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Current status of the ICNAF Div. 4X haddock stock

by

R. G. Halliday

Fisheries and Marine Service
Biological Station
St. Andrews, N. B.
Canada

INTRODUCTION

Haddock in ICNAF Div. 4X has been the subject of a cooperative research programme between the St. Andrews Biological Station, Canada and the Northeast Fisheries Center, Woods Hole, USA, since 1956. Abundance, age composition of landings, and total mortality of Div. 4X haddock in the period 1956-61 is reviewed in detail by Hennemuth et al. (1964), and for the 1962 - 68 period by Schultz and Halliday (MS 1969). Commercial landings, population estimates and mortality rates from USA research vessel surveys through 1971 are reviewed by Heyerdahl (MS 1972) and similar data from Canadian research vessel surveys in 1970-72 by Halliday (MS 1973). The data presented below result from the research activities of both the Woods Hole and St. Andrews laboratories. However, as cooperating scientists at Woods Hole have not had an opportunity to review this analysis, full responsibility for the conclusions lies with the author.

(See Fig. 1 for definition of statistical unit areas referred to in the following text.)

STOCK STRUCTURE

Tagging experiments on Div. 4X haddock by Halliday and McCracken (1970) and by McCracken (1956, 1960) demonstrate that:

(1) haddock occurring on the northwestern side of the Bay of Fundy (Div. 4X-S) in the summer and autumn months predominantly migrate southwestwards into Div. 5Y for the winter-spring months, returning to Div. 4X-S the following summer; thus, Div. 4X-S haddock apparently belong to the Div. 5Y spawning stock:

(2) haddock occurring on the southeastern side of the Bay of Fundy (Div. 4X-R) in the summer and autumn months predominantly migrate southwards to the Browns Bank area (Div. 4X-NOP) for the winter-spring months, returning to Div. 4X-R the following summer; thus, Div. 4X-R haddock apparently belong to the Browns Bank spawning stock:

(3) haddock occurring off southwestern Nova Scotia (Div. 4X-O) in the summer and autumn predominantly migrate southwards to the Browns Bank area for the winter-spring months, returning the following summer:

(4) there is evidence of small localised coastal stocks throughout the area which are essentially none migratory.

These results support and extend the tagging results of McKenzie (1940) and Needler (1930).

Circumstantial evidence for the stock separation of haddock on the two sides of the Bay of Fundy is provided by differences in mean length-at-age (Needler, 1930) (but this difference could not be demonstrated by Hennemuth et al. (1964), size and age compositions of commercial catches (Hennemuth et al., (1964), and in abundance as implied by catch rates of commercial trawlers (see table 9).

On the basis of the above evidence, haddock caught in Div. 4X-S are excluded from the analysis of the main Div. 4X haddock stock. Landings from inshore stocks in the remainder of the Division cannot be distinguished from those from the main migrating stock, and are therefore considered with it. It is apparent from seasonality of fisheries and distribution of tagging returns that inshore stocks are small in relation to the main stock. Thus, this procedure should not introduce substantial error to the analysis.

LANDINGS

Although statistics of haddock landings broken down by ICNAF Division are available only since the early 1950's, less reliable landings statistics for Div. 4X haddock back to 1931 have been extracted from Canadian and USA national statistical digests (Schultz and Halliday, MS 1969). Average landings in the period 1931-60 are estimated to have been:

1931-40	18,000 m.t. (range 15-22,000 m.t.)
1941-50	14,000 m.t. (range 8-19,000 m.t.) (lowest in war years)
1951-60	19,000 m.t. (range 15-20,000 m.t.)
1931-60	17,000 m.t.

Declining USA landings in the 1960's were more than offset by increasing Canadian landings (Table 1). Spain and USSR entered the fishery during this period although their landings were small with the exception of 10,000 m.t. removed by USSR in 1966. Total landings increased to 42,224 m.t. in 1966 decreasing to 30,396 m.t. by 1969 (1961-69 mean = 29,700 m.t.).

The Commission introduced catch quota and closed area-season regulations from 1970 as follows:

Year	Quota (m.t.)	Closed Season	Landings (m.t.)	Quota Closure date
1970	18,000	March - April	18,139	Not closed
1971	18,000	March - April	17,600	Not closed
1972	9,000	March - May	13,499	10 October
1973	9,000	March - May(Preliminary)	13,076	6 May
1974	Nil	March - May	----	N/A

The closed area enforced in 1970-71 was reduced in size for 1972-74 to exclude deep-water regions, and thus minimise interference with silver hake and argentine fisheries.

All non-Canadian haddock catches were made using trawl gear (at least since 1955). However, a substantial portion of Canadian catches have been made by longline and handline, and small proportions by Danish seine, gillnet, and shrimp trawl (Table 2). (In table 2 the "line" category includes small catches by inshore gears such as traps, and possibly also small quantities of Danish seine and gillnet catches prior to 1967.)

As noted above, haddock caught in Div. 4X-S can appropriately be assigned to the Div. 5Y stock. Landings from Div. 4X-S were about 2,000 m.t. in 1962, increasing to over 5,000 m.t. in 1966, but declining to less than 200 m.t. by 1973 (Table 3). Thus, landings attributable to the Div. 4X stock increased from almost 16,000 m.t. in 1962 to 37,000 m.t. in 1966, declining to about 13,000 m.t.

by 1973 (Table 3).

AGE COMPOSITION OF LANDINGS

Composition of landings has been analysed for the period 1962-73 inclusive. No commercial samples are available from the landings of Spain and the USSR. Thus, their landings are adjusted on the basis of Canadian and USA samples.

Hennemuth et al. (1964) observe that Div. 4X-R haddock landings have a substantially different size and age composition that those from Div. 4X-MNOPQ. Thus, the age composition's are weighted separately for these areas. Otter trawl and line landings are also weighted separately when samples are available. Small Canadian Danish seine and shrimp trawl landings are combined with Canadian otter trawl landings, and gillnet with line landings, as landings of these minor gears have not been sampled. The author did not have full access to USA sampling data due to time limitations on the analysis. Thus, USA landings composition for the 1962-64 period were taken from the analysis by Schultz and Halliday (MS 1969). From 1965, USA landings were prorated on Canadian sampling data. This should not introduce major errors as Canadian and USA landings have been similar in composition (Hennemuth et al., 1964), and since 1965, USA landings have been small in proportion to those of Canada. For 1962, Canadian landings are prorated on USA sampling data, as Canadian sampling was inadequate. An inventory of Canadian samples from Div. 4X landings excluding Div. 4X-S are given in Table 4.

Numbers of fish removed from the population at age increased from 13.4 million in 1962 to 39.3 million in 1966, declining to 8.6 million in 1972. Preliminary estimate of removals in 1973 is 9.0 million (Table 5). Haddock aged 1 and 2 contribute little to the fishery, although 1973 landings of 2 year olds were considerably higher than in earlier years. Similarly, the contribution of fish over age 9 is small with the exception of the 1962 and 1963 year classes. The importance of the 1962 and 1963 year classes, particularly that of 1963, is apparent when weight contributions to the landings at each age are considered (Table 6). (These are derived from numbers landed at age multiplied by observed annual mean weight at age in commercial landings (table 7). From 1966 to 1971 the 1962 and 1963 year classes formed over 50% of the landings by weight, and in 1967 and 1968 they formed almost 80%. The 1963 year class at 10 years old still contributed significantly to the 1973 fishery.

COMMERCIAL CATCH RATES

The USA otter trawl fishery provides the longest complete series of catch per effort data for the Browns Bank area although in recent years it is based on relatively small amounts of effort.

Year	US landings/ day fished (m.t.)*	Can. landings/ hr. fished (m.t.)	Year	US landings/ day fished (m.t.)*	Can. landings/ hr. fished (m.t.)
1956	11.0	-	1965	6.5	.30
1957	8.4	-	1966	4.7	.32
1958	8.7	-	1967	5.4	.30
1959	5.6	-	1968	4.5	.28
1960	6.9	-	1969	3.4	.25
1961	6.7	-	1970	(3.2)	(.20)
1962	7.3	-	1971	(2.5)	(.19)
1963	6.5	.49	1972	(3.3)	(.16)
1964	7.5	.39	1973	---	(.19)

*(From USA Research Reports - ICNAF Redbooks Part II.)

Canadian catch per effort for side otter trawlers of 151-500 gross tons fishing haddock in Div. 4X-NOP (Browns-LaHave banks) is available from 1963 (see above and table 8). As 1963 was a transition year from relatively little to substantial otter trawl effort on the offshore banks of Div. 4X, the high c.p.e. value may be spurious.

USA c.p.e. indicate high catch rates in 1956-58 of over 8 m.t./day, dropping in 1959. In 1960-65 catch rates fluctuated between 6.5 and 7.5 m.t./day, averaging 6.9 m.t./day. Catch rates decline from 1965 to 3.4 m.t./day in 1969. Under regulation, catch rates averaged 3.0 m.t./day in 1970-72. Canadian catch rates were stable at about 0.30 m.t./hr. in 1965-67, declining to 0.25 m.t./hr in 1969, and averaging 0.19 m.t./hr under regulation in 1970-73. Thus, there is a trend of declining abundance between 1965 and 1969 which is more apparent in USA than Canadian data. Closure of the spawning area in March-April 1970 and 1971 and in March-May 1972-73 combined with closure to directed fishing in November-December 1972 and from May to December 1973 reduced catch rates in the 1970-73 period. Adjusting catch rates in 1970-72 by the ratio of catch rates during months of closure to those during the remainder of the year in the 1963-69 period gives estimates for these years comparable to those for the pre-regulation period (table 8). These indicate that catch rates continued to decline from 0.25 m.t./day in 1969 to 0.18 m.t./day in 1972. In 1970-73, the fishery in the months January to April were prosecuted under similar conditions. Thus, catch rates are comparable. These indicate that the 1973 mean Jan.-Apr. catch rate was the same as that for 1971 (0.23 m.t./hr.), up from that of 1972 (0.20 m.t./hr.).

In the Bay of Fundy, catch rates (metric tons/trip) are available for Canadian otter trawlers of 26-50 g.t. and 51-150 g.t. for Div. 4X-R and Div. 4X-S separately for 1960-73 (table 9). This is a seasonal fishery with peak catches in the July-September period and almost no fishing activity during the months of January to March. The 9 month means (April-December) of the monthly mean catch rates are probably distorted for the first few years from 1960 as the fishery was expanding rapidly at this time with new boats entering the fishery. In Div. 4X-S, catch rates increased almost threefold between the 1960-62 period and 1966, then declined drastically through 1971. In Div. 4X-R, catch rates peaked in 1963, then again in 1966-68, declining by about 60% and 70% for 26-50 g.t. vessels and 51-150 g.t. vessels respectively between 1968 and 1971. Closure of the directed fishery in November and December of 1972 when the fishery was virtually over is unlikely to have greatly affected the average catch rates for the 1972 fishery as a whole. Thus, a comparison with 1971 catch rates is probably valid. Catch rates continued to decline in Div. 4X-S but remained close to 1971 levels in Div. 4X-R in 1972. The 1973 values reflect bycatch rates only as the directed fishery was closed throughout the normal fishing season, and these cannot be taken as indicators of abundance.

For the main Div. 4X haddock stock (i.e. excluding Div. 4X-S), taking commercial catch rates as indicators of stock abundance, abundance declined on the offshore banks from 1965 (USA data) or from 1967 (Canadian data) through 1969 and probably this decline continued through 1972, 1973 abundance may have returned to the 1970-71 level. In Div. 4X-R, abundance declined from 1968 to approximately 30%-40% of the 1966-68 abundance by 1971. In 1972, abundance was at about the same level as in 1971 and not greatly different from that in 1970. Thus, after the substantial decline in abundance from the mid-1960's, abundance (by weight) may not have changed much from 1970 through the spring of 1973.

RESEARCH VESSEL SURVEY ABUNDANCE ESTIMATES

Research vessel surveys in Div. 4X have been conducted (using a stratified-random survey design) by USA since 1963 and by Canada since 1970. Differences in gear used, area covered, and timing of surveys, preclude direct comparison of numbers caught per tow, or population estimates, between the two survey series. However, relative year class strengths and abundance trends within the two data series can be compared and these show good agreement between Canadian and USA surveys.

Number caught per tow in USA spring surveys declined from 1968 through 1972 both for all age groups and for "adults" (age 4+)(table 10). In USA autumn surveys, adults declined from 1967 through 1972 but total numbers/tow declined from 1963 through 1970, then increased in both 1971 and 1972. Total no./tow in 1972 was comparable to the 1967 level.

Numbers per age group per tow (table 11) indicate that the 1963 year class was by far the most abundant in the data series, with the 1962 and 1959

year classes also being above average strength. Unfortunately, the 1963 and 1964 surveys did not cover the same area as subsequent surveys. Thus, the strengths of year classes subsequent to that of 1963, when compared with it at age 0 and 1, should be biased upward. They can be compared at ages 2 and 3 although some distortion is introduced since these year classes were probably subjected to varying fishing intensities at these ages. Mean numbers per tow at ages 2 and 3, and at ages 0 and 1, for 1963 and subsequent year classes were:

Year class	Mean no./tow at ages 2 and 3	% of 1963 y.c.	Mean no./tow at ages 0 and 1	% of 1963 y.c.
1963	23.6	(100)	48.6	(100)
1964	2.0	(8)	3.1	(6)
1965	1.3	(6)	0.9	(2)
1966	2.5	(11)	2.1	(4)
1967	0.8	(3)	0.6	(1)
1968	1.9	(8)	3.2	(7)
1969	5.0	(21)	7.4	(15)
1970	-	-	0.0	(0)
1971	-	-	15.1	(31)

These comparisons give similar results indicating that:

- the 1964-68 year classes were relatively poor, probably being less than 10% of the strength of the 1963 year class,
- the 1969 year class is 15-20% of the strength of the 1963 year class,
- the 1970 year class is the poorest on record,
- and that the 1971 year class may be 30% as strong as that of 1963 and two times as good as that of 1969.

Canadian surveys also reflect the strength of the 1963 year class which was the most abundant year class in 1970 although 7 years old (Table 12). As 0-group haddock are not usually available to bottom trawls until autumn, haddock first become available to Canadian summer surveys at age 1. It is apparent from the data that substantial availability changes occur from year to year. This may, in part, be due to minor gear changes effected between 1970 and 1971 surveys, but this could not have been the only factor involved, as 1972 and 1973 surveys are probably also affected. Taking means of population estimates at ages 1 and 2 to even out availability changes to some extent, the following mean population estimates are obtained:

Year class	Mean Population at ages 1 and 2 ($\times 10^{-6}$)	% of 1969 y.c.
1969	11.59	100
1970	0.24	2
1971	19.34	167

These data confirm that the 1970 year class is extremely poor and indicate that the 1971 year class is two-thirds again as strong as that of 1969.

The 1972 year class at age 0 in USA surveys and at age 1 in Canadian surveys is comparable to the abundance of 1969 and 1971 year classes at these ages. There is insufficient information available to resolve which of these it more closely resembles in abundance. (Preliminary USA data for 1973 surveys indicate that it is comparable to the 1969 y.c. and that the 1973 y.c. is very poor - Brown, personal communication.)

MORTALITY RATES

Estimates of natural mortality, M, are not available for Div. 4X haddock. However, analyses of adjacent haddock stocks on Georges and on Sable Island banks give estimates of M = 0.20 (cited by Hennemuth (MS 1969) for Georges Bank haddock as "Previous studies have indicated --- M = 0.2"; from a regression

of total mortality, Z, on fishing effort for Sable Island Bank haddock by Halliday (1971)). Thus, in this analysis M = 0.20 is assumed for Div. 4X haddock.

Estimates of Z were obtained from commercial and survey catch per effort data. Canadian commercial c.p.e. data for January-April in 1970-73 (presented in table 8) were used to weight Canadian commercial catch age compositions for the same periods to give estimates of numbers at age caught per 100 hours fishing (Table 13). Estimates of Z between years was calculated from:

$$Z = -\log_e \left(\frac{\sum_{age=6}^{13} N\ year(x+1)}{\sum_{age=5}^{12} N\ year(x)} \right)$$

giving estimates of Z for ages 5+ of 0.23 (1970-71), 0.81 (1971-72), and 0.31 (1972-73). Similarly, USA and Canadian survey data (presented in tables 11 and 12) give the estimates of Z presented in table 14. USA survey data indicate $\overline{Z}_{5+} = 0.69$ in the 1963-70 period. Estimates for the 1970-73 period are particularly variable, mean values being $\overline{Z}_{5+} = 0.39$ from USA surveys and $\overline{Z}_{5+} = 0.60$ from Canadian surveys. The amount of variation in these data preclude much confidence being placed on the mortality estimates. The three independent estimates imply that in 1970-73, $\overline{Z}_{5+}$ was in the range 0.39 - 0.60. Thus, fishing mortality, $F = 0.19 - 0.40$, in 1970-73 was apparently lower than in 1956-61, $\overline{F}_{6+} = 0.53$ (Hennemuth et al., 1964), and in 1963-70, $\overline{F}_{5+} = 0.49$.

POPULATION NUMBERS AND MORTALITIES FROM COHORT ANALYSIS

Numbers removed at age from table 5 were used to estimate population numbers and fishing mortalities (F) at age using Pope's cohort analysis (Pope, 1972). Natural mortality, M = 0.20, fishing mortality in the last year of contribution to the fishery (age 13), F = 0.50, and fishing mortality in the last calendar year (1973) equalling the mean for each age calculated for 1962-72, were assumed.

The values of F assumed for 1973, being essentially arbitrarily chosen, will create errors in estimates of F and population in most recent years which will decrease in proportion to the errors in the initial assumption, in each preceeding year. Thus, population and F estimates for 1962-70 are not greatly affected by this assumption.

Thus it is valid to conclude that the 1963 year class was the strongest recruiting to the fishery in this period, containing about 160×10^6 fish at age 2; the 1959 and 1964 year classes were also strong, each containing about 75×10^6 fish at age 2; the 1960 and 1961 year classes were poorer containing 30×10^6 and 20×10^6 fish at age 2 respectively; and that year classes of 1964-1968 were even poorer containing $8 - 16 \times 10^6$ fish at age 2 (table 15). Average fishing mortality during 1962-70 was F = 0.42, slightly lower than that estimated from USA research vessel surveys for 1963-70 (ie F = 0.49).

STOCK STATUS IN 1973

In order to predict the effects of various management policies through 1975, it is necessary to reach firm conclusions on population size and mortality in 1973.

The cohort analysis presented above used $\bar{F}$ = 0.41 for fully recruited age groups (age 5+) in 1973, which is about the same as that estimated for these age groups in 1962-70 (F = 0.42). Research vessel and commercial catch/effort data indicated that recent F's were in the range 0.19-0.40, and that they were lower than those for earlier years. Thus, the F values used for 1973 are upper estimates. Thus, bias upwards in the $\bar{F}$'s estimated for the immediately precceding years and underestimation of population size in these years and in 1973, is more likely than the reverse.

Comparison of numbers at age 2($\times 10^{-6}$) from cohort analysis for 1963-68 year classes with USA survey catch per tow at ages 0-3 indicates close agreement in relative year class strengths (table 15 and p.5). Best agreement is with mean no./tow at ages 2 and 3, the ratio (cohort analysis no. at age 2/survey no. per tow at ages 2 and 3) being close to 7.0 for all year class comparisons (range 5.5 - 9.5)). Extrapolating this to the 1969 year class gives an estimate of 35 x 10^{-6} fish at age 2(5.0 x 7.0). The comparable ratio with USA survey no/tow at ages 0 and 1 is more variable. However, both USA and Canadian surveys estimate the 1970 year class to be very poor and the 1971 year class to be approximately twice that of 1969. USA surveys in 1973 confirm that the 1971 y.c. = 2 x 1969 y.c. (Brown, personal communication.) Again, USA surveys indicate that the 1972 year class is approximately equal to the 1969 year class, with first indications that the 1973 year class is poor. Thus, the following recruitment predictions are obtained for year classes at age 2:

1969 y.c. = 35.0 x 10^6

1970 y.c. = 1.5 x 10^6 (approximately from cohort analysis-table 15)

1971 y.c. = 70 x 10^6

1972 y.c. = 35.0 x 10^6

1973 y.c. = 1.5 x 10^6 (assumed as poor as that of 1970)

Using 1969-71 y.c. values as best estimates of recent year class strength, and taking 1973 $\bar{F}$ =0.41 on ages 5-11 to give conservative estimates of population sizes at age for these ages, gives population numbers at the beginning of 1973 as shown in table 16.

PROJECTED CATCH IN 1975

Removals at age in 1973 (table 5) from this population imply revised F values for age 2-4 (table 16) and, with recruitment of 35 x 10^6 fish of the 1972 y.c. at age 2, population numbers at the beginning of 1974 are as shown.

Removals and mortality rate in 1974 are unknowns and essentially unestimatable. Although the 1974 TAC is zero, the fishery remained partly open until 17 March. However, directed catches can be expected to be lower than in 1973 when the fishery remained fully open until 6 May. Nevertheless, with a 5,000 lb. or 10% of catch bycatch exemption, and increased stock abundance, bycatches can be expected to be greater. There are also reliable reports of substantial discards being made by Canadian vessels to avoid prosecution under the bycatch clause which is rigourously enforced on landings, but much less effectively enforced on catches. Thus, mortality in 1974 may not be substantially less than in 1973. The pessimistic assumption is made that 1974 mortality will be similar to that in 1973 (i.e. $\bar{F}$ = 0.40 for ages 5+).

These assumptions allow population numbers at the beginning of 1975 to be calculated, with an estimated recruitment of 1.5 x 10^6 fish of the 1973 y.c. at age 2.

A yield-per-recruit function has not been derived for this stock. For Div. 4VW haddock, Halliday (1971) determined that maximum yield-per-recruit was obtained at F = 0.50 (mean age at recruitment = 3.7 yrs.); and for Georges Bank haddock, Hennemuth (MS 1969) concluded that maximum long-term yield was obtained at a mean F = 0.50 (mean age at recruitment = approx. 2.75 yrs.). Thus, it is assumed that maximum yield-per-recruit for Div. 4X haddock is obtained at F = 0.50 also, which, given similarities in growth and recruitment patterns, is

probably a reasonable assumption.

– Assuming a management objective to maximise yield-per-recruit in 1975 (i.e. F_{5+} = 0.50) the total allowable catch is estimated to be 26,000 tons (table 16). (This assumes mean weight at age similar to that observed in 1973.)

This analysis is subject to error due to erroneous assumptions on F in 1973 and 1974, and to changes in mean weights at age between 1973 and 1975. However, errors from these sources are certainly much smaller than potential errors in assumptions on the strength of the 1969, 1971, and 1972, year classes.

Assuming the scaling of these year classes to that of 1963 is erroneous, and that, as indicated by USA surveys of 0- and 1- group fish, the 1969 year class is only 15% as strong as that of 1963, the following year class strengths at age 2 are obtained:

1969 y.c. = 25.0×10^6
1970 y.c. = 1.5×10^6
1971 y.c. = 50.0×10^6
1972 y.c. = 25.0×10^6
1973 y.c. = 1.5×10^6

Using these values and other parameters as before, the predicted 1975 catch is 19,000 tons.

CONCLUSIONS

The Div. 4X haddock stock has not been over-exploited in the sense that it has been subjected to unduly high exploitation rates. Mortality (F) on fully recruited age groups has been at or below the level giving maximum yield-per-recruit in the period 1962-73. The stock did experience recruitment failure, the 1964-68 year classes all being much weaker than those of 1959-63. This resulted in a substantial decline in stock abundance. This decline has been reversed with recruitment of the 1969 (and 1972) year classes which are probably comparable in abundance to those of 1960 and 1961, and of the 1971 year class which may be as strong as those of 1959 and 1962. However, occurrence of the very weak 1970 and 1973 year classes indicates that recruitment has not yet consistently returned to pre-1963 year class levels.

If the management option is chosen to exploit the year classes now dominant in the population at the level maximising yield-per-recruit, 1975 removals should lie between 19,000 and 26,000 tons. The implications of this policy are largely dependent on future (post-1973 year class) recruitment. If 1974 and subsequent year classes are substantially better than those currently in the fishery, i.e. those of 1969-72, this level of yield can probably be maintained. If 1974+ year classes are of similar strengths to those of 1969 and 1972, a reduction in catches to 15,000-20,000 tons in 1977 and 1978 will be necessary to maintain F = 0.50, as the poor 1970 and 1973 year classes pass through the fishery. If 1974+ year classes return to the levels of those of 1964-68, a reduction in 1977 and 1978 catches to 11,000-14,000 tons will be necessary, and this decline will continue, stabilising at a level of approximately 8,000-9,000 tons.

It has not yet been possible to examine in detail the implications of this policy on spawning stock size. Such a study is complicated by changes in growth and age at maturity which appear to vary in relation to population abundance. In 1969, female haddock in Div. 4X were about 50% mature at a length of 40 c.m., males at about 38 c.m. (personal observation). Thus, the spawning stock roughly consists of fish age 4 and older. Thus, the good year classes of 1962 and 1963 were spawned by an adult biomass of approximately 70,000 and 90,000 tons respectively, the poor 1967 year class from 135,000 tons, the extremely poor 1970 year class and the moderately good 1971 year class from 50,000 tons. Spawning stock sizes predicted using the two different recruitment level options

described above and fishing at F = 0.50 are:

Calendar year	low recruitment		high recruitment	
1973	42,000		50,000	
1974	32,000		42,000	
1975	54,000		74,000	
1976	56,000		77,000	
1977	38,000		52,000	
	①	②	①	②
1978	29,000	38,000	37,000	53,000
1979	26,000	42,000	31,000	59,000
1980	24,000	44,000	26,000	62,000

① 1974+ year classes as strong as 1964-68.

② 1974+ year classes as strong as 1969-72.

Some increase in spawning stock size in 1975 and 1976 is likely, but it will decline in 1977 to the 1973 level. Poor recruitment to the spawning stock in 1978 (i.e. of the 1974 year class) would result in further decline to the 1974 level which is the lowest in the data series.

Thus, a management objective to rebuild the spawning stock above the present (1974) low level implies that F in 1975 should be below F_{max}.

(It is assumed that the Div. 5Y haddock will contribute very little to the Div. 4X haddock fishery in the period discussed.)

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Table 1. ICNAF Div. 4X haddock - nominal catches (metric tons round).

Year	Canada	Spain	USSR	USA	Others	Total
1954	7,124	-	-	14,613	-	21,737
1955	8,709	-	-	12,067	-	20,776
1956	9,251	-	-	12,130	-	21,381
1957	9,862	-	-	7,296	-	17,158
1958	9,695	-	-	12,141	-	21,836
1959	9,807	-	-	5,465	-	15,272
1960	7,946	-	-	8,315	-	16,261
1961	8,556	-	-	9,306	-	17,862
1962	11,537	-	-	6,388	-	17,925
1963	16,763	-	400	7,223	28	24,414
1964	26,343	-	1,108	8,488	40	35,979
1965	22,740	-	2,582	3,685	-	29,007
1966	29,543	143	10,065	2,473	-	42,224
1967	32,012	78	199	5,014	-	37,303
1968	28,837	116	335	3,156	36	32,480
1969	28,074	473	-	1,830	19	30,396
1970	16,012	370	2	1,743	12	18,139
1971	16,404	347	97	751	1	17,600
1972	12,570	470	10	448	1	13,499
1973*	12,680	108	13	272	3	13,076

*Preliminary

Table 2. ICNAF Div. 4X haddock - Canadian nominal catches (metric tons round) by gear type.

Year	Otter trawl	Line (LL + HL)	Danish seine	Gill-net	Shrimp trawl	Total
1956	2,625	6,626	-	-	-	9,251
1957	3,867	5,995	-	-	-	9,862
1958	4,347	5,348	-	-	-	9,695
1959	4,076	5,731	-	-	-	9,807
1960	3,890	4,056	-	-	-	7,946
1961	4,175	4,381	-	-	-	8,556
1962	7,813	3,724	-	-	-	11,537
1963	12,063	4,700	-	-	-	16,763
1964	20,532	5,811	-	-	-	26,343
1965	18,048	4,692	-	-	-	22,740
1966	25,800	3,743	-	-	-	29,543
1967	28,696	3,108	208	-	-	32,012
1968	25,515	2,997	99	226	-	28,837
1969	24,333	3,302	195	242	2	28,074
1970	11,750	3,907	211	86	58	16,012
1971	12,152	3,940	198	72	42	16,404
1972	7,586	4,841	55	58	30	12,570
1973	6,097	6,402	38	143	-	12,680

Table 3. ICNAF Div. 4X haddock-nominal catches (metric tons round) by "Statistical areas"

Year	Country	4X-M,N,O,P,Q	4X-R	4X-S	Total	Total excl. 4X-S
1962	Canada	4,154	5,964	1,419	11,537	
	USA	5,467	294	627	6,388	
	Total	9,621	6,258	2,046	17,925	15,879
1963	Canada	7,773	6,612	2,378	16,763	
	USSR	400	-	-	400	
	USA	5,829	568	826	7,223	
	Others	28	-	-	28	
	Total	14,030	7,180	3,204	24,414	21,210
1964	Canada	19,231	5,237	1,875	26,343	
	USSR	1,108	-	-	1,108	
	USA	7,332	245	911	8,488	
	Others	40	-	-	40	
	Total	27,711	5,482	2,786	35,979	33,193
1965	Canada	15,305	5,257	2,178	22,740	
	USSR	2,582	-	-	2,582	
	USA	1,898	552	1,235	3,685	
	Total	19,785	5,809	3,412	29,007	25,594
1966	Canada	14,544	10,948	4,051	29,543	
	Spain	143	-	-	143	
	USSR	10,065	-	-	10,065	
	USA	1,179	213	1,081	2,473	
	Total	25,931	11,161	5,132	42,224	37,092
1967	Canada	18,944	10,154	2,914	32,012	
	Spain	78	-	-	78	
	USSR	199	-	-	199	
	USA	2,508	433	2,073	5,014	
	Total	21,729	10,587	4,987	37,303	32,316
1968	Canada	20,121	7,156	1,560	28,837	
	Spain	116	-	-	116	
	USSR	335	-	-	335	
	USA	2,449	408	299	3,156	
	Others	36	-	-	36	
	Total	23,057	7,564	1,859	32,480	30,621
1969	Canada	22,722	4,697	655	28,074	
	Spain	473	-	-	473	
	USA ↓	1,372	275	183	1,830	
	Others	19	-	-	19	
	Total	24,586	4,972	838	30,396	29,558

Table 3. (continued)

Year	Country	4X-M,N,O,P,Q	4X-R	4X-S	Total	Total excl. 4X-S
1970	Canada	12,942	2,619	451	16,012	
	Spain	370	-	-	370	
	USSR	2	-	-	2	
	USA	1,570	64	109	1,743	
	Others	12	-	-	12	
	Total	14,896	2,683	560	18,139	17,579
1971	Canada	13,866	2,198	340	16,404	
	Spain	347	-	-	347	
	USSR	97	-	-	97	
	USA	609	45	97	751	
	Others	1	-	-	1	
	Total	14,920	2,243	437	17,600	17,163
1972	Canada	10,493	1,901	176	12,570	
	Spain	470	-	-	470	
	USSR	10	-	-	10	
	USA	384	25	39	448	
	Others	1	-	-	1	
	Total	11,358	1,926	215	13,499	13,284
1973 [3]	Canada	11,180	1,400	100	12,680	
	Spain	108	-	-	108	
	USSR	13	-	-	13	
	USA [2]	233	15	24	272	
	Others	3	-	-	3	
	Total	11,537	1,415	124	13,076	12,952

[1] Prorated among areas on 1968 data

[2] Prorated among areas on 1972 data

[3] Preliminary statistics

Table 4. ICNAF Div. 4X haddock - inventory of Canadian commercial samples.

Year	Div 4X-MNOPQ		Div 4X-R		Total
	O.T.	Line	O.T.	Line	
1962	2	-	11	-	13
1963	6	9	9	-	24
1964	10	10	1	-	21
1965	14	2	7	-	23
1966	13	3	11	-	27
1967	35	-	7	-	42
1968	42	-	6	-	48
1969	52	-	3	-	55
1970	23	-	3	-	26
1971	23	3	5	-	31
1972	24	8	2	2	36
1973	17	9	4	-	30

Table 5. Div. 4X haddock - numbers removed at age (x 10^{-3})

Age	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
1	-	-	-	-	-	-	-	-	-	-	41	149
2	139	713	155	70	219	22	665	10	1,055	788	22	3,054
3	4,524	2,013	1,272	3,038	18,341	515	297	2,016	724	1,617	3,434	112
4	1,415	7,185	4,286	1,981	9,796	20,380	1,164	1,968	1,502	788	1,841	2,232
5	1,778	3,087	9,337	3,153	3,167	9,148	17,448	1,621	379	1,422	509	1,062
6	1,708	1,649	3,018	5,409	2,149	1,039	4,684	11,243	524	404	645	528
7	1,648	1,415	1,492	1,973	3,747	735	713	3,220	4,536	69	90	599
8	973	593	1,370	1,000	840	1,052	518	455	1,863	3,316	57	323
9	645	478	612	745	409	187	672	249	133	1,020	1,166	259
10	232	152	412	288	424	102	190	194	96	163	512	618
11	205	113	297	203	88	90	131	172	175	181	26	55
12	64	59	168	114	62	23	65	94	27	146	193	14
13+	100	43	36	113	84	81	89	69	37	105	92	6
Totals	13,431	17,500	22,455	18,087	39,327	33,373	26,635	21,311	11,050	10,017	8,628	9,011
Landings (m.t.)	15,879	21,210	33,193	25,594	37,092	32,316	30,621	29,558	17,579	17,163	13,284	12,952

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Table 6. ICNAF Div. 4X haddock - weight removed at age (metric tons round).

Age	1965	1966	1967	1968	1969	1970	1971	1972	1973
1	-	-	-	-	-	-	-	23	40
2	20	64	6	247	6	601	433	10	1,558
3	2,005	10,454	309	175	1,532	579	1,358	2,885	84
4	1,882	8,424	15,896	908	1,752	1,592	961	2,596	2,678
5	3,657	3,642	9,514	17,797	2,204	451	2,176	850	1,869
6	8,330	3,116	1,559	6,136	15,740	912	671	1,309	1,125
7	3,630	6,670	1,316	1,276	5,410	8,301	121	194	1,456
8	2,140	1,856	2,115	1,020	874	3,707	7,295	150	875
9	1,743	990	451	1,579	491	359	2,458	2,892	686
10	804	941	283	452	514	295	417	1,362	2,151
11	501	238	257	347	427	520	478	80	194
12	308	194	69	187	237	94	418	569	42
13+	380	252	207	253	212	133	321	302	33
Calculated total	25,400	36,841	31,982	30,377	29,399	17,544	17,107	13,222	12,791
Observed total	25,594	37,092	32,316	30,621	29,558	17,579	17,163	13,284	12,952
1962 + 63 y.c. (m.t.)	2,025	18,878	25,410	23,933	21,150	12,008	9,753	4,254	2,345
(%)	8%	51%	79%	79%	72%	68%	57%	32%	18%

Table 7. ICNAF Div. 4X haddock - annual mean weight at age in commercial landings (kilogrammes). Observations in parentheses based on age groups forming less than 1% of annual landings.

	AGE														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Mean
1965	-	(.28)	.66	.95	1.16	1.54	1.84	2.14	2.34	2.79	2.47	(2.70)	(3.36)	(2.90)	1.41
66	-	(.29)	.57	.86	1.15	1.45	1.78	2.21	2.42	2.22	(2.70)	(3.13)	(3.00)	(2.64)	0.94
67	-	(.29)	.60	.78	1.04	1.50	1.79	2.01	(2.41)	(2.77)	(2.85)	(3.00)	(2.55)	(2.88)	0.97
68	-	.37	.59	.78	1.02	1.31	1.79	1.97	2.35	(2.38)	(2.65)	(2.88)	(2.84)	(2.99)	1.15
69	-	(.56)	.76	.89	1.36	1.40	1.68	1.92	1.97	(2.65)	(2.48)	(2.52)	(3.07)	(3.04)	1.39
1970	-	.57	.80	1.06	1.19	1.74	1.83	1.99	2.70	(3.07)	2.97	(3.48)	(3.59)	-	1.59
71	-	.55	.84	1.22	1.53	1.66	1.75	2.20	2.41	2.56	2.64	2.82	3.06	(5.18)	1.71
72	(.56)	(.45)	.84	1.41	1.67	2.03	2.16	2.64	2.48	2.66	(3.09)	2.95	(3.28)	(3.03)	1.54
73	.27	.51	.75	1.20	1.76	2.13	2.43	2.71	2.65	3.48	(3.53)	(3.00)	(5.46)	-	1.31
$\bar{w}_{65-67}$	-	(.29)	.61	.86	1.12	1.50	1.80	2.12	(2.39)	(2.59)	(2.67)	(2.94)	(2.97)		
$\bar{w}_{68-70}$	-	(.50)	.72	.91	1.19	1.48	1.77	1.96	2.34	(2.70)	(2.70)	(2.96)	(3.17)		
$\bar{w}_{71-73}$	-	(.50)	.81	1.28	1.65	1.94	2.11	2.52	2.51	2.90	(3.09)	(2.92)	(3.93)		

Table 8. ICNAF Div. 4X haddock - Catch rates (metric tons per hour) of Canadian side otter trawlers of 151-500 gross tons on Browns-LaHave banks (Div. 4X-NOP) for those trips when the main species caught was haddock.

Month	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
Jan.	.31	.41	.15	.27	.32	.42	.22	.18	.17	.18	.19
Feb.	.44	.48	.30	.39	.35	.43	.33	.20	.21	.23	.22
Mar.	.56	.56	.47	.52	.44	.43	.51	(.17)↓	(.29)↓	(.17)↓	(.27)↓
Apr.	.69	.56	.51	.42	.49	.36	.41	(.25)↓	(.23)↓	(.19)↓	(.24)↓
May	.27	.56	.39	.38	.40	.30	.24	.39	.29	(.13)↓	(.22)↓
June	1.47	.45	.30	.38	.30	.23	.22	.34	.22	.22	(.31)[2]
July	.61	.33	.19	.30	.22	.24	.16	.19	.19	.21	(.19)[2]
Aug.	.41	.33	.31	.29	.28	.24	.23	.09	.18	.13	(.15)[2]
Sept.	.37	.32	.25	.25	.21	.26	.24	.32	.17	.16	(.08)[2]
Oct.	.34	.26	.31	.27	.24	.17	.16	.11	.12	.10	(.15)[2]
Nov.	.24	.19	.21	.22	.17	.17	.21	.10	.11	(.13)[2]	(.06)[2]
Dec.	.21	.21	.19	.20	.23	.10	.12	.11	.14	(.11)[2]	(.20)[2]
Mean (Jan-Dec)	.49	.39	.30	.32	.30	.28	.25	(.20)	(.19)	(.16)	(.19)
Adjusted for seasonal closure =								.22	.20	.18	-
Mean (Jan-Apr) =								.20	.23	.20	.23

↓ Season-area closure

[2] Quota closure

Table 9. ICNAF Div. 4X haddock - catch rates (metric tons/trip) of Canadian otter trawlers of 26-50 g.t. and 51-150 g.t. in Div. 4X-R and Div. 4X-S for 1960-73. April-December (9 month) means of monthly values.

	Div. 4X - R		Div. 4X - S	
Year	26-50 g.t.	51-150 g.t.	26-50 g.t.	51-150 g.t.
1960	0.79	1.46	1.14	2.75
1961	1.00	1.70	1.27	2.19
1962	2.13	2.57	1.58	2.37
1963	4.39	5.14	2.20	3.13
1964	2.41	2.68	2.67	2.41
1965	1.99	2.75	2.84	4.45
1966	2.36	3.75	3.66	5.81
1967	2.45	3.66	2.74	4.89
1968	2.32	3.70	1.93	2.89
1969	1.50	2.18	1.08	1.53
1970	1.17	1.19	0.59	1.22
1971	0.98	1.10	0.42	0.79
1972 ↓	(0.87)	(1.23)	(0.34)	(0.39)
1973 [2]	(0.51)	(0.88)	(0.20)	(0.27)

↓ Directed fishery closed in November and December

[2] Directed fishery closed from May to December

Table 10. ICNAF Div. 4X haddock - U.S.A. research vessel survey numbers per tow from Browns-LaHave banks (USA Strata 31-34 for 1963-64, USA Strata 31-34, 41-42 for 1965-72.) Data for 1963-1971 spring from Heyerdahl (MS 1972). Data for 1971 spring and 1972 from Hennemuth (personal communication).

	Spring			Autumn		
Year	Total	Age 4+	% of total	Total	Age 4+	% of total
1963	-	-	-	193	34	18
1964	-	-	-	44	13	30
1965	-	-	-	55	13	24
1966	-	-	-	39	14	36
1967	-	-	-	37	30	81
1968	28	25	89	21	14	66
1969	28	15	54	23	5	23
1970	29	18	59	14	6	45
1971	23	14	59	23	6	26
1972	18	8	43	36	4	11
1973						

Table 11. ICNAF Div. 4X haddock - USA autumn research vessel survey numbers per tow at age from Browns-LaHave banks. (Credits as for table 10) (*-excludes LaHave Bank.)

	AGE									
Year	0	1	2	3	4	5	6	7	8	9
1963*	83.1	46.8	15.6	14.0	19.4	7.5	3.2	1.5	1.2	0.8
1964*	0.2	14.1	10.6	3.4	4.4	7.1	2.1	0.6	0.7	0.3
1965	0.5	6.0	25.7	9.7	3.5	3.2	4.1	1.2	0.3	0.4
1966	0.7	1.2	1.5	21.4	7.1	2.2	1.5	2.2	0.8	0.5
1967	0.1	3.5	1.3	2.5	22.9	4.3	1.0	0.9	0.5	0.2
1968	2.2	1.0	2.8	1.2	0.4	9.1	3.2	0.4	0.4	0.6
1969	10.3	4.2	0.8	2.2	0.3	0.1	2.9	1.2	0.1	0.3
1970	0	4.5	2.2	0.7	1.3	0.2	0.7	2.4	0.8	0.3
1971	9.5	+	5.8	1.6	0.7	1.0	0.2	0.1	2.6	0.8
1972	7.4	20.6	0.2	4.2	1.3	0.3	0.6	0.1	0.1	1.2
1973										

Table 12. ICNAF Div. 4X haddock - Canadian summer research vessel survey population estimates at age from all of Div. 4X ($x10^{-6}$).

	AGE									
Year	0	1	2	3	4	5	6	7	8	9+
1970	-	7.99	6.43	1.88	3.55	1.45	3.25	8.48	1.19	1.06
1971	-	0.16	15.19	6.48	2.93	4.23	1.99	3.03	8.37	1.39
1972	-	7.25	0.32	4.60	1.99	1.28	1.40	0.91	1.45	2.32
1973	-	8.16	31.43	0.80	4.10	1.94	0.75	1.05	0.79	1.41

Table 13. ICNAF Div. 4X haddock - catch in numbers at age per 100 hrs. fishing in January-April by Canadian side otter trawlers of 151-500 g.t. fishing haddock in Div. 4X-NOP and estimates of total instantaneous mortality (Z) for ages 5+.

Year	2	3	4	5	6	7	8	9	10	11	12	13	Total	Z_{5+}
1970	83	1430	2766	869	687	5638	1796	84	139	78	11	20	13,601	
1971	34	3391	1610	1755	808	-	4377	1482	256	201	181	55	14,150	0.23
1972	-	5105	4093	1225	1377	248	95	1733	370	58	92	48	14,444	0.81
1973	3	172	6824	3274	1361	1133	177	331	757	32	11	-	14,075	0.31

Table 14. ICNAF Div. 4X haddock - total instantataneous mortality estimate (Z) from Canadian and USA research vessel catch rates at age given in tables 11 and 12 and from Canadian commercial catch rates as given in table 13.

	USA surveys		Canadian surveys		Can. Comm. cpe
Years	Ages 4-5	Ages 5+	Ages 4-5	Ages 5+	Ages 5+
1963-64	1.01	1.29	-	-	-
1964-65	0.32	0.56	-	-	-
1965-66	0.46	0.57	-	-	-
1966-67	0.50	0.95	-	-	-
1967-68	0.92	0.38	-	-	-
1968-69	1.39	1.07	-	-	-
1969-70	0.41	0.02	-	-	-
1970-71	0.26	0.10	(-0.18)	0.04	0.23
1971-72	0.85	0.67	0.83	1.14	0.81
1972-73			0.03	0.61	0.31
$\bar{Z}_{1970-73}$	0.56	0.39	0.23	0.60	0.45

Table 15. ICNAF Div. 4X haddock - estimated population numbers at age (x 10^{-6}) and F's from Pope's cohort analysis.

A. Population Numbers (x 10^{-6})

Age	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
2	30.2	20.4	75.1	160.1	10.9	8.9	15.9	7.6	13.5	21.7	1.3	138.1
3	59.6	24.6	16.0	61.4	131.0	8.7	7.3	12.4	6.2	10.1	17.0	1.0
4	19.8	44.7	18.3	12.0	47.5	90.7	6.7	5.7	8.4	4.4	6.8	10.9
5	11.1	14.9	30.1	11.1	8.0	30.0	55.8	4.4	2.9	5.5	2.9	3.9
6	9.5	7.5	9.4	16.2	6.2	3.7	16.3	29.9	2.1	2.0	3.2	1.9
7	4.9	6.2	4.7	5.0	8.4	3.2	2.1	9.1	14.3	1.3	1.3	2.0
8	3.3	2.5	3.8	2.5	2.3	3.5	1.9	1.1	4.5	7.6	1.0	1.0
9	1.9	1.8	1.5	1.9	1.1	1.1	1.9	1.1	0.5	2.0	3.2	0.8
10	1.0	1.0	1.0	0.7	0.9	0.5	0.8	0.9	0.7	0.3	0.7	1.6
11	0.4	0.6	0.7	0.5	0.3	0.3	0.3	0.4	0.6	0.5	0.1	0.1
Totals 2-11	141.7	124.2	160.6	271.4	216.6	150.6	109.0	72.6	53.7	55.4	37.5	161.3

B. Fishing Mortality - F

Age												
2	.01	.04	.00	.00	.02	.00	.05	.00	.09	.04	.02	.02
3	.09	.09	.09	.06	.17	.07	.05	.20	.14	.19	.25	.13
4	.08	.20	.30	.20	.26	.29	.21	.48	.22	.22	.35	.26
5	.19	.26	.42	.38	.57	.41	.42	.52	.16	.34	.22	.35
6	.22	.28	.44	.46	.48	.37	.38	.54	.32	.25	.25	.36
7	.46	.29	.44	.57	.68	.30	.47	.50	.43	.06	.08	.39
8	.40	.30	.50	.60	.52	.41	.35	.64	.60	.66	.07	.46
9	.47	.35	.58	.57	.52	.20	.50	.28	.38	.81	.51	.47
10	.31	.19	.58	.60	.77	.23	.33	.26	.17	1.21	1.43	.55
11	.90	.24	.69	.64	.37	.36	.54	.56	.40	.55	.61	.53
Weighted $\bar{F}$ 5-11	.29	.27	.44	.47	.58	.39	.41	.52	.41	.51	.35	.41

Table 16. Div. 4X haddock - calculation of projected 1975 catch.

Age	1973 Popn. no. ($x10^{-3}$)	1973 Catch no. ($x10^{-3}$)	1973 F	Mean wt.(kg.)	1974 Popn. no. ($x10^{-3}$)	1974 F	1974 Catch no. ($x10^{-3}$)	1974 Catch wt. (tons)	1975 Popn. no. ($x10^{-3}$)	1975 F	1975 catch no. ($x10^{-3}$)	1975 Catch wt. (tons)
2	70,000	3,054	.05	0.51	35,000	.02	628	320	1,500	.03	40	21
3	1,205	112	.11	0.75	54,516	.13	6,036	4,527	28,088	.18	4,206	3,155
4	19,617	2,232	.13	1.20	885	.26	184	221	39,192	.36	10,803	12,964
5	3,904	1,062	.35	1.76	14,046	.40	4,225	7,436	559	.50	201	354
6	1,902	528	.36	2.13	2,241	.40	674	1,436	7,709	.50	2,772	5,904
7	2,029	599	.39	2.43	1,082	.40	325	791	1,229	.50	442	1,075
8	958	323	.46	2.71	1,123	.40	337	916	593	.50	213	579
9	750	259	.47	2.65	494	.40	148	394	616	.50	221	588
10	1,578	618	.56	3.48	381	.40	114	400	271	.50	97	340
11+	143	55	.55	3.50	805	.40	242	849	651	.50	233	821
Totals.	102,086	8,842			110,578		12,918	17,291	80,413		19,232	25,799

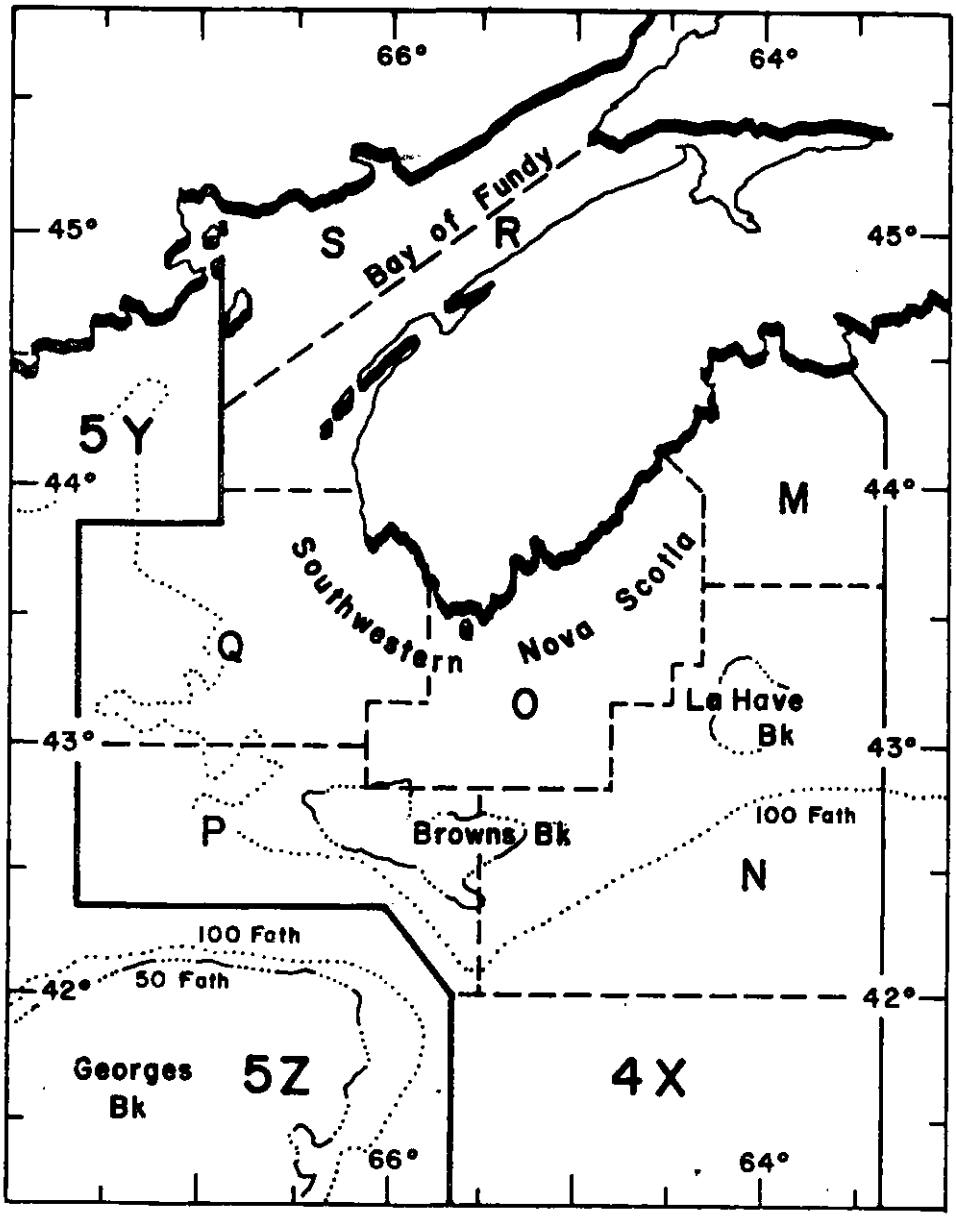

Fig. 1. Unit areas of ICNAF Div. 4X.