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# Stock Assessment of Cod in Divisions 3NO

by

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## INTRODUCTION

Cod catches in Divisions 3NO remain at a low level when compared with those reported from the late 1960's and early 70's. Recent catches and TAC's are as follows:

| | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 |
|---|---|---|---|---|---|---|---|---|
| TAC (000t) | 103 | 101 | 88 | 43 | 30 | 15 | 25 | 26 |
| Catch (000t) | 80 | 73 | 44 | 24 | 18 | 15 | 28 | 18.5* |

* provisional data

The most recent assessment on this stock (NAFO SCR Doc. 80/11/49) indicated that fishing at $F_{0.1}$ = 0.18 in 1980 would yield a catch of 26,000 t. There were indications that with average recruitment the stock size (Age 3+) would increase substantially by 1982. The report (NAFO SCR Doc. 80/11/1) pertaining to this assessment expressed some cautionary statements. There was uncertainty with regard to the assumed level of fishing mortality in 1979. Projected catch and biomass levels were well below those determined as the optimum levels. Also it was emphasized that two year classes (1974 and 75) would constitute 70% of the spawning biomass in 1982 and that the next two year classes (1976 and 77) were estimated to be weak. A cautious approach to exploitation was advised until there was clear evidence of stock rebuilding to optimum levels.

The present assessment considers the current status of the stock and the effect of specified exploitation levels in the immediate future.

## SAMPLING AND AGE COMPOSITIONS

To obtain an estimate of stock removals at age, length and age sampling data were obtained from as many components of the commercial fishery as possible. Table 1 indicates the sampling data available for the 1980 catch and the methods used to adjust the catches to numbers at age. Sampling data was obtained by the Commercial Sampling and Foreign Co-operative Research units of Fisheries and Oceans. The resulting catch at age figures are shown in Table 2 and Figure 3. Catch data for Spain, Portugal and other countries was obtained from NAFO circular letters and from FLASH. It is evident that the 1974 and 75 year classes were predominant, as they had been in 1979, in that they comprised over 70% of the total catch. After obtaining monthly catch statistics from the Spanish fleet it was necessary to adjust the catch at age data for 1979. Table 3 shows the adjusted figures. The only major change resulted in an increase in the number of 5 year olds by 27% over that reported previously (NAFO SCR Doc. 80/11/49).

The results of research surveys in 3NO in terms of mean numbers per standard tow are shown in Table 4. It is evident that there was a considerable change in numbers from 1979 to 1980. The difference occurred mainly in Division 3O where the numbers were 1/10 those of 1979 survey, while that for 3N remained virtually unchanged. The reasons for the pronounced change are not known but might be related to survey timing. The 1979 survey occurred in June while that for 1980 was in April. It would appear from Table 4 that the 1978 year class is relatively good. Figures 1 and 2 show the length and permille age frequencies from the 1980 survey.

## CATCH-EFFORT DATA

Catch rate and effort data were updated from the most recent assessment (NAFO SCR Doc. 80/11/24). Additional information included the final statistics from NAFO for 1978, the preliminary STATLANT figures for 1979 and catch rate information from the Foreign Observer Program. Standardized catch per unit effort and effort values were derived using the multiplicative model as described by Gavaris (1980). The country, gear and month category groupings are shown in Table 5 along with ln power. The second listed groups in country-gear and month categories were used as the standards. Table 6 lists the historical catch and standardized effort and catch rate. Catch rates reached their lowest level (0.30) in 1978, increased by a factor of four in 1979 and decreased in 1980 to 0.68 tons. Also listed in Table 6 are the proportions of the total catch that were used in estimating the catch rates. There was some improvement in the proportion used in 1980 over the low 1979 figure. In the most recent assessment (NAFO SCR Doc. 80/11/24) a general production model analysis was presented using similar catch and effort data. The committee considered the model inadequate to represent the status of the stock as it was obviously not in equilibrium.

In the present assessment, attempts to fit a symmetric surplus production model to the catch and effort data failed, therefore an assymmetric model was used. The non-equilibrium version described by Fletcher (1978) was applied because the stock is not at equilibrium. Examination of the predicted and observed yield indicates that the model predicted higher catch rates than have been realized in the past few years (Fig. 4). The equilibrium maximum sustainable yield was 125,000 t. The non-equilibrium catch for 1981 at a fishing level of 2/3 effort $_{MSY}$ was 43,000 t. However as mentioned earlier this figure applies to a very optimistic catch rate of 1.2 tonnes/hour. If the observed catch rate of 0.7 tonnes/hour is used the non-equilibrium catch would be approximately half or 22,000 t.

## COHORT ANALYSIS

In previous assessments catch-at-age data beginning in 1972 was used because of the unavailability of sampling data in 1971. For the present assessment catch at age for 1971 was estimated using data from the most recent assessment (NAFO SCR Doc. 80/11/49) and an earlier assessment covering the period 1959-70 (Pinhorn and Wells, 1975). Using stock and catch at age data for 1969 a stock in 1970 was obtained. This stock estimate together with available catch at age data for 1970, was used to obtain Fs for 1970 and from this a stock in 1971 was obtained. By comparing stock at age in 1971 with that for 1972, catch at age for 1971 was estimated. This catch at age matrix (Table 7) for the 1959-1980 was used in a cohort analysis.

The partial selection multiplier was obtained by comparing commercial catch at age with Research catch at age (Table 8). In the cohort presented the fish were considered to be fully recruited to the fishery from age 6 and older. Figure 5 indicates this pattern plus that obtained using the values shown in Table 8. Table 9 shows average weights at age for each of the years 1977-80 plus an average over the four year period. Average weight at age data from previous years indicated that there was little variation for the period 1959-65, and that those for 1966 to 1970 were similar to current data. Average weights used in the cohort are shown in Table 7. An average weight over the period 1959-65 was used for each of those years and the average for the period 1977-80 was used for each of the years 1966-76. The values obtained from sampling data (Table 9) were used for the years 1977-80.

A cohort analysis was applied over a range of terminal F's and with an M value of 0.2. The output data from a run at Ft = 0.25 is shown in Tables 10-13. The age 3+ and 4+ mean population biomasses from cohort runs at Ft ranging from 0.10 to 0.30 was compared with standard catch rates for the years 1959-78 (ommitting 1963 and 1976) and regression analyses were performed. The results are shown in Table 14 and Fig. 6.

Table 14 also indicates the predicted 1980 biomass from the different regressions. It would appear that the terminal F producing the best predictive value of 3+ biomass in 1980 is between 0.20 and 0.25. The cohort run at Ft = 0.25 produced a mean population biomass of 101,000 t and this terminal F was considered an adequate estimate of that occurring during the 1980 fishery.

A comparison of Canadian survey results in terms of mean number per tow (Age 3+), with cohort population numbers (Age 3+) produced a good relationship (Fig. 7) with on $r^2$ of 0.80.

It is apparent from Table 10 that population numbers at age 3 (recruitment) are at a level much lower than those of the late 60's. The mean population biomass of age 3+ in Table 11 shows some improvement since the mid-seventies but remains at one quarter that of the late sixties.

## RECRUITMENT

Recruitment estimates at age 3 for the 1976-1978 year classes were obtained from catch at age per tow data from surveys, and population numbers at age 3 from the cohort run at Ft = 0.25 (Table 15). From the regression equations shown, estimated strengths of the 1976, 77 and 78 year classes were determined as approximately 23, 22 and 58 million individuals. The strength of the 1976 and 77 year classes from the cohort were 18 and 25 million respectively.

## YIELD PER RECRUIT

Estimates of yield per recruit (Table 16) were obtained using average weight at age data over the period 1977-80 (Table 9) and the 'flat topped' partial selection values from the 1980 survey and commercial sampling data. The weights for ages 13-20 were obtained from a line fitted by eye to the 1977-80 average weight data (Table 9, Fig. 8). Estimates of $F_{0\cdot1}$ and $F_{max}$ were 0.14 and 0.23 respectively.

## PROJECTION OF CATCHES AND POPULATION BIOMASS

The population numbers at age for 1980 from the cohort at Ft = 0.25 were used to project catches and population biomass to 1982. Recruitment in 1981 at age 3 was assumed to be approximately 60 million individuals (Table 15) while in 1982 the geometric mean of recruitment over the ten year period 1971-1980 of 40 million was used.

Because of the difference in $F_{0\cdot1}$ from the 1980 and 1979 assessments (0.14 and 0.18 respectively) the projections were run using both the above $F_{0\cdot1}$ levels for 1981 and 1982. The catch in 1981 is predicted to range from 12 ($F_{0\cdot1}$ = 0.14) to 15 ($F_{0\cdot1}$ = 0.18) thousand tons.

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Table 1. Details of sampling available and method used to estimate catch at age by the commercial fishery in 3NO during 1980.

| Country | Qtr. | Div. | Gear | No. otoliths | Sampling months | No. of measurements | Ave. wt. | Nominal catch (tons) | Adjusted numbers (000) |
|---|---|---|---|---|---|---|---|---|---|
| Can(N) | 1+2 | 3NO | OT | 1235[a] | 5 | 511 | 1.94 | 763 | 393 |
| | 3+4 | 3N | OT | 206 | 11 | 1929 | 1.94 | 1878 | 968 |
| | 3+4 | 3O | OT | 229 | 11+12 | 2970 | 2.27 | 1403 | 618 |
| | 1-4 | 3NO | OT | | | | 2.04 | 4044 | 1979 |
| Spain | 1+2 | 3N | PT | 319 | 5,6 | 4086 | 1.93 | 1477 | 766 |
| | 3 | 3N | PT | 159 | 7,8 | 3155 | 2.59 | 775 | 299 |
| | 4 | 3N | PT | 204 | 10,11 | 991 | 3.93 | 618 | 157 |
| | 1+2 | 3Ø | PT | 916 | 6 | 12937 | 2.53 | 2946 | 1164 |
| | 3 | 3Ø | PT | 281[b] | 7,8,9 | 3819 | 3.27 | 648 | 198 |
| | 4 | 3Ø | PT | 598[c] | 10,11 | 9909 | 2.24 | 2343 | 1046 |
| | 1-4 | 3NO | PT | | | | 2.43 | 8807 | 3630 |
| Portugal | 3 | 3N | GN | 712[d] | 7,8,9 | 14305 | 4.87 | 691 | 142 |
| | 1-4 | 3N | GN | | | | 4.87 | 747 | 153 |
| | 3 | 3Ø | GN | 712[d] | 7,9 | 1481 | 3.92 | 102 | 26 |
| | 1-4 | 3Ø | GN | | | | 3.92 | 258 | 66 |
| | 1-4 | 3NO | GN | | | | 4.59 | 1005 | 219 |
| Other | 1-2 | 3NO | OT | 1235[a] | 5 | 511 | 1.94 | 2053 | 1058 |
| | 3-4 | 3NO | OT | 206[e] | 11 | 1929 | 1.94 | 2596 | 1338 |
| | 1-4 | 3NO | OT | | | | 1.94 | 4686 | 2415 |
| All | 1-4 | 3NO | All | 3262 | | 56093 | 2.25 | 18542 | 8243 |

[a]From Spain PT-3NO-qtr 2

[b]=Spain PT-3NO-qtr 3

[c]=Spain PT-3NO qtr 4

[d]=Portugal GN-3NO-qtr 3

[e]=Can OT-3N-qtr 4

Table 2. Age compositions of the 3NO cod catch in 1980

| Age | Can(N) | Spain(PT) | Port(GN) | Other(OT)[a] | Total |
|---|---|---|---|---|---|
| 2 | | 5 | | | 5 |
| 3 | 73 | 104 | | 103 | 280 |
| 4 | 300 | 399 | | 439 | 1138 |
| 5 | 889 | 1689 | 19 | 1192 | 3789 |
| 6 | 548 | 916 | 79 | 514 | 2057 |
| 7 | 144 | 322 | 65 | 134 | 665 |
| 8 | 17 | 115 | 33 | 20 | 185 |
| 9 | 3 | 50 | 17 | 5 | 75 |
| 10 | 2 | 19 | 3 | 3 | 27 |
| 11 | | 4 | 2 | 1 | 7 |
| 12 | 2 | 7 | 1 | 3 | 13 |
| 13 | | | | | |
| 14 | | | | | |
| 15 | | | | | |
| 16 | | | | | |
| 17 | 1 | | | 1 | 2 |
| 18 | | | | | |
| 19 | | | | | |
| 20 | | | | | |
| # | 1979 | 3630 | 219 | 2415 | 8243 |
| Ave. wt. | 2.04 | 2.43 | 4.59 | 1.94 | 2.25 |
| land-ings | 4044 | 8807 | 1005 | 4686 | 18542 |

[a]Other(OT): Can(M) - 1224t.
Cuba - 37
France - 103
Poland - 33
Portugal - 62
Spain - 367
USA - 4
USSR - 2856
4686

Table 3. Revised age composition of the 1979 commercial cod catch in Div. 3NO.

| Age | Can N | Portugal (GN) | Spain (PT) | Other[a] (OT) | Can M | Total |
|---|---|---|---|---|---|---|
| 3 | 19 | | 42 | 4 | 7 | 72 |
| 4 | 947 | 20 | 2222 | 288 | 350 | 3827 |
| 5 | 2445 | 80 | 4572 | 1104 | 1007 | 9208 |
| 6 | 653 | 89 | 1359 | 388 | 295 | 2784 |
| 7 | 208 | 55 | 335 | 176 | 109 | 883 |
| 8 | 69 | 23 | 75 | 61 | 37 | 265 |
| 9 | 10 | 8 | 23 | 11 | 6 | 58 |
| 10 | 4 | 2 | 9 | 1 | 1 | 17 |
| 11 | 2 | 1 | 7 | 1 | 1 | 12 |
| 12 | 1 | | 6 | | | 7 |
| 13 | 1 | | 6 | | | 7 |
| 14 | | | | | | |
| 15 | 1 | | 7 | | | 8 |
| 16 | | | | | | |
| 17 | | | | | | |
| 18 | | | | | | |
| 19 | 1 | | | | | 1 |
| 20 | | | | | | |
| # | 4361 | 278 | 8663 | 2034 | 1813 | 17149 |
| Ave. wt. | 1.60 | 3.85 | 1.57 | 1.69 | 1.63 | 1.64 |
| Landings | 6983 | 1069 | 13595 | 3447 | 2955 | 28049 |

[a]Other

| | |
|---|---|
| France | 531 t |
| Port. (OT) | 71 |
| Rom. | 6 |
| Cuba | 8 |
| USSR | 2446 |
| Spain (OT) | 385 |

Table 4. Cod 3NO - mean number per standard tow from Research

| | 1971* | 1972* | 1973 | 1974* | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 |
|---|---|---|---|---|---|---|---|---|---|---|
| Sets | 38 | 45 | 95 | 37 | 56 | 75 | 87 | 88 | 166 | 140 |
| Age | | | | | | | | | | |
| 1 | .00 | .01 | .07 | .05 | .44 | .58 | .01 | .54 | 3.19 | .01 |
| 2 | 4.18 | 1.17 | 2.54 | 1.39 | 3.15 | 3.88 | 2.34 | .70 | .86 | 5.51 |
| 3 | 42.14 | 9.01 | 2.76 | 4.97 | 4.58 | 2.85 | 9.69 | 6.99 | 2.08 | 1.23 |
| 4 | 5.80 | 19.28 | 1.81 | .89 | 2.58 | 1.84 | 6.27 | 8.40 | 8.65 | .65 |
| 5 | 4.43 | 1.78 | 2.43 | .44 | .54 | 1.70 | 4.62 | 2.62 | 8.68 | 1.12 |
| 6 | 1.06 | .71 | .58 | .38 | .29 | .26 | 1.54 | .76 | 1.99 | .42 |
| 7 | 1.08 | .58 | .30 | .14 | .49 | .07 | .49 | .56 | .64 | .22 |
| 8 | .48 | .41 | .19 | .04 | .21 | .13 | .22 | .07 | .27 | .17 |
| 9 | .24 | .30 | .27 | .01 | .17 | .06 | .10 | .02 | .11 | .22 |
| 10 | .03 | .17 | .08 | .07 | .09 | .07 | .10 | .03 | .01 | .07 |
| 11 | .08 | .08 | .05 | .03 | .00 | .02 | .01 | .03 | .05 | .02 |
| 12 | .14 | .05 | .06 | .00 | .02 | .00 | .04 | .04 | .00 | .02 |
| 13 | .47 | .36 | .49 | .15 | .13 | .06 | .20 | .04 | .03 | .04 |
| 13+ | | | | | | | | .03 | .11 | .06 |
| Total age 3+ | | 32.73 | 9.02 | 7.12 | 9.10 | 7.06 | 23.28 | 19.59 | 22.62 | 4.33 |

*Survey in 3N only

Table 5. Regression co-efficients for grouped categories and the analysis of variance from the regression of ln catch rate for 3NO cod.

| Country - gear | | ln power | Month | ln power |
|---|---|---|---|---|
| Span | PT-5 | | Jun | |
| Span | PT-6 | 0.620 | Jul | 0.275 |
| Can M | OT-5 | | Dec | |
| Span | PT-4 | | Feb | |
| Can M | OT-4 | 0.316 | May | 0.178 |
| | | | Aug | |
| Port | OT-6 | 0.135 | | |
| | | | Jan | |
| Span | OT-6 | 0.000 | Apr | 0.000 |
| USSR | OT-7 | | Sep | |
| | | | Nov | |
| Can N | OT-5 | -0.132 | | |
| | | | Mar | -0.136 |
| Can N | OT-4 | -0.481 | Oct | |
| USSR | OT-5 | -0.855 | | |
| USSR | OT-6 | | Division | ln power |
| USSR | OT-4 | -1.893 | 3N | 0.000 |
| | | | 3O | |

REGRESSION OF MULTIPLICATIVE MODEL

MULTIPLE R.....0.715
MULTIPLE R SQUARED.....0.512

ANALYSIS OF VARIANCE

| SOURCE OF VARIATION | DF | SUMS OF SQUARES | MEAN SQUARES | F-VALUE |
|---|---|---|---|---|
| TYPE 1 | 7 | 2.12814E2 | 3.04020E1 | 96.012 |
| TYPE 2 | 3 | 2.71627E1 | 9.05424E0 | 28.594 |
| TYPE 3 | 21 | 2.25985E2 | 1.07612E1 | 33.985 |
| REGRESSION | 31 | 4.22843E2 | 1.36401E1 | 43.077 |
| RESIDUALS | 1274 | 4.03409E2 | 3.16648E-1 | |
| TOTAL | 1305 | 8.26252E2 | | |

Table 6. Historical catch and standardized effort and catch rate. The proportion of the catch used in estimating the catch rate is indicated.

| Year | Catch (t) | Prop. | Catch rate | | Effort (hr) |
|---|---|---|---|---|---|
| | | | Mean (t/hr) | Std. Err. | |
| 1959 | 62,459 | 0.088 | 1.025 | 0.137 | 60,936 |
| 1960 | 79,677 | 0.437 | 1.225 | 0.099 | 65,042 |
| 1961 | 72,724 | 0.483 | 1.032 | 0.080 | 70,469 |
| 1962 | 34,948 | 0.559 | 1.171 | 0.109 | 29,845 |
| 1963 | 69,742 | 0.585 | 2.080 | 0.174 | 33,530 |
| 1964 | 64,461 | 0.594 | 1.726 | 0.138 | 37,347 |
| 1965 | 99,187 | 0.723 | 1.705 | 0.120 | 58,174 |
| 1966 | 108,919 | 0.569 | 1.749 | 0.126 | 62,275 |
| 1967 | 226,784 | 0.901 | 2.133 | 0.122 | 106,322 |
| 1968 | 165,512 | 0.429 | 1.564 | 0.117 | 105,826 |
| 1969 | 117,705 | 0.619 | 1.443 | 0.104 | 81,570 |
| 1970 | 111,561 | 0.617 | 1.312 | 0.092 | 85,031 |
| 1971 | 126,296 | 0.717 | 1.497 | 0.105 | 84,366 |
| 1972 | 103,374 | 0.741 | 1.113 | 0.072 | 92,879 |
| 1973 | 80,429 | 0.531 | 0.806 | 0.060 | 99,788 |
| 1974 | 73,389 | 0.524 | 0.763 | 0.061 | 96,186 |
| 1975 | 44,174 | 0.391 | 0.711 | 0.072 | 62,129 |
| 1976 | 24,283 | 0.507 | 1.031 | 0.103 | 23,553 |
| 1977 | 17,575 | 0.567 | 0.451 | 0.044 | 38,969 |
| 1978 | 14,718 | 0.623 | 0.297 | 0.025 | 49,556 |
| 1979 | 28,049 | 0.146 | 1.279 | 0.179 | 21,930 |
| 1980 | 18,542 | 0.275 | 0.678 | 0.080 | 27,348 |

Table 7. Catch numbers at age (a) and average weights at age (b) matrices used in the cohort analysis.

(a)

| Age | 1959 | 1960 | 1961 | 1962 | 1963 | 1964 | 1965 | 1966 | 1967 | 1968 | 1969 | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 1711 | 1846 | 812 | 1026 | 313 | 6202 | 1013 | 753 | 20086 | 16359 | 8154 | 2105 | 950 | 69 | 10058 | 6425 | 671 | 4054 | 607 | 920 | 72 | 280 |
| 4 | 13036 | 6503 | 4400 | 3882 | 5757 | 15555 | 7611 | 18413 | 62442 | 56775 | 12924 | 19703 | 26900 | 19797 | 27600 | 9501 | 8781 | 7534 | 2469 | 4337 | 3827 | 1138 |
| 5 | 5068 | 22050 | 11696 | 2206 | 11210 | 19496 | 7619 | 19681 | 50317 | 48608 | 26949 | 10799 | 30300 | 12289 | 15098 | 10907 | 3528 | 5945 | 2531 | 2518 | 9208 | 3789 |
| 6 | 6025 | 3095 | 15258 | 1581 | 4849 | 7919 | 13258 | 11795 | 18517 | 18485 | 11191 | 9481 | 11700 | 13432 | 5989 | 10872 | 2505 | 1084 | 1500 | 818 | 2784 | 2057 |
| 7 | 3935 | 2377 | 2014 | 3594 | 1935 | 2273 | 9861 | 8486 | 4774 | 6337 | 2089 | 3646 | 3500 | 5883 | 1971 | 2247 | 3057 | 211 | 572 | 354 | 883 | 665 |
| 8 | 1392 | 2504 | 1672 | 773 | 3840 | 1109 | 4827 | 4467 | 4651 | 1592 | 1393 | 1635 | 2500 | 1686 | 972 | 2147 | 1059 | 238 | 177 | 102 | 265 | 185 |
| 9 | 757 | 583 | 847 | 668 | 1165 | 788 | 1081 | 1829 | 236 | 505 | 518 | 541 | 500 | 285 | 707 | 1015 | 921 | 44 | 209 | 58 | 58 | 75 |
| 10 | 926 | 387 | 196 | 433 | 608 | 328 | 1248 | 1694 | 180 | 178 | 292 | 149 | 200 | 216 | 243 | 676 | 461 | 37 | 65 | 51 | 17 | 27 |
| 11 | 1220 | 898 | 25 | 226 | 322 | 37 | 163 | 122 | 71 | 90 | 134 | 227 | 100 | 78 | 137 | 428 | 252 | 13 | 41 | 8 | 12 | 7 |
| 12 | 103 | 242 | 245 | 216 | 208 | 112 | 141 | 57 | 45 | 45 | 202 | 90 | 50 | 74 | 116 | 257 | 152 | 9 | 25 | 5 | 7 | 13 |

(b)

| Age | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 0.42 | 0.42 | 0.42 | 0.42 | 0.42 | 0.42 | 0.42 | 0.66 | 0.66 | 0.66 | 0.66 | 0.66 | 0.66 | 0.66 | 0.66 | 0.66 | 0.66 | 0.66 | 0.57 | 0.72 | 0.65 | 0.71 |
| 4 | 0.82 | 0.82 | 0.82 | 0.82 | 0.82 | 0.82 | 0.82 | 1.02 | 1.02 | 1.02 | 1.02 | 1.02 | 1.02 | 1.02 | 1.02 | 1.02 | 1.02 | 1.02 | 1 | 1.05 | 0.98 | 1.04 |
| 5 | 1.25 | 1.25 | 1.25 | 1.25 | 1.25 | 1.25 | 1.25 | 1.53 | 1.53 | 1.53 | 1.53 | 1.53 | 1.53 | 1.53 | 1.53 | 1.53 | 1.53 | 1.53 | 1.48 | 1.55 | 1.39 | 1.69 |
| 6 | 1.95 | 1.95 | 1.95 | 1.95 | 1.95 | 1.95 | 1.95 | 2.33 | 2.33 | 2.33 | 2.33 | 2.33 | 2.33 | 2.33 | 2.33 | 2.33 | 2.33 | 2.33 | 2.48 | 2.25 | 2.09 | 2.5 |
| 7 | 2.82 | 2.82 | 2.82 | 2.82 | 2.82 | 2.82 | 2.82 | 3.45 | 3.45 | 3.45 | 3.45 | 3.45 | 3.45 | 3.45 | 3.45 | 3.45 | 3.45 | 3.45 | 3.51 | 3.74 | 2.87 | 3.69 |
| 8 | 3.39 | 3.39 | 3.39 | 3.39 | 3.39 | 3.39 | 3.39 | 4.64 | 4.64 | 4.64 | 4.64 | 4.64 | 4.64 | 4.64 | 4.64 | 4.64 | 4.64 | 4.64 | 4.74 | 4.61 | 3.7 | 5.49 |
| 9 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 6.52 | 6.52 | 6.52 | 6.52 | 6.52 | 6.52 | 6.52 | 6.52 | 6.52 | 6.52 | 6.52 | 7.17 | 6.19 | 4.75 | 7.98 |
| 10 | 4.68 | 4.68 | 4.68 | 4.68 | 4.68 | 4.68 | 4.68 | 8.1 | 8.1 | 8.1 | 8.1 | 8.1 | 8.1 | 8.1 | 8.1 | 8.1 | 8.1 | 8.1 | 8.81 | 7.23 | 7.15 | 9.22 |
| 11 | 5.25 | 5.25 | 5.25 | 5.25 | 5.25 | 5.25 | 5.25 | 9.94 | 9.94 | 9.94 | 9.94 | 9.94 | 9.94 | 9.94 | 9.94 | 9.94 | 9.94 | 9.94 | 11.7 | 9.48 | 7.98 | 10.6 |
| 12 | 6.17 | 6.17 | 6.17 | 6.17 | 6.17 | 6.17 | 6.17 | 11.77 | 11.77 | 11.77 | 11.77 | 11.77 | 11.77 | 11.77 | 11.77 | 11.77 | 11.77 | 11.77 | 11.47 | 12.87 | 10.11 | 12.61 |

Table 8. Selection pattern in 1980 from survey abundance estimates and commercial catch estimates at age.

| Age | Survey abundance estimates ($X\ 10^{-3}$) | Commercial catch | Relative exploitation rate | Partial selection |
|---|---|---|---|---|
| 1 | 20 | | | |
| 2 | 13817 | 5 | | |
| 3 | 3364 | 280 | .083 | .05 |
| 4 | 1734 | 1138 | .656 | .36 |
| 5 | 2711 | 3789 | 1.398 | .77 |
| 6 | 1127 | 2057 | 1.825 | 1.00 |
| 7 | 511 | 665 | 1.301 | .71 |
| 8 | 478 | 185 | .387 | .21 |
| 9 | 462 | 75 | .162 | .09 |
| 10 | 241 | 27 | .112 | .06 |
| 11 | 138 | 7 | .051 | .03 |
| 12 | 171 | 13 | .076 | .04 |
| 13 | 80 | | | |
| 14 | 65 | | | |
| 15 | 64 | | | |
| 16 | 19 | | | |
| 17 | 30 | 2 | | |
| 18 | 18 | | | |
| 19 | 19 | | | |
| 20 | 18 | | | |
| 21 | | | | |
| 22 | 48 | | | |
| Total | 25135 | 8243 | | |

Table 9. Ave. wts. at age of 3NO Cod from the commercial fishery for the years 1977 - 1980.

| Age | 1977 | 1978 | 1979 | 1980 | Ave. | Ave from fitted line |
|---|---|---|---|---|---|---|
| 3 | 0.57 | .72 | .65 | .71 | .66 | |
| 4 | 1.00 | 1.05 | .98 | 1.04 | 1.02 | |
| 5 | 1.48 | 1.55 | 1.39 | 1.69 | 1.53 | |
| 6 | 2.48 | 2.25 | 2.09 | 2.50 | 2.33 | |
| 7 | 3.51 | 3.74 | 2.87 | 3.69 | 3.45 | |
| 8 | 4.74 | 4.61 | 3.70 | 5.49 | 4.64 | |
| 9 | 7.17 | 6.19 | 4.75 | 7.98 | 6.52 | |
| 10 | 8.81 | 7.23 | 7.15 | 9.22 | 8.10 | |
| 11 | 11.70 | 9.48 | 7.98 | 10.60 | 9.94 | |
| 12 | 11.47 | 12.87 | 10.11 | 12.61 | 11.77 | |
| 13 | 11.19 | 15.38 | 10.11 | | 12.23 | (13.2) |
| 14 | 15.39 | 17.85 | | | 16.62 | (15.0) |
| 15 | 23.05 | 18.00 | 16.63 | | 19.23 | (16.6) |
| 16 | 16.29 | 19.00 | | | 16.65 | (18.0) |
| 17 | 17.93 | 23.85 | | 19.31 | 20.36 | (19.2) |
| 18 | | 21.00 | | | 21.00 | (20.2) |
| 19 | | 15.38 | 16.63 | | 16.01 | (21.0) |
| 20 | | 22.26 | | | 22.26 | (21.6) |

Table 10. Population numbers from the cohort run at $F_t$=0.25

POPULATION NUMBERS 11/ 2/81

| | 1959 | 1960 | 1961 | 1962 | 1963 | 1964 | 1965 | 1966 | 1967 |
|---|---|---|---|---|---|---|---|---|---|
| 3 | 53651 | 52732 | 82065 | 107694 | 78106 | 111665 | 162299 | 210017 | 183178 |
| 4 | 93912 | 42377 | 41503 | 66454 | 87244 | 63665 | 85812 | 131962 | 171266 |
| 5 | 19562 | 65093 | 28811 | 29999 | 50895 | 66220 | 38050 | 63370 | 91381 |
| 6 | 16682 | 11430 | 33342 | 13006 | 22565 | 31526 | 36576 | 24258 | 34075 |
| 7 | 12250 | 8207 | 6558 | 13492 | 9218 | 14087 | 18646 | 17950 | 9189 |
| 8 | 4911 | 6469 | 4568 | 3547 | 7794 | 5796 | 9477 | 6344 | 7017 |
| 9 | 3506 | 2761 | 3031 | 2227 | 2204 | 2907 | 3742 | 3391 | 1152 |
| 10 | 3110 | 2185 | 1733 | 1715 | 1219 | 751 | 1667 | 2085 | 1122 |
| 11 | 2352 | 1708 | 1439 | 1242 | 1012 | 448 | 318 | 236 | 175 |
| 12 | 317 | 821 | 586 | 1155 | 812 | 537 | 333 | 113 | 82 |
| 3+ | 210251 | 193784 | 203636 | 240531 | 261070 | 297603 | 356919 | 459726 | 498636 |
| 4+ | 156601 | 141052 | 121571 | 132836 | 182964 | 185937 | 194620 | 249709 | 315458 |
| 5+ | 62689 | 98675 | 80068 | 66382 | 95720 | 122273 | 108808 | 117747 | 144192 |
| 6+ | 43127 | 33582 | 51257 | 36384 | 44825 | 56052 | 70759 | 54376 | 52811 |

| | 1968 | 1969 | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 |
|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 100454 | 127793 | 80266 | 84245 | 61871 | 34410 | 34680 | 21401 | 24922 | 40324 |
| 4 | 131799 | 67443 | 97250 | 63812 | 68114 | 50594 | 19072 | 22580 | 16915 | 16737 |
| 5 | 83721 | 56536 | 43523 | 61793 | 27905 | 37854 | 16449 | 7018 | 10541 | 7032 |
| 6 | 29288 | 24562 | 21903 | 25863 | 23176 | 11727 | 17331 | 3598 | 2554 | 3251 |
| 7 | 11143 | 7253 | 9984 | 9354 | 10588 | 6821 | 4182 | 4352 | 679 | 1110 |
| 8 | 3203 | 3390 | 4048 | 4875 | 4491 | 3345 | 3801 | 1391 | 797 | 365 |
| 9 | 1537 | 1182 | 1515 | 1835 | 1729 | 2152 | 1860 | 1169 | 180 | 437 |
| 10 | 729 | 801 | 499 | 751 | 1050 | 1158 | 1122 | 604 | 124 | 108 |
| 11 | 755 | 436 | 392 | 274 | 434 | 664 | 728 | 307 | 77 | 68 |
| 12 | 79 | 537 | 236 | 115 | 134 | 284 | 420 | 209 | 23 | 52 |
| 3+ | 362709 | 289933 | 259616 | 252916 | 199491 | 149009 | 99644 | 62629 | 56814 | 69484 |
| 4+ | 262255 | 162140 | 179350 | 168671 | 137620 | 114599 | 64964 | 41228 | 31891 | 29159 |
| 5+ | 130456 | 94697 | 82100 | 104860 | 69506 | 64005 | 45892 | 18648 | 14977 | 12423 |
| 6+ | 46735 | 38161 | 38576 | 43066 | 41601 | 26151 | 29443 | 11630 | 4435 | 5391 |

| | 1978 | 1979 | 1980 |
|---|---|---|---|
| 3 | 41685 | 17871 | 24864 |
| 4 | 32466 | 33296 | 14566 |
| 5 | 11469 | 22656 | 23798 |
| 6 | 3467 | 7111 | 10218 |
| 7 | 1305 | 2098 | 3303 |
| 8 | 391 | 748 | 919 |
| 9 | 139 | 228 | 373 |
| 10 | 169 | 61 | 134 |
| 11 | 30 | 92 | 35 |
| 12 | 19 | 17 | 65 |
| 3+ | 91138 | 84180 | 78274 |
| 4+ | 49453 | 66309 | 53410 |
| 5+ | 16987 | 33012 | 38844 |
| 6+ | 5519 | 10356 | 15046 |

Table 11. Mean population biomass from the cohort run at $F_t$=0.25

MEAN POPULATION BIOMASS (KG) 11/ 2/81

| | 1959 | 1960 | 1961 | 1962 | 1963 | 1964 | 1965 | 1966 | 1967 |
|---|---|---|---|---|---|---|---|---|---|
| 3 | 20073 | 19695 | 31074 | 40786 | 29669 | 41232 | 61575 | 125389 | 103014 |
| 4 | 64472 | 28830 | 29061 | 47830 | 62525 | 40806 | 60701 | 112640 | 124762 |
| 5 | 18917 | 59325 | 24840 | 32632 | 50551 | 62425 | 38298 | 72243 | 83492 |
| 6 | 23298 | 17101 | 42784 | 21456 | 35089 | 47824 | 51026 | 36169 | 47804 |
| 7 | 25532 | 17514 | 13815 | 29283 | 20797 | 32796 | 32177 | 40159 | 19595 |
| 8 | 12656 | 15373 | 11047 | 9569 | 16798 | 15913 | 20075 | 14120 | 16745 |
| 9 | 11119 | 8785 | 9197 | 6658 | 5371 | 8874 | 11277 | 13374 | 6029 |
| 10 | 10949 | 8359 | 6897 | 6238 | 3605 | 2357 | 3423 | 6240 | 7504 |
| 11 | 7638 | 5507 | 6783 | 5311 | 3937 | 2036 | 1039 | 1450 | 1196 |
| 12 | 1444 | 3829 | 2478 | 5794 | 3889 | 2658 | 1403 | 839 | 588 |
| 3+ | 196097 | 184319 | 177975 | 205557 | 232231 | 256922 | 280994 | 422622 | 410729 |
| 4+ | 176024 | 164623 | 146902 | 164771 | 202562 | 215690 | 219419 | 297233 | 307715 |
| 5+ | 111553 | 135793 | 117841 | 116941 | 140037 | 174884 | 158718 | 184593 | 182953 |
| 6+ | 92636 | 76467 | 93001 | 84309 | 89486 | 112459 | 120420 | 112350 | 99462 |

| | 1968 | 1969 | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 |
|---|---|---|---|---|---|---|---|---|---|
| 3 | 54685 | 73806 | 47338 | 50090 | 36989 | 17154 | 18611 | 12586 | 13569 |
| 4 | 90699 | 55705 | 79750 | 44279 | 52541 | 30997 | 12298 | 16120 | 11485 |
| 5 | 73811 | 55880 | 51914 | 60248 | 28552 | 40193 | 12937 | 6756 | 9483 |
| 6 | 36783 | 37732 | 34366 | 39851 | 31155 | 17049 | 21885 | 4080 | 4037 |
| 7 | 22477 | 18959 | 24588 | 22867 | 21688 | 17818 | 8747 | 7226 | 1746 |
| 8 | 9408 | 10800 | 12978 | 14083 | 14752 | 11740 | 10358 | 2750 | 2781 |
| 9 | 7365 | 5165 | 7096 | 9166 | 9288 | 10310 | 7280 | 3037 | 920 |
| 10 | 4620 | 4637 | 3040 | 4679 | 6822 | 7505 | 5093 | 2077 | 755 |
| 11 | 6362 | 3239 | 2249 | 1943 | 3516 | 5293 | 4134 | 1093 | 633 |
| 12 | 546 | 4486 | 1962 | 920 | 947 | 2314 | 2775 | 1169 | 193 |
| 3+ | 306755 | 270409 | 265279 | 248126 | 206250 | 160374 | 104117 | 56893 | 45600 |
| 4+ | 252070 | 196603 | 217940 | 198036 | 169261 | 143220 | 85506 | 44307 | 32031 |
| 5+ | 161371 | 140898 | 138190 | 153757 | 116720 | 112223 | 73208 | 28187 | 20547 |
| 6+ | 87560 | 85018 | 86277 | 93509 | 88168 | 72030 | 60271 | 21431 | 11064 |

| | 1977 | 1978 | 1979 | 1980 |
|---|---|---|---|---|
| 3 | 20664 | 26880 | 10506 | 15904 |
| 4 | 13937 | 28631 | 27716 | 13150 |
| 5 | 7461 | 14132 | 21712 | 33264 |
| 6 | 5287 | 6132 | 10380 | 20570 |
| 7 | 2419 | 3742 | 4099 | 9815 |
| 8 | 1110 | 1393 | 1993 | 4063 |
| 9 | 2023 | 587 | 840 | 2394 |
| 10 | 533 | 916 | 334 | 996 |
| 11 | 446 | 215 | 619 | 297 |
| 12 | 382 | 184 | 118 | 656 |
| 3+ | 54261 | 82812 | 78317 | 101109 |
| 4+ | 33597 | 55932 | 67811 | 85205 |
| 5+ | 19660 | 27301 | 40095 | 72055 |
| 6+ | 12199 | 13169 | 18383 | 38790 |

Table 12. Catch biomass from the cohort run at $F_t$=0.25.

CATCH BIOMASS 11/ 2/81

| | 1959 | 1960 | 1961 | 1962 | 1963 | 1964 | 1965 | 1966 | 1967 | 1968 |
|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 719 | 775 | 341 | 431 | 131 | 2605 | 425 | 497 | 13257 | 10797 |
| 4 | 10690 | 5332 | 3608 | 3183 | 4721 | 12755 | 6241 | 18781 | 63691 | 57911 |
| 5 | 6335 | 27563 | 14620 | 2758 | 14013 | 24370 | 9524 | 30112 | 76985 | 74370 |
| 6 | 11749 | 6035 | 29753 | 3083 | 9456 | 15442 | 25853 | 27482 | 43145 | 43070 |
| 7 | 11097 | 6703 | 5679 | 10135 | 5457 | 6410 | 27808 | 29277 | 16470 | 21863 |
| 8 | 4719 | 8489 | 5668 | 2620 | 13018 | 3760 | 16364 | 20727 | 21581 | 7387 |
| 9 | 3013 | 2320 | 3371 | 2659 | 4637 | 3136 | 4302 | 11925 | 1539 | 3293 |
| 10 | 4334 | 1811 | 917 | 2026 | 2845 | 1535 | 5841 | 13721 | 1458 | 1442 |
| 11 | 6405 | 4715 | 131 | 1187 | 1691 | 194 | 856 | 1213 | 706 | 895 |
| 12 | 636 | 1493 | 1512 | 1333 | 1283 | 691 | 870 | 671 | 530 | 530 |
| 3+ | 59695 | 65236 | 65601 | 29414 | 57251 | 70898 | 98084 | 154406 | 239360 | 221556 |
| 4+ | 58976 | 64461 | 65260 | 28984 | 57119 | 68293 | 97658 | 153909 | 226104 | 210759 |
| 5+ | 48286 | 59129 | 61652 | 25800 | 52398 | 55538 | 91417 | 135128 | 162413 | 152848 |
| 6+ | 41951 | 31566 | 47032 | 23043 | 38386 | 31168 | 81893 | 105016 | 85428 | 78478 |

| | 1969 | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 |
|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 5382 | 1389 | 627 | 46 | 6638 | 4241 | 443 | 2676 | 346 | 662 |
| 4 | 13182 | 20097 | 27438 | 20193 | 28152 | 9691 | 8957 | 7685 | 2469 | 4554 |
| 5 | 41232 | 16522 | 46359 | 18802 | 23100 | 16688 | 5398 | 9096 | 3746 | 3903 |
| 6 | 26075 | 22091 | 27261 | 31297 | 13954 | 25332 | 5837 | 2526 | 3720 | 1841 |
| 7 | 7207 | 12579 | 12075 | 20296 | 6800 | 7752 | 10547 | 728 | 2008 | 1324 |
| 8 | 6464 | 7586 | 11600 | 7823 | 4510 | 9962 | 4914 | 1104 | 839 | 470 |
| 9 | 3377 | 3527 | 3260 | 1858 | 4610 | 6618 | 6005 | 287 | 1499 | 359 |
| 10 | 2365 | 1207 | 1620 | 1750 | 1968 | 5476 | 3734 | 300 | 573 | 369 |
| 11 | 1332 | 2256 | 994 | 775 | 1362 | 4254 | 2505 | 129 | 480 | 76 |
| 12 | 2378 | 1059 | 589 | 871 | 1365 | 3025 | 1789 | 106 | 287 | 64 |
| 3+ | 108994 | 88315 | 131822 | 103711 | 92460 | 93038 | 50127 | 24636 | 15965 | 13622 |
| 4+ | 103612 | 86925 | 131195 | 103665 | 85821 | 88797 | 49684 | 21960 | 15619 | 12959 |
| 5+ | 90430 | 66828 | 103757 | 83472 | 57669 | 79106 | 40728 | 14276 | 13150 | 8406 |
| 6+ | 49198 | 50306 | 57398 | 64670 | 34569 | 62419 | 35330 | 5180 | 9404 | 4503 |

| | 1979 | 1980 |
|---|---|---|
| 3 | 47 | 199 |
| 4 | 3750 | 1184 |
| 5 | 12799 | 6403 |
| 6 | 5819 | 5143 |
| 7 | 2534 | 2454 |
| 8 | 980 | 1016 |
| 9 | 276 | 598 |
| 10 | 122 | 249 |
| 11 | 96 | 74 |
| 12 | 71 | 164 |
| 3+ | 26493 | 17483 |
| 4+ | 26446 | 17284 |
| 5+ | 22696 | 16101 |
| 6+ | 9897 | 9698 |

Table 13. Fishing mortality from the cohort run at $F_t$=0.25.

FISHING MORTALITY 11/ 2/81

| | 1959 | 1960 | 1961 | 1962 | 1963 | 1964 | 1965 | 1966 | 1967 | 1968 | 1969 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 0.036 | 0.039 | 0.011 | 0.011 | 0.004 | 0.063 | 0.007 | 0.004 | 0.129 | 0.198 | 0.073 |
| 4 | 0.167 | 0.186 | 0.125 | 0.067 | 0.076 | 0.315 | 0.103 | 0.167 | 0.516 | 0.646 | 0.238 |
| 5 | 0.337 | 0.469 | 0.595 | 0.085 | 0.279 | 0.394 | 0.250 | 0.420 | 0.938 | 1.026 | 0.748 |
| 6 | 0.509 | 0.356 | 0.705 | 0.144 | 0.271 | 0.325 | 0.512 | 0.771 | 0.918 | 1.196 | 0.700 |
| 7 | 0.439 | 0.386 | 0.415 | 0.349 | 0.264 | 0.196 | 0.878 | 0.739 | 0.854 | 0.990 | 0.383 |
| 8 | 0.376 | 0.558 | 0.518 | 0.276 | 0.786 | 0.238 | 0.828 | 1.506 | 1.319 | 0.797 | 0.605 |
| 9 | 0.273 | 0.266 | 0.369 | 0.403 | 0.877 | 0.356 | 0.385 | 0.906 | 0.257 | 0.451 | 0.662 |
| 10 | 0.399 | 0.218 | 0.134 | 0.327 | 0.801 | 0.660 | 1.757 | 2.280 | 0.195 | 0.314 | 0.515 |
| 11 | 0.852 | 0.870 | 0.019 | 0.225 | 0.433 | 0.096 | 0.837 | 0.850 | 0.597 | 0.141 | 0.415 |
| 12 | 0.440 | 0.390 | 0.610 | 0.230 | 0.330 | 0.260 | 0.620 | 0.800 | 0.900 | 0.970 | 0.530 |
| 6+ | 0.465 | 0.413 | 0.592 | 0.263 | 0.408 | 0.287 | 0.675 | 0.913 | 0.929 | 1.064 | 0.621 |

| | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 0.029 | 0.013 | 0.001 | 0.390 | 0.229 | 0.035 | 0.198 | 0.017 | 0.025 | 0.004 | 0.013 |
| 4 | 0.253 | 0.627 | 0.387 | 0.924 | 0.800 | 0.562 | 0.678 | 0.178 | 0.160 | 0.136 | 0.090 |
| 5 | 0.321 | 0.781 | 0.667 | 0.581 | 1.320 | 0.811 | 0.976 | 0.507 | 0.278 | 0.596 | 0.192 |
| 6 | 0.651 | 0.693 | 1.023 | 0.831 | 1.182 | 1.467 | 0.633 | 0.713 | 0.302 | 0.567 | 0.250 |
| 7 | 0.517 | 0.534 | 0.952 | 0.385 | 0.901 | 1.497 | 0.420 | 0.843 | 0.356 | 0.626 | 0.250 |
| 8 | 0.591 | 0.836 | 0.536 | 0.387 | 0.979 | 1.842 | 0.400 | 0.767 | 0.340 | 0.497 | 0.250 |
| 9 | 0.502 | 0.358 | 0.201 | 0.451 | 0.924 | 2.044 | 0.314 | 0.751 | 0.619 | 0.330 | 0.250 |
| 10 | 0.400 | 0.349 | 0.258 | 0.264 | 1.096 | 1.854 | 0.400 | 1.096 | 0.406 | 0.366 | 0.250 |
| 11 | 1.022 | 0.517 | 0.222 | 0.259 | 1.049 | 2.380 | 0.205 | 1.098 | 0.356 | 0.155 | 0.250 |
| 12 | 0.540 | 0.640 | 0.920 | 0.590 | 1.090 | 1.530 | 0.550 | 0.750 | 0.350 | 0.600 | 0.250 |
| 6+ | 0.604 | 0.653 | 0.890 | 0.584 | 1.092 | 1.627 | 0.531 | 0.759 | 0.329 | 0.564 | 0.250 |

Table 14. Relationship of CPUE to $3^+$ and $4^+$ biomass from cohort runs at indicated terminal $F^S$ assuming 'flat topped' recruitment.

| | | $3^+$ biomass at $F_t$ | | | | $4^+$ biomass at $F_t$ | | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | CPUE | 0.10 | 0.20 | 0.25 | 0.30 | 0.10 | 0.20 | 0.25 | 0.30 |
| 1959 | 1.025 | 196 | 196 | 196 | 196 | 176 | 176 | 176 | 176 |
| 60 | 1.225 | 184 | 184 | 184 | 184 | 165 | 165 | 165 | 165 |
| 61 | 1.032 | 178 | 178 | 178 | 178 | 147 | 147 | 147 | 147 |
| 62 | 1.171 | 206 | 206 | 206 | 206 | 165 | 165 | 165 | 165 |
| 63 | 2.080* | 232 | 232 | 232 | 232 | 203 | 203 | 203 | 203 |
| 64 | 1.726 | 257 | 257 | 257 | 257 | 216 | 216 | 216 | 216 |
| 65 | 1.705 | 281 | 281 | 281 | 281 | 219 | 219 | 219 | 219 |
| 66 | 1.749 | 423 | 423 | 423 | 423 | 297 | 297 | 297 | 297 |
| 67 | 2.133 | 411 | 411 | 411 | 411 | 308 | 308 | 308 | 308 |
| 68 | 1.564 | 307 | 307 | 307 | 307 | 252 | 252 | 252 | 252 |
| 69 | 1.443 | 270 | 270 | 270 | 270 | 197 | 197 | 197 | 197 |
| 70 | 1.312 | 265 | 265 | 265 | 265 | 218 | 218 | 218 | 218 |
| 71 | 1.497 | 248 | 248 | 248 | 248 | 198 | 198 | 198 | 198 |
| 72 | 1.113 | 207 | 206 | 206 | 206 | 170 | 169 | 169 | 169 |
| 73 | .806 | 161 | 161 | 160 | 160 | 144 | 143 | 143 | 143 |
| 74 | .763 | 107 | 105 | 104 | 104 | 87 | 86 | 86 | 85 |
| 75 | .711 | 62 | 58 | 57 | 56 | 47 | 45 | 44 | 44 |
| 76 | 1.031* | 58 | 48 | 46 | 44 | 38 | 33 | 32 | 31 |
| 77 | .451 | 82 | 59 | 54 | 51 | 48 | 36 | 34 | 32 |
| 78 | .297 | 152 | 94 | 83 | 75 | 93 | 62 | 56 | 52 |
| 79 | 1.279* | 168 | 93 | 78 | 68 | 143 | 80 | 68 | 59 |
| 80 | .678* | 253 | 126 | 101 | 84 | 213 | 107 | 85 | 71 |
| Predicted 1980 Biomass | | 127 | 113 | 109 | 107 | 100 | 92 | 91 | 90 |
| | Slope | 179.74 | 197.91 | 201.66 | 204.16 | 140.96 | 150.70 | 152.56 | 153.95 |
| | Int. | 5.14 | -21.67 | -27.26 | -30.94 | 4.71 | -9.71 | -12.45 | -14.51 |
| | $r^2$ | .79 | .86 | .86 | .87 | .85 | .88 | .88 | .89 |
| | t value | 7.77 | 9.73 | 10.10 | 10.34 | 9.57 | 10.87 | 11.05 | 11.17 |

* Regression values excluded from regression

Table 15. Numbers of cod at age 3 from a cohort analysis at $F_t$=0.25 compared with the number of cod of the same year classes as 3 yr olds and 2 yr olds per survey tow.

| Yr. class | Catch/tow Age 2 | Catch/tow Age 3 | $Pop^N$ Numbers at Age 3 ($x10^{-6}$) |
|---|---|---|---|
| 1969 | 4.18 | 9.01 | 61.9 |
| 1970 | 1.17 | 2.76 | 34.4 |
| 1971 | 2.54 | 4.97 | 34.7 |
| 1972 | 1.39 | 4.58 | 21.4 |
| 1973 | 3.15 | 2.85 | 24.9 |
| 1974 | 3.88 | 9.69 | 40.3 |
| 1975 | 2.34 | 6.99 | 41.7 |
| 1976 | .70 | 2.08 | |
| 1977 | .86 | 1.23 | |
| 1978 | 5.51 | | |

| | Age 3 survey vs. Age 3 cohort | Age 2 survey vs. Age 3 cohort |
|---|---|---|
| m | 3.51 | 7.24 |
| B | 16.80 | 17.99 |
| 'r' | .73 | .62 |
| t | 2.42 | 1.79 |
| df | 5 | 5 |

| Predicted Age 3's | Predicted Age 3's |
|---|---|
| 1976 yr class = 24 | 1976 yr class = 23 |
| 1977 yr class = 21 | 1977 yr class = 24 |
| | 1978 yr class = 58 |

Table 16. Yield per recruit analysis - 3NO cod.

| | FISHING MORTALITY | CATCH (NUMBER) | YIELD (KG) | AVG. WEIGHT (KG) | YIELD PER UNIT EFFORT |
|---|---|---|---|---|---|
| | 0.1000 | 0.235 | 1.104 | 4.696 | 1.000 |
| F0.1---- | 0.1371 | 0.288 | 1.222 | 4.239 | 0.807 |
| | 0.2000 | 0.357 | 1.295 | 3.632 | 0.586 |
| FMAX---- | 0.2280 | 0.381 | 1.300 | 3.415 | 0.516 |
| | 0.3000 | 0.431 | 1.280 | 2.971 | 0.386 |
| | 0.4000 | 0.481 | 1.224 | 2.542 | 0.277 |
| | 0.5000 | 0.518 | 1.166 | 2.249 | 0.211 |
| | 0.6000 | 0.547 | 1.116 | 2.040 | 0.168 |
| | 0.7000 | 0.570 | 1.074 | 1.884 | 0.139 |
| | 0.8000 | 0.589 | 1.039 | 1.765 | 0.118 |
| | 0.9000 | 0.605 | 1.010 | 1.670 | 0.102 |
| | 1.0000 | 0.619 | 0.986 | 1.593 | 0.089 |
| | 1.1000 | 0.631 | 0.965 | 1.530 | 0.079 |
| | 1.2000 | 0.641 | 0.947 | 1.477 | 0.071 |
| | 1.3000 | 0.651 | 0.932 | 1.431 | 0.065 |
| | 1.4000 | 0.659 | 0.918 | 1.392 | 0.059 |
| | 1.5000 | 0.667 | 0.906 | 1.358 | 0.055 |
| | 1.6000 | 0.674 | 0.895 | 1.328 | 0.051 |
| | 1.7000 | 0.681 | 0.886 | 1.301 | 0.047 |
| | 1.8000 | 0.687 | 0.877 | 1.277 | 0.044 |
| | 1.9000 | 0.692 | 0.869 | 1.256 | 0.041 |
| | 2.0000 | 0.698 | 0.862 | 1.236 | 0.039 |

| Age | P.S. | Ave. Weight |
|---|---|---|
| 3 | .05 | .66 |
| 4 | .36 | 1.03 |
| 5 | .77 | 1.53 |
| 6 | 1.00 | 2.33 |
| 7 | 1.00 | 3.45 |
| 8 | 1.00 | 4.64 |
| 9 | 1.00 | 6.52 |
| 10 | 1.00 | 8.10 |
| 11 | 1.00 | 9.94 |
| 12 | 1.00 | 11.77 |
| 13 | 1.00 | 13.20 |
| 14 | 1.00 | 15.00 |
| 15 | 1.00 | 16.60 |
| 16 | 1.00 | 18.00 |
| 17 | 1.00 | 19.20 |
| 18 | 1.00 | 20.20 |
| 19 | 1.00 | 21.00 |
| 20 | 1.00 | 21.60 |

Table 17. Results of a population and catch projection for 3NO cod at $F_{0.1}$=0.14.

POPULATION NUMBERS

| | 1980 | 1981 | 1982 |
|---|---|---|---|
| 3 | 24864 | 60000 | 40000 |
| 4 | 14566 | 20104 | 48781 |
| 5 | 23798 | 10899 | 15651 |
| 6 | 10218 | 16072 | 8012 |
| 7 | 3303 | 6515 | 11440 |
| 8 | 919 | 2106 | 4637 |
| 9 | 373 | 586 | 1499 |
| 10 | 134 | 238 | 417 |
| 11 | 35 | 85 | 169 |
| 12 | 65 | 22 | 61 |
| 3+ | 78275 | 116629 | 130667 |
| 4+ | 53411 | 56629 | 90667 |
| 5+ | 38845 | 36525 | 41886 |
| 6+ | 15047 | 25625 | 26235 |

POPULATION BIOMASS (AVERAGE)

| | 1980 | 1981 | 1982 |
|---|---|---|---|
| 3 | 14783.86 | 35770.15 | 23846.77 |
| 4 | 12896.98 | 18140.28 | 44016.23 |
| 5 | 30115.20 | 14353.59 | 20611.17 |
| 6 | 19171.92 | 31746.49 | 15824.63 |
| 7 | 9176.26 | 19055.33 | 33457.90 |
| 8 | 3433.83 | 8284.10 | 18241.27 |
| 9 | 1958.70 | 3238.90 | 8285.43 |
| 10 | 873.94 | 1633.70 | 2864.01 |
| 11 | 280.39 | 719.80 | 1426.96 |
| 12 | 616.60 | 223.09 | 606.66 |
| 3+ | 93307.70 | 133165.42 | 169181.03 |
| 4+ | 78523.83 | 97395.26 | 145334.26 |
| 5+ | 65626.85 | 79254.99 | 101318.04 |
| 6+ | 35511.65 | 64901.40 | 80706.87 |

CATCH NUMBERS

| | 1980 | 1981 | 1982 |
|---|---|---|---|
| 3 | 280 | 379 | 253 |
| 4 | 1138 | 896 | 2175 |
| 5 | 3789 | 1011 | 1452 |
| 6 | 2057 | 1908 | 951 |
| 7 | 665 | 773 | 1358 |
| 8 | 185 | 250 | 550 |
| 9 | 75 | 70 | 178 |
| 10 | 27 | 28 | 50 |
| 11 | 7 | 10 | 20 |
| 12 | 13 | 3 | 7 |
| 3+ | 8236 | 5328 | 6994 |
| 4+ | 7956 | 4949 | 6741 |
| 5+ | 6818 | 4053 | 4566 |
| 6+ | 3029 | 3041 | 3114 |

CATCH BIOMASS

| | 1980 | 1981 | 1982 |
|---|---|---|---|
| 3 | 185 | 250 | 167 |
| 4 | 1161 | 914 | 2218 |
| 5 | 5797 | 1547 | 2222 |
| 6 | 4793 | 4445 | 2215 |
| 7 | 2294 | 2668 | 4684 |
| 8 | 858 | 1160 | 2554 |
| 9 | 489 | 453 | 1160 |
| 10 | 219 | 229 | 401 |
| 11 | 70 | 101 | 200 |
| 12 | 153 | 31 | 85 |
| 3+ | 16018 | 11798 | 15906 |
| 4+ | 15834 | 11548 | 15739 |
| 5+ | 14673 | 10634 | 13521 |
| 6+ | 8876 | 9086 | 11299 |

FISHING MORTALITY

| | 1980 | 1981 | 1982 |
|---|---|---|---|
| 3 | 0.013 | 0.007 | 0.007 |
| 4 | 0.090 | 0.050 | 0.050 |
| 5 | 0.192 | 0.108 | 0.108 |
| 6 | 0.250 | 0.140 | 0.140 |
| 7 | 0.250 | 0.140 | 0.140 |
| 8 | 0.250 | 0.140 | 0.140 |
| 9 | 0.250 | 0.140 | 0.140 |
| 10 | 0.250 | 0.140 | 0.140 |
| 11 | 0.248 | 0.140 | 0.140 |
| 12 | 0.248 | 0.140 | 0.140 |
| 3+ | 0.127 | 0.053 | 0.062 |

Table 18. Results of a population and catch projection for 3NO cod at $F_{0.1}$=0.18.

POPULATION NUMBERS

| | 1980 | 1981 | 1982 |
|---|---|---|---|
| 3 | 24864 | 60000 | 40000 |
| 4 | 14566 | 20104 | 48684 |
| 5 | 23798 | 10899 | 15427 |
| 6 | 10218 | 16072 | 7769 |
| 7 | 3303 | 6515 | 10991 |
| 8 | 919 | 2106 | 4456 |
| 9 | 373 | 586 | 1440 |
| 10 | 134 | 238 | 401 |
| 11 | 35 | 85 | 163 |
| 12 | 65 | 22 | 58 |
| 3+ | 78275 | 116629 | 129388 |
| 4+ | 53411 | 56629 | 89388 |
| 5+ | 38845 | 36525 | 40705 |
| 6+ | 15047 | 25625 | 25278 |

POPULATION BIOMASS (AVERAGE)

| | 1980 | 1981 | 1982 |
|---|---|---|---|
| 3 | 14783.86 | 35735.64 | 23823.76 |
| 4 | 12896.98 | 18015.70 | 43626.60 |
| 5 | 30115.20 | 14145.94 | 20022.59 |
| 6 | 19171.92 | 31155.15 | 15058.84 |
| 7 | 9176.26 | 18700.39 | 31547.22 |
| 8 | 3433.83 | 8129.79 | 17199.57 |
| 9 | 1958.70 | 3178.57 | 7812.27 |
| 10 | 873.94 | 1603.26 | 2700.46 |
| 11 | 280.39 | 706.39 | 1345.47 |
| 12 | 616.60 | 218.93 | 572.01 |
| 3+ | 93307.70 | 131589.77 | 163708.79 |
| 4+ | 78523.83 | 95854.13 | 139885.03 |
| 5+ | 65626.85 | 77838.43 | 96258.43 |
| 6+ | 35511.65 | 63692.49 | 76235.84 |

CATCH NUMBERS

| | 1980 | 1981 | 1982 |
|---|---|---|---|
| 3 | 280 | 487 | 325 |
| 4 | 1138 | 1145 | 2772 |
| 5 | 3789 | 1281 | 1814 |
| 6 | 2057 | 2407 | 1163 |
| 7 | 665 | 976 | 1646 |
| 8 | 185 | 315 | 667 |
| 9 | 75 | 88 | 216 |
| 10 | 27 | 36 | 60 |
| 11 | 7 | 13 | 24 |
| 12 | 13 | 3 | 9 |
| 3+ | 8236 | 6751 | 8696 |
| 4+ | 7956 | 6263 | 8371 |
| 5+ | 6818 | 5119 | 5599 |
| 6+ | 3029 | 3837 | 3785 |

CATCH BIOMASS

| | 1980 | 1981 | 1982 |
|---|---|---|---|
| 3 | 185 | 322 | 214 |
| 4 | 1161 | 1167 | 2827 |
| 5 | 5797 | 1961 | 2775 |
| 6 | 4793 | 5608 | 2711 |
| 7 | 2294 | 3366 | 5678 |
| 8 | 858 | 1463 | 3096 |
| 9 | 489 | 572 | 1406 |
| 10 | 219 | 289 | 486 |
| 11 | 70 | 127 | 242 |
| 12 | 153 | 39 | 103 |
| 3+ | 16018 | 14914 | 19539 |
| 4+ | 15834 | 14593 | 19325 |
| 5+ | 14673 | 13425 | 16498 |
| 6+ | 8876 | 11465 | 13722 |

FISHING MORTALITY

| | 1980 | 1981 | 1982 |
|---|---|---|---|
| 3 | 0.013 | 0.009 | 0.009 |
| 4 | 0.090 | 0.065 | 0.065 |
| 5 | 0.192 | 0.139 | 0.139 |
| 6 | 0.250 | 0.180 | 0.180 |
| 7 | 0.250 | 0.180 | 0.180 |
| 8 | 0.250 | 0.180 | 0.180 |
| 9 | 0.250 | 0.180 | 0.180 |
| 10 | 0.250 | 0.180 | 0.180 |
| 11 | 0.248 | 0.180 | 0.180 |
| 12 | 0.248 | 0.180 | 0.180 |
| 3+ | 0.127 | 0.068 | 0.079 |

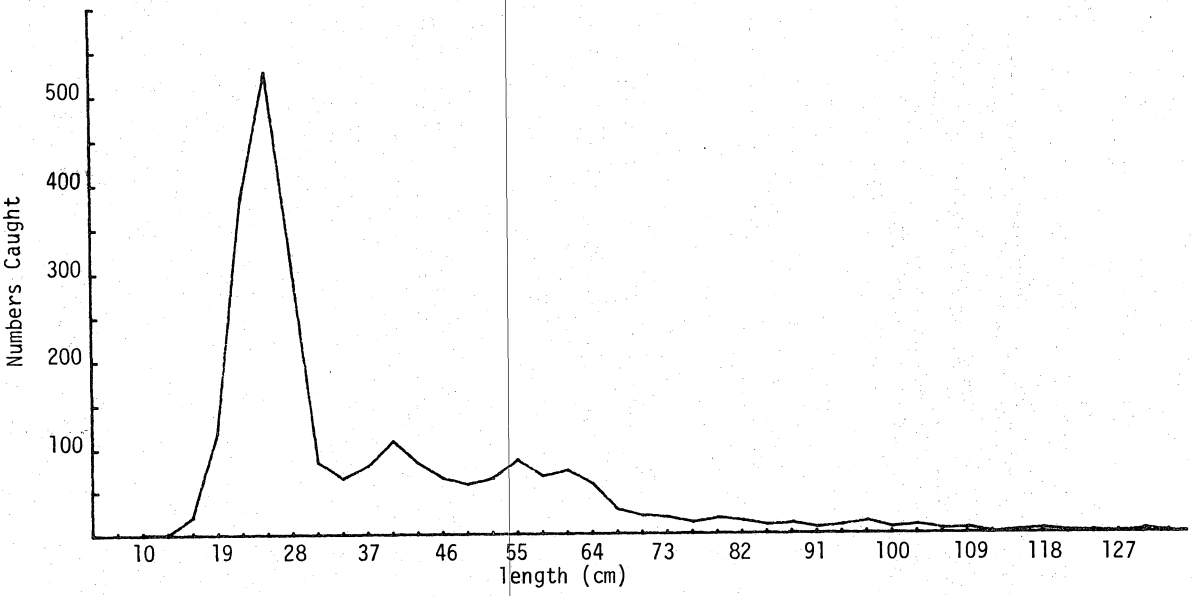


Figure 1. Length frequency of the research survey catch in 3NO during 1980.

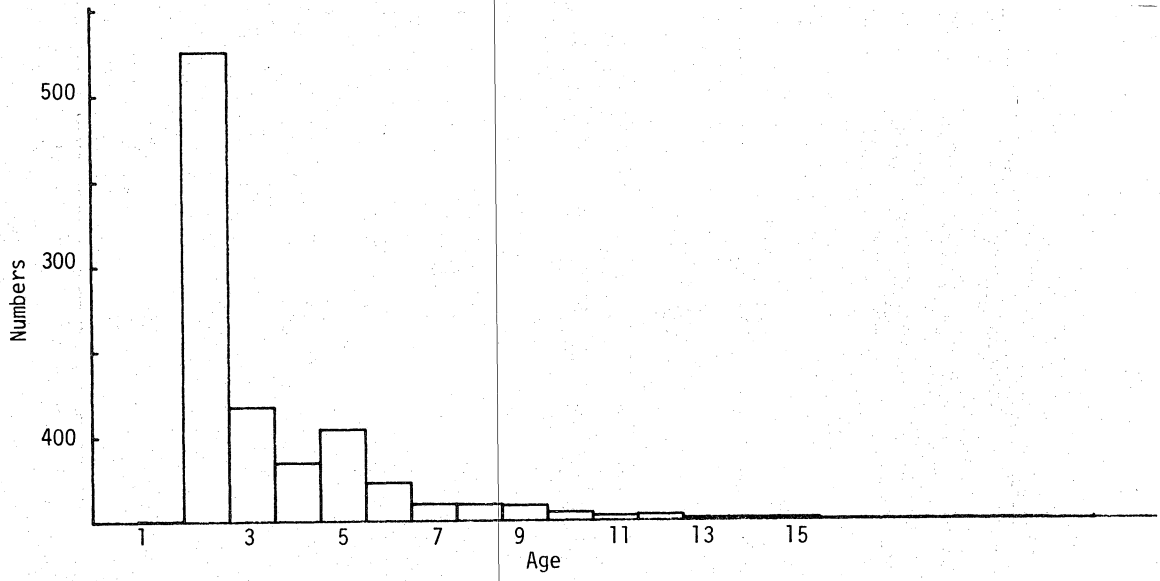


Figure 2. Per mille age frequency of the research survey catch in 3NO during 1980.

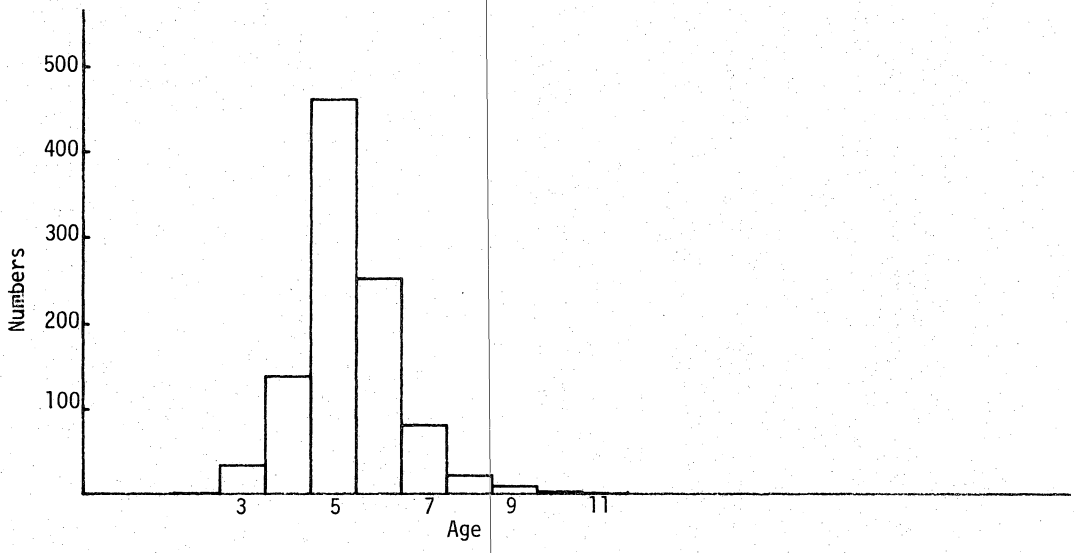


Figure 3. Per mille age frequency of the commercial catch in 3NO during 1980.

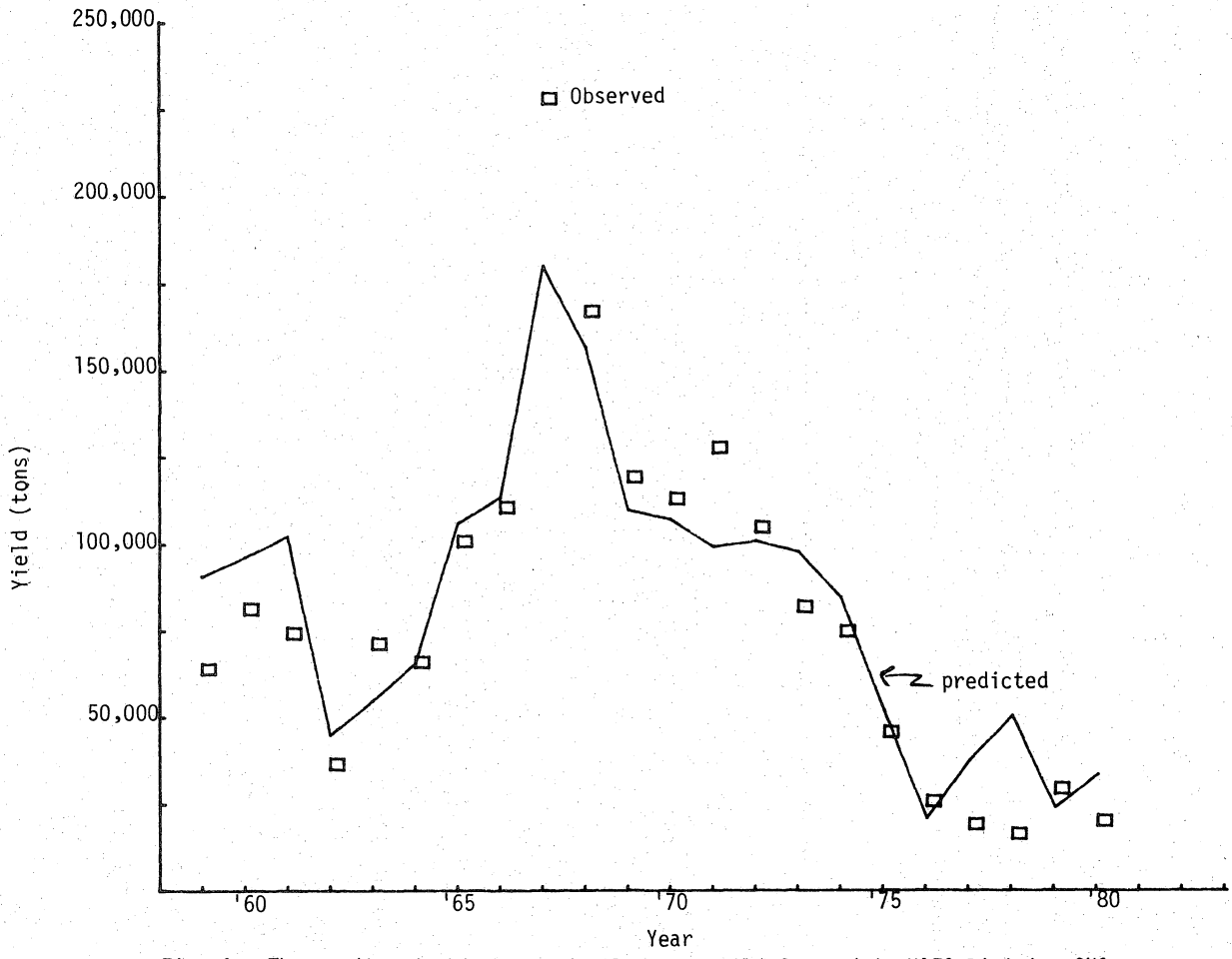


Fig. 4. The predicted and observed values of yield for cod in NAFO Division 3NO.

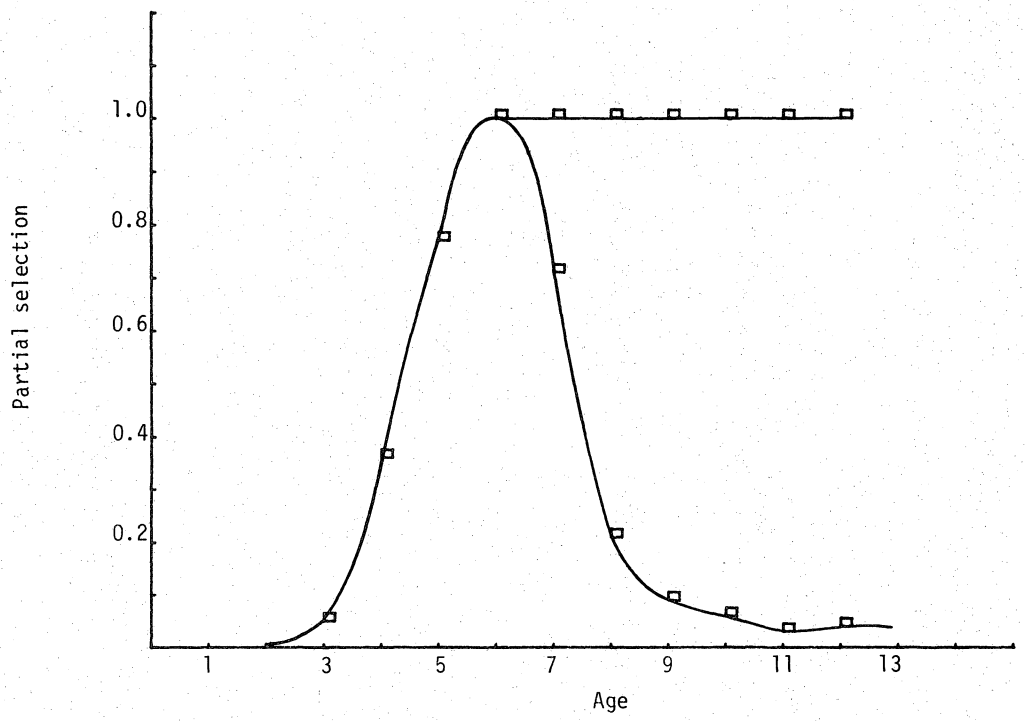


Figure 5. Partial selection patterns with age from the ratio of commercial catch at age to survey catch at age assuming (a) full recruitment of the older age groups and (b) the values obtained from the ratio

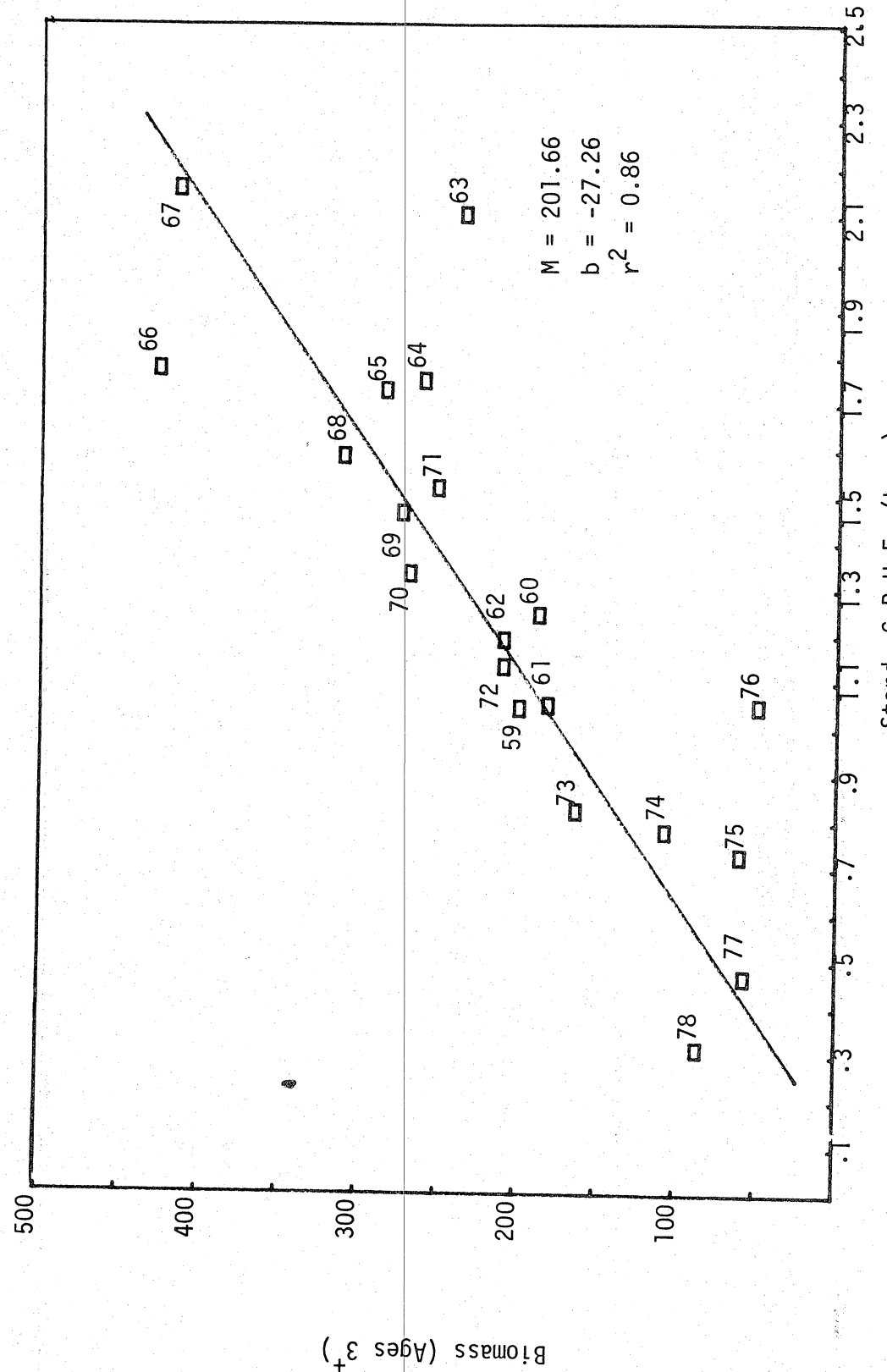


Fig. 6. Relationship of standard catch per unit effort with Biomass (Ages $3^+$) for the period 1959-78 with regression line and associated values (1963, 1976 omitted.)

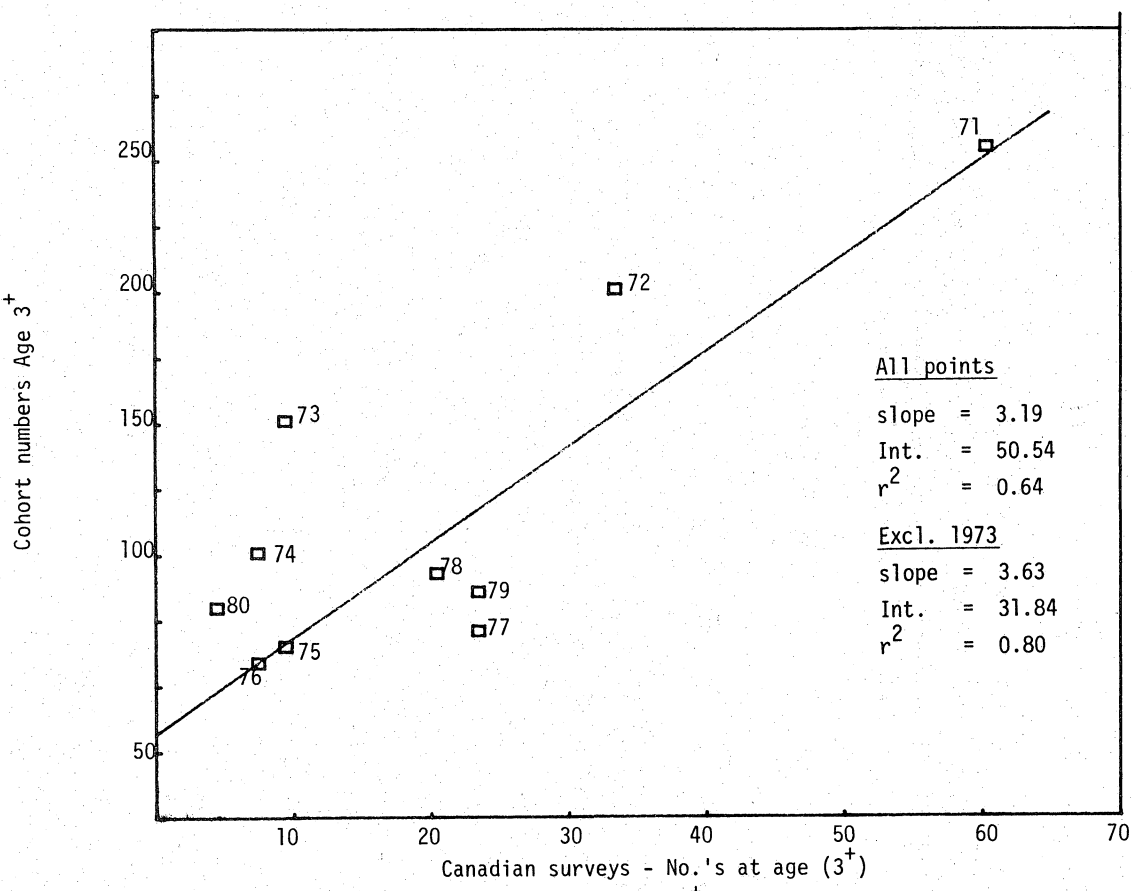


Fig. 7. Relationship of cohort numbers (Age $3^+$) to Canadian survey mean No's at age per tow (Age $3^+$).

| Year | Canadian Survey No./tow Age 3+ | Cohort pop $_+$ No.'s Age $3^+$ |
|---|---|---|
| 1971 | 60 | 253 |
| 1972 | 33 | 199 |
| 1973 | 9 | 149 |
| 1974 | 7 | 99 |
| 1975 | 9 | 63 |
| 1976 | 7 | 57 |
| 1977 | 23 | 69 |
| 1978 | 20 | 91 |
| 1979 | 23 | 84 |
| 1980 | 4 | 78 |

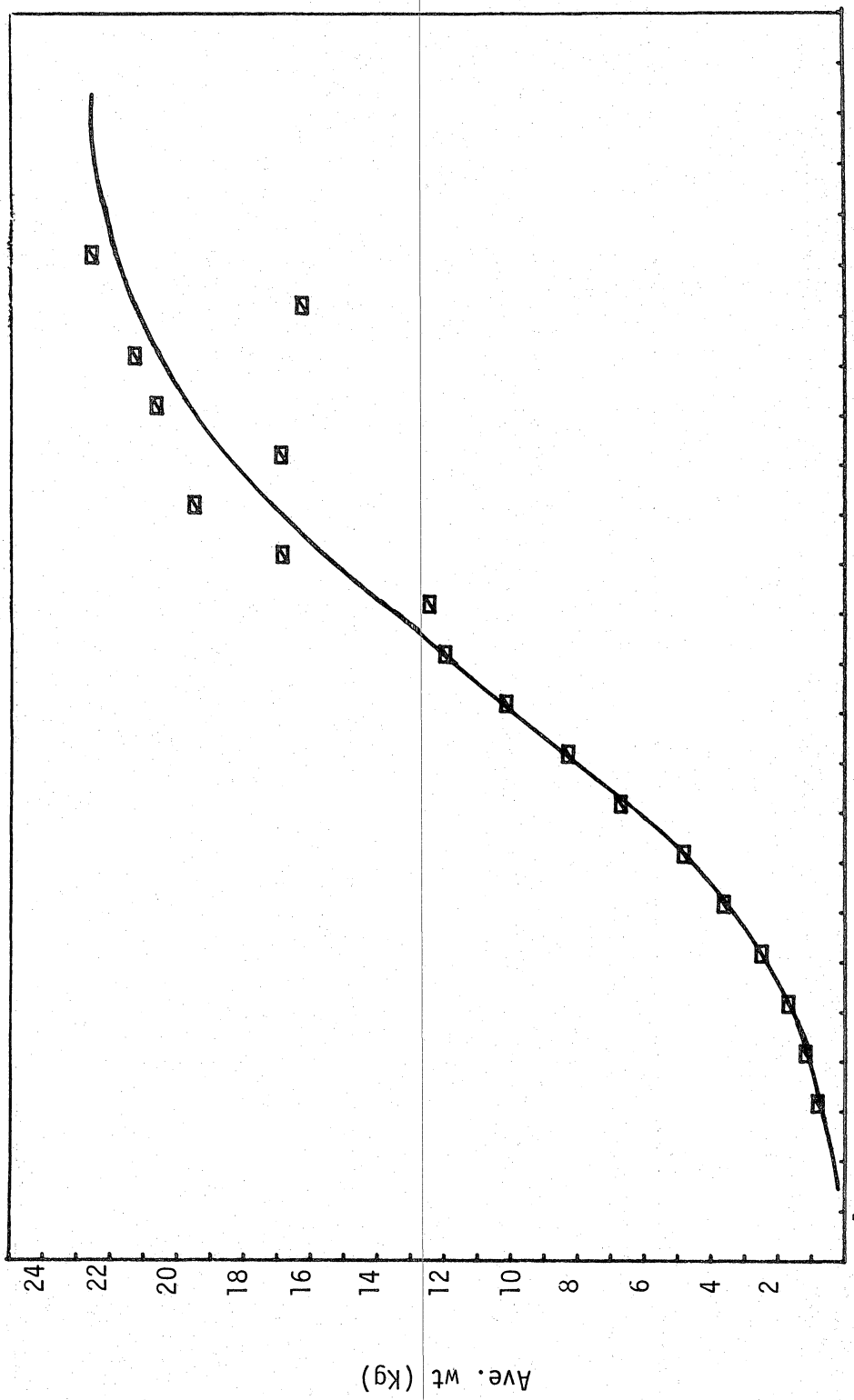


Figure 8. Ave. weight at age of 3NO cod from the commercial fishery over the period 1977-1980.

Northwest Atlantic Fisheries Organization

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NAFO SCR Doc. 81/II/11
Addendum

SPECIAL MEETING OF SCIENTIFIC COUNCIL - FEBRUARY 1981

# Stock Assessment of Cod in Divisions 3NO

by

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The information presented[1] gives estimates of stock and catch biomass over different time periods and assuming various possible conditions or options. Table 1 shows projections to 1986 using the population at age obtained in 1980 assuming $F_t$ = 0.25 (Table 10, Orig. Doc.). The options are basically either a constant catch or a constant fishing mortality from 1981-86. The details of these constants and other parameters are listed in the "notes" of Table 1.

Table 2 shows the results of longer term (to 1994) projections with similar options as shown in Table 1. The average recruitment used was 85 million, the arithmetic mean of recruitment from the cohort (Table 10, Orig. Doc.) from 1959-78. The two options of partial recruitment were obtained from the 1980 sampling (a) and from an estimate of selection which might have applied to a period when the stock was lightly exploited (b).

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[1]This information was requested at the April 1981 meeting of the Fisheries Commission of NAFO (NAFO/FC Doc. 81/VI/4) and is presented as an addendum to NAFO SCR Doc. 81/II/11 for reference purposes.

Table 1. 3NO cod projections of mean stock biomasses, fishing mortalities and catches for the period 1981-86 under various options.

| Year | 3+ Biomasses (000 tons) | | | | Fishing mortalities (age 6+) | | | |
|---|---|---|---|---|---|---|---|---|
| | Option 1 | Option 2 | Option 3 | Option 4 | Option 1 | Option 2 | Option 3 | Option 4 |
| 1981 | 126 | 113 | 132 | 129 | 0.333 | 0.755 | 0.18 | 0.30 |
| 1982 | 148 | 107 | 164 | 151 | 0.276 | 0.872 | 0.18 | 0.30 |
| 1983 | 172 | 99 | 193 | 169 | 0.216 | 0.919 | 0.18 | 0.30 |
| 1984 | 201 | 91 | 222 | 184 | 0.171 | 1.028 | 0.18 | 0.30 |
| 1985 | 232 | 80 | 245 | 195 | 0.142 | 1.263 | 0.18 | 0.30 |
| 1986 | 264 | 68 | 263 | 202 | 0.121 | 1.710 | 0.18 | 0.30 |

| Year | Catch 000 tons | | | |
|---|---|---|---|---|
| | Option 1 | Option 2 | Option 3 | Option 4 |
| 1981 | 26 | 50 | 15 | 24 |
| 1982 | 26 | 50 | 20 | 29 |
| 1983 | 26 | 50 | 25 | 35 |
| 1984 | 26 | 50 | 31 | 41 |
| 1985 | 26 | 50 | 35 | 44 |
| 1986 | 26 | 50 | 38 | 46 |

NOTE (1) Option 1 - Catch of 26,000 tons each year 1981-86
Option 2 - Catch of 50,000 tons each year 1981-86
Option 3 - Fishing mortality of $F_{0.1}$ = 0.18, 1981-86
Option 4 - Fishing mortality of $F_{max}$ = 0.30, 1981-86

(2) Recruitment at age 3 in 1980 = 25 million
1981 = 60 million
1983-86 = 40 million

(3) Selection pattern as in NAFO SCR Doc. 81/II/II

(4) Average weights-at-age as in NAFO SCR Doc. 81/II/II for the period 1977-80

(5) All year-classes in the 1980 population (up to 1968 year-class) plus recruiting year-classes were used in the projection i.e. the 1968 year-class (age 12 in 1980) contributed to the biomass estimates when they were 18 years old in 1986.

Table 2. 3NO cod projections assuming an average recruitment of 85 million with the listed options.

| Option | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1988 | 1991 | 1994 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Biomass (000 t) | | | | | |
| F = .18 (a) | 101 | 134 | 193 | 256 | 321 | 384 | 544 | 641 | 688 |
| F = .18 (b) | 101 | 135 | 197 | 265 | 337 | 408 | 592 | 703 | 757 |
| F = .30 (a) | 101 | 129 | 178 | 227 | 276 | 318 | 407 | 446 | 459 |
| F = .30 (b) | 101 | 131 | 184 | 241 | 298 | 351 | 464 | 512 | 529 |
| C = 10,000 | 101 | 137 | 204 | 284 | 378 | 484 | 862 | 1244 | 1564 |
| C = 26,000 | 101 | 128 | 178 | 236 | 307 | 389 | 695 | 1028 | 1328 |
| C = 50,000 | 101 | 115 | 136 | 164 | 197 | 239 | 407 | 630 | 870 |
| F = .30 (a)[1] | 101 | 96 | 132 | 170 | 207 | 242 | 302 | 323 | 329 |
| | | | | Catch (000 t) | | | | | |
| F = .18 (a) | 19 | 15 | 20 | 28 | 39 | 50 | 79 | 97 | 105 |
| F = .18 (b) | 19 | 13 | 18 | 24 | 34 | 46 | 79 | 99 | 109 |
| F = .30 (a) | 19 | 24 | 29 | 39 | 52 | 65 | 92 | 103 | 108 |
| F = .30 (b) | 19 | 20 | 26 | 34 | 46 | 61 | 94 | 109 | 114 |
| C = .10,000 | 19 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| C = .26,000 | 19 | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 26 |
| C = 50,000 | 19 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| F = .30 (a)[1] | 19 | 19 | 23 | 30 | 40 | 51 | 69 | 75 | 77 |
| | | | | Partial recruitment at age (%) | | | | | |
| | 3 | 4 | 5 | 6 | 7 | 8+ | | | |
| (a) | 1 | 36 | 77 | 100 | 100 | 100 | | | |
| (b) | 1 | 20 | 50 | 80 | 100 | 100 | | | |

[1]Average weights at age from commercial fishery 1959-65.