

4Vsw Cod Assesement

by

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Abstract

The 4Vsw cod fishery is, since 1977, almost 100% Canadian. Due to misreporting of catch locations the Canadian mobile fleet catch per unit effort is believed to be unreliable. Because no other country participated in the fishery, the Canadian research vessel survey is the only available index of abundance and was used to find the 1979 fishing mortality. The stock abundance still appears to be increasing but at a slower rate. Assuming a 1980 catch of 45,000 tons, the 1981 catch at $F_{0.1}$ would be 49,000 tons.

Résumé

Depuis 1977, la presque totalité des captures de morue dans les Divisions OPANO (Organisation des Pêcheries de l'Atlantique du Nord-Quest) 4Vs et 4W ont été effectuées par des bateaux canadiens. Il appert que depuis la même année la flotte hauturière canadienne n'a pas rapporté fidèlement la localisation de ses captures attribuant à d'autres Divisions des captures qui en réalité avaient été effectuées dans 4Vsw. Bien que des mesures aient été prises pour corriger les données quant à la zone de capture, il fut impossible d'apporter des corrections semblables aux données d'effort, le résultat immédiat étant que les données d'effort, de prise par unite d'effort flotte canadienne sont inutilisables à des fins d'évaluations des stocks. Puisqu'aucun autre pays n'a participé à la pêche depuis 1977, l'indice d'abondance calculé à partir des résultats des campagnes d'échantillonnage scientifique est le seul qui soit disponible et il fut utilisé pour déterminer la mortalité due à la pêche en 1979. L'abondance du stock semble continuer à augmenter bien qu'à un taux moindre. Supposant des captures de 45,000 t en 1980, la prise correspondant à $F_{0.1}$ en 1981 serait de 49,000 t.

Introduction

The cod fishery in NAFO Divisions 4Vs and 4W is based on a stock complex (Templeman, 1962; Martin and Jean, 1964) but due to the considerable mixing among adults of these stocks and given the present state of knowledge it appears most practical to consider this complex as a single unit for assessment purposes (Halliday, 1972). This stock complex first came under quota management in 1973 when ICNAF set the Total Allowable Catch at 60,500 t. The TAC was lowered to 60,000 t in 1974 and 1975 and to 30,000 t in 1976. The TAC was not caught in any of these years supporting Halliday who had already stated in 1972, based on yield-per-recruit calculations and recruitment predictions from research vessel surveys and commercial catch, that the 1973 TAC was higher than desirable for that stock. Both commercial and research vessel catch per unit effort indicated an increase in abundance in 1978. The stock now appears to be continuing to increase in 1979 but at a slower rate than between 1977 and 1978.

Nominal catches

Table 1 shows the nominal catches since 1958 by country and by NAFO Divisions and associated TAC's. The catches from 1958 to 1972 fluctuated between 40,000 (1958) and 80,000 tons (1968) averaging 61,000 tons. For the period 1958 to 1976 Spain was the main harvester taking 57% of the total catch followed by Canada (29%), USSR (6%), France (3%), Portugal (2%) while other countries caught about 2% of the total catch. The average catches for Spain and Canada were respectively 32,000 and 16,500 tons. The participation of France and Portugal were highly variable from one year to the next while the USSR showed more consistency. Since 1977 Canada took almost 100% of the catch. The proportion of that total catch taken in each Division varied from year to year with the catches in 4Vs being more variable. During the whole period each Division contributed about equally to the catch.

For the first three years of quota management (1973-1974-1975), the TAC was set at about the average catch for 1958-1972 (60,500 - 60,000 - 60,000 t). However after the 1975 fishing season, during which only 54% of the TAC was caught, the 1976 TAC was lowered to 30,000 tons of which only 81% was caught. As a result of the analyses of the status of the stock that indicated a severe decline and a 1976 catch still below the allowed levels, the TAC was reduced to 7,000 tons for 1977 and 1978. In both of these years there appeared to be a problem with the accuracy of catch location reporting for the Canadian mobile fleet and it is estimated that for both years the catch was above allocations. The data for 1977 comes from the ICNAF Statistical Bulletin and has not been corrected while the 1978 figure is the best estimate developed for assessment purposes through analysis of surveillance data. In 1979 misreporting apparently was less of a problem. Table 1 shows the corrected figures for 1978 and 1979. Prior to 1977, there does not appear to be a problem with the reported area of catch for the Canadian fleet and therefore the Canadian nominal catches are probably fairly accurate. In spite of low allocations and of a shortage of fish in most areas, Canada never took its allocation in the years 1973-1976 with utilization falling to only 41% in 1975.

Abundance indices:

Research vessel surveys

Random stratified surveys have been conducted on the Scotian Shelf in a standardized manner since 1970 on the *A. T. Cameron* during the summer months. In 1978 and 1979 there was also a fall survey by the *Lady Hammond*. Although in both years the fall survey appeared to agree quite well with the summer survey as to age composition and population estimates, the former survey was not used in this analysis because it is too soon to say whether any differences are due to the vessel used, the time of year or simply random fluctuations.

The research vessel survey population estimate for 1973 appeared abnormally high, almost an order of magnitude higher than any of the adjacent years. Gray (1979) found that this was due to extraordinary high catches of small fish in strata 58 and 59 (the area on and north of Middle Bank). Although young fish are known to concentrate in this area it was Gray's conclusion that these two sets should be removed and the abundance estimated without them to render the 1973 population estimate comparable to other years. Table 2a presents the population at age estimates from 1970 to 1979 with the two abnormal sets in 1973 excluded and table 2b with these two sets included. Figure 2 shows the trends in the total population estimates and in the age 4 and older population estimates. This figure indicates that the age 4 and older data appear to be less subject to random fluctuations. According to the survey data, the abundance would have gone from a low value in 1970 to a maximum in 1972 and would have increased steadily from 1976 to 1978 and would have stabilized at the 1978 level in 1979.

Commercial catch per unit of effort

The catch per unit of effort of the Spanish pair trawl fleet (tonnage class 4) was analysed by Gray (1979). He found that the CPUE data was well correlated with both the 1+ and 4+ biomass. However, this data set is of no use at this time due to the ending of the Spanish participation in that fishery in 1977.

Although it was possible to correct for misreporting of catch location for the Canadian mobile fleet, a realistic correction of effort has proven to be impossible. The research vessel survey population estimate is thus the only abundance index used and presented in this analysis. However, it should be noted that this index agrees fairly well with most of the other indices for the period prior to 1977.

Catch-at-age

The catch at age data for the period 1966 to 1978 was taken from Gray (1979). The sampling coverage of the 4VSW cod catches in 1979 was adequate with 54 commercial samples being taken. The temporal and gear coverage has generally been acceptable except that only one sample (OTB-1) has been taken in the first quarter. For the remainder of the year, the otter-trawl, long-line and seine catches have been fairly well sampled while no samples for gillnets or traps were available for any period of the year but these gears did not contribute significantly to the catch (330 tons or 1% of the total). Thus due to time and gear type representation it was necessary to combine the catch on the basis of available samples. Gillnet catches were added to the long-line and hand-line catches and the quarterly length-frequencies and age-length keys derived were applied to quarterly catches. Quarter 1 and 2 catches and samples were combined for these gears since no samples were available for the first quarter. Seine samples of the third quarter were applied to seines, and trap and shrimp trawl catches for the first three quarters combined (no samples in quarter one and two). The fourth quarter for these gears was treated separately.

The catch at age for 1979 is similar to that of 1977 and 1978 with few young fish caught, reflecting the closure of the Spanish fishery in 1977. The fishery concentrated on age 4, 5 and 6 fish. Table 3 shows the 4VSW cod catch at age since 1966.

Assessment Parameters

Partial recruitment multipliers

Partial recruitment multipliers were calculated by taking the ratios of the percent catch at age (ages 2 to 10) in the commercial fishery to the percent catch at age (same age groups) in the research vessel survey and then dividing this vector by the highest ratio to obtain a maximum of 1 (table 4). In 1979 fishes appeared to be fully recruited at age 6 and to be recruited at 93% at age 5. The partial recruitment multipliers dropped after age 6 to reach 28% at age 10. Such a vector may seem surprising when the selectivity of the different gears are considered. The drop in partial recruitment multipliers after age 6 is probably due to the distribution characteristics of older fish.

These are probably present in a smaller proportion in the areas or depths where most of the fishery occurs as they grow older. These partial recruitment multipliers are given in table 4 and were used in trial runs of virtual population analysis.

Fishing mortality

Age 2 to 12 were used to run virtual population analysis. Age 1 was excluded because no age one fish were caught in 1979 and the table was chopped after age 12 because of the presence of zero catches in several instances.

With the partial recruitment multipliers given in table 4, trials were made to find the final F that gave the best agreement between estimates of the age 4 and older population size from the research data and from virtual population analysis.

The research vessel surveys are conducted in July and thus estimate the population abundance in the middle of the year while the virtual population analysis estimates the population abundance at the beginning of the year. In order to make things comparable the VPA population corresponding to the middle of the year was estimated by taking the year-class specific averages of VPA population abundance estimates for year t and year t + 1. The value for 1979 was calculated by projecting to 1980 the population estimates from known catches, fishing mortality and natural mortality.

The process was started with an arbitrarily chosen fully recruited F of 0.1 with F being increased by 0.05 after. After a few runs were made it became obvious that the 1970 point was out of line and could not be brought into line whatever the 1979 starting F was. Although the relationship was good, the 1970 point was causing a high intercept value. In that year the research vessel survey indicated a low population abundance while VPA suggest that the stock was then at its maximum for the period considered. Since 1970 was the first year of the survey and as minor gear modifications were made for 1971 and subsequent surveys which, despite their minor nature, may have affected the catchability of cod by the gear (Halliday, pers. comm.), the 1970 point was not included when the regressions were calculated. The best relationship was then found for a fully recruited F of 0.25 ($r^2 = 0.81$). However, the 1979 value was not well predicted by earlier points. At a fully recruited F of 0.30, the correlation between the two sets of numbers gave a $r^2 = .79$ and the difference between the 1979 point from VPA and that predicted by earlier points was about 5%.

This method of adjusting the VPA only considered ages 4+ and this is not affected by the size of the 1976-1977 year-classes. When the research vessel estimated abundance at age 2 and 3 for these year-classes were compared to previous year-classes abundances, it appeared that these were underestimated in the VPA. The same appeared to be true for the 1975 year-class. The 1979 partial recruitment multipliers at age 2 - 3 - 4 were consequently adjusted in the manner described below. The first step was to calculate the average population abundance for ages

2, 3 and 4 during the period 1970 to 1975 for both the VPA and the research data. Then the ratios of the population estimates at age to the mean (1970-75) for the 1975 to 1977 year-classes were calculated again for both the VPA and the research data. This provided one or more ratios for each year-class and the average was taken for each year-class. The ratio of research to VPA is then the correction factor that should be applied to VPA year-class size estimate. This ratio was used to correct the partial recruitment multipliers in 1979. This procedure is, for all practical purposes, identical to correcting the year-class sizes and then calculating the F's at age in 1979 from known catches. Table 5 shows the details of the calculations and tables 6 and 7 the resulting population and fishing mortality at age tables.

Yield per recruit

The corrected set of partial recruitment multipliers derived above and mean weights at age of table 8 were used, with an $M = 0.2$, to run a Thompson-Bell yield per recruit analysis. This gave a maximum yield per recruit of 0.83 kg at a fishing mortality of 0.56 and a $F_{0.1}$ of 0.33 with a yield per recruit of .78 kg.

Catch projections

The estimated VPA population abundance corrected by the research cruise data estimates of the sizes of the 1976-77 year-classes were projected to 1981 assuming a 1980 catch of 45,000 tons. The 1978 and 1979 year-classes at age 2 were set at 85 million fish, the geometric mean of the 1964 to 1974 year-classes. The results are presented in table 9. This analysis implies that fishing at $F_{0.1}$ in 1981 would result in a yield of 49,000 tons.

Conclusion

This analysis shows an increased abundance in 1979 over 1978. However, the rate of increase appears to be slower than during the period 1975 to 1978. The long term predictions would indicate that a yield of 65,000 tons can be attained if average year-class sizes are produced. But these predictions are built on a weak basis due to the uncertainties about past year-class sizes. If the historical catch of young fish was different than estimated by Gray (1979), the estimated year-class strengths presented in this analysis will be in error. The low variability of year-class strengths at age 2 since 1969 is very striking and suggest some misassignment of catches to year-classes. The extent to which these potential errors affect the prognosis can only be ascertained after several years of data are obtained for which all removals are accurately accounted.

Bibliography

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Table 1. 4VSW cod nominal catches by country and NAFO Divisions

| <u>YEAR</u> | <u>CANADA</u> | <u>FRANCE</u> | <u>PORTUGAL</u> | <u>SPAIN</u> | <u>USSR</u> | <u>OTHERS</u> | <u>TOTAL</u> | <u>DIV. 4Vs</u> | <u>DIV. 4W</u> | <u>TAC</u> |
|-------------------|---------------|---------------|-----------------|--------------|-------------|---------------|--------------|-----------------|----------------|-------------------|
| 1958 | 17938 | 4577 | 1095 | 14857 | 0 | 124 | 28591 | 23790 | 14801 | |
| 1959 | 20069 | 16378 | 8384 | 19999 | 0 | 1196 | 66026 | 47063 | 18963 | |
| 1960 | 18389 | 1018 | 1720 | 29391 | 0 | 126 | 50645 | 27689 | 22956 | |
| 1961 | 19697 | 3252 | 2321 | 40884 | 113 | 42 | 66309 | 34237 | 32072 | |
| 1962 | 17579 | 2645 | 341 | 42146 | 2383 | 60 | 65154 | 26350 | 38804 | |
| 1963 | 13144 | 72 | 617 | 44528 | 9505 | 307 | 68173 | 27566 | 40607 | |
| 1964 | 14330 | 1010 | 0 | 39690 | 7133 | 1094 | 63257 | 25496 | 37761 | |
| 1965 | 23104 | 536 | 88 | 39280 | 7856 | 124 | 70988 | 36713 | 34275 | |
| 1966 | 17690 | 1494 | 0 | 43157 | 5473 | 356 | 68170 | 27136 | 41007 | |
| 1967 | 18464 | 77 | 102 | 33934 | 1068 | 512 | 54157 | 26607 | 27550 | |
| 1968 | 24888 | 225 | 0 | 50418 | 4865 | 29 | 80425 | 48781 | 31644 | |
| 1969 | 14188 | 217 | 0 | 32305 | 2783 | 664 | 50157 | 22309 | 27848 | |
| 1970 | 11818 | 420 | 296 | 41926 | 2521 | 446 | 57427 | 28632 | 28795 | |
| 1971 | 17064 | 4 | 18 | 30864 | 4506 | 107 | 52563 | 24128 | 28435 | |
| 1972 | 19987 | 495 | 856 | 28542 | 4646 | 7119 | 61645 | 36533 | 25112 | |
| 1973 | 15929 | 922 | 849 | 30883 | 2918 | 2569 | 54070 | 23401 | 30669 | 60500 |
| 1974 | 10700 | 34 | 1464 | 27384 | 3096 | 1060 | 43739 | 19610 | 24130 | 60000 |
| 1975 | 9939 | 1867 | 546 | 15611 | 3042 | 1512 | 32517 | 11694 | 20823 | 60000 |
| 1976 | 9567 | 697 | 0 | 11090 | 1018 | 2035 | 24407 | 11553 | 12854 | 30000 |
| 1977 | 9890 | 68 | 0 | 0 | 97 | 31 | 10086 | 2873 | 7213 | 7000 |
| 1978 | 24631 | 250 | 22 | 31 | 479 | 41 | 25454 | - | - | 7000 ² |
| 1979 ¹ | 39219 | 0 | 0 | 0 | 0 | 497 | 39716 | 15377 | 23842 | 30000 |

¹ Preliminary

² By-catch only

Table 2a. 4VsW cod research vessel survey population estimates with two anomalous sets in 1973 removed.

| AGE | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 |
|-----|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 0 | 97 | 23 | 0 | 0 | 866 | 69 | 0 | 0 | 174 | 1017 |
| 1 | 1273 | 1539 | 6210 | 2295 | 5174 | 3372 | 2242 | 808 | 3053 | 1213 |
| 2 | 16123 | 7680 | 9674 | 8778 | 32961 | 8412 | 14066 | 10145 | 13065 | 10612 |
| 3 | 5196 | 35664 | 11881 | 13760 | 19246 | 13000 | 16098 | 26372 | 31245 | 16044 |
| 4 | 7682 | 8027 | 31536 | 10788 | 5623 | 6171 | 10187 | 17059 | 34205 | 16595 |
| 5 | 3734 | 15803 | 5812 | 6799 | 2017 | 2959 | 6621 | 11353 | 9461 | 18075 |
| 6 | 1227 | 5775 | 5989 | 428 | 2244 | 675 | 1264 | 4893 | 3490 | 9053 |
| 7 | 1532 | 3459 | 1621 | 951 | 372 | 867 | 656 | 1081 | 889 | 2696 |
| 8 | 466 | 1475 | 547 | 676 | 463 | 235 | 1308 | 878 | 185 | 1009 |
| 9 | 104 | 638 | 495 | 96 | 224 | 433 | 0 | 244 | 90 | 411 |
| 10 | 701 | 471 | 153 | 534 | 340 | 91 | 1180 | 223 | 158 | 152 |
| UK | 274 | 112 | 0 | 202 | 44 | 74 | 36 | 114 | 53 | 253 |

Table 2B. 4VsW cod research vessel survey population estimates with the two anomalous sets in 1973 included.

| AGE | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 |
|-----|-------|-------|-------|--------|-------|-------|-------|-------|-------|-------|
| 0 | 97 | 23 | 0 | 0 | 866 | 69 | 0 | 0 | 174 | 1017 |
| 1 | 1273 | 1539 | 6210 | 16128 | 5174 | 3372 | 2242 | 808 | 3053 | 1213 |
| 2 | 16123 | 7680 | 9674 | 122780 | 32961 | 8412 | 14066 | 10145 | 13065 | 10612 |
| 3 | 5196 | 35664 | 11881 | 104965 | 19245 | 13000 | 16098 | 26372 | 31245 | 16044 |
| 4 | 7682 | 8027 | 31536 | 59948 | 5623 | 6171 | 10187 | 17059 | 34205 | 16595 |
| 5 | 3734 | 15803 | 5812 | 22524 | 2017 | 2959 | 6621 | 11353 | 9461 | 18075 |
| 6 | 1227 | 5775 | 5989 | 1870 | 2244 | 675 | 1264 | 4893 | 3490 | 9053 |
| 7 | 1532 | 3459 | 1621 | 2907 | 372 | 867 | 656 | 1081 | 889 | 2696 |
| 8 | 466 | 1475 | 547 | 901 | 463 | 235 | 1308 | 878 | 185 | 1009 |
| 9 | 104 | 638 | 495 | 431 | 224 | 433 | 0 | 244 | 90 | 411 |
| 10 | 701 | 471 | 153 | 910 | 340 | 91 | 1180 | 223 | 158 | 152 |
| UK | 274 | 112 | 0 | 202 | 44 | 74 | 36 | 114 | 53 | 253 |

Table 3. 4VsW cod catch at age ('000).

| AGE | 1966 | 1967 | 1968 | 1969 | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 |
|-----|-------|------|-------|-------|-------|-------|-------|-------|-------|------|------|------|------|------|
| 1 | 2806 | 548 | 2495 | 1426 | 1293 | 2311 | 2383 | 1418 | 1482 | 1792 | 728 | 2 | 177 | 0 |
| 2 | 17891 | 4235 | 16045 | 9096 | 8631 | 15218 | 17738 | 12142 | 8451 | 9979 | 4061 | 24 | 153 | 36 |
| 3 | 17493 | 6267 | 17413 | 7684 | 8886 | 12582 | 14227 | 14881 | 12885 | 9485 | 3587 | 386 | 1004 | 1538 |
| 4 | 13973 | 7989 | 17783 | 13724 | 14802 | 9146 | 13361 | 7507 | 9947 | 4341 | 3713 | 1073 | 3650 | 6006 |
| 5 | 10577 | 9456 | 15633 | 10248 | 13673 | 8809 | 9661 | 9755 | 7130 | 4549 | 4818 | 1559 | 4621 | 9048 |
| 6 | 4461 | 4338 | 8297 | 7073 | 4539 | 10262 | 8780 | 3823 | 2766 | 2594 | 2412 | 871 | 2441 | 4873 |
| 7 | 3256 | 1467 | 3482 | 2144 | 1941 | 5160 | 3432 | 2996 | 944 | 2627 | 1426 | 501 | 768 | 1168 |
| 8 | 1590 | 1239 | 895 | 510 | 759 | 1849 | 1919 | 3724 | 1323 | 612 | 611 | 220 | 213 | 374 |
| 9 | 856 | 664 | 816 | 237 | 236 | 496 | 358 | 1166 | 413 | 497 | 184 | 128 | 112 | 76 |
| 10 | 496 | 647 | 361 | 50 | 72 | 114 | 393 | 273 | 369 | 660 | 49 | 35 | 80 | 23 |
| 11 | 666 | 325 | 152 | 95 | 137 | 131 | 79 | 299 | 15 | 153 | 22 | 44 | 26 | 10 |
| 12 | 24 | 65 | 211 | 58 | 56 | 72 | 2 | 3 | 5 | 126 | 107 | 55 | 28 | 4 |
| 13 | 14 | 16 | 33 | 12 | 9 | 98 | 37 | 7 | 0 | 36 | 1 | 11 | 26 | 4 |
| 14 | 0 | 5 | 17 | 2 | 12 | 12 | 0 | 5 | 0 | 9 | 4 | 3 | 9 | 1 |
| 15 | 2 | 7 | 1 | 2 | 4 | 51 | 1 | 5 | 0 | 9 | 1 | 2 | 4 | 0 |
| 16 | 1 | 2 | 10 | 2 | 3 | 17 | 1 | 20 | 0 | 18 | 1 | 7 | 2 | 0 |

Table 4. Partial recruitment multipliers derived from the comparison of percent catch at age in the research vessel surveys and the percent catch at age in the commercial fishery.

| AGE | % SURVEY | % COMMERCIAL | COMMERCIAL/SURVEY | P.R.% |
|-----|----------|--------------|-------------------|-------|
| 2 | 13.804 | 0.153 | 0.011 | 0.616 |
| 3 | 20.870 | 6.641 | 0.318 | 17.8 |
| 4 | 21.587 | 25.938 | 1.202 | 67.3 |
| 5 | 23.512 | 39.071 | 1.662 | 93.0 |
| 6 | 11.776 | 21.045 | 1.787 | 100.0 |
| 7 | 3.507 | 5.042 | 1.438 | 80.5 |
| 8 | 1.313 | 1.617 | 1.232 | 68.9 |
| 9 | 0.535 | 0.329 | 0.615 | 34.4 |
| 10 | 0.198 | 0.099 | 0.500 | 28.0 |

Table 5. Corrections to partial recruitment multipliers to adjust the 1975 to 1977 year-classes strengths.

| AGE | Average R. V. Survey population estimate (1970-75) | Population estimate R.V. survey in the year | | |
|-----|--|---|--------|--------|
| | | 1977 | 1978 | 1979 |
| 2 | 13,938 | 10,145 | 13,065 | 10,612 |
| 3 | 16,458 | - | 31,245 | 16,044 |
| 4 | 11,638 | - | - | 16,595 |

Ratios of the 1975 to 1977 R.V. surveys year-classes population estimates to the average (1970-75).

| AGE | 1977/MEAN | 1978/MEAN | 1979/MEAN |
|-----|-----------|-----------|-----------|
| 2 | .73 | .94 | .76 |
| 3 | - | 1.90 | .97 |
| 4 | - | - | 1.43 |

| Age | Average VPA population estimate | VPA 1977 | Population estimate 1978 | Population estimate in the year 1979 |
|-----|---------------------------------|----------|--------------------------|--------------------------------------|
| 2 | 70,550 | 55274 | 39993 | 21304 |
| 3 | 46,954 | - | 45233 | 32605 |
| 4 | 32,988 | - | - | 36127 |

Ratios of the 1975 to 1977 VPA population estimates to the average (1970-75).

| Age | 1977/MEAN | 1978/MEAN | 1979/MEAN |
|-----|-----------|-----------|-----------|
| 2 | .78 | .57 | .30 |
| 3 | - | .96 | .69 |
| 4 | - | - | 1.10 |

| Year-class | Average ratio research | Average ratio VPA |
|------------|------------------------|-------------------|
| 1975 | 1.35 | .95 |
| 1976 | .96 | .63 |
| 1977 | .76 | .30 |

| Year-class | ratio research/ratio VPA | Age | Old P.R. | Old P.R./ (RES/VPA) |
|------------|--------------------------|-----|----------|---------------------|
| 1977 | 2.533 | 2 | .00616 | .0024 |
| 1976 | 1.524 | 3 | .17800 | .1168 |
| 1975 | 1.421 | 4 | .673 | .4736 |

New partial recruitment

| AGE | 2 | 3 | 4 |
|--------|-----|-------|-------|
| P.R. % | .24 | 11.68 | 47.36 |

Table 6. 4VSW cod population at age table ('000).

| AGE | 1966 | 1967 | 1968 | 1969 | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 |
|---------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| 2 | 121957 | 133573 | 108315 | 71922 | 86222 | 75589 | 76257 | 59015 | 52440 | 72776 | 85363 | 75846 | 60328 | 54649 |
| 3 | 81712 | 83736 | 105536 | 74229 | 50688 | 62811 | 48197 | 46489 | 37395 | 36143 | 50594 | 66224 | 62076 | 49254 |
| 4 | 51864 | 51169 | 62904 | 70729 | 53847 | 33501 | 40106 | 26692 | 24715 | 19068 | 21072 | 38187 | 53871 | 49917 |
| 5 | 25190 | 29913 | 34699 | 35536 | 45560 | 30794 | 19215 | 20857 | 15113 | 11335 | 11709 | 13910 | 30296 | 40813 |
| 6 | 9312 | 11165 | 16009 | 14444 | 19895 | 25031 | 17304 | 7118 | 8367 | 6009 | 5210 | 5277 | 9983 | 20643 |
| 7 | 7404 | 3643 | 5258 | 5713 | 6395 | 12208 | 11314 | 6340 | 2424 | 4371 | 2601 | 2112 | 3536 | 5980 |
| 8 | 3717 | 3152 | 1670 | 1223 | 2758 | 3493 | 5381 | 6184 | 2517 | 1139 | 1246 | 860 | 1279 | 2205 |
| 9 | 2394 | 1622 | 1472 | 570 | 545 | 1576 | 1213 | 2687 | 1756 | 882 | 388 | 475 | 507 | 855 |
| 10 | 1590 | 1193 | 734 | 479 | 255 | 235 | 846 | 672 | 1156 | 1067 | 290 | 153 | 274 | 314 |
| 11 | 892 | 856 | 401 | 279 | 347 | 144 | 91 | 342 | 306 | 617 | 288 | 185 | 94 | 152 |
| 12 | 53 | 144 | 411 | 192 | 143 | 161 | 5 | 6 | 20 | 237 | 367 | 216 | 112 | 54 |
| TOTAL | 306086 | 320167 | 337409 | 275317 | 266655 | 245546 | 219931 | 176401 | 147212 | 153644 | 179118 | 203446 | 222356 | 224836 |
| 2+ bio- mass (t) | 227178 | 283788 | 254109 | 221515 | 240530 | 163055 | 171951 | 133931 | 127684 | 99828 | 126825 | 187100 | 266150 | 268812 |
| 4+ bio- mass (t) | 130717 | 155361 | 145469 | 145676 | 168835 | 111554 | 118660 | 89631 | 80933 | 55238 | 57756 | 90671 | 169402 | 203403 |
| Mean age | 3.29 | 3.21 | 3.36 | 3.56 | 3.63 | 3.71 | 3.64 | 3.63 | 3.48 | 3.20 | 30.01 | 3.13 | 3.50 | 3.81 |

Table 7. 4VsW cod fishing mortality at age table.

| AGE | 1966 | 1967 | 1968 | 1969 | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 |
|---------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 2 | 0.176 | 0.036 | 0.178 | 0.150 | 0.117 | 0.250 | 0.295 | 0.256 | 0.191 | 0.164 | 0.054 | 0.000 | 0.003 | 0.001 |
| 3 | 0.268 | 0.086 | 0.200 | 0.121 | 0.214 | 0.249 | 0.391 | 0.432 | 0.474 | 0.340 | 0.081 | 0.006 | 0.018 | 0.035 |
| 4 | 0.350 | 0.188 | 0.371 | 0.240 | 0.359 | 0.356 | 0.454 | 0.369 | 0.580 | 0.288 | 0.215 | 0.031 | 0.078 | 0.142 |
| 5 | 0.614 | 0.425 | 0.676 | 0.380 | 0.399 | 0.376 | 0.793 | 0.713 | 0.722 | 0.577 | 0.597 | 0.132 | 0.184 | 0.279 |
| 6 | 0.739 | 0.553 | 0.830 | 0.615 | 0.288 | 0.594 | 0.804 | 0.877 | 0.449 | 0.637 | 0.703 | 0.200 | 0.312 | 0.300 |
| 7 | 0.654 | 0.580 | 1.258 | 0.528 | 0.405 | 0.619 | 0.404 | 0.724 | 0.555 | 1.055 | 0.906 | 0.302 | 0.273 | 0.241 |
| 8 | 0.629 | 0.562 | 0.875 | 0.608 | 0.359 | 0.858 | 0.495 | 1.059 | 0.849 | 0.878 | 0.764 | 0.329 | 0.202 | 0.207 |
| 9 | 0.496 | 0.593 | 0.923 | 0.605 | 0.640 | 0.423 | 0.391 | 0.642 | 0.299 | 0.948 | 0.728 | 0.351 | 0.278 | 0.103 |
| 10 | 0.418 | 0.891 | 0.767 | 0.122 | 0.371 | 0.750 | 0.707 | 0.587 | 0.430 | 1.110 | 0.214 | 0.289 | 0.386 | 0.084 |
| 11 | 1.622 | 0.536 | 0.536 | 0.466 | 0.565 | 3.200 | 2.545 | 2.643 | 0.056 | 0.318 | 0.088 | 0.302 | 0.361 | 0.075 |
| 12 | 0.677 | 0.676 | 0.819 | 0.402 | 0.557 | 0.667 | 0.606 | 0.817 | 0.323 | 0.864 | 0.385 | 0.328 | 0.321 | 0.095 |
| Ave. 2+ | 0.308 | 0.147 | 0.329 | 0.231 | 0.256 | 0.346 | 0.442 | 0.455 | 0.417 | 0.313 | 0.155 | 0.029 | 0.071 | 0.127 |

Table 8. Yield per recruit calculations, partial recruitment multipliers and mean weights at age (1979 fishery).

| AGE | Weights (kg) | P.R. % | FISHING MORTALITY | YIELD |
|-----|--------------|--------|-------------------|-------|
| 2 | .53 | .24 | .05 | .249 |
| 3 | .76 | 11.68 | .10 | .428 |
| 4 | 1.06 | 47.36 | .15 | .557 |
| 5 | 1.70 | 93.0 | .20 | .649 |
| 6 | 2.39 | 100.0 | .25 | .713 |
| 7 | 3.13 | 80.5 | .30 | .758 |
| 8 | 3.71 | 68.9 | $F_{0.1}$.328 | .776 |
| 9 | 4.77 | 34.4 | .350 | .788 |
| 10 | 6.84 | 28.0 | .400 | .807 |
| 11 | 7.96 | 25.0 | .450 | .818 |
| 12 | 9.41 | 25.0 | .500 | .824 |
| 13 | 10.63 | 25.0 | .550 | .826 |
| 14 | 10.03 | 25.0 | F_{max} .563 | .827 |
| 15 | 11.45 | 25.0 | .600 | .826 |
| 16 | 12.51 | 25.0 | .650 | .823 |

Table 9. 4Vsw cod projection results

| <u>YEAR</u> | <u>POPULATION BIOMASS (t)</u> | <u>CATCH BIOMASS (t)</u> |
|-------------|-------------------------------|--------------------------|
| | Age 2+ | |
| 1980 | 308747 | 45,000 |
| 1981 | 337707 | 49,140 |

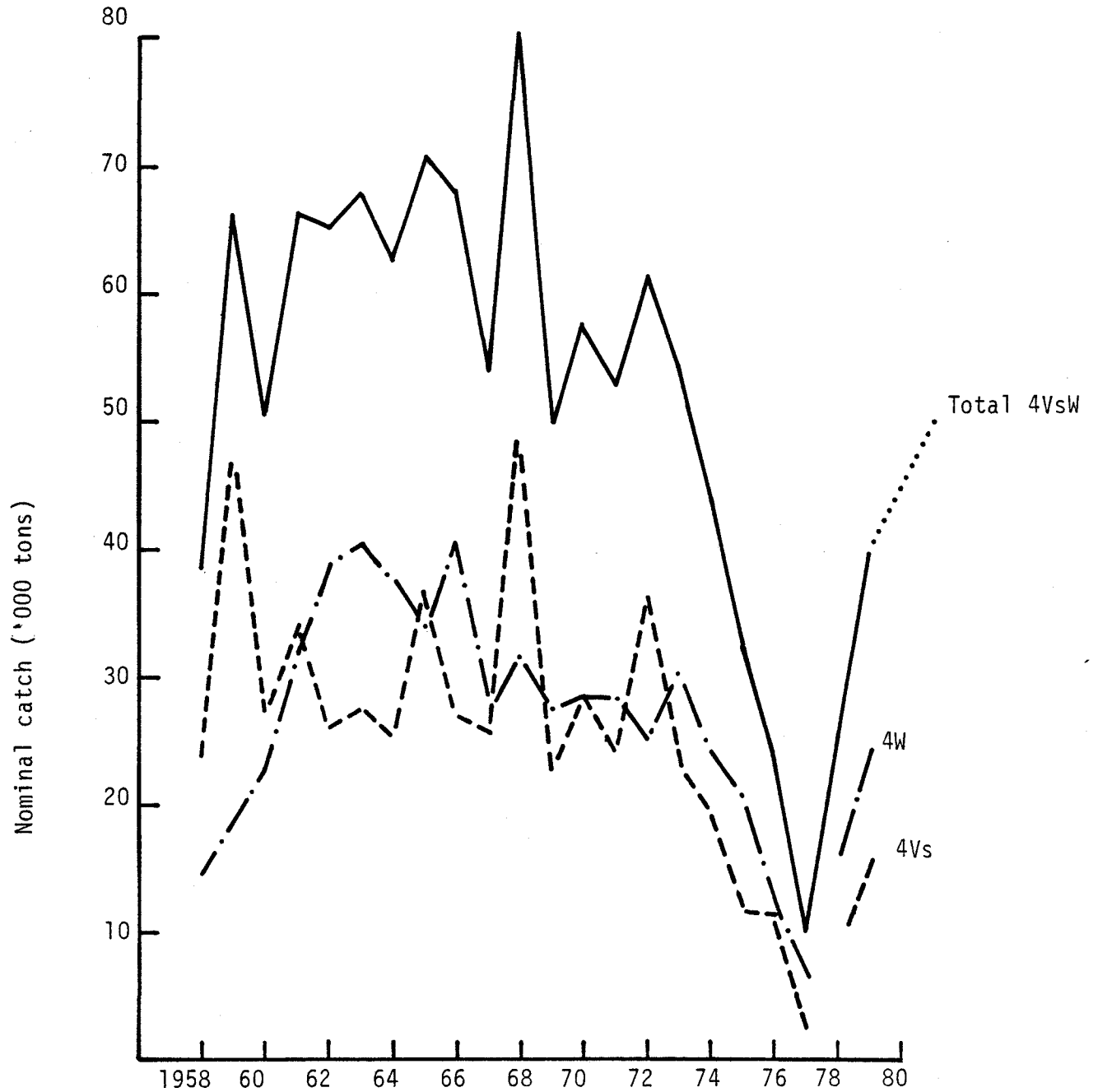


Figure 1. 4VsW cod nominal catches by NAFO Division.

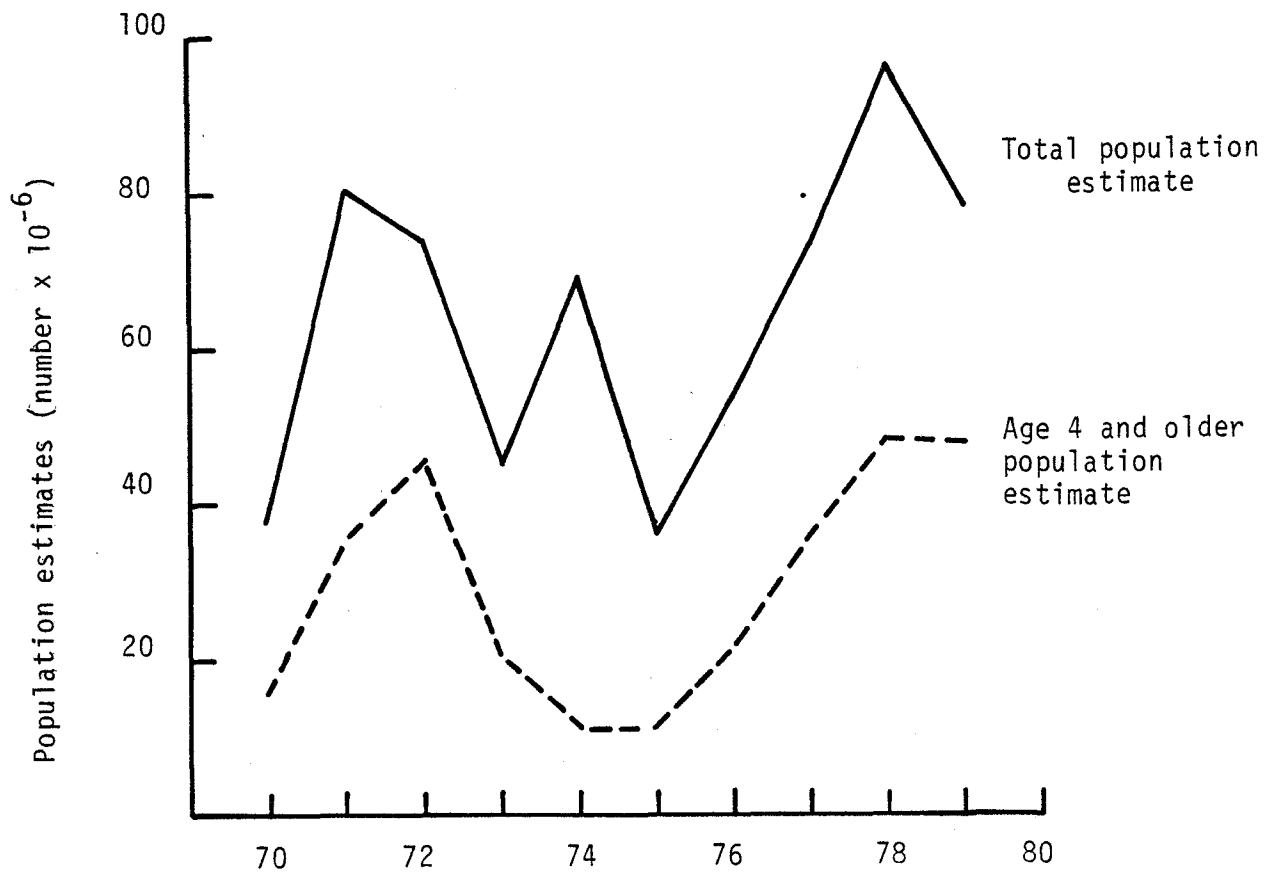


Figure 2. 4VSW Cod Research Vessel surveys population estimates (1973 value corrected).

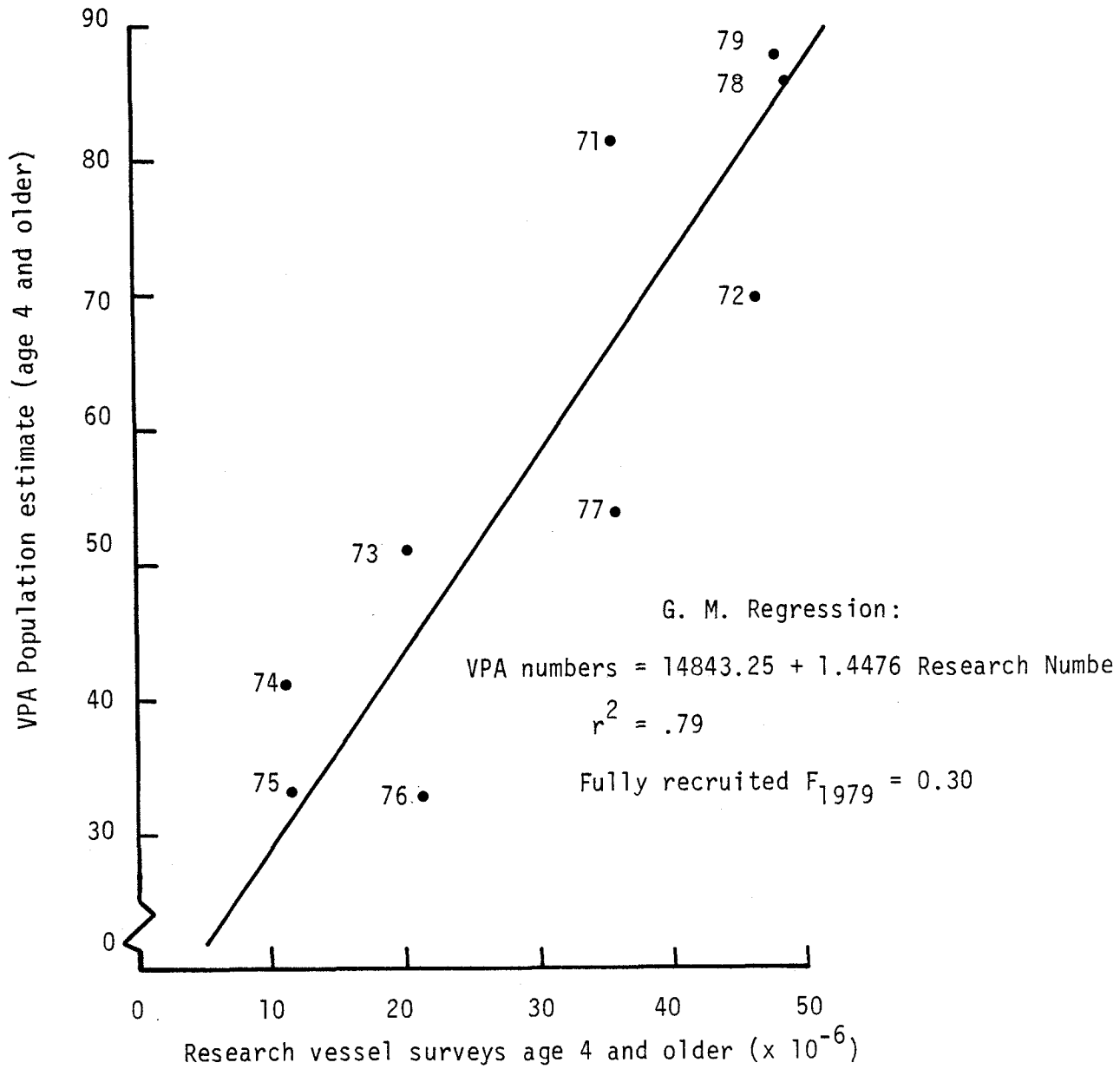


Figure 3. 4VSW cod VPA age 4 and older population estimates versus research vessel survey age 4 and older population estimate.

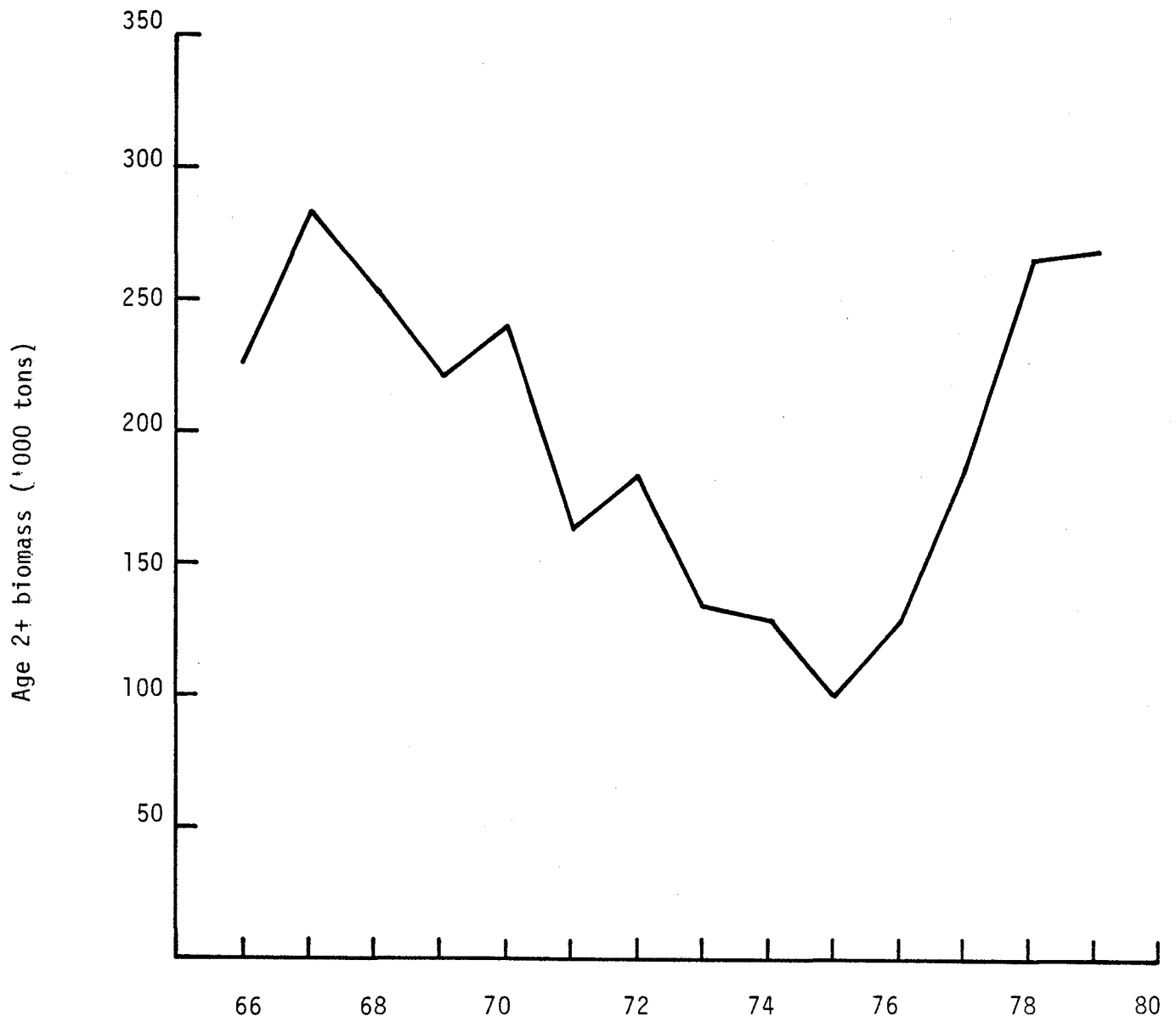


Figure 4. 4VsW cod population biomass.

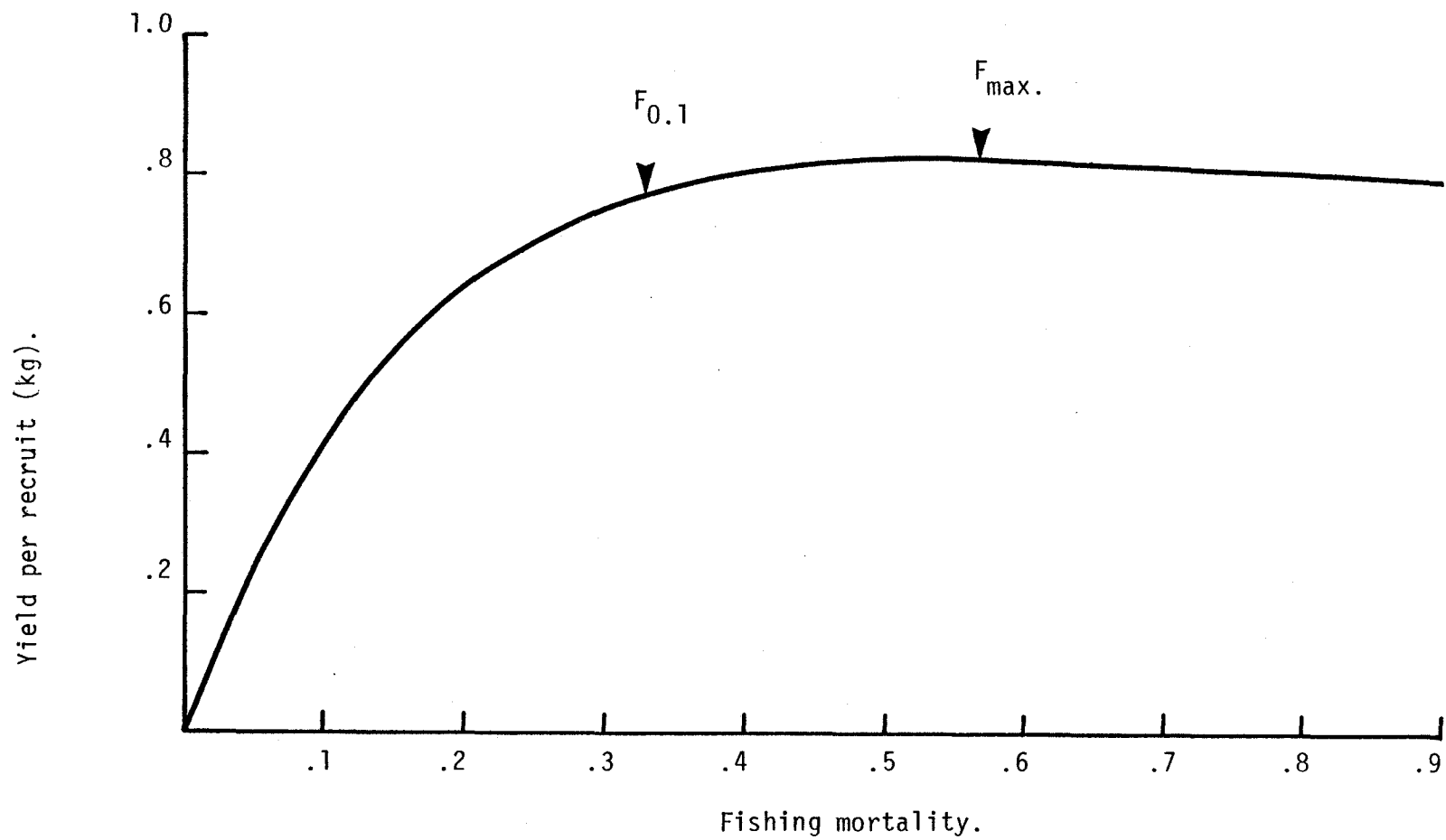


Figure 5. 4VsW cod yield-per recruit calculations.