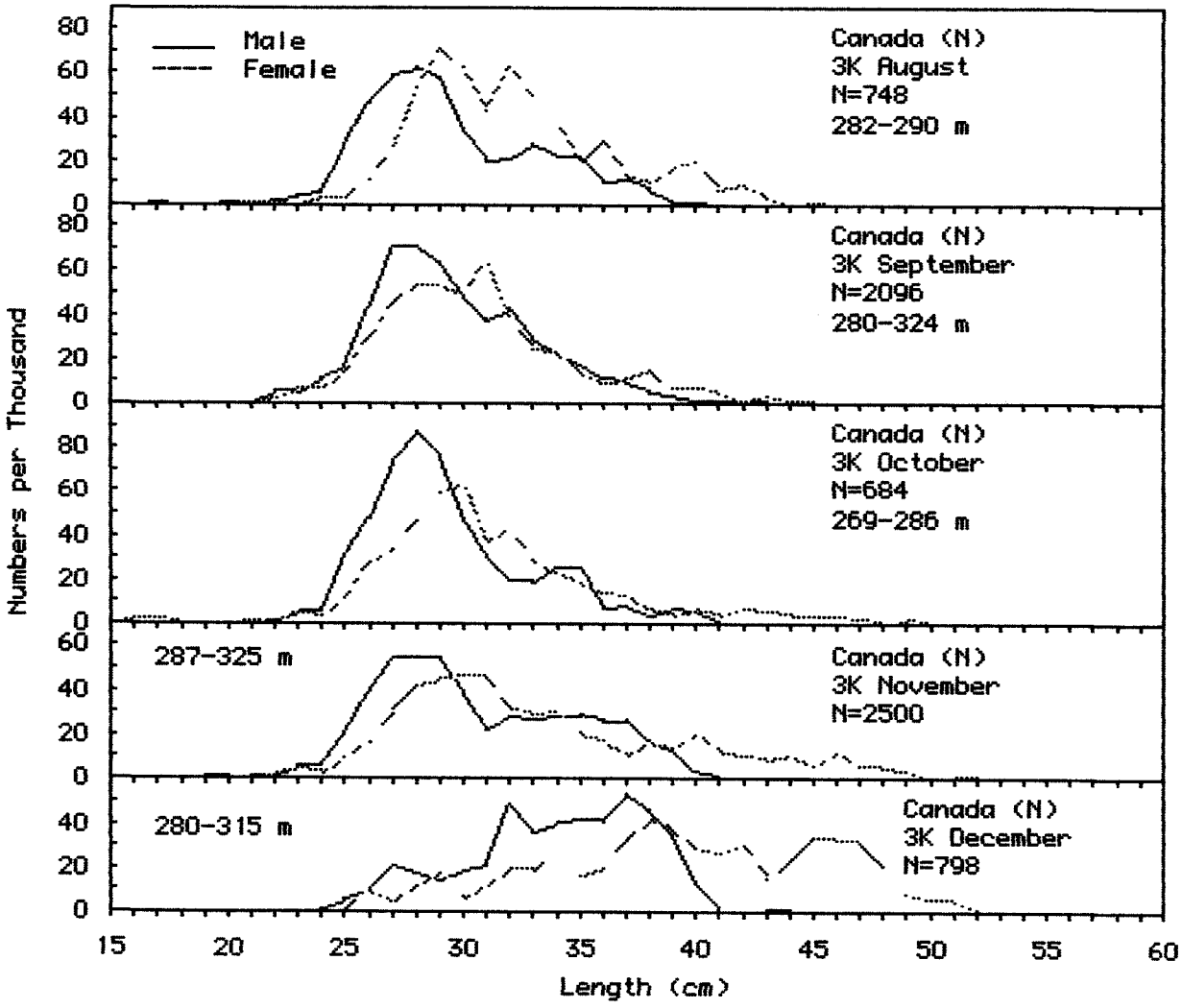

Fig.15: Commercial length frequencies of redfish caught by Canada in NAFO SA 2 and Division 3K in 1986 (port sampling).

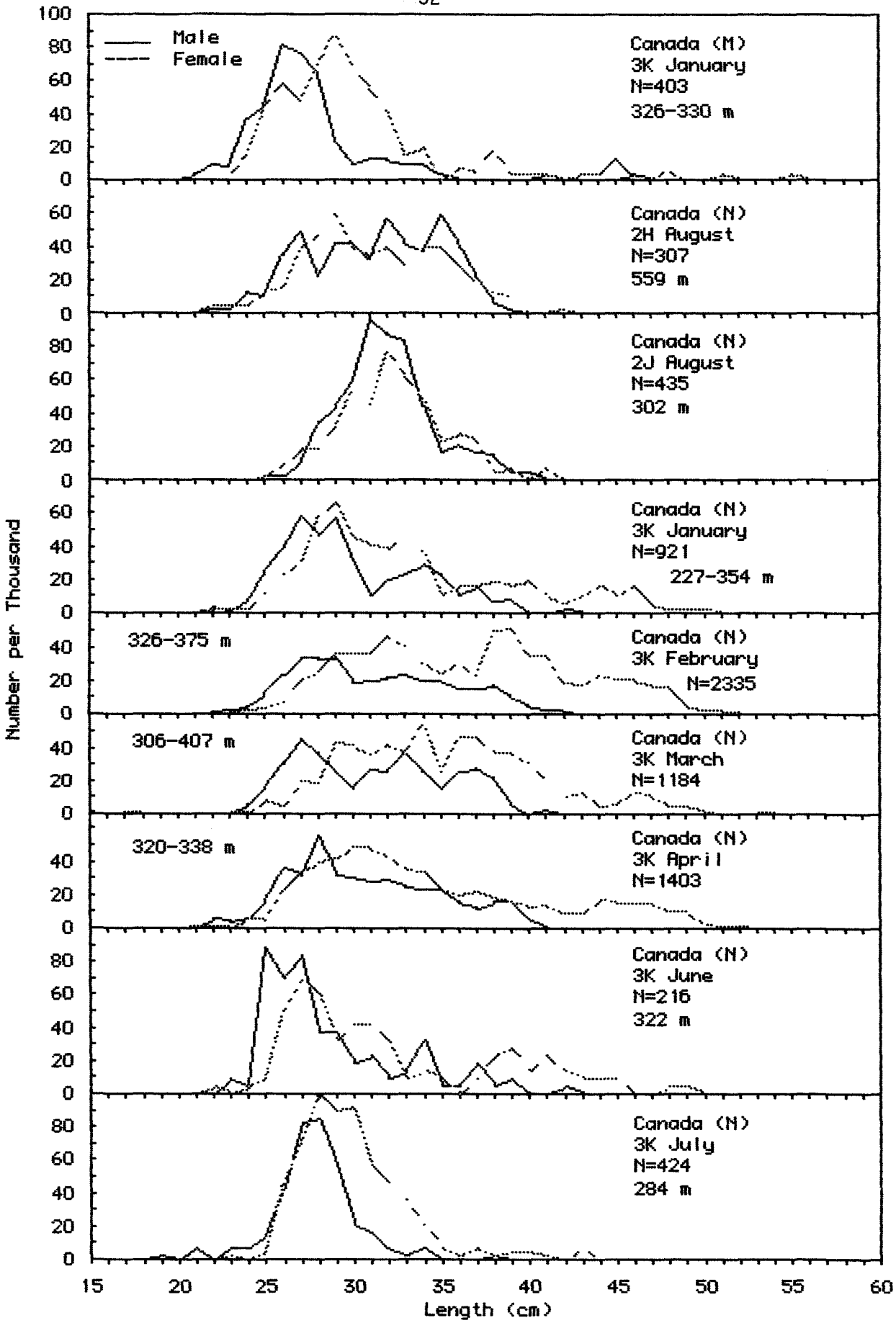

Fig.16: Commercial length frequencies of redfish caught by Canada in NAFO SA 2 and Division 3K in 1986 (port sampling).

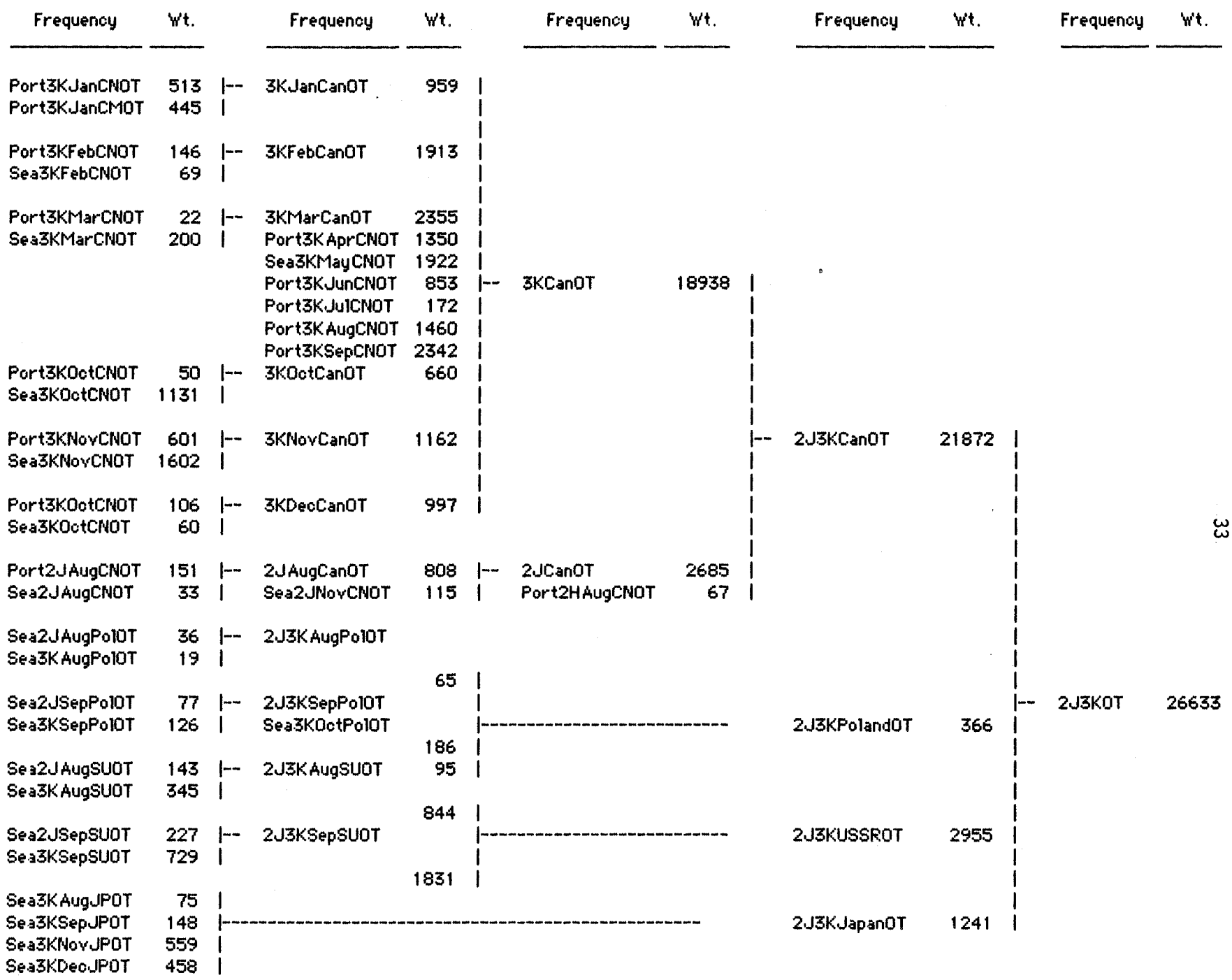

Figure 17. Commercial frequencies used and the process followed to derive the estimated numbers of redfish caught at age in NAFO Subarea 2 and Division 3K in 1986.

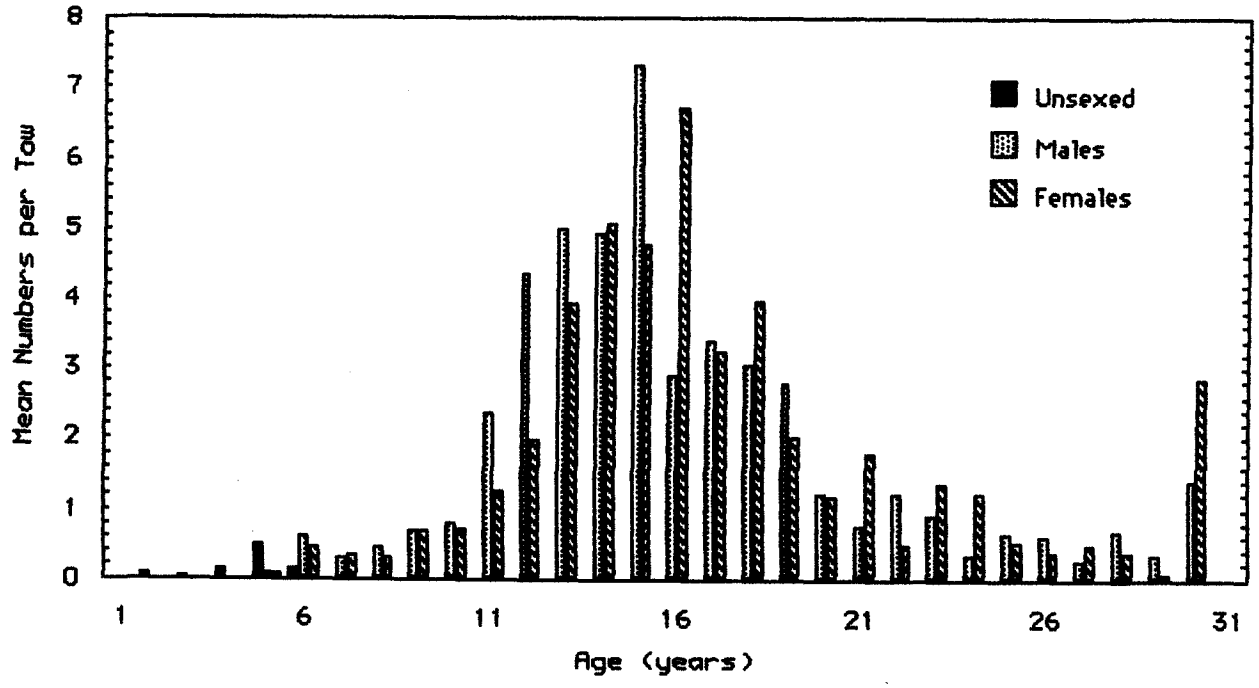

Figure 19. Mean Numbers of redfish caught per tow at age during a Canadian research cruise to NAFO Divisions 2J+3K in the fall of 1986.