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Assessment of Cod Stock in 3Pn4RS

by

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ABSTRACT

The recent increase in catch rates for cod in Area 3Pn4RS coincides with observations of exceptional recruitment of age four fish during 1978-80. Research surveys did not confirm this trend. By comparing catch rates and exploitable biomass from cohort analysis, the fishing mortality in 1980 was estimated at 0.30 for fully recruited ages. The projected catch for 1982 at $F_{0.1}$ was 105,000 metric tons (t).

RESUME

L'augmentation récente des taux de capture de morue dans les divisions 3Pn4RS coïncide avec le recrutement exceptionnel de poissons de 4 ans observé en 1978-80. Cette tendance n'est cependant pas confirmée par les relevés des navires de recherche. En comparant les taux de capture et la biomasse exploitable déduite de l'analyse des cohortes, on a estimé à 0,30 la mortalité par pêche des âges pleinement recrutés en 1980. Des prises de 105 000 t à $F_{0.1}$ sont prédites pour 1982.

SOURCE OF ASSESSMENT DATA

Commercial catch and effort data were derived from the ICNAF Statistical Bulletin for 1959-78, from the preliminary STATLANT report and the Foreign Observer Program for 1979, and from the Economics Branch, Dept. of Fisheries and the Foreign Observer Program for 1980. Some preliminary data for 1981 were also available.

Sampling for lengths and ages in 1980 was obtained from the Commercial Sampling section for Canadian landings and from the Foreign Observer Program for catches by France. The extent of coverage is evident from Table 1. Catch at age and weight at age for previous years were taken from Bishop (1980).

The results from four years, (1978-81), of research surveys were examined. The cruises in all years were conducted over approximately a three week period during January and February.

DATA ANALYSIS AND RESULTS

The catch and effort data were standardized by use of a multiplicative model (Gavaris, 1980) using a weighting factor of $(\text{catch} \times \text{effort})^{0.25}$. There were differences in relative density between divisions with 4R showing the highest catch rates and 4S the lowest. There was also a substantial seasonal trend, January and February being the best months. Different country-gear classes were similarly variable (Table 2). The multiplicative model accounted for approximately 82% of the variation in the data. Figure 1 shows that there has not been any persistent trends in the catch rate and that it has generally been about 1.5 t/hr. The categories used for standards were CanN OT-5 during January-February in Division 4R. The corresponding effort is presented in Table 3.

The catch at age was computed separately for each division (Table 4) and then added. The weight at age was obtained by applying a weight-length relationship (Wells, 1978) and the length frequencies to the age length keys. No measures were taken to account for the 7% discrepancy between the reported and calculated total catch weights.

The research surveys were analyzed using the standard arithmetic mean method. Strata which were not surveyed in all years were deleted and a few strata which appeared homogeneous were combined in order to increase the within strata sample size. Mortality rates computed from the abundance at age (Table 5) were relatively large for 1978-79 and 1980-81. The total abundance (Table 6) shows wide fluctuations which do not agree with trends in the commercial catch rate.

Partial selection at age was computed by comparing the commercial catch at age to the research catch at age (Table 7). Since the age structure and fishing fleet have not altered substantially in the last three years, the smoothed median was computed for use in cohort analysis. For the smoothing, the medians were weighted by the range divided by the median.

The catch at age and weight at age matrices in Table 8 were used as input for cohort analysis. The weight at age for 1973-77 was obtained by smoothing the mean for 1978-80 weighted by its standard error. Several preliminary attempts indicated that the partial selection used in 1980 was different from that being computed for previous years. As there has been no substantial change in the fleet, the partial selection was modified to reflect past exploitation patterns in the following manner: the average partial selection, relative to the total fishing mortality for ages 7-12 from a cohort analysis for the period 1974-79 ($F_t = 0.2$) was computed for ages 4, 5 and 6 (Table 9). All ages over six were assumed to be fully recruited.

Cohort analysis was performed for terminal fishing mortalities of 0.15, 0.25 and 0.35. The exploited biomass was computed by multiplying the biomass by a partial selection matrix. The partial selection matrix was constructed by assuming a value of 1.0 for ages 7-12 and computing the ratio of fishing mortality to total fishing mortality of ages 7-12 for all the other ages. The corrected multiple correlation coefficient and the relative deviation of predicted and observed 1980 biomass are presented in Table 10 for regressions of exploited biomass versus catch rate and biomass versus catch rate using 1974-80 data points. Figure 2 shows the graph of the regression for $F = 0.25$. It was not possible to discriminate between the three fishing mortalities from the regressions, therefore normalized catch rate and exploited biomass were compared. Table 11 summarizes the results for terminal fishing mortalities of 0.25, 0.30 and 0.35. The results from cohort analysis with a terminal fishing mortality of 0.30 are presented in Table 12. A fishing mortality of 0.30 was selected because the pattern of exploited biomass more closely resembled the normalized catch rate series. Although 0.35 gives closer agreement for 1980, the preliminary nature of the data precluded placing more emphasis on this year. Production analysis (Rivard 1980) indicates that recruitment of 4 year olds in 1980 is slightly down but growth of previous good year-classes is maintaining total production at a high level (Fig. 3).

The partial selection used in the cohort analysis and the smoothed average weights at age were used in a yield per recruit analysis using ages 4-19. A $F_{0.1}$ value of 0.20 was obtained (Table 13).

Projections were computed using the population size for 1980 (Table 12), the current commercial average weights (Table 8) and the same partial recruitment as the cohort analysis. The TAC (75,000 t) was used for 1981. The catch at $F_{0.1}$ for 1982 was 105,000 t (Table 14).

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- Rivard, D. 1980. Back-calculating production from cohort analysis, with discussion on surplus production for two redfish stocks. CAFSAC Res. Doc. 80/23.
- Wells, R. 1978. Length weight relationships of cod in Subdivision 3Ps and area 3Pn4RS in winter, 1978. CAFSAC Res. Doc. 78/9.

Table 1. Sample sizes and extent of coverage of commercial sampling for 3Pn4RS cod in 1980.

Gear	Quarter	Country	Otoliths	Month	Div.	Length Measurement		
OT	1	Can(N)	695	Feb.	4R	6,522		
					4S	3,434		
				Mar.	4R	593		
					4S	1,054		
					France	414	Jan.	4R
	2	Can(N)	421	Apr.	4R	784		
					May	4R	2,417	
				France	506	Apr.	4R	12,059
					May	4R	1,043	
					LT	1	Can(N)	269
LT	2	Can(N)	521	Mar.	3Pn	2,719		
				May	3Pn	2,265		
				4	Can(N)	467	Nov.	3Pn
GN	2	Can(N)	396	May	4R	3,007		
	3	Can(N)	463	July	4R	2,808		
Trap	3	Can(N)	-	July	4R	884		

Table 2. Regression coefficients for grouped categories and the analysis of variance from the regression of \ln catch rate for 3Pn4RS cod.

Country - gear		\ln power	Month	\ln power
CanM	OT-2	-1.251	Oct.	-0.919
CanM	OT-3	-0.969	Nov.	-0.836
CanN	OT-2	-0.711	Sept. Dec.	-0.757
CanN	OT-3			
CanN	OT-4	-0.154	Aug.	-0.624
France	OT-7			
CanM	LL-2		May June	-0.537
CanM	OT-4	0.000	July	
France	OT-6			
CanN	OT-5	0.156	Apr.	-0.340
CanM	OT-5	0.402	Mar.	-0.119
Port	OT-6		Jan. Feb.	0.000
Span	OT-6	0.705		
Span	PT-4			
Port	OT-7	1.019	Div. 4S	$\frac{\ln \text{ power}}{-0.054}$
			3Pn	0.000
			4R	0.210

REGRESSION OF MULTIPLICATIVE MODEL

MULTIPLE R.....0.907
 MULTIPLE R SQUARED.....0.822

ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DF	SUMS OF SQUARES	MEAN SQUARES	F-VALUE
TYPE 1	8	3.12800E2	3.91001E1	162.695
TYPE 2	7	8.18631E1	1.16947E1	48.662
TYPE 3	2	1.43461E1	7.17306E0	29.847
TYPE 4	22	7.04975E1	3.20443E0	13.334
REGRESSION	39	1.77565E3	4.55294E1	189.447
RESIDUALS	1600	3.84525E2	2.40328E-1	
TOTAL	1639	2.16017E3		

Table 3. Historical catch and standardized effort and catch rate for 3Pn4RS cod. The proportion of the catch used in estimating the catch rate is indicated.

Year	Catch (t)	Prop.	Catch rate		Effort(hr)
			Mean (t/hr)	Std. err.	
1959	58,060	0.04	1.294	0.197	44,869
1960	94,350	0.25	1.334	0.147	70,727
1961	100,010	0.43	1.794	0.152	55,747
1962	91,682	0.32	1.673	0.173	54,801
1963	76,151	0.28	1.981	0.217	38,441
1964	84,234	0.28	2.006	0.218	41,991
1965	68,929	0.27	1.823	0.181	37,811
1966	65,085	0.32	1.644	0.152	39,589
1967	79,312	0.26	1.429	0.118	55,502
1968	89,671	0.25	1.647	0.133	54,445
1969	71,140	0.25	1.598	0.131	44,518
1970	106,736	0.42	1.475	0.112	72,363
1971	84,310	0.40	1.124	0.088	75,009
1972	57,062	0.37	1.193	0.097	47,831
1973	66,489	0.31	0.984	0.082	67,570
1974	66,428	0.36	1.124	0.084	59,100
1975	60,215	0.31	0.949	0.076	63,451
1976	76,981	0.20	1.015	0.075	75,843
1977	73,566	0.36	1.105	0.078	66,576
1978	78,506	0.34	1.139	0.081	68,925
1979	82,677	0.36	1.459	0.104	56,667
1980	90,000	0.36	1.853	0.137	48,570
1981	75,000	0.03	1.836	0.355	40,850

Table 4. Catch at age in each division during 1980 (thousands of fish).

Age	3Pn		CanN (inshore)	4R		Can (OT)
	CanN (inshore)	France (OT)		Can (OT)	France (OT)	
4	95	1	1716	98	219	10
5	703	27	6846	3685	1454	225
6	1680	79	6357	5358	2432	458
7	746	50	2738	3552	1134	389
8	321	21	1393	2299	455	340
9	88	4	365	443	66	45
10	27	1	86	159	20	28
11	12		53	80	8	23
12	7		44	130	7	29
13	4		11	34	2	5
14	4		7	50	3	5
15	3		5	8	2	1

Table 5. Cod abundance at age and total mortality rates calculated from the research surveys in 3Pn4RS.

Age	1978	1979	1980	1981
1	0	49	0	30
2	906	2,609	2,263	1,028
3	4,804	3,309	19,165	4,133
4	23,459	10,710	25,795	15,752
5	34,046	16,964	46,110	11,946
6	43,516	12,483	35,454	25,048
7	12,799	9,825	16,951	17,930
8	4,407	4,462	9,112	9,212
9	1,705	938	3,661	2,882
10	2,592	529	615	631
11	889	1,062	522	0
12	1,066	392	438	246
13	391	290	390	147
14	294	190	300	311
15	12	110	87	108
16	0	68	53	25
17	0	15	7	0
18	11	0	24	0
19	0	7	13	0
20	11	0	7	14
	3-4	-0.802	-2.054	0.196
	4-5	0.324	-1.460	0.770
	5-6	1.003	-0.737	0.610
	6-7	1.488	-0.306	0.682
	7-8	1.054	0.075	0.610
	8-9	1.547	0.198	1.151
	9-10	1.170	0.422	1.758

Table 6. Total cod abundance for each division separately and combined.

Year	3Pn	4R	4S	3Pn4R	3Pn4RS
1978	5,410	115,609	9,736	121,019	130,877
1979	687	48,940	14,185	49,627	64,027
1980	2,420	145,952	12,562	148,372	160,966
1981	5,368	73,747	10,459	79,115	89,565

Table 7. Partial selection computed by comparing commercial and research numbers caught at age for 3Pn4RS cod. The last column is the smoothed median of the three years.

	1978	1979	1980	
4	0.165	0.254	0.154	0.182
5	0.405	0.633	0.524	0.535
6	0.500	0.730	0.873	0.828
7	1.000	0.869	0.965	1.000
8	0.683	0.693	1.000	0.848
9	0.845	1.000	0.521	0.838
10	0.567	0.805	0.978	0.818
11	0.640	0.295	0.628	0.667
12	0.443	0.426	0.925	0.515
13	0.614	0.256	0.264	0.434
14	0.497	0.289	0.443	0.434
15	0.000	0.169	0.417	0.384

Table 8. Catch at age (numbers $\times 10^{-3}$) and weight at age (Kg) in cohort analysis for 3Pn4RS cod.

		<u>Numbers</u>							
	1	1973	1974	1975	1976	1977	1978	1979	1980
4	1	8824	1471	2924	1984	3141	3134	4110	2620
5	1	20463	5121	4380	14724	10292	11159	16209	15975
6	1	10055	11537	6446	7570	15321	17601	13751	20475
7	1	5515	7353	9048	3775	7653	10346	12890	10821
8	1	3196	10987	3392	5867	2882	2432	4669	6029
9	1	2137	3902	5808	2016	3041	1164	1416	1262
10	1	709	2722	1647	2584	949	1188	643	398
11	1	306	704	815	1717	612	460	473	217
12	1	56	273	870	600	292	382	252	268
13	1	19	147	64	196	171	194	112	68
14	1	31	48	52	90	49	106	83	88
15	1	5	40	150	27	11	17	28	24

		<u>Average Weight</u>							
	1	1973	1974	1975	1976	1977	1978	1979	1980
4	1	0.574	0.574	0.574	0.574	0.574	0.679	0.550	0.516
5	1	0.859	0.859	0.859	0.859	0.859	0.865	0.890	0.818
6	1	1.300	1.300	1.300	1.300	1.300	1.299	1.320	1.288
7	1	1.790	1.790	1.790	1.790	1.790	1.840	1.780	1.761
8	1	2.430	2.430	2.430	2.430	2.430	2.559	2.410	2.365
9	1	3.060	3.060	3.060	3.060	3.060	3.008	3.150	3.423
10	1	3.600	3.600	3.600	3.600	3.600	2.880	3.570	4.166
11	1	4.060	4.060	4.060	4.060	4.060	3.229	3.790	4.428
12	1	4.480	4.480	4.480	4.480	4.480	3.961	4.510	3.775
13	1	4.890	4.890	4.890	4.890	4.890	4.121	5.230	4.979
14	1	5.300	5.300	5.300	5.300	5.300	5.838	4.740	3.931
15	1	5.710	5.710	5.710	5.710	5.710	9.334	5.430	6.997

Table 9. Historical partial selection pattern for 3Pn4RS cod (ages 4-6).

Age	Selectivity						Avg.
	1974	1975	1976	1977	1978	1979	
4	0.062	0.080	0.033	0.050	0.037	0.079	0.05
5	0.340	0.299	0.539*	0.203	0.260	0.354	0.29
6	0.547	0.816	0.753	0.840	0.558	0.649	0.60

*Omitted

Table 10. Results of the regression analysis of exploited biomass versus catch rate and biomass versus catch rate for 3Pn4RS cod.

	Fishing mortality		
	0.15	0.25	0.35
<u>Exploited biomass</u>			
Corrected R ²	0.95	0.92	0.78
1980 % deviation	4	4	4
<u>Biomass</u>			
Corrected R ²	0.87	0.86	0.84
1980 % deviation	6	5	5

Table 11. The normalized catch rate and exploitable biomass obtained by dividing the value for each year by the average for 1974-77 for 3Pn4RS cod.

Year	Catch rate	Exploitable biomass		
		F = 0.25	F = 0.30	F = 0.35
1974	1.07	1.15	1.17	1.19
1975	0.91	1.02	1.03	1.04
1976	0.97	0.94	0.93	0.93
1977	1.05	0.88	0.86	0.85
1978	1.09	1.03	0.98	0.94
1979	1.39	1.50	1.35	1.24
1980	1.77	2.34	1.99	1.74

Table 12. Cohort analysis using a fishing mortality of 0.30 for fully recruited fish in 1980 for 3Pn4RS cod.

POPULATION NUMBERS ($\times 10^{-3}$)								
	1973	1974	1975	1976	1977	1978	1979	1980
4	51566	51263	95216	127897	124724	230887	266877	198049
5	82308	34235	40640	75310	102918	99274	186199	214781
6	36499	48873	23395	29310	48336	74950	71181	137780
7	40281	20785	29574	13322	17147	25711	45438	45836
8	16990	27989	10364	16027	7491	7114	11689	25538
9	9654	11018	12974	5416	7813	3526	3624	5346
10	3811	5971	5491	5367	2610	3645	1833	1686
11	1055	2479	2425	3005	2056	1278	1909	919
12	476	587	1393	1248	907	1129	630	1135
13	724	339	234	353	479	478	579	288
14	164	576	145	133	112	238	216	373
15	30	106	428	71	28	47	99	102
4+	243560	204220	222278	277460	314621	448277	590274	631832
5+	191993	152957	127062	149562	189897	217390	323397	433783
6+	109685	118722	86422	74252	86979	118116	137198	219002
7+	73186	69849	63027	44942	38642	43166	66017	81222

MEAN POPULATION BIOMASS (t)								
	1973	1974	1975	1976	1977	1978	1979	1980
4	24286	26258	48718	65985	64010	141057	131938	91967
5	55100	24457	29779	52253	75760	73049	143091	152837
6	36281	49945	23255	29494	46594	76599	76008	147741
7	60435	26805	39583	18130	20414	32731	61477	63519
8	33508	47455	18527	27780	12786	13241	19540	47529
9	23457	24285	26371	11762	16728	7784	7977	14399
10	11151	14168	14845	12422	6716	7731	4727	5527
11	3241	7648	7195	7110	6280	2959	5643	3203
12	1809	1718	3393	3599	3000	3263	1971	3372
13	3164	1116	874	1025	1684	1359	2450	1129
14	703	2640	550	356	396	923	719	1153
15	143	429	1770	289	110	315	408	560
4+	253279	226924	214859	230204	254478	361013	455948	532936
5+	228993	200666	166141	164219	190468	219955	324010	440969
6+	173892	176208	136362	111967	114708	146906	180919	288132
7+	137612	126263	113107	82473	68114	70307	104911	140391

FISHING MORTALITY								
	1973	1974	1975	1976	1977	1978	1979	1980
4	0.210	0.032	0.035	0.017	0.028	0.015	0.017	0.015
5	0.321	0.181	0.127	0.243	0.117	0.133	0.101	0.085
6	0.363	0.302	0.363	0.336	0.431	0.300	0.240	0.178
7	0.164	0.496	0.413	0.376	0.680	0.588	0.376	0.300
8	0.233	0.569	0.449	0.518	0.554	0.475	0.582	0.300
9	0.281	0.497	0.683	0.530	0.562	0.454	0.565	0.300
10	0.230	0.701	0.403	0.760	0.514	0.447	0.490	0.300
11	0.386	0.377	0.464	0.998	0.399	0.507	0.320	0.300
12	0.139	0.722	1.173	0.758	0.440	0.468	0.583	0.300
13	0.029	0.652	0.361	0.951	0.502	0.595	0.240	0.300
14	0.235	0.097	0.506	1.371	0.664	0.679	0.553	0.300
15	0.200	0.533	0.484	0.534	0.569	0.503	0.373	0.300
7+	0.201	0.538	0.493	0.551	0.597	0.542	0.426	0.300

Table 13. Thompson-Bell yield per recruit analysis using ages 4-19 for 3Pn4RS cod.

YIELD PER RECRUIT ANALYSIS

	FISHING MORTALITY	CATCH (NUMBER)	YIELD (KG)	AVG. WEIGHT (KG)	YIELD PER UNIT EFFORT
	0.1000	0.223	0.589	2.643	1.000
	0.2000	0.341	0.780	2.287	0.661
F0.1---	0.2032	0.344	0.783	2.277	0.654
	0.3000	0.413	0.840	2.034	0.475
	0.4000	0.462	0.856	1.850	0.363
FMAX---	0.4304	0.475	0.856	1.804	0.338
	0.5000	0.499	0.854	1.712	0.290
	0.6000	0.527	0.846	1.605	0.239
	0.7000	0.550	0.835	1.519	0.202
	0.8000	0.569	0.824	1.449	0.175
	0.9000	0.585	0.813	1.391	0.153
	1.0000	0.598	0.803	1.342	0.136

Table 14. Projections for the cod stock in Area 3Pn4Rs using 75,000 t as the catch in 1981 and $F_{0.1} = 0.20$ in 1982-83.

POPULATION NUMBERS ($\times 10^{-3}$)					CATCH NUMBERS ($\times 10^{-3}$)				
	1980	1981	1982	1983		1980	1981	1982	1983
4	198049	250000	85000	85000	4	2620	2058	751	751
5	214781	159782	202824	68913	5	15975	7492	10195	3464
6	137780	161438	124057	156857	6	20475	15374	12640	15982
7	45836	94364	118311	90174	7	10821	14577	19502	14864
8	25538	27801	64132	79307	8	6029	4294	10571	13073
9	5346	15489	18894	42989	9	1262	2393	3115	7086
10	1686	3242	10527	12665	10	398	501	1735	2088
11	919	1023	2204	7056	11	217	158	363	1163
12	1135	558	695	1477	12	268	86	115	243
13	288	689	-379	466	13	68	106	62	77
14	373	175	468	254	14	88	27	77	42
15	102	226	119	314	15	24	35	20	52
4+	631832	714786	627609	545472	4+	58245	47102	59147	58885
5+	433783	464786	542609	460472	5+	55625	45043	58395	58134
6+	219002	305004	339785	391559	6+	39650	37551	48200	54670
7+	81222	143566	215728	234701	7+	19175	22177	35561	38688

POPULATION BIOMASS (AVERAGE) (t)					CATCH BIOMASS (t)				
	1980	1981	1982	1983		1980	1981	1982	1983
4	91967.35	116404.55	39564.65	39564.65	4	1352	1062	388	388
5	152836.84	115474.57	146305.05	49710.14	5	13068	6128	8339	2833
6	147741.18	178722.16	136806.46	172977.81	6	26372	19802	16280	20584
7	63519.28	137846.34	171719.11	130879.85	7	19056	25669	34344	26176
8	47528.62	54540.49	125007.94	154586.88	8	14259	10156	25002	30917
9	14399.42	43981.77	53304.68	121281.78	9	4320	8190	10661	24256
10	5526.89	11204.67	36145.61	43487.05	10	1658	2087	7229	8697
11	3202.92	3755.88	8041.89	25752.90	11	961	699	1608	5151
12	3372.33	1745.81	2162.18	4595.68	12	1012	325	432	919
13	1128.57	2843.79	1554.87	1911.61	13	339	530	311	382
14	1153.09	569.68	1516.10	822.88	14	346	106	303	165
15	559.76	1312.25	684.72	1808.92	15	168	244	137	362
4+	532936.26	668401.95	722813.26	747380.14	4+	82909	75000	105035	120831
5+	440968.91	551997.40	683248.60	707815.49	5+	81557	73938	104647	120443
6+	288132.07	436522.83	536943.55	658105.36	6+	68489	67809	96307	117610
7+	140390.89	257800.67	400137.10	485127.54	7+	42117	48007	80027	97026

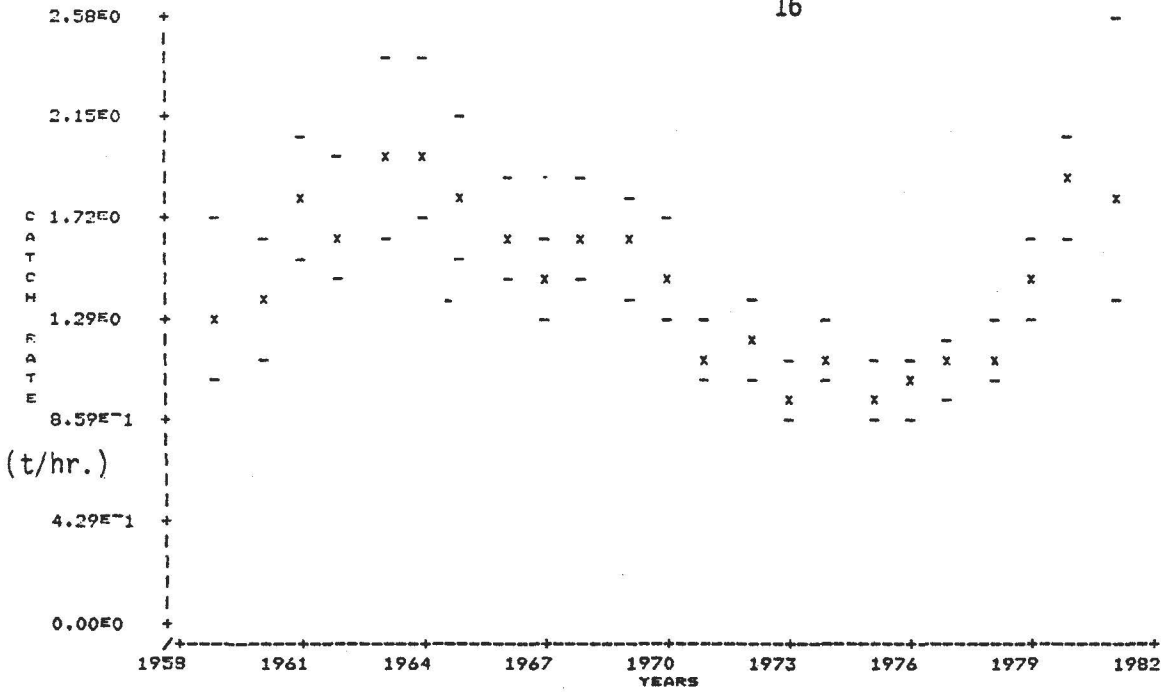


Fig. 1. Historical catch rates and approximate 90% confidence intervals - 3Pn4RS cod.

TERMINAL F 0.25

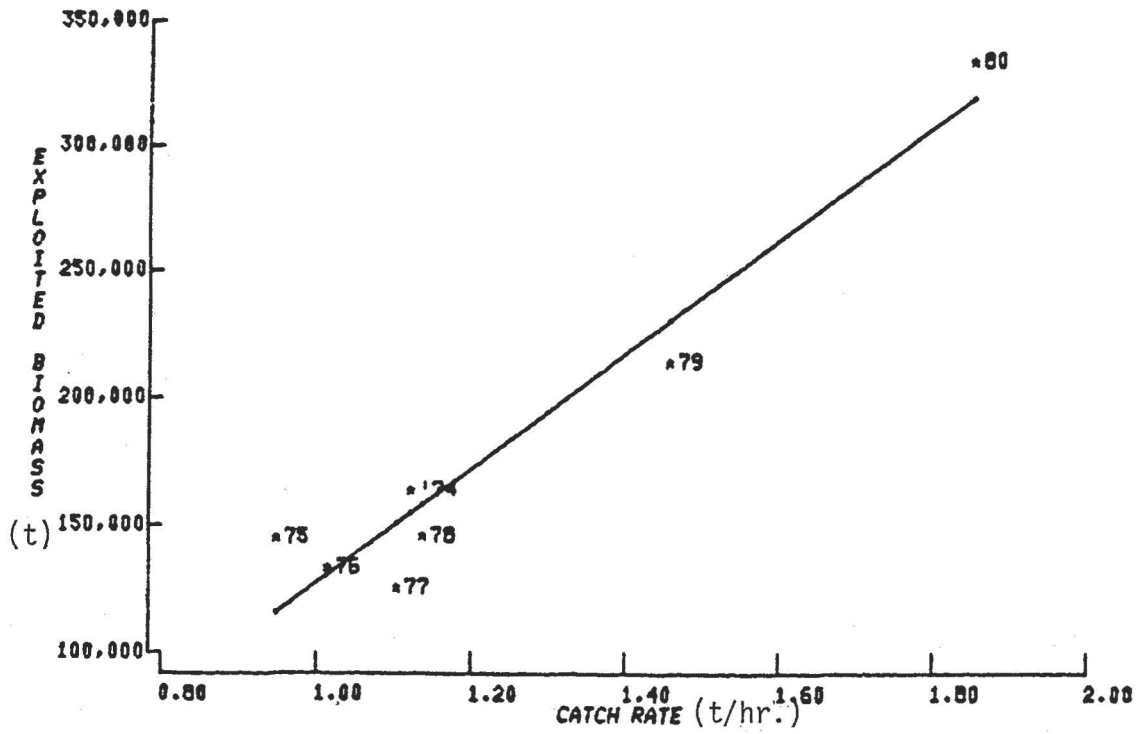
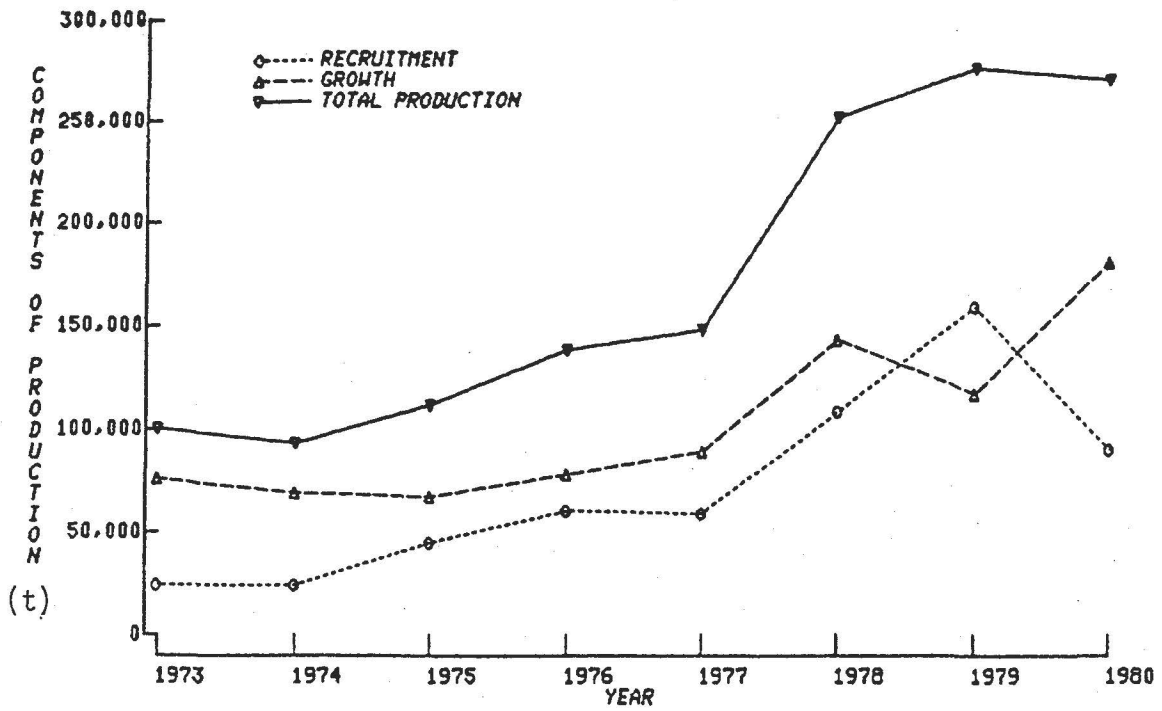


Fig. 2. The plot of points used in the regression of exploited biomass on catch rate 3Pn4RS cod. The relationship is determined primarily by the 1980 point i.e. the input terminal F.

PRODUCTION VERSUS TIME



SURPLUS PRODUCTION AND YIELD VERSUS TIME

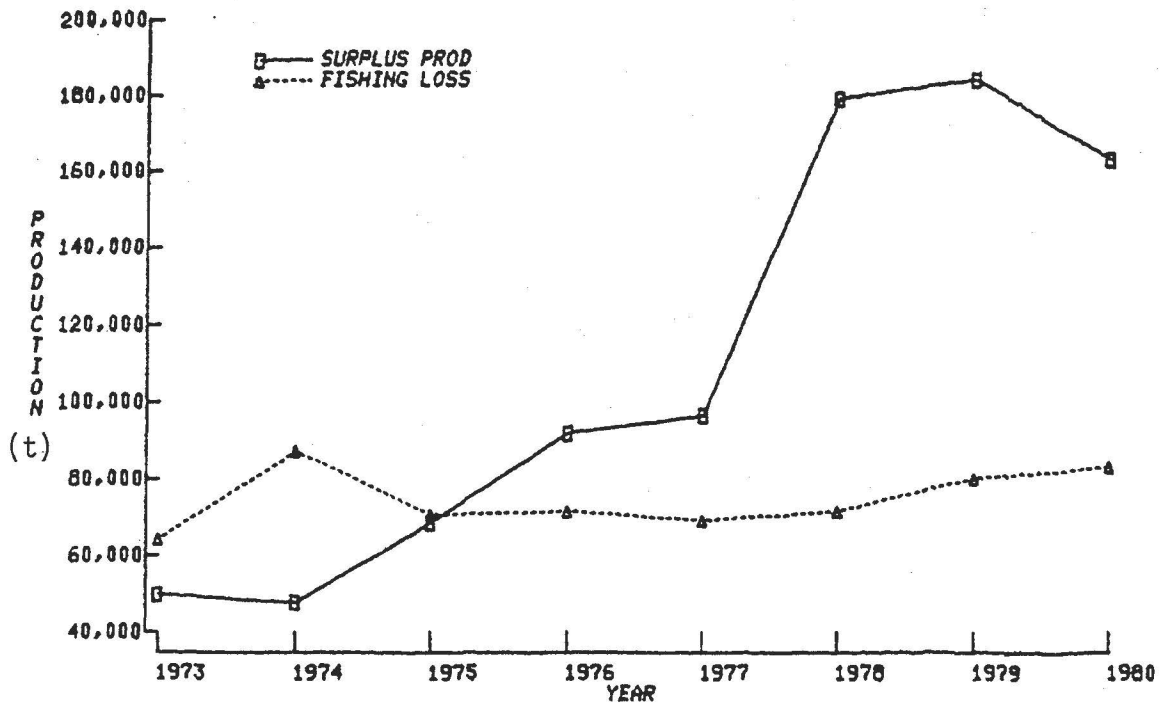


Fig. 3. Production, surplus production and yield vs. time analyses for 3Pn4RS cod.

Assessment of Cod Stock in 3Pn4RS

by

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An error was detected in the computation of partial selection for age 6 (Table 9). The correct average partial selection was 0.69 not 0.60 as indicated. To determine the consequences of such a change cohort analysis and a projection were performed with this correction. The changes with respect to management options were minor. In particular the catch projection for 1982 at $F_{0.1} = 0.2$ decreased from 105,000 t to 103,000 t, when the TAC of 75,000 t was used for 1981. Using $F_{0.1} = 0.2$ for both 1981 and 1982 the projected catch for each year was 79,000 t and 102,000 t respectively.