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A Preliminary Report on an Assessment of the Offshore Cod Stock in ICNAF Div.4X

by R.G.Halliday
Fisheries Research Board of Canada
Biological Station
St. Andrews, N.B.

Abstract

Rapid increase in cod landings from ICNAF Div. 4X in the 1960's resulted mainly from development of an offshore, predominantly Canadian, otter trawl fishery on Brown's and LaHave banks. In 1965–69, Canadian landings from the offshore fishery were composed predominantly of fish 40–80 cm, aged 3–6 years. Decreases in means of length, age, and weight of landings in 1966 and 1967 reflected recruitment of strong 1962 and 1963 year-classes whereas increases in 1968 and 1969 reflect recruitment of poor 1964 and 1965 year-classes. Abundance (by weight) of the exploited stock declined 30% between 1965 and 1969. Analysis of the fishery using the constant parameter yield per recruit model indicates that the 1965–69 level of fishing mortality (F=0.70) was considerably above that giving maximum sustainable yield. The fishery would benefit from reduced effort and/or increased otter trawl mesh size. Thus, any reduction in effort on offshore cod brought about inadvertantly by present regulations for the haddock fishery in Div. 4X will be beneficial.

Introduction

There are two major divisions of the cod fishery in ICNAF Div. 4X; a traditional, inshore fishery prosecuted almost entirely by Canadians mainly by hand-lining and long-lining from small boats, and a recent international fishery prosecuted by large otter and pair trawlers on the offshore banks of Brown's and LaHave. Templeman (1962) in his review of cod stock divisions in the northwestern Atlantic, concludes that the cod on Brown's and LaHave banks probably form a separate spawning stock from those on Georges Bank or inshore along southwestern Nova Scotia. Tagging experiments have given conflicting results on the extent of mixing of these stocks (McKenzie, 1956; McCracken, 1956; Wise, 1962), but taken together with the results of vertebral counts and parasitological studies (McKenzie and Smith, 1955; Scott and Martin, 1957, 1959), indications are that little mixing occurs. Thus, cod on Georges Bank, Brown's-LaHave banks, and inshore around southwestern Nova Scotia, are probably sufficiently discrete to be treated as separate units for stock management purposes.

Although the cod fishery in the waters off southwestern Nova Scotia has been important to Canadian fishermen for a great many years, landings statistics can be calculated separately for the area designated ICNAF Div. 4X only from 1947 (Table 1). At that time landings by all countries were approximately 20,000 metric tons, subsequently declining with fluctuations to about 12,000 metric tons by 1958. From 1958, landings increased gradually to 1963, then increased rapidly to over 35,000 metric tons by 1968, dropping to 32,720 metric tons in 1969. Throughout this 23-year period Canada dominated the fishery, landing on average 90% of the total prior to 1964 and 82% in 1964–69.

Subsequent to 1956 a more detailed breakdown of Canadian landings by area of capture is possible using "unit areas" based on the "subareas" of the North American Council on Fishery Investigations (Fig. 1). Landings from the "offshore" fishery i.e. from the Brown's-LaHave banks cod stock, are defined as all landings from unit areas N and P and those from O taken by otter trawl and longline vessels over 50 gross tons. (Those vessels normally fish the offshore part of O which encompasses the northern edges of the offshore banks.) Landings from the complex of inshore stocks around southwestern Nova Scotia are taken as all landings from unit areas M and Q and those from O which are not included in the offshore category. Landings from the Bay of Fundy are all landings from unit areas R and S.

Between 1957 and 1961, Canadian landings were fairly constant averaging about 12,500 metric tons. Sixty-five percent of this came from the inshore fishery around southwestern Nova Scotia, 25% from the Bay of Fundy, and only 10% from the offshore banks (Table 2). Landings from the Bay of Fundy and southwestern Nova Scotia were made almost entirely from small boats less than 25 gross tons, fishing handlines or longlines. The limited offshore fishery was prosecuted almost exclusively by longline vessels of 26–150 gross tons. The nature of the fishery in 1957–61 is probably representative of a much longer period prior to those dates, this fishery historically being an inshore one from small boats using hook and line gear. Radical changes were effected from 1962 with the rapid expansion of otter trawling in the offshore and Bay of Fundy fisheries. The inshore fishery around southwestern Nova Scotia was little affected by this event, the bottom being too rough for otter trawling throughout most of the region. In the Bay of Fundy, landings in 1957–61 of about 3,000 metric tons increased steadily to almost 7,500 metric tons by 1967, the increase being entirely due to increased landings by otter trawlers of 26–150 gross tons. Average landings of 1,250 metric tons from the offshore fishery in 1957–61 increased fairly steadily to 12,135 metric tons in 1968, then declined to 9,136 metric tons in 1969. The changes were brought about almost entirely by otter trawlers of 151–900 gross tons.

Cod landings from Div. 4X by the U.S.A. did not exceed 2,660 metric tons annually between 1947–69 (Table 1). Landings were made from all three of the fisheries discussed above (Table 2), but principally from offshore until 1965 when the Bay of Fundy fishery became equally important (Power, 1959-63; Lyles and Power, 1964; Lyles, 1965-69; U.S. Bureau of Commercial Fisheries, 1968; Hennemuth, personal communication). Offshore landings were approximately 1,000 metric tons in 1957–64 and less than 450 metric tons in 1965–69.

Landings by countries other than Canada and the U.S.A. principally by Spain and the U.S.S.R., increased erratically from zero in 1960 to 8,218 metric tons in 1969. It is likely that all of these otter trawl and pair trawl landings were from the offshore fishery.

Thus, increased cod landings from Div. 4X subsequent to the stable period 1957–61 resulted from increased landings from all areas but principally from the offshore banks. Landings from this area by all countries increased from about 2,300 metric tons, amounting to 17% of cod landings from Div. 4X, to about 17,600 metric tons in 1969, representing 54% of the landings.

Canadian cod landings have been sampled for length and age composition since 1946. Samples collected between 1946 and 1963 came almost exclusively from the inshore fishery around southwestern Nova Scotia. The 1946–58 samples were used in an assessment of the effects of cod-end mesh size changes by an ICNAF Working Group (Beverton and Hodder, 1962) which concluded that the average total mortality rate (Z) for this period was 0.45, and that declining landings were due to concurrent trends of decreasing fishing effort and fish abundance. Sampling and effort data lapsed in 1964 with diversion of interest to the developing offshore fishery. Thus, the current status of the inshore fishery cannot be assessed. Landings in the period 1958–69 probably averaged much the same as in the period 1947–58. Thus, unless marked abundance changes have occurred, mortality is probably still close to the relatively low level of 1947–58.

Sufficient sampling data are available from the Canadian offshore trawl fishery for 1965–69 to allow an analysis of this fishery. Otter trawl landings formed 87–91% of Canadian landings in those years. No sampling data for Div. 4X cod has been published by other countries which could with certainty be attributed to their commercial fleet. Thus, in the following analysis it is necessary to assume that Canadian otter trawl landings which formed 47–72% (mean = 60%) of the total landings from the offshore fishery, have length and age compositions representative of the entire fishery.

The remainder of this document is concerned only with the offshore fishery.

LENGTH AND AGE COMPOSITION OF LANDINGS

Cod of 35 cm to over 130 cm occurred in the landings, but the great majority were fish 40–80 cm (Fig. 2). In 1969, a considerably higher proportion of larger fish, 80–105 cm, were present than in the preceding four years. Cod aged 3–6 predominated in the landings, 4 or 5 year-olds being the dominant age groups in 1965–68 landings (Fig. 3). In 1969, 6 year-olds were dominant and 7 year-olds more important than in previous years. Annual means of length, weight, and age, of landings declined from 1965 to 1967, then increased to their highest values for the five-year period in 1969 (Table 3).

ABUNDANCE

Canadian side otter trawlers of 151–500 gross tons provide the greatest quantity of, and most detailed, records of catch and effort for the offshore fishery in Div. 4X. The catch per hour of these vessels, calculated for each month then averaged for each calendar year, is used as an index of abundance. Dickie (1965) has pointed out the difficulties in interpreting trends in catch per unit effort values (C/E) for cod and haddock from Canadian statistics, due to the interactions of these fisheries. Certainly, there is no clear distinction between Canadian fisheries for cod and haddock on the offshore banks of Div. 4X, most landings containing substantial quantities of both species. No information on species sought is available from past or current data collections, but main species caught can be used as a crude approximation to this. In 1963–69, landed value of haddock per pound at Nova Scotia ports was 1.3–1.6 times that of cod (Canadian Fisheries Service, 1970). Thus, haddock trips (i.e. those on which the main species caught was haddock) were almost certainly predominantly seeking haddock. Due to the price differential, it is likely that many of the trips which landed more cod than haddock still spent considerable time fishing for haddock. Nevertheless, it is probable that abundance indices based only on cod trips are more accurate than indices based on all trips.

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Trends in annual C/E values for cod based on cod trips and on all trips are almost identical subsequent to 1964, those based on all trips being 58% (range 54–60%) of those for cod trips only (Fig. 4A). Thus, the biases caused by interactions of the cod and haddock fisheries apparently remained consistent between 1965–69, but they did not during the developing years of the fishery, 1963–64. Annual C/E values from cod trips only are used here as abundance indices.

Cod abundance declined 30% between 1965 and 1969 from 0.34 metric tons per hour fished to 0.24 metric tons per hour fished (Fig. 4A). In terms of numbers, abundance increased 7% from 134 cod per hour fished in 1965 to 144 per hour in 1967, then sharply declined by 51% to 71 per hour in 1969 (Fig. 4B).

Variation in the abundance of year classes in the fishery can be followed by allocating total numbers caught per hour fished to individual age-groups using percentage age compositions of the landings (Table 4). Greatest contribution to landings by numbers is made at ages 4 and 5, by weight at ages 5 and 6. The abundance at ages 4+5 is taken as an index of year-class strength. Estimating the abundance at age 4 for the 1960 year-class and at age 5 for the 1965 year-class from the ratio of numbers at ages 4:5 of 1.4: 1.0 for the 1961–64 year-classes, allows indices of year-class strength to be calculated for the six year-classes, 1960–65 (Fig. 4C).

Of the 1960–65 year-classes, those of 1962 and 1963 were the strongest, and those of 1964 and 1965 were considerably weaker than the other four. Thus, the slight increases in population abundance in 1966 and 1967 were due to the recruitment of strong 1962 and 1963 year-classes. The sharp declines in abundance in 1968 and 1969 reflected recruitment of the poor year-classes of 1964 and 1965. These recruitment variations explain the variations in mean lengths, weights, and ages, of landings described above, decreases in 1966 and 1967 being associated with good recruitment, increases in 1968 and 1969 being associated with poor recruitment and thus greater dependence of the fishery on older fish.

MORTALITY

It is apparent from Table 4 that recruitment to the gear is complete or almost complete at age 5. Annual survival rates, expressed as the ratio of number of fish of age groups 6–12 caught per hour in year X+1 to number of fish of age groups 5–11 caught per hour in year X, are:

for	1965–66	0.41
	1966–67	0.39
	1967–68	0.43
	1968–69	0.41,

the geometric mean being 0.41. This corresponds to a Z value of 0.89. The catch curve of average numbers of each age group caught per 100 hours fished in 1965–69 has a straight right limb (Fig. 5), indicating an essentially constant mortality rate from age 5 of 0.86. Thus, the average value of Z for fully recruited age groups in 1965–69 lay between 0.85 and 0.90.

Fishing effort (calculated by dividing landings by C/E) increased from about 8,000 to 75,000 standard hours between 1963 and 1969, standard hours being in Canadian 151–500 gross ton side otter trawler units (Table 5). A suitable measure of the effort effecting mortality between successive years is the mean of the effort in those years (Paloheimo, 1961). Thus the effort effecting the mortalities in 1965–66 to 1968–69 increased 60% over the period from about 41,000 to 66,000 hours. However, this substantial increase in effort is not reflected by a corresponding increase in calculated Z values (Table 5). Of a number of possible explanations for this, the most likely is that the sampling data are inadequate to provide accurate mortality estimates for single years.

Virtually all values of M (instantaneous natural mortality) used in assessments of cod stocks in the ICNAF area have ranged from 0.10–0.30, the favoured value being 0.20 (e.g. Beverton and Hodder, 1962; Beverton, 1965; Horsted, 1969; Pinhorn and Wells, 1970). As there are no available estimates of M for the offshore cod stock in Div. 4X, the same convention is followed here.

At the risk of going beyond reasonable bounds of speculation, crude estimates of the possible variation in F (instantaneous fishing mortality) can be obtained. There are two points, one at zero effort when Z ($\equiv$ M) is assumed to be 0.20, and one at an average effort of 50,200 hours when Z averages 0.89, through which to fit a line describing the relationship of Z to effort. This hypothetical relationship suggests that Z increased from 0.46 in 1963–64 to 1.10 in 1968–69 (F from 0.28 to 0.90), (Table 5).

GROWTH CHARACTERISTICS

The von Bertalanffy growth equation, fitted by the method of Allen (1966) to annual summaries of commercial age and length data from age 6 onwards, give widely varying estimates of growth parameters:

Year	K	L_∞	t_0
1965	0.061	199	-1.11
1966	0.211	109	1.34
1967	0.329	103	2.72
1968	0.186	126	1.71
1969	0.200	117	1.21

where K = rate of completion of the growth curve, L_∞ = asymptotic length, and t_0 = hypothetical age at which the fish would have zero length if growth had always conformed to the equation.

As the values for 1966, 1968, and 1969 lie close to each other, while those of 1965 and 1967 diverge considerably from these, the latter are rejected and the means of the former three years taken to represent the population, giving K = 0.20, L_∞ = 117, t_0 = 1.42 . An estimate of W_∞ = 15.66 kg is obtained by substituting the L_∞ value of 117 cm in an unpublished length-weight equation based on data collected in March 1970.

LENGTH AND AGE AT RECRUITMENT TO THE FISHERY

Data on materials and mesh sizes of otter trawls used by Canadian vessels are collected regularly by the Canadian Fisheries Service. Cod selection factors for the different net materials are presented by the joint ICES/ICNAF Working Group on Selectivity Analysis (1970). Thus, cod mean selection lengths are calculated for each material by multiplying the appropriate selection factor by the average mesh size for that material in the Canadian fleet fishing Subarea 4 in 1968-69. A mean selection length for the fleet is calculated by taking the mean of the selection lengths for each material weighted by the proportion of the fleet using that material.

The resulting mean selection length is 41.0 cm. Substituting this value in the von Bertalanffy growth equation gives a mean selection age of 3.6 years.

Independent estimates of mean length and age at recruitment can be obtained using Horsted's and Garrod's (1969) method of estimating partial recruitment values, using total landings weighted by Canadian commercial sampling data for 1965-69. The method involves calculating the numerical abundance (N) of each age-group at the beginning of each year using a single value of instantaneous fishing mortality F (taken here as 0.70) firstly as the survivors of the stock in year $i-1$, from the equation:

$$N_i = N_{i-1} e^{-Z_{i-1}}$$

secondly, as the number of fish at the beginning of the year i necessary to generate the catch (C) in that year, from the equation:

$$N_i = \frac{C_i Z_i}{F_i (1 - e^{-Z_i})}$$

The difference between these estimates represents the number of new recruits entering the age-group, and the ratio between this and the number in the stock of the year-class at the beginning of the year $i-1$ measures the new recruits as a proportion of the previous stock of that year-class. The 1965-69 cod data give four observations for each pair of age-groups and the mean of these is used to calculate the partial recruitment value (Table 6).

The ratios of age-groups 6/5 are close to zero and contain one negative value indicating that full recruitment to the gear may occur at age 5. The ratios of age groups 7/6 indicate that there is full recruitment at least by age 6. This confirms the conclusions reached from examination of catch curves. Assuming full recruitment at age 5, new recruits at age 5 (R_5) to the stock at age 4 (N_4) is 0.5999 (Table 6). Therefore:

$$R_5 = 0.5999 N_4$$

Also $N_4 + R_5 = N_5$

therefore $N_4 + 0.5999 N_4 = N_5$

and $N_4 = \frac{N_5}{1.5999}$.

Taking $N_5 = 1$, signifying full recruitment

then $N_4 = 0.63$

i.e. cod at age 4 are 63% recruited to the fishery. Similarly, partial recruitment indices are calculated for age 3 = 24% and age 2 = 0.2%. A graphical estimate gives an age at 50% recruitment of 3.7 years. The corresponding length at 50% recruitment, estimated from the von Bertalanffy growth equation, is 42.8 cm.

Assuming full recruitment at age 6 does not greatly affect the results, partial recruitment values then becoming:

at age 2 = 0.2%
age 3 = 22%
age 4 = 55%
age 5 = 89%

Age and length at 50% recruitment become 3.8 years and 44.3 cm.

YIELD PER RECRUIT

The constant parameter yield per recruit equation of Beverton and Holt (1957) is calculated for various values of F and M using the following values for other parameters:

W_∞ = 15.66 kg

K = 0.20

t_o = 1.42

t_ρ = 3.7 years (= age at recruitment to the fishing area)

t_ρ' = 3.7 years (= age at recruitment to the exploited phase)

t_λ = 12 years (= maximum age of significant contribution to the fishery)

With M = 0.10, 0.20, 0.30, the values of F giving maximum yield per recruit are 0.30, 0.35, 0.45, respectively (Fig. 6). All of these F values are substantially below the range estimated earlier for the 1965-69 period. Taking the average value of Z = 0.90, even if M = 0.30, a reduction in F of 25% from 0.60 to 0.45 would result in a slight increase in yield. If M = 0.20, a reduction in F of 50% from 0.70 to 0.35 would increase yield by 13%, and if M = 0.10, a reduction in F of 62% from 0.80 to 0.30 would increase yield by 36%. Thus, a reduction in effort of at least 25% and probably greater would not result in decreased yield and would almost certainly increase it.

Increased mesh size would also result in increased yield per recruit (Fig. 7). The yield isopleth diagram, constructed by varying F and t_ρ', and taking M = 0.20 and other parameters as before, indicates that increasing t_ρ' to 3.8 years equivalent to a mesh size of 127 mm (5 in.) manilla would increase yield by 3%, for a value of F = 0.70. Increasing t_ρ' to 4.1 years, equivalent to a mesh size increase to 140 mm (5½ in.) manilla would increase yield by 13%. The constant parameter model predicts increased yield per recruit with mesh sizes up to 230 mm (9 in.) at F = 0.70.

DISCUSSION

Rapid increase in cod landings from Div. 4X in the last decade was largely a reflection of the development of the offshore trawl fishery on Brown's and LaHave banks, although inshore landings from the Bay of Fundy and southwestern Nova Scotia also increased.

This assessment of the offshore fishery indicates that fishing effort in the period 1965–69 was far in excess of that giving maximum yield per recruit under present mesh regulations, and that either reduced effort or increased mesh size, or both, would be beneficial. It has been necessary to make a number of assumptions particularly concerning stock separation and composition of non-Canadian landings. Growth parameters are only crudely estimated, and no estimate of the true value of natural mortality rate could be obtained. Thus, it would be presumptuous to be specific about the magnitude of benefits to be gained from effort or mesh size changes. However, most data currently available indicate that the offshore Div. 4X cod stock is sufficiently autonomous to be considered separately in stock management. Spanish and U.S.A. landings are unlikely to differ greatly from Canadian landings in size composition, all three countries being interested in relatively large fish and fishing trawls with mesh sizes of at least 114 mm. Some Soviet cod catches were probably taken incidentally in small mesh fisheries for unregulated species. However, the characteristic unavailability of small cod makes it unlikely that Soviet landings differed radically from those of Canada in size composition, and at any rate these landings formed only a small proportion of the total. Although growth parameters estimated in the above fashion are unlikely to be very accurate those used lie close to those of Subarea 3 cod stocks (Wells and Pinhorn, 1970) and are almost certainly not widely different from the truth. Large differences would be required to significantly affect the shape of yield curves. Similarly, although the natural mortality rate is not known, it is most unlikely that it exceeds 0.30. Thus, despite the deficiencies in various aspects of this analysis, none of these are likely to alter the general conclusions on the state of the fishery.

The offshore cod fishery in Div. 4X is closely related, but secondary, to the haddock fishery for Canadians, although it is the primary concern of Spanish fishermen. Concentrations of cod and haddock are commonly found in the same areas at the same times (McCracken, 1968; kohler, 1969). Thus, the recent quota regulations for Div. 4X haddock, including closed season and area provisions, may well result in reduced effort on cod, as well as on haddock. This will almost certainly be beneficial to the cod fishery.

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Table 1. Cod landings from ICNAF Div. 4X by country and year. (1947-53 landings from Beverton and Hodder (1962, Appendix I). 1954-68 landings from ICNAF Statistical Bulletins Vols. 4-18 (1956-70). 1969 landings from ICNAF Res. Doc. 70/31. Weights in metric tons round fresh.)

Year	Canada (M&Q)	U.S.A.	Spain	USSR	Others	Total
1947	18,264	2,260	-	-	-	20,524
1948	17,761	1,999	-	-	-	19,760
1949	14,282	1,799	-	-	-	16,081
1950	19,088	1,581	-	-	-	20,669
1951	16,543	1,639	-	-	-	18,182
1952	16,570	1,651	-	-	-	18,221
1953	12,903	1,461	-	-	-	14,364
1954	14,406	2,660	-	-	19	17,085
1955	13,432	1,371	-	-	-	14,803
1956	14,849	1,625	-	-	-	16,474
1957	13,579	1,083	-	-	-	14,662
1958	11,074	1,147	-	-	-	12,221
1959	12,866	862	-	-	-	13,728
1960	12,123	1,605	-	-	-	13,728
1961	12,423	1,261	2	9	-	13,695
1962	14,549	1,197	3	80	-	15,829
1963	15,790	1,301	1	684	9	17,785
1964	21,067	1,413	-	2,922	353	25,755
1965	24,221	871	144	1,553	125	26,914
1966	24,164	966	803	4,961	5	30,899
1967	27,813	1,445	2,536	667	1	32,462
1968	30,770	859	2,829	1,061	24	35,543
1969	24,054	448	8,217	1	-	32,720

Table 2. Cod landings from ICNAF Div. 4X by locality of capture

	Bay of Fundy			Inshore S.W. Nova Scotia			Offshore — Brown's-LaHave banks				
Year	Canada	U.S.A.	T0tal	Canada	U.S.A.	Total	Canada	U.S.A.	Others	Total	Total
1957	2,657	86	2,743	9,445	45	9,490	1,477	952	-	2,429	14,662
1958	2,633	69	2,702	7,216	44	7,260	1,225	1,034	-	2,259	12,221
1959	3,679	116	3,795	8.090	74	8,164	1,097	672	-	1,769	13,728
1960	3,201	104	3,305	7,883	149	8,032	1,039	1,352	-	2,391	13,728
1961	3,354	101	3,455	7,663	17	7,680	1,406	1,143	11	2,560	13,695
1962	4,273	345	4,618	8,293	48	8,341	1,983	804	83	2,870	15,829
1963	3,998	378	4,376	9,252	98	9,350	2,540	825	694	4,059	17,785
1964	4,889	261	5,150	10,369	150	10,519	5,809	1,002	3,275	10,086	25,755
1965	5,306	425	5,731	8,998	66	9,064	9,917	380	1,822	12,119	26,914
1966	6,639	395	7,034	8,657	181	8,838	8,868	390	5,769	15,027	30,899
1967	7,476	870	8,346	10,402	151	10,553	9,935	424	3,204	13,563	32,462
1968	6,628	487	7,115	12,007	48	12,055	12,135	324	3,914	16,373	35,543
1969	4,819	110	4,929	10,099	69	10,168	9,136	269	8,218	17,623	32,720

Table 3. Mean length, weight, and age, of Canadian cod landings from offshore Div. 4X, and the sampling data from which they are derived.

Year	Season	SAMPLES			LANDINGS		
		No.	Lengths	Ages	Mean Length (cm)	Mean Weight (kg)	Mean Age (yrs)
1965							
	Jan-June	5	2083	450	63.0	2.8	5.0
	July-Dec.	4	1460	231	59.2	2.4	4.6
	Annual	9	3543	681	60.9	2.6	4.8
1966							
	Jan-June	4	1090	232	60.5	2.5	5.2
	July-Dec.	3	717	116	57.6	2.1	4.4
	Annual	7	1807	348	58.8	2.3	4.7
1967							
	Jan-June	8	2385	606	57.2	2.2	4.8
	July-Dec.	3	1090	252	59.4	2.4	4.5
	Annual	11	3475	858	57.9	2.2	4.7
1968							
	Jan-June	10	3092	557	60.2	2.4	5.0
	July-Dec.	1	225	66	60.3	2.6	4.7
	Annual	11	3317	623	60.2	2.5	4.9
1969							
	Jan-June	2	669	114	64.5	3.2	5.3
	July-Dec.	2	491	120	71.2	4.2	5.7
	Annual	4	1190	234	65.5	3.3	5.4

Table 4. Year class and age composition of cod landings from offshore Div. 4X as numbers per 100 hours fished, percentage age composition by numbers and weight, and average length and weight of each age group in the landings.

Year Class	Age 2	3	4	5	6	7	8	9	10	11	12
1953	-	-	-	-	-	-	-	-	-	-	7
1954	-	-	-	-	-	-	-	-	-	13	3
1955	-	-	-	-	-	-	-	-	40	7	11
1956	-	-	-	-	-	-	-	80	53	36	23
1957	-	-	-	-	-	-	209	59	70	28	3
1958	-	-	-	-	-	868	416	198	47	14	-
1959	-	-	-	-	2669	810	363	184	294	-	-
1960	-	-	-	3601	1707	502	168	147	-	-	-
1961	-	-	3524	3677	1444	347	204	-	-	-	-
1962	-	2304	5087	4031	2032	607	-	-	-	-	-
1963	68	2177	5869	4837	1874	-	-	-	-	-	-
1964	17	1810	2246	1468	-	-	-	-	-	-	-
1965	10	1711	1135	-	-	-	-	-	-	-	-
1966	10	1251	-	-	-	-	-	-	-	-	-
1967	2	-	-	-	-	-	-	-	-	-	-
Ave. no./100 hrs	21	1851	3572	3523	1945	627	272	134	101	20	9
% contribution by no.	0.2	15.3	29.6	29.2	16.1	5.2	2.3	1.1	0.8	0.2	0.1
% contribution by wt.	0.1	6.3	18.4	29.0	22.0	10.5	6.0	3.6	2.9	0.9	0.5
Average weight (kg)	0.7	1.0	1.5	2.4	3.3	4.9	6.3	7.8	8.5	10.9	11.4
Average length (cm)	40.8	46.2	53.1	61.7	69.5	78.9	85.8	92.1	94.8	103.3	105.0

Table 5. Estimated effort in terms of "hours fished by Canadian side otter trawlers of 151–500 gross tons" required to make the offshore Div. 4X cod catches of 1963-69, and possible values of Z associated with this effort.

Year	Catch (metric tons)	C/E	Estimated effort (f) (hours)	$\frac{1}{2}(f_x + f_{x+1})$	Calculated Z	Estimated Z
1963	4,059	.493	8,233			
				18,862	-	0.46
1964	10,086	.342	29,491			
				32,412	-	0.64
1965	12,119	.343	35,332			
				41,073	0.89	0.76
1966	15,027	.321	46,813			
				44,599	0.94	0.81
1967	13,563	.320	42,384			
				49,422	0.84	0.87
1968	16,373	.290	56,459			
				65,725	0.89	1.10
1969	17,623	.235	74,991			

Table 6. New recruits to the offshore Div. 4X cod stock as a proportion of the same year class one year earlier. (Means calculated diagonally as shown.)

Year Class	Calendar years 1965-66	1966-67	1967-68	1968-69	Mean	Age groups in ratio
1956	0.4819	-	-	-	-	-
1957	neg.	1.5256	-	-	-	-
1958	0.3193	0.0403	neg.	-	-	-
1959	neg.	0.0141	0.2404	1.6647	-	10/9
1960	0.2207	neg.	0.0197	0.7388	-	9/8
1961	0.9744	neg.	neg.	0.3558	0.1772	8/7
1962	2.5138	0.3366	0.2380	0.2301	-	7/6
1963	41.6227	2.1214	0.6470	0.0962	-	6/5
1964		102.9942	1.1799	0.4416	0.5999	5/4
1965			207.4519	0.4549	1.5675	4/3
1966				147.2662	124.8338	3/2

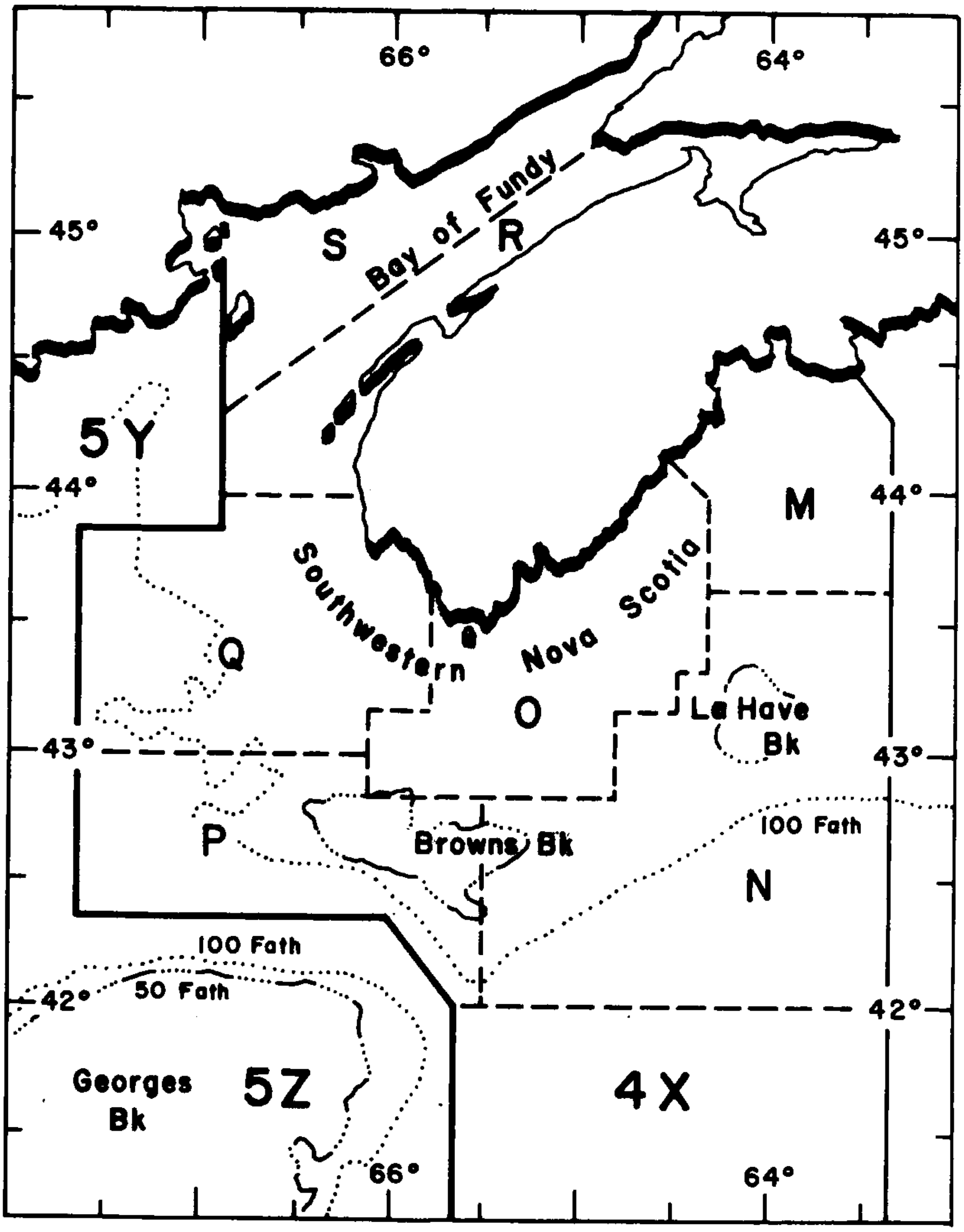

Fig. 1. Unit areas of ICNAF Div. 4X.

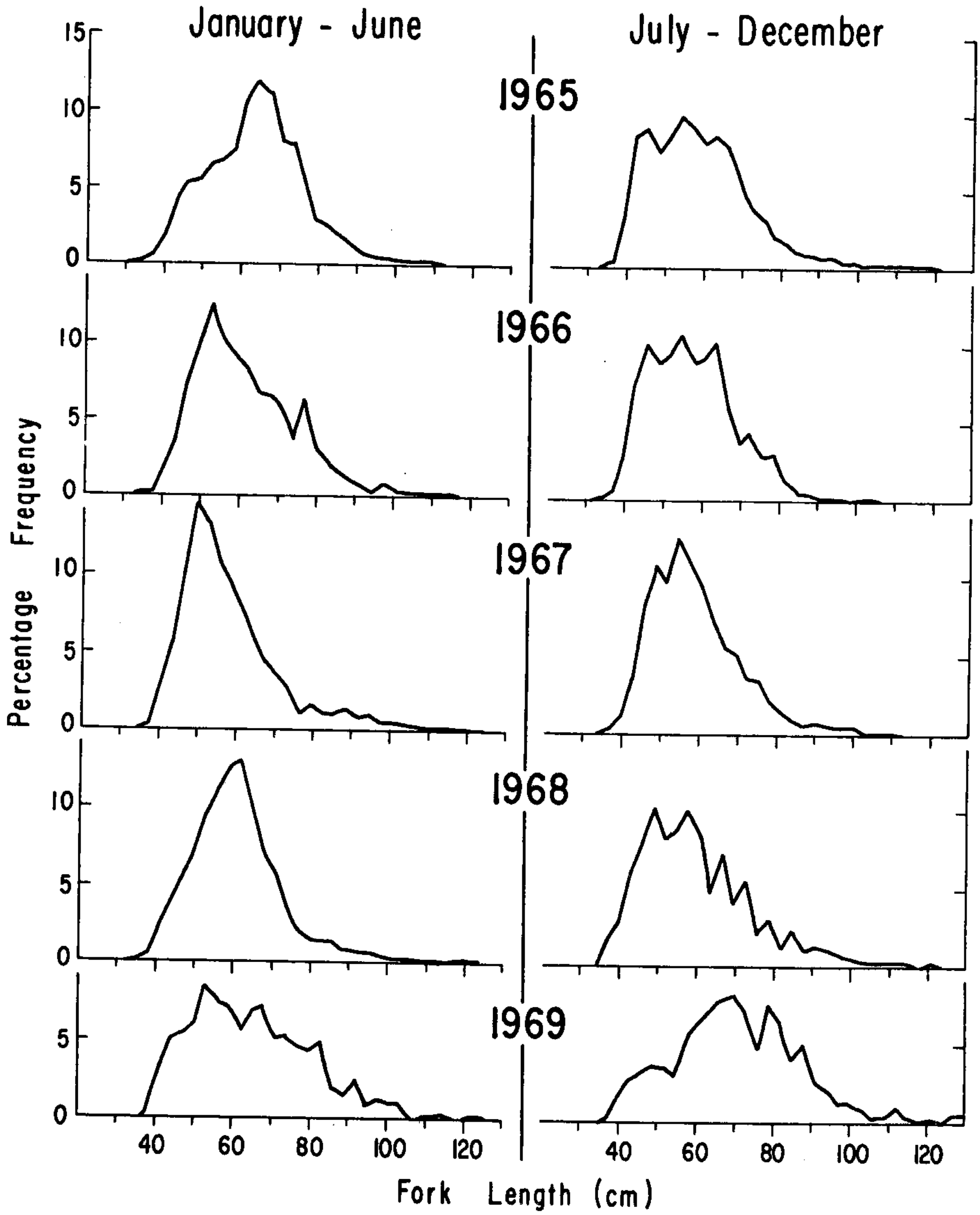

Fig. 2. Length composition of Canadian commercial landings of cod from offshore Div. 4X, 1965–69.

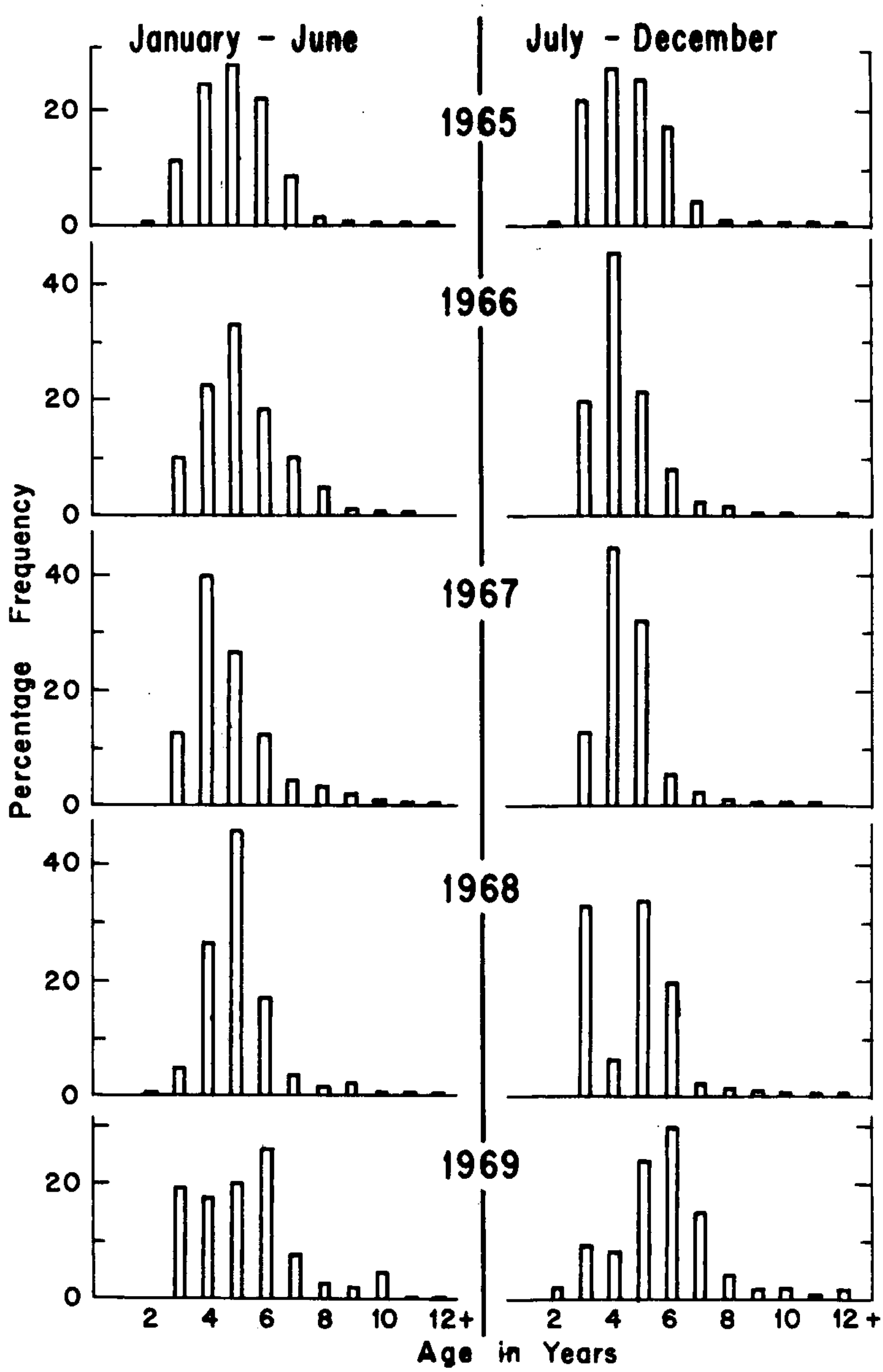

Fig. 3. Age composition of Canadian commercial landings of cod from offshore Div. 4X, 1965–69.

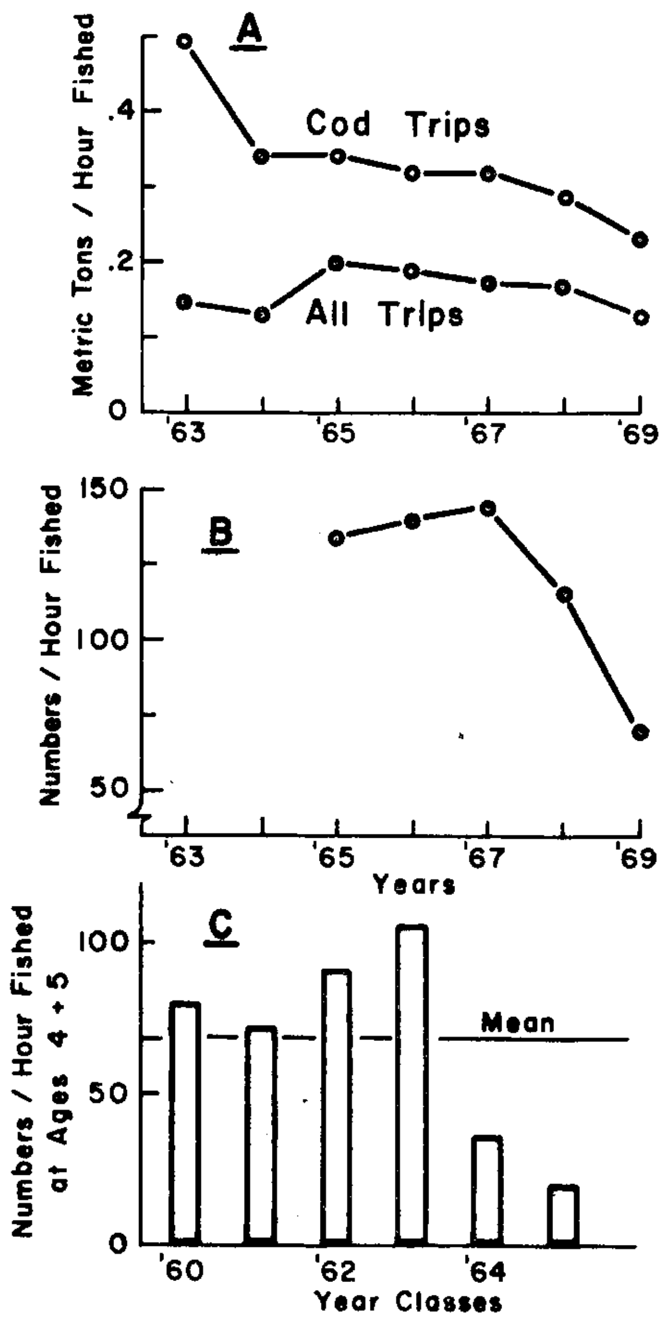

Fig. 4. Abundance of Div. 4X offshore cod: A. metric tons per hour fished by Canadian side otter trawlers, 151–500 gross tons, for all trips in 4X-N,O,P, and for those in which cod was the main species caught, 1963–69. B. numbers caught per hour fished for trips which cod was the main species caught. C. Year-class strength (as numbers caught at ages 4+5 per hour fished) of 1960–65 year-classes.

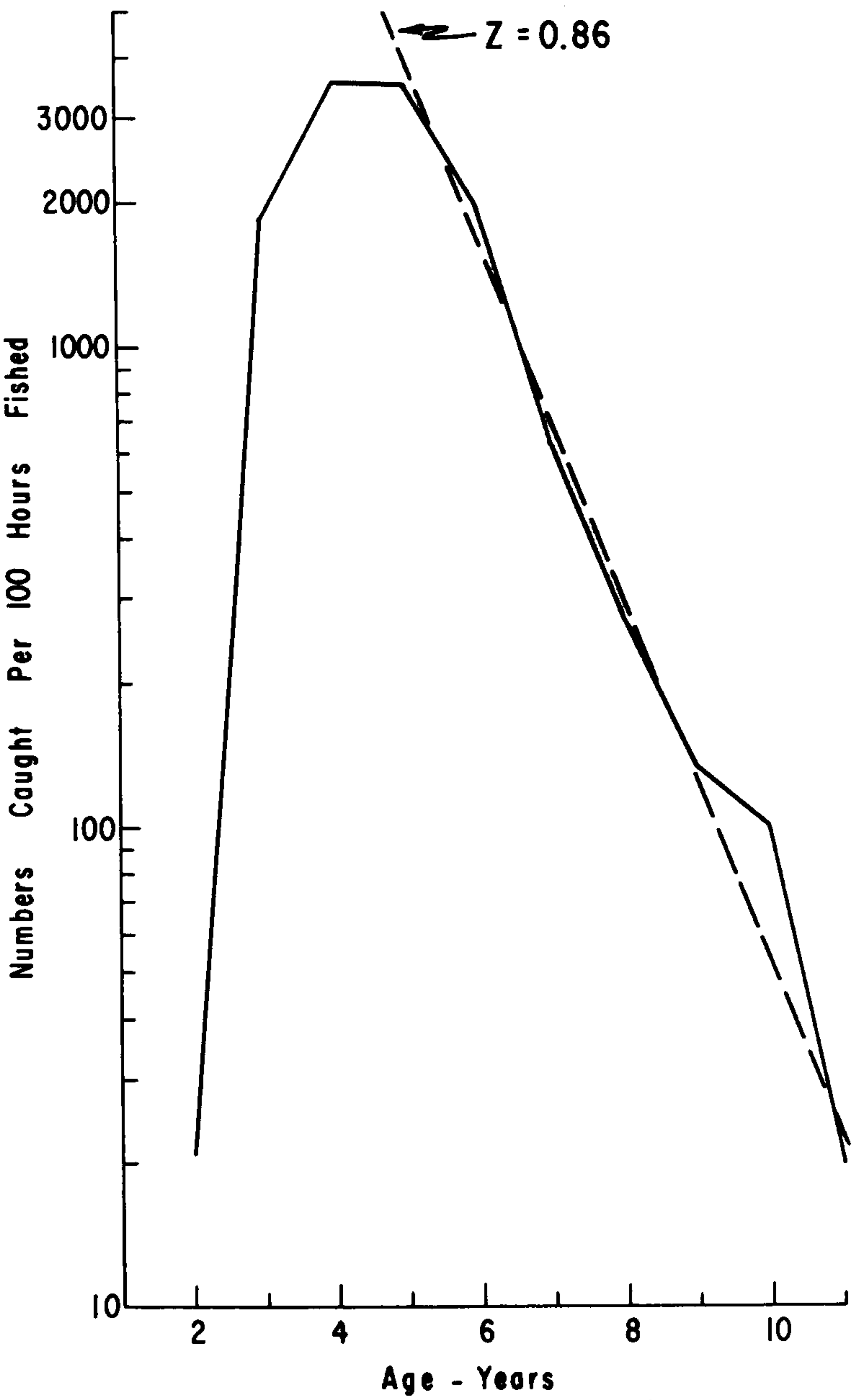

Fig. 5. Catch curve of average numbers of each age group of Div. 4X offshore cod caught per 100 hours fished by Canadian 151–500 gross ton side otter trawlers in 1965–69.

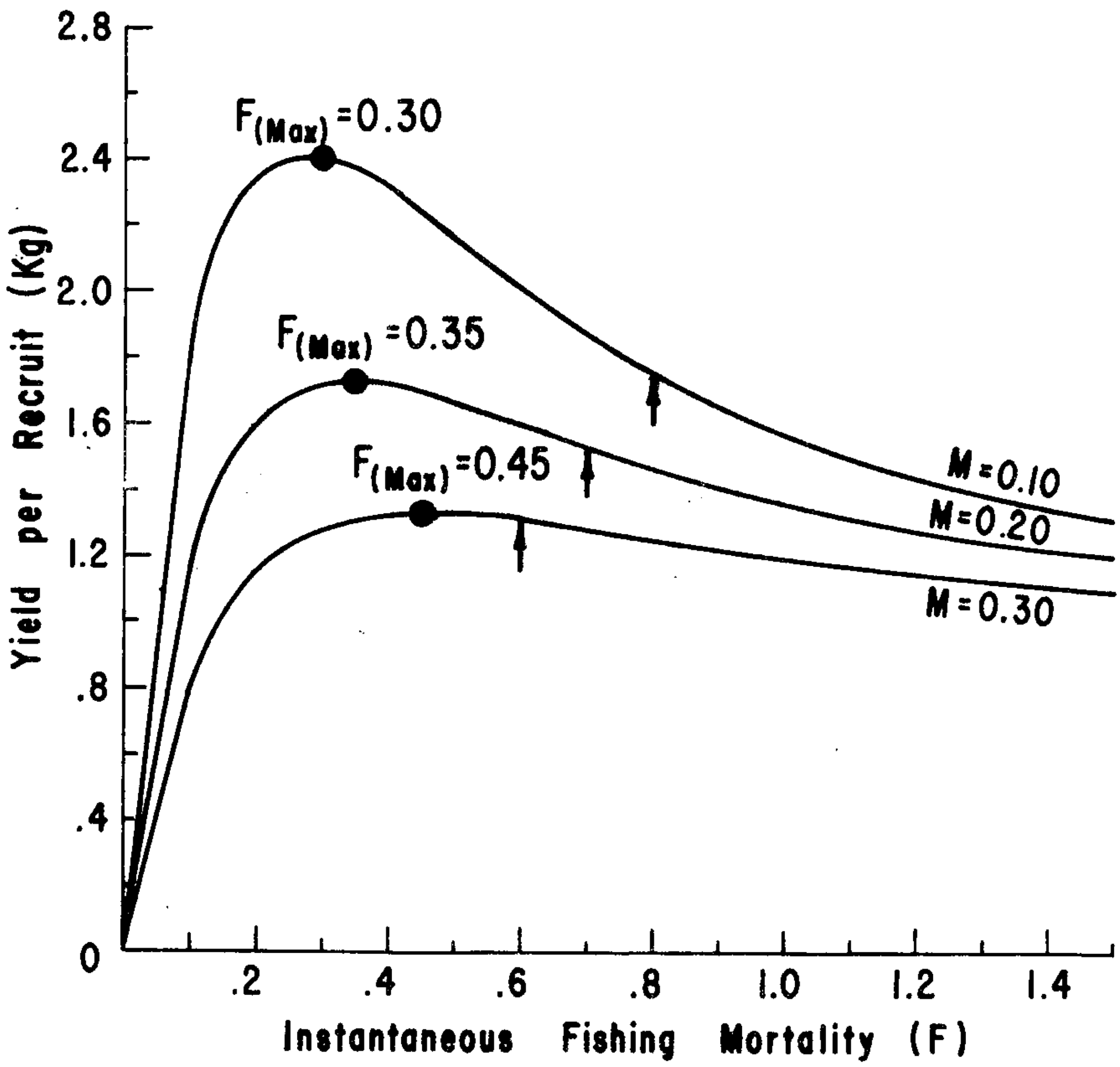

Fig. 6. Yield curves for Div. 4X offshore cod when W_∞ = 15.66 kg, K = 0.20, t_0 = 1.42, t_ρ and $t_\rho{}'$ = 3.7 yrs, t_λ = 12 yrs, for M = 0.10, 0.20, 0.30. Arrows indicate 1965–69 condition. F_{max} = F giving maximum yield per recruit.

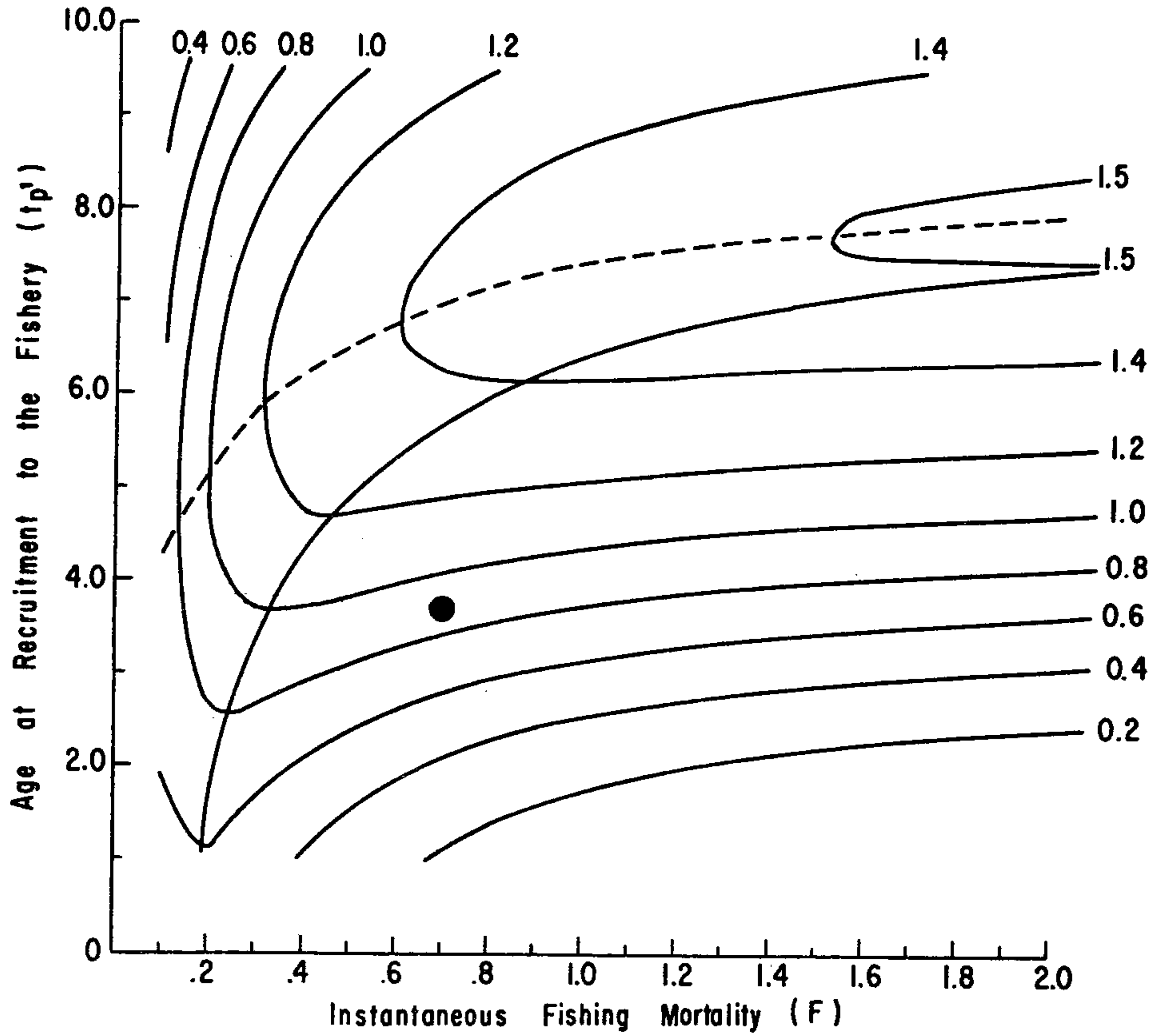

Fig. 7. Yield isopleth diagram for Div. 4X offshore cod when W_∞ = 15.66 kg, K = 0.20, t_o = 1.42, t_ρ = 1.0 yrs, t_λ = 12 yrs, M = 0.20. Dot shows state of the fishery in 1965–69.

RESTRICTED

INTERNATIONAL COMMISSION FOR THE NORTHWEST ATLANTIC FISHERIES

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(ADDENDUM)

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An Addendum to A preliminary report on an assessment of the offshore cod stock in ICNAF Div.4X

by R.G. Halliday
Fisheries Research Board of Canada
Biological Station, St. Andrews, N.B., Canada

LANDINGS: Canadian cod landings from ICNAF Div. 4X declined markedly to about 17,500 metric tons in 1970 from 24,000 metric tons in 1969. Landings from the almost totally Canadian inshore fisheries off southwestern Nova Scotia and in the Bay of Fundy declined from about 15,000 to 13,000 metric tons. Canadian offshore landings declined 50% from 9,000 to 4,500 metric tons.

COMPOSITION OF LANDINGS - OFFSHORE STOCK: Only 3 samples from the offshore trawl fishery were obtained in 1970 all in the second half of the year. These indicate that, compared with 1969, mean length of landings declined by about 15 cm, mean weight by 1.8 kg, and mean age by 1.4 yrs, to 51.0 cm, 1.5 kg, and 4.0 yrs in 1970.

ABUNDANCE: Catch per hour by those Canadian side otter-trawlers of 151-500 gross tons which caught mainly cod continued to decline in 1970 to 0.17 metric tons per hour, down 23% from the 1969 value. (This value is adjusted to compensate for effects of closure regulations in March and April.) Numbers caught per hour increased by 67% however.

DISCUSSION: On the basis of only 3 samples and incomplete landings and effort data only tentative conclusions can be reached on the nature of the fishery in 1970. The increase in numbers caught per hour while weight caught per hour continued to decrease, and decrease in size and age composition of the landings, probably reflects a change in emphasis of the fishery to younger fish rather than an increase in numerical stock abundance. Fully recruited age groups are considerably less abundant in 1970 than could be expected from likely trends in effort, apparent survival rate in 1969-70 being only 20% compared to an average of 40% in 1965-69. Furthermore, partially recruited age groups have considerably higher apparent survival rates in 1969-70 than in the earlier period suggesting a change in the pattern of recruitment to the fishery. Essentially this change lowers the age at recruitment to the fishery and is predicted from the constant parameter yield per recruit model to decrease yield per recruit.

The 1970 data confirm that the 1965 year-class is poor, being comparable in strength to that of 1964. Both the 1966 and 1967 year-classes appear slightly better than the average 1960-65 year-class strength. However, if the fishery did in fact concentrate on these partially recruited year-classes, they will prove to be considerably weaker than indicated by 1970 data.

CORRECTION

In ICNAF Res. Doc. 71/ , page 4, third paragraph, it is stated: "-- the abundance at age 4 for the 1960 year-class and at age 5 for the 1965 year-class (is estimated) from the ratio of numbers at ages 4:5 of 1.4 : 1.0 for the 1961-64 year-class,---". This ratio should read 1.24 : 1.00.