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Assessment of Haddock on Eastern Georges Bank

by

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ABSTRACT

Landings of haddock from eastern Georges Bank, from the early 1980s to 1993, fluctuated around 5,000 tons. Under restrictive management measures, the 1994 and 1995 landings declined to 2561t and 2164t respectively. The 1995 fisheries were largely supported by the 1991 and 1992 year-classes which comprised about 75% of the landed weight. Survey trends indicate a decline of adult abundance since about 1990 to almost the lowest levels observed but an increase has been observed since 1993. Indices for the 1992 year-class suggest that it is the strongest since the 1983, 1985 and 1987 year-classes.

The adaptive framework was used to calibrate the sequential population analysis to the research survey trends. Biomass for ages 3 and older increased to about 23,000t at the beginning of 1996 after declining to below 10,000t, approaching the historic low. The abundance of the1992 year-class was estimated at about 17 million, comparable to the 1983, 1985 and 1987 year-classes. The fishing mortality rate for ages 4 and older decreased to 0.16 in 1995 from about 0.6 in 1992 and 1993, the highest observed since 1971.

A projected yield of about 6,800t in 1996 would correspond to the $F_{0.1}$= 0.28 fishing mortality rate and result in a marginal increase of about 1,000t for ages 3 and older biomass. Roughly half the projected yield in 1996 and the biomass in 1997 though, was attributed to the 1992 year-class. A risk analysis showed that a catch of 5,000t in 1996 would ensure that the $F_{0.1}$ fishing mortality rate was not exceeded and would enhance the probability that the biomass would increase between 1996 and 1997.

Résumé

Du début des années 1980 à 1993, les débarquements d'aiglefin en provenance de la partie est du banc Georges ont été de l'ordre de 5 000 t. L'application de mesures restrictives en 1994 et 1995 ont fait tomber cette valeur à, respectivement, 2561 t et 2164 t. La pêche de 1995 a largement été alimentée par les classes de 1991 et 1992 qui constituaient 75 % environ du poids des débarquements. Les relevés indiquent un déclin de l'abondance des adultes depuis 1990 environ, à un niveau comptant parmi les plus faibles jamais notés, mais une tendance à la hausse est observée depuis 1993. Les indices obtenus pour la classe de 1992 portent à croire que cette classe est la plus importante à avoir été produite depuis celles de 1983, 1985 et 1987.

La cadre adaptatif a été utilisé pour l'étalonnage de l'analyse séquentielle de population à partir des tendances des relevés recherche. La biomasse des âges 3 et plus s'est accrue pour atteindre 23 000 t environ au début de 1996, après être tombée à moins de 10 000 t, soit presque le minimum historique. L'effectif de la classe de 1992, estimé à 17 millions environ, se compare à celui des classes de 1983, 1985 et 1987. La mortalité par pêche des âges 4 et plus a chuté à 0,16 en 1995; elle était de 0,6 en 1992 et 1993, soit la valeur la plus élevée notée depuis 1971.

Un rendement prévu de 6 800 t environ en 1996 correspondrait au taux de mortalité par pêche $F_{0,1}$ de 0,28 et donnerait lieu à une augmentation marginale de la biomasse des âges 3 et plus de 1 000 t environ. Près de la moitié du rendement prévu en 1996 et de la biomasse de 1997 est cependant attribuée à la classe de 1992. Une analyse des risques a montré que des prises de 5 000 t en 1996 permettraient de ne pas dépasser le taux de mortalité par pêche de niveau $F_{0,1}$ et d'accroître la probabilité que la biomasse augmente entre 1996 et 1997.

DESCRIPTION OF THE FISHERY

The haddock on Georges Bank have supported a commercial fishery since the early 1920's (Clark et al. 1982). Record high landings were reported in the 1960s, reaching about 60,000t for eastern Georges Bank, unit areas 5Zjm (Fig. 1). From 1969 to 1992, landings ranged between 3,800t and 25,000t (Table 1, Fig. 2) and declined since 1992 to just over 2,000t. It was determined that substantial discarding of small haddock from the 1972, 1975 and 1978 year-classes occurred and catches were augmented to account for this (Overholtz et al. 1983). During 1988, almost 2,000t of haddock reported from unit areas 5Zjm in the Canadian fishery were suspected of originating from Division 4X. Landings for the year were adjusted accordingly.

A Total Allowable Catch was introduced in 1970 by the International Commission for the Northwest Atlantic Fisheries. Seasonal closures of haddock spawning areas were also instituted in that year as an adjunct and have been retained by Canada and the USA (Halliday 1988). Since 1977, with the extension of jurisdiction by coastal states, only Canada and the USA have conducted haddock fisheries on Georges Bank. Following the establishment of a maritime boundary in 1984 by the International Court of Justice, the Canadian and USA fisheries have been restricted to their respective jurisdictions.

Under increasingly restrictive management, total Canadian landings decreased from almost 4,000t in 1993 to about 2,000t in 1995. The quota of 2,500t for 1995 was not reached due to closure of the fisheries for most sectors when the cod quota was reached. Prior to 1994, allocations to fishery sectors in recent years have either been exceeded or have not been restrictive.

Fishery Sector	1992		1993		1994		1995	
	Quota	Catch	Quota	Catch	Quota	Catch	Quota	Catch
Fixed gear <65'	1185	1377	1508	1216	791	784	592	357
Mobile gear <65'	2535	1704	2212	1646	1439	1206	1268	1175
Fixed gear 65'-100'	50	5	50	8	30	8	25	0
Mobile gear 65'-100'	50	55	32	32	30	33	25	27
Vessels >100'	1180	853	1198	826	710	290	590	444
Totals	5000	3994	5000	3728	3000	2411	2500	2003

Catches are from quota reports and may not correspond exactly with statistics.

Bottom otter trawl and longline have been the predominant gears in the Canadian fishery and landings by both have declined since 1992 (Table 2). The number of vessels participating in the fishery and the number of trips they made have also been decreasing since 1992. For 1995, vessels on individual quotas were not eligible to depart for a trip on Georges Bank with less than 2t of cod and 8t of haddock quota remaining. Fixed gear vessels were again required to choose between and designate either Georges Bank or Division 4X for their fishery during June to September. They could not fish both stock areas during 1995. Additionally, only vessels with a history since 1990 of 25t or more for 3 years of cod, haddock, pollock, hake or cusk combined could participate in the Georges Bank fishery. A small fish protocol (fisheries would be closed if an unacceptably high proportion of the catch was comprised of small fish) with increased at-sea monitoring was also implemented during 1994 to protect incoming recruitment and continued in 1995. The traditional spawning closure during March 1 to May 31 has been extended to include January and February since 1994. Landings in recent years have generally peaked during June or July (Table 3) though substantial landings have also occurred in the past during the early months of the year. Though some discarding and mis-reporting may have occurred, the quality of information was reported to be much improved since 1992, after the introduction of dockside monitoring.

The USA fishery is almost exclusively an otter trawl fishery (Table 4). In recent years catches have generally been concentrated during the first half of the year, peaking in June (Table 5). During 1994 the USA extended the February to May spawning season closure into June and expanded the restricted area. For 1995, the expanded restricted area was retained and the closure was imposed year round. The 500 lb. haddock trip limit which was also introduced in 1994 continued in 1995. Mandatory log books were introduced in 1994, replacing the existing interview system for obtaining catch and effort information. Statistics for the 1994 and 1995 fisheries were not available but it is estimated that about 150t and 100t of haddock were landed in those years respectively (pers. comm. R.W. Brown, NMFS Woods Hole).

CATCH AND WEIGHT AT AGE

The catch and weight at age for the commercial fishery from 1969 to 1994 were taken from Gavaris and Van Eeckhaute (1995). The catch for 1994 was adjusted for the reduced USA estimated landings. Catch and weight at age for 1995 were calculated by applying age length keys to length frequencies using the methods described by Gavaris and Gavaris (1983). Growth patterns of haddock do not appear to differ between the two unit areas 5Zj and 5Zm or between catches by gears participating in the fishery. Accordingly, age length samples were pooled to construct keys by quarter for each country where information was available. Length compositions of catches can vary between gears, therefore, length frequency samples were pooled within gears and applied to the respective landings before being aggregated to the level of age length keys. When landings occurred in a month-gear category for which samples were not available, suitable adjacent samples were used. Examination of comparative interpretation of ages from otolith samples by the 3 age readers involved did not reveal any problematic inconsistencies (see Appendix A).

The Canadian otter trawl fishery has undergone considerable evolution in recent years with a greater prevalence of square mesh in the codend. During 1995, all otter trawlers used square mesh but the nature of the fishery differed between vessels of tonnage class 3 and less and those of tonnage class 4 and greater. The 1995 Canadian commercial fishery was sampled sufficiently to permit computation of length and age composition for these separately as well as for longline and gillnet catches (Appendix B). The length frequency samples for 1995 were augmented with samples collected by at sea observers as in 1994 since examinations revealed that port and sea samples were comparable. The observer samples were obtained on a set by set basis and these were pooled to the trip level to make them compatible with port samples before being combined with them. The calculations were done using the length-weight relationship which was derived from commercial fishery samples (Waiwood and Neilson 1985) ;

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

During 1995, the otter trawl and longline catches peaked between 50 and 54 cm while the gillnet catches peaked at about 65 cm (Fig. 3) similar to what occurred in 1994.

Processing of USA sample information is linked to the landings database. As noted earlier, the mandatory logbook system introduced in 1994 for USA landings data has resulted in delays. Consequently, samples from the 1994 and 1995 USA fishery were not available. In the absence of samples for the USA fishery, the Canadian age composition for the June otter trawl fishery was applied to the estimated landings as most USA landings in recent years have occurred in the first half of the year. The USA catch at age for 1994 was adjusted to reflect the reduced landings estimate.

The fishery in 1995 was largely supported by the 1991 (average length of 56 cm) and 1992 (average length of 51 cm) year-classes which comprised about 75% of the landed weight. The 1987 (average length of 65 cm) year-class continued to contribute, accounting for about 8% of the landed weight (Fig. 4, Tables 6 - 11). Few age 2 haddock were caught compared to the average proportion caught during 1969-94, and this may be due in part to the use of square mesh by the otter trawl fleets and to monitoring associated with the small fish protocol. There were no marked, persistent, long term trends in weight at age however the year-classes after 1988 appear larger at age during 1991 to 1994. Fishery weights for most of these year-classes decreased in 1995. Weights at age obtained during the Canadian survey were examined to ascertain whether the increase in fishery weights at age observed for cohorts starting at age 2 with the 1989 year-class were reflecting an increase in growth. The average weights at age from the Canadian spring survey for 1986 to 1996 were determined (Fig. 5). The 1989 and 1990 year-class weights were generally higher than adjacent weights though not out of range when compared with the whole series. Cohorts after the 1990 show weights similar to earlier year-classes. The increased weights for the 1989 and 1990 year-classes in addition to fishery related factors are most likely causing the observed increase in weight at age. Contributing factors probably include changes to larger mesh size, the switch from diamond to square mesh for the otter trawlers, the small fish protocol in 1994 and changes in the seasonal pattern of fishing due to, for example, the introduction of ITQ's in 1992.

ABUNDANCE INDICES

Commercial Catch Rate

The catch and effort data from tonnage classes 2 and 3 otter trawlers and longliners for 1993 to 1995 were summarized (Fig. 6). Only those vessels which fished during 1994 and reported more than 1t of landings for the year were selected for inclusion in these comparisons. Further, only trips or sub-trips where gadoid (cod, haddock and pollock) catch was 90% or more of the total catch were included to avoid counting yellowtail or hake/cusk directed effort. For otter trawlers, the catch rate was computed as the catch per hour aggregated by month and tonnage class, while for longliners, the aggregate catch per trip was used since days fished were not available for 1994. The trends suggest that both otter trawl and longline catch rates increased progressively from 1993 to 1995. As in the past, catch rates from the commercial fishery were considered only for qualitative corroboration of results due to concern regarding comparability over years when fishing practices were changing.

Industry/Science Surveys

A survey of the Georges Bank area was completed by five longliners in July of 1995. The area was partitioned into equal sized boxes and one set was selected in each. Gear was standardized between vessels (number of hooks, hook size, bait, etc.) to minimize between vessel variance and boxes were assigned to vessels to achieve a mix of high and low expected catch rates. Twenty-two sets were completed and catches were sampled to determine length frequency and weight caught for cod and haddock. Catch rates and size composition were similar to those observed in the commercial fishery. This is the first year of this survey and as additional years of observation are completed, analyses will be conducted on the trends in abundance.

Research Surveys

Annual depth stratified random surveys have been conducted by the USA in the spring since 1968 and in the fall since 1963 (Fig. 7) and by Canada in the spring since 1986 (Fig. 8). Conversion factors to account for vessel and door changes (Tables 12 and 13) were applied to the USA surveys as suggested by O'Brien and Brown (1996). These conversion factors were slightly different than those used in previous assessments. Results for the 1995 Canadian survey were revised to correct for errors in strata designation of one set. The difference in results, due to these modifications, from those reported by Gavaris and Van Eeckhaute (1995) were minor. Fall survey results were compared to the beginning of year indices from the Canadian and USA spring surveys for the respective cohorts.

The distribution of haddock for 3 age groupings as observed from the three surveys are shown in Figs. 9, 10 and 11. The catches from the most recent surveys, 1995 for the USA and 1996 for Canada, are compared to the 1990 to 1994 long term averages (1990 to 1995 for the Canadian survey). In the fall, age 0 haddock are distributed throughout the 5Zjm survey area, but by spring, at age 1, they are more concentrated on the Canadian side although aggregations occur along the south-west flank in USA territory. In the fall, age 1 haddock are found along the edges of the bank in Canadian territory and have moved westward at age 2 the following spring. Spring concentrations are highest on the Canadian side with aggregations along the southern flank similar to age 1. In fall, the older ages are found along the edge of the bank, similar to the age 1 haddock, and they spread westward in spring, like the age 1 and 2 haddock. The older age groups appear to move somewhat further westward into USA territory. No change in distribution was noted for the most recent survey in each series when compared to the long term average.

Abundance estimates for ages 1 to 4 from the 1995 fall USA survey increased substantially from the previous year's estimates of the same cohorts (Table 16). This may have resulted from the distribution of sampling locations as there were proportionately more sets in areas where abundance is higher, i.e. near the north and east edge of the bank.

Abundance trends for ages 3-8 increased during the late 1970s after having declined to their lowest in the early 1970s. Following a rapid decline in the early 1980s, abundance remained stable at relatively low levels through the mid to late 1980s before declining again in the early 1990s, approaching the lowest levels observed. An increasing trend has been observed since 1992-93 (Tables 14-16, Fig. 13). Note that the fall surveys are compared to the beginning of the subsequent year. Survey results for ages 1 and 2 identified the strong 1975 and 1978 year-classes and the moderate 1983, 1985 and 1987 year-classes. Recruitment since then has been low but the 1992 year-class appears comparable to those of 1983, 1985 and 1987 while the 1993 year-class does not appear as abundant. Preliminary indications suggest that the 1994 and 1995 year-classes are about a third to a half the abundance of the 1992 year-class.

ESTIMATION OF STOCK PARAMETERS

The adaptive framework, ADAPT, (Gavaris 1988) was used to calibrate the sequential population analysis with the research survey results using the following data :

$C_{a,y}$ = catch

for ages a = 1 to 8 and for years y = 1969 to 1995 and

$I_{s,a,y}$ = abundance index

for s = Canadian spring survey, ages a = 1 to 8, years y = 1986 to 1996;
USA spring survey, ages a = 1 to 8, years y = 1969 to 1995;
and USA fall survey, ages a = 0 to 5, y = 1968 to 1995.

The spring survey results were compared to beginning of year population abundance in the same year while the fall survey results were compared to beginning of year population abundance in the following year for the respective cohort. The frequent occurrence of zero catches and the large variation in the relationship between population abundance and USA fall survey indices at ages 6 and 7 led to the exclusion of these ages. All other available data since 1968 were used except when the indices were 0 (logarithm not defined). During years when discarding was high, survey information was used along with interviews to obtain estimates of the USA catch. This lack of complete independence between catch and survey data does not influence population estimates but may deflate variance estimates marginally. The model formulation employed assumed that the error in the catch at age was negligible. The error in the survey abundance indices was assumed to be independent and identically distributed after taking natural logarithms of the values. Natural mortality, M, was assumed constant and equal to 0.2 and fishing mortality, F, for age 8 was assumed equal to the arithmetic average for ages 4 to 7.

Following Gavaris (1993), a model formulation using as parameters the ln population abundance at the beginning of the year following the terminal year for which catch at age is available was considered. The following model parameters were defined:

$\theta_{a,1996}$ = ln population abundance
for a = 1 to 8 at the beginning of the year 1996,

$\kappa_{s,a}$ = ln calibration constants
for each survey source, denoted by s, and the relevant ages.

ADAPT was used to solve for the parameters by minimizing the sum of squared differences between the ln observed abundance indices and the ln population abundance adjusted for catchability. The objective function for minimization was defined as

$$\Psi_{s,a,y}(\theta,\kappa) = \sum_{s,a,y}\left(\ln I_{s,a,y} - \kappa_{s,a} + \ln N_{a,y}(\theta)\right)^2$$

For convenience, the beginning of year population abundance $N_{a,y}(\theta)$ is abbreviated by $N_{a,y}$. For year y = 1996, the population abundance was obtained directly from the parameter estimates, $N_{a,1996} = e^{\theta_{a,1996}}$. For all other years, the population abundance was computed using the virtual population analysis algorithm which incorporates the exponential decay model

$$N_{a,y} = N_{a+1,y+1} e^{F_{a,y}+M}$$

where the natural mortality M is assumed and the fishing mortality $F_{a,y}$, for ages a = 1 to 7, is obtained by solving the catch equation using a Newton-Raphson algorithm

$$N_{a,y} = \frac{C_{a,y}\left(F_{a,y} + M\right)}{F_{a,y}\left(1 - e^{-(F_{a,y}+M)}\right)}$$

The fishing mortality rate for age 8 was assumed equal to the average for ages 4 to 7.

$$F_{8y} = \sum_{a=4}^{7} F_{ay} \Big/ 4$$

The magnitude of the residuals is large, particularly for younger ages in the USA fall surveys. The text table below shows the average of squared residuals for each series.

Survey	Age							
	1	2	3	4	5	6	7	8
Can. Spring	.58	.93	.29	.21	.52	.62	.66	.19
USA Spring	1.12	.86	.60	.31	.50	.88	1.34	.79
USA Fall	1.37	1.79	1.23	.74	.61	.76		

Though several large residuals occur (Fig. 12), the respective observations do not appear to be influential and should not unduly distort parameter estimates. For example, the Canadian survey observation for age 1 in 1987 appears low but the calibration line appears to fit the other observations. The residuals for the most recent year of observation are generally small except for the USA fall survey at age 3 where it is amongst one of the larger residuals. The age 3 USA fall survey abundance accounted for about half of the total abundance, an unexpected result as the 1993 year-class is not estimated to be that strong in any other survey. The variance and bias of population abundance estimates and corresponding projected yield were derived using an analytical approximation (Gavaris 1993). The population abundance estimates show a large relative error and substantial bias at ages 1 and 2 reflecting the variability in the abundance indices (Table 17). However, the survey indices, scaled by the calibration constants and converted to biomass, correspond well with the trends estimated by the sequential population analysis (Fig. 13).

Index error assumptions

Myers and Cadigan (1995) reported that correlated errors among ages within years of a survey can be sufficiently large to produce model mis-specification biases in estimates of population parameters from standard assessment methods. Their simulation however, showed that maximum likelihood estimators from models which ignored correlation performed similar to those from models which incorporated correlation when the correlated errors were small, e.g. $\rho = 0.15$. An estimate of the correlation between ages within years was computed using the standard sample estimator for the coefficient of linear correlation where the pairs of observations were the residuals from each abundance index source: $\left(e_{i,y}, e_{j,y}\right)$ for all ages $i \neq j$ and all years y. For the three survey sources used in this assessment, the correlation was found to be small; Canadian spring survey $\hat{\rho} = 0.01$, USA spring survey $\hat{\rho} = 0.17$ and USA fall survey $\hat{\rho} = 0.18$. Accordingly, no further corrective measures were taken to account for bias from this type of model mis-specification for this stock.

Catch at age error assumptions

The calibration model employed assumes that the catch at age is known without error. Some calibration models allow for random error in the observed catch at age but to keep the number of estimated parameters at a practicable small number, they impose a constant exploitation pattern by age over years. We consider that the random error in the catch at age is indeed small relative to the error in the indices but that systematic error in the catch at age which may be introduced due to biased reporting of landings could be significant. Systematic errors are not adequately handled by models which assume random error. To investigate the impact of such systematic error, we employed two alternative models which did not use the suspect data and compared the results with those from the previous traditional assessment (Gavaris and Van Eeckhaute 1995). With both these models, only relative year-class abundance and fishing mortality rates can be estimated. Estimation of absolute abundance requires scaling of the sequential population analysis with known catch at age. For convenience in comparisons, the relative year-class abundances were scaled to the 1994 age 1 abundance from the traditional calibration. The approach is similar to that described by Gavaris (1991) for exploring how ADAPT could be used with alternative model assumptions and information sources to investigate the robustness of parameter estimates from traditional calibration models. The following text table summarizes the traditional and variant model formulations. Details of the computations for the alternative models are provided in Appendix C.

	Traditional	Proportion Caught at Age and Abundance Indices	Abundance Indices
Input Data	$C_{a,y}$ = catch ages a = 1 to 8 years y = 1969 to 1995	$P_{a,y}$ = proportion caught ages a = 1 to 8 years y = 1969 to 1994	N/A
	$I_{s,a,y}$ = abundance index s = Canadian spring survey, ages a = 1 to 8, years y = 1986 to 1996; USA spring survey, ages a = 1 to 8, years y = 1969 to 1995; USA fall survey, ages a = 0 to 5, y = 1968 to 1995		
Parameters	$\theta_{a,1996}$ = ln population abundance ages a = 1 to 8 at the beginning of the year 1996	$\theta_{a,1996}$ = ln population abundance ages a = 2 to 8 at the beginning of the year 1996	
	$\kappa_{s,a}$ = ln calibration constants	$\kappa_{s,a}$ = ln calibration constants common calibration constant for ages 3 to 8	
	N/A	$\varphi_{5,y}$ = ln fishing mortality years y = 1969 to 1994	$\varphi_{a,y}$ = fishing mortality ages a=2,3,4 years y = 1969 to 1994
Objective function	$\underset{s,a,y}{\Psi}(\theta,\kappa) = \sum_{s,a,y}\left(\ln I_{s,a,y} - \kappa_{s,a} + \ln N_{a,y}(\theta)\right)^2$		
Assumptions	constant natural mortality; M = 0.2		
	$F_{8y} = \sum_{a=4}^{7} F_{ay} \Big/ 4$	N/A	$N_{8,y} = \sum_{a=4}^{7} \frac{N_{a,y}P_{8,y}}{P_{a,y}} \Big/ 4$

The first model option represents the situation where landings are not reported accurately due to non-reporting or mis-reporting by area or species. Samples obtained from the fishery though, would be representative of the size and age composition of the catch. This model estimates relative year-class abundance and fishing mortality using abundance indices and proportion caught at age in the commercial fishery based on sampling information but does not employ landings data. The results from this model agree fairly well with those from the traditional calibration model (Fig. 14). The relative magnitude of most year-classes showed good correspondence except for the 1971, 1972 and 1975 year-classes. Fishing mortality estimates were erratic, displaying more extreme values, but their average magnitude approximated estimates from the traditional model. The wide fluctuations in fishing mortality are a reflection of the variability in the abundance indices. Fishing mortality estimates from traditional calibration models are tempered by the information contained in the catch at age.

The second model option represents the case where activities at sea such as high-grading, discarding or dumping distort the estimates of proportion caught at age which are obtained by sampling landings. This model considers that even the sampling information is unreliable and estimates relative year-class abundance and fishing mortality using abundance indices, employing proportion caught at age only for fully recruited ages to calculate oldest age abundance. The results from this model indicate that estimates of year-class abundance for larger year-classes prior to the early 1980s were generally greater than traditional estimates (Fig. 15). This could have been caused by greater discarding at sea of small haddock during those years, resulting in unrepresentative sampling. Estimated fishing mortality at age 2 was very erratic and was also considerably higher than the traditional estimates on average. This reflects the confounding of survey catchability and survival for ages which are not fully recruited to the fishery. Essentially, it is not possible to estimate mortality on the ascending limb of a catch curve. Estimated fishing mortality for age 3 and for ages 4+ are also fairly erratic but their average level generally corresponds to the estimates from the traditional model. This reflects the variability of abundance index estimates and confirms that annual estimates of total mortality obtained from indices alone will be too imprecise for practical purposes but it may be possible to extract average trends. It appears then that the general level of exploitation estimated from the traditional model may not be unduly impacted by the degree of high-grading, discarding or dumping which might have occurred, but the estimates of relative year-class abundance may be distorted.

The comparison of results from these two model variants and the traditional model suggest that the information on year-class abundance estimates contained in the abundance index observations may not be consistent with the sequential population information contained in the catch at age. To investigate further whether the estimates of abundance for contemporary year-classes may be biased due to systematic errors in the catch at age, the traditional assessment model was applied to data since 1981. This was done because it is known that there were substantial discards at ages 1 and 2 of the 1975 and 1978 year-classes (Overholtz et. al. 1983). The comparison in the following text table suggests that use of all years from 1969-96 results in somewhat lower contemporary population abundance estimates. Considering the uncertainty in the estimates, these differences would not be significant but the pattern warrants further investigation.

Years	Age								
	1	2	3	4	5	6	7	8	9
1969-96	5738	4420	5965	8645	2079	339	193	13	363
1981-96	6832	5234	6742	9505	2357	392	233	21	434

Age structure assumptions

Calibration of sequential population analysis relies on age structured data. Production models offer an alternative for estimation of stock status. They are typically less demanding of information, not requiring age structure, but they incorporate more assumptions about population dynamics than calibrated sequential population analysis models. ASPIC, a production model which accepts multiple indices of abundance (Prager 1994, 1995), was used to estimate population parameters and reconstruct the predicted stock history. The yield for ages 3 and older was used with the survey biomass for ages 3 and older, from the three survey sources, in fitting the model. These data did not fit the model well, particularly near periods of high recruitment when biomass was low. Production models implicitly incorporate a stock-production relationship and do not perform well for relatively short lived species with highly variable recruitment which is not correlated to stock biomass (Prager 1994). The results from these attempts were not considered reliable and are not reproduced here.

ASSESSMENT RESULTS

The examination of parameter estimates and diagnostics and the evaluation of assumptions regarding error correlation, catch misreporting and age structure, indicate that the results from the traditional SPA calibration model using all data from 1969 should provide a reasonable basis for interpretation of stock status. For each cohort, therefore, the terminal population abundance estimates from ADAPT were adjusted for bias and used to construct the history of stock status (Tables 18,19). Gavaris and Van Eeckhaute (1994) considered that this approach for bias adjustment, in the absence of an unbiased point estimator with optimal statistical properties, was preferable to using the biased point estimates. The weights at age from the Canadian spring survey (Table 20) were used to calculate beginning of year population biomass for 1986-96 (Table 21). A weight of 2.6 kg was used for age 7 in 1995. For 1969-85, the 1986-96 average weight at each age was used. A weight of 3.4 kg was used for age 9 in all years.

By the mid 1970s, following heavy exploitation by foreign distant water fleets, biomass had decreased to its lowest recorded level, but subsequently increased as the strong 1975 and 1978 year-classes recruited (Figs. 16, 17). The stock biomass again declined rapidly in the early 1980s as subsequent recruitment was poor and these two year-classes were fished intensely at a young age (Fig. 18). The biomass fluctuated around 18,000t during the late 1980s, supported by the 1983, 1985 and 1987 year-classes, which were estimated to be the most abundant since the strong 1975 and 1978 year-classes, before declining to about 13,000t in 1993. The biomass has since steadily increased to about 26,000t in 1996. The recent increase, due principally to the 1992 year-class, but also supported by the 1991 and 1993 year-classes, was enhanced by increased weight at age of haddock from the 1989 and 1990 year-classes as well as increased survivorship of young haddock from reduced capture of small fish in the commercial fisheries. The biomass trend for ages 3 and older is similar to total biomass but at a lower magnitude. The strength of the 1992 year-class was estimated to be about 17 million, comparable to the 1983, 1985 and 1987 year-classes while those between 1987 and 1991 were weak (Table 18 and Fig. 17). The 1991 and 1993 year-classes were estimated at about a third to a half of the magnitude of the 1992 year-class while the 1994 year-class was estimated to be weaker at about 5 million. Early indications for the 1995 year-class suggest that it is also weak at about 5 million. The fishing mortality rate for ages 4 and older has generally exceeded $F_{0.1} = 0.25$ and increased markedly between 1989 and 1992 to about 0.6, amongst the highest observed (Table 19 and Fig 18). The previous occasion when the fishing mortality exceeded 0.5 was during the early 1970s when abundance was at its lowest. The exploitation rate declined moderately in 1993, but then more substantially in 1994 and 1995 to a level below the $F_{0.1}$ target.

Results from assessments for several other stocks have revealed a discrepancy between past estimates of stock status and current estimates using additional data. Generally, the current estimates are more optimistic but as additional data becomes available, the current view of the past is more pessimistic. This characteristic has been referred to as a retrospective pattern. Examination of year-class estimates at age 1 from assessments done using a comparable formulation with years 1990 through 1995 considered the terminal year for the assessment show remarkable consistency (Fig. 19). It was concluded that this stock assessment does not suffer from a retrospective pattern.

The Georges Bank ecosystem is complex with numerous species interactions. Further, species adapt to fluctuations in abundance of both their prey and predators. These interactions were modeled by a constant natural mortality and there were no indications that this assumption was severely violated. Currently available information does not permit more complex models to be employed.

Environmental conditions on Georges Bank have varied but have not displayed extreme deviations in recent years (Page et. al. 1996). Though environmental conditions are thought to influence fisheries processes, convincing relationships with quantities such as recruitment, survival rates and fish catchability have not been established.

Yield Per Recruit

Clark et al. (1982) reported results from a yield per recruit analysis showing $F_{0.1}$ ranging from 0.21 to 0.26 with the age of full recruitment ranging from 2-3. Gavaris (1987) investigated the effect of varying minimum fish size on yield per recruit and effort under an $F_{0.1}$ strategy. Recent assessments have used an $F_{0.1}$ of 0.25 (Gavaris and Van Eeckhaute 1995) and 0.24 (O'Brien and Brown 1996).

Recently, a significant gear change occurred in Canada during 1993 and 1994 when diamond mesh otter trawl gear was replaced with square mesh. By 1995 all Canadian otter trawlers were required to use square mesh. The change in gear selectivity on smaller fish can potentially affect the partial recruitment to the fishery and the fishery weights at age. A yield per recruit analysis was therefore undertaken to determine the impact on $F_{0.1}$.

Yield per recruit was determined using the Thompson and Bell method (Rivard 1982). Average weights at age were determined from the annual average weights at age from the 5Zjm commercial fishery (Fig. 20). For ages 1 to 3, 1993-95 weight data was used as these years reflect the change in gear selectivity for the younger fish. For the fully recruited ages, 4-16, 1985-95 data were used as these years were viewed as representative of the recent seasonal fishing pattern. Three outliers, two in 1994 at age 13 and 14 and one at age 12 in 1980 were omitted as only 2, 1 and 1 fish, respectively, were aged. Partial recruitment to the fishery has changed in recent years and values used follows Gavaris and Van Eeckhaute (1995). The oldest age was based on the oldest observed age from Canadian surveys since 1986 and Canadian commercial fishery samples. The input data are summarized below:

Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Wgt.(kg)	0.62	1.111	1.63	1.903	2.235	2.569	2.878	3.26	3.395	3.549	3.968	4.235	4.273	4.288	4.505	4.798
PR	0	.05	.5	1	1	1	1	1	1	1	1	1	1	1	1	1

The resulting yield per recruit and yield per unit effort are shown in Fig. 21. $F_{0.1}$ increased to 0.28 from 0.25, the value used in previous assessments of this stock.

PROGNOSIS

Yield projections were done using the 1995 beginning of year population numbers as estimated from ADAPT, the average fishery catch weight at age for 1993-95 for the yield and the average Canadian spring survey weight at age for 1994-96 for the beginning of year biomass. Following Gavaris and Van Eeckhaute (1994), the partial recruitment to the fishery for ages 1, 2 and 3 was 0, 0.05 and 0.5 respectively. The abundance of year-classes after 1995 was assumed to be 10 million, but this assumption does not affect short term forecasts. As with the population abundance estimates, the adjustment for bias of the projected yield was considered more appropriate than using the biased point estimate. The projected yield at $F_{0.1} = 0.28$ in 1996 would be about 6,800t with the 1992 year-class accounting for more than half of the landed weight (Table 22, Fig. 22). The biomass for ages 3 and older is projected to increase marginally from 23,000t to over 24,000t at the beginning of 1997 with the 1992 year-class accounting for almost half of that biomass.

MANAGEMENT CONSIDERATIONS

With the current state of the stock, the 1992 year-class makes a relatively large contribution to the projected yield. As the 1992 year-class gets fished down, the biomass will decline unless there is good recruitment. Uncertainty regarding the abundance of any single year-class gets translated to the projected yield which, in this case, had a relative error of roughly 25%. A yield of about 5,000t should ensure that $F_{0.1}$ is not exceeded and increases the chances that the biomass for ages 3 and older will increase between 1996 and 1997 (Fig. 23). The calculations of uncertainty are based on approximations and do not include variations in weight at age or partial recruitment and other factors but should provide useful rough guidelines. Increasing the number of age groups contributing to the yield should lead to greater precision in the advice. Increased abundance over a broader age span would also moderate fluctuations in biomass caused by recruitment variability and result in more stable yield between years. A larger spawning biomass could enhance recruitment by capitalizing on the opportunities for greater egg and larval survival when environmental conditions are favorable.

The projected increase in haddock abundance is due primarily to recruitment of one year-class, the moderately strong 1992 year-class, but is also bolstered by the adjacent 1991 and 1993 year-classes. Continuing conservation efforts such as low exploitation and fishing practices.

which permit recruits to realize their growth and reproductive potential are needed to sustain the rebuilding of the population biomass and to expand the age structure.

Carry-over allocations

The Groundfish Management Plan is issued annually and designates allocations to fishermen for the calendar year. The allocations must be caught in the calendar year in which they are granted. For a variety of reasons other than low abundance of the target species, fishermen may choose not to catch their entire allocation (Gavaris and d'Entremont in press). Fishermen with some of their allocation remaining at the end of the year receive no credit though leaving fish in the water may have actually been beneficial or at worst, benign. Consequently allocations are often viewed as a limit which must be reached by the end of the year. This may lead to dangerous situations where fishermen sail under unfavorable conditions towards the end of the year in order to catch their remaining allocation rather than lose it. Further, in complex multi-species fisheries, fishermen are challenged to exhaust all their allocations simultaneously. This situation may create an undesirable incentive to dump species with lower quotas. Finally, in multi-species fisheries, a fisherman may choose, for operational reasons, not to pursue a particular fishery in a given year. These fishermen are faced with foregoing any benefits, temporarily selling their allocation or permanently selling their allocation.

The complications created by annual allocations may be alleviated by permitting fishermen to carry-over uncaught allocation into the subsequent fishing season (Gavaris and d'Entremont in press). This is accomplished by taking the uncaught quantity and projecting it forward into the subsequent fishing season to determine what amount it would represent after accounting for losses due to natural deaths and gains due to fish growth. This amount would be the maximum carry-over. Using the 1995 haddock fishery in 5Zjm as an example, where about 436t were left uncaught during 1995, the maximum carry-over into 1996 would be 445t. It was assumed that the age composition of the 436t of uncaught haddock was the same as that for the 2,064t which were caught (Table 23). The numbers were diminished by applying the assumed natural mortality rate of 0.2 for a period of one year (Table 23, Fig. 24). The carry-over biomass for 1996 was obtained by applying the weight at age to the carry-over numbers. Though there is a net loss in weight for older year-classes, fast growth at younger ages results in a net gain for tonnage carried over (Table 23, Fig. 25).

Allowing a carry-over may lead to greater depletion of the population biomass than would have occurred if the allocations had been caught in the year they were granted. To prevent this, the maximum carry-over is reduced to the permitted carry-over level. To determine the permitted carry-over in the haddock example, a projection is conducted starting with the 1995 estimated population abundance, assuming that the full 2,500t allocation was caught and forecasting for 1996 at the target fishing mortality rate, $F_{0.1} = 0.28$. This results in a beginning of year 1997 biomass for ages 2 and older (age 1 is assumed recruitment) of 26,659t and a yield in 1996 of 6,691t. The yield of 6,691t is the amount that would be allocated in 1996 according to traditional shares. If the maximum carry-over of 445t were allowed the total allocation in 1996 would amount to 7,136t. A projection starting with the 1996 estimated population abundance, assuming a catch of 7,136t in 1996, results in a 1997 beginning of year biomass of 26,601t, less than the

26,659t benchmark. A projection starting in 1996, assuming a catch of 7,091t in 1996, which corresponds to a 400t carry-over, results in a 1997 beginning of year biomass approximating the 26,659t benchmark. Therefore, the permitted carry-over for 1996 would be about 400t and could be allocated among those fishery sectors which had not caught their allocations in proportion to the amount they had left.

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LITERATURE CITED

Clark, S. H., W. J. Overholtz, and R. C. Hennemuth. 1982. Review and assessment of the Georges Bank and Gulf of Maine haddock fishery. J. Northw. Atl. Fish. Sci. 3: 1-27.

Gavaris, S. 1987. An evaluation of the effect of minimum fish size on yield per recruit for Georges Bank haddock. CAFSAC Res. Doc. 87/37: 13 p.

Gavaris, S. 1988. An adaptive framework for the estimation of population size. CAFSAC Res. Doc. 88/29: 12 p.

Gavaris, S. 1991. Experience with the adaptive framework as a calibration tool for finfish stock assessment in CAFSAC. ICES C.M. 1991/D:19 Sess. U. 8p. + corrigendum.

Gavaris, S. 1993. Analytical estimates of reliability for the projected yield from commercial fisheries. p. 185-191. In S.J. Smith, J.J. Hunt and D. Rivard [ed.] Risk evaluation and biological reference points for fisheries management. Can. Spec. Publ. Fish. Aquat. Sci. 120.

Gavaris, S. and J. G. d'Entremont. 1996. Phased implementation of local fishery management opportunities under conservation constraints. In D.L. Burke, R.N. O'Boyle, P. Partington and M. Sinclair. Report of the second workshop on Scotia-Fundy groundfish management. Can. Tech. Rep. Fish. Aquat. Sci. 2100: vii + 247p.

Gavaris, S. and C.A. Gavaris. 1983. Estimation of catch at age and its variance for groundfish stocks in the Newfoundland Region. In Doubleday, W.G. and D. Rivard [ed.] Sampling commercial catches of marine fish and invertebrates. Can. Spec. Publ. Fish. Aquat. Sci. 66: 1-290.

Gavaris, S. and L. Van Eeckhaute. 1994. Assessment of haddock on eastern Georges Bank. DFO Res. Doc. 94/31: 38 p.

Gavaris, S. and L. Van Eeckhaute. 1995. Assessment of haddock on eastern Georges Bank. DFO Res. Doc. 95/6: 36 p.

Halliday, R.G. 1988. Use of seasonal spawning area closures in the management of haddock fisheries in the Northwest Atlantic. NAFO Sci. Coun. Studies 12: 27-36.

Myers, R.A. and N.G. Cadigan. 1995. Statistical analysis of catch-at-age data with correlated errors. Can. J. Fish. Aquat. Sci. 52: 1265-1273.

O'Brien, L. and R.W. Brown. 1996. Assessment of the Georges Bank haddock stock for 1994. Northeast Fisheries Science Center Reference Document 95-13, Woods Hole, Ma.

Overholtz, W.J., S.H. Clark and D.Y. White. 1983. A review of the status of the Georges Bank and Gulf of Maine haddock stocks for 1983. Woods Hole Lab. Ref. Doc. No. 83-23.

Page, F., R. Losier and J. McRuer. 1996. Overview of near-bottom water temperature and salinity conditions observed during the groundfish research vessel surveys conducted within the Scotia-Fundy Region, NAFO areas 4VWX and 5Z in 1995. DFO Res. Doc. 96/20.

Prager, M.H. 1994. A suite of extensions to a nonequilibrium surplus-production model. Fish. Bull. (U.S.) 92: 374-389.

Prager, M.H. 1995. A stock-production model incorporating covariates, program version 3.6x. Miami Lab. Doc. MIA-92/93-55: 29 p.

Rivard, D. 1982. APL programs for stock assessment (revised). Can. Tech. Rep. Fish. Aquat. Sci. 1091: 146 p.

Waiwood K.G. and J.D. Neilson. 1985. The 1985 assessment of 5Ze haddock. CAFSAC Res. Doc. 85/95:49 p.

Appendix A. Aging comparisons.

There are 3 readers for 5Z haddock, N. Munroe for the USA and M. Strong and L. Van Eeckhaute for Canada. A summary of inter-reader tests between the 3 readers and intra-reader tests for the Canadian readers is presented in Table A1. Percent agreement is calculated as: the number of otoliths aged the same ÷ by the no. aged by both readers × 100.

Otoliths for the USA/Canada exchange were selected from the USA spring and fall 1993 and 1994 and the spring 1995 surveys. N. Munroe's ages for the 1995 spring survey were not available for this report. Otoliths for Canadian tests were selected from the 1994 and 1995 commercial fishery samples and from the 1995 spring survey. Otolith selections for Canadian tests covered the entire length range and incorporated seasonal aspects.

Intra-reader tests

Percent agreements for L. Van Eeckhaute and M. Strong were 88% and 81%, respectively, with no bias detected.

Inter-reader tests

Although there was some bias between the Canadian readers versus the USA reader, agreement was considered acceptable and the bias was not expected to impact results substantially. To address the bias problem, images of the problem otoliths with L.Van Eeckhaute's interpretations were sent to NEFSC so that age interpretations could be compared. Results have not yet been received.

Canadian inter-reader agreement for the Can/USA exchange was acceptable at 79% with no bias detected. Agreement for the 1994 commercial fishery samples and the Canadian spring survey was somewhat lower but still acceptable at 77%, however some bias was detected (see Table A1). To address the bias problem, interpretations were compared using annotated images. Several causes were identified (numbers following indicate frequency of problem):

- when reading the proximal axis, one reader assigned 2 hyaline zones to the 2nd annulus while the other reader counted each zone as an annulus (5)
- difference in interpretation of 1st and 2nd annulus on ventral axis (4)
- several otoliths were cut off center making interpretation more difficult (3)
- interpretation of hyaline zone as check or annulus (2)
- edge counted by one reader and not the other (2)

No bias was observed in the last test using otoliths from the 1995 commercial fisheries samples, which followed the above comparison of age interpretations, and agreement was satisfactory.

Questionable ages identified by inter-reader tests and comparison of age-length keys from the two Canadian readers were re-examined as well as 50 otoliths which were cut off center in the Canadian spring survey. Those without consensus were omitted from the database and ages revised where appropriate.

Table A1. Summary of inter- and intra-reader aging tests for 5Z haddock in 1995.

Source		Qty	Production Read By	Test Requirements LVE	Test Requirements MS	Test Results: Between Reader NMxMS	NMxLVE	MSxLVE		Within Reader MS	Within Reader LVE
Can/USA	9302	39	NM	39	39	72%	83%	79%			
	9306	14	NM	14	14	(105)	(105)	(155)			
	9402	33	NM	33	33	NM+	NM+				
	9406	19	NM	19	19						
	9503	50	NM	50	50						
CGS 1994	Q2	36	LVE	36	36			77%	77%		88%
(Blind	Q4	32	LVE	32	32			(68)	(103)		(68)
Test)	Q3	35	MS	35	35			75% (35)	MS+	69% (35)	
N216	1-350	350	MS	30	30			71% (65)		96% (30)	
	351-700	350	LVE	35	35			MS-			88%(35)
CGS 1995	Q2	166	LVE		108			83% (109)			
		0	MS								
	Q3	53	LVE								
		231	MS	105				85% (105)			
	Q4	108	LVE								
		113	MS								

NM=N. Munroe
MS=M. Strong
LVE=L. Van Eeckhaute

Ageing bias is indicated by a '+' or '-' after initials, indicating overaging or underaging, with respect to the other ager.
CGS=Commercial Fishery Samples

Appendix B. Derivation of catch at age for the 1995 5Zjm haddock fishery.

Country	Qtr.	Length Frequency Samples										Aged Samples	
		Gear	Month	Observer		Port		Landings	Combinations				
				Samples	Measured	Samples	Measured	(kg)				No. of Samples	No. Aged
Canada	1	Misc.	Jan	1	117			1,284	JanMisc		CanQ1	5	166
			Feb					744					
			Mar	2	123			1,103	MarMisc				
	2	OTIN	June	2	1701	3	841	572,281	Q2OTOF		CanQ2		
		OTOF	June			2	401	123,595	Q2OTIN				
		GN	June			1	228	3,299	Q2GN				
		LL	June	3	396			61,941	Q2LL				
		Misc	Apr					674					
			May					345					
			June					1,123					
	3	OTIN	Jul	2	1573			179,879	JulOTIN		CanQ3	10	277
			Aug			8	1873	196,238	AugOTIN				
			Sept			2	455	171,276	SepOTIN				
		OTOF	Jul	Used Q2OTOF				16,518	Q3OTOF				
			Sept					29,801					
		GN	Jul	Used Q2GN				3,992	Q3GN				
			Sept					14,231					
		LL	Jul	2	147			124,187	Jul LL	Q3LL			
			Aug	5	2799			92,899	AugLL				
			Sept					65,308					
		Misc	Jul					1,235					
			Aug					452					
			Sept					8					

Country	Qtr.	Length Frequency Samples										Aged Samples	
		Gear	Month	Observer		Port		Landings (kg)	Combinations				
				Samples	Measured	Samples	Measured					No. of Samples	No. Aged
Canada	4	OTIN	Oct			1	200	90,559	OctOTIN	Q4OTIN	CanQ4	8	209
			Nov	1	463	6	1370	138,200	NovOTIN				
			Dec			1	230	70,345					
		OTOF	Oct					76		Q4OTOF			
			Nov	5	1611	2	469	36,893	NovOTOF				
			Dec	1	35	1	215	21,259	DecOTOF				
		LL	Oct					18,539	Q4LL				
			Nov			1	234	21,543					
			Dec					4,323					
	Totals			24	8,965	28	6,516	2,064,151			CAN	23	652
USA	Total	Can. If samples from JunOTIN						100,000			USA		
Total landings for Canada and USA								2,164,151					

OT=Otter Trawl, GN=Gill Net, LL=Long Line, IN=Inshore (Tonnage Classes <=3), OF=Offshore (Tonnage Classes >=4), Q=Quarter

Appendix C. Alternative models which did not use catch at age.

Proportion Caught at Age & Abundance Indices

This model estimates relative year-class abundance and fishing mortality using abundance indices and proportion caught at age in the commercial fishery based on sampling information but does not employ landings data:

$P_{a,y}$ = proportion caught at age in year y

for ages a = 1 to 8 and for years y = 1969 to 1994 and

$I_{s,a,y}$ = abundance index

for s = Canadian spring survey, ages a = 1 to 8, years y = 1986 to 1995
USA spring survey, ages a = 1 to 8, years y = 1969 to 1994
and USA fall survey, ages = 0 to 5, y = 1968 to 1994

The following model parameters were defined:

$\theta_{a,1995}$ = ln population abundance

for a = 2 to 8 at the beginning of the year 1995,

$\varphi_{5,y}$ = ln fishing mortality

for age 5 and years y = 1969 to 1994 and

$\kappa_{s,a}$ = ln calibration constants

for each survey source, denoted by s, and the relevant ages.

Results from a preliminary trial indicated that ages 3 to 8 were fully recruited to the spring surveys. To minimize the number of parameters estimated, a constant calibration constant was used for ages 3 to 8 for each of the Canadian and USA spring surveys. The objective function for minimization was defined as

$$\Psi_{s,a,y}(\theta,\varphi,\kappa) = \sum_{s,a,y}\left(\ln I_{s,a,y} - \kappa_{s,a} + \ln N_{a,y}(\theta,\varphi)\right)^2$$

For convenience, the beginning of year population abundance $N_{a,y}(\theta,\varphi)$ is abbreviated by $N_{a,y}$. For year y = 1995, the population abundance was obtained directly from the parameter estimates, $N_{a,1995} = e^{\theta_{a,1995}}$. For all other years, the population abundance was computed using the virtual population analysis algorithm which incorporates the exponential decay model

$$N_{a,y} = N_{a+1,y+1}e^{F_{a,y}+M}$$

where the natural mortality M is assumed and the fishing mortality $F_{a,y}$, a ≠ 5, is obtained by solving the following equation using a Newton-Raphson algorithm

$$\frac{N_{a+1,y+1}F_{a,y}\left(e^{F_{a,y}+M}-1\right)}{P_{a,y}\left(F_{a,y}+M\right)}=\frac{N_{6,y+1}F_{5,y}\left(e^{F_{5,y}+M}-1\right)}{P_{5,y}\left(F_{5,y}+M\right)}$$

and $F_{5,y}=e^{\varphi_{5,y}}$.

During the iterative estimation process, some $\varphi_{5,y}$ values tended towards zero, therefore it was necessary to constrain estimation by applying a penalty function for $\varphi_{5,y}$ estimates less than 0.05.

Abundance Indices

This model estimates relative year-class abundance and fishing mortality using abundance indices, employing proportion caught at age only for fully recruited ages to calculate oldest age abundance:

$I_{s,a,y}$ = abundance index

for s = Canadian spring survey, ages a = 1 to 8, years y = 1986 to 1995
USA spring survey, ages a = 1 to 8, years y = 1969 to 1994

and USA fall survey, ages = 0 to 5, y = 1968 to 1994

The following model parameters were defined:

$\theta_{a,1995}$ = ln population abundance
for a = 2 to 8 at the beginning of the year 1995,

$\varphi_{a,y}$ = fishing mortality
for ages a=2,3,4 and years y = 1969 to 1994 and

$\kappa_{s,a}$ = ln calibration constants
for each survey source, denoted by s, and the relevant ages.

As was done with the first model, a constant calibration constant was used for ages 3 to 8 for each of the Canadian and USA spring surveys. The objective function for minimization was defined as

$$\underset{s,a,y}{\Psi}(\theta,\varphi,\kappa)=\sum_{s,a,y}\left(\ln I_{s,a,y}-\kappa_{s,a}+\ln N_{a,y}(\theta,\varphi)\right)^{2}$$

For convenience, the beginning of year population abundance $N_{a,y}(\theta,\varphi)$ is abbreviated by $N_{a,y}$. For year y = 1995, the population abundance was obtained directly from the parameter estimates, $N_{a,1995}=e^{\theta_{a,1995}}$. For all other years, the population abundance was computed using the virtual population analysis algorithm which incorporates the exponential decay model

$$N_{a,y} = N_{a+1,y+1} e^{F_{a,y}+M}$$

where the natural mortality M is assumed and the fishing mortality $F_{a,y}$, for ages 2,3 and 4 was obtained from $F_{a,y} = \varphi_{a,y}$. The fishing mortality for age 1, was assumed to be zero for all years and the fishing mortality for ages 5 to 8 was assumed to be equal to the fishing mortality at age 4 in the same year. The population abundance at age 8 for years y = 1969 to 1994 was calculated using the proportion caught at age for ages 4 to 8

$$N_{8,y} = \sum_{a=4}^{7} \frac{N_{a,y} P_{8,y}}{P_{a,y}} \Big/ 4 .$$

Table 1. Nominal catches (t) of haddock from unit areas 5Zjm. For "others" it was assumed that 40% of the total 5Z catch was in 5Zjm.

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[1]
1975	1353	1705	29	3087
1976	1355	973	24	2352
1977	2871	2429	0	9174[1]
1978	9968	4724	0	16269[1]
1979	5080	5211	0	10291
1980	10017	5615	0	25036[1]
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	6121
1988	4046[2]	1693	0	5739
1989	3059	787	0	3846
1990	3340	1189	0	4529
1991	5446	931	0	6377
1992	4061	1629	0	5690
1993	3727	421	0	4148
1994	2411	150[3]	0	2561
1995	2064	100[3]	0	2164

[1] Values augmented by 760t, 3874t, 1577t, and 9404t in 1974, 1977, 1978, and 1980, respectively, to account for USA discards

[2] 1895t excluded because of suspected area misreporting

[3] R. W. Brown pers. com.

Table 2. Canadian catch (t) of haddock in unit areas 5Zjm by gear category and tonnage class for principle gears.

Year	Otter Trawl						Longline			Other	Total
	Side	Stern									
		2	3	4	5	Total	2	3	Total		
1969	777	0	1	225	2902	3127	2	21	23	15	3941
1970	575	2	0	133	1179	1314	6	72	78	2	1970
1971	501	0	0	16	939	955	18	129	151	3	1610
1972	148	0	0	2	260	263	23	169	195	3	609
1973	633	0	0	60	766	826	23	80	105	0	1565
1974	27	0	6	8	332	346	29	59	88	1	462
1975	222	0	1	60	963	1024	25	81	107	0	1353
1976	217	0	2	59	905	967	48	108	156	15	1355
1977	370	92	243	18	2025	2378	43	51	94	28	2871
1978	2456	237	812	351	5639	7039	121	47	169	305	9968
1979	1622	136	858	627	1564	3185	190	80	271	2	5080
1980	1444	354	359	950	6254	7917	129	51	587	69	10017
1981	478	448	629	737	2344	4159	331	99	1019	2	5658
1982	115	189	318	187	3341	4045	497	187	712	0	4872
1983	106	615	431	107	1130	2283	593	195	815	4	3208
1984	5	180	269	21	149	620	614	192	835	3	1463
1985	72	840	1401	155	348	2745	562	33	626	41	3484
1986	51	829	1378	95	432	2734	475	98	594	35	3415
1987	48	782	1448	49	1241	3521	854	113	1046	89	4703
1988[1]	72	1091	1456	186	398	3183	428	200	695	97	4046
1989	0	489	573	376	536	1976	713	175	977	106	3059
1990	0	928	890	116	471	2411	623	173	853	76	3340
1991	0	1610	1647	81	679	4018	900	271	1309	119	5446
1992	0	797	1084	56	645	2583	984	245	1384	90	4061
1993	0	535	1179	67	699	2490	794	156	1144	94	3727
1994	0	495	911	79	112	1597	498	47	714	100	2411
1995	0	510	896	14	214	1647	261	69	389	28	2064

[1] Catches of 26t, 776t, 1091t and 2t for side otter trawlers and stern otter trawlers tonnage classes 2, 3 and 5 respectively were excluded because of suspected area misreporting.

Table 3. Monthly catch (t) of haddock by Canada in unit areas 5Zjm.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
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[1]	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	1179	668	678	469	199	18	22	3340
1991	144	166	49	26	21	1928	1004	705	566	576	123	137	5446
1992	118	205	97	152	36	1381	619	414	398	401	209	28	4061
1993	466	690	96	78	25	723	505	329	202	198	230	185	3727
1994	1	3	1	2	0	398	693	373	375	220	211	134	2411
1995	1	1	1	1	0	762	326	290	281	109	197	96	2064

[1] Catches of 3t, 1846t and 46t for Jan., Feb., and Mar., respectively for otter trawlers were excluded because of suspected area misreporting

Table 4. USA catch (t) of haddock (excluding discard estimates) in unit areas 5Zjm by gear category and tonnage class.

Year	Otter Trawl			Other	Total
	3	4	Total		
1969	3010	3610	6621	0	6622
1970	1602	1551	3154	0	3153
1971	1760	1768	3533	0	3534
1972	861	690	1551	0	1551
1973	637	759	1396	0	1396
1974	443	512	955	0	955
1975	993	675	1668	36	1705
1976	671	302	972	2	973
1977	1721	700	2423	5	2429
1978	3140	1573	4713	11	4724
1979	3281	1927	5208	4	5211
1980	3654	2955	5611	4	5615
1981	3591	5408	9031	45	9077
1982	2585	3657	6242	37	6280
1983	1162	3261	4423	29	4454
1984	1854	3260	5115	5	5121
1985	856	823	1679	4	1683
1986	985	1207	2192	9	2200
1987	778	639	1417	1	1418
1988	920	768	1688	6	1693
1989	359	419	780	6	787
1990	486	688	1178	4	1189
1991	400	517	918	13	931
1992	597	740	1337	292	1629
1993	142	191	333	88	421
1994		n/a			150[1]
1995		n/a			100[1]

[1] R. W. Brown pers. com.

Table 5. Monthly catch (t) of haddock (excluding discard estimates) by USA in unit areas 5Zjm.

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	105	28	76	133	89	434	1	20	6	0	19	19	931
1992	253	81	51	149	353	669	20	20	17	3	2	12	1629
1993	15	12	16	55	84	209	6	3	3	7	2	8	421
1994												n/a	150[1]
1995												n/a	100[1]

[1] R. W. Brown pers. com

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

Year	Age Group									
	1	2	3	4	5	6	7	8	9+	Total
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
1992	7	230	237	62	1020	14	212	3	86	1871
1993	7	246	319	245	69	551	7	143	69	1656
1994	0	210	703	137	49	33	107	13	37	1289
1995	1	57	502	407	52	25	2	51	15	1112

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

Year	Age Group							
	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
1992	0.538	1.163	1.687	1.694	2.264	2.073	2.977	2.633
1993	0.659	1.160	1.750	2.236	2.113	2.677	2.987	3.133
1994	0.405	1.141	1.669	2.246	2.664	2.439	2.835	3.240
1995	0.797	1.047	1.513	2.038	2.554	2.761	2.916	3.011

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

Year	Age Group									
	1	2	3	4	5	6	7	8	9+	Total
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
1992	0	0	74	65	426	75	103	22	3	768
1993	0	1	24	35	17	84	26	10	5	202
1994[1]	0	6	34	10	5	2	15	0	4	77
1995[1]	0	1	22	20	3	2	0	3	1	52

[1] Estimated using Canadian otter trawler, quarter 2 age composition.

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

Year	Age Group							
	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
1992	-	1.311	1.417	1.616	1.946	2.573	3.011	3.505
1993	-	1.044	1.395	1.794	1.772	2.273	2.217	2.825
1994[1]	-	0.923	1.491	2.091	2.395	2.146	2.805	2.593
1995[1]	-	0.964	1.506	1.958	2.476	2.657	-	3.308

[1] Estimated

Table 10. Total[1] commercial catch-at-age numbers (000's) of haddock from unit areas 5Zjm.

Year	Age Group									
	1	2	3	4	5	6	7	8	9+	Total
1969	0	19	1449	262	333	2881	816	88	280	6128
1970	25	83	7	350	148	127	1140	366	184	2431
1971	0	1219	261	32	249	163	166	748	404	3242
1972	281	1	398	75	22	87	42	13	418	1336
1973	1015	1728	7	360	37	10	37	8	161	3363
1974	17	2080[2]	272	0	40	3	0	35	69	2517
1975	0	184	1418	237	6	46	1	3	39	1935
1976	67	148	175	818	121	0	16	0	21	1367
1977	0	7623[2]	65	178	305	163	0	15	14	8362
1978	1	289	9832[2]	160	169	299	81	10	9	10850
1979	0	22	202	4403	325	182	195	39	13	5380
1980	2	9519	351	305	2391	192	128	52	12	12951
1981	0	661	6593	384	585	1220	121	31	24	9619
1982	0	714	1048	2809	196	379	724	62	65	5997
1983	0	205	582	512	1652	221	108	413	32	3725
1984	0	79	252	348	256	1062	196	160	331	2684
1985	0	2063	374	176	189	123	371	53	114	3463
1986	6	38	2557	173	142	122	118	173	40	3368
1987	0	1990	127	1515	96	56	82	68	108	4042
1988	4	51	2145	121	877	109	36	46	98	3487
1989	0	1153	78	734	129	320	31	20	44	2510
1990	2	7	1265	126	743	68	163	42	42	2457
1991	6	441	89	2041	88	389	72	145	60	3332
1992	7	230	311	127	1446	89	315	26	89	2639
1993	7	247	343	279	85	635	34	153	74	1857
1994	0	217	738	148	54	35	123	14	41	1368
1995	1	58	524	427	55	27	2	54	16	1164

[1] Prior to 1977 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 5Zjm.

Year	Age Group							
	1	2	3	4	5	6	7	8
1969	0.600	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	0.600	0.928	1.059	1.272	2.011	2.255	2.262	2.613
1972	0.759	1.000	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	0.600	0.970	1.418	1.800	1.984	3.760	2.700	3.128
1975	0.600	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	2.700	2.702	3.000
1977	0.600	0.970	1.442	1.809	2.337	2.809	2.700	3.095
1978	0.619	1.151	1.433	2.055	2.623	2.919	2.972	2.829
1979	0.600	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	0.600	0.890	1.262	1.592	2.270	2.611	3.505	4.009
1982	0.600	0.965	1.363	1.786	2.327	2.557	2.958	3.531
1983	0.600	1.024	1.341	1.750	2.118	2.509	2.879	3.104
1984	0.600	0.876	1.354	1.838	2.159	2.605	2.856	3.134
1985	0.600	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	0.600	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	0.600	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
1992	0.538	1.163	1.622	1.654	2.171	2.491	2.988	3.388
1993	0.659	1.160	1.724	2.181	2.047	2.623	2.386	3.112
1994	0.405	1.135	1.661	2.235	2.639	2.422	2.831	3.223
1995	0.797	1.045	1.513	2.034	2.550	2.751	2.916	3.027

Table 12. Vessel and door used in the spring survey on Georges Bank with respective conversion coefficients (from O'Brien and Brown 1996).

Year(s)	Vessel	Conversion Coefficient	Door	Conversion Coefficient
1968-80	ALBATROSS IV	1.00	BMV	1.49
1981-82	DELAWARE II	0.82	BMV	1.49
1983-84	ALBATROSS IV	1.00	BMV	1.49
1985-88	ALBATROSS IV	1.00	POLY	1.00
1989-91	DELAWARE II	0.82	POLY	1.00
1992-93	ALBATROSS IV	1.00	POLY	1.00
1994	DELAWARE II	0.82	POLY	1.00
1995	ALBATROSS IV	1.00	POLY	1.00

Table 13. Vessel and door used in the fall survey on Georges Bank with respective conversion coefficients (from O'Brien and Brown 1996).

Year(s)	Vessel	Conversion Coefficient	Door	Conversion Coefficient
1963-76	ALBATROSS IV	1.00	BMV	1.49
1977-81	DELAWARE II	0.82	BMV	1.49
1982-84	ALBATROSS IV	1.00	BMV	1.49
1985-88	ALBATROSS IV	1.00	POLY	1.00
1989-91	DELAWARE II	0.82	POLY	1.00
1992	ALBATROSS IV	1.00	POLY	1.00
1993	DELAWARE II	0.82	POLY	1.00
1994-95	ALBATROSS IV	1.00	POLY	1.00

Table 14. Total estimated abundance-at-age numbers (000's) of haddock from unit areas 5Zjm from the Canadian spring surveys.

Year	Age Group									
	1	2	3	4	5	6	7	8	9+	Total
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	19671
1989	48	6664	991	2910	247	528	40	36	260	11725
1990	726	108	12302	166	4465	299	1370	144	389	19968
1991	393	2159	137	10876	116	1899	119	507	225	16431
1992	1914	3879	1423	221	4810	18	1277	52	655	14248
1993	3448	1759	545	431	34	1186	19	281	147	7849
1994	4197	15163	5332	549	314	20	915	18	356	26864
1995	1231	3224	6236	3034	720	398	0	729	849	16422
1996	1477	2059	4784	5247	3391	326	246	20	698	18247

Table 15. Total estimated abundance-at-age numbers (000's) of haddock in unit areas 5Zjm 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	9+	Total
1968	0	3254	67	679	4853	2046	240	124	234	11497
1969	17	35	614	235	523	3232	1220	358	489	6724
1970	478	190	0	560	998	441	3169	2507	769	9113
1971	0	655	261	0	144	102	58	1159	271	2650
1972	2594	0	771	132	25	47	211	27	1214	5019
1973	2455	5639	0	1032	154	0	276	0	1208	10763
1974	1323	20596	4084	0	354	0	43	72	322	26795
1975	528	567	6016	1063	0	218	127	45	208	8773
1976	8279	402	433	1229	582	0	0	0	22	10948
1977	138	25922	294	855	816	586	0	22	98	28730
1978	0	743	20859	641	880	1163	89	23	116	24516
1979	10496	441	1313	9764	475	72	445	42	9	23057
1980	4364	67961	1129	1117	5822	628	381	705	359	82466
1981	3595	3041	27694	2887	719	2389	335	57	21	40738
1982	584	3697	1649	7743	745	447	669	0	0	15534
1983	238	770	686	359	2591	30	0	798	57	5529
1984	1366	1415	996	1001	936	1245	138	89	470	7656
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	84	6665	619	1343	267	791	58	92	47	9966
1990	1654	70	10338	598	1042	110	182	0	0	13995
1991	740	2071	432	3381	192	203	66	87	25	7198
1992	529	287	214	141	609	32	46	46	0	1905
1993	1870	1116	197	232	195	717	77	35	43	4481
1994	1025	4272	1487	269	184	118	278	28	85	7745
1995	921	2307	4096	1691	259	151	51	269	214	9959

Table 16. Total estimated abundance-at-age numbers (000's) of haddock in unit areas 5Zjm 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	8+	Total
1963	106461	49869	14797	5050	7581	6172	2301	599	273	193101
1964	1177	114880	55741	6128	976	2435	502	280	167	182287
1965	259	1512	51521	8360	489	299	148	165	216	62970
1966	9324	751	1742	20324	3631	671	139	133	83	36797
1967	0	3998	73	328	1845	675	140	88	88	7234
1968	55	113	800	28	37	2223	547	177	313	4293
1969	384	0	0	519	63	30	753	458	115	2323
1970	0	6400	336	16	415	337	500	902	578	9483
1971	2626	0	788	97	0	265	27	73	594	4471
1972	4747	2396	0	232	0	0	53	0	276	7703
1973	1345	16797	1606	0	180	1	0	16	16	19961
1974	151	234	961	169	0	6	0	0	69	1589
1975	30365	664	192	1018	222	0	0	0	26	32487
1976	784	132622	456	25	484	71	0	17	36	134496
1977	47	238	26323	445	125	211	84	4	4	27480
1978	14642	547	530	7706	56	42	94	0	0	23617
1979	1573	21117	14	327	1461	44	12	0	0	24549
1980	3581	2817	5877	0	101	1085	109	26	4	13598
1981	616	4617	2585	2752	105	136	297	0	15	11123
1982	62	0	669	460	2576	159	91	469	42	4527
1983	3609	444	324	435	283	396	19	9	79	5598
1984	45	3849	781	221	210	43	254	0	47	5451
1985	12148	381	1646	199	70	68	46	30	21	14610
1986	30	7471	109	961	52	50	72	24	23	8793
1987	508	4	839	28	152	38	22	0	0	1592
1988	122	3983	206	2326	155	400	142	140	38	7513
1989	167	83	2645	112	509	68	73	0	0	3656
1990	1217	1036	24	1474	90	172	21	5	0	4040
1991	705	331	274	68	266	25	10	0	0	1679
1992	3484	1052	172	110	0	95	0	18	18	4948
1993	677	6666	3601	585	0	87	96	30	0	11742
1994	625	782	927	419	96	32	0	24	0	2905
1995	892	1465	6165	3484	547	30	0	0	53	12637

Table 17. Statistical properties of estimates for population abundance and survey calibration constants for haddock in unit areas 5Zjm.

Age	Estimate	Standard Error	Relative Error	Bias	Relative Bias
		Population Abundance			
1	7614	5302	0.70	1876	0.25
2	4915	2165	0.44	494	0.10
3	6375	2234	0.35	411	0.06
4	9098	2843	0.31	453	0.05
5	2202	740	0.34	123	0.06
6	360	128	0.35	21	0.06
7	207	83	0.40	15	0.07
8	16	10	0.62	3	0.17
		Survey Calibration Constants			
Canadian Spring Survey					
1	0.164	0.050	0.303	0.007	0.040
2	0.403	0.119	0.295	0.015	0.038
3	0.836	0.245	0.293	0.032	0.038
4	0.677	0.198	0.292	0.026	0.039
5	0.817	0.240	0.294	0.033	0.041
6	0.578	0.171	0.295	0.025	0.043
7	0.826	0.255	0.308	0.044	0.053
8	0.740	0.227	0.307	0.041	0.055
USA Spring Survey					
1	0.145	0.028	0.193	0.002	0.016
2	0.366	0.069	0.188	0.006	0.016
3	0.455	0.087	0.191	0.007	0.016
4	0.511	0.098	0.191	0.008	0.017
5	0.586	0.110	0.188	0.010	0.017
6	0.456	0.089	0.196	0.008	0.019
7	0.706	0.140	0.198	0.015	0.021
8	0.645	0.129	0.200	0.015	0.023
USA Fall Survey					
1	0.139	0.026	0.187	0.002	0.015
2	0.309	0.060	0.193	0.005	0.016
3	0.233	0.044	0.188	0.004	0.016
4	0.207	0.039	0.188	0.003	0.016
5	0.166	0.033	0.200	0.003	0.020
6	0.155	0.029	0.189	0.003	0.017

Table 18. Beginning of year population abundance numbers (000's) for haddock in unit areas 5Zjm.

Year	Age Group										
	1	2	3	4	5	6	7	8	9	1+	2+	3+
1969	798	197	3515	871	856	6708	2325	239	0	15509	14711	14514
1970	3627	653	144	1582	479	403	2916	1172	117	11093	7466	6813
1971	192	2947	460	112	981	259	215	1367	631	7164	6972	4025
1972	5078	157	1323	145	63	579	67	30	454	7896	2818	2661
1973	10944	3904	128	726	52	32	396	18	13	16213	5269	1365
1974	2827	8045	1652	99	273	10	17	291	7	13221	10394	2349
1975	3416	2299	4718	1108	81	187	6	14	206	12035	8619	6320
1976	53925	2797	1717	2590	693	61	112	3	9	61907	7982	5185
1977	6299	44089	2156	1248	1386	459	50	77	3	55767	49468	5379
1978	4143	5158	29235	1707	861	861	230	41	50	42286	38143	32985
1979	40482	3391	3962	15122	1253	553	437	116	24	65340	24858	21467
1980	6175	33144	2757	3061	8429	734	289	184	60	54833	48658	15514
1981	4445	5054	18591	1941	2232	4755	429	122	104	37673	33228	28174
1982	2070	3639	3542	9314	1243	1302	2796	242	73	24221	22151	18512
1983	2423	1695	2337	1960	5105	841	726	1639	143	16869	14446	12751
1984	15454	1984	1203	1390	1145	2698	490	497	971	25832	10378	8394
1985	1543	12653	1553	758	826	707	1259	226	264	19789	18246	5593
1986	13301	1263	8502	935	463	506	468	698	137	26273	12972	11709
1987	1243	10885	1000	4666	610	252	304	277	416	19653	18410	7525
1988	15594	1018	7121	705	2462	413	156	176	166	27811	12217	11199
1989	780	12764	787	3905	468	1230	240	95	103	20372	19592	6828
1990	2512	639	9410	574	2536	267	719	169	59	16885	14373	13734
1991	2230	2055	517	6565	357	1410	157	442	100	13833	11603	9548
1992	7031	1821	1286	343	3544	213	805	64	231	15338	8307	6486
1993	16914	5751	1283	774	167	1609	95	377	30	27000	10086	4335
1994	8976	13842	4486	742	383	60	748	47	172	29456	20480	6638
1995	5400	7349	11137	3008	475	265	18	502	26	28180	22780	15431
1996	5738	4420	5965	8645	2079	339	193	13	363	27755	22017	17597

Table 19. Fishing mortality rate for haddock in unit areas 5Zjm.

Year	Age Group								
	1	2	3	4	5	6	7	8	4+
1969	0.000	0.111	0.598	0.399	0.554	0.633	0.485	0.518	0.571
1970	0.008	0.151	0.058	0.278	0.415	0.426	0.557	0.419	0.440
1971	0.000	0.601	0.957	0.374	0.327	1.150	1.762	0.903	0.700
1972	0.063	0.006	0.400	0.824	0.475	0.180	1.132	0.653	0.349
1973	0.108	0.660	0.058	0.778	1.437	0.411	0.109	0.684	0.515
1974	0.007	0.334	0.200	0.000	0.177	0.394	0.003	0.143	0.134
1975	0.000	0.092	0.400	0.268	0.088	0.312	0.312	0.245	0.263
1976	0.001	0.060	0.119	0.425	0.213	0.000	0.176	0.000	0.361
1977	0.000	0.211	0.034	0.171	0.277	0.491	0.000	0.235	0.255
1978	0.000	0.064	0.459	0.109	0.244	0.478	0.484	0.329	0.240
1979	0.000	0.007	0.058	0.384	0.335	0.447	0.666	0.458	0.389
1980	0.000	0.378	0.151	0.116	0.373	0.337	0.661	0.372	0.308
1981	0.000	0.156	0.491	0.245	0.339	0.331	0.371	0.321	0.316
1982	0.000	0.243	0.392	0.401	0.191	0.384	0.334	0.328	0.367
1983	0.000	0.143	0.319	0.338	0.438	0.341	0.178	0.323	0.371
1984	0.000	0.045	0.262	0.321	0.282	0.562	0.575	0.435	0.440
1985	0.000	0.198	0.307	0.294	0.290	0.213	0.390	0.297	0.308
1986	0.000	0.033	0.400	0.228	0.409	0.309	0.323	0.317	0.301
1987	0.000	0.224	0.150	0.439	0.191	0.279	0.349	0.315	0.394
1988	0.000	0.057	0.401	0.208	0.494	0.342	0.295	0.335	0.405
1989	0.000	0.105	0.115	0.232	0.361	0.337	0.151	0.270	0.259
1990	0.001	0.012	0.160	0.275	0.387	0.330	0.287	0.320	0.348
1991	0.003	0.269	0.210	0.416	0.317	0.361	0.695	0.447	0.409
1992	0.001	0.150	0.308	0.521	0.590	0.611	0.558	0.569	0.580
1993	0.000	0.048	0.347	0.503	0.816	0.565	0.497	0.586	0.561
1994	0.000	0.017	0.199	0.247	0.168	0.987	0.199	0.378	0.231
1995	0.000	0.009	0.053	0.170	0.137	0.118	0.145	0.126	0.157

Table 20. Average weight at age from the Canadian spring survey.

Year	Age Group							
	1	2	3	4	5	6	7	8
1986	0.135	0.452	0.975	1.444	3.039	2.843	3.598	3.373
1987	0.150	0.500	0.716	1.673	2.011	2.548	3.150	3.147
1988	0.097	0.464	0.932	1.795	1.816	1.917	2.720	3.269
1989	0.062	0.474	0.650	1.392	1.994	2.528	2.155	2.820
1990	0.149	0.527	0.925	1.184	1.863	2.072	2.508	2.819
1991	0.120	0.689	0.801	1.510	1.686	2.427	2.103	3.125
1992	0.122	0.602	1.118	1.061	2.078	2.165	2.708	2.283
1993	0.122	0.481	1.228	1.803	1.270	2.332	2.340	2.738
1994	0.107	0.469	1.047	1.621	1.926	2.154	3.152	2.688
1995	0.086	0.493	0.963	1.556	2.224	2.447		2.994
1996	0.134	0.475	0.878	1.327	1.904	2.501	2.969	3.190

Table 21. Beginning of year biomass for haddock in unit areas 5Zjm.

Year	Age Group										
	1	2	3	4	5	6	7	8	9	1+	2+	3+
1969	93	101	3270	1296	1697	15816	6364	705	0	29342	29249	29148
1970	423	334	134	2354	950	950	7982	3457	398	16982	16558	16224
1971	22	1507	428	167	1945	611	588	4032	2145	11446	11424	9916
1972	593	80	1231	216	125	1365	183	88	1544	5425	4832	4752
1973	1277	1997	119	1080	103	75	1084	53	44	5833	4556	2559
1974	330	4115	1537	147	541	24	47	858	24	7623	7293	3178
1975	399	1176	4389	1649	161	441	16	41	700	8972	8573	7397
1976	6295	1431	1597	3854	1374	144	307	9	31	15040	8745	7315
1977	735	22551	2006	1857	2748	1082	137	227	10	31354	30618	8067
1978	484	2638	27196	2540	1707	2030	630	121	170	37516	37032	34394
1979	4725	1734	3686	22500	2484	1304	1196	342	82	38054	33328	31594
1980	721	16953	2565	4554	16713	1731	791	543	204	44774	44053	27100
1981	519	2585	17295	2888	4425	11211	1174	360	354	40811	40292	37707
1982	242	1861	3295	13858	2465	3070	7653	714	248	33406	33164	31303
1983	283	867	2174	2916	10122	1983	1987	4834	486	25653	25370	24503
1984	1804	1015	1119	2068	2270	6361	1341	1466	3301	20746	18942	17927
1985	180	6472	1445	1128	1638	1667	3446	667	898	17540	17360	10888
1986	1791	570	8292	1351	1407	1439	1684	2354	466	19353	17562	16992
1987	187	5438	716	7805	1227	642	957	872	1414	19259	19072	13634
1988	1516	473	6634	1266	4471	792	424	575	564	16714	15199	14726
1989	48	6051	511	5436	933	3109	517	268	350	17225	17177	11125
1990	374	337	8703	680	4724	553	1803	476	201	17851	17477	17141
1991	269	1415	414	9916	602	3422	330	1381	340	18089	17820	16405
1992	860	1097	1438	364	7363	461	2180	146	785	14695	13835	12738
1993	2062	2767	1576	1396	212	3753	222	1032	102	13122	11060	8293
1994	957	6494	4698	1203	738	129	2358	126	585	17289	16331	9837
1995	465	3626	10724	4680	1056	649	49	1503	88	22839	22374	18748
1996	767	2100	5238	11475	3959	848	573	41	1234	26236	25469	23369

Table 22. Projection results at $F_{0.1}$ for haddock in unit areas 5Zjm.

Year	Age Group 1	2	3	4	5	6	7	8	9	1+	2+	3+
Population Numbers (000s)												
1996	5738	4420	5965	8645	2079	339	193	13	363	27755	22017	17597
1997	10000	4698	3569	4245	5349	1286	210	119	8	29484	19484	14786
Fishing Mortality												
1996	0.000	0.014	0.140	0.280	0.280	0.280	0.280	0.280				
Weight at beginning of year for population (kg)												
1997	0.11	0.48	0.96	1.50	2.02	2.37	2.94	2.96	3.40			
Projected Population Biomass (t)												
1997	1100	2255	3426	6368	10806	3048	617	353	27	28000	26900	24645
Projected Catch Numbers (000s)												
1996	0	56	708	1922	462	75	43	3				
Average weight for catch (kg)												
1996	0.62	1.11	1.63	2.15	2.41	2.60	2.71	3.12				
Projected Yield (t)												
1996	0	62	1154	4133	1114	196	116	9		**6784**		

Table 23. For the derivation of the maximum carry-over, it was assumed that the age composition of the uncaught haddock in 1995 was the same as the age composition of those that were caught.

Age	Weight	Caught in 1995 Number	Caught in 1995 Biomass (kg)	Left in 1995 Number	Left in 1995 Biomass (kg)	Carry-over in 1996 Number	Carry-over in 1996 Biomass (kg)
1	0.797	1287	1025	272	217	0	0
2	1.047	56544	59193	11944	12504	223	233
3	1.513	502036	759741	106050	160488	9779	14799
4	2.038	407038	829367	85983	175196	86827	176915
5	2.554	52090	133056	11003	28107	70397	179818
6	2.761	24511	67668	5178	14294	9009	24871
7	2.916	2266	6608	479	1396	4239	12363
8	3.011	50882	153204	10748	32363	392	1180
9	3.033	5322	16138	1124	3409	8800	26687
10	3.613	5718	20661	1208	4364	920	3325
11	3.907	1481	5785	313	1222	989	3864
12	4.233	2712	11479	573	2425	256	1084
Total			**2063925**		**435984**		**445139**

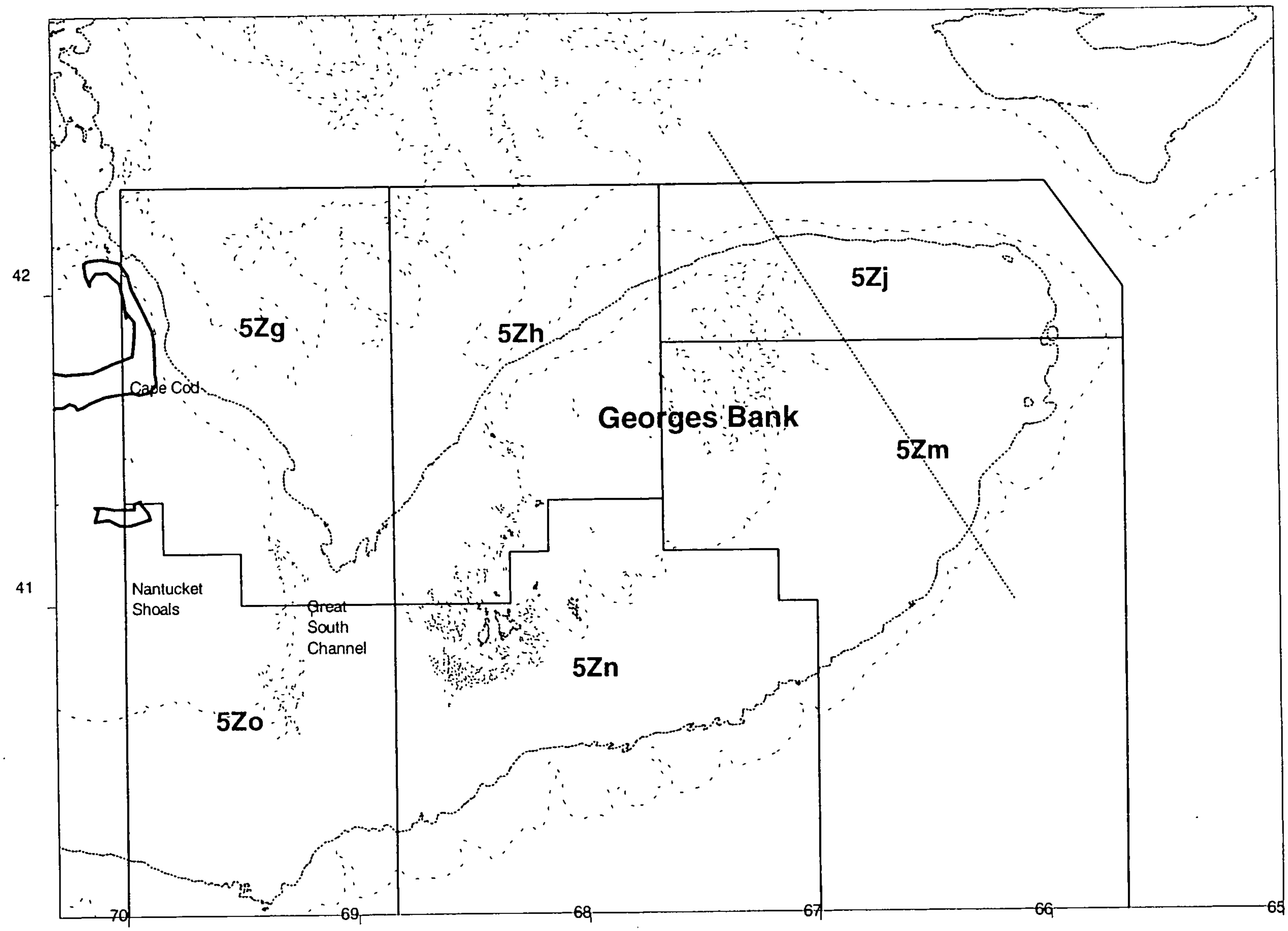

Fig. 1. Canadian fisheries statistical unit areas in NAFO Subdivision 5Ze.

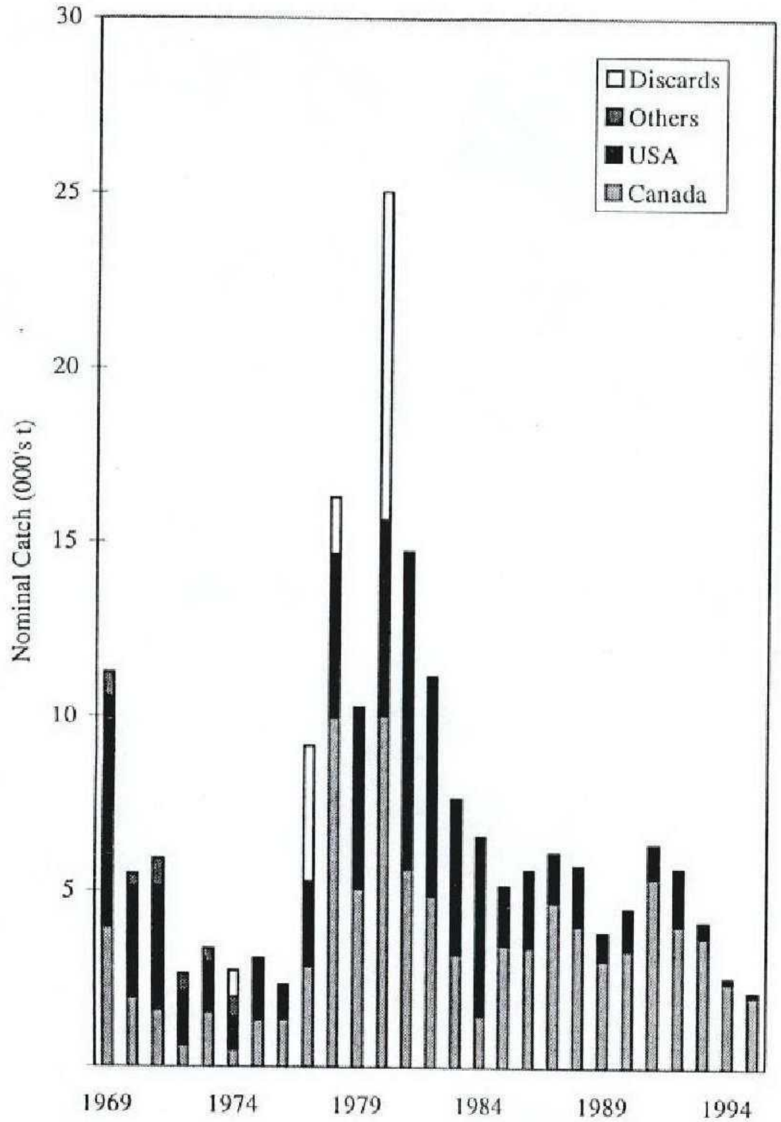

Fig. 2. Nominal catch of haddock in unit areas 5Zjm.

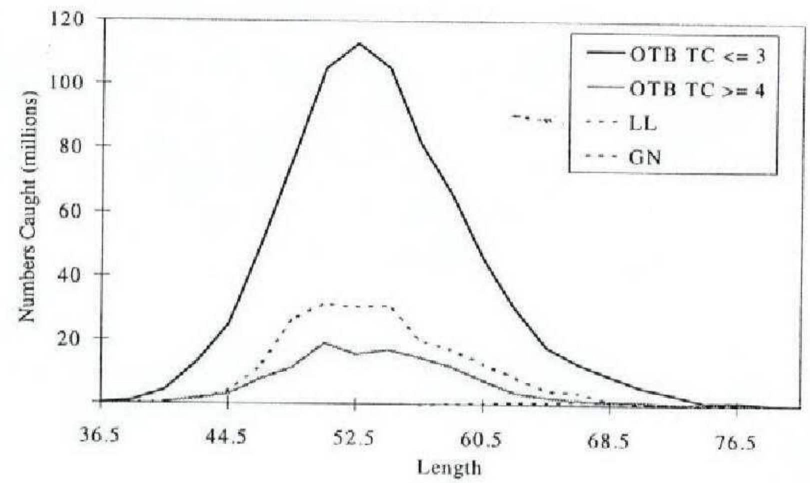

Fig. 3. Length composition of haddock catch in 1994 by the principle gear sectors for the Canadian fishery in unit areas 5Zjm.

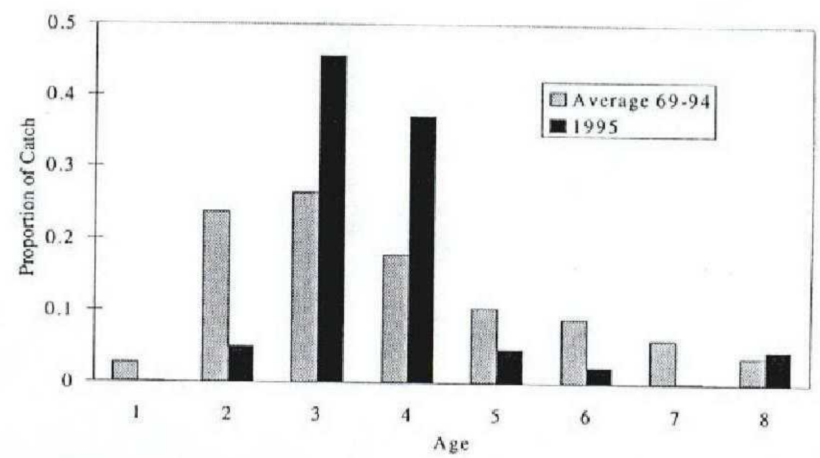

Fig. 4. Commercial fishery catch proportioned by age for 1995 compared to the average for 1969-94.

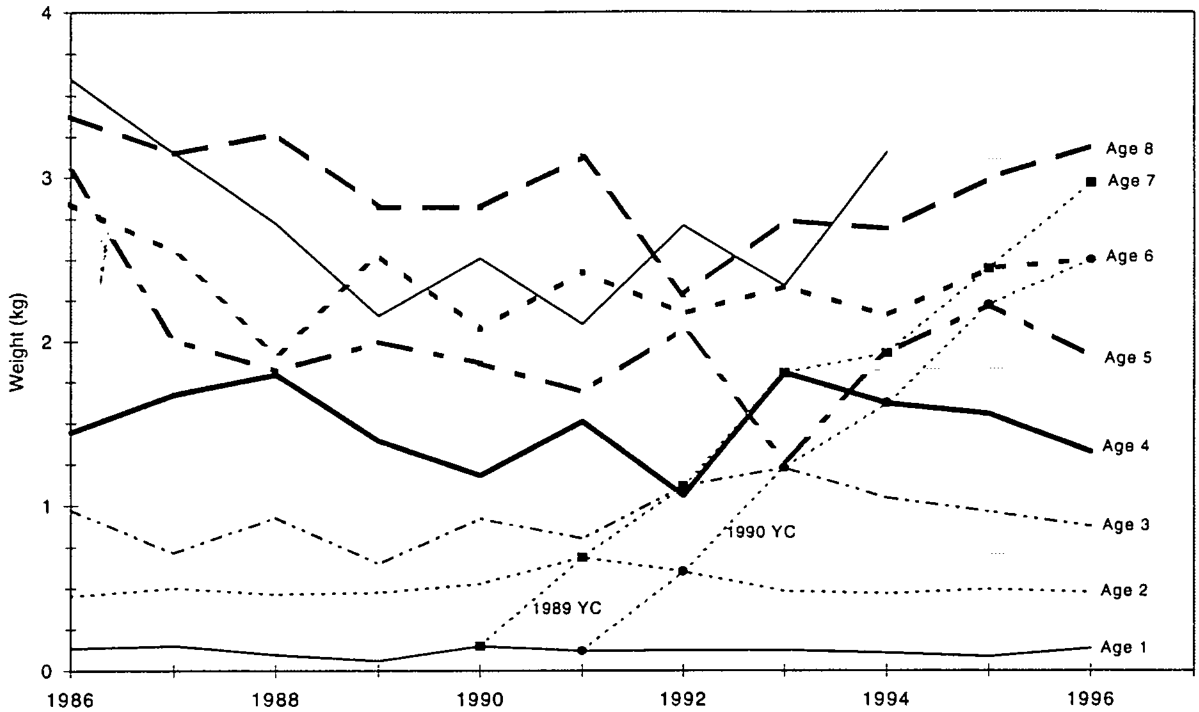

Fig. 5. Average weights at age from the Canadian spring survey. The 1989 and 1990 year-classes weights at age are generally larger than the adjacent weights in this series, especially for ages 2, 3, 4 and 5.

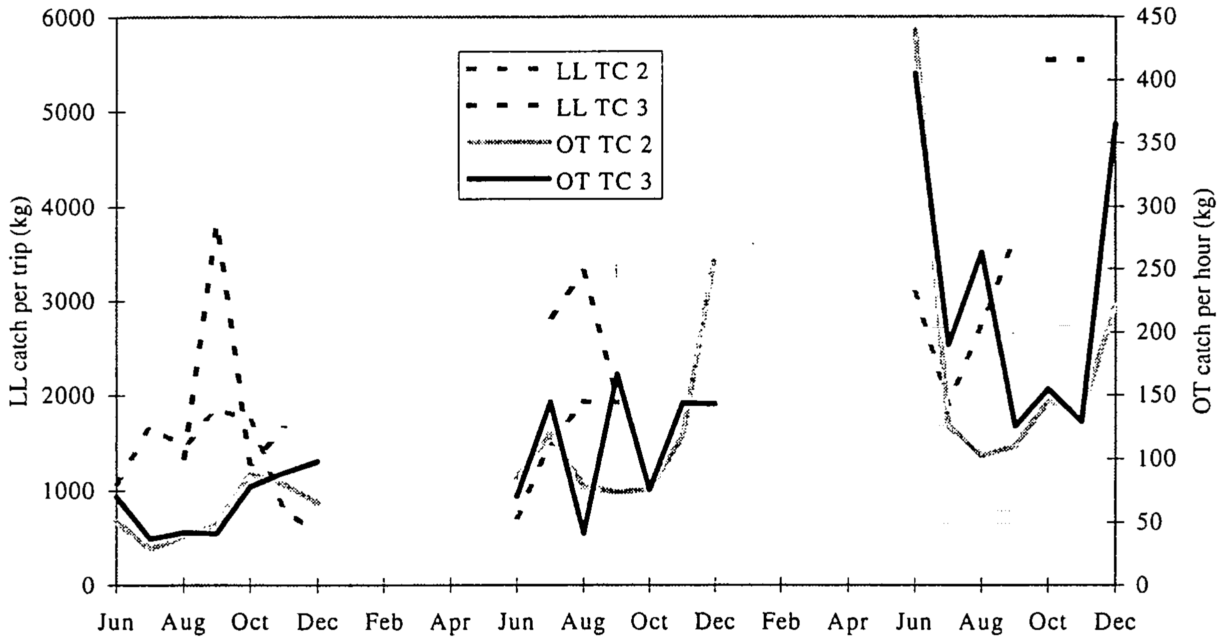

Fig. 6. Indices of catch per hour for otter trawls and catch per trip for longlines from the Canadian commercial fisheries.

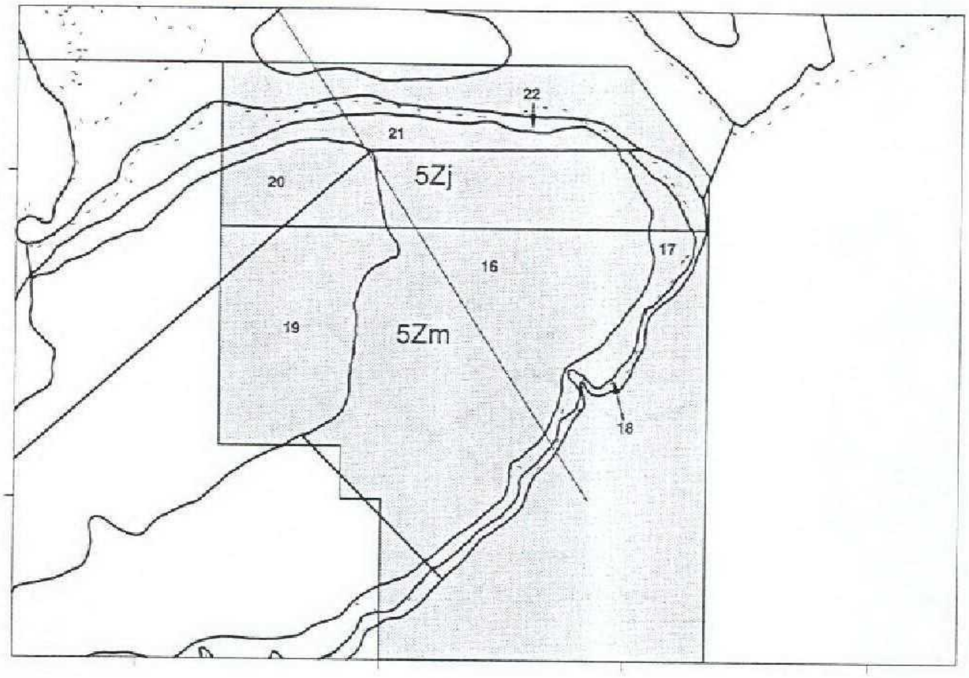

Fig. 7. Stratification scheme used for USA surveys.

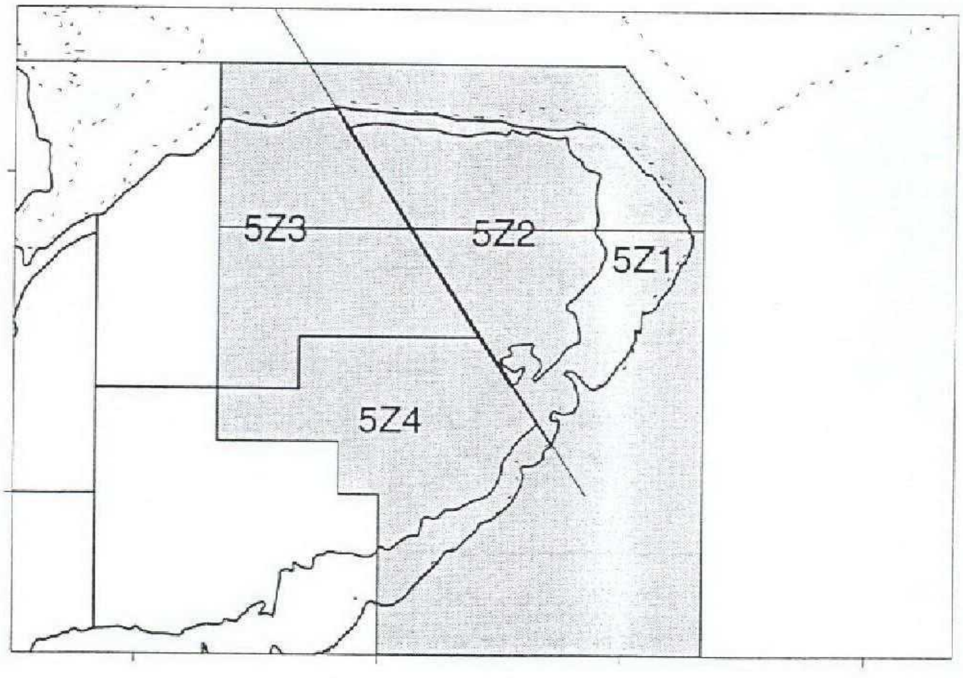

Fig. 8. Stratification scheme used for the Canadian survey.

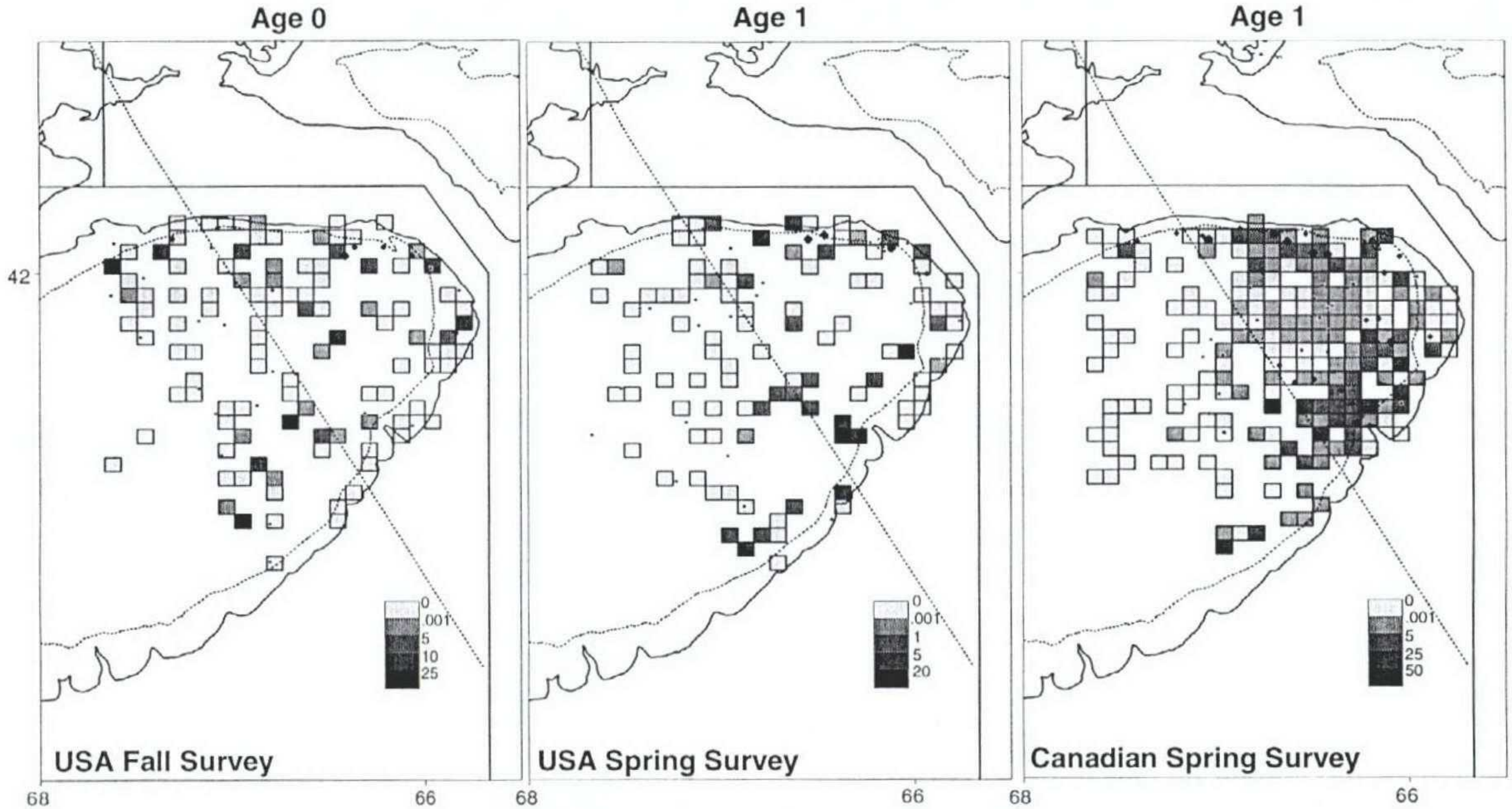

Fig. 9. Distribution of 5Zjm haddock at age 0 as observed from the USA fall survey and at age 1 from the USA and Canadian spring surveys. The squares are shaded relative to the average catch for 1990 to 1994 for the USA surveys and for 1990 to 1995 for the Canadian survey. The expanding symbols represent the 1995 USA survey catches and the 1996 Canadian survey catches. During the fall, age 0 haddock are distributed throughout the survey area but by the next spring, at age 1, they are concentrated on the Canadian side although aggregations occur along the southern flank of the bank in USA territory.

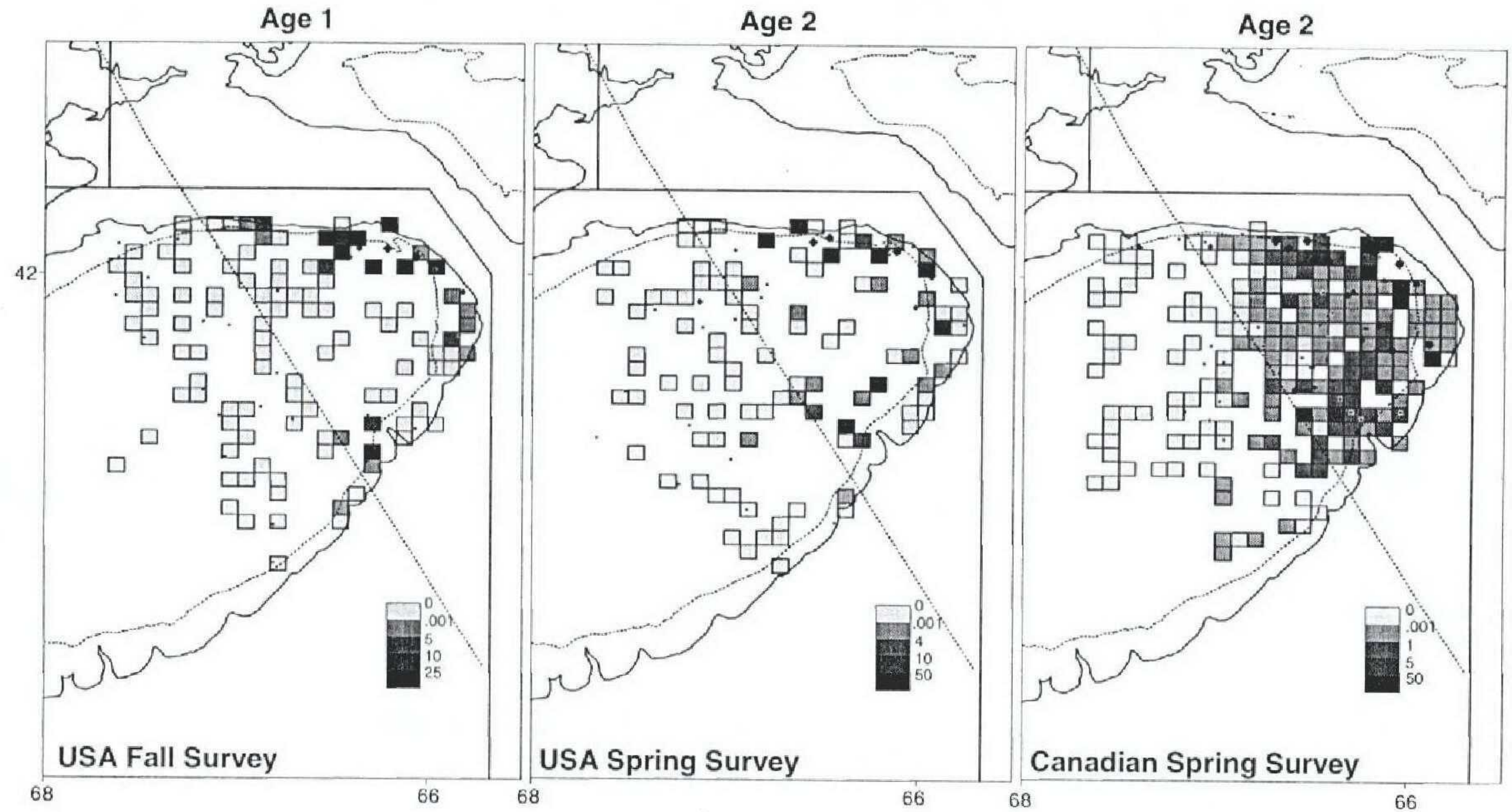

Fig. 10. Distribution of 5Zjm haddock at age 1 as observed from the USA fall survey and at age 2 from the USA and Canadian spring surveys. The squares are shaded relative to the average catch for 1990 to 1994 for the USA surveys and for 1990 to 1995 for the Canadian survey. The expanding symbols represent the 1995 USA survey catches and the 1996 Canadian survey catches. During the fall, age 1 haddock are concentrated along the edge of the bank, especially the north-eastern edge. In the spring, at age 2, they are concentrated on the Canadian side although aggregations may occur along the southern flank of the bank in USA territory as observed from the Canadian survey.

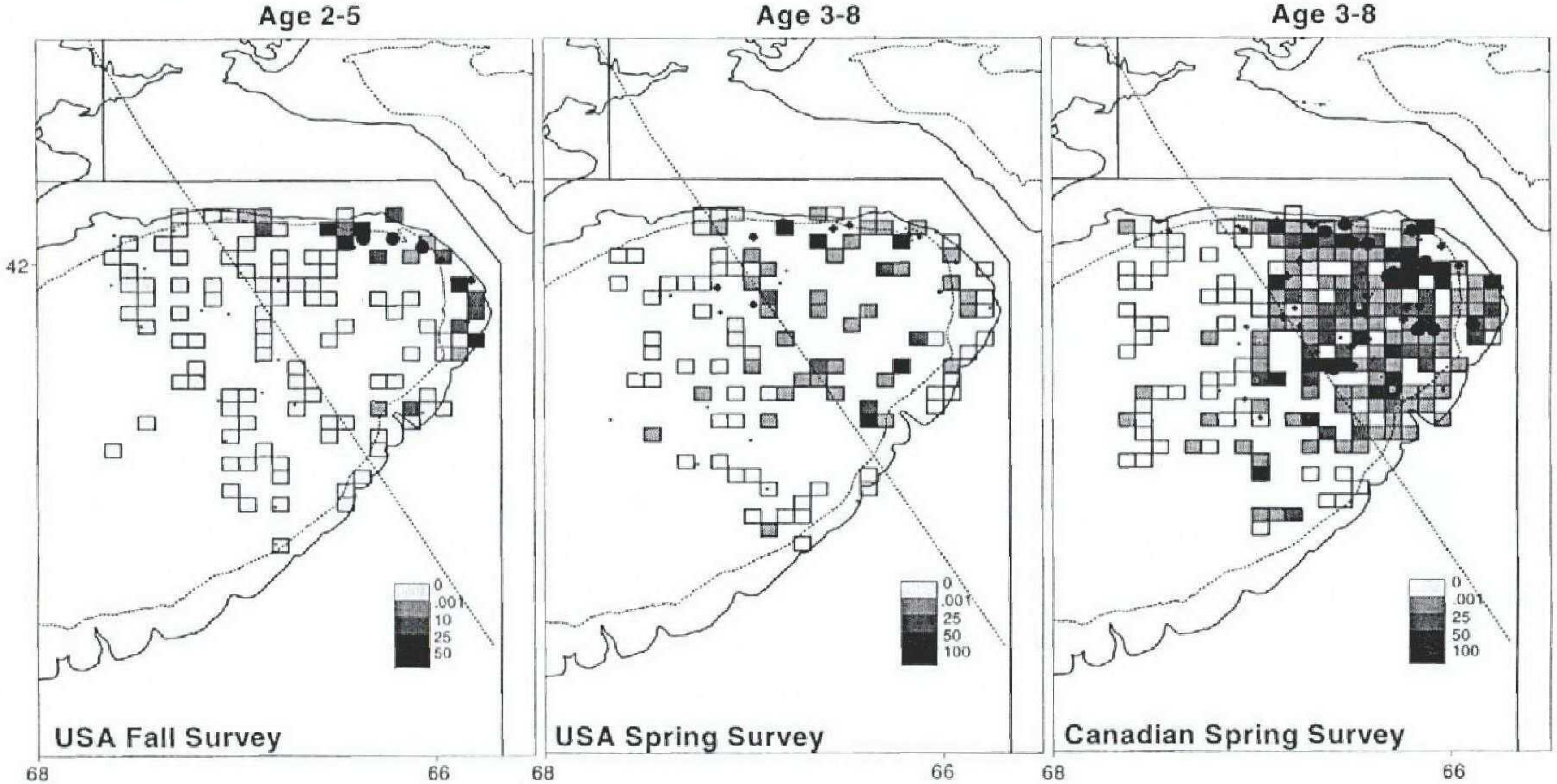

Fig. 11. Distribution of 5Zjm haddock at ages 2 to 5 as observed from the USA fall survey and at ages 3 to 8 from the USA and Canadian spring surveys. The squares are shaded relative to the average catch for 1990 to 1994 for the USA surveys and for 1990 to 1995 for the Canadian survey. The expanding symbols represent the 1995 USA survey catches and the 1996 Canadian survey catches. During the fall, age 2 to 5 haddock are concentrated along the edge of the bank, especially the north-eastern edge, in Canadian territory. In the spring, at age 3 to 8, movement across the Canada/USA boundary line into USA territory has occurred but the Canadian side still maintains the highest concentrations.

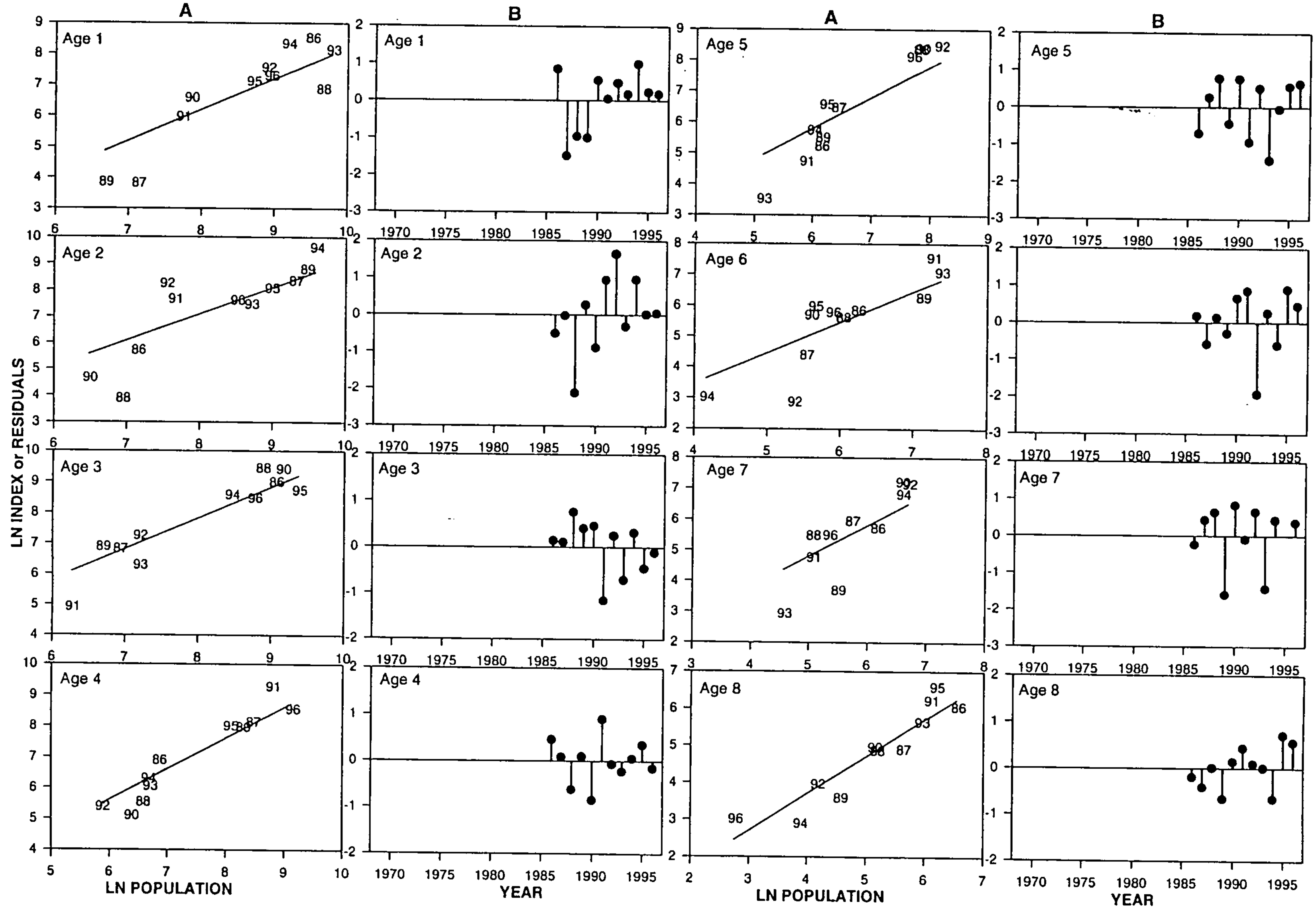

Fig. 12a. Age by age plots of A) the observed and predicted ln abundance index versus ln population numbers, and B) residuals plotted against year for haddock in unit areas 5Zj and 5Zm for the Canadian spring survey.

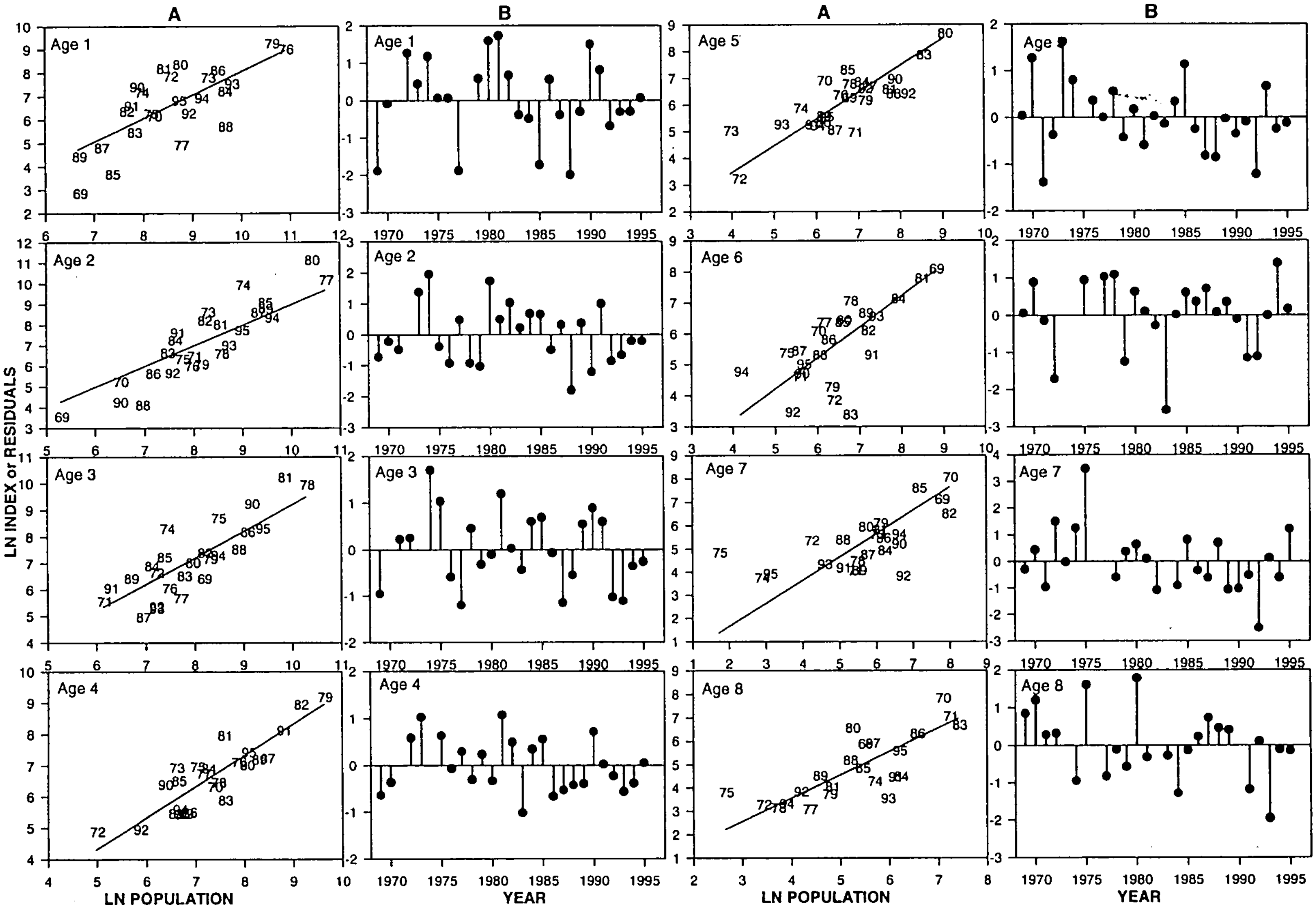

Fig. 12b. Age by age plots of A) the observed and predicted ln abundance index versus ln population numbers, and B) residuals plotted against year for haddock in unit areas 5Zj and 5Zm for the USA spring survey.

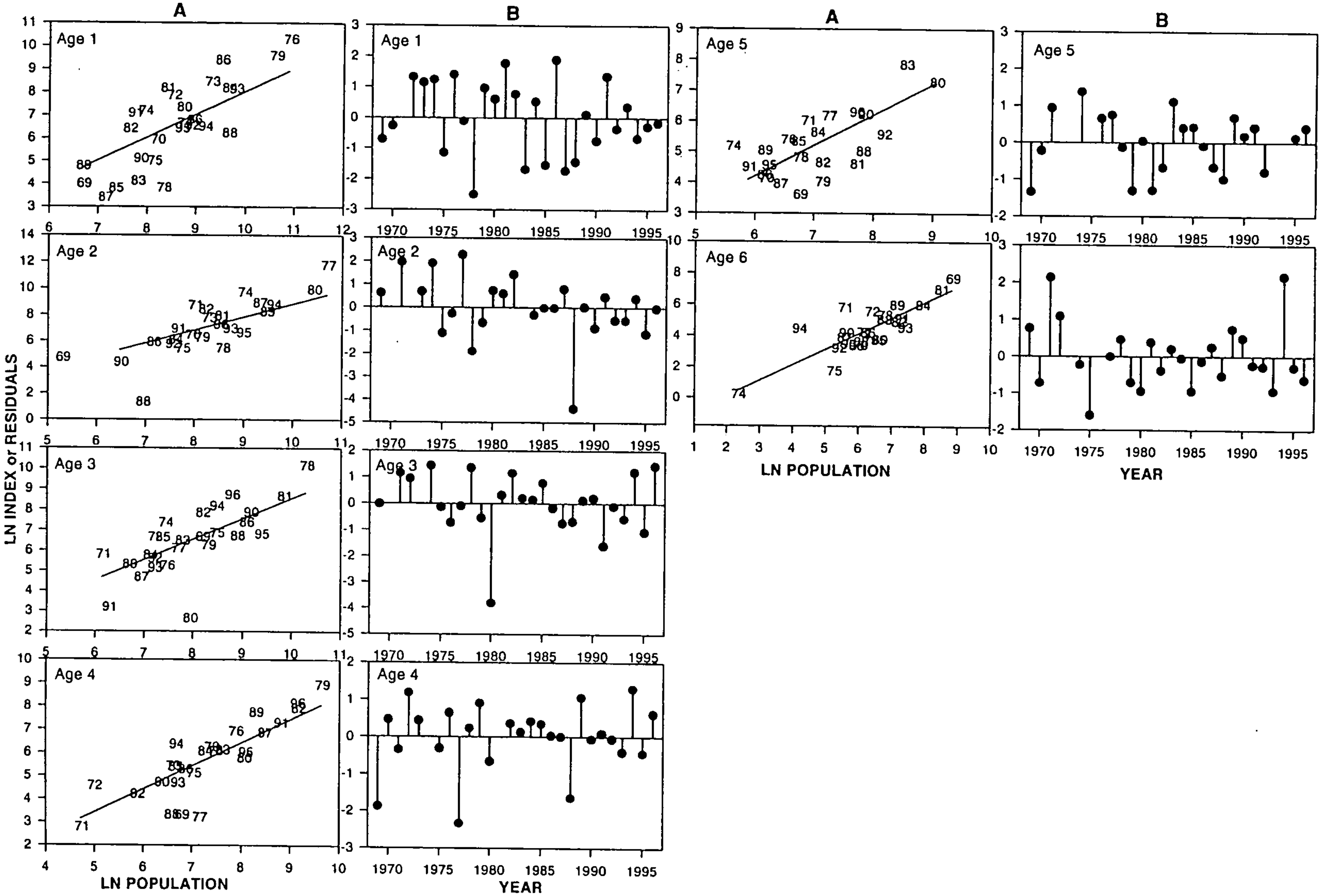

Fig. 12c. Age by age plots of A) the observed and predicted ln abundance index versus ln population numbers, and B) residuals plotted against year for haddock in unit areas 5Zj and 5Zm for the USA fall survey.

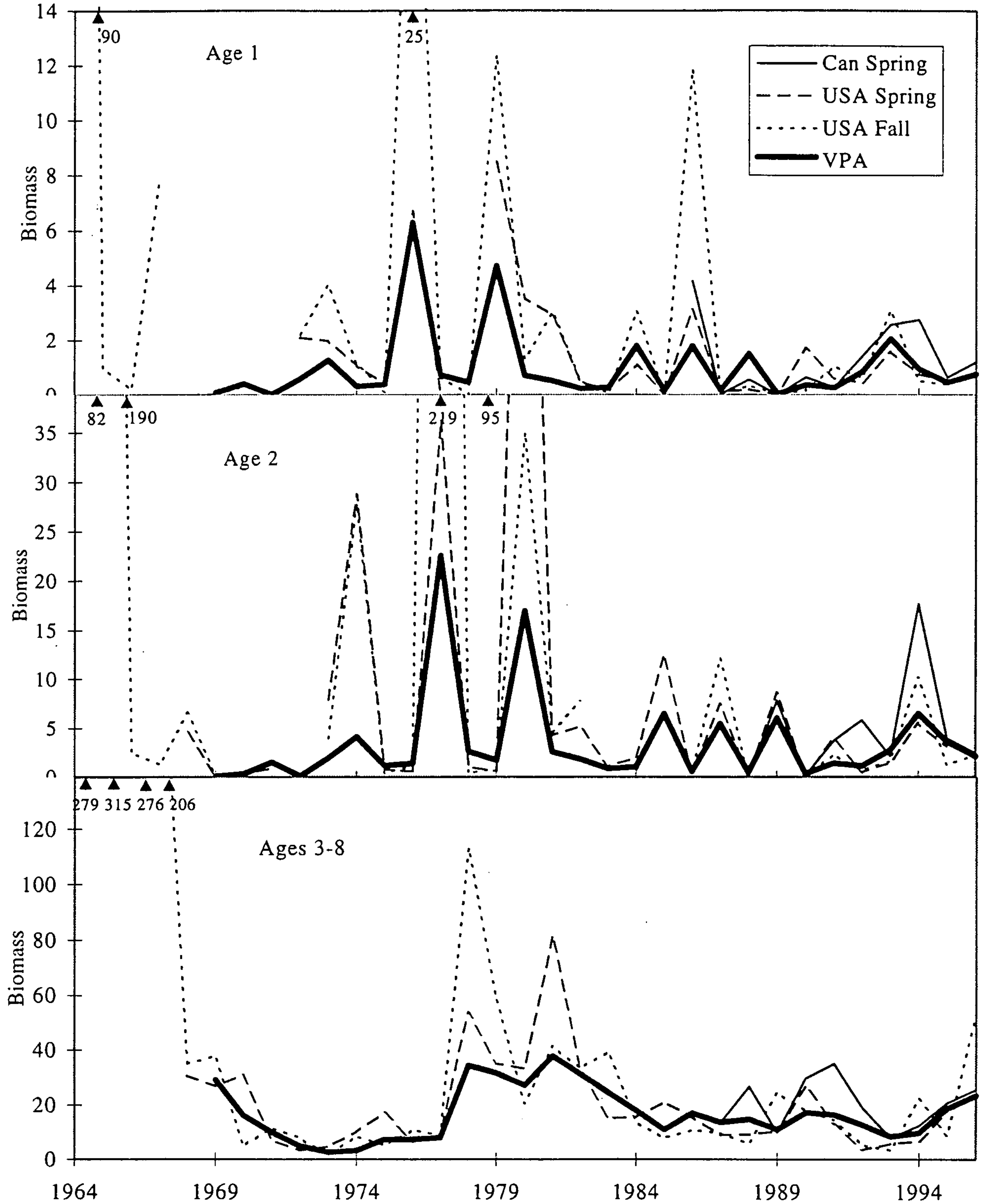

Fig. 13. Beginning of year biomass from sequential population analysis and research survey indices, adjusted by calibration constants, for haddock in unit areas 5Zjm. Fall survey values are compared to beginning of the subsequent year.

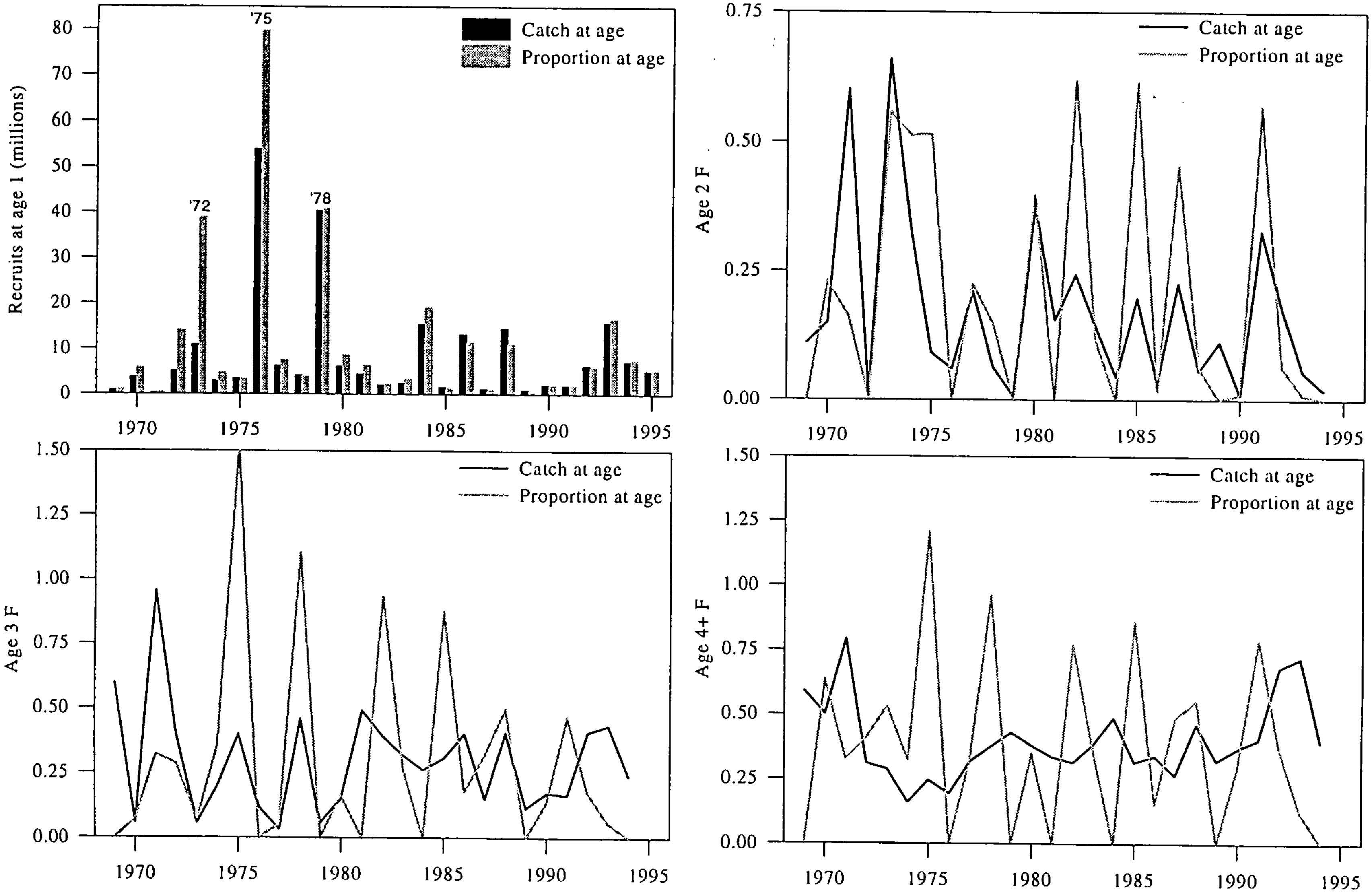

Fig. 14. Comparison of results from a traditional calibaration model to one using abundance indices and proportion caught at age. The relative year-class abundances were scaled to the 1994 age 1 abundance from the traditional calibration.

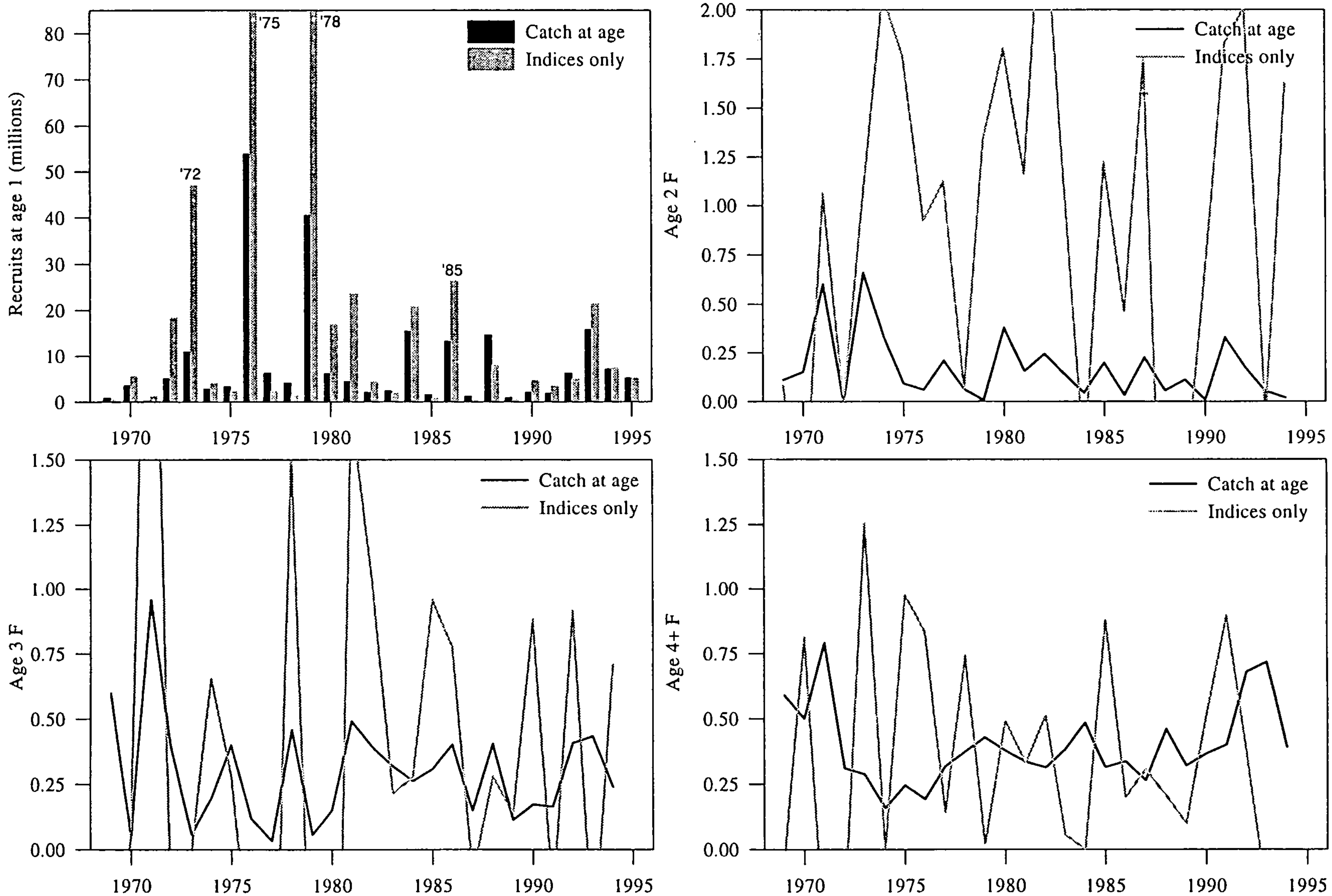

Fig. 15. Comparison of results from a traditional calibration model to one using abundance indices, employing proportion caught at age only for fully recruited ages to calculate oldest age abundance. The relative year-class abundances were scaled to the 1994 age 1 abundance from the traditional calibration.

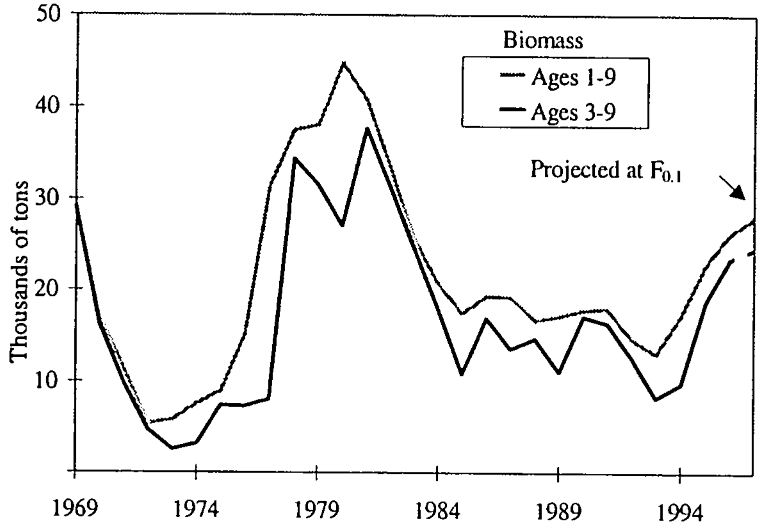

Fig. 16. Beginning of year biomass for haddock in unit areas 5Zjm.

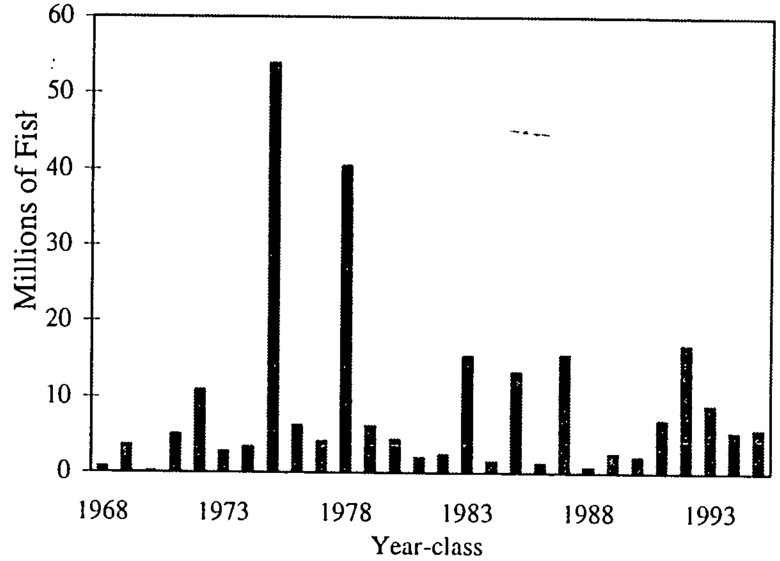

Fig. 17. Number of age 1 recruits for haddock in unit areas 5Zjm.

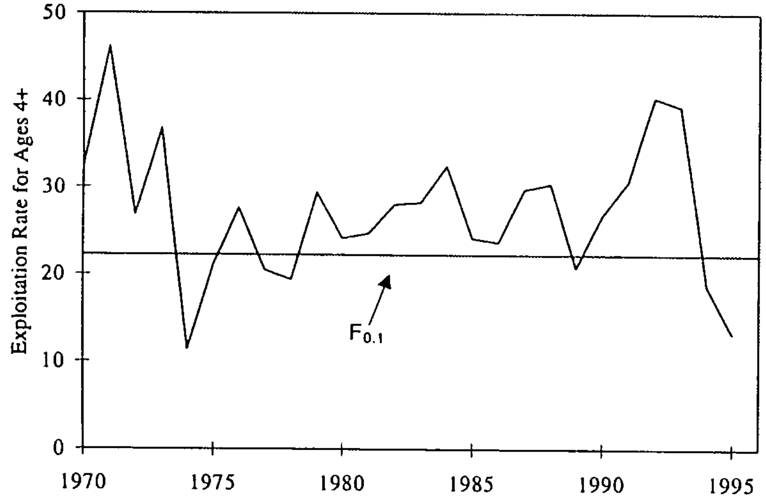

Fig. 18. Exploitation rate for haddock ages 4 and older in unit areas 5Zjm.

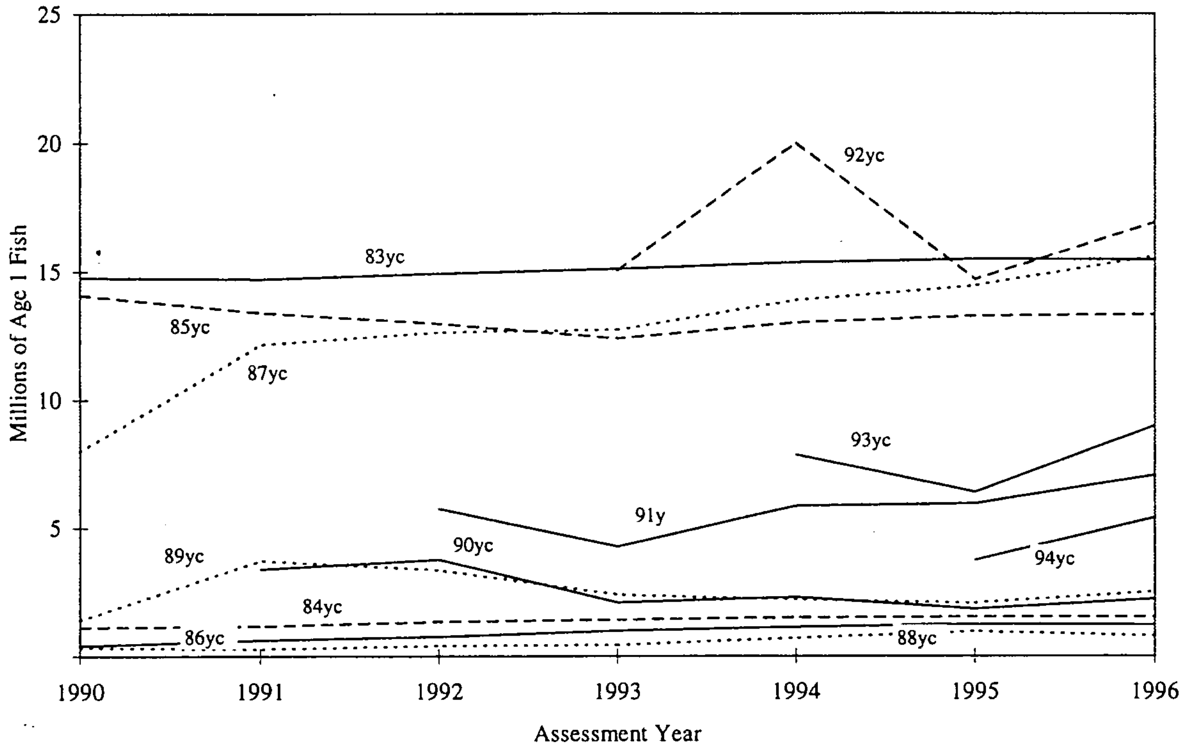

Fig. 19 . Successive estimates of year-class abundance as additional years of data were included in the assessment did not display any persistent trends.

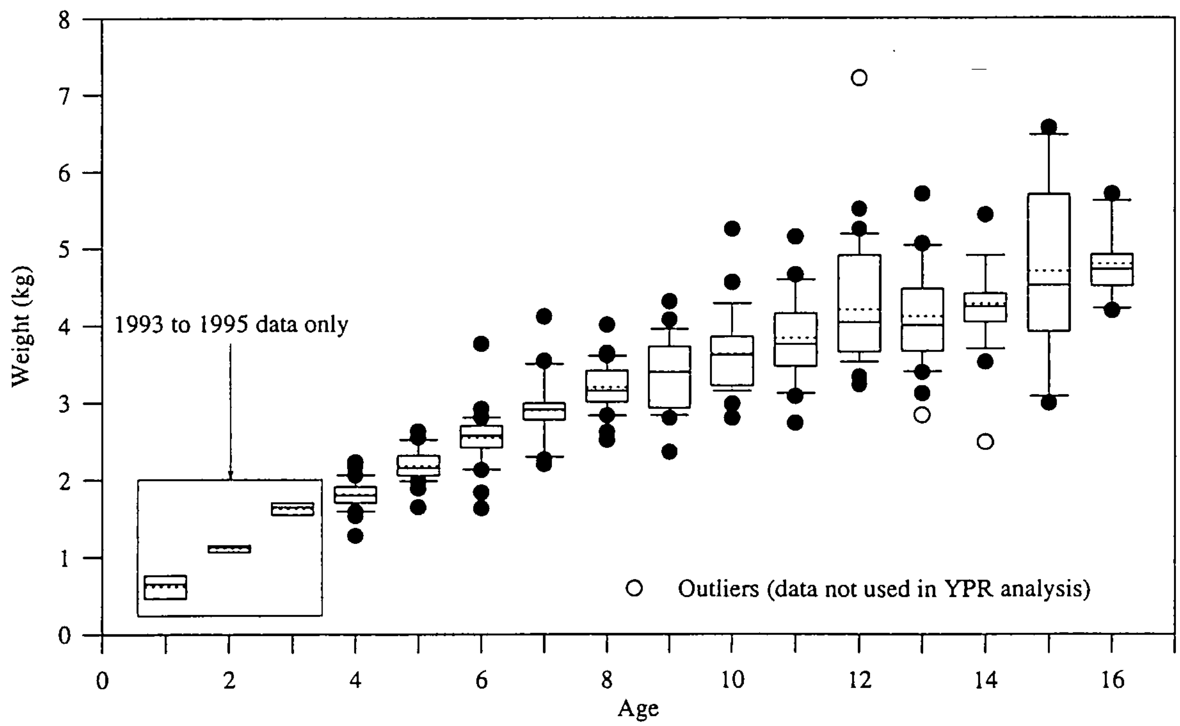

Fig. 20. Weights at age used in yield per recruit analysis. 1985-95 data was used for ages 4-16.The means, as indicated by the dotted lines, were used in the analysis. Three points were omitted as only 1 or 2 fish were aged.

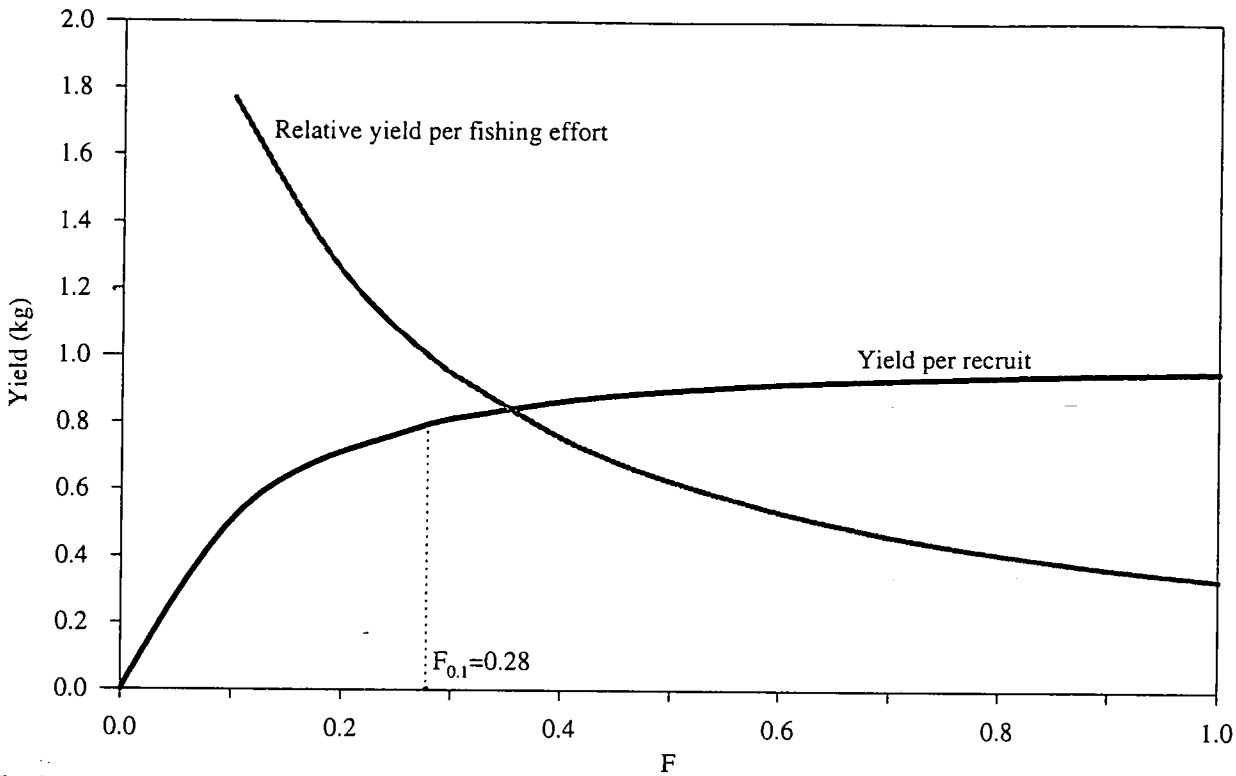

Fig. 21. Yield per recruit and yield per unit fishing effort relative to $F_{0.1}$ for 5Zj,m haddock.

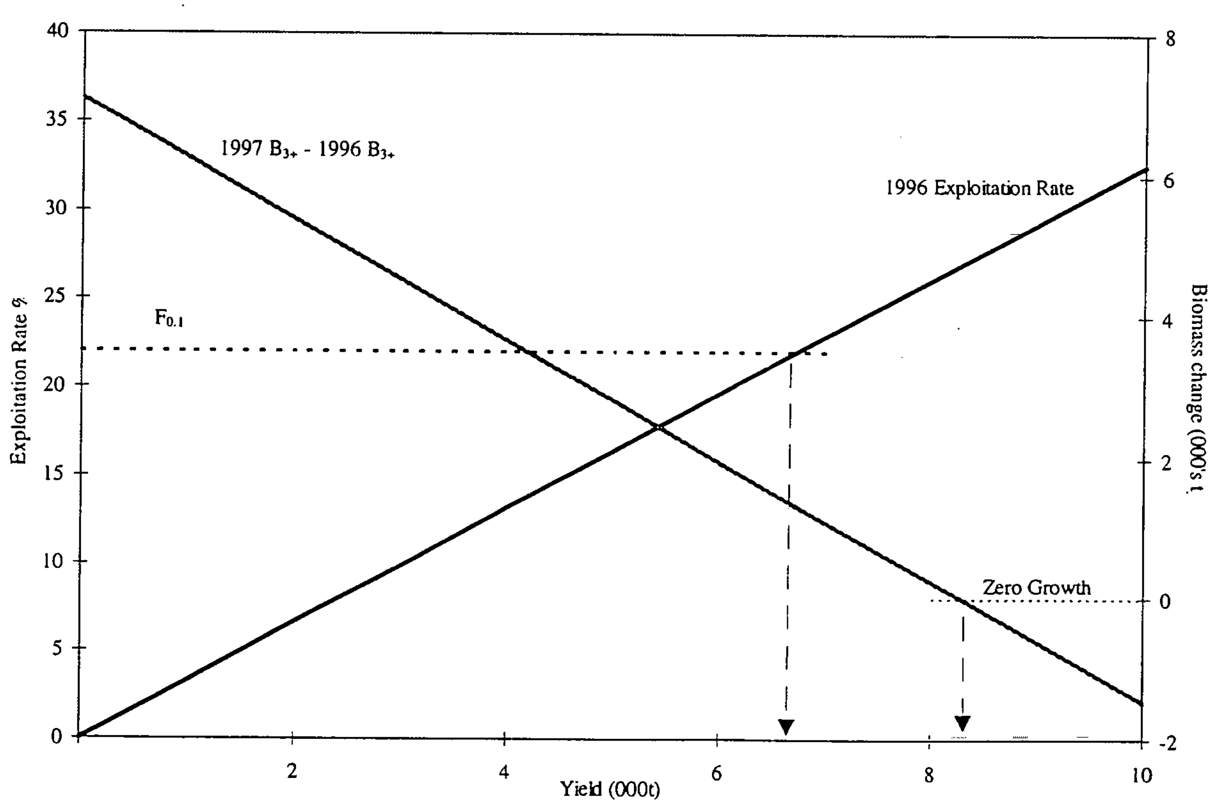

Fig. 22. Projected change in biomass from 1996 to 1997 at various exploitation rates.

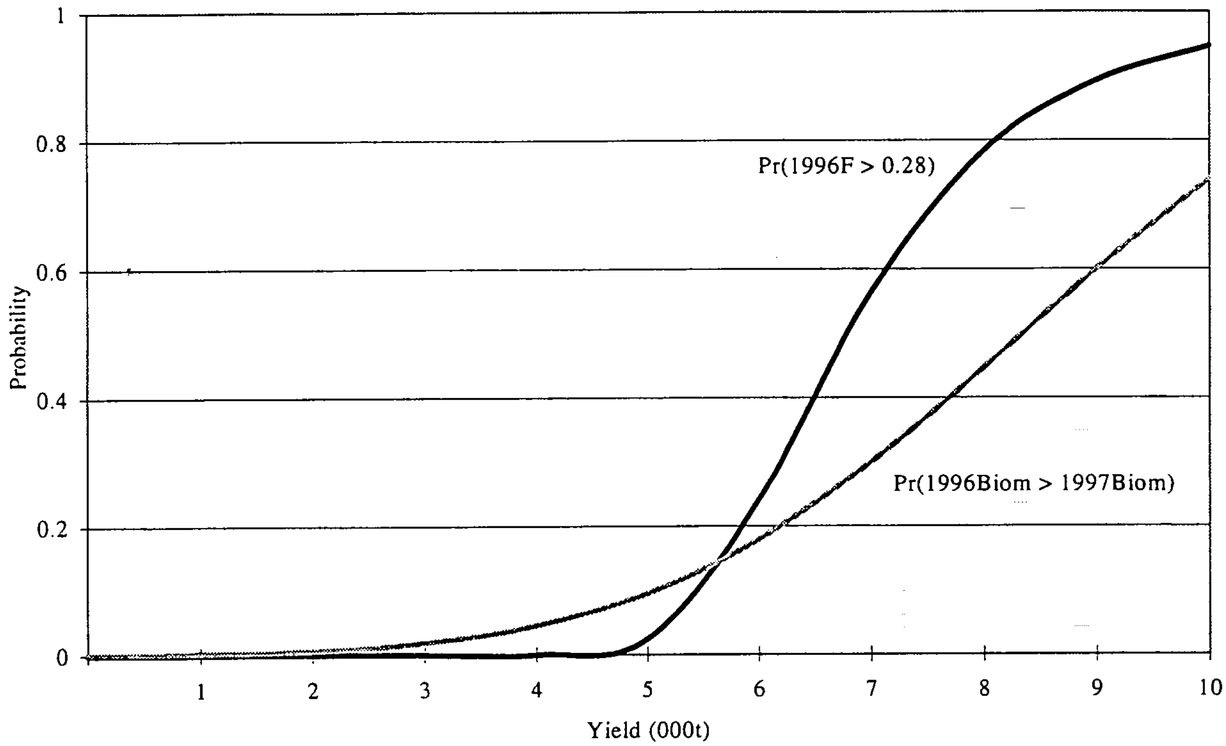

Fig. 23. Probability of the fishing mortality exceeding the $F_{0.1}$ (=0.28) reference level and of the 1997 biomass being less than that of 1996 for various harvest levels.

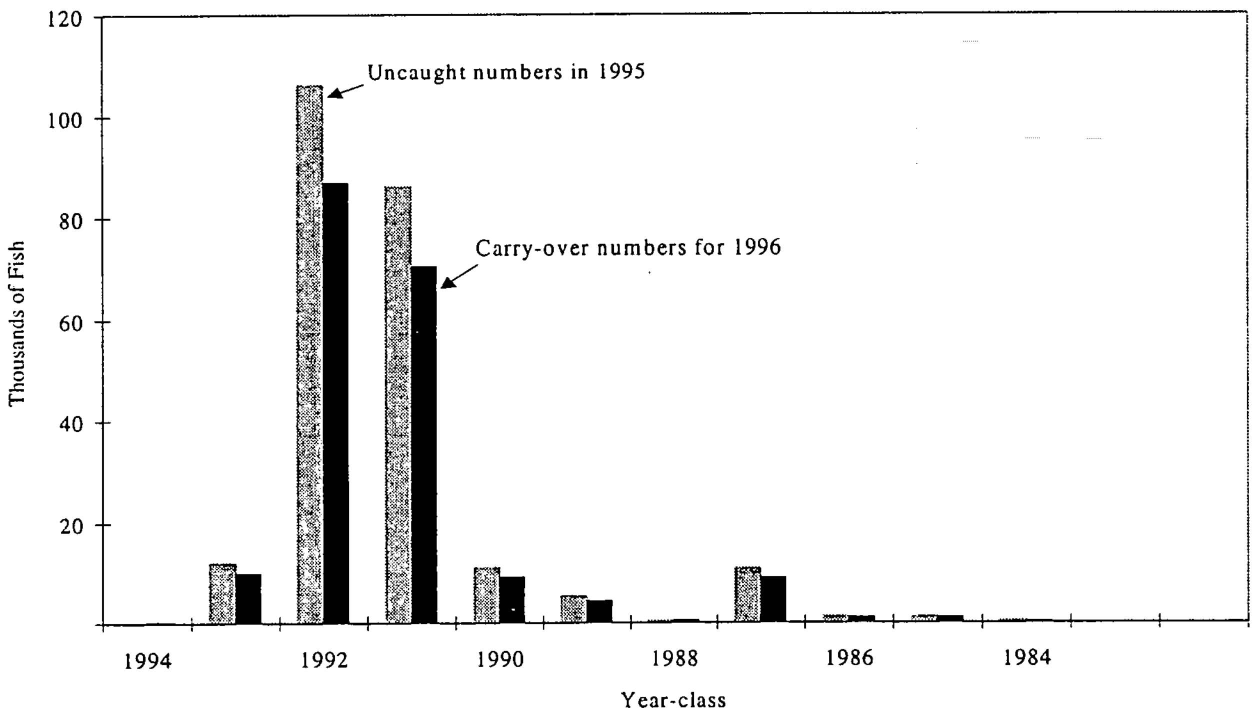

Fig. 24. Decrease of 1995 uncaught numbers to 1996 carry-over numbers due to natural martality.

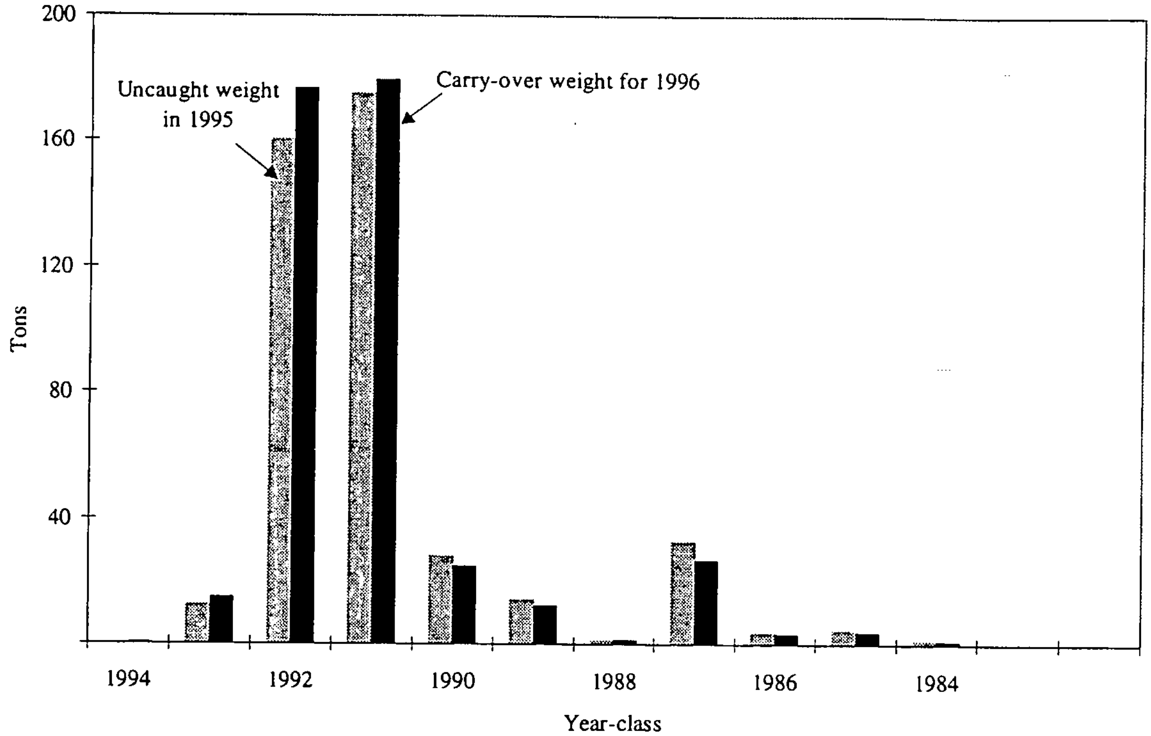

Fig. 25. The maximum carry-over weight for young fast growing year-classes may be greater than the uncaught weight even after accounting for natural mortality.