81-20

LABORATORY REFERENCE DOCUMENT NO. 81-20

# STATUS OF HERRING STOCKS OF THE GULF OF MAINE AREA FOR 1981

by

Vaughn C. Anthony, Gordon T. Waring, and Michael J. Fogarty

[X] Approved for Distribution

[X] Distribution to F/NWC, F/SWC; F/SEC; F/NWR1, & F/NEC (Technical Writer-Editor)

Signature Michael R

Date July 7, 1981

National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole Laboratory
Woods Hole, Massachusetts 02543

## Introduction

Management of Atlantic herring was initiated in the Northwest Atlantic in 1972 under the auspices of the International Commission for Northwest Atlantic Fisheries (ICNAF). Three major management units were defined based on known spawning areas: Georges Bank, Jeffreys Ledge (western Gulf of Maine) and southwestern Nova Scotia (Figure 1). The Georges Bank fishery began in 1961 with the increase in foreign fishing activity off the northeast coast of the United States. Herring fisheries in the western Gulf of Maine and southwestern Nova Scotia underwent significant development in the latter part of the 1960's (Table 1). A winter purse seine fishery was initiated in Chedabucto Bay (northeastern Nova Scotia) during 1968-69 exploiting herring migrating from the Trinity Ledge-Lurcher shoals region of the northern Gulf of Maine. In addition, important fisheries, primarily for young herring, have operated along the Maine and New Brunswick coasts since 1875.

The sea herring resource of the United States has been regulated under extended jurisdiction since December 1978 with the implementation of the Fishery Management Plan (FMP) for Atlantic herring. Since 1979, management advice has been provided by the Ad Hoc Herring Assessment Working Group, comprised of representatives of New England state fisheries organizations, the New England Fishery Management Council, and the National Marine Fisheries Service.

## Catch Statistics

Landings from the Georges Bank fishery during 1961-76 ranged from 43,000-374,000 mt and peaked during the latter part of the 1960's. Landings subsequently

declined during the 1970's with a complete stock collapse by 1977 (Table 1). The Nova Scotia spawning stock, second in size only to the Georges Bank stock in the Northwest Atlantic, provided catches ranging from 114,000-175,000 mt during 1966-77 (Table 1). Large catches of herring in this fishery and the Jeffreys Ledge fishery prior to 1972 were due to accumulated biomass from good year-classes which recruited to the fisheries during the early 1960's. From 1972 to 1980, the very good 1970 year-class sustained the fisheries in both Nova Scotia and the western Gulf of Maine. Reported landings in 1980 of over 108,000 mt in the Nova Scotia fishery were comprised primarily of the strong 1976 year-class. The 1980 catch of 36,000 mt in the western Gulf of Maine fishery was the largest since 1972 and 54% greater than the 1979 catch. The 1976 year-class contributed an estimated 19,200 mt to the 1980 catch in the western Gulf of Maine, the largest catch of age 4 fish in the history of this fishery.

Both the New Brunswick and Maine coastal fisheries have concentrated primarily on juvenile herring (ages 1-3) with annual catches highly dependent on recruiting year-class strength. Catches of juvenile herring off New Brunswick were relatively high during 1950-70 and subsequently declined during 1971-77; landings in 1978 and 1979 increased with recruitment of the strong 1976 year-class (Table 1). The 1980 catch of 15,000 mt was the lowest observed in the New Brunswick fishery due to the very poor 1978 year-class and the scarcity of the 1977 year-class in New Brunswick waters.

Catches of juvenile herring along the Maine coast were high during 1950-63 and subsequently declined during 1964-76. Catches of 40,200 and 45,900 mt in 1979 and 1980, respectively, were the largest since 1963 and were primarily due to the 1976 and 1977 year-classes. Although the 1978 year-class was poor in Maine

waters, the 1977 year-class was concentrated in central and eastern Maine and provided a catch of 26,500 mt in 1980.

Management efforts have been applied to herring of ages 3 and older since catches on the offshore shoals areas, such as Georges Bank and Jeffreys Ledge, are comprised primarily of these age groups. Although age 3 herring are seldom mature, they begin to move into deep water and school with older herring and often appear in large numbers on the spawning grounds. Table 2 provides catches of ages 3+ and ages 1 and 2 for the major herring fisheries.

Virtual Population Analysis

Recent tagging experiments have supported the hypothesis of intermixing of herring stocks in the northwest Atlantic, however, the extent of this mixing cannot currently be determined. Due to the potentially high stock intermixture, ad hoc working groups advocated an holistic approach to assessment of herring resources. Accordingly, catch at age data were pooled for herring fisheries from Chedabucto Bay south with the exception of the Georges Bank fishery which collapsed in 1976. It was necessary to exclude the contribution of the Georges Bank spawning stock to the juvenile coastal fisheries. Thus, an attempt was made to discount catches of age 1 and 2 herring from the Georges Bank stock. The relative proportion of the Georges Bank stock during 1965-76 of the total pooled stock was determined by comparing stock size estimates derived by Virtual Population Analysis (VPA; Gulland 1965) pooled catches both with and without Georges Bank. The proportion of the entire stock due to the Georges Bank population at age 3 was then assumed to equal the proportion of age 1 and 2 fish attributable to the Georges Bank stock. Catches at age 1 by number were discounted by 50% during 1965-1970 and age 2 by 50% during 1965-1971.

Reductions of 40% were applied to age 1 in 1971 and age 2 in 1972, and discounts of 14% were applied to ages 1 in 1972 and age 2 in 1973. Estimates of spawning stock biomass, recruitment and fishing mortality rates for 1965-80 were then derived by VPA for the pooled stock, except discounted for Georges Bank (Table 3).

Fishing mortality rates on age 2 and age 3+ fish generally increased from 1965 to 1977-78 and greatly exceeded 0.3 in nearly every year (Table 3, Figure 2). The $F_{0.1}$ (Gulland and Boerema (1973)) level varies between about 0.2 and 0.4 depending on the various exploitation patterns (Fogarty et al 1981). In 1976 the age 2 fishing mortality exceeded 1.0 and fishing mortality on age 3 and older in 1978 reached 0.89. These high levels of fishing mortality result in rapid decrease in population size. The estimated fishing mortality rates during 1978-80 are much lower than those from 1975-77, due to assumed increase in recruitment in recent years.

Recruitment and spawning stock biomass levels derived by VPA are presented in Figure 3. With the exception of the strong 1970 year class, recruitment (at age 3) remained at low levels during 1970-78 (Table 3). The 1976 year-class, which recruited in 1979 to the offshore fisheries, is clearly a strong year-class and the 1977 year-class appears to be above average in size. Based on information from the juvenile fisheries in 1978 and 1979, the offshore fisheries in 1979, 1980, and early 1981, and the distribution of catches of these year classes, the assessment working group assumed that the 1976 and 1977 year classes equal to 75% and 50% respectively of the strong 1970 year class for input into the VPA. Based on performance in the juvenile fishery, as 2 year olds and in the early 1981 offshore fishery as 3 year olds, the 1978 year-class appears to be below average in size and is assumed to be about equal to the

poor 1974 year-class (at age 2). The information on the size of the 1979 year-class is considerably less than for any of the previous year-classes since catches to date have only been taken from this year-class at age 1. It is estimated, however, that this year-class is stronger than average and will provide a good catch at age 2 fish during 1981. Terminal fishing mortality rates for the VPA based on catch and estimates of stock size were .060, .325, .245, .435 for ages 1-4, .600 for ages 5 and 6, .700 for ages 7-10 and 1.00 for ages 1 and older. For the purpose of determining catches in 1982 and resulting stock sizes in 1983, the herring assessment working group assigned the 1979 year-class a range of 138,000-263,000 mt at age 3, corresponding to abundance levels of the 1973 and 1977 year-classes at age 3 respectively (Figure 4). For reference, recruitment levels from 1965-81 derived by VPA were rank ordered (Figure 4). The 1973 year-class is designated as an average year-class while the assumed levels of the 1976-77 year-classes are clearly above average.

Catch Projections

Short term catch projections of catch and spawning stock biomass were made given the above assumption on year class size for 1981 and 1982. Figure 5 indicates the effect of fishing in 1981 on the spawning stock biomass at the beginning of 1982 for the pooled herring resource (excluding Georges Bank according to the above mentioned discounted procedure). Spawning stock biomass increased from a very low level in 1979 of 131,000 mt to 562,000 mt at the beginning of 1981 (Table 3, Figure 3). With the estimated poor recruitment of the 1978 year-class, this spawning stock biomass level will decrease during 1981, with virtually any realistic level of catch during 1981. The total allowable

catches for age 2 and older in Canada have been set at 101,000 mt for 1981 and at 33,000 mt for ages 3 and older in the United States waters. Assuming that some age 3 fish would be caught in the unregulated inshore waters of Canada, we assume that the 1981 catch would be approximately 150,000 mt. This would produce a fishing mortality rate of approximately 0.34 and a spawning stock biomass at the beginning of 1981 of approximately 425,000 mt, representing a decline in spawning stock biomass from 1981 to the beginning of 1982 of 24%.

Figure 6 demonstrates the effect of fishing in 1982 on the spawning stock biomass at the beginning of 1983 under the assumption of two recruitment levels for the 1979 year-class. If fishing is restricted to the same level of fishing mortality as in 1981 (F = 0.34), the catch in 1982 will vary between 135,000 and 160,000 and results in a range of spawning stock biomass estimates at the beginning of 1983 from 405,000 mt to 530,000 mt depending on the size of the 1979 year-class. At the lower estimate of recruitment, the level of spawning stock biomass is only slightly below the level existing at the beginning of 1982. If recruitment of the 1979 year class is of the larger amount, the spawning stock biomass will increase by 25%. Table 3 indicates that the catch of age 3 herring from 1965 to 1980 has varied between 113,000 mt to 229,000 mt with an average of 175,000 mt. The average spawing stock biomass during that same period was 505,000 mt.

## References

Fogarty, M.J., V.C. Anthony, and G.T. Waring 1981. Yield and recruitment simulations for Atlantic herring. National Marine Fish. Ser., Woods Hole Laboratory. Laboratory Reference Document No. 81-22.

Gulland, J.A. 1965. Estimation of mortality rates. Annex to Rep. Arctic Fish. Working Group, Int. Coun. Explor. Sea C.M. 1965(3):9 p.

Gulland, J.A. and L.K. Boerema. 1973. Scientific advice on catch levels. Fish. Bull. 71(2) 325-335.

Table 1. Herring catches in major fishing areas between southwest Nova Scotia and Cape Hatteras.

| YEAR | Maine Coastal Fishery | Western Gulf of Maine Fishery | Georges[1] Banks | New[2] Brunswick | Nova Scotia[2] | Total |
|---|---|---|---|---|---|---|
| | | | METRIC TONS | | | |
| 1950 | 90,557 | 3,661 | | 62,981[3] | | 157,199 |
| 1 | 34,411 | 1,305 | | 51,316[3] | | 87,032 |
| 2 | 79,139 | 1,598 | | 62,399[3] | | 143,136 |
| 3 | 58,337 | 2,032 | | 44,961[3] | | 105,330 |
| 4 | 64,067 | 1,303 | | 46,716[3] | | 112,086 |
| 5 | 43,506 | 1,561 | | | 33,313[3] | 78,380 |
| 6 | 66,494 | 2,058 | | 21,533 | 22,712 | 112,797 |
| 7 | 68,623 | 3,007 | | 33,733 | 27,114 | 132,477 |
| 8 | 80,759 | 3,182 | | 18,854 | 46,444 | 149,239 |
| 9 | 53,037 | 1,472 | | 47,762 | 28,771 | 131,042 |
| 1960 | 59,348 | 1,126 | | 49,563 | 32,216 | 142,253 |
| 1 | 24,131 | 3,178 | 67,655 | 18,614 | 41,272 | 154,850 |
| 2 | 69,376 | 2,485 | 152,242 | 34,403 | 35,367 | 293,873 |
| 3 | 66,895 | 3,217 | 97,968 | 36,237 | 23,393 | 227,710 |
| 4 | 26,295 | 8,815 | 131,438 | 45,023 | 41,405 | 252,976 |
| 5 | 32,088 | 2,635 | 42,882 | 49,101 | 70,639 | 197,345 |
| 6 | 26,178 | 4,360 | 142,704 | 61,450 | 124,681 | 359,373 |
| 7 | 28,490 | 7,807 | 218,743 | 50,920 | 135,853 | 441,813 |
| 8 | 30,205 | 31,900 | 373,598 | 75,368 | 154,139 | 665,210 |
| 9 | 23,852 | 32,406 | 310,758 | 39,741 | 137,250 | 544,007 |
| 1970 | 15,581 | 40,187 | 247,294 | 30,589 | 175,633 | 509,284 |
| 1 | 12,407 | 38,575 | 267,347 | 17,528 | 124,233 | 460,090 |
| 2 | 19,513 | 42,918 | 174,190 | 32,720 | 153,428 | 422,769 |
| 3 | 16,400 | 15,926 | 202,335 | 22,102 | 120,093 | 376,856 |
| 4 | 19,143 | 18,098 | 149,525 | 30,733 | 139,170 | 356,669 |
| 5 | 15,182 | 21,076 | 146,096 | 31,971 | 142,745 | 357,068 |
| 6 | 30,195 | 20,124 | 43,502 | 30,046 | 114,006 | 237,874 |
| 7 | 32,357 | 17,891 | 2,157 | 34,723 | 115,935 | 203,063 |
| 8 | 29,857 | 18,558 | 2,059 | 45,361 | 89,353 | 185,188 |
| 9 | 40,218 | 23,546 | 1,270 | 41,021 | 55,182 | 161,237 |
| 1980 | 45,902 | 36,175 | 1,700 | 14,969 | 108,131 | 206,877 |
| Total | 1,302,543 | 412,181 | 2,775,463 | 1,215,751 | 2,259,165 | 7,964,390 |

[1]incorporates USA 5Zw catches

[2]1965-80 revised Canadian catches as per Dr. Mike Sinclair, Division of Fisheries and Oceans, Halifax, Canada.

[3]cannot be separated into New Brunswick and Nova Scotia fishery components

Table 2. Atlantic herring catch in tons (Ages 1-2; and Ages 3 and older) by major fishing areas

| | Maine Coastal Fishery | | Western Gulf of Maine Fishery | | USA S. New England Winter Fishery | | Georges Bank Fishery | | Bay of Fundy Fishery | | Southwest Nova Scotia Fishery | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | AGES 1-2 | AGES 3 and older | AGES 1-2 | AGES 3 and older | AGES 1-2 | AGES 3 and older | AGES 1-2 | AGES 3 and older | AGES 1-2 | AGES 3 and older | AGES 1-2 | AGES 3 and older | TOTAL AGES 1-2 | TOTAL AGES 3 and older | GRAND |
| 1965 | 6,504 | 25,584 | - | 2,635 | - | 1,191 | 948 | 40,743 | 32,313 | 16,788 | 3,671 | 66,968 | 43,436 | 153,909 | 197, |
| 1966 | 25,125 | 1,053 | - | 4,360 | - | 4,308 | 42 | 138,354 | 13,074 | 48,376 | 1,523 | 123,158 | 39,764 | 319,609 | 359, |
| 1967 | 6,860 | 21,630 | 2 | 7,805 | - | 1,211 | 108 | 217,424 | 22,579 | 28,341 | 1,966 | 133,887 | 31,555 | 410,298 | 441, |
| 1968 | 21,117 | 9,088 | 49 | 31,851 | - | 758 | 150 | 372,690 | 50,316 | 25,052 | 12,779 | 141,360 | 84,411 | 580,799 | 665, |
| 1969 | 6,774 | 17,078 | 150 | 32,256 | - | 3,678 | - | 307,080 | 15,589 | 24,152 | 1,904 | 135,346 | 24,417 | 519,590 | 544, |
| 1970 | 6,552 | 9,029 | 297 | 39,890 | - | 2,011 | 756 | 244,527 | 23,588 | 7,001 | 4,490 | 171,143 | 35,683 | 473,601 | 509, |
| 1971 | 4,747 | 7,660 | 55 | 38,520 | - | 3,822 | 747 | 262,778 | 9,474 | 8,054 | 7,641 | 116,592 | 22,664 | 437,426 | 460, |
| 1972 | 17,363 | 2,150 | 959 | 41,959 | 6 | 2,776 | 1,680 | 169,728 | 27,586 | 5,134 | 35,060 | 118,368 | 82,654 | 340,115 | 422, |
| 1973 | 8,264 | 8,136 | 144 | 15,782 | - | 4,627 | 600 | 197,108 | 6,674 | 15,428 | 801 | 119,292 | 16,483 | 360,373 | 376, |
| 1974 | 9,560 | 9,583 | 235 | 17,863 | - | 3,370 | 129 | 146,026 | 18,915 | 11,818 | 4,969 | 134,201 | 33,808 | 322,861 | 356, |
| 1975 | 9,248 | 5,934 | 20 | 21,056 | - | 4,582 | 84 | 141,430 | 19,010 | 12,961 | 7,067 | 135,677 | 35,429 | 321,640 | 357, |
| 1976 | 13,706 | 16,489 | 4 | 20,120 | 6 | 738 | 25 | 42,733 | 8,660 | 21,386 | 836 | 113,169 | 23,238 | 214,635 | 237, |
| 1977 | 19,328 | 13,029 | 60 | 17,831 | 54 | 307 | 6 | 1,790 | 3,862 | 30,861[1] | 1,669 | 114,266 | 24,979 | 178,084 | 203, |
| 1978 | 13,506 | 16,351 | 204 | 18,354 | 8 | 2,051 | - | - | 25,674 | 19,687[1] | 3,425 | 85,928 | 42,817 | 142,371 | 185, |
| 1979 | 25,969 | 14,249 | 220 | 23,326 | - | 1,270 | - | - | 10,973 | 30,048[1] | 2,526 | 52,656 | 39,688 | 121,549 | 161, |
| 1980 | 10,062 | 35,840 | 38 | 36,137 | - | 1,700 | - | - | 2,621 | 12,348[1,2] | 111 | 108,020[2] | 12,996 | 194,035 | 207, |

[1] Estimated from Canadian Catch in age (numbers) data and mean weight at age data.

[2] Provisional.

TABLE3 HERRING VPA FOR THE AREA FROM SW NOVA SCOTIA TO CAPE HATTERAS EXC. GEORGES BANK AND DISCOUNTED FOR AGES 1 AND 2

AGE

| YEAR | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | MEAN F | AGE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | FISHING MORTALITY | | | | | | | | | |
| 1965 | .047 | .321 | .117 | .199 | .136 | .102 | .052 | .080 | .000 | .000 | .000 | .170 | 4+ |
| 1966 | .030 | .294 | .432 | .127 | .407 | .152 | .191 | .330 | .299 | .368 | .000 | .252 | 4+ |
| 1967 | .079 | .254 | .230 | .290 | .219 | .360 | .329 | .097 | .174 | .180 | 1.000 | .286 | 4+ |
| 1968 | .055 | .613 | .346 | .133 | .431 | .242 | .456 | .447 | .588 | 1.236 | 1.000 | .308 | 4+ |
| 1969 | .053 | .429 | .636 | .204 | .283 | .314 | .336 | .322 | .443 | .581 | 1.000 | .279 | 4+ |
| 1970 | .239 | .497 | .235 | .509 | .505 | .392 | .618 | .469 | .717 | .795 | 1.000 | .512 | 4+ |
| 1971 | .024 | .349 | .468 | .457 | .498 | .527 | .661 | .664 | .717 | .476 | 1.000 | .547 | 4+ |
| 1972 | .004 | .186 | .175 | .024 | .798 | .942 | .755 | .771 | .669 | .561 | 1.000 | .813 | 4+ |
| 1973 | .017 | .321 | .228 | .357 | .452 | .638 | .683 | .625 | .765 | .523 | 1.000 | .479 | 4+ |
| 1974 | .018 | .669 | .258 | .342 | .291 | .366 | .363 | .315 | .695 | .503 | 1.000 | .345 | 4+ |
| 1975 | .050 | .531 | .304 | .289 | .390 | .520 | .459 | .372 | .390 | .432 | 1.000 | .379 | 4+ |
| 1976 | .048 | 1.065 | .503 | .429 | .407 | .420 | .398 | .375 | .638 | .273 | 1.000 | .421 | 4+ |
| 1977 | .089 | .790 | .701 | .625 | .666 | .579 | .594 | .460 | .348 | .416 | 1.000 | .611 | 4+ |
| 1978 | .056 | .351 | .468 | .475 | 1.038 | .946 | .630 | .996 | .742 | .525 | 1.000 | .885 | 4+ |
| 1979 | .006 | .439 | .240 | .549 | .541 | .774 | .814 | .554 | 1.130 | .677 | 1.000 | .674 | 4+ |
| 1980 | .060 | .325 | .245 | .435 | .600 | .600 | .700 | .700 | .700 | .700 | 1.000 | .455 | 4+ |

| YEAR | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | AGE 4+ NUMBERS | AGE 4+ TONS(000) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | STOCK SIZE (MILLIONS) | | | | | | | | | |
| 1965 | 3748.4 | 5731.2 | 1501.0 | 1767.4 | 528.9 | 123.7 | 39.7 | 9.7 | .0 | .0 | .0 | 2469.3 | 497.5 |
| 1966 | 3317.1 | 2928.3 | 3403.0 | 1151.9 | 1186.0 | 378.0 | 91.5 | 30.8 | 7.3 | .8 | .0 | 2846.3 | 640.0 |
| 1967 | 6336.6 | 2635.4 | 1787.6 | 1809.1 | 830.6 | 646.1 | 265.9 | 61.9 | 18.1 | 4.4 | .5 | 3636.6 | 888.2 |
| 1968 | 1791.9 | 4795.2 | 1673.4 | 1163.3 | 1108.2 | 546.6 | 366.3 | 156.7 | 46.0 | 12.5 | 3.0 | 3402.6 | 805.3 |
| 1969 | 2000.1 | 1388.2 | 2125.9 | 969.0 | 833.7 | 589.7 | 351.3 | 190.1 | 82.1 | 20.9 | 3.0 | 3039.7 | 735.8 |
| 1970 | 1876.6 | 1554.0 | 740.1 | 921.8 | 647.2 | 514.4 | 352.6 | 205.4 | 112.8 | 43.1 | 9.6 | 2806.8 | 687.6 |
| 1971 | 8103.1 | 1210.2 | 773.9 | 478.8 | 453.7 | 319.7 | 284.5 | 155.7 | 105.2 | 45.1 | 16.0 | 1858.6 | 473.0 |
| 1972 | 1819.0 | 6478.4 | 698.8 | 396.7 | 248.2 | 225.8 | 154.6 | 120.3 | 65.6 | 42.0 | 22.9 | 1276.1 | 321.9 |
| 1973 | 2858.2 | 1485.2 | 4403.5 | 488.1 | 142.5 | 91.5 | 72.1 | 59.5 | 45.5 | 27.5 | 19.6 | 938.4 | 218.8 |
| 1974 | 2978.5 | 2295.7 | 882.3 | 2869.6 | 274.9 | 74.3 | 39.6 | 29.8 | 26.1 | 17.3 | 13.4 | 3344.9 | 647.9 |
| 1975 | 1185.1 | 2389.2 | 962.6 | 557.9 | 1668.9 | 168.3 | 42.2 | 22.5 | 17.8 | 10.7 | 8.6 | 2496.9 | 588.9 |
| 1976 | 1706.7 | 923.3 | 1150.1 | 536.8 | 342.0 | 925.3 | 81.9 | 21.8 | 12.7 | 9.9 | 5.7 | 1936.1 | 468.8 |
| 1977 | 7674.4 | 1394.0 | 268.5 | 569.2 | 286.1 | 186.4 | 497.7 | 45.0 | 12.3 | 5.5 | 6.1 | 1608.3 | 388.8 |
| 1978 | 5362.1 | 5758.4 | 518.0 | 105.8 | 249.5 | 128.3 | 85.5 | 225.0 | 23.3 | 7.1 | 3.0 | 819.4 | 228.2 |
| 1979 | 1153.5 | 4149.5 | 3314.7 | 265.7 | 53.9 | 72.3 | 38.2 | 37.3 | 68.0 | 9.1 | 3.4 | 547.9 | 131.3 |
| 1980 | 6153.2 | 948.5 | 2198.7 | 2135.6 | 125.7 | 25.7 | 27.3 | 13.9 | 17.5 | 18.0 | 3.8 | 2367.4 | 458.5 |
| 1981 | | 4744.4 | 556.4 | 1403.9 | 1131.7 | 56.5 | 11.6 | 11.1 | 5.7 | 7.1 | 7.3 | 2634.9 | 561.7 |

| YEAR | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | TOTAL AGE 3+ NUMBERS | TOTAL AGE 3+ TONS(000) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | CATCH AT AGE (MILLIONS) | | | | | | | | | |
| 1965 | 156.2 | 1435.0 | 158.0 | 289.9 | 61.1 | 18.8 | 1.8 | .7 | .0 | .0 | .0 | 522.3 | 113.2 |
| 1966 | 89.6 | 678.5 | 1089.4 | 124.7 | 362.1 | 48.4 | 14.4 | 7.9 | 1.7 | .2 | .0 | 1649.8 | 181.2 |
| 1967 | 435.6 | 538.3 | 333.7 | 414.9 | 148.3 | 181.2 | 67.9 | 5.2 | 2.6 | .7 | .3 | 1154.8 | 192.9 |
| 1968 | 87.5 | 2012.9 | 446.6 | 131.7 | 354.1 | 107.0 | 122.5 | 51.6 | 18.7 | 8.2 | 1.8 | 1242.1 | 208.1 |
| 1969 | 92.9 | 442.0 | 916.0 | 162.3 | 187.1 | 145.0 | 91.5 | 47.7 | 26.8 | 8.4 | 1.7 | 1586.5 | 212.5 |
| 1970 | 362.6 | 556.3 | 141.3 | 336.0 | 234.7 | 152.2 | 148.7 | 70.3 | 52.9 | 21.7 | 5.6 | 1163.4 | 229.1 |
| 1971 | 173.3 | 325.2 | 264.3 | 168.5 | 162.6 | 119.6 | 126.1 | 69.2 | 49.4 | 15.6 | 9.3 | 976.6 | 174.6 |
| 1972 | 7.1 | 1000.1 | 102.2 | 284.6 | 125.3 | 126.8 | 75.2 | 59.4 | 29.3 | 16.5 | 13.4 | 752.6 | 170.4 |
| 1973 | 43.1 | 371.3 | 817.6 | 131.6 | 47.3 | 39.5 | 32.7 | 25.3 | 22.4 | 10.2 | 11.4 | 1138.2 | 163.3 |
| 1974 | 47.9 | 1026.3 | 182.9 | 757.6 | 63.1 | 20.8 | 11.0 | 7.3 | 12.0 | 6.3 | 7.8 | 1068.7 | 176.9 |
| 1975 | 52.1 | 988.2 | 288.0 | 127.6 | 491.5 | 62.4 | 14.2 | 6.4 | 5.3 | 3.4 | 5.0 | 995.7 | 188.2 |
| 1976 | 76.6 | 558.0 | 415.7 | 171.1 | 104.4 | 289.7 | 24.6 | 6.2 | 5.5 | 2.1 | 3.3 | 1022.6 | 171.9 |
| 1977 | 591.1 | 699.1 | 128.4 | 242.2 | 127.5 | 74.9 | 204.0 | 15.1 | 3.3 | 1.7 | 3.6 | 792.7 | 176.3 |
| 1978 | 266.9 | 1551.5 | 176.7 | 36.6 | 148.6 | 67.7 | 36.6 | 139.7 | 11.2 | 2.6 | 1.7 | 612.4 | 142.4 |
| 1979 | 6.1 | 1345.5 | 642.7 | 102.6 | 28.6 | 35.8 | 19.6 | 14.5 | 42.5 | 4.1 | 2.0 | 884.5 | 121.5 |
| 1980 | 325.1 | 237.8 | 433.2 | 687.7 | 51.9 | 18.6 | 12.6 | 6.4 | 8.1 | 8.3 | 2.2 | 1221.8 | 194.0 |

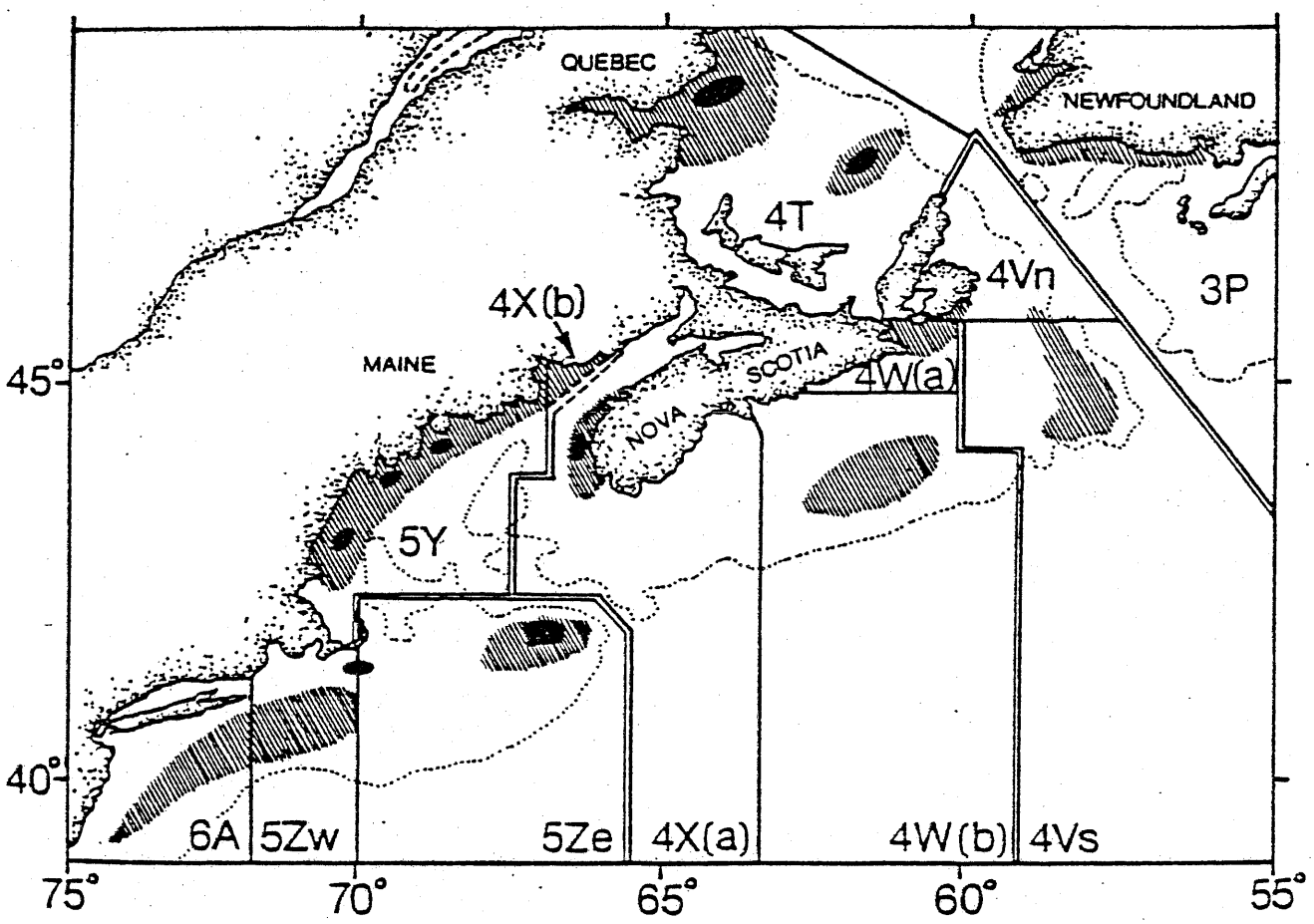


Figure 1. Major fishing areas (dashed line) and spawning grounds (dark circles) for Atlantic herring in the Northwest Atlantic. Chedabucto Bay is in NAFO Subarea 4Wa.

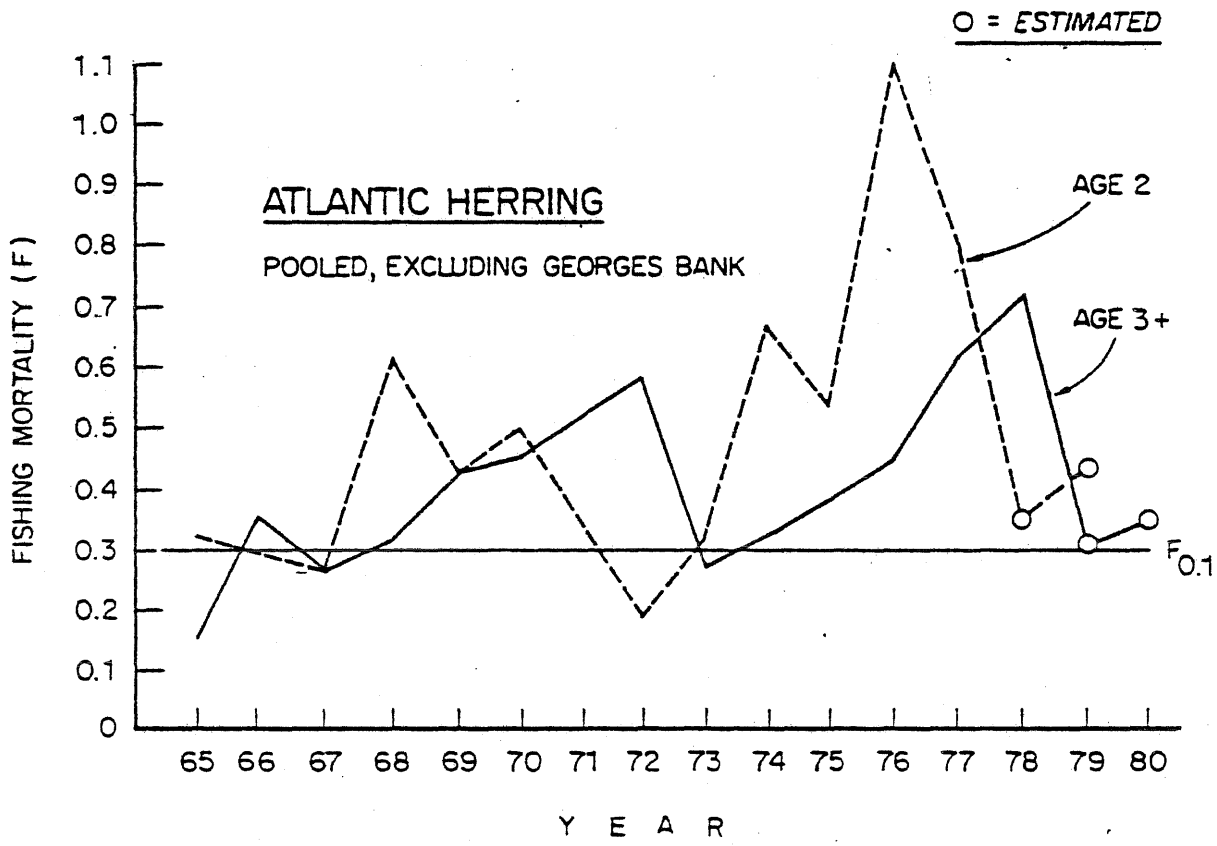


Figure 2. Instantaneous fishing mortality rate (F) for ages 2 and 3+ Atlantic herring derived from pooled virtual population analysis (discounted for Georges Bank).

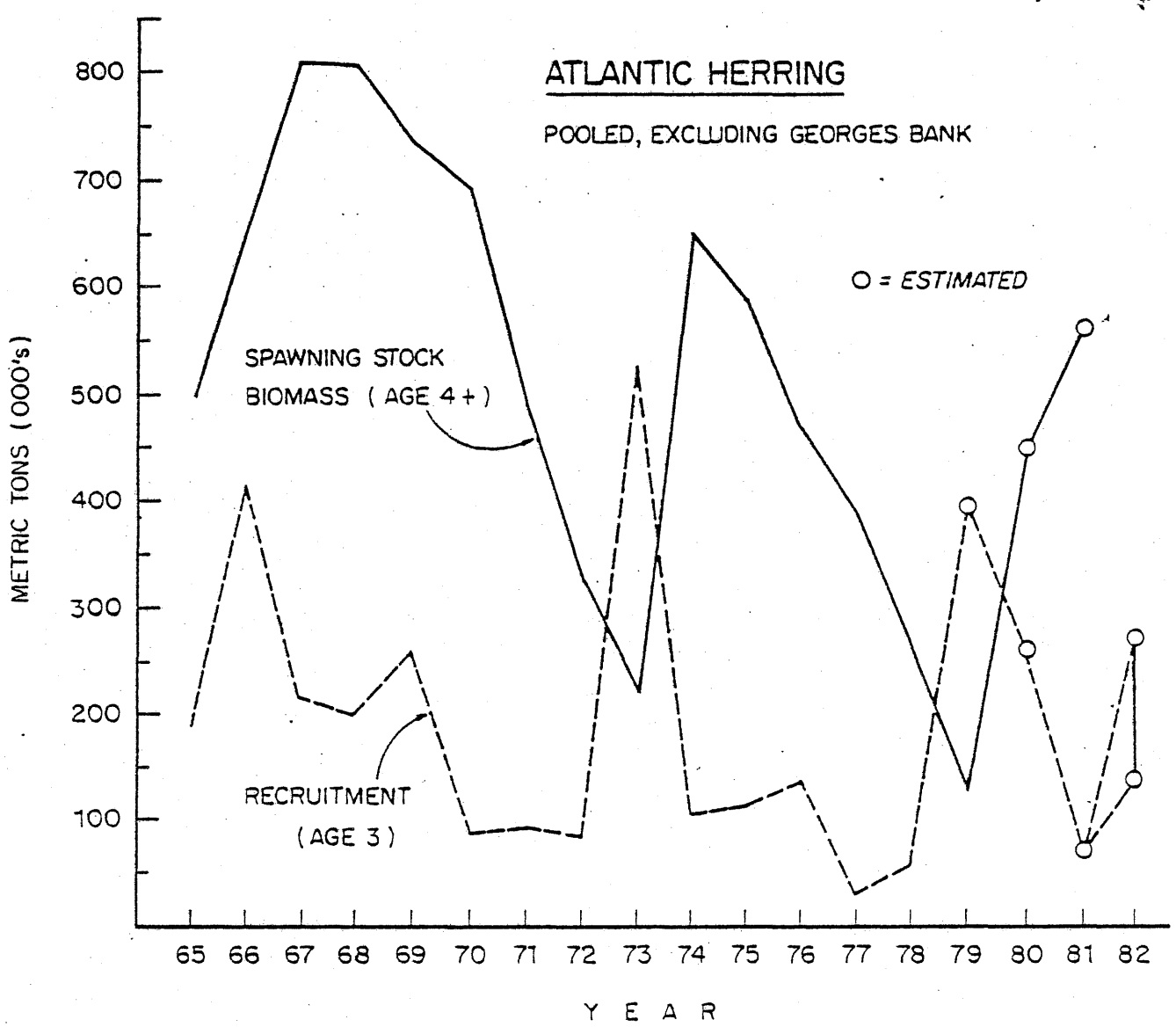


Figure 3. Spawning stock biomasss (age 4+) and recruitment at age 3 for Atlantic herring derived from pooled VPA discounted for Georges Bank.

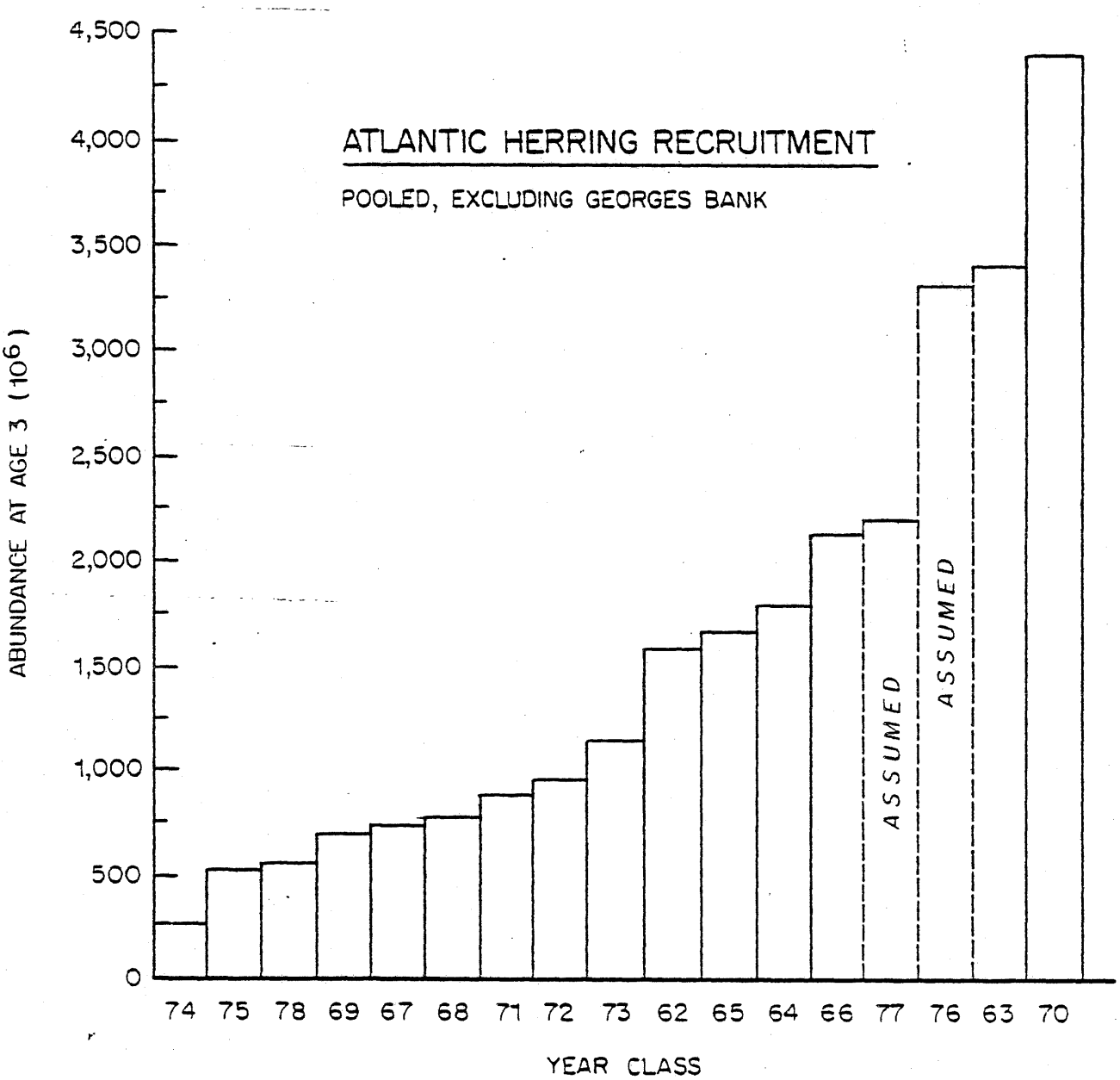


Figure 4. Recruitment at age 3 in increasing order of abundance for Atlantic herring year classes derived from pooled VPA discounted for Georges Bank.

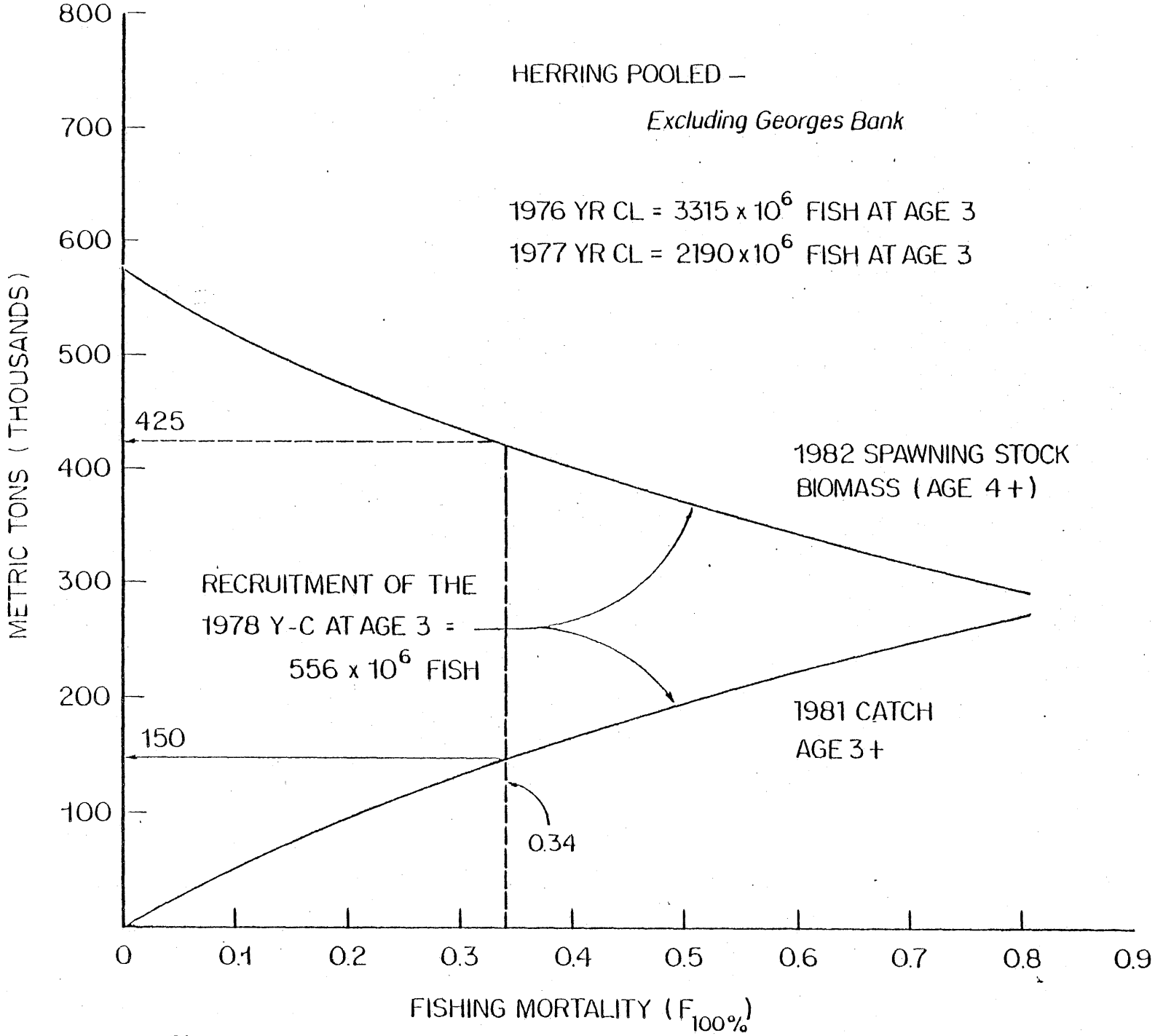


Figure 5. Atlantic herring catch projection for 1981 and resulting spawning stock biomass for 1982.

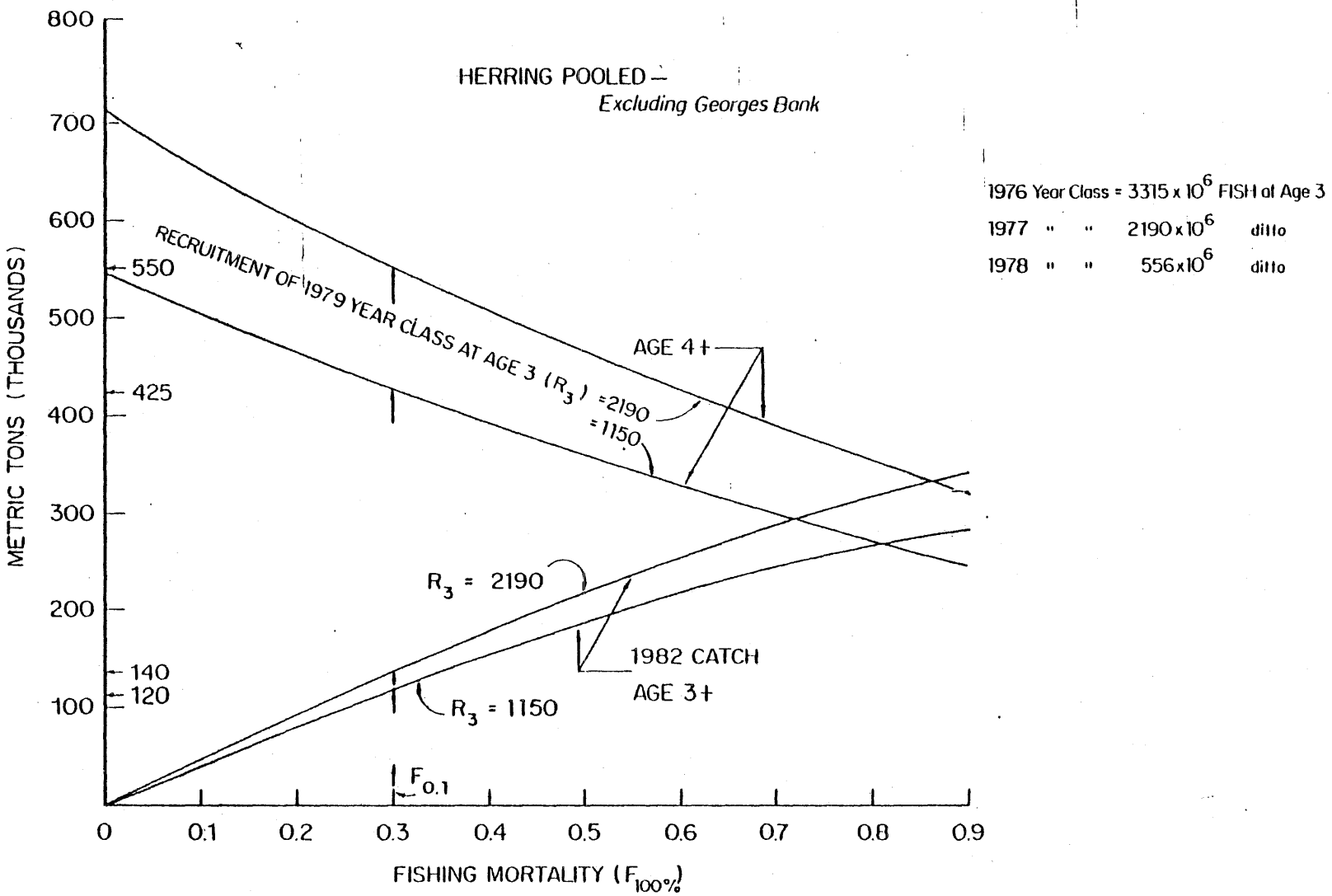


Figure 6. Atlantic herring catch projection for 1982 and resulting spawning stock biomass for 1983.