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Analysis of stock size and yield of Fortune Bay herring

by

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Introduction

Traditionally Fortune Bay, on the south coast of Newfoundland, has been one of the main centers of the Newfoundland herring fishery with catches averaging about 16,000 tons during the period 1945-50 (Templeman 1966). Annual catches declined to less than 700 tons during the period 1954-66 but with the advent of purse-seining in 1966 landings of Fortune Bay herring increased rapidly to nearly 14,000 tons in 1968 and remained at high levels until 1973 when landings dropped to less than 3300 tons (Table 1). Since 1973, landings have continued to decline to about the 500 ton level in 1976 and 1977. This document presents an analysis of the dynamics of Fortune Bay herring over the past decade, particularly in relation to annual catch fluctuations and projects yield and biomass levels for the near future.

A. Data Compilation

(i) Numbers-at-age

Numbers-at-age in the annual landings for the period 1966-77 have been computed for spring-spawners only since this component has traditionally constituted 90-95% of annual landings. Numbers-at-age have been computed on a monthly basis for each of the gear components which are then combined for total age-specific removals in a particular year.

(ii) Effort statistics

Log records and/or landing statistics (on a trip-to-trip basis) are available for purse-seiner operations in Fortune Bay for the period 1967-73. Operating days of the purse-seine fleet have been selected as the standard measure of effort. Effort (extrapolated to the total catch)and catch-per-unit effort (CPUE) data are summarized in Table 2. CPUE remained relatively high during the late 1960's but has shown a continuous decline from 1970 to 1973, the last year for which effort statistics are available for the purse-seine fleet. The substantial increases in effort levels during the early 1970's was a result of significant diversions of effort from southwest Newfoundland where abundance levels were declining rapidly as a result of stock depletion.

(iii) Partial recruitment rates

Selection factors, calculated as the ratio of fishing mortality at age to the fully recruited fishing mortality (age-groups 5+), are given for year-classes 1966-72 in Table 3. Considerable fluctuations in selection factors have occurred in this stock and this is undoubtedly due to the effect of several strong year-classes (1966, 1968) entering the fishery over this period.

(iv) Calculation of F_T

Since effort data were not available from 1974 onwards, a direct calculation of F_T for 1977 was not possible. Instead, a range of 1977 starting F's was utilized as a basis for selecting the F_T giving the best correlation of fishing effort and fishing mortality for the period 1967-73. The best correlation obtained in this manner was derived when F_T (1977) = 0.10 (Fig. 1).

Total instantaneous mortality rates were also calculated by the method of Paloheimo (1961) from effort data for the years 1967-72. The estimates of Z thus derived are plotted against Z from cohort analysis in Fig. 2. The high correlation coefficient provides support for the F_T value estimated for 1977 and also suggests that the value of natural mortality used (M = 0.20) is a reasonable one.

B. Results of Assessment

(i) Recent age-composition data

Age-composition data of commercial catches of spring-spawning herring in Fortune Bay are shown in Fig. 3. The 1968 year-class which was substantially recruited at age-group 2 continued to dominate the catches up to 1977 when the 1974 year-class accounted for 66% of the landings. The 1971 and 1972 year-classes which constituted about 20% of the catches at age-group 4 in 1975 and 1976, respectively, appeared to be much less dominant in 1977, suggesting that the older fish are very much depleted to the extent that weak year-classes make a significant contribution to the population age structure.

(ii) Trends in biomass and fishing mortality 1966-77

Biomass estimates and fishing mortality rates of Fortune Bay herring are given in Table 4 and Fig. 4. Adult (5+) biomass levels were at low levels during the mid 1960's but increased substantially to nearly 36,000 tons in 1968 with the entry into the adult stock of the very strong 1963 year-class. Adult biomass decreased to 14,000 tons in 1970, increased to 22,500 tons in 1971 with the full recruitment of the strong 1966 year-class and has declined almost continually since then to less than 3500 tons in 1977. The reason for such a drastic decline in biomass levels is due to a combination of high fishing mortality rates particularly with regard to the 1968 year-class and poor recruitment during the 1970's. While estimates of the strength of the 1974 year-class must be considered to be very tenuous, our best estimates suggest that it is less than 1/3 as strong as the 1968 year-class at age-group 2. Thus, whereas strong year-classes occurred every 2-3 years during the 1960's, it would appear that strong year-classes will be much less frequent during the 1970's. Since similar patterns of recruitment have been observed in other spring-spawning

stocks of herring around the Newfoundland coast, one can conclude that factors other than egg production, i.e. environmental, are the main determinants of year-class strength in these herring populations.

(iii) Calculation of F_{opt}

Yield-per-recruit calculations have been carried out based on the average partial recruitment rates given in Table 3. The results (Fig. 5) indicate a flat-topped curve with the marginal yield-per-recruit (F_{opt}) occurring at a fishing mortality rate of 0.30, yielding 90% of the maximum yield-per-recruit.

(iv) Stock and yield projection

Mean recruitment strengths and standard deviations of spring-spawning herring in Fortune Bay have been calculated for the year-classes 1958-72. Using a random number generator a 10-year projection of stock size and yield (at F_{opt}) has been calculated and the results are shown in Fig. 6. They suggest that under average conditions yields in the next decade from this stock will average about 3000 tons, reflecting in part the much reduced abundance of the present adult biomass. This catch level may be compared with average catches of 6300 tons during the past decade and an estimated long-term average yield of 5000 tons.

Projected stock size and yield at $F_{opt} = 0.30$ for 1978 are shown in Table 5. The projected catch for 1978 is 1800 tons, a level which will result in a decline in population biomass in 1978 under the recruitment strengths chosen. A yield of 1300 m tons in 1978 would allow the biomass to remain at the 1978 level in 1979 and would allow faster rebuilding of the stock as well as afford some protection to the 1974 year-class which will not reach maximum biomass levels until 1979.

References

Paloheimo, J. E. 1961. Studies on estimation of mortalities. I. Comparison of a method descri-ed by Beverton and Holt and a new linear formula. J. Fish. Res. Board Can. 18: 645-662.

Templeman, W. 1966. Marine resources of Newfoundland. Fish. Res. Board Can. Bull. 154: 167 p.

Table 1. Fortune Bay Herring Catches, 1966-77 (metric tons)

Year	Purse Seine	Bar Seine	Inshore	Total
1966	-	-	193	193
1967	4,577	881	210	5,668
1968	11,686	2,921	122	14,729
1969	4,837	1,590	440	6,867
1970	7,920	1,044	425	9,389
1971	14,579	200	226	15,005
1972	9,316	721	533	10,570
1973	2,053	1,117	84	3,254
1974	1,928	268	72	2,268
1975	809	81	19	909
1976	109	310	43	462
1977*	188	322	23	533

* to end of July

Table 2. Effort and CPUE Data for Fortune Bay Herring 1967-73

Year	CPUE (tons/day)	Effort (days)
1967	63.7	89
1968	69.2	213
1969	53.7	128
1970	62.2	151
1971	49.5	303
1972	33.7	314
1973	24.8	131

Table 3. Selection factors (partial recruitment)

Year Class	Selection Factor ar age (%)			
	2	3	4	5
1966	10.1	40.1	71.7	100.0
1967	5.9	100.0	100.0	100.0
1968	80.8	56.7	74.4	100.0
1969	10.1	15.8	14.4	28.5
1970	46.5	100.0	100.0	100.0
1971	10.0	69.7	86.7	100.0
1972	13.9	24.7	62.5	100.0
Mean	25.3	58.1	72.8	90.0

Table 4

ESTIMATED POPULATIONS

AGE	1966	1967	1968	1969	1970	1971
2	3470.	5934.	136759.	29442.	149082.	2951.
3	220468.	2840.	4857.	106043.	23639.	83708.
4	2179.	180296.	2245.	3861.	75977.	12118.
5	2212.	1773.	125206.	1551.	3084.	52764.
6	5824.	1791.	1410.	58569.	1101.	2446.
7	7663.	4687.	1422.	959.	36155.	730.
8	5063.	6214.	3456.	1052.	615.	22985.
9	3349.	4064.	4680.	2277.	625.	285.
10	192.	2716.	2863.	3135.	1240.	497.
11	1247.	155.	1900.	1512.	816.	804.
12	50.	1005.	114.	997.	438.	541.
13	40.	40.	712.	70.	280.	301.
14	32.	32.	32.	391.	34.	190.
15	25.	25.	25.	25.	135.	26.
16	20.	20.	20.	20.	20.	97.
17	15.	15.	15.	15.	15.	15.
18	12.	12.	12.	12.	12.	12.

TOTAL POPULATION

	1966	1967	1968	1969	1970	1971
WT	39112.4	45291.1	46491.5	37777.3	43151.6	36571.2
NO	251859.	211618.	285726.	209929.	293267.	180470.

POPULATION AT AGE 5 TO 18

	1966	1967	1968	1969	1970	1971
WT	7996.0	7343.0	35785.7	20287.1	13802.5	22316.6
NO	25743.	22549.	141866.	70584.	44569.	81693.

WEIGHTED F AGE 5 TO 18

1966	1967	1968	1969	1970	1971
0.014	0.103	0.520	0.331	0.232	0.668

1972	1973	1974	1975	1976	1977
5138.	9613.	7574.	536.	44300.	6636.
2258.	2817.	5862.	5849.	437.	35380.
46734.	1614.	1470.	3593.	4536.	344.
4208.	20188.	1261.	712.	2415.	3426.
21161.	784.	11397.	923.	482.	1771.
908.	7429.	231.	5193.	677.	278.
417.	420.	4500.	84.	2903.	544.
10326.	242.	274.	2671.	54.	2072.
110.	3567.	153.	216.	2059.	12.
269.	58.	2207.	107.	157.	1516.
422.	148.	34.	1539.	78.	116.
301.	221.	90.	23.	1115.	58.
181.	172.	129.	64.	16.	822.
112.	114.	109.	88.	47.	12.
20.	69.	79.	78.	63.	35.
64.	15.	47.	60.	59.	46.
12.	46.	12.	35.	46.	46.

1972	1973	1974	1975	1976	1977
21710.0	10595.7	7873.8	5425.2	7948.5	9800.5
92639.	47517.	35426.	21770.	67746.	60726.

1972	1973	1974	1975	1976	1977
11411.6	9201.6	6231.9	3840.4	3271.6	3332.2
38510.	33473.	20521.	11793.	10171.	10753.

0.864	0.353	0.416	0.219	0.128

Table 5

STOCK PROJECTION AREA I SS '000

NATURAL MORTALITY# 0.2000 YEAR 1977

AGE	POP. NO. %X10-3<	CATCH NO. %X10-3<	FISHING MORT.	MEAN WT. KG.	POP. WT. %METRIC TONS<	CATCH WT. %METRIC TONS<	RESIDUAL POP. NOS.
2	6636.	30.	0.006	0.070	464.5	2.1	5400.6
3	35890.	1902.	0.061	0.138	4952.8	262.5	27645.4
4	344.	24.	0.080	0.206	70.9	4.9	260.0
5	3426.	296.	0.101	0.240	822.2	71.0	2535.5
6	1771.	153.	0.100	0.276	488.8	42.2	1312.0
7	278.	24.	0.100	0.310	86.2	7.4	205.9
8	544.	47.	0.101	0.335	182.2	15.7	402.6
9	2072.	179.	0.100	0.345	714.8	61.8	1535.0
10	12.	1.	0.097	0.360	4.3	0.4	8.9
11	1516.	131.	0.101	0.390	591.2	51.1	1122.0
12	116.	10.	0.100	0.390	45.2	3.9	85.9
13	58.	5.	0.100	0.390	22.6	1.9	43.0
14	822.	71.	0.100	0.390	320.6	27.7	609.0
15	12.	1.	0.097	0.390	4.7	0.4	8.9
16	35.	3.	0.100	0.390	13.6	1.2	25.9
17	46.	4.	0.101	0.390	17.9	1.6	34.0
18	46.	4.	0.101	0.390	17.9	1.6	34.0
TOTAL	53624.	2885.			8820.7	557.4	41268.6

NATURAL MORTALITY# 0.2000 YEAR 1978

AGE	POP. NO. %X10-3<	CATCH NO. %X10-3<	FISHING MORT.	MEAN WT. KG.	POP. WT. %METRIC TONS<	CATCH WT. %METRIC TONS<	RESIDUAL POP. NOS.
2	877.	58.	0.075	0.070	61.4	4.0	666.3
3	5401.	809.	0.180	0.138	745.3	111.6	3693.3
4	27645.	5067.	0.225	0.206	5694.9	1043.9	18073.7
5	260.	61.	0.300	0.240	62.4	14.7	157.7
6	2536.	599.	0.300	0.276	699.8	165.2	1537.9
7	1312.	310.	0.300	0.310	406.7	96.0	795.8
8	206.	49.	0.300	0.335	69.0	16.3	124.9
9	403.	95.	0.300	0.345	138.9	32.8	244.2
10	1535.	362.	0.300	0.360	552.6	130.5	931.0
11	9.	2.	0.300	0.390	3.5	0.8	5.4
12	1122.	265.	0.300	0.390	437.6	103.3	680.5
13	86.	20.	0.300	0.390	33.5	7.9	52.1
14	43.	10.	0.300	0.390	16.8	4.0	26.1
15	609.	144.	0.300	0.390	237.5	56.1	369.3
16	9.	2.	0.300	0.390	3.5	0.8	5.4
17	26.	6.	0.300	0.390	10.1	2.4	15.7
18	34.	8.	0.300	0.390	13.3	3.1	20.6
TOTAL	42112.	7867.			9186.7	1793.4	27399.9

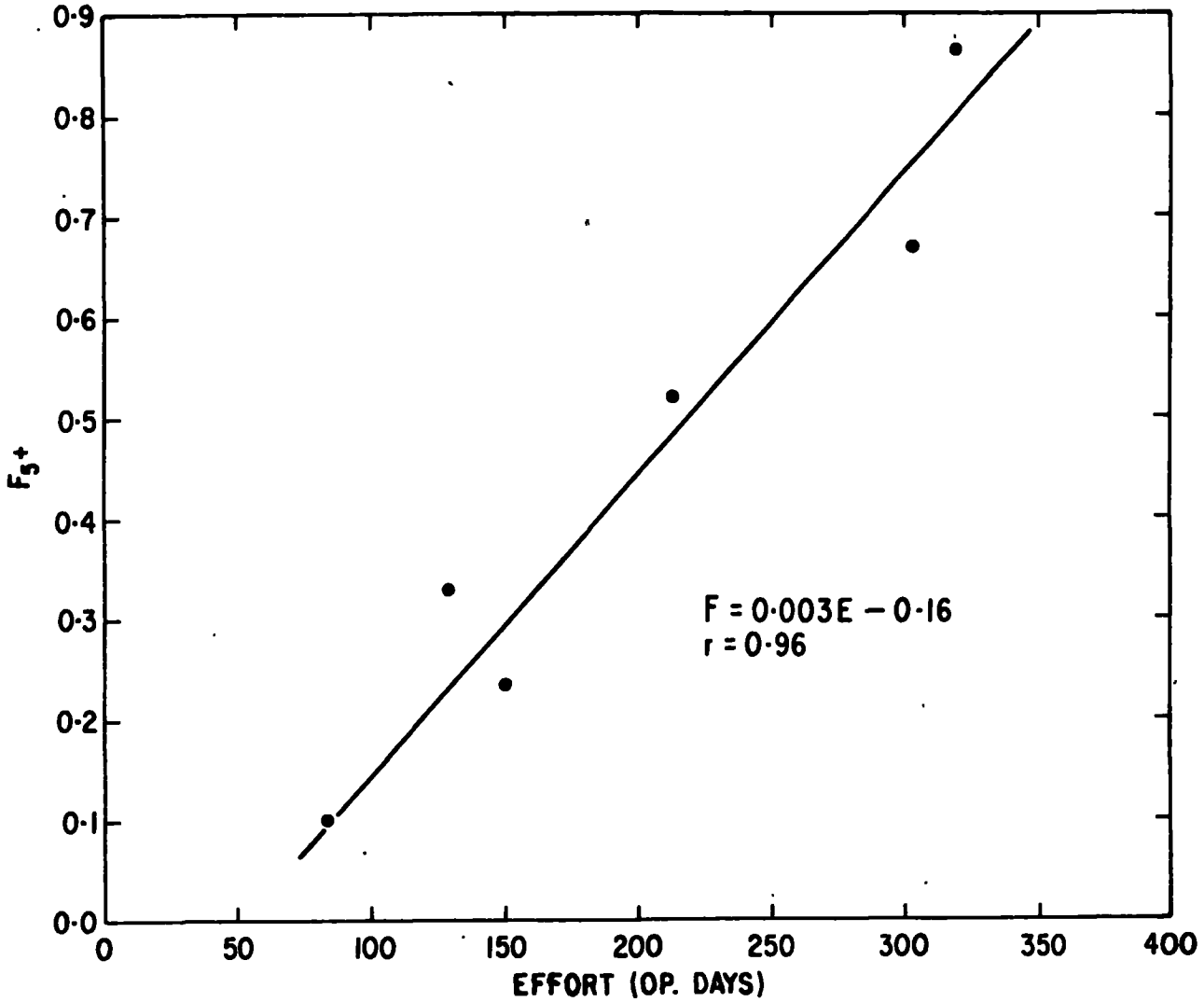

Fig. 1. Relationship between effort and fully-recruited fishing mortality estimates of Fortune Bay herring 1967-73.

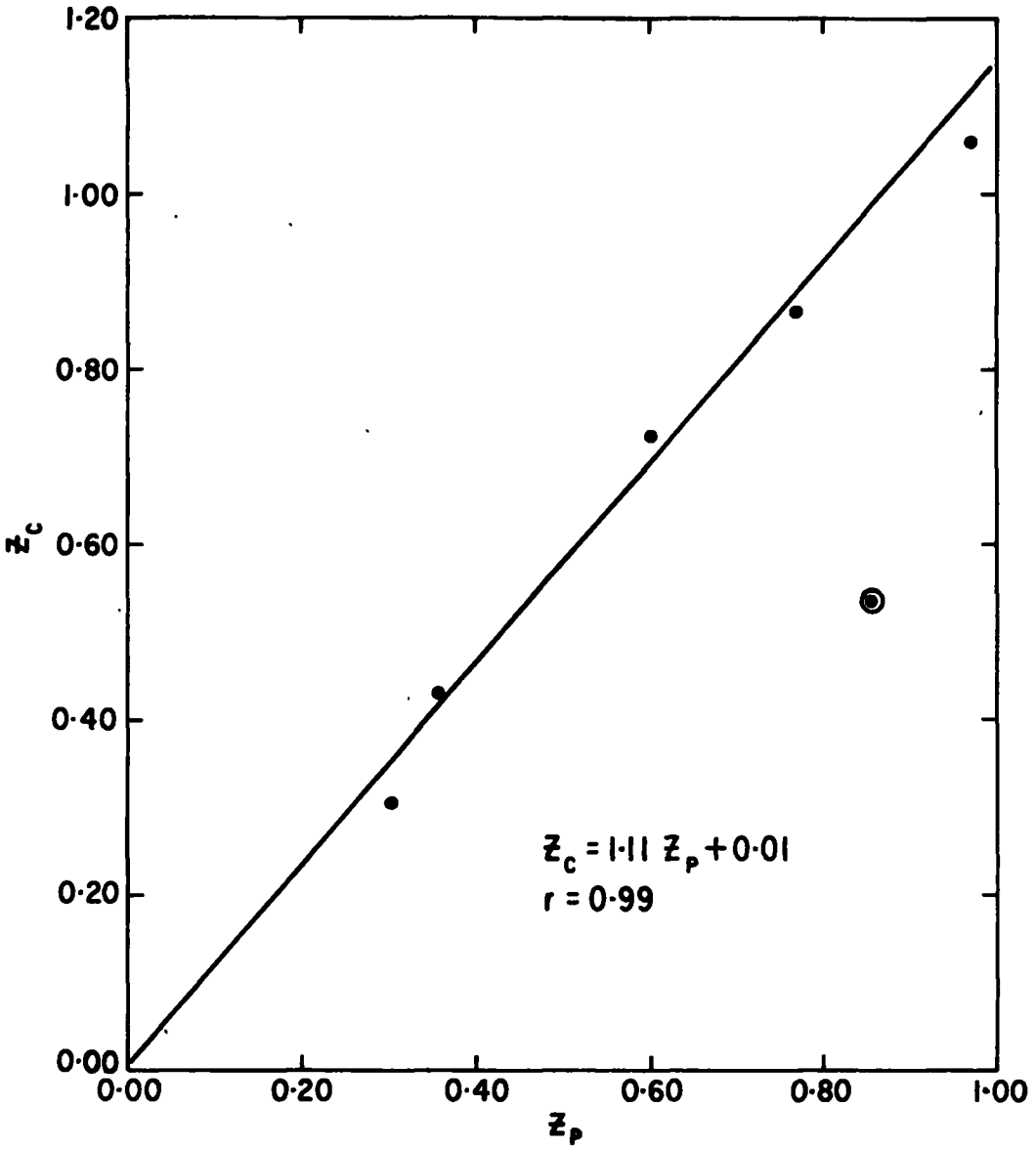

Fig. 2. Relationship between total mortality (M=.20) estimates from cohort analyses (Z_c) and estimates by the Paloheimo linear formula (Z_p), 1967-72.

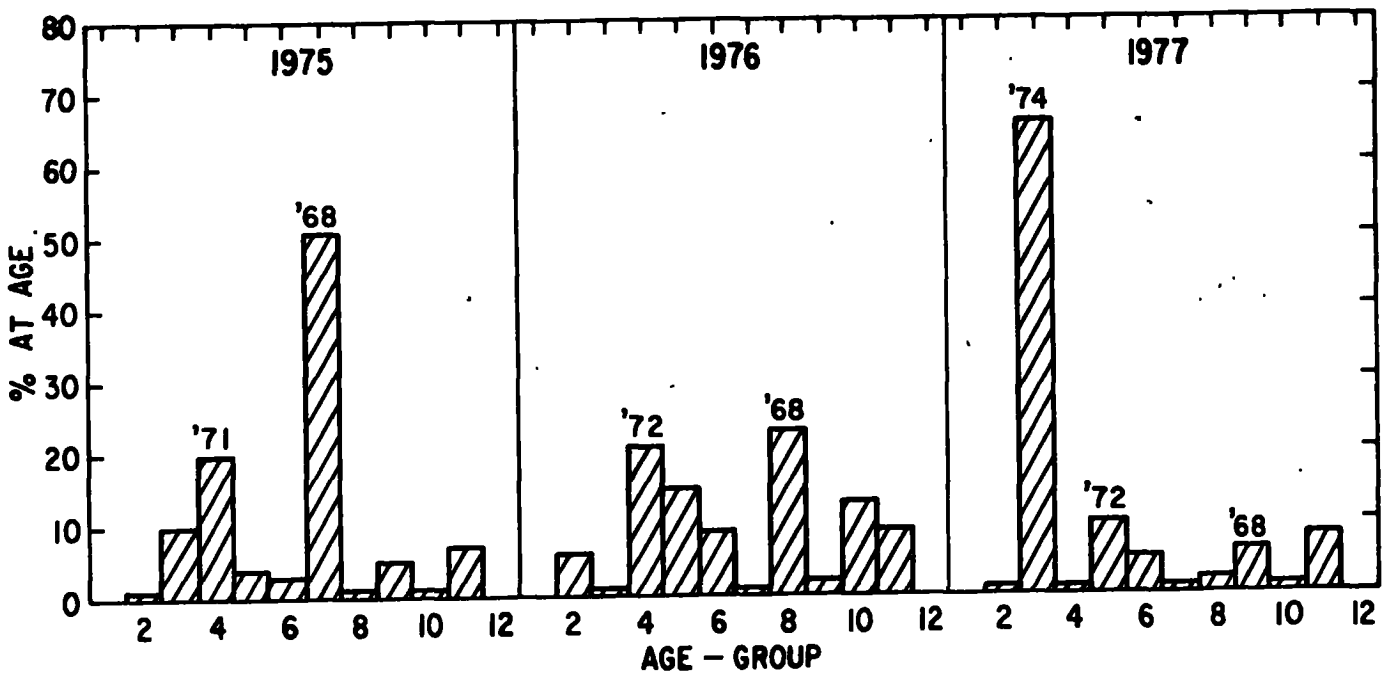

Fig. 3. Commercial age-composition data of Fortune Bay herring 1975-77.

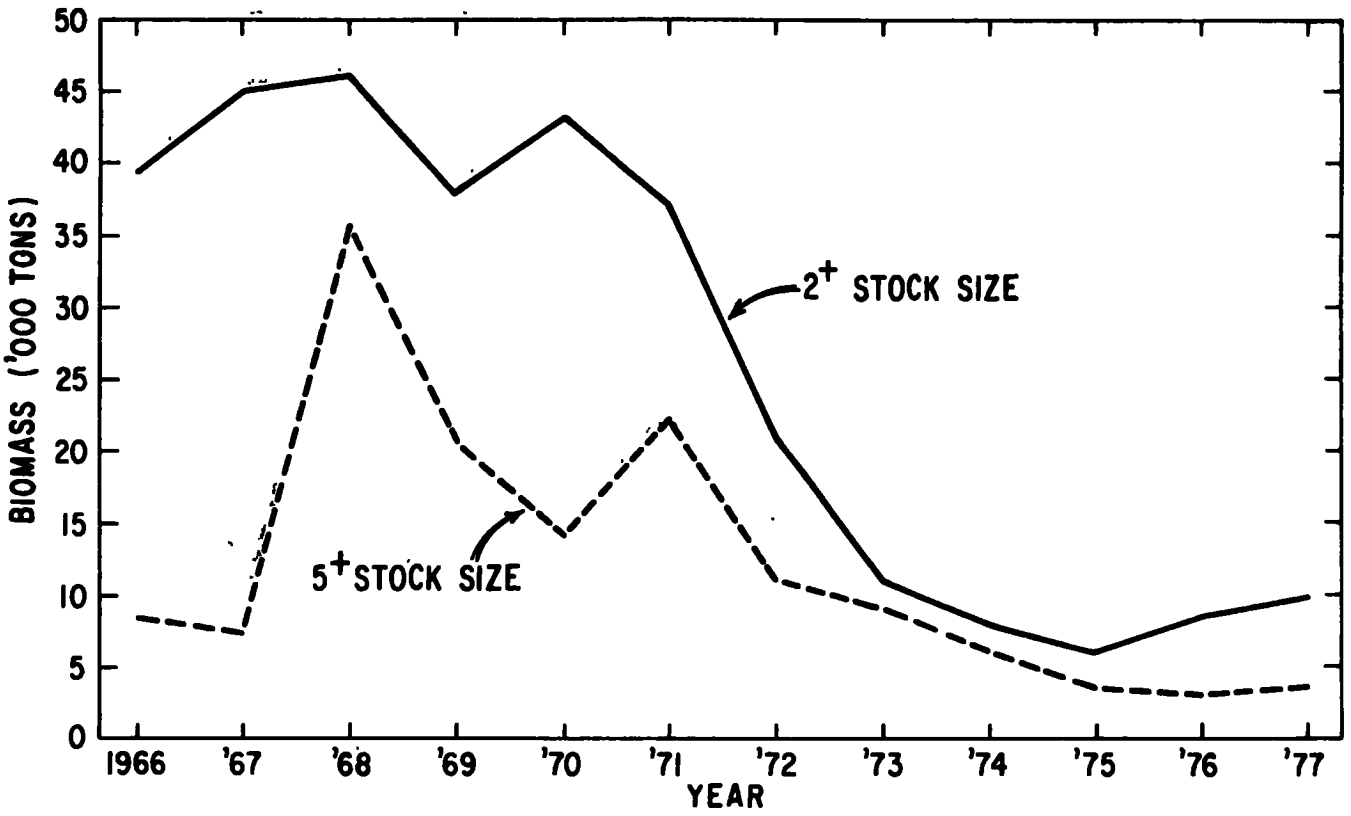

Fig. 4. Biomass levels of Fortune Bay herring as estimated from cohort analyses 1966-77.

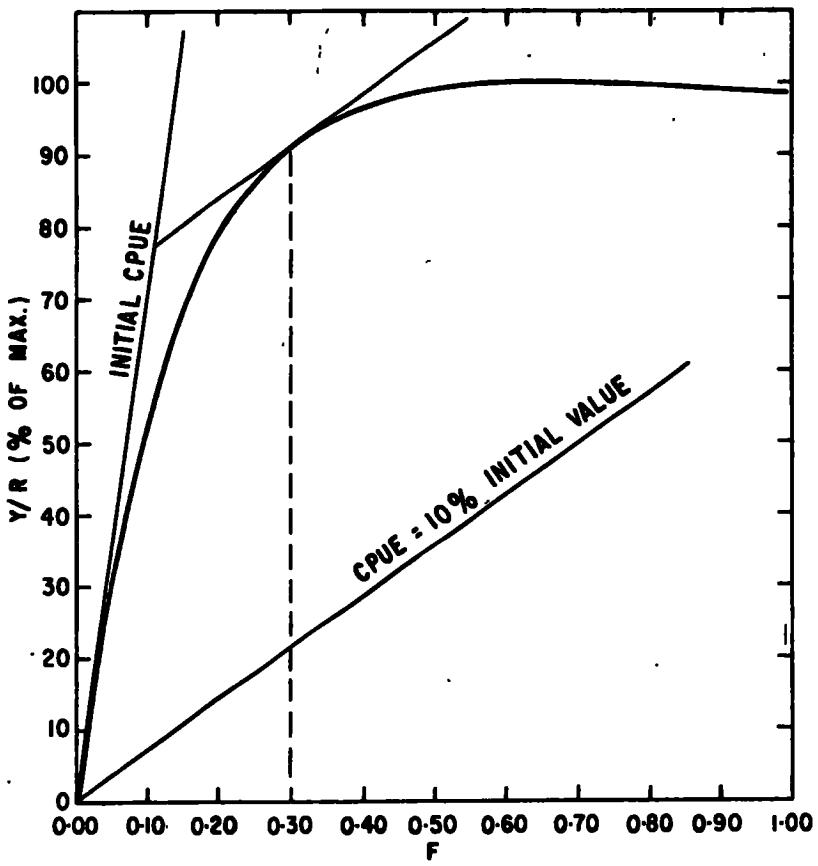

Fig. 5. Calculation of optimal yield-per-recruit for Fortune Bay herring.

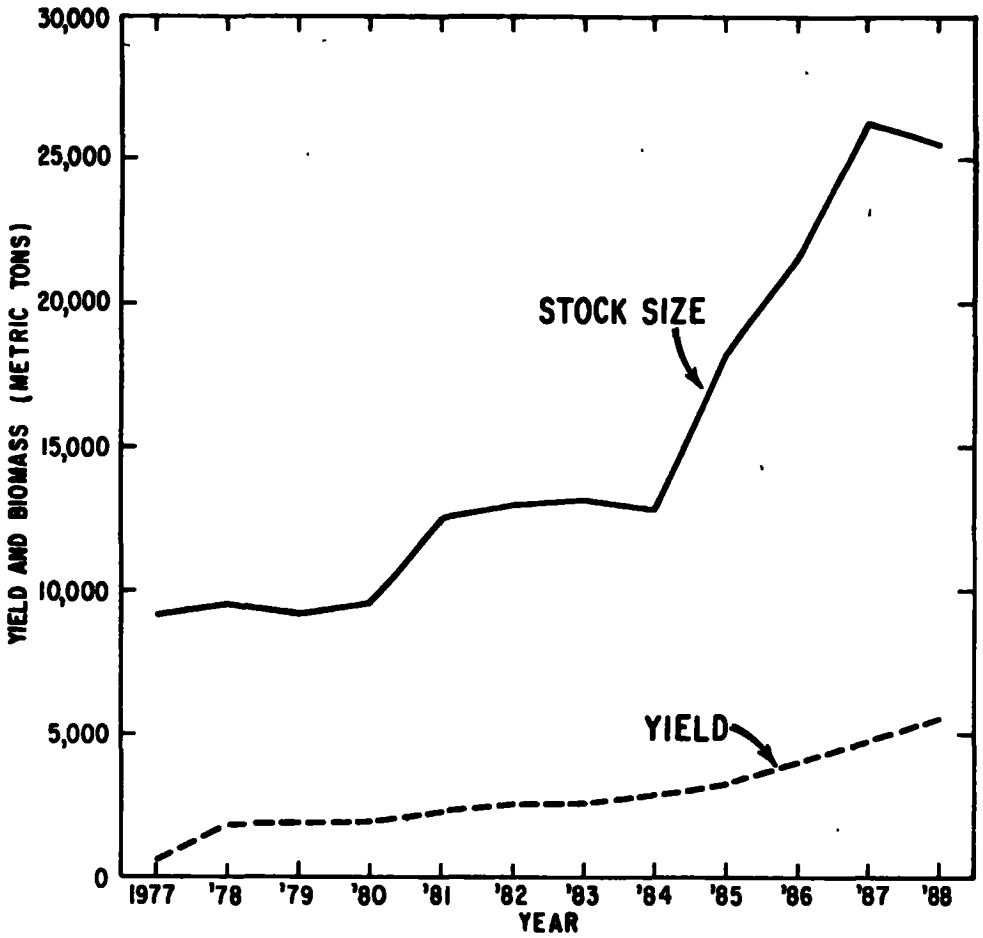

Fig. 6. Projection of stock size and yield (F_{opt} = 0.30) of Fortune Bay herring 1978-88.