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Assessment of Haddock on Eastern Georges Bank

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Abstract

Haddock catches from eastern Georges Bank fluctuated around 5,000 tons from the early 1980s to 1993. Under restrictive management measures, catches declined from 6,377 t in 1991 to a low of 2,111 t in 1995, but increased again to 3,720 t and 2,850 t in 1996 and 1997 respectively. About 70% of the 1997 catch weight was comprised of haddock from the 1992 and 1993 year-classes. The trend in ages 3-8 abundance from surveys increased from 1992 to 1995 and has fluctuated since then. Surveys indicate that the 1996 year-class may be comparable to the moderate 1983, 1985, 1987 and 1992 year-classes.

Total population biomass (ages 1+) has steadily increased from near historic low levels of 12,171 t in 1993 to 28,809 t in 1998. The recent increase, due principally to the 1992 year-class, but also supported by the 1991 and 1993 year-classes, was enhanced by increased survivorship of young haddock resulting from reduced capture of small fish in the fisheries. The abundance of the 1996 year-class was estimated at about 13 million. The incoming 1995 and 1997 year-classes appear relatively weak at about 6 and 3 million respectively. Exploitation rate for ages 4 and older has consistently been below the $F_{0.1}$ target of 20% since 1995. Reduced fishing mortality in recent years has resulted in increased survival of incoming year-classes and greater abundance at older ages.

Combined Canada/USA projected yield at $F_{0.1} = 0.25$ in 1998 would be about 6,000 t. If fished at $F_{0.1}$ in 1998, the biomass for ages 3 and older is projected to increase from 22,726 t to 28,012 t at the beginning of 1999. The 1996 year-class was estimated to contribute almost 30% to the 1999 age 3+ biomass. A catch of 3,000 t in 1998, about what was caught in 1997, results in a negligible risk that fishing mortality rate will exceed $F_{0.1}$ and that the biomass for ages 3 and older will decrease. That same yield gives risks of 10% and 35% that an increase in biomass of 10% and 20% respectively would not be achieved.

Résumé

Les captures d'aiglefin dans la partie est du banc Georges ont été de l'ordre de 5 000 t entre les années 1980 et 1993. Suite à l'imposition de mesures de gestion strictes, elles sont tombées de 6 377, en 1991, à 2 111 t en 1995 pour ensuite augmenter à 3 720 t et 2 850 t en, respectivement, 1996 et 1997. Environ 70 % des captures de 1997, en poids, étaient formées d'aiglefins des classes d'âges de 1992 et 1993. L'abondance classes d'âges 3 à 8, déterminée par relevés, s'est accrue de 1992 à 1995 et a ensuite fluctué. Les relevés montrent que la classe de 1996 pourrait être comparable aux classes moyennes de 1983, 1985, 1987 et 1992.

La biomasse de la population totale (âges 1+) a augmenté de façon constante du niveau historiquement faible de 12 171 t, en 1993, à 28 809 t, en 1998. L'augmentation récente, s'expliquant surtout par la classe de 1992 mais aussi par celles de 1991 et 1993, s'est vue favorisée par une meilleure survie des jeunes aiglefins s'expliquant par une réduction de la capture des poissons de petite taille. L'abondance de la classe de 1996 a été estimée à 13 millions de poissons environ. Les classes de 1995 et 1997 semblent relativement faibles comptant respectivement 6 et 3 millions d'individus. Depuis 1995, le taux d'exploitation des âges 4 et plus a constamment été inférieur à l'objectif du $F_{0,1}$ de 20 %. La faible mortalité par pêche des dernières années a donné lieu à une augmentation de la survie des classes à venir et à une abondance accrue des classes plus âgées.

Le rendement prévu total du Canada et des États-Unis au niveau $F_{0,1}$= 0,25 serait de 6 000 t environ en 1998. À une exploitation au niveau du $F_{0,1}$ en 1998, la biomasse des âges 3 et plus devrait augmenter pour passer de 22 726 t à 28 012 t au début de 1999. Il a été estimé que la classe de 1996 devrait représenter près de 30 % de la biomasse des âges 3+ en 1999. Des captures de 3 000 t en 1998, soit environ le volume de 1997, devraient constituer un risque négligeable que la mortalité par pêche soit supérieure à celle du niveau $F_{0,1}$ et que la biomasse des âges 3 et plus diminue. Ce même rendement correspond à un risque de 10 % ou de 35 % qu'une augmentation de la biomasse respective de 10 % et 20 % ne soit pas atteinte.

Introduction

Since 1990 Canada has used eastern Georges Bank, fishery statistical units 5Zj and 5Zm (Fig. 1), as the basis for a management unit (Gavaris 1989). Results from the previous assessment (Gavaris and Van Eeckhaute 1997) showed that biomass increased from 12,000 t in 1993 to about 24,000 t in 1996 and declined slightly to 23,000 t in 1997. Present biomass levels were estimated to be well below historical levels. In the 1930s to the mid 1950s when biomass was over 60,000 t and about 40,000 t in the late 1970s and early 1980s. Recent year-classes sizes were also well below historical levels. Since 1968, only two year-classes, the 1975 and 1978 at about 50 million each, have been comparable to average recruitment during the 1930s to the mid 1950s. The 1991, 92 and 93 year-classes were estimated at 7, 15 and 10 million respectively while others since the 1987 year-class were considerably weaker. Exploitation rate declined from over 40% in 1991 and 1992 to below 20% in 1995 and 1996, resulting in increased survival of the moderate 1992 and 1993 year-classes. The 1997 Canadian quota was 3,200 t. For a catch of about this level, there was a greater than 80% chance of 3+ biomass increasing with an expected biomass increase of about 10% and less than a 10% chance of exceeding $F_{0.1}$.

In this assessment update we included the latest information from the 1997 Canadian and USA fisheries and made minor revisions to the 1996 data. Results from the Department of Fisheries and Oceans, Canada (DFO) survey in the spring of 1998 and the National Marine Fisheries Service,USA (NMFS) surveys in the spring and fall of 1997 were incorporated. We also explored some alternative assessment model formulations and evaluated the effect of the change in trawl nets used for the NMFS spring survey.

The Fishery

Commercial Catches

Under restrictive management measures, catches declined from 6,377 t in 1991 to a low of 2,111 t in 1995, but increased again to 3,720 t and 2,850 t in 1996 and 1997 respectively (Table 1, Fig. 2). Greater catches in the late 1970s and early 1980s, ranging up to 23,189 t in 1980, were associated with good recruitment. Substantial quantities of small fish were discarded in those years (Overholtz et al 1983). Catches subsequently declined and fluctuated at about 5,000 t during the mid to late 1980s.

The haddock on Georges Bank have supported a commercial fishery since the early 1920s (Clark et al 1982). Catches during the 1930s to 1950s ranged between 15,000 t and 40,000 t, averaging about 25,000 t (Fig. 3). Catches probably attained record high levels of about 60,000 t during the early 1960s but since the early 1970s catches have been lower.

The predominantly USA fishery was joined by Canadian and distant water fleets notably the USSR and Spain by the early 1960s. In 1953, the International Commission for the Northwest Atlantic Fisheries (ICNAF) implemented a minimum mesh size of 114 mm in the body and codend of towed gear. A Total Allowable Catch was introduced in 1970 by ICNAF in an attempt to curb rapidly declining abundance. 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). Both the season and the area closed have gone through several modifications.

Following the declaration of economic zones to 200 mi by coastal states in 1977, only Canada and the USA continued haddock fisheries on Georges Bank. After 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. Canada has retained a quota regulatory system and uses ancillary measures to augment management. Fishermen now pay for access to the fishery, for dockside monitoring and contribute to the costs of at sea observer coverage. The USA has not regulated catch by quotas since 1977 but has relied on other measures (area closures, trip limits, fish size, etc.) and has recently instituted an effort regulatory system. Further details of regulatory measures since 1977 are summarized in Table 2.

As in 1995 and 1996, Canadian catches in 1997 of 2,739 t were below the quota due to closure of the fisheries when the cod quotas were reached. During 1994 to 1997, all Canadian groundfish fisheries on Georges Bank remained closed from January to early June.

Fishery Sector	1993		1994		1995		1996		1997	
	Quota	Catch	Quota	Catch	Quota	Catch	Quota	Catch	Quota	Catch
Fixed gear <65'	1508	1216	791	784	592	357	1085	919	754	714
Mobile gear <65'	2212	1646	1439	1206	1268	1175	2280	1713	1625	1451
Fixed gear 65'-100'	50	8	30	8	25	0	45	49	32	36
Mobile gear 65'-100'	32	32	30	33	25	27	189	181	32	35
Vessels >100'	1198	826	710	290	590	444	921	513	757	573
Totals	5000	3728	3000	2411	2500	2003	4500	3375	3200	2809

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

Although the number of vessels fishing with fixed gear declined in 1997, the number of vessels fishing with mobile gear and the total number of days fished by all fishing sectors was about the same as in 1996. All landings were monitored at dockside and at-sea monitoring by observers resulted in coverage of almost 10% of days fished. Discarding and misreporting have been considered negligible since 1992.

In recent years the Canadian fishery has been conducted by vessels using otter trawls, longlines, handlines and gillnets. During 1997, all vessels over 65 ft operated on enterprise allocations, otter trawlers under 65 ft operated on individual quotas, fixed gear vessels 45-65 ft operated on self-administered individual quotas and fixed gear vessels under 45 ft operated on community quotas administered by local boards. Most haddock were caught by otter trawlers less than 65 ft (roughly equivalent to tonnage classes 1-3) and longliners less than 65 ft (Table 3). Unlike recent years, catches in June were not very high but the fishery improved in July (Table 4).

USA catches for 1997 were derived from logbooks coupled with dealer reports, as was done for 1994-96. Catches in 1997, which come almost exclusively from tonnage classes 3 and 4 otter trawlers (Table 5), remained low because the seasonal spawning area was closed to fishing during the entire year (Table 6). Effort in the USA fishery was regulated using Days-at-Sea limits. To curtail targeting of haddock, a 500 lb trip limit was introduced in 1994 and raised to 1,000 lb in July 1996. In September 1997 the limit was raised to 1,000 lb per day and a maximum of 10,000 lb per trip (Table 2). The trip limit resulted in an increase in the discard rate. USA discards for 1994-1997 were estimated from dealer data and vessel trip reports at 258 t, 25 t, 41 t and 63 t respectively. USA statistics for 1994-1997 are preliminary.

Size and Age Composition

Sampling of the 1997 Canadian fishery for size and age composition of the catch by at sea observers and port sampling achieved coverage of all principal gears and all seasons (Table 7, Fig. 4). No sampling was available for discards of groundfish by-catch in the 1997 Canadian scallop fishery, although haddock by-catch in previous years has not been substantial. 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) ; $weight(\text{kg round}) = 0.0000158 length(\text{cm})^{2.91612}$ .With decreasing landings of haddock in the USA fishery, few port samples were available to characterize the size and age composition of the landings. Sea sampling for discards was limited and current reporting rates in vessel trip reports (logbooks) are inadequate to reliably estimate the quantity of haddock discards.

The size composition of catch in the Canadian fisheries for otter trawlers less than 65ft, otter trawlers greater than 65ft and longliners was similar, peaking at about 56cm (Fig. 5). The gillnet catch represented a small proportion of the total catch, but consisted of larger haddock.

It has been suggested that fishery operations may not be typical when an observer is on board, therefore sampling by observers might not reveal high grading if it is occurring. Another source of data that may be examined for discarding or high grading is samples collected by surveillance officers. There are few length frequency samples from surveillance boardings of Georges Bank fisheries and the number of haddock measured per sample is low. The available data however, does not reveal any persistent patterns to suggest that high grading might be a significant problem (Appendix A).

Survey and commercial otoliths were read by L. Van Eeckhaute for DFO and by N. Munroe for NMFS. Results of intra-reader agreement tests for the DFO reader and inter-reader tests are detailed in Appendix B. No intra-reader agreement tests are available for the NMFS reader. Between reader tests for the DFO reader and the NMFS reader was poor for one of the tests with a substantial bias and, while the other test had satisfactory agreement, there was a slight bias in the opposite direction. At present, ageing discrepancies between NMFS and DFO have marginal impact on the fishery age composition as there is little catch by the USA in 5Zj and 5Zm. NMFS survey results are based on the NMFS readings. The cause of this bias and poor agreement should be investigated and appropriate measures taken to ensure that both agers are interpreting the otoliths in the same way.

Catch and weight at age for the commercial fishery were calculated by applying age length keys to length frequencies using the methods described in Gavaris and Gavaris (1983). About 70% of the 1997 catch weight was comprised of haddock from the 1992 and 1993 year-classes. In contrast to pre-1994 catches, few haddock of ages 2 and 3 were caught in 1997, due in part to the type of gear used and to avoidance of areas with small fish (Fig. 6). In comparison to the age composition of the catch during earlier periods, age groups 4 to 6 and 9+ appear to be well represented. Catches associated with the weak 1989 and 1990 year-classes are small. The strong 1962 and exceptional 1963 year-classes dominated catches in the early 1970s, therefore the haddock of ages 9+ constituted a greater than average proportion of the catch in that period.

The updated 1996 and the new 1997 catch at age by quarter (Table 8) were used to augment the 1969-95 results reported by Gavaris and Van Eeckhaute (1997). Annual catch at age and average fishery weight at age are summarised in Tables 9 and 10. Fishery weights at age may be affected by variations in fishing practices and the time of year that catches occur. Survey weights at age were used to investigate changes in growth.

Abundance Indices

Commercial Catch Rate

Catch rate trends from the Canadian commercial fishery for selected trips by tonnage class 2 and 3 otter trawlers and longliners showed an increasing trend from 1993 to 1995 and remained relatively stable through 1996 and 1997 (Fig. 7). In contrast to 1995 and 1996, otter trawlers catch rates were relatively low in June of 1997 but displayed the expected increase in December. Longliner catch rates for tonnage class 2 increased markedly through season in 1997. Changes to regulations, gear modifications and varying fishing practices in recent years make comparison of catch rates from year to year difficult to interpret. Therefore, these were not used as indices of abundance.

Research Surveys

Surveys have been conducted by the NMFS each year in the fall since 1963 and in the spring since 1968 and by DFO each year in the spring since 1986. All these surveys use a stratified random design. The strata boundaries for the NMFS spring and fall surveys are shown in Fig. 8 and those for the DFO spring survey are shown in Fig. 9. For the NMFS surveys, two vessels have been employed and there was a change in the trawl door in 1985. Conversion factors (Table 11), derived experimentally from comparative fishing, have been applied to the survey results to make the series consistent. Additionally, two trawl nets were used on the NMFS spring survey, a modified Yankee 41 during 1973-81 and a Yankee 36 in other years, but no conversion factors are available for haddock.

The distribution of catches for the most recent survey of each series was similar to the distribution over the previous 5 year period (Figs. 10-12). During spring, haddock of all ages are broadly distrubuted on top of the bank but ages 2 and older are more concentrated along the Northern Edge and Northeast Peak. In the fall, haddock are less prevalent on top of the bank and higher densities are found in deeper waters on the slopes of the Northern Edge and the Northeast Peak. The percent of biomass, ages 3-8, on the Canadian side of 5Zjm from the three surveys was summarised for the most recent years. During the NMFS fall survey almost all of the biomass occurred on the Canadian side. During the DFO spring survey, generally conducted in late February, most of the biomass was on the Canadian side although the percentage was lower in 1992 to 93. During the NMFS spring survey, generally conducted in late March, the percentage on the Canadian side was typically lower than for the DFO survey but these results were more variable.

Percentage of biomass on Canadian side			
	Spring		Fall
Year	DFO	NMFS	NMFS
1992	68	78	100
1993	67	43	99
1994	99	100	100
1995	98	62	100
1996	96	17	100
1997	92	93	100
1998	100	N/A	N/A

The trend in abundance for ages 3-8 increased from 1992 to 1995 and has fluctuated since then with no persistent pattern though all 3 surveys were low in 1997 (Fig. 13). Abundance peaked at record highs during the early 1960s. After declining to a record low in the early 1970s, it peaked again in the late 1970s, though at a lower level, and again during the mid to late 1980s at about half the level of the 1970s peak. Survey results for ages 1 and 2 indicate that the abundance of the 1996 year-class may be comparable to the moderate 1983, 1985, 1987 and 1992 year-classes (Fig. 14). These year-classes were considerably smaller than the strong 1975 and 1978 year classes and the very strong 1962 and exceptional 1963 year-classes. Age specific results from these surveys are shown in Tables 12-14.

The weights at age from the DFO spring survey, $\overline{W_a}$, were defined as the average of the mean weights at length, l, and age, a, $\overline{W_{la}}$ (defined below), weighted by the stratified numbers in 5Zj and 5Zm at that length and age, A_{la}:

$$\overline{W_a} = \frac{\sum_l \left(\overline{W_{la}} A_{la}\right)}{\sum_l A_{la}} .$$

$\overline{W_{la}}$ is defined as the average of the weights, W, at length and age for all haddock sampled for detail measurements, d, where A'_{lad} is the total numbers sampled for detailed measurements at that length and age:

$$\overline{W_{la}} = \frac{\sum_d W_{lad}}{\sum A'_{lad}} .$$

With the exception of the higher than average weight at age for the 1989 and 1990 yearclasses, average weight at age from surveys in recent years did not display persistent trends (Fig. 15).

Estimation of Stock Parameters

Calibration of VPA

The VPA used quarterly catch at age, $C_{a,t}$, for ages $a = 0, 1, 2...8$, and time $t = 1969.0$, 1969.25, 1969.5, 1969.75, 1970.0...1996.75, where t represents the beginning of the time interval during which the catch was taken. The VPA was calibrated to bottom trawl survey abundance indices, $I_{s,a,t}$, for

s = DFO spring, ages $a = 1, 2, 3...8$, time $t = 1986.16$, 1987.16...1998.0
s = NMFS spring (Yankee 36), ages $a = 1, 2, 3...8$, time $t = 1969.29$, 1970.29, 1971.29, 1972.29, 1982.29, 1983.29...1997.29
s = NMFS spring (Yankee 41), ages $a = 1, 2, 3...8$, time $t = 1973.29$, 1974.29...1981.29
s = NMFS fall, ages $a = 0, 1, 2...5$, time $t = 1969.69$, 1970.69...1997.69

Since forecast projections were required for the entire year 1998, the DFO spring survey in 1998 was designated as occurring at time 1998.0 instead of 1998.16. The NMFS fall survey captures young of the year and that information is included as 0 group, but older haddock appear less available during this season. Survey indices for older ages where catches were sparse and there were frequent occurrences of zero catches were not included. Zero observations for abundance indices were treated as missing data as the logarithm of zero is 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 adaptive framework, ADAPT, (Gavaris 1988) was used to calibrate the sequential population analysis with the research survey abundance trend results. The model formulation employed assumed that the random error in the catch at age was negligible. The errors in the abundance indices were assumed independent and identically distributed after taking natural logarithms of the values. The annual natural mortality rate, M, was assumed constant and equal to 0.2. A model formulation using as parameters the natural logarithm of population abundance at the beginning of the year was considered because of close to linear behavior for such a parameterization (Gavaris 1993). The following model parameters were defined:

$\theta_{a,t'}$ = ln population abundance

for ages $a = 1, 2, ... 8$ at time $t' = 1998.0$,

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

for each abundance index source, s, and relevant ages, a.

A solution for the parameters was obtained by minimizing the sum of squared differences between the natural logarithm observed abundance indices and the natural logarithm population abundance adjusted for catchability by the calibration constants. The objective function for minimization was defined as

$$\underset{s,a,t}{\Psi}\left(\hat{\theta},\hat{\kappa}\right) = \sum_{s,a,t}\left(\psi_{s,a,t}\left(\hat{\theta},\hat{\kappa}\right)\right)^2 = \sum_{s,a,t}\left(\ln I_{s,a,t} - \left(\hat{\kappa}_{s,a} + \ln N_{a,t}\left(\hat{\theta}\right)\right)\right)^2$$

For convenience, the population abundance $N_{a,t}\left(\hat{\theta}\right)$ is abbreviated by $N_{a,t}$. At time t', the population abundance was obtained directly from the parameter estimates, $N_{a,t'} = e^{\hat{\theta}_{a,t'}}$. For all other times, the population abundance was computed using the virtual population analysis algorithm, which incorporates the common exponential decay model

$$N_{a+\Delta t,t+\Delta t} = N_{a,t} e^{-(F_{a,t}+M_a)\Delta t} .$$

Year was used as the unit of time, therefore ages were expressed as years and the fishing and natural mortality rates were annual instantaneous rates. The fishing mortality rate, $F_{a,t}$, exerted during the time interval t to $t+\Delta t$, was obtained by solving the catch equation

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

using a Newton-Raphson algorithm. The fishing mortality rate for the oldest age in the last time interval of each year was assumed equal to the weighted average for ages fully recruited to the fishery during that time interval

$$F_{8,t} = \sum_{a=4}^{7} N_{a,t}F_{a,t} \Big/ \sum_{a=4}^{7} N_{a,t} .$$

The covariance matrix of the parameters was estimated using the common linear approximation (Kennedy and Gentle 1980 p.476)

$$Cov(\hat{\theta},\hat{\kappa}) = \hat{\sigma}^2\left[J^T(\hat{\theta},\hat{\kappa})J(\hat{\theta},\hat{\kappa})\right]^{-1}$$

where $\hat{\sigma}^2$ is the mean square residual and $J(\hat{\theta},\hat{\kappa})$ is the Jacobian matrix. The bias of the parameters was estimated using Box's (1971) approximation, which assumes that the errors are normally distributed

$$Bias(\hat{\theta},\hat{\kappa}) = \frac{-\hat{\sigma}^2}{2}\left(\sum_{s,a,t} J_{s,a,t}(\hat{\theta},\hat{\kappa})J^T_{s,a,t}(\hat{\theta},\hat{\kappa})\right)^{-1}\left(\sum_{s,a,t} J_{s,a,t}(\hat{\theta},\hat{\kappa})\right) tr\left[\left(\sum_{s,a,t} J_{s,a,t}(\hat{\theta},\hat{\kappa})J^T_{s,a,t}(\hat{\theta},\hat{\kappa})\right)^{-1} H_{s,a,t}(\hat{\theta},\hat{\kappa})\right]$$

where $J_{s,a,t}(\hat{\theta},\hat{\kappa})$ are vectors of the first derivatives for each $\psi_{s,a,t}(\hat{\theta},\hat{\kappa})$ and $H_{s,a,t}(\hat{\theta},\hat{\kappa})$ are the Hessian matrices of second derivatives for each $\psi_{s,a,t}(\hat{\theta},\hat{\kappa})$.

Population quantities of interest for management advice are functions of the estimated parameters. The variance and bias of an arbitrary quantity, $\hat{\eta} = g(\hat{\theta},\hat{\kappa})$ where g is the transformation function, were estimated using the methods described in Ratkowsky (1983)

$$Var(\hat{\eta}) = tr\left[GG^T \operatorname{cov}(\hat{\theta},\hat{\kappa})\right]$$

$$Bias(\hat{\eta}) = G^T Bias(\hat{\theta},\hat{\kappa}) + tr\left[W \operatorname{cov}(\hat{\theta},\hat{\kappa})\right]/2$$

where G is the vector of first derivatives of g with respect to parameters and W is the matrix of second derivatives of g with respect to parameters.

Confidence statements for management quantities of interest were obtained using the non-parametric bias corrected percentile bootstrap method. Non-parametric bootstrap techniques offer the advantage of not making any assumptions about the error distribution. The bootstrap samples are used to calculate the bootstrap replicate estimates, $\hat{\eta}^b$, of the quantity of interest.

The percentile method (Efron 1982) is a simple and direct way of forming an empirical cumulative frequency distribution. The probability that $\hat{\eta}$ is less than or equal to some value is defined as the proportion of bootstrap replicates, $\hat{\eta}^b$, less than or equal to that value.

$$\hat{\Omega}(x) = \text{Prob}\{\hat{\eta} \leq x\} = \frac{\#\{\hat{\eta}^b \leq x\}}{B},$$

where B is the total number of bootstrap replicates. For conceptual and graphing purposes, it is convenient to consider the empirical cumulative frequency distribution as the set of paired values $(\alpha, \vec{\eta}^b)$, where $\vec{\eta}^b$ are the ordered bootstrap replicates and α are the respective probability levels equal to $\frac{1}{B}, \frac{2}{B}, \frac{3}{B}, \cdots, \frac{B}{B}$.

Frequently, the median of the bootstrap percentile density function does not equal the estimate obtained with the original data sample. The bias-corrected percentile method (Efron 1982) makes an adjustment for this type of bias. The bias-corrected percentile method can be thought of as an algorithm to replace the $\vec{\eta}^b$ in the paired values $(\alpha, \vec{\eta}^b)$ with the bias adjusted quantity $\vec{\eta}^b_{BC}$. The notation $\hat{\Omega}^{-1}(\;)$ or $\Phi^{-1}(\;)$ is used to represent the inverse distribution function, i.e. the critical value corresponding to the specified probability level. For each α in the paired values $(\alpha, \vec{\eta}^b)$, calculate the bias adjusted quantity $\vec{\eta}^b_{BC}$.

$$\vec{\eta}^b_{BC} = \hat{\Omega}^{-1}(\Phi(2z_0 + z_\alpha)).$$

Here, Φ is the cumulative distribution function of a standard normal variate, $z_\alpha = \Phi^{-1}(\alpha)$ and $z_0 = \Phi^{-1}(\hat{\Omega}(\hat{\eta}))$. The term z_0 achieves the bias adjustment. If the median of the bootstrap density function is equal to $\hat{\eta}$, then $\hat{\Omega}(\hat{\eta})$ will be 0.5, z_0 will be zero, and $\vec{\eta}^b_{BC}$ will equal $\vec{\eta}^b$ (i.e. no bias adjustment). Note that computations are not carried out for $\alpha = \frac{B}{B}$ because $z_\alpha = \Phi^{-1}(\alpha = 1)$ is not defined.

In previous assessments the NMFS spring survey has been treated as a continuous index for the entire time series. As noted earlier, the NMFS spring survey used a Yankee 41 trawl during 1973-81 and a Yankee 36 in other years. The limited comparative fishing done between these nets caught few haddock thereby not permiting computation of a conversion factor, but analyses by Hayes and Buxton (1992) suggested that differences were not significant. We examined this issue again by treating the NMFS spring survey data for 1973-81 as a distinct survey. We refer to this as the split model and we refer to the approach used in last year's assessment as the base.

Box plots of the age specific annual catchabilities (ln and linear) showed that those for the Yankee 41 net were higher than for the Yankee 36 net (Fig. 16). A graph of the estimated ln catchabilities showed little or no overlap in the one standard error range for most ages (Fig. 17). Although the overall mean square residual for the split model improved marginally, this is hardly detectable in the residual time series (Fig. 18).

We concluded that the evidence for a difference in catchability between the Yankee 36 and the Yankee 41 was compelling and the assessment was conducted in a manner which takes this into account. Nevertheless, the impact on terminal year population abundance was not great as the greater number of observations for the Yankee 36 trawl largely determined the average catchability (Fig. 19).

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 15). The average magnitude of residuals is large and though several large residuals can be identified, the respective observations do not appear influential and should not impact parameter estimates of current abundance (Fig. 20). The table below shows the average of squared residuals for each series.

Survey	Age								
	0	1	2	3	4	5	6	7	8
Can. Spring	-	0.68	0.91	0.28	0.21	0.48	0.60	0.99	0.64
NMFS Spring 36	-	0.89	0.52	0.49	0.34	0.60	0.94	1.36	0.64
NMFS Spring 41		1.03	1.23	0.89	0.29	0.60	0.90	3.55	2.08
NMFS Fall	1.33	1.78	1.18	0.60	0.47	0.67	-	-	-

Myers and Cadigan (1995) reported that correlated errors among ages within 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 among ages within a survey 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: $(e_{i,t}, e_{j,t})$ for all ages $i \neq j$ and all times t. For the four survey sources used in this assessment, the correlation was found to be small; DFO spring survey $\hat{\rho} = 0.08$, NMFS spring survey with the Yankee 36 net $\hat{\rho} = 0.10$, NMFS spring survey with the Yankee 41 net $\hat{\rho} = 0.18$ and NMFS fall survey $\hat{\rho} = 0.19$. Accordingly, no further corrective measures were taken to account for bias from this type of model mis-specification for this stock.

Results from analyses assuming a multinomial error structure for the objective functions were examined (Appendix C). The multinomial error model, which places less reliance on small catches, resulted in a 40% lower estimate of population abundance in 1998. The model based on the logarithm of survey observations assumes that small catches are as reliable as large catches on the logarithmic scale. The results from the multinomial model were considered illustrative and further work is required to investigate the robustness of such alternate error structure models. Diagnostics to help discriminate between alternative models need to be investigated. Model mis-specification is an additional source of uncertainty that has not been incorporated in the subsequent risk analyses.

A further variation in model formulation which was explored retained the standard error assumption about the logarithm of survey observations but did not make any assumptions about the fishing mortality on age 8 being equal to the average on ages 4 to 7 by estimating the abundance of all cohorts directly as parameters (Appendix C). The population abundance trends from this model, for constant catchability at ages 3 to 8 in the Canadian spring survey, were similar to those from the standard model therefore the assumption on fishing mortality for age 8 was considered appropriate.

Retrospective Analysis of Calibrated VPA

Results from assessments for several other stocks have identified a discrepancy between past estimates of stock status and current estimates using additional data (retrospective pattern). Results for this stock indicate that this assessment does not suffer from a retrospective pattern (Fig. 21). Fig. 21 tracks successive estimates of year-class abundance at age and shows that estimates are fairly stable although there is sometimes a substantial change after the first estimate of a year-class when more data becomes available, as evidenced for the 1992 and 1996 year-classes. There were no trends of concern in the 3+ biomass pattern and the 4+ F when weighted by population numbers (Fig. 22). The unweighted 4+ F pattern was not as stable as the weighted Fs, the increased variability probably due to poorly estimated Fs on small year-classes.

Projections based on the previous assessment (Gavaris and Van Eeckhaute 1997) indicated that with a Canadian quota of 3,200 t in 1997, biomass for ages 3 and older was expected to increase by about 8% and there was a very high chance that fishing mortality would be lower than $F_{0.1}$. The realised biomass growth between 1997 and 1998 was about 10% and the realised fishing mortality rate in 1997 was about half of $F_{0.1}$ with a Canadian catch of 2,739 t.

Mortality Estimates from Surveys

Survey abundance estimates for this stock are very variable, therefore age specific mortality derived from them fluctuate widely. Age aggregated total mortality for adult fish has somewhat lower variablility but also fluctuates considerably. Ages 3-8 from the DFO and NMFS spring surveys and ages 2-5 from the NMFS fall survey were used to calculate mortality estimates. Applying a 3 year running median smoother to the mortality estimates helps to identify some general patterns (Fig. 23). Total mortality was relatively stable at just below 1 until about the mid 1980s when it decreased. During the late 1980s and early 1990s it increased to above 1 before declining to the current lower level below 0.5.

Stock Status

The results from the standard lognormal model formulation were considered appropriate on which to base the status of the stock. For each cohort, the terminal population abundance estimates from ADAPT were adjusted for bias and used to construct the history of stock status. Gavaris and Van Eeckhaute (1997) 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 (Tables 16-17). The weights at age from the DFO spring survey, $\overline{W_a}$, (Table 18) were used to calculate beginning of year population biomass (Table 19)

A weight of 2.4 kg, which was midway between the age 6 and 8 weight for that cohort, was used for age 7 in 1995. For 1969-85, the 1986-95 average weight at each age was used. The weight at age for ages 9+ haddock was used for age 9.

Total population biomass (ages 1+) has steadily increased from near historic low levels of 12,171 t in 1993 to 28,809 t in 1998 (Fig. 24). The recent increase, due principally to the 1992 yearclass, but also supported by the 1991 and 1993 yearclasses (Fig. 25), was enhanced by increased survivorship of young haddock resulting from reduced capture of small fish in the fisheries. The continuing increase is being sustained by the 1996 year-class. The biomass trend for ages 3 and older is similar. The strength of the 1996 yearclass was estimated to be about 13 million, comparable to the 1983, 1985, 1987 and 1992 year-classes, while those during 1988-90 were less than 3 million. The 1991 and 1993 yearclasses were estimated at about 7 and 10 million respectively while the incoming 1995 and 1997 yearclasses appear to be relatively weak at about 6 and 3 million respectively. Population biomass during the late 1970s and early 1980s was considerably higher, ranging to almost 50,000 t due to recruitment of the strong 1975 and 1978 year-classes whose abundance was estimated at about 50 million. However, biomass declined rapidly in the early 1980s as subsequent recruitment was poor and these two yearclasses were fished intensely at a young age.

Exploitation rate for ages 4 and older has consistently been below the $F_{0.1}$ target of 20% ($F_{0.1} = 0.25$) since 1995 (Fig. 26). Historically, exploitation rate has generally exceeded $F_{0.1}$ and showed a marked increased between 1989 and 1992 to almost 50%, the highest level observed. Reduced fishing mortality in recent years has resulted in increased survival of incoming yearclasses (Fig. 27). The number of haddock surviving to age 6 of the 1992 yearclass was about twice that of the equally abundant 1983 yearclass, and about the same as that of the 1975 or 1978 yearclasses which were more than 3 times as abundant. Examination of the percent age composition and the absolute abundance at age in 1998 compared to the averages over earlier time periods suggests that all ages are well represented in the population proportionally but absolute abundance at recruiting ages is considerably lower that the 1931-55 average (Fig 28).

Gains in fishable biomass may be partitioned into those associated with somatic growth of haddock which have previously recruited to the fishery and those associated with new recruitment to the fishery. We used age 2 as a convenient age of first recruitment to the fishery. It is evident (Fig. 29) that in most years since 1969, the bulk of the biomass gain was attributed to somatic growth, but in years of strong recruitment, about half the biomass gain was due to incoming recruits. Surplus production is defined as the gains in fishable biomass which are in excess of the needs to offset losses from natural mortality. When the fishery yield is less than the surplus production, there is a net increase in the population biomass. Since 1993, the surplus production has either exceeded or has been about equal to the yield and consequently, the population has sustained a net biomass growth (Fig 30).

Fishery Reference Points

Yield per Recruit

The yield per recruit formulation used previously was revised to assume complete fishing on the last age group (i.e. +group). A partial recruitment of 0, .05, .5, 1, 1 ...1, was assumed for ages 1, 2, 3, 4, 5...16+. Fishery weights at age for ages 1 to 16 were estimated from the 1985-97 fishery to reflect recent fishery conditions. These weights were converted to length using $L = (W/0.0000158)^{1/2.91612}$ (the inverse of the relationship used to convert fishery lengths to weights) to enable a Von Bertalanffy fit of average length and age data. The predicted lengths at age from the resulting relationship, $L_t = 76.22\left(1 - e^{-0.1925(t-(-2.509))}\right)$, were then converted back to weight using $W = 0.0000158L^{2.91612}$ (Fig. 31). Using these predicted weights, the estimated $F_{0.1}$ was 0.25 with a yield of 0.75 kg per age 1 recruit (Fig. 32).

Stock and Recruitment

Exact age composition of the catch from unit areas 5Zj and 5Zm was not available prior to 1969. Although total catch of haddock from unit areas 5Zj and 5Zm is considered reliable, only an approximate age composition of the catch could be obtained by prorating the 5Z catch at age with the 5Zjm:5Z landings ratio. Using these data however, it was possible to reconstruct an illustrative population analysis for the period between 1930 and 1955 which is suitable for comparing productivity. The results indicated that the current total biomass was less than a third of the average sustained over those two decades (Fig. 33).

The pattern of recruitment against adult biomass indicates that the chance of observing a strong year-class is significantly worse for biomass below about 40,000 t. Since 1969, only the 1975 and 1978 year-classes have been near the average abundance of year-classes observed during that historic period (Fig. 34).

Prognosis

Yield projections were done using the bias adjusted 1998 beginning of year population abundance estimates. The abundance of the 1998 year-class was assumed to be 6 million at age 0. Partial recruitment to the fishery for ages 1, 2 and 3, fishery weights at age and beginning of year population weights at age were averaged over the previous 4 years for use in the 1998 forecasts (Table 20).

Combined Canada/USA projected yield at $F_{0.1} = 0.25$ in 1998 would be about 6,000 t (Table 20, Fig. 35). If fished at $F_{0.1}$ in 1998, the biomass for ages 3 and older is projected to increase from 22,726 t to 28,012 t at the beginning of 1999. The 1992 and 1993 year-classes would comprise about 40% of the 3+ biomass and 60% of the forecast yield. With the recruitment of the 1996 year-class, the adult biomass can be expected to increase further if exploitation rate is maintained at the current moderate level. The 1996 yearclass was estimated to contribute almost 30% to the 1999 age 3+ biomass.

Uncertainty about year-class abundance generates uncertainty in forecast results. This uncertainty was expressed as risk of achieving reference targets. For example, a combined Canada/USA catch of 3,000 t in 1998, about what was caught in 1997, results in a negligible risk that fishing mortality rate will exceed $F_{0.1}$ and that the biomass for ages 3 and older will decrease (Fig. 36). That same yield gives risks of 10% and 35% that an increase in biomass of 10% and 20% respectively would not be achieved. These uncertainty calculations do not include variations in weight at age, partial recruitment to the fishery and natural mortality, or systematic errors in data reporting and model mismatch. Therefore, overall uncertainty would be greater but these results provide rough guidelines. Increasing the number of age groups contributing to the yield should lead to greater precision in the advice, reduced 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 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 modelled 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. Although environmental conditions are thought to influence fisheries processes, convincing relationships with quantities such as recruitment, survival rates and fish catchability have not been established for this stock.

Comparison of Results for Canadian and USA Management Units

The existence of two centers of haddock aggregation on Georges Bank with distinct spawning components has long been recognized (Fig. 37). One aggregation spawns on the Northeast Peak in the spring and migrates to the bank slopes on the Northeast Edge and Peak as the waters warm in the summer. The other component spawns around the Nantucket Shoals in the spring and migrates to the bank slopes around the Great South Channel as the waters warm in the summer. The former is referred to as the Eastern component and the latter as the Western component. There is evidence for limited but poorly quantified exchange between the two components. Haddock from the Western component are characterized by faster growth.

The USA conducts fisheries for haddock on both the Western and Eastern components. The USA defines a management unit encompassing both Eastern and Western components of the Georges Bank haddock resource, specifically NAFO Division 5Z (small amounts of haddock caught in NAFO Subarea 6 are included). Canada conducts fisheries for haddock on the Eastern component only and is concerned with regulatory measures which could be applied to it in order to achieve benefits. Accordingly, Canada defines unit areas 5Zj and 5Zm as a management unit.

Between 1969 and 1985, catches from 5Zjm averaged about 56% of the total catches from 5Z, ranging between 44% and 67% (Fig. 38). During 1985 to 1996, catches from 5Zjm were consistently above 83% of the total catches from 5Z, averaging about 88%, but in 1997 that percentage dropped to 67%.

Over this period, the total biomass for the two management units showed a similar pattern (Fig. 39). The biomass in 5Z declined from 94,000 t in 1980 to 17,000 t in 1993 and has since increased to 40,000 t in 1998. In 5Zjm, the biomass declined from 49,000 t in 1980 to 12,000 t in 1993 and has reached about 29,000 t in 1998. Since 1985, the biomass in 5Zjm has consistently been over about 70% of the total 5Z biomass.

The 1975 and 1978 year-classes were the most abundant on Georges Bank since 1969 (Fig. 40). The abundance at age 1 for these two year-classes was about 105 million and 83 million respectively for all of 5Z and about 54 million and 52 million in 5Zjm. Subsequent year-classes have been considerably weaker with the strongest among them being the 1983, 1985, 1987, 1992 and 1996 year-classes. The abundance at age 1 of these year-classes was 17, 15, 17, 17 and 13 million respectively for all of 5Z and 15, 13, 15, 14 and 13 million in 5Zjm. The 1968 through 1980 year-classes in 5Zjm averaged about 60% of the abundance for all of 5Z while those after 1980, with the exception of 1994 and 1995, have generally comprised over 70% of the total for 5Z, averaging about 80%.

The fishing mortality rates in 5Zjm and in all of 5Z showed a decline between the early and mid 1970s, followed by an increase until 1980 (Fig. 41). Between 1980 and 1990, the fishing mortality rate fluctuated between about 0.3 and 0.4. It then increased rapidly to about 0.45 in 5Z and 0.65 in 5Zjm by 1993 and subsequently declined to below 0.2 in both 5Zjm and 5Z by 1995.

Between 1969 and 1985, the contribution to production by the Eastern and Western components was roughly equivalent, and both components appeared to have been exploited to the same degree. Since 1985 however, over 80% of the production on Georges Bank was attributed to the Eastern component. By 1997, the Eastern component increased to almost half of its biomass level observed during the late 1970s and early 1980s while Georges Bank as a whole only increased to about a third of its respective biomass level. There is some evidence that the production from the Western component is improving over the last few years. The 1994 and 1995 year-classes were estimated to be about equally represented in both components, however the 1996 year-class is poorly represented in the Western component.

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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	2747[1]
1975	1353	1705	29	3087
1976	1355	973	24	2352
1977	2871	2429	0	8266[1]
1978	9968	4724	0	16223[1]
1979	5080	5211	0	10291
1980	10017	5615	0	23189[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	33	0	2702[3]
1995	2064	22	0	2111[3]
1996	3643	36	0	3720[3]
1997	2739	48	0	2850[3]

[1] Includes 757t, 2966t, 1531t and 7557t in 1974, 1977, 1978 and 1980 respectively for USA discards.
[2] 1895t excluded because of suspected area misreporting.
[3] Includes 258t, 25t, 41 and 63t in 1994,1995, 1996 and 1997 respectively for USA discards.

Table 2. Regulatory measures implemented for the 5Z and 5Zjm fishery management units by the USA and Canada, respectively, from 1977, when jurisdiction was extended to 200 miles for coastal states, to the present.

	USA	Canada
1977-82	**Mesh** size of 5 1/8" (140 mm), seasonal spawning closures, quotas and trip limits.	
1982-85	**All** catch controls eliminated, retained closed area and mesh size regulations, implemented minimum landings size (43 cm).	**First** 5Ze assessment in 1983.
1984 Oct.	**Implementation of the 'Hague' line .**	
1985	**5 ½"** mesh size,. **Areas** 1 and 2 closed during February-May.	
1989		**Combined** cod-haddock-pollock quota for 4X-5Zc
1990		**5Zjm** adopted as management unit. **For** MG < 65 ft. – trip limits with a 30% by-catch of haddock to a maximum of 8 trips of 35,000 lbs per trip between June 1 and Oct. 31 and 130 mm square mesh required. **Fixed** gear required to use large hooks until June
1991	**Established** overfishing definitions for haddock.	**MG** < 65 ft similar to 1990 but mesh size increased to 145 mm diamond.
1992		**Introduction** of ITQs and dockside monitoring.
1993	**Area** 2 closure in effect from Jan 1-June30.	**OT** fishery permitted to operate in Jan. and Feb. **Increase** in use square mesh.
1994	Jan.: **Expanded** Area 2 closure to include June and increased extent of area. **Area** 1 closure not in effect. **500** lb trip limit. **Catch** data obtained from mandatory log books combined with dealer reports (replaces interview system). May: **6"** mesh restriction. Dec.: **Area** 1,2 closed year-round.	**Spawning** closure extended to Jan. 1 to May 31. **Fixed** gear vessels must choose between 5Z or 4X for the period of June to September. **Small** fish protocol. **Increased** at sea monitoring. **OT** > 65 could not begin fishng until July 1. **Predominantly** square mesh by end of year.
1995		**All** OT vessels using square mesh. **Vessels** with a history since 1990 of 25t or more for 3 years of cod, haddock pollock, hake or cusk combined can participate in 5Z fishery. **ITQ** vessel require at least 2t of cod and 8t of haddock quota to fish Georges.
1996	July: **Additional** Days-at-Sea restrictions, trip limit raised to 1000 lbs.	**Fixed** gear history requirement dropped.
1997	May: **Additional** scheduled Days-at-sea restrictions. September: **Trip** limit raised to 1000 lbs/day, maximum of 10,000 lbs/trip.	
1998	Proposed: Trip limit raised to 3000 lbs/day, maximum of 30,000 lbs/trip.	

Table 3. 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
1996	1	836	1405	166	270	2689	548	107	932	21	3643
1997	0	681	1123	91	96	1991	494	116	713	36	2739

[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 4. 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
1996	0	0	0	0	0	1067	660	700	357	278	191	391	3643
1997	0	0	0	0	0	328	751	771	417	190	116	166	2739

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

Table 5. USA catch (t) of haddock (excluding discard estimates) in unit areas 5Zjm by gear category and tonnage class. Details for 1994-1997 are not available because data is preliminary.

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			32	0	33
1995			21	0	22
1996			36	0	36
1997			48	0	48

Table 6. Monthly catch (t) of haddock (excluding discard estimates) by USA in unit areas 5Zjm. Details for 1994-1997 are not available because data is preliminary.

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													33
1995													22
1996													36
1997													48

Table 7. Derivation of catch at age for the 1997 5Zjm Canadian haddock fishery.

Country	Qtr.	Length Frequency Samples											Aged Samples			
		Gear	Month	Observer		Port		Landings	Combinations				Observer		Port	
				Samples	Measured	Samples	Measured	(kg)					Samples	Aged	Samples	Aged
Canada	2	OT IN	June	8	2,435	8	1,788	226,290	Q2OTIN							
		OT OF	June	1	709	1	199	36,564	Q2OTOF		Q2		2	27	8	210
		GN	June	1	286	2	335	9,019	Q2GN							
		LL	June	5	1,678	1	249	56,111	Q2LL							
	3	OT IN	July	2	294	6	1,364	488,671	JulOTIN							
		OT IN	Aug	1	1,951	3	724	511,124	AugOTIN	Q3OTIN						
		OT IN	Sept	1	822	1	211	257,095	SepOTIN							
		OT OF	July			2	400	39,980	JulOTOF							
		OT OF	Aug			1	210	55,550	AugOTOF	Q3OTOF						
		OT OF	Sept			1	225	27,410	SepOTOF							
		GN	July	1	44	2	193	12,702								
		GN	Aug					7,343	Q3GN		Q3				9	239
		GN	Sept					2,599								
		LL	July	7	2,419	2	474	206,916	JulLL							
		HL	July					2,833								
		LL	Aug	6	3,474	2	444	197,189	AugLL	Q3LL						
		HL	Aug					26								
		LL	Sept	3	2,273	1	134	130,173	SepLL							
		HL	Sept					10								
	4	OT IN	Oct	4	762			103,692	Oct OT IN							
		OT IN	Nov	3	2,466	4	853	82,445	Nov OT IN	Q4OT IN						
		OT IN	Dec	4	1,475	3	720	134,081	Dec OT IN							
		OT OF	Oct					6,190								
		OT OF	Nov	2	650	1	198	12,645	NovOTOF	Q4OTOF						
		OT OF	Dec	2	516	2	396	9,090	DecOTOF		Q4		10	173	12	317
		GN	Oct	Q3GN				1,060	Q4GN							
		LL	Oct	1	706	1	201	79,028	Oct LL							
		HL	Oct					5								
		LL	Nov			1	253	20,708	Nov LL	Q4LL						
		LL	Dec					22,826								
	Totals			52	22,960	45	9,571	2,739,375					12	200	29	766

OTB=Otter Trawl Bottom, OTS=Otter Trawl Side, GN=Gill Net, LL=Longline, HL=Handline, IN=Inshore (Tonnage Classes <=3), OF=Offshore (Tonnage Classes >=4).

Table 8. Components of catch at age numbers (000's) of haddock from unit areas 5Zjm by quarter.

Quarter	Age Group										Annual
	1	2	3	4	5	6	7	8	9+	1+	Total
Canadian											
1996	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
1996.25	0.031	2.657	135.030	254.856	125.126	15.622	6.168	0.000	21.350	560.841	
1996.5	0.000	16.206	234.318	431.968	177.203	19.791	5.475	2.584	34.187	921.733	
1996.75	0.087	8.109	102.654	163.708	109.190	23.765	5.607	0.000	15.085	428.206	1910.780
1997	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
1997.25	0.020	0.613	2.427	37.160	69.322	32.539	4.355	1.835	6.372	154.641	
1997.5	0.091	44.041	45.146	411.285	311.587	134.305	3.455	3.409	21.114	974.433	
1997.75	0.777	28.045	21.052	76.918	88.967	19.722	3.790	1.759	4.061	245.092	1374.166
USA											
1996	0.000	0.007	0.323	0.936	1.127	0.312	0.183	0.157	0.418	3.463	
1996.25	0.000	0.026	0.872	1.840	1.706	0.443	0.254	0.218	0.581	5.940	
1996.5	0.000	0.154	0.980	0.870	0.349	0.047	0.037	0.016	0.021	2.474	
1996.75	0.000	0.104	0.850	0.918	0.387	0.055	0.044	0.018	0.028	2.404	14.281
1997	0.000	0.000	0.000	0.335	1.183	0.934	0.148	0.089	0.276	2.965	
1997.25	0.000	0.000	0.000	0.828	2.925	2.309	0.367	0.220	0.682	7.332	
1997.5	0.000	0.016	0.022	0.923	2.165	1.634	0.065	0.092	0.510	5.427	
1997.75	0.000	0.035	0.045	0.585	1.509	0.610	0.179	0.080	0.153	3.196	18.919
USA Discards											
1996	0.024	0.291	1.199	1.878	1.363	0.289	0.070	0.052	0.249	5.415	
1996.25	0.038	0.454	1.873	2.934	2.130	0.451	0.110	0.081	0.388	8.459	
1996.5	0.164	0.618	1.425	0.927	0.385	0.030	0.028	0.005	0.023	3.605	
1996.75	0.170	0.638	1.472	0.957	0.397	0.031	0.029	0.006	0.023	3.723	21.202
1997	0.680	4.321	6.554	7.914	2.889	1.117	0.316	0.194	0.291	24.275	
1997.25	0.452	2.876	4.363	5.268	1.923	0.743	0.210	0.129	0.194	16.159	
1997.5	0.391	1.006	0.670	0.806	0.313	0.102	0.003	0.048	0.061	3.399	
1997.75	0.075	0.194	0.129	0.155	0.060	0.020	0.001	0.009	0.012	0.656	44.490
Total											
1996	0.024	0.298	1.522	2.814	2.490	0.601	0.253	0.209	0.667	8.878	
1996.25	0.069	3.137	137.775	259.630	128.962	16.516	6.532	0.299	22.319	575.240	
1996.5	0.164	16.978	236.723	433.765	177.937	19.868	5.540	2.605	34.231	927.812	
1996.75	0.257	8.851	104.976	165.583	109.974	23.851	5.680	0.024	15.136	434.333	1946.263
1997	0.680	4.321	6.554	8.249	4.072	2.051	0.464	0.283	0.567	27.240	
1997.25	0.472	3.489	6.790	43.256	74.170	35.592	4.932	2.184	7.248	178.132	
1997.5	0.482	45.063	45.838	413.014	314.065	136.041	3.523	3.548	21.685	983.258	
1997.75	0.852	28.275	21.226	77.658	90.536	20.352	3.970	1.848	4.226	248.944	1437.575

Table 9. Total 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	18	1441	260	331	2885	819	89	279	6123
1970	25	82	7	347	147	126	1140	364	189	2425
1971	0	1182	247	31	246	157	159	756	407	3185
1972	259	1	376	71	21	92	37	16	431	1303
1973	1015	1722	6	358	37	10	37	8	163	3358
1974	17	2105	247	0	31	3	0	29	57	2488
1975	0	270	1428	201	5	34	1	2	28	1969
1976	73	149	166	814	125	0	19	0	17	1363
1977	0	7836	64	178	303	162	0	15	14	8571
1978	1	285	9831	161	169	302	80	10	9	10848
1979	0	15	199	4250	362	201	215	43	14	5300
1980	3	17561	342	299	2407	191	129	51	12	20995
1981	0	660	6687	393	494	1234	119	33	7	9627
1982	0	713	1048	2799	201	377	723	62	65	5988
1983	0	140	648	546	1629	207	104	402	34	3710
1984	0	76	249	341	264	1120	186	165	314	2716
1985	0	2063	374	176	189	123	371	53	114	3463
1986	6	38	2557	173	142	122	118	173	41	3369
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	45	2510
1990	2	7	1265	126	743	68	163	42	42	2457
1991	6	441	89	2041	88	389	72	145	61	3332
1992	7	230	311	127	1446	89	315	26	90	2640
1993	7	247	343	279	85	635	34	153	74	1856
1994	1	241	737	148	54	48	125	29	39	1423
1995	2	60	525	414	53	25	3	51	16	1149
1996	1	29	481	862	419	61	18	3	72	1946
1997	2	81	80	542	483	194	13	8	34	1438

Table 10. 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	1.055	1.511	2.033	2.550	2.755	2.908	3.010
1996	0.576	1.022	1.439	1.795	2.294	2.485	3.322	2.032
1997	0.685	1.216	1.336	1.747	2.121	2.476	3.034	3.367

Table 11. Conversion factors used in the ADAPT calibration.

		Spring		Fall	
Year	Door	Vessel	Conversion	Vessel	Conversion
1968	BMV	Albatross IV	NA	Albatross IV	1.49
1969	BMV	Albatross IV	1.49	Albatross IV	1.49
1970	BMV	Albatross IV	1.49	Albatross IV	1.49
1971	BMV	Albatross IV	1.49	Albatross IV	1.49
1972	BMV	Albatross IV	1.49	Albatross IV	1.49
1973	BMV	Albatross IV	1.49	Albatross IV	1.49
1974	BMV	Albatross IV	1.49	Albatross IV	1.49
1975	BMV	Albatross IV	1.49	Albatross IV	1.49
1976	BMV	Albatross IV	1.49	Albatross IV	1.49
1977	BMV	Albatross IV	1.49	Delaware II	1.2218
1978	BMV	Albatross IV	1.49	Delaware II	1.2218
1979	BMV	Albatross IV	1.49	Delaware II	1.2218
1980	BMV	Albatross IV	1.49	Delaware II	1.2218
1981	BMV	Delaware II	1.2218	Delaware II	1.2218
1982	BMV	Delaware II	1.2218	Albatross IV	1.49
1983	BMV	Albatross IV	1.49	Albatross IV	1.49
1984	BMV	Albatross IV	1.49	Albatross IV	1.49
1985	Polyvalent	Albatross IV	1	Albatross IV	1
1986	Polyvalent	Albatross IV	1	Albatross IV	1
1987	Polyvalent	Albatross IV	1	Albatross IV	1
1988	Polyvalent	Albatross IV	1	Albatross IV	1
1989	Polyvalent	Delaware II	0.82	Delaware II	0.82
1990	Polyvalent	Delaware II	0.82	Delaware II	0.82
1991	Polyvalent	Delaware II	0.82	Delaware II	0.82
1992	Polyvalent	Albatross IV	1	Albatross IV	1
1993	Polyvalent	Albatross IV	1	Delaware II	0.82
1994	Polyvalent	Delaware II	0.82	Albatross IV	1
1995	Polyvalent	Albatross IV	1	Albatross IV	1
1996	Polyvalent	Albatross IV	1	Albatross IV	1
1997	Polyvalent	Albatross IV	1	Albatross IV	1

Table 12. Total estimated abundance at age numbers (000's) of haddock for 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
1997	1033	1550	1222	2742	2559	1397	150	65	372	11090
1998	2438	10893	4312	3608	5217	5029	2645	329	653	35124

Table 13. Total estimated abundance at age numbers (000's) of haddock for unit areas 5Zjm from the USA spring surveys. From 1973-81, a 41 Yankee trawl was used while a 36 Yankee trawl 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
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
1996	912	1351	3772	3232	1896	235	36	0	496	11931
1997	1635	1226	380	595	470	343	24	44	20	4736

Table 14. Total estimated abundance at age numbers (000's) of haddock for unit areas 5Zjm from the USA fall surveys. Conversion factors to adjust for changes in door type and survey vessel were applied.

Year	Age Group									
	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
1996	1742	453	570	2302	963	167	0	0	0	6196
1997	217	5726	3128	890	645	385	0	0	13	11004

Table 15. 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	4597	3255	0.71	1162	0.25
2	12135	5449	0.45	1248	0.10
3	4158	1500	0.36	275	0.07
4	2565	802	0.31	127	0.05
5	3504	1081	0.31	132	0.04
6	3866	1145	0.30	126	0.03
7	1101	392	0.36	46	0.04
8	148	58	0.39	8	0.06
			Survey Calibration Constants		
Canadian Spring Survey					
1	0.182	0.051	0.284	0.007	0.037
2	0.447	0.124	0.277	0.016	0.036
3	0.852	0.234	0.275	0.03	0.035
4	0.762	0.209	0.274	0.027	0.035
5	0.913	0.251	0.275	0.033	0.037
6	0.714	0.197	0.276	0.026	0.037
7	1.005	0.290	0.288	0.041	0.041
8	0.974	0.268	0.275	0.034	0.035
USA Spring Survey – Yankee 36 – 1969-72/1982-97					
1	0.129	0.029	0.227	0.003	0.024
2	0.340	0.077	0.226	0.008	0.024
3	0.430	0.097	0.225	0.010	0.024
4	0.460	0.103	0.225	0.011	0.024
5	0.556	0.122	0.219	0.013	0.023
6	0.454	0.100	0.219	0.010	0.023
7	0.559	0.126	0.225	0.013	0.023
8	0.703	0.167	0.237	0.017	0.025
USA Spring Survey – Yankee 41 – 1973-81					
1	0.231	0.079	0.343	0.014	0.059
2	0.522	0.169	0.323	0.027	0.052
3	0.665	0.228	0.343	0.039	0.059
4	0.814	0.279	0.343	0.048	0.059
5	1.021	0.350	0.343	0.060	0.059
6	0.937	0.371	0.396	0.073	0.078
7	2.332	0.855	0.367	0.157	0.067
8	0.893	0.327	0.367	0.060	0.067
USA Fall Survey					
0	0.129	0.024	0.188	0.002	0.016
1	0.274	0.053	0.193	0.005	0.017
2	0.217	0.041	0.189	0.004	0.016
3	0.209	0.039	0.188	0.003	0.017
4	0.157	0.031	0.200	0.003	0.020
5	0.133	0.025	0.189	0.002	0.017

Table 16. 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	762	161	3994	849	885	8401	2799	177	0	18028	17266	17105
1970	3342	624	115	1982	461	431	4314	1564	66	12899	9557	8933
1971	311	2713	435	88	1313	246	240	2509	955	8810	8499	5786
1972	5154	255	1126	135	45	855	61	56	1383	9070	3916	3661
1973	11029	3977	208	586	46	19	620	17	32	16534	5505	1528
1974	3144	8121	1684	165	152	5	7	474	7	13759	10615	2494
1975	3218	2558	4749	1162	135	98	2	5	363	12290	9072	6514
1976	53818	2634	1842	2592	772	106	50	1	3	61818	8000	5366
1977	5914	43996	2023	1360	1403	520	87	24	0	55327	49413	5417
1978	4210	4842	28868	1600	955	884	285	71	7	41722	37512	32670
1979	52003	3446	3690	14543	1161	631	457	161	50	76142	24139	20693
1980	6645	42577	2807	2839	8106	626	342	185	93	64220	57575	14998
1981	5136	5438	19009	1995	2057	4521	343	168	107	38774	33638	28200
1982	1711	4205	3844	9586	1285	1244	2617	177	109	24778	23067	18862
1983	2629	1401	2780	2204	5325	869	683	1496	90	17477	14848	13447
1984	14880	2153	1016	1685	1313	2914	525	466	872	25824	10944	8791
1985	1548	12183	1694	607	1073	842	1395	267	236	19845	18297	6114
1986	13218	1267	8041	1040	338	709	579	816	171	26179	12961	11694
1987	1292	10817	1003	4296	700	150	472	372	517	19619	18327	7510
1988	14981	1058	7054	707	2156	486	73	313	243	27071	12090	11032
1989	787	12262	821	3837	470	991	301	28	216	19713	18926	6664
1990	2380	644	8999	601	2478	269	525	220	5	16121	13741	13097
1991	2134	1947	521	6220	379	1361	160	284	142	13148	11014	9067
1992	7609	1742	1190	347	3238	231	764	67	102	15290	7681	5939
1993	14382	6224	1214	693	171	1355	111	343	32	24525	10143	3919
1994	9522	11769	4860	681	319	65	547	61	146	27970	18448	6679
1995	4623	7795	9409	3290	421	211	8	333	23	26113	21490	13695
1996	5907	3783	6326	7219	2314	296	150	4	226	26225	20318	16535
1997	13300	4836	3070	4735	5116	1507	186	106	1	32857	19557	14721
1998	3435	10887	3883	2439	3372	3740	1054	140	80	29030	25595	14708

Table 17. Fishing mortality rate for haddock in unit areas 5Zjm. The rate for ages 4+ (ages 4 to 8) is weighted with population numbers.

Year	Age Group								
	1	2	3	4	5	6	7	8	4+
1969	0	0.132	0.5	0.41	0.519	0.466	0.382	0.788	0.451
1970	0.009	0.161	0.068	0.212	0.43	0.388	0.342	0.293	0.309
1971	0	0.679	0.971	0.465	0.23	1.19	1.252	0.396	0.405
1972	0.059	0.003	0.454	0.865	0.692	0.121	1.062	0.355	0.251
1973	0.106	0.659	0.033	1.149	2.062	0.837	0.069	0.748	0.492
1974	0.006	0.336	0.171	0	0.244	0.839	0.006	0.067	0.086
1975	0	0.129	0.405	0.21	0.037	0.466	0.898	0.52	0.208
1976	0.002	0.064	0.103	0.414	0.194	0	0.534	0	0.349
1977	0	0.221	0.034	0.153	0.262	0.402	0	1.06	0.233
1978	0	0.072	0.486	0.121	0.214	0.46	0.373	0.165	0.234
1979	0	0.005	0.062	0.385	0.418	0.414	0.705	0.346	0.395
1980	0	0.606	0.141	0.122	0.384	0.402	0.509	0.347	0.320
1981	0	0.147	0.485	0.24	0.303	0.347	0.463	0.235	0.314
1982	0	0.214	0.356	0.388	0.191	0.399	0.359	0.478	0.366
1983	0	0.121	0.301	0.318	0.403	0.303	0.184	0.34	0.352
1984	0	0.04	0.314	0.251	0.244	0.536	0.477	0.481	0.394
1985	0	0.215	0.288	0.386	0.214	0.174	0.337	0.243	0.271
1986	0	0.034	0.427	0.196	0.61	0.206	0.243	0.256	0.254
1987	0	0.228	0.149	0.489	0.165	0.527	0.211	0.226	0.405
1988	0	0.054	0.409	0.208	0.577	0.278	0.758	0.171	0.422
1989	0	0.109	0.112	0.237	0.358	0.435	0.116	1.597	0.276
1990	0.001	0.012	0.169	0.26	0.4	0.32	0.415	0.235	0.365
1991	0.003	0.292	0.207	0.453	0.298	0.377	0.671	0.82	0.447
1992	0.001	0.161	0.341	0.506	0.671	0.531	0.601	0.536	0.637
1993	0.001	0.047	0.378	0.576	0.768	0.706	0.398	0.651	0.654
1994	0	0.024	0.19	0.282	0.213	1.861	0.297	0.772	0.319
1995	0	0.009	0.065	0.152	0.152	0.14	0.488	0.188	0.155
1996	0	0.009	0.09	0.144	0.229	0.267	0.146	1.839	0.167
1997	0	0.019	0.03	0.139	0.113	0.157	0.081	0.087	0.129

Table 18. Average weight at age from the Canadian spring survey.

Year	Age Group								
	1	2	3	4	5	6	7	8	9+
1986	0.135	0.452	0.974	1.445	3.039	2.843	3.598	3.373	3.914
1987	0.150	0.500	0.716	1.672	2.011	2.548	3.149	3.147	3.629
1988	0.097	0.464	0.931	1.795	1.816	1.916	2.721	3.267	3.869
1989	0.062	0.474	0.649	1.392	1.995	2.528	2.155	2.820	2.963
1990	0.149	0.527	0.924	1.185	1.863	2.072	2.507	2.819	3.469
1991	0.120	0.689	0.801	1.510	1.687	2.428	2.103	3.125	3.435
1992	0.122	0.602	1.118	1.060	2.078	2.165	2.709	2.283	3.443
1993	0.122	0.481	1.227	1.803	1.272	2.333	2.340	2.740	3.293
1994	0.107	0.469	1.047	1.621	1.926	2.154	3.153	2.688	3.084
1995	0.086	0.493	0.963	1.556	2.224	2.447	2.400	2.991	3.184
1996	0.139	0.495	0.919	1.320	1.932	2.555	2.899	2.603	3.588
1997	0.132	0.507	0.782	1.205	1.664	2.177	2.450	2.586	3.163
1998	0.053	0.542	0.993	1.139	1.567	1.975	2.511	3.589	3.414

Table 19. 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	88	83	3735	1277	1762	19686	7511	518	0	34659	34571	34489
1970	384	321	108	2981	918	1010	11576	4575	226	22100	21715	21394
1971	36	1398	407	132	2614	576	644	7339	3274	16421	16385	14987
1972	593	131	1053	203	90	2004	164	164	4741	9142	8549	8418
1973	1269	2049	194	881	92	45	1664	50	110	6353	5084	3035
1974	362	4183	1575	248	303	12	19	1387	24	8112	7750	3567
1975	370	1318	4441	1748	269	230	5	15	1244	9639	9269	7951
1976	6191	1357	1722	3898	1537	248	134	3	10	15102	8911	7554
1977	680	22664	1892	2045	2794	1219	233	70	0	31597	30917	8253
1978	484	2494	26993	2406	1902	2071	765	208	24	37348	36864	34369
1979	5982	1775	3450	21873	2312	1479	1226	471	171	38740	32757	30982
1980	764	21933	2625	4270	16140	1467	918	541	319	48977	48212	26279
1981	591	2801	17775	3001	4096	10594	920	491	367	40636	40045	37244
1982	197	2166	3594	14418	2559	2915	7022	518	374	33762	33566	31399
1983	302	722	2599	3315	10603	2036	1833	4376	309	26095	25793	25071
1984	1712	1109	950	2534	2614	6828	1409	1363	2989	21509	19798	18688
1985	178	6276	1584	913	2136	1973	3743	781	809	18394	18216	11940
1986	1780	572	7835	1503	1027	2016	2083	2752	669	20238	18458	17886
1987	194	5404	718	7184	1408	382	1486	1171	1876	19823	19629	14225
1988	1456	491	6564	1269	3916	931	199	1023	940	16789	15333	14842
1989	49	5813	533	5342	938	2505	649	79	640	16548	16499	10686
1990	354	339	8318	712	4616	557	1316	620	17	16851	16496	16157
1991	257	1341	417	9395	640	3304	336	887	488	17065	16808	15467
1992	931	1049	1331	368	6730	500	2069	153	351	13482	12552	11502
1993	1754	2994	1490	1250	217	3161	260	940	105	12171	10417	7423
1994	1016	5522	5087	1104	614	140	1725	164	450	15822	14806	9284
1995	399	3846	9062	5121	936	516	19	996	73	20967	20569	16723
1996	819	1872	5814	9530	4470	756	435	10	811	24517	23699	21826
1997	1758	2450	2400	5706	8511	3281	456	274	3	24839	23080	20631
1998	183	5900	3856	2777	5284	7386	2647	502	273	28809	28626	22726

Table 20. Projection results for 1998 at $F_{0.1}$ of haddock in unit areas 5Zjm.

Year	Age Group										
	1	2	3	4	5	6	7	8	9	1+	2+	3+
Beginning of Year Population Numbers (000s)												
1998	3435	10887	3883	2439	3372	3740	1054	140	80			
1999	5731	2813	8737	2841	1555	2150	2385	672	89			
Partial Recruitment to the Fishery												
1998	0.00	0.08	0.45	1.00	1.00	1.00	1.00	1.00				
Fishing Mortality												
1998	0.000	0.020	0.113	0.250	0.250	0.250	0.250	0.250				
Weight at beginning of year for population (kg)												
1999	0.10	0.51	0.91	1.31	1.85	2.29	2.62	2.94	3.34			
Beginning of Year Projected Population Biomass (t)												
1999	588	1432	7988	3708	2851	4921	6248	1978	298	30032	29444	28012
Projected Catch Numbers (000s)												
1998	0	195	375	491	679	753	212	28				
Average weight for catch (kg)												
1998	0.62	1.11	1.49	1.95	2.40	2.53	3.02	2.91				
Projected Yield (t)												
1998	0	216	558	959	1630	1908	642	82		5995		

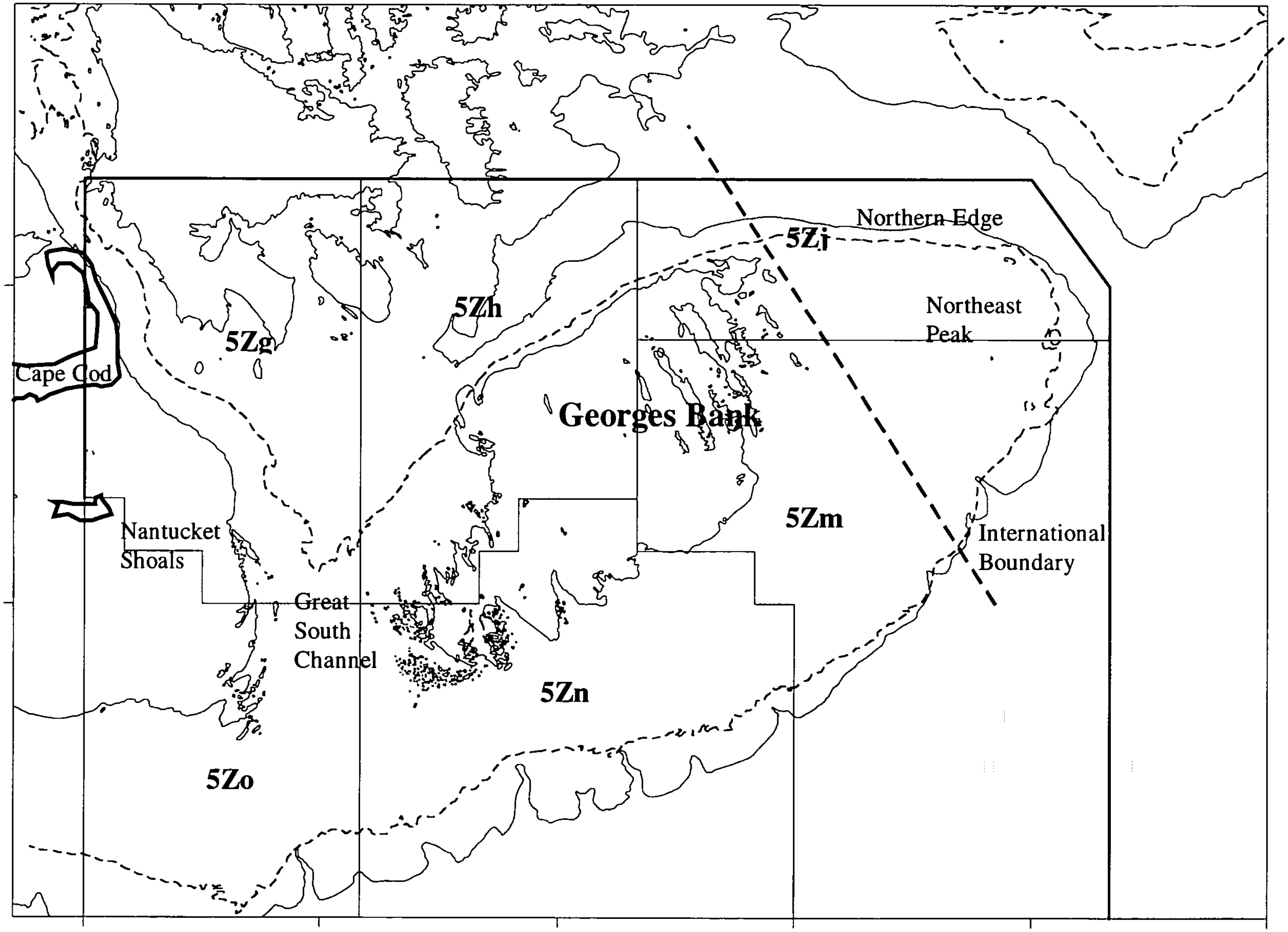


Fig. 1. Fisheries statistical unit areas in NAFO Subdivision 5Ze.

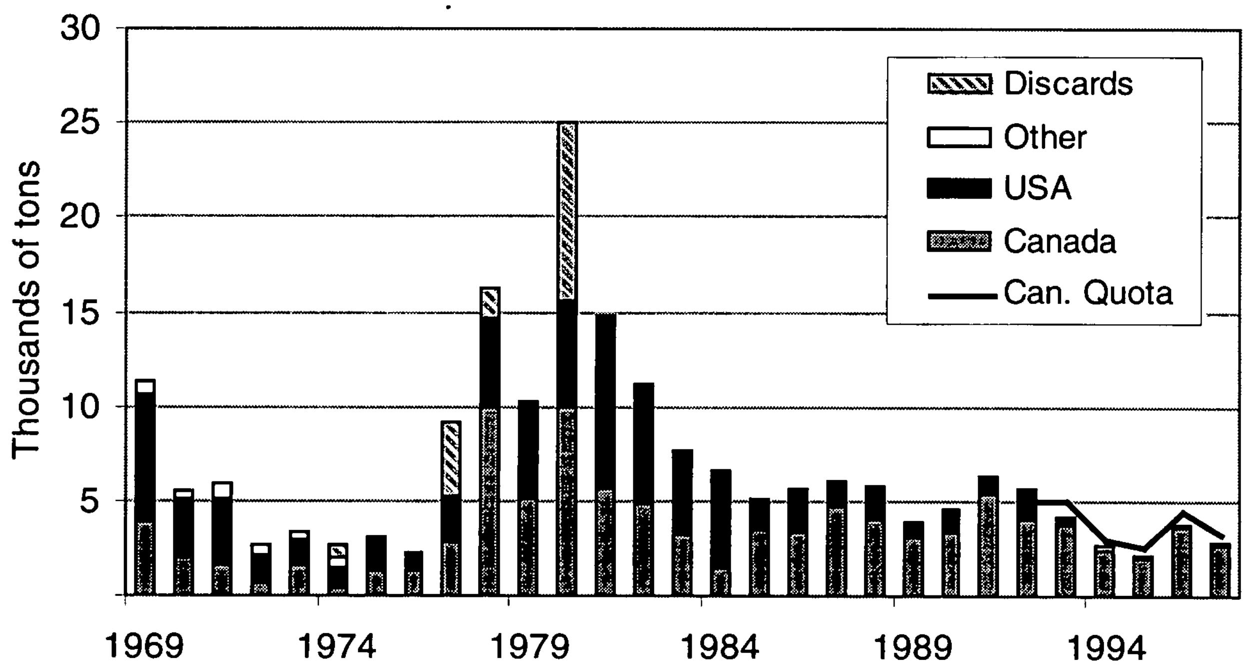


Fig. 2. Nominal catch of haddock in unit areas 5Zjm.

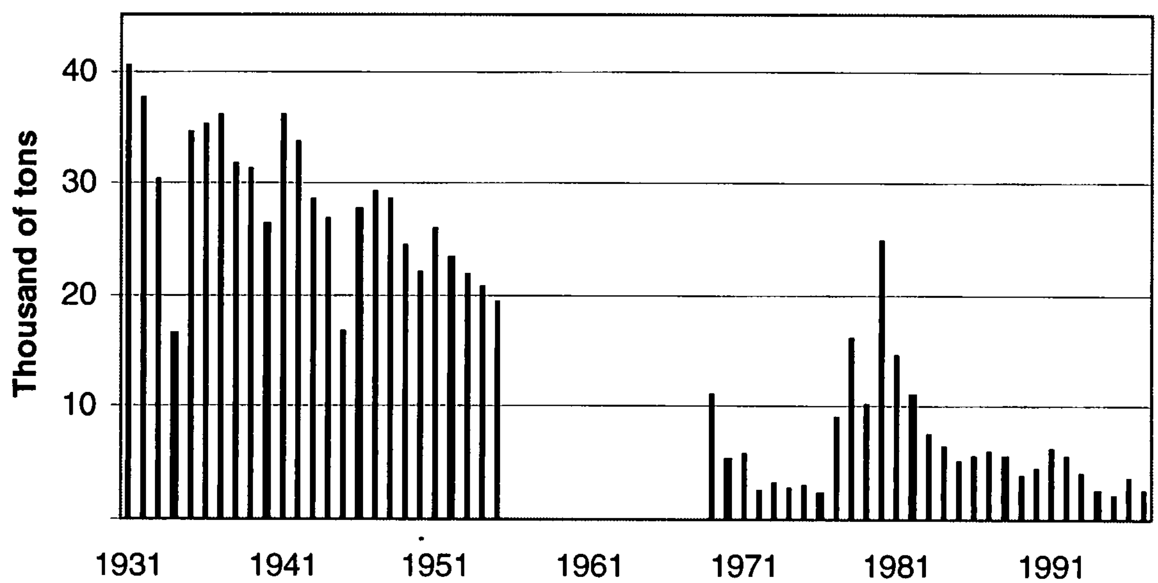


Fig. 3. Historic catch of haddock in 5Zjm compared to recent catches.

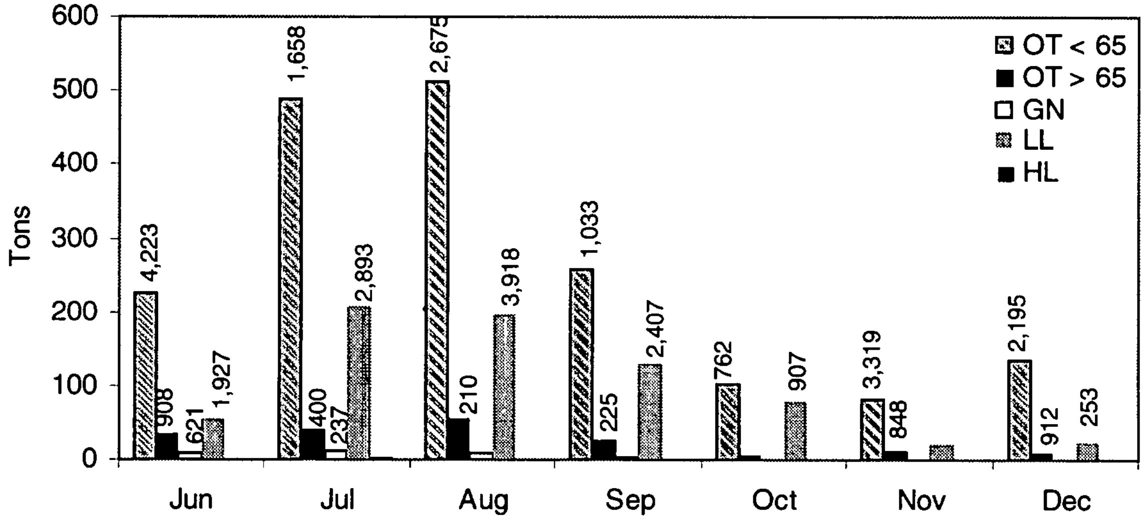


Fig. 4. Haddock landed in 5Zjm by month and gear by the Canadian commercial fishery in 1997 with sampling levels.

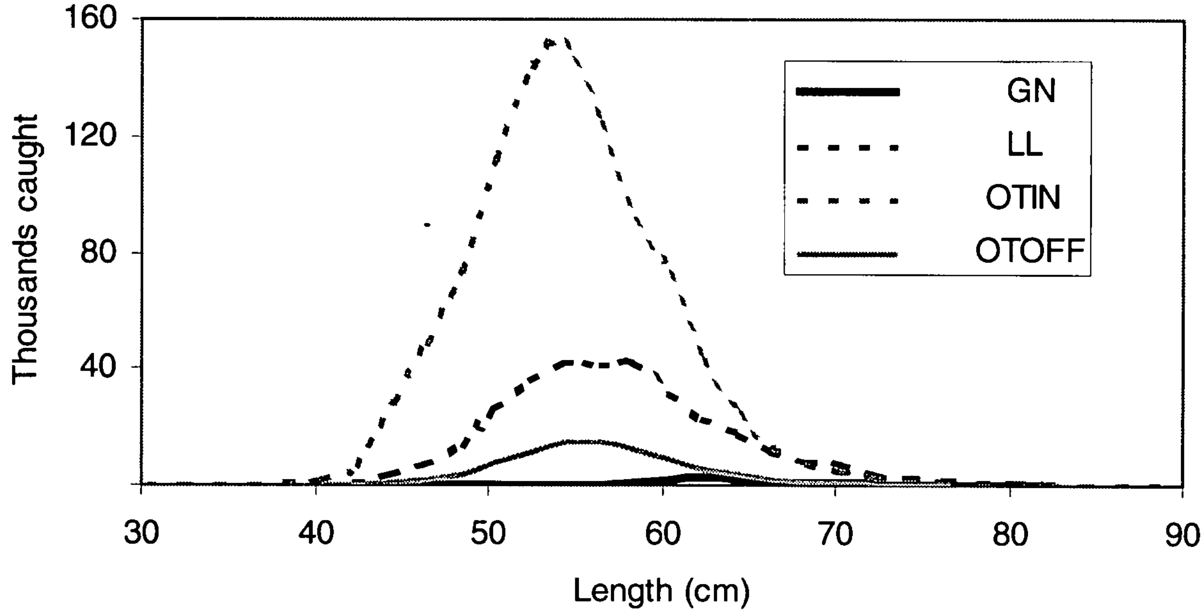


Fig. 5. Length compositions of the principal Canadian 5Zjm commercial haddock fisheries in 1997 are fairly similar but haddock caught by gillnets are somewhat larger than those caught by other gears.

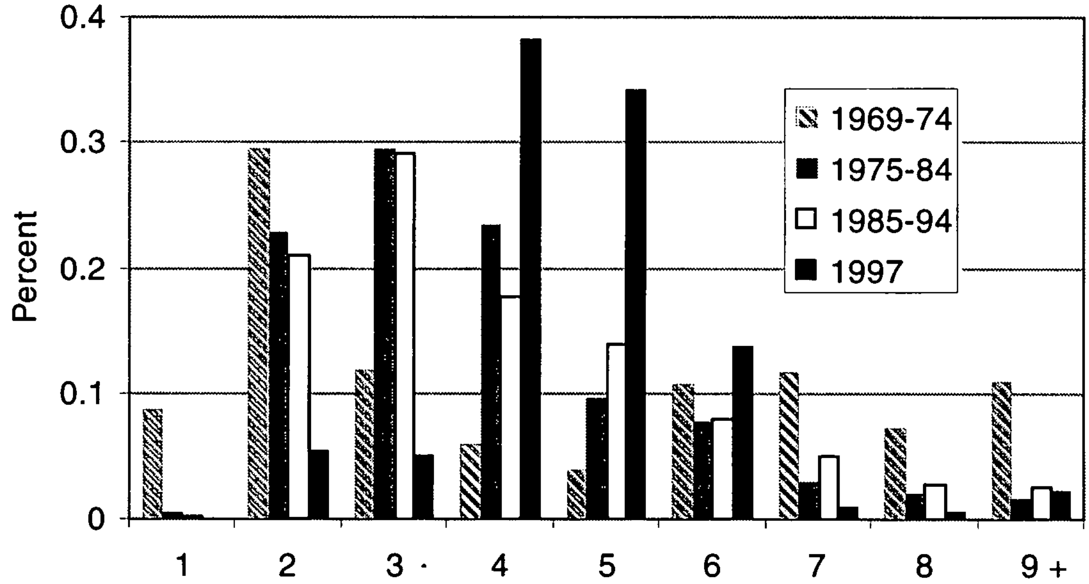


Fig. 6. Age composition of the Canadian 5Zjm commercial fisheries haddock catch in 1997 compared to the average for three periods which represent different stages in the Georges Bank fishery. Ages 4 and 5 made up the bulk of the catch, a consequence of lower selection for smaller haddock than in the past and the resulting higher survival of the 1992 year-class.

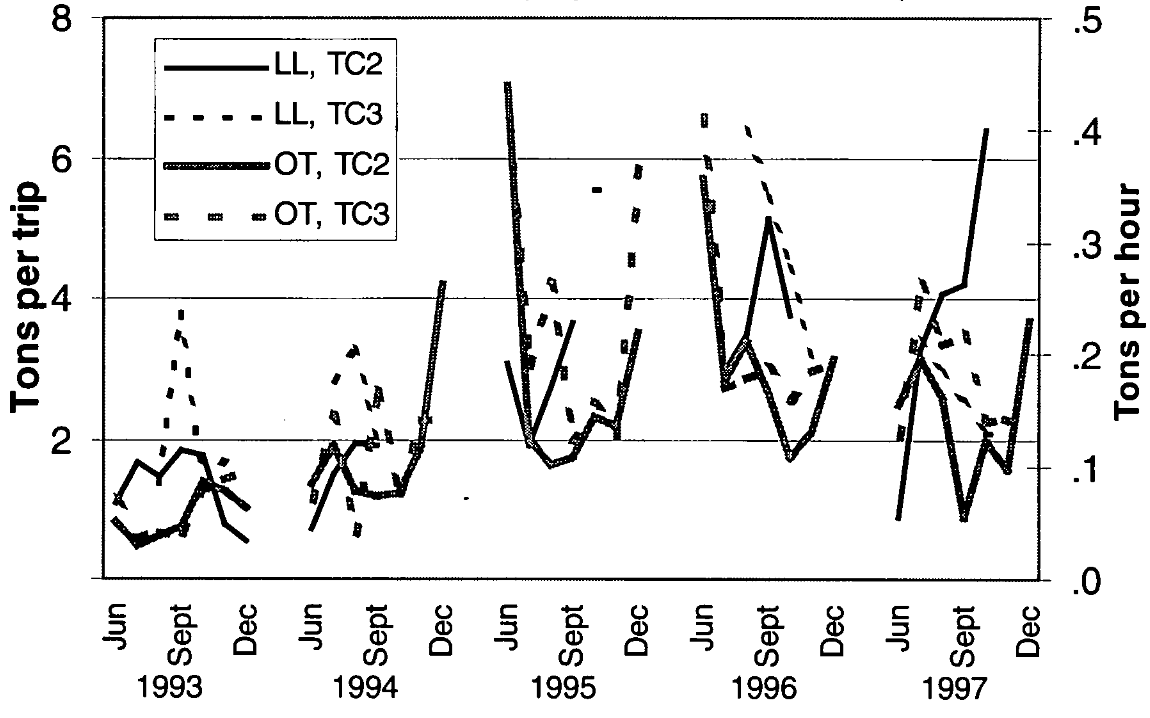


Fig. 7. Catch rates for haddock from Canadian commercial fishery gadoid trips (90% cod, haddock and pollock) in 5Zjm for vessels which fished during 1994 and reported more than 1t of landings. A generally increasing trend is seen from 1993 to 1995 with 1996 and 1997 values similar to 1995. (LL = longline, OT = otter trawl, TC = tonnage class).

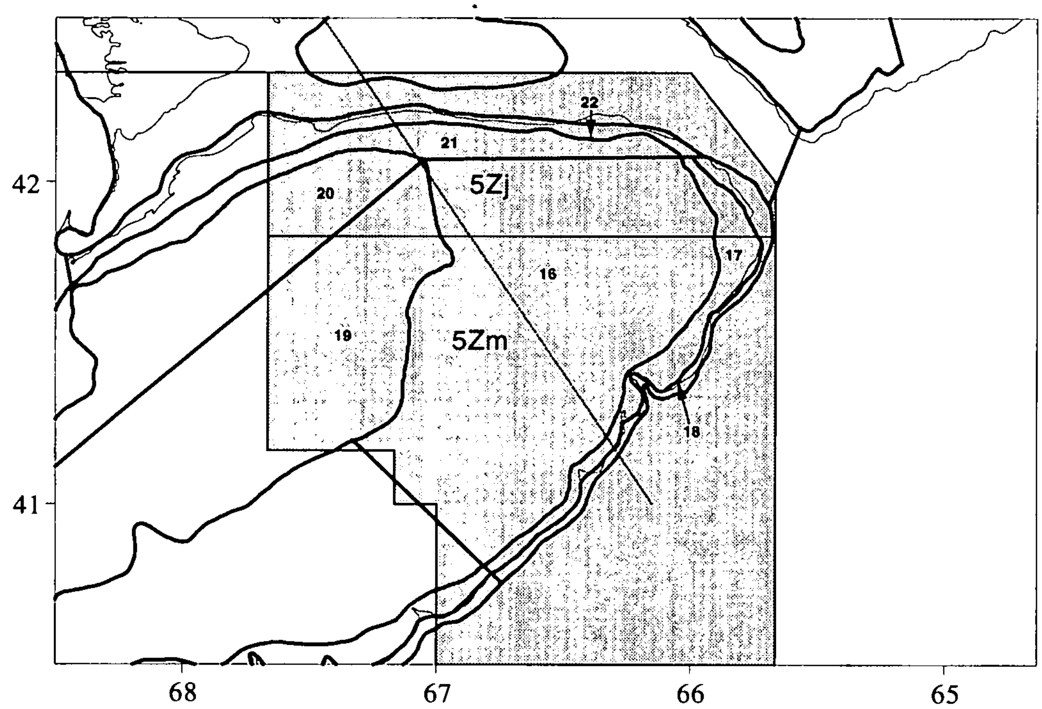


Fig. 8. Stratification scheme used for USA surveys. The 5Zjm management area is indicated by shading.

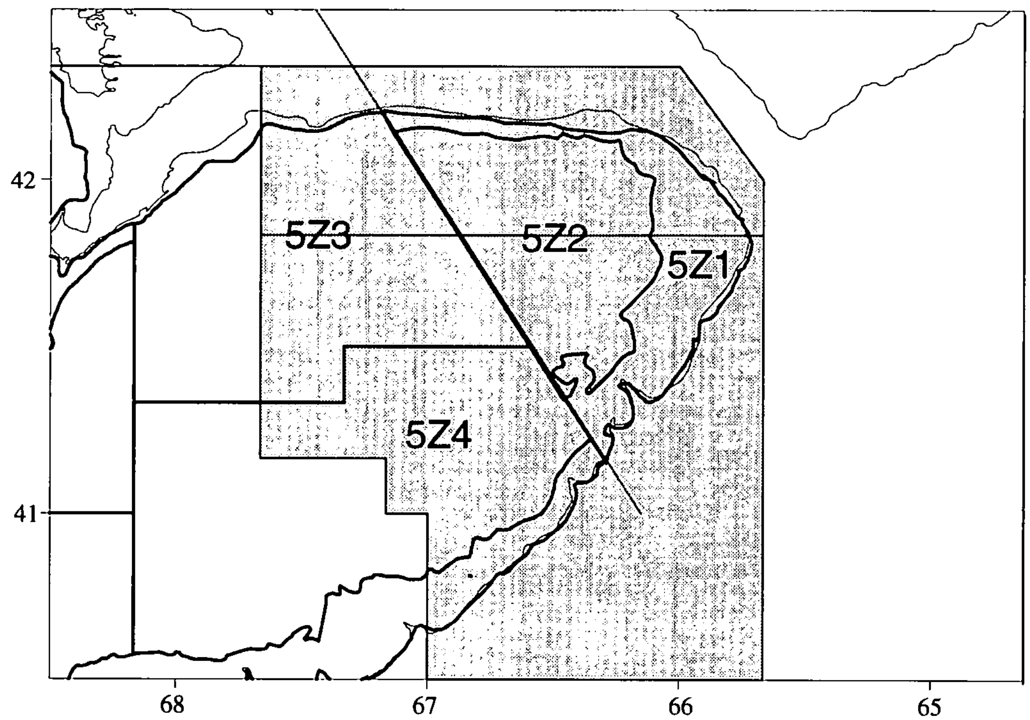


Fig. 9. Stratification scheme used for the Canadian survey. The 5Zjm management area is indicated by shading..

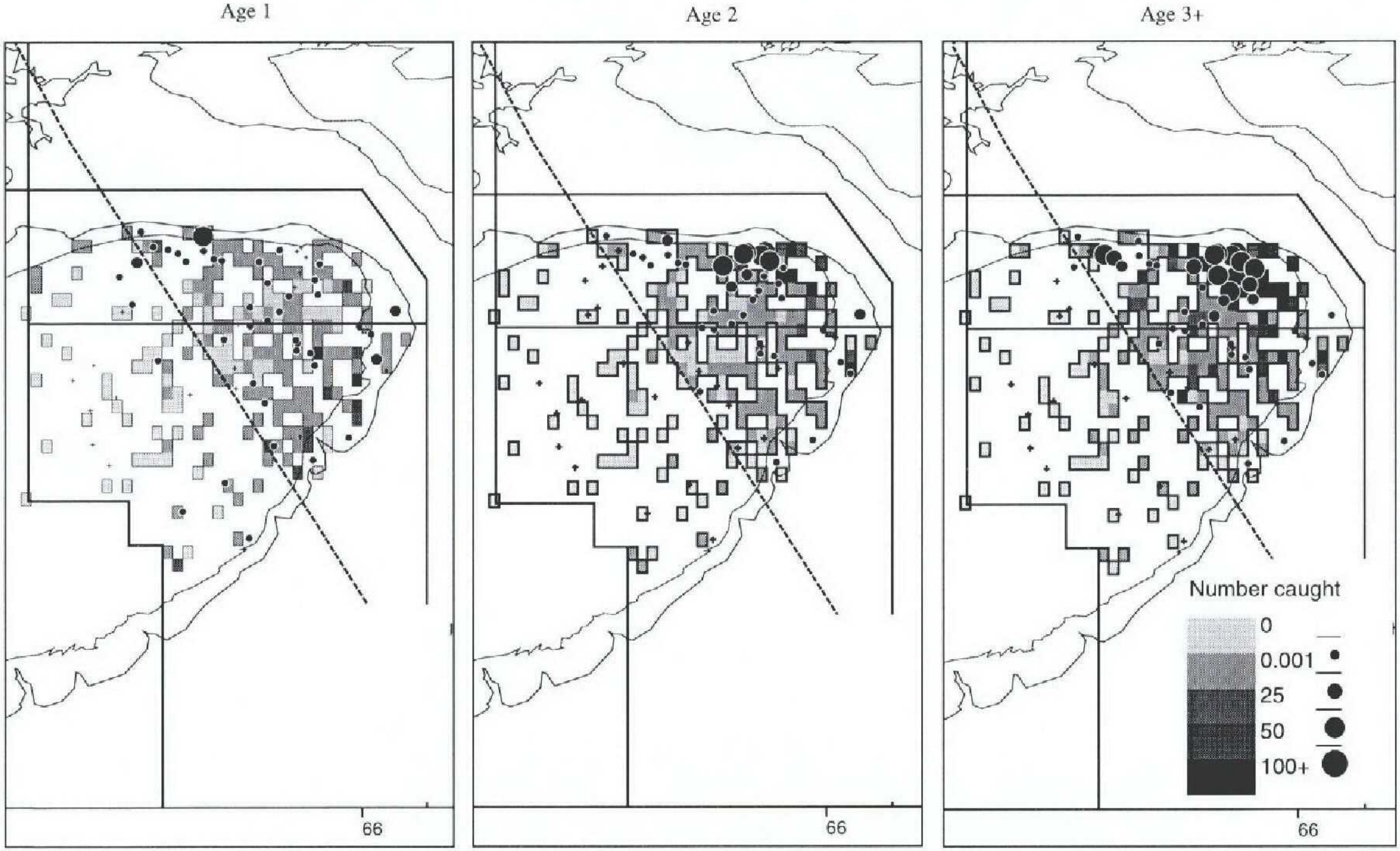


Fig. 10. Distribution of 5Zjm haddock as observed from the **DFO spring** survey. The squares are shaded relative to the average catch for 1993 to 1997. The expanding symbols represent the 1998 survey catches.

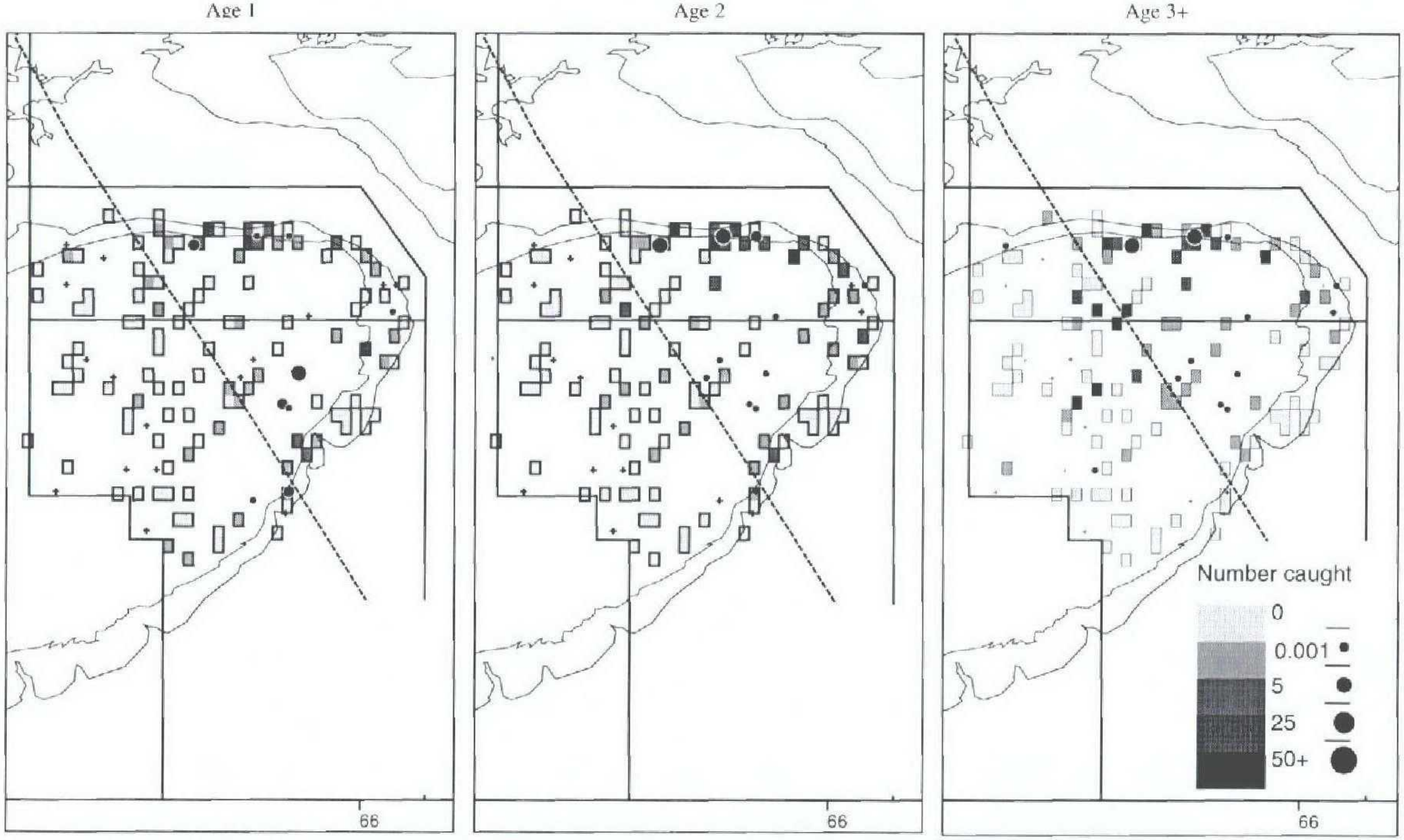


Fig. 11. Distribution of 5Zjm haddock as observed from the **NMFS spring** survey. The squares are shaded relative to the average catch for 1992 to 1996. The expanding symbols represent the 1997 survey catches.

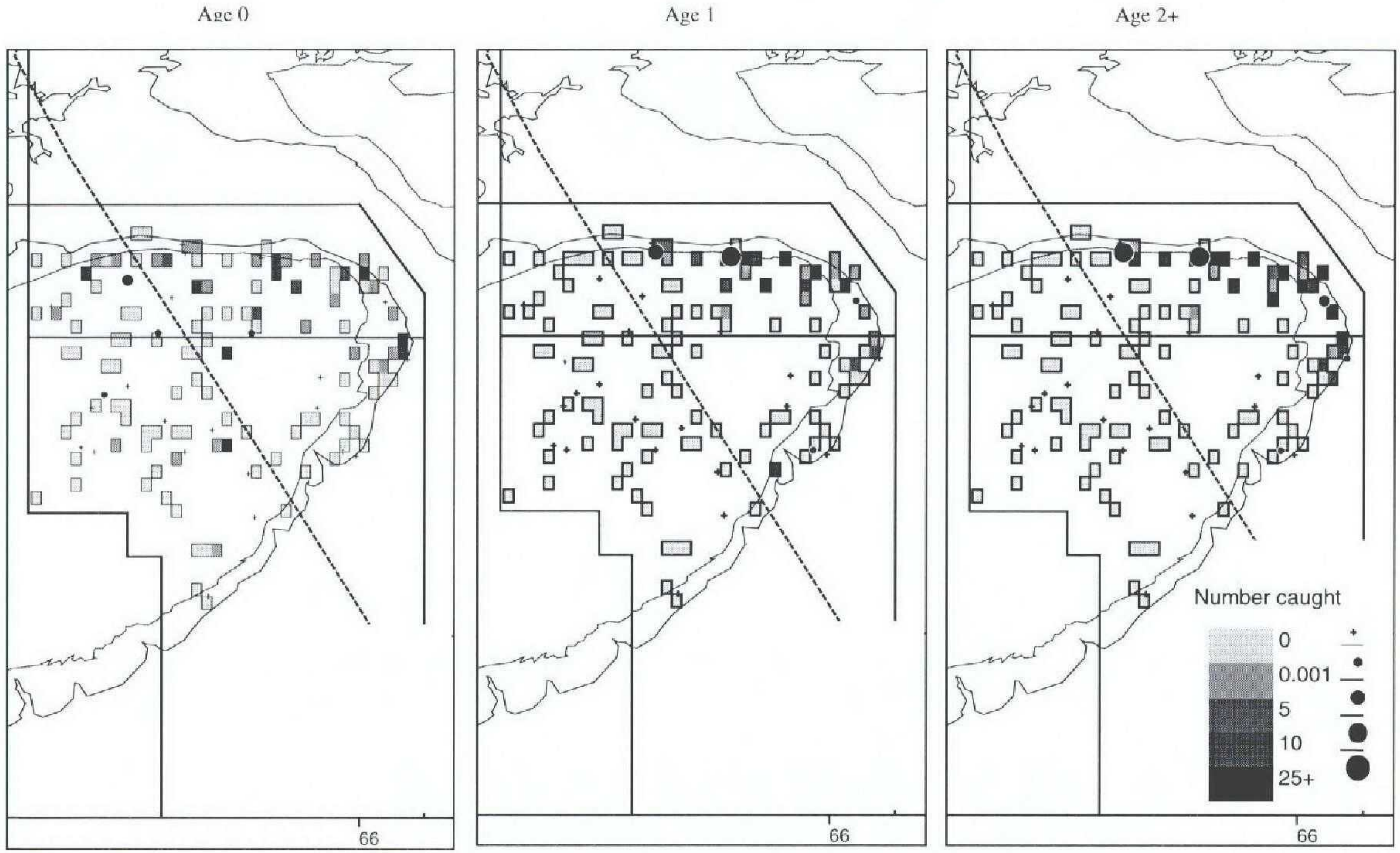


Fig. 12. Distribution of 5Zjm haddock as observed from the **NMFS fall** survey. The squares are shaded relative to the average catch for 1992 to 1996. The expanding symbols represent the 1997 survey catches.

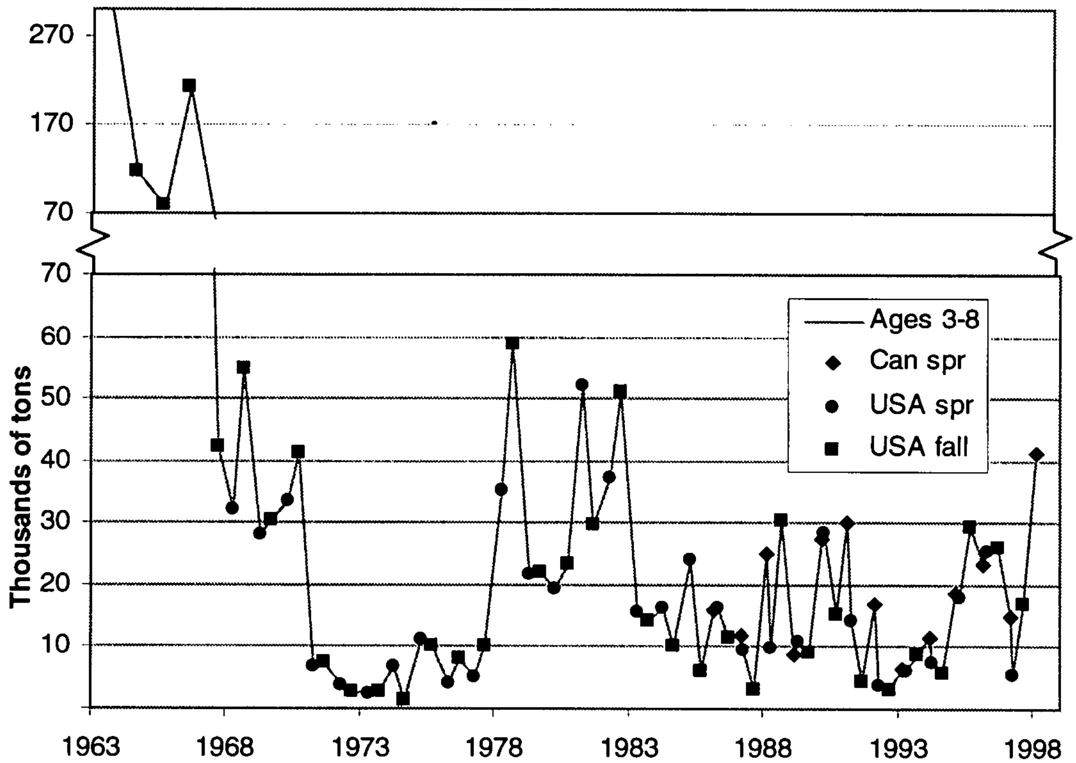


Fig. 13. Beginning of year biomass for ages 2+ from the NMFS fall and ages 3+ from the NMFS and DFO spring research surveys (adjusted by calibration constants) for haddock in unit areas 5Zjm. Square = NMFS fall (October/November); circle = NMFS spring (March/April); diamond = DFO spring (February/March).

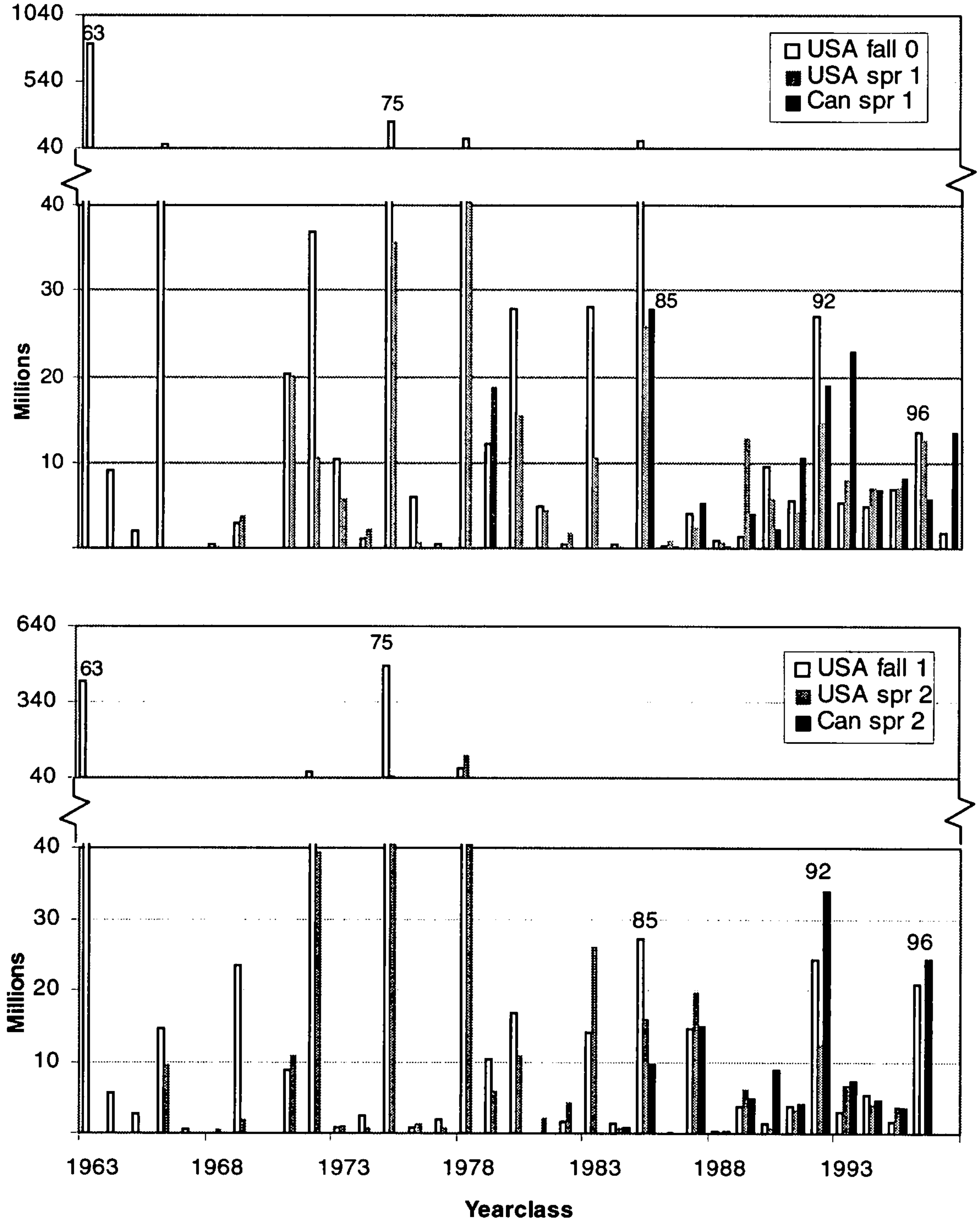


Fig. 14. Beginning of year biomass for ages 0 and 1 from the NMFS fall and ages 1 and 2 from the NMFS and DFO spring research surveys (adjusted by calibration constants) for haddock in unit areas 5Zjm. Fall values are compared to the beginning of the subsequent year.

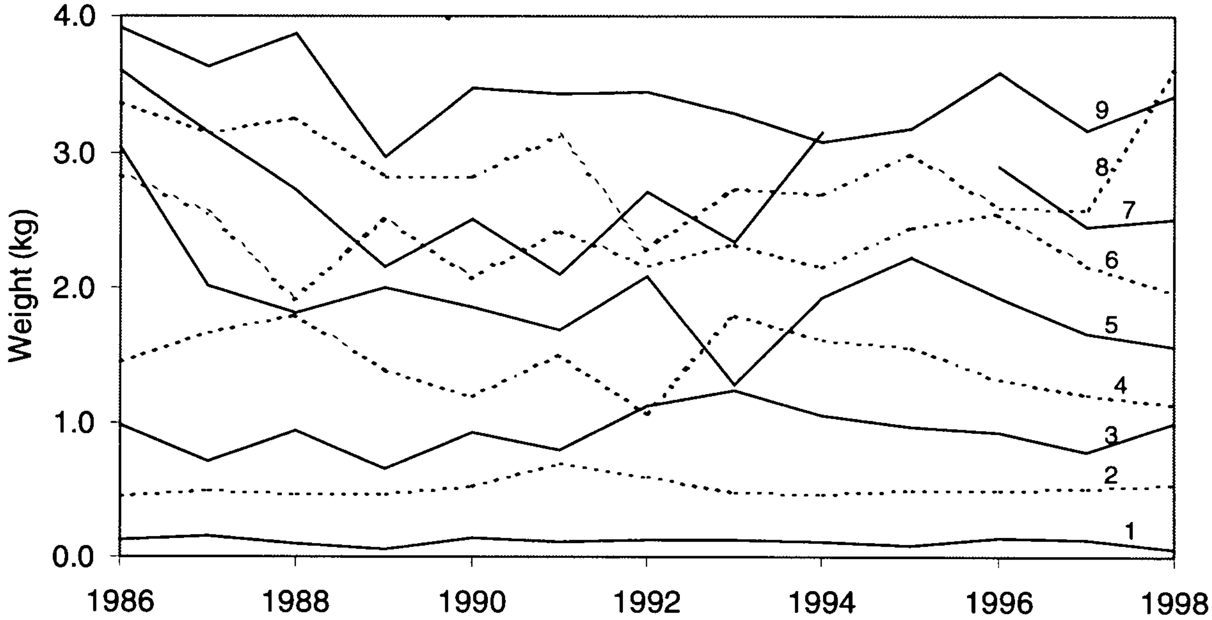
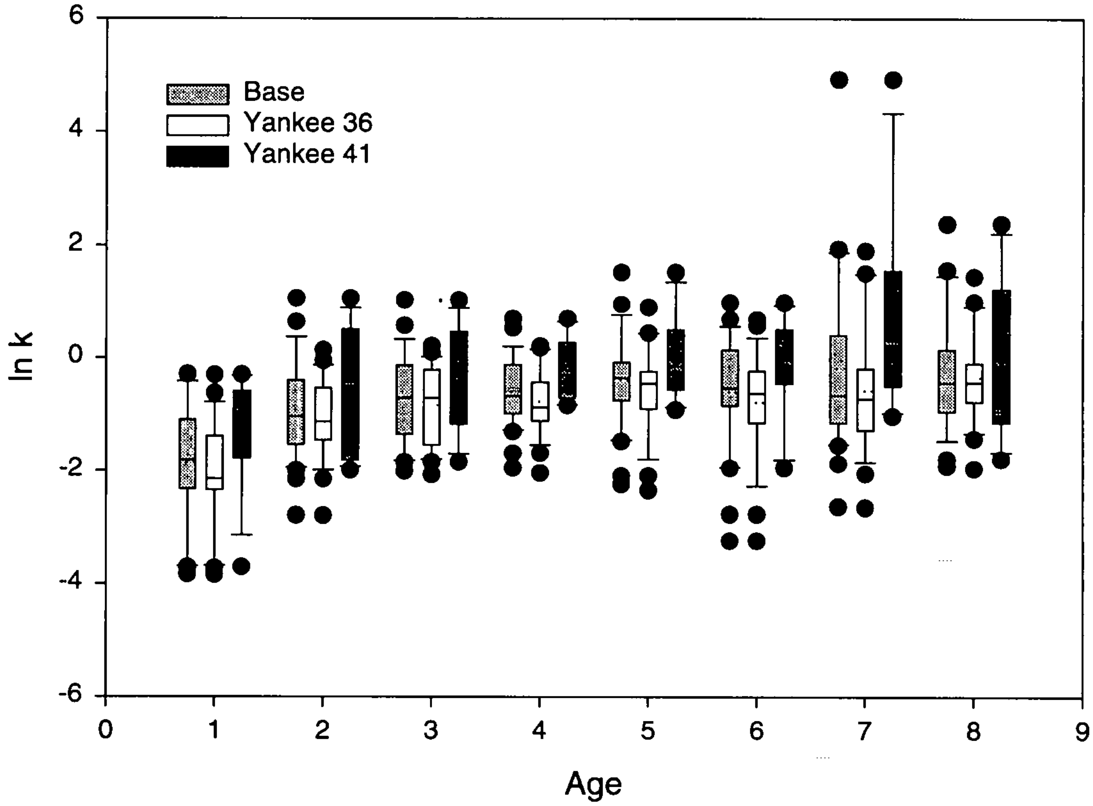


Fig. 15. Weight at age for haddock in unit areas 5Zjm derived from the DFO spring surveys.



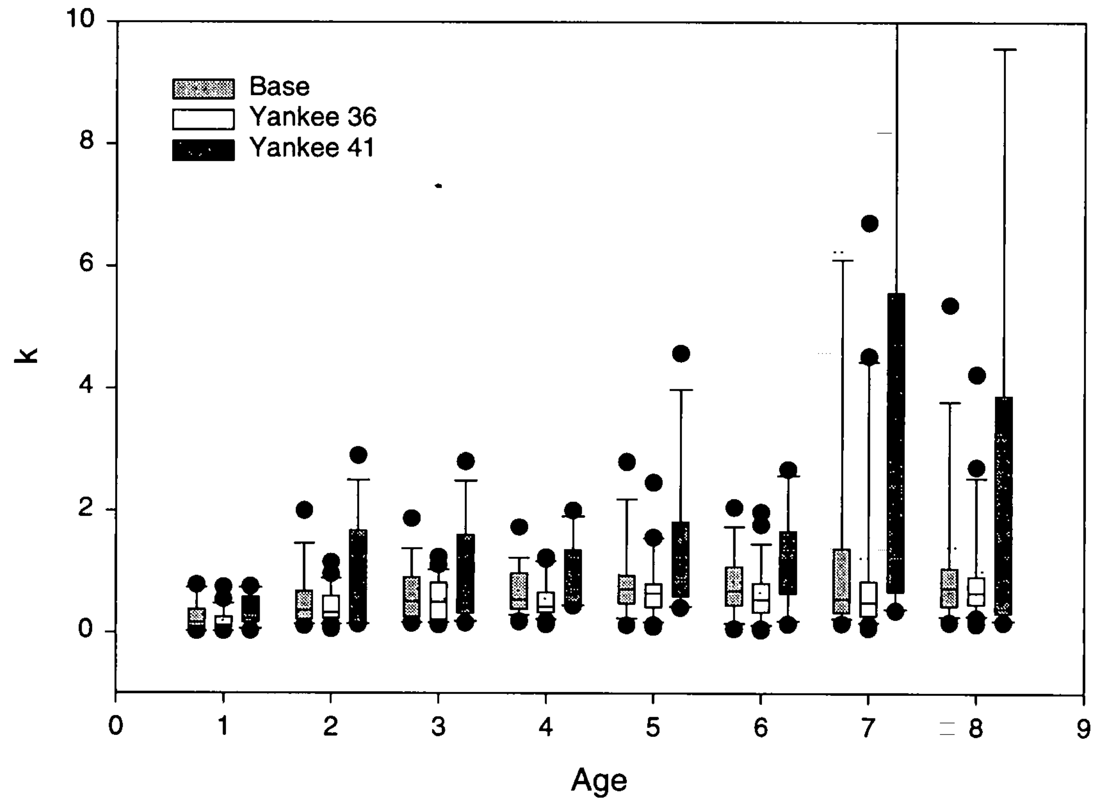


Fig. 16. Ln and linear age specific annual catchabilites for base, Yankee 36 ('69-'72',82-'97) and Yankee 41 ('73-'81) indices from NMFS spring survey.

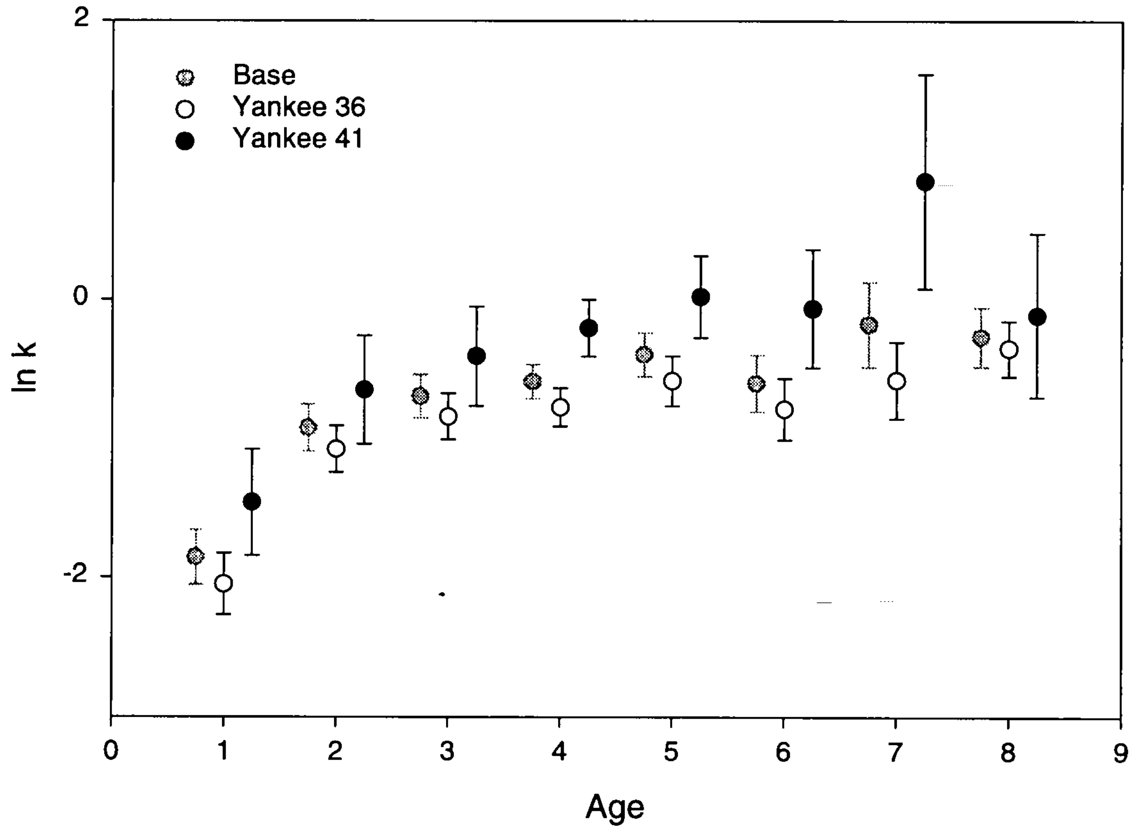


Fig. 17. Ln catchabilities with one standard deviation for base, Yankee 36 and Yankee 41 indices from NMFS spring survey.

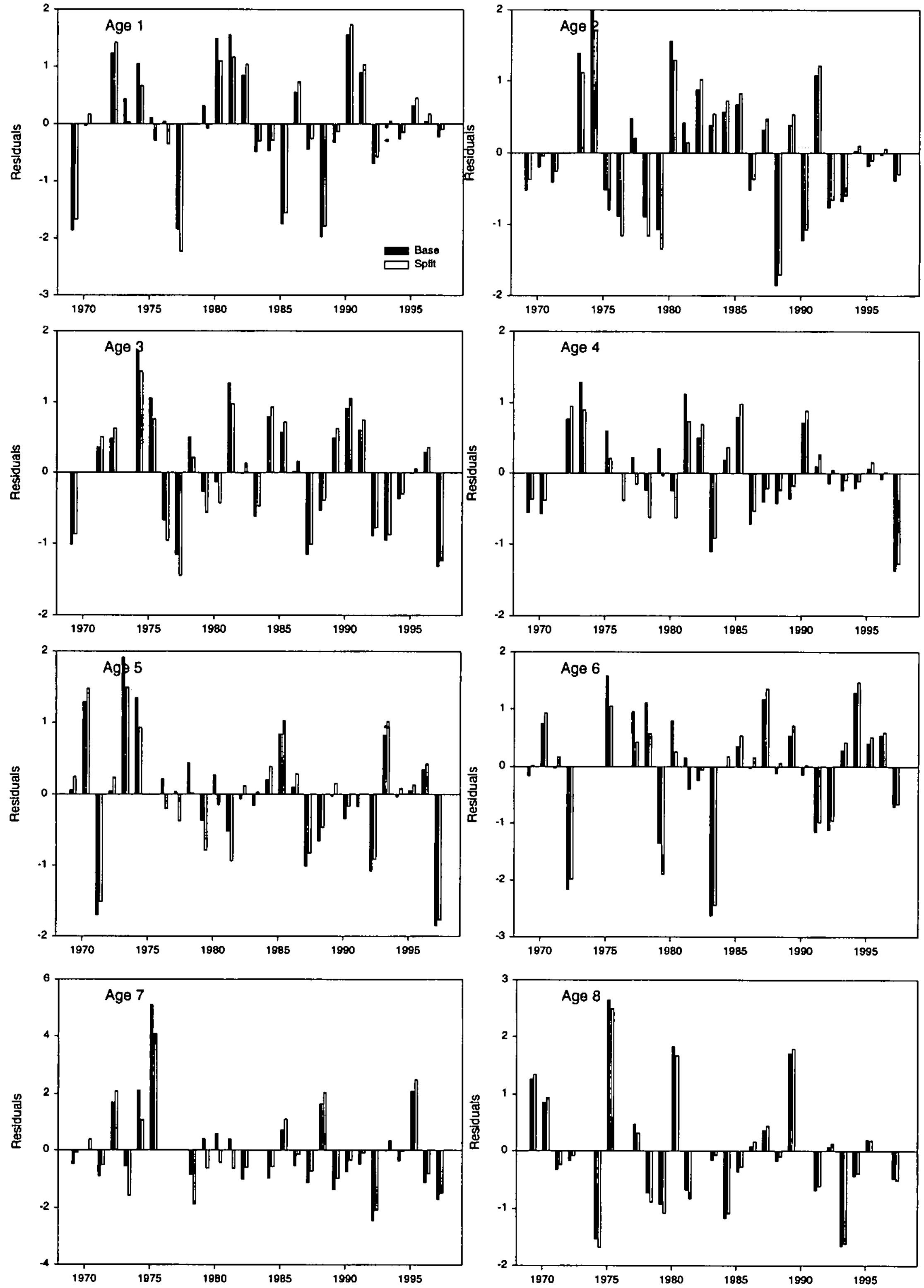


Fig. 18. Residuals for base and split model from NMFS spring survey.

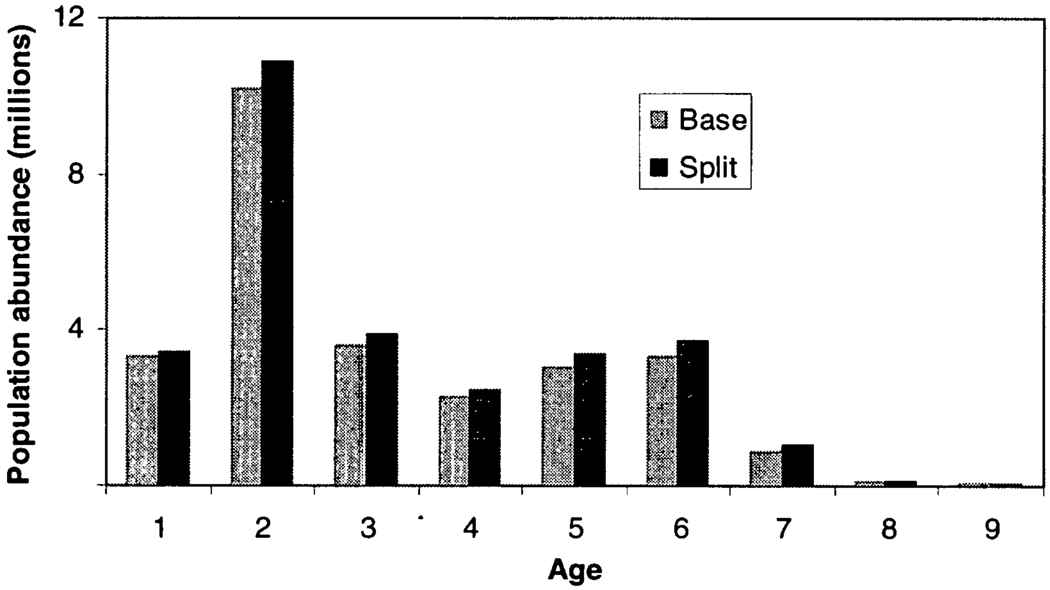


Fig. 19. Impact on terminal year population numbers of base versus split model.

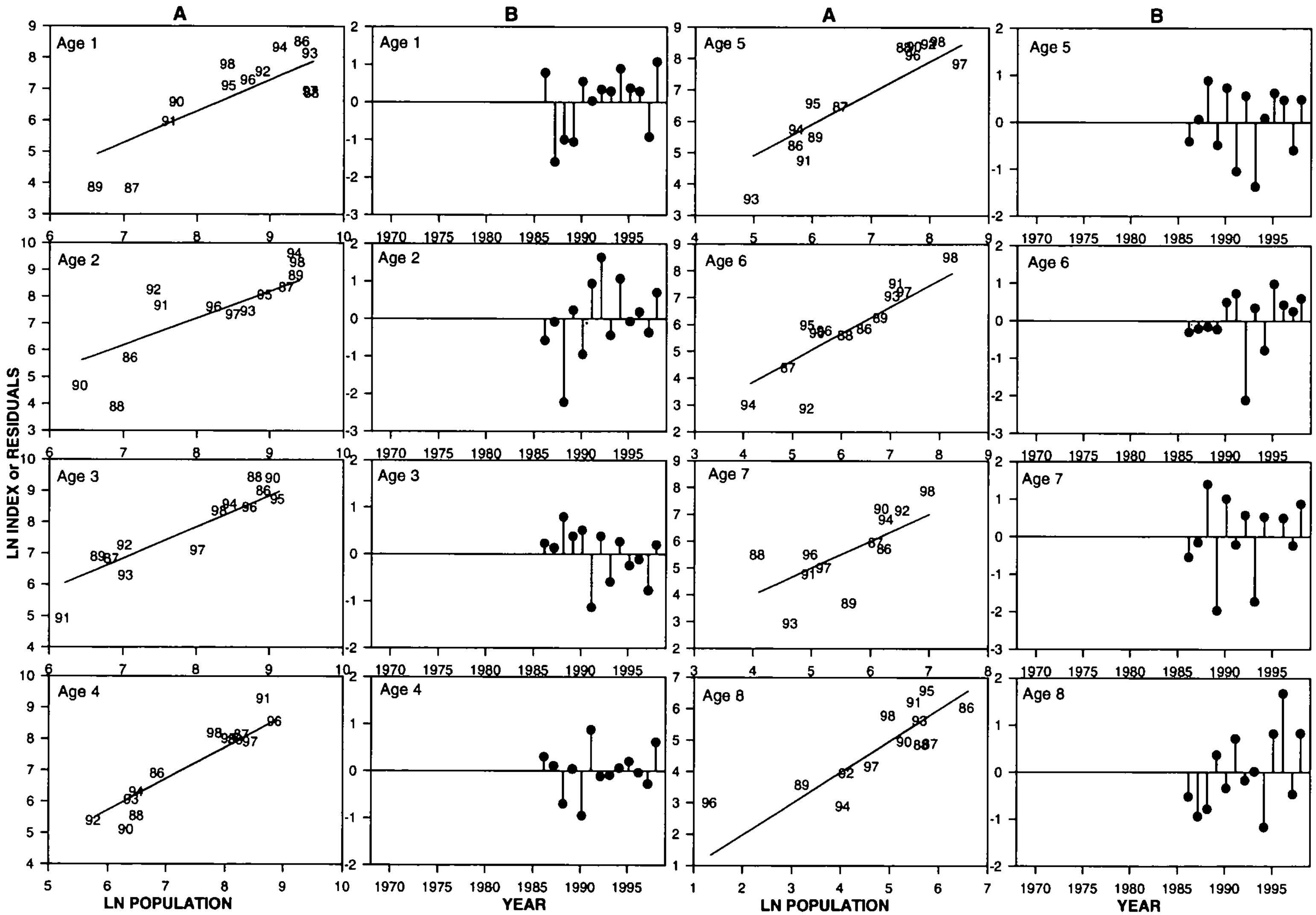


Fig. 20a. Age by age plots of A) the observed and predicted ln abundance index versus ln population numbers, and B) residuals plotted against year for haddock in unit areas 5Zj and 5Zm for the **DFO spring** survey.

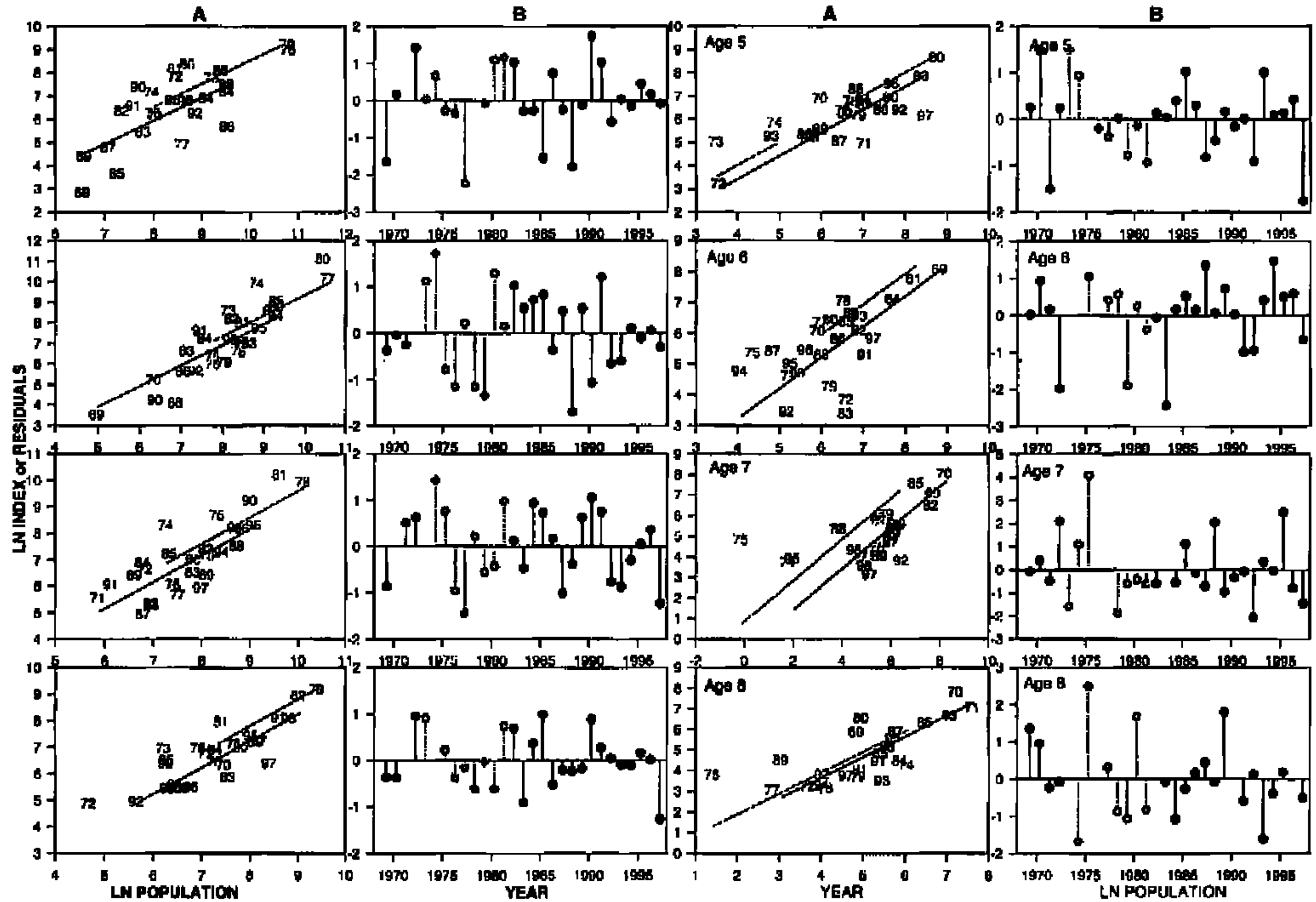


Fig. 20b. Age by age plots of A) the observed and predicted ln abundance index versus ln population numbers, and B) residuals plotted against year for haddock in unit areas 5Zj and 5Zm for the **NMFS spring** survey. The survey was used as two separate indices as a net change occurred in the series. During 1969-72/1982-97 a Yankee 36 was used while a Yankee 41 was used from 1973-81.

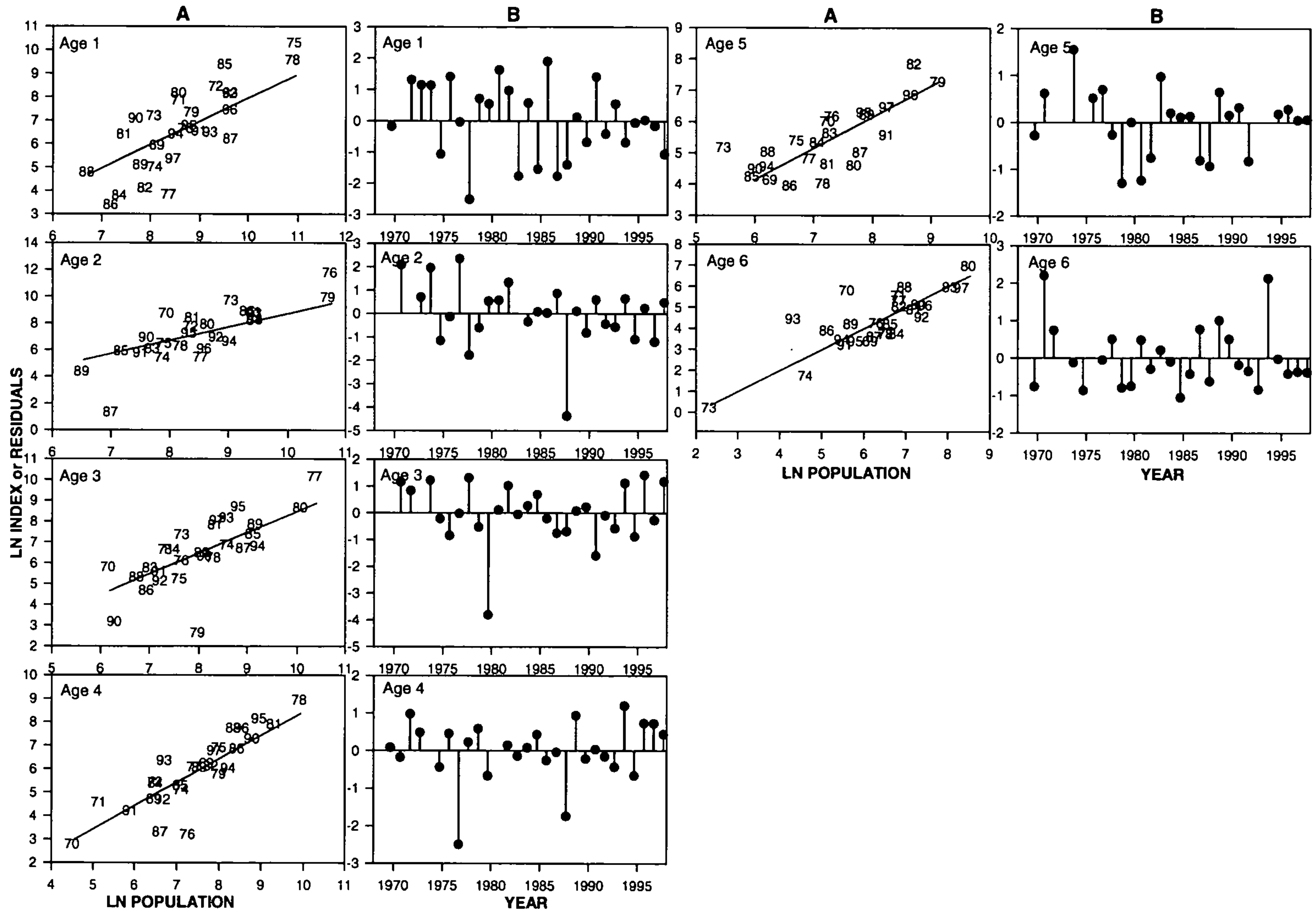


Fig. 20c. Age by age plots of A) the observed and predicted ln abundance index versus ln population numbers, and B) residuals plotted against year for haddock in unit areas 5Zj and 5Zm for the **NMFS fall** survey.

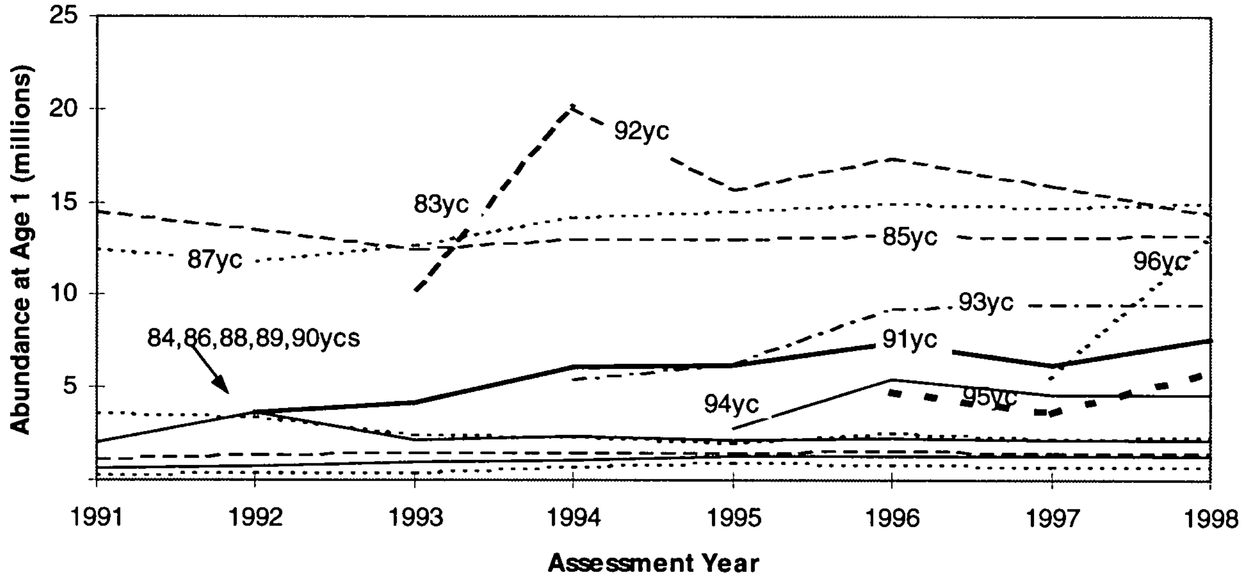


Fig. 21. Successive estimates of year-class abundance as additional years of data were included in the assessment did not display any persistent trends.

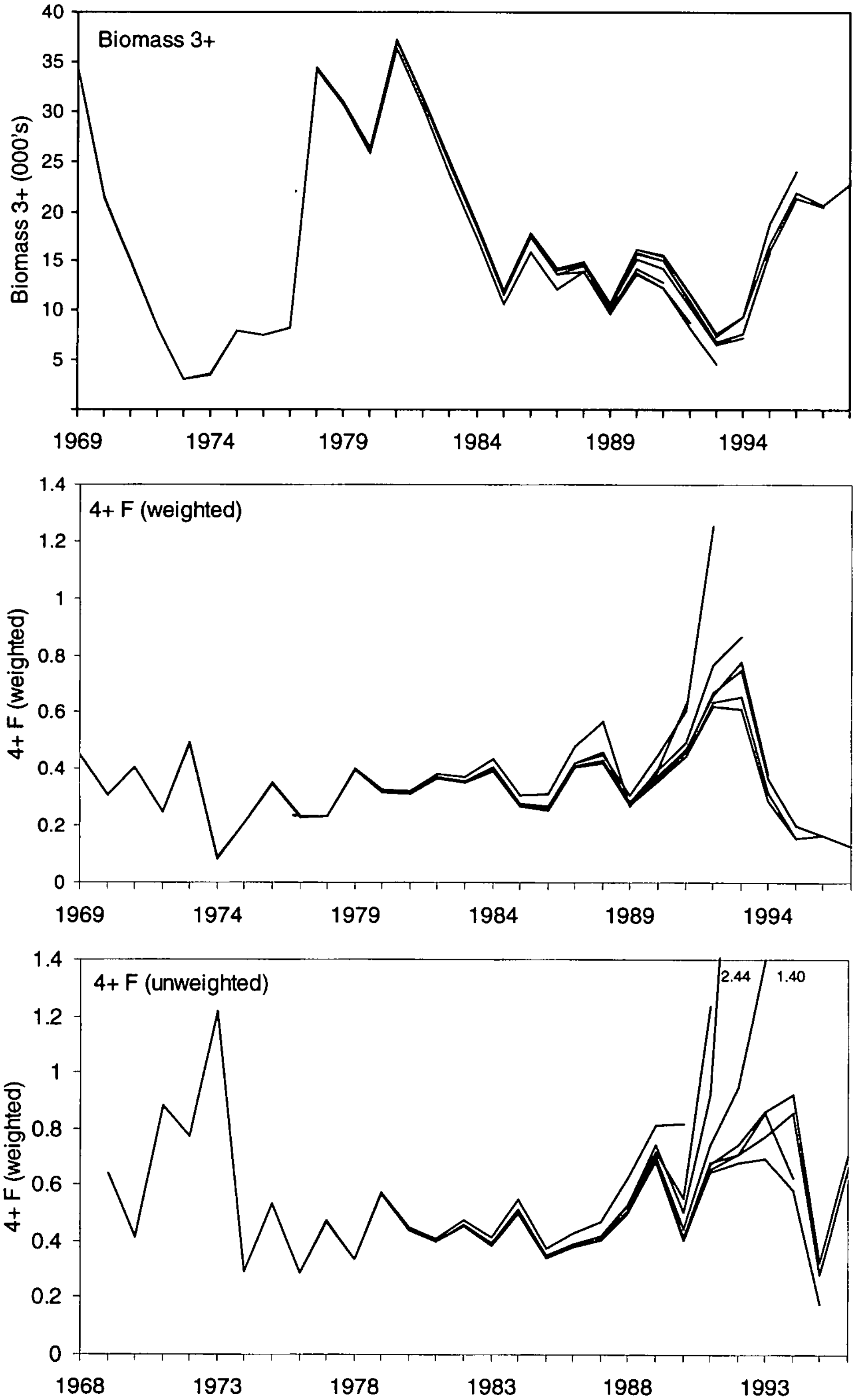


Fig. 22. Retrospective estimates of biomass and fishing mortality did not display any persistent trends for over or under estimation as successive years of data were excluded in the assessment.

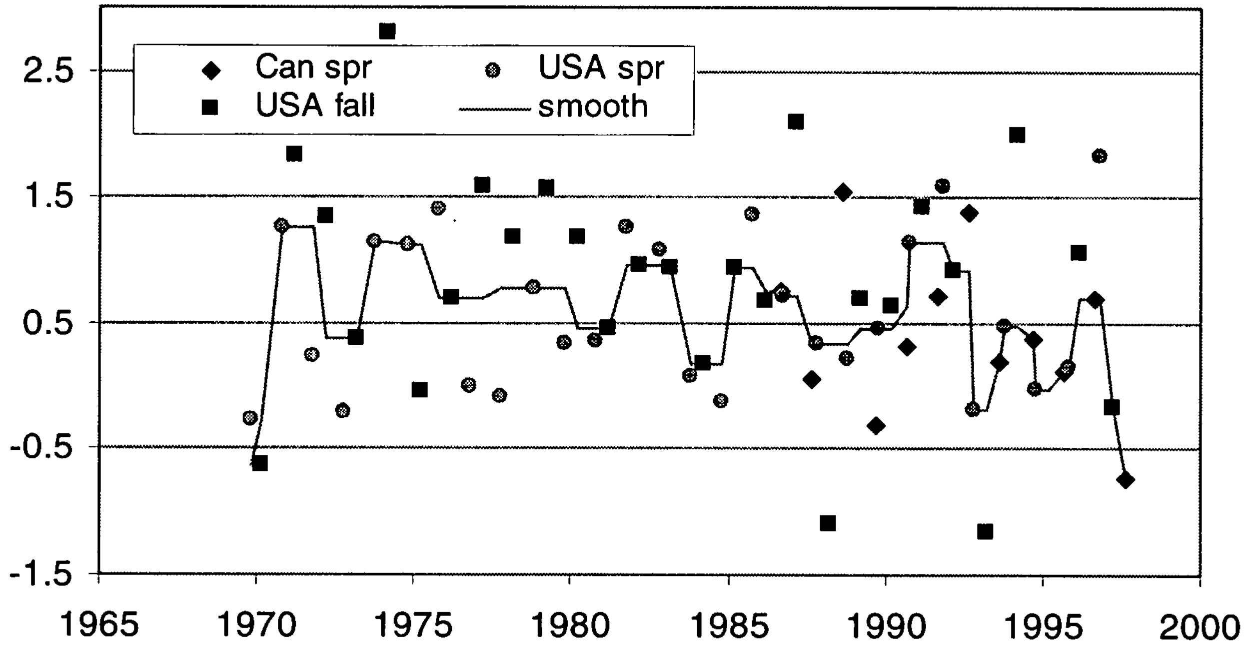


Fig. 23. Mortality estimates from surveys show considerable year to year variation. A 3 year running median smoother was applied to examine the trends.

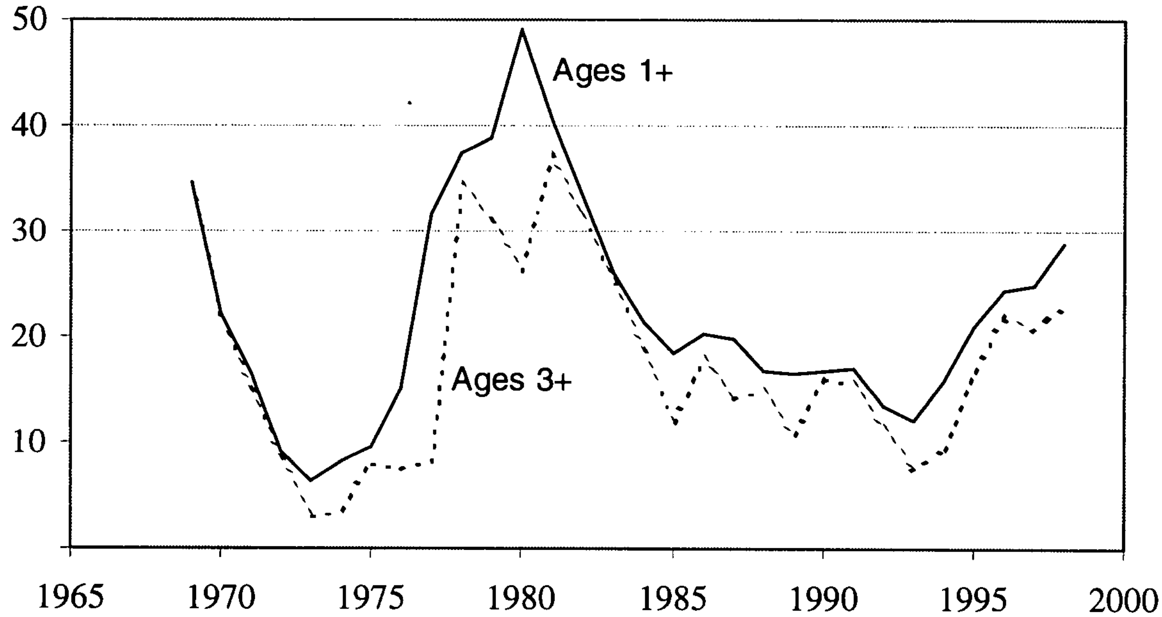


Fig. 24. Beginning of year biomass for haddock in unit areas 5Zjm.

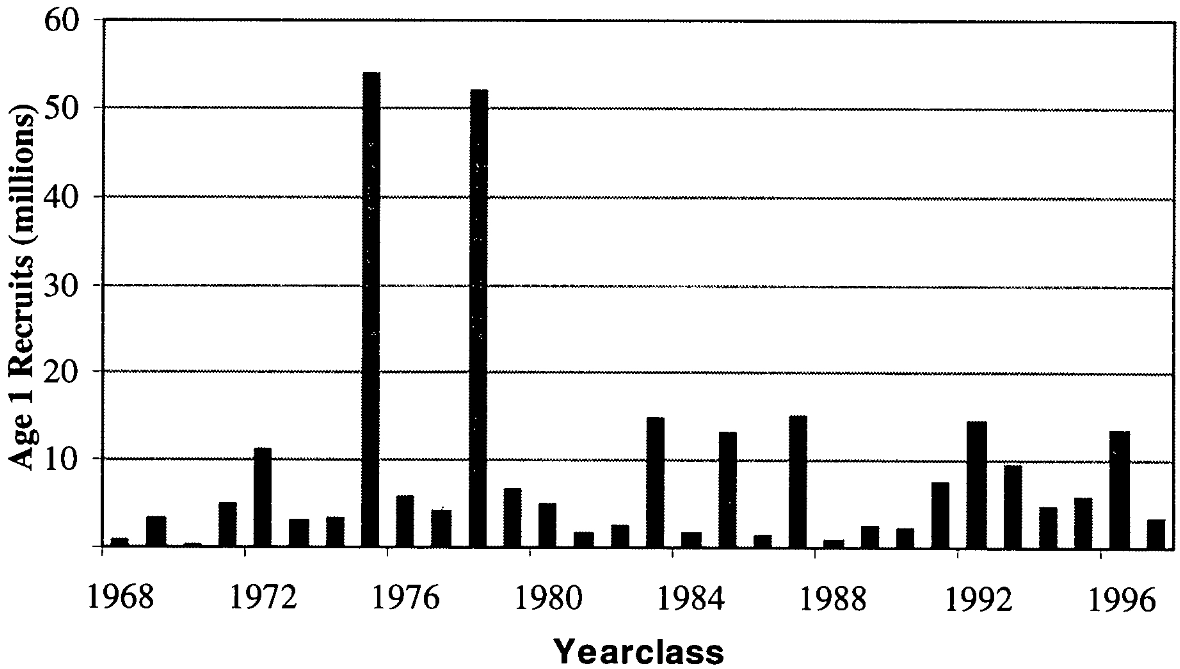


Fig. 25. Number of age 1 recruits for haddock in unit areas 5Zjm.

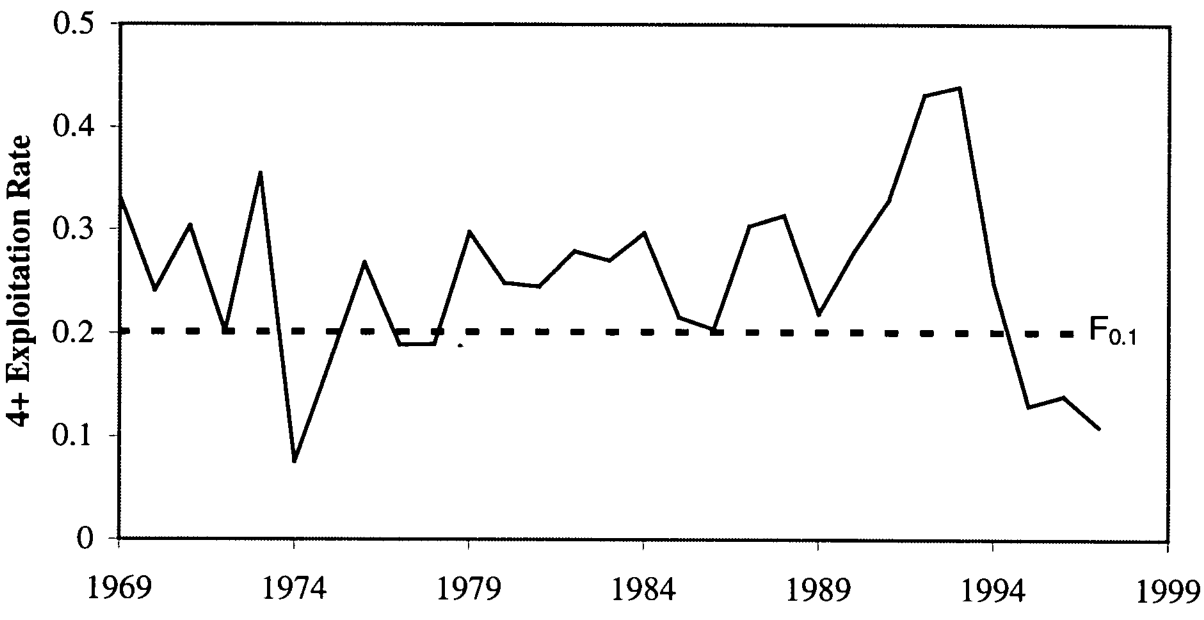


Fig. 26. Fishing mortality rate for haddock ages 4 and older in unit areas 5Zjm.

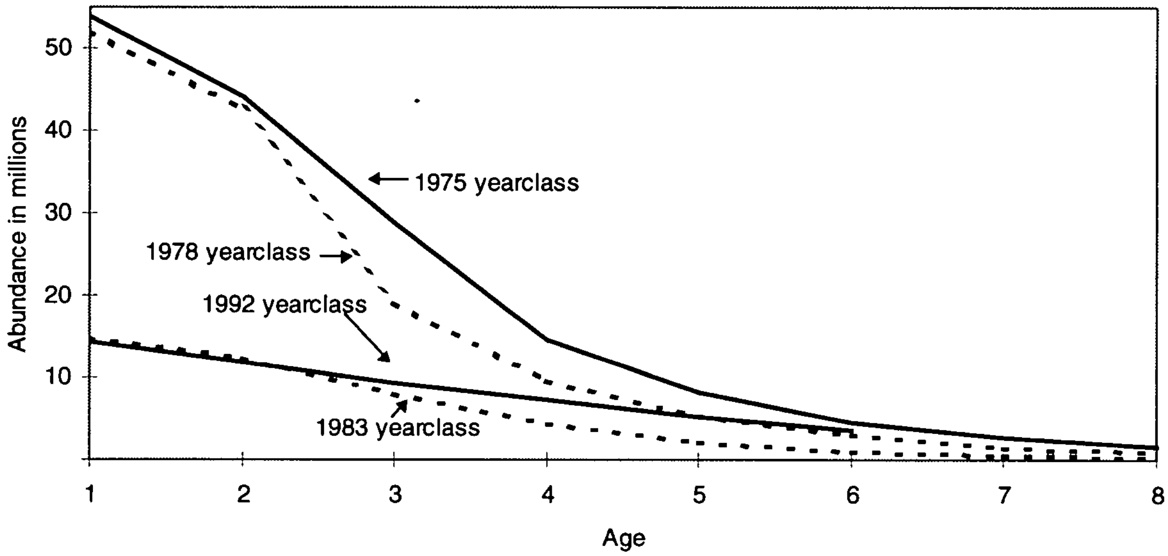


Fig. 27. Decay of the 1992 5Zjm haddock year-class versus the 1983, 1975 and 1978 as they progress through the fishery.

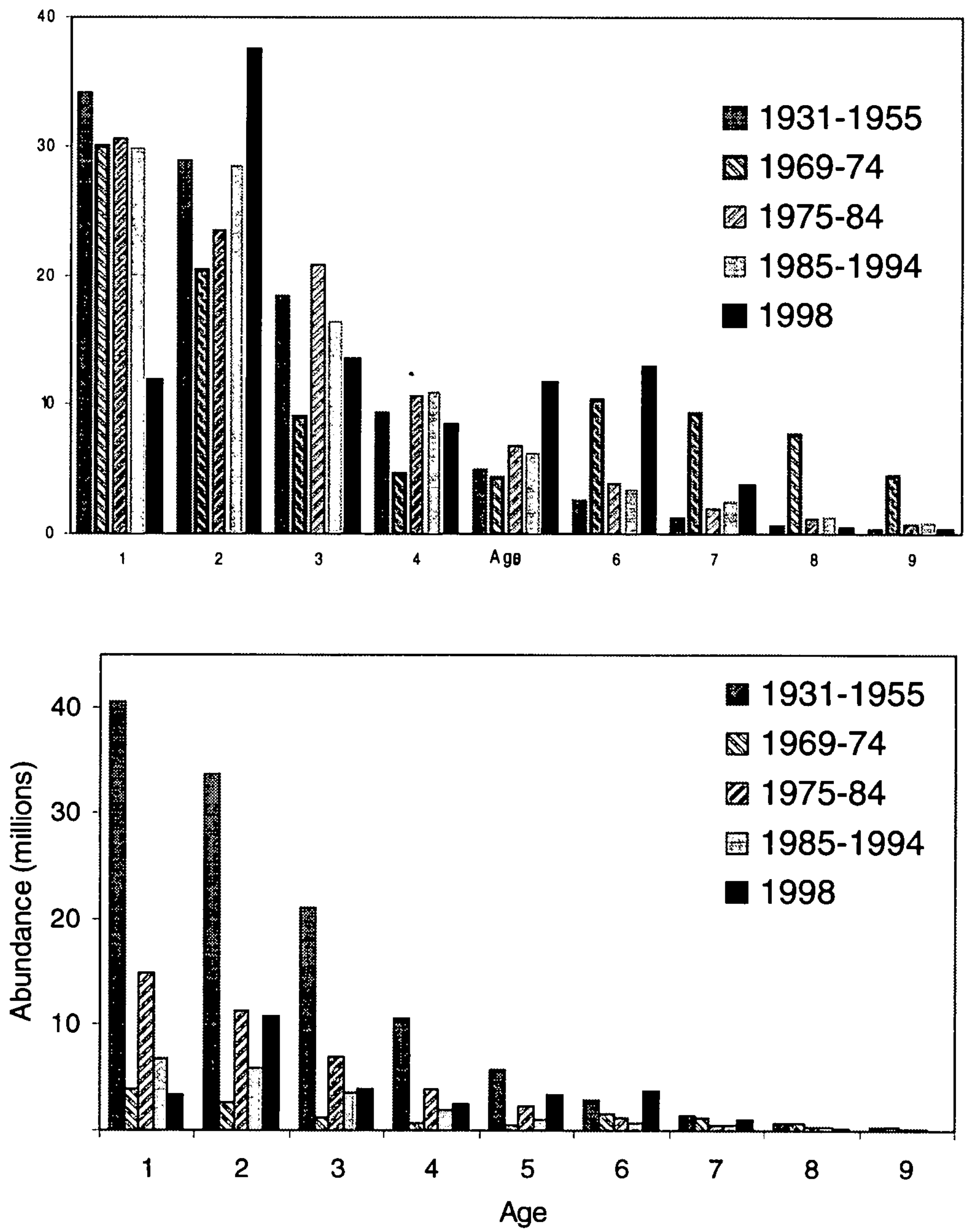


Fig. 28. Comparison of age composition and absolute abundance of the 5Zjm haddock population in 1998 to earlier periods.

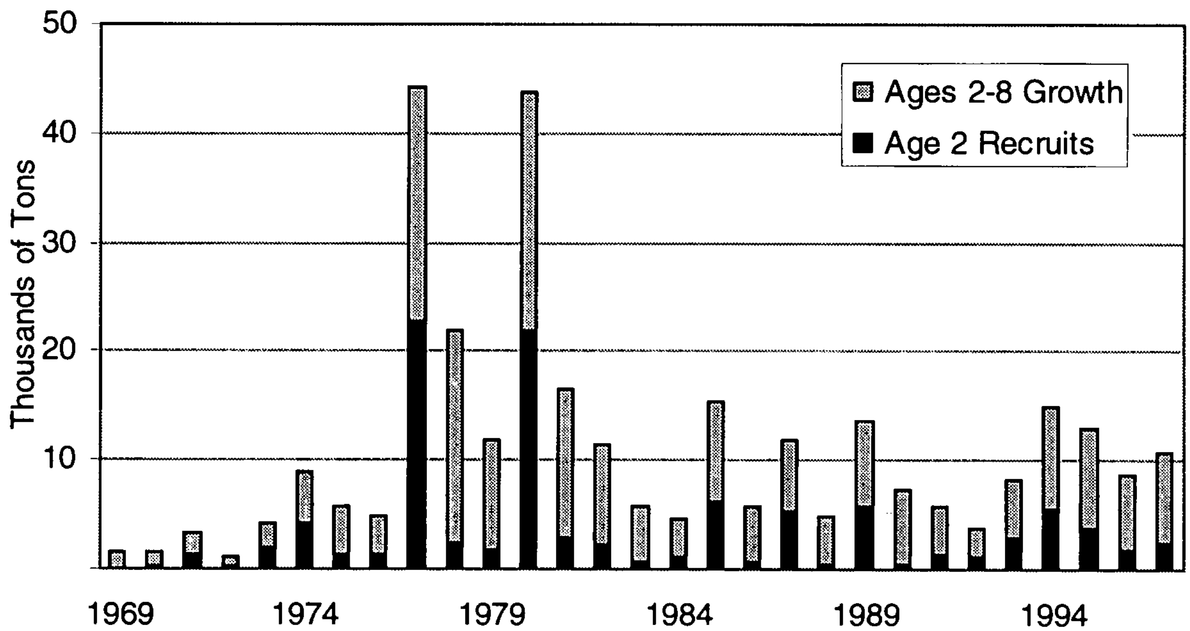


Fig. 29. Amount of productivity attributible to growth of ages 2 to 8 5Zjm haddock and the amount contributed by recruitment of age 2 haddock.

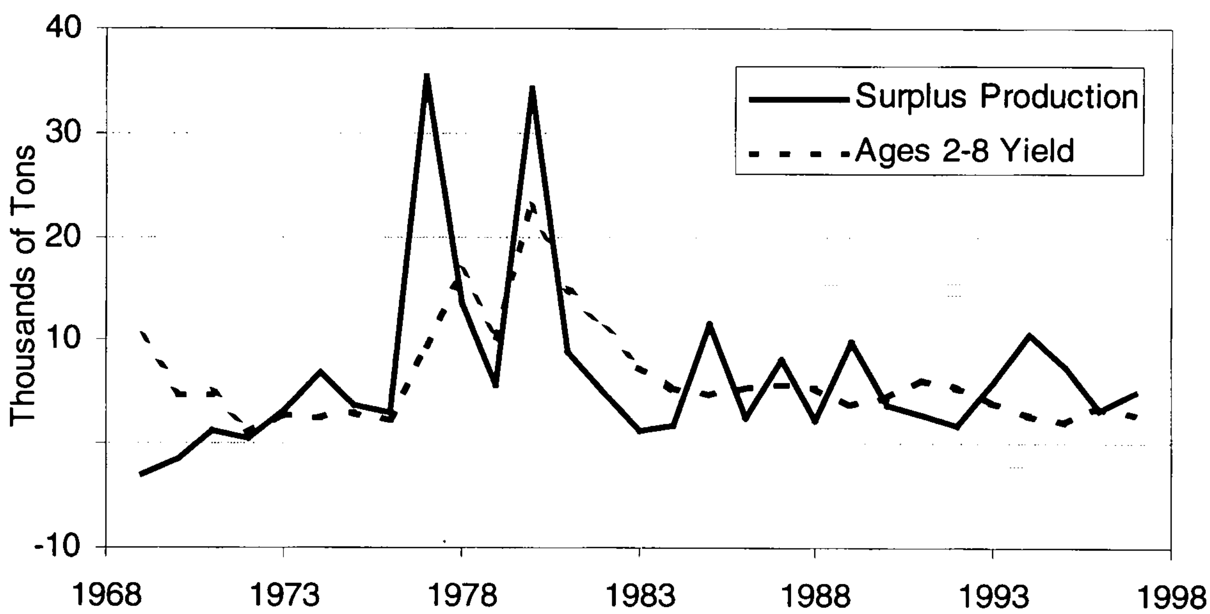


Fig. 30. Surplus production of 5Zjm haddock available to the commercial fishery compared to amount actually harvested.

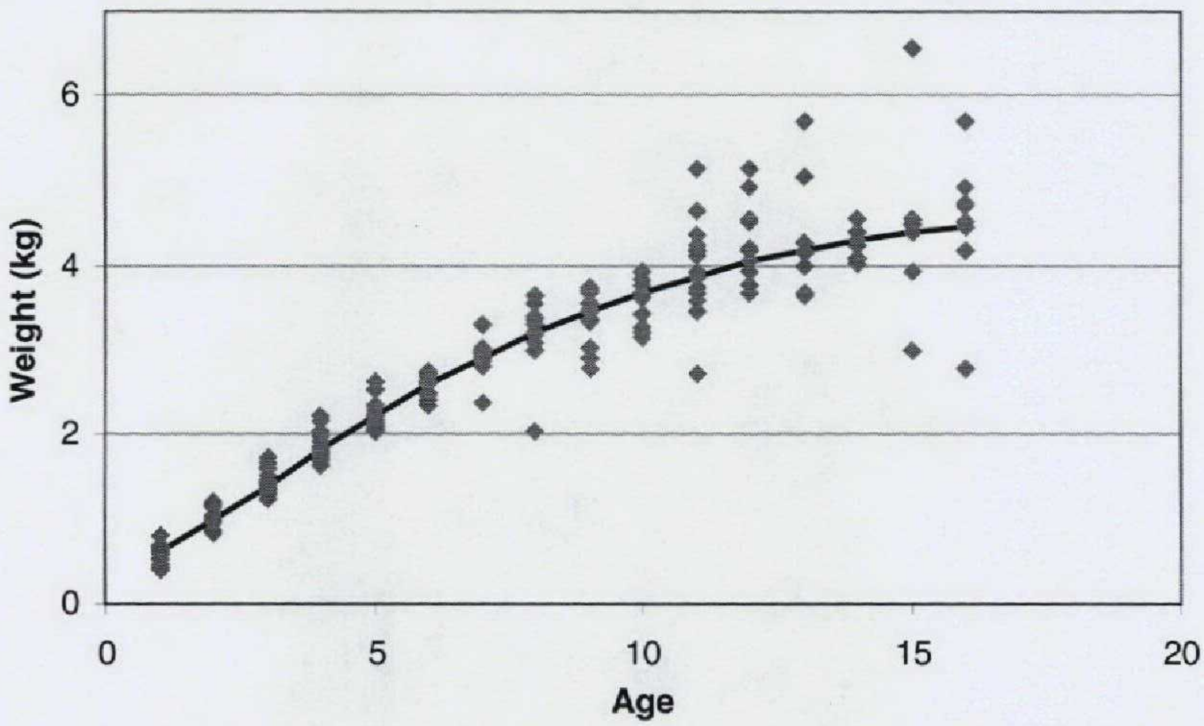


Fig. 31. Predicted weight at age for 5Zjm haddock as used in yield per recruit analysis.

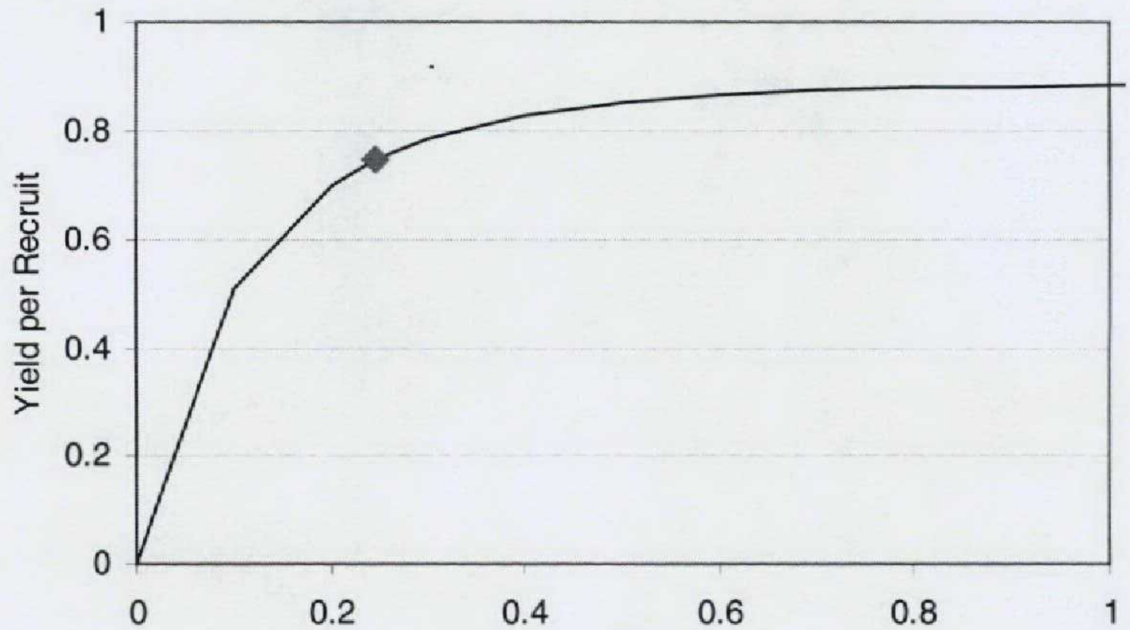


Fig. 32. Yield per recruit analysis for 5Zjm haddock assuming complete fishing on last age group (i.e. + group) with the $F_{0.1}$ value identified.

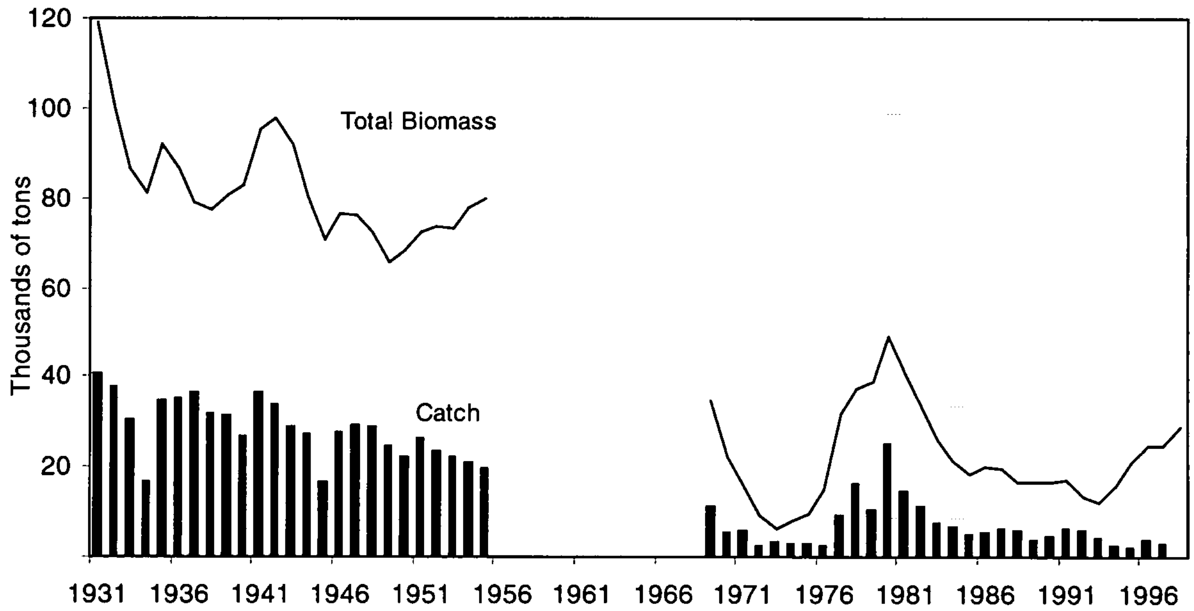


Fig. 33. Historic catch and biomass of haddock in 5Zjm compared to recent catches and biomass.

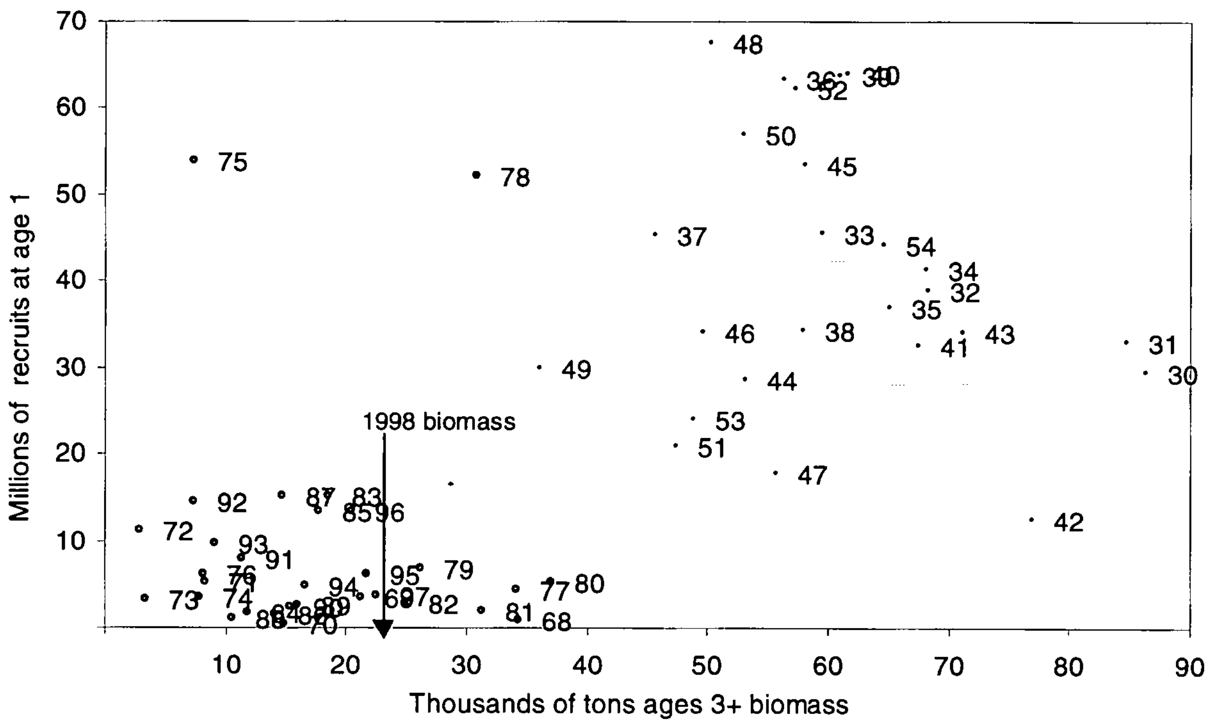


Fig. 34. Relationship between mature (3+) 5Zjm haddock biomass and recruits at age 1 from 1931 to 1955 and 1969 to 1997.

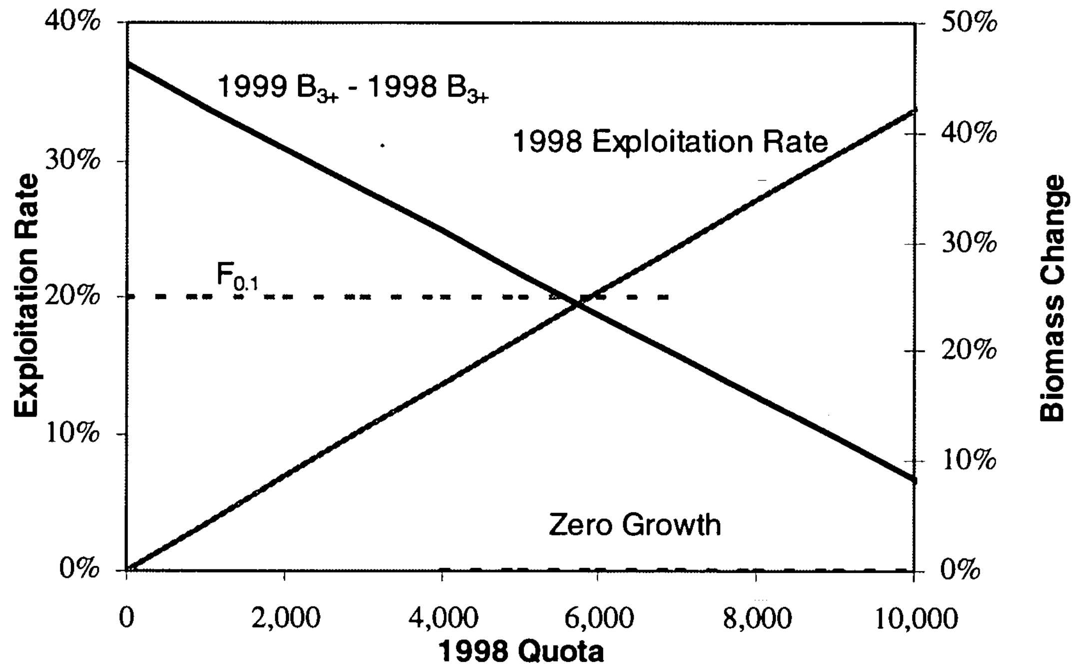


Fig. 35. Expected exploitation rate in 1998 and expected change in biomass from 1998 to 1999 for 5Zjm haddock at various quotas.

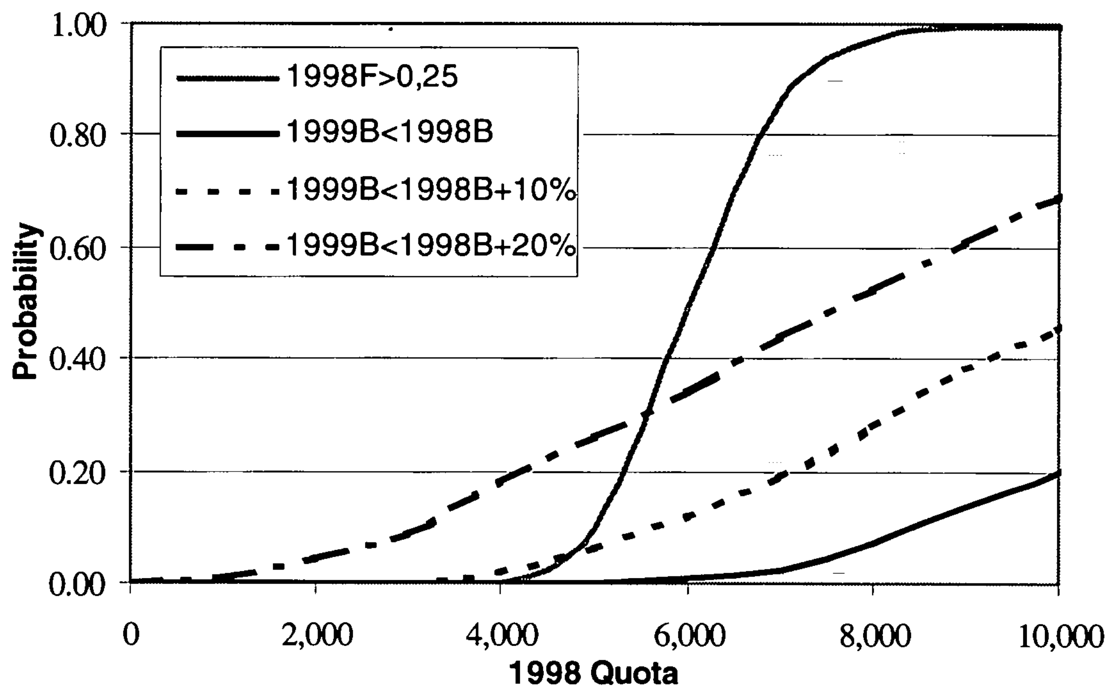


Fig. 36. Probability of fishing mortality exceeding the $F_{0.1}$ (=0.25) reference level and of the 1999 biomass being less than the 1998 biomass by 0%, 10% and 20% for 5Zjm haddock at various quotas.

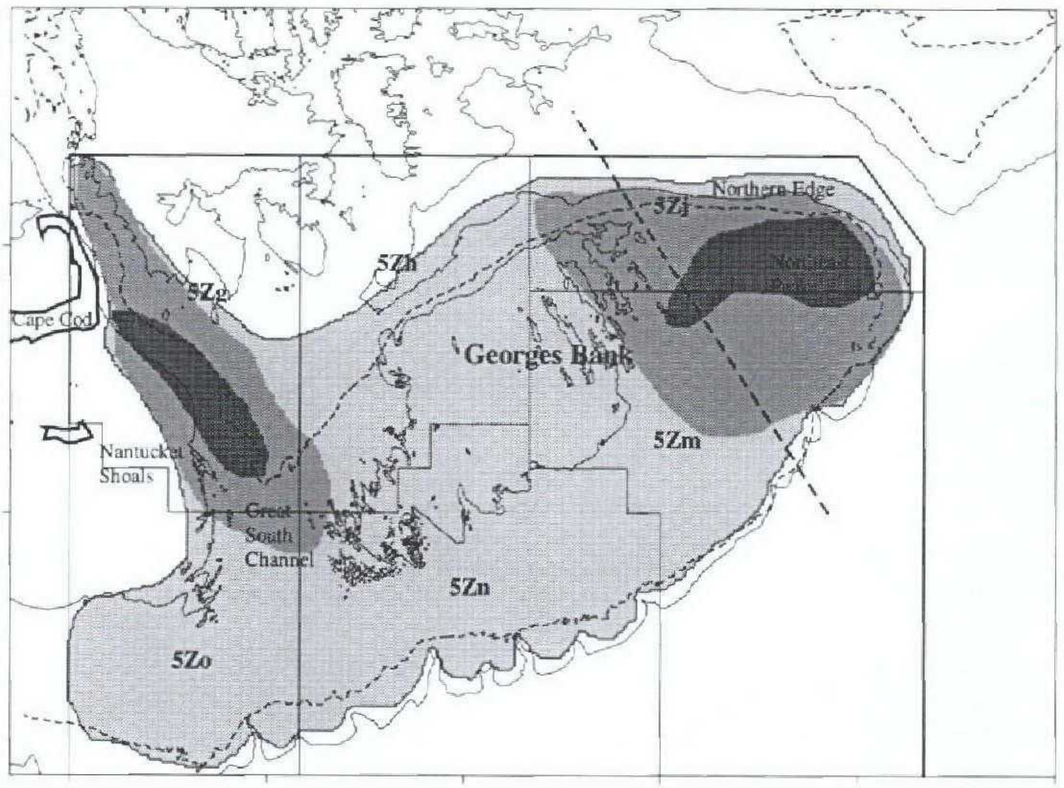


Fig. 37. The spawning components of the Georges Bank haddock stock are comprised of an eastern component on the Northeast Peak and a western component in the Great South Channel. Darker shading indicates higher density of aggregation on average over the year.

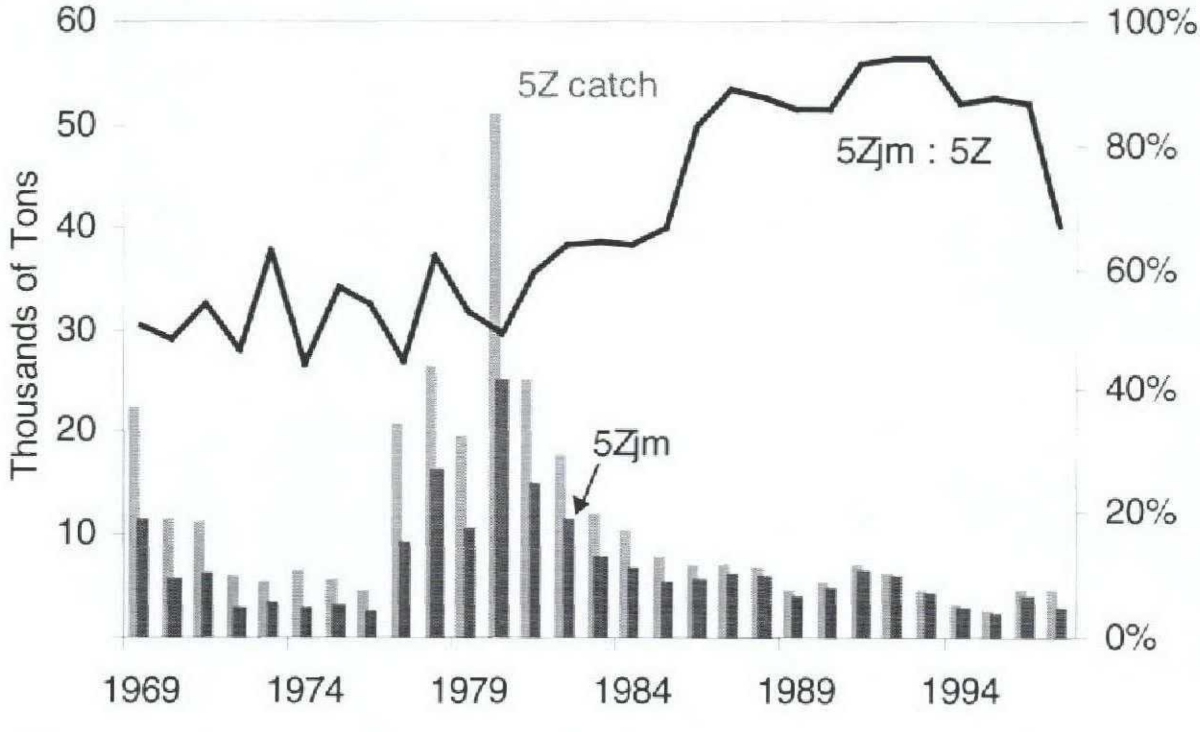


Fig. 38. Comparison of the catches of haddock in 5Z and 5Zjm and the 5Zjm to 5Z catch ratio.

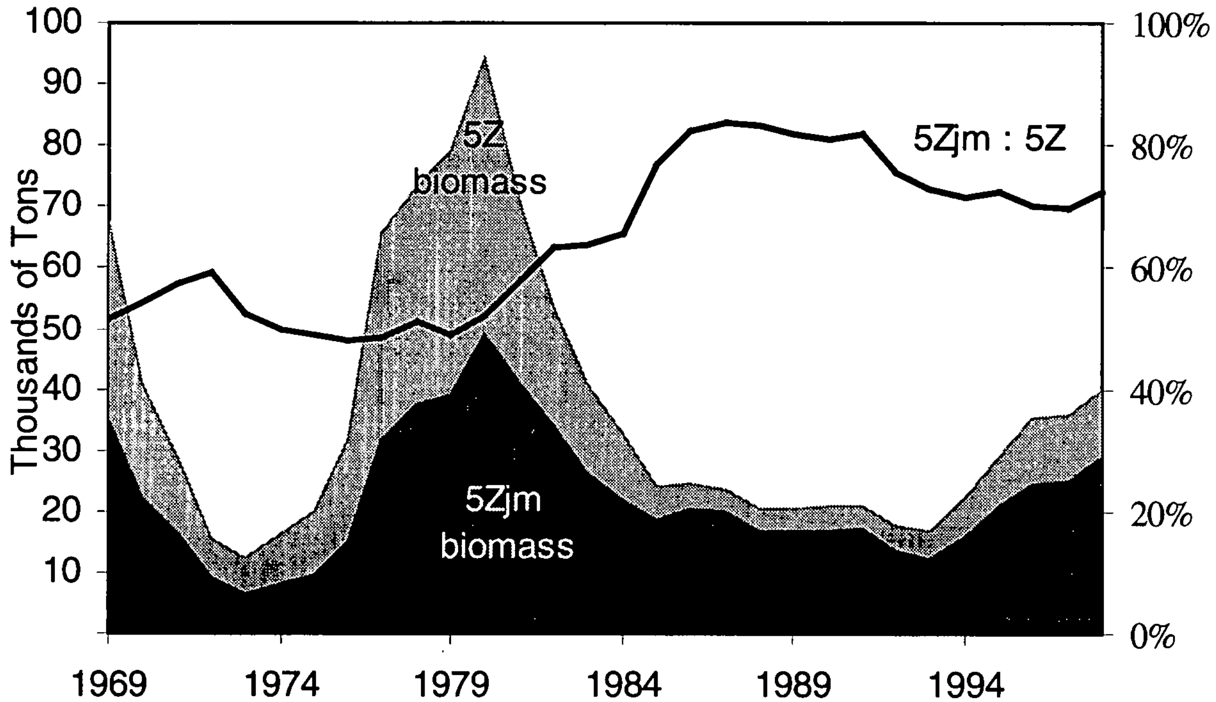


Fig. 39. Comparison of total haddock biomass in 5Z and 5Zjm and the 5Zjm to 5Z biomass ratio.

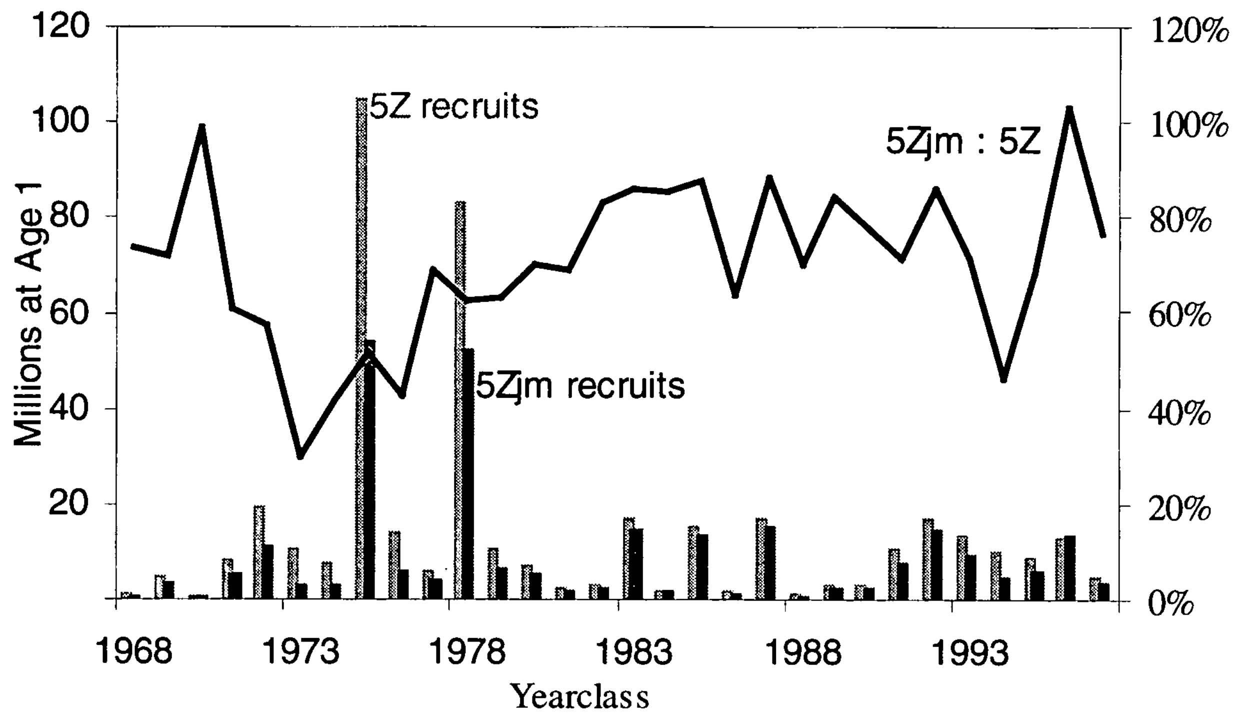


Fig. 40. Comparison of the number of haddock recruits at age 1 in 5Z and 5Zjm and the ratio of 5Zjm to 5Z recruits.

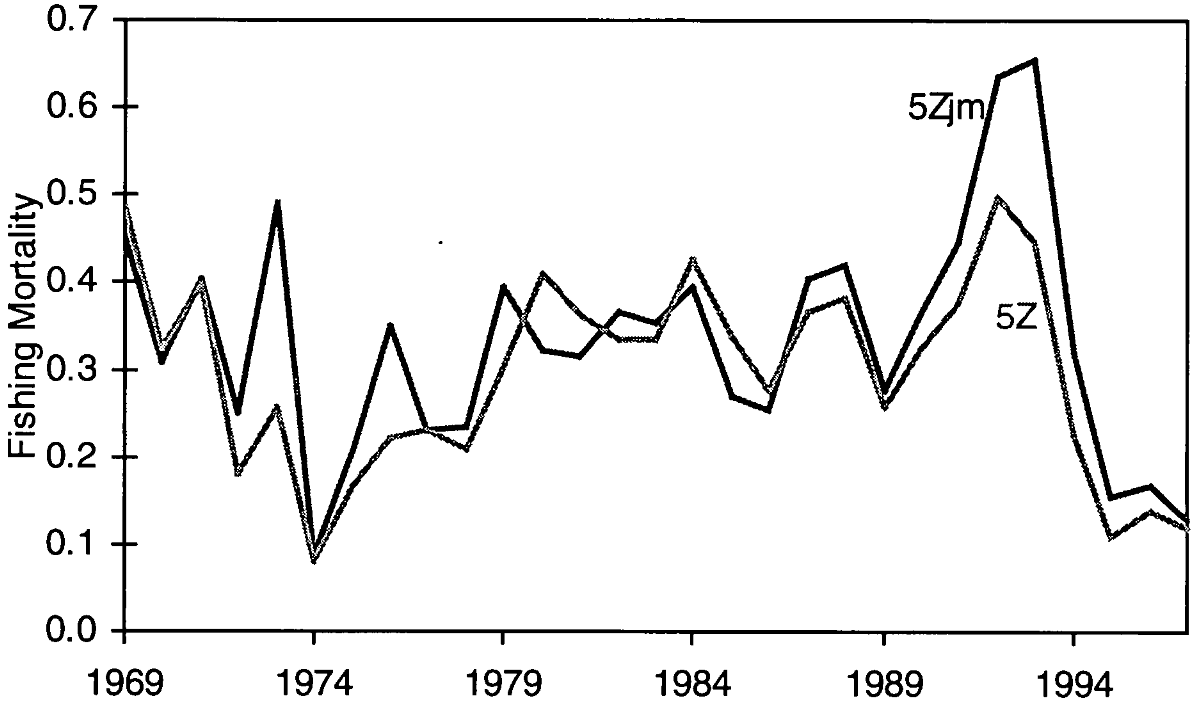


Fig. 41. Comparison of the fishing mortality levels for haddock in 5Z and 5Zjm.

Appendix A. Comparison of 5Zjm haddock length frequencies from port and observer sampling with those from fishery officer surveillance boardings.

Haddock length frequencies from boardings made by surveillance officers in 5Zjm were compared to those from port and observer samplers to look for evidence of discarding. The amount of data available for comparison is low. Twenty-nine surveillance samples taken from 1994 to 1997 (Tables A1 and A2) were available for comparison.

Individual length frequencies from the surveillance samples were plotted, on a percentage basis, with the combined port and observer length frequencies from the same month and gear type or the closest month/gear type category available (Fig. A1). No observer samples were used in 1994 so these comparisons are with port samples only. The number of boardings with length frequency data in any category is low and the number of haddock measured per sample is low resulting in spiky length frequencies and high sampling variability. Six comparisons were possible for each of 1994 and 1995, 1 for 1996 and 7 for 1997. Most categories had only 1 surveillance length frequency. Only 3 of 29 surveillance samples had greater than 200 measurements and 17 had less than 100 measurements. The available data show no persistent patterns to indicate a discard problem.

Table A1. Details of fishery officer boardings of fishing vessels on eastern Georges Bank from 1994 to 1997 during which haddock length measurements were taken.

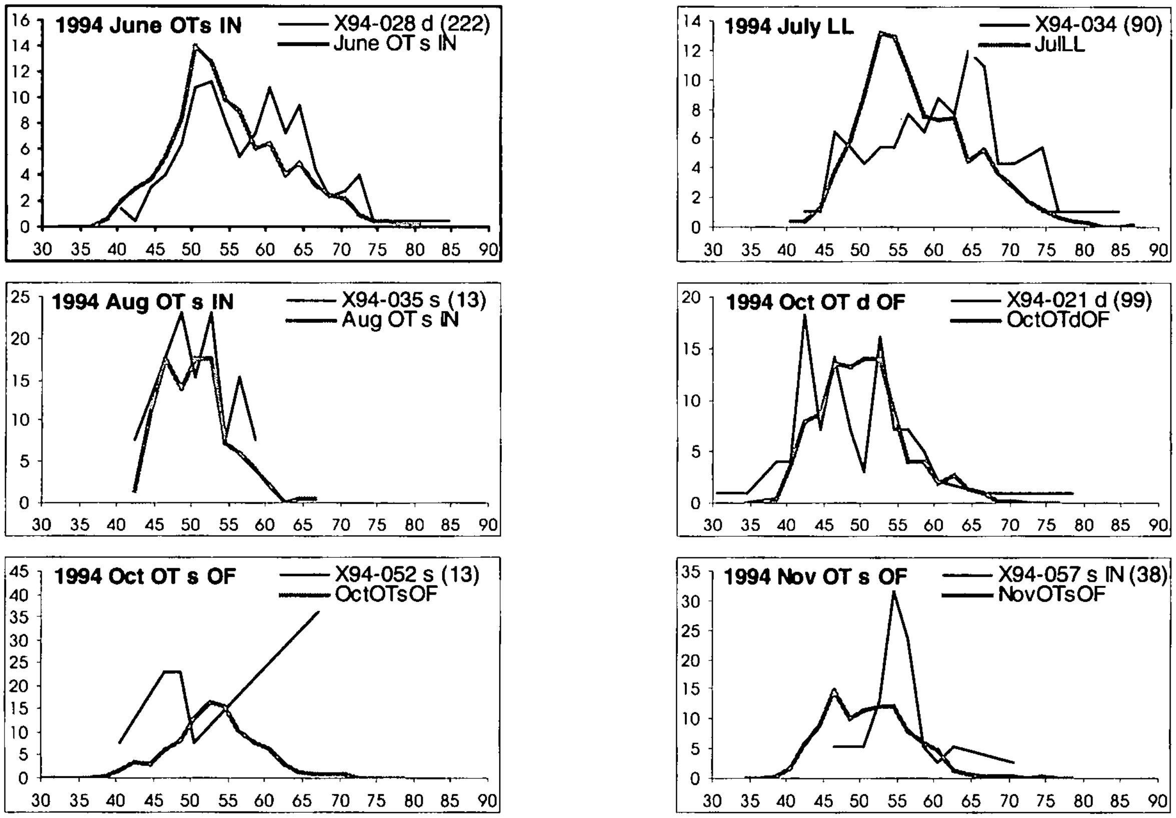
Reference No.	Boarding Date	Latitude	Longitude	Gear Type	Tonnage Class Code	Number Measured
X94-028	94/06/03.	4152	6650	12	3	222
X94-034	94/07/24.	4154	6546	51	2	90
X94-035	94/08/01.	4202	6600	19	3	13
X94-021	94/10/05.	4202	6559	12	5	99
X94-052	94/10/28.	4208	6615	19	5	13
X94-057	94/11/14.	4211	6611	19	2	38
X95-074	95/06/18.	4153	6653	19	2	214
X95-026	95/07/01.	4217	6640	51	2	81
X95-024	95/07/11.	4209	6636	19	2	133
X95-003	95/07/31.	4207	6558	51	2	191
X95-005	95/08/10.	4201	6606	19	2	32
X95-017	95/10/26.	4207	6622	19	3	49
X95-019	95/12/07.	4208	6623	51	3	73
X96-011	96/08/05.	4208	6630	19	3	255
X96-012	96/08/11.	4209	6633	19	2	116
X97-042	97/06/09.	4201	6609	19	3	76
X97-043	97/06/09.	4215	6620	19	3	157
X97-045	97/06/09.	4210	6611	19	2	82
X97-032	97/06/26.	4207	6618	51	3	23
X97-025	95/06/27.	4203	6605	12	2	33
X97-036	97/07/08.	4209	6641	19	2	199
X97-037	97/07/08.	4209	6639	51	1	44
X97-039	97/07/08.	4209	6639	51	2	25
X97-074	9/1/97	4206	6559	19	2	29
X97-061	9/11/97	4209	6638	51	2	128
X97-053	9/28/97	4208	6639	19	3	104
X97-054	9/28/97	4208	6641	19	3	119
X97-079	10/13/97	4206	6628	12	3	162
X97-076	10/14/97	4202	6600	19	2	79

Table A2. Number of boardings by fishery officers of eastern Georges Bank fishing vessels for which haddock length frequecies were taken. Shading indicates that the vessels were tonnage class 4, 5 or 6. All other vessels were tonnage class 1, 2 or 3.

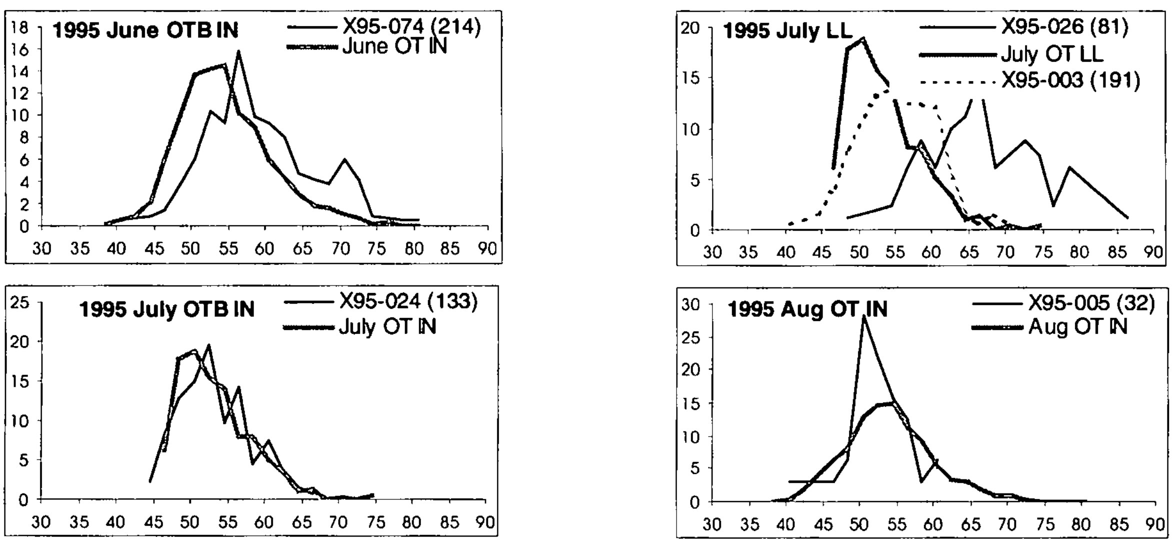
Year	Gear	Q2 June 6	July 7	Q3 Aug 8	Sept 9	Oct 10	Q4 Nov 11	Dec 12
1994	12	1				1		
	51		1					
	19			1		1	1	
1995	19	1	1	1		1		
	51		2					1
1996	19			2				
1997	19	4	1		3	2		
	51	1	2		1			

Fig. A1. Comparison of 5Ze haddock length frequencies from port and observer samples with those from fishery officer surveillance boardings during 1994 to 1997. In 1994 port samples only were used. Port and observer samples are combined by month and gear type and compared to individual surveillance samples which show numbers measured in brackets. (OT=otter trawl bottom;IN=tonnage class 1-3;OF-tonnage class 4-6;s=square mesh;d=diamond mesh)

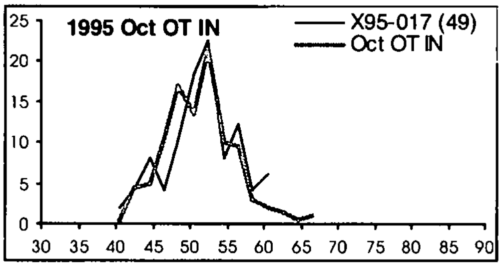
A. 1994

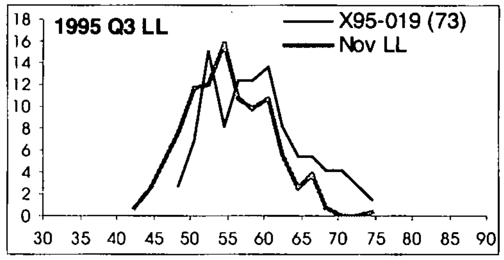


B. 1995

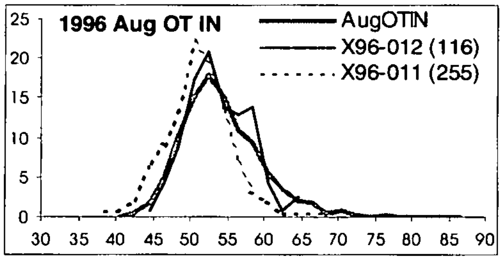


B. 1995 (continued)

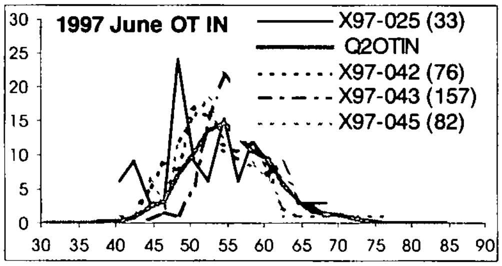


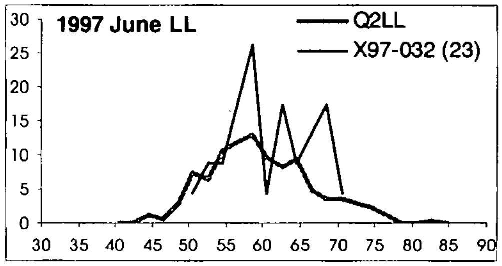


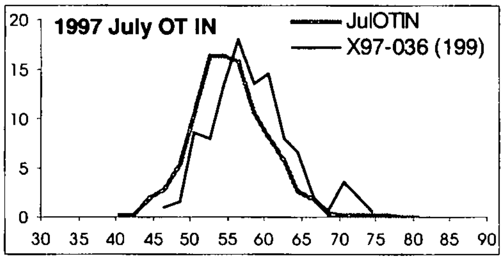
C. 1996

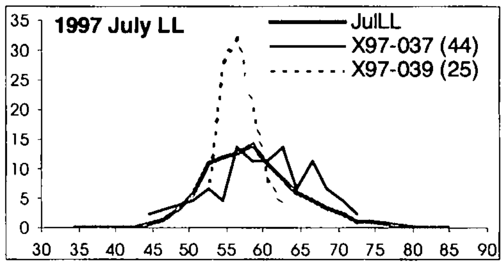


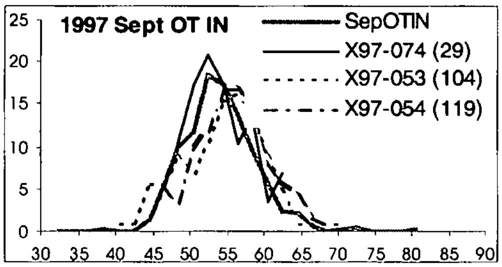
D. 1997

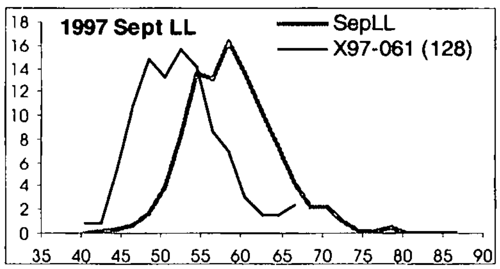


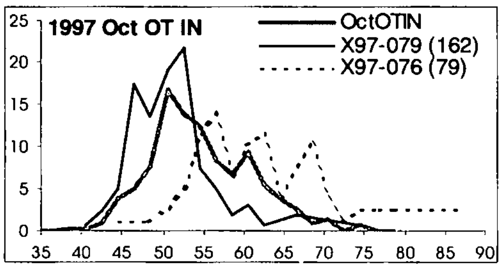












Appendix B. Ageing

A subsample of the 1998 DFO spring survey otoliths (N773) plus the remainder of the 1997 DFO spring survey (N254) otoliths and the Canadian commercial fishery otoliths obtained by port samplers and by the observer program were read by L. Van Eeckhaute (LVE). Numbers of otoliths examined are summarized below:

Name	Year	Description	Total	Not aged	Ages
N254	1997	DFO spring survey	346	2	344
CGS	1997	Canadian commercial fishery-Port Samplers	781	15	766
IOP	1997	Canadian commercial fishery-Observer Program	207	1	206
N773	1998	DFO spring survey	363	9	354

Intra-reader and inter-reader tests

Within reader tests were conducted for L.Van Eeckhaute using otoliths from the N254 survey (n=95) and the 1997 commercial fishery (n=100). Between reader tests with the USA reader, N.Munroe, (NM) and the Canadian reader were also completed. Fifty otoliths from the 1997 DFO survey (N254) and 50 from the 1996 NMFS fall survey (9604) were selected. Agreement matrices for the four tests are given in Figs. 1 to 4. A summary of test results follows:

Source	Description	Test	N	% agreement
N254	1997 DFO spring survey	LVE x LVE	95	95
		LVE x NM	50	63
CGS '97	1997 Canadian Commercial Fishery	LVE x LVE	100	95
9604	1996 NMFS fall survey	LVE x NM	50	84

Intra-reader agreement is high with no bias (Figs. B1 and B3). One of the between reader tests shows low agreement and a bias with the NMFS reader ageing younger than the DFO reader (Fig. B2). The second inter-reader test shows acceptable agreement but there is a slight bias towards older ages by the NMFS reader versus the DFO reader (Fig B4).

Fig. B1. Intra-reader agreement matrix for L.Van Eeckhaute for ageing material from the 1997 DFO spring survey.

DFO 1997 spring survey (N254)													
Second Reading	First Reading												
	1	2	3	4	5	6	7	8	10	12	15	Omit	Total
1	24												24
2		13	1										14
3			5										5
4				12	2								14
5					9								9
6					1	10							11
7						1	3						4
8								2					2
10									7				7
12										3			3
15											1		1
Omit										1			1
Total	24	13	6	12	12	11	3	2	7	4	1	0	95
Percent agreement: 89 agreements out of 94 with 2 ages = 95%													

Fig. B2. Agreement matrix between N.Munroe, the NMFS reader, and L.Van Eeckhaute, the DFO reader for ageing material from the 1997 DFO spring survey.

DFO 1997 spring survey (N254)														
L.Van Eeckhaute	N.Munroe													
	1	2	3	4	5	6	7	8	9	10	12	15	omit	Total
1	11	1												12
2		7												7
3			2											2
4			1	7										8
5				5	1									6
6				1	3	2								6
7						1								1
8													1	1
9														0
10							1	1	2				1	5
12							1							1
15										1				1
omit														0
Total	11	8	3	13	4	3	2	1	2	1	0	0	2	50
Percent agreement: 30 agreements out of 48 read by both readers = 63%														

Fig. B3. Intra-reader agreement matrix for L.Van Eeckhaute for ageing material from the Canadian commercial fishery samples.

1997 Canadian Commercial Samples												
Second Reading	First reading											
	2	3	4	5	6	7	9	10	12	13	omit	Total
2	12											12
3	1	5										6
4			18									18
5			1	26	1						1	29
6					11							11
7						5						5
9												
10							1	9				10
12									5			5
13									1			1
omit			1			1					1	3
Total	13	5	20	26	12	6	1	9	6	0	2	100
Percent agreement: 91 agreements out of 96 aged twice = 95%												

Fig. B4. Agreement matrix for N.Munroe and L.Van Eeckhaute for ageing material from the NMFS 1996 fall survey.

NMFS 1996 Fall Survey (9604)											
L. Van Eeckhaute	N.Munroe										
	1	2	3	4	5	6	7	8	9	Omit	Total
1	4										4
2		2									2
3			14								14
4				13	4						17
5				1	8						9
6							1				1
7						1					1
8									1		1
9											0
Omit				1							1
Total	4	2	14	15	12	1	1	0	1		50
Percent agreement: 41 agreements out of 49 aged by both readers = 84%											

Appendix C. Alternative catch-age analyses

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A catch-age model, employing the same model structure and objective function as used by Gavaris and van Eeckhaute(this document), was implemented using ADModel Builder Software (Otter Consulting Ltd.). This implementation, which assumes a log-normal error structure for the survey catch-at-age data and omits zero observations from the objective function, is termed the *ADAPT* model. A second implementation of *ADAPT*, based on the same model structure but with a different objective function was also coded. In this case the objective function was based on the assumption of a multinomial distribution for the age-composition data and a log-normal distribution for the total (i.e. summed over ages) abundance in each survey. The objective functions (quantities to be minimized) for the alternate error structure models are:

ADAPT

$$\sum_{kij}\left(\ln I_{kij} - \left(\ln K_{kij}\right)\right)^2$$

multinomial ADAPT

$$-\sum_{kij} S_{kij} \ln P_{kij} + W\sum_{ki}\left(\ln I_{ki.} - \ln K_{ki.}\right)^2$$

where,

I_{kij} is the survey index for survey k in year i for age j
N_{ij} is the model estimate of numbers at age j in year i

$$S_{kij} = S\left({I_{kij}} \Big/ {\sum_j I_{kij}} \right)$$

$$K_{kij} = N_{ij} \exp(q_{kj})$$

$$K_{ki.} = \sum_j K_{kij}$$

$$P_{kij} = {K_{kij}} \Big/ {K_{ki.}}$$

S is a sample size weight
W is the survey catch weight
t is the terminal year of the analysis

The quantities, S and W, are fixed inputs to the analysis and the quantities, q_{kj} and N_{tj}, are fundamental model parameters estimated through the minimization.

An alternate catch-age model, where the N matrix is calculated moving forward in time, was also implemented. For this model, parameters for the numbers at each age in the first year and the numbers in the first age class for each year are estimated. This frees the assumption that the terminal age fishing mortality is equal to the average fishing mortality for younger ages, but also results in imprecise estimates of absolute stock abundance. Hence, analyses were also conducted where the catchability (q) for ages 3 through 8 are estimated as a single parameter for the Canadian Spring Survey (i.e. assume flat-top or asymptotic catchability).

Table C1. Estimates of eastern Georges Bank haddock number-at-age for the beginning of year 1998 from the analysis for the alternative model structures and error models are shown.

model structure	objective function	numbers (000's) at age							
		1	2	3	4	5	6	7	8
standard	log-normal[1]	4597	12135	4158	2565	3504	3866	1101	148
ADAPT	log-normal	4603	12148	4163	2569	3514	3881	1107	149
	multinomial	1766	7838	2526	1600	2264	2642	616	144
forward	log-normal	23731	62614	22327	14853	2578	34209	13580	3008
catch-age	multinomial	7203	32289	11297	8164	15945	23369	8415	2378
asymptotic	log-normal	5136	13571	4809	2999	4385	4861	1583	267
selectivity	multinomial	2080	9261	3082	2015	3125	3925	1066	276

[1] results reported in Gavaris and van Eeckhaute (1998)

Differences between the numbers-at-age reported by Gavaris and van Eeckhaute (this document) and those produced by the AdModel Builder implementation of *ADAPT* are small, which supports that the model formulations are the same in the two analyses (Table C1). The estimates of numbers-at-age for the standard *ADAPT* model, but using the multinomial error structure objective function, are considerably lower than those for the log-normal objective function, particularly for younger ages. The time-series of recruitment estimates from the two analyses, indicates that the stock estimates diverge only in the most recent years (Fig. C1).

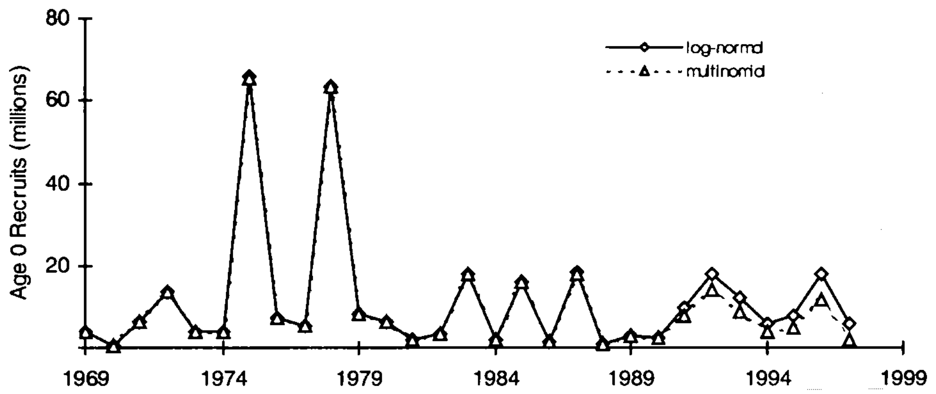

Fig. C1. Estimates of recruitment at age 0 from the alternative error structure models for 5Zjm haddock.

Estimates of the catchabilities (*q*) from the "multinomial" analysis are substantially higher for two of the surveys.

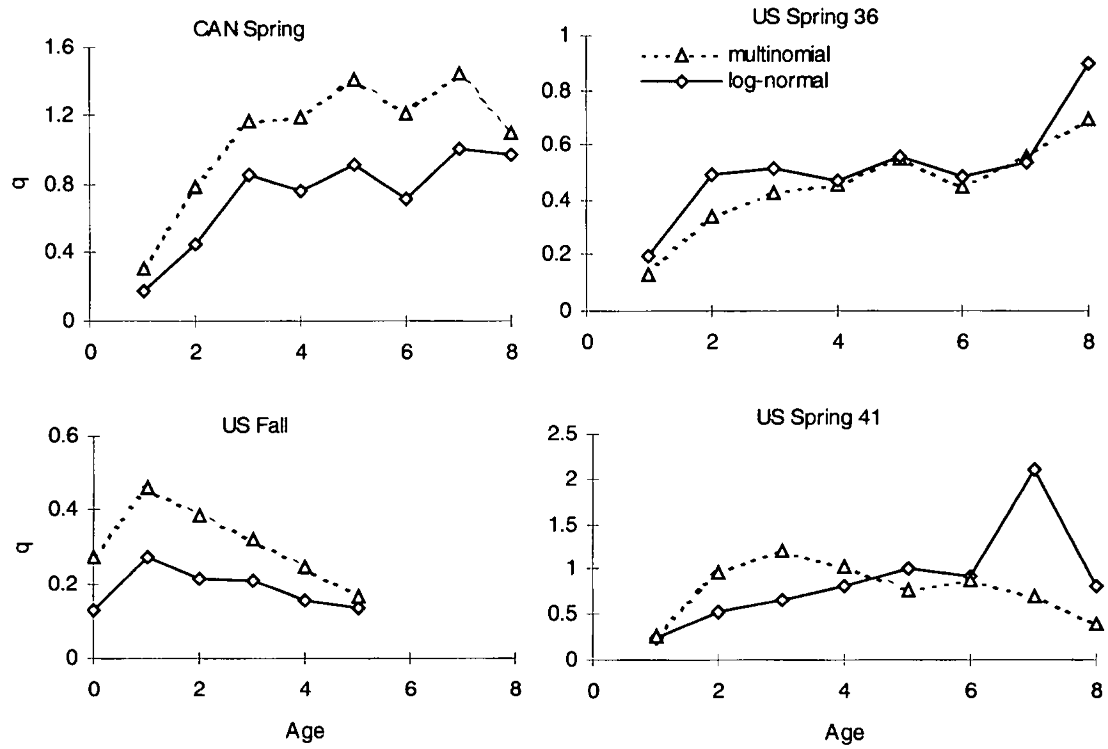

Fig. C2. Estimates of survey catchability at age for eastern Georges Bank haddock from the two error structure models.

The estimated numbers-at-age in the terminal year from the *forward catch-age* model are substantially higher for both forms of the objective function than they are from the *ADAPT* formulation. The partial recruitment parameters from these runs suggest decreasing partial recruitment at higher ages (i.e. 6 to 8). When catchability of ages 3 through 8 in the Canadian spring survey are estimated as a single parameter, the estimates of terminal year numbers are fairly similar to those from the *ADAPT* analysis. Also, the time-series of recruitment estimates (shown in the following figure) have high coherence between the *ADAPT* and *forward catch-age* models (Fig. C3.).

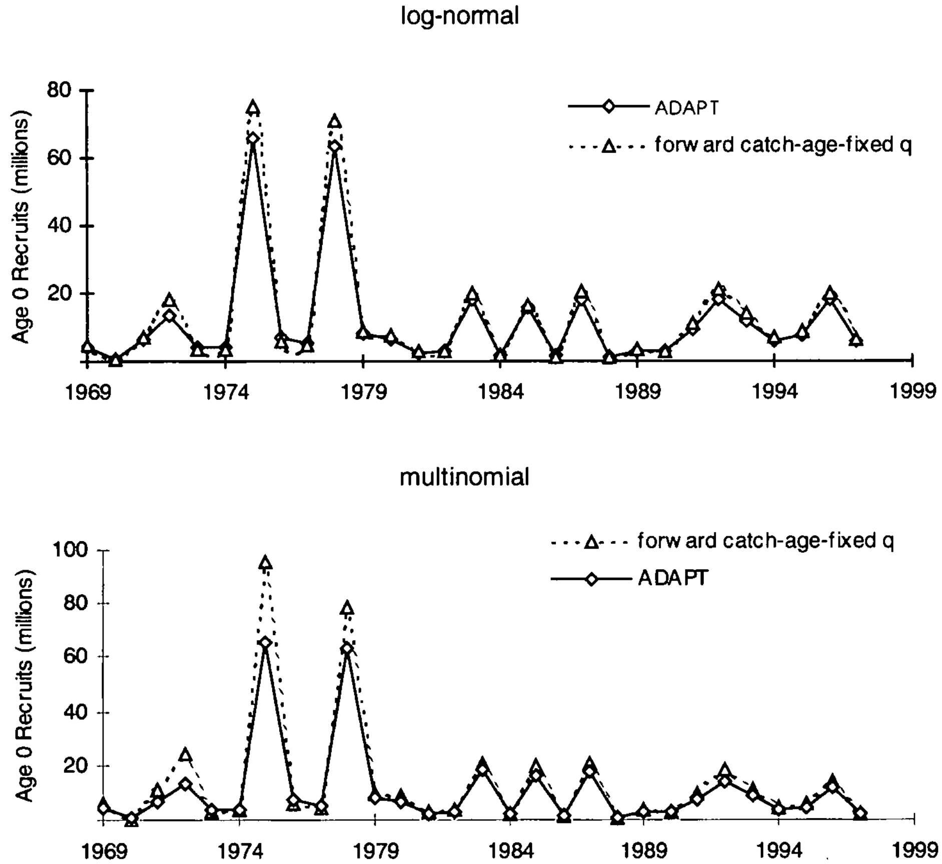

Fig. C3. Estimates of recruitment at age 0 for eastern Georges Bank haddock from "forward" and "backward" VPA for both error structure models.

The intent of analysing the eastern Georges Bank haddock data with alternative model formulations and error structure assumptions was to explore the potential uncertainty in stock abundance estimates. The range in terminal stock estimates obtained from these analyses suggest a greater uncertainty than what is estimated for a single model. Further work is required to investigate the robustness of the alternate error structure models.