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A virtual population assessment of the Div. 4X offshore cod stock¹

by

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INTRODUCTION

Cod on the offshore banks (Browns-LaHave) of ICNAF Div. 4X belong to a discrete stock which mixes very little with the complex of inshore stocks around southwestern Nova Scotia and in the Bay of Fundy (Halliday, MS 1971, MS 1973).

An earlier assessment of the offshore stock based on catch-per-unit-effort analysis (Halliday, MS 1971) indicated that the stock was seriously over-exploited, fishing mortality, F , in 1965-69 being about double that giving maximum yield-per-recruit ($F_{max} = 0.35$). More recent data from Canadian research vessel surveys suggested continuing adult stock (age 5+) decline in 1970-72 of about 75% and an even higher mortality rate of $F = 0.95$ (Halliday, MS 1973). The methodology for Canadian surveys is given by Halliday and Kohler (MS 1971).

LANDINGS

Total Div. 4X cod landings increased from almost 16,000 metric tons in 1963 to 35,500 tons in 1968, then declined to 22,400 tons by 1972 (Table 1). Most of the landings were by Canada, but Spain, USSR and USA landed moderate quantities in some years.

Apportioning landings between inshore and offshore stocks is difficult. The stock boundary lies along the gully between the inshore coastal shelf and the offshore banks, and this does not coincide with present statistical boundaries, nor are there clear distinctions between gears used and types and sizes of vessels engaged in the fisheries. A number of assumptions are made to give approximate landings from inshore and offshore stocks. For the Canadian fishery these assumptions are based on the knowledge of Canadian Fisheries Service field staff stationed in the major fishing ports, and on fishing log records from, and interviews with, Canadian fishermen who are engaged in this fishery.

Canadian statistics are recorded by "unit areas" which are based on the "subareas" of the North American Council on Fishery Investigations (Fig. 1). All Canadian landings from unit areas 4X-N and 4X-P are assigned to the offshore stock. So also are those taken from 4X-0 by otter trawl and longline vessels over 50 gross tons as these vessels normally fish the offshore part of 4X-0 which encompasses the northern edges of the offshore banks. A portion of the landings by longliners of 0-50 gross tons are also assigned to the offshore stock, and some are assigned to the Georges Bank stock. These vessels commonly fish offshore in summer months as far as the northern edge of Georges Bank but their landings are erroneously recorded in Canadian statistics as all originating from inshore around southwestern Nova Scotia. The offshore component of these landings between 1967 and 1972 was estimated on the basis of interviews with the fishermen concerned.

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Landings by the USA are also available by unit areas, and were supplied to the author by the Northeast Fisheries Center, Woods Hole, Mass. USA landings from unit areas 4X-NOP were arbitrarily assigned to the offshore stock and those from the remaining unit areas to inshore stocks.

Landings by countries, other than Canada and the USA, were all assigned to the offshore stock.

These assumptions on origin of catch result in the following estimates of landings by stock. From 1967 to 1972, between 280 tons and 800 tons of cod have been misreported as originating from Di. 4X when in fact they were caught in Div. 5Z (Table 2). Landings from inshore stocks ranged from 12,800 tons to 17,400 tons between 1962 and 1972, landings in 1972 being 14,400 tons (Table 2). Landings from the offshore cod stock rose from 2,900 tons in 1962 to slightly over 19,000 tons in 1969, then declined to 7,300 tons by 1972 (Table 3).

DIV. 4X OFFSHORE COD - STOCK STATUS

Numbers removed.

There are no commercial biological sampling data reported in ICNAF Sampling Yearbooks for Div. 4X offshore cod by countries other than Canada. Thus, it is necessary to assume that removals by other countries are identical in composition to those of Canada. Canadian samples are available for each year from 1965 but the numbers of samples in each year are small (Table 4). The data were sufficient to allow samples to be applied to landings on a semi-annual basis except for 1970 when the annual landings were weighted by July-December samples. Numbers of fish at age landed in each year, derived from these samples, are probably similar to numbers removed from the population as Canadian discards are negligible and this is likely, also, to be true of other countries.

In 1965-72, 2 yr.-old cod contributed very little to the fishery, first significant recruitment occurring at age 3 (Table 5). Age groups 3-6 predominate in the landings and there has been a tendency in most recent years to concentrate on younger fish. Removals increased from 5.3 million fish in 1965 to 7.9 million in 1968, then declined to 3.2 million in 1971. Removals in 1972 were 3.9 million.

Population numbers.

Population numbers are derived by Pope's cohort analysis assuming natural mortality, $M = 0.20$.

Population declined from 47 million age 2+ fish in 1965 to 24 million in 1972 (Table 6). The year classes of 1962 and 1963 were the strongest among those of 1962 to 1968, numbering 16 million and 19 million respectively at age 2. Population numbers declined with recruitment of five poorer year class averaging 8 million fish at age 2 (range 6.7 - 9.4 million).

The abundance of fully recruited age groups (age 5+ - see below) increased from 8 million in 1965 to 11 million in 1968, but declined to 4 million by 1970.

Fishing mortality rate.

Full recruitment to the fishery occurred at age 5 in 1965-69, but 4 year olds sustained a higher mortality than older age groups in 1970 (Table 7). Fishing mortality on fully recruited age groups increased from $F = 0.5$ in 1965 to $F = 0.6$ in 1966-68, and to $F = 1.1$ in 1969. F on ages 5+ declined to 0.5 in 1970 but in that year F more than doubled on 3 and 4 yr. olds.

Yield-per-recruit.

Halliday (MS 1971), having described the growth pattern and the pattern of recruitment to the fishery, constructed Beverton and Holt yield-per-recruit models for $M = 0.10, 0.20, \text{ and } 0.30$, using the following parameters:

$$W_{\infty} = 15.66 \text{ kg.}$$

$$K = 0.20$$

$$t_0 = 1.42 \text{ yrs.}$$

$$t_p = 3.7 \text{ yrs. (=age at recruitment to the fishing area)}$$

$$t_{p'} = 3.7 \text{ yrs. (= age at recruitment to the exploited phase)}$$

$$t_{\lambda} = 12 \text{ yrs. (= last age of significant contribution to the fishery).}$$

These curves are reproduced in Fig. 2. Taking $M = 0.20$ as the most likely value of natural mortality, maximum yield-per-recruit is obtained at $F = 0.35$. Halliday further concluded that some increase in yield would accrue from increase in size at first capture.

Recruitment predictions.

Estimated population numbers at age from 1970-72 Canadian research vessel surveys (reproduced from Halliday (MS 1973)) suggest that total, and adult, population continued to decline between 1970 and 1972 (Table 8). Insufficient overlap between survey and commercial data prevents formal calculation of the relationship between pre-recruit year class abundance in surveys and subsequent performance in the fishery. However, crude predictions are possible. From cohort analysis the 1966-68 year classes contained 9.1, 6.7, and 9.4 million fish respectively at age 2 (Table 6). Surveys estimated the 1967 year class as being considerably poorer than the 1966 and 1968 year classes at comparable ages, and further indicated that the 1966 and 1968 year classes are almost of identical abundance. Thus, these independent estimates are in good agreement although the 1967 year class is probably not as poor as indicated by surveys. The 1969 year class was 5x the 1968 year class in surveys at age 2, but only 0.7x at age 3. Averaging the two estimates gives 1969 = 1.8 x 1968 = 17 million fish at age 2. A similar calculation for the 1970 year class gives 1970 = 0.2 x 1969 = 3 million fish at age 2. As poor year classes may be underestimated by surveys, it appears that the 1969 year class is probably comparable in strength to those of 1962 and 1963, while the 1970 year class is comparable to that of 1967.

Yield.

With a mean age of recruitment to the fishery of 3.7 yrs., maximum yield per recruit of 1.73 kg is obtained at $F = 0.35$. Average strength of the 1962-68 year classes was 10.9 million fish at age 2 which is equivalent to 7.8 million at age 3.7 when $M = 0.20$. If this represents the average long-term recruitment pattern to the stock, the maximum long-term yield is about 13,000 metric tons.

The expanding fishery from 1964 depended heavily on the good 1962 and 1963 year classes, and in the 4 years 1965-69 landings exceeded 13,000 tons. This resulted in mortality rates of $F = 0.53 - 1.14$, considerably in excess of that giving maximum yield-per-recruit. With poorer year-classes entering the exploited stock, abundance of fully recruited age-groups declined drastically in 1969 and 1970, and research vessel surveys indicate this decline continued through 1972. Landings more than halved in 1970-72, but mortality rate remained high for age 5+ fish, being $F = 0.49$ in 1970, and estimates from surveys are $F = 1.27$ and $F = 0.62$ for 1970/71 and 1971/72

respectively. These reduced landings were maintained in part by directing more effort to younger fish.

The 1974 fishery will depend largely on the 1969 and 1970 year classes, and the good 1969 year-class could result in some increase in abundance of the exploited stock. However, this year-class was exploited fairly heavily in 1972 and possibly also in 1973. Thus, significant stock recovery in 1974 is unlikely.

Assuming abundance in 1974 is close to the average 1970-72 level when landings were about 8,500 tons generating a mortality at least twice and perhaps three times that which maximises yield-per-recruit, landings in 1974 should be 2,800 - 4,200 tons to give $F = 0.35$.

REFERENCES

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Table 1 Div. 4X Cod - Nominal Catches (metric tons round).

Year	Canada		Spa.	USSR	USA	FRG	Ice.	UK	Pol.	Fra.	Jap.	Non-M	Total
	Total	Inshore											
1962	14,549	(4,373)	3	80	1,197	-	-	-	-	-	-	-	15,829
1963	15,790	(3,937)	1	684	1,301	9	-	-	-	-	-	-	17,785
1964	21,067	(4,916)	-	2,922	1,413	338	8	7	-	-	-	-	25,755
1965	24,221	(5,164)	144	1,553	871	125	-	-	-	-	-	-	26,914
1966	24,164	(6,024)	803	4,961	966	-	-	-	4	-	-	1	30,899
1967	27,814	(6,673)	2,536	667	1,445	-	-	-	-	-	-	-	32,462
1968	30,770	(7,815)	2,829	1,061	859	-	-	-	-	24	-	-	35,543
1969	24,056	(5,424)	8,217	1	448	-	-	-	-	3	-	1	32,726
1970	17,994	(4,148)	3,647	10	499	-	-	-	-	-	152	-	22,302
1971	20,181	(3,774)	2,615	337	239	-	-	-	-	-	6	-	23,378
1972*	20,479	(3,613)	1,547	30	323	2	-	-	-	-	-	-	22,381

*Preliminary

TABLE 2. Div. 4X inshore cod stocks. Nominal catches, and estimates of Div. 5Z catches misreported as originating from Div. 4X inshore (metric tons round).

<u>Year</u>	<u>Canada</u>	<u>U.S.A.</u>	<u>Total</u>	<u>Div. 5Z catches reported as Div. 4X</u>
1962	12,566	383	12,949	
1963	13,250	464	13,714	
1964	15,258	400	15,658	
1965	14,304	480	14,784	
1966	15,296	562	15,858	
1967	16,379	995	17,374	550
1968	16,465	513	16,978	800
1969	12,789	179	12,968	700
1970	12,617	180	12,797	280
1971	13,841	116	13,957	600
1972*	14,195	229	14,424	625

*Preliminary

TABLE 3. Div. 4X offshore cod stock. Nominal catches (metric tons round).

<u>Year</u>	<u>Canada</u>	<u>Spain</u>	<u>USSR</u>	<u>FRG</u>	<u>Ice.</u>	<u>UK</u>	<u>Pol.</u>	<u>Fr.</u>	<u>Jap.</u>	<u>USA</u>	<u>Non-M</u>	<u>Total</u>
1962	1,983	3	80	-	-	-	-	-	-	814	-	2,880
1963	2,540	1	684	9	-	-	-	-	-	837	-	4,071
1964	5,809	-	2,922	338	8	7	-	-	-	1,013	-	10,097
1965	9,917	144	1,553	125	-	-	-	-	-	391	-	12,130
1966	8,868	803	4,961	-	-	-	4	-	-	404	1	15,041
1967	10,885	2,536	667	-	-	-	-	-	-	450	-	14,538
1968	13,505	2,829	1,061	-	-	-	-	24	-	346	-	17,765
1969	10,567	8,217	1	-	-	-	-	3	-	269	1	19,058
1970	5,097	3,647	10	-	-	-	-	-	152	319	-	9,225
1971	5,740	2,615	337	-	-	-	-	-	6	123	-	8,821
1972*	5,659	1,547	30	2	-	-	-	-	-	94	-	7,332

*Preliminary

Table 4. Div. 4X offshore cod. Commercial sample inventory. (All samples are from the Canadian fishery.)

Year	January - June			July - December		
	No. of samples	No. meas.	No. aged	No. of samples	No. meas.	No. aged
1965	5	2,083	451	4	1,460	230
1966	4	1,090	232	3	717	118
1967	8	2,385	608	3	1,090	252
1968	10	3,092	557	1	225	66
1969	2	699	114	2	491	120
1970	-	-	-	3	676	141
1971	3	441	125	1	202	53
1972	5	1,533	237	4	1,033	182

Table 5. Div. 4X - Offshore Cod

Numbers landed (x10⁻³)

<u>Age</u>	<u>1965</u>	<u>1966</u>	<u>1967</u>	<u>1968</u>	<u>1969</u>	<u>1970</u>	<u>1971</u>	<u>1972</u>
2	27	9	5	7	37	538	106	226
3	914	1,146	931	1,217	1,024	1,868	545	1,248
4	1,391	2,668	3,064	1,508	925	2,794	487	1,271
5	1,419	1,922	2,135	3,285	1,308	1,255	875	674
6	1,050	891	782	1,389	1,662	222	543	221
7	341	421	257	234	584	189	209	115
8	82	217	162	114	186	60	295	51
9	31	31	80	123	126	49	72	41
10	16	28	28	32	234	5	23	17
11	5	3	13	19	15	2	20	1
12	3	1	5	16	4	5	14	2
Total	5,279	7,337	7,462	7,944	6,105	6,987	5,189	3,867

Table 6. Div. 4X - Offshore Cod Population numbers (x10⁻³)

<u>Age</u>	<u>1965</u>	<u>1966</u>	<u>1967</u>	<u>1968</u>	<u>1969</u>	<u>1970</u>
2	19,430	8,017	7,879	9,085	6,678	9,361
3	12,995	15,883	6,556	6,446	7,432	5,434
4	6,592	9,812	11,967	4,525	4,176	5,158
5	3,832	4,138	5,619	7,025	2,340	2,502
6	2,884	1,854	1,649	2,669	2,779	732
7	920	1,411	711	642	928	772
8	228	445	774	350	314	231
9	130	112	168	487	183	89
10	31	79	64	65	288	36
Total	47,042	41,751	35,387	31,294	25,118	24,395
Total 5+	8,025	8,039	8,985	11,238	6,832	4,442

Table 7. Div. 4X - Offshore Cod Fishing Mortality (F)

<u>Age</u>	<u>1965</u>	<u>1966</u>	<u>1967</u>	<u>1968</u>	<u>1969</u>	<u>1970</u>	<u>F₆₅₋₆₇</u>	<u>F₆₈₋₇₀</u>	<u>F₆₅₋₇₀</u>
2	0.00	0.00	0.00	0.00	0.01	0.07	0.00	0.03	0.01
3	0.08	0.08	0.17	0.23	0.17	0.48	0.11	0.29	0.20
4	0.27	0.36	0.33	0.46	0.28	0.91	0.32	0.55	0.44
5	0.53	0.72	0.54	0.73	0.96	0.77	0.60	0.82	0.71
6	0.51	0.76	0.74	0.86	1.08	0.41	0.67	0.78	0.73
7	0.53	0.40	0.51	0.51	1.19	0.32	0.48	0.67	0.58
8	0.51	0.77	0.26	0.45	1.06	0.34	0.51	0.62	0.57
9	0.30	0.36	0.75	0.33	1.41	0.93	0.47	0.89	0.68
10	0.83	0.50	0.66	0.78	(2.28)	0.16	0.66	-	0.59
F₅₋₁₀	0.53	0.59	0.58	0.61	1.14	0.49	0.57	0.75	0.66
F₂₋₁₀	0.36	0.40	0.40	0.44	0.68	0.44	0.39	0.52	0.45

Table 8. Div. 4X offshore cod stock. Estimated population numbers (x10⁻³) from Canadian research vessel survey cruises (Strata 70-85 inclusive).

<u>Year class</u>	<u>1970</u>	<u>1971</u>	<u>1972</u>
1971	-	-	19
1970	-	286	1,320
1969	891	7,604	2,871
1968	1,588	4,265	1,988
1967	2,660	574	413
1966	4,375	1,465	414
1965	1,935	638	95
1964	2,610	855	385
1963	1,148	28	214
1962	578	-	99
1961	202	-	3
1960	110	-	3
1959 & older	16	-	99
Totals	16,112	15,715	7,923
Totals age 5+	6,599	2,986	1,725

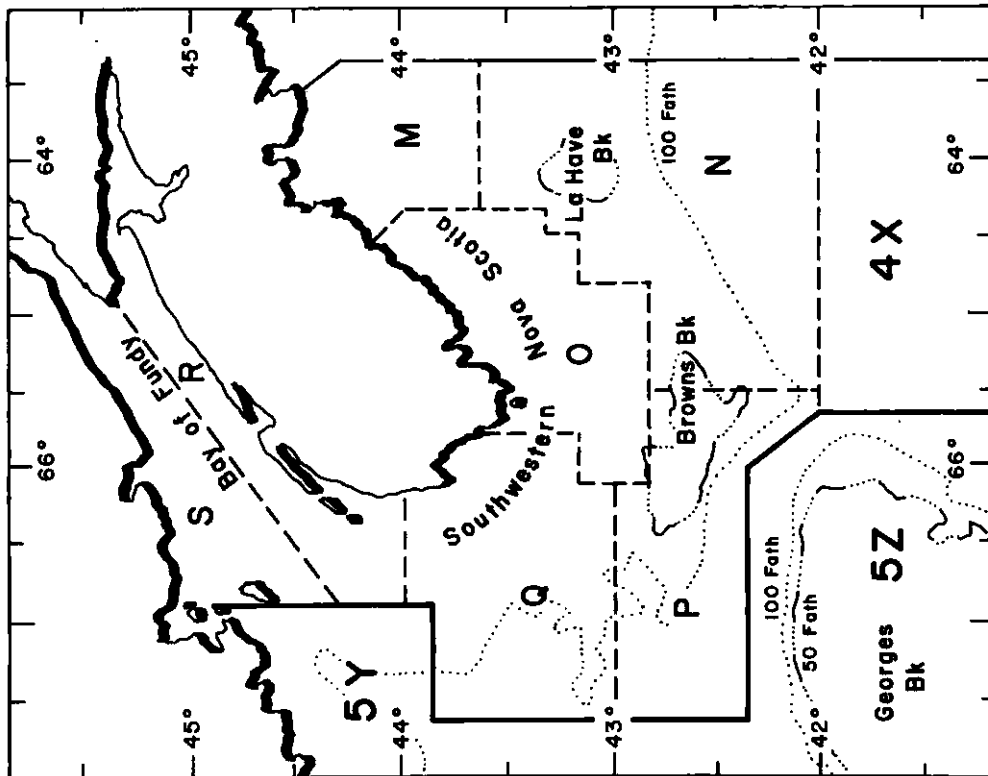


Fig. 1. Unit areas of ICNAF Div. 4X.

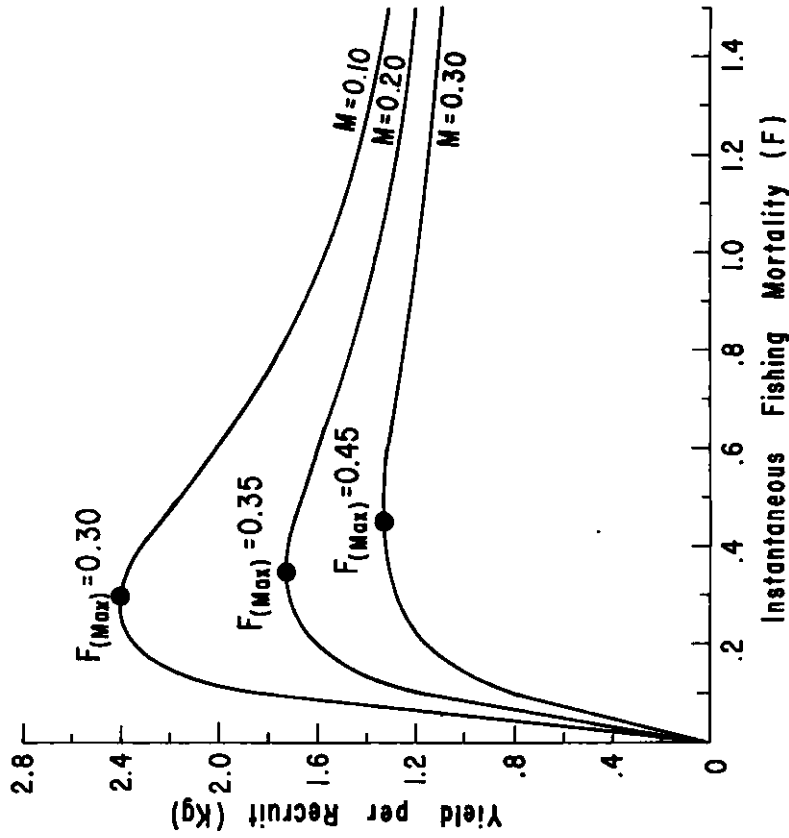


Fig. 2. Yield-per-recruit curves for Div. 4X offshore cod.

F_{max} = F giving maximum yield-per-recruit.

