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General Production and Cohort Analysis of Witch in Divisions 3NO

by

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The witch population in 3NØ is located along the deep muddy southwest slope of the Grand Bank in warm waters with little movement over higher portions of the Bank. Early exploitation occurred during the lucrative haddock fishery of the 1950's and early 1960's, however, since then it has essentially been a small directed fishery by Canada and the Soviet Union when ice prohibits fishing in the northern waters.

The witch in this area generally form prespawning concentrations in the winter and very early spring along the most southerly tip of the bank and it is during this time when catch rates are fair that the fishery usually occurs. Landings over the past 10-12 years indicated catches as high as 10,000-15,000 tons annually up to 1971 (Table 1), however, these catches were reported originally as unspecified flounder and in view of the more recent landing reports and previous assessments (Bowering, 1977 and 1978) it is likely that the earlier reports may have been exaggerated. A pre-emptive quota of 10,000 tons annually was agreed to for this stock in 1974 based on these figures and remained at 10,000 tons until 1979 when it was subsequently reduced to 7,000 tons as the result of a preliminary cohort analysis by Bowering (1978). This document will take a more detailed look at the status of this stock from two different points of view (1) General Production (2) Cohort Analysis

Catch and effort

Since effort directed towards this fishery is quite small in comparison to most fisheries it was difficult to secure reliable effort and catch data. The Canada (Nfld.) boats, however, have for many years reported catch and effort data both in the directed fishery and as a bycatch. For the purpose of this analysis, all catches for the years 1964-78 where effort was reported from this area, was considered to be a directed fishery for witch when witch was the main species caught. Therefore only main species witch catch/effort data were used in the analysis. Since the fishing pattern was generally the same over the years and the same type vessels were being used each year, the catch per unit of effort was calculated by dividing total catch by total effort annually for all classes of Canadian (Newfoundland) stern trawlers. Side trawlers were omitted from the calculations. Using this as a standard, a value of total units of effort annually was derived.

Catch per unit of effort was regressed upon effort for 1967-78 using a 4-year running average (Fig.1). The two appeared to be highly correlated ($r = 0.77$). The values derived from the regression were then used to generate a Shaeffer type yield curve as presented in Fig. 2. The maximum sustainable yield from this curve is 8,000 tons at an effort of 16,000 hours. The 2/3 F_{msy} level is between 6,000-7,000 tons. A line drawn from the origin through the 1978 point shows that the 1975 to 1978 points are distributed almost along the same line indicating that catch per unit effort over the last few years has been fairly constant at varying units of effort. If the effort level remains in the order of the 1978 level which is likely to be the case, then the catch can be expected to be much the same, that is, 3,000-4,000 metric tons. To control effort at 2/3 F_{msy} would imply a catch of about 3,000 tons.

Cohort Analysis

Calculation of numbers

In 1974 and 1975 samples were obtained from only one quarter of the year and these were applied to the total catch for the whole year (Bowering, 1978). It was assumed that all countries (essentially Canada and the Soviet Union) were fishing the same age and length distribution of fish. The 1976-78 data had samples from more than one quarter of the year. These samples were applied to the catches of the specific quarter in which they were taken; for quarters in which no samples were taken, the catches were broken down by the samples of the nearest quarter in which samples were taken. Since the fishery is an offshore fishery only one gear (OT) had to be considered. The weighted average length was calculated from the length frequencies for each quarter or year and an average weight was derived from the equation $W = 0.00063709L^{3.6142}$ where W = weight in gm. and L = length in centimeters (Bowering, 1976). From these average weights, the total number of fish caught in each year could be calculated from total landings. The total numbers caught at age were then computed by breaking down the total numbers caught by the percentages sampled at each age.

Terminal F

In a previous assessment of this stock (Bowering 1978), terminal F was based upon the average level of fishing mortality over a number of years as computed from catch curves, since there was a lack of catch/effort information. With the refinement of some catch and effort data this year a more realistic value was determined. Numbers caught at age for a standard unit of effort were calculated for 1977 and 1978 and a survival rate between what appeared to be the fully recruited year classes was derived using the Ricker method (Ricker 1958). The natural log of this survival rate is an estimate of total mortality. Subtracting natural mortality (0.20 for males and 0.15 for females) yielded estimates of fishing mortality approximately half way between the 1977 and 1978 fishing seasons. These values were used to represent terminal F of the cohort analysis. For the males $F_T = 0.60$ and females $F_T = 0.35$.

Partial recruitment

Partial recruitment was obtained from a matrix of catch numbers at age (Tables 2 & 3) averaged over the 1974-77 period. A value of 1.00 was assigned to the fishing mortality of the first age group which appeared fully recruited and each age group adjusted accordingly. These values were plotted (Fig. 3) and a curve by eye drawn through the plotted points. The actual values on the curve itself were then used as indices of partial recruitment in the cohort analysis. For flatfish species generally, there appears to be no real asymptote for full recruitment (Fig.3), therefore the values of partial recruitment were carried beyond 1.00 which would probably give a better representation of the data.

Catch projections

Fishing mortality values based upon partial recruitment patterns (Fig. 3) were determined to duplicate the 1979 TAC using the same proportion of males and females calculated from the 1978 catches. Recruitment values of 4.5 million for the males (Table 4) and 14.2 million for females were used (Table 5) and were calculated by taking the average number of 8 year-olds for 1974-76.

Using the same recruitment and fishing mortality pattern as 1978 the 1980 catches were projected at the $F_{0.1}$ level (0.43 for males and 0.33 for females) assuming the TAC of 7,000 metric tons for 1979 would be taken (Tables 4 & 5). The implied catch under these conditions for 1980 is 3,000 metric tons.

Summary

In view of the information presented here, it appears that this stock has been either heavily fished or else the amount of fish reported from breakdowns of unspecified flounder is greatly overestimated. The average catch over the past 4-5 years when reporting was probably most accurate indicated landings to be in the order of 4,000-6,000 tons. Reduced catches are probably the result of less effort and the removal of the older age groups since during the 1950's and 1960's witch of 25-30 years of age was not uncommon to the area, (unpublished data of the St. John's Biological Station). The one sided proportion of females to males in the catch projections can probably be explained by the fact that this fishery is generally directed towards prespawning concentrations of fish in which the females may be more susceptible to fishing since they move into shallower water to spawn. The fact that males mature earlier than females (Bowering, 1976) would indicate that mortality on males is also higher than on females.

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Table 1. Nominal catches of witch in ICNAF Divisions 3N and 3Ø for 1967-78 ('000 metric tons).

YEAR	CANADA	FRANCE	USSR	UK	POLAND	GDR	OTHERS	TOTAL
1967	2,863		8,565	26	29	20		11,503
1968	1,503	18	9,078					10,599
1969	479	6	4,215					4,700
1970	723	1	6,039					6,763
1971	178	10	14,774		3			14,965
1972	3,419	17	5,738	3				9,177
1973	4,943	20	1,714	5	9			6,691
1974	2,807	1	5,235	2				8,045
1975	1,137		5,019				12	6,168
1976	3,044		2,991					6,035
1977	3,001		2,805					5,806
1978	1,178		2,276					3,454

Table 2. Results of cohort analysis for male witch flounder in Div. 3NO.

NATURAL MORTALITY= 0.20

PARTIAL RECRUITMENT MULTIPLIER
0.0200 0.0500 0.2800 0.5500 1.0000 1.2000 1.3000 1.3700 1.4100 1.0000

ASSUMED FISHING MORTALITY FOR LAST AGES
0.3000 0.3000 0.3000 0.3000 0.5000

ESTIMATED POPULATION

AGE YEAR	1974	1975	1976	1977	1978
8	4435.	3498.	5313.	29302.	43238.
9	5228.	3611.	2841.	4329.	23942.
10	4951.	4126.	2806.	2222.	3278.
11	5457.	3452.	3197.	2028.	1265.
12	5398.	3494.	2323.	2068.	715.
13	3750.	3481.	2025.	990.	366.
14	2077.	2062.	1394.	508.	142.
15	1723.	1020.	746.	354.	187.
16	692.	1055.	396.	93.	166.
17	4.	500.	682.	89.	28.

KNOWN CATCHES

AGE YEAR	1974	1975	1976	1977	1978
8	22.	25.	23.	53.	390.
9	170.	166.	115.	295.	536.
10	665.	201.	298.	612.	389.
11	1077.	556.	607.	1045.	277.
12	1037.	923.	1008.	1467.	257.
13	1114.	1609.	1271.	739.	151.
14	752.	1041.	870.	253.	62.
15	393.	485.	573.	137.	85.
16	74.	201.	260.	53.	77.
17	1.	118.	161.	21.	10.

ESTIMATE FISHING MORTALITY

AGE YEAR	1974	1975	1976	1977	1978
8	0.0055	0.0079	0.0048	0.0020	0.0
9	0.0366	0.0521	0.0458	0.0783	0.0
10	0.1607	0.0553	0.1248	0.3630	0.0
11	0.2460	0.1961	0.2356	0.8428	0.0
12	0.2387	0.3453	0.6532	1.5327	0.0
13	0.3980	0.7151	1.1829	1.7444	0.0
14	0.5112	0.8163	1.1702	0.7994	0.0
15	0.2905	0.7458	1.8875	0.5578	0.0
16	0.1257	0.2364	1.2933	1.0023	0.0
17	0.3000	0.3000	0.3000	0.3000	0.5000

POPULATION WTS AND NOS

	1974	1975	1976	1977	1978
WT	18205.	14672.	11234.	14875.	24399.
NO	33714.	26296.	21723.	41982.	73326.

POPULATION WTS AND NOS AGE 10 TO 17

	1974	1975	1976	1977	1978
WT	14999.	12335.	8673.	4993.	3882.
NO	24051.	19189.	13569.	8351.	6146.

Table 3. Results of cohort analysis for female witch flounder in Div. 3NO.

NATURAL MORTALITY= 0.15

PARTIAL RECRUITMENT MULTIPLIER

0.0200 0.0900 0.2000 0.3500 0.6700 1.0000 1.3900 1.6100 1.7400 1.8900 2.0400 1.0000

ASSUMED FISHING MORTALITY FOR LAST AGES

0.2000 0.2000 0.2000 0.2000 0.2000

ESTIMATED POPULATION

AGE YEAR	1974	1975	1976	1977	1978
8	11744.	11618.	19080.	20147.	40462.
9	6554.	10088.	9846.	16411.	17321.
10	6406.	5594.	8573.	8463.	14027.
11	6227.	5119.	4408.	7188.	6971.
12	5802.	5025.	3703.	3518.	5521.
13	5595.	4071.	3315.	2550.	1813.
14	4007.	3806.	2461.	1822.	756.
15	2375.	2570.	2387.	1194.	795.
16	1825.	1311.	1465.	1172.	646.
17	1533.	894.	722.	475.	647.
18	506.	805.	429.	133.	291.
19	640.	207.	539.	124.	65.

KNOWN CATCHES

AGE YEAR	1974	1975	1976	1977	1978
8	22.	166.	12.	21.	150.
9	51.	118.	12.	106.	287.
10	426.	438.	206.	338.	511.
11	361.	757.	298.	718.	438.
12	995.	1089.	687.	1309.	644.
13	1089.	1124.	1111.	1551.	306.
14	948.	958.	996.	834.	171.
15	790.	805.	951.	412.	204.
16	729.	438.	847.	390.	177.
17	554.	367.	527.	127.	190.
18	246.	166.	264.	53.	91.
19	108.	35.	91.	21.	11.

ESTIMATE FISHING MORTALITY

AGE YEAR	1974	1975	1976	1977	1978
8	0.0020	0.0155	0.0007	0.0011	0.0
9	0.0084	0.0127	0.0013	0.0070	0.0
10	0.0744	0.0882	0.0262	0.0440	0.0
11	0.0645	0.1736	0.0757	0.1139	0.0
12	0.2044	0.2660	0.2231	0.5127	0.0
13	0.2354	0.3533	0.4483	1.0658	0.0
14	0.2944	0.3165	0.5731	0.6798	0.0
15	0.4440	0.4120	0.5612	0.4649	0.0
16	0.5632	0.4463	0.9762	0.4442	0.0
17	0.4935	0.5841	1.5433	0.3399	0.0
18	0.7421	0.2512	1.0879	0.5621	0.0
19	0.2000	0.2000	0.2000	0.2000	0.2000

POPULATION WTS AND NOS

	1974	1975	1976	1977	1978
WT	33617.	30163.	30150.	29744.	37468.
NO	53216.	51108.	56929.	63199.	89314.

POPULATION WTS AND NOS AGE 10 TO 19

	1974	1975	1976	1977	1978
WT	27824.	23203.	21011.	18043.	19301.
NO	34918.	29402.	28003.	26640.	31531.

Table 4. Projections of stock size and catch for male witch flounder in Div. 3NO.

RESULTS FOR YEAR 1977

AGE	POPULATION NUMBERS	POPULATION WEIGHTS	FISHING MORTALITY	CATCH NUMBERS	CATCH WEIGHTS	RESIDUAL NUMBERS	RESIDUAL WEIGHTS
8	4500.0	1269.0	0.0131	53.2	15.0	3636.2	1025.4
9	4329.0	1619.0	0.0781	295.0	110.3	3278.2	1226.0
10	2222.0	957.7	0.3597	612.0	263.8	1269.7	547.2
11	2028.0	1103.2	0.8231	1045.0	568.5	729.0	396.6
12	2068.0	1338.0	1.4472	1467.0	949.1	398.3	257.7
13	990.0	732.6	1.6230	739.0	546.9	159.9	118.3
14	508.0	439.9	0.7819	253.0	219.1	190.3	164.8
15	354.0	265.5	0.5502	137.0	102.8	167.2	125.4
16	93.0	68.2	0.9650	53.0	38.9	29.0	21.3
17	89.0	84.9	0.2998	21.0	20.0	54.0	51.5
TOTAL	17181.	7878.		4675.	2834.	9912.	3934.

RESULTS FOR YEAR 1978

AGE	POPULATION NUMBERS	POPULATION WEIGHTS	FISHING MORTALITY	CATCH NUMBERS	CATCH WEIGHTS	RESIDUAL NUMBERS	RESIDUAL WEIGHTS
8	4500.0	1269.0	0.0126	51.0	14.4	3638.2	1026.0
9	3636.2	1359.9	0.0314	102.1	38.2	2884.9	1079.0
10	3278.2	1412.9	0.1761	481.2	207.4	2250.5	970.0
11	1269.7	690.7	0.3459	338.5	184.1	735.5	400.1
12	729.0	471.7	0.6290	311.7	201.7	318.2	205.9
13	398.3	294.7	0.7548	193.7	143.3	153.3	113.4
14	159.9	138.5	0.8177	82.1	71.1	57.8	50.1
15	190.3	142.7	0.8617	101.0	75.8	65.8	49.4
16	167.2	122.6	0.8868	90.4	66.3	56.4	41.3
17	83.0	79.2	0.6290	35.5	33.9	36.2	34.6
TOTAL	14412.	5982.		1787.	1036.	10197.	3970.

RESULTS FOR YEAR 1979

AGE	POPULATION NUMBERS	POPULATION WEIGHTS	FISHING MORTALITY	CATCH NUMBERS	CATCH WEIGHTS	RESIDUAL NUMBERS	RESIDUAL WEIGHTS
8	4500.0	1269.0	0.0322	129.4	36.5	3567.4	1006.0
9	3638.2	1360.7	0.0806	255.6	95.6	2748.1	1027.8
10	2884.9	1243.4	0.4512	956.6	412.3	1504.2	648.3
11	2250.5	1224.3	0.8863	1216.5	661.8	759.5	413.2
12	735.5	475.9	1.6114	547.4	354.2	120.2	77.8
13	318.2	235.5	1.9337	254.3	188.1	37.7	27.9
14	153.3	132.8	2.0949	125.8	109.0	15.4	13.4
15	57.8	43.4	2.2077	48.2	36.2	5.2	3.9
16	65.8	48.2	2.2721	55.4	40.6	5.6	4.1
17	92.6	88.4	1.6114	68.9	65.8	15.1	14.4
TOTAL	14697.	6121.		3658.	2000.	8779.	3237.

RESULTS FOR YEAR 1980

AGE	POPULATION NUMBERS	POPULATION WEIGHTS	FISHING MORTALITY	CATCH NUMBERS	CATCH WEIGHTS	RESIDUAL NUMBERS	RESIDUAL WEIGHTS
8	4500.0	1269.0	0.0070	28.5	8.0	3658.6	1031.7
9	3567.4	1334.2	0.0175	56.1	21.0	2870.1	1073.4
10	2748.1	1184.5	0.0980	232.9	100.4	2040.0	879.2
11	1504.2	818.3	0.1925	239.5	130.3	1015.9	552.7
12	759.5	491.4	0.3500	204.5	132.3	438.2	283.5
13	120.2	88.9	0.4200	37.6	27.8	64.7	47.8
14	37.7	32.6	0.4550	12.6	10.9	19.6	16.9
15	15.4	11.6	0.4795	5.4	4.0	7.8	5.9
16	5.2	3.8	0.4935	1.9	1.4	2.6	1.9
17	20.7	19.7	0.3500	5.6	5.3	11.9	11.4
TOTAL	13279.	5254.		824.	441.	10129.	3904.

Table 5. Projections of stock size and catch for female witch flounder in Div. 3NO.

RESULTS FOR YEAR 1977

AGE	POPULATION NUMBERS	POPULATION WEIGHTS	FISHING MORTALITY	CATCH NUMBERS	CATCH WEIGHTS	RESIDUAL NUMBERS	RESIDUAL WEIGHTS
8	14147.0	4286.5	0.0016	21.1	6.4	12156.9	3683.5
9	16411.0	5596.2	0.0070	106.3	36.2	14026.6	4783.1
10	8463.0	3664.5	0.0440	338.7	146.6	6970.4	3018.2
11	7188.0	4090.0	0.1136	718.0	408.5	5522.2	3142.1
12	3518.0	2540.0	0.5078	1309.0	945.1	1822.3	1315.7
13	2550.0	2073.1	1.0407	1551.2	1261.1	775.3	630.3
14	1822.0	1847.5	0.6711	834.0	845.7	801.6	812.8
15	1194.0	1344.4	0.4612	412.0	463.9	648.0	729.6
16	1172.0	1482.6	0.4407	390.0	493.4	649.2	821.3
17	475.0	628.9	0.3380	127.0	168.2	291.6	386.1
18	133.0	163.2	0.5555	53.0	65.0	65.7	80.6
19	124.0	207.6	0.2008	21.0	35.2	87.3	146.2
TOTAL	57197.	27924.		5881.	4875.	43817.	19549.

RESULTS FOR YEAR 1978

AGE	POPULATION NUMBERS	POPULATION WEIGHTS	FISHING MORTALITY	CATCH NUMBERS	CATCH WEIGHTS	RESIDUAL NUMBERS	RESIDUAL WEIGHTS
8	14200.0	4302.6	0.0042	55.4	16.8	12170.7	3687.7
9	12156.9	4145.5	0.0190	212.0	72.3	10267.1	3501.1
10	14026.6	6073.5	0.0421	537.4	232.7	11574.9	5011.9
11	6970.4	3966.2	0.0737	460.3	261.9	5573.3	3171.2
12	5522.2	3987.1	0.1411	675.9	488.0	4127.6	2980.1
13	1822.3	1481.5	0.2106	322.1	261.9	1270.6	1033.0
14	775.3	786.1	0.2927	183.3	185.9	498.0	504.9
15	801.6	902.6	0.3390	214.9	242.0	491.6	553.5
16	648.0	819.7	0.3601	182.8	231.2	389.1	492.2
17	649.2	859.6	0.3980	198.9	263.4	375.3	496.9
18	291.6	357.8	0.4296	95.1	116.6	163.3	200.4
19	153.0	256.1	0.2106	27.0	45.3	106.7	178.6
TOTAL	58017.	27938.		3165.	2418.	47008.	21812.

RESULTS FOR YEAR 1979

AGE	POPULATION NUMBERS	POPULATION WEIGHTS	FISHING MORTALITY	CATCH NUMBERS	CATCH WEIGHTS	RESIDUAL NUMBERS	RESIDUAL WEIGHTS
8	14200.0	4302.6	0.0082	108.0	32.7	12122.0	3673.0
9	12170.7	4150.2	0.0370	410.7	140.1	10094.9	3442.4
10	10267.1	4445.7	0.0822	753.4	326.2	8139.4	3524.4
11	11574.9	6586.1	0.1439	1443.1	821.1	8627.4	4909.0
12	5573.3	4023.9	0.2755	1250.4	902.8	3642.0	2629.5
13	4127.6	3355.8	0.4111	1298.7	1055.9	2355.1	1914.7
14	1270.6	1288.4	0.5715	517.3	524.5	617.6	626.2
15	498.0	560.7	0.6619	225.7	254.2	221.1	249.0
16	491.6	621.8	0.7030	232.5	294.1	209.5	265.0
17	389.1	515.1	0.7770	197.1	260.9	154.0	203.9
18	375.3	460.5	0.8387	199.9	245.3	139.6	171.3
19	270.0	452.0	0.4111	85.0	142.2	154.1	257.9
TOTAL	61208.	30763.		6722.	5000.	46477.	21866.

RESULTS FOR YEAR 1980

AGE	POPULATION NUMBERS	POPULATION WEIGHTS	FISHING MORTALITY	CATCH NUMBERS	CATCH WEIGHTS	RESIDUAL NUMBERS	RESIDUAL WEIGHTS
8	14200.0	4302.6	0.0038	50.0	15.2	12175.7	3689.2
9	12122.0	4133.6	0.0171	190.9	65.1	10256.6	3497.5
10	10094.9	4371.1	0.0380	349.7	151.4	8364.8	3621.9
11	8139.4	4631.3	0.0665	486.7	276.9	6555.0	3729.8
12	8627.4	6229.0	0.1273	959.1	692.5	6538.1	4720.5
13	3642.0	2960.9	0.1900	586.6	476.9	2592.2	2107.5
14	2355.1	2388.1	0.2641	509.3	516.4	1556.6	1578.3
15	617.6	695.4	0.3059	151.7	170.8	391.5	440.8
16	221.1	279.7	0.3249	57.2	72.3	137.5	173.9
17	209.5	277.3	0.3591	58.9	78.0	125.9	166.7
18	154.0	188.9	0.3876	46.2	56.6	89.9	110.4
19	293.7	491.7	0.1900	47.3	79.2	209.1	350.0
TOTAL	60677.	30950.		3494.	2651.	48993.	24187.

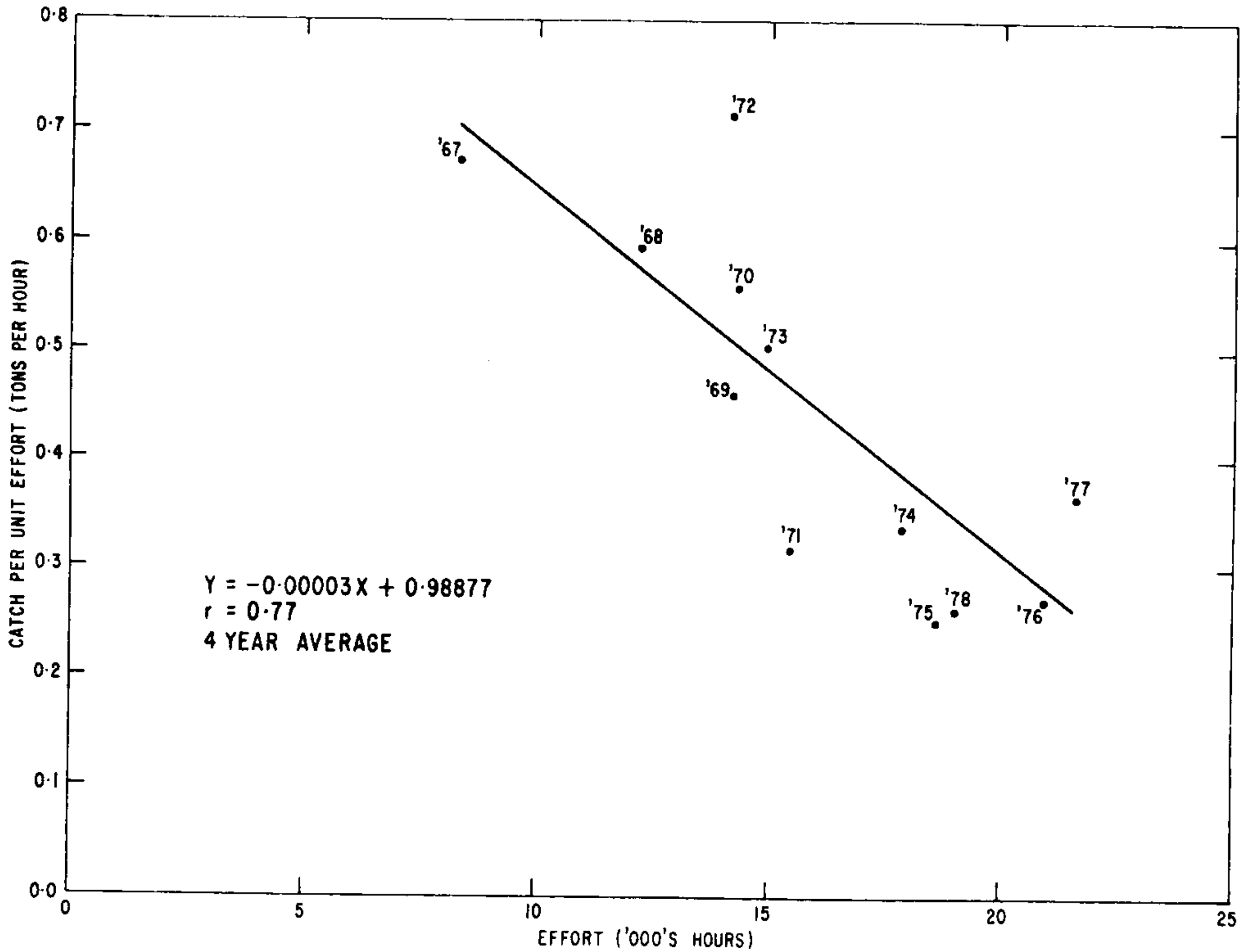

Fig. 1. Regression of catch per unit effort up on effort for ICNAF Divisions 3NØ using a 4-year running average.

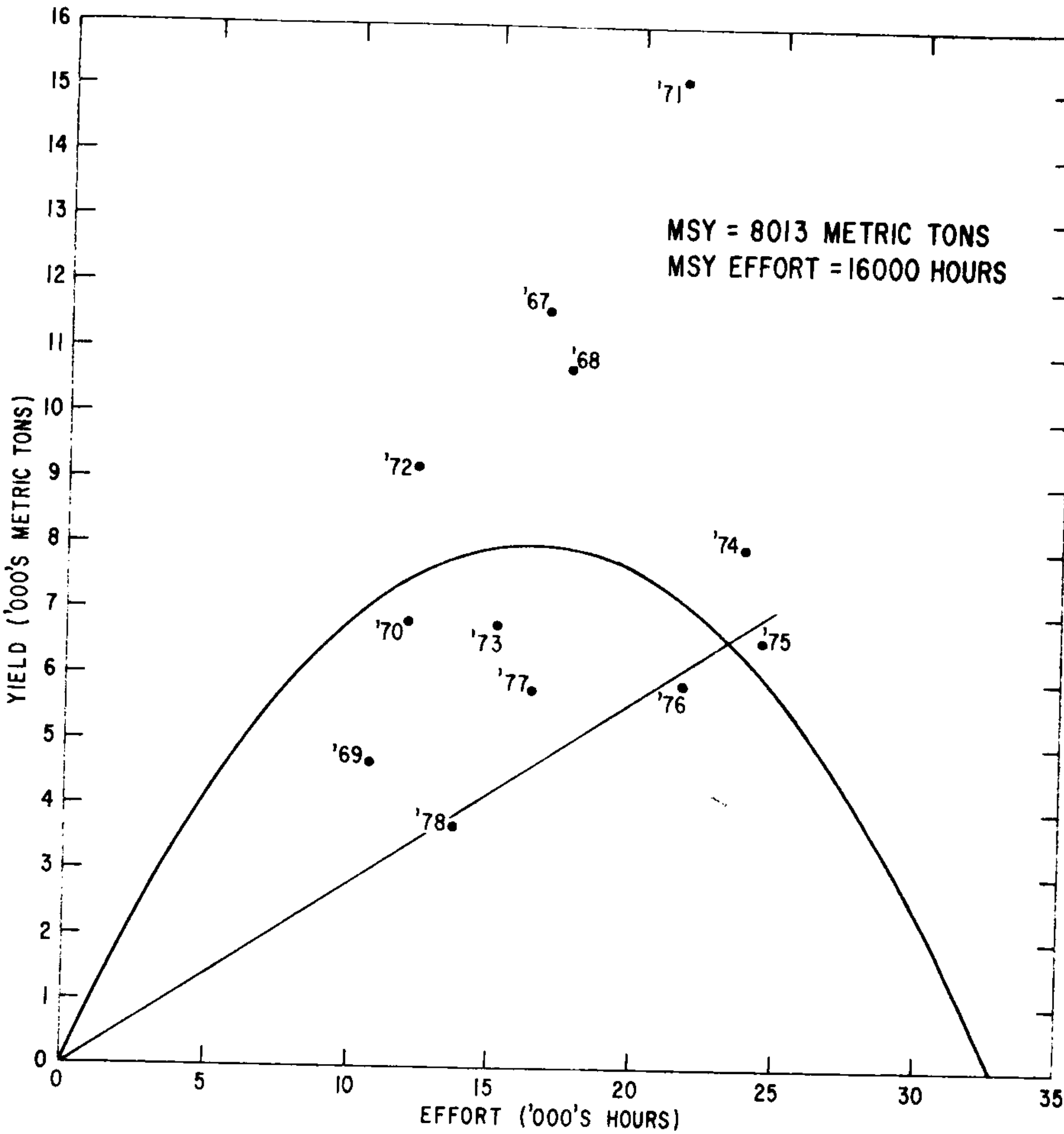

Fig. 2. General production curve for ICNAF Divisions 3NO witch.

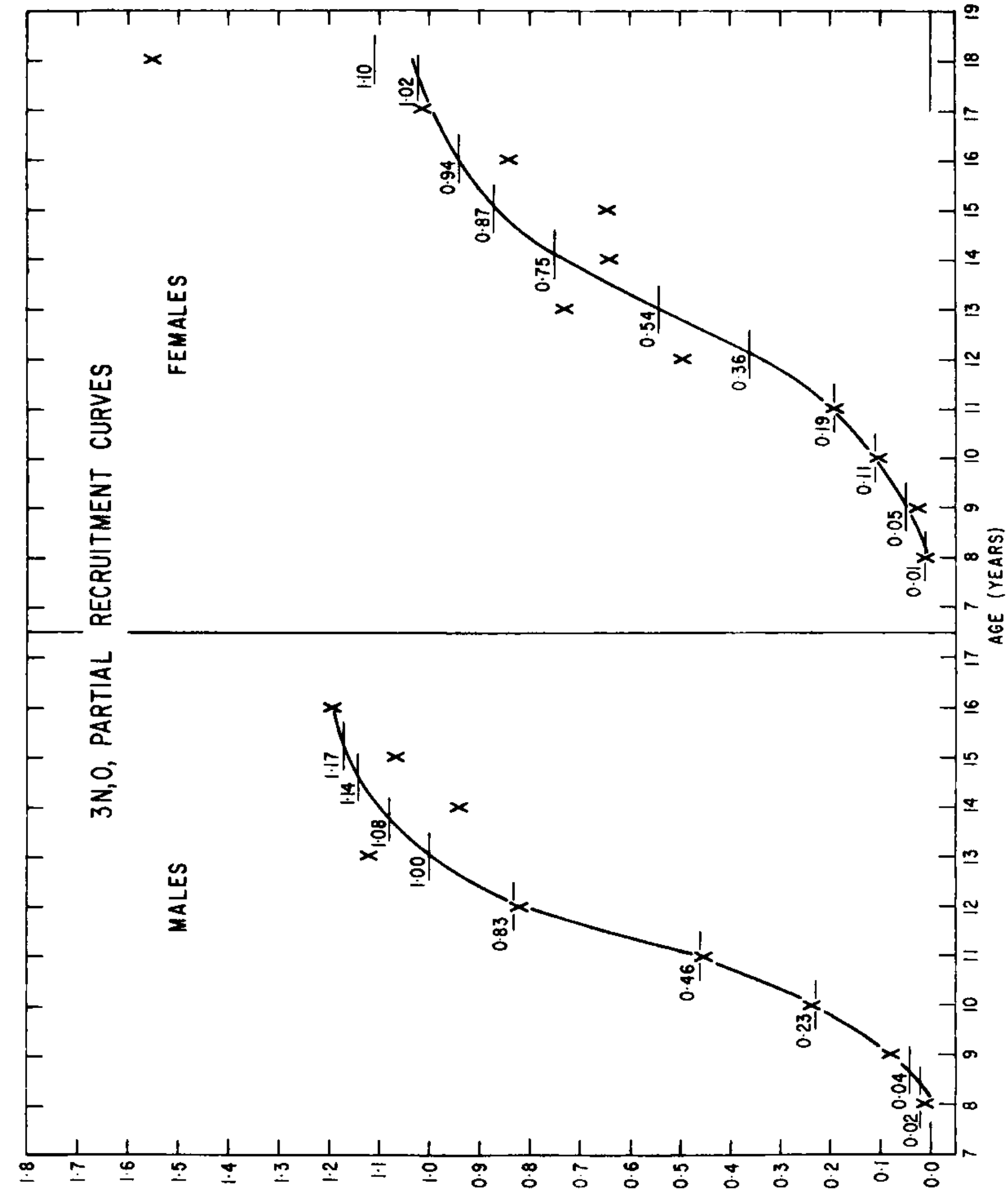

Fig. 3. Partial recruitment curves for ICNAF Divisions 3NØ witch.