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Assessment of Haddock on Eastern Georges Bank

by

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Abstract

Georges Bank haddock have been fished only by Canada and the USA since 1977 and since 1985, when the International maritime boundary was established, each country has been restricted to their territory. The Canadian fishery was managed using trip limits with a 30% by-catch of haddock in 1990 and 1991. In 1991, the 1987 year-class accounted for about 60% of the landings by weight. Three surveys are used to calibrate the sequential population analysis, the USA spring and fall and the Canadian spring. The USA surveys have undergone boat, door and trawl changes for which conversion factors were applied. The USA fall 1991 survey abundance estimates were very low. The calibration framework used was similar to last year's but employed no weighting and age specific calibration constants for all age groups. Population estimates from ADAPT were adjusted for bias due to non-linearity in the models. Results showed the 1989, 1990 and 1991 year-classes to be of moderate strength. The fishing mortality rate has been about 0.4 in recent years but almost doubled through 1990 and 1991. Adult biomass is projected to decline to levels comparable to historical low values. Three factors were significant in generating a more pessimistic perception of this stock than was presented in the last review; the application of conversion factors to the USA surveys, the low abundance estimates from the USA fall 1991 survey and the exclusion of weighting in the model formulation.

Résumé

Depuis 1977, seuls le Canada et les États-Unis pêchent l'aiglefin dans les eaux du banc Georges et depuis 1985, lorsque la frontière canado-américaine fut établie, chaque pays se limite à ses eaux maritimes. La pêche canadienne en 1990 et 1991 a été gérée à l'aide de limites de sortie et d'une limite de 30% de prise accidentelle d'aiglefin. En 1991, la classe d'âge de 1987 représentait quelque 60% des débarquements. L'analyse séquentielle des populations a été étalonnée d'après trois relevés de recherche, soit ceux de printemps et d'automne par les États-Unis et celui du printemps par le Canada. Les relevés américains ont subi des modifications aux bateaux, au panneaux et aux chaluts. Ils ont donc été ajustés à l'aide facteurs de conversion. Les estimations d'abondance provenant du relevé d'automne 1991 par les États-Unis étaient très basses. L'étalonnage fut semblable à celui appliqué l'année dernière, sauf que les constantes de pondération ont été omises et que des facteurs de calibration ont été calculées pour tous les âges. Les effectif prévus par la méthode ADAPT ont été corrigés pour un biais résultant du fait que le modèle est non-linéaire. Les classes d'âge de 1989, 1990 et 1991 semblaient moyennement fortes. Le taux de mortalité par pêche qui se retrouvait aux environs de 0,4 depuis quelques années, a presque doublé en 1990 et 1991. On projète que la biomasse d'adultes s'approchera de planchers historiques. Trois éléments sont identifiés comme étant responsable pour le développement d'un aperçu plus pessimiste cette année que l'année dernière en ce qui est de ce stock, soit l'application de facteurs de conversion sur les données des relevés américains, les faibles indices d'abondance provenant du relevé américain de l'automne, et l'exclusion d'une pondération dans l'expression du modèle.

Description of the fishery

The haddock (*Melanogrammus aeglefinus* L.) on Georges Bank have supported an important commercial fishery since the early 1920s (Clark et al 1982). Before the 200 mile limit was imposed in 1977 there was a strong foreign presence with many countries fishing small mesh directed at species other than haddock. Since 1977, only Canada and the USA have had fisheries on Georges Bank, and since 1985 each country has been restricted to their respective side of the maritime boundary. Since 1990 CAFSAC has considered haddock on eastern Georges Bank, unit areas 5Zj and 5Zm, as a management unit (Fig. 1).

High catches were taken in the mid-1960s (roughly 60,000 t) from 5Zj,m which were dominated by the exceptional 1963 year-class. Since then catches declined to a low of 2,352 t in 1976 (Table 1, Fig. 2). Catches climbed to 25,036 t in 1980 and have declined to 3,846 t in 1989 when the trawler fishery was closed after only a few weeks.

The Canadian fishery is mainly an otter trawl fishery but has a substantial longline component (Table 2). In recent years, the otter trawl fishery has not opened until June and the highest catches occur from mid-summer to early fall (Table 3). Until 1984, tonnage class 5 dominated the fishery but since then tonnage classes 2 and 3 have been predominant. Canadian landings since 1987 have varied between 3059 t and 5417 t, accounting for over two thirds of the total 5Zj and 5Zm haddock landings.

The USA groundfish fishery has existed on Georges Bank since the early 1920s and has been predominantly a trawler fishery for groundfish, haddock being one of the more important species (Table 4). In the past, the fishery has been fairly evenly distributed throughout the year but in recent years it has been concentrated during the first half of the year (Table 5). The USA catch in 5Zj,m dropped to a record low of 787 t in 1989 which reflects the absence of a directed commercial fishery for haddock. The catch increased to 1182 t in 1990 and then declined to 949 t in 1991.

The Canadian haddock quota for NAFO Subdivision 5Zc (the Canadian portion of 5Zj,m) in 1987 and 1988 was set at 8,300 t. In 1989, a combined cod-haddock-pollock quota was applied to area 4X-5Zc. The Canadian otter trawl fishery in that year was stopped after only a few weeks of activity when quotas were reached. In 1990, for mobile gear less than 65 ft, Georges Bank was managed separately as an experimental fishery using 130 mm square mesh gear. Trip limits to a maximum of 8 trips of 35,000 lbs. per trip were permitted between June 1 and Oct 31 with a 30% by-catch of haddock permitted. A similar plan was employed for 1991 with a minimum mesh size of 130 mm square or 145 mm diamond. Fixed gear were permitted to fish year round but were required to use large hooks

until June. Reports from fishermen during the 1991 fishery indicated that haddock were found at greater depths. Some fishermen suggested that the increased gillnet activity interfered with haddock movement onto the bank.

Catch and weight at age

The catch and weight-at-age for 1969 to 1988 were taken from the previous assessment (Gavaris and Van Eeckhaute 1991). Estimates of discards by the USA fishery during the late 1970s (Overholtz et al 1983) 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.

Estimates of catch and weight-at-age for the Canadian fleet for 1989-1991 were calculated using the sampling data collected by the Department of Fisheries and Oceans to their landings. Individual samples were weighted by the number of fish landed, then pooled within month and gear type. Monthly results were aggregated and the respective age-length keys were applied to obtain the catch-at-age and weight-at-age (Tables 6 and 7). 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.

USA catch and weight-at-age for 1989 and 1990 were recalculated by applying the samples collected by the National Marine Fisheries Service (NMFS), which were made available for this assessment, to their landings. The 1991 catch and weight-at-age was also obtained by applying the NMFS samples. Length samples were weighted by the number sampled, then pooled within month and market category and applied to the respective landings. Months were combined within quarters or half years incorporating landings from those months without samples (Tables 8 and 9). The following length-weight relationships, provided by NMFS, were used in the calculations:

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

$$\text{Quarter 2 round weight (kg)} = 0.0000217 \text{ length (cm)}^{2.790}$$

$$\text{Quarter 3 round weight (kg)} = 0.0000093 \text{ length (cm)}^{3.023}$$

$$\text{Quarter 4 round weight (kg)} = 0.0000212 \text{ length (cm)}^{2.827}$$

In recent years the 1983, 1985 and 1987 year-classes have been dominant in both the Canadian and USA fisheries (Table 10). For these year-classes, the USA tends to catch the greatest numbers at

ages 3 and 4 while Canada's largest catches are at age 2 (except in 1989 when the fishery was closed early). In 1991, the 1987 year-class accounted for about 60% of the landings by weight. The weight at age in recent years has not displayed any persistent trends (Table 11).

Research survey

Annual surveys of 5Zj,m have been conducted by DFO during the springs of 1986-91 and by the NMFS during the springs of 1968-90 and during the falls of 1963-90. All surveys use a stratified random survey design but the strata boundaries were defined differently (Figs. 3-5).

The USA surveys have undergone boat, door and trawl changes. The USA spring surveys employed a modified Yankee 41 trawl from 1973-81 instead of the standard Yankee 36. Analysis showed that the impact of this change on haddock catches was not significant (Hayes and Buxton 1992). A polyvalent otter trawl door was introduced to both spring and fall USA surveys in 1985, replacing the BMV door. Two vessels, Albatross IV and Delaware II, have been used to conduct the USA surveys. Analyses showed that these changes had significant impact on haddock catches and conversion factors were estimated to account for these effects. The polyvalent doors were 1.633 times the efficiency of the BMV doors and the Albatross IV was 0.852 times the efficiency of the Delaware II (NEFSC 1992). Conversion factors were applied following Hayes and Buxton (1992) to reflect the vessel and door combinations used in each survey (Tables 12 and 13).

The 1983, 1985 and 1987 year-classes have been identified as being relatively strong by all three surveys, when compared to recent recruitment since 1968 (Tables 14-16). The 1988 year-class is poorly represented in all three surveys while the 1989, 1990 and 1991 year-classes are of moderate strength. The fall 1987 USA estimates show consistently low values for all age groups when compared to the 1986 and 1988 fall surveys suggesting reduced catchability for the survey. The fall 1991 survey results are almost as low as those for 1987, however, it is too early to determine if a reduced catchability was the cause. The Canadian spring survey for 1992 does not show a decline of the same magnitude and results from the USA spring survey for 1992 were not available for this analysis.

Estimation of Stock Parameters

The calibration framework used for this assessment is similar to that employed by Gavaris and Van Eeckhaute (1991) for assessment of this stock. Two modifications were incorporated. Age specific calibration constants were estimated for all age groups rather than

using a common constant for age groups 4-8. Estimated weighted least squares based on calculated residuals was not used due to concern regarding the appropriateness of the procedure for determining the degrees of freedom and indications from recent empirical studies (Freedman and Peters 1984) which suggest that the asymptotic statistical properties may be too optimistic for finite samples.

The spring survey data were compared to the beginning-of-year age specific population numbers, while the fall survey data were compared to the age specific population numbers for fish one year older at the beginning of the subsequent year. The Adapt (Gavaris 1988) formulation is as follows:

Parameters:

- Year-class estimates

$$N_{a,1992} \quad a = 1 \text{ to } 8$$

- Calibration constants

$$\begin{array}{ll} K_{1,a} & a = 0 \text{ to } 7 \text{ for fall USA survey} \\ K_{2,a} & a = 1 \text{ to } 8 \text{ for spring USA survey} \\ K_{3,a} & a = 1 \text{ to } 8 \text{ for spring Canadian survey} \end{array}$$

Structure:

- natural mortality assumed equal to 0.2
- error in catch at age assumed negligible
- F on age group 8 calculated as

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

where a = index for age group
 y = index for year

Input:

$$\begin{array}{ll} - C_{a,y} & a = 1 \text{ to } 8, y = 1969 \text{ to } 1991 \\ - RV_{1,a,y} & a = 0 \text{ to } 7, y = 1968 \text{ to } 1991 \\ - RV_{2,a,y} & a = 1 \text{ to } 8, y = 1969 \text{ to } 1991 \\ - RV_{3,a,y} & a = 1 \text{ to } 8, y = 1986 \text{ to } 1992 \end{array}$$

Objective function:

- minimize

$$\sum_{s,a,y} (\ln RV_{s,a,y} - \ln K_{s,a} N_{a,y})^2$$

where s=index for survey and $RV \neq 0$

Summary:

- number of observations = 383
- number of parameters = 32
- estimates shown in Table 17

Figure 6 indicates an adequate fit of the data to the model. Comparison of plots from analyses conducted on data without the conversion factors for the USA surveys were not useful for diagnosing differences in the fit.

The framework described above was considered suitable for the assessment however the impact of changes to the model formulation and data for this year's assessment were investigated. The effect of 1) adding in the fall USA survey 2) no weighting, 3) using individual k's for ages 1-8 instead of an average k for 4+ and 4) applying the boat and gear conversion factors to the USA surveys were considered by incorporating each change sequentially. Estimates of population numbers-at-age for the beginning of 1992 from the various model formulations are:

CHANGES TO DATA AND MODEL	Same Formulation as Last Year ^a	USA Fall 1991 Survey Added	No Weighting	k's For Ages 1-8	Door and Gear Conversion for USA surveys
Age 1	25897	18303	12812	12821	8115
2	9451	7020	5618	5622	3549
3	4563	3713	3423	3426	2053
4	281	280	261	256	149
5	7383	6607	3907	3833	1718
6	60	102	82	87	42
7	1714	1374	1012	1061	316
8	81	78	57	58	26

^awith 1992 Canadian and 1991 USA spring surveys added.

The inclusion of the 1991 fall USA survey, no weighting and the application of the boat and gear conversion factors all had a significant effect on the estimated population numbers. The effect of using individual k's for ages 1-8 is minimal.

Estimates of population abundance (Table 17) were obtained using the "cohort" approximation. Terminal estimates for the 1984-91 year-classes, ages 1-8 in 1992, were obtained by adjusting the

least squares estimates obtained from ADAPT for the bias calculated according to Box (1971):

Age	Beginning year 1992 population abundance			
	Estimate	Relative Error	Relative Bias	Bias Adjusted Estimates
1	8115	0.75	0.29	5740
2	3549	0.47	0.12	3113
3	2053	0.43	0.09	1865
4	149	0.44	0.09	136
5	1718	0.50	0.09	1556
6	42	0.65	0.19	34
7	316	0.61	0.15	268
8	26	0.91	0.33	17

Terminal estimates for all earlier year-classes were not explicit parameters estimated with ADAPT but are derived as functions of $N_{a,1992}$. By applying the equation from Ratkowsky (1983) for calculating the bias of functions of parameters, it was determined that the bias for these terminal estimates were smaller (less than 5%) than those for the 1984-91 year-classes, but the adjustments were made to maintain consistency. Fishing mortality estimates (Table 18) were calculated from population abundance. Beginning of year weight at age was approximated as described by Rivard (1982) and used to derive beginning of year biomass.

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 (Fig. 7). There are indications that the 1989, 1990 and 1991 year-classes are of moderate strength compared to recent recruitment. After recovering from the extremely low values it had reached during the early 1970s, the adult biomass declined to about 10,000 t (Fig. 8) and since 1984 has fluctuated around that size, being supported by the recruitment of the 1983, 1985, and 1987 year-classes. The fishing mortality rates have been about 0.4 in recent years, but almost doubled through 1990 and 1991 (Fig. 9). The early closure of the Canadian trawler fishery in 1989 resulted in a slight reduction in the fishing mortality rate on older fish and was an important factor in allowing the 1987 year-class to realize some of its growth potential.

Prognosis

Projections for 1993 were done using the bias adjusted estimates of population abundance for 1992.

Age	Beginning year 1992 population numbers (000)	Weight at age (kg) Average ^a	Beginning year ^b	Exploitation pattern
1	5740	0.607	0.466	0
2	3113	1.021	0.870	.5
3	1865	1.370	1.110	1
4	136	1.789	1.590	1
5	1556	2.137	1.930	1
6	34	2.542	2.360	1
7	268	2.912	2.700	1
8	17	3.141	2.900	1
9	0	3.500	3.250	1

^amean for 1989-1991

^bvalues for 1992

The estimated fishing mortality in 1991 was greater than twice $F_{0.1}$ therefore all projections were done assuming that the catch in 1992 would correspond to a fishing mortality of twice $F_{0.1}=0.5$ which is about 3,200 t. The estimated projected reference catches in 1993 at $F_{0.1}=0.25$ and twice $F_{0.1}=0.5$ were about 2,000 t and 3,500 t respectively. Adult biomass in 1992 to 1994 is projected to decline to levels comparable to historical low values, (6,000 to 7,000 t), even if fishing mortality in 1992 and 1993 is reduced to twice $F_{0.1}$.

Though a decline in stock abundance had been forecast (Gavaris and Van Eeckhaute 1991), this assessment gives a considerably more pessimistic perception of stock status compared to last year's review. Three factors were significant in generating this change, the application of conversion factors for the changes to the USA surveys, the exceptionally low abundance estimates from the USA fall 1991 survey, and exclusion of weighting in the model formulation. The productivity of this resource has not recovered to its historic potential. The USA has proposed management measures to reduce exploitation by their fishery and is presently conducting hearings regarding the proposals. It is likely that USA landings in 1992 and 1993 will be about 1,000 t. It is recommended that the Canadian quota should not exceed 2,500 t in both 1992 and 1993. More restrictive measures and further reduction in exploitation may be necessary to rebuild this stock. With current exploitation, further declines are likely as there is poor probability of good recruitment at such low biomass levels. Consistent management measures by Canada and the USA to conserve haddock may be required to succeed in rebuilding this stock.

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Table 1. Nominal catches (t) of haddock from unit areas 5Zj and 5Zm from 1969-91. For "others" it was assumed that 40% of the total 5Z 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	3339	1189	0	4528
1991	5417	949	0	6366

* 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. Canadian catch (t) of haddock in unit areas 5Zj and 5Zm by gear category and otter trawl tonnage class from 1969-91.

Year	OTTER TRAWL SIDE				OTTER TRAWL STERN					LONGLINE	OTHER	TOTAL
	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
1991	0	0	0	0	1585	1644	81	650	3991	1311	115	5417

* 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 excluded because of suspected misreporting.

Table 3. Monthly catch (t) of haddock by Canada in unit areas 5Zj and 5Zm for 1969-91.

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	14	50	0	7	1178	668	678	469	199	18	22	3339
1991	113	166	49	26	21	1931	1005	706	566	577	123	135	5418

* 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 4. USA catch (t) of haddock in unit areas 5Zj and 5Zm by gear category and otter trawl class for 1969-91.

Year	Otter Trawl			LL	Misc.	Total
	Class 3	Class 4	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
1991	410	526	936	0	13	949

Table 5. Monthly catch (t) of haddock by USA in unit areas 5Zj and 5Zm for 1969-91.

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	148	21	155	274	214	306	23	3	5	5	16	19	1189
1991	120	31	76	133	89	434	1	20	6	0	19	19	949

Table 6. Canadian commercial catch-at-age (numbers 000's) 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	6	1070	55	501	14	122	29	34	1833
1991	6	429	62	1809	50	297	28	123	57	2861

Table 7. Average weight-at-age (kg) 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	0.639	0.956	1.461	1.711	2.232	2.281	2.736	2.396
1991	0.581	1.204	1.220	1.838	2.023	2.630	2.341	2.891

Table 8. USA commercial catch-at-age (numbers 000's) of haddock from unit areas 5Zj and 5Zm. 16

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	21	10	111	66	118	18	13	7	364
1990	0	1	195	71	241	54	41	13	8	624
1991	0	12	27	232	39	92	45	22	3	472

Table 9. Average weight-at-age (kg) 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	-	1.246	1.455	1.706	2.152	2.381	3.170	3.650
1990	-	1.416	1.184	1.846	1.953	2.570	3.016	4.288
1991	-	0.939	1.288	1.515	2.169	2.485	3.276	3.687

Table 10. Total(1) commercial catch-at-age (numbers 000's) 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	1153	78	734	129	320	31	20
1990	2	7	1265	126	743	68	163	42
1991	6	441	89	2041	88	389	72	145

(1) Total catch includes small mesh foreign fishery.

(2) Includes discard estimates based on trip interviews.

Table 11. Average weight-at-age (kg) 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	-	0.868	1.450	1.777	2.183	2.522	3.012	3.411
1990	0.639	0.999	1.419	1.787	2.141	2.509	2.807	3.002
1991	0.581	1.197	1.241	1.802	2.087	2.596	2.918	3.012

Table 12. Vessel and door used in the spring survey on Georges Bank, and conversion coefficients used (from Hayes and Buxton 1992).

Year(s)	Vessel	Door	Conversion coefficient
1968-80	ALBATROSS IV	BMV	1.633
1981-82	DELAWARE II	BMV	1.391
1983-84	ALBATROSS IV	BMV	1.633
1985-88	ALBATROSS IV	POLY	1.000
1989-91	DELAWARE II	POLY	0.852

Table 13. Vessel and door used in the fall survey on Georges Bank, and conversion coefficients used (from Hayes and Buxton 1992).

Year(s)	Vessel	Door	Conversion coefficient
1963-76	ALBATROSS IV	BMV	1.633
1977-81	DELAWARE II	BMV	1.391
1982-84	ALBATROSS IV	BMV	1.633
1985-88	ALBATROSS IV	POLY	1.000
1989-91	DELAWARE II	POLY	0.852

Table 14. Total estimated abundance-at-age (numbers in 000's) of haddock from unit areas 5Zj and 5Zm 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
1992	1914	3879	1423	221	4810	18	1277	52	655	14249

Table 15. Total estimated abundance-at-age (numbers in 000's) 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. Conversion factors to adjust for changes in door type and survey vessel were applied.

Year	Age Group							
	1	2	3	4	5	6	7	8
1969	19	38	673	257	573	3543	1337	392
1970	524	209	0	614	1094	484	3473	2748
1971	0	718	286	0	158	111	63	1270
1972	2843	0	845	144	28	52	231	29
1973	2691	6180	0	1131	169	0	302	0
1974	1450	22573	4476	0	388	0	47	79
1975	579	621	6593	1165	0	239	139	50
1976	9073	441	475	1347	638	0	0	0
1977	151	28410	323	937	894	642	0	24
1978	0	815	22861	703	965	1275	98	26
1979	11503	483	1439	10701	521	78	488	46
1980	4782	74483	1237	1224	6381	688	418	773
1981	4093	3462	31529	3287	819	2720	382	65
1982	665	4208	1877	8816	848	509	761	0
1983	260	844	752	394	2840	32	0	875
1984	1497	1551	1092	1097	1026	1365	151	97
1985	40	8911	1396	674	1496	588	1995	127
1986	3334	280	3597	246	210	333	235	560
1987	122	5480	144	1394	157	231	116	370
1988	305	61	1868	235	611	203	218	178
1989	87	6925	643	1395	278	822	61	95
1990	1719	73	10742	621	1083	114	190	0
1991	769	2152	449	3513	199	211	68	91

Table 16. Total estimated abundance-at-age (numbers in 000's) of haddock in unit areas 5Zj and 5Zm from the fall USA survey. Conversion factors to adjust for changes in door type and survey vessel were applied.

Year	Age Groups							
	0	1	2	3	4	5	6	7
1968	60	124	877	30	41	2437	599	194
1969	420	0	0	569	69	33	825	502
1970	0	7014	368	18	454	369	548	989
1971	2878	0	864	107	0	290	30	80
1972	5202	2626	0	254	0	0	58	0
1973	1474	18409	1760	0	197	1	0	18
1974	166	256	1053	185	0	6	0	0
1975	33279	728	211	1116	243	0	0	0
1976	859	145350	500	28	531	78	0	19
1977	53	271	29969	506	142	240	96	4
1978	16670	623	603	8774	64	48	107	0
1979	1791	24041	16	373	1663	50	13	0
1980	4077	3207	6691	0	115	1235	124	29
1981	701	5256	2942	3133	120	155	338	0
1982	68	0	733	504	2823	174	100	514
1983	3956	487	355	476	311	434	21	10
1984	50	4219	856	242	230	47	278	0
1985	12148	381	1646	199	70	68	46	30
1986	30	7471	109	961	52	50	72	24
1987	508	4	839	28	152	38	22	0
1988	122	3983	206	2326	155	400	142	140
1989	174	86	2748	117	529	70	76	0
1990	1265	1076	25	1532	94	179	22	5
1991	733	344	285	71	277	26	10	0

Table 17. Estimated population numbers (000's) at the beginning of the year for haddock in unit areas 5Zj and 5Zm, 1969 - 1992.

Year	Age group							
	1	2	3	4	5	6	7	8
1969	797	197	3638	878	924	8259	2753	253
1970	3641	653	144	1668	482	455	4155	1516
1971	255	2959	459	111	1049	260	257	2370
1972	5171	209	1319	140	62	633	65	60
1973	11121	3979	170	720	47	31	440	16
1974	2823	8187	1694	133	264	5	17	327
1975	3314	2296	4820	1141	109	179	2	14
1976	53007	2713	1714	2663	719	84	105	0
1977	6224	43337	2087	1244	1440	479	69	71
1978	4150	5096	28584	1651	858	903	245	56
1979	40630	3396	3911	14507	1207	549	469	128
1980	5923	33265	2761	3019	7893	693	285	208
1981	4280	4848	18622	1943	2196	4299	394	117
1982	2004	3504	3370	9281	1243	1269	2416	213
1983	2168	1641	2223	1812	5057	840	696	1323
1984	14986	1775	1158	1293	1020	2645	488	472
1985	1360	12270	1382	720	744	603	1205	222
1986	11557	1113	8179	793	430	438	383	651
1987	759	9457	878	4383	492	224	248	207
1988	11154	622	5942	604	2218	316	133	129
1989	400	9129	463	2924	385	1022	160	76
1990	3378	327	6431	309	1729	198	547	104
1991	3808	2765	262	4121	139	744	100	300
1992	5715	3113	1864	134	1527	34	257	17

Table 18. Estimated fishing mortality rate for haddock in unit areas 5Zj and 5Zm from 1969 to 1991.

Year	Age Group							
	1	2	3	4	5	6	7	8
1969	0.00	0.11	0.58	0.40	0.51	0.49	0.40	0.49
1970	0.01	0.15	0.06	0.26	0.42	0.37	0.36	0.31
1971	0.00	0.61	0.99	0.38	0.30	1.18	1.25	0.43
1972	0.06	0.00	0.40	0.89	0.48	0.16	1.24	0.28
1973	0.11	0.65	0.04	0.81	2.01	0.42	0.10	0.85
1974	0.01	0.33	0.20	0.00	0.18	1.03	0.00	0.13
1975	0.00	0.09	0.39	0.26	0.06	0.33		0.26
1976	0.00	0.06	0.12	0.41	0.21	0.00	0.19	
1977	0.00	0.22	0.03	0.17	0.27	0.47	0.00	0.26
1978	0.00	0.06	0.48	0.11	0.25	0.46	0.45	0.23
1979	0.00	0.01	0.06	0.41	0.35	0.46	0.61	0.41
1980	0.00	0.38	0.15	0.12	0.41	0.36	0.69	0.32
1981	0.00	0.16	0.50	0.25	0.35	0.38	0.41	0.34
1982	0.00	0.26	0.42	0.41	0.19	0.40	0.40	0.39
1983	0.00	0.15	0.34	0.37	0.45	0.34	0.19	0.42
1984	0.00	0.05	0.28	0.35	0.32	0.59	0.59	0.47
1985	0.00	0.21	0.36	0.31	0.33	0.26	0.42	0.30
1986	0.00	0.04	0.42	0.28	0.45	0.37	0.42	0.35
1987	0.00	0.26	0.17	0.48	0.24	0.32	0.45	0.45
1988	0.00	0.09	0.51	0.25	0.57	0.48	0.36	0.50
1989	0.00	0.15	0.21	0.33	0.46	0.43	0.24	0.35
1990	0.00	0.02	0.25	0.60	0.64	0.48	0.40	0.60
1991	0.00	0.19	0.47	0.79	1.22	0.86	1.58	0.77

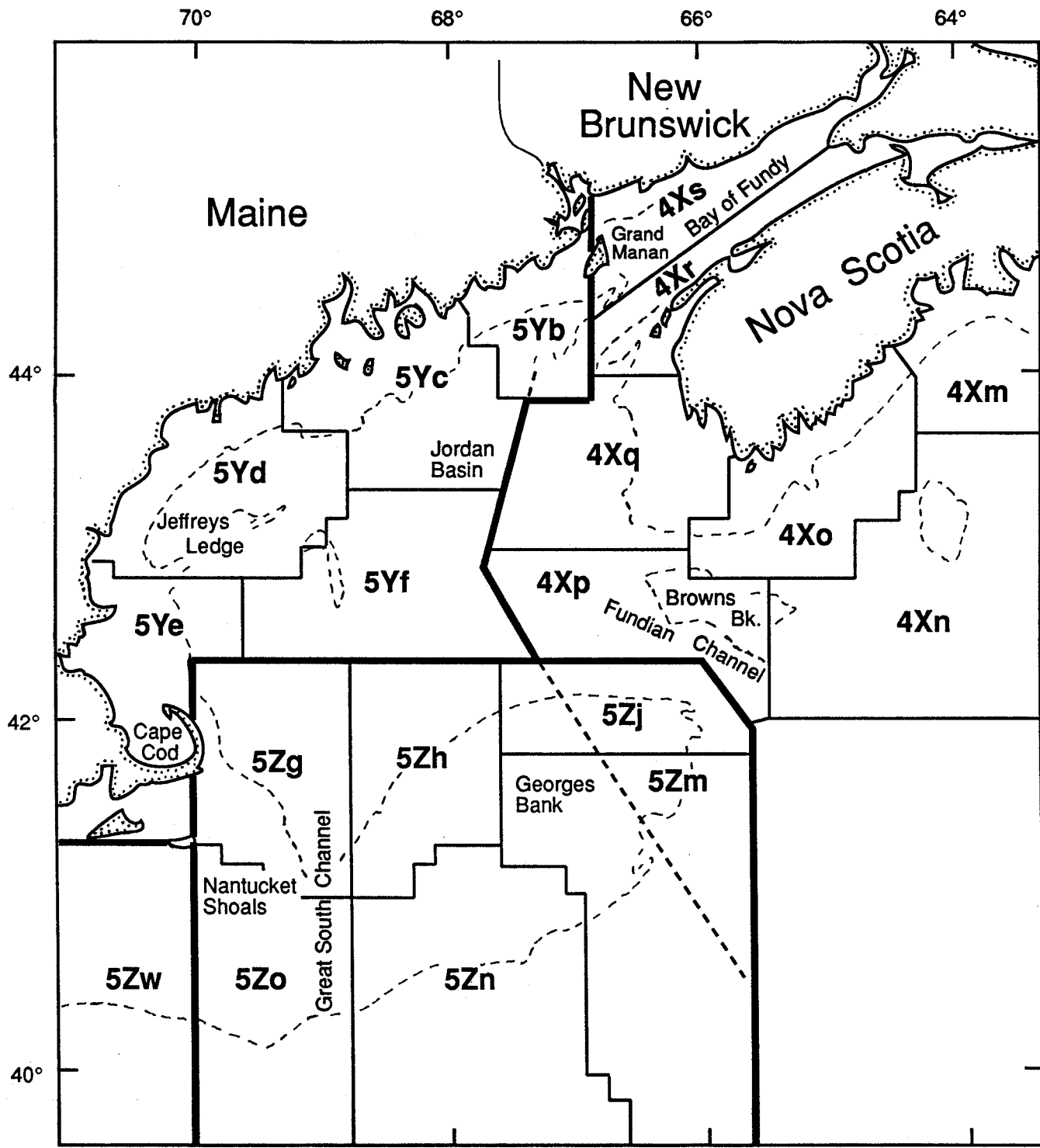


Fig. 1. Map of the Gulf of Maine area.

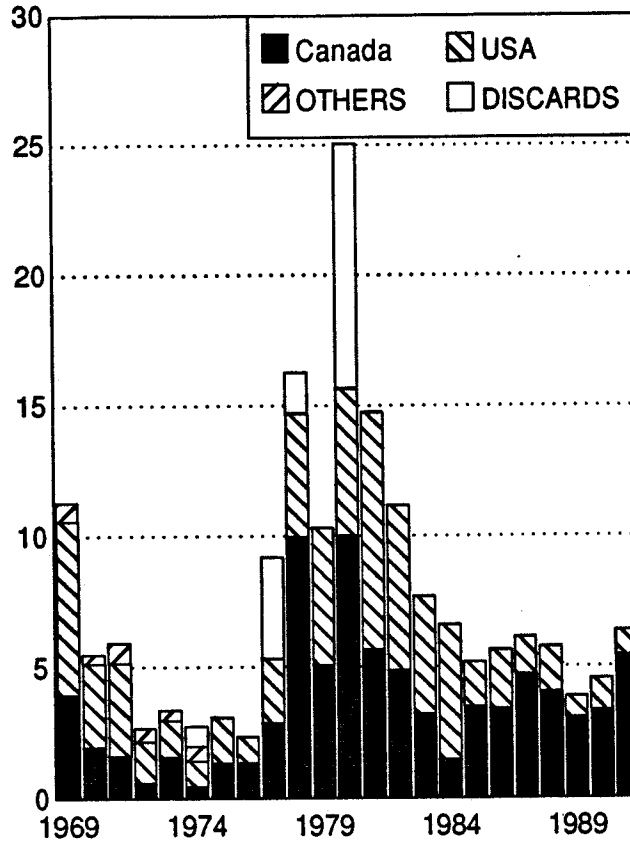


Fig. 2. Nominal catch of haddock in unit areas 5Zj and 5Zm.

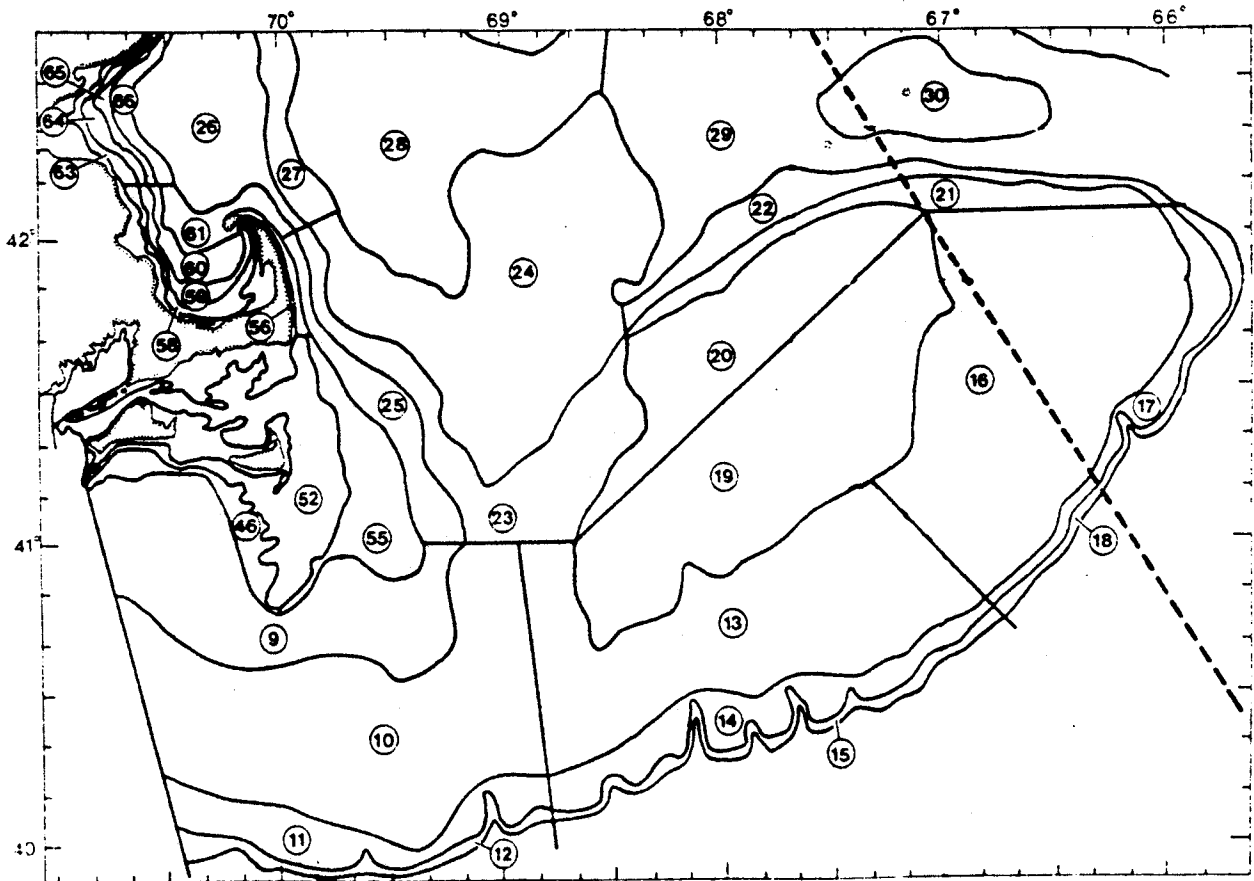


Fig. 3. Stratification scheme used for USA surveys.

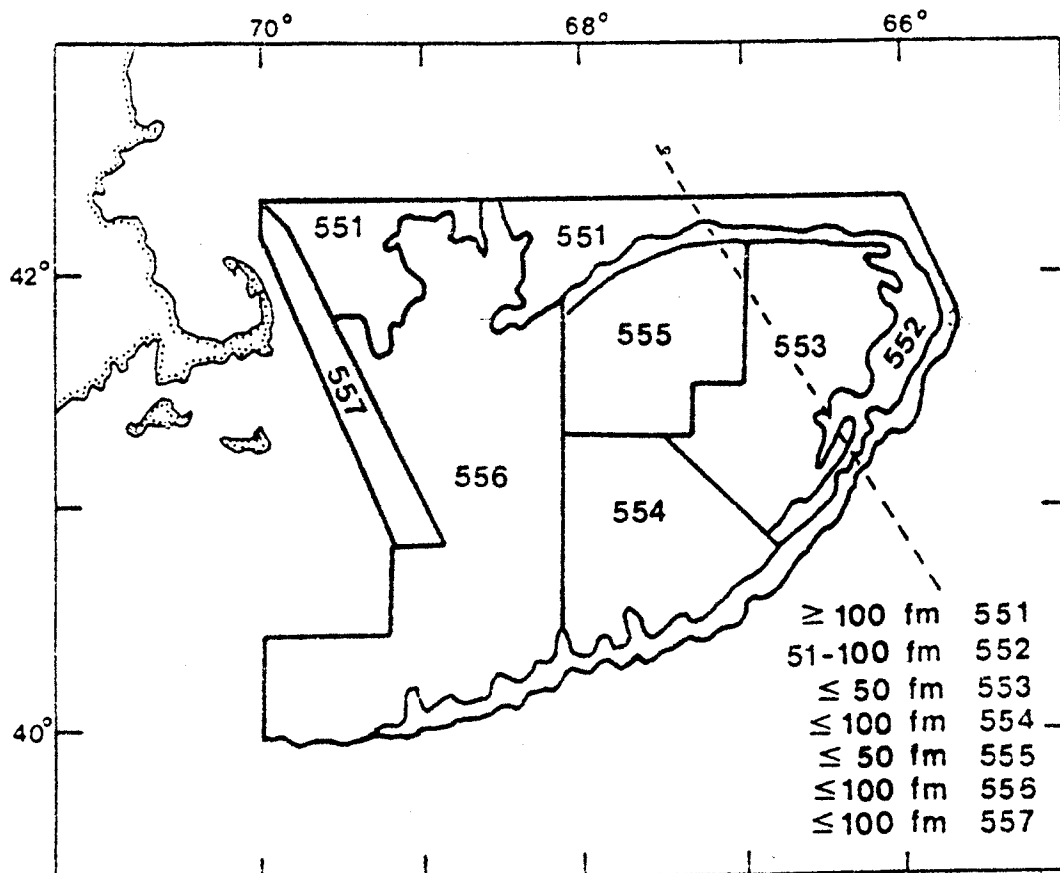


Fig. 4. Stratification scheme used for the Canadian spring survey in 1986.

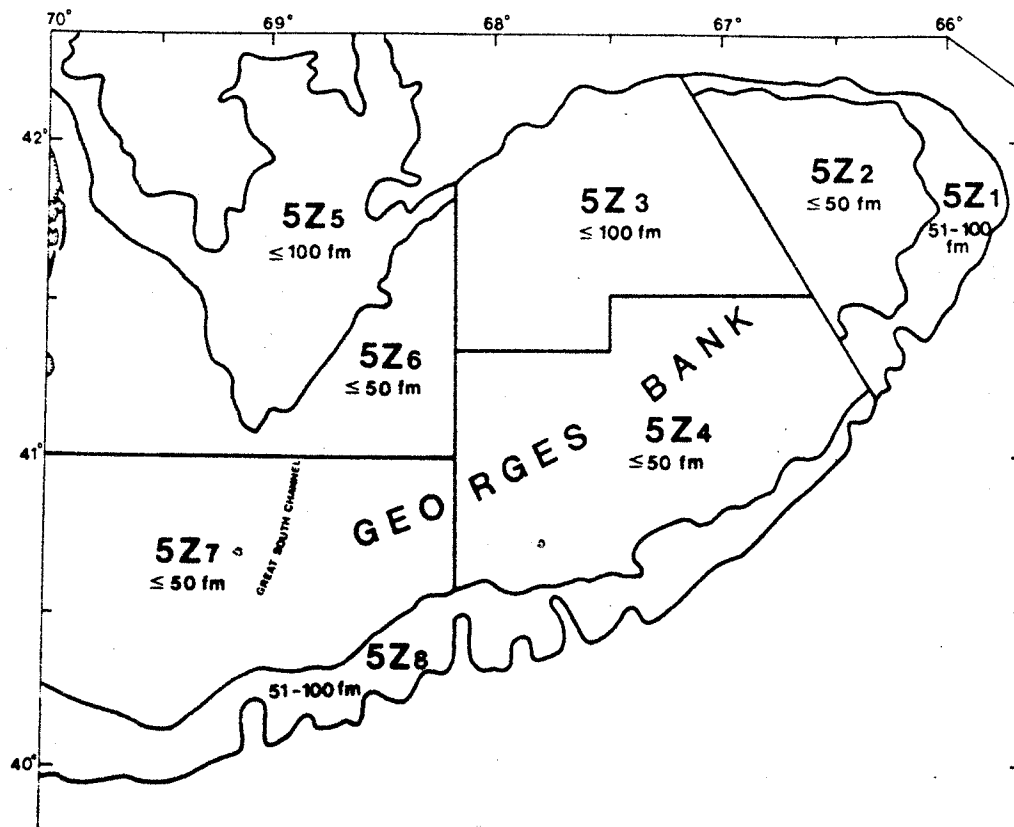


Fig. 5. Stratification scheme used for the Canadian spring survey since 1987.

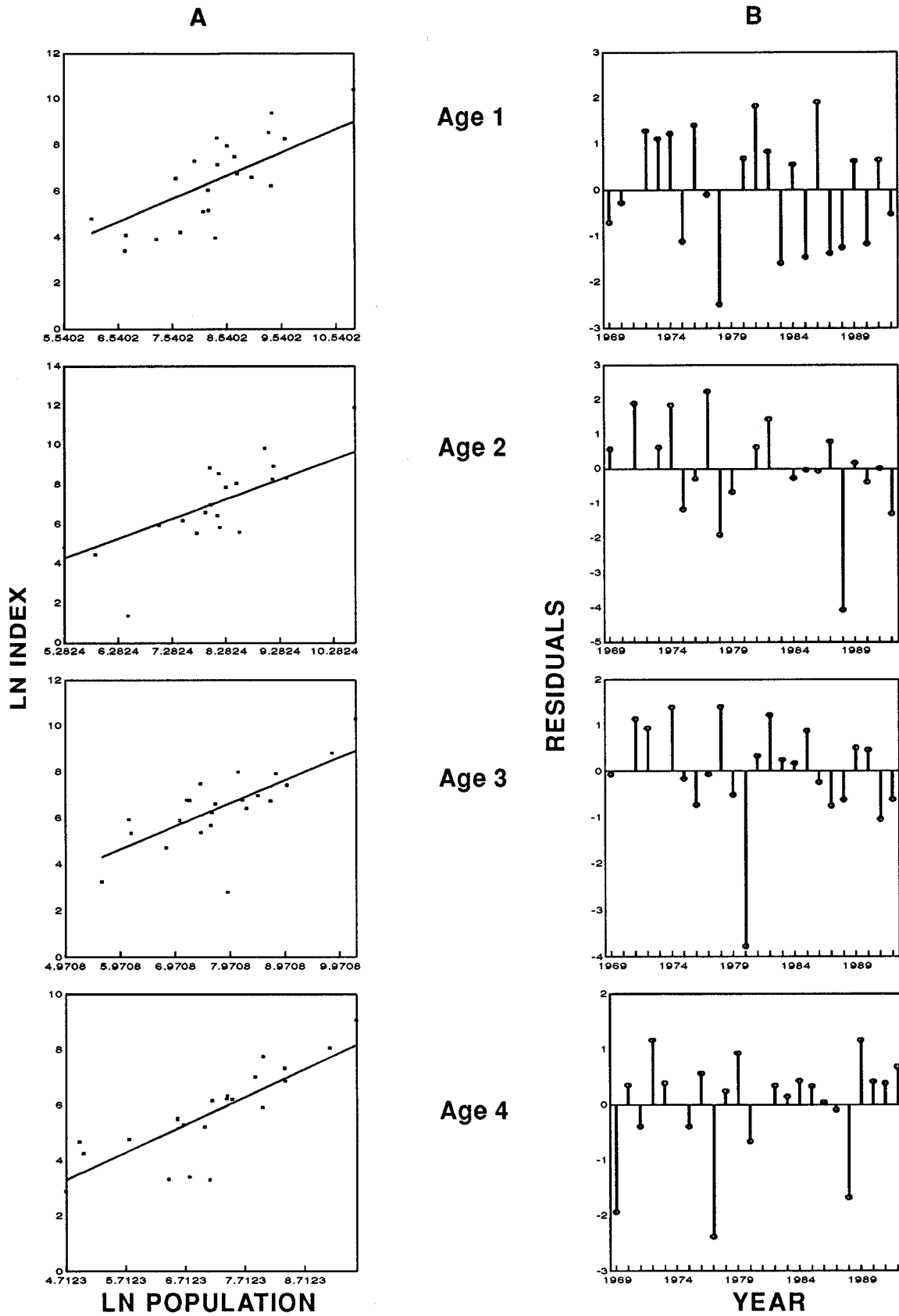


Fig. 6a. Age by age plots of A) the observed and predicted ln abundance index versus ln population numbers and B) residuals plotted against year for the USA fall survey for haddock in unit areas 5Zj and 5Zm.

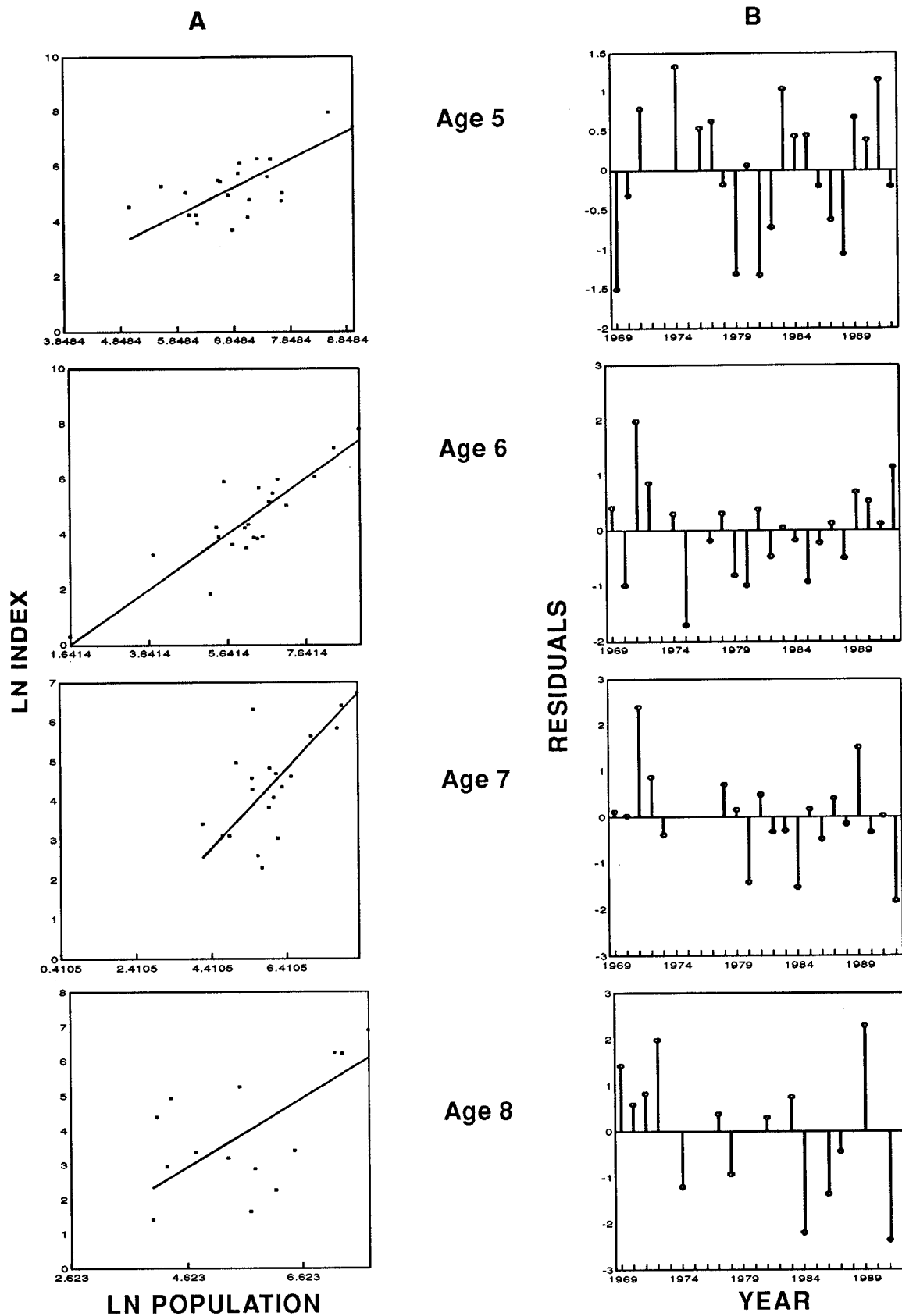


Fig. 6a. Continued.

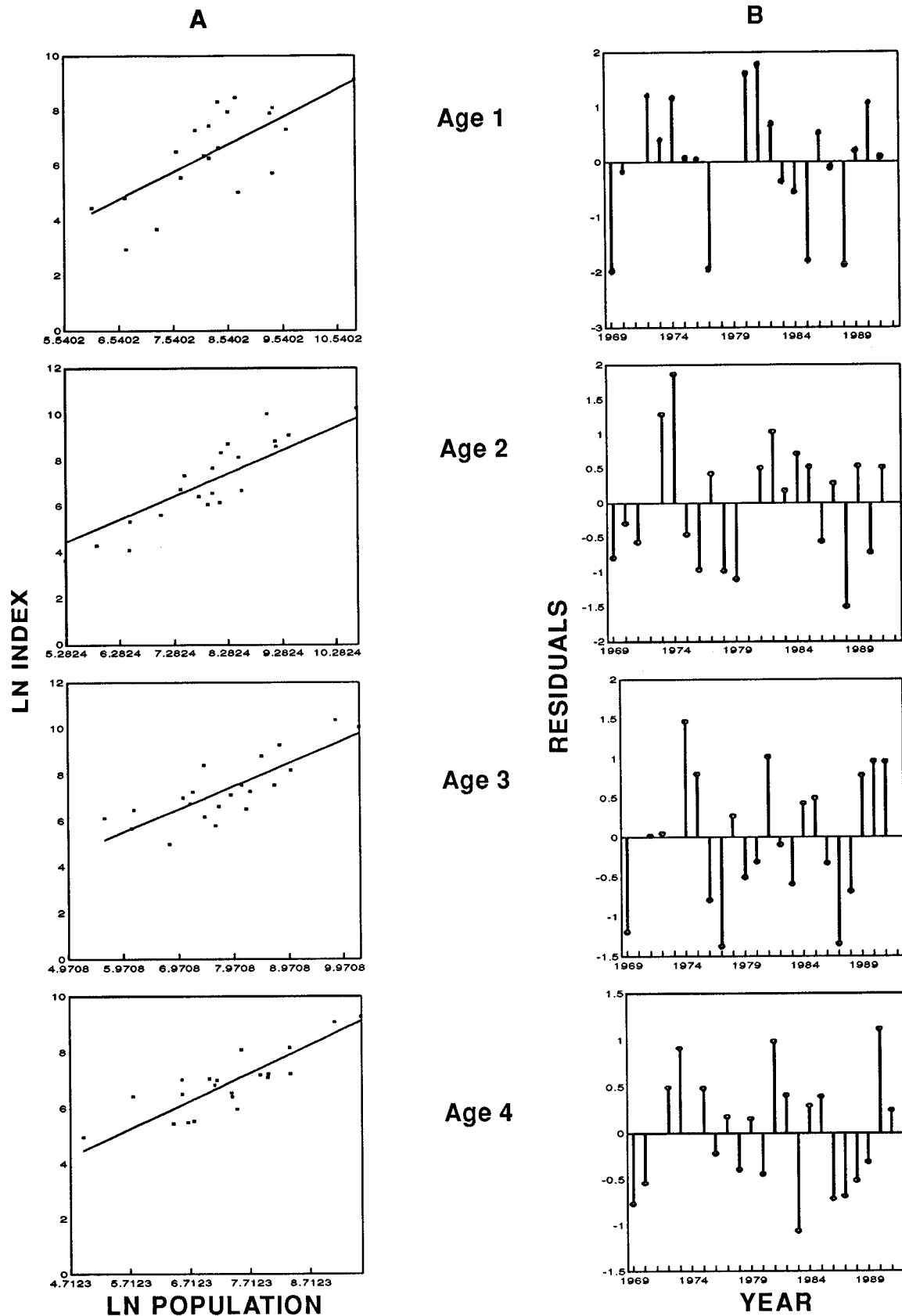


Fig. 6b. Age by age plots of A) the observed and predicted ln abundance index versus ln population numbers and B) residuals plotted against year for the USA spring survey for haddock in unit areas 5Zj and 5Zm.

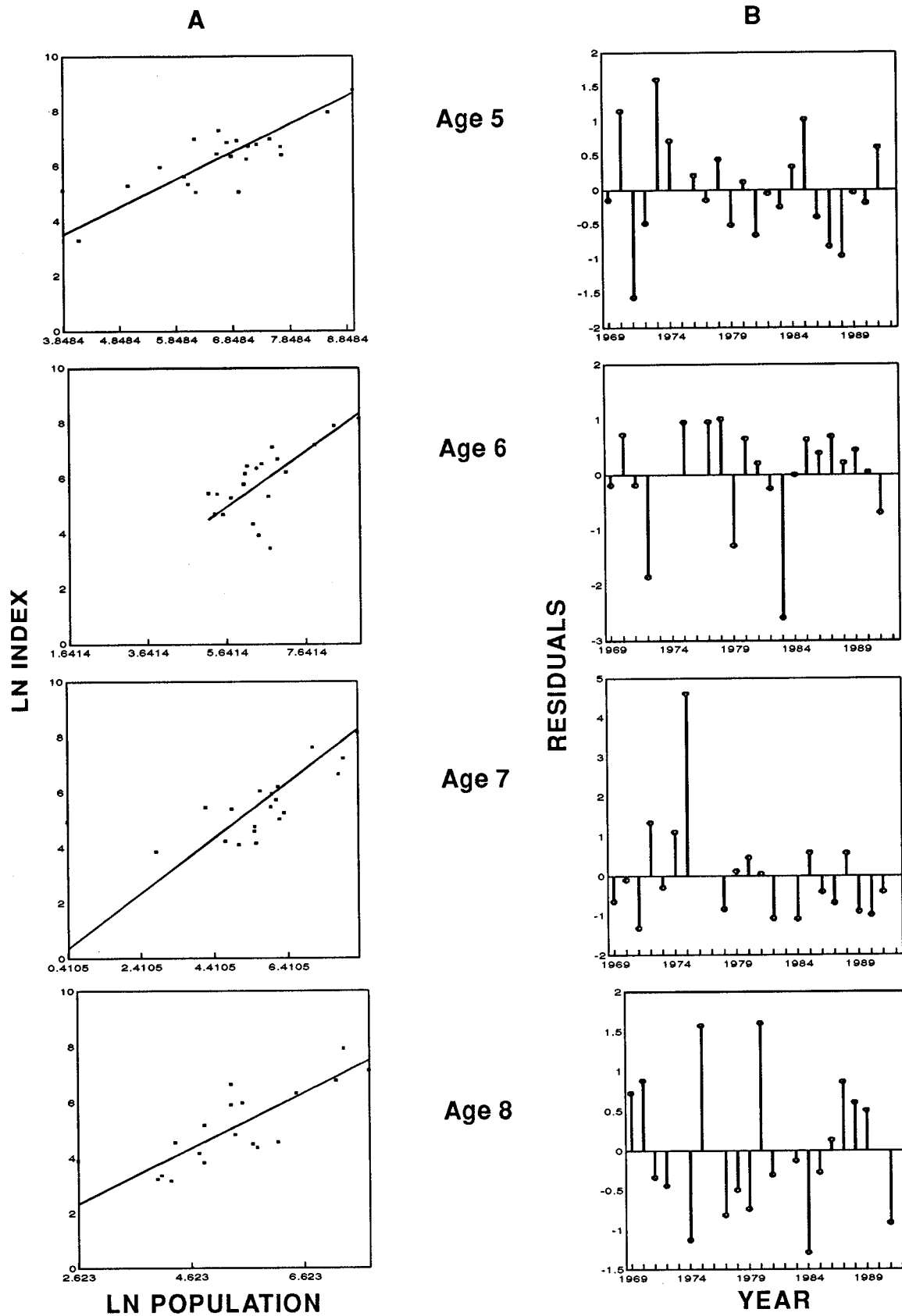


Fig. 6b. Continued.

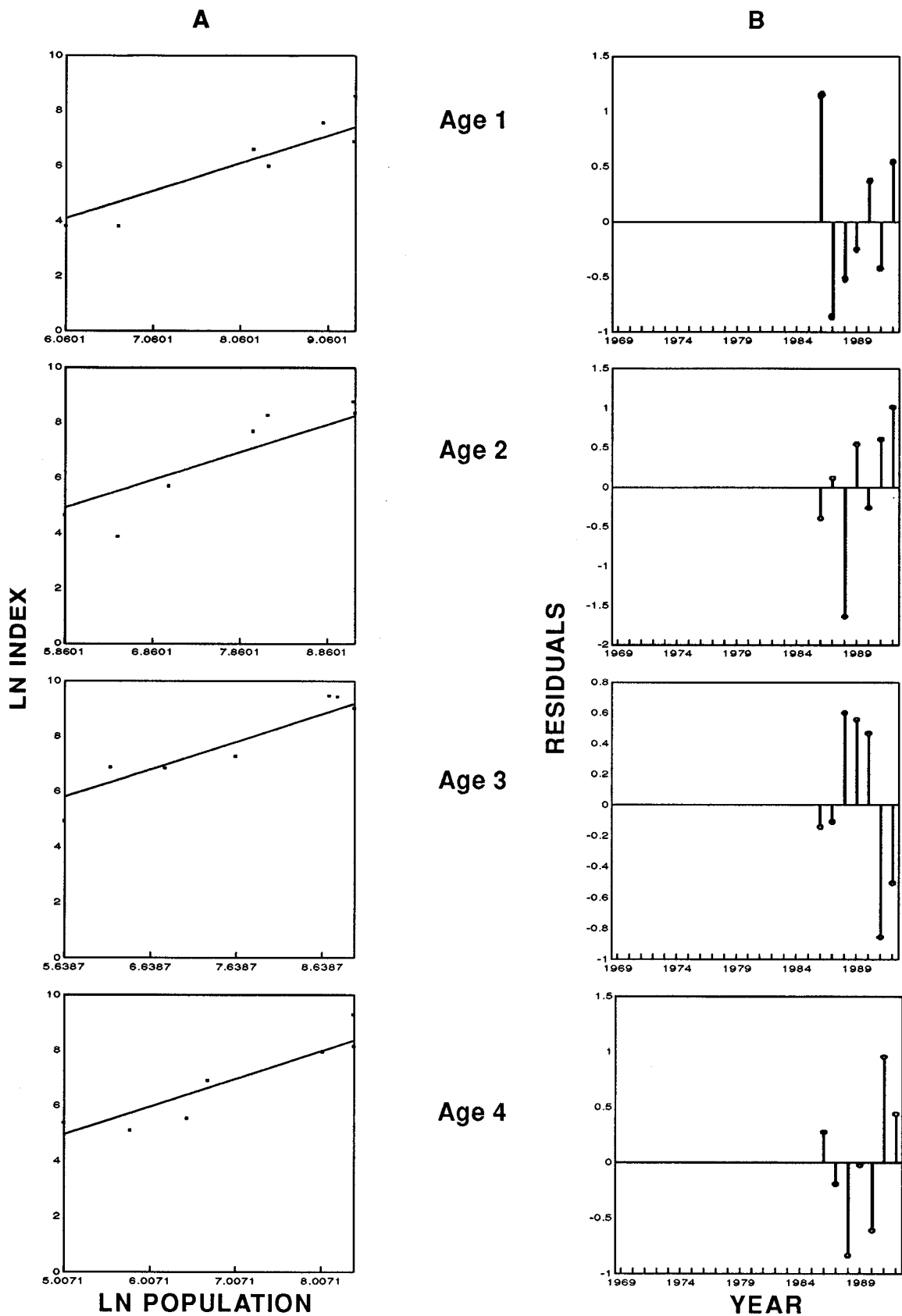


Fig. 6c. Age by age plots of A) the observed and predicted ln abundance index versus ln population numbers and B) residuals plotted against year for the Canadian spring survey for haddock in unit areas 5Zj and 5Zm.

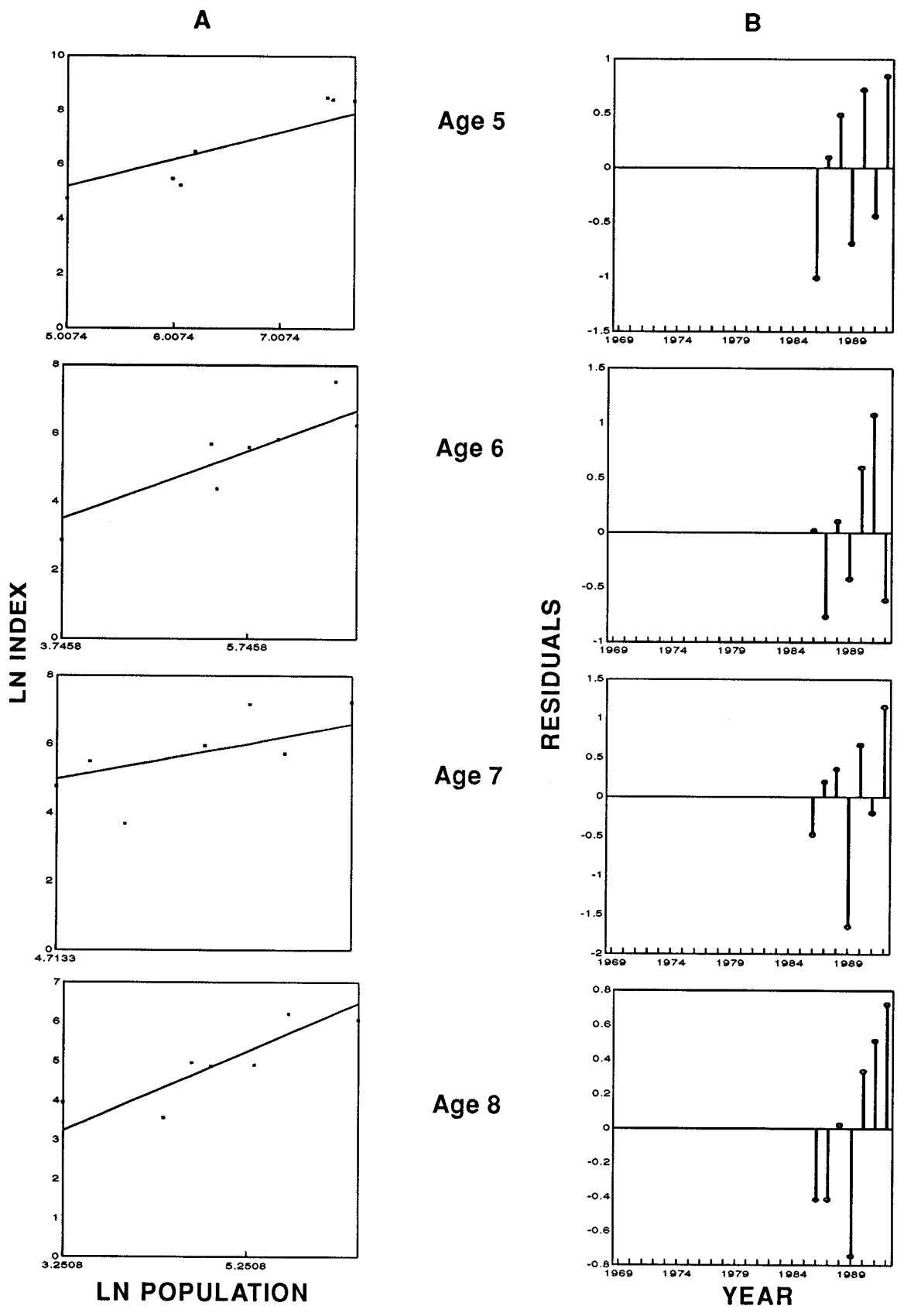


Fig. 6c. Continued.

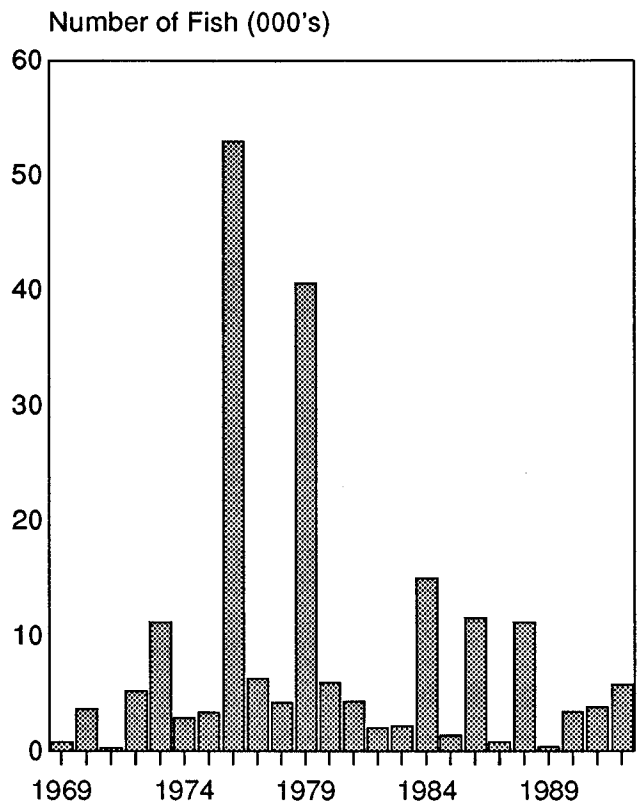


Fig. 7. Recruitment for haddock (age 1) in unit areas 5Zj and 5Zm.

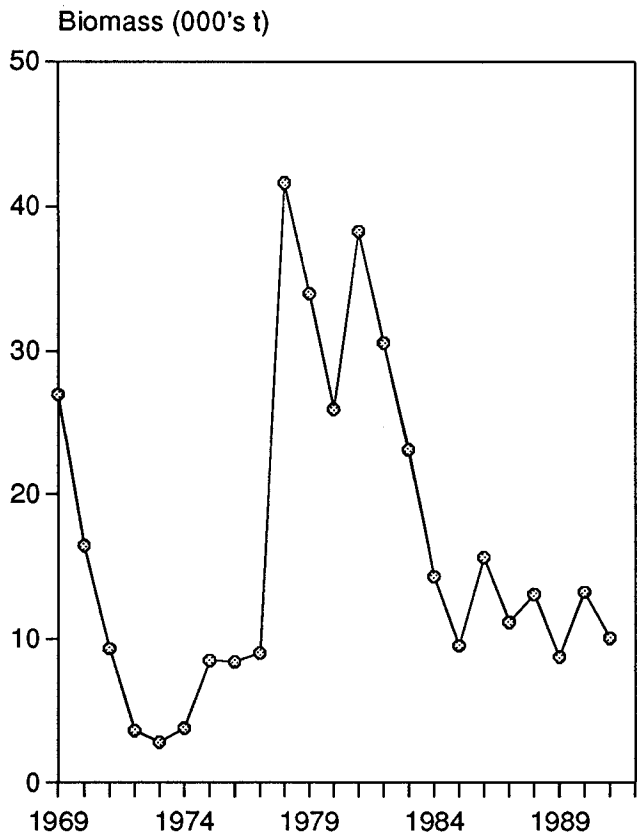


Fig. 8. Biomass (3+) for haddock in unit areas 5Zj and 5Zm.

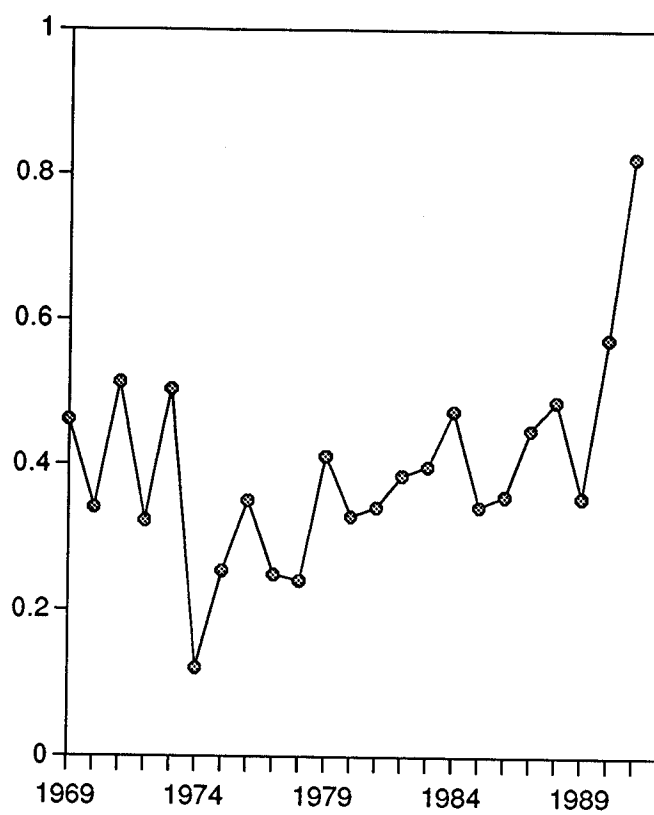


Fig. 9. Fishing mortality (3+) for haddock in unit areas 5Zj and 5Zm.