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An evaluation of the status of Flemish Cap redfish

by

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Introduction

At the 1973 Annual Meeting of ICNAF a precautionary catch quota was established for 1974 for Flemish Cap (ICNAF Division 3M) redfish to prevent an increase in fishing pressure on redfish in that area until such time as scientific information on the status of this stock became available. The total allowable catch for 1974 was set at the level of the estimated 1972 catch of 40,000 tons (actual catch 41,946 tons), which represented a considerable increase from the 1971 catch of about 8000 tons and was substantially above the 1957-71 average yearly catch of about 16,000 tons.

This paper assesses the status of ICNAF Division 3M redfish, utilizing the Schaefer yield model to provide estimates of sustainable yield and the Beverton Holt yield per recruit model and examines the limited available data on size and age for this stock.

Both mentella-type and marinus-type redfish occur on Flemish Cap and significant catches of marinus-type redfish are occasionally obtained there. However, an examination of catches by the Canadian research vessel A. T. Cameron in that area during 1961, 1964 and 1968 indicates that marinus-type redfish generally amounted to less than five per cent by weight of the total redfish catch in research surveys in that area. No data are available on the relative proportion of marinus-type redfish in the commercial catches. However, it seems reasonable to conclude, in light of the overwhelming predominance of mentella-type redfish in Canadian research catches and USSR research surveys (Yanulov, 1960a and b; Chekhova, MS 1973) that mentella-type redfish have comprised by far the major portion of the commercial catches.

Mead and Sindermann (1961) considered the mentella-type redfish inhabiting the Flemish Cap area to be a separate stock for assessment purposes. Yanulov (1960a and b), from a study of various morphological features and the degree of infestation with certain parasites, concluded that the mentella-type redfish on Flemish Cap constitute a self-contained stock. This is butressed by the occurrence in the vicinity of Flemish Cap of well-defined larval concentrations (Bainbridge and Cooper, 1971).

Materials and Methods

Fishing effort was standardized on the basis of tonnage category. Vessels of 151-500 tons fished most consistently in 3M during 1957-71; the catch per day of this tonnage category was selected as the standard unit of effort for this period and in general the total number of standard days fished for the entire fleet was estimated by dividing the catch per day of this tonnage category into the total catch. Effort data were lacking for 1962 and 1967 and the catch per standard day for each of these years was derived by interpolation between immediately adjacent years (Fig. 1). Virtually all of the 1972 catch was taken by vessels of tonnage category > 1800 tons. A conversion factor of 0.17 (from Pinhorn and Parsons, 1974) was used to convert the catch per unit of effort of this tonnage category to that of the standard category 151-500 tons. The total 1972 effort was thus estimated as days fished by the standard tonnage category.

The Schaefer yield model (Schaefer, 1954) was used to derive estimates of sustainable yields from these catch and effort data. Periods of 6, 8 and 10 years were used to average the total effort over the mean number of years that a given year-class might contribute to commercial catches. The fishing effort in year i and 5 years prior to year i (i.e. a 6-year period) was averaged and plotted against the catch per unit effort in year i; similar calculations were performed for 8- and 10-year averaging periods. Least squares linear regressions relating catch per unit effort to mean effort were then computed (Fig. 2). The parameters of the linear regressions for the 6-, 8- and 10-year averaging periods were then converted to those of the equilibrium yield versus effort parabolas depicted in Fig. 3.

In an attempt to determine the degree of variability in recruitment during the period of exploitation, size distributions of male and female redfish taken in catches by the Canadian research vessel A. T. Cameron during survey cruises to the Flemish Cap in 1961, 1964 and 1968 and in catches by the Canadian vessel Cape Farewell during exploratory surveys of the Flemish Cap in 1973 were plotted. The A. T. Cameron fished a no. 41-5 Yankee otter trawl (24.1 m headrope). The Cape Farewell fished an Engels-Demone high opening semipelagic trawl. The codends of both trawls were lined by a 29-mm mesh nylon liner. Only daylight survey sets were used in these analyses.

Catches on two survey lines across depth contours, one from 125 to 350 fathoms to the north of Flemish Cap and the other from 150 to 350 fathoms to the east of Flemish Cap, were examined. Generally the following depths were fished where applicable: 125, 150, 175, 200, 250, 300 and 350 fathoms. The combined size distribution for each survey line was weighted according to the numbers caught at each size at each depth. The 1973 data are not directly comparable with the earlier years to the extent that the Cape Farewell fished a more limited range of depths: from 175 to 250 fathoms to the north of Flemish Cap and from 150 to 250 fathoms to the east of Flemish Cap.

The few commercial length frequencies available in the ICNAF sampling yearbooks for 1970 to 1972 and USSR length frequencies for their 1972 exploratory catches were also plotted for comparison with the size distributions derived from the Canadian research surveys.

Polish age composition data for a single sample from the 1972 commercial catch and USSR age composition data for their 1972 exploratory catches were compared with the numbers caught per hour at each age during the 1973 Cape Farewell survey. The 1973 ages were determined by the authors from otoliths according to the method of Sandeman (1961, 1969). Age-length keys were derived from random samples taken from several depths and positions and these were used to estimate from the numbers caught per hour at each length interval the numbers caught per hour at each age on the northern and eastern survey lines.

Bertalanffy growth curves were fitted separately to the pooled length-at-age data for male and female redfish in the 1973 research samples by Allen's (1966) method. These are compared with earlier growth curves for Flemish Cap redfish.

Results

Trends in catches, effort and catch per unit effort

A directed fishery for redfish in Division 3M commenced in 1957 when a catch of about 32,000 tons was reported. The catch increased to 54,000 tons in 1958, remained at 52,000 tons in 1959 but then declined sharply to 8000 tons in 1960 (Fig. 1, Table 1). Catches remained less than 16,000 tons during 1961-64, increased to 29,000 tons in 1965 and subsequently declined to a very low level from 1966 to 1971 averaging 4400 tons during that latter period. The catch increased dramatically from

8000 tons in 1971 to approximately 42,000 tons in 1972. Preliminary statistics indicate that the 1973 catch was substantially lower at about 20,000 tons.

Trends in fishing effort were similar to catch trends (Fig. 1). Peaks in fishing effort occurred at about 10,000 to 11,000 standard days fished in 1958, 1965 and 1972. Catch per day fished was at a high level of 4.8 to 6.4 tons per day during 1957-59, subsequently declined to a low of 2.1 tons per day in 1964 and 1966 (Fig. 1). The fishery for redfish in 3M was virtually nonexistent in 1967. By 1968 the catch per day had recovered to 3.3 tons and subsequently showed a progressive increase to 4.4 tons in 1971 with only a slight decrease to 4.0 tons in 1972. The catches per day during 1970, 1971 and 1972 were equivalent to those experienced in 1960 and 1961. The greatly increased catch in 1972 was due to a dramatic increase in effort presumably in response to the improved catch per unit effort.

Maximum sustainable yields

Regressions of catch per unit effort against mean effort during 1957-71 resulted in correlation coefficients of 0.59, 0.88 and 0.91 for the 6, 8 and 10-year averaging periods, respectively (Fig. 2). Very little improvement in correlation was evident between the 8- and 10-year averaging periods as observed for Subarea 2 + 3K redfish (Pinhorn and Parsons, 1974).

Maximum sustainable yield estimates of 13,000 tons for the 10-year period, 14,400 tons for the 8-year period and 16,700 tons for the 6-year period were indicated by yield curves calculated from these regressions (Fig. 3).

Size and age

The size distributions of both males and females in 1961 research catches (Fig. 4) to the north of Flemish Cap were dominated by large fish 30-40 cm in length, with the males exhibiting a mode of 32-34 cm and the females 34 cm.

In 1964 the size distributions of both males and females in research catches were basically bimodal (Fig. 4). The dominant peaks were at 33 cm for the males and 35 cm for the females. A secondary mode was evident at 18 cm for both males and females. From Sandeman's growth curve (1969) based on 1956 and 1958 data those fish represented by the mode at 18 cm appear to be 5-year old fish of the 1959 year-class. Tokareva (1965) in a study of comparative year-class strengths of young redfish in the Northwest Atlantic attributes 3M redfish of 16-17 cm in 1964 to the 1960 year-class. These fish were less than half as abundant in terms of numbers caught per hour fished as the fish represented by peaks at 33 and 35 cm.

In 1968 on the northern survey line the dominant mode was at 26 cm for males and 25-26 cm for females (Fig. 4). Presumably these were predominantly the same year-class(es) represented by the peak at 18 cm in 1964. The females exhibited a second less prominent mode at 37 cm but the males had several modes of equal prominence at 29, 31 and 34 cm. The bulk of the fish in the 1968 research catches were of the smaller sizes. In 1973 research catches the size distribution of the males was again bimodal with peaks at 27 and 34 cm; the females were basically trimodal with prominent modes at 26 and 37 cm and a less prominent mode at 31 cm (Fig. 4). The broad range of sizes indicates that a range of ages were involved.

Size distributions on the survey line to the east of Flemish Cap (Fig. 5) were very similar in 1964 to those on the northern survey line. Numbers caught per hour of the larger fish were virtually identical; however, the smaller fish with modal lengths at 18 cm were somewhat more abundant to the east than to the north. In 1968 the size distributions were dissimilar. Fish of 25-26 cm were much less abundant on the eastern survey line than to the north. To the east several size groups were distinguishable among both males and females - males with modal lengths of 15-19 cm, 26 cm and 34 cm; females with modal lengths of 15-18 cm, 26 cm and 37 cm. In 1973 on the eastern line the males had peaks at 26 cm and 35 cm; the females approximated trimodality with peaks at 27 cm, 32-33 cm and 38 cm. Fish larger than 31 cm were markedly predominant among the males but less so among the females which were almost equally abundant over the broad size range of 26 to 40 cm. This contrasts with the predominance of the smaller size group (26-27 cm) to the north.

Cursory examination of the limited commercial length frequencies available for 1970, 1971 and 1972 reveals a broad size range in all three years (Fig. 6). In 1970 the bulk of the fish were between 26 and 40 cm with three slight modes at 29, 33 and 36 cm among the males. The female size distribution was more irregular. In 1971 the unsexed size distribution was trimodal with the dominant size group centered at 37 cm, a secondary peak at 30-31 cm and a few fish at modal length of 24 cm. The bulk of the fish were between 32 and 41 cm. The single unsexed commercial frequency for 1972 indicates a trimodal size distribution with modes at 25, 31 and 37 cm. The size groups centered at these modal lengths appear to be of approximately equivalent abundance in terms of numbers. There are no gaps in the size distribution; it would appear that the 1972 fishery was based upon a wide range of sizes.

The two 1972 USSR exploratory length frequencies (Fig. 7) are somewhat dissimilar. In March the dominant size group had modal lengths of 35 cm for males and 37 cm for females. However, a substantial number of 22-33 cm fish were also present. In July 1972 larger fish were dominant in the exploratory catches with modal lengths of 37 cm for males and 40 cm for females. Apparently only negligible quantities of fish less than 32 cm were caught. USSR age readings indicate that males of ages 12-14 and females of ages 13-16 were dominant in their March exploratory samples (Fig. 8).

The Polish age composition data for the March 1972 commercial sample indicate that 6- and 11-year-old fish were dominant among the males and 6-, 8- and 17-year-old fish among the females (Fig. 8). More older females were present than males.

Numbers caught per hour at each age in the 1973 Canadian research surveys (Fig. 9) indicate substantial agreement with the 1972 Polish commercial data in terms of the range of ages present. The males on the northern survey line had a peak at age 7 corresponding to the dominance of 6-year-olds in the 1972 commercial sample. Fish at ages 10, 11 and 12 were dominant among the males to the east of Flemish Cap; greater numbers of 7- and 8-year-old fish were caught to the north. Ages 9 and 12 were dominant among the females in both areas but on the whole greater numbers of young fish were present on the northern survey line as was apparent from the size distributions (Figs. 4-5).

Approximately 50% of the females caught in the 1973 research survey were immature whereas less than 10% of the males were immature (Fig. 9). The males obviously attain maturity at an age several years younger than the females. More than 50% of the males are mature at age 6 whereas the bulk of the females are immature as late as age 10. Sandeman (1969) found that in Hermitage Bay, Newfoundland, on the average males mature at about 20 cm or 6 years old whereas females mature at about 30 cm or 10-12 years of age. This difference in the age at maturity is probably primarily responsible for the different growth rates of males and females (Fig. 10). If we assume that males and females were present in the 1972 commercial catch in the proportions present in the Polish March sample, then more than 25% of the catch in numbers would have been immature fish.

Growth

The parameters for the von Bertalanffy growth curves fitted to the 1973 research data and their standard errors were as follows:

	Males	Females
K	0.20 ± 0.04	0.07 ± 0.02
t	-0.86 ± 1.11	-3.48 ± 1.63
L^{o}_{∞}	35.24 ± 0.83	49.76 ± 4.33

These curves are shown in Fig. 10 with Sandeman's (1969) growth curves for Flemish Cap, which were based on 1956 and 1958 data, and curves fitted to Surkova's (1962) data for the years 1956-60 combined and averaged over the 5 years.

Considerable differences are apparent but these must be interpreted with caution in view of the fact that some of these curves have been derived from data containing very few young fish. Hence, apparent differences at the younger ages may be an artifact. Our growth curve for males is intermediate, being more similar to Sandeman's curve than Surkova's. Sandeman (1969) attributed the lack of agreement between his and Surkova's growth curves to the fact that he used otoliths and Surkova scales. The 1973 calculated lengths at age of males are higher than Sandeman's by about 4 cm at age 6, 3 cm at age 10, 2 cm at age 14 and less than 1.5 cm at age 20. In view of the 15-year-interval between the periods represented by Sandeman's data and that presented in this paper, these differences might represent a real difference in growth, particularly since Sandeman's samples were taken from a virgin stock of accumulated old fish, but the possibility that these differences may to a large extent be one of technique rather than of real growth differences cannot be discounted.

Our growth curve for females is closer to Surkova's than Sandeman's. Very few females older than age 18 were present in the 1973 age samples. The curve beyond age 18 is primarily an extrapolation of the relatively faster growth in the earlier years and hence may not be representative of actual growth at those older ages.

Yield per recruit

The Beverton and Holt yield per recruit model was applied to males and females separately, using the following parameters:

	Males	Females
W_∞ (asymptotic weight)	0.618 kg	1.835 kg
K (from Bertalanffy equation)	0.195	0.073
t_0 (growth correction factor)	-0.864	-3.482
t_ρ (age at entry to exploited area)	6	6
t_ρ^1 (age at mean selection length)	8.5	9.0
t_λ (last age of significant contribution to fishery)	18	20

We have no precise estimates of the natural mortality coefficient for redfish. However, the natural mortality rate for slow-growing species such as redfish must be very low relative to faster growing species such as cod. Sandeman (1973) considers values of 0.2 and 0.01 to be extreme high and low values with the most likely value lying somewhere between 0.1 and 0.05. Values of M of 0.05, 0.1 and 0.15 were used here and yield per recruit values computed up to F = 2.5.

The yield curves were essentially flat-topped with F_{max} occurring at 0.6 for males and 0.35 for females with M = 0.05 and at 0.6 for females with M = 0.1 (Fig. 11). For other values of M no maximum values were obtained up to F = 2.5. However, beyond fishing mortality values of 0.4 the increments in yield per recruit were exceedingly small. Estimated levels of F_{opt} ($F_{0.1}$) (Gulland and Boerema, 1973) for the males were 0.22, 0.30 and 0.33 and for the females 0.16, 0.22 and 0.28 with M = 0.05, 0.10 and 0.15, respectively.

Estimates of total mortality (Z) from the 1973 Canadian research vessel catch curves were 0.54 for males and 0.35 for females (Fig. 12). Estimates of Z of 0.48 for males and 0.40 for females were derived from 1972 USSR exploratory catch curves (Fig. 13). These values are beyond $F_{0.1}$ for both males and females with M = 0.05 and 0.1, at or beyond $F_{0.1}$ for males and slightly less than $F_{0.1}$ for females with M = 0.15. The fishing mortality indicated by the 1972 USSR catch curve for females is at F_{max} with M = 0.05.

Discussion

From the data available on the size and age composition of the Flemish Cap commercial redfish during 1970-72, the fishery appears to have been based upon several year-classes of approximately equal strength rather than upon one or two abnormally successful year-classes as has been the case in the Gulf of St. Lawrence in recent years (Sandeman, 1973). Fluctuations in recruitment are evident but appear to be less pronounced on Flemish Cap. The Polish commercial age data for 1972 indicate that the fishery in 1972 was based upon 6- to 15-year-old males and 6- to 20-year-old females. The March 1972 USSR exploratory catches were apparently dominated by 12- to 15-year-old males and 13- to 16-year-old females. Chekhova (MS 1973) reported that in the April 1972 (USSR research survey) on Flemish Cap mentella-type redfish with an average length of 28.1 cm were dominant at 301-400 m and fish with an average length of 33.4 cm at 401-500 m. The mean length of males in the USSR March exploratory catches were 31.9 cm and that of females 32.4 cm. The mean lengths in the July exploratory catches were considerably larger - 36.3 cm for males and 39.2 cm for females.

The high redfish catches of 1957-59 (32,000-54,000 tons) in Division 3M were above any sustainable level. However, with the exception of a catch of 29,000 tons in 1965, catches during 1960-71 were generally below the sustainable yield level with the fishery at a very low level during 1966-71 (average yearly catch 4400 tons). The dramatic increase in catch to 42,000 tons in 1972 was due to a major diversion of fishing effort to that stock. Fishing effort in 1972 increased to the level which prevailed in 1958 and 1959, approximately double that required to produce the equilibrium yield under stabilized conditions.

The estimates of Z derived from the 1973 research vessel catch curves probably represent the average level of total mortality during 1963-72 when catches averaged approximately 11,800 tons annually. These values are at or beyond $F_{0.1}$ for both males and females with one exception (females with M = 0.15). The 1972 catch of about 42,000 tons was almost five times as large as the average catch from 1963-71 of 8500 tons annually and the estimated fishing effort in 1972 (10,421 standard days fished) was more than triple the 1963-71 average annual fishing effort of 3037 standard days fished. It seems highly likely that the 1972 value of F was considerably above the $F_{0.1}$ level.

The gradual increase in catch per unit of effort to a 1971 level double that obtained in 1966 indicates a gradual resurgence of this stock under relatively stabilized conditions of low fishing effort from 1967 to 1971. The catch per unit of effort levelled off with the greatly increased catch in 1972.

The 1972 catch of 42,000 tons is considerably above the sustainable yield level and was attained only by an increase in fishing effort to approximately twice the level required to attain the maximum sustainable yield under equilibrium conditions. Catches of the magnitude of the 1974 total allowable catch of 40,000 tons cannot be sustained. Indeed preliminary statistics indicate that the 1973 catch was substantially lower at about 20,000 tons. It would seem wise to limit catches to the estimated maximum sustainable yield level of 13,000-17,000 tons until such time as more rigorous assessments become available.

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Table 1. Nominal catches (metric tons) of redfish by country from ICNAF Division 3M, 1956-72.

Year	Canada	Fr	Germ (Fed)	Japan	Poland	Portugal	Romania	Spain	UK	USA	USSR	Non-Mem	Total
1956										54			54
1957											31573		31573
1958	9									32	53895		53936
1959											51977		51977
1960			135								8203		8338
1961			1168		183				85		14081		15517
1962	47		32		487				9		6383		6958
1963					287				132		6606		7025
1964			248		128				140		13465		13981
1965		4	73		1805				294		26994		29170
1966			11		105				167		6954	4	7241
1967					587				42		65	35	729
1968	26				50				1		4686		4763
1969	5										2061	421	2487
1970				1017	15						2136		3168
1971			10	1778	22						6213		8023
1972	1	2	306	177	960	1773	33	20	316		38358		41946
Total	88	6	1983	2972	4629	1773	33	20	1186	86	273650	460	286886

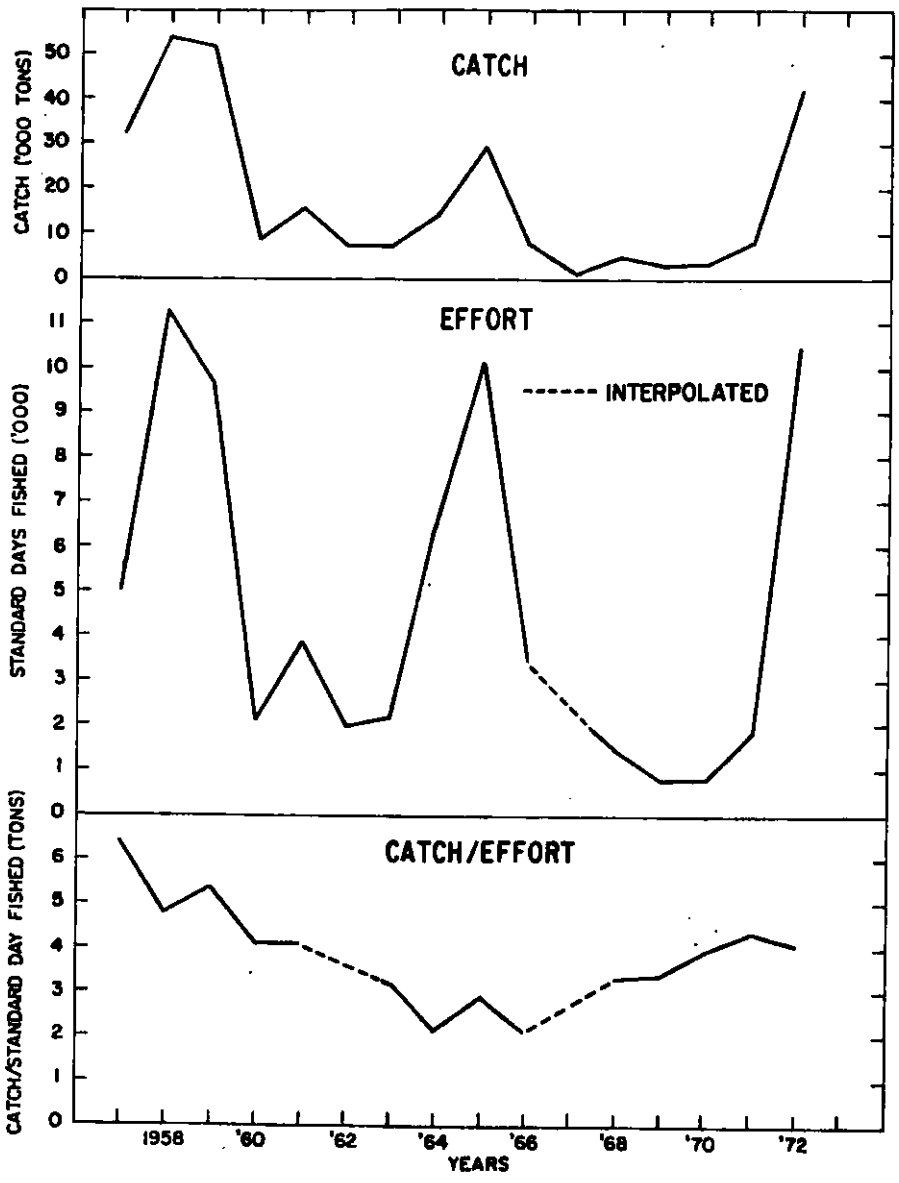

Fig. 1. Trends in redfish catch effort and catch per unit effort in standard trawler units - USSR tonnage class 4 - for redfish in Division 3M.

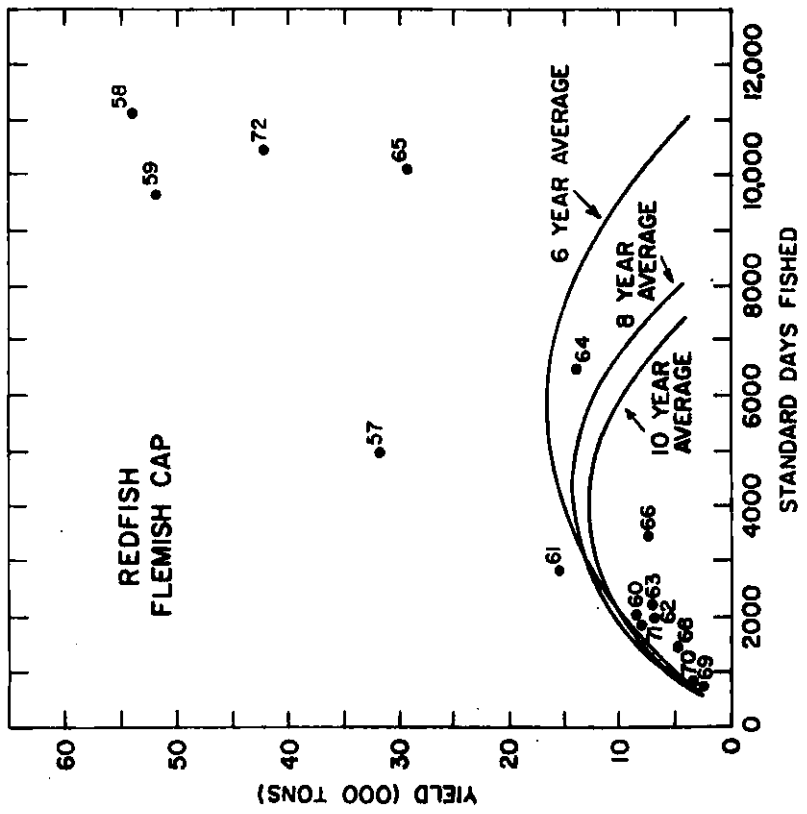

Fig. 3. Yield curves derived from the catch per unit effort/effort relation using 6-year, 8-year and 10-year running averages of standard days fished, redfish, Division 3M.

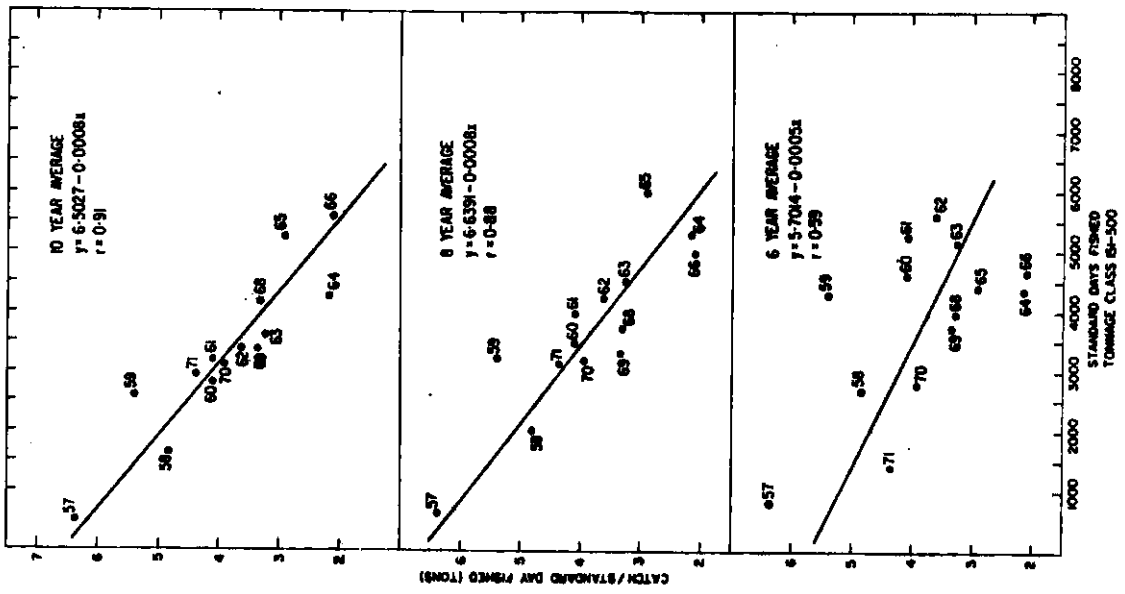

Fig. 2. Catch per standard day fished versus 6-year, 8-year and 10-year running averages of standard days fished, redfish, Division 3M.

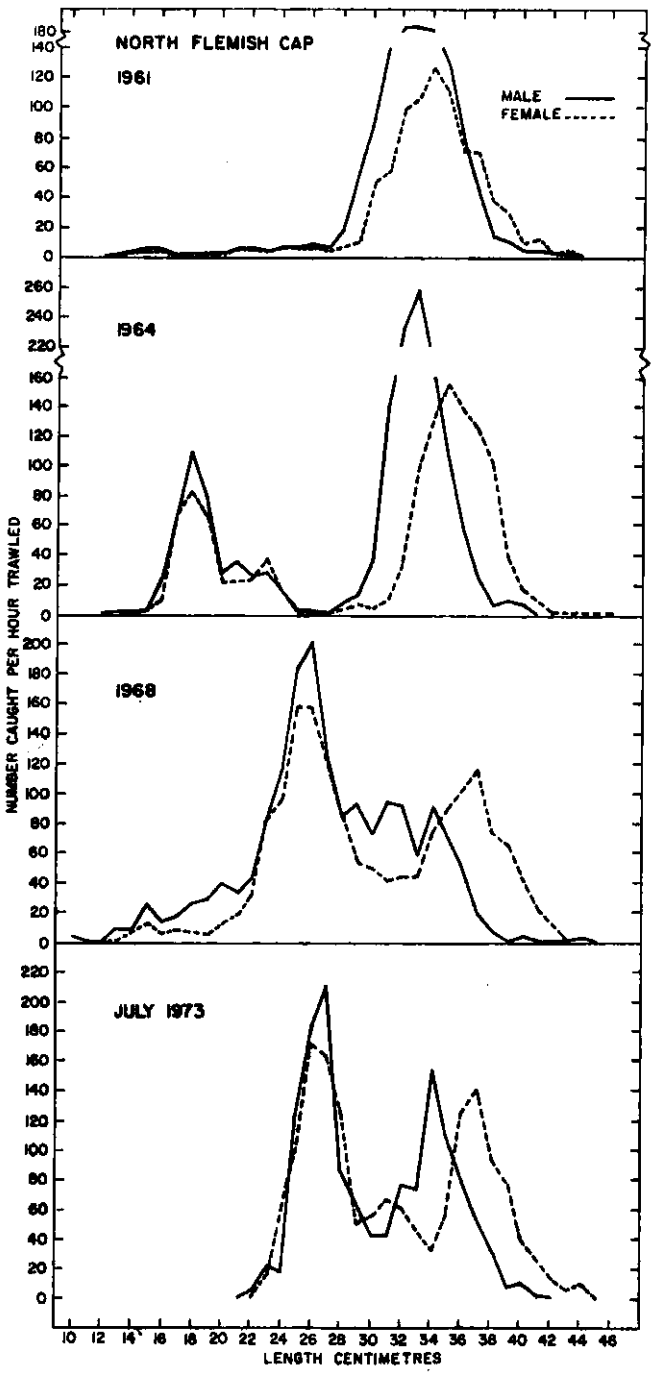

Fig. 4. Length distributions of mentella redfish taken by research vessel from the northern Flemish Cap (1961, 1964, 1968 A. T. Cameron; 1973 Cape Farewell).

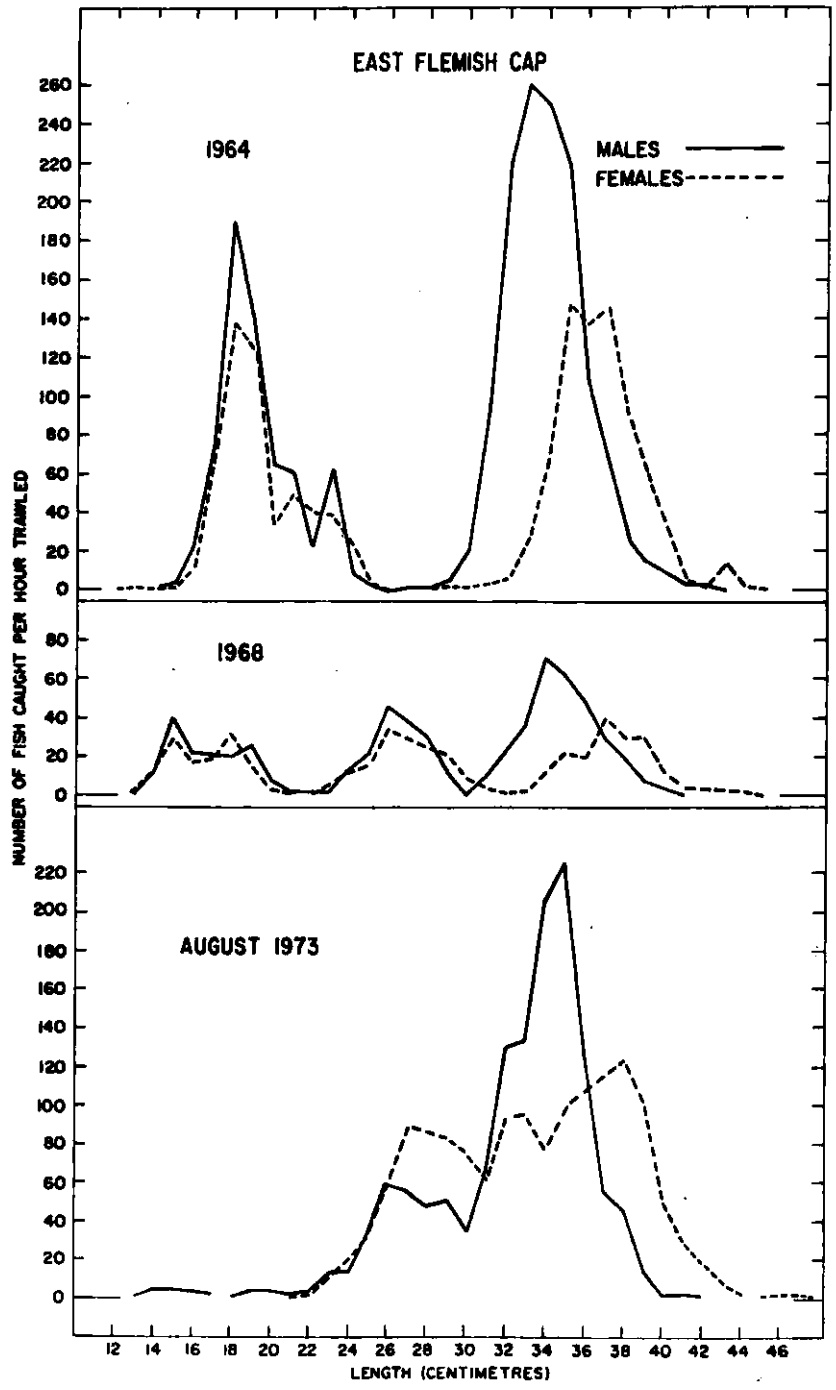

Fig. 5. Length distributions of mentella redfish taken by research vessel from the eastern Flemish Cap (1964, 1968 A. T. Cameron; 1973 Cape Farewell).

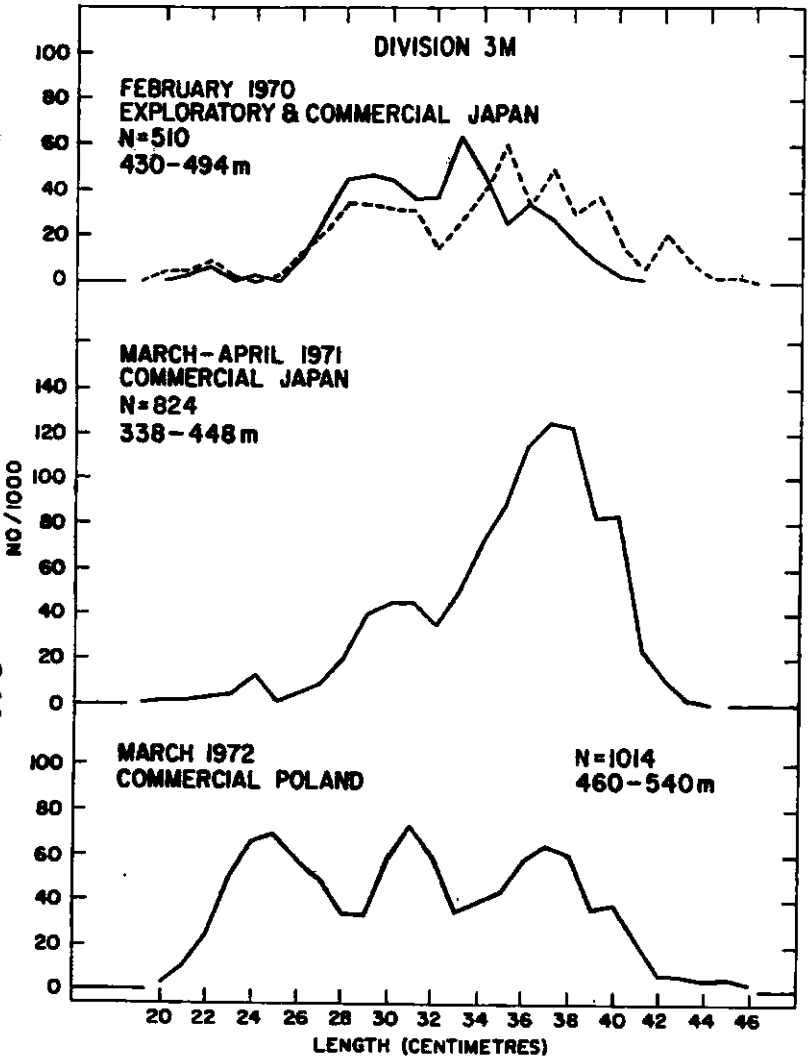

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Fig. 6. Commercial otter trawl length frequencies for Division 3M redfish, 1970-72.

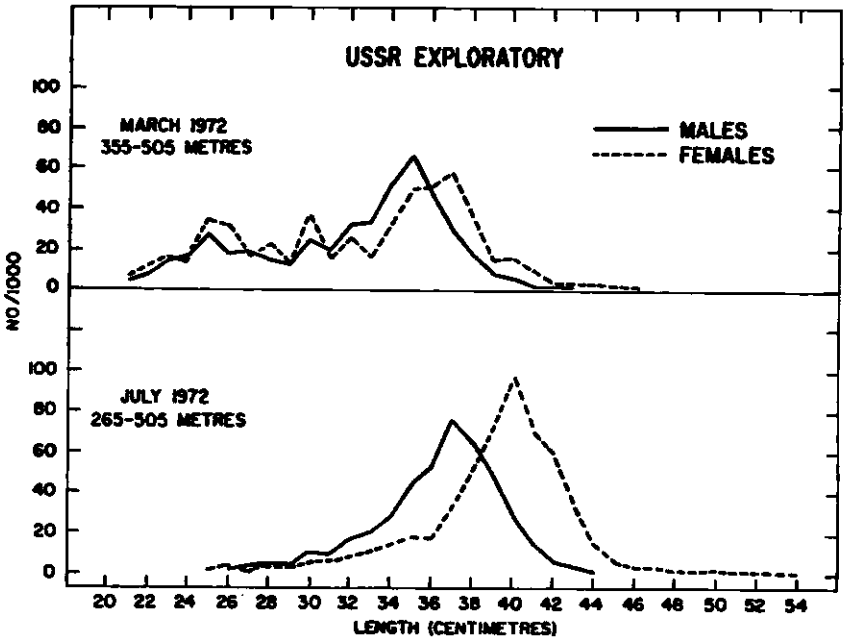

Fig. 7. Length distributions of mentella redfish taken in exploratory fishing by the USSR in Division 3M, 1972.

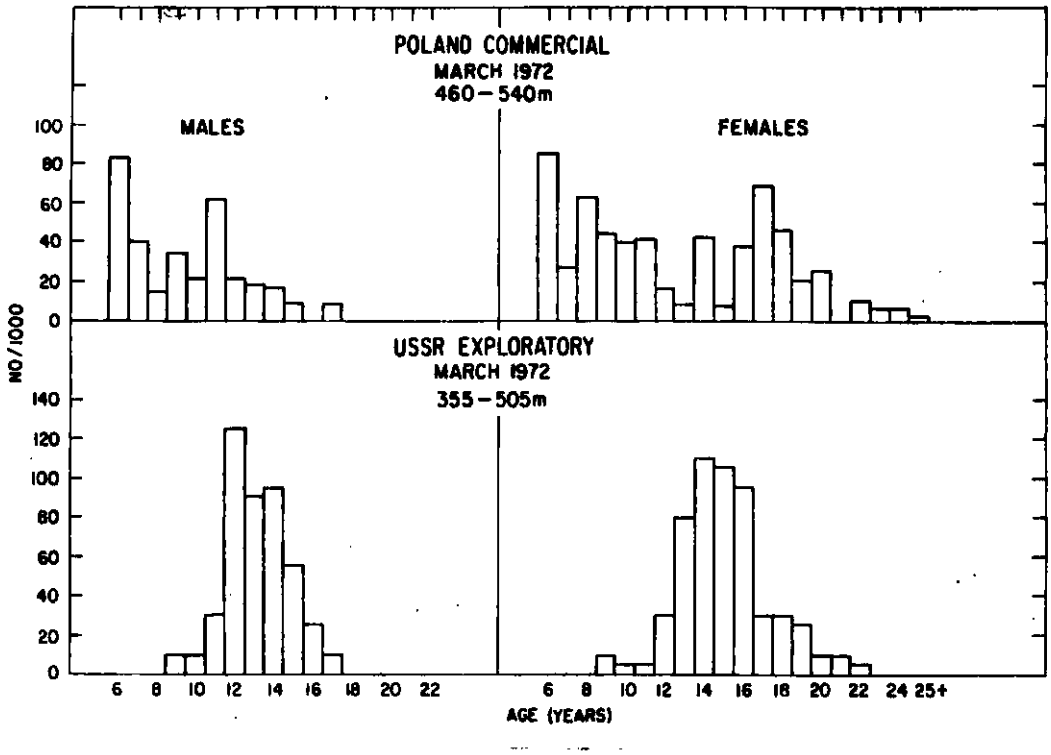

Fig. 8. Age distributions of 1972 Polish commercial and USSR exploratory redfish catches in Division 3M.

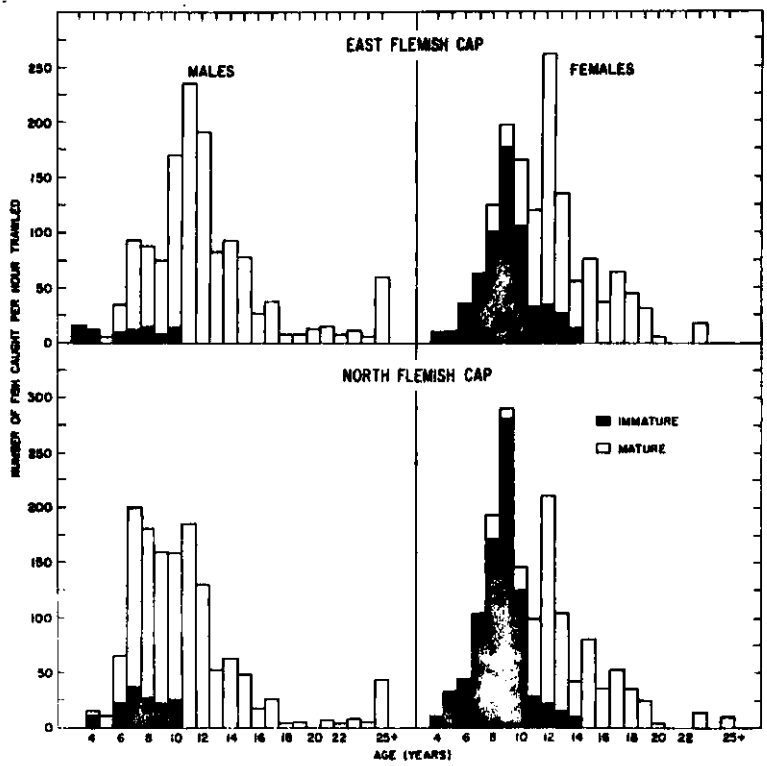

Fig. 9. Age distributions of 1973 Canadian research catches of mentella redfish in Division 3M.

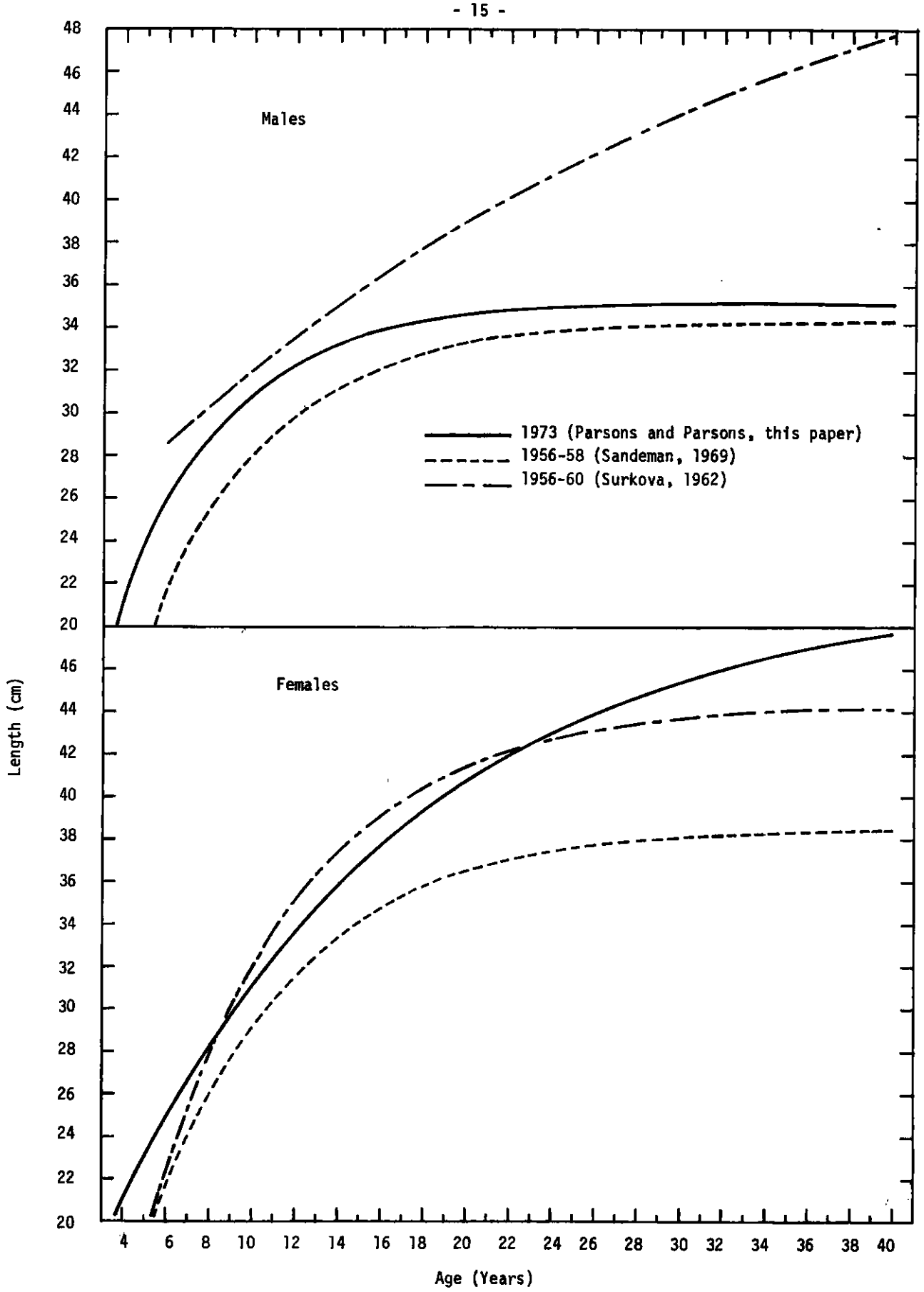

Fig. 10. Growth curves of male and female mentella redfish from Flemish Cap.

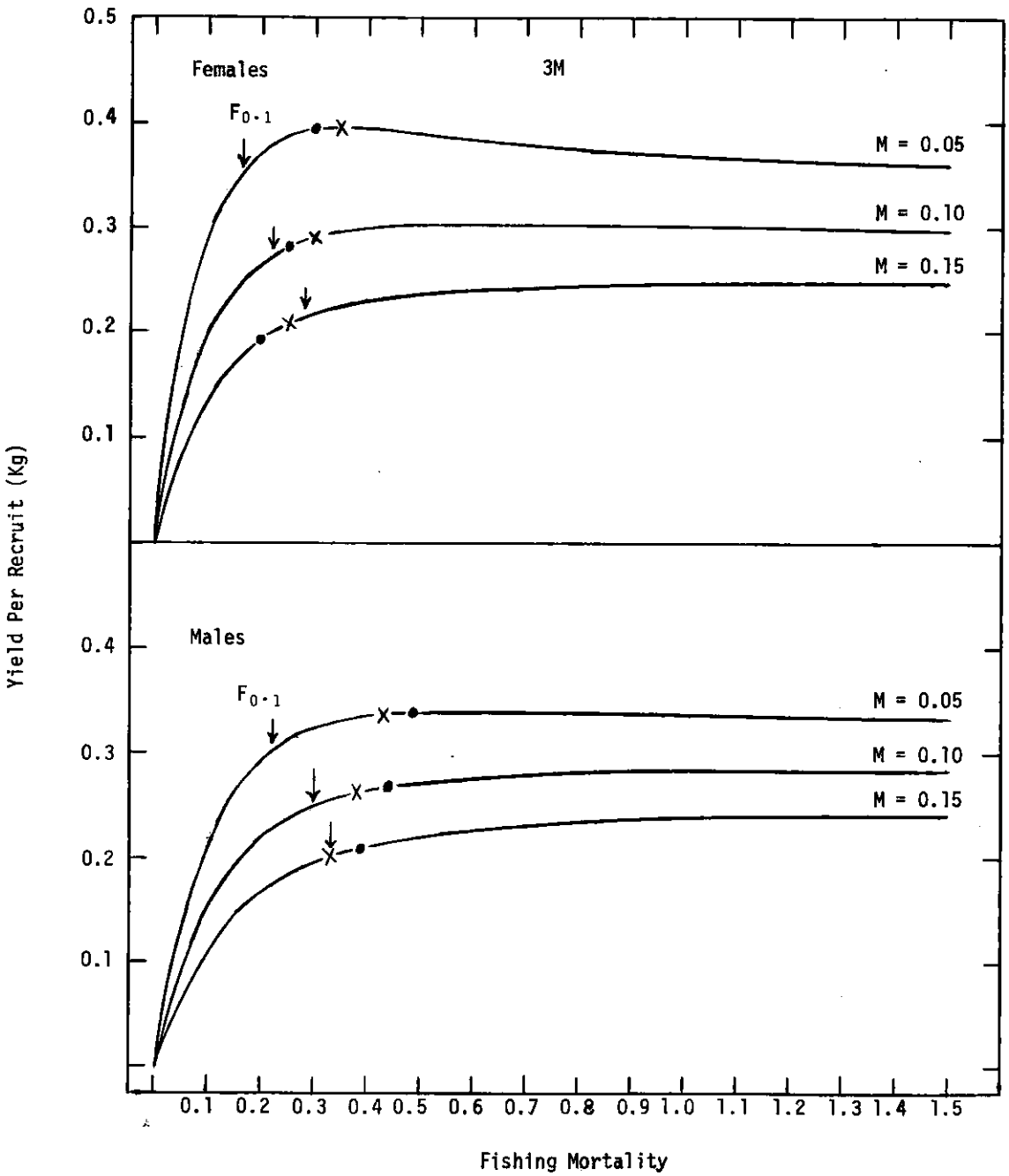

Fig. 11. Yield per recruit curves for male and female mentella redfish from Flemish Cap. Points on curves indicate fishing mortality estimates from 1973 Canadian research vessel data (.) and 1972 USSR exploratory catches (X).

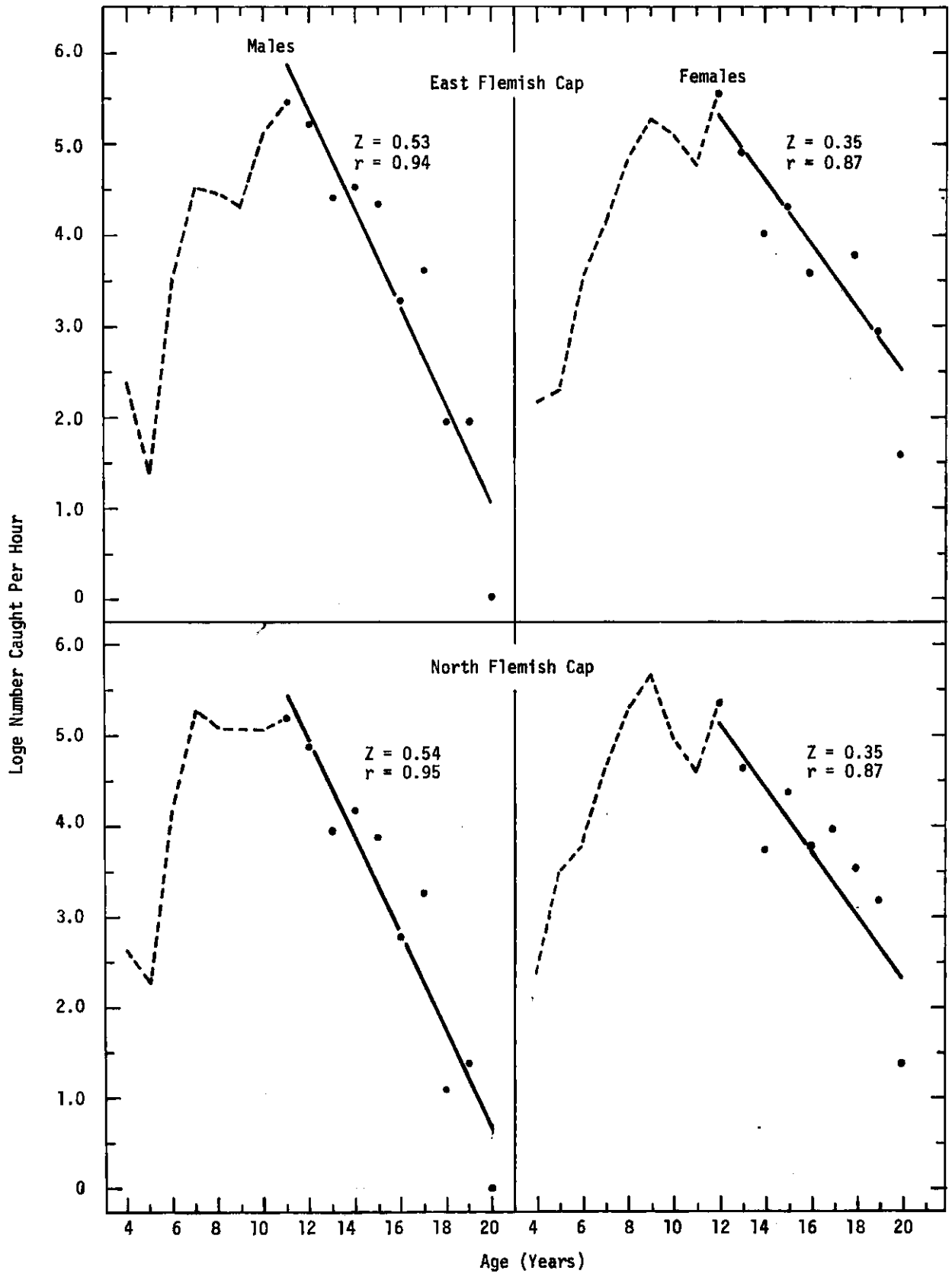

Fig. 12. Catch curves of redfish from 1973 Canadian research vessel data.

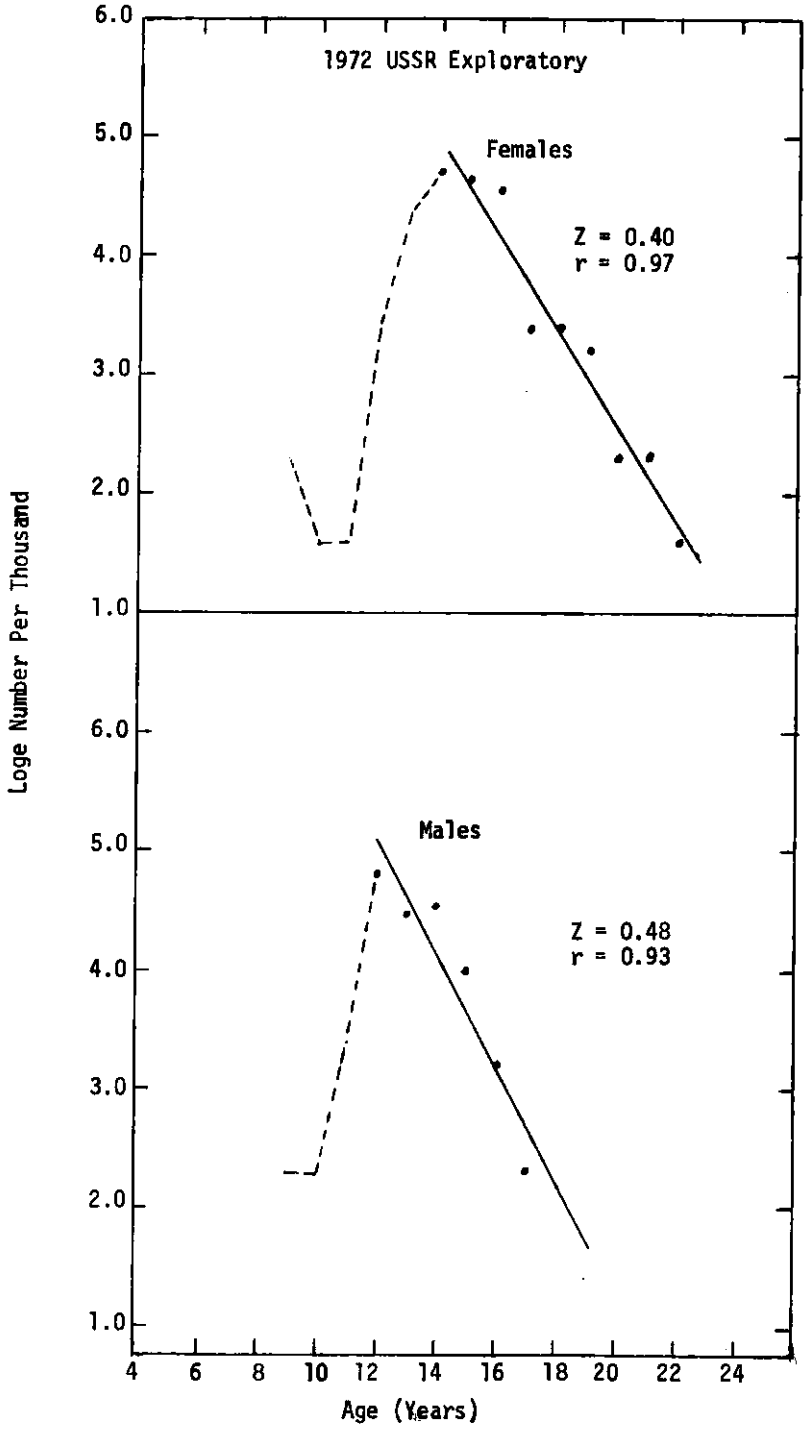

Fig. 13. Catch curves of redfish from 1972 USSR exploratory data.