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Assessment of Haddock on Eastern Georges Bank

by

S. Gavaris and L. Van Eeckhaute
Marine Fish Division
Department of Fisheries and Oceans
Biological Station
St. Andrews, New Brunswick E0G 2X0

Abstract

Since 1977, only Canada and the USA have had haddock directed fisheries on Georges Bank. Since 1985, each country has been limited to fishing on their side of the international maritime boundary. Catches by Canada have exceeded those of the USA since 1985. The 1983 and 1985 year-classes have supported the fisheries in recent years. Catches in 1990 increased as the 1987 year-class became available. The sequential population analysis was calibrated with the three available surveys, Canadian spring and USA spring and fall. The analysis confirmed the strength of the 1983, 1985 and 1987 year-classes. There are indications that the 1989 and 1990 year-classes, while not as strong, are moderate. The biomass has recovered from the low levels of the early 1970s and mid 1980s but is projected to decrease in 1992 as the 1983, 1985, and 1987 year-classes pass through the fishery. The moderately strong 1989 and 1990 year-classes depart from the recent pattern of alternating strong and weak year-classes.

Résumé

Depuis 1977, seuls le Canada et les États-Unis pratiquent la pêche sélective de l'aiglefin sur le banc Georges et depuis 1985 chaque pays se limite à ses eaux maritimes internationales. Les prises canadiennes sont supérieures aux prises américaines depuis 1985. La pêche des dernières années repose sur les classes d'âge de 1983 et 1985. Les prises de 1990 ont augmenté suite au recrutement de la classe d'âge de 1987. L'analyse séquentielle de population a été étalonnée à l'aide des résultats des trois relevés disponibles: le relevé de printemps du Canada et les relevés de printemps et d'automne des États-Unis. L'analyse a permis de confirmer l'importance des classes d'âge de 1983, 1985 et 1987. Les classes d'âge de 1989 et 1990, bien que moins importantes, semblent cependant se situer dans la moyenne. La biomasse s'est rétablie des faibles niveaux du début des années 1970 et du milieu des années 1980, mais elle devrait diminuer en 1992 à mesure que les classes d'âge de 1983, 1985 et 1987 seront exploitées. Les classes modérément fortes de 1989 et 1990 s'écartent de la tendance à l'alternance entre les classes d'âge importantes et faibles que l'on avait notée au cours des dernières années.

Description of Fishery

The haddock (*Melanogrammus aeglefinus L.*) on Georges Bank have supported an important commercial fishery since the early 1920s, harvested primarily by the USA in those early years. Substantial quantities of haddock were caught after 1960 by both Canada and distant water fleets from other countries, mainly USSR and Spain. The fisheries of the USSR, Poland, Romania, and minor landings by some other countries were not targeted on haddock and employed small mesh gear. These are collectively referred to as the small mesh fishery. Since 1977, with the establishment of the 200 mile limit, only the USA and Canada have had directed haddock fisheries on Georges Bank. Nominal catches include estimates of discards by the USA fishery (Overholtz et. al. 1983). There are no data pertaining to discards in the Canadian fishery and they are assumed negligible for this analysis.

Since 1990, CAFSAC has considered haddock on eastern Georges Bank, unit areas 5Zj and 5Zm (Fig. 1), as a management unit (Gavaris and Van Eeckhaute 1990). Historical landings for Canada and the USA were available by unit area (Table 1, Fig. 2). The proportion of catch taken in unit areas 5Zj and 5Zm by the USA prior to 1985, when establishment of the international maritime boundary altered fishing patterns, was about 40%. As there are no data on discards by unit area it was assumed that in all years, 40% of USA discards and of the catch by foreign fisheries targeting on groundfish (eg. Spain) was from unit areas 5Zj and 5Zm.

For the small mesh fisheries, the proportion caught in unit areas 5Zj and 5Zm was determined through analysis of an atlas describing the USSR fishery distribution (Anon. 1971). The atlas contained monthly maps of the eastern seaboard which outlined areas fished by the USSR fleet from 1961 to 1968. Each area was keyed with fishing statistics including species composition. It was assumed that the haddock catch was uniformly distributed within each of these fishing areas. We partitioned ICNAF catch records by relating them directly to the proportion of the atlas fishing areas which lay within 5Zj and 5Zm on a monthly basis. For months when haddock was not reported in the atlas, fishing areas which did not indicate haddock were used. The catch proportioned in this way for the 8-year period indicated that roughly 40% of the haddock caught in Division 5Z was from unit areas 5Zj and 5Zm. Therefore, 40% of the small mesh fishery landings were allotted to 5Zj and 5Zm.

From 1951 to 1977 Georges Bank was managed by ICNAF. During this period the measures introduced included minimum mesh size, catch quotas and a spawning ground trawling closure (Halliday 1988). Quotas continued to be used by both Canada and the US after extension of jurisdiction in 1977 when the fishery came under the control of both countries. Since 1981 US management strategies

have abandoned quotas but included spawning area closures, mesh size regulations and minimum landed size. Although Canada has continued to use quotas since 1977, neither fishery was restricted by these until recently.

The Canadian quota for NAFO Subdivision 5Zc in 1987 and 1988 was set at 8,300 t. A combined cod-haddock-pollock quota was used for 4X-5Zc in 1989. The Canadian otter trawl fishery in that year was stopped after only a few weeks of activity when quota limits were reached. In 1990 the mobile gear sector <65 ft were required to use 130-mm square mesh gear. Trip limits, with a 30% by-catch of haddock to a maximum of 8 trips of 35,000 lbs per trip between June 1 and October 31 were permitted. Fixed gear were permitted to fish year round but were required to use large hooks until June. A similar plan is being proposed for 1991 with an increased square mesh size to 140 mm.

High catches were taken from unit areas 5Zj and 5Zm during the mid-1960s (roughly 60,000 t) when the exceptionally strong 1963 year-class was being exploited. Since then, catches declined to 2,352 t in 1976 before increasing to 25,036 t in 1980 as a result of good 1975 and 1978 year-classes. Catches subsequently declined and stabilized between 5,000 and 8,000 t during the mid to late 1980s. The decline in landings to 3,846 t in 1989 was due primarily to the early closure of the Canadian trawler fishery. The Canadian catch only increased by 224 t in 1990 however. Canadian boats were catching their trip limits when the trawler fishery first opened in June but availability declined quickly thereafter and trip limits were usually not caught. The USA catch in unit areas 5Zj and 5Zm dropped to a record low of 787 t in 1989 reflecting the absence of a directed commercial fishery. This increased to 1182 t in 1990.

It was reported that several Canadian boats fished Georges Bank illegally in February 1990 and these catches were not reported. In June fishermen had trouble avoiding haddock and some discarding due to the 30% by-catch limit of haddock was reported.

The Canadian fishery is generally active through the summer although, there have, on occasion, been significant landings in winter (Table 2). In part, this pattern has been a result of the seasonal spawning area closure to bottom trawling (Halliday 1988). The dominant gear in the Canadian fishery is the otter trawl. Longliners catch predominantly cod but their haddock catch is substantial (Table 3). Between 1977 and 1984, tonnage class 5 trawlers were a major component but in recent years tonnage classes 2 and 3 have increased in importance. Side trawlers were phased out during the late 1970s and early 1980s.

The USA catch was fairly evenly distributed over the year in the past, but since 1985 catches in late summer and fall have been

low (Table 4). Bottom trawling gained in popularity in the USA fishery during the 1920s (Clark et al. 1982) and in recent years virtually all of the catch was taken by otter trawlers (Table 5) of tonnage classes 3 and 4.

Catch and Weight at Age

The catch and weight at age for 1969 to 1989 were taken from Gavaris and Van Eeckhaute (1990). Estimates of discards by the USA fishery during the late 1970s and estimates of the small mesh fishery catch by foreign fleets during the 1960s were accounted for in those calculations along with the information from the USA and Canadian groundfish fisheries.

The Canadian commercial fishery landings in 1990 were sampled by the Department of Fisheries and Oceans, Canada. Length samples were weighted according to landed numbers, then pooled within month and gear type and applied to the respective landings. Monthly results for otter trawl were aggregated for the first half and for the third and fourth quarters of the year. Monthly results for longline were aggregated for the whole year but most of the landings were between June and August. The respective aggregated age-length keys were applied to obtain statistics by age. The length-weight relationship

$$\text{round weight(kg)} = 0.0000158\ \text{length(cm)}^{2.91612}$$

derived from Canadian fishery samples (Waiwood and Neilson 1985), was used in these calculations. Resulting catch and average weight at age are presented in Tables 6 and 7, respectively.

The USA commercial fishery landings in 1990 were sampled by National Marine Fisheries Service (NMFS), USA. Length samples were weighted according to sampled numbers, then pooled within month and market category and applied to the respective landings. This weighting is different than the treatment of Canadian samples but is consistent with the usual use of this information by the USA. Month/market category results were aggregated by quarter or half year incorporating landings from those months without samples. Since no ageing of commercial samples is being conducted by NMFS, the Canadian otter trawl age-length key for the first half of the year was applied to these results to obtain the catch composition and size at age (Table 8 and 9). Following Gavaris and Van Eeckhaute (1990), we employed the following length-weight relationships which were extracted from the information provided by NMFS:

Quarter 1 $\quad \text{round weight(kg)} = 0.0000186\ \text{length(cm)}^{2.852}$

Quarter 2 $\quad \text{round weight(kg)} = 0.0000217\ \text{length(cm)}^{1.790}$

The Canadian and USA catch composition and size at age were combined to obtain Tables 10 and 11.

In recent years the 1983, 1985, and 1987 year-classes have been dominant in the Canadian fishery. These year-classes were also prominent in the USA catch but to a lesser degree at age 2. Size at age has been stable in recent years in the catches of both countries.

Research Survey

Annual surveys of Georges Bank have been conducted by Canada during the spring of 1986-1991 and by the USA during the spring of 1968-1990 and fall, 1963-1990. USA spring surveys employed different trawl gear from 1973-1981 than during other years. A new type of otter trawl door was introduced to both spring and fall USA surveys in 1985. The impact of these gear changes on abundance estimates has not been determined. Both Canadian and USA surveys are based on a stratified random survey design though the stratification differs (Figs. 3-5).

Abundance indices were obtained by calculating the mean number per tow using sets occurring in the 5Zj and 5Zm portion of strata (strata 16 to 22 for USA surveys and 5Z1 to 5Z4 for Canadian surveys) and applying the mean to the area of the stratum lying within 5Zj and 5Zm. In some years, no sets were made in the 5Zj/5Zm portion of strata 20 and 22. The mean numbers per tow for the entire stratum and the 5Zj/5Zm means were compared over the available time series. No consistent differences were observed, therefore the stratum mean was used to fill in the missing observations. For stratum 18, zeroes were used for two years of missing observations since haddock were not typically found there. The age composition for the whole stratum was then extrapolated to the area of the stratum within 5Zj/5Zm.

The Canadian spring series was recalculated for 1987-1990 after an error was found in two of the stratum areas but shows the same trends as were seen previously.

Because of the way the USA survey age samples are taken there are often gaps in their age-length keys which results in unaged fish at some lengths. Such gaps were filled in by using known length-to-age relationships, data from previous and subsequent keys, adjacent proportions at age and consideration of year-class strengths. The 1990 USA spring survey was reanalyzed with the USA ageing which recently became available.

The strong 1983, 1985, and 1987 year-classes have been detected by all three surveys (Tables 12, 13 and 14). The Canadian spring survey shows relatively higher estimates of these year-classes than the USA spring survey, especially at age 3 in 1988. The USA fall 1987 estimates show consistently low values for all age groups when compared to the 1986 and 1988 fall surveys, suggesting that reduced catchability may have impacted the results of that survey. The 1987 year-class is again very well represented in the Canadian survey in 1991. Results from the two recent spring surveys indicate that it is larger than the 1983 and 1985 year-classes. This trend is less evident in the USA fall survey. The 1988 year-class appears weak in all three surveys while the 1989 and 1990 year-classes show promise of being at least of moderate strength.

Estimation of Stock Parameters

The ADAPT framework (Gavaris 1988) was used for the calibration of the sequential population analysis with the survey results. The approach taken differed from that of Gavaris and Van Eeckhaute (1990) in that survivors for all age groups in the terminal year were estimated explicitly. To implement this modification, survey results were not aggregated for ages 4 to 8 to form a plus group as has been past practice. The new formulation was considered preferable because it allowed explicit estimation of the important 1983 and 1985 year-classes. The spring surveys were compared to the beginning of year population numbers, while the fall survey was compared to the population numbers one age older for the respective year-class at the beginning of the subsequent year. The details of the model formulation are summarized below:

Parameters:

- Year-class estimates

$N_{a,1991}$ a = 1 to 8

- Calibration constants

$K1_a$	a = 0 to 3	for fall USA survey
$K2_a$	a = 1 to 4	for spring USA survey
$K3_a$	a = 1 to 4	for spring Canadian survey

Structure:

- natural mortality assumed equal to 0.2
- error in catch at age assumed negligible
- $K1_3$ to $K1_7$ assumed equal
- $K2_4$ to $K2_8$ assumed equal
- $K3_4$ to $K3_8$ assumed equal
- F on age group 8 calculated as

$$F_{8,y} = \left(\ln\left(\sum_{a=4}^{6} N_{a,y} / \left(\sum_{a=5}^{7} N_{a,y+1}\right)\right)\right) - M \qquad (1)$$

where a = index for age
y = index for year

- relationships between indices and population assumed to take the form

Index = K x Population

Input:

- $C_{a,t}$ a = 1 to 8, t = 1969 to 1990
- $RV1_{a,t}$ a = 0 to 7, t = 1968 to 1990
- $RV2_{a,t}$ a = 1 to 8, t = 1969 to 1990
- $RV3_{a,t}$ a = 1 to 8, t = 1986 to 1991

Objective function:

- minimize

$$\sum\sum \left(\text{obs.}(\ln RV1_{a,t}) - \text{pred.}(\ln RV1_{a,t})\right)^2 / MSR^2_{a,RV1}$$
$$\sum\sum \left(\text{obs.}(\ln RV2_{a,t}) - \text{pred.}(\ln RV2_{a,t})\right)^2 / MSR^2_{a,RV2}$$
$$\sum\sum \left(\text{obs.}(\ln RV3_{a,t}) - \text{pred.}(\ln RV3_{a,t})\right)^2 / MSR^2_{a,RV3}$$

where obs. RV $\neq 0$
and the scaled mean square residuals (MSR) are iteratively updated according to:

$$MSR'_{s,a} = \left(\sum_{y} e_{s,a,y}\right) / n_{s,a} - 1 \quad (\textit{see Judge et al.}\ 1980)$$

and scaled by:

$$MSR_{s,a} = MSR'_{s,a} = \left(\left(\sum_{s,a,y} 1/MSR'_{s,a}\right) / \sum_{s,a} n_{s,a}\right)$$

where e = observed residual
s = index for survey

Summary:

- number of observations = 360
- number of parameters = 20

- estimates

		mean	s.e./mean
1991 beginning of year population	age 1	6097	72%
	age 2	7132	47%
	age 3	189	25%
	age 4	10995	24%
	age 5	362	24%
	age 6	3133	23%
	age 7	225	27%
	age 8	745	30%
USA fall survey	age 1	1.00	30%
	age 2	2.51	33%
	age 3	1.79	24%
	age 4-8	1.30	10%
USA spring survey	age 1	1.07	30%
	age 2	2.78	20%
	age 3	3.78	19%
	age 4-8	4.42	9%
CAN spring survey	age 1	0.86	36%
	age 2	2.35	33%
	age 3	9.66	15%
	age 4-8	5.56	15%

A single calibration constant was estimated for ages 4-8. Initial trials with age specific calibration constants indicated that this simplification was reasonable. Following Gavaris and Van Eeckhaute (1990), all three survey indices were used employing a weighted analysis as indicated above. The value of n represents the length of the time series used. Generally, the degrees of freedom, the denominator, should be reduced to account for the estimation of parameters. The magnitude of the reduction of the degrees of freedom is difficult to determine for this problem. As a practical alternative, each was reduced by 1, to account for the estimation of the respective calibration constant. Since the MSR are scaled and their absolute value is of no importance, this approximation only has an impact where the length of the time series, n varies substantially. Plots of the residual analysis indicated an adequate fit of the data to the model (Fig. 6).

Assessment Results

The analysis confirmed that the 1983, 1985, and 1987 year-classes, while not as big as the 1975 and 1978 year-classes, were considerably better than the intervening year-classes (Table

15, Fig. 7). There are indications that the 1989 and 1990 year-classes are of moderate to good strength as well. The adult population biomass has recovered from the extremely low values it had reached during the early 1970s and again in the mid 1980s (Fig. 8). The recent increase in population abundance has been supported by the recruitment of the 1983, 1985, and 1987 year-classes while the fishing mortality rate has remained at about 0.3 through 1988 (Table 16, Fig. 9). The early closure of the Canadian trawler fishery in 1989 resulted in a reduction in the fishing mortality rate on older fish but was a major factor in conserving the 1987 year-class allowing it to realize some of its growth potential. The low exploitation for 1990 was interpreted as being due to reduced availability of haddock during the latter part of the fishing season.

Generally, the population is showing some recovery but production for Georges Bank as a whole continues to be low compared to pre 1960's observations (Clark et al. 1982). The low exploitation in recent years has resulted in a greater abundance of older haddock. As a consequence, the biomass has increased in 1990. Recruitment has fluctuated widely over the past 8 years but the indications for two consecutive year-classes, 1989 and 1990, of moderate strength are promising.

Prognosis

The adaptive framework (Gavaris, 1988) was used with a formulation which estimates a projected reference catch in 1992 for a given reference exploitation rate. The details of the model formulation which was used are given below:

Parameters:

- Projected reference catch

PRC_{1992}

- Catch biomass proportion at age

$p_{a,1992}$ a = 2 to 9

- Calibration constants

$K1_a$	a = 0 to 3	for fall USA survey
$K2_a$	a = 1 to 4	for spring USA survey
$K3_a$	a = 1 to 4	for spring Canadian survey

Structure:

- natural mortality assumed equal to 0.2

- error in catch at age assumed negligible
- $K1_3$ to $K1_7$ assumed equal
- $K2_4$ to $K2_8$ assumed equal
- $K3_4$ to $K3_8$ assumed equal
- F on age group 8 calculated as

$$F_{8,y} = (\ln(\sum_{a=4}^{6} N_{a,y}) / (\sum_{a=5}^{7} N_{a,y+1})) - M$$

where a = index for age
y = index for year

- relationships between indices and population assumed to take the form

Index = K x Population

- the 1990 weight at age and a partial recruitment of 0 at age 1, 0.5 at age 2 and full recruitment there after with a fully recruited reference F ($F_{0.1}$ = 0.25) were assumed to apply for the projected years 1991 and 1992:

Age	1	2	3	4	5	6	7	8	9
Weight	0.64	0.89	1.40	1.73	2.13	2.20	2.62	2.53	2.80
F	0.0	0.125	0.25	0.25	0.25	0.25	0.25	0.25	0.25

Input:

- $C_{a,t}$ a = 1 to 8, t = 1969 to 1990
- $RV1_{a,t}$ a = 0 to 7, t = 1968 to 1990
- $RV2_{a,t}$ a = 1 to 8, t = 1969 to 1990
- $RV3_{a,t}$ a = 1 to 8, t = 1986 to 1991

Objective function:

- minimize

$$\sum\sum (\text{obs.}(\ln RV1_{a,t}) - \text{pred.}(\ln RV1_{a,t}))^2 / MSR^2_{a,RV1}$$
$$\sum\sum (\text{obs.}(\ln RV2_{a,t}) - \text{pred.}(\ln RV2_{a,t}))^2 / MSR^2_{a,RV2}$$
$$\sum\sum (\text{obs.}(\ln RV3_{a,t}) - \text{pred.}(\ln RV3_{a,t}))^2 / MSR^2_{a,RV3}$$

where obs. RV $\neq$ 0
and the scaled mean square residuals (MSR) are iteratively updated according to:

$$MSR'_{s,a} = \left(\sum_{y} e_{s,a,y}\right) / n_{s,a} - 1 \quad \textit{(see Judge et al. 1980)}$$

and scaled by:

$$MSR_{s,a} = MSR'_{s,a} = \left(\left(\sum_{s,a,y} 1/MSR'_{s,a} \right) / \sum_{s,a} n_{s,a} \right)$$

where e = observed residual
s = index for survey

Summary:

- number of observations = 360
- number of parameters = 20

The estimated projected reference catch in 1992 at $F_{0.1}$ = 0.25 was about 6,250 t. The expected catch in 1991 of about 6,000 t (5,000 t Canadian quota and about 1,000 t USA catch) will also result in an exploitation rate approximating $F_{0.1}$. The results from the projection show that greater numbers of older fish are expected to survive through 1992 than has been observed in the recent past. However, as the relatively strong 1983, 1985, and 1987 year-classes pass through the fishery biomass will decline during 1992 and 1993.

The estimated relative error for the $F_{0.1}$ reference catch was approximately 20%. If the errors on the abundance indices can be assumed to be lognormal, then the estimate of the projected reference catch would be approximately normally distributed. The estimate of precision is conditional on the assumptions of the model and therefore is most usefully considered as a minimal estimate of the variance. The most likely model violations which could substantively bias this estimate of precision are errors in the catch at age and deviation from a constant natural mortality.

It is expected that the USA catch in 1992 will be about 1,000 t. Given the uncertainty in the estimate of the projected reference catch and in recognition of the declining trend in the biomass, a Canadian catch in 1992 of about 5,000 t, the Canadian quota for 1991, in addition to the expected USA catch would approximate an $F_{0.1}$ exploitation rate.

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Table 1. Nominal catches (t) of haddock from unit areas 5Zj and 5Zm from 1969-90. For "others" it was assumed that 40% of the catch was in 5Zj and 5Zm.

Year	Canada	USA	Others	Total
1969	3941	6622	695	11258
1970	1970	3153	357	5480
1971	1610	3534	770	5914
1972	609	1551	502	2662
1973	1565	1396	396	3357
1974	462	955	573	2750*
1975	1353	1705	29	3087
1976	1355	973	24	2352
1977	2871	2429	0	9174*
1978	9968	4724	0	16269*
1979	5080	5211	0	10291
1980	10017	5615	0	25036*
1981	5658	9077	0	14735
1982	4872	6280	0	11152
1983	3208	4454	0	7662
1984	1463	5121	0	6583
1985	3484	1683	0	5167
1986	3415	2200	0	5615
1987	4703	1418	0	6111
1988	4046**	1693	0	5739
1989	3059	787	0	3846
1990	3283	1182	0	4465

* Values augmented by 760, 3874, 1577, and 9404 in 1974, 1977, 1978, and 1980, respectively, to account for USA discards.

** 1895 T excluded because of suspected misreporting.

Table 2. Monthly catch (t) of haddock by Canada in unit areas 5Zj and 5Zm for 1969-1990.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Totals
1969	105	74	6	291	588	691	559	580	551	360	102	34	3941
1970	2	105	0	1	574	345	103	456	242	103	26	12	1970
1971	0	9	1	0	400	132	283	278	97	246	141	21	1610
1972	0	119	2	0	2	111	84	116	98	68	7	2	609
1973	4	10	0	0	0	184	198	572	339	232	22	4	1565
1974	19	0	1	0	0	58	63	53	96	61	92	19	462
1975	4	14	0	0	0	166	256	482	100	166	118	45	1353
1976	0	7	62	68	60	587	152	190	186	26	9	7	1355
1977	102	177	7	0	23	519	1059	835	13	59	56	22	2871
1978	104	932	44	22	21	319	405	85	642	5433	1962	0	9968
1979	123	898	400	175	69	1393	885	396	406	261	53	22	5080
1980	38	134	14	29	223	2956	2300	965	1411	1668	104	176	10017
1981	38	481	568	4	254	1357	1241	726	292	82	378	239	5658
1982	129	309	1	11	46	1060	769	682	585	837	398	44	4872
1983	32	67	29	47	60	1288	387	483	526	195	88	6	3208
1984	3	5	81	88	73	433	219	254	211	71	25	0	1463
1985	1	11	33	99	26	354	392	1103	718	594	61	93	3484
1986	11	28	79	99	40	1339	1059	369	233	139	12	8	3415
1987	24	26	138	70	12	1762	1383	665	405	107	97	14	4703
1988*	39	123	67	79	15	1816	1360	315	130	65	13	24	4046
1989**	32	94	48	7	20	1398	356	566	141	272	108	18	3059
1990	35	11	50	0	7	1176	654	666	467	188	12	16	3283

* Catches of 3, 1846 and 46 T for Jan., Feb., and Mar., respectively for otter trawlers were excluded because of suspected misreporting.

** Early closure of fishery for otter trawlers in June (per. comm. P. Partington).

Table 3. Canadian catch (t) of haddock in unit areas 5Zj and 5Zm by gear and otter trawl tonnage class 2 to 5 from 1969 to 1990.

	OTTER TRAWL SIDE				OTTER TRAWL STERN					LL	MISC	TOTAL
Year	2	3	4	Total	2	3	4	5	Total			
1969	1	7	769	777	0	1	225	2902	3127	23	15	3941
1970	0	24	551	575	2	0	133	1179	1314	78	2	1970
1971	0	0	495	501	0	0	16	939	955	151	3	1610
1972	0	2	146	148	0	0	2	260	263	195	3	609
1973	0	25	608	633	0	0	60	766	826	105	0	1565
1974	0	0	27	27	0	6	8	332	346	88	1	462
1975	0	1	221	222	0	1	60	963	1024	107	0	1353
1976	0	2	193	217	0	2	59	905	967	156	15	1355
1977	5	46	319	370	92	243	18	2025	2378	94	28	2871
1978	70	134	2252	2456	237	812	351	5639	7039	169	305	9968
1979	13	190	1419	1622	136	858	627	1564	3185	271	2	5080
1980	9	15	1419	1444	354	359	950	6254	7917	587	69	10017
1981	4	87	387	478	448	629	737	2344	4159	1019	2	5658
1982	1	25	89	115	189	318	187	3341	4045	712	0	4872
1983	17	89	0	106	615	431	107	1130	2283	815	4	3208
1984	0	5	0	5	180	269	21	149	620	835	3	1463
1985	0	72	0	72	840	1401	155	348	2745	626	41	3484
1986	4	48	0	51	829	1378	95	432	2734	594	35	3415
1987	6	41	0	48	782	1448	49	1241	3521	1046	89	4703
1988*	0	41	31	72	1091	1456	186	398	3183	695	97	4046
1989	0	0	0	0	489	573	376	536	1976	977	106	3059
1990	0	0	0	0	915	873	93	471	2358	850	76	3283

* Catches of 26, 776, 1091 and 2 T for side otter trawlers class 3 and stern otter trawlers classes 2, 3 and 5 respectively were exluded because of suspected misreporting.

Table 4. Monthly catch (t) of haddock by USA in unit areas 5Zj and 5Zm for 1969-1990.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1969	525	559	976	1825	670	809	204	219	249	226	203	157	6622
1970	169	219	242	375	608	374	324	333	179	219	61	50	3153
1971	155	361	436	483	668	503	338	152	147	165	58	68	3534
1972	150	196	91	90	239	261	97	164	84	63	52	64	1551
1973	90	111	77	85	138	365	217	196	37	3	22	55	1396
1974	135	70	47	70	122	160	165	43	27	6	19	91	955
1975	152	123	32	116	388	489	138	95	57	24	52	39	1705
1976	116	147	83	106	323	162	7	6	5	2	3	13	973
1977	75	211	121	154	374	372	434	191	73	52	146	226	2429
1978	336	437	263	584	752	750	467	221	245	426	194	49	4724
1979	274	329	352	548	766	816	588	659	224	202	281	172	5211
1980	632	1063	742	784	711	461	324	254	221	91	110	222	5615
1981	550	1850	634	627	882	1326	1233	873	321	284	242	255	9077
1982	425	754	502	347	718	1801	757	145	201	216	276	138	6280
1983	492	931	272	181	310	1145	231	178	187	110	227	190	4454
1984	540	961	366	281	627	1047	370	302	250	196	92	89	5121
1985	165	190	254	300	352	206	60	47	1	24	41	43	1683
1986	184	396	334	479	496	221	31	6	12	6	6	29	2200
1987	225	52	43	307	233	342	67	30	24	4	23	68	1418
1988	196	152	207	245	366	316	30	19	6	1	45	110	1693
1989	114	56	47	164	161	145	15	8	1	5	25	46	787
1990	147	21	155	272	213	306	23	3	5	5	12	19	1182

Table 5. USA catch (t) of haddock in unit areas 5Zj and 5Zm by gear category and otter trawl class for 1969 to 1990.

	Otter Trawl					
Year	Class 3	Class 4	Total	LL	Misc.	Total
1969	3010	3610	6621	0	0	6621
1970	1602	1551	3154	0	0	3154
1971	1760	1768	3533	0	0	3533
1972	861	690	1551	0	0	1551
1973	637	759	1396	0	0	1396
1974	443	512	955	0	0	955
1975	993	675	1668	0	36	1705
1976	671	302	972	0	2	974
1977	1721	700	2423	0	5	2428
1978	3140	1573	4713	0	11	4725
1979	3281	1927	5208	0	4	5212
1980	3654	2955	5611	0	4	5615
1981	3591	5408	9031	0	45	9075
1982	2585	3657	6242	11	26	6279
1983	1162	3261	4423	11	18	4453
1984	1854	3260	5115	2	3	5120
1985	856	823	1679	0	4	1683
1986	985	1207	2192	0	9	2201
1987	778	639	1417	0	1	1418
1988	920	768	1688	0	6	1694
1989	359	419	780	0	6	785
1990	486	688	1178	0	4	1182

Table 6. Canadian commercial catch (numbers 000's) at age of haddock from unit areas 5Zj and 5Zm.

Year	Age Groups 1	2	3	4	5	6	7	8	9+	0-9+
1969	0	7	558	101	105	963	275	28	89	2127
1970	4	35	3	129	57	46	410	131	60	875
1971	0	491	71	6	67	41	33	173	84	968
1972	90	0	88	19	5	16	6	3	85	312
1973	107	829	1	188	15	3	18	3	49	1213
1974	0	240	66	0	10	1	0	9	16	341
1975	0	117	620	91	2	16	0	1	14	863
1976	53	119	120	391	57	0	7	0	10	757
1977	0	2398	34	63	94	46	0	3	1	2639
1978	1	250	5865	97	55	98	35	1	2	6404
1979	0	14	99	2196	136	70	56	11	2	2585
1980	2	8608	305	130	668	58	15	11	5	9802
1981	0	243	2279	140	275	390	38	3	18	3386
1982	0	313	469	1400	93	106	195	9	5	2590
1983	0	161	359	258	679	76	34	89	4	1660
1984	0	12	38	63	52	172	61	33	104	535
1985	0	2022	305	114	89	55	87	22	62	2755
1986	6	38	1701	86	70	52	29	40	21	2042
1987	0	1986	90	1088	59	32	30	28	68	3381
1988	4	51	1878	81	390	53	7	16	86	2566
1989	0	1132	68	623	64	202	13	8	37	2146
1990	2	7	1062	43	505	13	120	23	33	1808

Table 7. Average weight (kg) at age of haddock from the Canadian commercial fishery in unit areas 5Zj and 5Zm.

Year	Age Groups 1	2	3	4	5	6	7	8
1969	-	0.766	1.324	1.513	1.679	1.887	2.364	2.807
1970	0.721	1.062	0.812	1.653	1.905	2.137	2.201	2.855
1971	-	0.950	1.147	1.284	2.141	2.346	2.274	2.684
1972	0.759	-	1.703	1.820	2.209	2.624	2.469	2.792
1973	0.683	1.054	1.367	1.789	2.296	1.760	3.003	3.097
1974	-	1.025	1.449	-	1.995	3.760	-	3.145
1975	-	0.868	1.544	2.096	1.997	2.425	4.114	3.557
1976	0.596	0.996	1.351	2.076	2.808	-	3.251	-
1977	-	0.964	1.466	1.871	2.500	3.035	-	3.502
1978	0.619	1.168	1.505	2.186	3.100	3.290	3.188	3.364
1979	-	1.024	1.364	1.891	2.387	2.920	3.353	3.383
1980	0.405	0.888	1.032	1.792	2.294	2.593	3.948	3.803
1981	-	0.915	1.391	1.721	2.383	2.822	3.698	5.013
1982	-	1.056	1.556	1.915	2.348	2.801	2.909	3.414
1983	-	1.031	1.401	1.822	2.200	2.543	2.821	3.007
1984	-	0.883	1.401	2.010	2.257	2.770	2.918	3.326
1985	-	0.948	1.264	2.068	2.169	2.942	3.289	3.238
1986	0.452	0.981	1.458	2.104	2.913	2.899	3.646	4.248
1987	-	0.832	1.391	2.073	2.253	2.598	2.906	3.623
1988	0.421	0.974	1.315	1.787	2.234	2.264	2.978	3.036
1989	-	0.861	1.449	1.789	2.215	2.604	2.795	3.014
1990	0.635	0.960	1.443	1.764	2.228	2.498	2.750	2.553

Table 8. USA commercial catch (numbers 000's) at age of haddock from unit areas 5Zj and 5Zm.

Year	Age Groups 1	2	3	4	5	6	7	8	9+	0-9+
1969	0	10	818	145	207	1739	489	53	175	3636
1970	9	42	4	199	82	71	657	212	111	1387
1971	0	566	155	23	150	102	112	462	269	1837
1972	125	0	235	42	13	55	27	8	248	754
1973	42	662	5	155	20	6	17	5	104	1015
1974	0	552	133	0	20	2	0	18	33	757
1975	0	65	784	144	4	29	1	2	24	1053
1976	0	28	53	421	62	0	9	0	11	584
1977	0	1307	30	115	211	117	0	12	13	1806
1978	0	39	2770	63	115	201	46	9	7	3249
1979	0	8	103	2207	189	112	138	28	11	2795
1980	0	911	46	175	1722	134	113	41	7	3149
1981	0	419	4313	244	310	830	84	27	6	6234
1982	0	401	579	1409	103	273	529	53	60	3406
1983	0	44	223	254	973	146	74	324	28	2065
1984	0	67	214	285	204	890	135	127	227	2149
1985	0	41	70	62	101	68	284	30	52	708
1986	0	0	856	87	72	71	89	133	19	1327
1987	0	5	37	427	37	24	52	40	40	661
1988	0	0	267	40	487	56	29	30	12	921
1989	0	14	8	151	27	98	11	9	42	361
1990	0	4	244	11	209	14	96	12	53	643

Table 9. Average weight (kg) at age of haddock from the USA commercial fishery in unit areas 5Zj and 5Zm.

Year	Age Groups 1	2	3	4	5	6	7	8
1969	-	0.760	1.253	1.543	1.633	1.807	2.261	2.918
1970	0.721	1.071	0.813	1.653	1.873	2.116	2.198	2.833
1971	-	0.909	1.018	1.269	1.952	2.218	2.258	2.586
1972	0.759	-	1.509	1.719	2.125	2.470	2.397	2.414
1973	0.683	0.937	1.367	1.823	2.133	1.573	2.758	3.398
1974	-	0.946	1.402	-	1.979	3.760	-	3.120
1975	-	0.878	1.508	2.041	1.997	2.420	4.114	3.557
1976	-	0.785	1.163	1.654	2.057	-	2.293	-
1977	-	0.981	1.414	1.776	2.264	2.720	-	3.007
1978	-	1.043	1.280	1.852	2.397	2.737	2.808	2.745
1979	-	0.920	1.235	1.719	2.076	2.735	3.164	3.233
1980	-	0.929	1.050	1.640	2.045	2.593	3.481	3.553
1981	-	0.876	1.194	1.518	2.170	2.511	3.418	3.882
1982	-	0.894	1.207	1.657	2.308	2.463	2.976	3.551
1983	-	1.001	1.245	1.678	2.061	2.491	2.906	3.130
1984	-	0.875	1.345	1.801	2.134	2.573	2.828	3.084
1985	-	1.049	1.081	1.635	2.278	2.509	2.745	3.138
1986	-	-	1.142	1.630	1.830	2.576	2.749	3.367
1987	-	1.118	1.529	1.758	1.978	2.588	2.980	3.661
1988	-	1.160	1.239	1.546	1.888	2.431	3.019	3.449
1989	-	1.188	1.577	1.741	2.056	2.370	2.362	3.365
1990	-	0.761	1.191	1.614	1.906	1.930	2.467	2.478

Table 10. Total(1) commercial catch (numbers 000's) at age of haddock from unit areas 5Zj and 5Zm.

Year	Age Groups 1	2	3	4	5	6	7	8
1969	0	19	1449	262	333	2881	816	88
1970	25	83	7	350	148	127	1140	366
1971	0	1219	261	32	249	163	166	748
1972	281	1	398	75	22	87	42	13
1973	1015	1728	7	360	37	10	37	8
1974	17	2080(2)	272	0	40	3	0	35
1975	0	184	1418	237	6	46	1	3
1976	67	148	175	818	121	0	16	0
1977	0	7623(2)	65	178	305	163	0	15
1978	1	289	9832(2)	160	169	299	81	10
1979	0	22	202	4403	325	182	195	39
1980	2	9519	351	305	2391	192	128	52
1981	0	661	6593	384	585	1220	121	31
1982	0	714	1048	2809	196	379	724	62
1983	0	205	582	512	1652	221	108	413
1984	0	79	252	348	256	1062	196	160
1985	0	2063	374	176	189	123	371	53
1986	6	38	2557	173	142	122	118	173
1987	0	1990	127	1515	96	56	82	68
1988	4	51	2145	121	877	109	36	46
1989	0	1146	76	774	91	300	24	16
1990	2	10	1306	54	713	27	215	34

(1) Total catch includes small mesh foreign fishery.
(2) Includes discard estimates based on trip interviews.

Table 11. Average weight (kg) at age of haddock from the commercial fishery in unit areas 5Zj and 5Zm.

Year	Age Groups 1	2	3	4	5	6	7	8
1969	-	0.763	1.282	1.531	1.649	1.836	2.298	2.879
1970	0.721	1.067	0.812	1.653	1.886	2.124	2.199	2.841
1971	-	0.928	1.059	1.272	2.011	2.255	2.262	2.613
1972	0.759	-	1.562	1.750	2.147	2.505	2.411	2.514
1973	0.683	1.002	1.367	1.804	2.202	1.631	2.885	3.295
1974	-	0.970	1.418	-	1.984	3.760	-	3.128
1975	-	0.872	1.524	2.062	1.997	2.422	4.114	3.557
1976	0.596	0.956	1.293	1.857	2.417	-	2.702	-
1977	-	0.970	1.442	1.809	2.337	2.809	-	3.095
1978	0.619	1.151	1.433	2.055	2.623	2.919	2.972	2.829
1979	-	0.987	1.298	1.805	2.206	2.806	3.219	3.277
1980	0.405	0.892	1.034	1.705	2.115	2.593	3.535	3.608
1981	-	0.890	1.262	1.592	2.270	2.611	3.505	4.009
1982	-	0.965	1.363	1.786	2.327	2.557	2.958	3.531
1983	-	1.024	1.341	1.750	2.118	2.509	2.879	3.104
1984	-	0.876	1.354	1.838	2.159	2.605	2.856	3.134
1985	-	0.950	1.230	1.915	2.227	2.702	2.872	3.180
1986	0.452	0.981	1.352	1.866	2.367	2.712	2.969	3.570
1987	-	0.833	1.431	1.984	2.148	2.594	2.953	3.646
1988	0.421	0.974	1.305	1.708	2.042	2.350	3.011	3.305
1989	-	0.865	1.463	1.780	2.167	2.528	2.591	3.199
1990	0.635	0.890	1.396	1.734	2.134	2.202	2.624	2.527

Table 12. Total estimated abundance (numbers in 000's) at age of haddock from unit areas 5Zj and 5zZm from the Canadian spring surveys.

Year	Age Group 1	2	3	4	5	6	7	8	9+	1-9+
1986	5057	306	8175	997	189	348	305	425	401	16205
1987	46	4286	929	3450	653	81	387	135	1132	11099
1988	971	49	12714	257	4345	274	244	130	686	19670
1989	47	6473	959	2814	241	523	40	36	259	11391
1990	726	108	12302	166	4465	299	1370	144	389	19968
1991	400	2175	137	10776	115	1868	117	497	220	16306

Table 13. Total estimated abundance (numbers in 000's) at age of haddock in unit areas 5Zj and 5Zm from the spring USA surveys. From 1973-81 a 41 Yankee trawl was used while a 36 Yankee was used in other years.

Year	Age Group 1	2	3	4	5	6	7	8	9+	1-9+
1968	0	2184	45	456	3257	1373	161	83	157	7715
1969	12	23	412	158	351	2169	819	240	328	4513
1970	321	128	0	376	670	296	2127	1683	523	6123
1971	0	440	175	0	97	68	39	778	182	1778
1972	1741	0	517	88	17	32	142	18	815	3369
1973	1648	3785	0	692	103	0	185	0	810	7224
1974	888	13823	2741	0	238	0	29	48	216	17983
1975	355	381	4038	714	0	146	85	30	140	5888
1976	5556	270	291	825	391	0	0	0	26	7359
1977	93	17397	198	574	548	393	0	15	66	19282
1978	0	499	14000	430	591	781	60	16	78	16454
1979	7044	296	881	6553	319	48	299	28	6	15474
1980	2929	45611	757	750	3907	421	256	473	246	55350
1981	2942	2489	22667	2363	589	1955	274	47	18	33343
1982	478	3026	1349	6338	610	366	547	0	0	12714
1983	159	517	460	241	1739	20	0	536	39	3711
1984	917	950	669	672	628	836	92	60	315	5138
1985	40	8911	1396	674	1496	588	1995	127	483	15709
1986	3334	280	3597	246	210	333	235	560	159	8953
1987	122	5480	144	1394	157	231	116	370	0	8013
1988	305	61	1868	235	611	203	218	178	0	3678
1989	102	8128	754	1638	326	965	71	112	58	12154
1990	2017	86	12608	729	1271	134	222	0	0	17067

Table 14. Total estimated abundance (numbers in 000's) at age of haddock in unit areas 5Zj and 5Zm from the fall USA survey.

Year	Age Groups 0	1	2	3	4	5	6	7	8	9+	0-9+
1963	71450	33469	9931	3389	5088	4142	1544	402	58	125	129599
1964	790	77101	37410	4113	655	1634	337	188	96	16	122340
1965	174	1015	34578	5611	328	201	99	111	95	50	42263
1966	6258	504	1169	13640	2437	450	93	89	11	45	24696
1967	0	2683	49	220	1238	453	94	59	28	31	4854
1968	37	76	537	19	25	1492	367	119	30	180	2881
1969	257	0	0	349	43	20	505	308	22	55	1559
1970	0	4295	225	11	278	226	335	606	256	132	6365
1971	1762	0	529	65	0	178	18	49	275	124	3001
1972	3186	1608	0	155	0	0	36	0	0	185	5169
1973	902	11273	1078	0	121	1	0	11	2	77	13465
1974	102	157	645	113	0	4	0	0	0	47	1067
1975	20379	446	129	683	149	0	0	0	0	17	21803
1976	526	89008	306	17	325	48	0	12	0	25	90266
1977	38	195	21545	364	102	173	69	3	3	0	22491
1978	11984	448	433	6307	46	34	77	0	0	0	19330
1979	1288	17283	12	268	1196	36	10	0	0	0	20092
1980	2931	2306	4810	0	83	888	89	21	3	0	11130
1981	504	3779	2115	2252	86	112	243	0	0	12	9103
1982	42	0	449	309	1729	107	61	315	19	9	3038
1983	2422	298	217	292	190	266	13	6	53	0	3757
1984	30	2583	524	148	141	29	170	0	0	32	3658
1985	12148	381	1646	199	70	68	46	30	0	21	14611
1986	30	7471	109	961	52	50	72	24	5	18	8793
1987	508	4	839	28	152	38	22	0	0	0	1592
1988	122	3983	206	2326	155	400	142	140	0	38	7513
1989	204	101	3225	137	620	83	89	0	0	0	4459
1990	1485	1263	30	1798	110	210	26	6	0	0	4927

Table 15. Estimated population numbers (000's) at the beginning of the year for haddock in unit areas 5Zj and 5Zm.

Year	Age group 1	2	3	4	5	6	7	8
1969	797	197	3643	878	924	8267	2756	253
1970	3643	653	144	1672	482	455	4162	1518
1971	257	2960	459	111	1052	260	258	2376
1972	5177	210	1320	140	63	636	65	61
1973	11140	3984	172	721	47	32	442	16
1974	2838	8202	1698	134	264	5	17	328
1975	3350	2308	4833	1144	110	180	2	14
1976	53339	2743	1724	2674	722	85	106	0
1977	6402	43609	2112	1253	1449	482	69	72
1978	4267	5241	28807	1671	864	910	247	57
1979	41312	3493	4030	14689	1223	554	474	129
1980	6148	33823	2840	3117	8042	707	289	212
1981	4470	5031	19079	2008	2276	4421	405	121
1982	2186	3660	3521	9655	1296	1334	2516	222
1983	2668	1790	2350	1935	5363	883	749	1405
1984	16919	2184	1280	1397	1121	2896	523	516
1985	1557	13853	1717	820	830	686	1411	251
1986	18059	1274	9475	1067	512	508	450	819
1987	1109	14780	1009	5444	717	291	305	262
1988	23738	908	10300	712	3086	500	188	176
1989	295	19431	697	6492	474	1733	311	121
1990	8713	242	14873	502	4615	305	1148	232
1991	6097	7132	189	10995	362	3133	225	745

Table 16. Estimated fishing mortality rate for haddock in unit areas 5Zj and 5Zm.

Year	Age Group 1	2	3	4	5	6	7	8
1969		0.11	0.58	0.40	0.51	0.49	0.40	0.49
1970	0.01		0.06	0.26	0.42	0.37	0.36	0.31
1971		0.61		0.38	0.30	1.18	1.25	0.43
1972	0.06		0.40		0.48	0.16	1.24	0.28
1973	0.11	0.65		0.80		0.42	0.10	0.85
1974	0.01	0.33	0.19		0.18		0.00	0.13
1975	0.00	0.09	0.39	0.26		0.33		0.25
1976	0.00	0.06	0.12	0.41	0.20		0.19	
1977	0.00	0.21	0.03	0.17	0.27	0.47		0.26
1978	0.00	0.06	0.47	0.11	0.24	0.45	0.45	
1979	0.00	0.01	0.06	0.40	0.35	0.45	0.60	0.40
1980	0.00	0.37	0.15	0.11	0.40	0.36	0.67	0.32
1981	0.00	0.16	0.48	0.24	0.33	0.36	0.40	0.33
1982	0.00	0.24	0.40	0.39	0.18	0.38	0.38	0.37
1983	0.00	0.14	0.32	0.35	0.42	0.32	0.17	0.39
1984	0.00	0.04	0.25	0.32	0.29	0.52	0.53	0.42
1985	0.00	0.18	0.28	0.27	0.29	0.22	0.34	0.26
1986	0.00	0.03	0.35	0.20	0.37	0.31	0.34	0.27
1987	0.00	0.16	0.15	0.37	0.16	0.24	0.35	0.34
1988	0.00	0.06	0.26	0.21	0.38	0.28	0.24	0.34
1989	0.00	0.07	0.13	0.14	0.24	0.21	0.09	0.16
1990	0.00	0.05	0.10	0.13	0.19	0.10	0.23	0.18

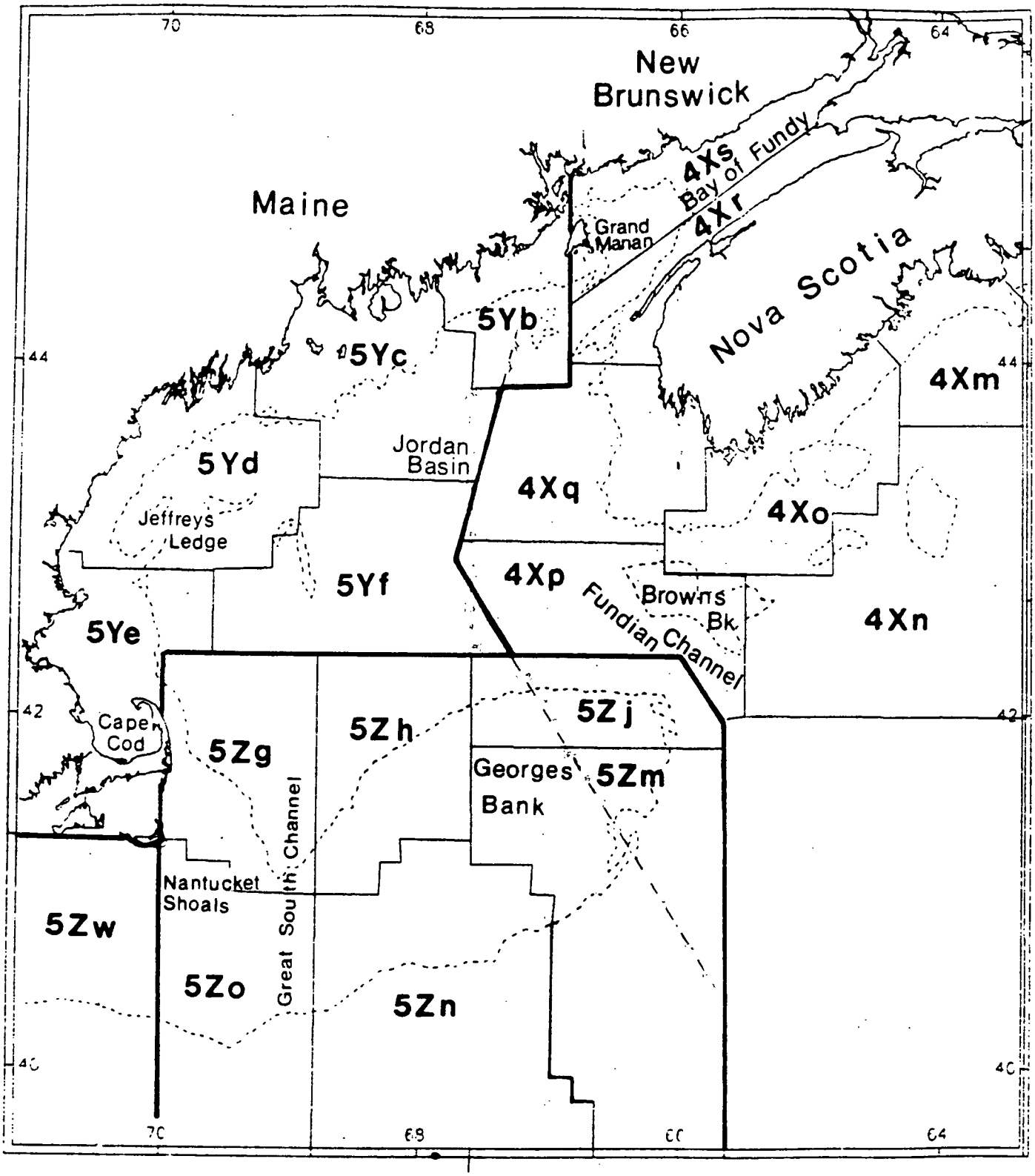

Fig. 1. Map of the Gulf of Maine area showing unit areas.

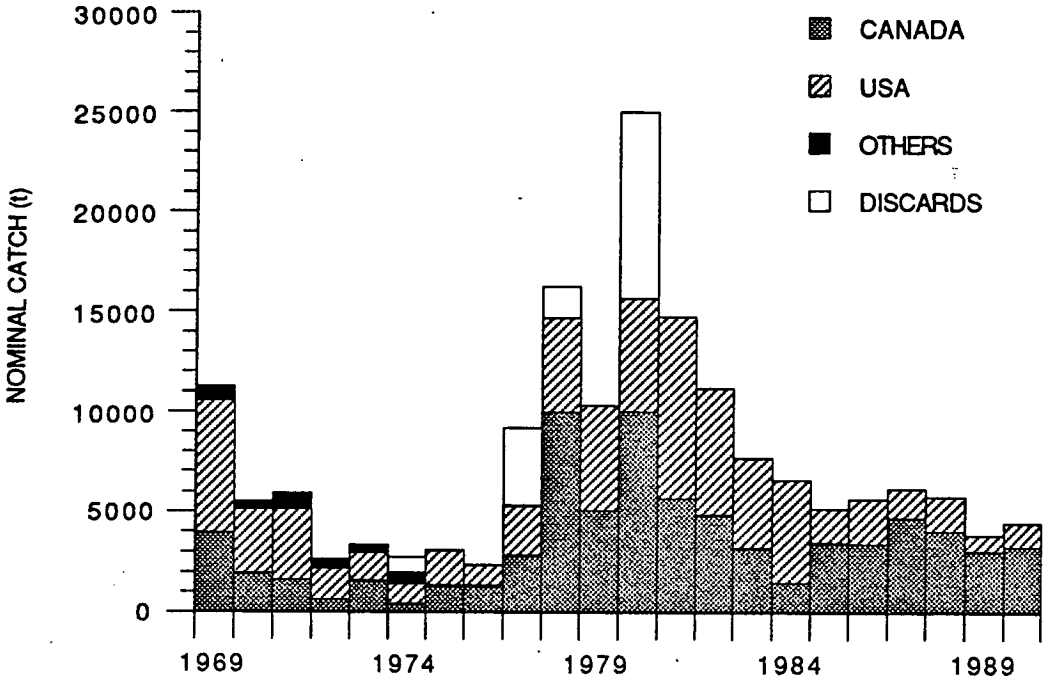

Fig. 2. Nominal catch of haddock in unit areas 5Zj and 5Zm.

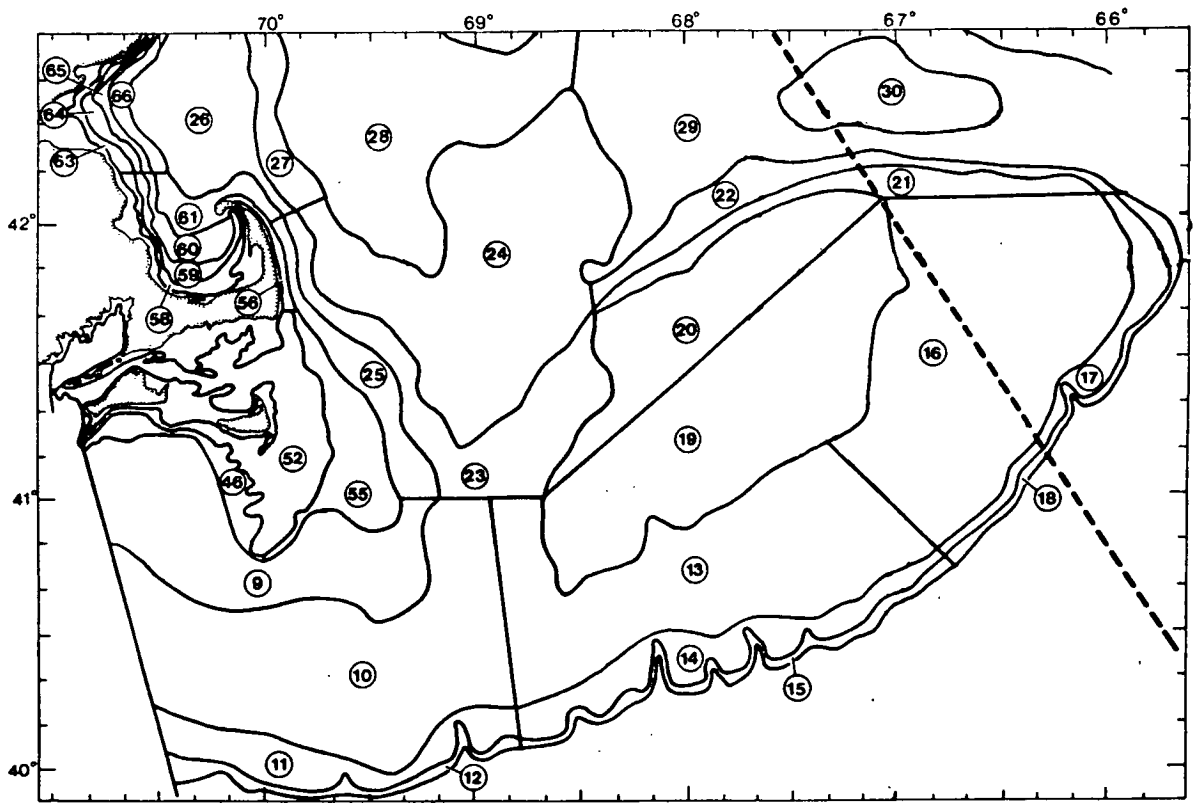

Fig. 3. Stratification scheme used for USA surveys.

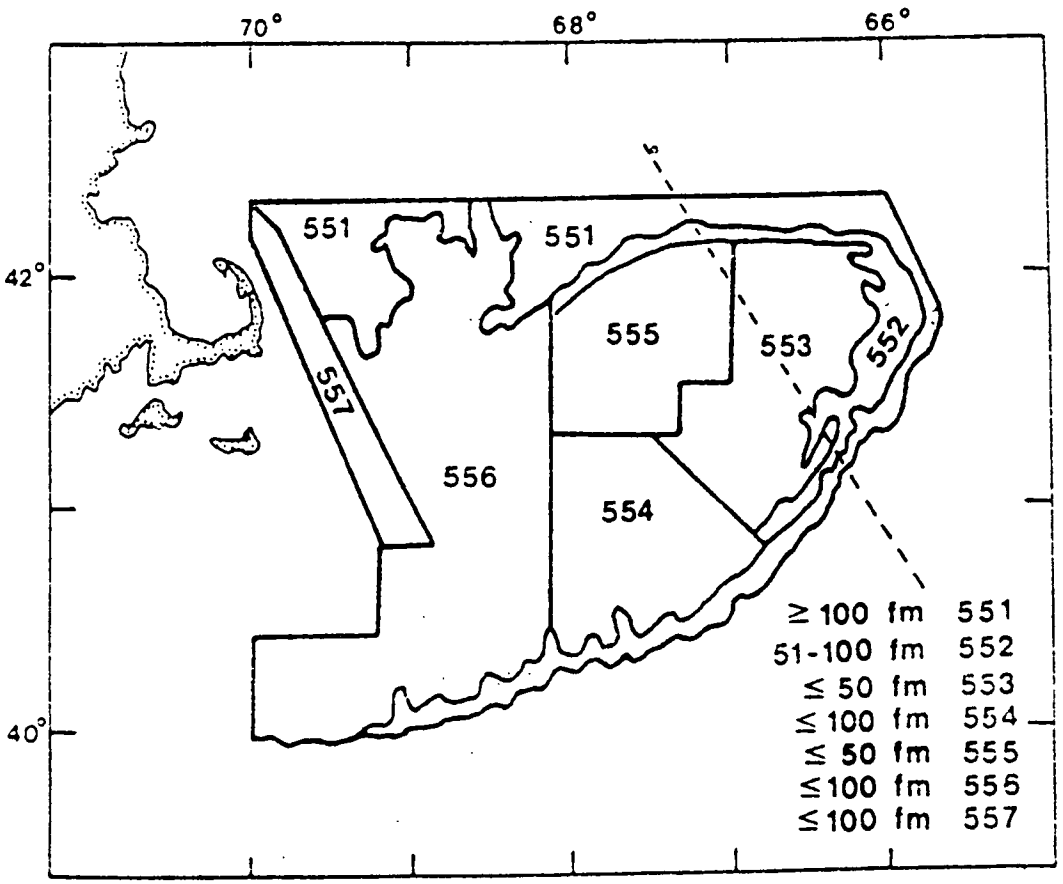

Fig. 4. Stratification scheme used for 1986 spring survey.

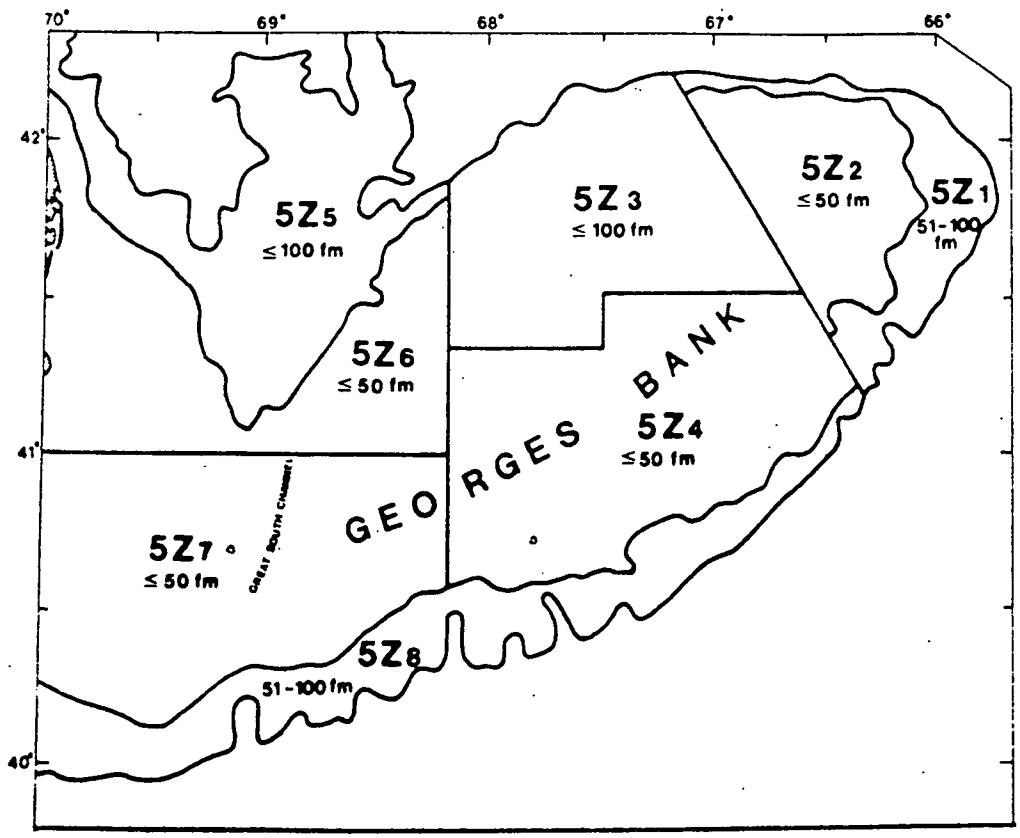

Fig. 5. Stratification scheme used for Canadian spring surveys since 1987.

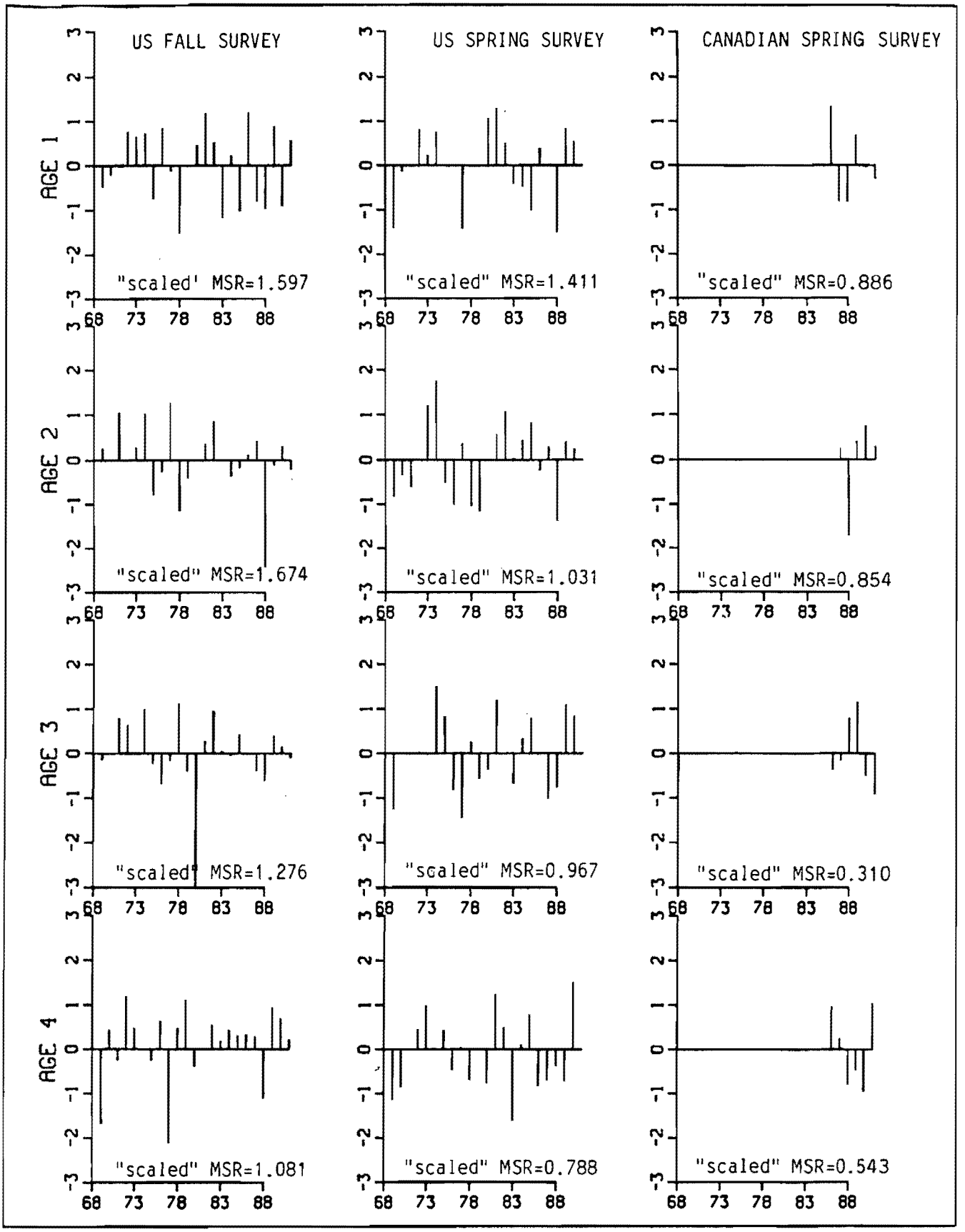

Figure 6. Weighted residuals from the calibration of the sequential population analysis for haddock in unit areas 5Zj and 5Zm are plotted by age group for each survey. The "scaled" MSR for each series is inversely proportional to the weight that series was given.

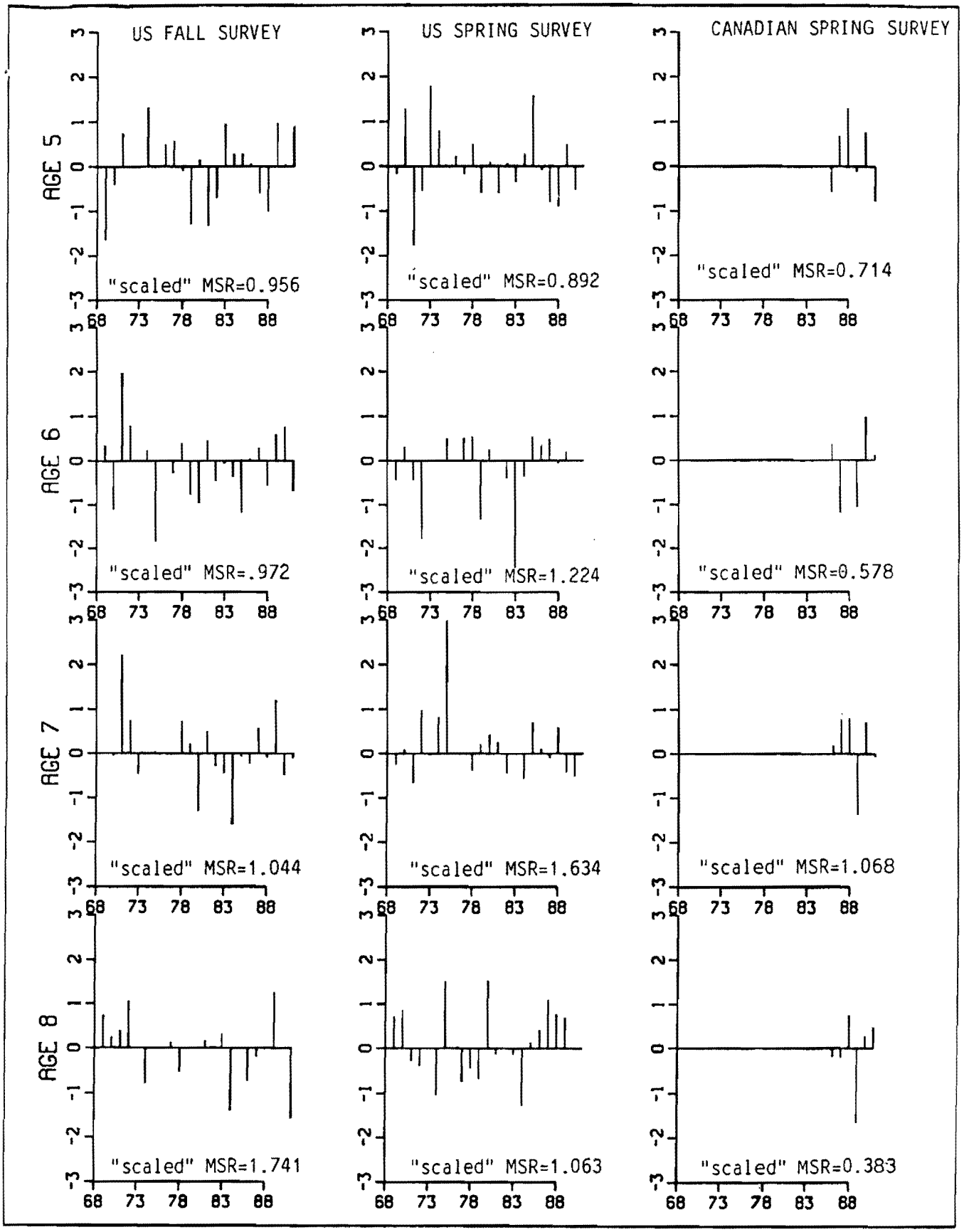

Figure 6 (continued)

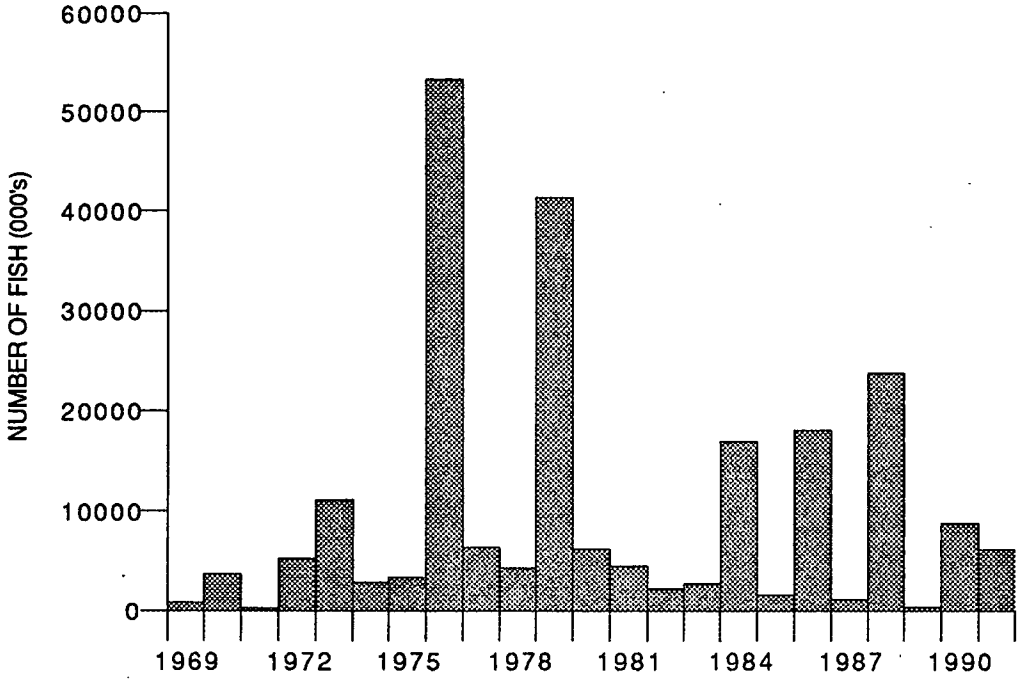

Fig. 7. Recruitment for haddock (age 1) in unit areas 5Zj and 5Zm.

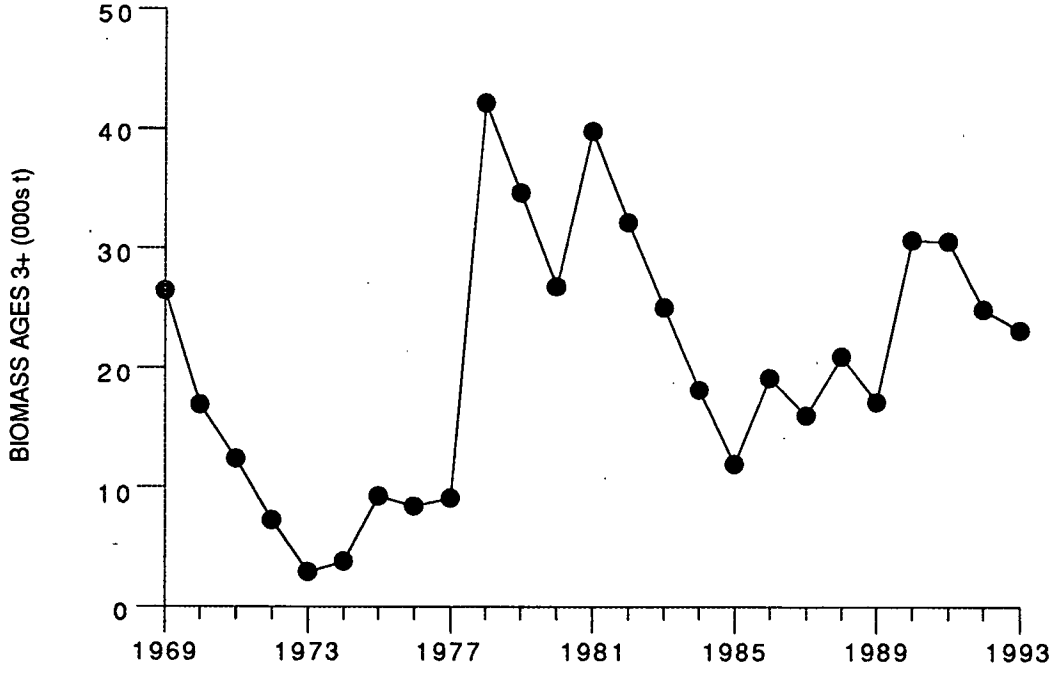

Fig. 8. Beginning of year biomass (ages 3+) of haddock in unit areas 5Zj and 5Zm with projections in 1991 and 1992 based on $F_{0.1}$.

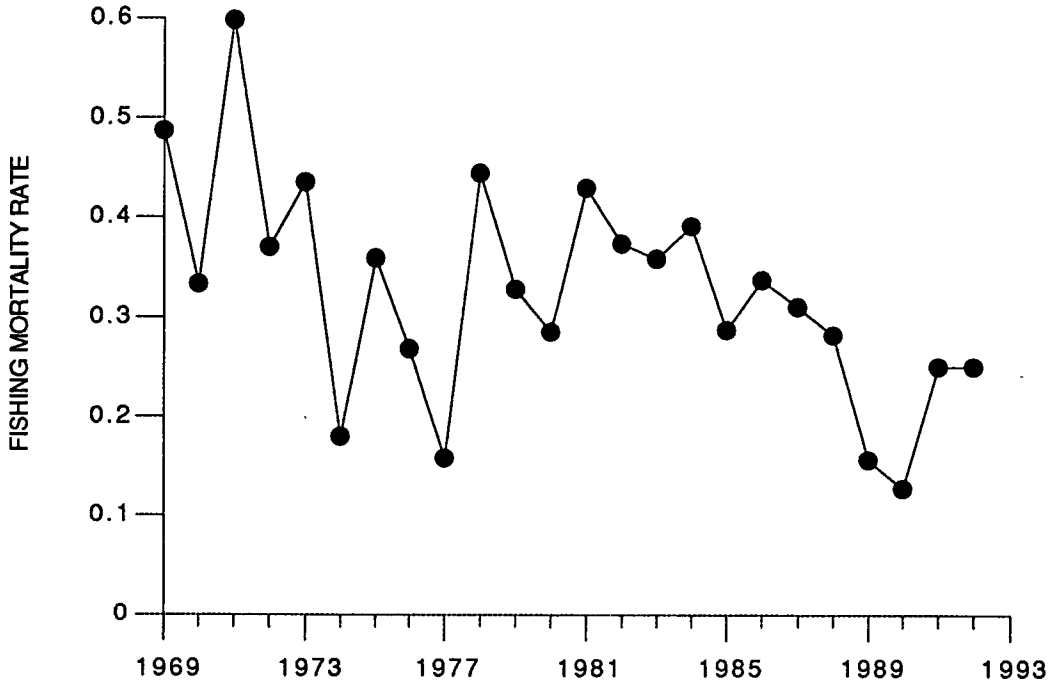

Fig. 9. Fishing mortality on ages 3+ haddock in unit areas 5Zj and 5Zm. F assumed to be at $F_{0.1}$ level in 1991 and 1992.