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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 6,366 t in 1991 to a low of 2,111 t in 1995, then increased again to 3,720 t, 2,733 t and 3,696 t in 1996, 1997 and 1998 respectively. Over half of the 1998 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 1996 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. The 1997 year-class is weaker and preliminary indications suggest that the 1998 year-class may be strong.

Population biomass for ages 3-8 has steadily increased from near historic low levels of 6,737 t in 1993 to 26,836 t in 1999. 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 continuing increase is being sustained by the 1996 year-class. The abundance of the 1996 year-class was estimated at about 16 million. The 1995 and 1997 year-classes appear weaker at about 6 million. The exploitation rate for fully recruited ages 4-8 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.

Projected total Canada/USA yield at $F_{0.1} = 0.25$ in 1999 would be about 6,300 t. If fished at $F_{0.1}$ in 1999, the biomass for ages 3-8 is projected to increase from 26,836 t to 27,430 t at the beginning of 2000. Ages 3-7 should comprise about 90% of the total yield in 1999 with all these year-classes contributing almost equally. A projected total Canada/USA catch of 4,000 t in 1999, about what was caught in 1998, results in a negligible risk that fishing mortality rate will exceed $F_{0.1}$ and that the biomass for ages 3-8 will decrease. At this yield, there is a risk of about 50% of not achieving 10% biomass increase and a risk of over 90% of not achieving 20% biomass increase.

Résumé

Dans la portion est du Banc Georges, les captures d'aiglefin réalisées du début des années 1980 jusqu'en 1993 on fluctué autour de 5 000 tonnes. Sous mesures de gestion restrictives, les captures sont passées de 6 366 t en 1991 à un minimum de 2 111 t en 1995, puis sont remontées respectivement à 3 720 t, 2 733 t et 3 696 t en 1996, 1997 et 1998. Plus de la moitié du poids des prises en 1998 était composée d'aiglefin des classes de 1992 et de 1993. Selon les relevés, il y a eu une tendance à la hausse de l'abondance des classes d'âges 3 à 8 entre 1992 et 1996, qui a ensuite fluctué. Les relevés indiquent que la classe de 1996 pourrait être comparable aux classes d'abondance moyenne des années 1983, 1985, 1987 et 1992. La classe de 1997 est plus faible, mais selon les constatations préliminaires, celle de 1998 pourrait être forte.

La biomasse de la population des classes d'âge 3 à 8 s'est accrue de façon régulière, partant d'un minimum historique de 6 737 t en 1993 pour atteindre 26 836 t en 1999. L'accroissement récent, attribuable en gros à la classe de 1992, mais en partie aussi à celles de 1991 et de 1993, s'est amplifié grâce à une meilleure survie des jeunes aiglefins, qui tient à la baisse des captures de petits poissons. Cet accroissement continu est alimenté par la classe de 1996, dont l'effectif a été estimé à environ 16 millions. Celui des classes de 1995 et de 1997 semble plus faible, aux environs de 6 millions. Depuis 1995, le taux d'exploitation des classes d'âges pleinement recrutées de 4 à 8 a régulièrement été sous le niveau cible $F_{0,1}$ de 20 %. Une baisse de la mortalité par pêche ces dernières années a contribué à augmenter la survie des classes d'âge non encore recrutées, et l'abondance des poissons plus âgés.

En 1999, la récolte totale prévue Canada/États-Unis au niveau $F_{0,1} = 0,25$ est d'environ 6 300 t. Si la pêche s'effectue au niveau $F_{0,1}$ en 1999, on prévoit que la biomasse des classes d'âges 3 à 8 augmentera de 26 836 t à 27 430 t au début de l'an 2000. Les classes d'âge 3 à 7 devraient former 90 % de la récolte totale en 1999, chacune contribuant à peu près également. Les risques sont négligeables que la récolte Canada/États-Unis de 4 000 t escomptée en 1999, l'équivalent de celle de 1998, entraîne une hausse du taux de mortalité par pêche supérieure au niveau $F_{0,1}$ et une baisse de la biomasse des classes d'âges 3 à 8. Avec une telle récolte, le risque est de 50 % environ de ne pas atteindre une hausse de la biomasse de plus de 10 % et il est de 90 % de ne pas atteindre une hausse de 20 %.

Introduction

Since 1990, Canada has used eastern Georges Bank, fishery statistical unit areas 5Zej and 5Zem (Figure 1), as the basis for a management unit (Gavaris 1989), referred to as 5Zjm for brevity. Results from the previous assessment (Gavaris and Van Eeckhaute 1998) indicated an increase in total biomass from 12,000 metric tonnes (t) in 1993 to almost 29,000 t at the beginning of 1998 and a decline in exploitation rate to below $F_{0.1}$ since 1995, resulting in increased survival of recent year-classes. However, current abundance remains below historical levels observed during the 1930's to mid 1950's when biomass was over 60,000 t and recent year-class sizes have also been well below historical levels.

In this assessment update, we included the latest information from the 1998 Canadian and USA fisheries and made minor revisions to the 1997 data. Results from the Department of Fisheries and Oceans, Canada (DFO) survey in the spring of 1999 and the National Marine Fisheries Service, USA (NMFS) surveys in the spring and fall of 1998 were incorporated. Methods similar to those used in the last assessment were applied to the updated information.

The Fishery

Commercial Catches

The haddock on Georges Bank have supported a commercial fishery since the early 1920s (Clark et al 1982). For details on the historical aspects of the Georges Bank haddock fishery see Gavaris and Van Eeckhaute (1998).

Under restrictive management measures, combined Canada/USA catches declined from about 6,400 t in 1991 to a low of about 2,100 t in 1995, then increased to about 3,700 t in 1996, 2,700 t in 1997 and 3,700 t in 1998 (Table 1, Figure 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.

Catches during the 1930s to 1950s ranged between 15,000 t and 40,000 t (Schuck 1951, R. Brown pers. com.), averaging about 25,000 t (Figure 3). Records of catches by unit area for the early 1960s period have not been located, however based on records for Subdivision 5Ze, catches probably attained record high levels of about 60,000 t. Since the early 1970s catches have been substantially lower, generally fluctuating between 5,000 t and 10,000 t.

As in 1995 to 1997, Canadian catches in 1998 of 3,371 t were below the quota due to closure of the fisheries when the cod quotas were reached. During 1994 to 1998, all Canadian groundfish fisheries on Georges Bank remained closed from January to early June to protect spawning.

All landings were monitored at dockside, and at-sea monitoring by observers resulted in coverage of almost 400 sea days, representing about 10% of the cod and haddock catch. One hundred and fifty-one vessels fished for groundfish on Georges Bank making 770 trips. Comparison of observer samples with port samples did not reveal any persistent patterns to

indicate that discarding or high grading occurred commonly. Discarding and misreporting have been considered negligible since 1992. During 1998, all vessels over 65 ft operated on enterprise allocations, otter trawlers under 65 ft and fixed gear vessels 45-65 ft operated on individual quotas and fixed gear vessels under 45 ft operated on community quotas administered by local boards (Table 2).

Fishery Sector	1994		1995		1996		1997		1998	
	Quota	Catch	Quota	Catch	Quota	Catch	Quota	Catch	Quota	Catch
Fixed gear <65’	791	784	592	357	1085	919	754	714	915	856
Mobile gear <65'	1439	1206	1268	1175	2280	1713	1625	1451	1984	1997
Fixed gear 65'-100'	30	8	25	0	45	49	32	36	39	39
Mobile gear 65'-100'	30	33	25	27	189	181	32	35	94	93
Vessels >100'	710	290	590	444	921	513	757	573	868	386
Totals	3000	2411	2500	2003	4500	3375	3200	2809	3900	3371

In recent years, the Canadian fishery has been conducted by vessels using otter trawls, longlines, handlines and gillnets (Table 3). Most haddock were caught by otter trawlers and longliners less than 65 ft. The catches by otter trawlers peaked in June while catches by longliners peaked in July (Table 4, Figure 4).

Changes in the way Canadian fishermen are conducting their fishing activities on Georges Bank have occurred in recent years because of the low cod quota and the need, therefore, to avoid cod. Avoidance of cod has been especially difficult for the fixed gear fleet whose gear has a higher catchability for cod than haddock. In an effort to avoid cod, they fished in the deeper water of the Fundian Channel where cod were not as abundant and avoided the shallower bank waters where cod abundance was higher. Mobile gear is less selective for cod than the fixed gear and they did not have as much difficulty keeping their cod catch to minimal levels.

USA catches for 1998 were derived from logbooks coupled with dealer reports, as was done for 1994-97. Effort in the USA fishery was regulated using closed areas and Days-at-Sea limits (Table 2). To curtail targeting of haddock, a 500 lb trip limit was introduced in 1994 and raised to 1,000 lb in July 1996. The trip limit resulted in an increase in the discard rate. In September 1997, the limit was raised to 1,000 lb per day and a maximum of 10,000 lb per trip. In September 1998, the limit was further raised to 3,000 lb per day and 30,000 lb per trip. The plan for the 1999 fishing year is to establish a limit of 2,000 lb/day (maximum of 20,000 lbs/trip) beginning on May 1, 1999 which will be adjusted upward if the industry is significantly under the established target TAC. The combination of area closures, effort restrictions, and trip limits has precluded most operators from making long trips to 5Zjm, with the result that USA catches from 5Zjm have been low since 1993. While Area II remained closed in 1998, landings from 5Zjm, which come exclusively from tonnage classes 3 and 4 otter trawlers (Table 5), increased to 311 t and discards declined to 14 t (Table 1 and 6) because the day and trip possession limits were increased.

Size and Age Composition

The size and age composition of the 1998 Canadian fishery was characterised by port and at sea samples from all principle gears and all seasons (Figure 4) and were applied to the 1998

catch (Table 7) similarly as in the previous year (Gavaris and Van Eeckhaute 1998). The size composition of the catch in the Canadian fisheries peaked at 53 cm (21 in) for otter trawlers and at 57 cm (22 in) for longliners (Figure 5) which is a change from previous years when these two gears caught more similarly sized fish. This may be a result of the longliner's switch to fishing in deeper water to avoid cod. Gillnetters caught few haddock but they were larger. No sampling was available for discards of groundfish by-catch in the Canadian scallop fishery though in previous years the amount caught has not been large.

With low landings of haddock in the USA fishery, available port samples were inadequate to characterise the size and age composition of the landings. The age composition of the Canadian otter trawler tonnage class 3 or less fishery were used here. Sea sampling for discards was limited but was used to obtain the discards at age.

Survey and commercial otoliths were read by L. Van Eeckhaute for DFO and by N. Munroe for NMFS. Results of intra-reader and between reader agreement tests for the 1998 DFO spring survey and an intra-reader test using the Canadian commercial sampling material for the DFO reader (Appendix A) indicate that age data are consistent.

The updated 1997 and the new 1998 catch at age by quarter (Table 8) was used to augment the 1969-96 results reported by Gavaris and Van Eeckhaute (1998). Annual catch at age and average fishery weight at age are summarized in Tables 9 and 10.

Over half of the 1998 catch weight was comprised of haddock from the 1992 (age 6) and 1993 (age 5) year-classes (Table 8,9; Figure 6). In contrast to pre-1994, few haddock of ages 2 and 3 were caught in 1998, due in part to the type of gear used and to avoidance of areas with small fish (Figure 7). In comparison to the age composition of the catch during earlier periods, age groups 4-7 were well represented.

Abundance Indices

Commercial Catch Rates

Catch rate trends from the Canadian commercial fishery were compiled for selected trips where cod, haddock and pollock comprised over 90% of the total catch of only those vessels which fished in 5Zjm during 1994 and reported more than 1 t of landings. Catch rates by tonnage class 2 and 3 otter trawlers and longliners showed an increasing trend from 1993 to 1995 and remained relatively stable but variable from 1996 through 1998 (Figure 8). Otter trawl catch rates were relatively high in June of 1998, decreased in the fall and increased again in December. Longliner catch rates for tonnage class 2 increased markedly through the 1998 season while those for tonnage class 3 decreased. 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

Groundfish surveys of Georges Bank have been conducted by NMFS each fall (Oct.-Nov.) since 1963 and each spring (Mar.-Apr.) since 1968, and by DFO each spring (Feb.-Mar.) since 1986. All these surveys use a stratified random design (Figures 9 and 10). 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 compartive 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 surveys of each series was similar to the distribution over the previous 5 year period (Figures 11, 12 and 13). In spring, adults are more abundant in unit area 5Zej but age 1 fish are distributed broadly over unit areas 5Zej and 5Zem (Figures 11 and 12). In fall, adult haddock are more concentrated in the deeper waters along the slopes of the Northeast Peak and the Northeast Edge, however, age 1 fish remain somewhat more widespread (Figure 13).

Haddock of all ages are more abundant east of the USA/Canada boundary line during all three surveys. 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 1992-93. During the NMFS spring survey, generally conducted in late March, the percentage on the Canadian side was typically lower but these results were more variable

Percentage of biomass on Canadian side

	Feb.-Mar.	Mar.-Apr.	Oct.-Nov.
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	78	100
1999	98	N/A	N/A

Age specific abundance patterns from the three surveys track year-class strengths fairly well (Tables 12, 13 and 14; Figure 14). Some year affects are evident as well, for example, the low spring catches observed for both the 1997 DFO and NMFS surveys. The trend in ages 3-8 abundance from surveys increased from 1992 to 1996 and has fluctuated with a moderate general increasing trend since then (Figure 15). 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 (Figure 16). These year-classes were considerably smaller than the strong 1975 and 1978 year-classes and the very strong

1962 and exceptional 1963 year-classes. The 1997 year-class is weaker but first indications for the 1998 year-class suggest it may be moderate to strong.

Average weights at age of haddock from the 1989 to 1991 year-classes were higher than adjacent year-classes in both the surveys (Figure 17) and the commercial fisheries (Figure 18), giving the false impression of a declining trend in recent years. The method of calculation of the weights at age from the DFO spring survey were given in Gavaris and Van Eeckhaute (1998) and were derived from actual weights observed during the survey and weighted by population numbers at length and age (Table 15). Fishery weights at age (Table 10; Figure 18) are derived from a length-weight relationship (Waiwood and Neilson 1985). In some cases, the mean weight at age in the catch is larger than the population mean weight at age at the beginning of the following year for the same cohort. This may be attributable to the different methods used to derive the two sets of weights. The use of eviscerated weights in length-weight equations would reduce variability due to gonad and stomach content effects and sampling size and ensure consistency between population and fishery weights at age.

Estimation of Stock Parameters

Calibration of Virtual Population Analysis (VPA)

The adaptive framework, ADAPT, (Gavaris 1988) was used to calibrate the virtual population analysis with the research survey abundance information. An investigation of model formulations and model assumptions was conducted by Gavaris and Van Eeckhaute (1998) where details of model equations and the objective function are provided. The model formulation adopted 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. Similar model assumptions and methods were applied to the updated information here. Minor differences in the handling of zero terminal catches for a year-class were implemented as a refinement to the software to afford more flexibility. Additionally, both analytical and bootstrap statistics of the estimated parameters were derived. For consistency with the risk analysis, bias adjusted VPA results were based on bootstrap statistics (Efron and Tibshirani 1993).

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…1998.75, 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…1998.16, 1999.0
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…1998.29
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…1998.69

Since forecast projections were required for the entire year 1999, the DFO spring survey in 1999 was designated as occurring at time 1999.0 instead of 1999.16. 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 population abundance estimates show a large relative error and substantial bias at ages 1 and 2 while the relative error for other ages is about 30% and the bias is small (Table 16). 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 (Figures 19-23). Some patterns in the residuals (by cohort and by age) merit further investigation.

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. Figure 24 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 (Figure 25).

A Canadian quota of 3,900 t in 1998 was expected to result in a negligible chance of exceeding $F_{0.1}$ and an 80% chance of getting 20% growth in the stock. The Canadian catch in 1998 was about 3,400 t and resulted in a fishing mortality about 65% of $F_{0.1}$ and an increase in ages 3-8 biomass of about 24%.

Stock Status

The results from the calibrated VPA 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 (Tables 17-18). This approach for bias adjustment, in the absence of an unbiased point estimator with optimal statistical properties, was considered preferable to using the biased point estimates (O'Boyle 1998). The weights at age from the DFO spring survey (Table 15) 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 as no data were available for that age group. For 1969-85, the 1986-95 average weight at each age was used.

Population biomass (ages 1-8) has steadily increased from near historic low levels of about 11,000 t in 1993 to over 30,000 t at the beginning of 1999 (Figure 26). 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 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 3-8 is similar with a 24% increase from 1998 to 1999 due largely to recruitment of the 1996 year-class.

The strength of the 1996 year-class was estimated to be about 16 million at age 1, comparable to the 1983, 1985, 1987 and 1992 year-classes, while those during 1988-90 were less than 3 million (Figure 27). The 1991 and 1993 year-classes were estimated at about 7 and 10 million respectively while the incoming 1995 and 1997 year-classes appear to be relatively weak at about 6 million. Preliminary indications for the 1998 year-class indicate that it may be strong at up to about 40 million recruits.

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 year-classes were fished intensely at a young age.

Exploitation rate for fully recruited ages 4-8 has consistently been below 20%, equivalent to $F_{0.1} = 0.25$, since 1995 (Figure 28). Historically, exploitation rate has generally exceeded $F_{0.1}$ and showed a marked increase between 1989 and 1993 to almost 50%, the highest level observed. Reduced fishing mortality in recent years has resulted in increased survival of incoming year-classes. The number of haddock of the 1992 year-class surviving to age 6 was about three times that of the equally abundant 1983 year-class, and about the same as that of the 1975 or 1978 year-classes, which were more than 3 times as abundant (Figure 29). In both absolute numbers and percent composition, the population structure displays a broad representation of age groups, reflecting improved recruitment and lower exploitation (Figure 30).

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 (Rivard 1980). We used age 2 as a convenient age of first recruitment to the fishery. In most years since 1969, the bulk of the biomass gain was attributable to somatic growth but in years of good recruitment, about half the biomass gain was due to incoming recruits at age 2 (Figure 31). 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, surplus production has exceeded or been about equal to the fishery yield resulting in net biomass growth (Figure 32).

Fishery Reference Points

Yield per Recruit

The yield per recruit analysis was updated in Gavaris and Van Eeckhaute (1998). We adopted those results here.

Stock and Recruitment

The age composition of the catch for Georges Bank haddock (Clark et al 1982) was used with catch statistics from unit areas 5Zej and 5Zem to approximate the catch at age for the 5Zjm

management unit for the period between 1930 and 1955. This was considered adequate in order to reconstruct an illustrative population analysis, 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 (Figure 33).

The pattern of recruitment against adult biomass indicates that the chance of a strong year-class is significantly reduced for biomass below about 40,000 t (Figure 34). Since 1969, only the 1975 and 1978 (and possibly the 1998) year-classes have been near the average abundance of year-classes observed during that historic period. Examination of the recruits per spawning biomass ratio suggests that egg/larval survivorship for several years during the 1980s may have been lower than the norm (Figure 35). The present survivorship appears comparable to that of the 1930s to 1950s period, supporting the expectation that higher recruitment might result if the biomass increases.

Prognosis

Yield projections were done using the bias adjusted 1999 beginning of year population abundance estimates. The abundance of the 1999 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 1999 forecasts (Table 20).

Projected total Canada/USA yield at $F_{0.1} = 0.25$ in 1999 would be about 6,300 t. If fished at $F_{0.1}$ in 1999, the biomass for ages 3-8 is projected to increase from 26,836 t to 27,430 t by the beginning of 2000 (Figure 36). Ages 3 to 7 should comprise about 90% of the total yield in 1999, with all these year-classes contributing almost equally.

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 4,000 t in 1999, about what was caught in 1998, results in a negligible risk that fishing mortality rate will exceed $F_{0.1}$ and that the biomass for ages 3-8 will decrease (Figure 37). At this yield there is a risk of about 50% of not achieving 10% biomass increase and a risk of over 90% of not achieving 20% biomass increase.

These uncertainty calculations do not include variations in weight at age, partial recruitment to the fishery and natural mortality, systematic errors in data reporting or model mis-specification. Therefore, overall uncertainty would be greater, but these results provide guidelines.

Cod and haddock are often caught together in the Canadian Georges Bank groundfish fisheries. However, their catchabilities to the fisheries differ and they are not necessarily caught in proportion to their relative abundance. This may compromise the joint achievement of objectives.

Literature Cited

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

Efron, B. and R.J. Tibshirani. 1993. An introduction to the bootstrap. Chapman & Hall. New York. 436p.

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

Gavaris, S. 1989. Assessment of eastern Georges Bank haddock. CAFSAC Res. Doc. 89/49: 27 p.

Gavaris, S. and L. Van Eeckhaute. 1998. Assessment of haddock on eastern Georges Bank. DFO Res. Doc. 98/66: 75 p.

O'Boyle, R.N. (Chair.) 1998. Proceedings of the Transboundary Resource Assessment Committee 20-24 April 1998. CSAS Proc. Ser. 98/10: 49p.

Rivard, D. 1980. Back-calculating production from cohort analysis, with discussion on surplus production for two redfish stocks. CAFSAC Res. Doc. 80/23: 26 p.

Overholtz, W.J., S.H. Clark and D.Y. White. 1983. A review of the status of the Georges Bank and Gulf of Maine haddock stocks for 1983. Woods Hole Lab. Ref. Doc. 83-23.

Schuck, H.A. 1951. Studies of Georges Bank haddock, Part I: Landings by pounds, numbers and sizes of fish. Fish. Bull. U.S., 52: 151-176.

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

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

Year	Canada	USA	Other	Discards	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	757	2747
1975	1353	1705	29		3087
1976	1355	973	24		2352
1977	2871	2429		2966	8266
1978	9968	4724		1556	16248
1979	5080	5211			10291
1980	10017	5615		7561	23193
1981	5658	9077			14735
1982	4872	6280			11152
1983	3208	4454			7662
1984	1463	5121			6584
1985	3484	1683			5167
1986	3415	2200			5615
1987	4703	1418			6121
1988	4046[1]	1693			5739
1989	3059	787			3846
1990	3339	1189			4528
1991	5417	949			6366
1992	4061	1629			5690
1993	3727	421			4148
1994	2427	33		258	2718
1995	2064	22		25	2111
1996	3643	36		41	3720
1997	2622	48		63	2733
1998	3371	311		14	3696

[1] 1895t excluded because of suspected area misreporting.

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. **Fixed** gear 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.	**Vessels** over 65 ft operated on enterprise allocations, otter trawlers under 65 ft on individual quotas, fixed gear vessels 45-65 ft on self-administered individual quotas and fixed gear vessels under 45 ft on community quotas administered by local boards.
1998	Sept. 1: **Trip** limit raised to 3000 lbs/day, maximum of 30,000 lbs/trip.	**Fixed** gear vessels 45-65 ft operated on individual quotas.
1999	May 1: **Trip** limit of 2,000 lb/day, maximum of 20,000 lbs/trip. To be adjusted upward if industry is significantly under the established target TAC.	

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	639	1094	91	96	1920	494	116	665	37	2622
1998	0	863	1340	98	71	2423	570	252	921	27	3371

[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	316	712	743	395	188	112	156	2622
1998	0	0	0	0	0	687	420	580	707	542	164	271	3371

[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 1994-1998 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
1998			311	0	311

Table 6. Monthly catch (t) of haddock (excluding discard estimates) by USA in unit areas 5Zjm. Details for 1994-1998 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
1998													311

Table 7. Scheme for derivation of catch at age for the 1998 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	5	2394	8	1857	575785	Q2 OT IN		Q2	9	129	10	312
		OTS	June					184							
		OT OF	June	2	311	2	399	34863	Q2 OT OF						
		MT	June					9659							
		GN	June			1[1]	25	3373	Q2 GN						
		LL	June	1	1001	1	280	63086	Q2 LL						
	3	OT IN	July	22	14744	5	1172	143485	Jul OT IN		Q3	14	140	20	546
		OT IN	Aug	10	4998	5	1222	383739	Aug OT IN	Q3 OT IN					
		OT IN	Sept	11	4960	1	230	460996	Sep OT IN						
		OT OF	Aug	1	759			28175	Aug OT OF	Q3 OT OF					
		OT OF	Sept	1	242			20313	Sep OT OF						
		GN	July			2	339	4191	Jul GN						
		GN	Aug			2	296	2823	Aug GN	Q3 GN					
		GN	Sept			1	215	2512	Sep GN						
		LL	July	2	1843	2	412	272677	Jul LL						
		LL	Aug	1	1158	3	670	164934	Aug LL	Q3 LL					
		HL	Aug					10							
		LL	Sept			4	895	222963	Sep LL						
	4	OT IN	Oct	13	5430	6	1455	332882	Oct OT IN		Q4			14	375
		OT IN	Nov	4	4194	1	250	118353	Nov OT IN	Q4 OT IN					
		OT IN	Dec	1	434	2	470	237621	Dec OT IN						
		OT OF	Oct	4	1146	1	230	70185	Oct OT OF						
		OT OF	Nov					2822		Q4 OT OF					
		OT OF	Dec	1	1121	1	202	13156	Dec OT OF						
		GN	Oct			1	154	4812	Q4 GN						
		LL	Oct	4	4582	3	715	134216	Oct LL						
		LL	Nov			1	210	43026	Nov Dec LL	Q4 LL					
		LL	Dec					20496							
	Totals			83	48596	53	17076	3371337				13	269	44	1233

OTB=Otter Trawl Bottom, OTS=Otter Trawl Side, MT =Midwater Trawl, GN=Gill Net, LL=Longline, HL=Handline, IN=Inshore (Tonnage Classes <=3), OF=Offshore (Tonnage Classes >=4).
[1]Used Jul GN samples to augment.

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											
1997	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	
1997.25	.019	.594	2.349	35.876	66.895	31.346	4.186	1.759	.796	4.666	
1997.5	.086	42.224	43.213	393.069	297.387	128.081	3.286	3.237	19.958	930.541	
1997.75	.743	26.758	20.178	74.005	85.791	19.110	3.689	1.706	3.963	235.944	1171.151
1998	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	
1998.25	.000	2.347	19.864	39.177	81.124	103.001	43.108	2.694	14.563	305.879	
1998.5	.000	97.563	136.277	136.588	274.232	182.064	42.564	6.326	14.479	890.094	
1998.75	.033	53.342	109.739	61.895	145.098	123.639	15.879	1.676	1.569	512.871	1708.844
USA											
1997	.000	.000	.000	.335	1.183	.934	.148	.089	.276	2.965	
1997.25	.000	.000	.000	.828	2.925	2.309	.367	.220	.682	7.332	
1997.5	.000	.016	.022	.923	2.165	1.634	.065	.092	.510	5.427	
1997.75	.000	.035	.045	.585	1.509	.610	.179	.080	.153	3.196	18.919
1998	.000	.082	.692	1.365	2.826	3.588	1.501	.094	.507	10.654	
1998.25	.000	.439	3.713	7.322	15.163	19.252	8.057	.503	2.722	57.171	
1998.5	.000	5.694	7.953	7.971	16.004	10.625	2.484	.369	.845	51.944	
1998.75	.001	1.198	2.465	1.390	3.259	2.777	.357	.038	.035	11.519	131.288
USA Discards											
1997	.680	4.321	6.554	7.914	2.889	1.117	.316	.194	.291	24.275	
1997.25	.452	2.876	4.363	5.268	1.923	.743	.210	.129	.194	16.159	
1997.5	.391	1.006	.670	.806	.313	.102	.003	.048	.061	3.399	
1997.75	.075	.194	.129	.155	.060	.020	.001	.009	.012	.656	44.490
1998	.000	.636	.428	.548	.644	.136	.096	.000	.000	2.487	
1998.25	.000	.834	.561	.718	.845	.178	.125	.000	.000	3.262	
1998.5	.999	1.307	.683	.991	.277	.424	.000	.000	.000	4.681	
1998.75	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	10.429
Total											
1997	.680	4.321	6.554	8.249	4.072	2.051	.464	.283	.567	27.240	
1997.25	.472	3.471	6.712	41.972	71.743	34.399	4.763	2.108	1.672	28.157	
1997.5	.477	43.246	43.905	394.797	299.865	129.817	3.355	3.376	20.530	939.367	
1997.75	.818	26.987	20.352	74.746	87.360	19.740	3.869	1.795	4.128	239.795	1234.560
1998	.000	.718	1.120	1.912	3.470	3.723	1.597	.094	.507	13.141	
1998.25	.000	3.620	24.138	47.218	97.132	122.431	51.291	3.197	17.285	366.311	
1998.5	.999	104.564	144.913	145.550	290.512	193.113	45.048	6.695	15.324	946.719	
1998.75	.034	54.540	112.204	63.285	148.357	126.416	16.236	1.714	1.604	524.389	1850.561

Table 9. Total commercial catch at age numbers (000's) of haddock from unit areas 5Zjm.

Year	Age Group										
	0	1	2	3	4	5	6	7	8	9+	Total
1969	0	0	18	1441	260	331	2885	819	89	279	6123
1970	0	25	82	7	347	147	126	1140	364	189	2425
1971	0	0	1182	247	31	246	157	159	756	407	3185
1972	0	259	1	376	71	21	92	37	16	431	1303
1973	0	1015	1722	6	358	37	10	37	8	163	3358
1974	0	17	2105	247	0	31	3	0	29	57	2488
1975	0	0	270	1428	201	5	34	1	2	28	1969
1976	0	73	149	166	814	125	0	19	0	17	1363
1977	0	0	7836	64	178	303	162	0	15	14	8571
1978	0	1	285	9831	161	169	302	80	10	9	10848
1979	0	0	15	199	4250	362	201	215	43	14	5300
1980	0	3	17561	342	299	2407	191	129	51	12	20995
1981	0	0	660	6687	393	494	1234	119	33	7	9627
1982	0	0	713	1048	2799	201	377	723	62	65	5988
1983	0	0	140	648	546	1629	207	104	402	34	3710
1984	0	0	76	249	341	264	1120	186	165	314	2716
1985	0	0	2063	374	176	189	123	371	53	114	3463
1986	0	6	38	2557	173	142	122	118	173	41	3369
1987	0	0	1990	127	1515	96	56	82	68	108	4042
1988	0	4	51	2145	121	877	109	36	46	98	3487
1989	0	0	1153	78	734	129	320	31	20	45	2510
1990	0	2	7	1265	126	743	68	163	42	42	2457
1991	0	6	441	89	2041	88	389	72	145	61	3332
1992	0	7	230	311	127	1446	89	315	26	90	2640
1993	0	7	247	343	279	85	635	34	153	74	1856
1994	0	1	241	737	148	54	48	125	29	39	1423
1995	0	2	60	525	414	53	25	3	51	16	1149
1996	0	1	29	481	862	419	61	18	3	72	1946
1997	0	2	78	78	520	463	186	12	8	27	1235
1998	0	1	163	282	258	539	446	114	12	35	1851

Table 10. Average weight at age (kg) of haddock from the commercial fishery in unit areas 5Zjm. The 1989 to 1991 year-classes (shaded) grew faster than adjacent year-classes.

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	1.215	1.336	1.747	2.120	2.476	3.034	3.365
1998	0.568	1.131	1.573	1.697	1.983	2.312	2.864	3.395
Low	0.405	0.763	0.812	1.272	1.649	1.631	2.199	2.032
High	0.797	1.215	1.724	2.235	2.639	3.760	4.114	4.009
Median	0.600	0.984	1.365	1.798	2.154	2.540	2.896	3.157
Avg. 69-98	0.597	1.000	1.371	1.808	2.182	2.540	2.902	3.169
Avg. 95-98	0.656	1.106	1.465	1.818	2.237	2.507	3.032	2.950

Table 11. Conversion factors used to adjust for changes in door type and survey vessel in the NMFS surveys.

		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
1998	Polyvalent	Albatross IV	1	Albatross IV	1

Table 12. Total estimated abundance at age (numbers in 000's) of haddock for unit areas 5Zjm from the DFO 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	2419	10626	5350	3190	5312	5028	2248	348	601	35124
1999	24593	4787	10067	3104	1963	1880	1759	453	175	48780

Table 13. Total estimated abundance at age (numbers in 000's) of haddock for unit areas 5Zjm from the NMFS 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
1968	0	3254	67	679	4853	2046	240	124	234	11497
1969	17	35	614	235	523	3232	1220	358	489	6724
1970	478	190	0	560	998	441	3169	2507	769	9113
1971	0	655	261	0	144	102	58	1159	271	2650
1972	2594	0	771	132	25	47	211	27	1214	5019
1973	2455	5639	0	1032	154	0	276	0	1208	10763
1974	1323	20596	4084	0	354	0	43	72	322	26795
1975	528	567	6016	1063	0	218	127	45	208	8773
1976	8279	402	433	1229	582	0	0	0	22	10948
1977	138	25922	294	855	816	586	0	22	98	28730
1978	0	743	20859	641	880	1163	89	23	116	24516
1979	10496	441	1313	9764	475	72	445	42	9	23057
1980	4364	67961	1129	1117	5822	628	381	705	359	82466
1981	3595	3041	27694	2887	719	2389	335	57	21	40738
1982	584	3697	1649	7743	745	447	669	0	0	15534
1983	238	770	686	359	2591	30	0	798	57	5529
1984	1366	1415	996	1001	936	1245	138	89	470	7656
1985	40	8911	1396	674	1496	588	1995	127	483	15709
1986	3334	280	3597	246	210	333	235	560	159	8953
1987	122	5480	144	1394	157	231	116	370	0	8013
1988	305	61	1868	235	611	203	218	178	0	3678
1989	84	6665	619	1343	267	791	58	92	47	9966
1990	1654	70	10338	598	1042	110	182	0	0	13995
1991	740	2071	432	3381	192	203	66	87	25	7198
1992	529	287	214	141	609	32	46	46	0	1905
1993	1870	1116	197	232	195	717	77	35	43	4481
1994	1025	4272	1487	269	184	118	278	28	85	7745
1995	921	2307	4096	1691	259	151	51	269	214	9959
1996	912	1351	3772	3232	1896	235	36	0	496	11931
1997	1635	1226	380	595	470	343	24	44	20	4736
1998	549	6046	2005	1281	1184	303	58	15	122	11562

Table 14. Total estimated abundance at age (numbers in 000's) of haddock for unit areas 5Zjm from the NMFS 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
1998	2577	3073	4364	1006	577	482	706	0	0	12784

Table 15. Average weight at age (kg) from the DFO 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	0.106	0.517	1.044	1.188	1.578	1.955	2.610	3.560	3.460
1999	0.129	0.474	0.911	1.289	1.257	1.869	2.121	2.724	2.986

Table 16. Statistical properties of estimates for beginning of 1999 population abundance (numbers in 000's) and survey calibration constants (unitless, survey:population) for haddock in unit areas 5Zjm.

		Bootstrap				Analytical Approximation			
Age	Estimate	Standard Error	Relative Error	Bias	Relative Bias	Standard Error	Relative Error	Bias	Relative Bias
				Population Abundance (000's)					
1	49964	40729	0.815	10018	0.200	34775	0.696	12182	0.244
2	5606	2511	0.448	473	0.084	2474	0.441	555	0.099
3	11240	3787	0.337	554	0.049	3970	0.353	711	0.063
4	3377	1133	0.335	206	0.061	1085	0.321	167	0.050
5	2038	605	0.297	81	0.040	602	0.295	79	0.039
6	2495	719	0.288	113	0.045	769	0.308	81	0.033
7	2331	766	0.328	138	0.059	744	0.319	78	0.033
8	552	216	0.392	18	0.032	220	0.398	29	0.052
				Survey Calibration Constants					
DFO Spring Survey									
1	0.192	0.049	0.257	0.003	0.017	0.052	0.268	0.007	0.034
2	0.475	0.110	0.232	0.012	0.026	0.125	0.263	0.015	0.032
3	0.895	0.226	0.253	0.043	0.048	0.233	0.261	0.029	0.032
4	0.806	0.215	0.267	0.019	0.024	0.210	0.260	0.026	0.032
5	0.989	0.253	0.256	0.018	0.018	0.257	0.260	0.032	0.032
6	0.791	0.193	0.244	0.016	0.021	0.207	0.261	0.026	0.033
7	1.106	0.314	0.283	0.037	0.034	0.301	0.272	0.039	0.035
8	1.093	0.293	0.268	0.026	0.024	0.287	0.262	0.035	0.032
NMFS Spring Survey – Yankee 36 – 1969-72/1982-98									
1	0.127	0.029	0.231	0.003	0.022	0.028	0.218	0.003	0.022
2	0.348	0.071	0.205	0.004	0.011	0.075	0.217	0.008	0.022
3	0.442	0.099	0.224	0.014	0.033	0.095	0.216	0.010	0.022
4	0.476	0.103	0.217	0.011	0.022	0.103	0.216	0.010	0.022
5	0.558	0.117	0.210	0.009	0.016	0.118	0.211	0.012	0.021
6	0.441	0.095	0.215	0.014	0.031	0.093	0.211	0.009	0.021
7	0.536	0.115	0.215	0.006	0.011	0.116	0.216	0.011	0.021
8	0.670	0.155	0.231	0.016	0.024	0.152	0.227	0.015	0.022
NMFS Spring Survey – Yankee 41 – 1973-81									
1	0.230	0.083	0.361	0.012	0.051	0.078	0.338	0.013	0.057
2	0.517	0.155	0.300	0.023	0.045	0.165	0.318	0.026	0.051
3	0.653	0.231	0.354	0.037	0.057	0.221	0.338	0.037	0.057
4	0.797	0.274	0.343	0.052	0.065	0.269	0.338	0.045	0.057
5	0.984	0.323	0.328	0.052	0.053	0.332	0.338	0.056	0.057
6	0.891	0.345	0.387	0.036	0.040	0.348	0.390	0.068	0.076
7	1.594	0.597	0.375	0.055	0.035	0.576	0.361	0.104	0.065
8	0.636	0.228	0.359	0.041	0.064	0.230	0.361	0.041	0.065
NMFS Fall Survey									
0	0.124	0.022	0.175	0.003	0.021	0.023	0.182	0.002	0.015
1	0.282	0.052	0.183	0.003	0.009	0.053	0.187	0.005	0.016
2	0.223	0.037	0.166	0.000	0.001	0.041	0.182	0.003	0.016
3	0.211	0.038	0.180	0.002	0.007	0.038	0.182	0.003	0.016
4	0.163	0.030	0.184	0.003	0.016	0.031	0.193	0.003	0.018
5	0.137	0.025	0.183	0.000	0.003	0.025	0.182	0.002	0.016

Table 17. Beginning of year population abundance (numbers in 000's) for haddock in unit areas 5Zjm from a virtual population analysis using the bootstrap bias adjusted population abundance at the beginning of 1999.

Year	Age Group										
	1	2	3	4	5	6	7	8	1-8	2-8	3-8
1969	768	189	4375	853	905	8991	3021	185	19287	18518	18329
1970	3345	629	138	2295	465	448	4797	1745	13862	10517	9888
1971	455	2715	439	107	1569	249	253	2904	8692	8237	5521
1972	5368	373	1128	138	61	1064	64	67	8262	2895	2522
1973	11031	4152	304	588	49	31	792	19	16967	5936	1783
1974	3338	8123	1827	244	153	7	17	614	14323	10985	2863
1975	3214	2717	4751	1279	200	99	4	14	12277	9063	6346
1976	53775	2631	1972	2593	868	159	51	2	62052	8277	5646
1977	5897	43961	2021	1467	1403	599	131	25	55503	49606	5645
1978	4197	4828	28839	1599	1042	885	349	107	41846	37649	32821
1979	51911	3435	3679	14520	1159	703	457	213	76077	24166	20731
1980	6624	42501	2798	2830	8086	624	400	185	64049	57425	14924
1981	5111	5421	18947	1987	2050	4505	342	216	38579	33468	28047
1982	1710	4184	3830	9535	1279	1238	2604	176	24556	22846	18662
1983	2521	1400	2763	2192	5284	864	678	1486	17189	14667	13267
1984	14864	2064	1015	1671	1304	2880	521	461	24782	9918	7853
1985	1539	12170	1621	607	1062	834	1368	264	19465	17925	5756
1986	13151	1260	8030	980	338	700	573	793	25825	12674	11414
1987	1266	10762	997	4287	651	150	465	367	18946	17680	6917
1988	14753	1036	7009	702	2149	446	73	307	26476	11723	10686
1989	786	12075	803	3801	466	985	269	28	19213	18427	6352
1990	2344	644	8846	586	2448	266	520	193	15848	13504	12860
1991	1787	1918	521	6095	368	1336	157	280	12462	10675	8757
1992	6673	1458	1167	347	3135	221	744	65	13808	7136	5678
1993	12820	5457	982	673	171	1271	103	326	21803	8983	3527
1994	9811	10490	4232	491	303	65	479	54	25926	16114	5625
1995	5064	8032	8362	2776	265	198	8	277	24982	19918	11886
1996	6372	4144	6520	6362	1893	168	140	4	25603	19231	15087
1997	16175	5217	3366	4893	4413	1162	81	98	35404	19230	14013
1998	6270	13240	4198	2683	3523	3183	780	55	33932	27663	14422
1999	39946	5132	10686	3171	1957	2382	2193	534	66001	26055	20923

Table 18. Fishing mortality rate for haddock in unit areas 5Zjm from a virtual population analysis using the bootstrap bias adjusted population abundance at the beginning of 1999. The rate for ages 4 to 8 is weighted by population numbers and is also shown as exploitation rate (%).

Year	Age Group									
	1	2	3	4	5	6	7	8	4-8	4-8 (%)
1969	0.000	0.112	0.445	0.407	0.504	0.428	0.349	0.737	0.419	31
1970	0.009	0.159	0.057	0.180	0.425	0.371	0.302	0.258	0.274	22
1971	0.000	0.678	0.956	0.367	0.188	1.164	1.131	0.332	0.369	28
1972	0.057	0.002	0.453	0.832	0.468	0.096	0.993	0.288	0.235	19
1973	0.106	0.621	0.022	1.143	1.738	0.414	0.054	0.641	0.558	39
1974	0.006	0.336	0.156	0.000	0.242	0.491	0.002	0.051	0.070	6
1975	0.000	0.121	0.405	0.189	0.025	0.460	0.336	0.172	0.185	15
1976	0.002	0.064	0.096	0.414	0.171	0.000	0.522	0.000	0.340	26
1977	0.000	0.222	0.034	0.142	0.261	0.339	0.000	1.007	0.221	18
1978	0.000	0.072	0.486	0.121	0.194	0.460	0.293	0.107	0.230	19
1979	0.000	0.005	0.062	0.385	0.419	0.363	0.704	0.249	0.394	30
1980	0.000	0.608	0.142	0.122	0.385	0.403	0.416	0.346	0.325	25
1981	0.000	0.147	0.487	0.241	0.304	0.348	0.465	0.178	0.315	25
1982	0.000	0.215	0.358	0.390	0.192	0.402	0.361	0.481	0.370	28
1983	0.000	0.121	0.303	0.320	0.407	0.305	0.185	0.343	0.357	27
1984	0.000	0.041	0.314	0.254	0.246	0.545	0.482	0.487	0.408	31
1985	0.000	0.216	0.303	0.387	0.217	0.176	0.345	0.246	0.278	22
1986	0.000	0.034	0.428	0.209	0.610	0.209	0.246	0.264	0.268	21
1987	0.000	0.229	0.150	0.491	0.178	0.528	0.214	0.229	0.419	31
1988	0.000	0.055	0.412	0.210	0.580	0.307	0.760	0.175	0.446	33
1989	0.000	0.111	0.115	0.240	0.362	0.438	0.131	1.612	0.287	23
1990	0.001	0.012	0.173	0.267	0.406	0.324	0.420	0.272	0.375	29
1991	0.004	0.297	0.207	0.465	0.310	0.386	0.687	0.837	0.462	34
1992	0.001	0.196	0.349	0.507	0.703	0.563	0.624	0.560	0.666	45
1993	0.001	0.054	0.493	0.598	0.769	0.776	0.437	0.698	0.705	46
1994	0.000	0.027	0.222	0.417	0.226	1.876	0.348	0.920	0.439	32
1995	0.000	0.009	0.073	0.183	0.254	0.150	0.499	0.229	0.191	16
1996	0.000	0.008	0.087	0.166	0.288	0.531	0.158	1.999	0.201	17
1997	0.000	0.017	0.026	0.128	0.127	0.199	0.190	0.091	0.136	12
1998	0.000	0.014	0.081	0.116	0.192	0.173	0.178	0.273	0.165	14

Table 19. Beginning of year biomass (tonnes in 000's) for haddock in unit areas 5Zjm from a virtual population analysis using the bootstrap bias adjusted population abundance at the beginning of 1999.

Year	Age Group										
	1	2	3	4	5	6	7	8	1-8	2-8	3-8
1969	88	97	4091	1283	1802	21068	8106	540	37075	36987	36890
1970	385	324	129	3452	926	1049	12871	5105	24240	23856	23532
1971	52	1399	411	161	3125	583	679	8495	14904	14852	13453
1972	618	192	1055	208	121	2494	171	196	5053	4436	4244
1973	1269	2139	285	884	98	73	2124	56	6928	5659	3520
1974	384	4184	1709	367	305	17	45	1797	8807	8423	4239
1975	370	1400	4442	1924	397	231	10	40	8814	8445	7045
1976	6186	1355	1844	3901	1727	374	137	6	15530	9344	7988
1977	678	22646	1889	2206	2794	1403	350	72	32040	31361	8716
1978	483	2487	26966	2404	2076	2073	937	313	37739	37256	34769
1979	5972	1769	3440	21838	2309	1647	1227	624	38826	32854	31084
1980	762	21894	2616	4257	16101	1463	1074	542	48708	47946	26052
1981	588	2792	17717	2989	4082	10557	917	632	40274	39686	36894
1982	197	2155	3581	14341	2546	2901	6987	514	33224	33027	30871
1983	290	721	2584	3297	10521	2024	1821	4346	25603	25313	24592
1984	1710	1063	950	2514	2596	6749	1399	1350	18330	16620	15557
1985	177	6269	1516	913	2114	1955	3670	771	17385	17208	10939
1986	1771	569	7824	1417	1026	1990	2062	2674	19333	17562	16993
1987	190	5376	714	7170	1310	383	1463	1154	17760	17570	12193
1988	1434	481	6522	1261	3903	855	197	1003	15657	14223	13742
1989	48	5725	522	5291	930	2491	580	78	15665	15617	9892
1990	349	339	8177	695	4560	551	1305	545	16520	16171	15832
1991	215	1321	417	9206	620	3243	331	875	16228	16013	14692
1992	816	878	1305	368	6516	478	2014	148	12523	11707	10829
1993	1563	2625	1204	1215	218	2965	241	894	10926	9362	6737
1994	1047	4921	4430	796	584	140	1510	146	13574	12527	7606
1995	437	3962	8053	4321	589	484	20	828	18695	18258	14296
1996	883	2051	5992	8398	3657	430	404	11	21827	20944	18893
1997	2139	2642	2631	5896	7343	2530	199	252	23631	21493	18851
1998	665	6845	4384	3189	5559	6224	2035	195	29097	28432	21587
1999	5171	2430	9733	4086	2461	4452	4650	1455	34438	29266	26836

Table 20. Deterministic projection results for haddock in unit areas 5Zjm for 1999 at $F_{0.1}$ using the bootstrap bias adjusted population abundance at the beginning of 1999.

Year	Age Group										
	1	2	3	4	5	6	7	8	1-8	2-8	3-8
Beginning of Year Population Numbers (000s)											
1999	39946	5132	10686	3171	1957	2382	2193	534			
2000	4912	32705	4129	7917	2022	1248	1519	1398			
Partial Recruitment to the Fishery											
1999	0.00	0.07	0.40	1.00	1.00	1.00	1.00	1.00			
Fishing Mortality											
1999	0.000	0.018	0.100	0.250	0.250	0.250	0.250	0.250			
Weight at beginning of year for population (kg)											
2000	0.13	0.50	0.91	1.25	1.61	2.14	2.52	2.87			
Beginning of Year Projected Population Biomass (t)											
2000	622	16287	3774	9900	3250	2669	3827	4010	44340	43718	27430
Projected Catch Numbers (000s)											
1999	0	81	923	638	394	479	441	108			
Average weight at age for catch (kg)											
1999	0.66	1.11	1.46	1.82	2.24	2.51	3.03	2.95			
Projected Yield (t)											
1999	0	89	1352	1160	881	1202	1338	317	6341		

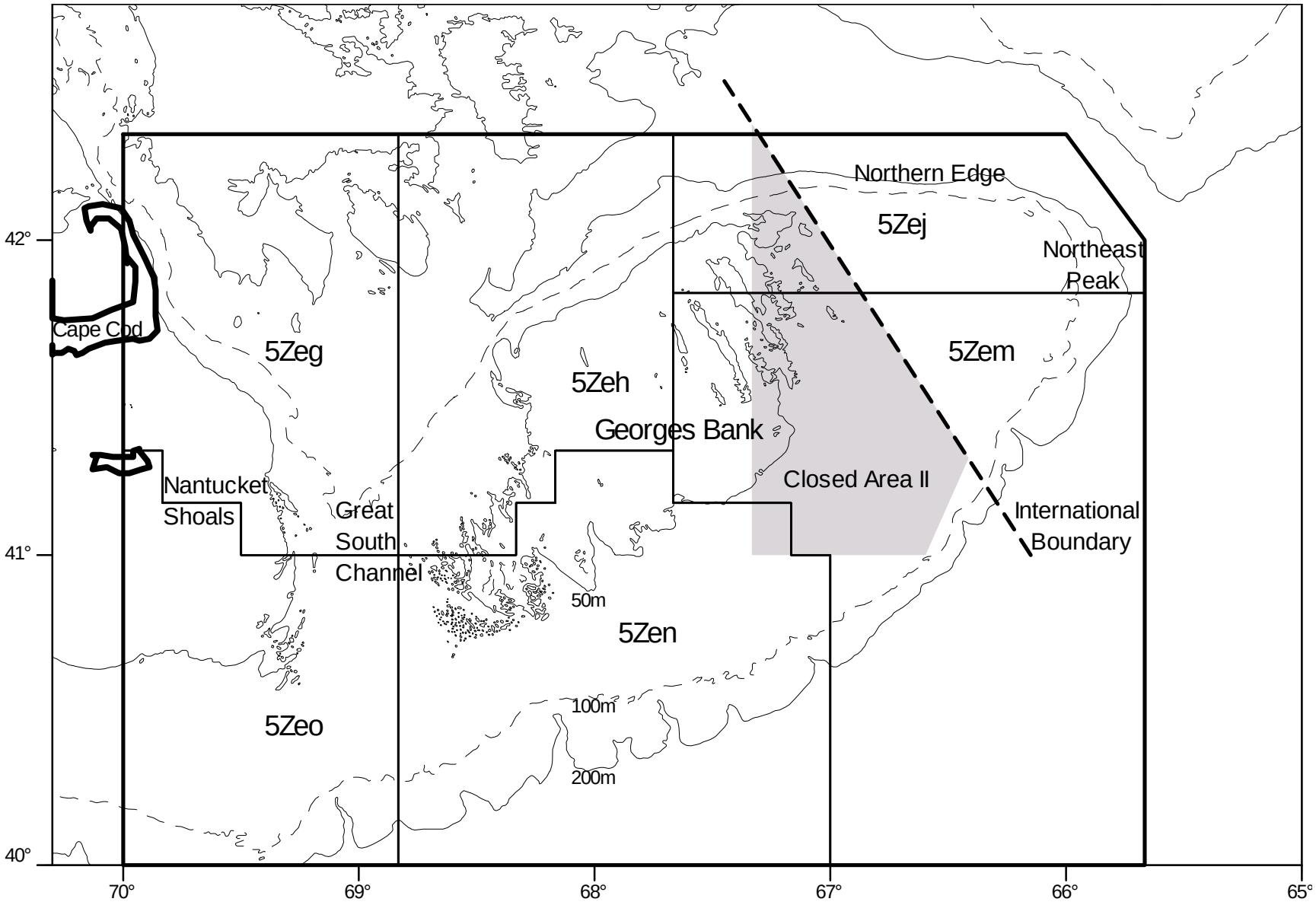

Figure 1. Fisheries statistical unit areas in NAFO Subdivision 5Ze.

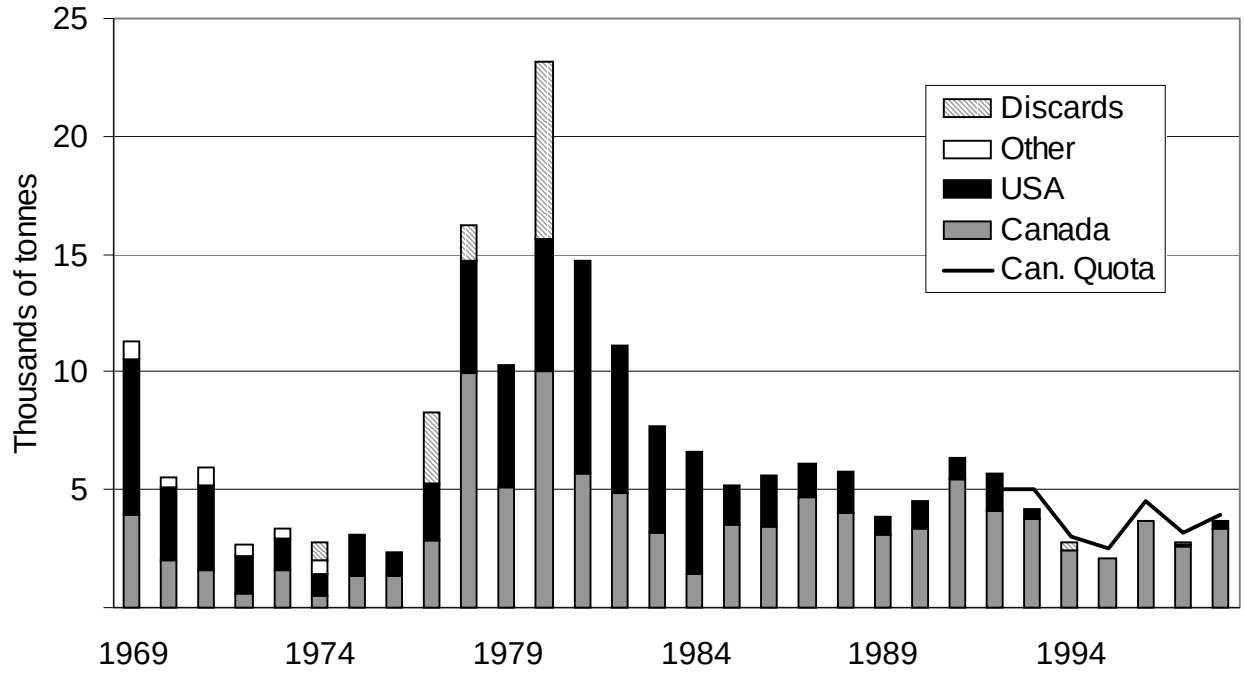

Figure 2. Nominal catch of haddock in unit areas 5Zjm.

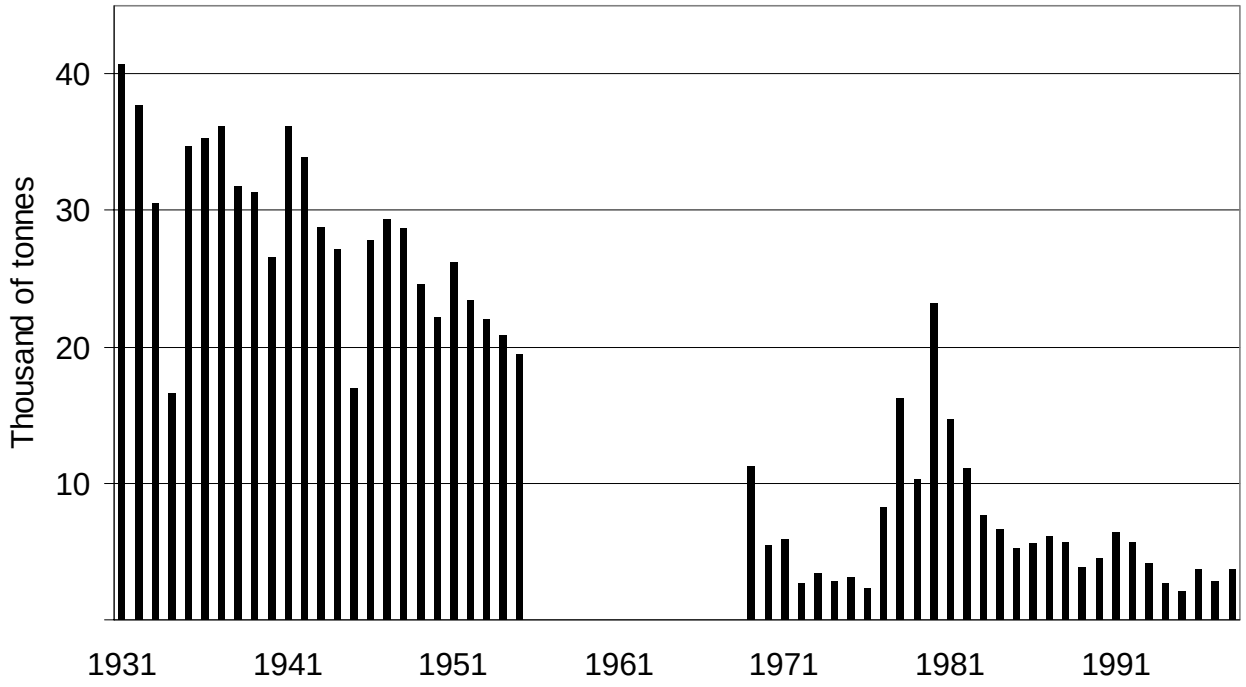

Figure 3. Historic catch of haddock in 5Zjm compared to recent catches.

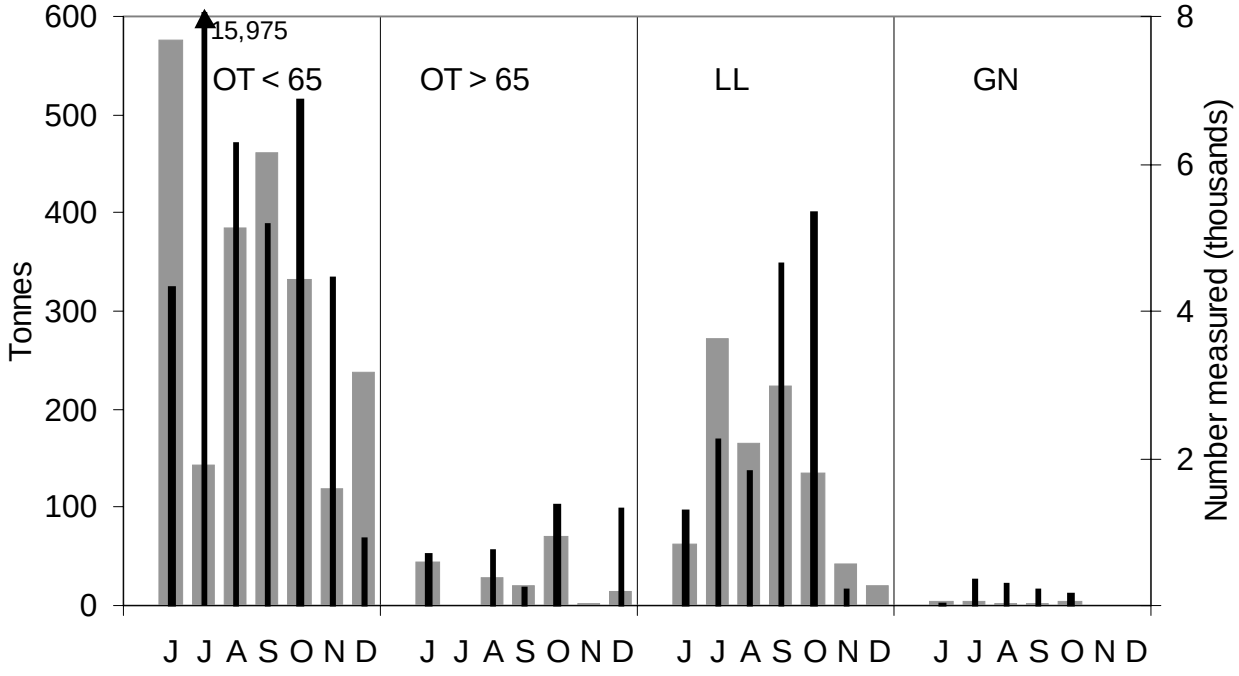

Figure 4. Haddock catches in 5Zjm by month and gear for the Canadian commercial fishery in 1998 (wide gray bars) with sampling levels (narrow black bars).

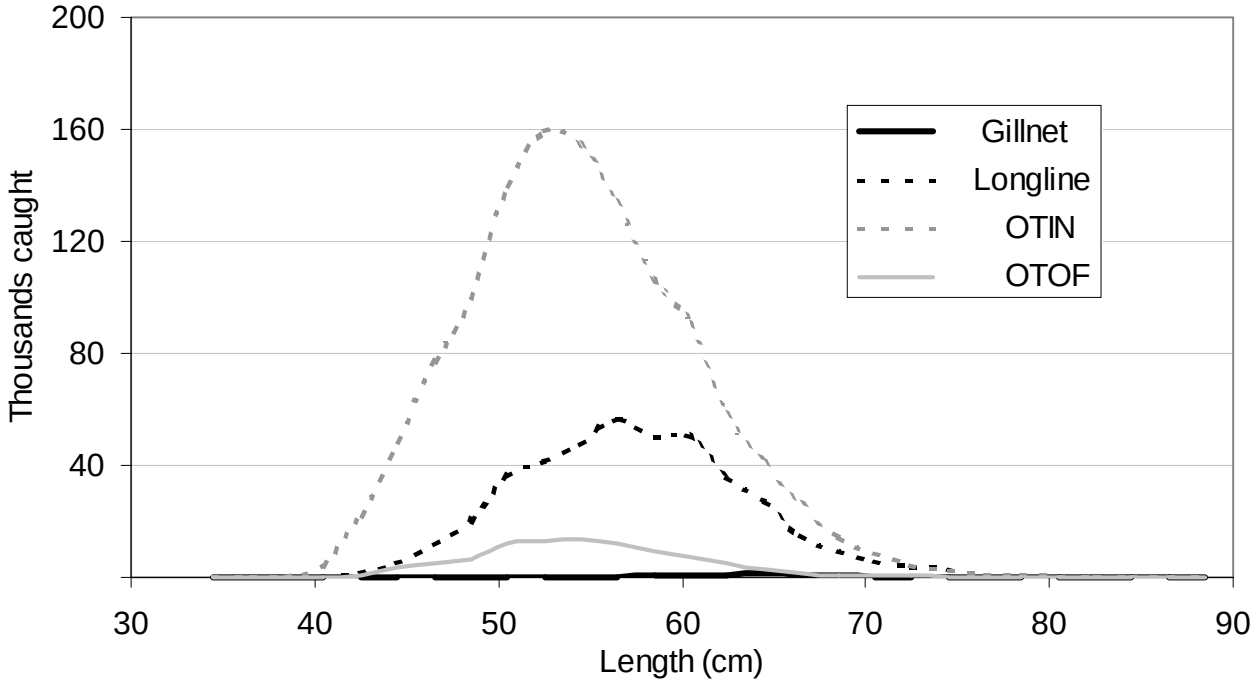

Figure 5. Length compositions of the principal Canadian 5Zjm commercial haddock fisheries in 1998.

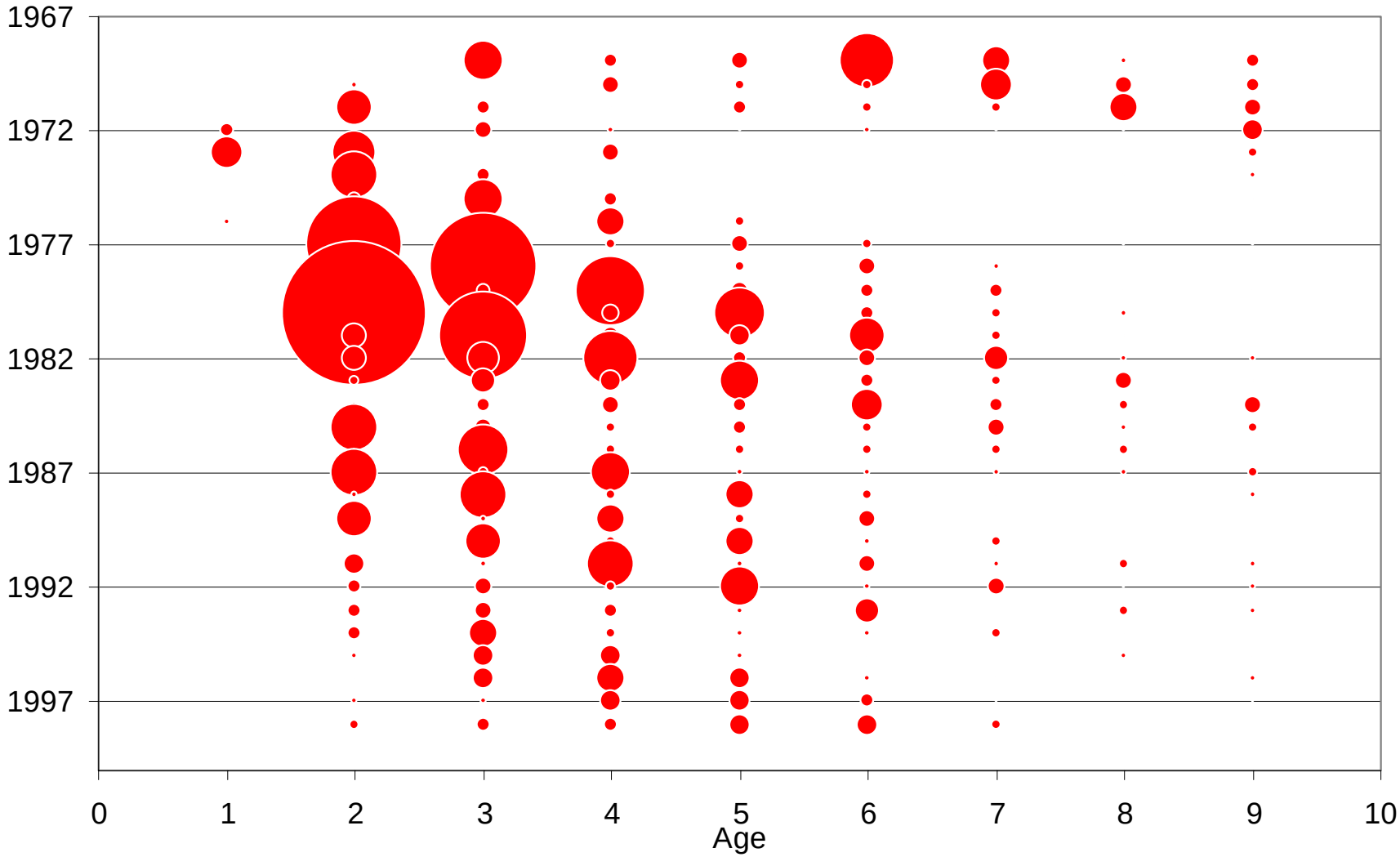

Figure 6. Total commercial catch at age (numbers) of haddock from unit areas 5Zjm. The bubble area is proportional to magnitude (see Table 9).

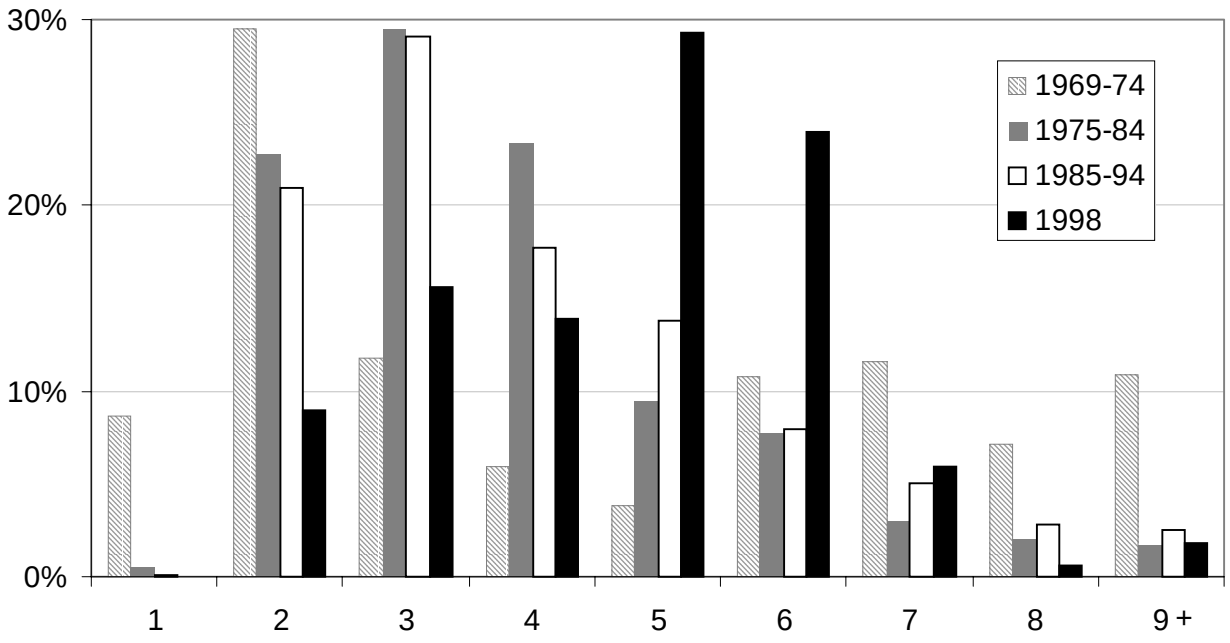

Figure 7. Age composition of the Canadian 5Zjm commercial fisheries haddock catch in 1998 compared to the average for three periods which represent different stages in the Georges Bank fishery.

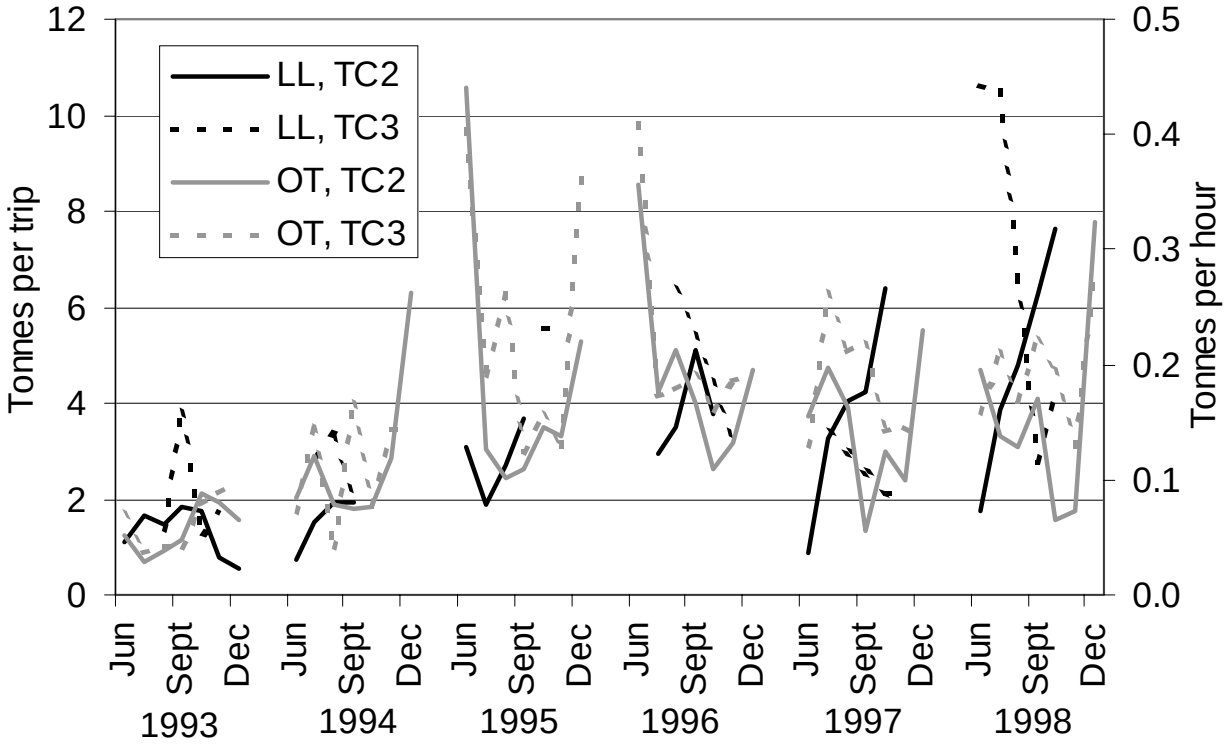

Figure 8. Catch rates for haddock from the Canadian commercial fishery in 5Zjm. (LL = longline, OT = otter trawl, TC = tonnage class).

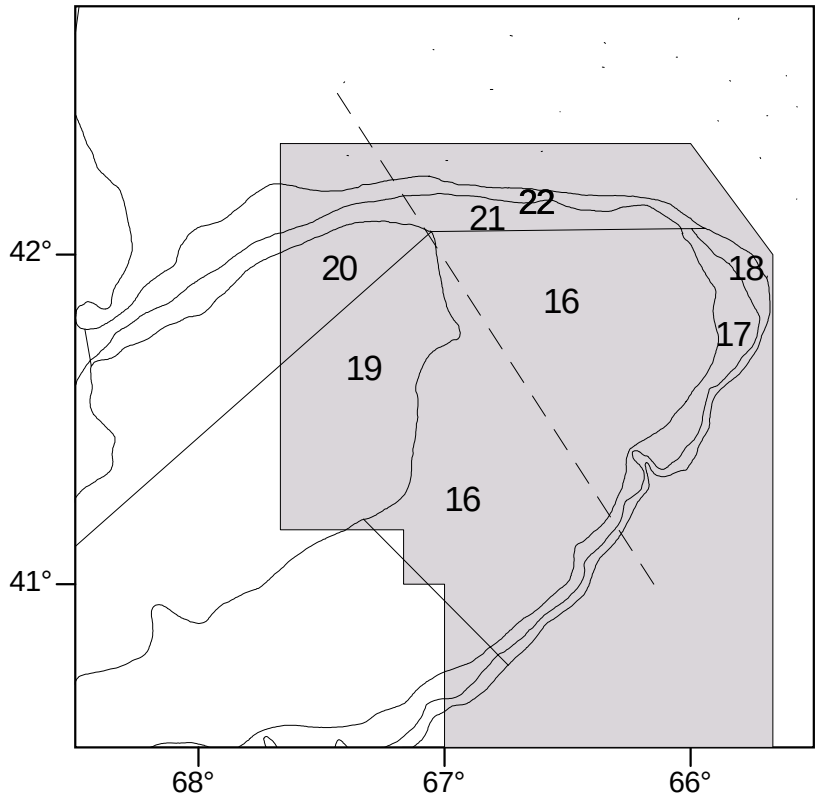

Figure 9. Stratification scheme used for NMFS surveys. The 5Zjm management area is indicated by shading.

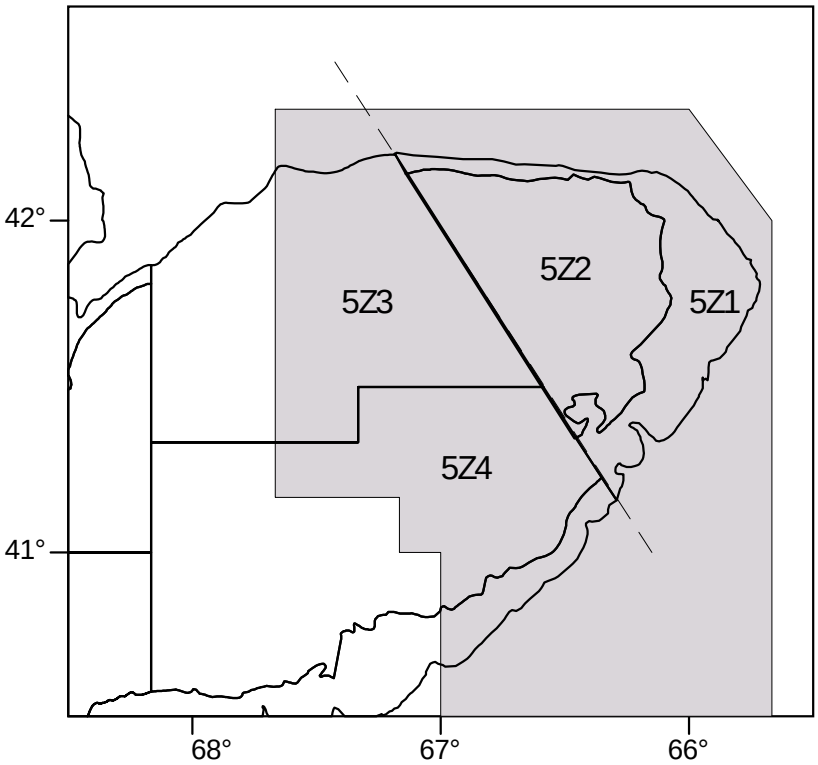

Figure 10. Stratification scheme used for the DFO survey. The 5Zjm management area is indicated by shading.

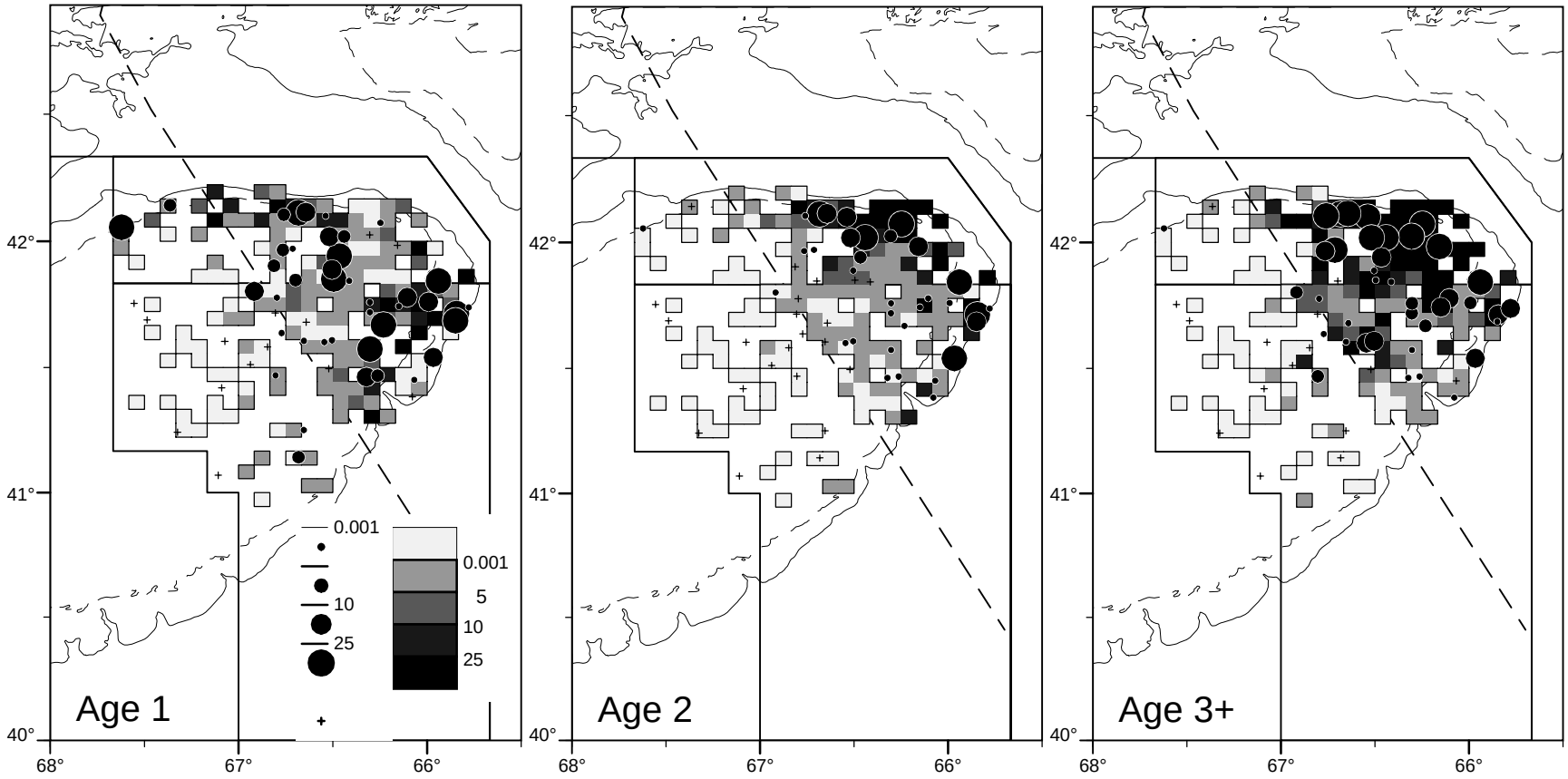

Figure 11. Distribution of 5Zjm haddock abundance (number/tow) as observed from the **DFO spring** survey. The squares are shaded relative to the average catch for 1994 to 1998. The expanding symbols represent the 1999 survey catches.

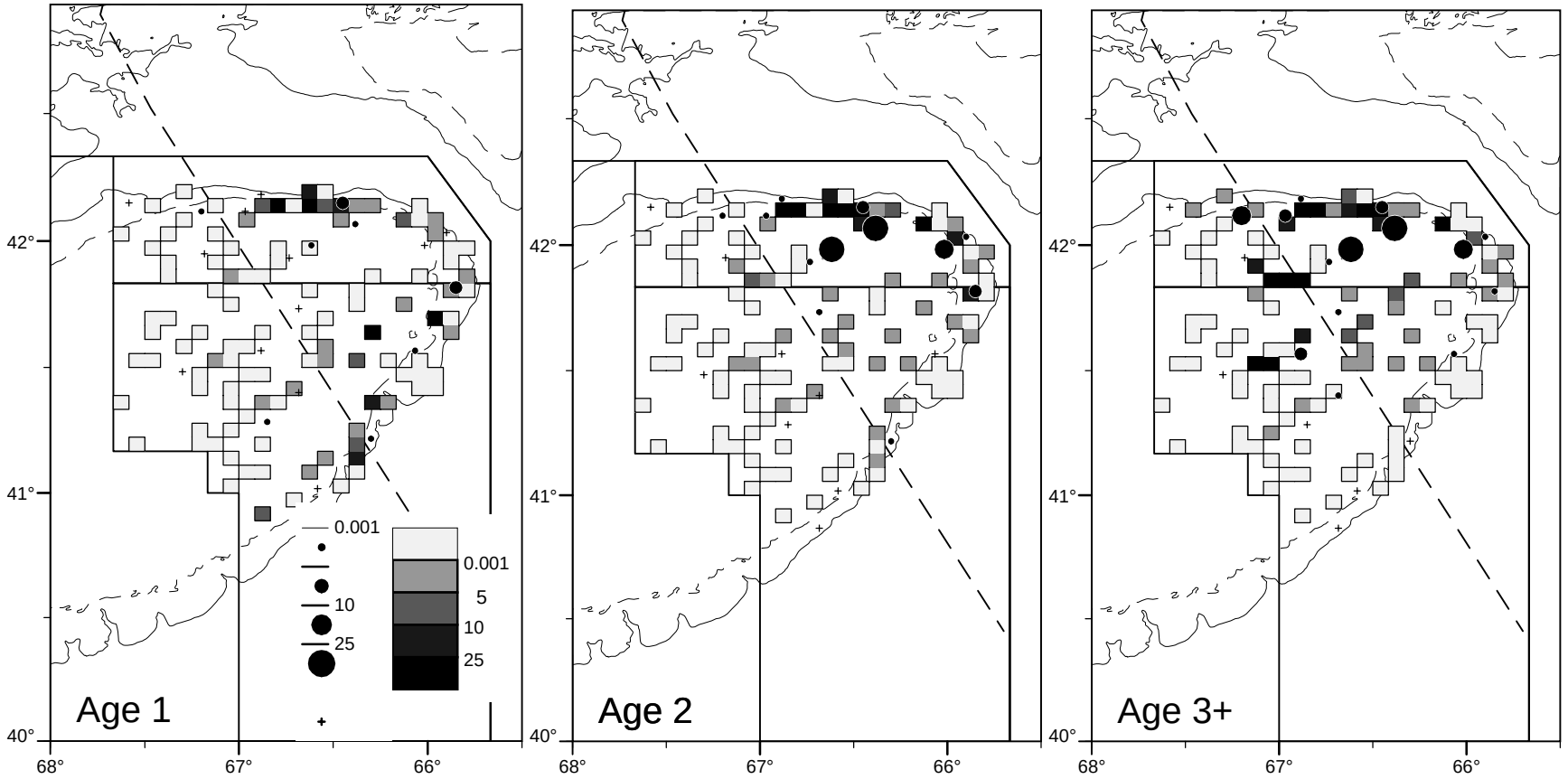

Figure 12. Distribution of 5Zjm haddock abundance (number/tow) as observed from the **NMFS spring** survey. The squares are shaded relative to the average catch for 1993 to 1997. The expanding symbols represent the 1998 survey catches.

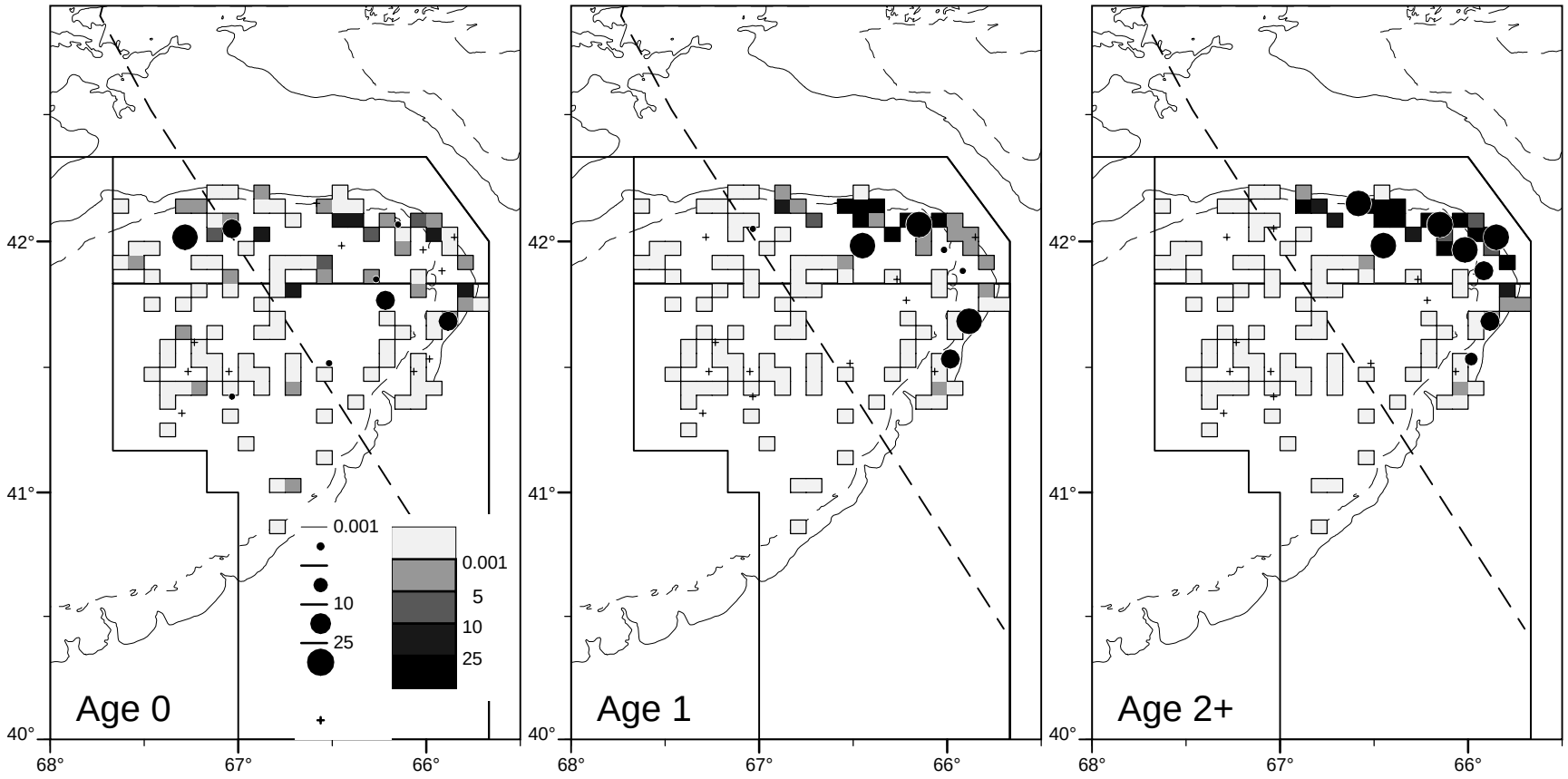

Figure 13. Distribution of 5Zjm haddock abundance (number/tow) as observed from the **NMFS fall** survey. The squares are shaded relative to the average catch for 1993 to 1997. The expanding symbols represent the 1998 survey catches.

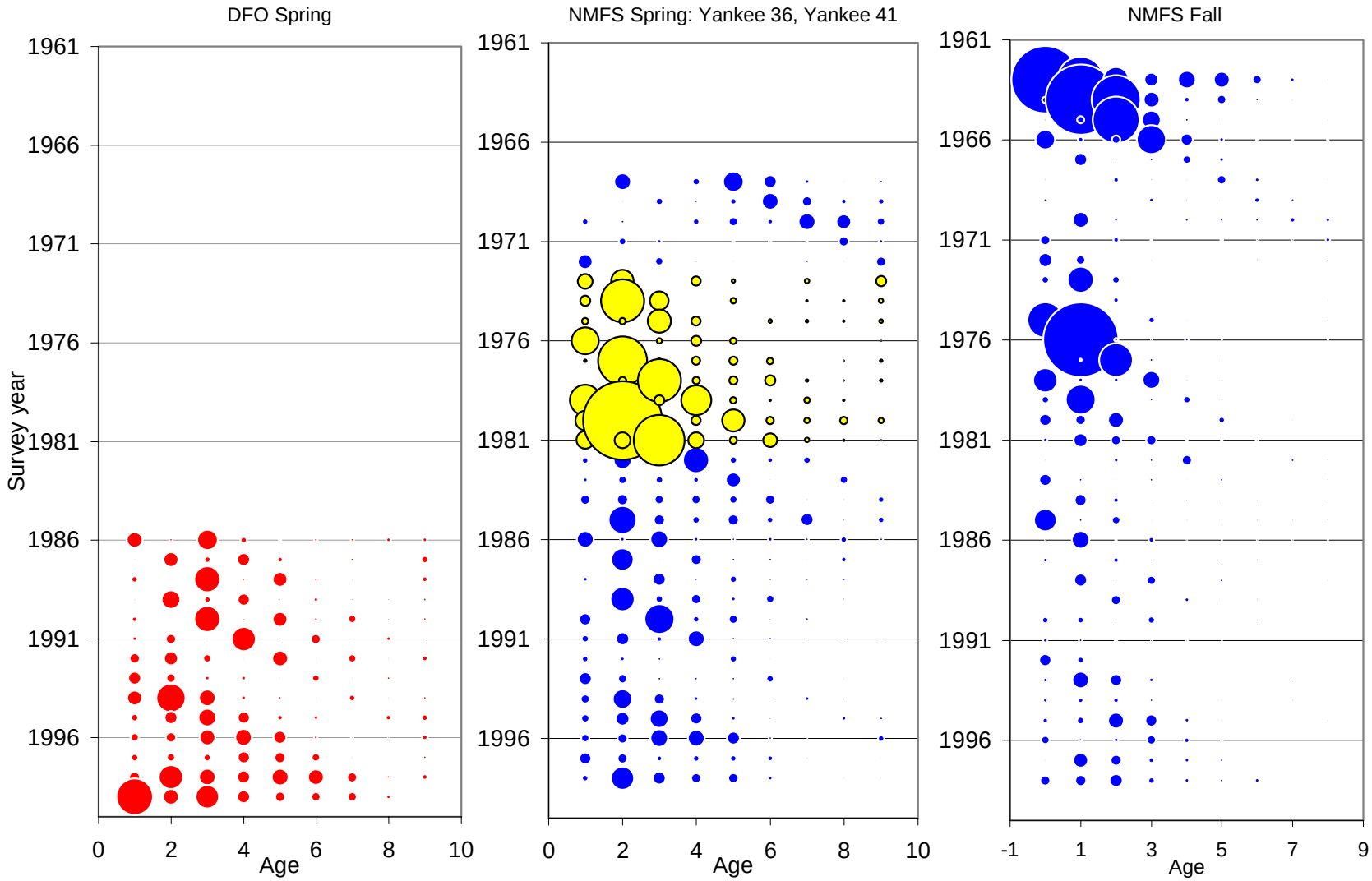

Figure 14. Estimated abundance at age (numbers in 000's) of haddock for the DFO and NMFS spring surveys and the NMFS fall survey. Bubble area is proportional to magnitude (see Tables 12-14). Conversion factors to adjust for changes in door type and survey vessel were applied to the NMFS surveys. From 1973-81, a 41 Yankee trawl was used for the NMFS spring survey while a 36 Yankee was used in the other years. Symbol size has not been adjusted between surveys for the catcability of the survey.

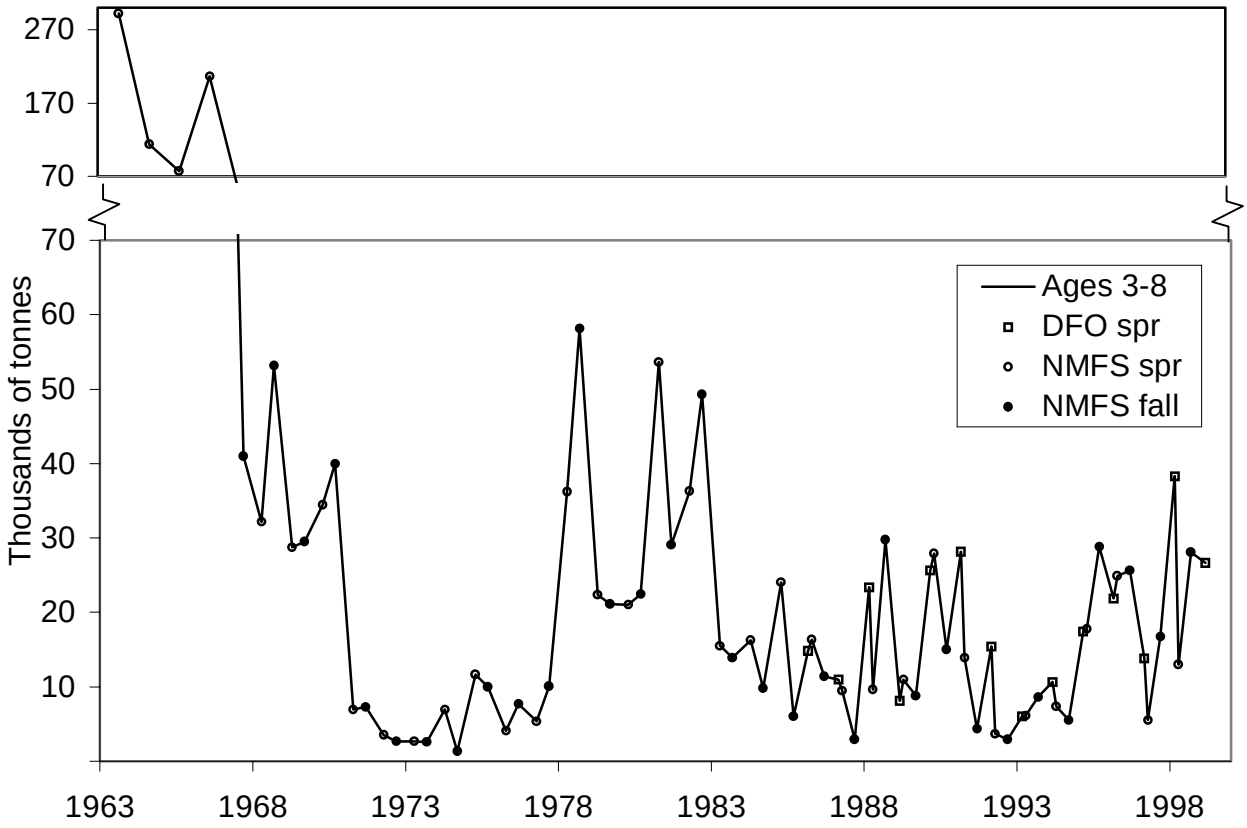

Figure 15. Biomass for ages 3-8 from the NMFS and DFO research surveys (adjusted by calibration constants) for haddock in unit areas 5Zjm. Solid circle = NMFS fall (October/November); Open circle = NMFS spring (March/April); Square = DFO spring (February/March).

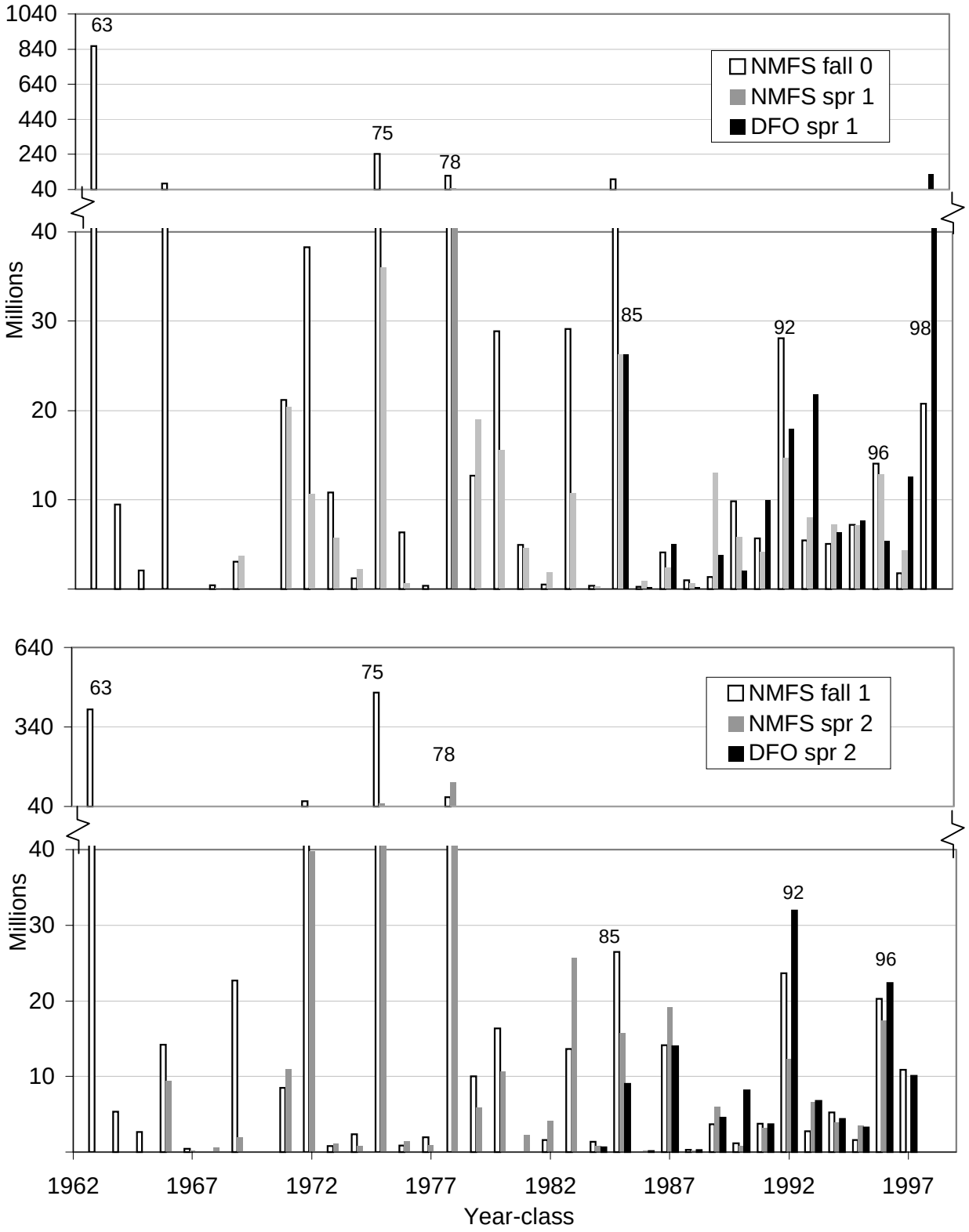

Figure 16. Year-class abundance for ages 0 and 1 from the NMFS fall and ages 1 and 2 from the NMFS and DFO spring research surveys (adjusted by calibration constants) for haddock in unit areas 5Zjm.

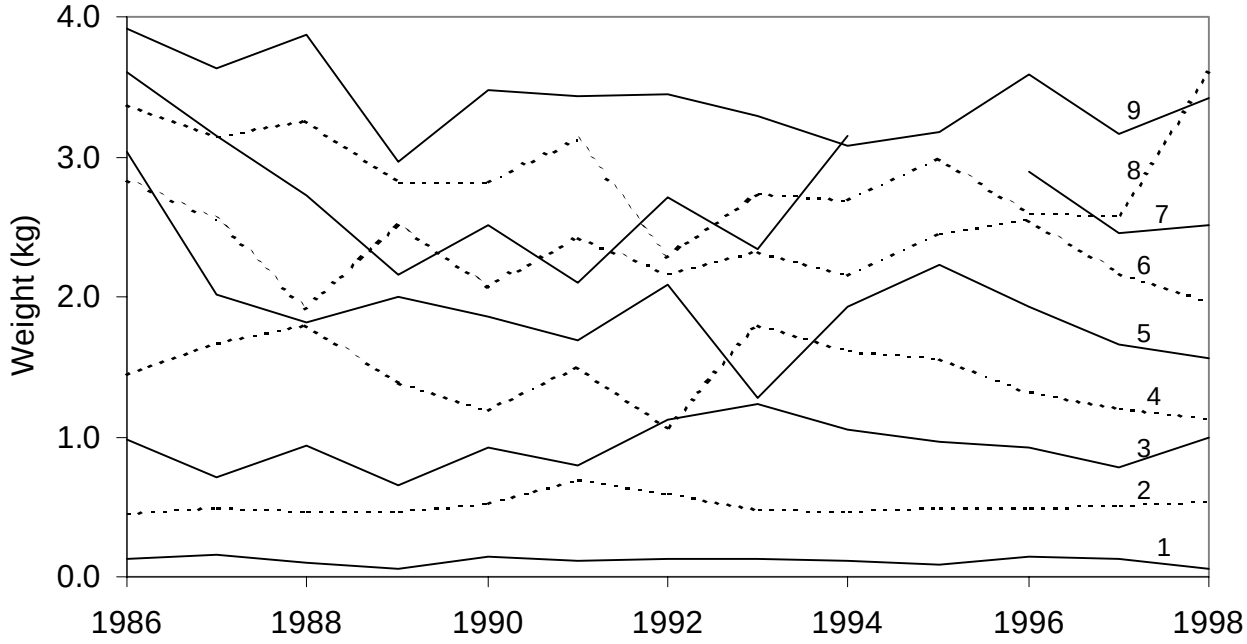

Figure 17. Weight at age for haddock in unit areas 5Zjm derived from the DFO spring surveys.

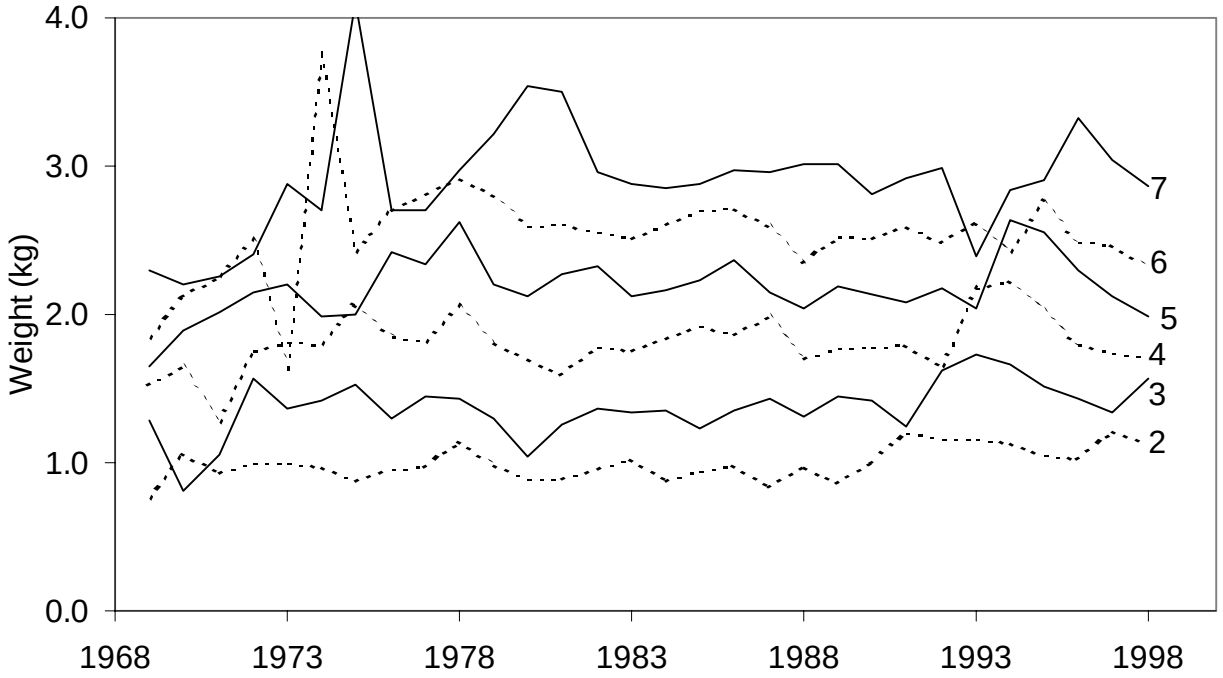

Figure 18. Weight at age for haddock in unit areas 5Zjm derived from the commercial fisheries.

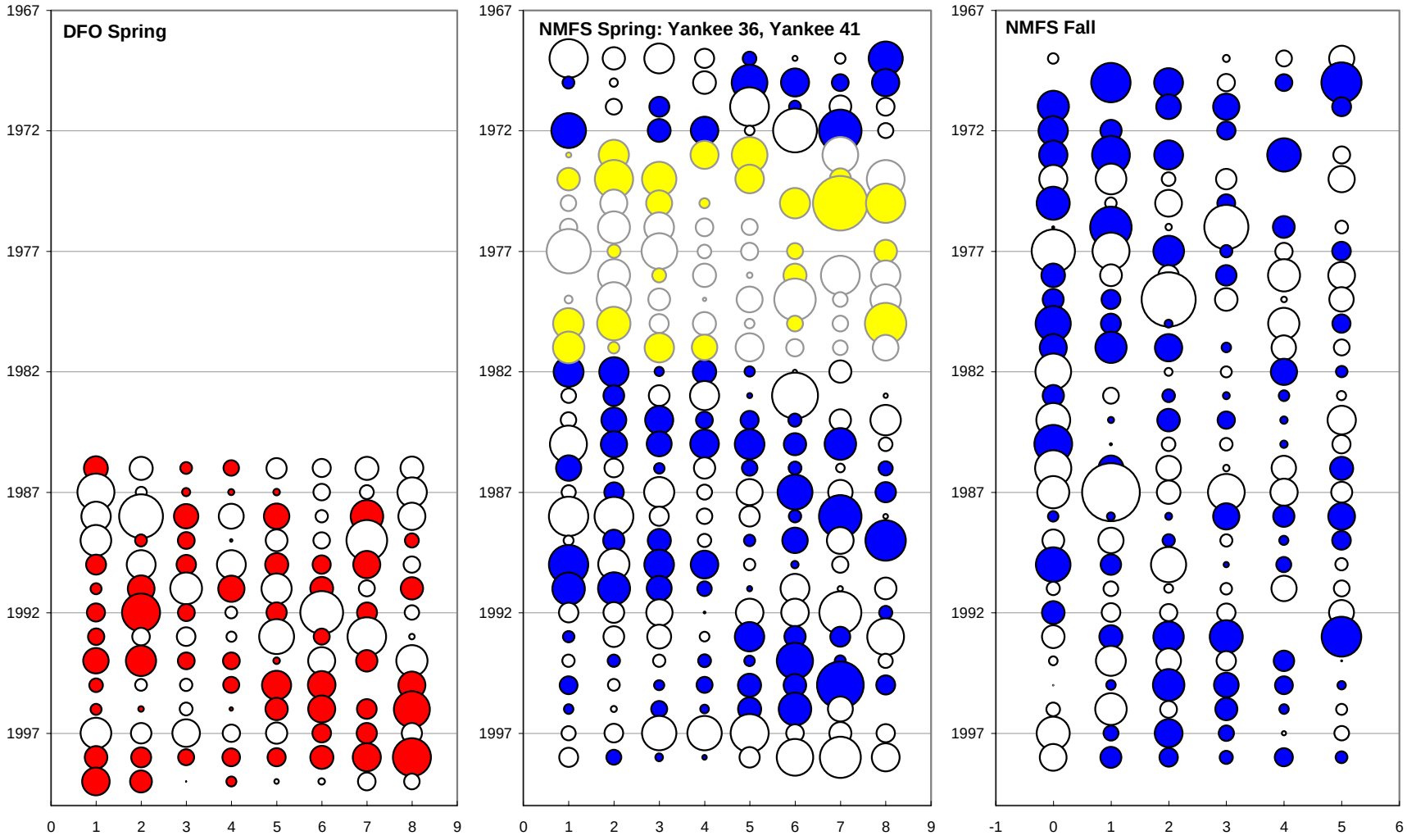

Figure 19. Residuals by year and age group for each research survey index. Solid symbols indicate positive values, open symbols indicate negative values. Bubble area is proportional to magnitude.

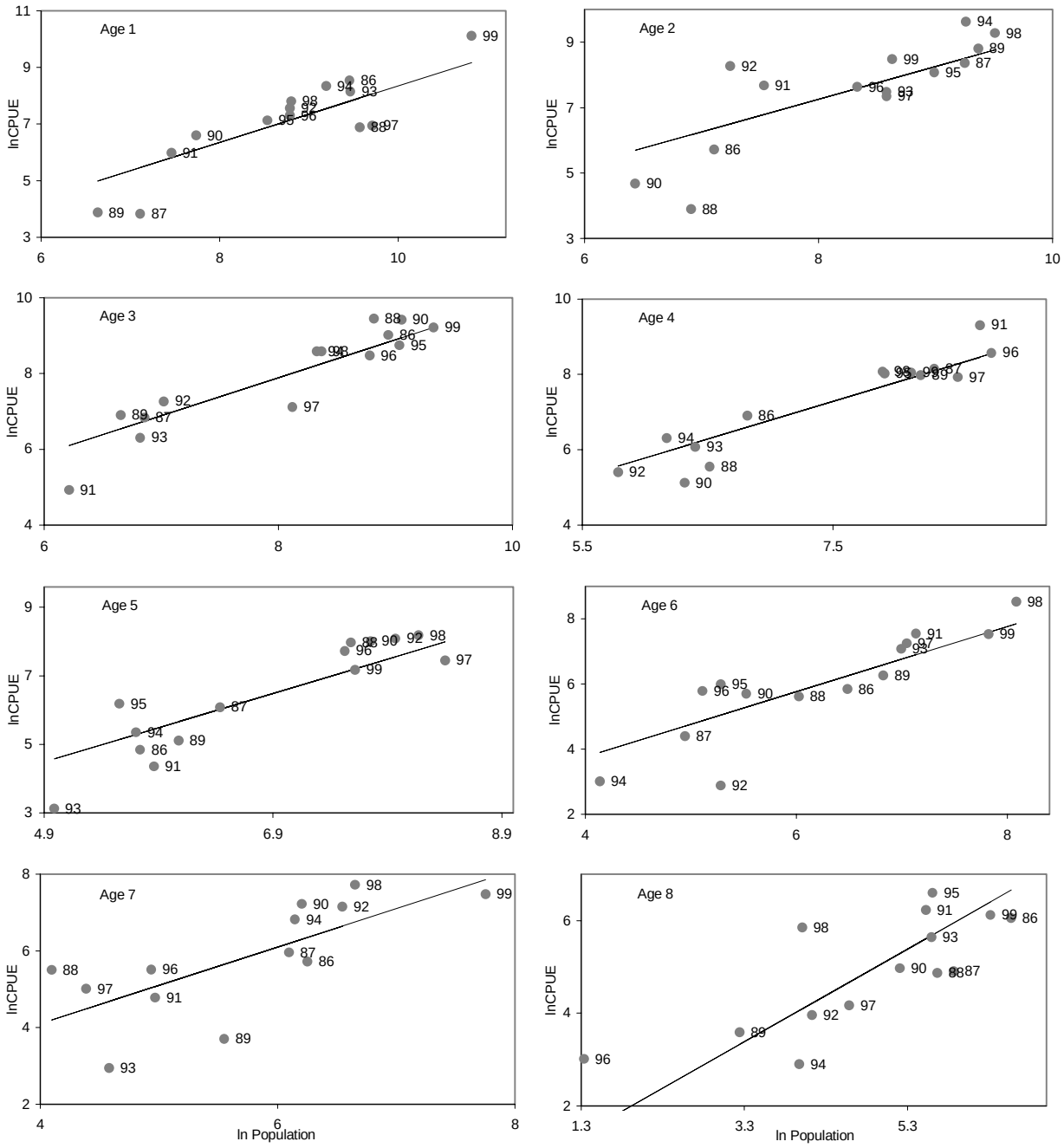

Figure 20. Age by age plots of the observed and predicted ln abundance index versus ln population numbers for haddock in unit areas 5Zj and 5Zm from the **DFO spring** survey.

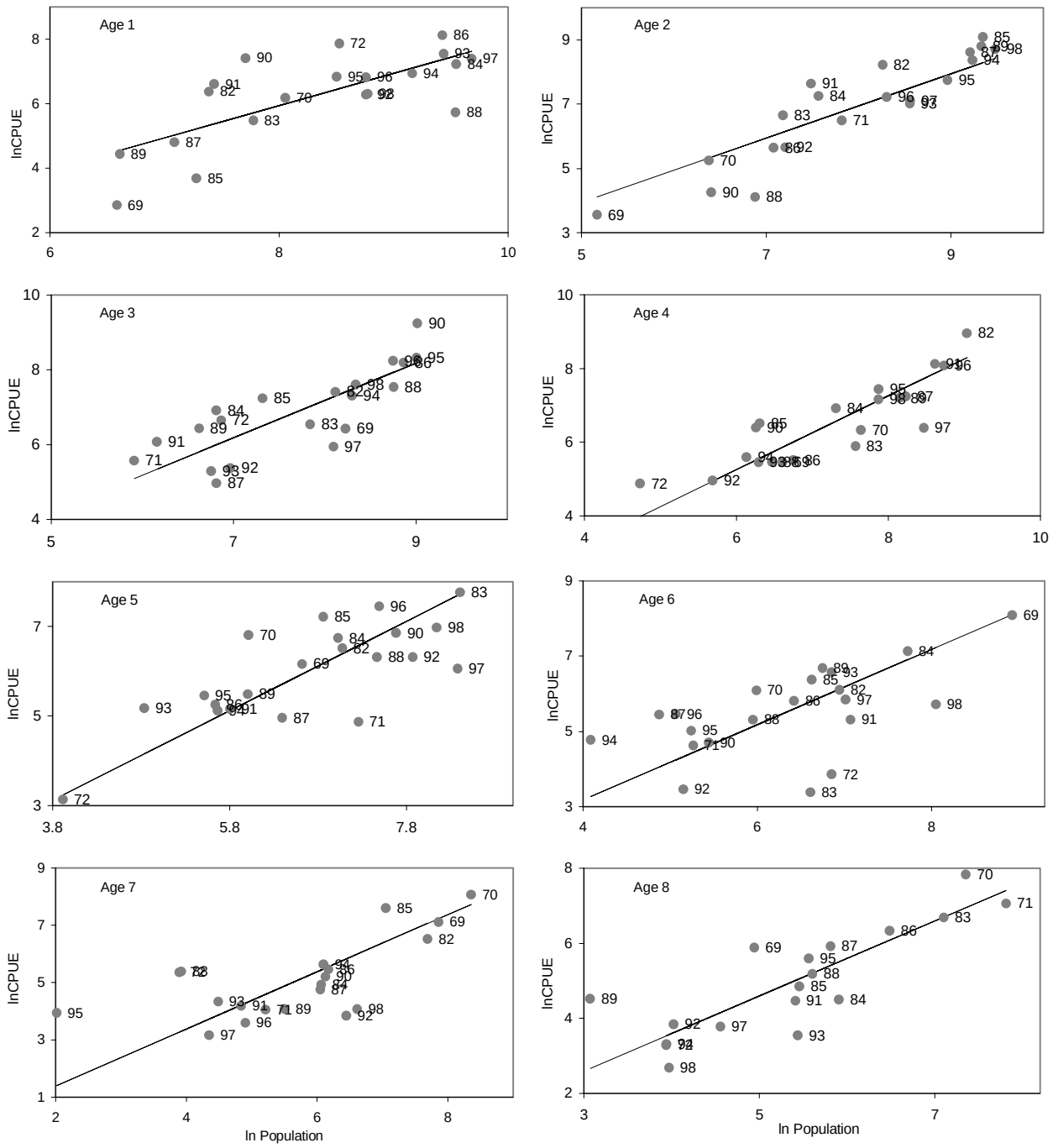

Figure 21. Age by age plots of the observed and predicted ln abundance index versus ln population numbers for haddock in unit areas 5Zj and 5Zm from the **NMFS spring** survey with a Yankee 36 net.

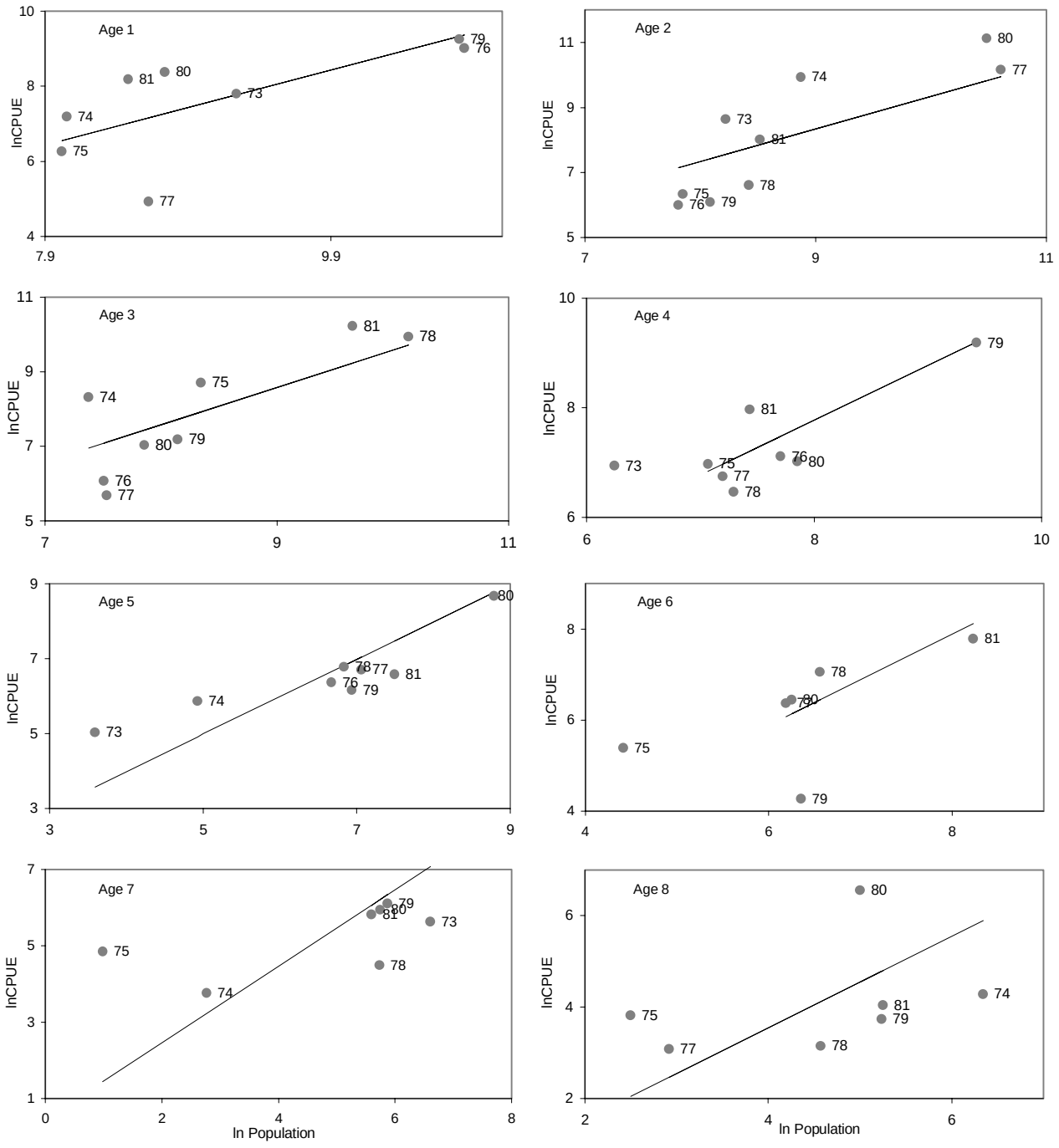

Figure 22. Age by age plots of the observed and predicted ln abundance index versus ln population numbers for haddock in unit areas 5Zj and 5Zm from the **NMFS spring** survey with a Yankee 41 net.

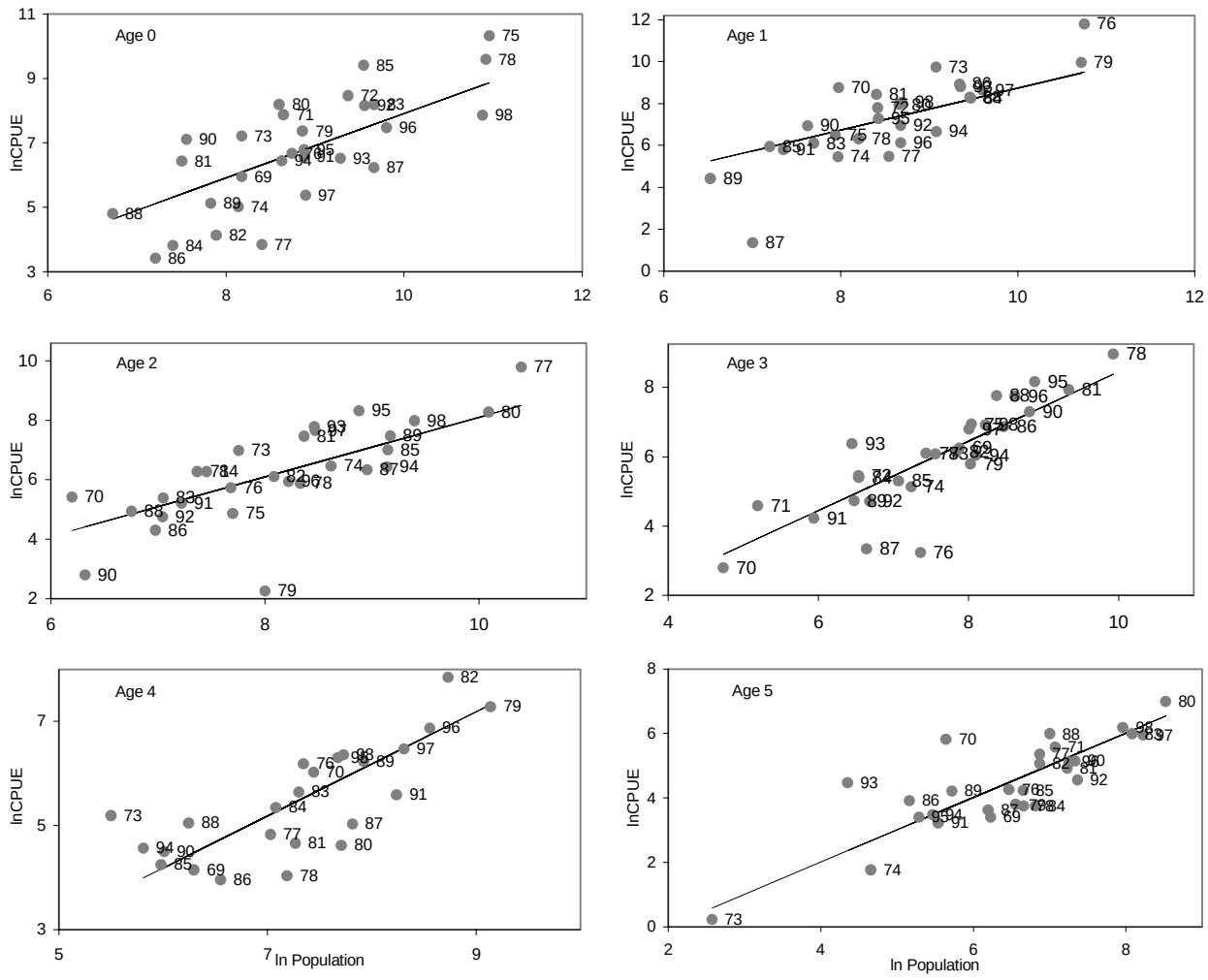

Figure 23. Age by age plots of the observed and predicted ln abundance index versus ln population numbers for haddock in unit areas 5Zj and 5Zm from the **NMFS fall** survey.

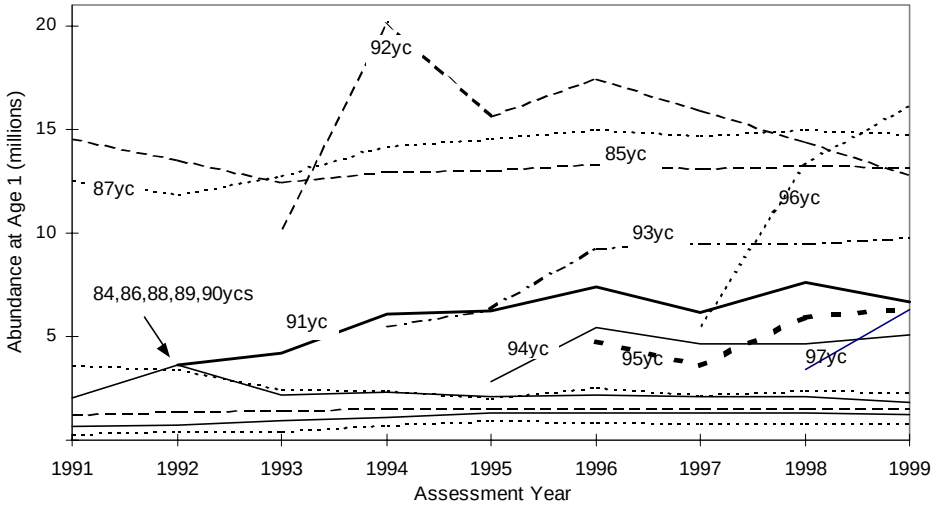

Figure 24. Successive estimates of year-class abundance as additional years of data were included in the assessment did not display any persistent trends.

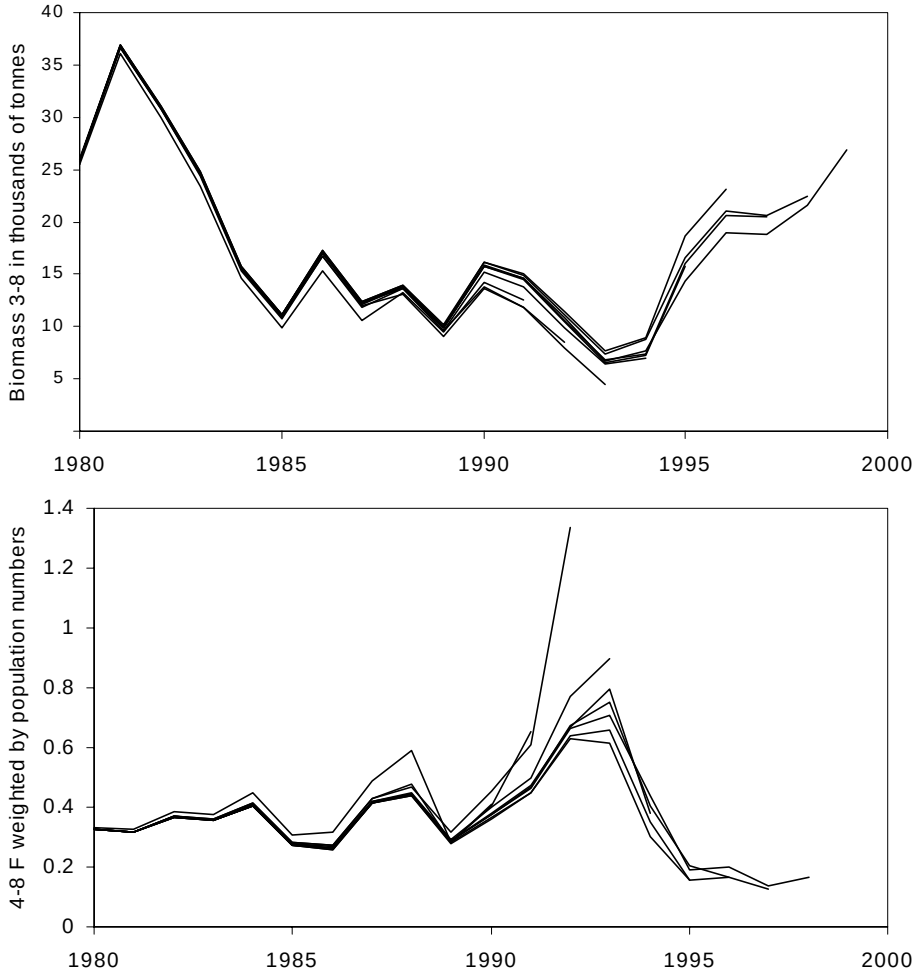

Figure 25. Retrospective estimates of biomass and fishing mortality did not display any persistent trends for over or under estimation as successive years of data were excluded in the assessment.

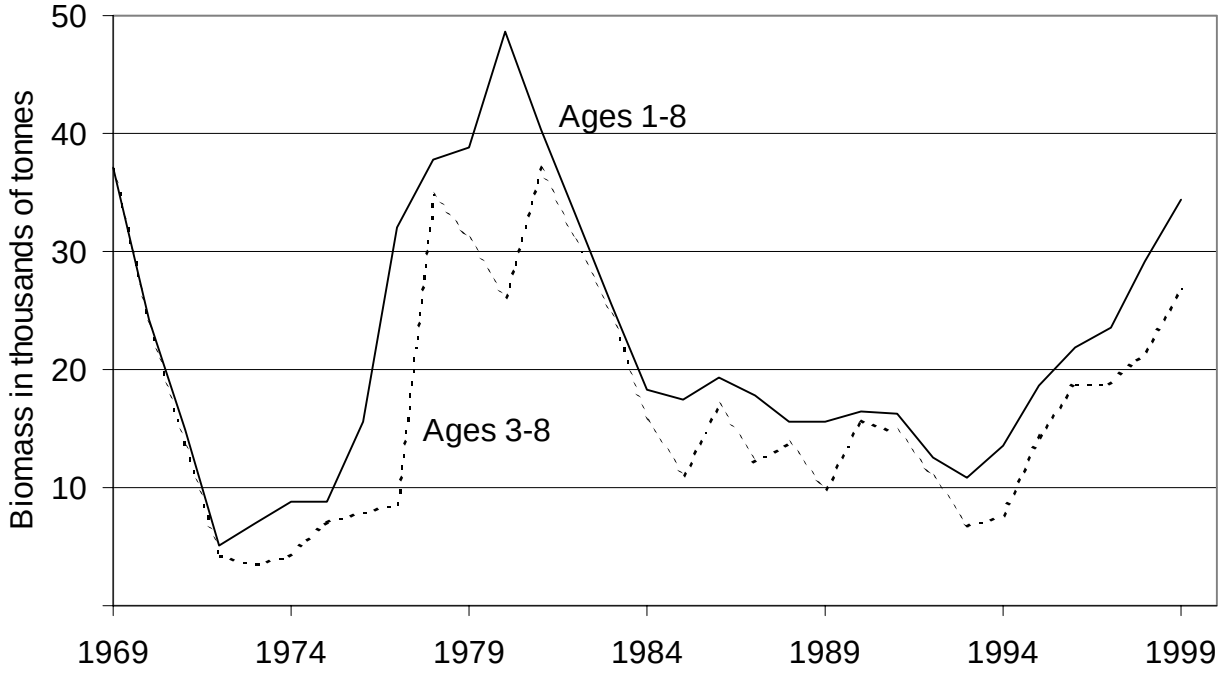

Figure 26. Beginning of year biomass for haddock in unit areas 5Zjm.

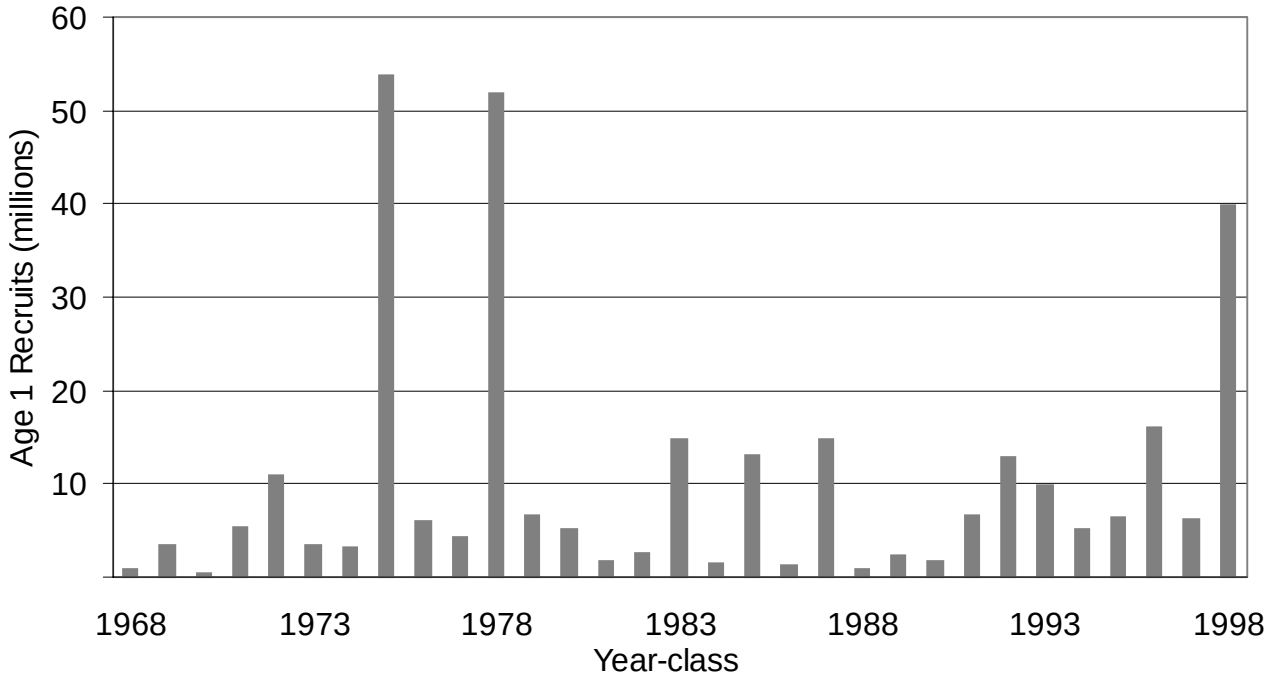

Figure 27. Number of age 1 recruits for haddock in unit areas 5Zjm.

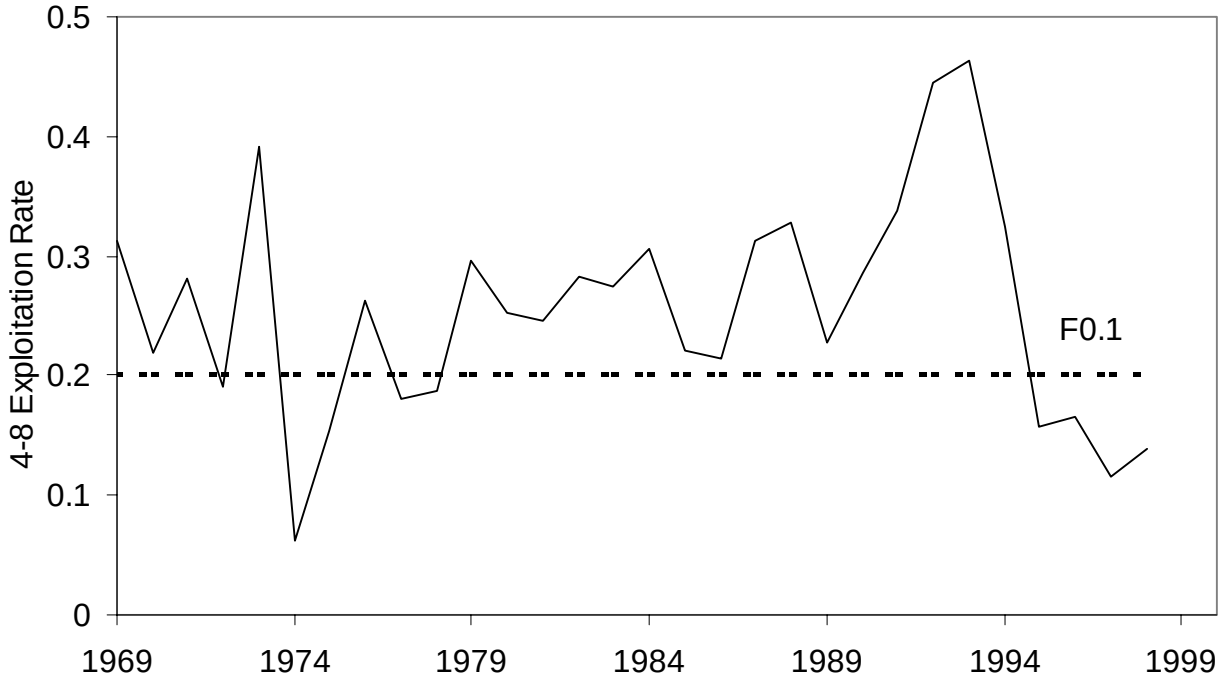

Figure 28. Exploitation rate for haddock ages 4 to 8 in unit areas 5Zjm.

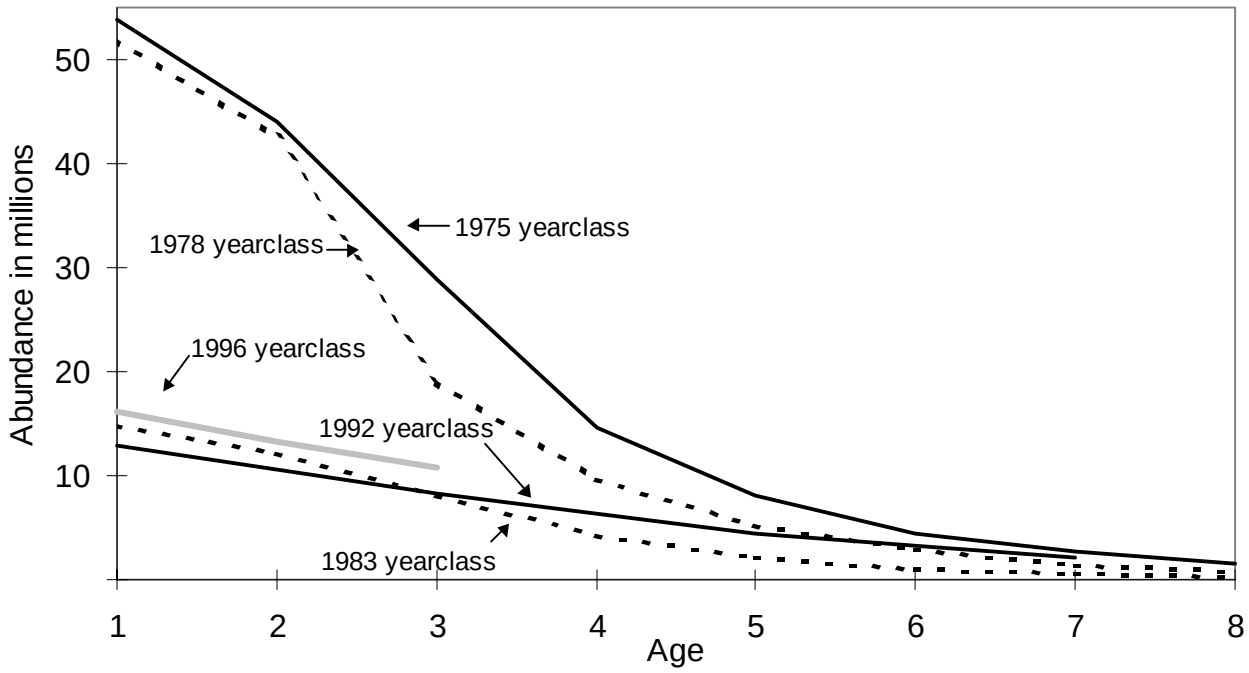

Figure 29. Decay of the 1992 5Zjm haddock year-class versus the 1983, 1975 and 1978 as they progress through the fishery.

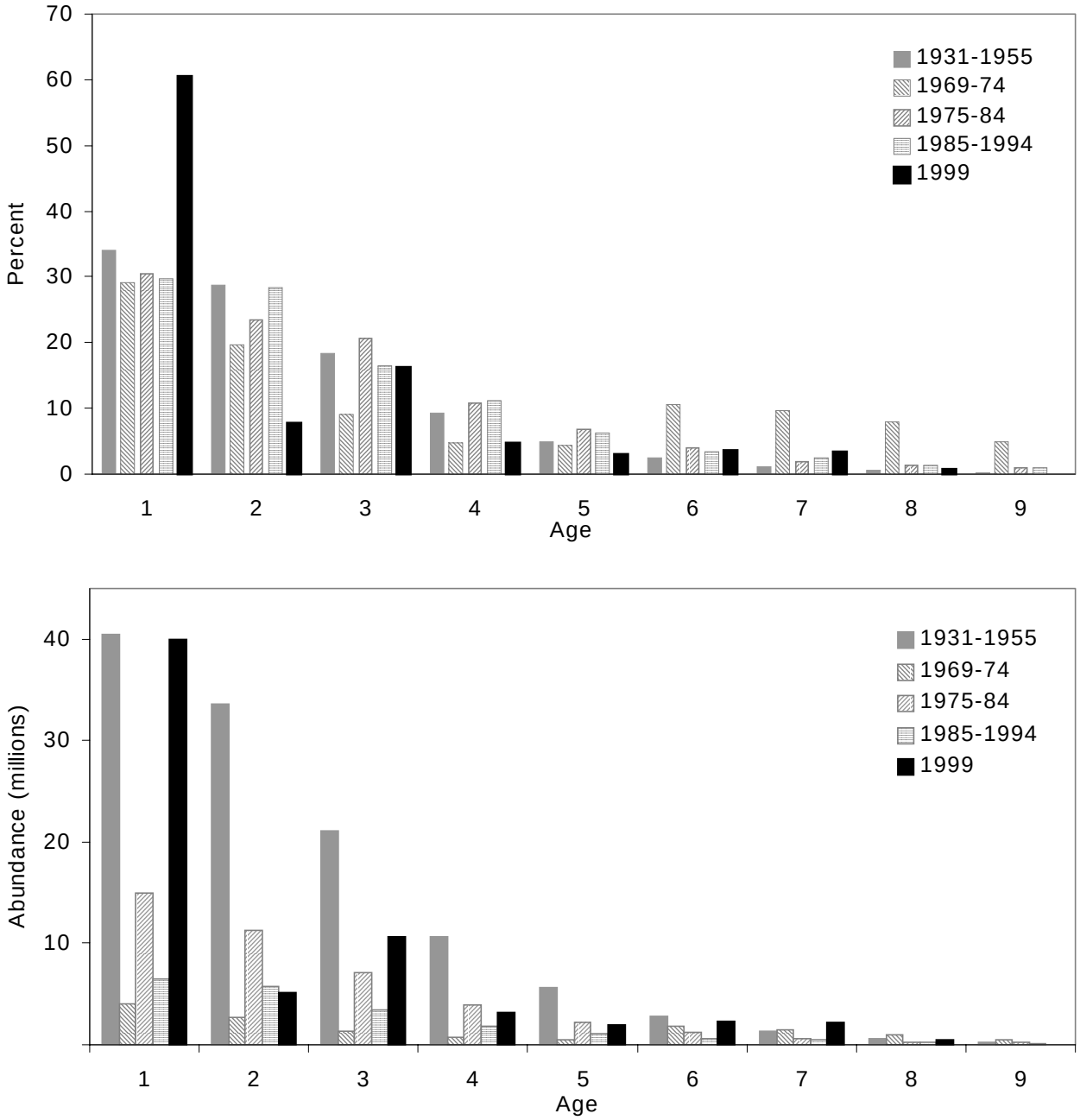

Figure 30. Comparison of age composition and absolute abundance of the 5Zjm haddock population in 1998 to earlier periods.

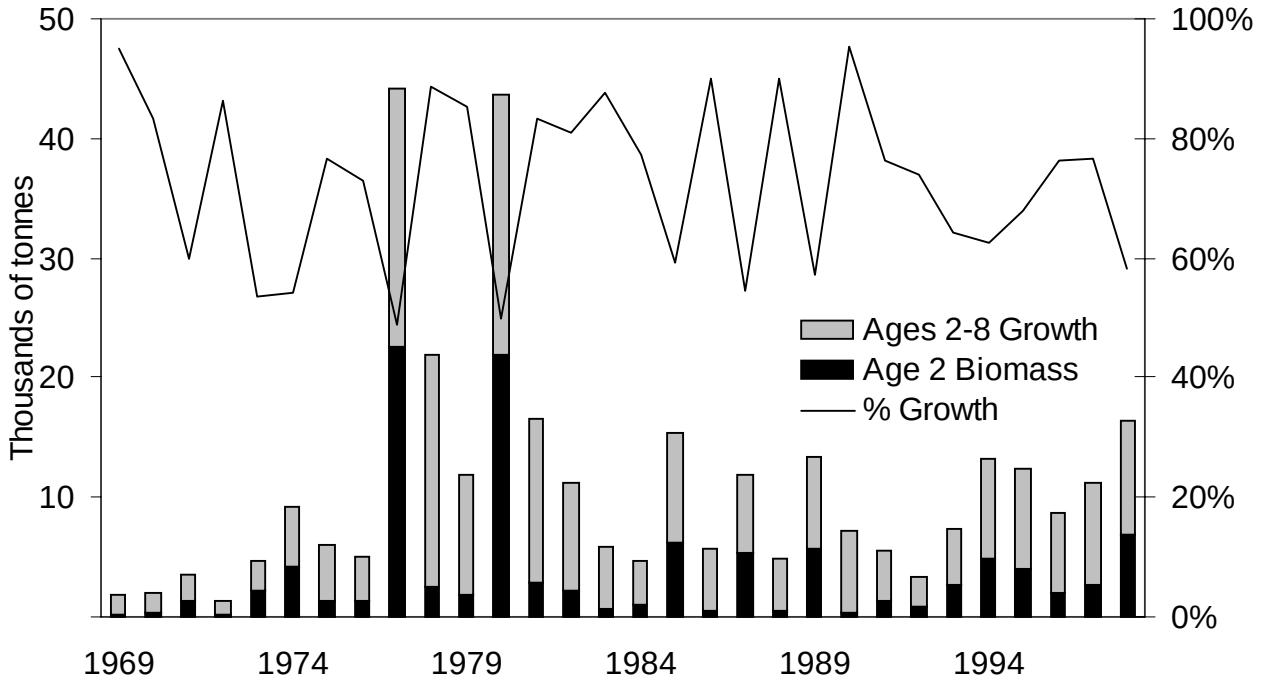

Figure 31. Amount of productivity attributible to growth of ages 2 to 8 5Zjm haddock and the amount contributed by recruitment of age 2 haddock.

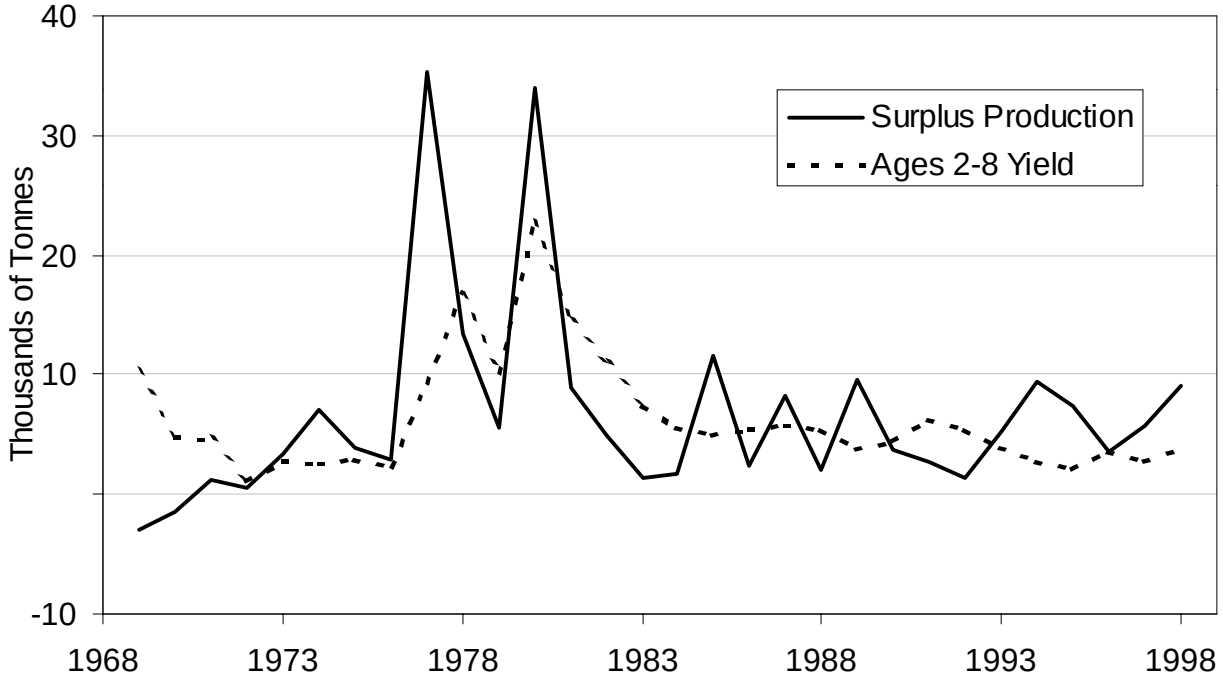

Figure 32. Surplus production of 5Zjm haddock available to the commercial fishery compared to amount actually harvested.

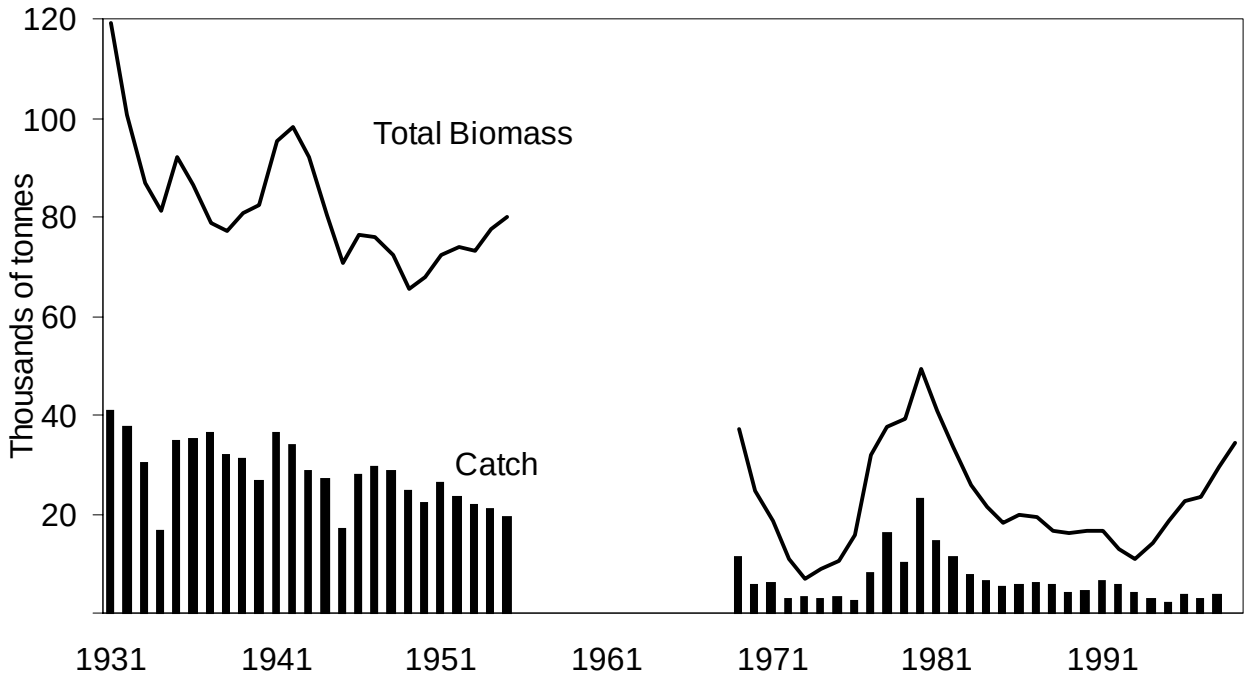

Figure 33. Historic catch and biomass of haddock in 5Zjm compared to recent catches and biomass.

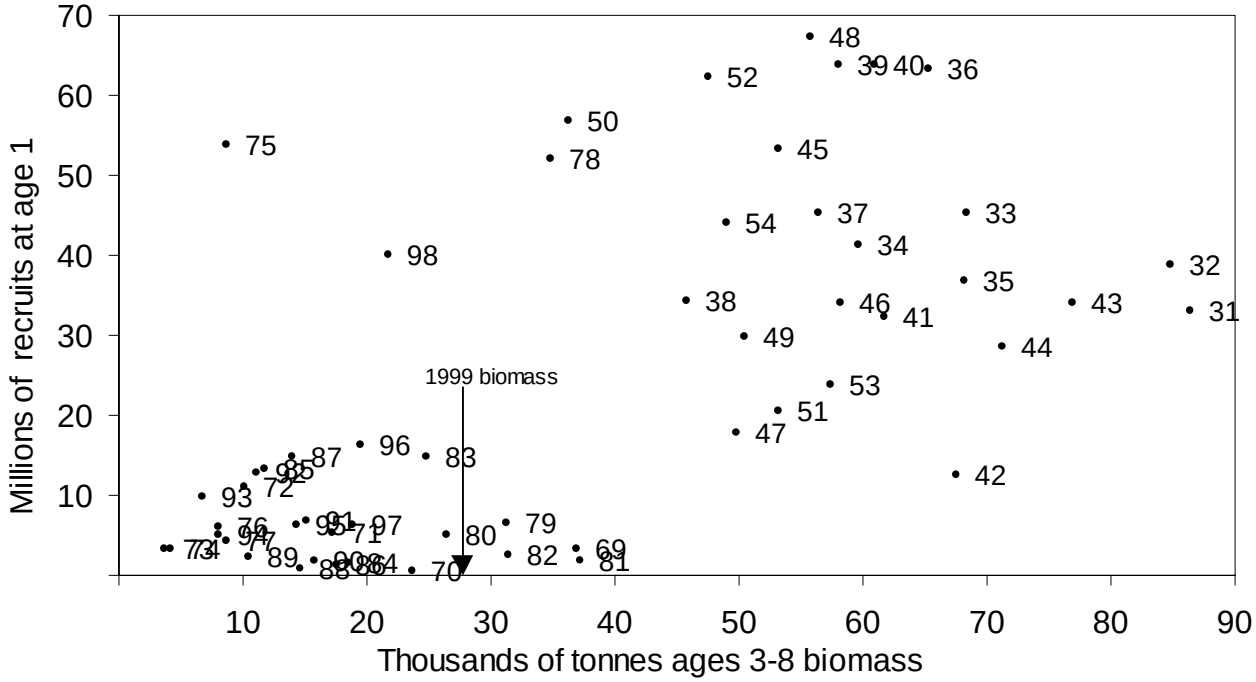

Figure 34. Relationship between mature (3-8) 5Zjm haddock biomass and recruits at age 1 from 1931 to 1955 and 1969 to 1997.

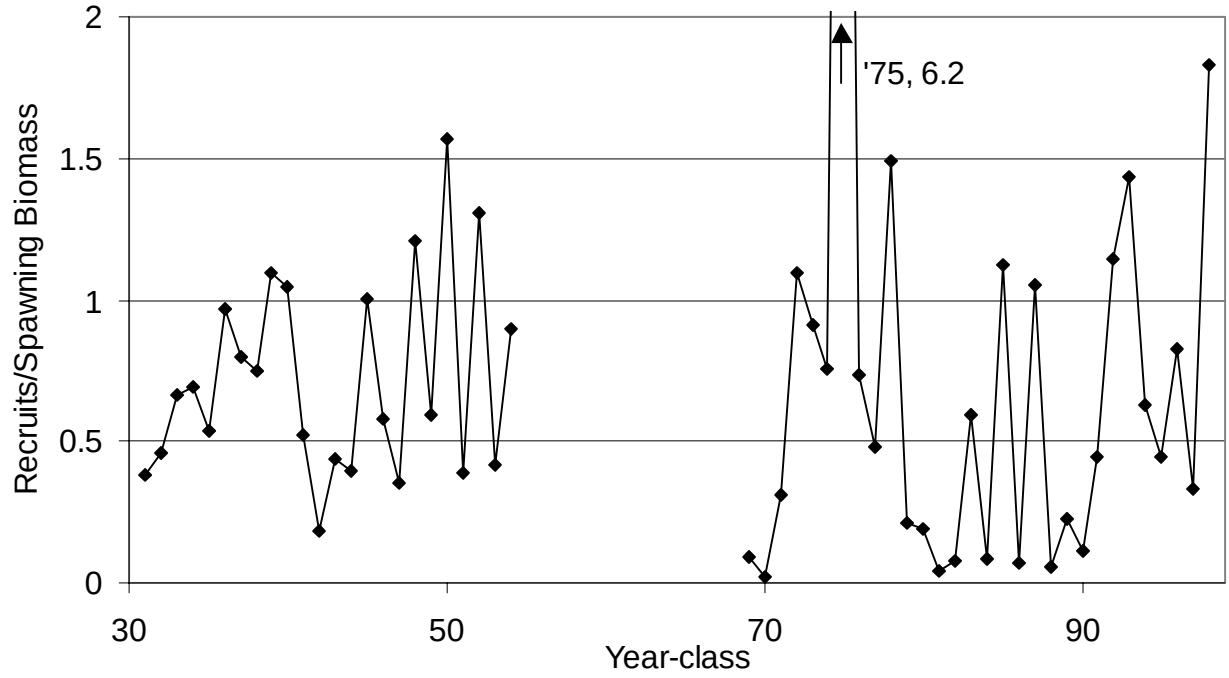

Figure 35. Ratio of recruits (numbers at age 1) per spawning biomass (kg) suggests that present survivorship appears comparable to that of the 1930s to 1950s.

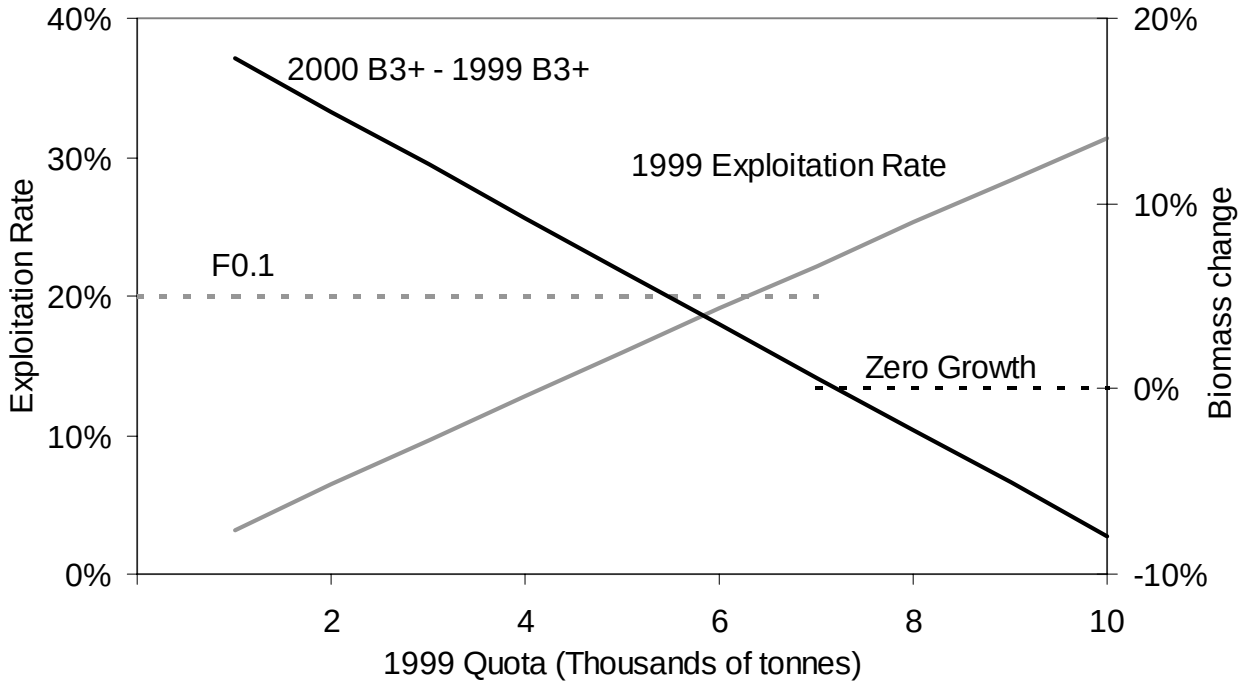

Figure 36. Expected exploitation rate in 1999 and expected change in biomass from 1999 to 2000 for 5Zjm haddock at various quotas.

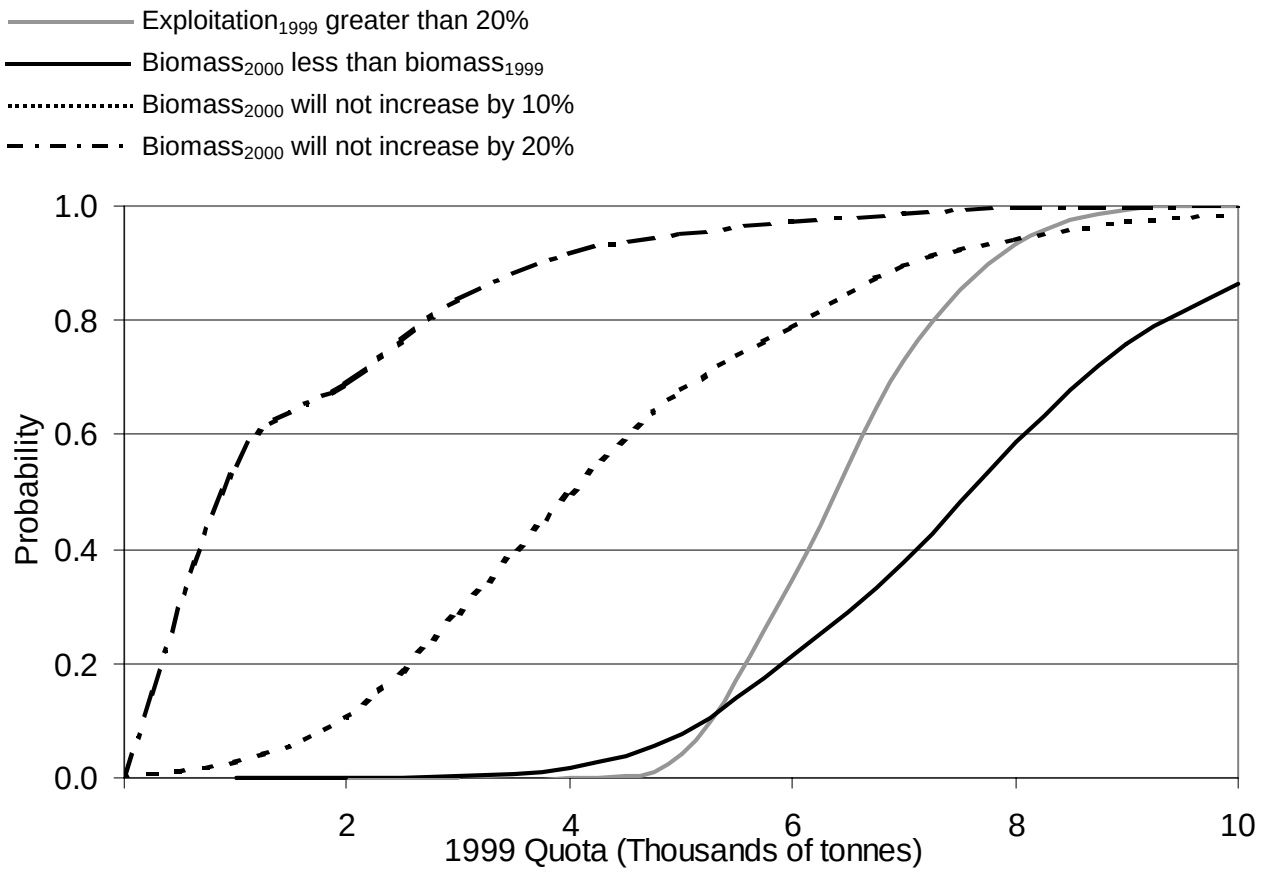

Figure 37. Probability of fishing mortality exceeding the $F_{0.1}$ (=0.25) reference level and of the 2000 biomass being less than the 1999 biomass by 0%, 10% and 20% for 5Zjm haddock at various quotas.

Appendix A.

Inter and intra-reader agreement tests for L. Van Eeckhaute, the DFO reader, and N. Munroe, the NMFS reader.

DFO 1998 Spring Survey (N773)													
First Reading	Second Reading												
	1	2	3	4	5	6	7	8	9	11	13	14	Total
1	22												22
2		23											23
3			9										9
4				3									3
5					7	1							8
6						12							12
7							7	1					8
8							1	4					5
9									3				3
10										1			1
11										4			4
13											1	1	2
Omitted						1							1
Total	22	23	9	3	7	14	8	5	3	5	1	1	101
Percent agreement = 95 ÷100 = **95 %** (1 omitted, not used in calculation)													

Figure A1. Intra-reader ageing agreement matrix for L. Van Eeckhaute for ageing material from the 1998 DFO spring survey.

DFO 1998 Spring Survey (N773)													
L. Van Eeckhaute	N. Munroe												
	1	2	3	4	5	6	7	8	9	10	11	12	Total
1	11												11
2		13		1									14
3			4										4
5					3								3
6						1	3						4
7							5						5
8							1	1	1				3
9										1			1
10										1			1
11											1	1	2
13												1	1
Omitted							1						1
Total	11	13	4	1	3	1	10	1	1	2	1	2	50
Percent agreement = 40 ÷ 49 = **82**% (1 omitted, not used in calculation)													

Figure A2. Ageing agreement matrix between N. Munroe, the NMFS reader, and L. Van Eeckhaute, the DFO reader, for ageing material from the 1998 DFO spring survey.

NMFS 1997 Fall Survey (9706)							
L. Van Eeckhaute	N. Munroe						
	1	2	3	4	5	8	Total
1	8						8
2		15	1				16
3		2	7				9
4		1		6			7
5				1	8		9
8						1	1
Total	8	18	8	7	8	1	50
Percent agreement = 45 ÷50 = **90 %**							

Figure A3. Ageing agreement matrix for N. Munroe, the NMFS reader, and L. Van Eeckhaute, the DFO reader, for ageing material from the 1997 NMFS fall survey.