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Catches of 4T-Vn (Jan.-Apr.) cod in the 4Vs winter fishery, 1980-1992.

J. Mark Hanson and Gloria A. Nielsen

Marine and Anadromous Fish Division,
Gulf Fisheries Centre,
P.O. Box 5030,
Moncton, N.B. E1C 9B6

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SUMMARY

The occurrence of significant numbers of 4T-Vn (Jan.Apr.) cod in the 4Vs winter fishery was first reported during the 1990 assessment of the 4VsW cod stock . Based on visual separation of the length-at-age distributions, 7,656 t of the January-April catches in 4Vs were attributed to the 4T-Vn (Jan.-Apr.) cod stock. Environmental conditions during the 1991 winter fishery in 4Vn and 4Vs were very similar to those observed during 1990 and an analytical technique was sought to estimate possible landings of 4T-Vn cod in the 4Vs winter fishery. The cod in 4VsW and 4T-Vn (Jan.-Apr.) grow at significantly different rates; 4T-Vn (Jan.-Apr.) cod are much smaller at age than 4VsW cod. An analytical method that uses length-at-age distributions for the two stocks when separate as templates to partition the quantities of the two stocks from mixed catches was evaluated. The method performed very well on an age-by-age basis when tested with a synthesized data set consisting of known mixtures of the two stocks. However, usage of the method to partition stocks from a mixed stock fishery requires accurate length-at-age data for the two templates representing the pure stocks and for the mixed fishery during the year in question. Catches in 4Vs were partitioned into subareas 4Vsb and 4Vsc to determine during which years significant catches of 4T-Vn (Jan.-Apr.) cod might occur. Catches in 4Vsb during the 4Vs winter fishery have only exceeded 3,000 t in 1982 and 1986 to 1992 (10,000 t in 1991). A comparison of lengths-at-age in 4Vn, 4Vsb, and 4Vsc suggested that average sizes at age in 4Vsb resembled those of 4T-Vn cod more than 4VsW cod in recent years. Sufficient data were available to calculate catches of 4T-Vn (Jan.-Apr.) cod in the 4Vs winter fishery between 1980 and 1991. Where possible, catches were analyzed separately for the winter fisheries in 4Vsb and 4Vsc (1986 and 1988 to 1992). Estimated catches of 4T-Vn (Jan.-Apr.) cod in 4Vsc ranged between 0 and 730 t during this period compared to 2,300 to 6,300 t in 4Vsb. The estimated catch of 4T-Vn (J.-A.) cod during the winter 1992 fishery in 4Vs was 4,170 t. Estimated catches of 4T-Vn (Jan.-Apr.) cod in the 4Vsb winter fishery represented and average of 55% of the total 4Vsb January to April landings during 1982, 1986 and 1988 to 1992. There currently is no allocation for catches of 4T-Vn (Jan.-Apr.) cod in 4Vsb under the current management plan. The management plan should be modified to account for these catches.

RÉSUMÉ

La présence de quantités importantes de morue de 4T-Vn (janvier à avril) dans les prises hivernales réalisées dans 4Vs, a été déclarée pour la première fois au cours de l'évaluation du stock de morue de 4VsW en 1990. Selon la séparation visuelle des différentes tailles de morue par classe d'âge, 7656 t des prises de la pêche de janvier à avril dans 4Vs ont été attribuées au stock de la morue de 4T-Vn (J-A). Les conditions écologiques qui ont prévalu au cours de la pêche hivernale de 1991 dans 4Vn et 4Vs étaient très semblables à celles observées en 1990, et nous avons cherché une technique d'analyse qui nous permettrait d'estimer les débarquements possibles de morue de 4T-Vn dans les prises de la pêche hivernale de 4Vs. La morue de 4VsW et celle de 4T-Vn (J-A) croissent à des rythmes très différents. La morue de 4T-Vn (J-A) est beaucoup plus petite que

celle de 4VsW du même âge. Nous avons évalué l'efficacité d'une méthode analytique qui se fonde sur la répartition des différentes tailles par classe d'âge pour les deux stocks, afin qu'ils servent de modèles pour séparer les prises mixtes en fonction des deux groupes d'appartenance. La méthode s'est révélée très efficace, groupe d'âge par groupe d'âge, lorsqu'on l'a essayée sur un ensemble de données synthétisé, comprenant des mélanges connus de ces deux stocks. Toutefois, l'utilisation de cette méthode pour distinguer deux stocks différents dans une pêche mixte nécessite des données précises sur la taille par classe d'âge pour les deux modèles qui représentent les deux stocks purs et pour la pêche mixte, durant l'année en question. Les prises dans 4Vs ont été réparties parmi les sous-divisions 4Vsb et 4Vsc, afin de déterminer en quelles années on peut s'attendre à d'importantes prises de morue de 4T-Vn (J-A). Les prises de la morue de 4Vsb durant la pêche hivernale dans 4Vs ont seulement dépassé le cap des 3000 t en 1982 et de 1986 à 1992 (10 000 t en 1991). Une comparaison des tailles par classe d'âge dans 4Vn, 4Vsb et 4Vsc suppose que les tailles moyennes par classe d'âge de la morue de 4Vsb ressemblent davantage à celles de la morue de 4T-Vn ainsi qu'à celles de la morue de 4VsW, depuis quelques années. Nous avions assez de données pour calculer les prises de morue de 4T-Vn (J-A) dans la pêche hivernale de 4Vs entre 1980 et 1991. Dans la mesure du possible, nous avons analysé séparément les données sur les prises des pêches hivernales dans 4Vsb et 4Vsc (1986, et 1988 à 1992). Les prises estimatives de la morue de 4T-Vn (J-A) dans 4Vsc variaient de 0 à 730 t durant cette période, contre 2300 t à 6300 t dans 4Vsb. Les prises estimatives de la morue de 4T-Vn (J-A) durant la pêche hivernale de 1992 dans 4Vs étaient de 4170 t. Les prises estimatives de la morue de 4T-Vn (J-A) dans la pêche hivernale de 4Vsb représentaient une moyenne de 55 p. 100 du total des débarquements de la morue de 4Vsb (J-A) durant 1982, 1986 et de 1988 à 1992. Il n'y a actuellement aucune disposition à l'égard des prises de morue de 4T-Vn (J-A) dans la pêche de 4Vsb en vertu du plan de gestion actuel. Ce plan de gestion devrait être modifié pour tenir compte de ces prises.

INTRODUCTION

One of the principal assumptions of analytical stock assessments is that the reported landings account for all of the catches from a particular stock. This requirement can become a problem if the species is migratory. It has long been known from tagging studies (e.g., McKenzie 1956; McCracken 1959; Powles 1959; Martin 1962; Martin and Jean 1964; Kohler 1975) that Atlantic cod from the 4T-Vn (Jan.-Apr.) stock primarily spend the winter in the Sidney Bight area (subdivision 4Vn; Fig. 1) and that some fish migrate as far south and east as Banquereau Banks (subdivision 4Vsc). Tagging studies also indicated that many of the cod caught during winter in the northern part of area 4Vs (subdivision 4Vsb) were of 4T-Vn (Jan.-Apr.) stock origin (McCracken 1959; Powles 1959; Martin and Jean 1964). Because cod catches were thought to be small during winter in this area, the winter movements of 4T-Vn (Jan.-Apr.) cod beyond the 4Vn boundary were not considered to be a problem in terms of managing the stocks. Consequently, detailed studies (including tagging studies with large numbers of fish) designed to determine the extent and variability of the winter migrations of 4T-Vn (Jan.-Apr.) cod were never initiated. Recent changes in locations fished by the otter trawl fleet and biological evidence from the area 4Vs winter landings indicate that the extent of movements of cod from the 4T-Vn (Jan.-Apr.) stock outside of

the 4Vn overwintering area needs to be reevaluated.

Cod from the 4T-Vn (Jan.-Apr.) stock are much smaller at age than those from the 4VsW stock. During the 1991 assessment of the 4VsW cod stock, Fanning and MacEachern (1991) noted that the average size-at-age of fish landed in the 1990 winter fishery was smaller than usual. Further, the length-at-age distributions for some age-classes appeared to be bimodal: one mode was near that of 4T-Vn cod during January to April and the second mode was near that of first-half-of-year catches in the 4VsW longline fishery. Based on these observations, the first quarter of 1990 catches from subdivision 4Vs were visually partitioned into a 4T-Vn (Jan.-Apr.) and 4VsW stock components. Consequently, 7,656 t of cod caught in the 4Vs winter fishery were considered to be of 4T-Vn (Jan.-Apr.) stock origin and this amount was added to the catches of the 4T-Vn (Jan.-Apr.) stock and subtracted from catches of the 4VsW stock (Fanning and MacEachern 1991; Hanson et al. 1991). We recognized, however, that a more objective method was needed to partition the catches. In addition, ice-conditions during January to April 1991 and 1992 were similar to those observed during the 1990 winter fishery in subdivisions 4Vn and 4Vs, and it was thought likely that similar mixing of the stocks in the 4Vs winter fishery had occurred.

Chouinard and Nielsen (pers. com.) used a maximum likelihood procedure (MacDonald and Pitcher 1979) to estimate the catch of 4T-Vn (Jan.-Apr.) cod in the 1991 winter fishery in the 4Vs area. This method uses estimates of mean size-at-age and the associated variances for two stocks, taken when the stocks were separate, to calculate the proportions of the two stocks in a mixed population (i.e., the 4Vs winter catch). One drawback of the method is that it requires the assumption of either a normal, lognormal, or gamma distribution for the data. Furthermore, it is tedious to use. Using this method, Chouinard and Nielsen estimated that 3,607 t of the 12,806 t of cod landed in area 4Vs during January to April 1991 came from the 4T-Vn (Jan.-Apr.) stock. To avoid potential problems caused by assuming specific data distributions, we examined a method that uses length-at-age distributions directly to separate stocks from a mixed population and have used it to calculate catches of 4T-Vn cod in the 4Vs winter fishery for as many years as possible.

There are two very similar techniques that use the Expectation Maximum algorithm with length-at-age distributions to calculate the proportions of two stocks in a mixed population. The Kimura and Chikuni (1987) method, which is used in this study, differs from the Hoenig and Heisey (1987) method in that the former assumes no sampling errors in the known length-at-age distributions. The two methods yield identical results when sample numbers are large (Hoenig and Heisey 1987), which is certainly the case in the expanded length-at-age distributions used to analyze commercial catches.

This study provides:

(1) a summary of catches and cod sampling in subdivisions 4Vn and 4Vs during January to April since 1971;

(2) where sufficient samples exist, a comparisons of average lengths at age in the winter catches in 4Vsb, 4Vsc, and 4Vn to identify years in which there

may have been large numbers of 4T-Vn (Jan.-Apr.) cod caught during the 4Vs winter fishery;

(3) a comparison of the length-at-age distributions from the 1990 winter fishery in 4Vs with those for the preceding quarter (October to December 1989) to determine whether the apparent bimodality in length-at-age distributions for the catches in the 1990 4Vs winter fishery were an isolated incident;

(4) an evaluation of how well the Kimura and Chikuni (1987) method separates mixtures of known proportions of the 4T and 4VsW stocks, in a synthesized data set, when: (a) only total length frequency distributions are available for the mixed samples and (b) when individual length frequency distributions are available for each age-class in the mixed samples; and

(5) estimates of landings and catches-at-age of 4T-Vn (Jan.-Apr.) cod in the 4Vs winter fishery for as many years as possible, splitting the catches into the 4Vsb and 4Vsc subareas where sufficient samples were collected.

(6) estimates of catches and catches-at-age of 4T-Vn (J.-A.) and 4VsW cod during the 1992 winter fishery in subdivisions 4Vsb and 4Vsc.

DATA AND ANALYSES

Age-length distributions

The Kimura and Chikuni (1987) method requires accurate length-at-age distributions from each of the two stocks thought to contribute to a mixed sample to use as templates to partition the catches of the two stocks from the mixed population. Ideally, the templates are based on samples collected at the same time as the mixed population samples but from an area where the two stocks do not mix. This is to avoid changes in length-at-age distributions caused by seasonal growth. It is also necessary to have accurate length-at-age distributions for the period when the stocks are thought to be mixed because the method performs poorly when only a total length-frequency distribution is available for the period of mixing (see results). All length-at-age distributions used in this study were determined by means of the same age-length program that is routinely used in the 4T-Vn (Jan.-Apr.) and 4VsW cod stock assessments.

The length-at-age distributions routinely used for the 4VsW cod stock assessment represent the January-March period rather than the January-April period of interest in this study. Therefore, we obtained the raw data for 4VsW cod commercial catches since 1971 and ran length-at-age analyses (mobile gears only) for the period of potential mixing (January to April), the period immediately before the mixing (October to December - with one year added to each age), and for the period immediately after the potential mixing (May and June). Sampling intensity (i.e., numbers of otoliths collected) has varied widely in the 4VsW stock during the 1971 to 1992 period included in this study (Table 1). For the presumed mixed populations, sufficient otoliths were available to permit

analysis for 1978 and 1980 to 1992. For the presumed pure 4VsW fish, there were very few otoliths collected during May and June in most years. Fortunately, there were adequate otoliths collected for the October-December period for most years between 1980 and 1992. For 1987, however, very few otoliths were collected during either the October-December 1986 or May-June 1987 periods and the samples for these two periods were combined to provide length-at-age distributions for the pure 4VsW stock.

Sufficient samples were available to calculate length-at-age distributions (mobile gears only) for 4T-Vn (Jan.-Apr.) cod from the winter fisheries in 4Vn (Jan.-Apr.) for all years since 1971 (Table 1).

Catches in the 4Vs winter fishery

All available data on winter catches in 4Vs were separated into catches in subdivisions 4Vsb, 4Vsc, and 4Vsu (unspecified) and summarized on a month-by-month basis to determine whether fishing patterns have changed in recent years. Data from the Statistics Branch of the Scotia-Fundy Region were available from 1971 to present. Catch data were available from the Statistics Branch of the Newfoundland Region for 1985 to 1992. Unfortunately no data were available for the foreign fishery (primarily prior to 1977) and the official NAFO data do not separate the catches into 4Vsb and 4Vsc components. The mobile gear sector landed an average (1980 to 1992) of 95% of the total catches in the winter fishery. The fixed gear sector (mostly longlines) landed less than 1,000 t annually during the same period (Table 2).

Statistical Analyses

The utility of the Kimura and Chikuni (1987) method for separating catches of 4T-Vn (Jan.-Apr.) cod from mixed stock catches in the 4Vs winter fishery was evaluated using two sets of synthesized data. The mixtures of known proportions of the two stocks were determined from the total length frequency or length-at-age distributions for 1990 catches in 4Vn (Jan.-Apr.) as the pure 4T-Vn (Jan.-Apr.) cod data and October-December catches in 4Vs during 1989 (one year added to each age) as the pure 4VsW cod data. Both age-length analyses were run with catches of 10,000 t to ensure that the total length frequency distributions and length-at-age distributions represented the same biomass of fish.

The first analysis used only the total length frequencies as the data for the mixed population. This analysis only assumes that the length frequency data routinely collected from the commercial fishery were representative of the catches. The total length frequencies for the two stocks when separate were combined at multiples of 10% 4T-Vn (Jan.-Apr.) fish, beginning at 0% 4T fish. The Kimura and Chikuni method was applied to these synthesized mixtures using the length-at-age distributions (based on the actual landings) for the January to April 1990 4T-Vn catches and the October-December 1989 4Vs catches as the pure distributions (or templates). The program used to analyze these mixtures was run using the SAS/IML software (SAS 1989). The output consisted of the relative

proportions (by number) of each stock in the mixture (by age), length-at-age distributions, and a total length-frequency distribution for each stock. The appropriate length-weight regression was applied to the total length-frequency distribution to calculate the biomass of each stock in the mixture.

The second analysis used the same length-at-age data as above but analyzed the data age-by-age. This analysis assumes that sufficient otoliths were collected to be representative of both stocks in the catches. The program used in the analysis is the same as above, but modified for age-by-age analysis. The output consisted of length frequency distributions on an age-by-age basis and the proportion (by number) of each stock in the mixture (for that age-class). Biomass was calculated in the same manner described above.

RESULTS AND DISCUSSION

Monthly catches in 4Vsb and 4Vsc

Data on catches in the two subareas of 4Vs were incomplete prior to 1977 because data from the foreign fleets were not available. From 1971 to 1976, the available data represented 0 to 38% of the NAFO and ICNAF total catches (Table 3). Complete information on catches by subarea were available from Scotia-Fundy region since 1977, however, complete information on location of catches from Newfoundland Region was only available since 1985. Nevertheless, the available information since 1977 represents over 78% of the official landings from the NAFO Statistical Bulletins and were considered to be representative of the total catches for the purposes of this study.

The spatial distribution of catches during the winter months have clearly changed in recent years. Beginning in 1977, winter catches in 4Vsb have ranged between 325 t during 1978 to almost 10,000 t during 1991 (Fig. 2). From 1978 to 1985, catches in 4Vsb comprised 4 to 30% of the landings in 4Vs during January to April. The catches in 4Vsb since 1986 have comprised 28 to 73% of the total 4Vs landings. Sampling of the commercial catches did not change correspondingly. With the exception of 1991, 1992, and 1988 (and in 1988 numbers of otoliths collected were very low - 260 otoliths for landings of 11,000 t), collections of otoliths since 1984 in 4Vsb have under-represented the catches by about 50%. Now that a change in the pattern of the fishery has been identified, special effort is being made to collect sufficient otoliths to permit calculation of separate length-at-age distributions for areas 4Vsb and 4Vsc. The number of otoliths needed to permit stock separation is higher (roughly 400 otoliths for each of 4Vsb and 4Vsc in January-April and 4VsW in October-December) than that required for simple age-determinations.

The temporal pattern of catches in 4Vn and 4Vs has not changed during the study period. For 1977 to 1991, the largest monthly catches in 4Vn occur in January and February (Table 4); the largest monthly catches of cod in 4Vsb were taken in February and March; and the largest monthly catches in 4Vsc were taken in March and April. During 1992, the landings during January in 4Vsb were the highest recorded since 1977. This temporal pattern in the fishery is not

surprising because many of the same boats fish in the three areas, moving out of 4Vn as they reach their quotas and into 4Vs (most recently 4Vsb, then 4Vsc). In years when 4T cod migrate extensively out of 4Vn, such a fishing pattern would maximize the landings from the 4T-Vn (Jan.Apr.) stock.

The proportion of catches of unspecified 4Vs origin have ranged between 0 and 6.5% of the total, since 1980 (Table 4). Where possible, these unspecified catches were apportioned to 4Vsb and 4Vsc in proportion to the landings in each subarea.

Length-at-age analyses

Average lengths-at-age during January to April 1980 to 1991 for cod caught in subdivision 4Vsb were compared to those in subdivisions 4Vsc and 4Vn to determine whether there were years when average lengths-at-age of cod caught in 4Vsb might indicate significant movements of 4T-Vn (Jan.-Apr.) cod into 4Vsb. Caution is needed in interpreting these comparisons because sample sizes were small for 4Vsb in some years. Average lengths of cod caught during January to April in 4Vsb were intermediate between those of cod caught in 4Vsc and 4Vn in most years (Table 5). For 1983 and 1985, the average sizes-at-age in 4Vsb closely resembled those in 4Vsc. For 1990 to 1992, the average sizes-at-age of 4Vsb cod were very similar to those of 4T-Vn cod. Coincidentally, 1990 to 1992 were the three years of highest landings in 4Vsb during January to April (Table 3).

Fanning and MacEachern (1991) separated the winter 1990 catches in 4Vs into 4T and 4VsW components (mobile gears only) based on visual identification of modes. These length-at-age distributions and the dividing line used by Fanning and MacEachern are reproduced in Table 6. For comparison, we have also included the October-December 1989 data for the 4Vs cod stock, which also appears to show polymodal distributions, particularly for ages 7 to 11. The same person did the age-determinations for both periods, thus age-determinations were consistent between periods. The causes of the apparent modes are unknown.

The positions of the 4VsW modes used by Fanning and MacEachern (1991) were those of the 4Vn winter fishery for 4T-Vn (Jan.Apr.) cod and those of the first half year longline catches in 4VsW for the 4VsW cod. The longline based length-at-age distribution overestimates the apparent differences in positions of modes between stocks because longlines catch larger individuals at age than mobile gears (here based on October-December 1989 samples with one year added to each age). Secondly, inclusion of May and June 1990 data means that some seasonal growth has already occurred, further increasing the apparent differences in average lengths-at-age between stocks. The average lengths-at-age in the 4VsW cod longline and otter trawl landings were:

Average length-at-age of 4VsW cod

	Age (y)									
Gear	3	4	5	6	7	8	9	10	11	12
Longline	43.0	48.0	54.8	58.7	62.1	71.0	71.8	76.6	89.9	96.1
Otter trawl	-	44.6	47.8	51.2	54.5	60.5	58.0	57.0	68.5	67.8

These differences in average size-at-age (greater than 10 cm for cod age-8 and older) would result in an overestimation of the size of the 4T-Vn cod component in the catches because they overestimate the average size of 4VsW cod in the January to April fishery, which is primarily prosecuted by otter trawlers.

Analysis of synthesized data

The method described by Kimura and Chikuni (1987) can only be applied on an age-by-age basis. The results of the analyses based only on overall length-frequencies in the mixed sample showed a strong symmetrical bias when the Kimura and Chikuni (1987) method was used to separate the mixture into the two stock components:

%4T fish in test data (TEST) and as separated analytically (K & C)

TEST	0	10	20	30	40	50	60	70	80	90	100
K & C	17	26	33	42	49	56	62	67	73	79	83

Even when no 4T cod were present, the analysis based only on the overall length distribution showed that significant numbers of 4T cod were present in the mixture (and vice versa). Clearly, the Kimura and Chikuni (1987) method cannot be used with total length frequencies alone. In contrast, the method performed very well when used on an age-by-age basis.

There were very few differences between the proportions-at-age in the test data and those calculated on an age-by-age basis by the Kimura and Chikuni method (Table 7), and those differences were small (< 4%). From these results, we concluded that the Kimura and Chikuni method could be used to estimate the

catches of 4T-Vn cod in the January-April fishery in 4Vs where sufficient samples were collected from subdivisions 4Vn and 4Vs for both the period of mixing and from the period when the stocks were separate. Sampling of the 4T-Vn (Jan.-Apr.) stock for the January to April period by port samplers and the International Observer Program has been adequate to date. As noted earlier, numbers of otoliths collected in subdivision 4Vs during the period of interest have varied substantially between years; this limits the number of years for which catches of 4T-Vn cod in the 4Vs winter fishery could be estimated (i.e., 1980 to 1992). More years could be analyzed if data from adjacent years could be used when the template for one or both pure stocks were missing.

Unfortunately, templates from adjacent years cannot be used in place of those for the year being analyzed. We examined the extreme case where both templates for 1990 pure stocks were replaced by templates from either 1989 or 1991. Neither templates based on 1989 nor 1991 length-at-age distributions adequately described the known 1990 mixtures (Table 8). This result was not unexpected. The technique was designed to be sensitive to differences between length-at-age distributions and significant annual variation in average length-at-age and length-at-age distributions is a normal occurence for samples collected from the commercial fisheries of nearly all fish stocks.

Catches of 4T cod in the 4Vs winter fishery

The estimates of catches of 4T-Vn cod in the 4Vs winter fishery for 1980 to 1991 were first performed on all 4Vs catches combined and, where sampling of otoliths permitted, on 4Vsb and 4Vsc catches separately. Estimates for 1992 were only based on 4Vsb and 4Vsc catches analyzed separately. Based on 4Vs as a whole, the calculated landings of 4T-Vn cod between 1980 and 1991 ranged between 277 and 4,487 t while landings in 4Vsb ranged between 1,000 and 10,000 t (Table 9). For all but 1990 and 1991, this represented less than 4% of the total 4T-Vn (Jan.-Apr) catches. These were the two years when the average lengths-at-age of cod caught in 4Vsb resembled those in 4T-Vn (Jan.-Apr.) more closely than those in 4Vsc (Table 5) and the two years of highest catches in 4Vsb. However, analyzing all 4Vs data combined underestimated catches of 4T-Vn (Jan.-Apr.) in the 4Vs winter fishery.

Sufficient otoliths were collected to permit calculation of catches-at-age of 4T-Vn (J.-A.) cod in 4Vsb separately from those in 4Vsc for 1982, 1986, and 1988 to 1992. With the exception of 1987, when few otoliths were collected in either subarea, these were the only years when greater than 3,000 t of cod were landed from 4Vsb between 1 January and 30 April (Table 9). Estimated catches of 4T-Vn (Jan.-Apr.) cod in 4Vsb were always much greater than those in 4Vsc (Table 10) and represented on average 55% of the landings in 4Vsb (see below). The estimated catches of 4T-Vn (J.-A.) cod in 4Vsc ranged between 68 and 730 t whereas catches in 4Vsb ranged between 2,100 and 6,300 t from 1986 to 1992.

Since 1986, the catches of 4T-Vn (Jan.-Apr.) cod in subdivisions 4Vsb and 4Vsc combined represent a significant source of fishing mortality outside of the

4T-Vn (Jan.-Apr.) stock area that is not accounted for in the Groundfish management plan:

Catches (t) of 4T-Vn (Jan.-Apr.) cod in 4Vs winter fishery when catches from 4Vsb and 4Vsc were analyzed separately.

Year	1982	1986	1987	1988	1989	1990	1991	1992
Estimated landings in 4Vs	805	3,469	2,087	2,496	2,475	4,606	6,330	4,170
As % 4T-Vn (Jan.-Apr.) landings in stock area	1.4	5.4	4.0	4.8	5.0	9.2	16.8	n/a
As % 4Vs winter landings	5.0	28.5	14.8	21.7	23.3	27.9	45.5	34.0
As % 4Vsb winter landings	25.8	76.7	52.9	49.8	57.1	67.4	63.3	45.3

The estimated landings of 4T-Vn cod in the 4Vs winter fishery during 1991 represented almost 17% of the catches in the 4T-Vn (Jan.-Apr.) stock area. The catches during the 1992 fishery in 4Vs represents 9.7% of the total TAC for the 4T-Vn (Jan.-Apr.) stock and 17.1% of the allocation of the mobile gear fleet within Division 4T (May to December 1992 fishery). These same catches also represented an overestimation of fishing mortality on the 4VsW stock during January to April 1986 to 1992 of 15 to 46%. If only 4Vsb is considered, the 4T-Vn (Jan.-Apr.) component has represented 26 to 77% of the landings in 4Vsb for 1982 and 1986 to 1992. There apparently was little movement of 4T-Vn (Jan.-Apr.) cod into 4Vs during January to April 1982 because estimated catches were 700 to 800 t regardless of whether the analysis was performed separately on 4Vsb and 4Vsc or on 4Vs as a whole.

The proportionately small catches of 4T-Vn cod in 4Vsc compared to those in 4Vsb (Table 10) are consistent with results of the tagging studies that indicated small numbers of 4T-Vn cod migrated as far as Banquereau Banks (in subdivision 4Vsc) in some years (McKenzie 1956; McCracken 1959; Powles 1959; Martin 1962; Martin and Jean 1964; Kohler 1975). One effect of basing analyses on 4Vs as a whole was that the large numbers of otoliths collected from 4Vsc, where there were few incursions of 4T-Vn cod, resulted in a significant underestimation of catches of 4T-Vn cod in 4Vs. The estimated catches in 4Vsb alone always exceeded those for 4Vs analyzed as a whole, therefore, future analyses should be performed separately for subdivisions 4Vsb and 4Vsc (as they were for the 1992 estimates). It is also important that the numbers of otoliths collected from the mobile gear fleet in 4VsW during October to December be sufficient (e.g., 400 or more) to permit calculation of an accurate template for the pure 4VsW stock. The sampling of the commercial fishery in 4VsW will be modified to meet these goals.

The estimated catches-at-age and biomasses of 4T-Vn (Jan.-Apr.) cod in the 4Vs winter fishery from 1986 to 1991 (Table 10) were added to the catches of the 4T-Vn (Jan.-Apr.) stock and subtracted from the catches of the 4VsW stock for the two assessments (Hanson et al. 1992; Mohn and MacEachern 1992). The estimates

based on separate analyses of 4Vsb and 4Vsc data were used for 1986 and 1988 to 1991. The analysis based on 4Vs as a whole was necessarily used for the 1987 catches. Nevertheless, the estimated catch of 4T-Vn (Jan.-Apr.) cod in the 1987 winter fishery in 4Vs was about 2,100 t.

The catch-at-age of the 4T-Vn (Jan.-Apr.) and 4VsW components of the 4Vs winter 1992 fishery have been calculated:

Catch-at-age (thousands) of 4T-Vn (J.-A.) and 4VsW in 4Vs during 1992 winter fishery

Area/age	3	4	5	6	7	8	9	10	11	12	Total
					4T-Vn (Jan.-Apr.) component						
4Vsb	0	135	793	181	428	701	283	183	135	58	2,897
4Vsc	0	0	155	0	0	27	35	0	8	8	233
Total	0	135	948	181	428	728	318	183	143	66	3,130
					4VsW component						
4Vsb	6	293	1920	2436	409	94	30	89	16	3	5,296
4Vsc	10	47	295	542	238	112	14	33	10	12	1,313
Total	16	340	2215	2978	647	206	44	122	26	15	6,609

These catches-at-age will be used in the assessments of the two stocks in the coming year.

The estimated catch of 4T-Vn (Jan.-Apr.) cod in the 1990 4Vs winter fishery from this study was substantially lower than those provided by Fanning and MacEachern (1991); 4,606 t versus 7,656 t. As pointed out earlier, however, the visual separation of the stocks based on modes and length-at-age distributions from first half-year longline samples would overestimate the 4T-Vn component in the mixed stock catches. The catches-at-age and biomasses of 4T-Vn cod in the 1990 winter fishery in 4Vs were calculated using templates based on otter trawl data (October to December 1989) and longline data (January to June 1990) to illustrate the difference in estimates caused by the larger sizes-at-age of cod caught by longlines versus otter trawls:

Catch-at-age (1000s) and biomass (tonnes) of 4T-Vn cod landed in 4Vs during January-April 1990 based on longline (LL) and otter trawl (OTB) data.

	Age										
Gear	3	4	5	6	7	8	9	10	11	12	Biomass
LL	0	58	809	1813	843	1102	733	882	101	36	8085
OTB	0	65	94	1082	602	276	709	824	5	0	4606

The estimated catch of 4T-Vn (Jan.-Apr.) cod calculated from longline data was almost twice that calculated from otter trawl data. The estimate based on the longline template, 8,085 t, was remarkably close to that estimated visually (7,656 t) by Fanning and MacEachern (1991). Because the winter fishery in 4Vs is prosecuted primarily by otter trawlers, the use of a template based on longline data was inappropriate.

Chouinard and Nielsen (pers. com.), using the MacDonald and Pitcher (1979) method, estimated that 3,607 t of 4T-Vn cod were caught during the 1991 winter fishery in 4Vs compared with 4,487 t estimated using the Kimura and Chikuni (1987) method on catches for 4Vs as a whole in this study. These results are consistent and the difference between the two estimates likely reflects the assumptions about the shape of the length-at-age distributions required by the MacDonald and Pitcher (1979) method. No attempt was made to apply the method of MacDonald and Pitcher (1979) to the data separated into subareas 4Vsb and 4Vsc, which is the preferred method of analyzing the catch data for the winter fishery in 4Vs.

Significant catches of 4T-Vn (Jan.-Apr.) cod have been taken in the winter fishery in 4Vsb since 1986 and these landings have increased since then as total cod landings have increased in 4Vsb during January to April. It has long been known that significant numbers of 4T-Vn (Jan.-Apr.) cod migrate as far as 4Vsb and this migration is expected to continue. Consequently, calculation of catches of 4T-Vn (Jan.-Apr.) cod will likely be an annual requirement as long as catches in 4Vsb continue at the levels observed since 1986. There is, however, no allocation of 4T-Vn (Jan.-Apr.) cod to the 4Vs fishery in the current management plan. Nevertheless, these catches of 4T-Vn (Jan.-Apr.) cod must be included in the catch data used in the assessment of this stock and removed from the catch data used in the assessment of the 4VsW stock. If resource managers wish to allocate catches of 4T-Vn cod to the 4Vs winter fishery, then these catches must be counted against the TAC of the 4T-Vn (Jan.-Apr.) stock. If it is desirable to reduce exogenous catches of 4T-Vn (Jan.-Apr.) cod, catches from the 4Vsb area should be brought under control by introduction of additional management measures. One such measure could be closure of the 4Vsb fishery from 1 January

to 30 April each year.

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REFERENCES

Fanning, L. P., and W. J. MacEachern. 1991. Assessment of 4VsW cod for 1991. CAFSAC Res. Doc. 91/44. 42 pp.

Hanson, J. M., G. A. Chouinard, G. A. Nielsen, and L. G. Currie. 1992. Status of the 4T-Vn (Jan.-Apr.) Atlantic cod stock in 1992. CAFSAC Working Paper 92/148.

Hanson, J. M., G. A. Chouinard, G. A. Nielsen, and L. G. Currie. 1991. Stock status of the southern Gulf of St. Lawrence cod stock (4T and 4Vn (Jan.-Apr.)) in 1991. CAFSAC Res. Doc. 91/49. 70 pp.

Hoenig, J. M., and D. M. Heisey. 1987. Use of a log-linear model with the EM algorithm to correct estimates of stock composition and to convert length to age. Trans. Am. Fish. Soc. 116: 232-243.

Kimura, D. K., and S. Chikuni. 1987. Mixtures of empirical distributions: an iterative application of the age-length key. Biometrics 43: 23-35.

Kohler, A. C. 1975. Recoveries from 1969 cod tagging in ICNAF Division 4Vn. ICNAF Res. Doc. 75/91.

MacDonald, P. D. M., and T. J. Pitcher. 1979. Age groups from size-frequency data: a versatile and efficient method of analyzing distribution mixtures. J. Fish. Res. Board Can. 36: 987-1001.

Martin, W. R. 1962. Returns from 1960 winter cod taggings. Fish. Res. Board Can., Atlantic Prog. Rep. 1961-62: 57-61

Martin, W. R., and Y. Jean. 1964. Winter cod taggings off Cape Breton and offshore Nova Scotia banks, 1959-62. J. Fish. Res. Board Can. 21: 215-239.

McCracken, F. D. 1959. Cod tagging off northern New Brunswick in 1955 and 1956. Fish. Res. Board Can., Atlantic Prog. Rep. 64: 10-15.

McKenzie, R. A. 1956. Atlantic cod tagging off the southern Canadian mainland. Bull. Fish. Res. Board Can. 105: 93 pp.

Mohn, R., and W. J. MacEachern. 1992. Assessment of 4VsW cod in 1991. CAFSAC Working Paper 92/149.

Powles, P. M. 1959. Magdalen Islands cod tagging. Fish. Res. Board Can., Atlantic Prog. Rep. 1958-59: 47-50.

SAS Institute Inc., 1989. SAS/IML software: usage and reference, Version 6, First Edition, Cary, N.C. 501 pp.

Table 1. Numbers of otoliths for which ages were determined for 4T-Vn (Jan.-Apr.) cod during January to April and for cod caught in 4Vs during January to April, 4VsW during May to June, and 4VsW during October to December from 1971 to 1992. (nr = age-length analysis not run).

Year	4T-Vn (J.-A.)	4Vs (J.-A.)	4VsW (May.-Ju.)	4VsW (O.-D.)[a]
1971	441	272	0	nr
1972	488	199	0	114
1973	471	164	0	169
1974	711	38	30	nr
1975	535	244	0	nr
1976	789	42	0	nr
1977	563	208	0	nr
1978	497	464	170	78
1979	457	45	330	241
1980	628	594	96	627
1981	618	472	181	1032
1982	709	1193	638	1131
1983	453	905	451	706
1984	402	722	484	237
1985	409	1053	185	480
1986	412	689	217	299
1987	411	777	148	165
1988	343	556	40	300
1989	672	673	27	449
1990	555	1250	81	517
1991	1055	498	nr	381
1992	619	640	nr	311

[a] moved ahead one year, e.g., 1980 otoliths were used for 1981 (one year added to each age).

Table 2. Catches by fixed gear fleet (mostly longlines) in 4Vs fishery during January to April of 1980 to 1992.

Year	Total Catches (t)	Fixed Gear Catches (t)	% Fixed Gear
1980	13,880	467	3.4
1981	8,060	736	9.1
1982	16,138	461	2.9
1983	6,836	346	5.1
1984	13,479	150	1.1
1985	18,630	191	1.0
1986	12,485	609	4.9
1987	14,139	402	2.8
1988	10,763	578	5.6
1989	10,592	742	7.0
1990	15,481	941	6.1
1991	12,806	-	-
1992	12,296	788	6.4

Table 3. Summary of cod catches during January to April in 4Vsb and 4Vsc (based on ZIFF summaries), total catches in 4Vs from NAFO statistical bulletins, and numbers of otoliths collected in 4Vsb and 4Vsc during January to April of 1977 to 1992.

	ZIFF Data				NAFO	No. otoliths collected	
Year	4Vsb	4Vsc	4Vs[a]	%Vsb	4Vs	4Vsb	4Vsc
1971[b]	114	1,791	7,412	1.5	19,497	-	-
1972[b]	511	2,678	6,377	8.0	26,348	-	-
1973[b]	1,233	1,595	3,127	39.4	15,530	-	-
1974		no data			12,968	-	-
1975[b]	186	677	1,135	16.4	7,441	-	-
1976[b]	649	1,191	2,332	27.8	6,272	-	-
1977[b]	879	689	1,598	55.0	1,898	-	-
1978[b]	325	1,849	2,364	13.7	2,872	-	-
1979[b]	366	3,005	4,079	9.0	4,130	-	-
1980[b]	2,557	8,092	10,985	23.3	13,880	91	420
1981[b]	1,022	5,198	6,295	16.2	8,060	163	309
1982[b]	3,120	9,332	12,580	24.8	16,138	183	859
1983[b]	1,775	3,995	5,778	30.7	6,836	130	298
1984[b]	549	11,964	12,513	4.3	13,479	0	670
1985	1,331	16,895	18,372	7.2	18,630	54	948
1986	4,522	7,438	12,177	37.1	12,485	134	466
1987	3,942	9,216	14,076	28.0	14,139	37	415
1988	5,010	5,986	11,504	43.6	10,763	112	148
1989	4,337	6,198	10,592	40.9	na	133	427
1990	6,828	9,168	16,533	41.2	na	161	544
1991	9,999	3,906	13,905	71.9	na	330	127
1992	9,214	3,075	12,296	75.0	na	458	182

[a] includes catches not identified to 4Vsb or 4Vsc

[b] Scotia-Fundy data only

na not available

Table 4. Monthly catches (t) of cod in 4Vn, 4Vsb, 4Vsc, and 4Vsu (unknown) during January to April 1977 to 1992.

Year	Area	Jan.	Feb.	Mar.	Apr.	Total	% Total 4Vs
1977[a]	4Vn	819	863	908	93	2,683	-
	4Vsb	266	275	314	24	879	55.0
	4Vsc	70	161	330	128	689	43.1
	4Vsu	0	0	21	9	30	1.9
1978[a]	4Vn	5,360	6,080	942	57	12,439	-
	4Vsb	21	52	60	192	325	13.7
	4Vsc	7	104	247	1,491	1,849	78.2
	4Vsu	0	4	152	34	190	8.0
1979[a]	4Vn	1,220	5,172	2,304	605	9,301	-
	4Vsb	233	75	29	30	366	9.0
	4Vsc	8	205	2,420	372	3,005	73.7
	4Vsu	2	6	602	98	708	17.4
1980[a]	4Vn	4,826	8,373	3,153	2,125	18,477	-
	4Vsb	26	78	2,307	146	2,557	23.3
	4Vsc	74	337	2,976	4,706	8,092	73.6
	4Vsu	6	0	90	246	343	3.1
1981[a]	4Vn	8,661	3,615	2,858	1,911	17,045	-
	4Vsb	71	171	663	117	1,021	16.2
	4Vsc	465	323	1,927	2,483	5,198	82.6
	4Vsu	0	0	71	3	74	1.2
1982[a]	4Vn	4,229	5,748	3,118	1,680	14,775	-
	4Vsb	841	1,451	587	241	3,120	24.8
	4Vsc	795	1,249	3,718	3,571	9,332	74.2
	4Vsu	0	9	119	0	128	1.0
1983[a]	4Vn	5,697	5,706	593	1,077	13,073	-
	4Vsb	575	615	460	125	1,775	30.7
	4Vsc	177	448	2,001	1,369	3,995	69.1
	4Vsu	0	0	8	0	8	0.1
1984[a]	4Vn	7,427	3,787	1,834	1,664	14,712	-
	4Vsb	225	237	50	37	549	4.4
	4Vsc	2,751	1,203	1,685	6,326	11,964	95.6
	4Vsu	0	0	0	0	0	0.0
1985	4Vn	5,230	7,141	1,086	862	14,319	-
	4Vsb	122	350	666	194	1,331	7.2
	4Vsc	1,684	2,419	4,932	7,860	16,896	92.0
	4Vsu	2	89	0	56	146	0.8

Table 4. Continued.

Year	Area	Jan.	Feb.	Mar.	Apr.	Total	% total 4Vs
1986	4Vn	6,366	6,559	789	1,995	15,709	-
	4Vsb	147	1,377	2,218	781	4,522	36.3
	4Vsc	1,123	1,183	2,086	3,320	7,711	61.9
	4Vsu	1	0	3	213	217	1.7
1987	4Vn	3,181	3,099	731	544	7,555	-
	4Vsb	448	1,227	1,714	553	3,942	28.0
	4Vsc	524	2,212	3,379	3,102	9,217	65.5
	4Vsu	15	92	588	223	918	6.5
1988	4Vn	2,737	1,887	1,391	1,427	7,442	-
	4Vsb	1,116	1,312	2,013	569	5,010	43.6
	4Vsc	1,746	2,085	697	1,458	5,986	52.0
	4Vsu	24	344	84	56	508	4.4
1989	4Vn	3,172	1,473	440	3,783	8,868	-
	4Vsb	1,372	1,539	913	513	4,337	39.1
	4Vsc	638	281	3,241	2,039	6,198	55.8
	4Vsu	66	16	418	69	568	5.1
1990	4Vn	3,680	2,862	1,243	1,788	9,573	-
	4Vsb	1,411	4,040	1,205	172	6,828	41.3
	4Vsc	745	2,840	4,456	1,128	9,168	55.5
	4Vsu	76	141	200	121	538	3.3
1991	4Vn	2,246	2,686	975	744	6,651	-
	4Vsb	1,339	4,907	2,631	1,123	9,999	71.9
	4Vsc	836	608	1,134	1,328	3,906	28.1
	4Vsu	0	0	0	0	0	0
1992	4Vn	na	na	na	na	6,453	-
	4Vsb	2,354	2,229	2,643	1,756	8,982	73.1
	4Vsc	430	1,035	746	805	3,017	24.6
	4Vsu	123	57	0	110	290	2.3

[a] Scotia-Fundy data only

Table 5. Comparison of average lengths-at-age of cod caught in 4T-Vn, 4Vsb, and 4Vsc during January to April 1980 to 1992.

		Age (y)									
Year	Area	3	4	5	6	7	8	9	10	11	12
1980	4T-Vn	41.4	42.3	45.6	50.3	54.1	63.3	65.8	67.0	76.7	72.3
	4Vsb	-	44.5	50.2	54.9	61.0	79.5	69.2	82.5	76.0	-
	4Vsc	42.6	47.1	54.0	58.9	68.3	77.0	85.6	92.2	94.4	85.7
1981	4T-Vn	-	39.3	34.4	48.1	51.5	54.4	67.4	71.3	80.8	87.4
	4Vsb	40.0	46.7	51.0	54.0	57.7	66.1	64.0	81.0	-	-
	4Vsc	40.5	47.0	53.6	61.3	69.5	76.5	87.4	94.3	95.9	-
1982	4T-Vn	34.0	39.1	45.1	48.8	52.8	55.7	62.2	66.9	71.8	76.3
	4Vsb	42.8	45.5	51.1	59.2	59.2	59.8	67.2	75.4	92.2	82.0
	4Vsc	43.1	46.8	54.2	62.2	63.8	72.8	77.9	86.7	94.6	107.0
1983	4T-Vn	-	38.7	46.5	49.2	51.9	55.6	58.3	60.3	82.3	88.7
	4Vsb	37.0	45.2	51.1	57.8	67.3	66.0	67.4	91.3	81.4	103.7
	4Vsc	40.4	46.0	52.7	58.5	66.3	69.9	66.8	90.2	97.9	101.0
1984	4T-Vn	-	38.2	41.4	46.1	50.6	52.8	56.5	56.8	62.4	74.5
	4Vsb	no data									
	4Vsc	45.0	49.1	54.0	59.4	66.3	72.4	72.4	79.6	93.6	92.2
1985	4T-Vn	30.6	37.3	42.3	47.1	51.1	54.8	58.3	58.3	61.7	65.2
	4Vsb	-	46.0	50.4	59.6	62.0	67.8	83.7	70.4	89.4	84.2
	4Vsc	41.6	46.2	52.5	58.0	62.6	67.0	72.8	78.8	79.1	68.8
1986	4T-Vn	31.0	37.2	40.9	44.9	48.1	52.6	54.2	54.7	58.2	56.1
	4Vsb	-	36.5	44.6	48.1	54.2	59.6	58.6	59.0	65.5	58.0
	4Vsc	38.3	46.2	50.3	57.0	64.5	65.3	71.1	78.1	78.3	99.8
1987	4T-Vn	33.4	37.1	42.4	44.8	46.3	49.5	51.5	53.2	56.3	61.8
	4Vsb	-	-	48.1	49.8	50.3	55.9	65.4	59.2	77.0	-
	4Vsc	36.9	45.5	51.2	55.2	61.0	67.8	70.5	73.8	95.6	-
1988	4T-Vn	25.0	36.3	40.4	45.0	47.5	48.5	49.9	54.9	55.0	72.7
	4Vsb	34.0	42.7	42.8	49.8	54.2	54.9	55.2	58.1	92.2	103.1
	4Vsc	-	43.4	48.4	58.2	61.6	66.1	69.0	76.0	73.0	76.6
1989	4T-Vn	-	37.5	40.1	43.7	46.7	49.1	49.2	50.9	59.2	58.1
	4Vsb	-	46.4	43.5	47.5	53.0	51.4	53.5	57.5	60.8	60.4
	4Vsc	38.5	45.8	49.5	55.4	62.0	64.6	67.7	75.5	93.0	80.0

Table 5. Continued.

Year	Area	Age (y) 3	4	5	6	7	8	9	10	11	12
1990	4T-Vn	37.0	41.4	45.5	48.9	50.4	51.0	51.4	51.6	52.1	55.2
	4Vsb	-	42.4	47.6	49.1	51.2	56.5	53.9	53.8	64.0	-
	4Vsc	28.0	45.5	48.5	52.1	55.6	60.1	58.4	59.3	63.7	72.4
1991	4T-Vn	-	39.0	45.7	47.9	50.5	52.9	54.4	54.8	53.4	56.5
	4Vsb	37.8	45.8	48.9	51.0	51.7	53.3	53.8	54.5	59.6	57.2
	4Vsc	40.0	45.1	50.8	55.3	57.4	62.4	64.0	63.8	76.4	70.5
1992	4T-Vn	31.0	40.7	43.6	47.9	51.2	54.4	54.7	57.3	56.5	56.8
	4Vsb	34.0	43.3	46.6	50.5	54.1	55.6	55.6	57.2	60.7	60.3
	4Vsc	46.0	47.4	50.8	55.1	59.6	59.5	62.7	60.4	61.8	56.2

Table 6. Length-at-age distributions for 4VsW cod during October-December 1989 (one year added to each age) and January-April 1990. Horizontal lines represent divisions into 4T-Vn (Jan.-Apr.) and 4VsW stocks from Fanning and MacEachern (1991).

	4		5		6		7		8		9	
FL (cm)	O-D	J-A	O-D	J-A	O-D	J-A	O-D	J-A	O-D	J-A	O-D	J-A
34	0	15	0	0	0	0	0	0	0	0	0	0
37	4	38	0	0	0	0	0	0	0	0	0	0
40	52	45	19	30	13	10	0	0	0	0	0	0
43	130	154	118	141	47	77	0	26	0	26	0	0
46	142	181	342	422	228	151	28	361	28	60	0	60
49	78	194	628	824	196	436	78	242	0	97	39	194
52	0	0	407	456	370	547	74	547	111	46	0	137
55	0	32	141	411	311	316	141	285	57	63	28	63
58			0	82	241	327	54	204	80	61	107	41
61			17	29	153	172	170	86	34	100	17	100
64					35	27	140	95	12	68	35	47
67					17	0	66	76	17	16	50	32
70					1	5	29	43	29	27	34	22
73							25	12	31	16	37	24
76									12	18	23	45
79									4	12	19	43
82									4	12	10	17
85									5	3	4	7
88									0	2	0	7
91											2	5
94											0	0
97											2	0

Table 6. Continued.

FL (cm)	10		11		12	
	O-D	J-A	O-D	J-A	O-D	J-A
34	0	0	0	0	0	0
37	0	0	0	0	0	0
40	0	0	0	0	0	0
43	0	0	0	0	0	0
46	0	30	0	0	0	0
49	39	97	0	0	0	0
52	0	91	37	46	0	46
55	28	158	57	0	0	0
58	54	61	27	61	0	0
61	34	71	17	43	0	0
64	12	7	35	27	0	0
67	25	27	8	38	8	5
70	17	11	0	22	6	0
73	0	24	18	4	0	0
76	0	5	6	9	6	0
79	4	6	8	6	0	0
82	15	7	2	3	0	3
85	8	2	12	2	0	0
88	9	4	5	0	5	0
91	0	2	2	0	7	2
94	3	0	3	11	6	0
97	2	0	0	1	4	1
100			1	0	1	5
103			2	0	2	1
106			3	0	1	0
109			3	0	0	0
112			0	0	0	1

Table 7. Test of Kimura and Chikuni (1987) method of separating 4T-Vn (Jan.-Apr.) and 4VsW cod using mixtures comprised of known proportions from each stock (1990 data). S = calculated proportions K = results from Kimura and Chikuni method. Results given as % 4VsW fish in mixture.

% 4T	10		30		50		70		90	
Age	S	K	S	K	S	K	S	K	S	K
3	0	0	0	0	0	0	0	0	0	0
4	98	98	93	93	84	84	70	70	37	38
5	98	98	92	92	83	83	67	67	35	34
6	91	91	73	73	54	54	33	34	12	11
7	88	89	66	67	45	46	26	27	8	9
8	81	81	52	52	32	32	17	17	5	5
9	83	83	55	55	35	35	19	19	6	6
10	77	77	47	47	27	28	14	15	4	5
11	63	64	30	31	16	17	7	8	2	3
12	73	73	41	41	23	26	11	10	3	0

Table 8. Effect of using templates from adjacent years on estimates of proportions of 4VsW cod in mixtures of known composition (1990 data). S = calculated proportions at age; 90 = results from 1990 templates; 91 = results from 1991 templates; 89 = results from 1989 templates.

	10% 4T				50% 4T				90% 4T			
Age	S	90	91	89	S	90	91	89	S	90	91	89
3	0	0	0	0	0	0	0	67	0	0	0	60
4	98	98	52	97	84	84	90	88	37	38	48	69
5	98	98	74	98	83	83	53	92	35	34	8	69
6	91	91	66	90	54	54	41	88	12	11	14	65
7	88	89	44	72	45	46	17	48	8	9	0	22
8	81	81	53	84	32	32	15	49	5	5	0	26
9	83	83	25	58	35	35	8	36	6	6	0	15
10	77	77	19	27	27	28	6	11	4	5	1	2
11	63	64	65	23	16	17	18	5	2	3	1	0
12	73	73	21	2	23	26	7	1	3	0	1	0

Table 9. Summary of estimated catches of 4T-Vn (Jan.-Apr.) cod in the 4Vs winter fishery (4Vs analyzed as a whole), catches of 4T-Vn (Jan.-Apr.) cod within the stock area, and catches of cod in subdivision 4Vsb from 1980 to 1992.

Year	4Vsb catches	4T-Vn cod in 4Vs	4T-Vn cod within stock area	Catch of 4T-Vn cod in 4Vs as %4T-Vn catches within the stock area
1980	2,557	1,541	54,634	2.8
1981	1,022	277	65,177	0.4
1982	3,120	737	58,193	1.3
1983	1,775	895	61,295	1.5
1984	549	1,404	55,364	2.5
1985	1,331	1,763	62,138	2.8
1986	4,522	2,240	63,695	3.5
1987	3,942	2,087	51,126	4.0
1988	5,010	1,345	52,058	2.6
1989	4,337	552	49,953	1.1
1990	6,828	2,530	49,936	5.1
1991	9,999	4,487	37,615	11.9
1992	9,214	-	-	-

Table 10. Estimated catches-at-age (1000s) and biomass of 4T-Vn (Jan.-Apr.) cod in the 4Vs winter fishery when 4Vsb and 4Vsc are estimated separately and when analyses were based on 4Vs as a whole.

	Age										
Area	4	5	6	7	8	9	10	11	12	Total	Biomass (t)
					1992						
4Vsb	135	793	181	428	701	283	183	135	58	2,897	3,826
4Vsc	0	155	0	0	27	35	0	8	8	233	344
Sum	135	948	181	428	728	318	183	143	66	3,130	4,170
4Vs					not done						
					1991						
4Vsb	92	336	645	1969	506	729	575	17	61	4,932	6,262
4Vsc	0	35	0	3	0	2	1	0	0	41	68
Sum	92	371	645	1972	506	731	576	17	61	4,973	6,330
4Vs	63	274	115	1287	342	597	462	0	46	3,187	4,487
					1990						
4Vsb	24	39	1082	516	91	530	815	0	0	3,097	3,876
4Vsc	41	55	0	86	185	179	9	5	0	560	730
Sum	65	94	1082	602	276	709	824	5	0	3,657	4,606
4Vs	33	76	496	114	404	358	410	39	0	1,930	2,530
					1989						
4Vsb	0	45	201	353	552	664	106	49	59	2,029	2,475
4Vsc	0	0	0	0	0	0	0	0	0	0	0
Sum	0	45	201	353	552	664	106	49	59	2,029	2,475
4Vs	0	22	27	98	132	148	23	42	30	522	552
					1988						
4Vsb	5	391	611	573	513	277	108	0	0	2,473	2,296
4Vsc	0	0	0	6	0	0	47	0	1	54	200
Sum	5	391	611	579	513	277	155	0	1	2,527	2,496
4Vs	11	47	170	326	239	154	126	21	0	1,094	1,345

Table 10. Continued.

Area	Age 4	5	6	7	8	9	10	11	12	Total	Biomass (t)
					1987						
4Vs	62	294	518	584	97	177	112	13	9	1,874	2,087
					1986						
4Vsb	121	515	1637	221	90	141	92	58	24	2,899	2,904
4Vsc	0	27	0	0	123	60	16	28	0	254	565
Sum	121	542	1637	221	213	201	108	86	24	3,153	3,469
4Vs	62	375	757	79	234	177	63	78	14	1,839	2,240
					1982						
4Vsb	0	91	25	147	136	17	4	0	1	421	630
4Vsc	2	4	14	92	0	2	5	0	0	119	175
Sum	2	95	39	239	136	19	9	0	1	540	805
4Vs	0	36	39	257	111	19	11	0	2	475	737

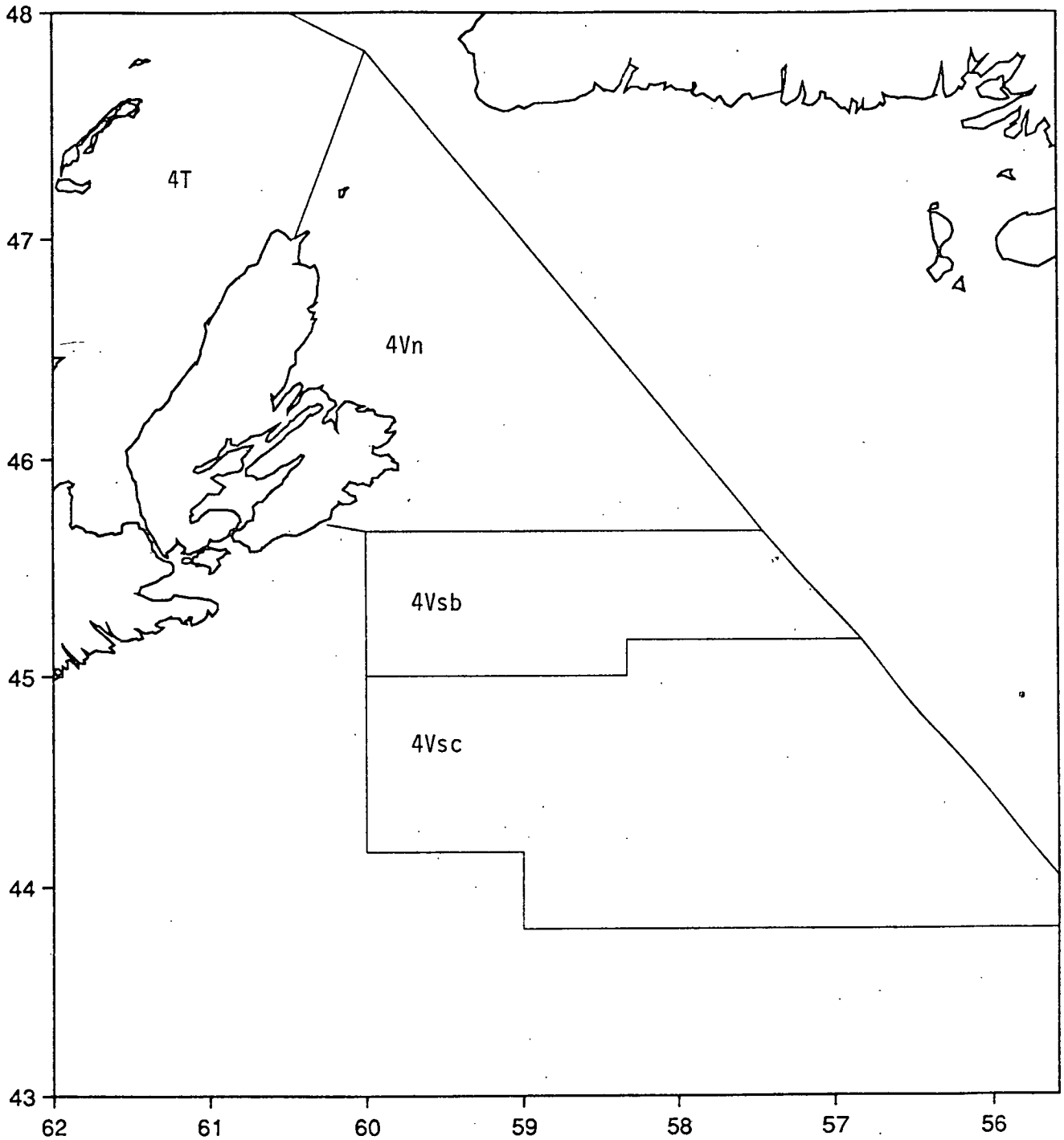

Figure 1. NAFO areas occupied by 4T-Vn (J.-A.) and 4VsW cod stocks.

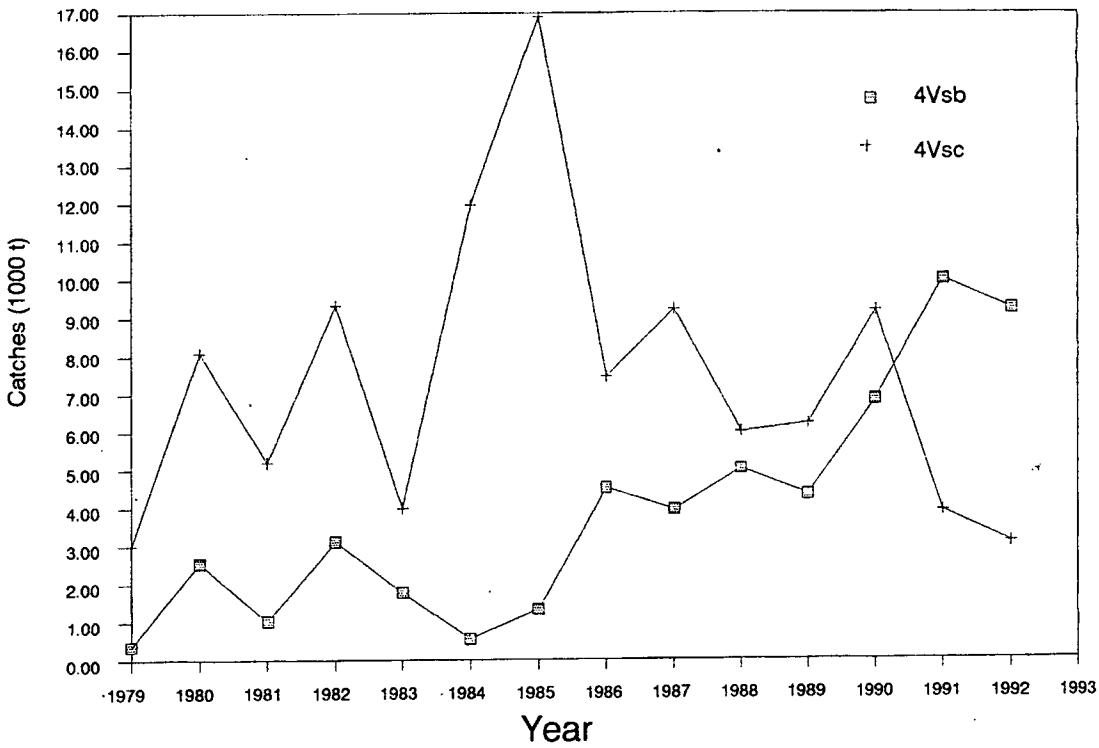

Figure 2. Catches of cod in 4Vsb and 4Vsc, 1979 to 1992.